WestConnex

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M4 East

Environmental Impact Statement

Appendices Q-R

Volume 2G

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Appendices

WestConnex

Appendix Q

Surface water: flooding and drainage

WestConnex

WestConnex Delivery Authority

WestConnex M4 East EIS

Surface Water: Flooding and Drainage

September 2015

Prepared for

WestConnex Delivery Authority

Prepared by

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Contents

List of Figures (embedded in text)

List of Figures (bound at end of report) (scales on figures are applicable when printed at A3 size)

List of Appendices

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Glossary of terms and abbreviations

Term	Meaning
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
AEP	Annual Exceedance Probability. The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 cubic metres per second has an AEP of five per cent, it means that there is a five per cent chance (that is one-in-20 chance) of a 500 cubic metres per second or larger events occurring in any one year (see also average recurrence interval).
ALS	Airborne Laser Scanning. A type of aerial survey used to measure the elevation of the ground surface.
AHD	Australian Height Datum. A common national surface level datum approximately corresponding to mean sea level.
ARI	Average Recurrence Interval. The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a 1 per cent chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability). The frequency of floods is generally referred to in terms of their AEP or ARI. In this report the frequency of floods generated by runoff from the study catchments is referred to in terms of their ARI, for example the 100 year ARI flood.
ARR	Australian Rainfall and Runoff (Institute of Engineers Australia, 1998).
BoM	Bureau of Meteorology
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
DECC	Department of Environment and Climate Change (now OEH).
DECCW	Department of Environment, Climate Change and Water (formerly, DECC, but now OEH).
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving (e.g. metres per second [m/s]).
DP	Deposited Plan.
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.

Term	Meaning
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).
Floodplain Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the NSW Floodplain Development Manual (FDM), (DIPNR, 2005). Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Floodway area	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
FPA	Flood Planning Area. The area of land inundated at the Flood Planning Level.
FPL	Flood Planning Level. A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as “greenhouse” and climate change. Freeboard is included in the Flood Planning Level.
GPT	Gross pollutant trap. A device designed to capture pollutants in stormwater runoff prior to discharge into the receiving system. GPT’s are typically designed to capture litter and debris but may also capture hydrocarbons, suspended sediments and particle bound pollutants such as nitrogen, phosphorus and heavy metals.

Term	Meaning
GSDM	Generalised Short Duration Method. A method for estimating the Probable Maximum Precipitation for catchments up to 1,000 square kilometres in area.
HHWSS	Highest High Water Solstice Spring. The tide level reached on average once or twice per year.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to the NSW Floodplain Development Manual (FDM), (DIPNR, 2005) the hazard is flooding which has the potential to cause damage to the community.
Headwater	The upper reaches of a drainage system.
Hydraulics	The term given to the study of water flow in waterways, in particular the evaluation of flow parameters such as water level and velocity
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Hyetograph	A graph which shows how rainfall intensities or depths vary with time during a storm burst. A design hyetograph shows the distribution of rainfall over a design storm burst.
Local Drainage	Land on an overland flow path where the depth of inundation during the 100 year ARI storm event is less than 150 millimetres.
Main Stream Flooding (MSF)	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major Overland Flow (MOF)	Land on an overland flow path where the depth of inundation during the 100 year ARI storm event is equal to or greater than 150 millimetres.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State’s rivers and floodplains
OEH	Office of Environment and Heritage (formerly DECCW)
Overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.
Peak flood level	The maximum water level occurring during a flood event.

Term	Meaning
PMF	Probable Maximum Flood. The flood that occurs as a result of the Probable Maximum Precipitation (PMP) on a study catchment. The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land (i.e. the floodplain).
PMP	Probable Maximum Precipitation. The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using a catchment hydrologic model which simulates the conversion of rainfall to runoff.
PRM	Probabilistic Rational Method
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RL	Reduced Level. The reduced level is the vertical distance between an elevation and an adopted datum plane such as the Australian Height Datum (AHD).
Roads and Maritime	NSW Roads and Maritime Services
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum)
SW	Sydney Water
Tonkin Pipe	An oviform shaped pipe that was a common form of construction in many parts of Sydney in the 1930's.
Flow Velocity	A measure of how fast water is moving (e.g. metres per second [m/s]).
Water surface profile	A graph showing the flood stage at any given location along a watercourse at a particular time.
WDA	WestConnex Delivery Authority

Executive summary

Overview

This report deals with the findings of an investigation which was undertaken by Lyall & Associates (L&A) on behalf of the NSW Roads and Maritime Services (Roads and Maritime) to assess flooding and drainage related issues associated with the construction and operation of the M4 East project (project).

This report has been prepared to support the environmental impact statement (EIS) for the project. **Chapters 1** to **3** provide details of the background to the current assessment, as well as a description of project-specific works which have the potential to influence flooding and drainage patterns in the catchments through which it runs. A more detailed description of the works comprising the project as a whole is contained in Chapter 5 (Project description) of the EIS.

Figures referred to in **Chapters 4** to **7** are located after **Chapter 9** of this report.

Existing environment

The project traverses a number of highly urbanised catchments in the inner-west of Sydney, all of which drain to the Parramatta River along its southern bank. The investigation found that the local stormwater drainage systems that control runoff from these catchments are of limited capacity. As a result, the project corridor is presently impacted by both main stream flooding (MSF) and major overland flow (MOF) during periods of heavy rainfall. **Chapter 4** contains a brief description of the characteristics of the catchments through which the project runs, as well as a description of the characteristics of MSF and MOF under present day (or pre-project) conditions for floods with average recurrence intervals (ARI) ranging between five and 100 years, as well as for the probable maximum flood (PMF). MSF and MOF have been collectively termed 'flooding' within this report.

Assessment of construction related issues

The ten temporary construction ancillary facilities are all affected by either main stream flooding or major overland flow. Inundation of these sites by flooding has the potential to:

- Cause damage to the project works
- Cause delays in construction programming
- Pose a safety risk to construction workers
- Detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters
- Alter the characteristics of flooding in adjacent development.

Table 5.1 in **Chapter 5** sets out the assessed flood risk at the 10 construction ancillary facilities. The assessment found that a number of the construction ancillary facilities would be affected by flooding during storms with ARI's less than five years.

Construction activities also have the potential to exacerbate flooding conditions in adjacent development. This arises due to the need to locate temporary measures on the floodplain outside the road footprint. A preliminary investigation was undertaken to assess the impacts construction activities could potentially have on the characteristics of flooding. The key findings of the investigation are summarised in **Table 5.2** in **Chapter 5**.

Assessment of operational related issues

Current (2015) climatic and ocean boundary conditions

Inundation of the project by floodwater during its operation has the potential to cause damage to infrastructure; impact on the safe operation of the motorway tunnels and pose a safety risk to road users and motorway operations staff. The project also has the potential to exacerbate flooding and drainage conditions in adjacent development.

An assessment was undertaken of the flood risk to the project in its as-built form, as well as the impact it would have on the characteristics of flooding in adjacent development.

Table 6.1 in **Chapter 6** provides a summary of the assessed flood risk to the project. A recommended level of flood protection to each project element has been identified with due consideration of the consequences of flooding in accordance with the *NSW Floodplain Development Manual*, (NSW Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005) and current Roads and Maritime standards.

The investigation found that once constructed, the project would have only a minor impact on flooding behaviour in adjacent development for storms with ARI's up to 100 years. While it will be necessary to undertake further design development during detailed design aimed at further reducing the residual impacts of the project on flooding behaviour, it is concluded that the minor nature of the changes in flooding patterns attributable to the project would not have a significant impact on the future development potential of land located outside the project corridor.

Post-climate change climatic and ocean boundary conditions

Projected changes in the intensity of flood producing rainfall, as well as a rise in sea level have the potential to impact on the characteristics of flooding in the vicinity of the project.

The potential impacts of future climate change on flooding were assessed in accordance with the recommended procedures set out in the NSW Office of Environment and Heritage's (OEH) Floodplain Risk Management Guideline – *Practical Considerations of Climate Change* (NSW Department of Environment and Climate Change (DECC), 2007) and current best practice. **Table 3.1** in **Chapter 3** summarises the combination of design storm rainfalls and sea level conditions which were used to assess the potential impact of future climate change on the characteristics of flooding in the vicinity of the project under 2050 and 2100 conditions.

The investigation found that changes in the characteristics of flooding associated with future climate change would not lead to a significant increase in the flood risk to the project. **Table 6.5** in **Chapter 6** summarises the potential impact future climate change would have on peak flood levels at key locations along the project corridor.

Assessment of potential mitigation measures

A flood management strategy (FMS) would be prepared prior to construction to minimise the potential project impacts on existing flooding characteristics within its vicinity. The FMS would identify appropriate design standards for managing the flood risk during the construction and operational phases of the project. It would also include procedures aimed at reducing the flooding threat to human safety and infrastructure, as well as controls that are aimed at mitigating the impact of the project (during construction and operation) on flooding behaviour.

While the findings of the initial assessment provide an indication of the potential impact construction activities would have on the characteristics of flooding, further investigation will need to be undertaken during detailed design based on more detailed site layouts and staging diagrams. A range of potential measures which would reduce the impact of construction activities on flooding behaviour are set out in **Table 7.1** in **Chapter 7**.

Measures that would need to be considered during detailed design to manage the flood risk to key operational elements of the project are set out in **Table 7.2**, while those that are aimed at mitigating the residual impacts of the project on flooding behaviour are set out in **Table 7.3** in **Chapter 7**.

1 Introduction

1.1 Overview of the project

The NSW Roads and Maritime Services (Roads and Maritime) is seeking approval to upgrade and extend the M4 Motorway (M4) from Homebush Bay Drive at Homebush to Parramatta Road and City West Link (Wattle Street) at Haberfield. This includes twin tunnels about 5.5 kilometres long and associated surface works to connect to the existing road network. These proposed works are described as the M4 East project (the project). The location of the project is shown in **Figure 1.1**.

Approval is being sought under Part 5.1 of the *Environmental Planning and Assessment Act 1979* (NSW) (EP&A Act). The project was declared by the Minister for Planning to be State significant infrastructure and critical State significant infrastructure and an environmental impact statement (EIS) is therefore required.

The project is a component of WestConnex, which is a proposal to provide a 33 kilometre motorway linking Sydney's west and south-west with Sydney Airport and the Port Botany precinct. The location of WestConnex is shown in **Figure 1.2**. The individual components of WestConnex are:

- M4 Widening – Pitt Street at Parramatta to Homebush Bay Drive at Homebush (planning approval granted and under construction)
- M4 East (the subject of this report)
- New M5 – King Georges Road at Beverly Hills to St Peters (planning application lodged and subject to planning approval)
- King Georges Road Interchange Upgrade (planning approval granted and work has commenced)
- M4–M5 Link – Haberfield to St Peters, including the Southern Gateway and Southern Extension (undergoing concept development and subject to planning approval).

Separate planning applications will be lodged for each individual component project. Each project will be assessed separately, but the impacts of each project will also be considered in the context of the wider WestConnex.

The NSW Government has established the WestConnex Delivery Authority (WDA) to deliver WestConnex. WDA has been established as an independent public subsidiary corporation of Roads and Maritime. Its role and functions are set out in Part 4A of the *Transport Administration (General) Regulation 2013* (NSW). WDA is project managing the planning approval process for the project on behalf of Roads and Maritime. However, for the purpose of the planning application for the project, Roads and Maritime is the proponent.

1.2 Project location

The project is generally located in the inner west region of Sydney within the Auburn, Strathfield, Canada Bay, Burwood and Ashfield local government areas (LGAs). The project travels through 10 suburbs: Sydney Olympic Park, Homebush West, Homebush, North Strathfield, Strathfield, Concord, Burwood, Croydon, Ashfield and Haberfield.

The project is generally located within the M4 and Parramatta Road corridor, which links Broadway at the southern end of the Sydney central business district (CBD) and Parramatta in Sydney's west, about 20 kilometres to the west of the Sydney CBD. This corridor also provides the key link between the Sydney CBD and areas further west of Parramatta (such as Penrith and western NSW).

The western end of the project is located at the interchange between Homebush Bay Drive and the M4, about 13 kilometres west of the Sydney CBD. The project at this location would tie in with the M4 Widening project in the vicinity of Homebush Bay Drive.

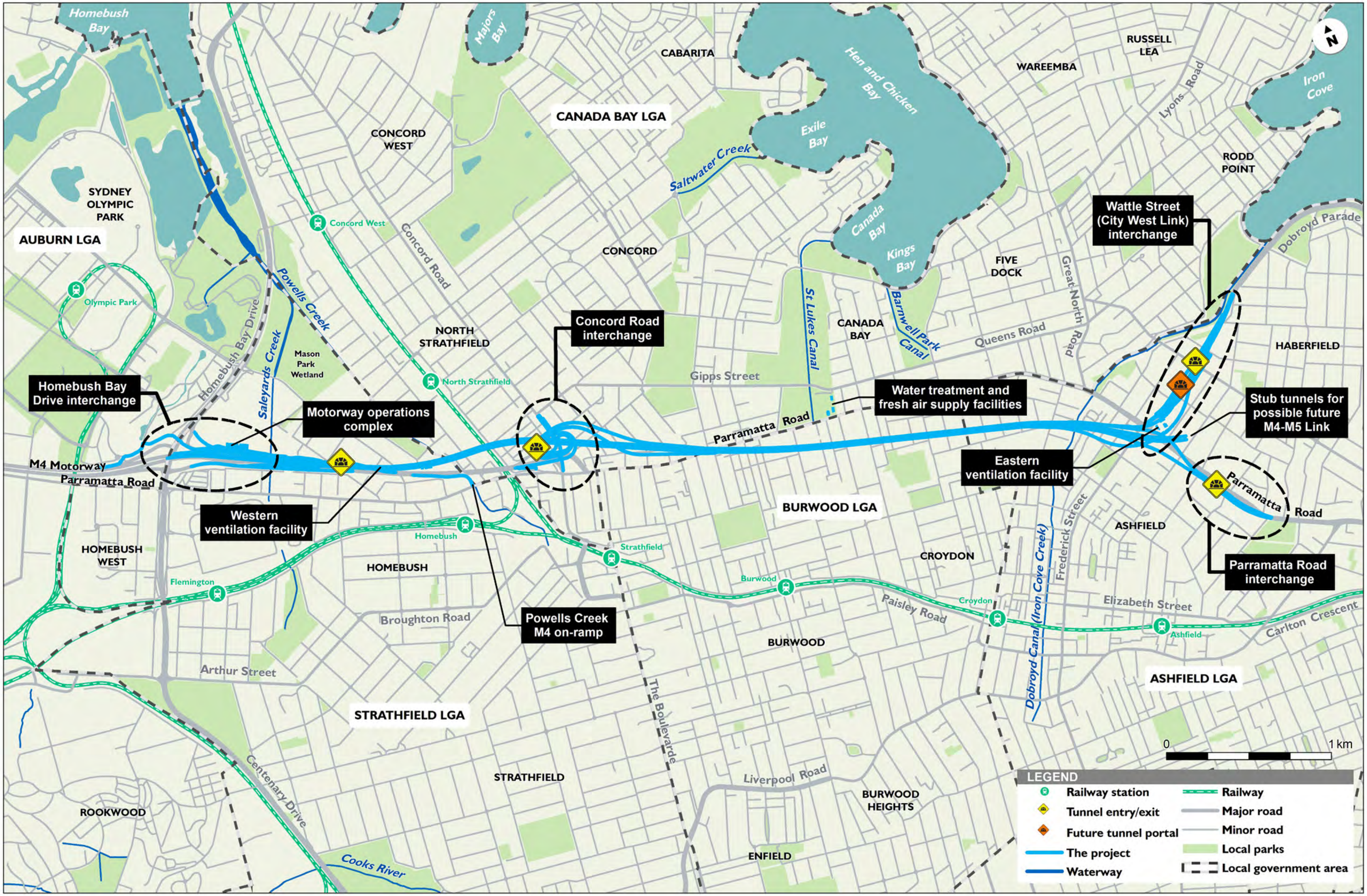

Figure 1.1 Local context of the project

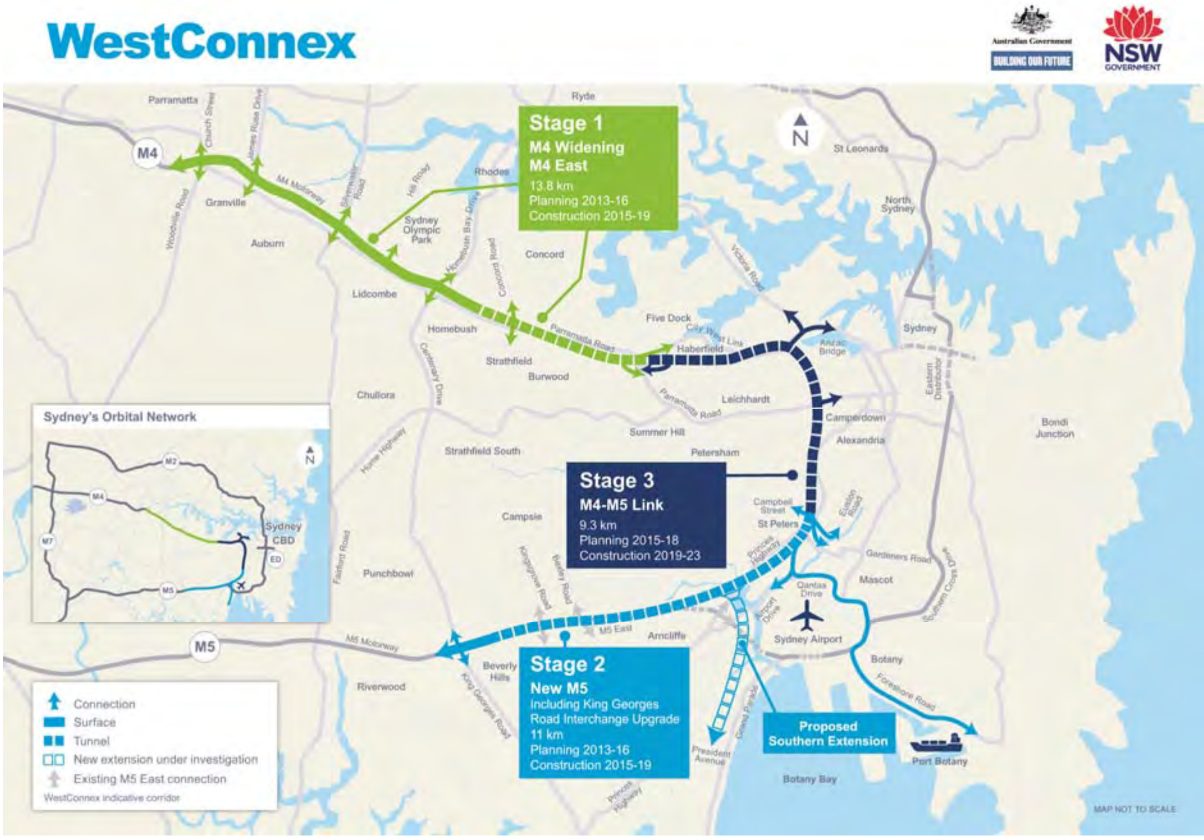

Figure 1.2 WestConnex

The tunnel dive structures would start at the centre of the M4, west of the existing pedestrian footbridge over the M4 at Pomeroy Street, and would continue underground to the north of the existing M4 and Parramatta Road, before crossing beneath Parramatta Road at Broughton Street at Burwood. The tunnels would continue underground to the south of Parramatta Road until the intersection of Parramatta Road and Wattle Street at Haberfield. Ramps would connect the tunnels to Parramatta Road and Wattle Street (City West Link) at the eastern end of the project. The tunnels would end in a stub connection to the possible future M4–M5 Link (M4–M5 Link), near Alt Street at Haberfield.

The project would include interchanges between the tunnels and the above ground road network, along with other surface road works, at the following locations:

- M4 and Homebush Bay Drive interchange at Sydney Olympic Park and Homebush (Homebush Bay Drive interchange)
- Powells Creek, near George Street at North Strathfield (Powells Creek M4 on-ramp)
- Queen Street, near Parramatta Road at North Strathfield (Queen Street cycleway westbound on-ramp)
- M4 and Sydney Street, Concord Road and Parramatta Road interchange at North Strathfield (Concord Road interchange)
- Wattle Street (City West Link), between Parramatta Road and Waratah Street at Haberfield (Wattle Street (City West Link) interchange)
- Parramatta Road, between Bland Street and Orpington Street at Ashfield and Haberfield (Parramatta Road interchange).

1.3 Secretary's environmental assessment requirements

The Secretary's Environmental Assessment Requirements (SEAR's) for the preparation of the EIS for the project were issued by the NSW Department of Planning and Environment (DP&E) on 16 June 2015. The SEAR's were prepared in consultation with relevant government agencies and local councils and include key issues that must be addressed in the EIS.

Table 1.1 sets out the surface water related SEAR's and where they have been addressed in this report. Surface water related impacts related to erosion and sediment transport/deposition, water quality and runoff volumes are presented in the *WestConnex M4 East EIS Technical Paper - Surface Water: Water Quality, Soil & Water* (GHD, 2015) (Appendix O of the EIS).

Comments received by NSW Office of Environment and Heritage (OEH), Strathfield Council and Ashfield Council during the preparation of the SEAR's relevant to flooding have also been considered in the preparation of this report (refer to **Table 1.2**).

Table 1.1Secretary's Environmental Assessment Requirements

SEARs	
Soil and Water	
Requirement	**Section where addressed in this report**
• Identification of potential impacts of the project on existing flood regimes, consistent with the Floodplain Development Manual (FDM) (DIPNR, 2005), including impacts to existing receivers and infrastructure and the future development potential of affected land, and	**Sections 5.7, 6.2** and **6.3**
• Demonstrating consideration of the changes to rainfall frequency and/or intensity as a result of climate change on the project.	**Section 6.4**
• The assessment shall demonstrate due consideration of flood risks in the project design.	**Sections 5.2** to **5.6**, as well as **Section 6.2**

Table 1.2 Agency Comments

Agency letters	
OEH	
Requirement	**Section where addressed in EIS**
Floodplain Management	
• A hydrology and hydraulic assessment shall be prepared for mainstream and overland flow paths associated with major drainage for sub-catchments including the project vicinity within Powells Creek, Hen and Chicken Bay and Dobroyd Canal sub-catchments.	**Section 3.3**, as well as **Appendices B** and **C**.
• The assessment is to address flooding behaviour for existing and developed conditions for the full range of flood sizes up to and including the PMF. The assessment should also examine both construction and operational phases and shall include:	
– A comprehensive understanding of flood risk to people and properties for the full range of the floods up to the PMF event including both construction and operational phases.	**Sections 5.2** to **5.6**, as well as **Section 6.2**
– The impact of the proposal on the existing flood behaviour including any potential reduction of floodway and flood storage areas or redistribution of flow which may result in increased flood levels on adjacent, downstream and upstream areas. This should be addressed for all proposed works on the flood prone land.	**Sections 5.7**, **6.2** and **6.3**
– An assessment of the impacts of earthworks and filling within the flood prone land up to the PMF level. Earthworks within the floodplain have the potential to alter the flood behaviour and impact the surrounding areas, therefore the assessment should be based on understanding of cumulative flood impacts of both construction and operational phase. Also filling should be limited to flood fringe areas, which are to be identified in accordance with the FDM.	**Sections 5.7**, **6.2** and **6.3**
– Details of the stormwater drainage infrastructure and overland flow paths associated with the proposed project. The assessment should examine both construction and operational stages.	**Sections 5.7**, **6.2** and **6.3**
– Identification of appropriate mitigation measures to offset potential flood risk arising from the project.	**Sections 7.2** and **7.3**
– Any proposed permanent mitigation work should be modelled and assessed on an overall catchment basis in order to overcome any adverse impact on surrounding properties and ensure the measure fits its purpose and meets the criteria of the Council where it is located.	**Section 6.2**
– Identification of temporary mitigation measures that may be implemented to protect the project's works during construction activities. Proposed temporary mitigation works would be assessed in regard to its affectation on flooding behaviour and surrounding properties during construction.	**Section 7.2**
– An assessment of the impacts of potential stockpile areas should be carried out to address their temporary impacts on flood behaviour and the	**Section 5.7**

surrounding environment. (Ideally, stockpile areas should be located in low flood risk areas i.e. above the 100 year ARI flood level).	
– A sensitivity analysis to determine the potential impacts from climate change on flooding behaviour.	**Section 6.4**
– An Emergency Response Plan (ERP) to manage larger floods considering mainstream and overland flow (local flooding) should be prepared in consultation with the State Emergency Services (SES) and relevant councils in the early stage of the construction works. The ERP would address flood evacuation needs during both construction and operational phases to ensure that safe evacuation can be achieved. Safety of construction personnel during construction stages should also be adequately addressed in the EPR to ensure that flood risk to personnel and damages to project works during construction is minimised.	**Section 7.1**
– Consideration should be given to locating the tunnel's openings outside the flood prone land taking into account both mainstream flooding and local overland flow paths. The FDM identifies flood prone land as land susceptible to flooding by the PMF event.	**Sections 5.4** and **6.2**
• Relevant Policies and Guidelines:	
– NSW Government Flood Prone Land Policy (1984) as set out in the FDM	**Section 1.4**
– Practical Consideration of Climate Change (Department of Environment, Climate Change and Water (DECCW), 2007)	**Section 1.4**
– Section 117(2) Local Planning Direction 4.3 "Flood Prone Land"	**Section 1.4**
– Planning circular PS 07-003 "New guideline and changes to section 117 direction and (Environmental Planning and Assessment (EP&A) Regulation on flood prone land"	**Section 1.4**
Strathfield Council	
Requirement	**Section where addressed in EIS**
Hydrology and Flooding	
• The flood study for Powells Creek and Saleyards Creek catchment completed by Council in 1998 indicates the extent of flooding along Powells Creek and Saleyards Creek within the Strathfield LGA.	**Appendix A**
• A flood study for the project shall be prepared by a suitably qualified hydraulics engineer competent in the catchment flood study and hydraulics analysis.	**Appendices B** and **C**
• The study would need to include assessment of the existing drainage conduits and overland flows for all durations of storm events up to and including 1 in 100 years ARI. The study should also include comment on the flood levels in the vicinity of the project up to and including PMF and demonstrate that the project has no adverse effects on the adjoining properties as a result of flooding and stormwater runoff, and there is adequate protection for the proposal against the ingress of stormwater runoff.	**Chapters 4**, **5** and **6**
• Strathfield Council Stormwater Management Policy.	**Section 1.4**

Ashfield Council	
Requirement	**Section where addressed in EIS**
Stormwater Flooding at Dobroyd Parade / Reg Coady Reserve Area: • The EIS must give consideration to the 'Dobroyd Canal Flood Study October 2013', produced for Ashfield and Burwood councils by 'WMA Water', and whether its findings will impact the position and design of the proposed Wattle Street portals. Consultation should therefore occur with the project consultants and Ashfield Council.	**Appendix A**

1.4 Relevant policies and guidelines

1.4.1 General

Policies and guidelines that have been considered as part of this assessment (arranged in date order) include:

- *Flood Prone Land Policy* (NSW Government)
- *Section 117(2) Local Planning Direction 4.3 "Flood Prone Land"* (NSW Government)
- *Planning circular PS 07-003 "New guideline and changes to section 117 direction and (Environmental Planning and Assessment (EP&A) Regulation on flood prone land"* (NSW Government)
- *Guideline on Development Controls on Low Flood Risk Areas* (NSW Government)
- *Stormwater Management Code* (Strathfield Council, 1994)
- *Australian Rainfall and Runoff* (AR&R) (Institution of Engineers Australia (IEAust), 1998)
- *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (Bureau of Meteorology (BoM), 2003)
- *Floodplain Development Manual* (Department of Infrastructure, Planning and Natural Resources (DIPNR), 2005)
- *Floodplain Risk Management Guideline – Practical Considerations of Climate Chang*e (Department of Environment, Climate Change and Water (DECCW), 2007).
- *Derivation of the NSW Government's Sea Level Rise Planning Benchmarks. Technical Note* (DECCW, 2009)
- *Specification for the Management of Stormwater* (City of Canada Bay, 2009)
- *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010).
- *AR&R Revision Projects – Project 11 – Blockage of Hydraulic Structures* (Engineers Australia (EA), 2013)
- *Stormwater Management Policy (*Ashfield Council, 2013).

