

Transport for NSW
Parramatta Light Rail
Flooding Technical Paper

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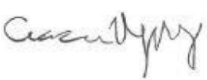


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Contents

	Page
1 Introduction	1
1.1 Project Background	1
1.2 Project Description	1
1.3 Purpose and Scope of this Report	4
1.4 Secretary's Environmental Assessment Requirements	4
1.5 Structure of this Report	5
2 Assessment Methodology	6
2.1 Data Review	6
2.2 Baseline Model Development	6
2.3 Existing Flood Behaviour	7
2.4 Existing Flood and Emergency Management	7
2.5 Development of PLR Scheme Flood Model	7
2.6 Impact of the Project on Flood Behaviour	7
2.7 Impact on Flood and Emergency Management	8
2.8 Climate Change Assessment	8
2.9 Performance Requirements and Mitigation Measures	8
3 Legislative and Policy Context	9
3.1 General	9
3.2 NSW Flood Policies and Guidelines	10
3.3 Local Flood-Related Policies and Plans	11
3.4 Climate Change Policy and Guidance	14
3.5 Sydney Water Requirements	15
4 Existing Environment and Baseline Data	16
4.1 Overview of Catchments and Waterways	16
4.2 Previous Studies and Investigations	19
4.3 Other Available Data	24
4.4 Data Limitations	35
4.5 Existing Flood Response and Flood Risk Management Plans	36
5 Hydraulic Model Development	38
5.1 General Approach	38
5.2 Hydrology	40
5.3 Hydraulic Model	46
5.4 Modelled Flood Events	52
5.5 Mapping of Flood Behaviour	53
5.6 Model Suitability	54

6	Climate Change	55
6.1	Overview	55
6.2	Modelled Scenarios	56
7	Existing Scenario Flood Results	56
7.1	Peak Flood Conditions	56
7.2	Preliminary Hydraulic Categorisation	61
7.3	Provisional Hazard Categories	63
7.4	Model Sensitivity	65
7.5	Climate Change	71
7.6	Model Comparison	74
7.7	Summary	85
8	PLR Performance Criteria and Design Status	85
8.1	Overview	85
8.2	Performance Criteria	86
8.3	Key Design Criteria	86
8.4	Stormwater Drainage	87
8.5	Design Flood Model Assumptions	89
9	Assessment of Potential Impacts	96
9.1	Construction Impacts	96
9.2	PLR Operational Performance	105
9.3	Post-Construction Impacts	109
10	Management of Potential Impacts	134
10.1	General Requirements	134
10.2	Management of Construction Impacts	134
10.3	Management of Post-Construction Impacts	141
11	Summary	155

Tables

Table 1 Secretary's environmental assessment requirements – flooding and hydrology

Table 2 Previous Flood Studies

Table 3 Comparison of Peak Flows at Charles Street Weir

Table 4 Drainage Network Data

Table 5 Westmead Sub-Model IFD Table

Table 6 North Parramatta Sub-Model IFD Table

Table 7 Parramatta CBD Sub-Model IFD Table

Table 8 Camellia Sub-Model IFD Table

Table 9	Carlingford Sub-Model IFD Table
Table 10	Initial and Continuing Losses Adopted for PLR TUFLOW Models
Table 11	Manning's n Roughness Values
Table 12	Storm Durations Modelled
Table 13	Catchment Yield for Urban Catchments in Sydney with Similar Characteristics to the PLR Catchments
Table 14	Catchment Yield Check for PLR Food Models
Table 15	Key Design Criteria
Table 16	Stormwater Design Categories
Table 17	Proposed Drainage Design Principles
Table 18	Key Stormwater Design Elements
Table 19	Modelled Drainage Alignment with Proposed Drainage Principles
Table 20	Key Waterway Crossings
Table 21	Flood Risks and Potential Impacts - Construction Compounds
Table 22	Potential Bridge Construction Impacts
Table 23	Key PLR Infrastructure Flood Affection
Table 24	Point locations and flood risk
Table 25	Stop communications equipment and flood risk
Table 26	Assessment of Off-Alignment Roadworks Impacts
Table 27	Summary of potential construction phase mitigation measures - key sites
Table 28	Degraded Mode Protocols
Table 29	Summary of PLR Impacts and Mitigation Measures

Figures

Figure 1	Key Features of the Project
Figure 2	The Parramatta River Catchment
Figure 3	Topography of the Catchment
Figure 4	Aerial photography of part of Parramatta River Catchment, 1943
Figure 5	Aerial photography of part of Parramatta River Catchment, 2014, illustrating increased urbanisation
Figure 6	Council Flood Extent Map - 1% AEP
Figure 7	Council Flood Extent Map - PMF
Figure 8	Riverbank Car Park facing east towards Wilde Avenue Bridge – 1988
Figure 9	Queen's Wharf Reserve facing west towards MacArthur Street Bridge - 1988
Figure 10	Overtopping of Charles Street Weir - date unknown
Figure 11	Lennox Bridge (downstream face – eastern side), 30 April 1988
Figure 12	Lennox Bridge (upstream face – western side), 30 April 1988
Figure 13	Riverside Theatres, Upstream of Lennox Bridge, 30 April 1988
Figure 14	Station Street East and Parkes Street East (facing south) – date unknown (Source - Google)

- Figure 15 Scouring of asphalt at Marsden Street / Macquarie Street due to overland flow, 30 April 1988
- Figure 16 Considerable stormwater structure at Clay Cliff Creek, River Road West (Source - Arup)
- Figure 17 Flow in gutter at Smith Street looking south towards the Macquarie Street intersection
- Figure 18 Flow in gutter along the southern side of Macquarie Street looking east towards Horwood Place intersection
- Figure 19 Ponding in footpath sag – north-west corner of George/Church Street intersection
- Figure 20 Flood Emergency Response Classification - Parramatta CBD
- Figure 21 Flood Model Catchment Boundaries
- Figure 22 Westmead Precinct existing flooding issues
- Figure 23 Parramatta North Precinct existing flooding issues
- Figure 24 Parramatta CBD Precinct existing flooding issues
- Figure 25 Rosehill and Camellia Precinct existing flooding issues
- Figure 26 Provisional Hydraulic Hazard Categories
- Figure 27 Church Street between Lennox Bridge and Phillip Street - 0.2EY event
- Figure 28 Church Street between Lennox Bridge and Phillip Street – 1% AEP event
- Figure 29 Macquarie Street east of Smith Street - 0.2EY event
- Figure 30 Macquarie Street east of Smith Street – 1% AEP event
- Figure 31 Change in Peak Water Levels with Lennox Bridge Bikeway Portals - 0.2EY Event
- Figure 32 Change in Peak Water Levels with Lennox Bridge Bikeway Portals - 1% AEP Event
- Figure 33 Peak Water Level Comparison - Westmead Model
- Figure 34 Peak Water Level Comparison - North Parramatta Model
- Figure 35 Peak Water Level Comparison - Parramatta CBD Model
- Figure 36 Peak Water Level Comparison - Camellia Model
- Figure 37 Test sub-catchment model areas (blue) developed in DRAINS for comparison of PLR TUFLOW models
- Figure 38 PLR Hazard Zone
- Figure 39 Westmead Precinct - Impacts of the PLR Project
- Figure 40 Parramatta North Precinct - Impacts of the PLR Project
- Figure 41 Parramatta CBD Precinct - Impacts of the PLR Project
- Figure 42 Rosehill and Camellia Precinct - Impacts of the PLR Project
- Figure 43 Carlingford Precinct - Impacts of the PLR Project
- Figure 44 1% AEP Peak Velocity Changes: Existing vs PLR Post-Construction (Parramatta CBD TUFLOW model)
- Figure 45 1% AEP Peak Velocity Changes (North Parramatta): Existing vs Post-Construction (North Parramatta TUFLOW model)
- Figure 46 Impact of Stabling and Maintenance Facility Fill on PMF Peak Water Level
- Figure 47 Preliminary Flood Event Process Map

Appendices

Appendix A

Maps

- Map 5.1 Catchment Plan
- Map 5.2 Digital Terrain Mapping - Westmead Model
- Map 5.3 Digital Terrain Mapping - North Parramatta Model
- Map 5.4 Digital Terrain Mapping - Parramatta CBD Model
- Map 5.5 Digital Terrain Mapping - Camellia Model
- Map 5.6 Digital Terrain Mapping - Carlingford Model
- Map 5.7 Stormwater Network Mapping - Westmead Model
- Map 5.8 Stormwater Network Mapping - North Parramatta Model
- Map 5.9 Stormwater Network Mapping - Parramatta CBD Model
- Map 5.10 Stormwater Network Mapping - Camellia Model
- Map 5.11 Existing Drainage Performance - Westmead Model
- Map 5.12 Existing Drainage Performance - North Parramatta Model
- Map 5.13 Existing Drainage Performance - Parramatta CBD Model
- Map 5.14 Existing Drainage Performance - Camellia Model
- Map 5.15 1% AEP Existing Critical Storm Duration - Westmead Model
- Map 5.16 1% AEP Existing Critical Storm Duration - North Parramatta Model
- Map 5.17 1% AEP Existing Critical Storm Duration - Parramatta CBD Model
- Map 5.18 1% AEP Existing Critical Storm Duration - Camellia CBD Model
- Map 5.19 1% AEP Existing Critical Storm Duration - Carlingford Model
- Map 7.1 Existing Peak Flood Depths - 0.2 EY - Westmead Model
- Map 7.2 Existing Peak Flood Depths - 0.2 EY - North Parramatta Model
- Map 7.3 Existing Peak Flood Depths - 0.2 EY - Parramatta CBD Model
- Map 7.4 Existing Peak Flood Depths - 0.2 EY - Camellia Model
- Map 7.5 Existing Peak Flood Depths - 0.2 EY - Carlingford Model - Sheet 1
- Map 7.6 Existing Peak Flood Depths - 0.2 EY - Carlingford Model - Sheet 2
- Map 7.7 Existing Peak Flood Depths - 5% AEP - Westmead Model
- Map 7.8 Existing Peak Flood Depths - 5% AEP - North Parramatta Model
- Map 7.9 Existing Peak Flood Depths - 5% AEP - Parramatta CBD Model
- Map 7.10 Existing Peak Flood Depths - 5% AEP - Camellia Model
- Map 7.11 Existing Peak Flood Depths - 5% AEP - Carlingford Model - Sheet 1
- Map 7.12 Existing Peak Flood Depths - 5% AEP - Carlingford Model - Sheet 2
- Map 7.13 Existing Peak Flood Depths - 1% AEP - Westmead Model
- Map 7.14 Existing Peak Flood Depths - 1% AEP - North Parramatta Model
- Map 7.15 Existing Peak Flood Depths - 1% AEP - Parramatta CBD Model
- Map 7.16 Existing Peak Flood Depths - 1% AEP - Camellia Model
- Map 7.17 Existing Peak Flood Depths - 1% AEP - Carlingford Model - Sheet 1
- Map 7.18 Existing Peak Flood Depths - 1% AEP - Carlingford Model - Sheet 2
- Map 7.19 Existing Hydraulic Categorisation - 1% AEP
- Map 7.20 Existing Hydraulic Hazard - 1% AEP

- Map 7.21 Existing Peak Flood Depths - PMF
- Map 8.1 Concept Stormwater Design - Westmead Model
- Map 8.2 Concept Stormwater Design - North Parramatta Model
- Map 8.3 Concept Stormwater Design - Parramatta CBD Model
- Map 8.4 Concept Stormwater Design - Camellia Model
- Map 8.5 Concept Stormwater Design - Carlingford Model - Sheet 1
- Map 8.6 Concept Stormwater Design - Carlingford Model - Sheet 2
- Map 9.1 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 1
- Map 9.2 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 2
- Map 9.3 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 3
- Map 9.4 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 4
- Map 9.5 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 5
- Map 9.6 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 6
- Map 9.7 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 7
- Map 9.8 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 8
- Map 9.9 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 9
- Map 9.10 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 10
- Map 9.11 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 11
- Map 9.12 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 12
- Map 9.13 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 1
- Map 9.14 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 2
- Map 9.15 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 3
- Map 9.16 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 4
- Map 9.17 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 5
- Map 9.18 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 6
- Map 9.19 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 7
- Map 9.20 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 8
- Map 9.21 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 9
- Map 9.22 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 10
- Map 9.23 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 11
- Map 9.24 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 12
- Map 9.25 Impact of PLR Project - 1% AEP - Sheet 1
- Map 9.26 Impact of PLR Project - 1% AEP - Sheet 2
- Map 9.27 Impact of PLR Project - 1% AEP - Sheet 3
- Map 9.28 Impact of PLR Project - 1% AEP - Sheet 4
- Map 9.29 Impact of PLR Project - 1% AEP - Sheet 5
- Map 9.30 Impact of PLR Project - 1% AEP - Sheet 6
- Map 9.31 Impact of PLR Project - 1% AEP - Sheet 7
- Map 9.32 Impact of PLR Project - 1% AEP - Sheet 8
- Map 9.33 Impact of PLR Project - 1% AEP - Sheet 9
- Map 9.34 Impact of PLR Project - 1% AEP - Sheet 10
- Map 9.35 Impact of PLR Project - 1% AEP - Sheet 11
- Map 9.36 Impact of PLR Project - 1% AEP - Sheet 12
- Map 9.37 PLR Post-Construction Hydraulic Categorisation - 1% AEP
- Map 9.38 Change in Hydraulic Hazard - 1% AEP - Westmead Model
- Map 9.39 Change in Hydraulic Hazard - 1% AEP - North Parramatta Model
- Map 9.40 Change in Hydraulic Hazard - 1% AEP - Parramatta CBD Model
- Map 9.41 Change in Hydraulic Hazard - 1% AEP - Camellia Model
- Map 9.42 Change in Hydraulic Hazard - 1% AEP - Carlingford Model - Sheet 1

Map 9.43 Change in Hydraulic Hazard - 1% AEP - Carlingford Model - Sheet 2
Map 9.44 Climate Change Impact on PLR Project - 0.2EY - Westmead Model
Map 9.45 Climate Change Impact on PLR Project - 0.2EY - North Parramatta Model
Map 9.46 Climate Change Impact on PLR Project - 0.2EY - Parramatta CBD Model
Map 9.47 Climate Change Impact on PLR Project - 0.2EY - Camellia Model
Map 9.48 Climate Change Impact on PLR Project - 0.2EY - Carlingford Model
Map 9.49 Climate Change Impact on PLR Project - 0.2EY - Carlingford Model
Map 9.50 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Westmead Model
Map 9.51 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - North Parramatta Model
Map 9.52 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Parramatta CBD Model
Map 9.53 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Camellia Model
Map 9.54 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Carlingford Model Sheet 1
Map 9.55 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Carlingford Model Sheet 2
Map 9.56 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Westmead Model
Map 9.57 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - North Parramatta Model
Map 9.58 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Parramatta CBD Model
Map 9.59 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Camellia Model
Map 9.60 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Carlingford Model Sheet 1
Map 9.61 Impact of PLR with Upper Bound Climate Change - 1% AEP - Carlingford Model Sheet 2
Map 9.62 PLR Post-Construction Peak Flood Depths - PMF

Glossary of Terms and Abbreviations

Acronym/Term	Definition
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.
AHD	Australian Height Datum
ALS	Airborne Laser Scanning, sometimes known as LiDAR
AR&R	Australian Rainfall and Runoff
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
CoP	City of Parramatta Council
DCP	Development Control Plan
DECC	Department of Environment & Climate Change (now OEH, see below)
DECCW	Department of Environment & Climate Change and Water (now OEH, see below)
DISPLAN	Parramatta Local Disaster Plan
DoP	Department of Planning (now DP&E, see below)
DP&E	Department of Planning and Environment
DRAINS	Hydrologic computer model
DTM	Digital Terrain Model
EIS	Environmental Impact Statement
EP&A	Environmental Planning and Assessment
EY	Exceedances per Year – The number of times an event is likely to occur or be exceeded within any given year
FMS	Flood Management Strategy
FPL	Flood Planning Level
FRMP	Flood (also Floodplain) Risk Management Plan
GIS	Geographic Information System
GPU	Graphics Processing Unit (referring to a different version of TUFLOW (2d overland flow only – no pipes) that simulates flooding with this processor. Note that conventional TUFLOW (1d/2d) uses a Core Processing Unit (CPU)
GSDM	Generalised Short Duration Method
HEC-RAS	1D hydraulic computer model
IFD	Intensity, Frequency and Duration of Rainfall

Acronym/Term	Definition
IPCC	Intergovernmental Panel on Climate Change
LEP	Local Environment Plan
LGA	Local Government Area
LiDAR	Light Detection And Ranging
LPR	Lower Parramatta River
LRV	Light Rail Vehicle
m	metre
MIKE 11	1D hydraulic computer model
m ³ /s	cubic metres per second (flow measurement)
m/s	metres per second (velocity measurement)
OCC	Operations Control Centre
OEH	Office of Environment and Heritage
OSD	On Site Detention
PLR	Parramatta Light Rail
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
RL	Reduced Level
Roads and Maritime	Roads and Maritime Services
SEARs	Secretary's Environmental Assessment Requirements
SES	State Emergency Service
TPS	Traction Power Substation
TUFLOW	One-dimensional (1D) and two-dimensional (2D) flood and tide simulation software program (hydraulic computer model)
UPR	Upper Parramatta River
1D	One dimensional
2D	Two dimensional
3D	Three dimensional

Executive Summary

Overview

Transport for New South Wales (TfNSW) is developing the Parramatta Light Rail (PLR) to deliver a light rail network from Westmead to Carlingford via Parramatta CBD, Camellia and Sydney Olympic Park. On 17 February 2017, the NSW Government announced that it would be proceeding with first stage of Parramatta Light Rail. Parramatta Light Rail (Stage 1) (the project) would extend from Westmead to Carlingford via Parramatta CBD and Camellia.

The project is subject to assessment by the Department of Planning and Environment and approval by the Minister for Planning under Part 5.1 of the (NSW) *Environmental Planning and Assessment Act 1979* (EP&A Act). This flooding impact assessment is one of a number of technical papers that forms part of the EIS. The purpose of this technical paper is to identify and assess the hydrology and flooding impacts of the project during both construction and operation. In doing so it responds directly to the Secretary's Environmental Assessment Requirements (SEARs) outlined in section 1.4. Additionally, this report addresses flood risks to the PLR infrastructure and operations.

Catchment context

The PLR project extents are wholly located within the Parramatta River Catchment. With reference to Figure 2, the Parramatta River Catchment covers a large area of Western Sydney, approximately 257 km² and spanning over several LGAs before discharging into Sydney Harbour at the confluence of Lane Cove River. Parts of the catchment through which the PLR alignment traverses are subject to mainstream riverine flooding and overland flow flooding.

Policy Context

An initial review of the requirements of the SEARs was carried out, in conjunction with a review of relevant legislation and guidelines, to determine the level of detail required in the development of suitable flood models to address these requirements. A discussion on policy context and relevant guidelines is provided in section 3.

Data Gathering and Model Development

Baseline data and previous flood model information was provided by City of Parramatta Council, Sydney Water and other stakeholders. Following assessment of all information received to date, it was concluded that the existing flood models were insufficient/inappropriate to assess either flood immunity or impact of the PLR project. Therefore, new models have been established for the PLR project, using baseline data and historic models provided. There were a number of limitations on the data available for model establishment, which are discussed in section 4.4. Notwithstanding the limited information provided, due care and diligence was carried out in developing models to determine the existing flooding conditions, and the mechanisms that cause them. Details of the data received and data review process are provided in section 4. Details on the model development process are provided in section 5.

Model Suitability

Comparative assessments of baseline model results were made against historical studies and comparison with alternative hydrological methods was carried out. In addition, noting the general uncertainty in hydraulic modelling, a level of sensitivity analysis was carried out appropriate to the level of design development and available information. These processes, as outlined in section 7.4 and section 7.6, confirmed the suitability of the models in assessing relative impacts for the PLR project.

Baseline Flood Behaviour

To complement modelled results for existing flood depth, hydraulic categorisation and hazard, existing flood risk management plans and emergency management plans were reviewed to understand current flood management procedures within and adjacent to the PLR project. Appropriate stakeholders, including CoP and the SES were consulted in relation to flood emergency management.

PLR Performance Criteria and Design

Having determined the existing hazard and flooding mechanisms, the concept design road and rail alignment was incorporated into the TUFLOW flood models, along with a concept stormwater design, to enable assessment of impacts.

Performance criteria for the PLR project in terms of drainage and flooding were provided in section 8, along with the recommended level of flood protection to each element of the project.

Assessment of Construction Impacts

Construction phase flood risks and impacts were qualitatively assessed using baseline flood depths and extents. These are summarised in section 9.1. Construction compounds and worksites with flood risks and potential for flood impact include Alfred Street, Tramway Avenue, James Ruse Drive, Parramatta River Bridge South and Vineyard Creek. Bridge construction and modification generally along the alignment has the potential to impact flooding. A Flood Management Strategy (FMS) would be prepared to address management of both flood risk and flood impact. Potential mitigation measures for construction phase flood impacts are identified in section 10.2.

Assessment of Operational Flood Risk

Flood risk during the operation phase was assessed for each project element against the recommended level of flood protection previously identified. It was demonstrated that it is likely to be hydraulically feasible to achieve operability for the PLR in a 0.2EY event. It was also demonstrated that the recommended level of flood protection for the stabling and maintenance facility, traction substations and communications equipment could be achieved with the exception of the communications equipment located on the Tramway Avenue platform. An outline of potential operational flood emergency management protocols for the PLR was developed. Flood risk is described in section 9.2 with relevant mitigation measures provided in section 10.3.3.

Assessment of Operational Flood Impact

Flood impact during the operation phase was assessed in the 1% AEP event. While the majority of impacts are contained within the road corridor, minor local impacts outside the road corridor are predicted at various locations. Detailed discussion on impacts is provided in section 9.3.2. It is noted that due to the extent of road network modification, a degree of afflux would occur solely as a consequence of change in road level, without significantly altering flood depth. A risk-based approach should be considered in further assessment.

A review of the peak velocities in Parramatta River was carried out to determine whether the PLR project would be likely to result in any increases to flow velocity in Parramatta River. It was found that the change in velocity as a result of the PLR project were generally minimal relative to the existing velocities in the river. Local changes in velocities were found near the PLR alignment and proposed bridges and would not result in potential for significant erosion and/or scour. Changes in peak flow velocity along the proposed PLR alignment are seen as a result of the inevitable change in road geometry. However, these changes are minimal and not likely to result in potential scour or erosion along the largely impermeable corridor.

The impact of raising levels by approximately 2m at the stabling and maintenance facility site was assessed for the PMF event. Results indicate that localised impacts of up to +400mm would occur within the surrounding road reserve. Further design development to address impacts within the road reserve would be undertaken during detailed design, including assessment of detailed stabling and maintenance facility grading plans, stormwater drainage within the facility and stormwater mitigation measures within affected roads.

Existing critical infrastructure was identified along the alignment, and no significant adverse impacts were identified for a PMF event. Results for the PMF event are to be considered broadly indicative only given the method of assessment, and require confirmation through detailed modelling in future project design stages. Future modelling would be required to assess impact of new bridges in the PMF event.

Change in hydraulic categorisation and provisional flood hazard was assessed. Results indicate that the project would have minimal impact on existing hydraulic categorisation and flood hazard. The project is therefore considered unlikely to impact existing flood emergency management procedures. The potential impacts of future climate change were also assessed, in accordance with current guidance documents.

General mitigation measures to achieve performance outcomes, as well as specific mitigation measures to address local impacts are identified in section 10.3.4.

The TUFLOW models established for the EIS have been built for the sole purpose of determining existing flood conditions in the vicinity of the light rail alignment and likely impacts of the alignment on flood behaviour. As such, the results should not be used for identifying flood prone or impacted properties, and subsequently notification of Section 149 certificates. The models are considered a suitable base for further model development in subsequent stages of the PLR design. Requirements for the further development of the models are outlined in section 10.3.2.

1 Introduction

1.1 Project Background

Transport for New South Wales (Transport for NSW) is developing the Parramatta Light Rail (PLR) to deliver a light rail network from Westmead to Carlingford via Parramatta CBD, Camellia and Sydney Olympic Park. This work builds on the actions identified in the NSW Long Term Transport Master Plan (Transport for NSW, 2012) Sydney's Light Rail Future – Expanding public transport, revitalising our city (NSW Government, 2012) and Unlocking Western Sydney's Potential with Light Rail: Western Sydney Light Rail Feasibility Study (Parramatta City Council, 2013).

In December 2015, the NSW Government announced a preferred network for Parramatta Light Rail to link areas that are being transformed by government and private investment, including Westmead, Parramatta North, Camellia, Telopea, Rydalmere and Sydney Olympic Park. Parramatta Light Rail would also serve major attractions in the Parramatta CBD including the new Western Sydney Stadium and the Museum of Applied Arts and Science.

On 17 February 2017, the NSW Government announced that it would be proceeding with first stage of Parramatta Light Rail. Parramatta Light Rail (Stage 1) (the project) would extend from Westmead to Carlingford via Parramatta CBD and Camellia.

1.2 Project Description

The proposed action would include the provision and operation of the following key features:

- A light rail network of around 12 kilometres in length (including approximately seven kilometres within the existing road corridor separated from general traffic and approximately five kilometres utilising the existing Carlingford Line and Sandown Line for use as dedicated light rail corridors and replacing heavy rail services).
- A total of 16 stops (subject to further design development). The stops would form a combination of side and island platforms depending on the final design of the proposed action and existing constraints at each stop location. Platforms would be approximately 45 metres long.
- Interchanges with existing rail and/or bus facilities at Westmead, Parramatta CBD, and Carlingford.
- Creation of two light rail priority zones (no general vehicle access) along Church Street (generally between Lennox Bridge and Macquarie Street) and Macquarie Street (generally between Horwood Place and Smith Street) within the Parramatta CBD.

- Light rail vehicle (LRV) driver amenities at light rail termini at Westmead and Carlingford and at the stabling and maintenance facility at Camellia.
- An integrated maintenance and stabling facility located in Camellia. The maintenance facility would consist of a number of elements including:
 - Stabling area for storage of LRVs.
 - A stabling and maintenance building including a workshop containing servicing tracks to carry out LRV inspections and administration facilities for managing the administration, operation and maintenance of the PLR Systems.
 - An automatic train wash plant and sanding plant for replenishing LRV sand boxes and for testing sanding equipment.
- Provision of a number of new bridge structures along the alignment including over James Ruse Drive, Clay Cliff Creek, Parramatta River (near the Cumberland Hospital) and Vineyard Creek, Rydalmere.
- Modification (including potential duplication at some locations) of Lennox Bridge (Church Street) and five existing bridge structures along the Carlingford Line (Parramatta River, Vineyard Creek, Kissing Point Road, Adderton Road and Pennant Hills Road) to accommodate the light rail alignment and active transport links.
- Alterations to the existing road network to accommodate the proposed action, including line marking, additional traffic lanes and turning lanes, new traffic signals, and changes to traffic flows (e.g. creation of left-in, left-out arrangements etc.).
- Ancillary infrastructure including up to eight electricity substations and overhead lines and poles to allow for LRV operations.
- Active transport corridors (shared paths) and additional urban design features along sections of the alignment and at stop locations.
- Replacement of existing rail infrastructure along the former Sandown Line corridor, between the junction at Camellia Station and the stabling and maintenance facility, and removal of the remaining rail infrastructure, east of the stabling and maintenance facility.
- Removal of existing rail infrastructure at the Parramatta Road level crossing and closure of the existing Carlingford Line north of Parramatta Road.

The proposed alignment for the proposed action is provided in Figure 1.

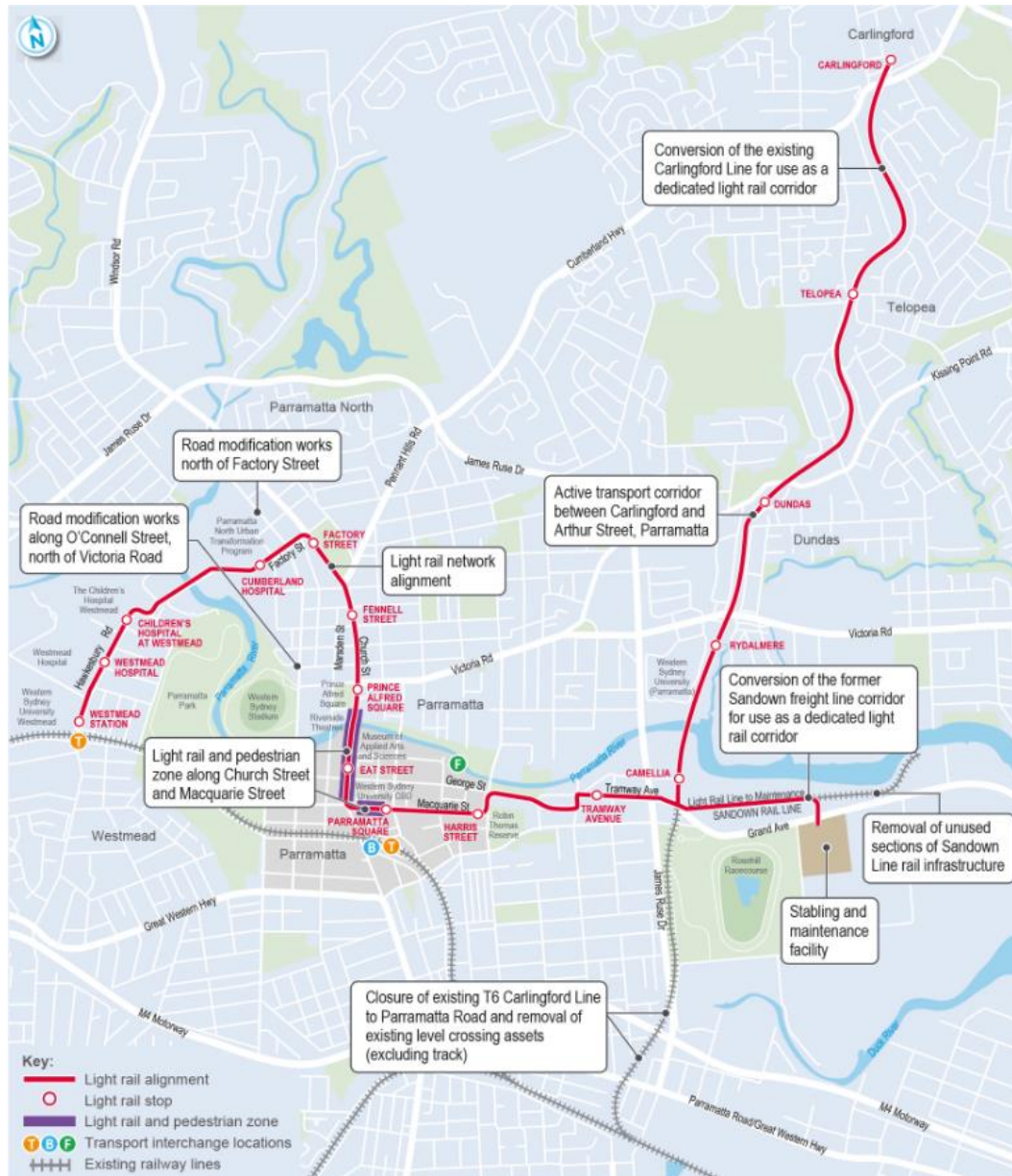


Figure 1 Key Features of the Project

The assessment of the project has been carried out using both a regional and local (or precinct-based) approach to assessment of potential environmental impacts. This approach has been used to reflect the different local areas along the project alignment, each which have a distinctive character and which would be impacted in different ways by the project. Five separate precincts have been identified along the project alignment and which have been used as the basis for reporting potential impacts within this assessment. The identified precincts are:

- Westmead – between the Westmead terminus and the Parramatta River crossing west of the Cumberland Hospital district
- Parramatta North – between the Parramatta River crossing west of the Cumberland Hospital district and Victoria Road

- Parramatta CBD – between Victoria Road and Purchase Street (inclusive of Robin Thomas Reserve)
- Rosehill and Camellia – between Purchase Street and the stabling and maintenance facility
- Carlingford – consisting of the heavy rail line, north of the Parramatta River.

However, the flooding analysis presented in this report has been carried out on a sub-catchment basis. Sub-catchments have been determined based on topography and therefore boundaries are not necessarily coincident with the above precinct extents. Hydraulic model development (as outlined in section 5 of this report) is therefore described in terms of sub-catchments rather than precincts.

1.3 Purpose and Scope of this Report

The project is subject to assessment by the Department of Planning and Environment and approval by the Minister for Planning under Part 5.1 of the (NSW) *Environmental Planning and Assessment Act 1979* (EP&A Act).

This flooding impact assessment is one of a number of technical papers that forms part of the EIS. The purpose of this technical paper is to identify and assess the hydrology and flooding impacts of the project during both construction and operation. In doing so it responds directly to the Secretary's Environmental Assessment Requirements (SEARs) outlined in section 1.4.

For the purpose of investigating impacts on flooding, the project study area includes the project corridor as defined in section 1.2 and adjacent lands potentially subject to indirect impacts.

1.4 Secretary's Environmental Assessment Requirements

Specific SEARs relating to flooding which have been identified for the project are described in Table 1.

Table 1 Secretary's environmental assessment requirements – flooding and hydrology

Requirement	Where addressed in this paper
The Proponent must model (where appropriate), assess and mitigate, taking into account relevant Council-adopted flood models or latest flood data available from Council, the impacts on flood behaviour during construction and operation for flood events ranging from the 1% AEP up to the Probable Maximum Flood (taking into account sea level rise and storm intensity due to climate change) to identify: <ul style="list-style-type: none"> (a) Increases in the potential flood affectation of other properties, assets and infrastructure; 	Section 9 Maps 9.1- 9.36 Maps 9.44 – 9.61 Map 9.62
<ul style="list-style-type: none"> (b) Consistency (or inconsistency) with applicable Council floodplain risk management plans; 	Section 3.3 Section 9.3.8
<ul style="list-style-type: none"> (c) Compatibility with the flood hazard of the land; 	Section 7.3 Section 9.3.4 Map 7.20 Maps 9.38 - 9.43
<ul style="list-style-type: none"> (d) Compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land; 	Section 7.2 Section 9.3.4 Map 7.19 Map 9.37
<ul style="list-style-type: none"> (e) Downstream velocity and scour potential; 	Section 9.3.3
<ul style="list-style-type: none"> (f) Impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council, and 	Section 9.3.8
<ul style="list-style-type: none"> (g) Any impacts the development may have on the social and economic costs to the community as consequence of flooding. 	Not included in this report. Addressed as part of separate “Business Impact Assessment and Social Impact Assessment” as part of wider EIS.

1.5 Structure of this Report

The structure and content of this report is as follows:

The working paper is structured as follows:

- Section 1 (this section) – Project background and description
- Section 2 – An overview of the methodology used for assessment
- Section 3 – Description of the legislative and policy context, and relevant criteria applicable to the project
- Section 4 – An overview of the existing hydrological environment

- Section 5 – A description of the development of the hydraulic model
- Section 6 – An overview of how climate change has been assessed
- Section 7 – Baseline (existing) case flood results
- Section 8 - An overview of the concept drainage design
- Section 9 – An assessment of potential impacts during the construction and operational phases of the project
- Section 10 – Recommended measures to mitigate and manage potential hydrology and flooding impacts during the project
- Section 11 – Summary and recommendations.

2 Assessment Methodology

The following outline methodology was adopted in assessing impacts of the project on flood behaviour during construction and operation. Detailed methodologies for each element of this assessment are provided in subsequent sections.

2.1 Data Review

An initial review of the requirements of the SEARs was carried out, in conjunction with a review of relevant legislation and guidelines, to determine the level of detail required in the development of suitable flood models to address these requirements. A discussion on policy context and relevant guidelines is provided in section 3.

A review of existing hydraulic models and all other available flood and drainage related information was then carried out. This enabled a determination on the suitability of existing models in addressing the SEARs, and identification of shortfalls in existing models provided in addressing these requirements. Data gathering and review is discussed in section 4.

The outcome of this process was the decision to develop new flood models, using various inputs from the existing models, in order to sufficiently understand flood behaviour and assess impact of the project.

2.2 Baseline Model Development

A TUFLOW GPU model was created to identify overland flow behaviour within the catchment, and enable derivation of sub-catchments for development of more manageable sub-models. Following this, 1d/2d sub-models were developed (except where noted) using TUFLOW to establish existing flooding behaviour. Further detail on the model development process is provided in section 5.

Each sub-model was reviewed to establish its suitability as a baseline against which impacts of the PLR project could be assessed. This review included comparison of results against known flood studies and anecdotal historical

flooding information. Sensitivity testing of sub-models was also carried out to understand the consequences of a deviation in model assumptions/parameters on reported flood behaviour.

At the conclusion of this process, the baseline models were deemed suitable for assessing impacts associated with the PLR project.

2.3 Existing Flood Behaviour

The baseline sub-models were then analysed to establish:

- Existing flood depths and levels
- Existing hydraulic categorisation
- Existing flood hazard.

Existing flood behaviour is discussed in section 7. These results, along with PLR operational requirements, were used to inform 3D alignment designs and stormwater drainage system concept designs for the project.

2.4 Existing Flood and Emergency Management

Existing City of Parramatta (CoP) Flood Risk Management Plans and the Parramatta Local Disaster Plan (DISPLAN) were reviewed to understand existing management measures to respond to flooding and flood risk. These formed the baseline for assessment of impacts on the PLR project on existing emergency management procedures.

2.5 Development of PLR Scheme Flood Model

Changes to the ground profile associated with the light rail and associated road adjustments were incorporated into the TUFLOW sub-models to assess changes in flood behaviour. A concept stormwater drainage design as well as new or modified waterway crossings were also included within the TUFLOW model.

The concept road, rail and drainage design was iteratively developed to minimise flood impact from PLR and minimise light rail operability impacts associated with existing flooding. The concept design is discussed in section 8.

At the time of preparing this report, the 3D model of proposed roadworks extended only to the roads into which the light rail is integrated. Additional “off-alignment” roadworks that are required for the project were available as a 2D design only. As such, topographical and drainage changes associated with these “off-alignment” areas were not included in the PLR scheme flood models.

2.6 Impact of the Project on Flood Behaviour

A qualitative approach was taken to the assessment of construction phase impacts, based on review of construction sites and project staging against existing overland flow and riverine flooding behaviour. Risks and impacts associated with each

construction activity were identified to inform the requirements for the construction phase flood risk management plans.

For the operations phase, the PLR Scheme models were analysed to establish:

- Post-PLR flood depths and levels
- Afflux
- Impact on velocity of floodwaters;
- Change to hydraulic categorisation
- Change in flood hazard, and consistency with applicable floodplain risk management plans.

The impacts presented represent residual impact following concept-level iteration of the road, rail and drainage design.

A qualitative approach was taken for assessment of impacts from “off-alignment” roadworks, as discussed in the preceding section.

Impact assessment is discussed in detail in section 9.

2.7 Impact on Flood and Emergency Management

Changes to flood behaviour were then reviewed to identify any impacts on flood emergency management. Operational strategies were also prepared to address management of PLR operations during flood events.

2.8 Climate Change Assessment

Climate change assessment was carried out for both existing and PLR Scheme models, and a comparative assessment of the relative difference carried out. Climate change scenarios, established in line with current guidance, are discussed in section 6 with results presented in section 9.

2.9 Performance Requirements and Mitigation Measures

Additional mitigation measures were then identified for any areas where residual impacts have been reported.

Final mitigation measures require further design development of road, rail, urban and stormwater designs, as well as receipt of additional topographical, property, drainage and utilities survey. Flood models would be subject to ongoing refinement of baseline and design information. As such, a set of performance requirements for flooding have been established. These are discussed in section 8.2.

3 Legislative and Policy Context

3.1 General

Relevant policies and guidelines that have been considered as part of this assessment include:

- Flood Prone Land Policy (NSW Government)
- Section 117(2) Local Planning Direction 4.3 “Flood Prone Land” (NSW Government)
- PS 07-003 New guideline and changes to section 117 direction and EP&A Regulation on flood prone land (NSW Government)
- Australian Rainfall and Runoff (Institute of Engineers, Australia 1998 - updated from 1987 edition) (AR&R 1987)
- Australian Rainfall and Runoff: A Guide to Flood Estimation (Commonwealth of Australia, 2016) (AR&R 2016)
- The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method (Bureau of Meteorology (BoM), 2003)
- Floodplain Development Manual (NSW Department of Infrastructure, Planning and Natural Resources, 2005)
- Practical Consideration of Climate Change - Flood risk management guideline (Department of Environment and Climate Change (DECC), 2007)
- NSW Sea Level Rise Policy Statement (NSW Government, 2009)
- Derivation of the NSW Government’s Sea Level Rise Planning Benchmarks. Technical Note (Department of Environment, Climate Change and Water (DECCW), 2009)
- CoP Climate Extremes Risk Assessment and Adaptation Plan (Parsons Brinckerhoff, 2011)
- Local Environment Plan (CoP, 2011)
- Floodplain Risk Management Policy (CoP, 2014)
- Lower Parramatta River Catchment Floodplain Risk Management Study & Plan (SKM for CoP, August 2005)
- Draft Update of Parramatta Floodplain Risk Management Plans (Molino Stewart for CoP, 2016)
- Parramatta Local Disaster Plan (Parramatta Local Emergency Management Committee, 2010) (DISPLAN)
- Building Bridges over Sydney Water's Open Stormwater Channels (Sydney Water, publication date not supplied).

Although listed as a reference document within the SEARs, the *Draft Best Practice Urban Design in Flood Prone Areas – Urban Design Strategy* (CoP,

2016 prepared by Architectus and Cardno) was not publically available at the time of preparing this report, and has therefore not been reviewed.

Similarly, the Upper Parramatta River Floodplain Risk Management Study and Plan has not been provided by CoP for review, and therefore has not been reviewed as part of this assessment.

3.2 NSW Flood Policies and Guidelines

3.2.1 Floodplain Development Manual

The Floodplain Development Manual incorporates the NSW Flood Prone Land Policy, which aims to reduce the impact of flooding on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. The policy also recognises the benefits of use, occupation and development of flood prone land.

This manual indicates that responsibility for management of flood risk remains with local government. The manual assists councils to balance the conflicting objectives of the floodplain through a risk management process.

The manual recommends against applying rigid and prescriptive criteria for assessing developments in flood prone land, and instead advocates that “*a merit approach shall be adopted for all development decisions in the floodplain to take into account social, economic and ecological factors, as well as flooding considerations*”.

This aligns with the approach being taken in assessing impacts from the PLR project and in developing a range of mitigation measures to minimise impacts.

3.2.2 Planning Circular PS07-003 – New Guideline and Changes to Section 117 Direction and EP&A Regulation on Flood Prone Land

In January 2007 the NSW Department of Planning (DOP) issued *Planning circular PS 07-003 "New guideline and changes to section 117 direction and Environmental Planning and Assessment Regulation on flood prone land"*.

This document provided guidance on changes to flood-related development controls on residential development on land above the 1% AEP flood but below the Probable Maximum Flood (PMF). This land is typically classified as low flood risk. The circular summarised:

- A new *Guideline on development controls on low flood risk areas – Floodplain Development Manual*
- An amendment to Schedule 4 of the Environmental Planning and Assessment Regulation 2000 – *Environmental Planning and Assessment Amendment (Flood Related Development Controls Information) Regulation 2007*
- Revisions to Direction No. 15 – Flood Prone Land under section 117 of the *Environmental Planning and Assessment Act 1979*.

Key elements of this circular and associated guideline and regulatory changes are as follows:

- The new Guideline confirms that unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the flood planning level (FPL) for residential development. In putting forward a case for exceptional circumstances, a council would need to demonstrate that local flood behaviour, flood history and associated flood hazards warranted a different FPL. This case would need to be put to the Department of Planning and Environment (DP&E) prior to exhibiting a draft Local Environment Plan (LEP) or draft Development Control Plan (DCP) containing the proposed controls.
- The new Guideline acknowledged that different controls may apply to critical infrastructure (such as hospitals) and consideration given to evacuation routes and vulnerable developments (e.g. nursing homes) in areas above the 1% AEP flood.
- Consistency with the Guideline will be required when councils are preparing draft local environmental plans.

In July 2007 the NSW Government's Minister for Planning issued a new set of directions under section 117(2) of the Environmental Planning and Assessment Act. *Direction 4.3 – Flood Prone Land* replaced the original *Direction No. 15 – Flood Prone Land*. The content of the direction was largely unchanged.

Direction 4.3 - Flood Prone Land applies to all councils that contain flood prone land within their Local Government Area (LGA) and applies when a council prepares a planning proposal that creates, removes or alters a zone of provision that affects flood prone land. The purpose of the direction is to ensure that provisions of a council's LEP are consistent with the NSW Government's *Flood Prone Land Policy*, *Floodplain Development Manual* and *Guideline on Development Controls on Low Flood Risk Areas* and adequately consider flood hazard and flood impacts.

Consistent with the Guideline and Direction, impacts the project would have on existing flood behaviour and also the future development potential of flood prone land outside the project corridor have been assessed primarily against the 1% AEP event for residential, commercial and industrial development.

Potential impacts of the project in the PMF have also been assessed, as required by the SEARs, with a focus on potential impacts to critical infrastructure (such as hospitals and substations) and vulnerable developments (such as aged care facilities).

3.3 Local Flood-Related Policies and Plans

3.3.1 CoP – Local Environment Plan (LEP)

CoP LEP 2011 outlines flood-related planning controls applicable to development at or below flood planning level in Section 6.3 - Flood planning. The LEP defines

flood planning level as “1:100 ARI (average recurrence interval) flood event plus 0.5 metre freeboard”. Key objectives outlined for flood planning areas as follows:

... “(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land’s flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment”.

These objectives are consistent with the SEARs provided for the PLR project.

3.3.2 CoP Floodplain Risk Management Policy

The CoP Floodplain Risk Management Policy applies to all flood prone land, whether private or publically owned, anywhere in the Local Government Area. The policy applies the flood management principles of the NSW Government at a local level.

The primary objective of the Parramatta Floodplain Risk Management Policy is to encourage measures that:

“Reduce or eliminate the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and reduce private and public losses resulting from floods.”

The policy outlines four principles that it is influenced by.

1. *Flood prone land is a valuable resource that should be managed and developed, subject to a merit approach that provides due consideration to social, economic and environmental criteria, as well as any flooding criteria, as identified in flood studies, independent assessments or strategically developed floodplain risk management studies and plans.*
2. *Both mainstream and overland flooding are to be considered when assessing flood risk.*
3. *Flood prone land should not be sterilised by unnecessarily precluding development through the application of rigid and prescriptive criteria, however inappropriate proposals should not be accepted.*
4. *Measures to increase resilience across the LGA should be encouraged so as to reduce the long term effects of flooding when it occurs.*

The PLR project is supportive of and seeks to be consistent with CoP’s Floodplain Risk Management Policy Principles listed above.

3.3.3 CoP Upper Parramatta River Catchment Floodplain Risk Management Study & Plan

This information has not been made available by CoP.

3.3.4 CoP Lower Parramatta River Catchment Floodplain Risk Management Study & Plan

The documents available to the PLR project team include the Floodplain Risk Management Study only, which includes options to be considered in a Floodplain Risk Management Plan. The Floodplain Risk Management Plan component has not been made available by CoP.

The PLR Project has considered, and does not preclude, potential future drainage improvement options presented in the study. There would be ongoing consultation with City of Parramatta to review consistency of the project with any future floodplain risk management study and / or planned development for the Parramatta River catchment.

3.3.5 CoP Draft Parramatta CBD Floodplain Risk Management Plan

City of Parramatta has recently released an update to the Parramatta Floodplain Risk Management Plan (FRMP). The draft document updates the existing Parramatta LGA FRMP for the CBD study area. The PLR alignment passes through the CBD area from the Church Street / Pennant Hills Road intersection through to Macquarie / Harris Street.

The plan identifies that a large part of the CBD would fall within the category of “low flood island”, which is defined as an area for which the evacuation route (typically the road network) is cut by flooding before the area itself is inundated. Macquarie Street is generally the boundary of the “low flood island” zone, with areas to the south of Macquarie Street having “rising road access”, i.e. an evacuation route that rises to a level above the PMF.

Key relevant proposed measures of the draft CBD Floodplain Risk Management Plan include:

- Revisions to Council’s DCP and LEP, in particular requirements for developments to include safe shelter-in-place or evacuation to a level above the PMF
- Council and the NSW State Emergency Service (SES) to develop the Local Flood Plan
- Council to continue to develop the proposed Flood Early Warning System for the CBD.

The PLR project seeks to be consistent with the floodplain risk management measures identified. There would be ongoing consultation with City of Parramatta to review consistency of the project with any future floodplain risk management study and / or planned development for the Parramatta River catchment. The emergency response categorisation of the CBD has been reviewed and potential impacts of the PLR project are addressed in section 9.3.8 of this report.

3.3.6 CoP Draft Best Practice Urban Design in Flood Prone Areas – Urban Design Strategy (CoP, 2016 prepared by Architectus and Cardno)

This information has not been made available by CoP, as it is not yet publically released. A presentation on key principles of the strategy was provided by CoP to the PLR design team on 19 April 2017, and these have been considered in the PLR design.

3.3.7 Existing Local Flood Response Plans

The current Parramatta Local Disaster Plan (DISPLAN) is dated December 2010. The DISPLAN does not reference a sub-plan related to flooding and the February 2016 *Draft Update of Parramatta Floodplain Risk Management Plans* (Molino Stewart for CoP) notes that there is currently no completed Local Flood Plan for the Parramatta LGA. The DISPLAN covers the whole of the City of Parramatta which represents an area of 60.5 square kilometres.

The DISPLAN broadly advocates an approach of Shelter-In-Place/stay at work rather than evacuation. A full discussion on the DISPLAN is provided in section 4.5.

Potential impacts of the project on emergency management arrangements outlined in the DISPLAN are addressed in section 9.3.8 of this report.

It is understood from consultation with CoP that the DISPLAN is currently under review.

3.4 Climate Change Policy and Guidance

3.4.1 Floodplain Risk Management Guideline – Practical Considerations of Climate Change (DECC, 2007)

The DECC guidance recommends that until further clarity is available on the impact of climate change on rainfall intensity, flood modelling should incorporate sensitivity analyses utilising increases in rainfall intensities of between 10 and 30 per cent.

Given the long design life of the PLR project, the effect of both the upper and lower bound intensity increases were evaluated.

3.4.2 NSW Sea Level Rise Policy Statement (NSW Government, 2009)

The NSW Government's *NSW Sea Level Rise Policy Statement (November 2009)* was prepared to predict sea level rise caused by climate change and inform both local and state plans for coastal development. The draft policy specifies NSW sea level rise planning benchmarks of 0.4 metres above 1990 mean sea levels by 2050 and 0.9 metres by 2100. At the time, this benchmark was consistent with the upper limit of the Intergovernmental Panel on Climate Change's Fourth

Assessment Report (AR4) projections of 0.79 metres global average sea level rise by the decade of 2090 to 2099.

3.4.3 Stage 1 Coastal Management Reforms (NSW Government, 2012)

In September 2012, the NSW Government abandoned the 2009 *NSW Sea Level Rise Policy Statement* and associated planning benchmarks. Local councils in NSW were subsequently encouraged to adopt local sea level rise projections to provide greater flexibility to local conditions across NSW.

3.4.4 CoP Climate Extremes Risk Assessment and Adaptation Plan (Parsons Brinkerhoff, 2011)

The CoP *Climate Extremes Risk Assessment and Adaptation Plan* (Parsons Brinkerhoff, 2011), references the sea level rise projections from the 2009 *NSW Sea Level Rise Policy Statement*.

There is no publically available information to suggest that CoP has since developed alternative sea level rise projections. Therefore, for the purposes of this assessment, the sea level rise projections from the 2009 *NSW Sea Level Rise Policy Statement* have been adopted for assessing the impact future climate change could have on flooding conditions in the vicinity of the project.

3.5 Sydney Water Requirements

The Sydney Water document “*Building Bridges over Sydney Water’s Open Stormwater Channels*” provides design requirements for structures over their open channel assets. For the PLR project, this would apply for bridging Clay Cliff Creek. Key requirements from this document include:

- 1% AEP + 500mm clearance to bridge soffit level
- Providing sufficient headroom for channel maintenance equipment
- Ensuring that the bridge has minimal impact on the flow of flood waters, and no off-site impacts
- Demonstrating that the proposal is consistent with the NSW Flood Policy, Floodplain Development Manual and relevant local council requirements.

Consistency with these requirement has been addressed in section 9 of this report.

4 Existing Environment and Baseline Data

4.1 Overview of Catchments and Waterways

4.1.1 Catchment Area

The PLR project extents are wholly located within the Parramatta River Catchment. With reference to Figure 2, the Parramatta River Catchment covers a large area of western Sydney, approximately 257km² and spanning over several LGA's before discharging to Sydney Harbour at the confluence of Lane Cove River.

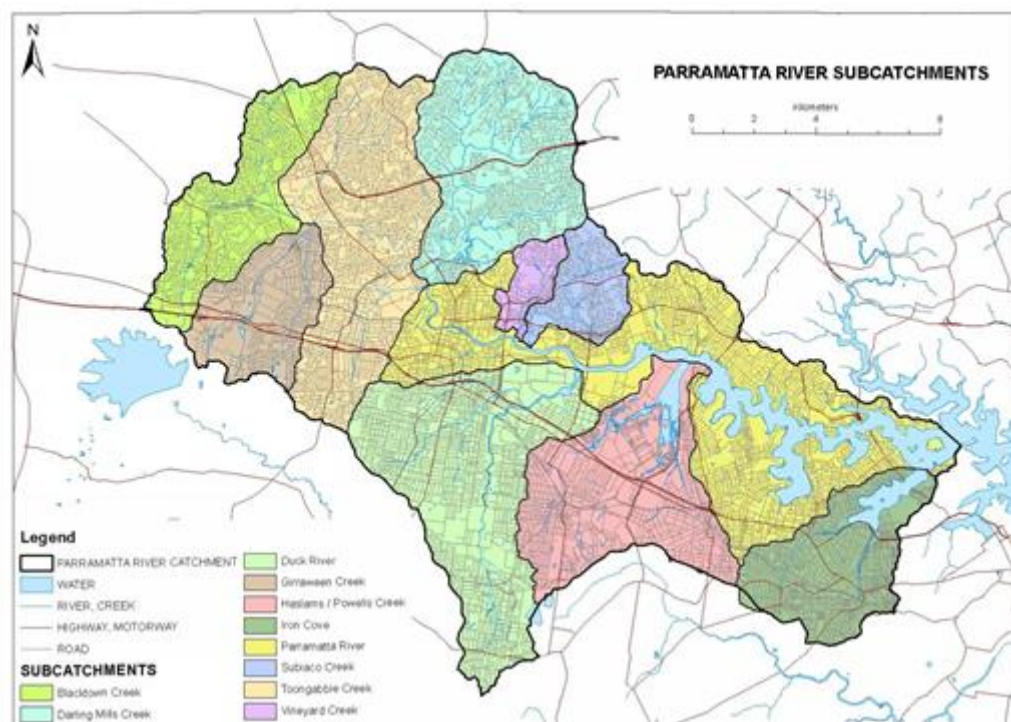


Figure 2 The Parramatta River Catchment
(Source: <http://www.parramattariver.org.au/>)

The Parramatta River has historically been divided into the Upper Parramatta River catchment, and the Lower Parramatta River catchment, with the delineation between the two occurring at the Charles Street weir. The catchment has several tributaries which drain to the Parramatta River, some of which have been formalised.

The extent of sub-catchments analysed for Stage 1 of the PLR project span both the Upper and Lower Parramatta River catchments and are predominantly within the City of Parramatta LGA. The catchment area upstream of the confluence of Toongabbie Creek / Darling Mills Creek is approximately 103km², whilst the total catchment area totals 170km² at the confluence of Duck / Parramatta Rivers. The main rivers / creeks that discharge into the Parramatta River within the extents analysed for the PLR project flood models are namely:

- Toongabbie Creek
- Darling Mills Creek
- Domain Creek
- Brickfield Creek (formalised channels)
- Vineyard Creek
- Subiaco Creek
- Clay Cliff Creek (formalised channels)
- Duck River.

4.1.2 Topography

The PLR (Stage 1) project spans across both the Upper and Lower Parramatta River catchment areas, from Westmead, at its western extent, to Camellia, at its easternmost point. The Carlingford line branches off to the north near the existing Camellia Railway Station and climbs gently along the existing heavy rail alignment to Carlingford Railway Station.

The catchment terrain through the Westmead and Parramatta North precincts of the PLR project is generally mildly-sloped. The banks are relatively high through this reach of the Parramatta River and most developments along the edges of the river sit above the 1% AEP flood level as shown in the current adopted Council flood study.

The terrain is generally flatter through the Parramatta CBD, Rosehill and Camellia areas to the south of Parramatta River. The PLR project passes through a number of areas which are below 5mAHD, particularly as it traverses Clay Cliff Creek.

The Carlingford section of the PLR project roughly traverses the boundary of the Vineyard and Subiaco Creek catchments and gradually ascends uphill after crossing the Parramatta River, reaching a height of approximately 100mAHD at Carlingford Railway Station.

The catchment topography is illustrated in Figure 3.

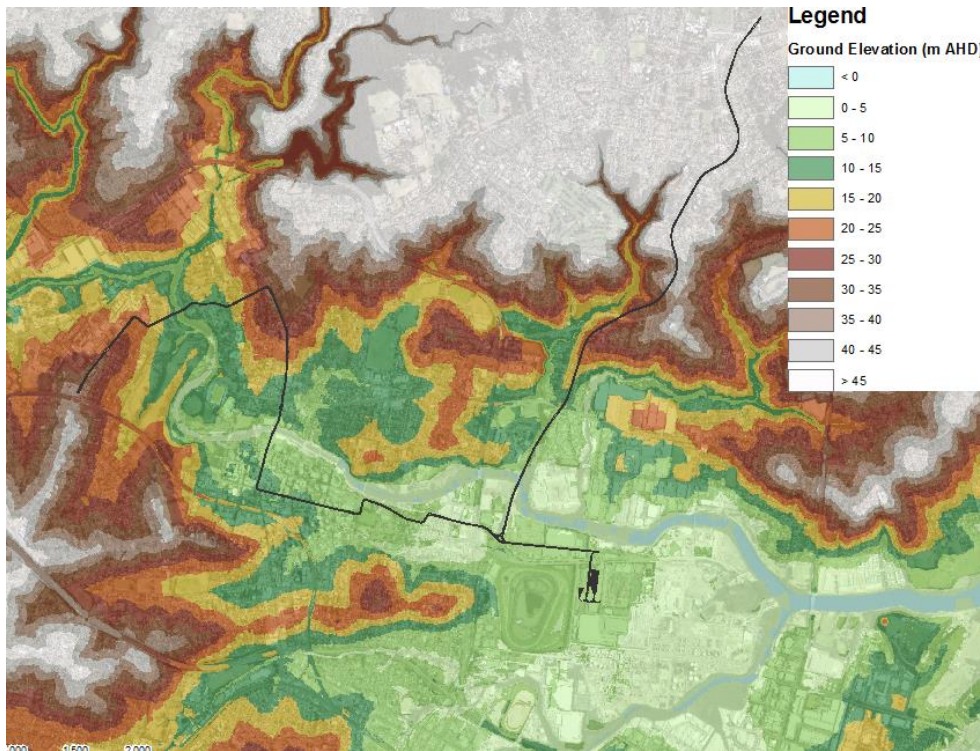


Figure 3 Topography of the Catchment

4.1.3 Land Use

With reference to Figure 4 and Figure 5, it can be seen that the Parramatta River catchment has become increasingly urbanised over the last 70 years. Current land use throughout the existing catchment is predominantly residential, with some localised urban commercial centres and industrial areas. A considerable portion of the catchment is therefore impervious. Much of the grassed area along the banks of the Parramatta River is classified as recreational.



Figure 4 Aerial photography of part of Parramatta River Catchment, 1943
(Source: SIX Maps – NSW Government Spatial Services)

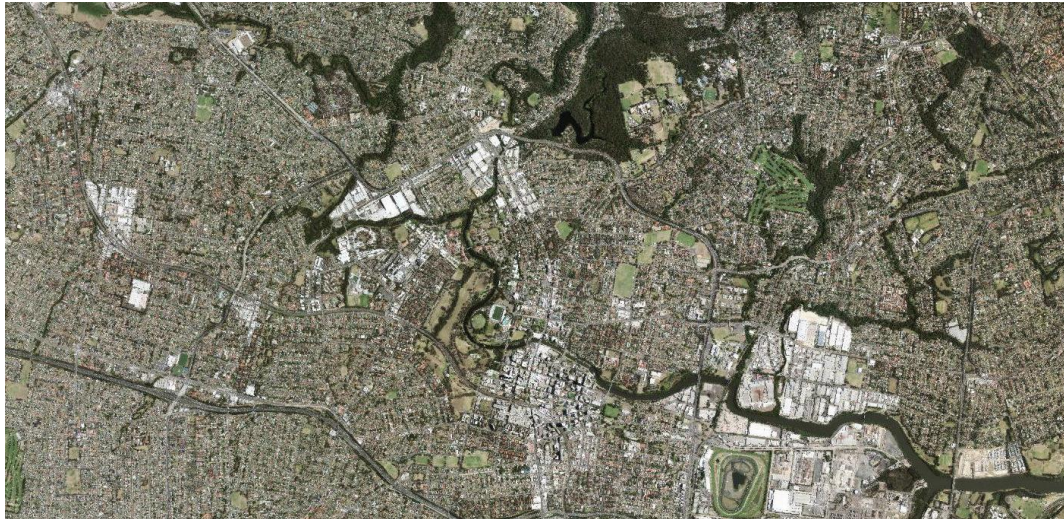


Figure 5 Aerial photography of part of Parramatta River Catchment, 2014, illustrating increased urbanisation
(Source: SIX Maps – NSW Government Spatial Services)

4.2 Previous Studies and Investigations

Table 2 provides a summary of flood studies and related reporting provided by Transport for NSW, CoP and other sources.

Table 2 Previous Flood Studies

Flood Study (Mainstream and Overland)	Author	Date	Model	Type	Information Received		
					Report	Results	Model Data
Upper Parramatta River Catchment Floodplain Risk Management Study and Plan	Bewsher Consulting	2003	MIKE 11	1D	No	Partial (extents only)	Partial (Draft 9)*
Lower Parramatta River Floodplain Risk Management Study and Plan (CoP)	SKM	2005	MIKE 11	1D	Yes (excl. final Plan)	Yes	Yes
Duck River and Duck Creek Flood Study Review (CoP)	WMA Water	2013	TUFLOW	2D/ 1D	Yes	Yes	Yes
Vineyard Creek Sub-Catchment Management Plan (CoP)	SMEC	2004	MIKE 11	1D	Yes	Yes	Yes
Subiaco Creek Sub-Catchment Management Plan (CoP)	SKM	2006	MIKE 11	1D	Yes	Yes	Yes

Flood Study (Mainstream and Overland)	Author	Date	Model	Type	Information Received		
					Report	Results	Model Data
Parramatta Square Flood Risk Assessment (Walker Corporation)	BG&E	2016	TUFLOW	2D/ 1D	Yes	No	No
Rosehill Camellia Flood Control Study (CoP)	Unknown	2012	TUFLOW	2D/ 1D	No	Yes	Yes
Camellia Precinct - Drainage and Flooding Study (DP&E)	Cardno	2015	TUFLOW	2D/ 1D	Yes	No	No
Lennox Bridge Bikeway Portals - Hydraulic Impact/Hazard Assessment (CoP)	COMPLETE Urban Pty Ltd	2011	MIKE 11	1D	Yes	No	No
Parramatta North Urban Transformation Civil Engineering Report (Urban Growth)	Arcadis	2016	TUFLOW	2D only	Yes	No	No
Rydalmere Knowledge Precinct Flood and Development Control Study (CoP)	SMEC	2013	XP- SWMM	2D/ 1D	Yes	Yes	Yes
Westmead Hospital Flood Study (NSW HI)	Arup	2016	TUFLOW	2D/ 1D	Yes	Yes	Yes
Update of Parramatta Floodplain Risk Management Plans (Draft)	Molino Stewart	2016	N/A – Report only	N/A	Yes	N/A	N/A

*It is important to note that the Upper Parramatta River Catchment MIKE11 model that was provided for the PLR project, and from which inflow hydrographs were extracted to establish baseline river boundary conditions for flood modelling, was Draft 9, developed circa 2012/2013. It is not clear which version of the Upper Parramatta River model was provided for the commission of the Lower Parramatta River Catchment Study (2005), which similarly extracted hydrographs to establish the Parramatta River inflow boundary condition. Further discussion is provided in section 5.6 of this report. Additionally, the hydrological model that was used to derive inflows for the MIKE 11 hydraulic model was not provided.

It should be noted that there were additional flood studies/reports that were received and reviewed at the data collation stage. Those studies have been excluded from Table 2 as the information contained therein could not be extracted for the purpose of building PLR flood models, or were not deemed suitable for use as references for comparison of PLR baseline flood model results, for example due to the age or limitations of the study.

Following assessment of all information received to date, it was concluded that the existing flood models were insufficient/inappropriate to assess either flood immunity or impact of the PLR project. The existing models are typically 1D

hydraulic models only, which provide limited accuracy on overland flow flooding within local streets. These existing models are dated, and based on older modelling software packages which are no longer industry-standard for catchments of this nature. Significant development has also occurred since the creation of these models, which affects the applicability of the results. New models have therefore been created for the PLR project, using the baseline data provided.

Results grids from several of the studies listed in Table 2 were provided in various GIS formats, which assisted with understanding the existing flooding issues along the PLR alignment. Figure 6 illustrates the 1% AEP flood extents provided by CoP, which has been derived based on Council's currently adopted flood studies through the Parramatta LGA.

The proposed PLR alignment crosses the Parramatta River on new or modified structures at three locations:

- North Parramatta Bridge (Cumberland Hospital)
- Lennox Bridge (Church Street)
- Carlingford Truss Bridge (existing T6 Carlingford Line).

Results from the existing flood models indicated that the existing or new road/rail levels over all bridges are located above the 1% AEP event.