1.4.2 Floodplain Development Manual

The FDM incorporates the NSW Government's Flood Prone Land Policy, the primary objectives of which are to reduce the impact of flooding and flood liability on owners and occupiers of flood prone property and to reduce public and private losses resulting from floods, whilst also recognising the benefits of use, occupation and development of flood prone land.

The FDM forms the NSW Government's primary technical guidance for the development of sustainable strategies to support human occupation and use of the floodplain, and promotes strategic consideration of key issues including safety to people, management of potential damage to property and infrastructure, and management of cumulative impacts of development. Importantly, the FDM promotes the concept that proposed developments be treated on their merit rather than through the imposition of rigid and prescriptive criteria.

Flood and floodplain risk management studies undertaken by local councils as part of the NSW Government's Floodplain Management Program are undertaken in accordance with the merits based approach promoted by the FDM. A similar merits based approach has been adopted in the assessment of the impacts the project would have on existing flood behaviour and also in the development of a range of potential measures which would be aimed at mitigating the impact of the project on the existing environment.

1.4.3 Planning Directions and Guidelines

In January 2007 the then NSW Department of Planning (DoP) issued *Planning circular PS 07-003 "New guideline and changes to section 117 direction and (Environmental Planning and Assessment (EP&A) Regulation on flood prone land"* which provided an overview of its new guideline to the FDM titled *Guideline on Development Controls on Low Flood Risk Areas* and changes to the Environmental Planning and Assessment Regulation 2000 and Section 117 Direction on flood prone land. More specifically, the circular provided advice on a package of changes concerning flood-related development controls on residential development on land above the 100 year average recurrence interval (ARI) flood and up to the probable maximum flood (PMF). These areas are sometimes known as low flood risk areas.

Guideline on Development Controls on Low Flood Risk Areas confirmed that unless there are exceptional circumstances, councils should adopt the 100 year ARI flood as the Flood Planning Level (FPL) for residential development. In proposing a case for exceptional circumstances, a council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. The guideline also notes that, unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas). However, the guideline does acknowledge that controls may need to apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (like nursing homes) in areas above the 100 year ARI flood.

In July 2007 the then NSW Government's Minister for Planning issued a list of directions to local councils under section 117(2) of the EP&A Act. *Direction 4.3 - Flood Prone Land* applies to all councils that contain flood prone land within their LGA and requires that:

- A draft Local Environmental Plan (LEP) shall include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the FDM (including the *Guideline on Development Controls on Low Flood Risk Areas*).
- A draft LEP shall not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone.
- A draft LEP shall not contain provisions that apply to the flood planning areas which:

  (a) permit development in floodway areas,

  (b) permit development that will result in significant flood impacts to other properties,

  (c) permit a significant increase in the development of that land,

  (d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or

  (e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development.

- A draft LEP must not impose flood related development controls above the residential flood planning level for residential development on land, unless a council provides adequate justification for those controls to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

- For the purposes of a draft LEP, a council must not determine a flood planning level that is inconsistent with the FDM (including the *Guideline on Development Controls on Low Flood Risk Areas*) unless a council provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General (or an officer of the Department nominated by the Director-General).

Based on the above requirements, the assessment of the impacts the project would have on existing flood behaviour and also the future development potential of flood affected land outside the project corridor relates to all storms with ARI's up to 100 years in the case of residential type development (and by default commercial and industrial type development) and for storms with ARI's greater than 100 years in the case of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities). The key findings of the assessment in this regard are set out in **section 6.3**.

1.4.4 Floodplain Risk Management Guidelines

Scientific evidence shows that climate change will lead to sea level rise and potentially increase flood producing rainfall intensities. The significance of these effects on flood behaviour will vary depending on geographic location and local topographic conditions. Climate change impacts on flood producing rainfall events show a trend for larger scale storms and resulting depths of rainfall to increase. Future impacts on sea levels are likely to result in a continuation of the rise which has been observed over the last 20 years.

OEH recommends that its guideline *Practical Considerations of Climate Change, 2007* (DECC, 2007) be used as the basis for examining climate change induced increases in rainfall intensities in projects undertaken under its State Floodplain Management Program, according to procedures set out in the FDM. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent. Under present day climatic conditions, increasing the 100 year ARI design rainfall intensities by 10 per cent would produce a 200 year ARI flood; and increasing those rainfalls by 30 per cent would produce a 500 year ARI event. On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit. Based on this understanding, the impact 10 and 30 per cent increases on 100 year ARI design rainfall intensities would have on flooding behaviour under post-construction conditions has been assessed. For similar reasons, the 50 and 100 year ARI events were adopted as being analogous to the 20 year ARI design rainfall intensities increased by 10 per cent and 30 per cent respectively.

The NSW Government had previously adopted a Sea Level Rise Policy Statement (NSW Government, 2009) to support adaptation to projected sea level rise impacts. The policy statement included sea level rise planning benchmarks for use in assessing potential impacts of projected sea level rise in coastal areas, including flood risk and coastal hazard assessment. These benchmarks were a projected rise in sea level (relative to 1990 mean sea level) of 0.4 metres by 2050 and 0.9 metres by 2100, based on work carried out by the Intergovernmental Panel on Climate Change and CSIRO. OEH recommends in its guideline *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (DECCW, 2010) that these benchmark rises should be used to assess the sensitivity of flood behaviour to future sea level rise.

The NSW Government announced its *Stage 1 Coastal Management Reforms* in September 2012. As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks, with local councils now having the flexibility to consider local conditions when determining local future hazards. In the absence of a formal State Government policy on sea level rise benchmarks, the previously recommended rises in sea level of 0.4 metres by 2050 and 0.9 metres by 2100 have been adopted for assessment of the project.

Details on the climate change scenarios that were assessed as part of this investigation are set out in **section 3.5.3**.

1.5 Study area

All project activities would lie within the following six catchments which form part of the larger Parramatta River catchment:

- Powells Creek – Homebush Bay Drive at Homebush to Concord Road at North Strathfield
- Exile Bay – Concord Road to Park Road at Concord
- St Lukes Park Canal –Park Road to Royce Avenue in Concord, Burwood and Croydon
- Barnwell Park – Royce Avenue to Scott Street at Croydon[1]
- Dobroyd Canal (Iron Cove Creek) – Scott Street at Croydon to Orpington Street at Ashfield
- Hawthorne Canal – east of Orpington Street at Ashfield[2]

Figure 1.3 over the page shows the extent of the project works within each of the above six catchments.

Hydrologic modelling was carried out to define peak flows and discharge hydrographs for a range of design storms within the study catchments shown in **Figure 1.3**[2]. The discharge hydrographs were then used as input to hydraulic models that were developed to define flooding patterns in the vicinity of the project corridor under present day, construction phase and post-construction phase conditions.

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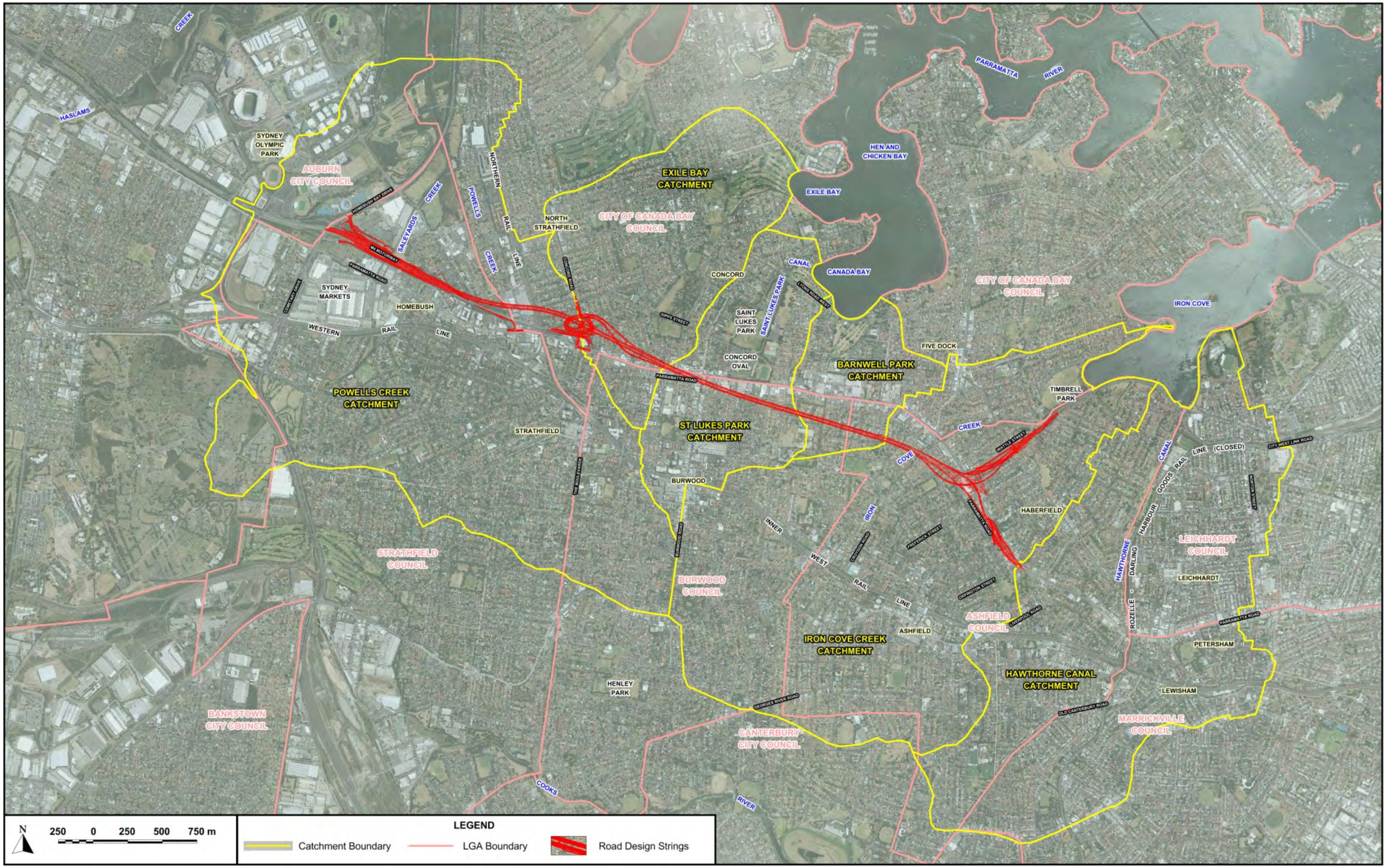
[1] The project is in tunnel where it crosses the Barnwell Park catchment and therefore the project works will not result in any change to flooding and drainage patterns within this catchment.

[2] The project extends along Parramatta Road east of Orpington Street for approximately 60 metres into the Hawthorne Canal catchment. However, proposed works east of Orpington Street would involve minor road adjustments and line marking and will therefore not result in any significant change to flooding and drainage patterns within the Hawthorne Canal catchment. As a result, proposed works east of Orpington Street have not been included in the flooding and drainage assessment.

Figure 1.3 Study area



1.6 Purpose and layout of this report

This report presents the findings of an investigation which was undertaken to assess flooding and drainage related issues associated with the construction and operation of the project. This report has been prepared to support the EIS.

Chapter 1 sets out the flooding and drainage related environmental requirements which were issued by the DP&E on 16 June 2015 for the preparation of the EIS. Also set out in **Chapter 1** are the relevant government policies and industry standards / guidelines which were taken into consideration during the investigation.

Chapter 2 describes the project-specific works which have the potential to alter flooding behaviour in the highly urbanised catchments through which it runs.

Chapter 3 sets out the methodology which was adopted for undertaking the flooding and drainage investigation for the project.

Chapter 4 provides a brief description of the catchments through which the project runs, as well as the drainage systems which control runoff in the vicinity of the project.

Chapter 5 deals with the flood risk at the proposed construction compounds (referred to herein as 'civil sites'), as well as the impact construction activities would have on flooding behaviour.

Chapter 6 deals with the impact the project would have on the flooding behaviour following its construction, as well as details of the hydrologic standard which is achieved at the various interchanges and tunnel portals.

Chapter 7 outlines additional measures which would be required to mitigate construction and operational related impacts of the project on flooding conditions in adjacent development.

Chapter 8 summarises the key findings of the investigation.

Chapter 9 contains a list of references.

Figures referred to in **Chapters 4** to **7** are located after **Chapter 9** of this report.

Appendix A summarises previous studies and reports related to the catchments through which the project runs.

Appendix B details the results of the hydrologic modelling which was undertaken to define discharge hydrographs for input to the hydraulic models. The appendix includes a description of the process that was undertaken in the development of the hydrologic models, the adopted set of model parameters and the derivation of design storm rainfalls for a range of storm durations and their conversion to discharge hydrographs.

Appendix C deals with the development of the (Two-dimensional Unsteady FLOW) TUFLOW hydraulic models that were used to define flooding patterns under present day, construction phase and post-construction phase conditions.

Appendix D contains a series of figures which show flooding patterns for design storms with ARI's of five, 20 and 200 years.

The scales on figures referred to in **Chapters 4** to **7** and **Appendices B**, **C** and **D** are applicable when printed at A3 size.

1.7 Available data

The following catchment related data were provided by WDA:

- Ortho-rectified aerial photography covering the study area
- Airborne laser scanning (ALS) survey which was flown in 2013
- Geographic Information System (GIS) datasets including property boundary information and 2 metre contour data

- Detailed field survey along Dobroyd Parade and City West Link between Ramsay Street and Robson Park

The following preferred design related data were provided by WDA:

- Drainage design report
- Drawings showing general arrangement, drainage design and construction site layouts
- Road and drainage design models
- TUFLOW hydraulic models developed as part of the preferred design

The following documents and data were obtained from other sources (as noted):

- Various study reports related to the catchments through which the project runs (refer Appendix A for details).
- GIS datasets which contain details of the existing stormwater drainage network in the catchments which drain across the project corridor (e.g. pits, pipes and open channels). Datasets were provided by Sydney Water (SW), City of Canada Bay Council, Ashfield Council and Burwood Council.
- Capacity assessment reports which were provided by SW for Powells Creek, St Lukes Park Canal, Dobroyd Canal (Iron Cove Creek) and Hawthorne Canal.

2 Proposed project

2.1 Project features

The project would comprise the construction and operation of the following key features:

- Widening, realignment and resurfacing of the M4 between Homebush Bay Drive and Underwood Road at Homebush
- Upgrade of the existing Homebush Bay Drive interchange to connect the western end of the new tunnels to the existing M4 and Homebush Bay Drive, while maintaining all current surface connections
- Two new three-lane tunnels (the mainline tunnels), one eastbound and one westbound, extending from west of Pomeroy Street at Homebush to near Alt Street at Haberfield, where they would terminate until the completion of the M4–M5 Link. Each tunnel would be about 5.5 kilometres long and would have a minimum internal clearance (height) to in-tunnel services of 5.3 metres
- A new westbound on-ramp from Parramatta Road to the M4 at Powells Creek, west of George Street at North Strathfield
- An interchange at Concord Road, North Strathfield/Concord with on-ramps to the eastbound tunnel and off-ramps from the westbound tunnel. Access from the existing M4 to Concord Road would be maintained via Sydney Street. A new on-ramp would be provided from Concord Road southbound to the existing M4 westbound, and the existing on-ramp from Concord Road northbound to the existing M4 westbound would be removed
- Modification of the intersection of the existing M4 and Parramatta Road, to remove the left turn movement from Parramatta Road eastbound to the existing M4 westbound
- An interchange at Wattle Street (City West Link) at Haberfield with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. The project also includes on- and off-ramps at this interchange that would provide access to the M4–M5 Link. In addition, the westbound lanes of Wattle Street would be realigned
- An interchange at Parramatta Road at Ashfield/Haberfield, with an on-ramp to the westbound tunnel and an off-ramp from the eastbound tunnel. In addition, the westbound lanes of Parramatta Road would be realigned
- Installation of tunnel ventilation systems, including ventilation facilities within the existing M4 road reserve near Underwood Road at Homebush (western ventilation facility) and at the corner of Parramatta Road and Wattle Street at Haberfield (eastern ventilation facility). The eastern ventilation facility would serve both the project and the M4–M5 Link project. Provision has also been made for a fresh air supply facility at Cintra Park at Concord
- Associated surface road work on the arterial and local road network, including reconfiguration of lanes, changes to traffic signalling and phasing, and permanent road closures at a small number of local roads
- Pedestrian and cycle facilities, including permanently re-routing a portion of the existing eastbound cycleway on the northern side of the M4 from west of Homebush Bay Drive to near Pomeroy Street, and a new westbound cycleway on-ramp connection from Queen Street at North Strathfield to the existing M4
- Tunnel support systems and services such as electricity substations, fire pump rooms and tanks, water treatment facilities, and fire and life safety systems including emergency evacuation infrastructure
- Motorway operations complex on the northern side of the existing M4, east of the Homebush Bay Drive interchange
- Provision of road infrastructure and services to support the future implementation of smart motorway operations (subject to separate planning approval)

- Installation of tolling gantries and traffic control systems along the length of the project
- Provision of new and modified noise walls
- Provision of low noise pavement for new and modified sections of the existing M4
- Temporary construction ancillary facilities and temporary works to facilitate the construction of the project.

An overview of the project at completion is shown in **Figure 2.1**.

The project does not include work required for reconfiguring Parramatta Road as part of the urban transformation program. The project does not include ongoing motorway maintenance activities during operation. These would be subject to separate assessment and approval as appropriate.

2.2 Construction activities

2.2.1 Overview

Construction activities associated with the project would generally include:

- Enabling and temporary works, including construction power, water supply, ancillary site establishment, demolition works, property adjustments and public transport modifications (if required)
- Construction of the road tunnels, interchanges, intersections and roadside infrastructure
- Haulage of spoil generated during tunnelling and excavation activities
- Fitout of the road tunnels and support infrastructure, including ventilation and emergency response systems
- Construction and fitout of the motorway operations complex and other ancillary operations buildings
- Realignment, modification or replacement of surface roads, bridges and underpasses
- Implementation of environmental management and pollution control facilities for the project.

The project assessed in this report does not include surveys, sampling or investigation to inform the design or assessment, such as test drilling, test excavations, geotechnical investigations, or other tests. It also does not include adjustments to, or relocation of, existing utilities infrastructure undertaken prior to commencement of construction. These would be subject to separate assessment and approval as appropriate.

2.2.2 Construction footprint

The total area required for construction of the project, including construction ancillary facilities, is referred to as the ‘construction footprint’. The construction footprint would be about 65 hectares in total, comprising about 48 hectares at the surface and about 17 hectares below ground.

In addition to below ground works, surface works would be required to support tunnelling activities and to construct surface infrastructure such as interchanges, tunnel portals, ventilation facilities, ancillary operations buildings and facilities, and new cycleway facilities near the Homebush Bay Drive interchange and Queen Street at North Strathfield.

The overall surface construction footprint generally aligns with the operational footprint, with the locations of future operational ancillary facilities being used to support construction work. Some additional areas adjacent to the operational footprint (around the portals and on- and off-ramps, and also at the tunnel mid-point) would also be required during the construction stage only to facilitate construction.

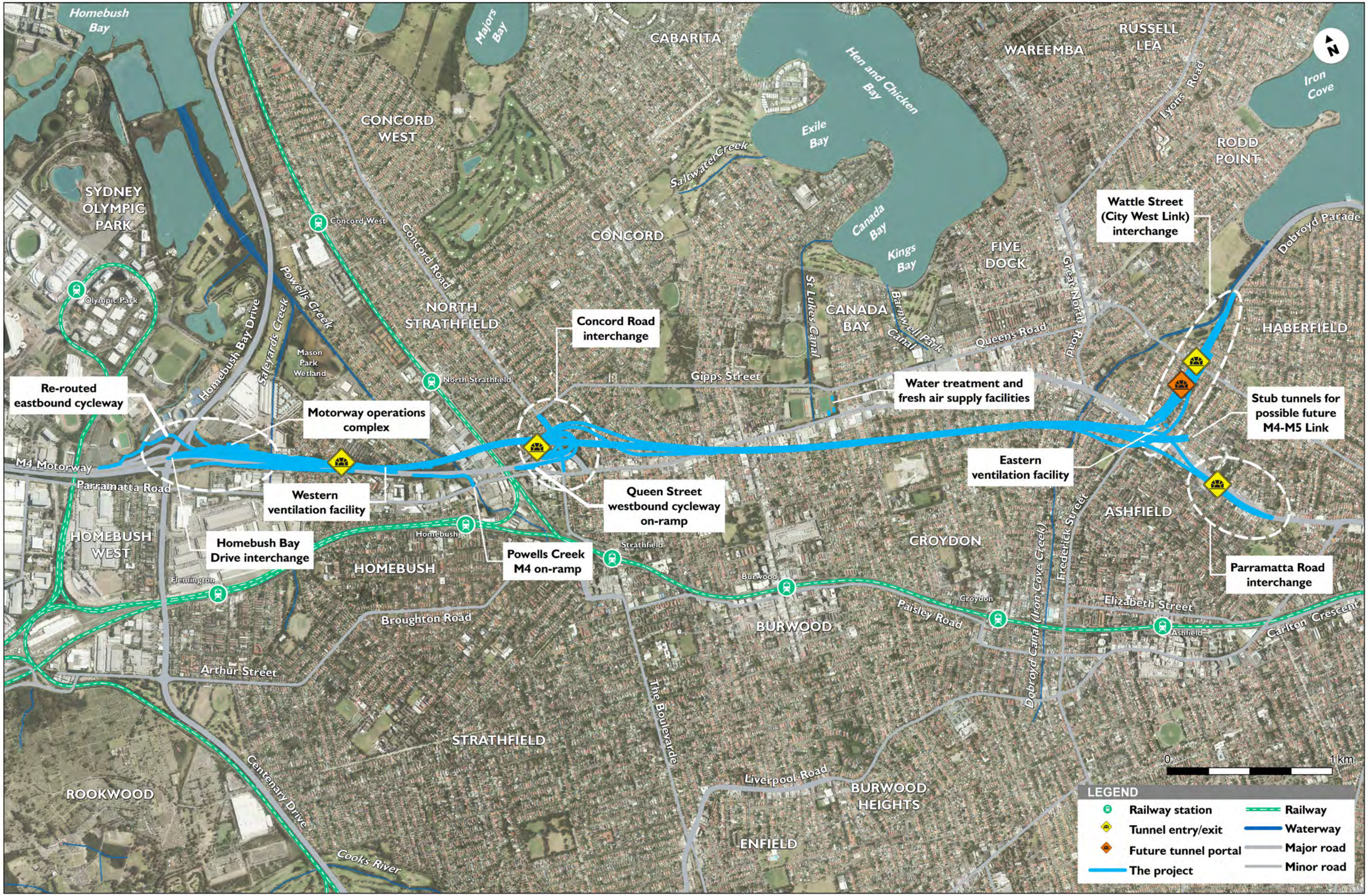


Figure 2.1 Overview of the proejct

Construction ancillary facilities currently proposed would be required at the following 10 locations:

- Homebush Bay Drive civil site (C1)
- Pomeroy Street civil site (C2)
- Underwood Road civil and tunnel site (C3)
- Powells Creek civil site (C4)
- Concord Road civil and tunnel site (C5)
- Cintra Park tunnel site (C6)
- Northcote Street tunnel site (C7)
- Eastern ventilation facility site (C8)
- Wattle Street and Walker Avenue civil site (C9)
- Parramatta Road civil site (C10).

An overview of the construction footprint is shown in **Figure 2.2**.

The final size and configuration of construction ancillary facilities would be further developed during detailed design.

2.2.3 Construction program

Subject to planning approval, construction of the project is planned to start in the second quarter of 2016, with completion planned for the first quarter of 2019. The total period of construction works is expected to be around three years, including nine months of commissioning occurring concurrently with the final stages of construction. The indicative construction program is shown in **Table 2.1**.

Table 2.1 Indicative construction program overview

Construction activity	Indicative construction timeframe															
	2016				2017				2018				2019			
Construction access excavation (all sites)		■	■	■												
Tunnelling (excavation)			■	■	■	■	■	■								
Tunnel drainage and pavement works						■	■	■	■	■						
Tunnel mechanical and electrical fitout works								■	■	■	■					
Tunnel completion works											■	■	■			
Homebush Bay Drive interchange			■	■	■	■	■	■	■	■						
M4 surface works		■	■	■	■	■	■	■	■	■	■	■				
Western ventilation facility							■	■	■	■	■					
Powells Creek on-ramp		■	■	■	■	■										
Concord Road interchange			■	■	■	■	■	■	■	■	■	■				
Wattle Street interchange		■	■	■	■	■	■	■	■	■	■	■	■			
Parramatta Road interchange		■	■	■	■	■	■	■	■	■	■	■	■			
Eastern ventilation facility		■	■	■	■	■	■	■	■	■	■	■				
Cintra Park fresh air supply facility				■	■	■	■	■	■	■	■	■	■			
Cintra Park water treatment facility										■	■					
Motorway operations complex						■	■	■								
Mechanical and electrical fitout works							■	■	■	■	■	■				
Site rehabilitation and landscaping						■	■	■	■	■	■	■	■			

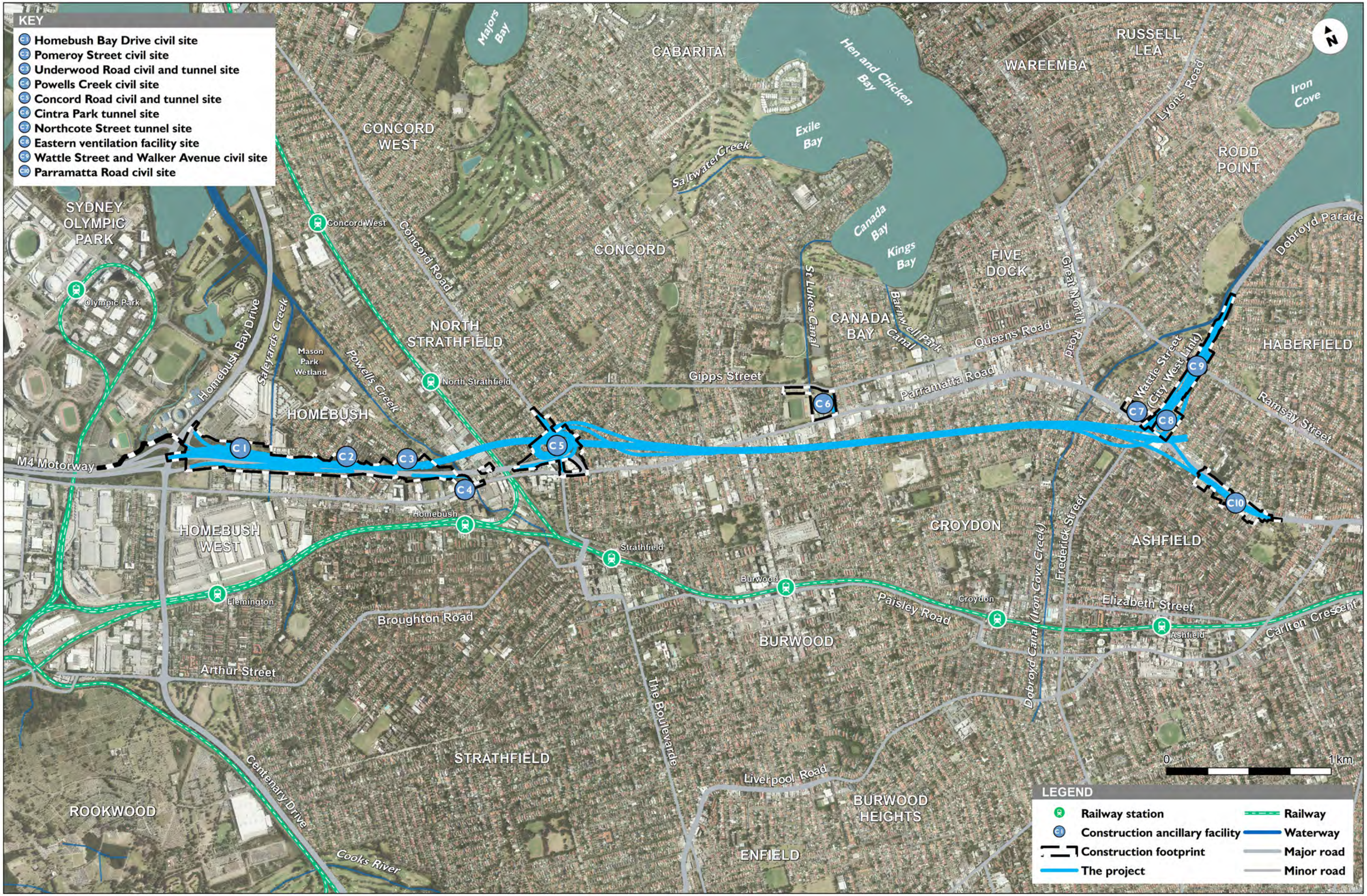


Figure 2.2 Overview of construction footprint and construction ancillary facilities

2.4 Flooding and drainage related components

2.4.1 Bridges and tunnel portals

Subject to detailed design, five new bridge structures would be constructed over Saleyards Creek to accommodate the widened and realigned eastbound and westbound carriageways, on and off-ramps associated with the realignment of the M4 between Homebush Bay Drive at Homebush and Underwood Road at North Strathfield, as well as an eastbound cycleway overpass. The project would also require an elevated bridge structure to be constructed over Powells Creek to accommodate the Powells Creek on-ramp from Parramatta Road to the M4 westbound.