Figure 6 Council Flood Extent Map - 1% AEP
(Source: CoP)

The existing flood model results illustrate that riverine flooding is generally confined to the Parramatta River banks between Westmead and O'Connell Street Bridge, on the western fringe of the Parramatta CBD. Further downstream of O'Connell Street, the 1% AEP flood starts to impact the performance of stormwater infrastructure draining the lower areas of the catchment. Flooding is also evident along two tributaries which discharge to Parramatta River (Brickfield Creek and Clay Cliff Creek), where flooding may either result from high water levels in Parramatta River preventing runoff from draining out of these catchments, or from local flooding within these individual catchments.

There was limited information available on overland flow flooding throughout the Parramatta LGA, although parts of the road carriageways in Parramatta CBD have been modelled in CoP's flood studies. The adopted flood studies do not provide any information on overland flooding through the Westmead and Parramatta North precincts, therefore areas where overland flow is a problem may not be illustrated in CoP's current flood extent grids.

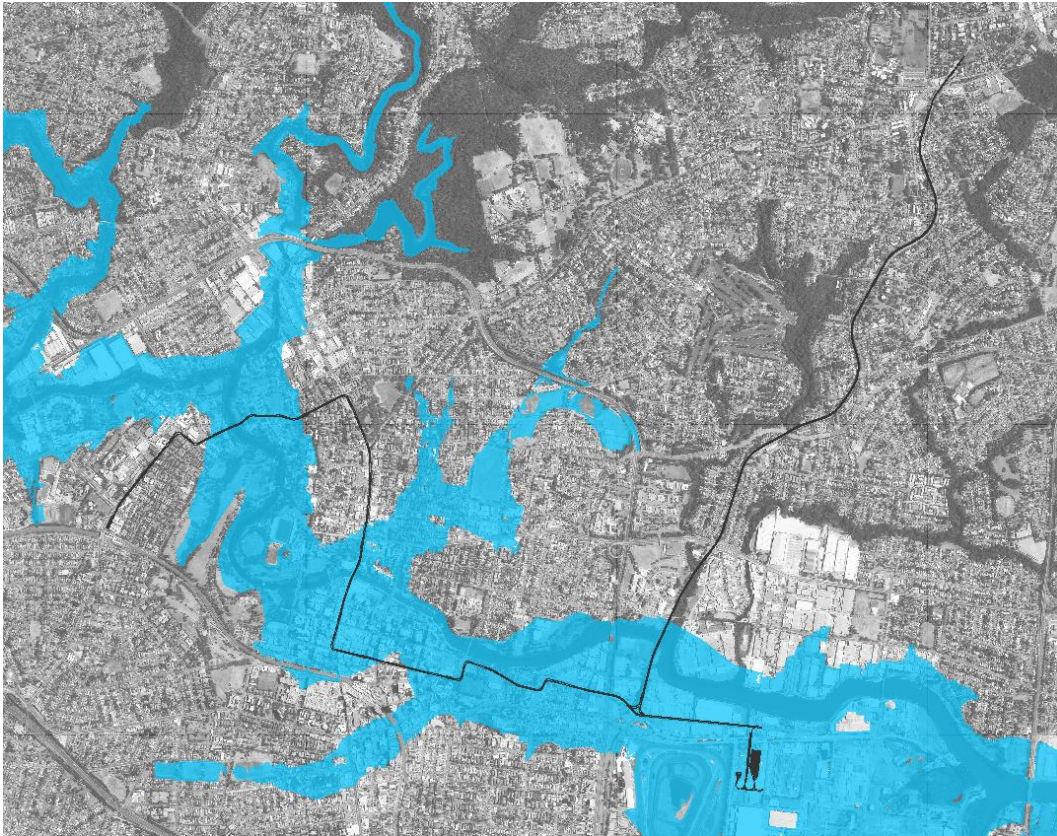


Figure 7 Council Flood Extent Map - PMF

(Source: CoP – note PMF extent grids for Vineyard/Subiaco Creek not provided)

The existing PMF flood extents shown in Figure 7 illustrate that sections of the PLR project are inundated by the PMF. The Parramatta CBD and Camellia precincts are flooded to a large extent during a PMF.

CoP's currently adopted flood levels through Parramatta River and Clay Cliff Creek are taken from the *Upper Parramatta River Catchment Floodplain Risk Management Study and Plan (Bewsher, 2003)*, and the *Lower Parramatta River Floodplain Risk Management Study and Plan (SKM, 2005)*.

The version of the *Upper Parramatta River Catchment Floodplain Risk Management Study and Plan* adopted by CoP is Draft 8, however, Council was unable to provide this version of the model. Draft 9 of the Upper Parramatta River model (developed 2012/13) was however made available. This version of the model has been utilised in the development of PLR project flood models, given that it is the only available model for this portion of Parramatta River. It is understood that Draft 9 may have been subject to further calibration against historical events than Draft 8. Additionally, the Draft 8 model was run in an older version of MIKE11, compared to Draft 9, and as such discrepancies are inevitable due to developments in the software.

It was noted that the peak flow through Parramatta River from the Draft 9 version of the Upper Parramatta River model is considerably less than that reported in the Draft 8 version. A comparison of the peak flow at Charles Street Weir between the two versions is presented in Table 3. The flows from Draft 8 have been extracted from the inputs into the Lower Parramatta River flood model, which

utilises flow hydrographs from Draft 8 of the Upper Parramatta River flood model as the upstream boundary condition.

Table 3 Comparison of Peak Flows at Charles Street Weir

Event	Upper Parramatta River MIKE 11 Model (Draft 9) (m ³ /s)	Lower Parramatta River MIKE 11 Model (m ³ /s)	Difference (m ³ /s)
1% AEP	746.1	847.3	101.1
5% AEP	539.4	697.2	157.7
0.2 EY	419.6	597.4	177.8

The implications of this discrepancy in the development and results of the PLR flood models are discussed in section 7.6.

CoP has recently commissioned the Parramatta River Flood Study, which is understood to encompass the majority of the Parramatta River catchment within the Parramatta LGA area. This model, which is understood will be fully calibrated, will assist CoP with strategic and statutory planning, development and emergency management. It will also provide outputs relating to flood levels, depths, velocities (including sensitivity testing and climate change analysis). It is understood that this study will not be completed until November 2019. No outputs from this study were available at the time of preparing this report.

Ongoing consultation with CoP to receive advance outputs from this study for comparison with PLR-specific flood modelling during development of the PLR design would be carried out.

4.3 Other Available Data

4.3.1 Rainfall Data

Where available, rainfall was sourced from the adopted flood models (or associated reporting) provided. It was noted in the review of the rainfall used within these models that the rainfall intensities were adopted towards the upstream ends of the respective catchments and therefore some distance from the PLR project. Rainfall for the adopted models was generally run through an appropriate hydrological model (e.g. XP RAFTS) to derive inflow boundary conditions for the hydraulic models used in each flood study.

Given that the rainfall on grid approach was adopted for the PLR project flood modelling, it was considered more appropriate to adopt IFD data at a centralised location within each sub catchment. Further details on the IFD tables used are presented in section 5.2.2.

4.3.2 Topographic Data

Topographical data available for flood analysis included:

- LiDAR (2013)

- Topographical survey (surface levels and features only - below ground services including drainage network information not included)
- Westmead and Parramatta North (28 November 2016)
 - Parramatta CBD and Camellia (2 December 2016)
 - Carlingford (18 January 2017, with additional survey received on 3 March 2017)
 - Maintenance and stabling facility (23 December 2016)
- Bathymetric Data for Lower Parramatta River and Duck River sections (point data collected over a period of many years)
- Bathymetric Data for Upper Parramatta River, Toongabbie Creek, Brickfield Creek and Clay Cliff Creek has been derived from cross-sectional data within the following hydraulic models;
 - Lower Parramatta River MIKE 11 model (2005)
 - Upper Parramatta River MIKE 11 model (2003).

Additional survey along the mainline corridor from Westmead to Camellia was received on 1 March 2017, which included additional detail such as line-marking and limited building outlines. As this information made negligible change to the surface profile, this has not been used in the flood analysis.

Some further topographical survey for the off-alignment works was received on 14 April 2017, however this was received after completion of the existing baseline flood models had been run. This survey should be incorporated into future flood modelling for the project.

4.3.3 Stormwater Drainage Network

Stormwater drainage network data was available from a number of sources. Table 4 summarises information received in relation to the existing stormwater drainage network.

Table 4 Drainage Network Data

Data Set	Owner/Retrieval Source
Parramatta LGA Stormwater GIS Data	CoP
Hills Shire LGA Stormwater Data	Hills Shire Council
Holroyd LGA Stormwater GIS Data	Holroyd Council
Sydney Water Drainage GIS Data	Sydney Water
Parramatta North Development stormwater survey data	Arcadis
Westmead Hospital stormwater survey data	Westmead Hospital
Stormwater Survey Data - James Ruse Drive/Tramway Avenue Intersection	Roads and Maritime
Stormwater Survey Data - Church Street between Barney Street and Pennant Hills Road	Roads and Maritime

Data Set	Owner/Retrieval Source
Sydney Trains Stormwater Survey Data (CC20_984)	Transport for NSW
Sydney Trains Stormwater Survey Data (CC21_605)	Transport for NSW
Sydney Trains Stormwater Survey Data (CC22_212)	Transport for NSW
Sydney Trains Stormwater Survey Data (CC23_916)	Transport for NSW
Sydney Trains Stormwater Survey Data (CC26_189)	Transport for NSW
CoP Stormwater CCTV Footage	CoP
Sydney Water Drainage Information - Brickfield Creek and Harris Street Culvert Drawings and CCTV	Sydney Water
Lennox Bridge Portal Civil Drainage Work As Executed Drawings	Transport for NSW
CoP Stormwater Drainage Drawing (circa 1980's - pre transfer to GIS)	CoP
Topographical Survey Stormwater Surface Features	Transport for NSW*
Additional CoP Stormwater Drainage Design Drawings (various dates - 1950's to 2006, not included within GIS)	CoP

*Note that the topographical survey at the time of modelling captured the locations of pits only, and did not provide information on pipe sizes/invert levels, or any pit inlet information

The approach taken to consolidate this information for the purposes of flood modelling is described in section 5.3.6.

4.3.4 Existing Bridges and Weir Structures

Information on existing bridge structures has been extracted either from existing structural drawings (where available) or from the MIKE 11 models.

Existing structural drawings have been provided for the following bridge crossings impacted by Stage 1 the PLR project:

- Lennox Bridge (Church Street)
- Parramatta River Truss Bridge (existing T6 Carlingford Line)
- James Hardie Underpass Bridge (existing T6 Carlingford Line)
- Bridge over Vineyard Creek (existing T6 Carlingford Line).

Structural drawings have not been received for the Bridge Road Bridge (Cumberland Hospital), however a structural inspection report was provided which contained some photographs of the bridge structure.

The existing MIKE 11 flood models have been used as a source of information for other existing bridge and weir structures which are outside of the PLR project corridor. Due to the method in which the bridges have been modelled in MIKE 11, it has generally only been possible to extract average soffit or deck levels for the structure, and there is no information contained on the pier sizes or arrangement.

Photographs from site visits or Google StreetView have been used to estimate the bridge pier arrangements where better sources of information have not been made available.

The approach for modelling the bridges in the TUFLOW 1D/2D models is described in section 5.3.2.

4.3.5 Historical Flood Records

A collection of historical drainage and flooding photographs was received from CoP ranging typically from 1977 to 1990.

Historical photographs of Parramatta River in flood are included below.



Figure 8 Riverbank Car Park facing east towards Wilde Avenue Bridge – 1988
(Source - CoP)



Figure 9 Queen's Wharf Reserve facing west towards MacArthur Street Bridge - 1988
(Source - CoP)



Figure 10 Overtopping of Charles Street Weir - date unknown
(Source - CoP)

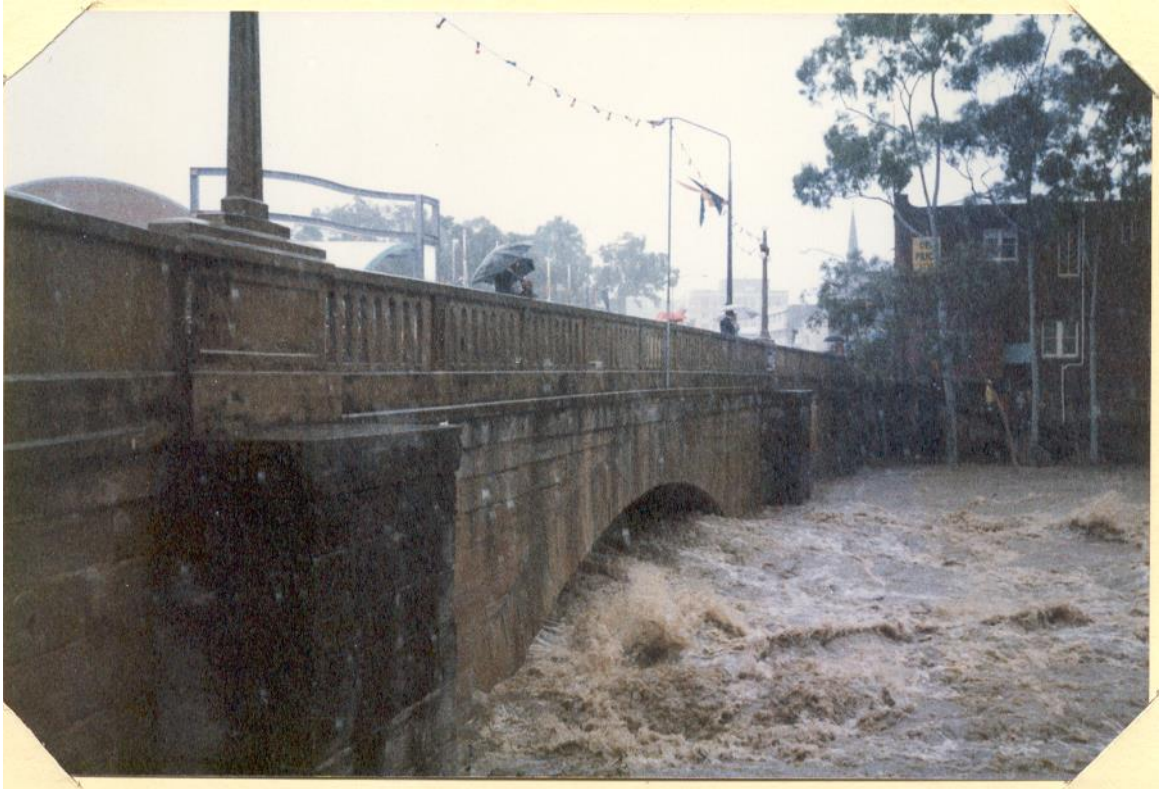


Figure 11 Lennox Bridge (downstream face – eastern side), 30 April 1988
(Source - CoP)



Figure 12 Lennox Bridge (upstream face – western side), 30 April 1988
(Source - CoP)



Figure 13 Riverside Theatres, Upstream of Lennox Bridge, 30 April 1988
(Source - CoP)

It is important to note that, although these photos are illustrative, they should not be relied upon for use in calibration of flood models.

With regards to determining areas potentially inundated by overland flow, there are limited historic photographs available, but the following images provide some context.

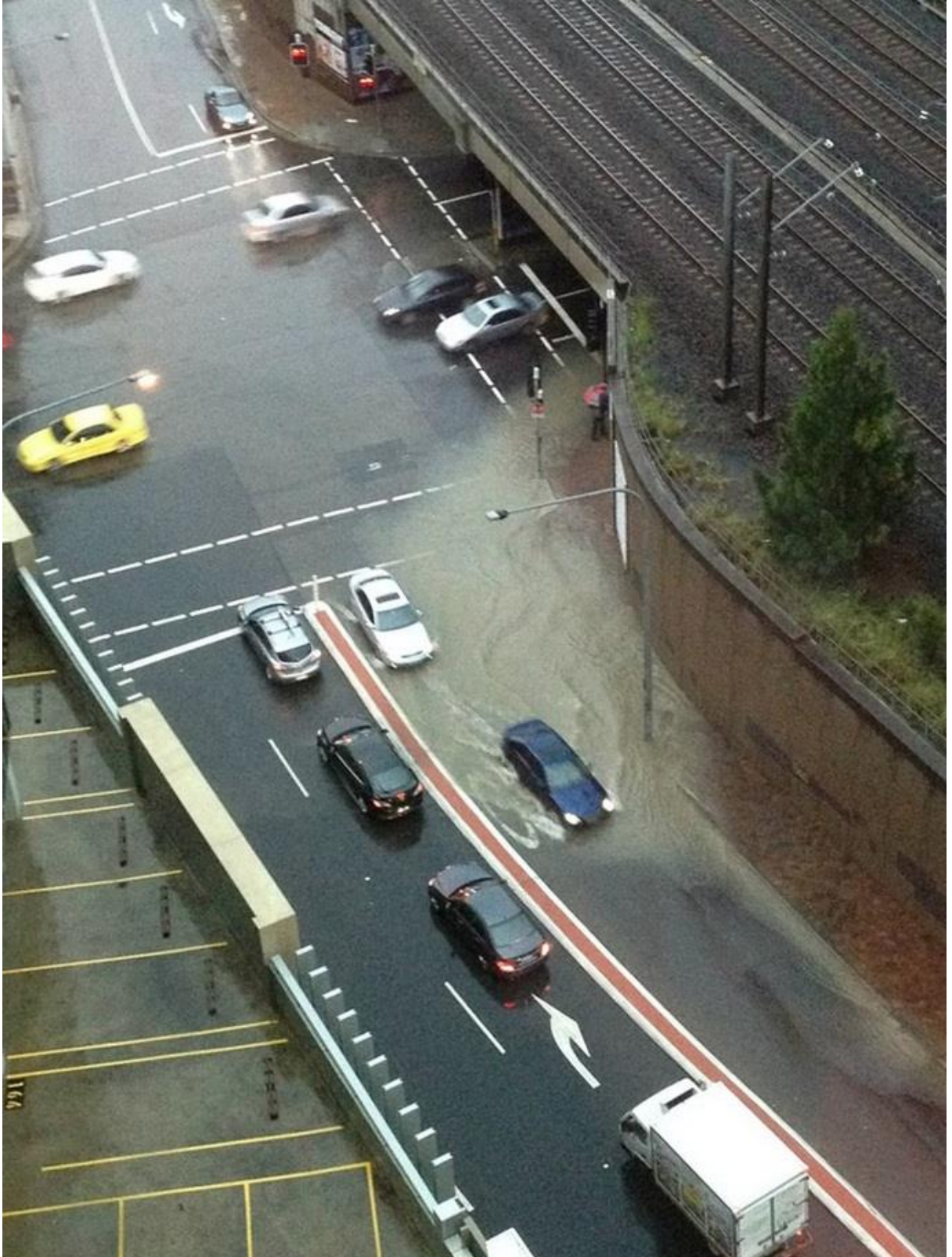


Figure 14 Station Street East and Parkes Street East (facing south) – date unknown
(Source - Google)



Figure 15 Scouring of asphalt at Marsden Street / Macquarie Street due to overland flow, 30 April 1988
(Source - CoP)



Figure 16 Considerable stormwater structure at Clay Cliff Creek, River Road West
(Source - Arup)

4.3.6 Site Observations and Stakeholder Input

In addition to the information provided within the previous flood studies and the historical flood records, anecdotal information on flooding within the PLR project precincts has been provided from various stakeholders.

A site walk on 12 December 2016 with CoP and Transport for NSW representatives identified that localised flooding was an issue along Church Street between George Street and Lennox Bridge, particularly on the eastern side of the road. In one section, there is a small sag within the footpath between the top of road kerb and the shopfronts. It was noted that once the limited storage within this footpath sag is exceeded (due to either insufficient stormwater network capacity or pit inlet capacity), water is likely to pond in the sags and drain into the adjacent shops.

A localised sag in Macquarie Street between Horwood Place and Smith Street was also noted by CoP as being an area where flooding was experienced in high intensity rainfall events.

Photographs taken on 3 March 2017 (following a brief but intense rainfall event) also provided visual evidence of some areas of the Parramatta CBD which are prone to localised overland flow flooding.



Figure 17 Flow in gutter at Smith Street looking south towards the Macquarie Street intersection
(Source: Transport for NSW)



Figure 18 Flow in gutter along the southern side of Macquarie Street looking east towards Horwood Place intersection
(Source: Transport for NSW)



Figure 19 Ponding in footpath sag – north-west corner of George/Church Street intersection

(Source: Transport for NSW)

A site walk of the James Ruse Drive and Tramway Avenue area, including Clay Cliff Creek, was carried out on 23 February 2017, attended by CoP, DP&E, Transport for NSW and Roads and Maritime.

Additional workshops were held with CoP on 7 February 2017 and 20 April 2017. CoP also presented key highlights from their draft publication *Draft Best Practice Urban Design in Flood Prone Areas – Urban Design Strategy* on 19 April 2017.

A meeting to discuss Sydney Water stormwater assets (Clay Cliff Creek and Harris Street culvert) was held on 11 May 2017.

4.3.7 Miscellaneous

Other information utilised in the PLR flood modelling includes:

- Aerial photography of the wider catchment extents provided by Transport for NSW
- Building footprint polygons (within the Parramatta LGA only) utilised where considered appropriate
- Land zoning shape files were sourced online from the NSW Planning and Environment website.

4.4 Data Limitations

There are a number of gaps and issues with the information available. These include but are not limited to:

- Missing stormwater drainage network information
- Incomplete stormwater drainage network information (including pipe diameters, pipe inverts, pit inlet types and sizes)
- Potential errors in provided stormwater drainage network information, for example due to errors in transition from old hard copy records to GIS, and/or land development and related changes to drainage of specific areas following the most recent update of CoP's stormwater GIS records
- Discrepancies between data sets from different sources for the same stormwater drainage elements (i.e. information from existing flood models/Sydney Water/CoP)
- Missing bathymetry in some reaches of the river/creek systems
- Inconsistency in approaches, assumptions, base data results between the various hydraulic models supplied
- LiDAR data not reflecting current land use due to recent developments and those currently under construction.

The implications of these gaps on flood modelling are discussed further in section 5 – Hydraulic Model Development and section 7 – Existing Scenario Flood Results. It is anticipated that these gaps can be closed in future design stages as information becomes available, e.g. surveyed pit and pipe information.

4.5 Existing Flood Response and Flood Risk Management Plans

The current Parramatta Local Disaster Plan (DISPLAN) is dated December 2010. The DISPLAN does not reference a sub-plan related to flooding and the February 2016 *Draft Update of Parramatta Floodplain Risk Management Plans* (Molino Stewart for CoP) notes that there is currently no completed Local Flood Plan for the Parramatta LGA. The DISPLAN covers the whole of the City of Parramatta which represents an area of 60.5 square kilometres.

As is typical practice, the DISPLAN identifies the State Emergency Service (SES) as the Combat Agency for flooding, i.e. the agency identified to control the response to flood emergencies.

The DISPLAN generally advocates an approach of Shelter-In-Place/stay at work rather than evacuation, as illustrated in the following extracts:

“Shelter-In-Place/Stay at work: In most circumstances the most appropriate course of action will be for the occupants of buildings to stay at work or shelter in place unless the building is unsafe. In the absence of other directions this should be the primary course of action. In the case of mass gatherings consideration must be given (based upon best advice at the time from Emergency Services) to evacuate in an orderly manner to designated safety sites OR Allow evacuation from area. In this case the Traffic Management Plan in place is to take effect.”

“In the event of an emergency which severely disrupts transport and requires an evacuation of an area of the CBD, the control arrangements will recommend business and residents to either:

Stay at Work:

This is used for all areas of the CBD (and surrounds) where the public are not directly threatened by the emergency. It may also imply that public transport may be affected and/or may not be available. This message is intended to stop or reduce the incidence of the public rushing to transport sites or exiting by private vehicles, thus allowing time for transport/traffic services to be re-established. Stay at Work protocols assist in achieving a desired response for business and residents in the areas of the CBD unaffected by the emergency, such as: To carry on normal business, advise staff and others on their site that an emergency has resulted in a disruption to public and private transport, and to allow for communication updates.

Shelter in Place:

This is used when it is assessed that for safety of the occupants of a building(s) or for control reasons, it is safer for occupants to remain in the building than to be on the streets. The time required to Shelter in Place will depend on the nature of the emergency.”

Safe Sites for evacuation have been designated in the plan as:

- Ollie Webb Reserve
- Macarthur Girls High School
- Parramatta Golf Course.

It is understood that the DISPLAN is currently under review by the Local Emergency Management Committee, which includes CoP and the SES.

The Draft Update of Parramatta Floodplain Risk Management Plans (Molino Stewart for CoP, Feb 2016), identifies that the majority of the CBD would fall within the category of “low flood island”, which is where the evacuation route (typically the road network) is cut by flooding before the area itself is inundated. Given also the short time to peak for major flood events, the report supports a shelter in place strategy for the CBD. However, the section of Macquarie Street between Smith Street and Argus Lane is classed as rising road access as it has an evacuation route that rises to a level above the PMF.

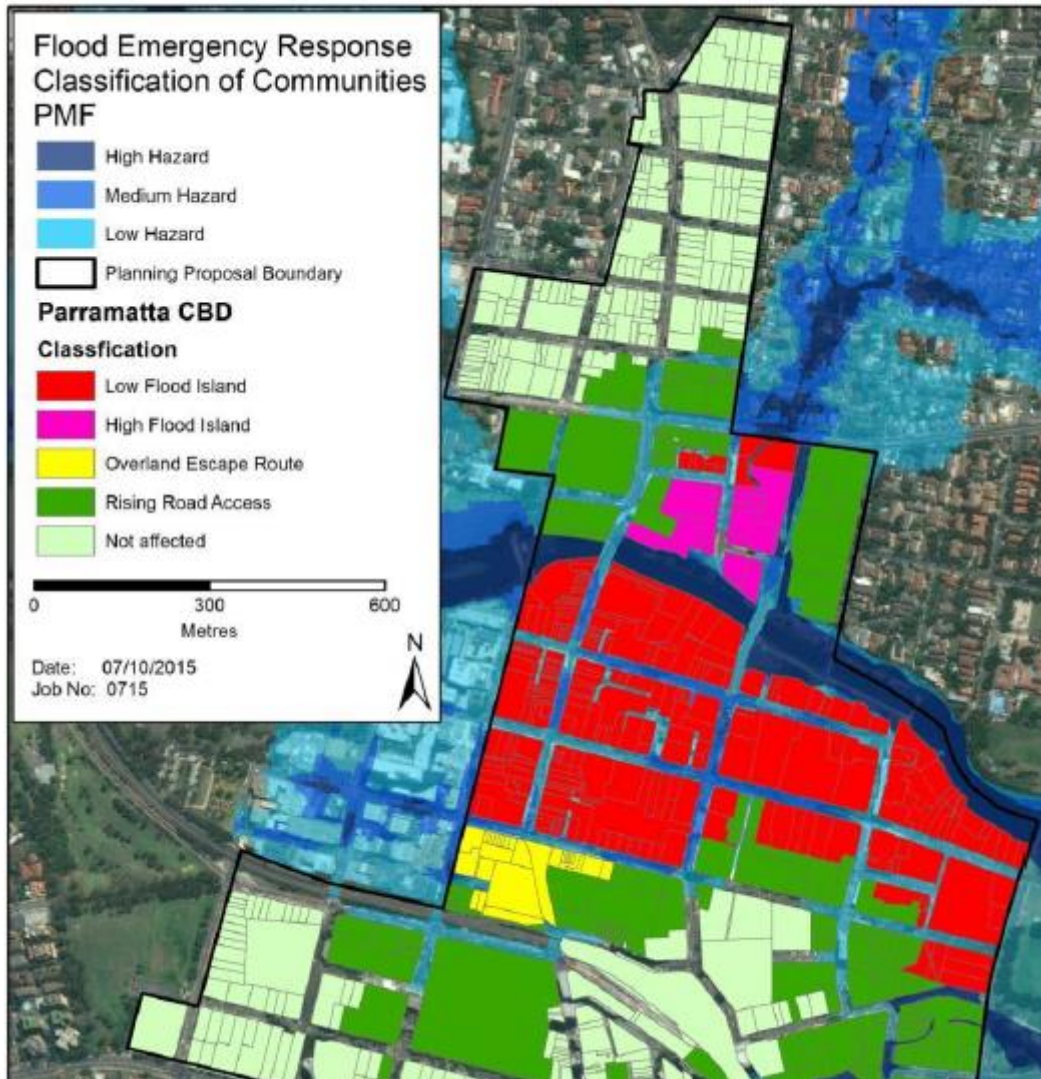


Figure 20 Flood Emergency Response Classification - Parramatta CBD
(Source: Draft Update of Parramatta Floodplain Risk Management Plans, Molino Stewart, 2016)

As CoP's current flood modelling does not include areas affected by overland flow flooding mechanisms, emergency response for flooding of overland flow areas is not covered by any existing emergency response plan.

5 Hydraulic Model Development

5.1 General Approach

Two modelling approaches have been utilised for the PLR project, these being either:

- An integrated 1D (pipe network)/2D (overland flow) modelling approach (TUFLOW "Classic") or
- 2D (overland flow) only approach (TUFLOW GPU).

The 1D/2D modelling approach was taken for four of the five catchments, namely:

- Westmead
- North Parramatta
- Parramatta CBD
- Camellia.

Within the above four catchments, the PLR project generally runs along existing road corridors (where the stormwater network plays an important part in draining water off the road) and also traverses known flood-prone areas of land. Given the complex nature of flooding throughout these catchments, it was considered that utilising 1D/2D hydrodynamic modelling software would provide adequate representation of flood behaviour within these four catchments within Stage 1 of the PLR project, based on a need to satisfy:

- The requirements of the environmental assessment and approvals process which are focussed around impacts in rare events such as the 1% AEP
- The requirements of PLR operations, which are governed by more frequent events where the capacity of the underground drainage has a large bearing on results.

TUFLOW is a 1D/2D hydrodynamic modelling software widely used in Australia that simulates complex flood behaviour in floodplains, rural, and urban environments by solving the shallow water equations. TUFLOW utilises a rectangular grid to represent the underlying bathymetry of the model. TUFLOW utilises ESTRY as 1D solution engine to solve the full one-dimensional St. Venant flow equations. Hydraulic structures such as pits, pipes, culverts and bridges are represented in 1D incorporating a 1D/2D dynamic link where appropriate.

A fully 2D TUFLOW GPU model was established for the Carlingford catchment, given the size of the catchment and the location of the light rail alignment. The light rail alignment runs almost parallel to the ridge that divides Vineyard Creek and Subiaco Creek. Any stormwater issues identified are expected to be minor and are likely to be addressed by provision of adequate local drainage, particularly as the light rail would have a ballast trackform. As such, minimal changes in flood behaviour are expected within this catchment.

A 2D only TUFLOW GPU model has also been utilised for assessing the impacts of the PLR project in the PMF. Further detail of this approach is provided in section 5.2.1.

Whilst TUFLOW modelling is widely used for urban flood modelling and is considered suitable for the purpose of the PLR project, results need to be interpreted with appropriate judgement and understanding, particularly where ground features are smaller than the adopted grid size, or areas which are particularly sensitive to small changes. Where such instances occur, cross checking against other software packages or other methods should be carried out in subsequent design stages to confirm the suitability of the TUFLOW results.

5.2 Hydrology

5.2.1 Catchment Delineation

For the extents of Stage 1, a review of stormwater network information, previous flood studies and preliminary TUFLOW GPU modelling (overland flow only) was carried out to delineate the catchment boundaries. The extents of the flood models developed for this project are illustrated in Figure 21, and in greater detail in Map 5.1.

The catchment boundaries were primarily selected for modelling events up to the 1% AEP event for the PLR project. In very rare to extreme events, interaction between catchments may occur. It was therefore decided that a TUFLOW GPU model combining all the sub-models would be utilised to investigate the PMF.

The approach outlined above was adopted considering the following:

- The existing stormwater network plays an important role in draining the PLR project, therefore modelling the stormwater network in as much detail as possible was considered critical in assessing the existing flood behaviour (particularly for minor events which may affect operability of the Light Rail) and increases in potential flood affectation to other properties or sensitive receptors.
- The grid size is required to be as small as reasonably possible to accurately represent physical features in the TUFLOW models.
- Model extents of the individual integrated 1D/2D models need to be small enough to allow for practicable run times.
- In the PMF (modelled as 2D only), the performance of the stormwater network is less critical than in more frequent events and is unlikely to significantly influence the overall flood behaviour.