The following four interchanges and their associated tunnel portals would provide surface connections to the proposed road tunnels:

- the M4 at Homebush (Homebush Bay Drive interchange);
- the M4 and Concord Road at North Strathfield (Concord Road interchange);
- Parramatta Road at Haberfield (Parramatta Road interchange); and
- Wattle Street at Haberfield (Wattle Street (City West Link) interchange).

As part of the project, on and off-ramps would also be constructed on Wattle Street to provide a surface connection from the eastbound and westbound tunnels that would form part of a future M4−M5 Link project.

2.4.2 Surface drainage works

Surface works associated with the project are located in areas where existing stormwater drainage systems presently control runoff from the surrounding highly urbanised catchments. As a result, it would be necessary to upgrade/alter several of these systems where they are impacted by the project. These changes would comprise the following:

- Widening, realignment and resurfacing of the M4 between Homebush Bay Drive at Homebush and Underwood Road at North Strathfield:
  - Installation of a new pavement drainage system which would control runoff from the widened section of the M4 extending from Homebush Bay Drive to the overbridge at Underwood Road. This pavement drainage system would also control runoff from a 130 metre length of the M4 Widening project west of Homebush Bay Drive.
  - Provision of water quality and spill containment measures which would comprise a series of basins or similar. These measures would treat runoff from the new pavement drainage systems prior to its discharge into Saleyards Creek.
- Powells Creek on-ramp:
  - Installation of a new pavement drainage system which would control runoff from the new on-ramp connecting the M4 to Parramatta Road west of George Street at North Strathfield.
  - Provision of a gross pollutant trap (GPT) (or similar device) and spill containment tank which would treat runoff prior to its discharge to Powells Creek.
- Homebush Bay Drive interchange:
  - Diversion of the existing piped drainage system between Pomeroy Street and Underwood Road around the tunnel dive structure at the Homebush Bay Drive interchange.
- Concord Road interchange:
  - Installation of a new stormwater drainage system which would control runoff from the section of the M4 near the modified Concord Road bridge. The new stormwater drainage line would run in a westerly direction along the road corridor and connect to the existing stormwater drainage system in Queen Street.
  - Installation of a new drainage line which will be located on the eastern side of Concord Road and connect to the existing stormwater drainage system in Alexandra Street.

- Realignment and extension of existing drainage lines along Sydney Road and Concord Road to accommodate the proposed road adjustments.
- Provision of GPT's at outlet of new drainage lines in Queen Street and Alexandra Street.

- Parramatta Road interchange:
  - Installation of a new drainage line from along Bland Street and connection to the existing Sydney Water (SW) trunk drainage line that runs in a westerly direction south of Parramatta Road.
  - Alterations to the existing stormwater drainage system in Parramatta Road between Orpington Street and Bland Street.
  - Provision of an on-site detention tank at Bland Street.
  - Provision of GPT's at selected drainage outlets in Bland Street and Chandos Street.
- Wattle Street (City West Link) interchange:
  - Extension of existing stormwater drainage lines along Dobroyd Parade and Wattle Street and the provision of new stormwater drainage lines along the new sections of road.
  - Connection of the new stormwater drainage lines to the existing drainage system in Wattle Street at Parramatta Road, Ash Lane and Martin Street.
  - New drainage outlets into Dobroyd Canal (Iron Cove Creek) at Reg Coady Reserve.
  - Provision of a GPT at the new connection in Martin Street and also GPT's at the new outlets in Reg Coady Reserve.

Runoff at the tunnel dive structures would be collected by the tunnel drainage system where it would discharge to the sump located in the vicinity of the tunnel low point. The sump will be fitted with accidental spill containment tank. Runoff will then be pumped from the sump to Cintra Park where it will flow through a water quality basin (bio-retention basin), prior to discharging to the existing stormwater drainage system at St Lukes Park Canal.

3 Assessment methodology

3.1 Overview

This chapter sets out the methodology that has been adopted in the definition of flooding behaviour in the vicinity of the project and also the impact the project would have on flooding behaviour. The hydrologic standards adopted in the assessment of impacts and identification of mitigation measures is also presented in this chapter.

The approach adopted in the assessment of flood impacts and identification of mitigation measures was as follows:

- Development of computer based hydrologic models which were used to generate discharge hydrographs for input to the hydraulic models. The DRAINS software was used for this purpose. Details of the hydrologic modelling are presented in **Appendix B**.
- Development of computer based hydraulic models which were used to convert the aforementioned discharge hydrographs into peak flood levels, depths of inundation and flow velocities. The TUFLOW software was used for this purpose. Details of the hydraulic modelling are presented in **Appendix C**.
- Definition of flood behaviour under pre-project conditions (refer **Chapter 4**).
- Assessment of the impact the project would have on flooding behaviour and also the flood risks associated with the construction and operation of the project (refer **Chapters 5** and **6**).
- Assessment of the impact the project will have on the development potential of land adjacent to the project corridor (**Chapter 6**)
- Identification of measures that are aimed at:
  - mitigating the impacts of the project on flood behaviour, and
  - achieving the required level of flood immunity to the project infrastructure (refer **Chapter 7**).

3.2 Adopted minimum hydrologic standards

3.2.1 General

Hydrologic standards adopted in the assessment of transverse drainage and flood mitigation measures were established in accordance with the FDM and current Roads and Maritime standards. In accordance with the FDM the hydrologic standards adopted are based on matching the level of protection to the risk and consequence of flooding.

3.2.2 Tunnel portals and ancillary facilities

Tunnel portals are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). This level of security against ingress is commensurate with the consequence of flooding to the tunnels and the risk to road users and is consistent with the current standard adopted in the design of road and rail tunnels in NSW.

The same hydrologic standard would also apply to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.

3.2.3 Emergency response facilities

Emergency response facilities would include the motorway control centre which would contain incident response rooms and an emergency vehicle depot, as well as fire water tank and pump buildings to service the tunnels.

Emergency response facilities are to be located above the probable maximum flood (PMF) level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). This level of security against inundation is commensurate to the consequence of these facilities being non-operational during a flood. This approach is consistent with current best floodplain risk management practice in NSW.

The same hydrologic standard would apply to electrical substations that are reliant upon for the safe operation of the motorway and associated emergency response facilities.

3.2.4 M4 upgrade

A 100 year ARI level of flood immunity is to be provided to the upgraded section of the M4 between Homebush Bay Drive and Parramatta Road. This level of flood immunity is consistent with the current standard adopted by Roads and Maritime for motorways and is also consistent with the level of flood immunity provided to the existing M4 between Homebush Bay Drive and Parramatta Road (refer **section 4.3.2** for details).

3.2.5 Bridge waterway crossings

Bridge crossings over waterways are to provide a minimum clearance of 0.5 metres between the underside of the bridge structure and the 100 year ARI flood level. This level of clearance is consistent with the current standard adopted by Roads and Maritime.

3.2.6 Modifications to existing road network

Modifications to existing roads at their point of connection to the project are to be configured to ensure that the existing level of flood immunity is maintained.

3.2.7 Impacts of flooding on existing development

A 100 year ARI flood standard is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions are also to be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazard as a result of the project.

3.2.8 Construction related flood risks and impacts

Construction related flood risks and impacts need to be evaluated in the context of the construction period in order to set requirements that are commensurate to the period of time that the risk exposure occurs. To this end, this report identifies the risks and impacts associated with each construction activity such that informed decisions can be made on the flood criteria that are set as part of the flood risk management plan for the construction of the project.

3.3 Definition of present day flooding behaviour

In order to define the nature of flooding in the vicinity of the project it was necessary to develop a set of computer-based flood models. The DRAINS rainfall-runoff modelling software package was used to generate design discharge hydrographs (rate of flow (discharge) versus time at a particular point) for input to the hydraulic models, while flooding patterns in the vicinity of the project were defined using the TUFLOW two-dimensional (in plan) hydraulic modelling software.

Four TUFLOW models were developed covering the catchments of Powells Creek (denoted the ‘Powells Creek TUFLOW Model’), St Lukes Park Canal (‘St Lukes Canal TUFLOW Model’), Dobroyd Canal (Iron Cove Creek) (‘Iron Cove Creek TUFLOW Model’) and drainage line XD04 (Exile Bay Catchment) where it crosses the project west of Concord Road (‘Concord Road TUFLOW Model’.

In the case of the Powells Creek, St Lukes Park Canal and Iron Cove Creek TUFLOW models, it was necessary to decide upon coincident catchment and ocean flooding conditions from which design flood envelopes could be derived. Site specific ocean level data were used to define peak storm tide levels for ocean floods ranging between 20 and 100 year ARI. An estimate of the peak storm tide level which would be reached for an extreme ocean flood event was also derived by extrapolation of the site specific data. **Section C4.2** in **Appendix C** contains further background to the derivation of storm tide hydrographs which were used for defining design flood levels in the vicinity of the project.

Flooding behaviour in the vicinity of the project was defined for a range of events with ARI's of five to 200 years, as well as the PMF. A brief description of flooding behaviour in the vicinity of the project under present day conditions is presented in **Chapter 4**.

3.3.1 Sensitivity analyses

The sensitivity of the hydraulic model was tested to variations in model parameters such as hydraulic roughness and varying tailwater conditions. In the case of the Iron Cove Creek TUFLOW model, the sensitivity of the model was also tested to variations in blockage of two pedestrian bridge structures that are located over the creek west of Dobroyd Parade. The main purpose of these studies was to give some guidance on the freeboard which might be adopted in the design of the Surface Works.

The findings of the sensitivity analyses in relation to the resulting changes in flooding behaviour are presented in **sections C6.1** to **C6.3** within **Appendix C**.

3.3.2 Comparison of results with previous studies

Results from the Iron Cove Creek TUFLOW model were compared to peak flood levels presented in WMAwater (2014) at five locations in the vicinity of the project for the 100 year ARI and PMF events. The findings of this comparison are presented in **section C7** of **Appendix C**.

3.4 Assessment of construction related impacts

A preliminary investigation was undertaken to assess the potential impacts of construction activities on flooding behaviour under 100 year ARI conditions. This involved making adjustments to the structure of the TUFLOW models that were originally developed to define flooding behaviour under present day conditions to reflect the blocking effects of the construction ancillary facilities. The changes that were made to the structure of the hydraulic models are shown in **Table 5.2** in **Chapter 5**, while a discussion on the impact the construction of the project would have on flooding behaviour is contained in **sections 5.2** and **5.3**.

3.5 Assessment of post-construction related impacts

3.5.1 Present day (2015) climatic and ocean boundary conditions

The structure of the TUFLOW models that were originally developed to define flooding behaviour under present day conditions was adjusted to incorporate details of the project under post-construction conditions. The results of modelling a range of events with ARI's of five to 200 years, together with the PMF event were used to prepare a series of figures showing flooding patterns under post-construction conditions and afflux diagrams showing the impact the project would have on flooding behaviour.[3] The changes that were made to the structure of the hydraulic models used to define flooding behaviour in the vicinity of the project is discussed in **Section C9** of **Appendix C**, while a discussion on the potential project impacts on flooding behaviour under post-construction conditions is contained in **section 6.2**.

3.5.2 Assumed future catchment conditions

The assessment of transverse drainage and flood mitigation requirements was based on flows which result from the current level of development within the catchments which drain across the project corridor (denoted herein as 'present day' or 'pre-project' conditions). As noted in **Chapter 4**, the catchments upstream of the project corridor are already highly urbanised in nature. As a result, there is limited scope for additional infill development that could result in a significant increase in catchment runoff.

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[3] *In the context of this report, afflux is the difference in peak flood levels caused by changes to the floodplain. For example, due to a change in hydraulic roughness or the construction of the project.*

The proposed surface works for the project are located within the LGA's of Auburn, Strathfield, Ashfield and City of Canada Bay.[4] All four Councils have prepared stormwater management codes or specifications for the management of runoff from proposed developments which include a requirement that peak discharges from the development sites are limited to pre-development conditions for all storms up to 100 year ARI.

3.5.3 Future climate change induced conditions

Based on the guidelines set out in **section 1.4.3**, the following scenarios were adopted as being representative of the likely lower and upper bound estimates of climate change impacts over the design life of the project:

- Scenario 1 – based on an assumed 10 per cent increase in 2015 rainfall intensities, together with a rise in sea level of 0.4 metres.
- Scenario 2 – based on an assumed 30 per cent increase in 2015 rainfall intensities, together with a rise in sea level of 0.9 metres.

The combinations of catchment and coincident storm tide conditions that were used to define the 100 year ARI and PMF design flood envelopes under scenario 1 and 2 climatic conditions are shown in **Table 3.1**.

There are currently no guidelines which quantify the likely increase in probable maximum precipitation (PMP) associated with future climate change. By its definition, the PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism in regards to rainfall production. On this basis, no adjustment has been made to the PMP rainfall intensities for future climate change.

The assessment of future climate change impacts has been based on the TUFLOW models established to define mainstream flooding and major overland flow paths. Potential impacts of future climate change on local drainage patterns at the proposed interchanges would need to be considered when setting minimum height of flood protection barriers and entries to tunnel dive structures during detailed design.

Future climate change also has the potential to increase the frequency and magnitude of flows surcharging the tunnel drainage systems and entering the tunnels. During detailed design the impact of future climate change would also need to be considered in the sizing the tunnel drainage system including the tunnel deluge and stormwater collection tanks and pumps.

The findings of the assessment of the impact of climate change on flood behaviour in the vicinity of the project are contained in **section 6.4**.

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[4] *The section of cycleway west of Homebush Bay Drive is located within the Auburn Council LGA. However, this section of cycleway is to be at-grade over the existing road pavement and would therefore result in no significant impact on flooding and drainage patterns. As a result, the section of cycleway west of Homebush Bay Drive has not been included in the flooding and drainage assessment.*

Table 3.1 Derivation of design flood envelopes for assessment of climate change impacts

Design flood envelope	Local catchment flood	Harbour boundary condition
DESIGN FLOOD – 2015 CONDITIONS [1]		
100 year ARI	100 year ARI	HHWSS peak tide level (1.0 m AHD)
	20 year ARI	1 in 100 year peak storm tide level (1.735 m AHD)
PMF	PMF	HHWSS peak tide level (1.0 m AHD)
	100 year ARI	Extreme tide peak storm tide level (1.9 m AHD)
DESIGN FLOOD – SCENARIO 1		
100 year ARI	Based on 100 year ARI rainfall intensities increased by 10%[2]	2015 HHWSS peak tide level plus 0.4 m (1.4 m AHD)
	Based on 20 year ARI rainfall intensities increased by 10%[3]	2015 1 in 100 year peak storm tide level plus 0.4 m (2.135 m AHD)
PMF	PMF	2015 HHWSS peak tide level plus 0.4 m (1.4 m AHD)
	Based on 100 year ARI rainfall intensities increased by 10 %[2]	2015 Extreme tide peak storm tide level plus 0.4 m (2.3 m AHD)
DESIGN FLOOD – SCENARIO 2		
100 year ARI	Based on 100 year ARI rainfall intensities increased by 30 %[2]	2015 HHWSS peak tide level plus 0.9 m (1.9 m AHD)
	Based on 20 year ARI rainfall intensities increased by 30%[3]	2015 1 in 100 year peak storm tide level plus 0.9 m (2.635 m AHD)
PMF	PMF	2015 HHWSS peak tide level plus 0.9 m (1.9 m AHD)
	Based on 100 year ARI rainfall intensities increased by 30 %[2]	2015 Extreme tide peak storm tide level plus 0.9 m (2.8 m AHD)

(1) Refer to **Appendix C** for derivation of design flood envelopes comprising combinations of local catchment flood and harbour boundary conditions.

(2) Design rainfall intensities for the 200 and 500 year ARI events were adopted as being analogous to the 100 year ARI design rainfall intensities increased by 10 per cent and 30 per cent respectively.

(3) Design rainfall intensities for the 50 and 100 year ARI events were adopted as being analogous to the 20 year ARI design rainfall intensities increased by 10 per cent and 30 per cent respectively.

4 Existing environment

4.1 General

The following five catchments presently contribute runoff to the existing drainage systems and waterways that are located along the route of the project (refer **Figure 4.1**):

- Powells Creek – Homebush Bay Drive at Homebush to Concord Road at North Strathfield
- Exile Bay – Concord Road to Park Road at Concord
- St Lukes Park Canal – Park Road to Royce Avenue in Concord, Burwood and Croydon
- Barnwell Park – Royce Avenue to Scott Street at Croydon[5]
- Dobroyd Canal (Iron Cove Creek) – Scott Street at Croydon to Orpington Street at Ashfield

All the above catchments form part of the larger Parramatta River catchment. Each system is described separately in **section 4.2** to assist the reader in understanding the source of flows in the existing drainage lines that cross the project corridor.

Figures 4.2 to **4.4** show details of the existing drainage arrangements and features within each catchment, and should be referred to when reading the descriptions in **section 4.2**.

4.2 Rainfall and evaporation

The study area is characterised by generally high summer-autumn and low winter-spring rainfall. Average monthly rainfall ranges from approximately 80-140 millimetres in the summer-autumn months to approximately 60-110 millimetres in the winter-spring months with an average annual rainfall of 884 millimetres[6].

Average monthly evaporation in the study area ranges from 60 millimetres in the winter months to 200 millimetres in the summer months[7].

4.3 Topography

The project corridor traverses relatively flat or gently undulating terrain within the lower reaches of the Parramatta River catchment with ground slopes of six per cent or less.

Elevations are highest at the eastern end of the project corridor along the ridge which separates the Dobroyd Canal (Iron Cove Creek) and Hawthorne Canal catchments, where ground levels are about 30 metres Australian height datum (m AHD). The lowest lying areas are where the project corridor traverses the watercourses of Saleyards Creek, Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), where ground levels are below five metres AHD.

4.4 Catchment description

4.4.1 Powells Creek

The Powells Creek catchment (refer **Figure 4.2**) drains in a northerly direction, extending from the Hume Highway in Enfield to Homebush Bay. The catchment spans the LGA's of Strathfield, Burwood and Canada Bay and includes the suburbs of Enfield, Strathfield, Burwood, North Strathfield and Liberty Grove, as well as part of Sydney Olympic Park.

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5 The M4 East alignment is in tunnel where it crosses the Barnwell Park catchment and therefore the project works would not result in any change to flooding and drainage patterns within this catchment.
6 Monthly climate statistics for Sydney Olympic Park (Site No. 66195) for period 1995-2011 obtained from Bureau of Meteorology website, www.bom.gov.au.
7 Monthly average pan evaporation maps for period 1975 to 2005 obtained from Bureau of Meteorology website, www.bom.gov.au.

The major transport corridors of the Western Rail Line, Parramatta Road and the M4 run east-west across of middle reaches of the catchment. The Northern Rail Line (also referred to as the Main North Line) runs north-south along the eastern side of the catchment, crossing a series of tributary arms which drain to the main arm of Powells Creek downstream of the proposed motorway corridor.

The catchment predominantly comprises low to medium density residential development, with higher density residential and commercial development located in the vicinity of the three major transport corridors and Strathfield town centre. Downstream of the M4 the catchment includes a significant proportion of open space, including Powells Creek Reserve and Bicentennial Park.

The main and tributary arms of Powells Creek have been highly modified as a result of urbanisation. The main arm of the creek consists of a series of pipe and box culvert systems from its headwaters to a location immediately upstream of the Western Rail Line at Strathfield. At this location the culvert system discharges into a concrete lined open channel, which continues under Parramatta Road and the M4. At the M4, the concrete channel measures six metres wide by 1.5 metres deep (refer cross drainage identifier XD03 on **Figure 4.2**). The M4 crosses in an elevated bridge structure that is approximately 10 metres above the level of the floodplain.

Downstream of the M4 the concrete lined channel continues to a location just upstream of Homebush Bay Drive, where it discharges into a mangrove lined channel which runs through Powells Creek Reserve and the Badu Wetlands to its outlet into the Parramatta River.

Two tributaries to Powells Creek cross the M4 to the west of the main arm (refer cross drainage identifiers XD01 and XD02 on **Figure 4.2**). The larger of these tributaries (XD02) runs under the M4 immediately east of Underwood Road, via a single 2.6 metre wide by 1.3 metre high reinforced concrete box culvert (RCBC). The smaller of the two (XD01) runs along the rear of properties in Powell Street and under the M4 via a single 600 millimetre reinforced concrete pipe (mm RCP). Both of these tributaries join Powell Creek downstream of Allen Street.

Saleyards Creek (refer cross drainage identifier XD01a on **Figure 4.2**) is the largest tributary of Powells Creek, joining the main arm immediately upstream of Homebush Bay Drive. Saleyards Creek comprises a nine metre wide by 1.5 metre high concrete lined open channel where it flows beneath the M4 corridor. The M4 crosses the concrete lined channel via a single span bridge structure.

4.4.2 Exile Bay

The Exile Bay catchment (refer **Figure 4.2** for extent) covers the LGA's of Burwood and Canada Bay and includes the suburbs of Strathfield, Burwood and Concord.

Parramatta Road runs east-west across the upper reach of the catchment. The catchment comprises mainly low and medium density residential development, with higher density residential and commercial development located generally along the Parramatta Road corridor. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (e.g. Goddard Park, Queen Elizabeth Park and the Massey Park Golf Club).

There are two existing drainage lines that cross the proposed motorway corridor within the Exile Bay catchment, denoted as XD04 and XD05 on **Figure 4.2**.

Cross drainage structure XD04 drains a catchment of 3.7 hectares and comprises a single 450 millimetre RCP where it crosses the proposed motorway corridor immediately east of Concord Road. It then runs along Ada Street via a single 1.2 metre wide by 0.6 metre high Tonkin[8] pipe before joining cross drainage structure XD05 north (downstream) of Parramatta Road. Cross drainage structure XD05 comprises a single 1050 millimetre RCP where it crosses the low point in Parramatta Road at Coles Street. It then continues north via a series of standard circular and Tonkin pipes to Ian Parade.

Downstream of Ian Parade the drainage system discharges into a concrete lined open channel which continues north to its outlet into Exile Bay.

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[8] A Tonkin pipe is oviform in shape and was a common form of construction in many parts of Sydney in the 1930's.

4.4.3 St Lukes Park Canal

The headwaters of the St Lukes Park Canal catchment (refer **Figure 4.3**) starts southwest of Burwood Station, and runs in a northern direction to Canada Bay. The catchment covers the LGA's of Burwood and Canada Bay and includes the suburbs of Burwood, Croydon and Concord.

The Inner West Rail Line runs east-west across the upper reach of the catchment and includes Burwood Station. Further north, Parramatta Road runs east-west across the middle reach of the catchment.

The catchment predominantly comprises low to medium density residential development, with higher density residential and commercial development located in the Burwood Town Centre, as well as along the Parramatta Road corridor. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (e.g. Concord Oval, St Lukes Park, Cintra Park and the Barnwell Golf Course).

The catchment upstream of Parramatta Road is drained via a series of street drainage systems comprising pipes and box culvert sections. These systems convey flows across Parramatta Road by a 3.6 metre wide by 1.37 metre high RCBC and a 2.6 metre wide by 1.37 metre high RCBC (refer cross drainage identifier XD06 on **Figure 4.3**) which then discharge into an open channel that runs between Concord Oval and Cintra Hockey Centre. This open channel continues between Cintra Park and St Lukes Park and along the western edge of Barnwell Park to its outlet into Canada Bay.

4.4.4 Barnwell Park

The Barnwell Park catchment (refer **Figure 4.4**) drains in a northerly direction into Canada Bay. The catchment covers the LGA's of Burwood, Ashfield and Canada Bay and includes the suburbs of Croydon, Five Dock and Canada Bay.

Parramatta Road runs east-west across the middle reach of the catchment. The area upstream of Parramatta Road predominantly comprises low to medium residential development. Between Parramatta Road and Queens Road there is a mixture of commercial and industrial development. Barnwell Park Golf Course is located in the lower reaches of the catchment, adjacent to Canada Bay.

The catchment upstream of Parramatta Road is drained via a street drainage system of pits and pipes to the low point in Parramatta Road immediately west of Short Street. From the low point in Parramatta Road the drainage system discharges into two 1.2 metre wide by 900 millimetre high RCBC's (refer cross drainage identifier XD07 on **Figure 4.4**). The drainage line then runs along William Street via a series of RCBC's before discharging into a concrete lined open channel that runs through Barnwell Park Golf Course, under Lyons Road West and into Canada Bay.

4.4.5 Dobroyd Canal (Iron Cove Creek)

The Dobroyd Canal (Iron Cove Creek) catchment (refer **Figure 4.4**) drains in a north-easterly direction, from its headwaters in Burwood Heights to its outlet in Iron Cove. The catchment spans the LGA's of Burwood, Canada Bay, Ashfield and Canterbury and includes the suburbs of Burwood Heights, Burwood, Ashfield, Ashbury, Croydon, Five Dock and Haberfield.

The major transport corridors of the Inner West Rail Line and Parramatta Road run east-west across the middle reaches of the catchment. Wattle Street runs north-south from its intersection with Parramatta Road, along the eastern bank of Dobroyd Canal (Iron Cove Creek). Other arterial roads within the catchment include Liverpool Road in the south and Great North Road in the north.

The main land use type within the catchment is low to medium density residential development. Higher density residential, commercial and industrial development exists along the main rail and road corridors (described above), as well as the Burwood town centre.

Local parks are interspersed throughout the suburban areas of the catchment, including Algie Park in Haberfield, which also acts as a stormwater detention basin. A significant portion of the catchment north (downstream) of Parramatta Road comprises open space (e.g. Timbrell Park).

The main arm of Dobroyd Canal (Iron Cove Creek) comprises a concrete-lined open channel that extends from Liverpool Road in the south, through to its outlet into Iron Cove. Where it crosses

Parramatta Road the channel is 15 metre wide by 1.8 metre deep (refer cross drainage identifier XD08 on **Figure 4.4**). The channel dimensions increase to 21.6 metre (width) by 2.6 metre (depth) at its outlet into Iron Cove.