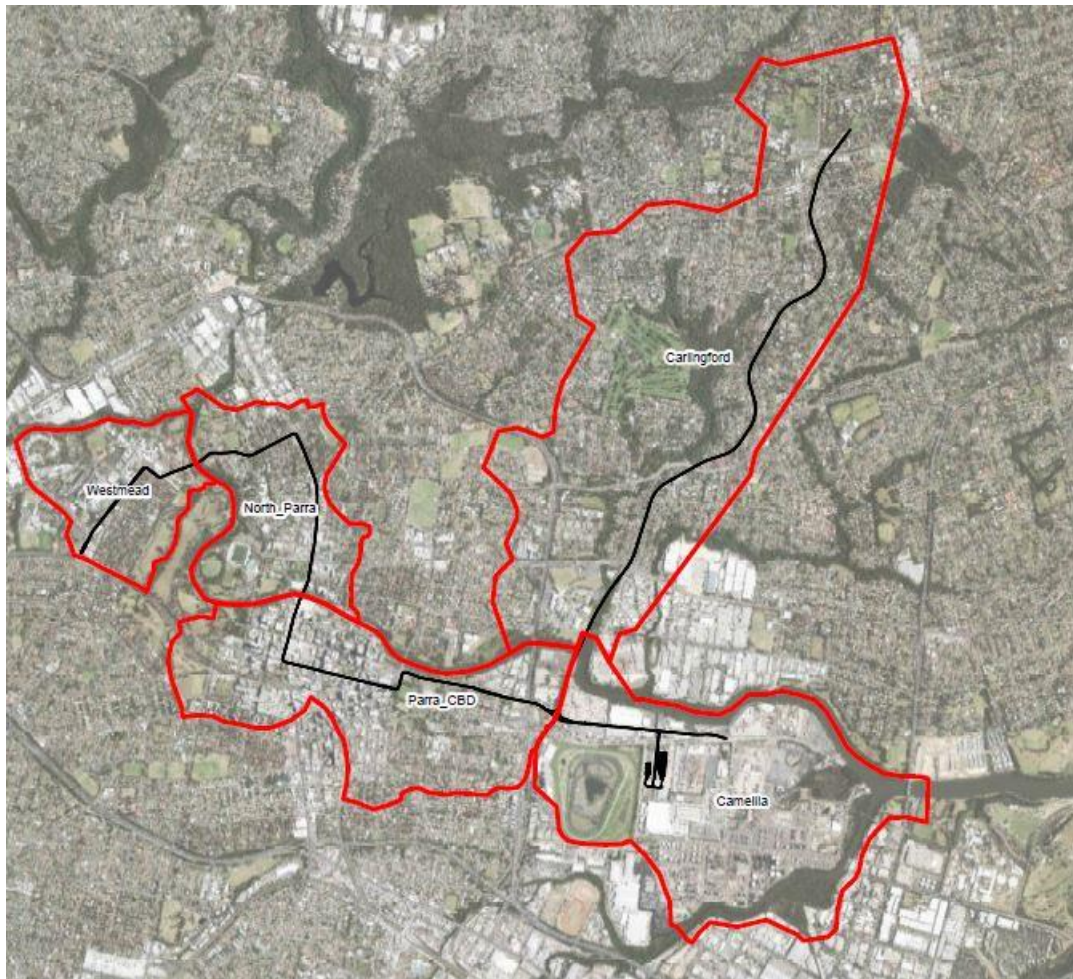


Figure 21 Flood Model Catchment Boundaries

5.2.2 Design Storm Events

5.2.2.1 Rainfall Intensities

As noted in section 4.3.1, rainfall data provided in the existing flood studies was generally found to be taken at locations some distance upstream in the respective catchments being analysed. It was determined to be more appropriate to generate rainfall data specific to each sub-model for use on the PLR project, in order to model overland flooding.

For all events up to the 1% AEP, IFD data was obtained from the online BoM IFD tool (AR&R87) for each sub-model. AR&R2016 are the current guidelines to estimate design flood behaviour, however, these guidelines became available after the commencement of the PLR work. As such, the AR&R87 data was adopted.

The IFD tables obtained from the BoM were compared against those adopted in previous flood studies (refer Table 2) where IFD data was presented. The rainfall intensities were adopted for the PLR project were found to be relatively consistent with the previous studies.

A comparison of the AR&R87 IFD intensities against those in AR&R 2016 was carried out for all sub-models. The AR&R87 IFD intensities were generally found to be higher than those from AR&R2016, although for shorter durations (less than 30 minutes), the AR&R2016 rainfall intensities were found to be marginally higher (less than 4%). The use of AR&R87 in estimating the rainfall intensities was therefore considered appropriate for the purposes of the PLR project.

The IFD tables were found to be fairly consistent across the sub-models for the PLR project. In general, the rainfall intensities increase the further east the catchment is located. The IFD tables for each sub-catchment are presented below:

Table 5 Westmead Sub-Model IFD Table

Intensity-Frequency-Duration Table							
Location: 33.800S 150.975E NEAR.. Westmead NSW Issued: 30/9/2016							
Rainfall intensity in mm/h for various durations and Average Recurrence Interval							
Average Recurrence Interval							
Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	82.1	105	134	150	172	200	222
6Mins	76.8	98.6	125	141	161	188	208
10Mins	62.8	80.7	103	115	132	154	170
20Mins	45.9	58.8	74.7	83.7	95.8	112	123
30Mins	37.3	47.8	60.7	68.0	77.8	90.6	100
1Hr	25.3	32.5	41.3	46.4	53.2	62.0	68.6
2Hrs	16.7	21.5	27.5	31.0	35.6	41.7	46.2
3Hrs	13.0	16.7	21.6	24.4	28.1	32.9	36.6
6Hrs	8.41	10.9	14.2	16.2	18.7	22.1	24.6
12Hrs	5.48	7.11	9.38	10.7	12.5	14.8	16.5
24Hrs	3.57	4.66	6.18	7.09	8.26	9.83	11.0
48Hrs	2.28	2.98	3.97	4.57	5.35	6.37	7.16
72Hrs	1.71	2.23	2.99	3.45	4.04	4.83	5.44

(Raw data: 32.52, 7.11, 2.23, 61.72, 14.77, 4.83, skew=0.00, F2=4.3, F50=15.83) © Australian Government, Bureau of Meteorology

Table 6 North Parramatta Sub-Model IFD Table

Intensity-Frequency-Duration Table

Location: 33.800S 151.000E NEAR.. North Parramatta Issued: 7/2/2017

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	83.1	106	135	152	174	202	224
6Mins	77.9	99.8	127	142	163	190	210
10Mins	63.7	81.7	104	117	134	156	172
20Mins	46.4	59.5	75.7	84.9	97.2	113	125
30Mins	37.7	48.4	61.6	69.0	79.0	92.0	102
1Hr	25.7	32.9	42.0	47.2	54.1	63.1	69.9
2Hrs	16.9	21.8	28.0	31.6	36.3	42.5	47.3
3Hrs	13.1	17.0	22.0	24.9	28.7	33.7	37.5
6Hrs	8.52	11.0	14.5	16.5	19.1	22.6	25.3
12Hrs	5.56	7.24	9.58	11.0	12.8	15.2	17.0
24Hrs	3.66	4.77	6.33	7.28	8.49	10.1	11.3
48Hrs	2.37	3.09	4.10	4.71	5.50	6.53	7.34
72Hrs	1.79	2.33	3.10	3.56	4.16	4.95	5.57

(Raw data: 32.98, 7.23, 2.33, 62.85, 15.19, 4.95, skew=0.00, F2=4.3, F50=15.83) © Australian Government, Bureau of Meteorology

Table 7 Parramatta CBD Sub-Model IFD Table

Intensity-Frequency-Duration Table

Location: 33.825S 151.000E NEAR.. Parramatta Railway Station Issued: 28/11/2016

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	83.7	107	136	152	174	203	224
6Mins	78.4	101	128	143	164	190	211
10Mins	64.2	82.2	104	117	134	156	173
20Mins	46.9	60.0	76.1	85.3	97.5	113	126
30Mins	38.1	48.9	61.9	69.4	79.3	92.3	102
1Hr	25.8	33.2	42.2	47.4	54.2	63.2	70.0
2Hrs	16.9	21.8	27.9	31.5	36.2	42.4	47.1
3Hrs	13.1	16.8	21.8	24.7	28.5	33.4	37.2
6Hrs	8.38	10.8	14.2	16.2	18.8	22.2	24.9
12Hrs	5.43	7.06	9.35	10.7	12.5	14.8	16.7
24Hrs	3.57	4.66	6.20	7.12	8.31	9.89	11.1
48Hrs	2.33	3.04	4.04	4.64	5.41	6.45	7.24
72Hrs	1.76	2.29	3.05	3.51	4.10	4.89	5.50

(Raw data: 33.24, 7.04, 2.29, 63.06, 14.83, 4.89, skew=0.00, F2=4.3, F50=15.83) © Australian Government, Bureau of Meteorology

Table 8 Camellia Sub-Model IFD Table

Intensity-Frequency-Duration Table

Location: 33.825S 151.025E NEAR.. Camellia NSW Issued: 17/11/2016

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	85.0	109	138	154	177	205	227
6Mins	79.7	102	129	145	166	193	213
10Mins	65.1	83.4	106	119	136	158	175
20Mins	47.5	60.9	77.3	86.7	99.2	115	128
30Mins	38.7	49.6	62.9	70.6	80.8	94.0	104
1Hr	26.2	33.7	42.9	48.3	55.3	64.5	71.5
2Hrs	17.2	22.1	28.5	32.1	37.0	43.3	48.1
3Hrs	13.2	17.1	22.2	25.2	29.1	34.2	38.1
6Hrs	8.48	11.0	14.5	16.5	19.2	22.7	25.5
12Hrs	5.50	7.17	9.52	10.9	12.8	15.2	17.0
24Hrs	3.65	4.75	6.32	7.26	8.48	10.1	11.3
48Hrs	2.40	3.12	4.13	4.74	5.52	6.56	7.36
72Hrs	1.81	2.36	3.13	3.59	4.18	4.97	5.58

(Raw data: 33.78, 7.14, 2.36, 64.4, 15.17, 4.97, skew=0.00, F2=4.3, F50=15.84) © Australian Government, Bureau of Meteorology

Table 9 Carlingford Sub-Model IFD Table

Intensity-Frequency-Duration Table

Location: 33.800S 151.025E NEAR.. Teloepa Issued: 5/12/2016

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	84.4	108	137	154	176	205	227
6Mins	79.1	101	129	145	165	193	213
10Mins	64.8	83.0	106	118	136	158	175
20Mins	47.2	60.5	77.0	86.4	98.9	115	128
30Mins	38.4	49.2	62.7	70.3	80.5	93.9	104
1Hr	26.1	33.5	42.8	48.2	55.2	64.5	71.5
2Hrs	17.2	22.2	28.6	32.3	37.2	43.6	48.4
3Hrs	13.4	17.3	22.4	25.4	29.4	34.5	38.5
6Hrs	8.68	11.3	14.8	16.9	19.6	23.2	25.9
12Hrs	5.68	7.40	9.80	11.2	13.1	15.6	17.5
24Hrs	3.76	4.90	6.50	7.46	8.70	10.3	11.6
48Hrs	2.45	3.19	4.22	4.84	5.64	6.69	7.50
72Hrs	1.85	2.41	3.19	3.66	4.26	5.06	5.67

(Raw data: 33.55, 7.38, 2.41, 64.29, 15.58, 5.06, skew=0.00, F2=4.3, F50=15.84) © Australian Government, Bureau of Meteorology

The Generalised Short Duration Method (GSDM) procedure was utilised to estimate Probable Maximum Precipitation (PMP) and derive PMF.

5.2.2.2 Temporal Patterns

The temporal patterns adopted for the PLR project for events up to the 1% AEP are as per the Zone 1 patterns outlined in AR&R87.

The design temporal distribution specified in the Generalised Short Duration Method (GSDM) procedure was utilised for determining PMP temporal rainfall distribution.

5.2.2.3 Rainfall Losses

The TUFLOW sub-models incorporate an Initial/Continuing rainfall loss mechanism depending on the material surface that rainfall lands on. The initial and continuing losses applied across all sub-models are standard values which are commonly used in hydraulic modelling and are listed below:

Table 10 Initial and Continuing Losses Adopted for PLR TUFLOW Models

Land Type	Initial Loss (mm)	Continuing Loss (mm/h)
Grass/Medium or Heavy Vegetation	10	2.5
Roof and Paved Ground, Roads or other impervious areas	1	0
Creeks and Rivers	0	0

5.2.2.4 River Boundary Conditions

Inflow boundaries within the TUFLOW sub-models (where the upstream catchment area of a watercourse has been excluded from the model area) have been extracted from the applicable MIKE 11 models provided by CoP. This approach was adopted to achieve consistent results with Council's adopted flood studies and to capture the difference in the timing between local and regional catchment flooding.

There is a notable discrepancy in the peak flow in Parramatta River between the Upper Parramatta River and Lower Parramatta River MIKE 11 models at the boundary between the two models (Charles Street Weir). The inflow boundary in the Lower Parramatta River MIKE 11 model was adopted from the Upper Parramatta River MIKE 11 model, however this was adopted from a previous version of the Upper Parramatta River MIKE 11 model (Draft 8) to that provided for the PLR project (Draft 9).

Draft 9 predicts smaller peak flows at Charles Street Weir compared to Draft 8 (refer to Table 3). However, the Lower Parramatta River MIKE 11 model adopts the upstream inflow hydrograph boundary condition from the Draft 8 version of the Upper Parramatta River MIKE 11 model. This discrepancy in flows is resulting in the higher peak water levels being predicted in Parramatta River by the Lower Parramatta River MIKE 11 model, compared with the Parramatta CBD TUFLOW model. This is particularly evident in the 0.2EY event, where the discrepancy in the flows is largest.

The adoption of inflow boundaries from Draft 9 of the Upper Parramatta River MIKE 11 model into all applicable PLR TUFLOW models (Westmead, North Parramatta and Parramatta CBD) is considered justifiable given that Draft 9 was calibrated to historical events (and being run nearly 10 years after the release of Draft 8, may also have incorporated developmental impacts further upstream in the catchment). It is therefore considered that the Draft 9 version of the Upper Parramatta River MIKE 11 model is likely to provide a more accurate estimate of the peak flow and water levels through Parramatta River.

For the Parramatta CBD model (which spans across the Upper and Lower Parramatta River flood study extents), the downstream stage hydrograph boundary was adopted from the Lower Parramatta River MIKE 11 model as this model establishes design flood behaviour in the lower Parramatta River reaches. Refer to section 4.2 for further discussion.

5.3 Hydraulic Model

The TUFLOW models developed herein (that is, the Westmead, North Parramatta, Parramatta CBD, Camellia and Carlingford models) adopt a 2m grid cell size. This grid size has been selected to provide appropriate representation of floodplain features within the 2D model domains, without compromising model run times.

The Combined PMF TUFLOW GPU model utilises a 4m grid cell size. This was considered reasonable given the larger scale of the model area and the size of the PMF relative to more frequent events,

5.3.1 Topography

The baseline (existing) digital terrain model (DTM) for each TUFLOW model have been derived utilising the following information:

- 1m ALS (LiDAR) data, which constitutes the vast majority of ground terrain data through the catchment areas.
- Topographical survey, which has been carried out along the PLR project corridor (as noted in section 4.3.2, only certain portions of topographic survey was available prior to the completion of the existing baseline modelling. Topographical survey received following this run should be incorporated into the baseline flood models at a later stage).
- River bathymetry information provide as noted in section 4.3.2. The point bathymetric data covering Duck River and Parramatta River between Silverwater Bridge and Charles Street Weir has been used over the MIKE 11 cross-sectional data over the areas both datasets were available).
- Channels modelled as 1D elements (Clay Cliff Creek and Brickfield Creek) utilise cross-sectional data from the MIKE 11 hydraulic models covering these two watercourses.

For the assessment of PLR scheme impacts and mitigation, the 3D design rail/road digital terrain models have been incorporated into the TUFLOW models.

The baseline DTM's utilised for each sub-catchment are shown in Maps 5.2 – 5.6 in Appendix A.

5.3.2 Key Hydraulic Structures

Existing bridges have been incorporated into the TUFLOW models (excluding Carlingford/Combined PMF) as 2D layered flow constrictions, with the exception of the existing footbridge over Clay Cliff Creek (between Tramway Avenue and Grand Avenue North), which has been modelled as a combination of 1D bridge and weir components.

Bridge information has been incorporated into the TUFLOW model based on the following sources:

- Information extracted from existing MIKE 11 models
- Existing structural drawings where these have been made available
- Where no better information has been available, photographs/images of the bridges.

Form loss coefficients for each bridge structure at this stage have been estimated based on previous experience and engineering judgement and require further validation.

Other hydraulic structures within Parramatta River such as Marsden weir and Charles Street weir have been incorporated in the relevant models (excluding Carlingford) based on information extracted from existing MIKE 11 models.

5.3.2.1 Lennox Bridge

Lennox Bridge is the most significant hydraulic control on the Parramatta River system, and as such the representation of the bridge within the TUFLOW models has been analysed and verified to replicate head loss through the structure modelled in the Upper Parramatta River MIKE 11 model. Lennox Bridge has been schematised such that a reasonable match with the MIKE 11 peak water levels was achieved. Refer to section 7.6 for the results of this comparison.

It was noted that the Lennox Bridge Bikeway Portals project created two additional openings which floodwater can be conveyed through. The Lennox Bridge Hydraulic Impact/Hazard Assessment (refer to Table 2) indicated that the incorporation of the bikeway portals would decrease the peak water level immediately upstream of Lennox Bridge by 586mm in the 1% AEP event, and by up to 353mm approximately 1km further upstream. This was reported to be offset by an increase of approximately 30mm in water levels downstream between Lennox Bridge and Charles Street Weir.

The CoP adopted flood model pre-dates the portals. Therefore, analysis of the relevant TUFLOW model incorporating the bikeway portals was carried out to assess the sensitivity of the peak water level in the 1% AEP event. Discussion can be seen in section 7.4.

5.3.2.2 New Bridge Structures

The new bridge structures proposed as part of the PLR project were incorporated into the TUFLOW models where it was practicable to do so. Assumptions on the representation of the proposed bridges are outlined in section 8.5.4.

5.3.3 Buildings

Buildings in the 1d/2d TUFLOW models (Westmead, North Parramatta, Parramatta CBD and Camellia) were represented as blocked-out elements. Rainfall polygons were applied around the perimeter of the buildings to evenly distribute rainfall falling on the roofs. Buildings in the combined PMF TUFLOW model have been represented as raised areas of the model DTM.

CoP provided building polygons in the form of GIS data. The data covered the majority of PLR TUFLOW model extents. Building polygons from the *Duck River and Duck Creek Flood Study* TUFLOW model (refer to Table 2) were also utilised where available. Minor modifications to the CoP building polygons were made where considered appropriate.

Building polygon data was not available for the majority of the Carlingford sub-catchment. As such, a high Manning's roughness value was adopted to model the impact of buildings and urbanised areas in obstructing natural overland flow paths. This approach was also adopted in the combined PMF model TUFLOW GPU model, where building layers were not available.

No walls/fences have been included in flood models with the exception of one wall in the North Parramatta model (representing the outer wall of the Parramatta Gaol), which was determined to be necessary to obtain adequate overland flow routing behaviour. Exclusion of walls/fences is a standard approach for 1D/2D flood models in urban settings that is adopted by councils in flood studies.

5.3.4 On Site Detention

On site detention facilities have not been included in existing baseline flood models, with the exception of an existing on site detention facility modelled in the Westmead Hospital Flood Study (refer to Table 2). This was maintained within the PLR Westmead TUFLOW model for consistency.

Exclusion of these is a standard approach for integrated 1D/2D flood models in urban settings that is adopted by councils in flood studies.

5.3.5 Basements

No basements were included in the models. This is a typical approach in assessing flood risk in urban environments that is adopted by councils in flood studies. This will result in slightly conservative flood level estimates in some places, as the storage capacity of the basements have not been modelled.

5.3.6 Stormwater Drainage Network

Stormwater drainage network information has been incorporated into all the 1d/2d TUFLOW models (i.e. excluding the Carlingford and Combined PMF TUFLOW GPU models).

As noted in section 4.3.3, there were a variety of sources from which stormwater data was made available. The GIS stormwater dataset provided by CoP contained geo-referenced pit and pipe information for the majority of the Parramatta LGA. Notable areas where pit and pipe data was not available or was incomplete included:

- Westmead health precinct
- Cumberland health precinct
- T6 Carlingford Railway corridor
- Significant portions of Camellia, which is generally privately-owned land (the dataset did include information within the road corridors).

Upon review, whilst this dataset provided a fairly comprehensive record of pipe and pit locations within the Parramatta LGA, there was considerable amounts of pit and pipe data missing, or later shown to be out-of-date. Many pipe sizes were also noted to be “assumed” within the data attributes.

Most of the other stormwater datasets provided within the Parramatta LGA (refer to Table 4 for further information) were either survey data, or historical design/works-as-executed drawings. CCTV footage was also provided along parts of the PLR project corridor.

Where stormwater network information was available and able to be verified from the sources noted above, this was generally used in preference to the CoP GIS dataset. In some cases, engineering judgement was used to piece together the stormwater network components where different sources provided conflicting information, or where stormwater works are known to have been carried out since the publication of each dataset (e.g. Church Street, which has seen significant stormwater alterations on several occasions in recent decades).

The most significant changes made to the CoP stormwater GIS, in terms of the impact on flooding behaviour along the Parramatta Light Rail corridor are listed below:

- Harris Street Culvert - The inclusion of a 900mm diameter pipe, linking the Clay Cliff Creek open channel to Parramatta River, beneath Harris and MacArthur Streets. This pipe, which is a Sydney Water asset and has been verified by Sydney Water as being functional, has not been incorporated into any of Council’s previous flood models (as far as can be ascertained). The inclusion of the pipe within the Parramatta CBD TUFLOW model impacts upon the predicted flooding within the lower reaches of Clay Cliff Creek.
- Brickfield Creek culvert between Ross Street and Victoria Road and upstream open channel section - culvert sizes/invert levels through this Brickfield Creek

were incorporated based on historical drawings and CCTV footage provided by Sydney Water.

- Westmead Hospital - Stormwater data through the Westmead health precinct collected as part of the Westmead Hospital Flood Study; has been incorporated into the PLR project flood modelling.
- Cross-sectional data from the adopted MIKE 11 models for the Clay Cliff Creek and Brickfield Creek open channel sections has been adopted in preference to the Council GIS dataset, except for those areas covered by Sydney Water data noted above.

Where the CoP Council GIS stormwater dataset indicates the existence of stormwater infrastructure but is missing any data on pipe sizes or levels, and no other sources of information were available, the 1D stormwater component of the TUFLOW sub-models were developed as follows:

- For missing inverts between two points with known information, inverts between were determined by interpolating an average gradient between the two points. Minimum cover checks were carried out for all inferred points. Note only minor checks have been carried out for those drainage networks where it was determined that they have independent overland flow paths / outfalls that have no bearing on the PLR project, or where the PLR project would not cause an impact.
- For missing inverts at outlets, longitudinal gradients were extrapolated from the upstream point to be consistent with ground level. Minimum cover checks were made at the outlet, and invert levels were checked against available river bed information. Assumptions were validated where possible through review of aerial photography.
- Where PLR topographical survey has identified pits and stormwater outlets (i.e. evidence that a stormwater network exists), assumptions have been made on the network connectivity, with pipe sizes of 375mm added to the existing case model. This is considered to be a more realistic schematisation than that compared to if they were excluded, and provides a fairer base for assessment of potential impact of the light rail. Areas where this has occurred will be highlighted, with attempts to receive more accurate information ongoing.
- Where additional pits have been identified by review of aerial photography, Google Street View, and from CCTV (where available), these have been added into the TUFLOW sub-models. Invert levels have been set by average gradient between upstream and downstream points.

The extents of the stormwater network that have been added to, or modified from the CoP stormwater GIS dataset can be seen in Maps 5.7 – 5.10 in Appendix A.

Given limitations in the available data and the study programme, all modelling assumes that the inlet pits have unlimited inlet capacity. Junction pits are modelled as sealed pits, with water not being able to transfer between the 1D/2D domains at these locations. This may underestimate flooding where existing pits allow flows to bypass that could otherwise be conveyed by the pipe's capacity, either due to insufficient intake capacity or blockage. Sensitivity testing carried out in this regard is described in section 7.4.

Once stormwater asset survey information is available (understood to be post-EIS), the TUFLOW models should be updated to incorporate all surveyed pit and pipe information to accurately simulate stormwater entering the pit/pipe network.

Tailwater conditions for modelled pipe networks are determined by the mainstream river water levels, which vary through the duration of the storm.

Although pit inlet rating curves have been excluded from the models, a preliminary pipe network capacity assessment has been carried out, which indicates that the majority of the existing drainage network has capacity of a 0.2EY event or less (refer pipe capacity mapping in Maps 5.11 – 5.14). Given that the existing stormwater network has such limited capacity, the impact on baseline results due to the exclusion of pit capacities is likely to be limited (compared to a scenario where the existing stormwater network has greater capacity). A sensitivity analysis of the impact of pit inlet capacities on baseline flood results has been carried out and is described in section 7.4.

5.3.7 Hydraulic Roughness

Hydraulic roughness refers to the frictional resistance experienced by water when passing over various surfaces. Manning's n-value roughness coefficients have been utilised to model hydraulic roughness in all PLR TUFLOW models.

The Manning's roughness map was developed using information from a combination of roughness layers from existing flood models, aerial photography, and land zoning information. Within the major watercourses, the Manning's roughness was matched to those in the applicable MIKE 11 flood models to attain good agreement in peak water levels between the PLR TUFLOW models, and the adopted Council flood studies. Manning's n values adopted for the PLR project are listed in Table 11.

Table 11 Manning's n Roughness Values

Material	Manning's n
Grass	0.030
Medium Density Vegetation	0.045
Roof and Paved Ground	0.020
Road Pavement	0.020
Creeks and Rivers (varies to match adopted Council models)	0.035 0.030 0.025
Heavy Density Vegetation	0.070
Low Density Residential (in areas no building polygons were available)	0.100

5.3.8 Boundary Conditions

Boundary conditions for all TUFLOW models are described below:

- Direct rainfall was applied across all active areas of each TUFLOW model, in line with the IFD data outlined in section 5.2.2.
- Inflow boundary conditions for the major water courses were extracted from the MIKE 11 hydraulic models provided by CoP. Inflow hydrographs from the 30 minute duration storm were incorporated into the TUFLOW models for all durations less than 30 minutes, as this was the shortest duration run common to all MIKE 11 models provided.
- Stage hydrographs were adopted as the downstream boundary condition for all models. These were extracted from the MIKE 11 hydraulic models provided by CoP. Stage hydrographs from the 30 minute duration storm were incorporated into the TUFLOW models for all durations less than 30 minutes, as this was the shortest duration run common to all MIKE 11 models provided.
- In isolated instances where elements of the 1D stormwater network discharge to outside the active model area, a constant tailwater condition has been adopted correlating with the applicable storm event.

5.4 Modelled Flood Events

The 0.2 EY, 5% AEP and 1% AEP design flood events were investigated. The 1% AEP event was required to be modelled to address the requirements of the SEARs, whilst the 0.2 EY and the 5% AEP events were modelled to understand how the operability of the PLR might be affected by flooding, and to assist in the development of the PLR scheme stormwater design.

A suite of durations was modelled for each of the return periods stated above. This approach was considered necessary as the critical duration varies considerably over the extent of the PLR alignment. Rainfall durations between 10 minutes and 9 hours were run for the 0.2 EY, 5% AEP and 1% AEP events, noting that the Upper and Lower Parramatta River flood studies show that the critical duration of Parramatta River is the 9 hour duration storm for the events noted above.

From the suite of durations run for the existing case models, it was determined that the 15 minute, 25 minute, 90 minute, 2 hour and 9 hour duration storms were critical for flooding along the majority of the alignment. The only notable exception to this is in the Parramatta CBD TUFLOW model, where the 4.5 hour storm was shown to be critical along a section of Macquarie Street in the 5% AEP event. Critical storm duration mapping for the existing case in the 1% AEP event is shown in Maps 5.15 – 5.19, Appendix A.

Given the critical storm durations across the alignment were fairly consistent between all the TUFLOW models, the PLR scheme and climate change scenarios only model the durations known to be critical along the PLR alignment. It is

acknowledged that critical duration could vary from the existing as a result of design changes and this assumption should be checked at later design stages.

For the PMF model, the 30 minute, 45 minute, 60 minute, 2 hour, 4 hour and 6 hour duration storms were modelled for both the existing and scheme cases, noting the Upper and Lower Parramatta River flood studies show that the critical duration of Parramatta River is the 4 hour duration storm for the PMF. Table 12 summarises the durations modelled for the various events and scenarios.

Table 12 Storm Durations Modelled

0.2 EY, 5% AEP, 1% AEP			PMF	
Existing Case	Climate Change (Existing and Design Cases)	Design Case	Existing Case	Design Case
10 minute	15 minute	15 minute	30 minute	30 minute
15 minute	25 minute	25 minute	45 minute	45 minute
20 minute	90 minute	90 minute	60 minute	60 minute
25 minute	2 hour	2 hour	2 hour	2 hour
30 minute	4.5 hour*	4.5 hour*	3 hour	3 hour
45 minute	9 hour	9 hour	4 hour	4 hour
60 minute			6 hour	6 hour
90 minute				
2 hour				
3 hour				
4.5 hour				
6 hour				
9 hour				

*Parramatta CBD model only

5.5 Mapping of Flood Behaviour

The flood depth reported for any given area is the maximum depth extracted from the suite of durations simulated for each return period. As the TUFLOW models use the rainfall on grid approach, the results have been processed with a minimum depth cut-off of 50mm. In the context of light rail, depths of greater than 50mm are also likely to impact on the system operability.

Due to the rainfall on grid approach, the baseline flood maps require interpretation in determining whether reported flooding is likely be real, as some ponded areas may be a function of water being trapped on the grid (particularly around buildings).

For the Carlingford section of the alignment, the depth reporting and commentary is based on 2D modelling (overland flow) only. Results can therefore be considered to be conservative in these areas.

As the models have been built for the sole purpose of determining areas of existing flood affectation likely to affect the light rail alignment, the results should not be used for identifying impacted properties, and subsequently notification of Section 149 certificates.

5.6 Model Suitability

TUFLOW models have been developed for the purpose of identifying critical areas affected by flooding which would impact the operations of the PLR, and identifying those areas that the scheme may adversely impact. In order for the models to be suitable for this purpose, it is important to compare baseline results against historical information that is available.

Assessment of the performance of the PLR sub-models can be subdivided into two areas, mainstream and overland flow. The two areas differ on the hydrological input used to derive design flood levels and velocities within the TUFLOW hydraulic model. As such, they require different approaches to verify the suitability of the model results for both areas.

5.6.1 Mainstream River Areas

Rivers have been included in the TUFLOW models to adequately represent local and regional storm events. This provides the tailwater conditions of the stormwater networks within the local urban areas, and also identifies those areas that are susceptible to inundation due to fluvial conditions.

A review of the hydraulic performance of the bridge and weir structures in the rivers in each TUFLOW model was carried out, and an appraisal of TUFLOW baseline flood model river levels (and correlation against existing studies) is provided in section 7.6.

As the accuracy of the river levels in the PLR TUFLOW modelling is limited to the information provided and project time constraints, it would be prudent to carry out a comparative analysis of the PLR TUFLOW river levels against the ongoing CoP Flood Study, when the results become available. For example, the CoP study may take into account the cumulative impact of developments across the catchment that include OSD, the use of AR&R 2016 hydrological inputs, and any other modifications to hydraulic controls in the catchment since the publication of the original Upper Parramatta River Flood Study. Should there be any discrepancies, an appraisal of how these differences may affect light rail should be carried out.

5.6.2 Overland Flow Areas

Limited historic information of flooding in urban areas inhibits the ability to calibrate or validate the models in these locations, although areas prone to flooding have been discussed with CoP. This occurs in every urban environment due to the fast response of the catchment. As such, obtaining historical flood levels in urban areas is challenging in most circumstances.

The direct rainfall approach is an alternative approach in hydrologic modelling. Some discussion of the method is presented herein along with consideration of the advantages and disadvantages of the method.

Many studies carried out by specialised consultants for both private and government clients, both in Australia and overseas, have been conducted using a direct rainfall approach. Also, within the literature on hydrological/hydraulic modelling there are examples of research which demonstrate the ability of this approach to emulate more established lumped conceptual hydrological models and more importantly to match the observed data. Refer to section 7.6.2 for verification of the approach.

The main advantages of the approach are that:

- Flows can be applied to the drainage system avoiding non-conservative over attenuation of flows due to the non-inclusion of sub grid features
- Routing is based on relatively high resolution topography and the full St Venant equations and hence parameterisation of storage/routing processes is implicit
- Avoidance of double routing of flows which often occurs as a result of adopting a joint modelling system

In the absence of calibrating the models in these areas, a comparison against an alternative hydrologic modelling method (lumped sub-catchments) is considered appropriate. Further details of this assessment is provided in section 7.6.

6 Climate Change

6.1 Overview

A summary of current climate change policy and adopted climate change projections for both sea level rise and rainfall intensity is provided in section 3.4.

The impacts of sea level rise and increased rainfall intensity have been applied in the TUFLOW models in combination to help minimise model run scenarios. It should be noted that the timing of the predicted rainfall increases and sea level rise does not align between the applicable guidelines. The combinations adopted could be considered as the estimated best-case (lower bound) and worst-case (upper bound) scenarios of the impacts of climate change on flooding, based on current guidance. The two climate change scenarios modelled are outlined below:

- Scenario 1 (Lower Bound) – 10% increase in rainfall intensity and a 400mm rise in sea level
- Scenario 2 (Upper Bound) – 30% increase in rainfall intensity and a 900mm rise in sea level.