A tributary to Dobroyd Canal (Iron Cove Creek) runs in a north-westerly direction and joins the main arm immediately upstream of Parramatta Road. This tributary is drained via a series of pipes and box culverts, and comprises a 2.4 metre wide by 2.1 metre high RCBC where it discharges into Dobroyd Canal (Iron Cove Creek).

Runoff from the catchments that lie to the east of Parramatta Road between Walker Avenue and Chandos Street are controlled by pavement drainage systems draining across Parramatta Road at Walker Street (XD09a), Alt and Bland Streets (XD09b) and Chandos Street (XD09c) as shown on **Figure 4.4**.

There are two drainage lines that cross the project corridor at Dobroyd Parade (refer cross drainage identifiers XD10 and XD11 on **Figure 4.4**). Cross drainage structure XD10 crosses Dobroyd Parade at Martin Street and comprises a single 375 millimetre RCP. Cross drainage structure XD11 crosses Dobroyd Parade between Martin Street and Waratah Street and comprises a 2.6 metre wide by 1.4 metre high RCBC and a 1050 millimetre RCP. The 1050 millimetre RCP discharges into two 900 millimetre RCP's immediately downstream of Dobroyd Parade. Cross drainage structures XD10 and XD11 discharge into Dobroyd Canal (Iron Cove Creek) north of Dobroyd Parade.

4.5 Characteristics of flooding

4.5.1 General

The followings sections of the report provide a brief description of patterns of both main stream flooding and major overland flow under present day (or pre-project) conditions for a storm with an ARI of 100 years ARI, as well as for the PMF event. The following figures are also referred to in the following discussion:

- **Figures 4.5**, **4.6**, **4.7** and **4.8** show design 100 year ARI and PMF water surface profiles along the main arms of Saleyards Creek, Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively.
- **Figures 4.9**, **4.11** and **4.12** show 100 year ARI flooding patterns along the modelled reaches of Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively. **Figure 4.10** also shows detailed 100 year ARI flooding patterns in the vicinity of the Concord Road interchange.
- **Figures 4.13**, **4.15** and **4.16** show flooding patterns in a PMF event along the modelled reaches of Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively. Detailed PMF flooding patterns in the vicinity of the Concord Road interchange are shown on **Figure 4.14**.

Figures showing flooding patterns for design storms with ARI's of five, 20 and 200 year ARI are contained in **Appendix D**.

4.5.2 100 year ARI

Figures 4.5 and **4.9** show that the existing M4 Motorway Bridge at Saleyards Creek (XD01a) has a hydraulic standard in excess of 100 year ARI. The clearance between the 100 year ARI flood level due to mainstream flooding in Saleyards Creek and the underside of the bridge is approximately one metre.

The existing Underwood Road underpass operates as a major overland flow path during a 100 year ARI event, conveying flows in excess of the capacity of cross drainage structures XD01 and XD02 (refer **Figure 4.9**). Depths of overland flow along Underwood Road are typically between 0.4 and 0.7 metres, but would reach up to 0.9 metres in three locations.

Flow along Powells Creek immediately downstream of Parramatta Road is generally confined to the main arm (refer XD03 on **Figure 4.9**). Further downstream at the existing M4, flow extends onto the overbank areas either side of the main arm inundating the area to a maximum depth of 0.8 metres during a 100 year ARI event.

Flows in excess of the capacity of stormwater drainage line XD04 would travel along a major overland flow path between Sydney Street and Alexandra Street, east of Concord Road. During a 100 year ARI event depths of overland flow would be typically less than 0.2 metres, but reach up to 0.4 metres at three locations (refer **Figure 4.10**).

A major overland flow path is shown to develop along the eastern side of the Cintra Hockey Complex due to insufficient capacity in the local stormwater drainage system south of Parramatta Road (refer **Figure 4.11**). Depths of overland flow along the flow path are typically less than 0.3 metres but would reach up to 0.5 metres at two locations during a 100 year ARI event.

Parramatta Road, between Chandos Street and Wattle Street would operate as a major overland flow path due to surcharge of the local stormwater drainage system (refer **Figure 4.12**). Depths of overland flow along Parramatta Road would be typically less than 0.15 metres, but would reach up to 0.3 metres in three locations locations during a 100 year ARI event.

Dobroyd Parade at its intersection with Waratah Street would be inundated by up to 0.6 metres depth in a 100 year ARI event due to a combination of flow surcharging of the main arm of Dobroyd Canal (Iron Cove Creek) and also transverse drainage structure XD11 (refer **Figure 4.12**).

4.5.3 Probable maximum flood

Figures 4.5 and **4.13** show that the M4 would be inundated to a maximum depth of about 1.5 metres by floodwater which would surcharge the main arm of Saleyards Creek during a PMF event.

Overland flow from XD01 and XD02 travels along Underwood Road, where flow depths in excess of two metres would be experienced upstream of the existing M4, reducing to 1.5 metres on the downstream side (refer **Figure 4.13**).

Figure 4.13 shows that during a PMF event, Parramatta Road would be inundated to a maximum depth of about 1.5 metres over a 200 metre length by floodwater which surcharges the main arm of Powells Creek. A similar width of flow continues downstream along Powells Creek to the existing M4.

Depths of overland flow resulting from the surcharge of stormwater drainage line XD04 would typically be less than 0.4 metres but would reach up to 0.9 metres at three locations during a PMF event (refer **Figure 4.14**).

Figure 4.15 shows that depths of overland flow along the flow path that develops along the eastern side of the Cintra Hockey Complex due to insufficient capacity in the local stormwater drainage system south of Parramatta Road would reach a maximum of about 0.8 metres during a PMF.

Surcharge of the local stormwater drainage system during a PMF event would result in depths of overland flow along Parramatta Road between Chandos Street and Wattle Street of typically less than 0.3 metres. However depths of overland flow along this section of Parramatta Road would exceed 0.5 metres in five locations during an event of this magnitude (refer **Figure 4.16**).

Floodwater which would surcharge the main arm of Dobroyd Canal (Iron Cove Creek) and transverse drainage structure XD11 during a PMF event would inundate Dobroyd Parade at its intersection with Waratah Street to a depth of about two metres.

5 Assessment of construction related issues

5.1 Overview

The following chapter provides an assessment of the flood risk at the 10 construction ancillary facilities as well as other areas of proposed surface construction works. This chapter also provides an overview of the potential impacts that these construction activities could have on flooding behaviour.

A range of potential measures aimed at mitigating the impact of construction activities on flooding behaviour are discussed in **Chapter 7**.

5.2 Flood risk at construction ancillary facilities

5.2.1 General

Inundation of the construction ancillary facilities by floodwater has the potential to cause damage to the project works and cause delays in construction programming; pose a safety risk to construction workers; and detrimentally impact the downstream waterways through the transport of sediments and construction materials by floodwaters. The provision of temporary measures such as site sheds, stockpiles, noise walls and flood protection walls also has the potential to exacerbate flooding conditions in existing development located outside the construction footprint.

Table 5.1 provides a summary of the assessed flood risk at the construction ancillary facilities, while **Figures 5.1** to **5.7** show the extent to which floods of varying recurrence interval affect each site. For a more detailed description of each construction activity and ancillary facility refer to **Chapter 6** of the EIS. Note that the Underwood Road civil and tunnel site C3 has been spilt into two for the purpose of the following discussion, whereby construction ancillary facility C3a comprises the civil site, while C3b comprises the tunnelling site.

5.2.2 Spoil management and stockpile areas

The construction of the project would generate a significant amount of spoil which would need to be temporarily stored in stockpile areas. Stockpiles located on the floodplain have the potential to obstruct floodwater and thereby alter flooding patterns. Inundation of stockpile areas by floodwater can also lead to significant quantities of material being washed into the receiving drainage lines and waterways.

Stockpiling of spoil material is proposed at all of the construction ancillary facilities with the exception of site C4. While sites C1, C3a, C3b, C5, C6, C9 and C10 are affected by mainstream flooding and/or major overland flow (refer **Table 5.1**), C3a is at greatest risk of being flooded during the construction phase of the project.

5.2.3 Site facilities

A range of site facilities including offices, staff amenities, workshops and parking are proposed at all ten construction ancillary facilities. Sites C1, C3a, C3b, C4, C5, C6, C9 and C10 are affected by mainstream flooding and/or major overland flow (refer **Table 5.1**). Site facilities located on the floodplain, particularly in areas of high hazard, pose a safety risk to construction personnel. It would therefore be necessary to located site facilities in low hazard areas with safe evacuation routes.

5.3 Flood risk during tunnelling

Tunnel boring would be carried out using road headers that would be launched from the tunnelling sites. The operation of the road header would involve the use of a pump at the tunnel low point, and potentially a mobile sump at the cutting face to collect water generated for heat and dust suppression, groundwater ingress and stormwater runoff from the tunnel openings.

While the tunnel boring arrangement would be designed to accommodate a nominal amount of stormwater runoff, the ingress of floodwater to the tunnel excavations poses a significant risk to personnel safety. It also has the potential to cause damage to machinery and delays in the project timetable. Tunnel openings which would facilitate the launch and support of the road headers are to be provided at construction ancillary facilities C3b, C5, C6, C7 and C8.

Table 5.1 summarises the consequences of flooding at the five tunnelling sites. The assessment found that tunnelling operations at construction ancillary facilities C5 and C6 are at greatest risk of being inundated by floodwater during the construction phase of the project as they are both affected by flooding during events more frequent than 5 year ARI. The assessment also identified that there is the potential for local catchment runoff to enter the tunnel excavations at all five sites.

The flood standard adopted at each tunnel opening during construction would need to be developed during detailed design taking into consideration the duration of construction, the magnitude of inflows and the potential risks to the project works and personnel. Protection to the tunnel entries during construction through the provision of physical barriers would also need to be designed so as not to exacerbate flooding conditions in adjacent development. **Chapter 7** sets out measures which could be implemented to mitigate the impact of tunnelling activities on flooding behaviour.

5.4 Flood risk during cut and cover tunnel construction

Sections of cut and cover tunnel are located adjacent to the tunnel dive structures at the following four interchanges providing surface connections to the proposed road tunnels:

- the M4 at Homebush (Homebush Bay Drive interchange);
- the M4 and Concord Road at North Strathfield (Concord Road interchange);
- Parramatta Road at Haberfield (Parramatta Road interchange); and
- Wattle Street at Haberfield (Wattle Street (City West Link) interchange).

Construction of the cut and cover tunnel sections would involve an open excavation, installation of the tunnel structure and filling to finished ground level. Similar to the construction of the driven tunnels, ingress of floodwater into the open excavations poses a significant risk to personal safety, as well as having the potential to cause damage to machinery and delays to the project timetable.

The cut and cover sections of tunnel at the Concord Road and Wattle Street (City West Link) interchanges are located outside the extent of the PMF due to MSF or MOF. However, local catchment runoff presently drains in a westerly direction along Sydney Street and across the location of the cut and cover tunnel section at the Concord Road interchange. Similarly, the cut and cover tunnel section at Allum Street is potentially affected by local catchment runoff draining north along the Wattle Street (City West Link) interchange. Flooding to the cut and cover tunnel sections can be addressed through local stormwater management at these locations.

The cut and cover section of tunnel at the Homebush Bay Drive interchange crosses Underwood Road, which operates as an overland flow path during storms more frequent than five year ARI. Construction of the cut and cover section of tunnel would therefore need to be staged to maintain the existing overland flow path. Barriers would also need to be provided to prevent overland flow from entering the open excavation.

The cut and cover section of tunnel at the Parramatta Road interchange is located across an existing overland flow path that operates during storms more frequent than five year ARI. To facilitate construction of the cut and cover section of tunnel, the existing stormwater drainage line that crosses Parramatta Road at Chandos Street would be converted to a siphoned arrangement, with overland flows directed along Parramatta Road and Bland Street, with this mitigation measure to be further developed during detailed design and construction planning (refer **Chapter 7** for further details).

5.5 Flood risk during surface earthworks

The construction of the widened section of the M4, as well as road connections at the four interchanges listed in above would involve surface earthworks.

Figures 5.1 to **5.3** show that the surface earthworks associated with the realignment of the M4; the road connection works at the Homebush Bay Drive interchange and construction of the Powells Creek on-ramp are principally located outside the 100 year ARI flood extent. As a result, the flood risks associated with the construction of these surface earthworks is low and would be addressed through local stormwater management of the construction site.

Surface earthworks associated with the road connections at the Concord Road interchange are located in an area which is affected by flow which surcharges the stormwater drainage system in the M4 and ponds at the low point east of the Concord Road overbridge (refer **Figure 5.4**).

Surface earthworks at the Wattle Street (City West Link) and Parramatta Road interchanges intersect overland flow paths that operate during storms more frequent than five year ARI (refer **Figures 5.6** and **5.7**, respectively).

Concentrated flow which presently discharges onto the road corridor within areas of surface earthworks has the potential to cause scour of disturbed surfaces and transport of sediment and construction materials into the receiving waterways. It would therefore be necessary to plan, implement and maintain measures which are aimed at managing the discharge of overland flow either through or around the construction areas (refer **Chapter 7** for further details).

5.6 Flood risk during bridge construction

The existing 9.4 metre single span bridge over Saleyards Creek would be replaced by a 13 metre single span bridge which would accommodate the wider M4 East Motorway, as well as its associated slip lanes. An additional 17 metre single span bridge would also be constructed upstream of the aforementioned bridge in order to accommodate the proposed westbound off-ramp to Homebush Bay Drive.

While there is the potential for temporary falsework to reduce the available waterway area beneath the two new bridges, it is noted that the longer spans should mitigate the impact this would have had on flooding behaviour (i.e. because the increase in waterway area created by the longer bridges is likely to exceed the loss of waterway areas caused by the temporary falsework). It is also likely that the superstructure would comprise pre-cast members, meaning that the waterway would not be obstructed by additional falsework associated with the alternative cast-in situ type approach, and the timeframe for installation on site would be comparatively shorter.

All formwork, access tracks and other temporary works associated with the Powells Creek on-ramp would be located outside the concrete channel. However, temporary crossings over the channel would be required for access and construction of the bridge structure. The assessment of the potential impact of these temporary crossings on flood behaviour is summarised in **section 5.7**. **Chapter 7** sets out measures which could be implemented to mitigate the impact of bridge construction activities on flooding behaviour.

5.7 Potential impacts of construction activities on flooding behaviour

Construction activities have the potential to exacerbate flooding conditions when compared to both present day and post-construction conditions. This arises due to the need to locate temporary measures on the floodplain outside the operational project footprint which would be removed following the completion of construction activities.

A preliminary investigation was undertaken to assess the potential impacts of construction activities on flooding behaviour, under 100 year ARI conditions. This involved making adjustments to the structure of the TUFLOW models (originally developed to define flooding behaviour under present day conditions, **Appendix C**) to reflect the potential blocking effects of the construction activities. A 100 year ARI standard was adopted for describing the likely impact construction activities would have on flooding behaviour. While the findings of the initial assessment provide an indication of the potential impacts of construction activities on flood behaviour, further investigation would need to be undertaken during detailed design, as layouts and staging diagrams are developed. Consideration would also need to be given to setting an appropriate hydrologic standard for mitigating the impacts of construction activities on flood behaviour, taking into account their temporary nature.

The key findings of the assessment are summarised in **Table 5.2**, while **Figures 5.8** to **5.21** show flooding patterns and the afflux which could be caused by project construction activities for a design storm with an ARI of 100 years.

The assessment found that project construction activities have the potential to exacerbate flooding conditions in adjacent development at a number of locations along the project corridor. While the greatest impacts are associated with construction ancillary facilities C3a and C10, adverse flooding conditions arising in adjacent development is also associated with construction ancillary facilities C1, C4, C5, C6 and C9. There is also the potential for all ten construction ancillary facilities to impact local catchment runoff, requiring appropriate local stormwater management controls to be implemented during the construction phase of the project.

While the assessment represents a worst case scenario in terms of the potential impact construction activities would have on flooding behaviour, it is recognised that measures would be implemented by the contractor which are aimed at reducing such impacts. It is noted that the contractor is required to prepare a FMS which will set out measures which are aimed at mitigating the impacts of construction activities on flooding behaviour. Further details on the requirements of the FMS, as well as a range of measures which could be implemented to mitigate the construction and operational related impacts of the project are contained in **Chapter 7**.

Table 5.1 Summary of assessed flood risk at proposed construction ancillary facilities

Location	Threshold of Flooding[1]	Affected facilities and activities[2]						Description of flood behaviour
		Driven tunnel launch and support	Cut and cover tunnel construction	Surface earthworks	Bridge construction	Spoil management[3]	Site facilities[4]	
M4 Motorway - Homebush Bay Drive to Underwood Road and Homebush Bay Drive Civil Site (C1)	5 year ARI		✔	✔	✔	✔	✔	• Surface earthworks associated with the Homebush Bay Drive interchange western works are principally located outside the 100 year ARI extent. • Flow along Saleyards Creek would surcharge the main arm and inundate an area along the eastern boundary of site C1 during storms in excess of 5 year ARI (refer **Figure 5.1**). • Should a 100 year ARI event occur during the construction phase of the project, then floodwater would extend into site C1 over a width of about 8 m along the eastern boundary and reach a maximum depth of about 0.6 m.
Pomeroy Street civil site (C2)	Not affected by mainstream flooding or major overland flow.		✔	✔		✔	✔	• The site is not located on flood prone land (i.e. it lies outside the extent of the PMF).

Location	Threshold of Flooding[1]	Affected facilities and activities[2]						Description of flood behaviour
		Driven tunnel launch and support	Cut and cover tunnel construction	Surface earthworks	Bridge construction	Spoil management[3]	Site facilities[4]	
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	< 5 year ARI		✔	✔		✔	✔	• **Figure 5.2** shows that flows in excess of the capacity of cross drainage structures XD01 and XD02 would travel overland along Underwood Road and across the proposed cut and cover tunnel section at the Homebush Bay Drive interchange. Overland flow along Underwood Road would also inundate site C3a, with more than half of the site inundated during a 5 year ARI event. • The portion of site C3a of Underwood Road would also be inundated by flows that surcharge the open channel that runs between the outlet to cross drainage structure XD02 and Ismay Avenue. • Should a 100 year ARI event occur during the construction phase of the project, then depths of overland flow along Underwood Road and through the site would typically reach between 0.4 and 0.7 m.
Underwood Road tunnel site (C3b)	200 year ARI	✔				✔	✔	• The site is located outside the extent of mainstream flooding from Powells Creek for all events up to 200 year ARI (refer **Figure 5.2**). • Should a PMF event occur during the construction phase of the project, then floodwaters would inundate the northern third of the site to a maximum depth of about 0.8 m.

Location	Threshold of Flooding(1)	Affected facilities and activities(2)						Description of flood behaviour
		Driven tunnel launch and support	Cut and cover tunnel construction	Surface earthworks	Bridge construction	Spoil management(3)	Site facilities(4)	
Powells Creek civil site (C4) incorporating Powells Creek on-ramp	< 5 year ARI			✔	✔		✔	• Powells Creek flows in a northerly direction through the eastern portion of the site via a concrete lined channel (refer **Figure 5.3**). • Surface earthworks associated with the Powells Creek on ramp are principally located outside the 100 year ARI extent. • While depths of flow on the western overbank of Powells Creek, within site C5, would reach a maximum of about 0.8 m during a 100 year ARI event, the extent of the affected area is confined to a relatively localised area in the immediate overbank area of the creek.
Concord Road interchange, M4 Motorway – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	< 5 year ARI	✔	✔	✔	✔	✔	✔	• Surface earthworks associated with the Concord Road interchange are located in an area which is affected by flow which surcharges the stormwater drainage system in the M4 and ponds at the low point east of the Concord Road overbridge (refer **Figure 5.4**). • The cut and cover tunnel section at the Concord Road interchange is not affected by MSF or MOF. However, the cut and cover tunnel section is affected by local catchment runoff draining west along Sydney Street. • **Figure 5.4** shows that site C5 is affected by overland flow from stormwater drainage line XD04 that travels along the local depression east of Concord Road. • Should a 100 year ARI event occur during the construction phase of the project, then depths of overland flow through site C5 would be typically less than 0.2 m, but reach a maximum of about 0.4 m at three locations. • Site C5 is also affected by local stormwater runoff that surcharges the drainage system in the M4 and ponds at the low point west of the Concord Road overbridge.

Location	Threshold of Flooding[1]	Affected facilities and activities[2]						Description of flood behaviour
		Driven tunnel launch and support	Cut and cover tunnel construction	Surface earthworks	Bridge construction	Spoil management[3]	Site facilities[4]	
Cintra Park tunnel site (C6) incorporating Cintra Park fresh air supply and water treatment facility	< 5 year ARI	✔				✔	✔	• **Figure 5.5** shows the site extends across St Lukes Park Canal, which is a concrete lined channel where it runs between Parramatta Road and Gipps Street. • An overland flow path also operates along the eastern portion of the site during storms in excess of a 5 year ARI event. Depths of overland flow would typically be less than 0.3 m, reaching a maximum of about 0.5 m at two locations should a 100 year ARI event occur during the construction phase of the project.
Northcote Street tunnel site (C7)	Not affected by mainstream flooding or major overland flow.	✔				✔	✔	• The site fronts onto Parramatta Road which operates as an overland flow path during storms which surcharge the stormwater drainage system (refer **Figure 5.6**). • Depths of overland flow along this section of Parramatta Road are typically less than 150 mm for all storms up to 100 year ARI. • The site is also affected by local catchment runoff draining west along Northcote Street.
Eastern ventilation facility site (C8)	Not affected by mainstream flooding or major overland flow.					✔	✔	• The site fronts onto Parramatta Road which operates as an overland flow path during storms which surcharge the stormwater drainage system (refer **Figure 5.6**). • Depths of overland flow along this section of Parramatta Road do not exceed 250 mm for all storms up to 100 year ARI.

Location	Threshold of Flooding[(1)]	Affected facilities and activities[(2)]						Description of flood behaviour
		Driven tunnel launch and support	Cut and cover tunnel construction	Surface earthworks	Bridge construction	Spoil management[(3)]	Site facilities[(4)]	
Wattle Street (City West Link) interchange and Wattle Street and Walker Avenue civil site (C9)	< 5 year ARI		✔	✔		✔	✔	• Surface earthworks north of the Dobroyd Parade tunnel dive structure and the northern end of site C9 is affected by flow in Dobroyd Parade which would occur due to a combination of surcharge of the stormwater drainage system and Dobroyd Canal (Iron Cove Creek) (refer **Figure 5.6**). • During a 100 year ARI storm event, Dobroyd Parade is inundated to a maximum depth of about 600 mm at its intersection with Waratah Street. • The cut and cover tunnel section at the Wattle Street tunnel site structure and site C9 are also affected by local catchment runoff draining north along Allum Street.
Parramatta Road interchange and Parramatta Road civil site (C10)	< 5 year ARI		✔	✔		✔	✔	• **Figure 5.7** shows stormwater drainage line XD09c crosses Parramatta Road at Chandos Street before running in a westerly direction along Chandos Street. Flows in excess of the capacity of stormwater drainage line XD09c collect at the low point in Parramatta Road north of Chandos Street before travelling north along Parramatta Road and west along Chandos during storms more frequent that the 5 year ARI event. During a 100 year ARI storm event, depths of overland flow along Parramatta Road and Chandos Street are typically less than 150 mm, but reach up to 300 mm in three locations. • Overland flow from stormwater drainage line XD09c crosses the area of proposed surface earthworks in Parramatta Road as well as the location of the cut and cover section of tunnel within site C10.

(1) Refer **Figures 5.1** to **5.7** for flood extent mapping at each construction site under present day conditions.
(2) Refer **sections 5.2** to **5.6** for discussion of flood risks associated with each facility and activity.
(3) Spoil management includes stockpiling.
(4) Site facilities include site offices, staff amenities, stores and laydown, workshops and parking.

Table 5.2 Summary of impacts of construction activities on flooding behaviour – 100 year ARI flood

Location	Preliminary peak flood level (m AHD)	Preliminary assessment of construction activity	Potential Impacts on Flooding Behaviour
M4 Motorway - Homebush Bay Drive to Underwood Road and Homebush Bay Drive Civil Site (C1)	3.4	• In the model, the footprint of construction ancillary facility C1 was raised above the 100 year ARI flood level to represent a complete blockage to flow and thus provide an upper bound of potential flood impacts due to obstructions caused by site works. The area over which ground levels were raised is shown in **Figure 5.8** (defined as the 'Construction Site Boundary). • No changes were made in the model to the dimensions of the existing bridge over Saleyards Creek.	• **Figure 5.8** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.9** shows the afflux which could potentially be caused by the blocking effects of the construction site. • Peak 100 year ARI flood levels could be increased within industrial development that is located upstream of the M4 to a maximum of 20 mm. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether construction activities would increase flood damages in the affected properties.
Pomeroy Street civil site (C2)	N/A	• Construction ancillary facility C2 is not affected by MSF or MOF for events up to the PMF. Consequently, no hydraulic assessment has been carried out for these construction works.	• No impacts on MSF or MOF during a 100 year ARI event.

Location	Preliminary peak flood level (m AHD)	Preliminary assessment of construction activity	Potential Impacts on Flooding Behaviour
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	5.2	• In the model, the footprint of construction ancillary facility 3a was raised above the 100 year ARI flood level to represent a complete blockage to flow and thus provide a worse case of potential flood impacts due to obstructions caused by site works and noise walls. • The width of Underwood Road was reduced to 10 metres in the model to reflect the concept design for temporary traffic arrangements during construction of the cut and cover tunnel section. The area of cut and cover construction either side of Underwood Road was blocked off to overland flow by raising ground elevations above the 100 year ARI flood level. The extent of cut and cover construction and the narrowing to Underwood Road is shown in **Figure 5.10**.	• **Figure 5.10** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.11** (left hand side) shows the afflux which could potentially be caused by the blocking effects of the construction site. • Narrowing of Underwood Road to accommodate the construction of the cut and cover section of tunnel, combined with the obstruction caused by construction site C3a, would divert additional overland flow north into existing residential development located along Underwood Road and Ismay Avenue. • There is the potential for peak 100 year ARI flood levels to be increased by a maximum of 460 mm in these properties. • The constriction imposed on overland flow along Underwood Road would also result in an increase in peak flood levels of up to 220 mm in existing residential development which is located along Underwood Road and Powell Street south of the M4. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether construction activities would increase flood damages in the affected properties.
Underwood Road tunnel site (C3b)	N/A	• The Underwood Road tunnel site is not affected by either MSF or MOF for all storms up to 200 year ARI. As a result, no initial hydraulic assessment has been carried out of the works proposed at construction site C3b.	• No impacts on MSF or MOF during a 100 year ARI event.

Location	Preliminary peak flood level (m AHD)	Preliminary assessment of construction activity	Potential Impacts on Flooding Behaviour
Powells Creek civil site (C4) incorporating Powells Creek on ramp	4.8	• In the model, the footprint of the proposed access road west of the Powells Creek bridge was raised to the level of Parramatta Road. The area of the proposed access road is shown on **Figure 5.12**. • The two proposed access road crossings over the concrete lined channel were added to the model as bridge structures. These bridge decks were assumed to be 1 metre thick with the underside of the structure set at the top of the concrete channel. The area of the proposed access road and location of the two bridge crossings are shown on **Figure 5.12**.	• **Figure 5.12** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.13** shows the afflux which could potentially be caused by the blocking effects of the construction site. • The proposed construction works could result in a maximum increase in peak flood levels of about 180 mm. within Powells Creek and in the commercial property on its eastern overbank, north of Parramatta Road. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether construction activities would increase flood damages in the affected properties.
Concord Road interchange, M4 Motorway – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	28.3	• In the model, the footprint of construction ancillary facility C5 was raised above the 100 year ARI flood level to represent a complete blockage to flow and thus provide a worse case of potential flood impacts due to obstructions caused by site works and noise walls. The area that was raised is shown in **Figure 5.14**. • Existing stormwater drainage line XD04 was realigned between Sydney Street and Alexander Street to run along the eastern boundary of the construction site. A temporary diversion channel and bund was also modelled along the eastern side of construction ancillary facility C5 as shown on **Figure 5.14**.	• **Figure 5.14** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.15** shows the afflux which could potentially be caused by the blocking effects of the construction site. • There is the potential for peak flood levels to be increased by up to 50 mm in a single residential property which is located on the southern side of Alexandra Street adjacent to the civil site. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether construction activities would increase flood damages in the affected properties on the southern side of Alexandra Street adjacent to the civil site. • Subject to detailed design, a possible measure to prevent adverse flooding conditions arising in residential development located along Sydney and Edward Streets would involve the provision of a temporary earth bunding and the provision of a 0.5 m deep diversion channel along the eastern side of construction ancillary facility C5.