In order to assess climate change impact on light rail operations, as well as sensitivity of project impact assessment to climate change, the 1% AEP and 0.2EY events were adopted for analysis.

The 0.2EY climate change scenarios were modelled to assess how climate change may impact the operability of the PLR project, whilst the 1% AEP climate change scenarios were modelled to compare the impact of the PLR project (under each climate change scenario) against the impact of the PLR project under present-day conditions.

6.1.1 Ocean Water Level

Given the PLR project is located a significant distance upstream from the coast it is not realistic to apply the full increase of the sea level rise at the downstream boundaries of each of the PLR project TUFLOW models.

To incorporate the impact of sea level rise, both the Upper Parramatta River and Lower Parramatta River MIKE 11 models were re-run incorporating both the respective rainfall increases and sea level rises listed in section 6.1. The relevant stage hydrographs were then extracted from the MIKE 11 models and applied as the downstream boundary conditions in the TUFLOW models.

6.1.2 Design Rainfall Intensity

The direct rainfall inputs into the TUFLOW models were factored up by the respective rainfall intensity increases outlined in section 6.1 for assessing climate change impacts.

The original Upper Parramatta River MIKE 11 has not assessed changes due to climate change. The original hydrological models used to derive runoff for the Upper Parramatta River and Lower Parramatta River MIKE 11 models were not made available at the time of carrying out this flood assessment. As such, inflow hydrographs from the MIKE 11 models have been factored by 10% and 30%, respectively to account for the increase in rainfall intensities. For the river inflow boundaries, the applicable inflow hydrographs were generally extracted from the Upper Parramatta River and Lower Parramatta River MIKE 11 climate change runs and incorporated into the TUFLOW models in a similar manner to the stage hydrograph boundary conditions.

6.2 Modelled Scenarios

The upper and lower bound climate change scenarios were modelled for the 0.2EY and 1% AEP existing and design case flood events. The durations modelled were limited to those found to be critical for each sub-catchment as listed in section 5.4.

7 Existing Scenario Flood Results

7.1 Peak Flood Conditions

The PLR project passes through a number of flood-prone areas as a result of both mainstream (riverine) and overland flow flooding (or some combination of the

two). This section provides an overview of the existing peak flood conditions along the PLR project.

Peak flood depth maps along the PLR alignment are provided in Maps 7.1 – 7.18 in Appendix A for the 0.2EY, 5% AEP and 1% AEP events.

Note that all flood depths reported in the following sections refer to depths over the proposed track alignment and are not necessarily peak depth values in the adjoining road carriageway.

7.1.1 Westmead Precinct

The PLR project through the Westmead Precinct is not impacted by mainstream flooding in all events up to and including the 1% AEP. The existing Bridge Road Bridge (Cumberland Hospital) is predicted to be above the 1% AEP flood level with greater than 500mm to soffit level, both from the Upper Parramatta River MIKE 11 model and the PLR TUFLOW modelling.

Overland flow flooding occurs at the location illustrated in Figure 22 and is briefly described below:



Figure 22 Westmead Precinct existing flooding issues

- Westmead Children's Hospital stop - localised ponding is shown to occur where there is a localised sag at the intersection of Hawkesbury Road and Hainsworth Street. Depths of up to 200mm are predicted in the 0.2 EY event and up to 300mm in the 1% AEP event. This flooding is due to insufficient capacity in the existing stormwater network. The time of inundation is predicted to be less than 1 hour in all events.

7.1.2 Parramatta North Precinct

Similarly, to Westmead, the Parramatta North Precinct is not impacted by mainstream flooding in all events up to and including the 1% AEP.

Flooding occurs at the locations illustrated in Figure 23 and are briefly described below:



Figure 23 Parramatta North Precinct existing flooding issues

- Cumberland Hospital west of the oval - localised trapped sag. Depths of up to 200mm are predicted in the 0.2 EY event and up to 250mm in the 1% AEP event. Given the lack of stormwater information through the Cumberland Hospital, it is possible these depths are overestimated.
- Cumberland Hospital near roundabout south of the oval – flooding is shown to occur in a sag point in the road once the stormwater network is at capacity. Depths of 250mm are predicted in the 0.2EY and up to 500mm in the 1% AEP event. Time of inundation in this sag is shown to be around 1-2 hours in the 0.2EY event and 3-5 hours in the 1% AEP event. Given the lack of stormwater information through the Cumberland Hospital, it is possible these depths are overestimated.
- Localised sag just south of the intersection of Church Street and Ross Street. Flooding occurs once the stormwater network reaches capacity. Depths of up to 200mm are predicted in the 0.2EY event, and up to 400mm in the 1% AEP event. The sag is predicted to be underwater for between 15 -30 minutes in a 1% AEP event.

7.1.3 Parramatta CBD Precinct

Flooding is a known problem throughout much of the Parramatta CBD Precinct, particularly when the water level in the receiving watercourses is high, preventing stormwater from being effectively discharged. Overland flow flooding is also a problem in several locations, primarily due to insufficient capacity in the stormwater network.

Flooding occurs at the locations illustrated in Figure 24 and is briefly described below:



Figure 24 Parramatta CBD Precinct existing flooding issues

- Macquarie Street near the proposed Parramatta Square stop – depths of approximately 300mm are predicted in the 0.2EY event and approximately 600mm in the 1% AEP event due to a trapped sag in the road and insufficient capacity of the stormwater network draining it out. Time of inundation through this sag is predicted to be between 15-30 mins in the 0.2 EY event, and 1-1.5 hours in the 1% AEP event.
- Macquarie Street near Harris Street stop – depths of approximately 300mm and 600mm are predicted for the 0.2 EY and 1% AEP events respectively. Time of inundation of this sag is predicted to be 2-3 hours in the 0.2 EY event and up to 6-8 hours in the 1% AEP event. The ability of this area to drain effectively is compromised by the existing stormwater network draining to the Clay Cliff Creek open channel, for which the critical duration is roughly coincident and hence high tailwater levels in Clay Cliff Creek prevent the water from escaping the sag.

It should be noted that areas along Church Street south of the Parramatta River, for which anecdotal and photographic evidence of flooding was observed, has not been shown as significantly flood-prone by flood modelling. This is likely to be a combination of the assumption of unlimited pit inlet capacity being applied to the

flood models, and limitations in how the road / footpath profile can be physically represented in a TUFLOW model. Pit blockage may also contribute to flooding through this area, which has not incorporated within the TUFLOW model.

7.1.4 Rosehill and Camellia Precinct

Flooding occurs at the locations illustrated in Figure 25 and is briefly described below:



Figure 25 Rosehill and Camellia Precinct existing flooding issues

- Tramway Avenue/Arthur Street intersection – localised sag point. Depths of up to 600mm are predicted in the 0.2EY event and approximately 1.6m predicted in the 1% AEP event. This area is located directly in the Clay Cliff Creek floodplain, and is shown to remain underwater for considerable periods of time even in more frequent events (time of inundation is greater than 5 hours in the 0.2EY event) due to high water levels in Clay Cliff Creek and Parramatta River preventing surface run-off from escaping this sag. In the 1% AEP event, floodwater overtops the bank of Clay Cliff Creek and inundates much of the alignment between Alfred Street and James Ruse Drive.
- Tramway Avenue stop – the proposed Tramway Avenue stop location is located on the fringe of the Clay Cliff Creek floodplain area and as such is subject to flooding. The stop location is generally dry in the 0.2EY event, however the eastern side of the stop location is flood affected in the 5% AEP event (at which point floodwater has breached the banks of the Clay Cliff Creek channel), and is under nearly 1m of water in the 1% AEP event. The stop location is predicted to be underwater for between 3-5 hours in the 1% AEP event. Greater depths are predicted in all events to the east of the proposed stop location closer to Clay Cliff Creek.

- Carlingford Junction – localised flooding of up to 420mm in the 0.2EY event near the former Grand Avenue level crossing. Whilst there is a trapped sag at this location, the illustrated flooding is likely a result of stormwater infrastructure within the rail corridor not being incorporated within the TUFLOW model.
- Camellia (Sandown Line) – localised overland flooding is shown along the disused Sandown railway corridor, with depths up to 200mm predicted in all events up to the 1% AEP. However, as existing stormwater survey of the Sandown line was unavailable at the time the flood models were run, it is possible that some of these ponded areas may be drained adequately, or pond to a lesser extent than shown in the flood maps. Whilst the PLR project through Camellia sits above the 1% AEP flood level in Parramatta River, the precinct is very flat and flooding is a known problem once the stormwater network reaches capacity.
- Camellia stop – the northern end of the proposed stop location is shown to be inundated in the 1% AEP when the water level in Parramatta River peaks. Depths of up to 250mm predicted to occur in the 1% AEP event for around 1-2 hours.

The existing Carlingford rail line starts to ascend as it heads north from the Camellia stop. The existing track is clear of the predicted 1% AEP flood level where it crosses the Parramatta River and Vineyard Creek, and also where the track traverses the James Hardie underpass slightly to the north of the Camellia stop.

7.1.5 Carlingford Precinct

The portion of the PLR project which traverses the existing T6 Carlingford rail corridor roughly traverses the catchment boundary between the Vineyard and Subiaco Creek catchments to the north of the Parramatta River and is therefore largely free from significant flooding. Some areas of minor ponding along the rail corridor can be observed on the mapping, however this is a function of the TUFLOW GPU model not incorporating 1D stormwater pit and pipe elements. It is expected, given that the existing rail corridor would be drained and the relative steepness of the terrain, that these ponded areas are not real and are arising due to the inability of the TUFLOW GPU model to incorporate stormwater drainage elements.

7.2 Preliminary Hydraulic Categorisation

The NSW *Floodplain Development Manual (2005)* defines three hydraulic categories for flood prone land, which are summarised below:

- Floodways – areas where a significant volume of water flows during floods, and which if partially or full blocked would cause a significant increase in flood levels, or redistribution of flood flow which may impact other areas.
- Flood Storage – areas of the floodplain that are important for the temporary storage of flood waters during the passage of a flood. Should the capacity of

flood storage areas be substantially reduced, flood levels in nearby areas may be increased and the peak discharge downstream may be increased.

Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flows.

- Flood Fringe – the remaining area of land affected by flooding after the floodway and flood storage areas have been defined.

The NSW Floodplain Development Manual does not provide quantitative criteria for defining floodways and flood storage areas, given the site-specific nature of such areas. For the PLR project, preliminary hydraulic categorisation has been defined as per the below:

- Floodway: All areas where:
 - $V \times D > 0.25 \text{m}^2/\text{s}$ and $V > 0.25 \text{m/s}$ or
 - $V > 1.0 \text{m/s}$
- Flood Storage: All areas not classified as a floodway where $D > 0.2 \text{m}$
- Flood Fringe: All areas not classified as a floodway or flood storage where $D > 0.05 \text{m}$.

The categories above are consistent with those adopted for a number of other urbanised catchments in the Greater Sydney area, and are considered to be suitable for the Parramatta Light Rail flooding assessment.

The existing preliminary hydraulic categorisation for the 1% AEP event is shown in Map 7.19 in Appendix A. Key points to note are listed below:

- Floodway areas are most prominently shown in the major watercourses (Parramatta River, Toongabbie Creek, Domain Creek, Brickfield Creek, Clay Cliff Creek, Vineyard Creek, Subiaco Creek and Duck River).
- There is an overland flow path shown, partially as a floodway, from north of the Factory Street/Church Street intersection down into the Cumberland Hospital. The categorisation changes to “Flood Storage” as this flow enters the sag, where significant ponding is shown in the flood depth mapping. There is also an area designated as “floodway” draining out to the west of this sag towards Parramatta River.
- The sag point to the Church Street/Ross Street intersection is shown as a significant flood storage area, which collects water from two overland flow paths (from Church Street and Villiers Street) that are classified as floodways. The overland flow path discharging from this sag to the south (via Victoria Road) as also classified as a floodway.
- Both the sags in Macquarie Street (see section 7.1.3) are shown to be areas of flood storage.
- Most of the area where the PLR project traverses the Clay Cliff Creek floodplain is classified as “flood storage”. The formalised Clay Cliff Creek channel is shown to be classified as a floodway. The overland flow path between the upstream end of the Arthur Street culvert and where this water re-enters Clay Cliff Creek via Grand Avenue North is also a floodway.

- The existing Carlingford T6 Railway embankment passes through a significant area of flood storage between the Camellia Junction and the Parramatta River. A floodway is shown to exist through the James Hardie underpass.
- Some areas along the existing Carlingford T6 Railway corridor are classified as floodways. These are likely to either be cess drains within the railway corridor, or areas where flow has accumulated due to stormwater elements not being incorporated in the TUFLOW GPU model.
- There is a detention basin to the north of the existing Carlingford Railway station, which is shown as an area of flood storage.

Compatibility of the PLR Project with the flood categorisation and impact of the PLR Project on flood categorisation is addressed in section 9.3.4.

7.3 Provisional Hazard Categories

The NSW *Floodplain Development Manual (2005)* breaks hydraulic hazard into two primary categories, which are summarised below:

- High Hazard – possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damages to buildings.
- Low Hazard – should it be necessary, a truck could evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

These hazard categories (along with a separate category between low and high hazard, referred to as “transition”) are defined quantitatively as a function of depth and velocity in the NSW Floodplain Development Manual as per Figure 26 below.

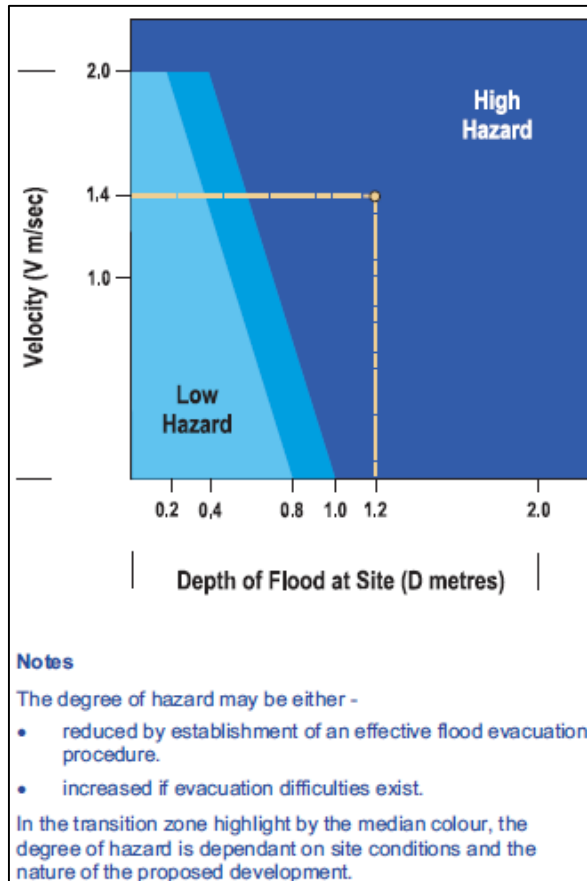


Figure 26 Provisional Hydraulic Hazard Categories
(Source NSW Floodplain Development Manual Appendix L, 2005)

The figure above is intended to be used as a tool for developing hazard categories in floodplain risk management plans, however it must be noted that it is only a provisional assessment of flood hazard, and a range of additional factors (such as effective warning time, rate of rise of floodwater, time of inundation etc.) influence the true flood hazard of a particular precinct.

The existing preliminary hydraulic hazard for the 1% AEP event is shown in Map 7.20 in Appendix A. Key points to note are listed below:

- Areas of “High Hazard” are generally limited to the major watercourses and the immediate surrounds.
- The only high hazard area passed through by the PLR project is the section between Alfred Street and James Ruse Drive. In all other locations where existing roads/rail structures cross a watercourse denoted as high hazard, these are all above the peak 1% AEP water level (note this excludes the existing pedestrian footbridge over Clay Cliff Creek).
- There are areas of high hazard flooding either side of the existing railway embankment between Camellia Junction and Parramatta River which are mainly due to mainstream river flooding. However, the existing Carlingford T6 rail line and therefore the PLR alignment is outside the 1% AEP high hazard envelope.

- The detention basin to the north of the existing Carlingford Railway station is classified as a high hazard area. Note that this may be an overestimate of the true hazard as stormwater is not incorporated in the Carlingford TUFLOW GPU model, which prevents this area from draining.

Compatibility of the PLR Project with the flood hazard of the land and impact of the PLR Project on flood hazard is addressed in section 9.3.4.

As previously stated, the NSW Floodplain Development Manual is a provisional guide to flood hazard only, and other factors in addition to flood depth and velocities must be considered. Other guidelines (e.g. AR&R 2016) may give differing classification of hazard compared to those in the NSW Floodplain Development Manual. The approach taken for PLR has been adopted to allow comparison with current CoP flood hazard assessment, as required by the SEARs.

7.3.1 Probable Maximum Flood (PMF)

PMF depths for the existing scenario are shown in Map 7.21. It can be seen that a significant portion of the proposed PLR project alignment is under several metres of water, particularly through the Parramatta CBD, Rosehill and Camellia precincts. It is also likely that all existing bridges proposed to carry the PLR (either being retained or replaced) would be impacted to some degree by the PMF, although these have not been explicitly modelled due to limitations of TUFLOW GPU.

7.4 Model Sensitivity

7.4.1 Overview

Two sensitivity tests were carried out to assess the impacts of the modelling assumptions in the baseline modelling. These sensitivity analyses were as follows:

- Adoption of average pit inlet rating curves (against unlimited inlet capacity pits assumed in the baseline model). This scenario was modelled for the 0.2EY, 5% AEP and 1% AEP events for two overland flow-critical durations (25 minute and 120 minutes).
- Incorporation of the recently constructed Lennox Bridge Bikeway Portals, which were excluded from the baseline modelling so that consistency with Council's adopted flood levels could be achieved. This scenario was modelled for the 0.2EY, 5% AEP and 1% AEP events for the river-critical duration (9 hour).

Both of these sensitivity tests were carried out in the Parramatta CBD TUFLOW model.

As detailed pit inlet information was unavailable for the majority of the stormwater network, two generic pit inlet rating curves (for on-grade and sag pits) were applied to the stormwater pits in the model based on the CoP GIS attributes (which specified whether a particular pit was on-grade or sag). Where other data

sources where used for the stormwater network, the pit type was estimated based on the surface elevation of the pit.

The intent of testing sensitivity to the pit inlet rating curves is to observe the difference in ponded depths along sections of the PLR project which traverse existing road corridors but are not impacted by mainstream flooding, as the assumption of unlimited pit inlets may underestimate ponding depths or time of inundation in these areas.

The Lennox Bridge bikeway portals were modelled in the Parramatta CBD TUFLOW model as culverts, and were roughly sized based on design drawings provided. The intent of this test was to observe the difference in peak water levels in the Parramatta River and assess whether this would significantly impact the tailwater levels at stormwater pipe outlets into Parramatta River.

It should be noted that these two sensitivity tests do not constitute an exhaustive list of sensitivity tests that can be applied to the flood models, and it is recommended to test for other scenarios (such as pit blockage or blockages at critical culvert or bridge structures) to assess the impacts on the PLR project at a later stage.

7.4.2 Results – Pit Inlet Sensitivity Test

Results for the pit inlet sensitivity test generally showed increases in ponded areas around known trapped sags in the roads. Some screenshots are provided below (refer Figure 27 through Figure 30) illustrating the difference between the existing baseline and the pit inlet sensitivity model runs.

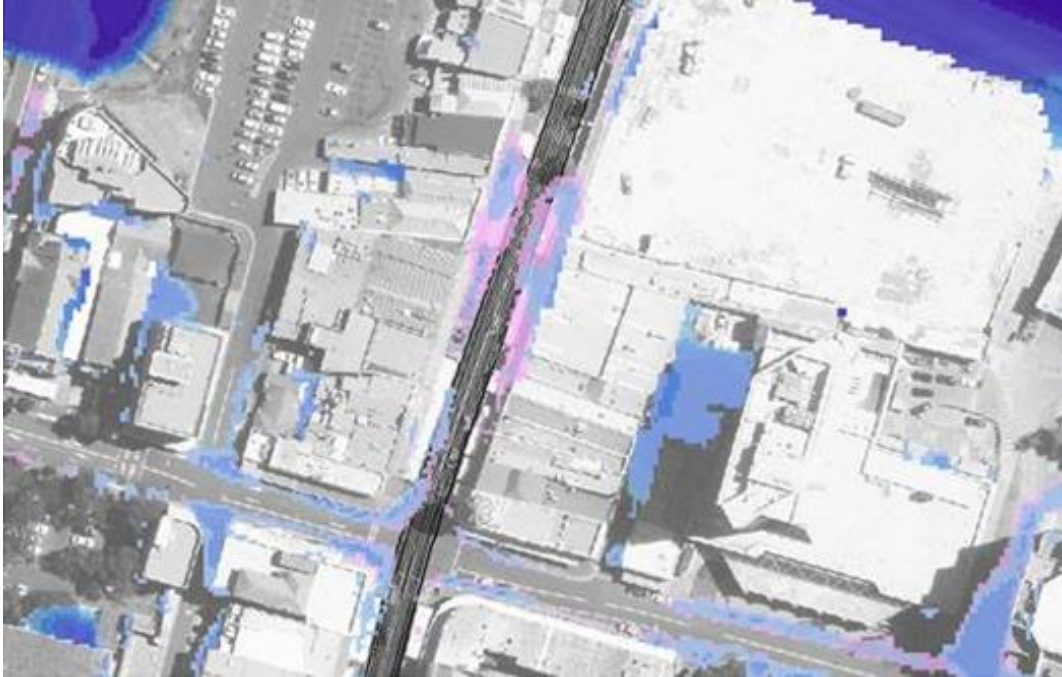


Figure 27 Church Street between Lennox Bridge and Phillip Street - 0.2EY event
Note: 25 minute duration storm grids shown. Blue extent is the existing baseline; purple is the existing baseline with pit inlet rating curves applied

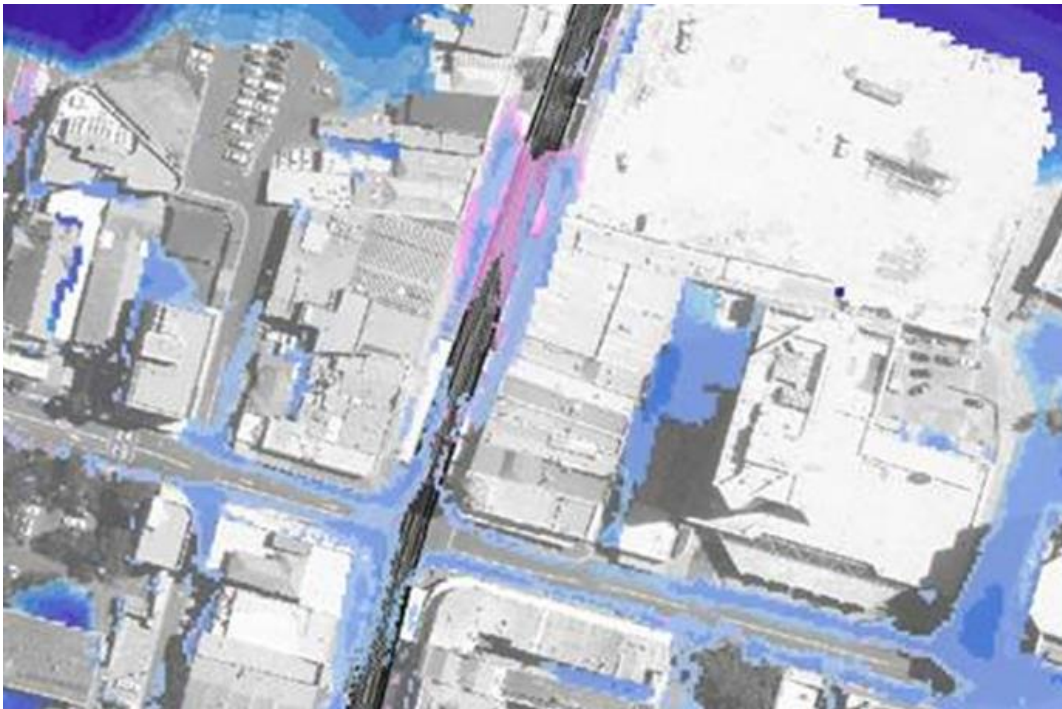


Figure 28 Church Street between Lennox Bridge and Phillip Street – 1% AEP event
Note: 25 minute duration storm grids shown. Blue extent is the existing baseline; purple is the existing baseline with pit inlet rating curves applied

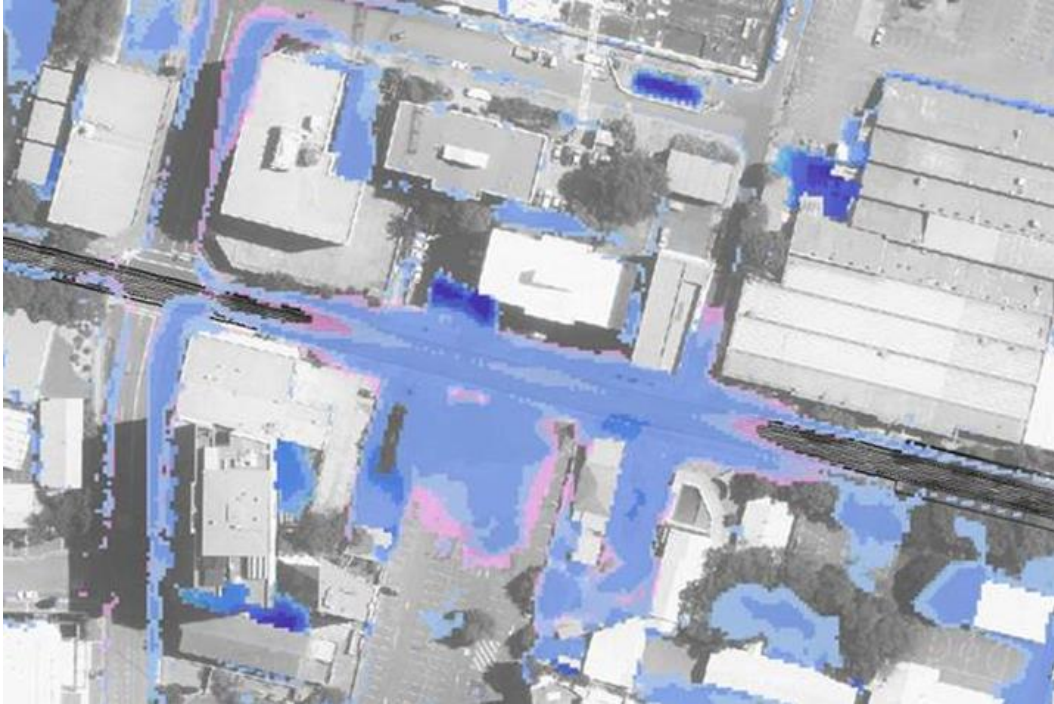


Figure 29 Macquarie Street east of Smith Street - 0.2EY event
Note: 120 minute duration storm grids shown. Blue extent is the existing baseline; purple is the existing baseline with pit inlet rating curves applied.

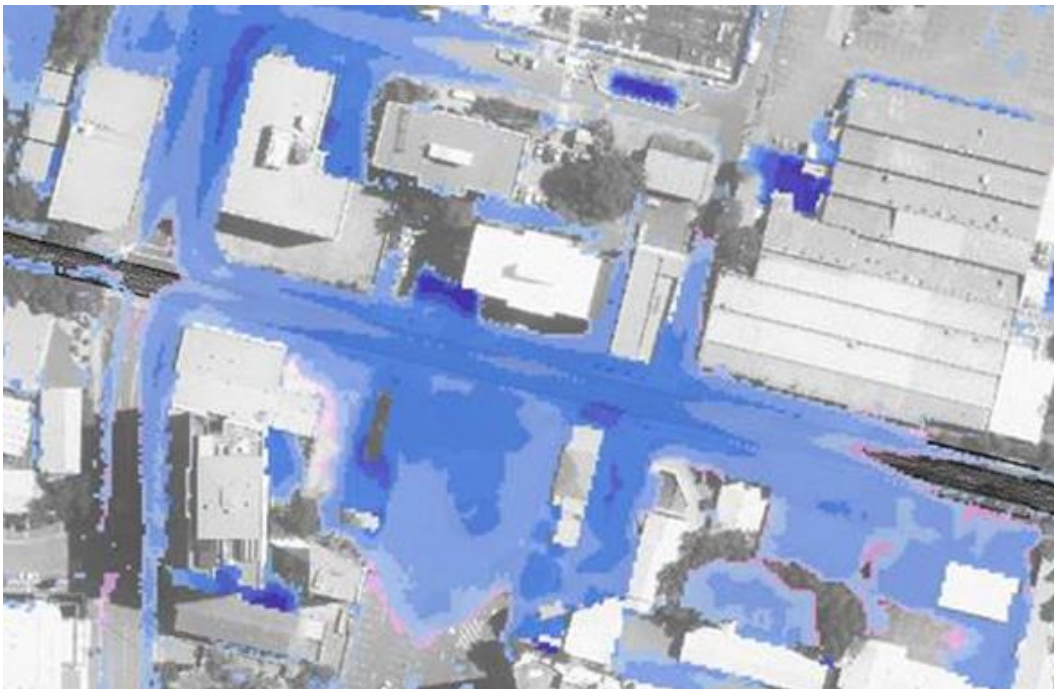


Figure 30 Macquarie Street east of Smith Street – 1% AEP event
Note: 120 minute duration storm grids shown. Blue extent is the existing baseline; purple is the existing baseline with pit inlet rating curves applied.

It can be seen in the figures above that there is an increase in ponded extent where the inlet rating curves have been applied to pits. This indicates the existing baseline model may be underestimating the existing flood depths in these areas. The results at Church Street could explain why the existing baseline model does

not illustrate significant flooding in this location despite anecdotal evidence that flooding is a known problem through this area.

The impact of unlimited pit inlet capacities being incorporated into the baseline modelling is relatively minor. The scheme design aims to demonstrate that providing immunity to the proposed PLR alignment in the 0.2EY is hydraulically feasible, and should pit inlet capacity be an issue, additional pits can be specified. This can be carried out at a later design stage, following the receipt of detailed drainage survey information confirming the existing pit inlet types.

7.4.3 Results – Lennox Bridge Bikeway Portal Test

Results from the Lennox Bridge bikeway portal test show that the addition of the bikeway portals results in a reduction of upstream peak water level, and an increase in the downstream peak water level in all flood events.

Upstream of Lennox Bridge, there is a decrease in peak water level between 10-30mm in the 0.2EY event, which only impacts the area between the upstream side of Lennox Bridge and Marsden Street Weir. The change in water levels are relatively small as only shallow water traverses the bikeway portals in the 0.2EY event.

In the 1% AEP event, the decrease in the peak water level is approximately 250mm on the upstream side on Lennox Bridge. The reduction in peak water levels relative to the existing baseline model extends to the upstream boundary of the Parramatta CBD TUFLOW model, at which point the reduction is approximately 75mm. The much larger reduction of peak water levels in the 1% AEP event is due to the bikeway portals conveying significantly larger flows than in the more frequent flood events.

Downstream of Lennox Bridge, there is an increase in peak water levels shown in the 0.2EY event, with any increase in water levels greater than 30mm having largely dissipated within a distance of 100m downstream of the bridge.

In the 1% AEP event, there is a localised increase in peak water levels relative to the existing baseline of approximately 100-150mm for a distance of approximately 160m downstream of the bridge. The increase in water level gradually reduces further downstream until Charles Street Weir. Downstream of this point, the peak water levels remain similar to the existing baseline.

Figure 31 and Figure 32 illustrate the predicted change to peak water levels with the bikeway portals incorporated into the Parramatta CBD TUFLOW model relative to the existing baseline.



Figure 31 Change in Peak Water Levels with Lennox Bridge Bikeway Portals - 0.2EY Event

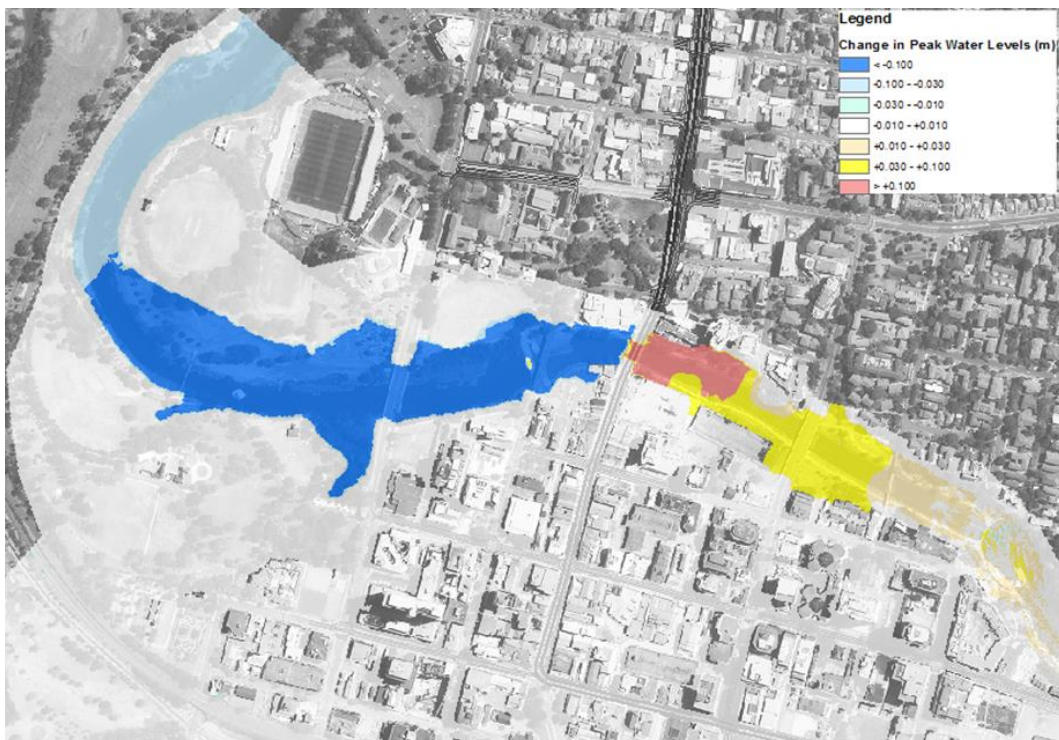


Figure 32 Change in Peak Water Levels with Lennox Bridge Bikeway Portals - 1% AEP Event

The *Lennox Bridge Bikeway Portals - Hydraulic Impact/Hazard Assessment Report* (refer to Table 2) also assessed the impact of the Lennox Bridge bike portals on predicted water levels in Parramatta River, using the adopted Council

MIKE 11 model. The report also concluded water levels would decrease upstream and increase downstream of the bridge structure in a 1% AEP event. The Lennox Bridge Bikeway Portals Hydraulic Assessment predicted a reduction in peak water levels upstream of Lennox Bridge between 350-600mm. This compares with a peak water level reduction of approximately 250mm predicted by the Parramatta CBD TUFLOW model.

On the downstream side of Lennox Bridge, the Lennox Bridge Bikeway Portals Hydraulic Assessment predicted an increase in peak water levels of approximately 30mm in the 1% AEP downstream of the bridge, extending downstream to Charles Street Weir. Impacts in the 0.2EY were predicted to be minimal, as the location of the bikeway portals was assumed to be almost outside the 0.2EY flood extents.

The differences between the predicted peak water levels in the two models (TUFLOW and MIKE 11) resulting from the inclusion of the bikeway portals is likely due to a combination of factors. These include the difference in hydrodynamic solution schemes that are utilised between different software packages (TUFLOW or MIKE 11) and assumptions built into modelling the bikeway portals (which was not able to be determined as the MIKE 11 flood model used in the *Lennox Bridge Bikeway Portals Hydraulic Assessment* was not made available to the PLR project). These factors make this discrepancy inevitable to some extent.

Regardless of the relative difference in peak water levels reported, it was considered that the impact of the Lennox Bridge bikeway portals on the PLR project is negligible. The stormwater outlets downstream of Lennox Bridge (where increases in peak water levels are predicted) are predicted to be submerged by several metres of water in the 1% AEP event, and hence an increase in peak water level of 150mm would likely have a minimal impact on the performance of the network. The new bikeway portals also do not impact on the timing of the peak flow passing through Lennox Bridge in Parramatta River, and so the lag between the local and regional catchments draining out is maintained compared with the baseline (no bikeway portals) case.

In the 0.2EY event, which may have a greater bearing on the performance of the stormwater network, the change in peak water level downstream of Lennox Bridge is unlikely to significantly influence any flooding issues related to the PLR project.

7.5 Climate Change

The climate change scenarios listed in section 6.1 (lower and upper bound scenarios) were modelled and compared with the existing baseline results to determine if a change in flood behaviour would impact the PLR project. Impacts of the climate change scenarios compared to the existing baseline are briefly summarised below.

7.5.1 Westmead Precinct

The two climate change scenarios show some mild increases in predicted flood depth (and extents) due to overland flow flooding in both the 0.2EY and 1% AEP events. As the PLR project is not impacted significantly by riverine flooding through the Westmead Precinct, any increases in flood extents are the result of the increased rainfall intensities in overland flow areas as opposed to increases in water levels in Toongabbie Creek/Parramatta River. There are no new areas of flooding predicted to be created through the Westmead Precinct in either climate change scenario relative to the existing baseline.

7.5.2 Parramatta North Precinct

As with the Westmead Precinct, the Parramatta North Precinct is generally impacted by overland flow flooding, and not by mainstream riverine flooding. As such, the climate change modelling generally only predicts increases in peak depths in overland flow flooding compared to the existing baseline.

The only significant change to the existing baseline of relevance to the PLR project is at the sag in Church Street between Ross Street and Victoria Road in the 0.2EY upper bound climate change events. Flooding is predicted to inundate the entire road carriageway in the upper bound climate change scenario, whereas in the existing baseline case, flooding is limited to the western side of Church Street.

The increased flood extents at this location are likely due to a combination of both increased rainfall intensity and higher water levels in the receiving watercourse (Brickfield Creek).

The sag is completely inundated in the 1% AEP existing baseline event, and the climate change scenarios only worsen the predicted depths rather than impacting on light rail performance.

7.5.3 Parramatta CBD Precinct

The PLR alignment through the Parramatta CBD Precinct is expected to experience slightly higher flood depths through the trapped sags in Macquarie Street, associated with the higher rainfall intensities predicted in each climate change scenario.

The major additional flooding issue encountered under the climate change scenarios is listed below:

- Part of George Street adjacent to Queen's Wharf Reserve (between Harris Street and Purchase Street) is predicted to be flooded to a depth of approximately 500mm in the 1% AEP upper bound climate change event (driven by sea level rise). This area remains dry in all other scenarios.

This issue is a function of the assumed rises in sea level under both climate change scenarios, along with increased flows from increased rainfall intensity.

7.5.4 Rosehill and Camellia Precinct

The Rosehill and Camellia Precinct is predicted to be subject to additional flooding issues under the climate change scenarios, primarily driven by sea level rise (and associated increase in peak water levels) in Parramatta River.

- Alfred Street (between George Street and Tramway Avenue), which is not predicted to be impacted by the 1% AEP existing baseline, is impacted in both 1% AEP climate change scenarios.
- Tramway Avenue stop location – the 0.2EY upper bound climate change event results in this area being inundated to a depth of 300mm, whereas it remains dry under the existing baseline and lower bound climate change scenarios.
- Tramway Avenue/Arthur Street intersection – there are predicted to be substantial increases in flood depth at the sag for both 0.2EY climate change events.
- North of Camellia Railway Station – the existing railway embankment is overtopped by flooding from Parramatta River in the 1% AEP event under both the lower and upper bound climate change scenarios. In the upper bound 1% AEP event, some sections of the alignment are predicted to be under nearly 1m of water.

Overland flow flooding along the Sandown Line is shown to be worse under both the climate change scenarios, however it remains clear of mainstream flooding from the Parramatta River.

7.5.5 Carlingford Precinct

As the PLR alignment largely traverses the crest between the Vineyard Creek and Subiaco Creek catchments, increases in flood depths in the climate change are generally minor and limited to overland flows along the proposed alignment corridor. There is one area predicted to experience significant additional flooding under climate change relative to the existing baseline:

- Vineyard Creek crossing – the existing railway embankment is predicted to be overtopped in the upper bound climate change scenario in the 1% AEP event. In this scenario the embankment on the southern side of this crossing is predicted to flood to a depth of up to 100mm (note that the bridge over Vineyard Creek has not been explicitly modelled in the Carlingford TUFLOW GPU model and further assessment is required to confirm project impacts at this location).

The issue noted above is driven by the assumed sea level rise in the upper bound climate change scenario, resulting in higher water levels in Parramatta River and preventing flows from the Vineyard Creek catchment draining effectively.

7.6 Model Comparison

As noted in section 5.6, it is important to assess whether the TUFLOW models can be considered suitable for use for the purpose of PLR impact assessment. This involves comparison with previous models and/or alternative methods of analysis. A comparative assessment of the flood results was therefore carried out on the following areas:

- Mainstream River Levels
- Overland Flow Areas.

An overview of this assessment is below.

7.6.1 Comparison of PLR TUFLOW Mainstream River Levels with Existing Models

A comparison of peak water levels between the Upper Parramatta River/Lower Parramatta River MIKE 11 flood models and the PLR existing base line TUFLOW sub-models is shown below (note titles refer to the names of the TUFLOW sub-models, rather than the PLR precinct names outlined in section 1.2).

7.6.1.1 Westmead Model

The peak water levels through Parramatta River are predicted to be significantly higher in the TUFLOW model than from the Upper Parramatta River MIKE 11 model all in events assessed. This discrepancy is attributed to a combination of factors, including differences in ground topography, roughness values, and inherent differences in hydraulic losses are applied through bridge structures in both models.

The critical duration for the peak water level in Parramatta River is the 9 hour event, whereas the critical durations for flooding along the PLR project corridor through Westmead are generally the shorter, more intense storm events (refer to Map 5.15). This indicates that flooding along this portion of the PLR alignment results from overland flow flooding and insufficient capacity in the stormwater network.

While there are discrepancies in peak flood levels along the Parramatta River between the two models, results indicate that riverine flooding is not the primary flooding mechanism through Westmead. As such, no further attempts were made to improve the correlation of the peak water levels within Parramatta River in the Westmead model.

Westmead - Toongabbie Creek/Parramatta River Profile

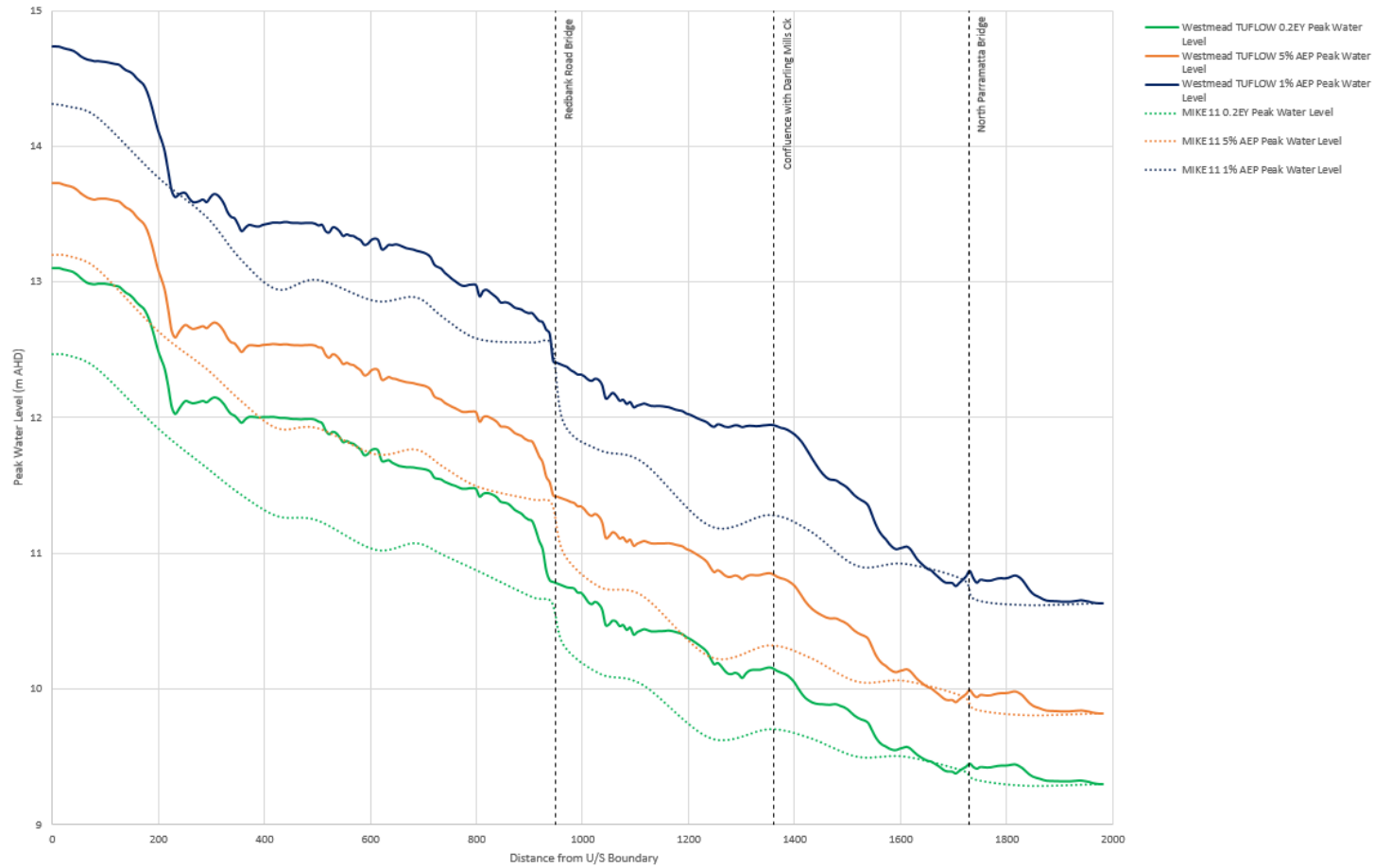


Figure 33 Peak Water Level Comparison - Westmead Model

7.6.1.2 North Parramatta Model

There is generally good agreement between the peak water levels in Parramatta River between the North Parramatta TUFLOW model, and the Upper Parramatta River MIKE 11 model. A good correlation of the head loss at Lennox Bridge was achieved through calibration of the TUFLOW model to match the peak water levels predicted by the Upper Parramatta River MIKE 11 model.

Upstream of O'Connell Street Bridge, the North Parramatta TUFLOW model predicts slightly higher water levels up to Cumberland Hospital Weir. The head drop over this weir structure is noticeably larger in the Upper Parramatta River MIKE 11 model than in the North Parramatta TUFLOW model. However the peak water levels begin to converge again further upstream of this weir.

Similar to the Westmead TUFLOW model, critical durations along the PLR project corridor tend to be the shorter, more intense duration storm events (refer to Map 5.16) indicating that flooding is caused by overland flow (and insufficient capacity in the stormwater network) as opposed to mainstream riverine flooding from the Parramatta River. There were no attempts to improve the correlation of the peak water levels upstream of the Cumberland Hospital Weir, as this section is not pertinent to the PLR project.

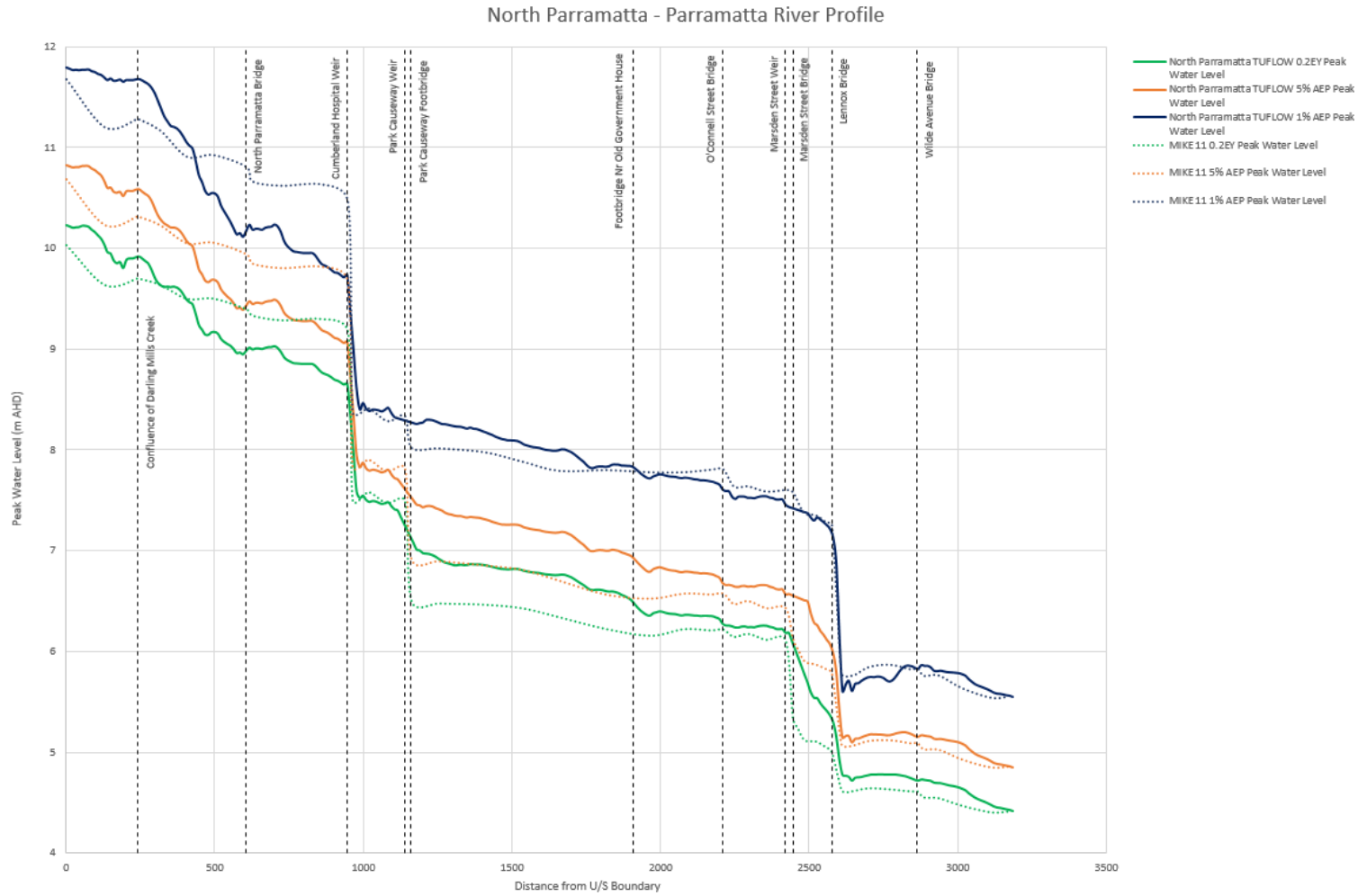


Figure 34 Peak Water Level Comparison - North Parramatta Model

7.6.1.3 Parramatta CBD Model

Flood model results indicate generally good agreement in predicted peak water levels between Charles Street Weir and O'Connell Street Bridge between both models.

Downstream of Charles Street Weir, the Parramatta CBD TUFLOW peak water levels are below those predicted by the Lower Parramatta River MIKE 11 model. This discrepancy is due to the difference in the peak flows through Parramatta River between the Draft 8 and Draft 9 versions of the Upper Parramatta River MIKE 11 model (refer to Table 3). Note that the difference in peak water levels also impacts peak water levels predicted in the lower reaches of Clay Cliff Creek.

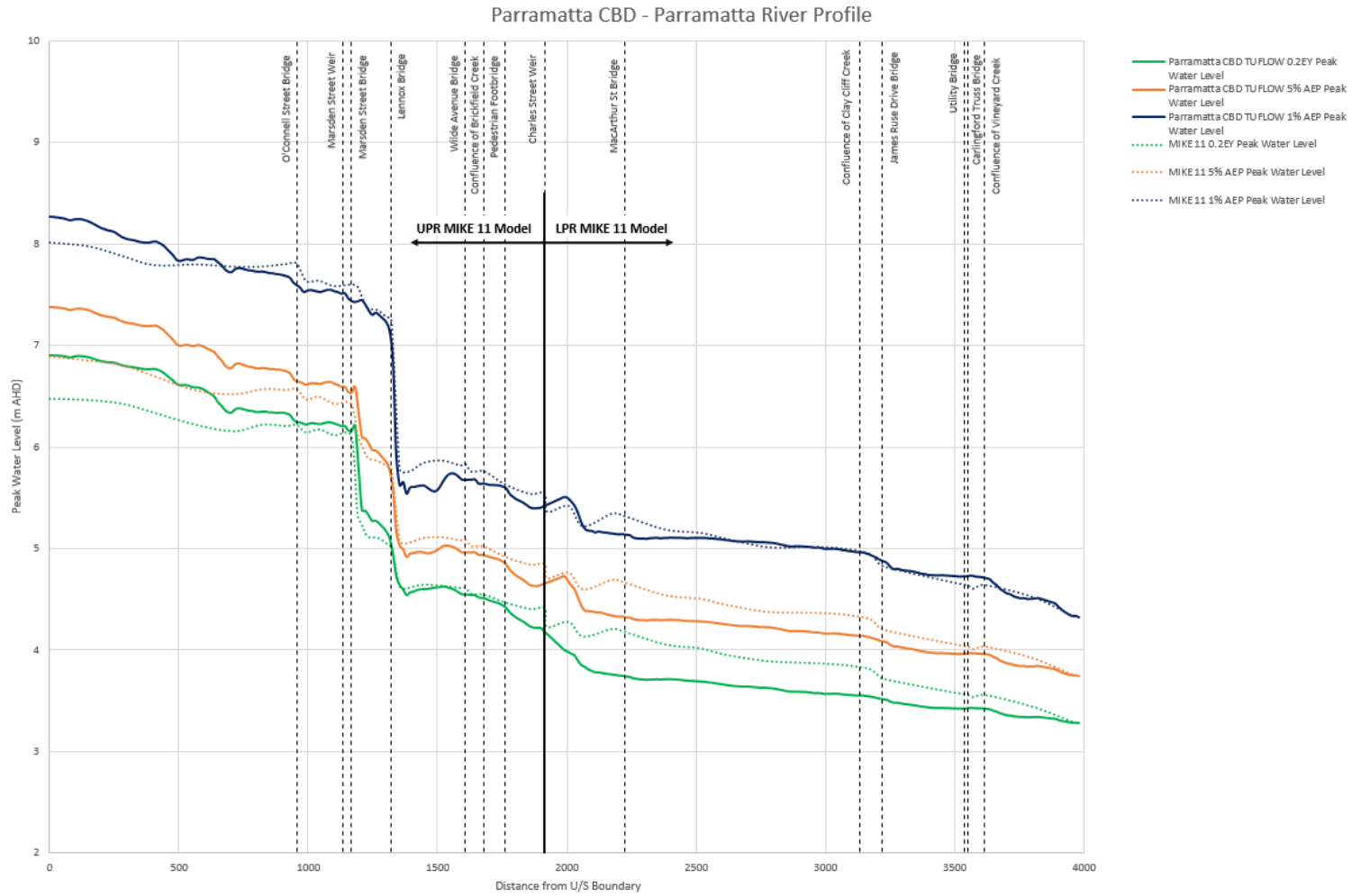


Figure 35 Peak Water Level Comparison - Parramatta CBD Model

7.6.1.4 Camellia Model

There was a good agreement achieved between the peak water levels in the Camellia TUFLOW model and the Lower Parramatta River MIKE 11 model, with only minor variations in peak water level along Parramatta River throughout.

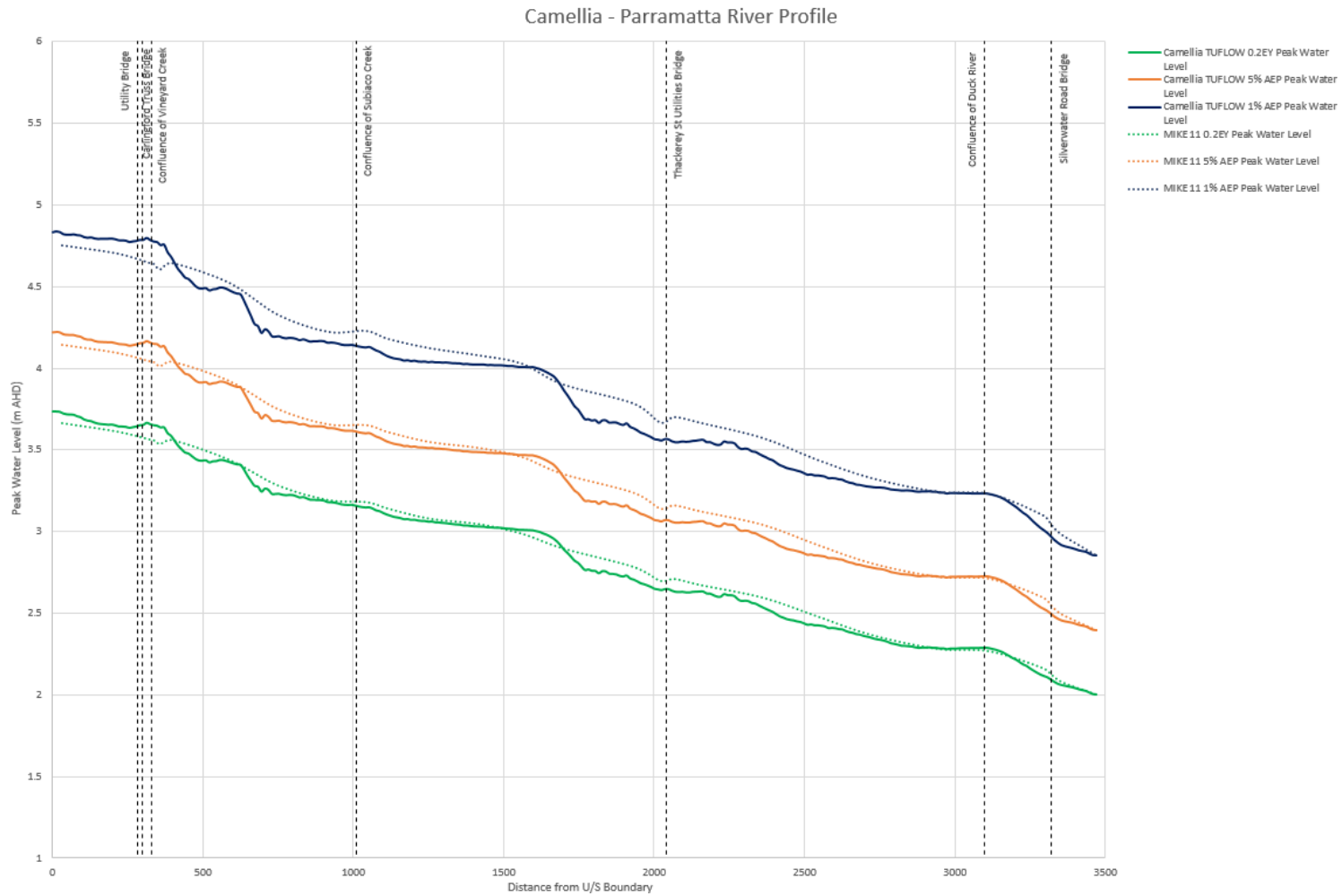


Figure 36 Peak Water Level Comparison - Camellia Model

7.6.2 Comparison of PLR TUFLOW Overland Flow Components (Rainfall on Grid Areas)

Whilst the direct rainfall approach to modelling overland flow can be used to great advantage, it is a relatively new method. As such it is best practice to verify flows derived from this method against alternative approaches (i.e. validation using other methods used to estimate peak flows), and against other TUFLOW models of similar type (i.e. utilising the direct rainfall approach on urbanised catchments).

In order to carry out this verification task, individual sub-catchment models were derived for each corresponding TUFLOW sub-model using DRAINS. This process was carried out for the Westmead, North Parramatta, Parramatta CBD and Carlingford TUFLOW models.

DRAINS is a hydrological modelling package for modelling stormwater runoff hydrographs and routing flows through networks of pipes, channels and streams. It is widely used for modelling urban catchment drainage systems and is suitable for use herein as an alternative modelling tool for verifying flows for the PLR sub-catchments.

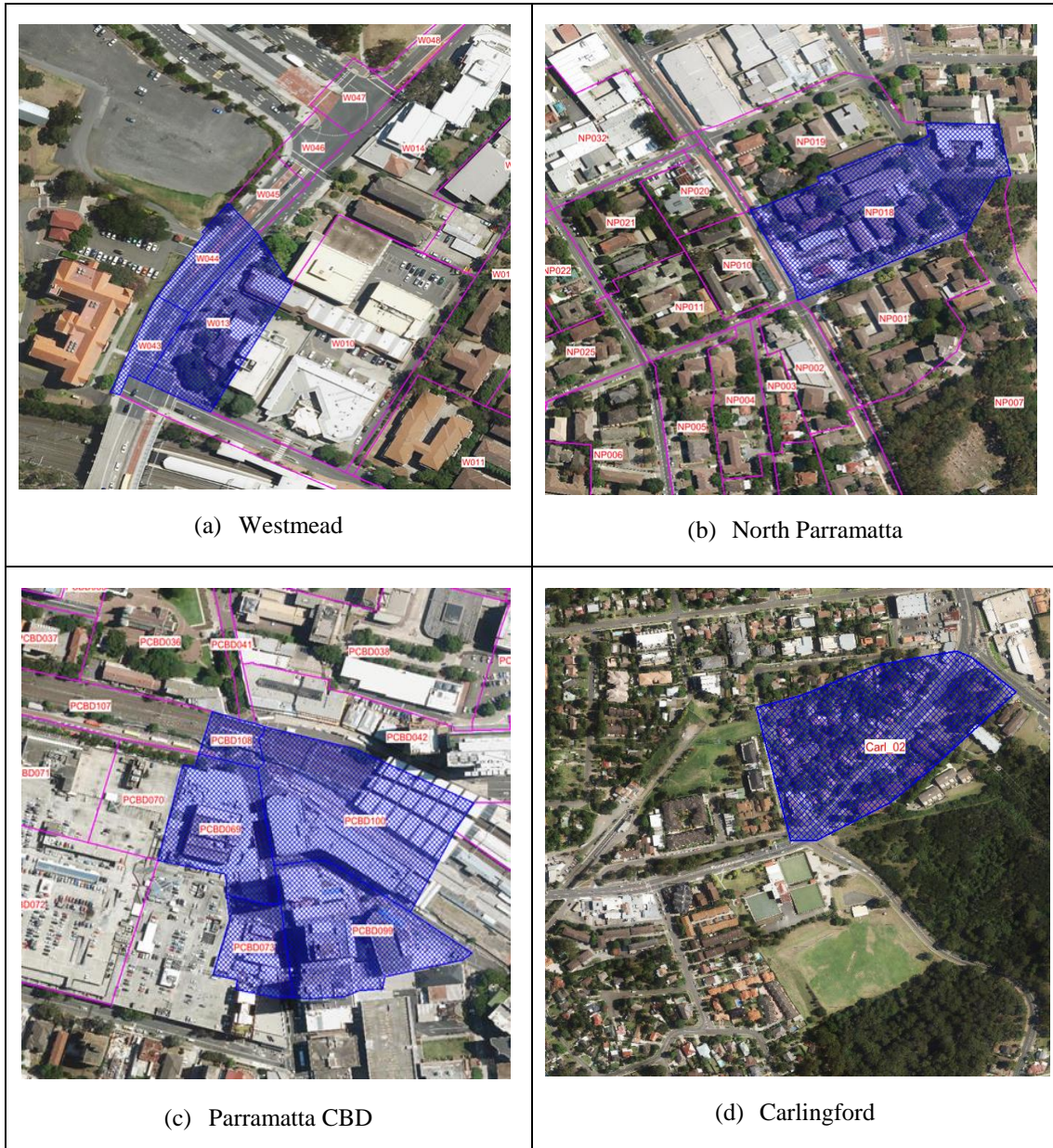


Figure 37 Test sub-catchment model areas (blue) developed in DRAINS for comparison of PLR TUFLOW models

To test the reliability of the applied rainfall on grid method on simulating overland flows, comparisons have been made to peak flows obtained for other urban catchment flood studies in Sydney such as the Rose Bay, Johnstons Creek and Blackwattle Bay Catchments Flood Studies. Flow results derived for these catchments which have similar characteristics to the catchments along the PLR project were compared to the flow results derived in the current study.

To remove the effects that differences in catchment delineation can have on peak discharge, specific yields were determined for the test sub-catchments. Specific yield is calculated by dividing the peak discharge by the area of the upstream catchment. This removes the obvious effects that differences in sub-catchment

size have on peak discharge. Table 13 and Table 14 provide the comparisons of the catchment runoff yield for the various sub-catchments.

Table 13 Catchment Yield for Urban Catchments in Sydney with Similar Characteristics to the PLR Catchments

Catchment	Storm Event (AEP)	Model	Specific Yield (m ³ /s/ha)
Johnstons Creek ²	1%	TUFLOW ¹	0.6-0.7
Blackwattle Bay ³	1%	TUFLOW ¹	0.7-0.8
Rose Bay ⁴	1%	DRAINS	0.6-0.7

¹ Modified direct rainfall approach used whereby rainfall is applied only to regions most likely to collect and distribute flow such as kerbs and gutters

² *Johnstons Creek Catchment Flood Study*, City of Sydney, September 2015

³ *Blackwattle Bay Catchment Flood Study*, City of Sydney, September 2015

⁴ *Rose Bay Catchment Flood Study*, Woollahra Municipal Council, September 2010

Table 14 Catchment Yield Check for PLR Food Models

Catchment	Test Catchment Area (ha)	Storm Event (AEP)	TUFLOW		DRAINS	
			Peak Outflow (m ³ /s)	Specific Yield (m ³ /s/ha)	Peak Outflow (m ³ /s)	Specific Yield (m ³ /s/ha)
Westmead	0.48	1%	0.27	0.6	0.23	0.5
		5%	0.22	0.5	0.20	0.4
		20%	0.17	0.4	0.16	0.3
North Parramatta	2.04	1%	1.35	0.7	1.11	0.5
		5%	1.09	0.5	0.93	0.5
		20%	0.77	0.4	0.72	0.4
Parramatta CBD	3.43	1%	2.13	0.6	2.51	0.7
		5%	1.46	0.4	2.12	0.6
		20%	1.13	0.3	1.38	0.4
Carlingford	6.12	1%	2.50	0.4	3.08	0.5
		5%	2.05	0.3	2.62	0.4
		20%	1.48	0.2	1.95	0.3

The discrepancies between the methods to obtain specific yields can be attributed to a number of reasons, such as variance in loss parameters and design rainfall values, difference in land use, difference in the applied routing method and factoring for floodplain storage. The TUFLOW models developed for the Johnstons Creek and Blackwattle Bay catchments used a modified rainfall on grid approach whereby the rainfall boundary conditions are primarily applied onto the road carriageways, hence the runoff discharge from the catchment is slightly more efficient compared against that of the PLR models.