Location	Preliminary peak flood level (m AHD)	Preliminary assessment of construction activity	Potential Impacts on Flooding Behaviour
Cintra Park tunnel site (C6) Incorporating Cintra Park fresh air supply and water treatment facility	5.4	• In the model, the footprint of construction ancillary facility C6 was raised above the 100 year ARI flood level to represent a complete blockage to flow, with the exception of a 16 metre wide corridor that was maintained along the alignment of St Lukes Park Canal and the area of carpark west of Saint Lukes Park Canal.	• **Figure 5.16** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.17** shows the afflux which could potentially be caused by the blocking effects of the construction site. • The obstruction of the existing overland flow path that presently runs along the eastern side of the Cintra Hockey Complex would have a minor impact on flooding behaviour external to the site. • Peak flood levels in the eastbound lanes of Parramatta Road would be increased in the range 0-100 mm.
Northcote Street tunnel site (C7)	N/A	• Construction ancillary facility C7is not affected by either MSF or MOF for events up to the PMF. Consequently, no hydraulic assessment has been carried out for these construction works.	• No impacts on MSF or MOF during a 100 year ARI event.
Eastern ventilation facility site (C8)	N/A	• Construction ancillary facility C8 is not affected by either MSF or MOF for events up to the PMF. Consequently, no hydraulic assessment has been carried out for these construction works.	• No impacts on MSF or MOF during a 100 year ARI event.
Wattle Street (City West Link) interchange and Wattle Street and Walker Avenue civil site (C9)	3.1	• In the model, the footprint of the proposed haul road along the southern side of Reg Coady Reserve was raised to the level of Dobroyd Parade. The area of the proposed haul road is shown on **Figure 5.18**.	• **Figure 5.18** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.19** shows the afflux which could potentially be caused by the blocking effects of the construction site. • The proposed haul road has the potential to cause localised increases of up to 200 mm in the depth of inundation in Dobroyd Parade at Martin Street. Increases in the range 10-20 mm would extend into the Sydney Water pump station on the corner of Dobroyd Parade and Martin Street.

Location	Preliminary Peak Flood Level (m AHD)	Preliminary assessment of construction activity	Potential Impacts on Flooding Behaviour
Parramatta Road interchange and Parramatta Road civil site (C10)		• In the model, the footprint of construction ancillary facility C10 was raised above the 100 year ARI flood level to represent a complete blockage to flow and thus provide a worse case of potential flood impacts due to obstructions caused by site works and perimeter hoarding. The area that was raised is shown in **Figure 5.20**. The construction site includes the extent of the cut and cover section of tunnel at the Parramatta Road (Chandos Street) Tunnel Portals. • The existing stormwater drainage line XD09c was maintained across the construction site to reflect the temporary siphon arrangement proposed during construction.	• **Figure 5.20** shows flooding patterns during a 100 year ARI flood under construction conditions, while **Figure 5.21** shows the afflux which could potentially be caused by the blocking effects of the construction site. • The construction site would obstruct overland flow that presently travels west across Parramatta Road at Chandos Street. • Depths of overland flow along Parramatta Road between Chandos Street and Bland Street would be increased by a maximum 120 mm. There would be a slight increase in the extent of inundation within development located at the corner of Parramatta Road and Chandos Street. • Flood levels within properties along Bland Street and Parramatta Road north of Bland Street could be increased by a maximum of 120 mm. • Subject to further hydraulic assessment during detailed design, floor level survey may be required to confirm whether construction activities would increase flood damages in the affected properties.

(1) Assessment to form part of future FMS which must be prepared by the contractor. Refer **Chapter 7** for details.

6 Assessment of operational flooding impacts

6.1 Overview

The following chapter provides an assessment of the flood risk to the project and the impact it would have on flooding behaviour is appropriate mitigation measures are not incorporated into its design.

For the purpose of the following discussion, the project has been divided into seven sections as per the descriptions presented in **section 2.3.2**. **Figures 6.1**, **6.5**, **6.9**, **6.13**, **6.17** and **6.21** show the general preferred design arrangement within each of these sections and should be referred to when reading the following sections of the report.

The assessment presented in this section of the report is based on hydrologic and hydraulic models that have been established of the catchments draining across and through the project based on a concept design provided by WDA. This has provided a suitable basis for understanding the scale and nature of the flood risk to the project its impact on the surrounding environment. However, the designers of the M4 East will need to review the proposed detailed design arrangements in the context of model extents, details and input data described in this report. In this context design flood levels and impacts presented in this report would be subject to further hydrologic/hydraulic modelling and assessment during detailed design.

6.2 Operational related flood risk and project related impacts on flooding behaviour

6.2.1 General

This section describes the assessment that was carried out into the operational related flood risk and its impact on flooding behaviour. The assessment has been based on concept road and drainage design drawings and models provided by WDA. Assumptions and limitations of the hydraulic assessment based on available details of the preferred design provided by WDA are identified that would need to be confirmed during detailed design.

Table 6.1 provides a summary of the assessed flood risk to the project. The recommended level of protection is based on the adopted hydrologic standard for the various project elements as set out in **section 3.2**. These hydrologic standard have been developed with due consideration of the consequences of flooding in accordance with the FDM and current Roads and Maritime standards.

Table 6.2 provides a summary of the key findings of the assessment of flood impacts of the project on the surrounding environment.

Measures which would need to be implemented during detailed design which are aimed at addressing the operational flood risk identified as part of this assessment are set out in **Chapter 7**. Also set out in **Chapter 7** are measures which would need to be implemented during detailed design in order to further mitigate the impact of the project on flooding behaviour.

Table 6.1 Summary of flood risks to the project

Location	Project Infrastructure (1)	Peak Flood Level (m AHD)		Required Level of Flood Protection	Assessed Flood Risk
		100 year ARI	PMF		
M4 Motorway – Homebush Bay Drive to Pomeroy Street (**Figures 6.1** and **6.3**)	Maintenance Facility and Motorway Control Centre	3.4	4.4	PMF or 100 year ARI plus 0.5 metres (whichever is greater).	The maintenance facility and motorway control centre are located outside the PMF extent, and therefore over 1 metre above the 100 year ARI flood level.
	Bridge over Saleyards Creek	3.6	6.3	100 year ARI plus 0.5 m	The concept bridge arrangement provides a minimum clearance of 0.7 m to the 100 year ARI flood level.
Homebush Bay Drive interchange (**Figures 6.5** and **6.7**)	Tunnel dive structure	5.1	6.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The tunnel dive structure is located outside the PMF extent, and therefore over 1 metre above the 100 year ARI flood level.
	Distribution substation and ventilation facilities	5.1	6.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The buildings are affected by overland flow that travels north along Underwood Road and inundates the eastern edge of the site during a 100 year ARI event.
	Substation and fire water tanks and pump buildings	5.1	6.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The buildings are located outside the PMF extent, and therefore over 1 metre above the 100 year ARI flood level.
Powells Creek Off-Ramp (**Figures 6.5** and **6.7**)	Bridge over Powells Creek	4.6	6.4	100 year ARI plus 0.5 m	Design levels for the bridge structure were not provided at preferred design stage.
Concord Road interchange (**Figures 6.9** and **6.11**)	Tunnel dive structure	28.4	28.5	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	On- and off-ramps at the entry to the tunnel dive structure cross an existing overland flow path that occurs as a result of surcharge of stormwater drainage line XD04.
	Distribution substation	N/A	N/A	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The buildings are not affected by mainstream flooding or major overland flow.

Location	Project Infrastructure (1)	Peak Flood Level (m AHD)		Required Level of Flood Protection	Assessed Flood Risk
		100 year ARI	PMF		
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** and **6.15**)	Water treatment facility comprising water treatment plant, water quality basin and electrical equipment building	5.4	6.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The facility is affected by overland flow that overtops Parramatta Road and inundates the southern end of the site during a 100 year ARI event.
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** and **6.15**)	Fresh air supply facility	5.4	6.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The fresh air supply facility is affected by overland flow that overtops Parramatta Road and inundates the southern end of the site during a PMF event.
Parramatta Road interchange (**Figures 6.17** and **6.19**)	Tunnel dive structure	20.2	20.4	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The tunnel dive structure crosses an existing overland flow path that occurs as a result of surcharge of stormwater drainage line XD09c during storms more frequent than 5 year ARI.
	Tunnel ancillary facility comprising fire water tank and pump, ventilation and electrical buildings	N/A	N/A	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The facility is not affected by mainstream flooding or major overland flow.
Wattle Street (City West Link) interchange (**Figures 6.21** and **6.24**)	Dobroyd Parade (M4 East) tunnel dive structure	2.8	4.1	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The Dobroyd Parade tunnel dive structure is located on the fringe of the PMF extent as shown on **Figure 6.24**.
	Wattle Street (Stage 3) tunnel dive structure	N/A	N/A	PMF or 100 year ARI plus 0.5 metres (whichever is greater)	The Wattle Street tunnel dive structure facility is not affected by mainstream flooding or major overland flow. However, local catchment runoff presently drains in a northerly direction along Allum Street and across the proposed location of the tunnel dive structure.

(1) Refer to the figures listed under 'Location' for location and extent of project infrastructure.

Table 6.2 Summary of impacts of the project on flooding behaviour

Location	Assessed Concept Design Arrangement	Assessed Impacts on Flooding Behaviour
M4 Motorway – Homebush Bay Drive to Pomeroy Street (**Figures 6.1** to **6.4**)	• Refer **Figure 6.1**. • Widening of the M4 between Homebush Bay Drive and Pomeroy Street. • New bridges over Saleyards Creek to accommodate the realignment of the M4, comprising: – 17 metre span plank bridge upstream of the existing M4, – 13 metre span plank bridge to replace existing 9.4 m span bridge – bridges to accommodate M4 eastbound cycleway overpass downstream of the existing M4, – two elevated bridge structures with total spans of 320 metres and 250 metres.	• A minor reduction in peak 100 year ARI flood levels upstream of the M4 of 0.02 metres or less (refer **Figure 6.2**). • An increase in peak PMF levels upstream of the M4, to a maximum of 0.3 metres. • The new 13 metre span plank bridge over Saleyards Creek provides 0.3 metres less freeboard to the 100 year ARI flood level compared to the existing 9.4 metre span bridge. However, freeboard is still in excess of 0.5 metres and the longer span results in an increase in total waterway area.
Homebush Bay Drive interchange (**Figures 6.5** to **6.8**)	• Refer **Figure 6.5**. • Realignment of cross drainage structures XD01 and XD02 to accommodate the cut and cover tunnel. • Provision of distribution substation and ventilation building over the cut and cover tunnel alignment, on the western side of Underwood Road.	• An increase in peak 100 year ARI flood levels by a maximum of 0.02 metres within two residential properties in Ismay Avenue, immediately north of the project corridor (refer Figure 6.6). • An increase in peak PMF levels upstream and downstream of the M4 by a maximum of 0.03 metre (refer **Figure 6.8**).
Powells Creek Off-Ramp (**Figures 6.5** to **6.8**)	• Refer **Figure 6.5**. • A new bridge structure over Powells Creek would be constructed to accommodate the Powells Creek off-ramp between Parramatta Road and the M4. • The bridge would have a total span of 120 metres and would be supported by a series of piers that would be located outside the Powells Creek channel.	• The bridge abutment at Parramatta Road is located outside the 100 year ARI extent and therefore does not impact on flooding behaviour during this event (refer Figure 6.6). • The bridge abutment at Parramatta Road would result in a minor increase in peak PMF levels in a commercial development on the corner of Powells Street and Parramatta Road by a maximum of 0.02 metres. Similar increases in flood level would be experience along Parramatta Road (refer **Figure 6.8**).

Location	Assessed Concept Design Arrangement	Assessed Impacts on Flooding Behaviour
Concord Road interchange (**Figures 6.9** to **6.12**)	• Refer **Figure 6.**9. • Surface road works to connect Concord Road to the eastbound and westbound tunnels and the M4. • Realignment of existing stormwater drainage line XD04 to accommodate the surface road works. • Provision of pit and pipe drainage systems to control runoff from the surface road works and connection to stormwater drainage line XD04. • Provision of a concrete barrier and grassed channel to divert overland flow from stormwater drainage line XD04 around the surface road works.	• An increase in the extent of inundation during a 100 year ARI affecting a residential property in Sydney Street east of the project (refer **Figure 6.10**). • An increase in peak 100 year ARI flood levels in three residential properties in Franklyn Street, south of Alexandra Street, by a maximum of 0.03 metres (refer **Figure 6.10**). • An increase in peak PMF levels in three residential properties in Franklyn Street and Alexandra Street by a maximum of 0.1 metres (refer **Figure 6.12**). Similar increases would be experienced within the road corridor in Alexandra Street. • Peak 5 year ARI overland flows along stormwater drainage line XD04, downstream of the project works, would be increased from 0.4 cubic metres per second (present day) to 0.5 cubic metres per second (post-construction). As a result, peak flood levels would be increased between Alexandra Street and Lloyd George Avenue which would potentially affect over ten residential properties.
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** to **6.16**)	• Refer **Figure 6.13**. • Water treatment facility at the Cintra Park site comprising a water treatment plant to treat groundwater seepage and water quality basin to treat stormwater and deluge water from the tunnels. • The site would also contain a fresh air supply facility and an electrical equipment building. • Provision of a nominal 3 metre wide overland flow path along the western side of the water treatment facility between Parramatta Road and Gipps Street.	• Changes in peak 100 year ARI flood levels in areas outside the project corridor would be less than 0.01 metres (refer **Figure 6.14**). • There would be localised increases in peak PMF flood levels in Parramatta Road and along St Lukes Park Canal by a maximum of 0.3 metres. Increases in PMF levels within commercial development along Parramatta Road would be 0.02 metres or less (refer **Figure 6.16**).

Location	Assessed Concept Design Arrangement	Assessed Impacts on Flooding Behaviour
Parramatta Road interchange (**Figures 6.17** to **6.20**)	• Refer **Figure 6.17**. • Surface road works and tunnel dive structure to connect Parramatta Road to the eastbound and westbound tunnels. • Realignment of stormwater drainage line XD09c along Parramatta Road to connect into the SW trunk drainage line in Bland Street. • Provision of a stormwater detention tank on the corner of Bland Street and Parramatta Road.	• An increase in peak 100 year ARI flood level in Parramatta Road north of Chandos Street, to a maximum of 0.32 metres, resulting in an increase in the extent of inundation in the adjacent commercial property. • An increase in peak 100 year ARI flood level on the corner of Parramatta Road and Bland Street by a maximum of 0.12 metres. Similar increases would be experienced in three commercial properties in Parramatta Road, north of Bland Street. • Localised increases in peak 100 year ARI flood levels along Bland Street, between Parramatta Road and Curt Street, by a maximum of 0.07 metres. These increases in peak flood levels have the potential to impact one residential property in Bland Street. • A reduction in peak 100 year ARI flows and flood levels along the SW trunk drainage line downstream (north) of Bland Street due to the attenuating effect of the stormwater detention tank and the diversion of a portion of the catchment at the tunnel dive structure to the tunnel drainage system. • An increase in peak PMF levels along Parramatta Road between Chandos Street and Walker Avenue, to a maximum of 0.48 metres north of Chandos Street, but typically 0.05 metres or less.
Wattle Street (City West Link) interchange (Figures 6.21 to 6.25)	• Refer **Figure 6.21**. • Surface road works and tunnel dive structures to connect Wattle Street and Dobroyd Parade to the M4 East tunnels as well as tunnels that would form part of a future M4−M5 Link project • Upgrades to the drainage system in Dobroyd Parade to accommodate the surface road works at cross drainage structures XD10 and XD11.	• Reduction in peak 100 year ARI flood levels along Dobroyd Canal (Iron Cove Creek) and Dobroyd Parade upstream (west) of Waratah Street, of up to 0.08 metres but typically 0.02 metres or less. • Localised increases in peak PMF levels in the vicinity of Loudon Avenue, by a maximum of 0.04 metres. • An increase in the depth of inundation in Dobroyd Parade of between 0.1 and 0.3 metres across the range of storm events assessed.

6.2.2 M4 Motorway - Homebush Bay Drive to Pomeroy Street

The proposed realignment of the M4 between Homebush Bay Drive and Pomeroy Street crosses Saleyards Creek at Transverse Drainage Structure XD01a (refer **Figure 6.1**).

To accommodate the realignment of the M4 and associated on- and off-ramps the following structures would be constructed over Saleyards Creek (subject to detailed design):

- A new 17 metre span plank bridge structure upstream of the existing M4 to accommodate the westbound off-ramp to Homebush Bay Drive (Bridge 1 on **Figure 6.1**).
- A 13 metre span plank bridge structure to replace the existing 9.4 metre span plank bridge to support the widened M4 carriageways and slip lanes (Bridge 2 on **Figure 6.1**).
- Two bridge structures elevated above the adjacent plank bridge structures to accommodate the eastbound and westbound carriageways. The elevated bridge structures would have total spans of 320 metres and 250 metres where they cross Saleyards Creek.
- A new bridge downstream of the existing M4 to accommodate the M4 eastbound cycleway overpass.

A maintenance facility and motorway control centre would be located on the northern side of the M4 as shown on **Figure 6.1**.

Figures 6.1 and **6.2** show flooding patterns and impacts, respectively, for the proposed bridge arrangements over Saleyards Creek for a 100 year ARI flood. Peak flood levels at the two plank bridge structures are summarised in **Table 6.3**.

Table 6.3 Peak 100 year ARI flood levels at Saleyards Creek (transverse drainage structure XD01A)

Bridge ID(1)	Bridge Location	Peak Flood Level (metres AHD)	Bridge Soffit Level (metres AHD)	Freeboard(2) (metres)
1	Westbound off-ramp to Homebush Bay Drive	3.55	4.60	1.05
2	M4 carriageways	3.50	4.20	0.70

1. Refer **Figure 6.1** for bridge locations.
2. Freeboard is the clearance between the flood levels and the soffit (underside) of the bridge structure.

Based on the flood assessment of present day conditions presented in **Chapter 4**, the existing bridge at Saleyards Creek has in excess of a 100 year ARI hydrologic standard. The clearance between the 100 year ARI flood level and the underside of the existing bridge structure is approximately 1 metre. The preferred design arrangement also provides in excess of a 100 year ARI hydrologic standard. While the freeboard between the soffit of Bridge 2 and the 100 year ARI flood level is approximately 0.3 metres less than the freeboard to the existing bridge, the total flow area would be slightly increased due to the longer span of the proposed bridge structure.

From inspection of **Figure 6.2**, the project would result in a minor reduction in peak 100 year ARI flood levels upstream of the M4, of less than 0.02 metres. The longer spans of the new bridges offsets the increased hydraulic losses associated with their longer width and multiple bridge arrangement when compared to the existing bridge.

Figure 6.3 and **6.4** show flooding patterns and impacts, respectively, for the proposed bridge arrangement during the PMF. As shown in **Figure 6.3**, overtopping of the M4 would occur to a maximum depth of 1.6 metres within the carriageways. The maintenance facility and motorway control centre are not affected by either MSF or MOF for events up to the PMF.

From inspection of **Figure 6.4**, the road upgrade would result in an increase in peak PMF levels upstream of the M4, by a maximum of 0.3 metres. This increase is due to the obstruction to flow caused by the concrete barriers between the M4 carriageways. The maximum depth of flooding in areas outside the Saleyards Creek concrete lined channel would be increased from 2.6 metres to 2.9 metres. **Figure 6.4** shows that this increase in peak flood levels would result in a minor increase in flood extents within industrial development upstream of the M4.

6.2.3 Homebush Bay Drive interchange

The mainline tunnels would cross existing transverse drainage structures XD01 and XD02 in a cut and cover arrangement, which would transition to a driven arrangement where the tunnels cross Powells Creek (transverse drainage structure XD03) as shown in **Figure 6.5**.

To accommodate the proposed works it is proposed to divert XD01 upstream of the M4 via a 900 millimetre RCP to connect into XD02 at Powell Street, subject to detailed design. The existing box culvert under the M4 at XD02 would be retained, subject to detailed design. However, the section of XD02 that is crossed by the cut and cover tunnel would be replaced by an open channel that is built into the lid of the cut and cover structure, subject to detailed design. This would also require realignment of a 20 metre length of open channel downstream of the cut and cover tunnel, subject to detailed design.

A distribution substation and ventilation facility would be located over the cut and cover tunnel west of Underwood Road. Fire water tank and pump building and substation would be located over the tunnels on the eastern side of Ismay Avenue (refer **Figure 6.5**).

Figures 6.5 and **6.6** show 100 year ARI flooding patterns and impacts, respectively, under post-construction conditions. As shown in **Figure 6.5**, the peak 100 year ARI flood level at the distribution substation and ventilation facility located west of Underwood Road is at RL 5.1 metres AHD.

From inspection of **Figure 6.6**, the proposed works would result in an increase in peak 100 year ARI flood levels within two residential properties in Ismay Avenue, north (downstream) of the project corridor. Increases in flood levels would be less than 0.02 metres and are the result of a minor redistribution of overland flow due to the diversion of XD01 and realignment of the open channel downstream of XD02. Floor level survey would be required to confirm whether the proposed works would result in an increase in flood damages in affected properties. Adverse flood impacts could be addressed during detailed design through refinement of the channel realignment downstream of XD02 and reshaping of the overbank area to partially divert overland flow away from the affected properties.

Figures 6.7 and **6.8** show flooding patterns and impacts, respectively, for a PMF event under post-construction conditions. As shown in **Figure 6.7**, the peak PMF level at the Homebush Bay Drive interchange tunnel vent is RL 6.1 metres AHD. Allowing for the results of the sensitivity analysis presented in Appendix C, it is recommended that a flood protection barrier be constructed around the ventilation facility to an elevation of RL 6.1 metres AHD in order to manage the ingress of floodwater into the tunnels in a PMF event. This would also provide greater than 0.5 metres freeboard to the 100 year ARI flood level.

The tunnel dive structure at the Homebush Bay Drive interchange and the substation and fire water buildings east of Ismay Avenue are not affected by either MSF or MOF for events up to the PMF.

The road upgrade would result in an increase in peak PMF levels upstream and downstream of the M4, by a maximum of 0.03 metres. The extent of this increase in flood level is shown on **Figure 6.8**.

It should be noted that catchment detention storage upstream of the railway corridor has not been explicitly included in the hydrologic and hydraulic models developed for the present investigation. While this is considered appropriate in the context of concept design development (i.e. for confirming PMF protection to the tunnel portals and relative changes in flood behaviour) it is possible that inclusion of catchment detention storage would reduce peak flows in Saleyard Creek and Powells Creek. The inclusion of this catchment storage would probably reduce peak flood levels that are reported in **Table 6.4**. It is recommended that details of the catchment detention storage upstream of the railway corridor be incorporated in the flood models which would be developed during detailed design. Consideration would need to be given to the possible failure of the railway embankment during an extreme flood event when undertaking the assessment.

6.2.4 Powells Creek off-ramp

A bridge structure would be constructed over Powells Creek to accommodate the Powells Creek off-ramp between Parramatta Road and the M4. Based on the preferred design the structure would have a total span of 120 metres. It is understood that the structure is to be supported by a series of piers that would be located outside of the Powells Creek channel.

Figures 6.5 and **6.6** show 100 year ARI flooding patterns and impacts, respectively, under post-construction conditions. As shown in **Figure 6.5**, the peak 100 year ARI flood level at the bridge is RL 4.6 metres AHD. The underside of the bridge would need to be set at a minimum elevation of RL 5.1 metres AHD to provide at least 0.5 metres of freeboard to the 100 year ARI flood level.

From inspection of **Figure 6.5**, the bridge abutment at Parramatta Road is located outside the 100 year ARI flood extent and therefore does not impact on existing flood behaviour during a 100 year ARI flood. The overall impact of the bridge on flooding is subject to layout and dimensions of the piers to support the bridge structure.

Figures 6.7 and **6.8** show flooding patterns and impacts, respectively, for a PMF event under post-construction conditions. From inspection of **Figure 6.8**, the bridge abutment would result in a minor increase in peak PMF levels in a commercial property on the corner of Powell Street and Parramatta Road by a maximum of 0.02 metres. Similar increases in flood level would be experienced in Parramatta Road. As noted previously, the impact of the bridge on flooding is subject to layout and dimensions of the piers to support the bridge structure.

6.2.5 Concord Road interchange

The surface road works connecting Concord Road to the eastbound and westbound tunnels and the M4 cross existing stormwater drainage line XD04 south of Sydney Street. XD04 would therefore need to be realigned to accommodate the proposed works.

Based on the preferred design the existing stormwater drainage line XD04 would be realigned to run along the kerb of the eastbound on-ramp as shown in **Figure 6.9**. The realigned XD04 would connect into the existing 450 millimetre RCP in Alexandra Street. A concrete barrier and grassed channel would also be constructed between Sydney Street and Edward Street to control flows in excess of the capacity of stormwater drainage line XD04.

Runoff from the surface road works in Concord Road and along the on- and off-ramps would be controlled by new pit and pipe drainage systems that would connect into the existing stormwater drainage line XD04. The area of surface road works drained by stormwater drainage line XD04 is shown in **Figure 6.9**.

A distribution substation would be located over the cut and cover tunnels west of Concord Road as shown in **Figure 6.9**.

The proposed road surface works and associated drainage arrangement would result in an increase in the catchment area draining to stormwater drainage line XD04. The impact of this increase in catchment area on peak flows downstream of the project would be greater for more frequent events. This is because flows in excess of the capacity of the drainage system in the on- and off-ramps would be directed into the tunnels.

During a five year ARI event there would be an increase in peak overland flow across Alexandra Street, immediately downstream of the project works, from 0.4 cubic metres per second (present day) to 0.5 cubic metres per second (post-construction). **Figure D14** in **Appendix D** shows that this increase in overland flow would increase peak flood levels between Alexandra Street and Lloyd George Avenue, with the potential to impact on 10 residential properties.

During detailed design it would be necessary to undertake further development of the concept drainage design arrangement to minimise changes to the existing catchment area draining to stormwater drainage line XD04 and peak discharges downstream of the project over the range of design storm events. This may involve connection of the pavement drainage line along the western side of Concord Road into Sydney Street to maintain the existing catchment distribution.

Figures 6.9 and **6.10** show 100 year ARI flooding patterns and impacts, respectively, under post-construction conditions.

From inspection of **Figure 6.10**, the proposed works would result in an increase in the extent of flooding within a residential property in Sydney Street, west of the project boundary during a 100 year ARI event. Three residential properties in Franklyn Street would also experience an increase in peak flood level by a maximum of 0.03 metres. Floor level survey would be required to confirm whether the proposed works would increase flood damages in affected properties. Adverse flood impacts could be addressed through refinement of the grass lined channel between Sydney Street and Alexandra Street and finished surface levels in the Alexandra Street during detailed design.

Under post-construction conditions the peak overland flow across Alexandra Street, immediately downstream of the project works, would be 1.0 cubic metres per second during a 100 year ARI event, which is the same as under present day conditions.

Figure 6.10 also shows localised increases in peak 100 year ARI flood levels between Lloyd George Avenue and Coles Street to a maximum of 0.01 metres. However, these increases in flood levels are in areas that are well removed from the project works and can be attributed to modelling artefacts rather than impacts of the project works.

Figure 6.11 and **6.12** show flooding patterns and impacts, respectively, for the proposed works during a PMF event. As shown in **Figure 6.11**, the grassed channel and concrete barrier divert overland flow that surcharges stormwater drainage line XD04 in Sydney Street around the surface road works.

The PMF level in Sydney Street, upstream of the proposed surface road works is RL 28.5 metres AHD. The barrier would need to be set above the 100 year ARI flood level plus 0.5 metres, which is greater than the PMF level at this location. The flood levels at this location and height of barrier required would be subject to the final design arrangement of the diversion channel and integration with the surface road works to be developed during detailed design.

Figure 6.11 also shows the area of surface road works that drains to stormwater drainage line XD04. Runoff from this area of surface road works in excess of the capacity of stormwater drainage line XD04 would travel overland along the on- and off-ramps and into the tunnel. During detailed design it would be necessary to refine the pavement drainage design to prevent excess flow from discharging to the tunnel drainage system.

The distribution substation west of Ismay Avenue is not affected by either MSF or MOF for events up to the PMF.

The project would result in an increase in the depth and extent of inundation in Alexandra Street during a PMF event. The area affected is shown in **Figure 6.12**.

6.2.6 Cintra Park fresh air supply and water treatment facility

Figure 6.13 shows a fresh air supply and water treatment facility is proposed for the Cintra Park site that would comprise:

- A water treatment plant to treat groundwater seepage collected from the tunnels.
- A water quality basin to treat stormwater and deluge water from the tunnels.
- An electrical equipment building.

The Cintra Park site would also contain a fresh air facility as shown in **Figure 6.13**.

Figures 6.13 and **6.14** show 100 year ARI flooding patterns and impacts, respectively, under post-construction project conditions. As shown in **Figure 6.13**, the peak 100 year ARI flood level in Parramatta Road adjacent to the water treatment plant is RL 5.4 metres AHD.

From inspection of **Figure 6.14**, the provision of an overland flow path along the western side of the water treatment plant would control flow that presently surcharges Parramatta Road and flows along the location of the water treatment plant. As a result, the proposed works do not impact on existing flood behaviour in areas outside the Cintra Park site during a 100 year ARI flood. Note that the location and dimensions of the proposed overland flow path is conceptual only and would need to be developed further during detailed design based on integration with the Cintra Park site layout.

Figures 6.15 and **6.16** show flooding patterns and impacts, respectively, for a PMF event under post-construction conditions. As shown in **Figure 6.15**, the peak PMF level in Parramatta Road, adjacent to the fresh air supply facility is RL 6.2 metres AHD. Consequently, entries to the facility would need to be set at a minimum RL 6.2 metres AHD to prevent the ingress of floodwater to the tunnels during a PMF event.

From inspection of **Figure 6.16**, the project would result in an increase in peak PMF levels in Parramatta Road, and along St Lukes Park Canal and in two commercial properties on the southern side of Parramatta Road. The maximum increase in peak flood levels in Parramatta Road and St Lukes Park Canal would be 0.3 metres, with only a minor increase in the extent of flooding. Properties upstream of the project would experience a minor increase in flood levels of 0.02 metres or less.

Based on the concept design, the peak discharge from the tunnel drainage into St Lukes Park Canal is estimated to be 0.15 cubic metres per second. This compares to the peak 100 year ARI discharge in St Lukes Park Canal of 46.3 cubic metres per second (refer **Table B1** in **Appendix B1**). Based on this finding, the discharge of flow from the tunnel drainage directly to St Lukes Park Canal would not have a significant impact on flooding behaviour.

6.2.7 Parramatta Road interchange

The proposed tunnel dive structure and surface road works at the Parramatta Road interchange would cross existing stormwater drainage line XD09c as shown on **Figure 6.17**. Adjustments to existing stormwater drainage line XD09c to accommodate the proposed interchange arrangement are also shown on **Figure 6.17** and include:

- Realignment of stormwater drainage line XD09c along Parramatta Road and Bland Street. The realigned stormwater drainage line would connect into the SW trunk drainage system in Bland Street, approximately 120 metres west of Parramatta Road.
- Provision of a stormwater detention tank on the south-east corner of Bland Street and Parramatta Road. Based on the preferred design drainage drawings the tank would have a nominal volume of 850 cubic metres and would control runoff from the diverted stormwater drainage line.

Runoff from the tunnel dive structure would be controlled by the tunnel drainage system and therefore would not contribute runoff to the surface drainage system under post-construction conditions.

Tunnel ancillary facilities comprising fire water tank and pump, ventilation and electrical buildings would be located on the eastern side of Parramatta Road between Wattle Street and Walker Avenue as shown in **Figure 6.17**.

Figures 6.17 and **6.18** show 100 year ARI flooding patterns and impacts, respectively, for the post-construction conditions.

By inspection of **Figure 6.18**, the project would result in an increase in peak 100 year ARI flood levels in Parramatta Road north of Chandos Street. The maximum increase in peak flood levels would be 0.3 metres and would result in an increase in the depth and extent of flooding in the adjacent commercial property. During detailed design it would be necessary to design the diversion of stormwater drainage line XD09c and overland flow path at Chandos Street to contain flows within the project boundary.

The project would result in localised increases in flood levels at three locations along Bland Street between Parramatta Road and Curt Street. These impacts are due to the diversion of overland flow that presently crosses Parramatta Road at Chandos Street, as well as the diversion of stormwater drainage line XD09c to run along Bland Street. The maximum increase in peak flood levels occurs at the corner of Bland Street and Parramatta Road, to a maximum of 0.12 metres, within the road reserve and adjacent commercial development. These localised increased in peak 100 year ARI flood levels could be addressed through further refinement of the road and drainage design during detailed design to control the increase in overland flow that occurs along Bland Street.

There would be a slight reduction in peak 100 year ARI flood levels along the SW trunk drainage line downstream of proposed connection of stormwater drainage line XD09c Bland Street. This is due to a reduction in the total catchment area due to diversion of runoff from the tunnel dive structure into the tunnel drainage system and the attenuating effect of the stormwater detention tank on peak discharges in Bland Street.

Figures 6.19 and **6.20** show PMF flooding patterns and impacts, respectively, for the post-construction conditions.

Under post-construction conditions overland flow would occur along Parramatta Road, adjacent to the tunnel dive structure, to a maximum depth of 0.5 metres. A flood protection wall would be required around the tunnel dive structure to provide security against the ingress of overland flow during the PMF event. The height of the wall would need to be confirmed during detailed design based on final road surface grading and drainage arrangements.

The tunnel ancillary facilities located on the eastern side of Parramatta Road between Wattle Street and Walker Avenue are not affected by either MSF or MOF for events up to the PMF.

From inspection of **Figure 6.20**, the proposed works would result in an increase in peak PMF levels in Parramatta Road between Chandos Street and Alt Street to a maximum of 0.5 metres. Peak flood levels along Bland Street and Alt Street west of Parramatta Road would be increased by a maximum of 0.20 metres but typically 0.05 metres or less.

6.2.8 Wattle Street (City West Link) interchange

The Wattle Street interchange would comprise:

- A tunnel dive structure that would connect to eastbound and westbound tunnels that would form part of a future M4−M5 Link project to the existing road network at (Wattle Street tunnel dive structure).
- A tunnel dive structure that would connect to the eastbound and westbound tunnels for the project to the existing road network at Dobroyd Parade (Dobroyd Parade tunnel dive structure)
- Road surface works to provide on- and off- ramp connections between Wattle Street and Dobroyd Parade and the tunnel dive structures.

The location of the Wattle Street tunnel dive structure and associated surface road works is shown on **Figure 6.17**.

The Dobroyd Parade tunnel dive structure crosses existing transverse drainage structure XD10 as shown on **Figure 6.21**. Adjustments to the width and elevation of Dobroyd Parade and local road connections between Ramsey Street and Loudon Avenue to accommodate the proposed on- and off-ramps would extend across existing transverse drainage structures XD10 and XD11, subject to detailed design. Consideration would therefore need to be given to the impact of the proposed works on existing flood behaviour as well as the level of flood immunity afforded to the upgraded section of road.

The hydraulic assessment presented in **Chapter 4** shows that Dobroyd Parade is presently subject to frequent inundation. The proposed adjustments to Dobroyd Parade would lower the existing low points along the eastbound and westbound lanes by 0.19 metres and 0.04 metres, respectively. The low points would also be shifted approximately 20 metres west (upstream) relative to Dobroyd Canal (Iron Cove Creek) and would therefore be influenced by (slightly) higher flood levels in the creek. These changes have the potential to reduce the existing level of flood immunity.

The TUFLOW model was run for a range of storms with ARI's of five, 20 and 100 years to assess potential reductions in flood immunity and increases in depth of inundation under the proposed preferred design arrangement. The results are summarised in **Table 6.4** which shows a comparison of peak flood levels and depths of ponding under present day and post-construction conditions. **Figure 6.22** illustrates the differences in flood behaviour along Dobroyd Parade between present day and post-construction conditions based on a storm with an ARI of five years.

Table 6.4 over page shows that flood depths in Dobroyd Parade would be increased by between 0.1 and 0.3 metres across the range of storm events assessed, which is largely attributed to the lowering and relocation of the low points in Dobroyd Parade as described above. The road would be trafficable for floods less than about a 5 year ARI.

Further hydraulic investigations would be required during detailed design to develop a design arrangement that maintains the existing level of flood immunity in Dobroyd Parade. It would also be necessary to manage the increase in flood depth during larger events that would otherwise lead to an increase in flood hazard. This may require lifting of the proposed road elevations and/or increasing the capacity of the stormwater drainage system at XD10 and XD11.

It should be noted that catchment detention storage at Algie Park and upstream of the railway corridor has not been explicitly included in the hydrologic and hydraulic models developed for the present investigation. While this is considered appropriate in the context of concept design development (i.e. for confirming PMF protection to the tunnel portals and relative changes in flood behaviour) it is possible that inclusion of catchment detention storage would reduce peak flows in Dobroyd Canal (Iron Cove Creek) and in XD10 and XD11. The inclusion of this catchment storage would probably reduce the depths of ponding that are reported in **Table 6.**4. It is recommended that details of the catchment detention storage in Algie Park and upstream of the railway corridor be incorporated in the flood models which would be developed during detailed design in order to confirm the frequency of flooding in Dobroyd Parade. Consideration would need to be given to the possible failure of the railway embankment during a flood event when undertaking the assessment.

Figures 6.21 and **6.23** show flooding patterns and impacts, respectively, for the proposed works during a 100 year ARI event. As shown in **Figure 6.21**, the peak 100 year ARI flood level at the Dobroyd Parade tunnel portal is RL 2.8 metres AHD. From inspection of **Figure 6.23**, the road upgrade would result in a slight reduction in peak 100 year ARI flood levels upstream of Dobroyd Parade of up to 0.08 metres, but typically 0.02 metres or less. This is due to the finished surface of the upgraded section of Dobroyd Parade being set at or below the level of the existing road.

Note that **Figure 6.23** also shows localised increases in peak 100 year ARI flood levels to a maximum of 0.02 metres in the vicinity of Ramsey Street and Martin Street. These impacts are removed from the project works and are the result of modelling artefacts rather than a direct result of the proposed works.

Figure 6.24 and **6.25** show flooding patterns and impacts, respectively, for a PMF event under post-construction conditions. As shown in **Figure 6.24**, the peak PMF level at the Dobroyd Parade Tunnel Portal is RL 4.1 metres AHD. Allowing for the results of the sensitivity analysis presented in Appendix C, it is recommended that the road level at the entry to the tunnel portal be set at or above RL 4.2 metres AHD in order to prevent the ingress of floodwater into the tunnels in a PMF event. From inspection of **Figure 6.25**, the road upgrade would have a minor effect on flooding in the vicinity of Dobroyd Parade during a PMF event, with a maximum impact of 0.04 metres in the vicinity of Loudon Avenue.

The Wattle Street tunnel dive structure facility is not affected by either MSF or MOF. However, local catchment runoff presently drains in a northerly direction along Allum Street and across the proposed location of the tunnel dive structure. During detailed design it would be necessary to provide a drainage path to drain local catchment runoff from Allum Street around the tunnel dive structure during a PMF event.

Table 6.4 Peak flood levels in the vicinity of Dobroyd Parade – present day versus post-project conditions (m AHD)(1)

Location (2)	5 year ARI	20 year ARI	100 year ARI
Present Day Conditions			
1a. Eastbound	2.03 *[0.24]*	2.23 *[0.44]*	2.54 *[0.75]*
1b. Westbound	2.05 *[0.22]*	2.23 *[0.40]*	2.55 *[0.72]*
1c. Dobroyd Canal	1.90	2.21	2.52
Post-Project Conditions			
2a. Eastbound	1.92 *[0.32]*	2.24 *[0.64]*	2.58 *[0.98]*
2b. Westbound	2.15 *[0.37]*	2.30 *[0.52]*	2.63 *[0.85]*

Location (2)	5 year ARI	20 year ARI	100 year ARI
2c. Dobroyd Canal	1.90	2.21	2.52

(1) Note that peak flood levels are necessarily preliminary in nature and may reduce when the effects of temporary flood storage in the upper reaches of the drainage system are taken into account during detailed design.

(2) Refer **Figure 6.22** for locations.

(3) Value in [ ] relates to the depth of inundation in metres.

6.3 Impact of project on future development of affected land

The investigation found that once constructed, the project would have only a minor impact on flooding behaviour in adjacent development for storms with ARI's up to 100 years (refer **Figures 6.2**, **6.6**, **6.10**, **6.14**, **6.18** and **6.23**, as well as those contained in **Appendix D**). Based on this finding, it is concluded that the project would not have a significant impact on the future development potential of flood affected land outside the project corridor for all storms with ARI's up to 100 years. However, it is recommended that further design development be undertaken during detailed design to further reduce the residual impacts associated with the project in adjacent development, as otherwise, a floor level survey will be required to confirm that the project will not result in above-floor inundation of existing development.

The investigation also found that the project would not lead to a significant increase in the extent of land impacted by a PMF event (refer **Figures 6.4**, **6.8**, **6.12**, **6.16**, **6.20** and **6.25**). Based on this finding, it is considered that the project would not have a significant impact on the development potential of land which lies above the residential FPL (i.e. in regards the provision of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities)).

6.4 Potential impacts of future climate change

Peak flood levels at key locations along the project for present day (2015) conditions, as well as for the assessed climate change scenarios set out in **Table 3.1** are shown in **Table 6.5**. Potential impacts of future climate change on flooding behaviour for a storm with an ARI of 100 years are as follows:

- M4 Motorway Bridge at Saleyards Creek - Peak 100 year ARI flood levels could potentially increase by between 0.11 metres and 0.23 metres under future climate conditions. Under the upper bound estimate there would still be approximately 0.5 metres of clearance to the proposed bridge structure.
- Homebush Bay Drive interchange - Peak 100 year ARI flood levels could potentially increase by between 0.04 and 0.09 metres under future climate conditions. It is noted that post-climate change 100 year ARI flood levels would be approximately 0.9 metres below the PMF level, which sets the minimum level of the tunnel portals and ancillary facilities.
- Powells Creek Off-Ramp – Peak 100 year ARI flood levels could potentially be increase by between 0.12 and 0.32 metres under future climate conditions. As noted in **section 6.2.4**, no details have been provided of the level of the bridge over Powells Creek. The reduction in freeboard due to the impact of climate change would need to be considered during detailed design.
- Concord Road interchange – There could potentially be a minor increase in peak 100 year ARI flood levels of between 0.01 metres and 0.02 metres under future climate conditions, which is well within the minimum 0.5 metres freeboard to be provided to the tunnel portals.
- Cintra Park Fresh Air Supply and Water Treatment Facility – There could potentially be a minor increase in peak 100 year ARI flood level of between 0.03 metres and 0.06 metres under future climate conditions. It is noted that post-climate change peak 100 year ARI flood levels would be approximately 0.5 metres below the PMF level, which sets the minimum level of the fresh air supply facility and tunnel ancillary facilities.

- Parramatta Road interchange - There could potentially be a minor increase in peak 100 year ARI flood level of between 0.04 and 0.08 metres under future climate conditions, which is well within the minimum 0.5 metre freeboard to be provided to the flood protection barriers around the tunnel dive structure.
- Wattle Street (City West Link) interchange - Peak 100 year ARI flood levels could potentially increase by between 0.13 metres and 0.30 metres under future climate conditions. Peak 100 year ARI flood levels would still be more than 1 metre below the PMF level which sets the minimum level of the tunnel portal.

The assessment found that peak PMF levels at the proposed M4 Motorway Bridge at Saleyards Creek, the Powells Creek Off-Ramp, the Cintra Park Fresh Air Supply and Water Treatment Facility and the proposed interchanges are not sensitive to a rise in sea level of up to 0.9 metres.

Table 6.5 Summary of peak flood levels – 2015 and future climate conditions [(1)] [(2)]

Location	100 year ARI					PMF				
	2015 Conditions	Scenario 1		Scenario 2		2015 Conditions	Scenario 1		Scenario 2	
	Level (metres AHD)	Level (metres AHD)	Change (metres)	Level (metres AHD)	Change (metres)	Level (metres AHD)	Level (metres AHD)	Change (metres)	Level (metres AHD)	Change (metres)
M4 Motorway Bridge at Saleyards Creek (**Figures 6.1** and **6.3**)	3.57	3.68	+ 0.11	3.80	+ 0.23	6.26	6.26	0.00	6.26	0.00
Homebush Bay Drive interchange (**Figures 6.5** and **6.7**)	5.06	5.10	+ 0.04	5.15	+ 0.09	6.03	6.05	+0.02	6.05	+0.02
Powells Creek off-ramp (**Figures 6.5** and **6.7**)	4.57	4.69	+0.12	4.89	+0.32	6.43	6.43	0.00	6.43	0.00
Concord Road interchange (**Figures 6.9** and **6.11**)	28.38	28.39	+ 0.01	28.40	+0.02	28.46	28.46	0.00	28.46	0.00
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** and **6.15**)	5.49	5.52	+0.03	5.55	+0.06	6.11	6.15	+0.04	6.15	+0.04
Parramatta Road interchange (**Figures 6.17** and **6.19**)	20.14	20.18	+ 0.04	20.22	+ 0.08	20.39	20.39	0.00	20.39	0.00
Wattle Street (City West Link) interchange (**Figures 6.22** and **6.24**)	2.78	2.87	+ 0.09	3.05	+0.27	4.12	4.12	0.00	4.15	+ 0.03

(1) Peak flood levels quoted to two decimal places for ease of comparison only. Adopted flood levels for design purposes should be rounded off to the nearest 0.1 metres.

(2) These are peak flood levels for the particular flood event and make no allowance for freeboard (refer to **section 6.4** and **Table 6.1** for freeboard requirements).

7 Assessment of potential mitigation measures

7.1 General requirements

A Flood Management Strategy (FMS) would be prepared for flood prone or flood affected land prior to construction, or as otherwise agreed by the Secretary, to ensure that the project does not exacerbate existing flooding characteristics within the vicinity of the project. The Strategy would include but not be limited to:

(a) The identification of flood risks to the project and adjoining areas, including the consideration of local drainage catchment assessments, and climate change implications on rainfall, drainage and tidal characteristics;

(b) Identify design and mitigation measures that would be implemented to protect proposed operations and not worsen existing flooding characteristics during construction and operation, including soil erosion and scouring;

(c) Identifying drainage system upgrades;

(d) The preparation of a flood/emergency management plan; and

(e) The strategy is to be prepared in consultation with the relevant Council's.

The strategy would be prepared by a suitably qualified and experienced person in consultation with directly affected landowners, the NSW Office of Water, OEH, and relevant Councils.

The Strategy would be peer reviewed and confirmed as meeting the requirements of this condition by a suitably qualified and experienced independent hydrological engineer. The Strategy shall be submitted to the Secretary and the relevant Council prior to the commencement of construction in the vicinity of the flood prone land and overland flow paths for the waterways and catchments in the vicinity of the project, or as otherwise agreed by the Secretary."

The following sections of this chapter list measures which should be considered during the preparation of the FMS in regards both construction and operational related impacts of the project on flooding and drainage patterns.

7.2 Mitigation of construction related impacts

The FMS would need to include consideration of the following in regards managing the impact construction activities could have on flooding and drainage patterns:

Tunnel construction

- Entries to tunnel excavations, including cut and over sections of tunnel would be protected against frequent flooding through site planning to locate the openings outside flood prone areas and/or the provision of local bunding and flood protection barriers.
- The flood standard adopted at each tunnel entry during construction would need to be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to personal safety and the project works.

Surface earthworks

- Surface earthworks associated with the Concord Road, Wattle Street (City West Link) and Parramatta Road interchanges are located in areas affected by overland flows. Concentrated flow, which presently discharges onto the road corridor within areas of surface earthworks, has the potential to cause scour of disturbed surfaces and transport of sediment and construction materials. It would therefore be necessary to plan, implement and maintain measures which are aimed at intercepting this concentrated flow and diverting it in a controlled manner whether through or around the construction ancillary facilities.

Bridge construction

- Temporary falsework and access road crossings over Powells Creek are to be designed and staged to minimise the impact of construction activities on flooding conditions in adjacent development.
- Wherever possible, temporary falsework and access roads are to be removed as soon as practical after serving their primary purpose so as to minimise their likelihood of them impacting on flooding behaviour.

Spoil management

- Spoil sites would need to be located in areas which are not subject to frequent inundation by floodwater and ideally outside the 100 year ARI flood extent. The exact level of flood risk accepted at stockpile sites would depend on the duration of stockpiling operations, the type of material stored, the nature of the receiving drainage lines and also the extent to which that would impact flooding conditions in adjacent development. The frequency at which each construction site is impacted by flooding is summarised in **Table 5.1**.

Site facilities and management

- The FMS would need to include details of:
  - how the contractor would monitor weather conditions and also disseminate warnings to construction personnel of impending flood producing rain, and
  - an evacuation plan for construction personnel should a severe weather warning be issued.
- As a minimum, site facilities are to be located outside high flood hazard areas as defined in the FDM.
- For site facilities located within the floodplain, the FMS is to identify how risks to personal safety and damage to construction facilities and equipment would be managed.

Management of adverse flood impacts on existing development

- The FMS would need to include details and procedures to manage the risk of adverse flood impacts being experienced in adjacent development.
- A more detailed assessment into the impacts construction activities would have on flooding behaviour and also measures which are required to mitigate those impacts would need to be undertaken during the preparation of the FMS with the benefit of more detailed site layouts and staging diagrams.
- Subject to more detailed assessment during the preparation of the FMS, a floor level survey would need to be undertaken in affected properties (i.e. properties where there is a potential increase in flood levels) to determine whether construction activities would increase flood damages in adjacent development.
- The layout of construction ancillary facilities would need to be designed to:
  - limit the extent of works located in high flood risk areas;
  - divert overland flow either through or around work areas in a controlled manner; and
  - minimise adverse impacts on flooding behaviour in adjacent development.
- Measures to manage residual flood impacts would include:
  - staging construction to limit the extent and duration of temporary works on the floodplain;
  - ensuring construction equipment and materials are removed from floodplain areas at the completion of each work activity or should a weather warning be issued of impending flood producing rain;
  - providing temporary flood protection to properties identified as being at risk of adverse flood impacts during any stage of construction of the project; and
  - developing flood emergency response procedures to remove temporary works during periods of heavy rainfall.

Table 7.1 contains a list of measures which could be implemented in order to mitigate construction related impacts on flooding behaviour.

Table 7.1 Summary of potential construction phase mitigation measures – 100 year ARI flood

Location	Potential Mitigation Measures
M4 Motorway - Homebush Bay Drive to Pomeroy Street and Homebush Bay Drive Civil Site (C1)	• The resulting increase in peak flood levels could be mitigated by providing a setback between the edge of the existing concrete channel and the construction site. The maximum set back required would be subject to detailed design, but is estimated to be about 8 m.
Pomeroy Street civil site (C2)	• None required.
Homebush Bay Drive interchange and Underwood Road civil site (C3a)	• The impact of construction activities on flooding conditions in existing development could be mitigated by increasing the width of the flow path where it crosses the cut and cover section of tunnel and lowering ground levels in the portion of Civil Site C3a which lies on the eastern side of Underwood Street. The overland flow path through this portion of the civil site would need to be maintained in order not to increase depths of inundation in adjacent residential development. • **Figure 5.11** (right hand side) shows the impact activities would have on flooding behaviour should the aforementioned measures be implemented during construction of the project. Mitigation measures to be further developed during detailed design.
Underwood Road tunnel site (C3b)	• None required.
Powells Creek civil site (C4) Incorporating Powells Creek on-ramp	• The increase in the depth of inundation in existing commercial development could be addressed by managing the number, location and dimensions of the temporary access crossings across the Powells Creek channel at any point in time over the period of construction. The implementation of temporary flood protection measures at the allotment level could also be considered.
Concord Road interchange, M4 Motorway – Sydney Street to Parramatta Road and Concord Road civil and tunnel site (C5)	• The impacts on depths of overland flow in existing residential development are localised and could be addressed by the provision of an overland flow path through the construction site or around its perimeter to control flows in excess of the capacity of stormwater drainage line XD04.
Cintra Park tunnel site (C6) Incorporating Cintra Park fresh air supply and water treatment facility	• The impact of construction activities in Cintra Park could be reduced by the provision of an overland flow path through the site, similar to that shown on **Figure 6.13**.
Northcote Street tunnel site (C7)	• None required.
Eastern ventilation facility site (C8)	• None required.
Wattle Street (City West Link) interchange and Wattle Street and Walker Avenue civil site (C9)	• Impacts could be mitigated by the provision of local bunding to direct overland flow along the haul road and around the SW pump station.
Parramatta Road interchange and Parramatta Road civil site (C10)	• Measures to mitigate impacts could include: – Provision of an overland flow path along Parramatta Road between Chandos Street and Bland Street to control flows in excess of the capacity of stormwater drainage line XD09c. – Subject to land access, the detention tank at Bland Street and upgrades to the drainage line along Parramatta Road and Bland Street may be built as part of enabling works. Alternatively, temporary storage on site C10 could be considered. – The implementation of temporary flood protection measures at the allotment level could also be considered to address residual flood impacts.

7.3 Mitigation of post-construction related impacts

The assessment of flood impacts associated with the project has provided an understanding of the scale and nature of the flood risk to the project infrastructure and its operation, as well as the increased flood risks on the surrounding environment. A broad outline of measures which would need to be implemented in order to manage the project related flood risks and impacts are outlined below.

Tunnel portals and ancillary facilities

- Tunnel entries and associated flood protection barriers are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).
- The same hydrologic standard would be applied to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.

Emergency response facilities

- Emergency response facilities, including the motorway control centre, tunnel fire water tank and pump buildings and associated electrical substations are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).

M4 Motorway upgrade

- A 100 year ARI level of flood immunity is to be provided to the upgraded section of the M4 between Homebush Bay Drive and Parramatta Road.

Bridge waterway crossings

- Bridge crossings over waterways at Saleyards Creek and Powells Creek are to provide a minimum clearance of 0.5 metres between the underside of the bridge structure and the 100 year ARI flood level.

Modifications to Parramatta Road, Concord Road, Dobroyd Parade and Wattle Street

- Modifications to existing roads at their point of connection to the project are to be configured to ensure that the existing level of flood immunity is maintained and flood depths and hazards are not increased.

Impacts of flooding on existing development

- A 100 year ARI flood standard is to be adopted in the assessment of measures which are required to mitigate any adverse impacts attributable to the project. Changes in flood behaviour under PMF conditions are also to be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazard as a result of the project.

Potential impacts of future climate change on flooding behaviour

- The project would be designed to manage the potential impacts due to climate change in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC, 2007).

Management of adverse flood impacts on existing development

- A detailed hydrologic and hydraulic assessment into the impacts the project would have on flooding behaviour and also measures which are required to mitigate those impacts would need to be undertaken during detailed design.
- Works within the floodplain would be designed to minimise adverse impacts on surrounding development for flooding up to the 100 year ARI event. Assessment would also be made of impacts during flooding in excess of the 100 year ARI event up to the PMF in the context of impacts on critical infrastructure and flood hazards.
- A floor level survey would need to be undertaken in affected areas to determine whether the project would increase flood damages in adjacent development (i.e. in properties where there is a potential for increases in peak flood levels for events up to 100 year ARI).