Overall, the specific yields for the PLR models are in the same order of the yields of the other catchments and also the yields derived from DRAINS. Therefore, it can be concluded that the flows produced by the PLR models are comparable to flows derived from lumped hydrology methods. The rainfall on grid method

employed for modelling the overland flows is therefore suitable for the purposes of this project.

It is important to note that Table 14 does not include an assessment of the catchment yield check for the Camellia TUFLOW sub-model. Upon completion of a DRAINS model in this area for a comparative assessment, it was determined that the topography was too flat in this area, with drainage in private areas unknown, to the extent that it should not be used for a suitable comparison. With the other TUFLOW sub-models being deemed as acceptable, and particularly given that there is little overland flooding within Camellia within the extents of PLR, the TUFLOW sub-model has been deemed suitable on this basis.

7.7 Summary

Notwithstanding the limitations to the information available for the development of the TUFLOW PLR models (as identified in above sections of this report), industry-standard assumptions have been made in developing 1d/2d models suitable for identifying areas that may be impacted by the proposed PLR alignment, and associated hazard for a given return period. In addition, checks on mainstream and overland flow components have been carried out to determine that the TUFLOW models are suitable for addressing the requirements of the SEARs.

Additional sensitivity analyses have been carried out to determine the impact of those factors / parameters identified as to potentially affect the results in areas of interest to the PLR study.

It is important to note that, despite diligence being carried out in developing these models in line with best flood modelling practice, there are nevertheless areas of the models that appear to be particularly sensitive, and consideration should be given to refinement of these areas in future detailed design stages.

8 PLR Performance Criteria and Design Status

8.1 Overview

This section outlines a set of performance criteria for the PLR project in terms of drainage and flooding, as well as outlining overarching stormwater design principles for the project. Key elements of the design included within the PLR design flood model developed to assess impacts are described, along with a summary of further development required to align with the stormwater design criteria.

8.2 Performance Criteria

The overarching performance criteria for drainage and flooding is to ensure that:

- No aspect of the project will materially adversely affect the existing flood characteristics of the land.
- The project will not seek to improve flood immunity levels outside the project boundary, unless required to achieve project flood immunity levels or mitigate materially adverse impacts.
- Where reasonably practicable, existing drainage assets directly impacted by the project will be replaced in a manner compliant with current laws and applicable standards.

The project proposes the following definition of an adverse impact from flooding:

- A negative change to a flood hazard category
- An increase in flood level that results in habitable floor levels or basements being inundated
- Increase in potential of risk to life and personal safety
- A negative effect on the structural soundness of a habitable building
- A negative effect on existing flood evacuation/access routes
- An increase in velocity that results in a significant increase in the potential for soil erosion and scouring
- Damage to, or temporary loss of service of existing critical infrastructure.

If flood modelling indicates that any of the above conditions are likely to occur, then, the project will:

- Carry out an impact assessment to determine the significance of the impact
- Investigate whether the design can be modified to avoid flooding impacts; and
- Identify mitigation measures to minimise adverse impacts.

PLR will propose to implement mitigation measures where reasonable and feasible.

8.3 Key Design Criteria

Key design criteria applied for the project relating to flooding and drainage are provided in Table 15 below.

Table 15 Key Design Criteria

Project element	Design Criteria	Additional notes
Stormwater drainage	Target minimum light rail operability in 0.2EY event. Designed in line with drainage principles outlined in Table 17.	For water sensitive urban design requirements and assessment, please refer to the relevant Chapter of the EIS.
Stabling and Maintenance Facility	Located above the 1% AEP flood level + 500mm freeboard	Consistent with other light rail projects within Australia.
Electrical, Mechanical and Communications equipment	Located above the 1% AEP flood level; or designed and rated for immersion or submergence to the extent predicted through flood modelling.	Consistent with other light rail projects within Australia
Bridges	<p><u>New bridges</u>: immunity and freeboard designed to current standards and codes, typically 1% AEP +500mm freeboard to soffit level, with scour and ultimate limit state requirements to be in accordance with AS 5100.</p> <p><u>Retained or replaced existing bridges</u>: immunity would be restricted to the lesser of 1% AEP +500mm freeboard and existing performance, which may be less than the current design code requirements.</p>	

8.4 Stormwater Drainage

8.4.1 Design Principles

Drainage infrastructure would be designed:

- To meet the proposed operational requirements of the project
- To avoid or minimise, as part of suite of potential mitigation solutions, the risk of, and adverse impacts from, flooding.

Given the scale of road adjustment associated with the project, significant change to stormwater infrastructure is required. Stormwater design across the project has been divided into three categories as shown in Table 16.

Table 16 Stormwater Design Categories

Category	Description
Category S1	Develop design to allow safe conveyance of the 5% AEP storm event within the drainage system, should the network external to the project (upstream and downstream) be upgraded by others to meet the 5% AEP standard. Mitigate against downstream impacts associated with increasing existing hydraulic capacity by constricting pipe and pit capacity where required until upgrade of downstream system by others is carried out.
Category S2	Develop design to meet PLR operational response requirements.
Category S3	Maintain operation of existing drainage.
All Categories	Develop design to minimise risk and impact from flooding

Drainage design would be developed using the principles in the matrix shown in Table 17. For the purposes of interpreting this table, the Hazard Zone is represented in Figure 38.

Table 17 Proposed Drainage Design Principles

Location	Test criteria	Design category		
		S1	S2	S3
Inside or crossing the Hazard Zone	PLR design clash with existing pits, pipes and other subsurface drainage infrastructure	Y [a]		
	New drainage is required for operational reasons		Y [a]	
	Condition assessment identifies defects that require rehabilitation or renewal		Y [a]	
	Transverse drainage infrastructure where there is no physical clash			Y [a]
Outside the Hazard Zone within road corridor	PLR design clash with existing pits, pipes and other subsurface drainage infrastructure	Y		
	New drainage is required for operational reasons		Y	
	Drainage infrastructure where there is no physical clash			Y

Notes: [a] In situations where it is not reasonable or feasible to upgrade or relocate the existing drainage system, safe access to pits would be provided for maintenance.

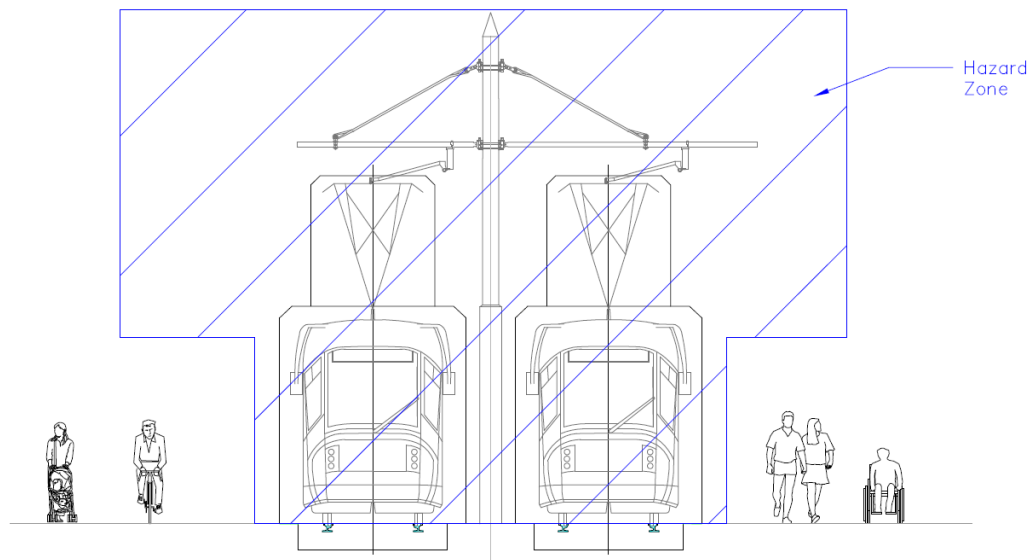


Figure 38 PLR Hazard Zone

8.5 Design Flood Model Assumptions

8.5.1 Operability

As the light rail would be integrated into an existing environment, there is limited opportunity to adopt rail levels significantly higher than the existing ground level for sections of at-grade running, particularly as the alignment between Westmead and Camellia is located entirely along existing road corridors. The achievable level of flood immunity is largely determined by the existing flood immunity of the corridor. The ability of the LRV to travel through standing water is dependent on the LRV selected. For the purposes of the current PLR design case, an assumption of light rail operability in up to 50mm depth of water was adopted, based on advice from the Operations Technical Advisor.

8.5.2 Topography

A concept 3D road and rail alignment DTM was prepared for the PLR corridor. This was reviewed and developed iteratively between the drainage and alignment design team to minimise impact on existing drainage patterns from proposed road and rail grading. The concept DTM was incorporated within the PLR design case flood model.

“Off-alignment” works were not represented in the design case flood model as a 3D DTM was not available. Impacts have been qualitatively assessed using existing flood risk, and inclusion within the flood model would be undertaken in subsequent stages of design.

Ground levels at the stabling and maintenance facility are proposed to be raised by approximately 2m from existing level. This was represented in the design case PLR Combined PMF flood model in order to assess impacts of filling the site.

8.5.3 Stormwater Drainage

A high level drainage layout was developed for the PLR corridor based on review of the concept 3D road and rail alignment profile and initial baseline flood modelling. This was included in the TUFLOW models (with the exception of the overland-flow only Carlingford model) for the purposes of assessing impact and operational performance. The design was updated iteratively with the concept 3D road and rail alignment to improve performance and reduce potential impact. As noted previously, given the scale of road adjustment associated with the project, significant change to existing stormwater infrastructure is required to align with new kerb lines and meet the proposed drainage principles outlined in Table 17.

No drainage layout was prepared for the “off-alignment” works as these have not been represented in the design case flood model. This would be undertaken during subsequent stages of design.

It is important to note that the intent of the stormwater design represented in the model is to demonstrate the hydraulic feasibility of achieving the performance based criteria identified above. Drainage is just one of a suite of measures available to achieve these criteria. More detail on management of post-construction impacts, including additional measures, is provided in section 10.3. Detailed hydraulic design would be required in subsequent project stages in conjunction with development of the concept road alignment and receipt of existing drainage network survey.

Concept drainage plans are provided on Maps 8.1-8.6. Key assumptions in developing the drainage arrangement were as follows:

- Accuracy of adjustments required to existing drainage were limited to accuracy of baseline drainage information (e.g. council GIS data accuracy)
- Proposed drainage arrangements did not consider impact of utility constraints, with the exception of a qualitative review of key utilities where a major new stormwater carrier is proposed
- Other constraints related to potential heritage, contamination, environmental or other, were not considered
- Inlet capacity requirements have not been assessed
- Transverse and longitudinal trench drain requirements, platform canopy connections, substation roof drainage connections, reconnection of property connections into relocated stormwater lines and internal stabling and maintenance facility drainage arrangements (including any required on site detention) were not included
- WSUD requirements are not shown.

A summary of key stormwater and flooding design elements for the PLR scheme design is provided in Table 18, noting that other designs could feasibly result in meeting the performance requirements also.

Table 18 Key Stormwater Design Elements

Location	Description
Westmead Precinct - Hawkesbury Road and Hainsworth Street	Upgraded drainage within Hawkesbury Road including connection across Hainsworth Street. New longitudinal carrier in Hainsworth Street connecting to drainage in Park Avenue.
Parramatta North Precinct - within Parramatta North Development	New trunk stormwater to align with future development proposals. New outfall to Parramatta River
Parramatta North Precinct - Church Street between Grose Street and Victoria Road	Upgraded drainage including connection across Church Street.
Parramatta CBD Precinct - Church Street, between Lennox Bridge and Macquarie Street.	Upgrade and rationalisation of drainage in Church Street (in conjunction with works on Macquarie Street due to existing bifurcation).
Parramatta CBD Precinct - Smith Street, from Macquarie Street to Parramatta River	New trunk drainage along Smith Street from Macquarie Street, to drain existing sag in Macquarie Street. New outfall to Parramatta River.
Parramatta CBD Precinct – Macquarie Street west and Harris Street to Parramatta River	New trunk drainage from Macquarie Street along Harris Street. New outfall to Parramatta River.
Rosehill and Camellia Precinct – Tramway Avenue and River Road West	New drainage from Tramway Avenue to River Road West. New outfall to Parramatta River. New / formalised flood storage area west of Clay Cliff Creek.
Rosehill and Camellia Precinct - Camellia	Upgrade of existing connections from the Sandown Line to Parramatta River.

The alignment of the current stormwater design with drainage design principles is outlined in Table 19 below. The approach is considered appropriate for flood risk and impact assessment.

Table 19 Modelled Drainage Alignment with Proposed Drainage Principles

Location	Test criteria	Design category			Design Case Model Alignment
		S1	S2	S3	
Inside or crossing the Hazard Zone	PLR design clash with existing pits, pipes and other subsurface drainage infrastructure	Y			Model currently aligns with this principle.
	New drainage is required for operational reasons		Y		Model currently assumes minimum pipe size required to achieve operational and impact mitigation requirements. Future-proofing (including requirements for interim measures to avoid impact) would be included in subsequent design stages.
	Condition assessment identifies defects that require rehabilitation or renewal		Y		Condition assessment of existing assets is currently not available. Model therefore does not include stormwater modifications to address this.
	Transverse drainage infrastructure where there is no physical clash			Y	As depth information stormwater drainage is limited, model currently assumes relocation of these assets. This would be reviewed once pipe survey is available.
Outside the Hazard Zone within road corridor	PLR design clash with existing pits, pipes and other subsurface drainage infrastructure	Y			Model currently aligns with this principle for platforms only. Clash with other PLR elements (overhead line stanchions, new utility routes etc.) would be addressed in detailed design.
	New drainage is required for operational reasons		Y		Model currently assumes minimum pipe size required to achieve operational and impact mitigation requirements. Future-proofing (including requirements for interim measures to avoid impact) would be included in subsequent design stages.
	Drainage infrastructure where there is no physical clash			Y	Model currently aligns with this principle.

8.5.4 Key Waterway Crossings

The PLR involves construction of new waterway crossings or modifications to existing crossings at the following locations:

- Bridge Road, North Parramatta (North Parramatta bridge)
- Lennox Bridge, Parramatta CBD (Lennox Bridge)
- Clay Cliff Creek/James Ruse Drive, Rosehill (James Ruse Drive bridge)
- Carlingford Railway Line Bridge over James Hardie underpass
- Parramatta River, Camellia/Rydalmere (Parramatta River bridge)
- Vineyard Creek, Rydalmere (Vineyard Creek bridge)

These are described in Table 20.

Table 20 Key Waterway Crossings

Structure	Description	1% AEP Flood Level (from CoP adopted models) (m AHD)	Approx. Soffit Level (m AHD)		Representation in PLR Design Model
			Existing	Proposed	
North Parramatta Bridge	<p>New bridge over Parramatta River, immediately downstream of existing bridge.</p> <p>Two-span bridge with central pier (assumed 1050mm diameter circular) aligned with the centremost existing bridge pier.</p> <p>New bridge abutments set back from the existing abutments</p> <p>Construction of a central pier within the Parramatta River would involve temporary access within the river.</p>	10.803	12.128 (>500mm freeboard to 1% AEP)	11.681 (>500mm freeboard to 1% AEP)	Modelled as a 2d layered flow constriction, effectively as widening of the existing structure, with abutments and central pier in line with existing structure. Soffit level lowered slightly from existing case. Form loss through the structure increased to account for the addition of the new pier, which is slightly wider than the existing.
Lennox Bridge	Existing bridge retained, works limited to installation of tracks and associated infrastructure within the road surface only.	7.252	6.96 (below 1% AEP level)	6.96 (existing retained)	As per existing model (2d layered flow constriction)

Structure	Description	1% AEP Flood Level (from CoP adopted models) (m AHD)	Approx. Soffit Level (m AHD)		Representation in PLR Design Model
			Existing	Proposed	
James Ruse Drive Bridge	<p>New bridge to span Clay Cliff Creek and James Ruse Drive between Albert Street, Parramatta (near the intersection of Tramway Avenue) and Grand Avenue North (in the vicinity of the existing Camellia Station).</p> <p>Consists of around eight spans with a total length of about 240 metres, with a maximum height of around nine metres above the existing surface.</p> <p>Bridge construction also includes:</p> <ul style="list-style-type: none"> • Removal of existing pedestrian and utilities structure at Clay Cliff Creek and relocation of associated utilities • Removal and relocation of existing Sydney Water maintenance access ramp into Clay Cliff Creek 	5.173	N/A (Existing adjacent cable bridge over Clay Cliff Drive soffit 4.10)	Varies – 4.899 at western abutment to 10.9 at highest point over James Ruse Drive)	<p>Represented as a 2D layered flow constriction over the Clay Cliff Creek floodplain, noting the peak water level in the 1D channel component does not impact the proposed bridge soffit in the 1% AEP event</p> <p>Soffit levels and pier geometry have been estimated based on preliminary structural drawings. The bridge soffit is assumed to be higher than the predicted 1% AEP level as it traverses the Clay Cliff Creek channel.</p>

Structure	Description	1% AEP Flood Level (from CoP adopted models) (m AHD)	Approx. Soffit Level (m AHD)		Representation in PLR Design Model
			Existing	Proposed	
Carlingford Railway Line Bridge over James Hardie underpass	Existing precast culvert opening through Carlingford Railway Line Bridge embankment to be replaced with a similar sized culvert structure which would be longer than the existing underpass to accommodate the second light rail track and the active transport path on the western side.	4.640	5.35 (>500mm freeboard to 1% AEP)	5.35 (proposed soffit to match existing)	Modelled a 2D layered flow constriction, bridge soffit and span assumed to be as per the existing structure.
Carlingford Railway Line Bridge over Parramatta River	The existing three span steel truss bridge over Parramatta River along the Carlingford Line and associated red face brick arch abutments would be modified as follows: <ul style="list-style-type: none"> • Replacement of the main structures of the end spans • Widening of bridge abutments following the deconstruction of the heritage listed brick arch abutments • Replacement of existing single heavy rail track with two new light rail tracks • A cantilevered structure would be constructed to the west to accommodate the active transport link 	4.640	6.60 (>500mm freeboard to 1% AEP)	6.60 (existing retained)	As per existing model (2d layered flow constriction) No changes to bridge geometry assumed from existing.

Structure	Description	1% AEP Flood Level (from CoP adopted models) (m AHD)	Approx. Soffit Level (m AHD)		Representation in PLR Design Model
			Existing	Proposed	
Carlingford Railway Line Bridge over Vineyard Creek	Replacement of existing two span concrete bridge of approximately 18 metres in length with a longer two span bridge. The central pier for the new bridge is located in same location as the existing central pier. The new structure would carry two light rail tracks as well as an active transport link, located on the western side of the bridge. Abutments would be set back from existing.	7.800	7.14 (below 1% AEP level)	7.07 (below 1% AEP level)	Not yet modelled as bridge is located in the Carlingford TUFLOW GPU model. Assessment of the impacts of proposed structure to be undertaken at a later stage

9 Assessment of Potential Impacts

9.1 Construction Impacts

9.1.1 Overview

This section provides a qualitative assessment of flood risk and potential flood impacts associated with construction compounds and construction activities generally within the construction footprint.

Flooding during construction activities has the potential to result in delays to construction and damage to plant and materials. It may also pose a safety risk to construction personnel.

In terms of potential impact, construction activities have the potential to:

- Adversely impact downstream waterways through release of sediment, pollution, hazardous materials and/or construction materials from the construction site.

- Change flood behaviour as a result of changes to site topography and installation of temporary buildings and other structures within the floodplain.

Consideration of flood risk and potential flood impact has been carried out for the following:

- Construction compounds
- Light rail alignment and road adjustments
- Bridge construction and modifications
- Stabling and maintenance facility construction.

9.1.2 Construction Compounds

Table 21 summarises both the assessed flood risk and potential flood impacts at each construction compound proposed by the project. A short description of proposed activities at each location is provided for context. For a detailed description of proposed activities to be carried out at each location, refer to Chapter 6 of the EIS.

It is acknowledged that the number and location of construction compounds is subject to change in detailed design, and re-assessment of flood risk and impact would be required.

Table 21 Flood Risks and Potential Impacts - Construction Compounds

Construction Compound	Key Activities	Extent of Flood Affection	Potential Flood Impacts
Westmead Precinct			
Westmead Station (corner Railway Parade and Hawkesbury Road, adjacent Westmead Railway Station)	Site offices and facilities Laydown area	Not affected by mainstream flooding (lies outside PMF extent) or major overland flow	Negligible impact anticipated.
Hawkesbury Road (corner Hawkesbury Road and Hainsworth Street)	Site offices and facilities Laydown area	Not affected by mainstream flooding (lies outside PMF extent). Overland flow along Hawkesbury Road ponds in the sag adjacent the site, but does not encroach on the site for the 1% AEP event.	Negligible impact anticipated.

Construction Compound	Key Activities	Extent of Flood Affection	Potential Flood Impacts
Parramatta North Precinct			
Parramatta North (within the Parramatta North Development site, along eastern bank of Parramatta River)	Initial placement of capping to level the site Site offices and facilities Laydown area Support bridge construction (North Parramatta Bridge)	Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling. Not subject to major overland flows.	Negligible impact anticipated.
Factory Street (corner Factory Street and Church Street)	Site offices and facilities Laydown area	Not affected by mainstream flooding (lies outside PMF extent) or major overland flow. Overland flows in adjacent streets do not exceed 100mm depth in 1% AEP event.	Negligible impact anticipated.
Fennell Street (corner Fennell Street and Church Street)	Site offices and facilities Laydown area	Not affected by mainstream flooding (lies outside PMF extent) or major overland flow. Overland flows in adjacent streets do not exceed 100mm depth in 1% AEP event.	Negligible impact anticipated.
Parramatta CBD Precinct			
O'Connell Street (southern foreshore of Parramatta River)	Site offices and facilities Laydown area	Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling. Overland flows in adjacent streets do not overtop the kerb in 1% AEP event.	Negligible impact anticipated.

Construction Compound	Key Activities	Extent of Flood Affection	Potential Flood Impacts
Barrack Lane (Existing Endeavour Energy Substation Site, 1A Barrack Lane)	Staff facilities Storage of small materials	<p>Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling.</p> <p>Overland flows in the adjacent street (Barrack Lane) do not exceed 100mm depth in a 1% AEP event. Existing site is also elevated 0.5-1.0m above existing gutter level.</p>	Negligible impact anticipated.
Rosehill and Camellia Precinct			
Alfred Street (129-133 Alfred Street Parramatta)	Site offices and facilities Laydown area Support bridge construction (Clay Cliff Creek and James Ruse Drive)	The eastern boundary of the site appears to have local trapped sags for the 0.2EY and 20% AEP events. The site is affected by Clay Cliff creek flooding in a 1% AEP event, with depths ranging up to 400mm.	Minor redirection of overland flows across the site as a result of removing existing buildings and introducing site phase structures. Unlikely to result in flood impact outside site boundary.
Parramatta River Bridge South (adjacent T6 Carlingford Line)	Site offices and facilities Laydown area Support modifications to Parramatta River Bridge	<p>The site is impacted by flooding from the Parramatta River in a 5% AEP event, with depths ranging up to 0.6m.</p> <p>While this site is not impacted for the 0.2EY event, the culvert below the rail corridor which is the proposed site access would be impassable for this event.</p> <p>The site is classified as high hazard for the 1% AEP event, however the culvert below the rail corridor is high hazard for the 0.2EY event and above.</p>	<p>Overbank flooding from Parramatta River may result in sediment/materials being washed into the River.</p> <p>Depending on the proposed structures/storage on the site, limited obstruction of floodwaters may occur.</p>

Construction Compound	Key Activities	Extent of Flood Affection	Potential Flood Impacts
Parramatta River Bridge North (adjacent T6 Carlingford Line and WSU Rydalmere Campus)	Site offices and facilities Laydown area Support modifications to Parramatta River Bridge	Located outside the 1% AEP mainstream flood extent, but partially within Parramatta River PMF extent from CoP modelling.	Negligible impact anticipated on flood behaviour. Transport of sediment/materials into Parramatta River due to proximity to river.
Carlingford Precinct			
Vineyard Creek (grassed area bordered by Railway Street, Vineyard Creek and the T6 Carlingford Line near Rydalmere Station)	Initial placement of capping to level the site Site offices and facilities Laydown area Support modifications to rail bridge over Vineyard Creek	As the site is immediately adjacent the creek, it is partially affected by flooding for the 5% AEP event and above. Flood depths range up to 500mm-1.0m in the 1% AEP event in close proximity to the creek. Access from the site to Railway Street is not affected in the 1% AEP.	Overbank flooding from Vineyard Creek may result in sediment/materials being washed into the Creek. Depending on the proposed structures/storage on the site, limited obstruction of floodwaters may occur.
Rydalmere Station (west) (existing Sydney Trains maintenance compound off Victoria Road)	Site offices and facilities Laydown area Support modifications to rail bridge over Vineyard Creek	The site is not affected by mainstream flooding from Vineyard Creek in the 1% AEP event, and is not affected by major overland flows	Negligible impact anticipated.
Rydalmere Station (east) (within existing Rydalmere commuter carpark)	Site offices and facilities Laydown area Support modifications to rail bridge over Vineyard Creek	The site is not affected by mainstream flooding from Vineyard Creek in the 1% AEP event, and is not affected by major overland flows.	Negligible impact anticipated.
Dundas Station (existing Sydney Trains maintenance compound and Dundas Station commuter carpark)	Site offices and facilities Laydown area	The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.	Negligible impact anticipated.

Construction Compound	Key Activities	Extent of Flood Affection	Potential Flood Impacts
Kissing Point Road (within Vineyard Creek Reserve located off Kissing Point Road)	Initial placement of capping to level the site. Site offices and facilities Laydown area Support duplication of Kissing Point Road underbridge	The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.	Negligible impact anticipated.
Adderton Road compound (existing Sydney Trains maintenance compound in the rail corridor off Adderton Road)	Site offices and facilities Laydown area	The site is not affected by mainstream flooding (lies outside PMF event). Overland flow modelling indicates there may be some overland flow to the rear of the site adjacent the rail corridor, but this would be expected to be managed through existing drainage (not modelled) or manageable through proposed drainage.	Negligible impact anticipated.
Telopea Station construction compound	Site offices and facilities Laydown area	The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.	Negligible impact anticipated.
Carlingford Station (RailCorp-owned land north of Carlingford Station)	Site offices and facilities Laydown area	This site is not affected by mainstream flooding (lies outside PMF event). The southern boundary of the site is within an existing stormwater detention area and as such is inundated in a 0.2EY event and above by up to 1m. Other than the area within 10-20m of the boundary, the site is unaffected by the 1% AEP. Access from either the commuter carpark or Boundary Road would be unaffected in the 1% AEP.	Proximity of construction activity to detention basin may result in sediment/materials being washed into the local drainage system. Depending on the proposed structures/storage on the site, limited change in detention storage footprint may occur.

It is noted that the above table constitutes an initial assessment only, and a detailed review would need to be carried out during detailed design once site staging and site arrangements are developed. Potential mitigation measures for sites where flood risks or potential flood impacts have been noted in Table 21 are provided in section 10.2.

9.1.3 Light Rail Alignment and Road Adjustments

Potential impacts associated with construction of the light rail and associated road adjustments would include the following:

- Overland flows discharging onto areas of surface works has potential to cause erosion of disturbed surfaces and transport of sediment/materials into waterways
- Erection of site hoardings or barriers (e.g. F-type barriers) to cordon off construction areas within existing road carriageways may affect local overland flow paths and result in flood impacts within and outside the road corridor.

It would therefore be necessary to plan, implement and maintain drainage measures aimed at managing the discharge of overland flow either through or around the construction areas. These are outlined in section 10.2.

9.1.4 Bridge Construction and Modification

The PLR has envisaged the construction of new waterway crossings or modifications to existing crossings at the following locations:

- Bridge Road, North Parramatta (North Parramatta bridge)
- Clay Cliff Creek/James Ruse Drive, Rosehill (James Ruse Drive bridge)
- Parramatta River, Camellia/Rydalmere (Parramatta River bridge)
- Vineyard Creek, Rydalmere (Vineyard Creek bridge)

Lennox Bridge is excluded from the above list as works are limited to installation of tracks and associated infrastructure within the road surface only.

Proposed works and potential construction stage flood impacts at each location are addressed in Table 22. Potential mitigation measures are identified in section 10.2.

Table 22 Potential Bridge Construction Impacts

Bridge	Description	Potential Construction Stage Flood Impacts
Parramatta North Precinct		
North Parramatta bridge	<p>New bridge over Parramatta River, immediately south of existing bridge.</p> <p>Two-span bridge with central pier aligned with the centremost existing bridge pier.</p> <p>New bridge abutments aligned with existing abutments.</p> <p>Construction of a central pier within the Parramatta River would involve temporary access within the river.</p>	<p>Potential impacts include:</p> <ul style="list-style-type: none"> • Obstruction of the waterway by temporary scaffolding/falsework. • Obstruction of the waterway through temporary access for central pier piling works.
Rosehill and Camellia Precinct		
James Ruse Drive bridge	<p>New bridge to span Clay Cliff Creek and James Ruse Drive between Albert Street, Parramatta (near the intersection of Tramway Avenue) and Grand Avenue North (in the vicinity of the existing Camellia Station).</p> <p>Consists of around eight spans with a total length of about 240 metres, with a maximum height of around nine metres above the existing surface.</p> <p>Bridge construction also includes:</p> <ul style="list-style-type: none"> • Removal of existing pedestrian and utilities structure at Clay Cliff Creek and relocation of associated utilities • Removal and relocation of existing Sydney Water maintenance access ramp into Clay Cliff Creek 	<p>There are no bridge supports within Clay Cliff Creek and as such construction works that are required to be carried out within Clay Cliff Creek would be limited to removal of existing Sydney Water maintenance ramp and construction of new ramp.</p> <p>Demolition of the existing pedestrian and utilities bridge is expected to be carried out primarily without accessing Clay Cliff Creek.</p> <p>Construction works lie within the floodplain for events including the 0.2EY and upwards.</p> <p>Access to and from Arthur Street would be affected by flooding of the street network in a 0.2EY event. This would limit evacuation of the site during a flood event.</p> <p>Site (excluding the Clay Cliff Creek culvert) is classified as high flood hazard east of Clay Cliff Creek for events beyond a 5% AEP event. This would be a safety risk to personnel.</p> <p>Depending on the proposed structures/storage on the site, limited obstruction of floodwaters may occur.</p>

Bridge	Description	Potential Construction Stage Flood Impacts
Parramatta River Bridge	<p>The existing three span steel truss bridge over Parramatta River along the Carlingford Line and associated red face brick arch abutments would be modified as follows:</p> <ul style="list-style-type: none"> • Replacement of the main structures of the end spans • Widening of bridge abutments following the deconstruction of the heritage listed brick arch abutments • Replacement of existing single heavy rail track with two new light rail tracks • A cantilevered structure would be constructed to the west to accommodate the active transport link 	<p>The cantilevered structure for the active transport link would be constructed from falsework connected to the existing bridge – no temporary structures are anticipated to be required within the river.</p> <p>A barge may be used during the works.</p> <p>Modifications to the end spans and abutments would involve access to the river banks. The abutments are submerged in all modelled events inclusive of the 0.2EY event.</p>
Carlingford Precinct		
Vineyard Creek bridge	<p>Replacement of existing two span concrete bridge of approximately 18 metres in length with a longer two span bridge. The central pier for the new bridge is located in same location as the existing central pier.</p> <p>The new structure would carry two light rail tracks as well as an active transport link, located on the western side of the bridge.</p> <p>Abutments would be set back from existing.</p>	<p>Construction of the new bridge would involve works within Vineyard Creek and on and adjacent to the steep river embankments.</p> <p>Piling rig would require access to the creek to install piles for the central pier. This may necessitate temporary access within the Creek, resulting in potential constriction of flow capacity in the river</p>

9.1.5 Stabling and Maintenance Facility

Construction works at the stabling and maintenance facility would include earthworks to create a two metre raised platform across the site using clean fill materials, as a foundation upon which buildings and structures would be constructed. Potential flood-related impacts during construction would include obstruction of overland flow, and sediment/pollutant transport.