- Measures would need to be incorporated in the design of the project that are aimed at mitigating its impact on flooding behaviour in properties where existing buildings would experience above floor inundation under present day (i.e. pre-project) conditions during storms with ARI's up to 100 years.
- The project and associated drainage arrangements would be designed to limit increases in peak discharges into the downstream drainage systems in accordance with local Council requirements.

Specific measures which would need to be incorporated into the detailed design in order to mitigate the residual operational flood risk identified as part of this assessment are set out in **Table 7.2**. During detailed design it would also be necessary to design surface road works at the four interchanges to maintain the existing hydrologic standard and limit increases in flood depths that would otherwise lead to an increase in flood hazard. This is of particular relevance to the road works at Dobroyd Parade which is discussed in **section 6.2.8**.

Specific measures which would need to be incorporated into the detailed design in order to mitigate the residual flood related impacts associated with storms with ARI's up to 100 years are set out in **Table 7.3**.

Table 7.2 Summary of measures aimed at reducing the operational related flood risk to the project

Location	Project Infrastructure [1]	Mitigation Requirements / Further Investigation
M4 Motorway – Homebush Bay Drive to Pomeroy Street (**Figures 6.1** and **6.3**)	Maintenance Facility and Motorway Control Centre	• Subject to appropriate local stormwater measures. • No further mitigation measures are required.
	Bridge over Saleyards Creek	• The preferred design provides in excess of minimum clearance required.
Homebush Bay Drive interchange (**Figures 6.5** and **6.7**)	Tunnel dive structure	• Subject to appropriate local stormwater measures. • No further mitigation measures are required.
	Distribution substation and ventilation facilities	• Openings to the buildings would need to be located at a minimum elevation of 6.1 metres AHD in order to prevent the ingress of floodwaters in a PMF event. This would provide a freeboard allowance for the results of the sensitivity analyses presented in Appendix C, and also provides greater than 0.5 metres freeboard to the 100 year ARI flood level.
	Substation and fire water tanks and pump buildings	• Subject to appropriate local stormwater measures. • No further mitigation measures are required.
Powells Creek Off-Ramp (**Figures 6.5** and **6.7**)	Bridge over Powells Creek	• During detailed design the bridge over Powells Creek would need to be designed to provide a minimum 0.5 m clearance between the underside of the bridge and the 100 year ARI flood level.
Concord Road interchange (**Figures 6.9** and **6.11**)	Tunnel dive structure	• A barrier wall and overland flow path would need to be provided along the eastern side of the on- and off-ramps to direct overland flow around the tunnel entry during a PMF event. • The top of the barrier wall would need to be located a minimum 0.5 metres above the 100 year ARI flood level.
	Distribution substation	• Subject to appropriate local stormwater measures. • No further mitigation measures are required.
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** and **6.15**)	Water treatment facility comprising water treatment plant, water quality basin and electrical equipment building	• Openings to the facility would need to be located at a minimum elevation of 6.2 metres AHD to prevent the ingress of floodwater in a PMF event. This would provide a freeboard allowance for the results of the sensitivity analyses presented in Appendix C, and also provides greater than 0.5 metres freeboard to the 100 year ARI flood level.

Location	Project Infrastructure [1]	Mitigation Requirements / Further Investigation
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** and **6.15**)	Fresh air supply facility	• Openings to the facility would need to be located at a minimum elevation of 6.2 metres AHD to prevent the ingress of floodwaters in a PMF event. This would provide a freeboard allowance for the results of the sensitivity analyses presented in Appendix C, and also provides greater than 0.5 metres freeboard to the 100 year ARI flood level.
Parramatta Road interchange (**Figures 6.17** and **6.19**)	Tunnel dive structure	• A barrier wall would need to be provided along the eastern side of the tunnel dive structure to direct overland flow around the tunnel entry during a PMF event. • The top of the barrier wall would need to be located a minimum 0.5 m above the 100 year ARI flood level.
	Tunnel ancillary facility comprising fire water tank and pump, ventilation and electrical buildings	• Subject to appropriate local stormwater measures. • No further mitigation measures are required.
Wattle Street (City West Link) interchange (**Figures 6.21** and **6.24**)	Dobroyd Parade tunnel dive structure	• Road level and barriers at the entry to the tunnel portals would need to be set at or above RL 4.2 metres AHD to prevent ingress of floodwaters during a PMF event. This would provide a freeboard allowance for the results of the sensitivity analyses presented in Appendix C, and also provides greater than 0.5 metres freeboard to the peak 100 year ARI flood level.
	Wattle Street tunnel dive structure	• Provision of drainage path required to drain local catchment runoff from Allum Street around the tunnel dive structure during a PMF event.

(1) Refer to the figures listed under ‘Location’ for location and extent of project infrastructure.

Table 7.3 Summary of measures aimed at mitigating the operational related impacts of the project on flooding behaviour

Location	Mitigation Measures	Comment / Further Investigation
M4 Motorway – Homebush Bay Drive to Pomeroy Street (**Figures 6.1** to **6.4**)	• The longer spans of the new bridges offset the increased hydraulic losses associated with their larger footprint and multiple bridges when compared to the existing arrangement. • Continuous walls would need to be provided between the abutments of the new bridges to provide a uniform waterway section.	• No details have been provided at the concept design stage on the dimensions of the M4 eastbound cycleway bridge. For the purpose of the flood impact assessment it was assumed that the bridge would be elevated above the floodplain. • Details of this bridge and its impact on flooding behaviour would need to be confirmed during detailed design. • The impact of the eastbound cycleway bridge could be managed by providing a waterway area consistent with that of the M4.
Homebush Bay Drive interchange (**Figures 6.5** to **6.8**)	• Adverse flood impacts during a 100 year ARI event could be addressed through refinement of the channel realignment at XD02, and reshaping of the overbank area to partially divert overland flow away from the affected properties.	• If the residual impacts cannot be removed during detailed design, then a floor level survey would be required to confirm whether the proposed works would increase flood damages in the affected properties. • Reinstatement of disturbed areas from the construction ancillary facilities north of the M4 need to be designed to minimise changes to the existing topographic features that would otherwise lead to an obstruction and/or redistribution of overland flows and adverse flood impacts.
Powells Creek Off-Ramp (**Figures 6.5** to **6.8**)	• The bridge abutment at Parramatta Road has been located to minimise impacts during a 100 year ARI event.	• No details have been provided at the preferred design stage on the location and dimensions of piers to support the bridge structure, or the elevation of the bridge deck. Piers layouts and bridge deck elevations and the management of their impact on flooding behaviour would need to be addressed during detailed design.

Location	Mitigation Measures	Comment / Further Investigation
Concord Road interchange (**Figures 6.9** to **6.12**)	• The grassed channel would need to be sized to contain 100 year ARI flows within the project corridor and thus prevent ng an increase in the extent of inundation within residential properties in Sydney Street. • Increases in flows downstream of Alexandra Street could be addressed through further development of the pit and pipe drainage system to minimise changes to the existing catchment area draining to stormwater drainage line XD04. This may involve connection of the pavement drainage line along the western side of Concord Road into Sydney Street.	• If the residual impacts cannot be removed during detailed design, then a floor level survey would be required to confirm whether the proposed works would increase flood damages in the affected properties (i.e. in properties where there is a potential increase in peak flood levels for events up to 100 year ARI). • Measures would need to be incorporated in the design of the project that are aimed at mitigating its impact on flooding behaviour in properties where existing buildings would experience above floor inundation under present day (i.e. pre-project) conditions during storms with ARI's up to 100 years.
Cintra Park Fresh Air Supply and Water Treatment Facility (**Figures 6.13** to **6.16**)	• Assessment of the preferred design arrangement shows that impacts on flooding behaviour during a 100 year ARI event can be addressed through the provision of an overland flow path through the Cintra Park site.	• The size and layout of the overland flow path is based on details provided in the LSJH Concord Oval TUFLOW model developed as part of the preferred design and would be subject to integration with the layout of the water treatment facility during detailed design.
Parramatta Road interchange (**Figures 6.17** to **6.20**)	• The diversion of stormwater drainage line XD09c and overland flow path at Chandos Street would need to be designed to contain flows within the project corridor and thus prevent an increase in the extent of inundation within the adjacent commercial property. • Increases in flows and flood levels along Parramatta Road and Bland Street could be addressed during detailed design through refinement of the pit and pipe drainage system design.	• The size and layout of the stormwater detention tank is based on details provided in the LJSH Iron Cove Creek TUFLOW model developed as part of the preferred design and would be subject to further design development and integration with the site layout during detailed design. • If the residual impacts cannot be removed during detailed design, then a floor level survey would be required to confirm whether the proposed works would increase flood damages in the affected properties (i.e. in properties where there is an identified increase in 100 year ARI flood level). • Mitigation measures would be designed to not worsen flood levels in existing buildings that experience above floor inundation under present day (i.e. pre-project) conditions during a 100 year ARI flood. In this context, not worsen is defined as a maximum increase of 0.01 m, which is considered to be within the limit of accuracy of the hydraulic model.

Location	Mitigation Measures	Comment / Further Investigation
Wattle Street (City West Link) interchange (**Figures 6.21** to **6.25**)	• Further hydraulic investigations would be required during detailed design to develop a design arrangement that maintains the existing level of flood immunity in Dobroyd Parade, and increases in depth of inundation. This may require lifting of the proposed road elevations and/or increasing the capacity of the stormwater drainage system at XD10 and XD11.	• As part of the further hydraulic investigations at Dobroyd Parade consideration should be given to the impact of detention storage within the catchment, including Algie Park and upstream of the railway corridor on flooding behaviour at Dobroyd Parade.

8 Conclusion

This report has documented the findings of a flooding and drainage related assessment that has been carried out to support the M4 East EIS. Baseline conditions with respect to existing flooding behaviour were established and the nature and extent of potential impacts associated with the proposed works identified. The potential impacts associated with both the construction and operational phases of the project were also considered as part of the assessment.

Assessment of flood risks to the project and impacts on the surrounding environment, as well as development of appropriate flood standards and mitigation measures has been carried out in accordance with the NSW Floodplain Development Manual (2005), the requirements of the environmental approvals process and industry guidelines.

A number of construction ancillary facilities have been identified that would be affected by flooding during events more frequent than a five year ARI event. **Table 5.1** summarises the construction related flood risk at the ten construction ancillary facilities. It would therefore be necessary to develop a Flood Management Strategy (FMS) which deals with the flooding and stormwater related issues that are specific to each construction site. The FMS would need to include details and procedures aimed at reducing risks to human safety and damage to infrastructure during the construction period.

A preliminary investigation into the impacts of the construction ancillary facilities on flooding (refer **Table 5.2** which summarises the key findings of the investigation) identified that the greatest potential impacts are associated with construction ancillary facilities C3a and C10. However, the investigation also found the potential for adverse flooding conditions to arise in adjacent development associated with construction ancillary facilities C1, C4, C5, C6 and C9. There is also the potential for all ten construction ancillary facility sites to impact local catchment runoff, requiring appropriate local stormwater management controls to be implemented during the construction phase of the project. The FMS would therefore need to include details and procedures to manage the risk of adverse flood impacts being experienced in adjacent development during the construction period. A range of measures aimed at mitigating the impact of construction activities on flooding behaviour are set out in **Table 7.1**.

Section 3.2 sets out the recommended level of flood protection to each project element based on a consideration of the consequences of flooding in accordance with the *NSW Floodplain Development Manual*, (DIPNR, 2005) and current Roads and Maritime standards. In particular, tunnel portals, as well as ancillary facilities such as substations, ventilation buildings and emergency response facilities are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). **Table 6.1** sets out the operational related flood risk associated with key elements of the project, while **Table 7.2** sets out measures which would need to be incorporated in the detailed design in order mitigate the assessed residual flood risk.

The investigation found that once constructed, the project would have only a minor impact on flooding behaviour in adjacent development for storms with ARI's up to 100 years (refer **Table 6.2** for summary of key findings). While it will be necessary to undertake further design development during detailed design aimed at further reducing the residual impacts of the project on flooding behaviour, it is concluded that the minor nature of the changes in flooding patterns attributable to the project would not have a significant impact on the future development potential of land located outside the project corridor for all storms with ARI's up to 100 years. **Table 7.3** sets out measures which would need to be incorporated in the detailed design in order mitigate the assessed residual flood related impacts of the project for storms with ARI's up to 100 years. It is also concluded that the project would not have a significant impact on the development potential of land which lies above the residential FPL (i.e. in regards the provision of critical infrastructure (such as hospitals) and vulnerable developments (such as aged care facilities)).

The investigation also found that changes in the characteristics of flooding associated with future climate change would not lead to a significant increase in the flood risk to the project.

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PWD (Public Works Department), 1986. *"Lower Parramatta River Flood Study".*

Sinclair Knight Merz (SKM), 2012. "*North Strathfield Rail Underpass Concept Design Report DP11.2 – Flood Impact Assessment"*

Strathfield Council, 1994. *"Stormwater Management Code".*

WMAwater, October 2014. *"Dobroyd Canal Flood Study".*

FIGURES

APPENDIX A

Overview of previous studies

Appendix A Overview of previous studies

Previous studies that have been reviewed as part of the flood assessment for the EIS are outlined below in chronological order.

The "*Powells Creek and Saleyards Creek Flood Study*" (Webb, McKeown and Associates (WMA), 1998) was requested from Strathfield Council, but was not available at the date of this report for use in the project.

Lower Parramatta River Flood Study (PWD, 1986)

NSW Public Works Department (PWD), 1986 provided Parramatta, Auburn, Ryde and Concord councils with information on the flood hazard along the lower reaches of Parramatta River and its tributaries. The study covered the Parramatta River from Charles Street Weir to Ryde Bridge and the lower reaches of Duck River, Haslams Creek and Powells Creek to Mona Street, M4 and Pomeroy Street respectively.

Hydrologic modelling was carried out using the Regional Stormwater Model (RSWM) to determine discharge hydrographs from design storms. Design rainfall data was based on the 1977 version of Australian Rainfall and Runoff. The study predated the release of the current version of AR&R (IEAust, 1998). Hydraulic modelling was undertaken using a combination of the USTFLO one-dimensional unsteady state software for the Lower Parramatta River, and the FLOWBD one-dimensional steady state software for Duck River, Haslams Creek and Powells Creek.

Survey data collected for PWD, 1986 along the lower reach of Powells Creek has been used in the present investigation to define creek bed levels within the tidal zone.

Fort Denison Sea Level Rise Vulnerability Study (DECC, 2008)

DECC, 2008 was carried out to assess the impact on Fort Denison of sea level rise projections under future climate changes conditions. The assessment was based on a comparison of current and future design still water and wave run-up levels with the existing level of infrastructure and assets on Fort Denison.

Design still water levels at Fort Denison were derived for recurrence intervals ranging from 0.02 to 200 years based on extreme value analysis using the Gumbel probability distribution function of tide gauge records at Fort Denison over the period 1914 to 2006.

The design still water levels derived in DECC, 2008 have been adopted in the present investigation (refer **Appendix C** for further details).

Parramatta River Estuary Data Compilation and Review Study (CLT, 2008)

Cardno Lawson Treloar (CLT), 2008 was prepared for Parramatta City Council, DECC (now OEH) and the Sydney Metropolitan Catchment Management Authority as part of the development of an Estuary Management Plan for the Parramatta River Estuary. The study covered the whole of the Parramatta River Estuary, which comprises the waterways, bays, foreshores and adjacent lands of the Parramatta River and its tidal tributary creeks, extending from Charles Street Weir, Parramatta and Clarkes Point, Woolwich in the north, to Yurilbin Point, Birchgrove in the south.

Relevant data comprised information on: catchment characteristics (such as climate and land use); urban stormwater, hydrology and flood behaviour; bathymetry and estuary sediments; hydrodynamics and water quality.

CLT, 2008 included contour mapping of bathymetry obtained from DECC. This mapping has been used in the present investigation to define bed levels in Homebush Bay, Canada Bay and Iron Cove.

Leichhardt Flood Study (CLT, 2010)

Cardno Lawson Treloar (CLT), 2010 was prepared for Leichhardt Council to define flood behaviour across the Leichhardt local government area. The study included the catchments of Whites Creek, Johnstons Creek and Hawthorne Canal.

Hydraulic modelling was carried out using the SOBEK two-dimensional modelling approach. Inflows to the hydraulic model were based on a combination of direct rainfall within the study area and an XP-RAFTS hydrologic model developed for catchments external to the study area.

The hydraulic model was calibrated to historical records of flooding that occurred in 1993 and validated against floods that occurred in 1991 and 1998. The 1993, 1991 and 1998 storms were estimated to be approximately 50, 20 and 10 year ARI rainfall events, respectively.

Historical flood records for the 1993 event included two observed flood levels in the Hawthorne Canal catchment, located south of Parramatta Road on George Street and Upward Street. However, CLT, 2010 found that the observed flood levels did not match well with modelled ground levels or flood depths. On this basis these observed flood levels were not considered suitable for use in the present investigation.

The use of a direct rainfall approach in CLT, 2010 (involving the application of rainfall to the surface of the hydraulic model) in lieu of the more traditional rainfall runoff hydrologic modelling of the catchments and the absence of quoted flows means that it was not possible to provide a direct comparison of design flows from the CLT, 2010 study with the present investigation. There are also no design flood levels in CLT, 2010 that could be compared with the results of the present investigation.

North Strathfield Rail Underpass Concept Design Report DP11.2 – Flood Impact Assessment (SKM, 2012)

Sinclair Knight Merz (SKM), 2012 was prepared for the Transport Construction Authority to assess the flood impacts of the proposed North Strathfield Rail Underpass (NSRU) on flows in Powell Creek. NSRU is located on the Northern Rail Line between the M4 and Pomeroy Street.

A hydraulic model was developed of the Powells Creek floodplain to assess the impact of the proposed works on existing flood behaviour. Inflows were based on hydrology developed for the *Powells Creek and Saleyards Creek Flood Study* ((WMA, 1998). The hydraulic model was developed using the TUFLOW two-dimensional modelling approach and extended from Homebush Bay to Parramatta Road.

No design flow estimates or flood levels are provided in SKM, 2012 for comparison with results of the present investigation. SKM, 2012 does include a long section profile of the peak 100 year ARI flood level along the main arm of Powells Creek. However, the scale of the figure precludes the extraction of flood levels at a level of accuracy sufficient to provide comparison with results from the present investigation.

Dobroyd Canal Flood Study (WMAwater, 2014)

WMAwater, 2014 was prepared for Sydney Water, Ashfield Council and Burwood Council to *"identify local overland flow as well as mainstream flow and define existing flood liability"* within the Dobroyd Canal catchment (referred to in this report as Iron Cove Creek).

Hydraulic modelling was carried out using the TUFLOW two-dimensional modelling approach. Inflows to the hydraulic model were based on a DRAINS hydrologic model developed for define the conversion of rainfall to runoff within subcatchments within the study area.

WMAwater, 2014 contains peak flood levels at key locations within the Dobroyd Canal (Iron Cove Creek) catchment that have been used for comparison purposes with the results of the flood assessment for the EIS. The findings of this comparison are presented in **Appendix C**.

APPENDIX B

Background to hydrologic model development

Appendix B Background to hydrologic model development

B1. General

The assessment of runoff characteristics from the catchments which contribute flows to the drainage systems along the project corridor was based on a hydrologic model developed using the DRAINS software.

DRAINS is a simulation program which converts rainfall patterns to stormwater runoff and generates discharge hydrographs. These hydrographs are then routed through networks of piped drainage systems, culverts, storages and open channels to calculate hydraulic grade lines and analyse the magnitude of overflows. Alternatively, discharge hydrographs generated by DRAINS can be used as inflows to alternative hydraulic models (such as the TUFLOW two-dimensional hydraulic modelling software) to calculate water surface levels and flooding patterns. The latter approach is particularly appropriate for modelling complex flood behaviour in urban areas involving multiple flow paths and has therefore been adopted in the present investigation. Refer Appendix C for further discussion on the development of the TUFLOW hydraulic models which have been used to define flood behaviour in the vicinity of the tunnel portals.

The extents of the various catchments that contribute flow to the existing drainage systems crossing the proposed motorway corridor are shown on **Figures 4.2** to **4.4**. The following sections of the report contain a brief description of the adopted modelling approach and present derived peak flows.

B2. DRAINS model development

B2.1. General

A number of hydrologic sub-models are available within DRAINS to simulate the conversion of rainfall to runoff. For the purpose of this present investigation, the ILSAX sub-model was selected as it is well suited to the urbanised nature of the study area.

Figures B1 to **B3** show the layout of the various sub-catchments which comprise the DRAINS models developed for the study area. Sub-catchment boundaries were digitised based on available contour information, which comprised ALS and two metre contour data. Sub-catchment slopes used for input to the DRAINS model were derived using the average sub-catchment slope, which were computed using available contour data. Aerial photography and site observations were used to assess the degree of urbanisation which is present in the study catchments.

B2.2. Design storms

Rainfall intensities for the 100 year ARI event were derived using procedures outlined in Australian Rainfall and Runoff (ARR) (IEAust, 1998) for storm durations ranging between 25 minutes and six hours. Separate design rainfall intensities were generated for each catchment to account for the variability in design rainfall values across the extent of the project corridor. The design rainfall depths were then converted into rainfall hyetographs using the temporal patterns presented in ARR.

No Aerial Reduction Factor (ARF) was applied to the design rainfall intensities obtained from ARR due to the size of the catchments within the study area (the largest of which is Dobroyd Canal (Iron Cove Creek) with an area of 6.4 square kilometres at the proposed motorway corridor).

Estimates of probable maximum precipitation were derived using the Generalised Short Duration Method (GSDM) as described in the BoM's update of Bulletin 53 (BoM, 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 square kilometres in area and storm durations up to six hours.

B2.3. Model parameters

Adopted DRAINS model parameters comprised initial losses of one and five millimetres for paved and grassed areas respectively. The soil type was set equal to three, which corresponds with a soil of comparatively high runoff potential. An antecedent moisture condition (AMC) of three was adopted, reflecting rather wet conditions prior to the onset of runoff producing rainfall.

Lagging was adopted to describe the translation of the hydrograph generated at each sub-catchment outlet along the various links to the next downstream sub-catchment. This approach required specifying a velocity of the flow along the link. The sensitivity of the results to assumed velocities ranging between one and three metres per second was tested for the 100 year ARI critical storm. After consideration a velocity of two metres per second was adopted for design.

In the absence of gauged streamflow data that could otherwise be used to calibrate the DRAINS model, peak 100 year ARI flows arriving at the project road corridor were compared to peak flow estimates derived using the Rational Method for urban catchments presented in ARR.

B3. Peak flow estimates for present day conditions

Table B1 over gives peak flow rates generated by DRAINS for each of the catchments that contribute runoff to existing cross drainage structures along the route of the project. Peak flow estimates derived by the Rational Method (RM) for the 100 year ARI event are also given for comparative purposes.

Peak 100 year ARI flows derived by DRAINS compared closely with those derived using the RM approach for all of the modelled catchments with the exception of the main arm of Dobroyd Canal (Iron Cove Creek) (i.e. the catchment contributing runoff to XD08). The reason for the higher flow in DRAINS is attributed to the shape of the catchment, where a large number of lateral branches in the drainage system combine a short distance upstream of the cross drainage structure. (The Rational Method does not account for the layout of the stormwater drainage system.)

The peak flows derived for the PMF are generally between four to five times greater than those for the corresponding 100 year ARI event, a finding which is consistent with those of similar flooding investigations undertaken in highly urbanised catchments.

Table B1 Peak flows at locations of existing cross drainage along project corridor

Catchment	I.D.	Catchment Area (hectre)	Peak Flows (cubic metres per second)(1,2) 100 year ARI RM	100 year ARI DRAINS	PMF
Powells Creek	XD01a	261	66.5	68.8[60]	362[30]
	XD01	3.8	2.1	1.8[25]	8.4[15]
	XD02	112	30.3	30.6[25]	154[30]
	XD03	300	71.4	74.9[60]	379[45]
Exile Bay	XD04	3.7	2.1	2.3[25]	9.1[15]
	XD05	21.3	8.8	7.7[25]	40.0[15]
St Lukes Park Canal	XD06	121	38.8	46.3[20]	224[15]
Barnwell Park Catchment	XD07	36.4	15.6	12.7[20]	67.4[15]
Dobroyd Canal (Iron Cove Creek)	XD08	636	135	192.1[60]	773[45]
	XD09**(3)**	9.4	5.9	4.0[25]	17.8[15]
	XD10	7.8	4.9	3.4[25]	14.9[15]
	XD11	49.0	18.3	18.4[25]	80.4[15]
Hawthorne Canal	XD12	9.7	6.3	5.6[25]	23.2[15]
	XD13	17.9	9.4	7.5[25]	32.9[15]
	XD14	295	87.4	98.1[60]	383[30]
	XD15	59.7	27.7	26.2[25]	115[15]

(1) Peak flows represent local catchment flows only and do not include bypass flows from nearby cross drainage systems.

(2) Values in [ ] represent critical storm duration in minutes.

(3) XD09 incorporates the catchments of the three cross drainage structures XD09a, XD09b and XD09c shown on **Figure 4.12**.

APPENDIX C

Background to hydraulic model development

Appendix C Background to hydraulic model development

C1. General

Detailed two-dimensional hydraulic modelling was undertaken using the TUFLOW software to define flooding behaviour along the main drainage lines which cross the proposed motorway corridor in the vicinity of the tunnel portals.

Three TUFLOW models covering the catchments of Powells Creek (denoted the ‘Powells Creek TUFLOW Model’), St Lukes Park Canal (‘St Lukes Canal TUFLOW Model’) and Dobroyd Canal (Iron Cove Creek) (‘Iron Cove Creek TUFLOW Model’) have been developed as part of the present investigation.

An additional TUFLOW model was established to undertake a detailed assessment of overland flow behaviour in the vicinity of drainage line XD04 (Exile Bay Catchment) where it crosses the project west of Concord Road (‘Concord Road TUFLOW Model’.

The TUFLOW models were initially developed to define flood behaviour at the M4 Motorway Bridge at Saleyards Creek, Powells Creek off-ramp and the four interchange under present day conditions.[9] **Chapters 5** and **6** describe how these models have subsequently been used to assess the impacts of the proposed works on flooding and drainage patterns and to evaluate potential mitigation measures.

C2. The TUFLOW modelling approach

TUFLOW is a two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system.

The basic equations of TUFLOW involve all of the terms of the St Venant equations of unsteady flow. Consequently the model is "fully dynamic" and once tuned will provide an accurate representation of the passage of the floodwave through the drainage system in terms of extent, depth, velocity and distribution of flow.

TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain and along streets. The grid system may also be used to describe the waterway area available in the channel system. Channel systems can also be modelled as one-dimensional elements embedded in the larger two-dimensional domain which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model depending on the capacity characteristics of the drainage system being modelled.

The approach adopted in the present analysis was to model open channels, culverts and pit and pipe networks as one-dimensional elements embedded in the larger two-dimensional domain representing the floodplain. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in floodplain dimensions, hydraulic structures which influence flow patterns, etc.).

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[9] *The TUFLOW models have been developed to define flow behaviour along mainstream and major overland flow paths. Protection of tunnels and ancillary facilities against local drainage and minor overland flow would be carried out through the sizing of the drainage infrastructure and design of surface grading, rather than setting minimum design levels based on existing flood behaviour. This is discussed further in* ***Chapter 6****.*

C3. Model layout

The layouts of the TUFLOW models are shown on **Figures C1** to **C4**.

An important consideration of two-dimensional modelling in an urbanised area is to ensure adequate representation of the roads, fences, buildings and other features which influence the passage of flow over the natural surface. A grid spacing of two metres was adopted to provide an appropriate level of definition of those features whilst maintaining a reasonable simulation run time.

Grid elevations were based on ALS survey data flown in 2013, with the exception of the Powells Creek TUFLOW Model (refer below for details). Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines and bridge approaches.

Harbour bed levels in Canada Bay and Iron Cove were defined using bathymetric contour data provided in the *Parramatta River Estuary Data Compilation and Review Study* (CLT, 2008).

Open channels, culverts and pit and pipe networks were defined using GIS based data obtained from SW and the local councils. This information included dimensions of channels, culverts and pipes and locations of pits, headwalls and channel junctions. At the date of this report, Strathfield Council had not provided any data pertaining to its drainage assets.

An assumed cover of 700 millimetres was adopted for those drainage elements where invert levels were not available (which applied to most of the system). This assumed cover was adjusted to ensure that the drainage system had positive fall in the downstream direction.

The footprints of a large number of individual buildings located in the two-dimensional model domain were digitised and either:

- assigned a high hydraulic roughness value which accounted for their blocking effect on flow while maintaining storage in the model; or
- assigned a grid elevation above the level of the PMF event which removed flood storage from the model and also accounted for their blocking effect on flow (this alternative approach was applied to large buildings where visual inspection identified locations where floodwater would preferentially flow around the perimeter of the structure rather than through it).

Bridge crossings over the main arms were typically defined using a combination of ALS survey data (to set bridge deck levels), SW's GIS data (to define the clear opening width) and visual inspection (to estimate the bridge deck thickness). Bridge crossings within the immediate vicinity of the project corridor, which are described in the summary below, were measured during a field inspection.

Model features and assumptions specific to each of the four models are summarised below.

Powells Creek TUFLOW Model (Figure C1):

- Dimensions of the Powells Creek (XD03) and Saleyards Creek (XD01a) channels were defined using GIS based data obtained from SW. These data were also used to define SW owned channel and pipe networks within the hydraulic model extent, including the two piped tributaries that cross the proposed motorway corridor (XD01 and XD02). Council pit and pipe data are not yet available in the Strathfield LGA.
- Invert levels in the main arm downstream of Pomeroy Street were defined using the long section profile of Powells Creek provided in the *Lower Parramatta River Flood Study* (PWD, 1986). Invert levels upstream of Pomeroy Street were based on ALS data.
- Bridge crossings over the Powells Creek (XD03) channel at Conway Avenue, Pomeroy Street, Allen Street and Parramatta Road were defined using a combination of ALS survey data (to set bridge deck levels) and measurements taken during a field inspection (to measure the thickness of the bridge deck and depth of the channel below bridge deck level).
- Bridge and culvert arrangements over the Saleyards Creek (XD01a) channel at Underwood Road, the M4, Parramatta Road, Western Rail Line and The Crescent were also defined based on the ALS survey data and field measurements described above.

- A separate model was established for the PMF to better represent flow behaviour in this extreme event. Local inflow boundaries that were causing surcharging in the channel upstream of the Western Rail Line were redistributed over a wider area. Hydraulic loss coefficients were adjusted for the bridge across Saleyards Creek at the M4 to reflect the change in flow conditions in the waterway from “unsubmerged” (in the 100 year ARI flood) to “submerged” (in the PMF).
- The reach of Saleyards Creek that runs under the Sydney Markets buildings between Parramatta Road and the Western Rail Line could not be accessed during the field inspection. The overbank either side of the main arm was therefore defined based on a uniform section. The dimensions of the overbank sections were based on the profile immediately upstream of Parramatta Road. It was also assumed that flow would be unrestricted by the buildings that lie over the channel.

Concord Road TUFLOW Model (Figure C2):

- Drainage pits and pipes were defined based on GIS based data obtained from City of Canada Bay Council.

St Lukes Park Canal TUFLOW Model (Figure C3):

- Dimensions of the main arm (XD06) were defined using GIS based data obtained from SW. Channel invert levels were defined based on ALS survey data. No ALS survey data were available within the channel in the lower reach of the canal below Gipps Street due to tidal inundation at the time the level data was captured. As a result, invert levels were defined based on the top of bank level (defined by the ALS) less the depth of channel provided in the SW data.

Iron Cove Creek TUFLOW Model (Figure C4):

- Grid elevations were defined using a combination of ALS survey data and detailed field survey in the vicinity of Dobroyd Parade.
- Dimensions of the main arm at XD08 and the two piped tributaries that cross the project corridor (XD10 and XD11) were defined using GIS based data obtained from SW.
- Invert levels in the main arm were defined using ALS survey data. These levels were then checked and adjusted between Timbrell Drive and Waratah Street based on detailed ground survey collected by WDA (to define bridge deck levels) and measurements taken during a field inspection (to measure the depth of the channel below bridge deck level).
- The bridge arrangements over the main arm at Timbrell Drive and the two pedestrian bridges opposite Crane Avenue and Waratah Street were also defined based on the detailed survey and the field measurements described above.
- Drainage pits and pipes were defined based on a combination of GIS based data obtained from Ashfield Council and SW, supplemented with detailed field survey along Dobroyd Parade.
- A separate model was established for the PMF event to remove inlet pits at Waratah Street that were causing upwelling.

C4. Model boundary conditions

C4.1. Upstream boundaries

Discharge hydrographs generated by DRAINS were applied at the inflow boundaries of the six TUFLOW models. These comprised both inflows applied at the external TUFLOW model boundary and internal point source and region[10] inflows as shown on **Figures 5.1** to **5.6**.

C4.2. Downstream boundary

The downstream boundary of the TUFLOW models comprised a tailwater representing the tidal conditions in Homebush Bay (Powells Creek TUFLOW Model), Canada Bay (St Lukes Park Canal TUFLOW Model) and Iron Cove (Iron Cove Creek TUFLOW Models). Due to the relatively short duration of catchment storm events affecting the study area, harbour levels were applied to the TUFLOW model as a static water level.

For the Concord Road TUFLOW model, the downstream boundary comprised a tailwater level based on normal depth flow conditions. The model extent was selected to ensure the downstream boundary was located a sufficient distance downstream of the project corridor to prevent any influence on flow behaviour within the vicinity of the proposed works.

Tidal harbour water levels

For the purpose of the present investigation, a static harbour level of RL 1.0 metre AHD was adopted for simulation of local catchment flood events in the absence of a storm tide. A water level of RL 1.0 metre AHD approximately corresponds to the peak water level reached on average once or twice per year during a HHWSS tide.

Storm tide harbour water levels

Office of Environment and Heritage's (OEH) guideline entitled *Flood Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments*, (DECCW, 2010) was prepared to assist councils, the development industry and consultants to incorporate the sea level rise planning benchmarks in floodplain risk management planning for new development. The guideline contains an appendix on modelling the interaction of catchment and coastal flooding for different classes of tidal waterway. The appendix may be used to derive scenarios for coincident flooding from those two sources for both present day conditions and conditions associated with future climate change.

For a catchment draining directly to the ocean via trained or otherwise stable entrances such as is the case for the catchments within the study area, the guideline offers the following alternative approaches for selecting storm tidal conditions under present day conditions. In order of increasing sophistication they are:

- A default tidal hydrograph which has a peak of 2.6 metres AHD for the 1 in 100 year event; or 2.3 metres AHD for the 1 in 20 year event. This default option is acknowledged (in DECCW, 2010) as providing a conservatively high estimate of tides for these types of entrances. Results achieved with these levels have been determined in the present investigation, but are only presented as a sensitivity study.
- A site-specific analysis of elevated water levels at the ocean boundary. The analysis should include contributions to the water levels such as tides, storm surge, wind and wave set up. The analysis should examine the duration of high tidal levels, as well as their potential coincidence with catchment flooding. This approach requires a more detailed consideration of historic tides and the entrance characteristics, but provides information which is more directly relevant to a particular entrance.

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[10] *In parts of the model area, inflow hydrographs were applied over individual regions called "Rain Boundaries". The Rain Boundaries act to "inject" flow into the one and two-dimensional domains of the TUFLOW model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow.*

The latter approach has been adopted for design purposes in the present investigation. Design still water levels applicable to Sydney Harbour were obtained from the *Fort Denison Sea Level Rise Vulnerability Study* (DECC, 2008) (refer **Table C1**). An estimate of the Extreme Tide design still water level was obtained by extrapolating the design still water level probability curve provided in Appendix C of DECC, 2008 and assuming a recurrence interval of 1 in 100,000 years.

An allowance of 0.3 metres to account for local storm effects such as wind setup and wave conditions was added to the design still water levels to yield the design peak 'storm tide' levels (also shown in **Table C1**) that were adopted for assessment of storm tide flooding in the study area.

Table C1 Design harbour water levels

Event	Design Still Water Level (1) (metres AHD)	Design Peak Storm Tide Level (metres AHD)
1 in 20 year	1.375	1.675
1 in 100 year	1.435	1.735
Extreme Tide	1.6 (2)	1.9

Source: DECC, 2008

(1) The design still water level for the Extreme Tide has been estimated based a return period of 1 in 100,000 years and extrapolation of design still water levels provided in DECC, 2008 for events up to the 1 in 200 year.

Derivation of design flood envelopes

A flood envelope approach was adopted for defining water surface elevations and flooding patterns throughout the study area. The process was as follows:

- Step 1 – Run the hydraulic model for local catchment storms of various return periods and durations in combination with the HHWSS tide level. [Note that a static water level of RL 1.0 metre AHD was adopted as the downstream boundary of the hydraulic model for these runs].
- Step 2 – Combine the results of Step 1 to create an envelope of maximum local catchment flood levels for each return period (i.e. the results of running storms of the same return period but different duration were combined to create a single envelope).
- Step 3 – Run the hydraulic model for local catchment storms in combination with peak design storm tide levels of various return periods. [Note that the static water levels shown in **Table C1** were adopted as the downstream boundary of the hydraulic model for these runs].
- Step 4 – Prepare a final set of flood envelopes for each return period using a combination of the envelopes derived from Step 2, and a corresponding storm tide condition from Step 3. **Table C2** sets out the combination of local catchment and storm tide conditions which were used to compile the design flood envelopes for the study area.

Table C2 Derivation of design flood envelopes

Design Flood Envelope (1)	Local Catchment Flood	Harbour Boundary Condition
100 year ARI	100 year ARI (2)	HHWSS peak tide level
	20 year ARI (3)	1 in 100 year peak storm tide level
PMF	PMF (4)	HHWSS peak tide level
	100 year ARI (3)	Extreme Tide peak storm tide level

(1) Indicates use of local catchment floods for durations ranging between 25 and 90 minutes.

(2) Indicates use of local catchment flood for duration of 60 minutes only.

(3) Indicates use of local catchment floods for durations ranging between 15 and 90 minutes.

C5. Model parameters

The main physical parameter represented in TUFLOW is the hydraulic roughness, which is required for each of the various types of surfaces comprising the overland flow paths in the two-dimensional domain, as well as for the streams incorporated as one-dimensional elements. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity, and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as “Manning’s n”.

Hydraulic roughness values adopted for design purposes were selected based on site inspection, past experience and values contained in the engineering literature (refer **Table C3**).

Table C3 ‘Best estimate’ of hydraulic roughness values adopted for TUFLOW modelling

Surface Treatment	Manning’s n Value
Reinforced concrete pipes and box culverts	0.015
Open channels – concrete lined	0.015 - 0.02
Roads/railways	0.02
Open channel – heavily vegetated	0.12
Grassed reserves	0.035 - 0.045
Treed areas	0.08
Buildings	10

C6. Sensitivity analyses

C6.1. Increase in hydraulic roughness

A sensitivity analysis was undertaken to assess the impact of a 20 per cent increase in the ‘best estimate’ values of hydraulic roughness (refer **Table C3**) on flooding patterns in the vicinity of the proposed tunnel entries and ancillary facilities during a PMF event. The findings of the sensitivity analysis were as follows:

- Homebush Bay Drive interchange – Peak flood levels on the northern side of the existing M4 corridor increased by up to 0.23 metres adjacent to the Underwood Road underpass, but are typically 0.1 metres or less in the vicinity of the proposed tunnel ventilation building.
- Wattle Street (City West Link) interchange – Peak flood levels adjacent to the proposed tunnel dive structure increased by up to 0.08 metres.

- Cintra Park fresh air supply and water treatment facility - Peak flood levels adjacent to the proposed facility increased by up to 0.01 metres.

Consideration of these sensitivity analyses in setting minimum design levels is discussed further in **section 6.4**.

Flood levels at the Concord Road and Parramatta Road interchanges would be dependent on the design the local surface grading, flood protection barriers and drainage infrastructure.

C6.2. Partial blockage of hydraulic structures

The impact a partial blockage of the safety fences associated with two pedestrian bridges that are located on the main arm of Dobroyd Canal (Iron Cove Creek) downstream of Ramsay Street (denoted respectively as Pedestrian Bridge ICC1 and ICC2 on **Figures 4.8** and **4.12**) has on flooding patterns in the vicinity of the Dobroyd Parade tunnel dive structure during a PMF event was assessed.

Due to the relatively close spacing of the vertical bars in the safety fence associated with Pedestrian Bridge ICC2 when compared to those on Pedestrian Bridge ICC1, blockage factors of 50 per cent and 25 per cent were respectively applied to each.

The analysis showed that peak flood levels at the location of the Dobroyd Parade tunnel dive structure would increase by 0.04 metres, from 4.12 metres AHD to 4.16 metres AHD should the safety fences along both pedestrian bridges experience a partial blockage during a PMF event.

C6.3 Increase in tailwater level

A sensitivity analysis was undertaken to assess the impact an increase in tailwater level would have on flooding patterns in the vicinity of the Dobroyd Parade tunnel dive structure and Cintra Park fresh air supply facility during a PMF event. A tailwater level of 2.6 metres AHD was modelled based on the 1 in 100 year ARI storm tide level of 1.7 metres AHD plus a 0.9 metres sea level rise[11].

The analysis showed that were a PMF event to occur following a rise in sea levels of 0.9 metres and in combination with a 1 in 100 year storm tide, then peak flood levels at the location of the Dobroyd Parade tunnel dive structure would only increase by 0.03 metres when compared to present day conditions (i.e. from RL 4.12 metres AHD to RL 4.15 metres AHD). The corresponding increase in peak flood level at the Cintra Park fresh air supply facility would be 0.04 metres.

C7. Comparison of results with previous studies

Results of hydraulic modelling were compared to peak flood levels presented in WMAwater, 2014 at five locations in the Dobroyd Canal (Iron Cove Creek) catchment in the vicinity of the project for the 100 year ARI and PMF events. The locations selected for the comparison are shown on **Figure C4** while a summary of results is presented in **Table C4**.

Table C4 shows that peak 100 year ARI flood levels from the present study are typically 0.2 to 0.4 metres higher than those in WMAwater, 2014, while PMF levels from the present study are typically 0.2 metres higher than corresponding values in WMAwater, 2014. The main exception to these trends was at Frederick Street (P5) where the result of the present study were within 0.02 metres of the WMAwater, 2014 results for both the 100 year ARI and PMF events.

The differences in peak flood levels can be attributed to the inclusion of catchment storage in the WMAwater, 2014 hydraulic model. For the present study the extent and detail in the hydraulic model has been tailored specifically to the assessment of flood behaviour in the vicinity of the project. In comparison, the WMAwater, 2014 study is based on a broad scale, catchment wide hydraulic model that includes catchment storage within areas upstream of the project. Upstream catchment storage has less of an influence on peak PMF flood levels due to the volume of runoff in this event. There is

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[11] *A rise in sea level of 0.9 metres is based on the 2100 projection from the OEH guideline "Floodplain Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments" (DECCW, 2010). Refer to **Section 6.5** for an assessment of the potential impacts of climate change on sea level rise and increased rainfall intensities across the project.*

limited catchment storage upstream of Frederick Street, which would explain the lower differences in results at this location.

With due consideration of the above comparison, the hydraulic model developed for the EIS is considered appropriate in the assessment of the concept design and in particular confirming PMF protection to the tunnel entries and ancillary facilities and relative changes in flood behaviour.

Table C4 Comparison of peak flood levels (m AHD)

Location		100 year ARI		PMF	
ID	Description	EIS	WMAwater(1)	EIS	WMAwater(1)
P1	Dobroyd Canal (Iron Cove Creek) upstream of Timbrell Drive	2.15	1.77	3.10	2.89
P2	Timbrell Drive	1.97	Not flooded	2.70	2.72
P3	Dobroyd Parade	2.37	2.23	3.16	2.99
P4	Dobroyd Canal (Iron Cove Creek) downstream of Parramatta Road	3.40	3.19	5.74	5.50
P5	Frederick Street	9.42	9.41	9.94	9.92

(1) Based on results presented in Table 24 of WMAwater, 2014.

C8. Model results – present day conditions

Results of the hydraulic modelling are presented in the following figures and described in **section 4.3** of this report:

- **Figures 4.5**, **4.6**, **4.7** and **4.8** show design 100 year ARI and PMF water surface profiles along the main arms of Saleyards Creek, Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively.
- **Figures 4.9**, **4.11** and **4.12** show 100 year ARI flooding patterns along the modelled reaches of Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively. **Figure 4.10** also shows detailed 100 year ARI flooding patterns in the vicinity of the Concord Road interchange.
- **Figures 4.13**, **4.15** and **4.16** show flooding patterns in a PMF event along the modelled reaches of Powells Creek, St Lukes Park Canal and Dobroyd Canal (Iron Cove Creek), respectively. Detailed PMF flooding patterns in the vicinity of the Concord Road interchange are show on **Figure 4.14**.

Figures showing flooding patterns from local catchment flooding in a 5, 20 and 200 year ARI event are provided at the end of this Appendix.

C9. Assessment of post-construction conditions

This section describes the changes that were made to the structure of the TUFLOW models that were originally developed to define flooding behaviour under present day conditions to incorporate details of the project under post-construction construction conditions.

Changes made to the TUFLOW models were based on concept road and drainage design drawings and models provided by WDA in May and June 2015. Assumptions and limitations of the hydraulic modelling based on available details of the concept design provided by WDA are identified that would need to be confirmed during detailed design.

M4 Motorway - Homebush Bay Drive to Pomeroy Street (Figure 6.1):

- The Powells Creek TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- Proposed bridge arrangements and design surface elevations were obtained from the TUFLOW model developed by the Leighton Samsung John Holland joint venture (LSJH) as part of the concept design (LSJH Powells Creek TUFLOW model).
- No details have been provided of the dimensions of the new bridge downstream of the existing M4 to accommodate the M4 eastbound cycleway overpass. For the purpose of the flood impact assessment it was assumed that this bridge would be elevated above the floodplain. Details of this bridge and its impact on flooding would need to be confirmed during detailed design.

Homebush Bay Drive interchange (Figure 6.5):

- The Powells Creek TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- Modifications to transverse drainage structures XD01 and XD02 and design surface elevations were obtained from the LSJH Powells Creek TUFLOW model.
- Existing buildings over the alignment of the cut and cover tunnel were removed from the TUFLOW model representing post-construction conditions as shown on **Figure 6.5**.
- For the purpose of assessing a 'worst-case' scenario, no changes were made to existing topographic features, including building footprints, in areas of the construction ancillary facilities north of the M4 (refer construction site C3a in **section 5.3** of this report). During details design it would be necessary to design the reinstatement of cut and cover and construction ancillary facilities to minimise changes to existing topographic features that would otherwise lead to an obstruction and/or redistribution of overland flow and adverse flood impacts in areas outside the project corridor.

Powells Creek off-ramp (Figure 6.5):

- The Powells Creek TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- Details of the Powells Creek off-ramp were not included in the LSJH Powells Creek TUFLOW model. The location of the bridge abutments were therefore obtained from concept road design.
- No details were provided of the proposed location and dimensions of piers to support the bridge structure. For the purpose of the flood impact assessment no piers have been included in the TUFLOW model representing post-construction conditions. Details of the pier layout and their impact on flooding would need to be confirmed during detailed design.

Concord Road interchange (Figure 6.9):

- The Concord Road TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- Modifications to the TUFLOW model to reflect the concept design was based on the concept road and drainage design drawings.
- Design surface elevations, including concrete barriers, were obtained from concept road design model.
- The proposed pit and pipe layout and alignment of the grass lined channel between Sydney Street and Alexandra Street were obtained from the concept drainage design drawings.
- Inflow boundaries in the TUFLOW model were adjusted to reflect the changes in catchment runoff attributable to the surface road works.

Cintra Park fresh air supply and water treatment facility (Figure 6.13):

- The St Lukes Park Canal TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- The footprint of the Cintra Park water treatment facility and emergency smoke extraction ventilation outlet were raised above the PMF level to represent a complete blockage to flow.
- A nominal three metre wide overland flow path was provided along the western side of the facility between Parramatta Road and Gipps Street based on details provided in the TUFLOW model developed by LSJH as part of the concept design (LSJH St Lukes Park Canal TUFLOW model).
- The car park area located in the north-west corner of the site was assumed to be constructed at-grade.
- No details have been provided on the peak combined discharge from the water treatment plant and water quality basin. For the purpose of the flood impact assessment no change has been made to the model inflow conditions. During detailed design it would be necessary to design the discharge of treated water from the water treatment facility to control peak discharges that would otherwise lead to adverse impacts on flood behaviour in St Lukes Park canal.

Parramatta Road interchange (Figure 6.17):

- The Iron Cove Creek TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- The following modifications were made based on details provided in the TUFLOW model developed by LSJH as part of the concept design (LSJH Iron Cove Creek TUFLOW model):
  - Ground levels within the project footprint were adjusted to suit the design elevations of the surface road works.
  - A flood protection barrier was inserted along the eastern side of the tunnel dive structure as shown in **Figure 6.17**.
  - Stormwater drainage line XD09c was diverted along Parramatta Road to connect into the Sydney Water trunk drainage line in Bland Street. The location of the connection point was adjusted from the southern side to the northern side of Bland Street to connect into the 1600 millimetre RCP instead of the 1350 millimetre RCP and thus reduce hydraulic losses that would otherwise cause surcharge of the drainage system in Bland Street.
  - The stormwater detention tank was modelled as an oversized culvert based on the dimensions provided in the LSJH Iron Cove Creek TUFLOW model. The location of the stormwater detention tank, which had been included in the LSJH Iron Cove Creek TUFLOW on the western side of Parramatta Road, was relocated to suit the latest concept design drawings (Revision W).
- In addition, inflow boundaries in the TUFLOW model were also adjusted to reflect the changes in catchment runoff attributable to the surface road works.

Wattle Street (City West Link) interchange (Figure 6.21):

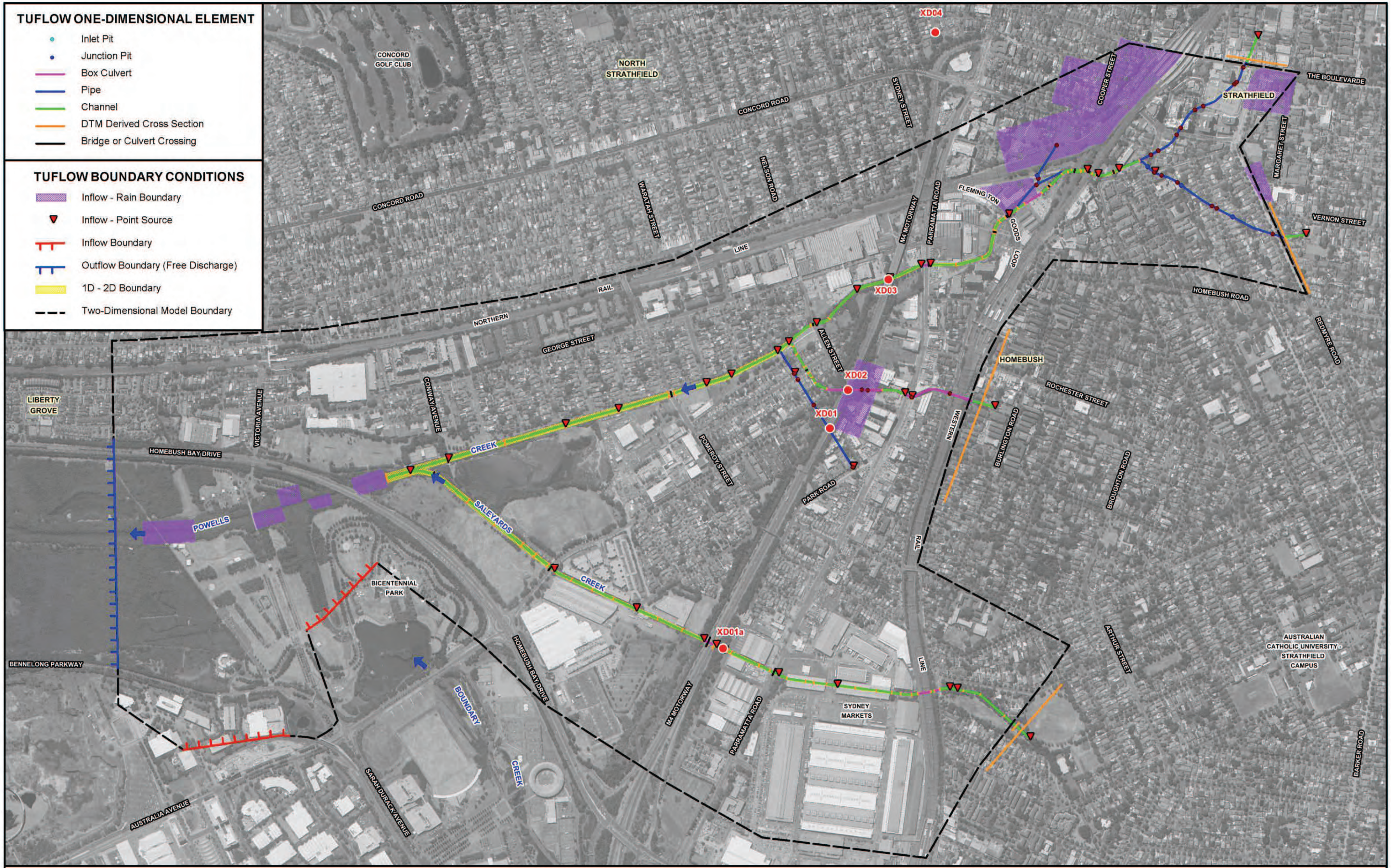
- The Iron Cove Creek TUFLOW model representing present day conditions was modified to reflect the proposed concept design arrangement.
- The following modifications were made based on details provided in the TUFLOW model developed by LSJH as part of the concept design of the Wattle Street interchange (LSJH Iron Cove Creek TUFLOW model):
  - Ground elevations within the project footprint were adjusted to suit the design elevations of the surface road works. This included a flood protection barrier at the tunnel portals.
  - Adjustments were made to the pit and pipe drainage systems along Dobroyd Parade to accommodate the proposed road works.
  - In addition, inflow boundaries in the model were adjusted to reflect changes in catchment runoff attributable to the proposed surface road works.

C10. Model results – post-construction conditions

Results of the hydraulic modelling of post-construction conditions are presented in the following figures and described in **section 6.2** of this report:

- **Figures 6.1** to **6.21** and **6.23** to **6.25** show flooding patterns and impacts under post-construction conditions in a 100 year ARI and PMF event.
- **Figure 6.24** shows a comparison of flooding patterns at Dobroyd Parade under present day and post-construction conditions in a five year ARI event.

Figures showing flooding patterns and impacts under post-construction conditions during a 5, 20 and 200 year ARI event are provided in **Appendix D**.



LEGEND

XD01 Location of Existing Cross Drainage Structures along M4 Motorway/Parramatta Road

Lyall & Associates

WESTCONNEX M4 EAST EIS
SURFACE WATER: FLOODING AND DRAINAGE

Figure C1

POWELLS CREEK TUFLOW MODEL LAYOUT

60 0 60 120 180 m

Scale: 1:6,000

LEGEND

XD01 ● Location of Existing Cross Drainage Structures along M4 Motorway/Parramatta Road

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WESTCONNEX M4 EAST EIS
SURFACE WATER: FLOODING AND DRAINAGE

Figure C2

CONCORD ROAD TUFLOW MODEL LAYOUT