The stabling and maintenance facility is located outside the 1% AEP flood extent, but within the PMF flood extent which inundates the majority of the Camellia area. Interrogation of the flood models indicates that the stabling and

maintenance facility site is not subject to local overland flows from external areas to the site. Therefore, there is expected to be negligible obstruction of overland flow associated with site filling, and management of sediment/pollutant transport would be through on-site construction phase stormwater and erosion controls.

9.2 PLR Operational Performance

9.2.1.1 Light Rail Corridor

The PLR design peak flood depths in the 0.2EY and 1% AEP events are shown in Maps 9.1 – 9.24. For the 0.2 EY event, the maps illustrate that it is hydraulically feasible for existing flooding within the PLR corridor to be improved considerably or removed altogether with suitable stormwater design and/or upgrades.

With the modelled scheme stormwater concepts, the light rail alignment is generally subject to flood depths <50mm in a 0.2 EY event, enabling light rail operations to proceed.

Where flood depths exceed 50mm, light rail operations are likely to be affected, with the result being either degraded (slow speed) or truncated (partial) operation of the network, depending on the depth of water experienced.

Operational procedures would be developed to mitigate impact of disruption in service and mitigate flood risk to light rail vehicles and passengers. A high-level potential operational strategy is provided in section 10.3.3.3. The final operational strategy would be dependent on detailed design and light rail vehicle selection.

9.2.1.2 Key PLR Infrastructure/Assets

The stabling and maintenance facility (including operational control centre) and all proposed traction power substations (TPS) are located outside mainstream river flood extents for the 1% AEP as a minimum. Further details are provided in Table 23.

Table 23 Key PLR Infrastructure Flood Affection

Precinct	Asset	Flood Affection
Westmead	TPS 1 – Ashley Lane, Westmead	Not subject to overland flow in 1% AEP from PLR model. Located outside the mainstream PMF extent provided by CoP.
Parramatta North	TPS 2 – Corner Church and Factory Street, North Parramatta	Not subject to overland flow in 1% AEP from PLR model. Located outside the mainstream PMF extent provided by CoP.

Precinct	Asset	Flood Affection
Parramatta CBD	TPS 3 – 1A Barrack Lane, Parramatta	Barrack Lane conveys minor overland flows in the 1% AEP, however the substation is sufficiently elevated above road level to be above the 1% AEP level with 500mm freeboard. Located outside the mainstream 1% AEP flood extent but within the PMF extent provided by CoP.
Rosehill and Camellia	TPS 4 – Camellia Junction, Grand Avenue North, Camellia	Subject to local overland flows that would require management through drainage and substation may require elevation above 1% AEP level from PLR model. Located within (riverine) PMF extent provided by Council.
Rosehill and Camellia	Stabling and maintenance facility	Located above 1% AEP + 500mm, but is within the PMF extents.
Rosehill and Camellia	TPS 8 – Stabling and maintenance facility	Located above the 1% AEP + 500mm, and assuming site filling is carried out to approximately 2m above existing level, would be at or near PMF level. Assuming the site is filled to 2m, the floor levels of Operation Control Centre could be elevated above PMF.
Carlingford	TPS 5 – Dundas stop, Station Street, Dundas	Not subject to overland flow in 1% AEP from PLR model. Located outside (riverine) PMF extent provided by CoP.
Carlingford	TPS 6 – North of Telopea stop, Adderton Road, Telopea	Not subject to overland flow in 1% AEP from PLR model. Located outside (riverine) PMF extent provided by CoP.
Carlingford	TPS 7 – Carlingford stop, off Pennant Hills Road, Carlingford	Not subject to overland flow in 1% AEP from PLR model. No PMF extent provided by Council.

Additional infrastructure that is important to operation of the wider PLR system includes:

- Track points
- Communications equipment for the points, located in a cabinet in close proximity to the track points
- Communications equipment located at each stop.

Final locations of the above equipment would be determined during detailed design, however a concept level review of flood risk at likely locations for this infrastructure is provided below.

Points and point machines (embedded in the slab) are designed and rated for submergence. Cabinetry containing power and communications equipment for points should be located outside areas prone to flooding where possible. This can

be achieved through elevating the cabinet above ground level if necessary. A summary of current point locations and flood risk is provided in Table 24 below.

Table 24 Point locations and flood risk

Point Location	Flood risk (PLR Scheme model)	Potential design requirements
Westmead Terminus	Negligible flood depth in 1% AEP – generally contained within kerb.	N/A
North of Cumberland Hospital stop (between New St and O’Connell Street)	Negligible flood depth in 1% AEP – generally contained within kerb.	N/A
West of Parramatta Square stop	Negligible flood depth in 1% AEP – generally contained within kerb.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required
Camellia Junction	Negligible flood depth in 1% AEP.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required.
North of Camellia stop	Negligible flood depth in 1% AEP.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required.
South of Pennant Hills Road bridge	Negligible flood depth in 1% AEP.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required.
South of Carlingford stop	Negligible flood depth in 1% AEP.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required.
Carlingford Stop	Negligible flood depth in 1% AEP.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP if required
Grand Avenue junction to stabling and maintenance facility	Localised flood depths up to 300mm in 1% AEP event.	Locate cabinet outside affected areas, elevate cabinetry on plinth/supports above 1% AEP.
Within the stabling and maintenance facility	Located above 1% AEP event.	N/A

Communications equipment is also located at each stop, within a cabinet on the platform. Platforms are typically elevated 300mm above surrounding ground level. Therefore, should a flood event occur, light rail vehicles would cease operating due to water depth (approximately >80mm on tracks) prior to communications equipment being affected. The PLR communications network also has a level of redundancy such that it remains operational with failure of equipment in one cabinet. Communications equipment typically has a design life

of 10-15 years, therefore a similar flood return period could be considered as appropriate.

Based on review of the PLR Scheme flood model, stops for which platforms may be subject to inundation and hence communications cabinetry requires further treatment are summarised in Table 25 below. The only location where sufficient elevation above flood levels is unlikely to be achievable is the Tramway Avenue stop. At this location, elevation to an agreed design event at or above the 5% AEP event and acceptance of replacement in events greater than the design event is recommended.

Table 25 Stop communications equipment and flood risk

Stop location	Flood risk (depth above platform level)	Potential design requirements
Parramatta Square stop	Negligible flooding on the stop platform in PLR scheme 1% AEP event. 600mm flood depth in existing road in the baseline flood model 1% AEP.	Elevation of cabinetry on plinth/supports above 1% AEP.
Harris Street stop	Negligible flooding on the stop platform in PLR scheme 1% AEP event. 200mm flood depth in existing road in the baseline flood model 1% AEP.	Elevation of cabinetry on plinth/supports above 1% AEP.
Tramway Avenue stop	Negligible flooding on the stop platform in PLR scheme 5% AEP event and up to 600mm flood depth in 1% AEP event.	Elevation of cabinetry on plinth/supports above at least 5% AEP event, review intermediate events (e.g. 2% AEP) in detailed design to establish design criteria, accept inundation and replacement of cabinetry and associated downtime in events exceeding design criteria.

9.3 Post-Construction Impacts

9.3.1 Overview

Impact of the PLR project has been assessed in terms of:

- Afflux
- Velocity and scour potential
- Change in hydraulic categorisation
- Change in flood hazard
- Impact on existing emergency management procedures
- Sensitivity of predicted impacts to climate change.

The 1% AEP event was adopted as the baseline for assessing flood impact. The PMF event has been considered for impacts to existing critical infrastructure and for the operation and maintenance facility, where significant site filling is proposed.

Maps 9.25 – 9.36 illustrate flood impacts in terms of afflux. A positive afflux represents an increase in peak flood level whereas a negative afflux represents a decrease in peak flood level when compared to existing conditions. Differences in peak flood levels of less than or equal to 0.01 metres (one centimetre or 10 millimetres) are considered to be within the accuracy of the hydraulic model. The project is therefore considered to have a negligible effect on flood behaviour in areas where an afflux of ± 0.01 metres is shown to be present. The maps also show the extent of additional land which would be inundated by floodwater, and conversely the extent of land which would be rendered flood free, as a result of the project.

Overall, the maps illustrate a considerable variation in peak flood levels from existing along the PLR project corridor. However, it must be noted that due to the rainfall on grid approach adopted for the modelling, that the entire project corridor always remains “wet” in both existing and design scenarios, and so a change in water level (afflux) is calculated regardless of the depth of water (even if below the 50mm threshold that has been adopted in the depth mapping). The difference in peak water levels illustrated within the project corridor are predominantly due to changes in road surface, although some areas within the road corridor may be subject to increased depths compared to existing. In these areas, flow checks were undertaken using flows extracted from the TUFLOW model to understand whether observed impacts are a result of actual increases in or redistribution in flow, or purely a change in road surface level. Flow calculations were also used to understand the feasibility of mitigating impacts through further grading modifications and/or stormwater design.

Areas outside the project corridor which indicate a change in peak water level can be considered to be a likely potential impact of the PLR project on flooding.

An overview of the impacts of the PLR project on flooding is presented in the sections below.

9.3.2 Flood Depths and Afflux

A discussion on the change in flood depths for the noted flooding issues outlined in section 7.1 and the predicted impacts on flood levels are presented in the sections below. Post-construction peak depth mapping is shown in Maps 9.1 – 9.24. Impacts of the PLR project on peak flood levels for the 1% AEP event are presented in Maps 9.25 – 9.36.

9.3.2.1 Westmead Precinct

Overall, existing overland flow flooding is shown to improve following the incorporation of stormwater upgrades within the concept design. Below is a summary of the improvements to the flood impacted areas noted in the existing conditions assessment in section 7.1.1.

- Westmead Children's Hospital stop - localised ponding has been restricted to the sides of the road corridor in the 0.2 EY event such that Light Rail should remain operable. In the 1% AEP event the track is predicted to be inundated up to a depth of 100mm. Improvements in predicted depths are due to extra storage being added in the road corridor through this area, and upgrades to the existing stormwater network.

Impacts of the PLR project on flooding through the Westmead Precinct are generally limited to within the project corridor. There are some localised areas of increased water levels in the 1% AEP which extend outside the project boundary, which are illustrated in Figure 39 and are described below:



Figure 39 Westmead Precinct - Impacts of the PLR Project

- East of proposed Westmead Station stop (Ashley Lane/Central Avenue) – increases in water levels of up to +40mm shown in the 1% AEP event. The afflux is occurring due to a redistribution of flow resulting from PLR rail/road corridor and the removal of some buildings in the model (properties to be acquired). This could be resolved with alterations to the design rail/road TIN to prevent this redistribution of flow and/or adding appropriate stormwater infrastructure to that already incorporated into the concept design.
- Car park adjacent to The Westmead Institute of Medical Research – increases in water level of up to + 50mm shown in the 1% AEP event. The afflux occurs due to a redistribution of flow resulting from the widening of Hawkesbury Road. This could be resolved with appropriate stormwater infrastructure in addition to that provided in the concept design.
- Caroline Street – increase in water levels of up to +200mm shown in the 1% AEP event due to a redistribution of flow resulting from the PLR rail/road corridor TIN being at concept stage only. This is not a real impact as water is being trapped behind the building in the TUFLOW model. Likely to be resolved through modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure.
- Westmead Hospital car park – increase in water level of up to +20mm shown within driveway, due to widening of Hawkesbury Road and associated redistribution of flow from Hawkesbury Road into the driveway. This is likely to be resolved with alterations to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.
- Cumberland Hospital near North Parramatta Bridge (western side) - increase in water level (up to +20mm) in the 1% AEP event due to a redistribution of flow resulting from PLR rail/road corridor design TIN. This could be resolved with alterations to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.
- Proposed North Parramatta Bridge (adjacent to existing) – The proposed North Parramatta Bridge is currently predicted to create an afflux of up to approximately +40mm in the 1% AEP event for a short distance upstream, whilst the predicted afflux remains above 30mm to the confluence of Darling Mills Creek and Toongabbie Creek. There is afflux up to +30mm shown for a short distance downstream. The impact of the proposed North Parramatta Bridge on flood levels are contained within the banks of the Parramatta River and does not impact upon any sensitive receptors adjacent to the river.

9.3.2.2 Parramatta North Precinct

Changes to the flooding issues outlined in section 7.1.2 are summarised below:

- Cumberland Hospital at west of the oval - localised trapped sag. In the 0.2 EY event, peak flood depths has been reduced from that in the existing case such that the track remains operable, due to the incorporation of stormwater upgrades.

- Cumberland Hospital at near roundabout south of the oval – flooding has been reduced in the 0.2EY event such that the track remains operable, with ponding only impacting the adjoining road corridors due to upgrades to the stormwater network. Flooding impacts the light rail corridor in the 1% AEP event.
- Localised sag just south of the intersection of Church Street and Ross Street. Flooding is restricted to the road corridors in the 0.2EY event, such that the track remains operable.

Localised areas of afflux created by the PLR project occur at the locations illustrated in Figure 40 and are described below:

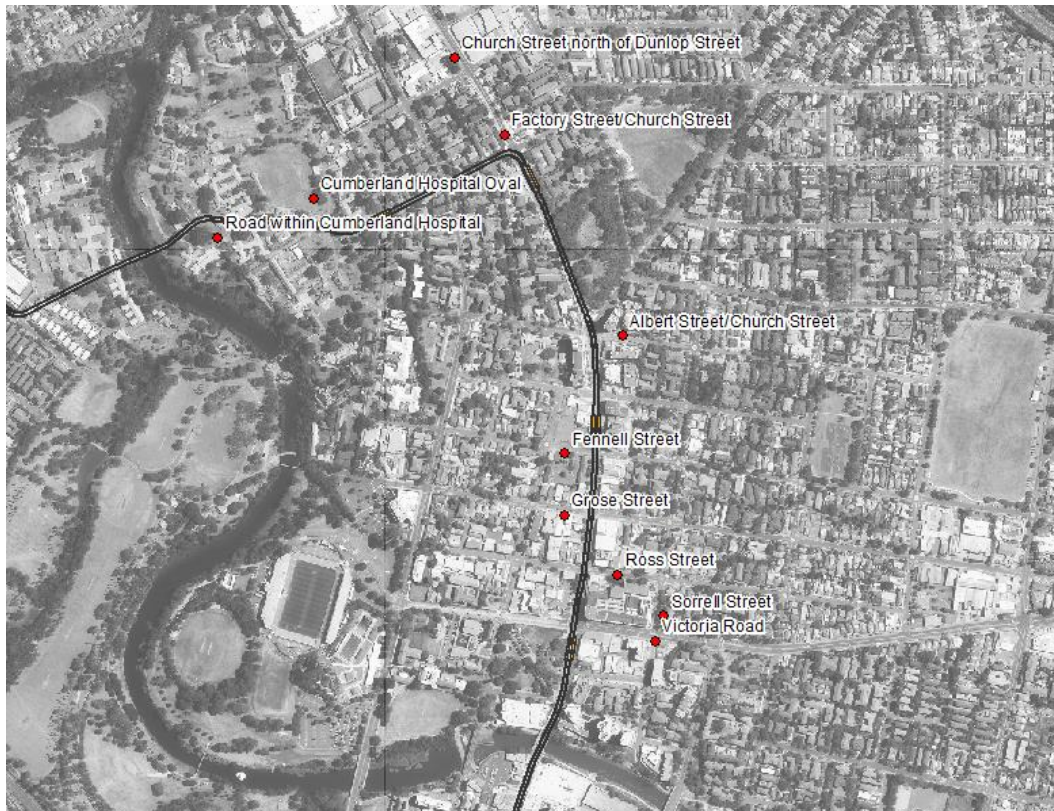


Figure 40 Parramatta North Precinct - Impacts of the PLR Project

- Road within Cumberland Hospital - increased water levels of up to +160mm predicted in the 1% AEP event. Afflux shown is likely due to changes to existing levels, and may also be a result of a lack of existing stormwater drainage information. Likely to be resolved either through incorporation of existing drainage survey or changes to the rail/road TIN, as stormwater flows do not increase in this area.
- Cumberland Hospital Oval – General reduction in peak water levels in the 1% AEP event due to a combination of:
 - Redistribution of flows resulting from project works near the intersection of Church Street and Factory Street; this reduces the overland flow being conveyed to this point stemming from Church Street. Note that the degree of redistribution can only be determined once topographical survey is

added to the existing base-case model for a more appropriate comparative assessment however.

- Stormwater upgrades included in the concept design. Note that a localised increase in peak water levels shown on the oval area is due to a model element designed to transfer overland sheet flow into the pipe network – this is unlikely to be real and is a function of how the stormwater design was schematised.
- Factory Street / Church Street – reduction in peak water levels shown to the north of intersection in the 1% AEP event due to the existing case only having LiDAR in this area, and the design TIN based off topographical survey received subsequent to finalisation of the existing base case assessment. This would be resolved either through incorporation of topographical survey in the existing case model, changes to the rail/road TIN and/or addition of appropriate stormwater infrastructure.
- Church Street north of Dunlop Street – increase in peak water levels of up to +50mm in the 1% AEP event due to redistribution of flow to the north along Church Street created by the grading at intersection and the inclusion of a central median on Church Street. Possibly also due to the design TIN tying into LiDAR north of the Church Street/Factory Street intersection. Likely to be resolved either through incorporation of topographical survey to existing case model, changes to the rail/road TIN and/or addition of appropriate stormwater infrastructure.
- Albert Street / Church Street – increase in peak water level of up to +50mm in the 1% AEP event due to a redistribution of flow resulting from the design rail/road TIN. Likely to be resolved through modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure.
- Fennell Street – increase in water levels (up to +15mm) in the 1% AEP event shown at private property on south of Fennell Street. Occurs due to a redistribution of flow resulting from coarseness of the design rail/road TIN, with additional water getting trapped behind the building in the TUFLOW model. Likely to be resolved through modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure.
- Grose Street – increase in water levels of approximately +60mm against two properties in the 1% AEP event due to a redistribution of flow resulting from the rail/road design TIN in Church Street. This is due to water getting “stuck” between the two buildings in the TUFLOW model and is not a true reflection of what would actually occur as a result of the PLR project. Could be resolved with changes to the rail/road TIN, or with appropriate stormwater infrastructure in addition to that provided in the concept design.
- Ross Street/Sorrell Street east of Church Street - localised increases in water levels of approximately +100mm in the 1% AEP event due to a redistribution of flow resulting from the rail/road design TIN in Church Street. Could be resolved with changes to the rail/road design TIN, or appropriate stormwater infrastructure in addition to that provided in the concept design.

- Victoria Road – localised increase in water levels of up to +170mm predicted in the 1% AEP event due to a redistribution of flow resulting from the PLR rail/road corridor works. Likely to be resolved through modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure.

9.3.2.3 Parramatta CBD Precinct

Changes to the flooding issues outlined in section 7.1.3 are summarised below:

- Macquarie Street near the proposed Parramatta Square stop – predicted depths have been reduced to <50mm in the 0.2EY event due to stormwater upgrades incorporated as part of the proposed scheme design, allowing the track to remain operable. Also significant improvement in predicted depths in the 1% AEP event.
- Macquarie Street near Harris Street stop – predicted depths over the track have been reduced to approximately 60mm in the 0.2EY event, with only a small portion of ponding visible. This would likely be reduced to <50mm with more detailed model resolution and appropriate stormwater design. Also significant improvement in predicted depths in the 1% AEP event.

Localised areas of afflux created by the PLR project occur at the locations illustrated in Figure 41 and are described below:



Figure 41 Parramatta CBD Precinct - Impacts of the PLR Project

- Robin Thomas Reserve - increase in water level of up to +20mm in the 1% AEP event due to a redistribution of flow resulting from PLR rail/road corridor design TIN. This is likely to be resolved with modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.

- George Street between Harris Street and Purchase Street - increase in water level of up to +30mm due to a redistribution of flow resulting from PLR rail/road corridor design TIN. This is likely to be resolved with modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.

9.3.2.4 Rosehill and Camellia Precinct

Changes to the flooding issues outlined in section 7.1.4 are summarised below:

- Tramway Avenue/Arthur Street intersection – depths have been reduced to 150mm in the 0.2 EY event over a small portion of track through the inclusion of a formalised flood storage area between Arthur Street and Clay Cliff Creek, and a new drainage line draining to Parramatta River. This water could be completely removed from the track with alterations to the rail/road design TIN, and the inclusion of appropriate stormwater infrastructure (further to that already incorporated into the concept design). The sag remains flooded in the 1% AEP event due to water from Clay Cliff Creek inundating this area.
- Tramway Avenue stop – the stop remains dry in the 0.2EY event and there is a reduction in depths shown in the 1% AEP event, however this is due to the design TIN having higher levels than the existing ground. Flooding in the 1% AEP event is similar to that in the existing case.
- Camellia (Sandown Line) – flooding shown in the existing case for the 0.2EY event has been eliminated due to upgrades to the existing stormwater network.
- Carlingford Junction – the predicted flood depths have been reduced to a peak of 160mm in the 0.2EY event, however the flood affected area has increased due to a new sag created by the proposed rail alignment TIN. It is anticipated that incorporating existing rail corridor drainage (when available) and any necessary stormwater upgrades should eliminate flooding from this area in the 0.2EY event, allowing the PLR project to be operable.
- Camellia stop – the northern end of the proposed Camellia stop which was shown to be partially inundated in the 1% AEP event under existing conditions is shown as being dry in the 1% AEP flood event due to the embankment being raised in the design TIN.

Localised areas of afflux created by the PLR project occur at the locations illustrated in Figure 42 and are described over:



Figure 42 Rosehill and Camellia Precinct - Impacts of the PLR Project

- George Street between Purchase Street and Alfred Street – increases in water levels at private properties shown in the 1% AEP event of up to +80mm, due to the existing case not having sufficient topographical survey in this area. This is likely to be resolved with incorporation of topographical survey in the existing case model for a more representative comparison of existing versus proposed scenarios. Remnant impacts would be resolved through modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.
- Alfred Street/Hassall Street – increases in water levels in the 0.2EY event up to +40mm due to a redistribution of flow resulting from the rail/road design TIN in George Street. This is likely to be resolved with modifications to the design rail/road TIN and/or addition of appropriate stormwater infrastructure further to that already incorporated into the concept design.
- Adjacent to Carlingford Line near James Hardie Underpass – increases in peak water level of up to +15mm shown on the upstream side of the James Hardie underpass in the 0.2EY event. This is likely due to the widening of the existing Carlingford Line. Afflux could be mitigated, or removed completely through appropriate design of the James Hardie underpass bridge widening, such that the hydraulic capacity of the existing structure is maintained.
- James Ruse Drive Bridge – There are no major impacts to flood levels predicted from the inclusion of the proposed James Ruse Drive Bridge. The piers are located outside of the main channel “floodway” area. The loss of flood storage from the embankment on the western side of the proposed bridge, does not result in substantially increased water levels through the Clay Cliff Creek floodplain for all events up to the 1% AEP.

9.3.2.5 Carlingford Precinct

A stormwater concept design for the Carlingford Precinct has been developed (but not modelled) and is illustrated in Maps 8.5 and 8.6.

There are two areas in which additional flooding is illustrated for the proposed case compared to the existing:

- Rydalmere stop – increase in flood extents on the western side of the PLR project corridor resulting from changes to the ground surface from the design rail TIN.
- North of Dundas stop – predicted depths to the north of the proposed stop have increased by approximately 0.5m. This is a result of the inclusion of the rail design TIN and due to stormwater not being incorporated into the TUFLOW GPU model.

It is expected that the PLR project through the Carlingford Precinct would remain operable in the 0.2EY event.

It should be noted that it is likely that the majority of the impacts reported below result from stormwater drainage not being incorporated in the Carlingford TUFLOW GPU model (existing and design scenarios). As flooding through the Carlingford Precinct is due to overland flow only, it is anticipated that appropriate stormwater design / design TIN modification would be likely to resolve all impacts noted below, having incorporated stormwater infrastructure in the existing and proposed case flood models.

Localised areas of afflux created by the PLR project occur at the locations illustrated in Figure 43 and are described below:

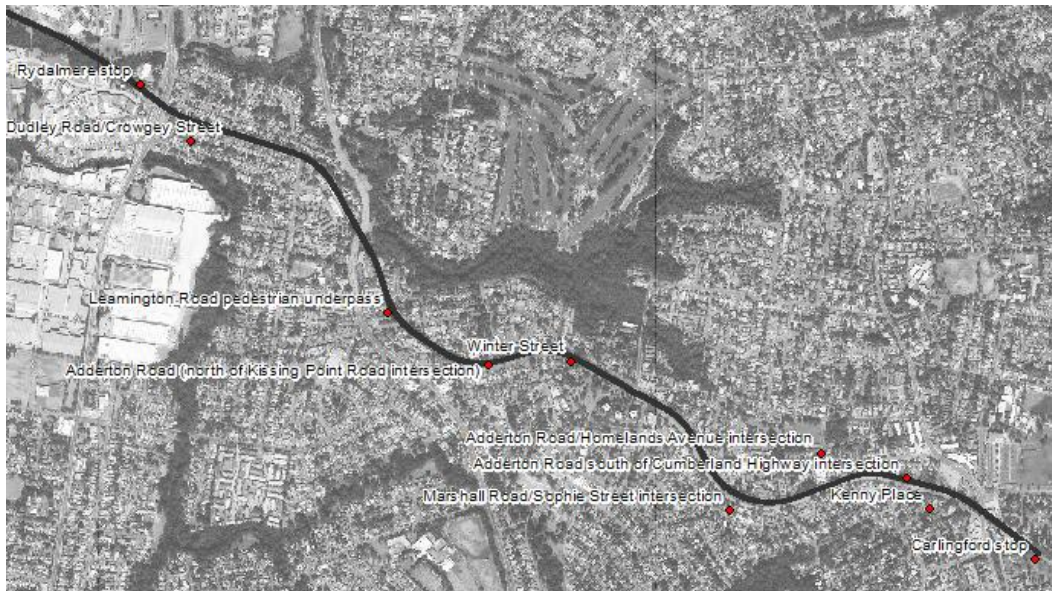


Figure 43 Carlingford Precinct - Impacts of the PLR Project

- Rydalmere stop (see above) – increase in water levels shown on the western side of the corridor of up to +400mm in the 0.2EY event, resulting from PLR rail corridor design TIN. This is likely to be resolved with alterations to the design rail TIN and/or addition of appropriate stormwater infrastructure (note

that stormwater infrastructure was not incorporated into the Carlingford TUFLOW GPU model).

- Dudley Road/Crowgey Street – reduction in peak water levels up to -200mm in the 1% AEP event due to a redistribution of flows resulting from PLR rail corridor design TIN. This is likely a result of the TUFLOW GPU model not incorporating stormwater elements. It is anticipated that peak water levels would remain as per existing following further design development and the incorporation of appropriate stormwater infrastructure.
- Leamington Road pedestrian underpass – increase in peak water level of approximately +400mm in the 1% AEP event due to the widening of the rail embankment removing some storage capacity on the upstream side. This is likely to be resolved through appropriate stormwater design.
- Adderton Road north of Kissing Point Road intersection – increase in peak water level of approximately +180mm in the 1% AEP event due to widening of the rail embankment removing some storage capacity on the upstream side. There is also a +30mm increase in peak water level on the downstream side of the embankment due to a redistribution of flow along the PLR project corridor resulting from the rail design TIN. This is likely to be resolved through appropriate stormwater design.
- Winter Street – increase in peak water level of approximately +180mm in the 1% AEP event due to a redistribution of flow resulting from PLR rail design TIN. This is likely to be resolved through appropriate stormwater design.
- Marshall Road/Sophie Street intersection – increase in peak water level up to +60mm due to a redistribution of flow resulting from PLR rail design TIN. This is likely to be resolved through appropriate stormwater design.
- Adderton Road/Homelands Avenue intersection – increase in peak water level up to approximately +60mm in the 1% AEP event due to a redistribution of flow resulting from PLR rail design TIN. The increased flow off the proposed alignment results in water level increases further downstream (in Vineyard Creek) of up to +120mm. This is likely to be resolved through appropriate stormwater design, specifically by draining overland flow in the northern part of the rail corridor to the Subiaco Creek catchment through the existing drainage network (refer to Kenny Place item).
- Adderton Road south of Cumberland Highway intersection – increase in peak water level of approximately +400mm in the 1% AEP event due to a redistribution of flow resulting from PLR rail design TIN (refer to above item). This is likely to be resolved through appropriate stormwater design, specifically by draining overland flow in the northern part of the rail corridor to the Subiaco Creek catchment through the existing drainage network (refer to Kenny Place item).
- Kenny Place – reduction in peak water level of up to -70mm in the 1% AEP event due to the redistribution of an existing flow path from the Carlingford line away from this area. This is likely a result of the TUFLOW GPU model not incorporating stormwater elements. It is anticipated that peak water levels would remain as per existing following the development of the stormwater

design for the Carlingford Precinct to maintain existing flow paths (refer to the two previous items).

- Carlingford stop – reduction in water level of approximately -20mm in the 1% AEP event in the detention basin north of the proposed stop location, due to a slight increase in storage area resulting from the design rail TIN.

9.3.3 Velocity and Scour Potential

A review of the peak velocities in Parramatta River was carried out to determine whether the PLR project works are likely to result in any increases to flow velocity in Parramatta River and/or other creeks or channels.

With reference to Figure 44, which illustrates the 1% AEP peak velocity changes (existing case vs PLR post-construction case for the Parramatta CBD TUFLOW model), results show that there is effectively no increase in peak velocity for the majority of the extents of Parramatta River. This is also the same for the stretches of Toongabbie Creek and Parramatta River within the Westmead and Camellia TUFLOW flood models.

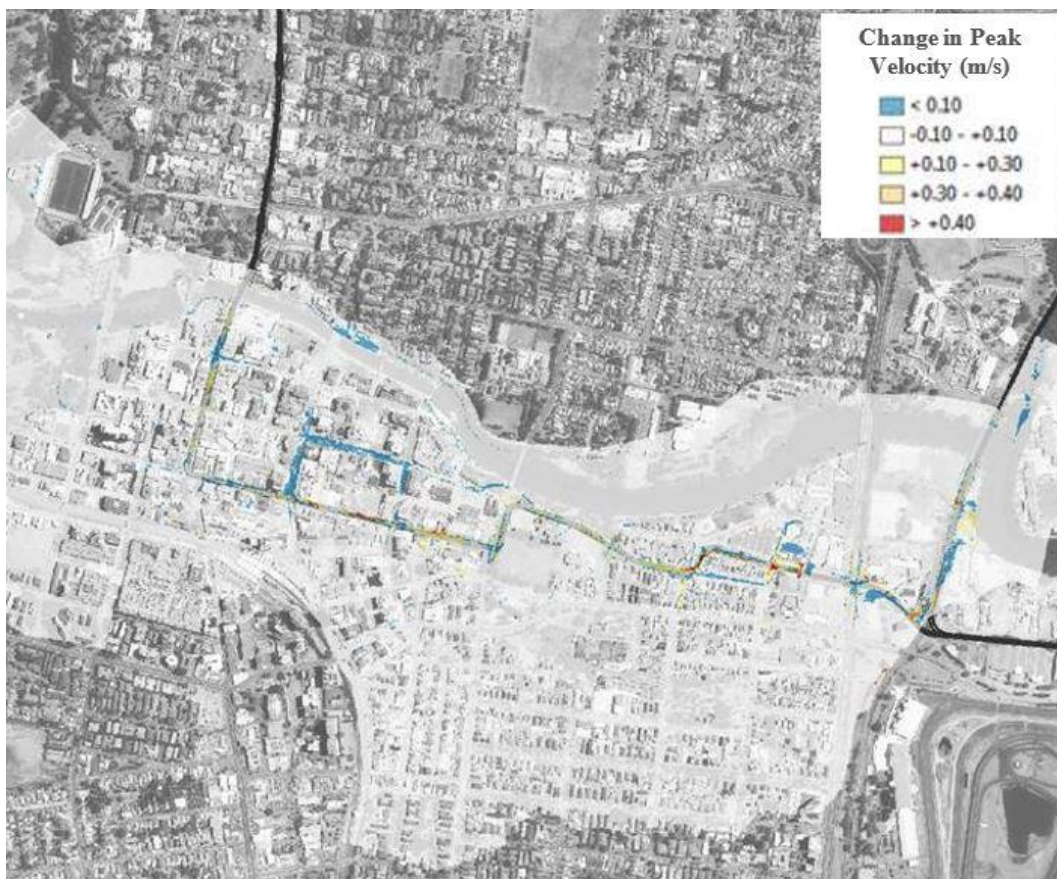


Figure 44 1% AEP Peak Velocity Changes: Existing vs PLR Post-Construction (Parramatta CBD TUFLOW model)

With reference to Figure 45, which illustrates the 1% AEP peak velocity changes in the North Parramatta TUFLOW model, it can be seen that the definition design currently shows an increase of approximately 0.3m/s for a limited section of Parramatta River around the North Parramatta Bridge at Cumberland Hospital.

This is considered minimal as existing peak velocities in the river for the 1% AEP are in the order of 3.5m/s, so this increase should not result in a change of potential for significant erosion and/or scour.

This minimal, localised increase in velocities also reflects a conservative approach of representing the pier (and appropriate losses) at definition design stage. A refined representation of the proposed bridge structure in the TUFLOW model, along with modifications to the proposed bridge design (if necessary), would be addressed in subsequent design stages.

Appropriate scour protection measures would be provided at the new bridge structures to protect the piers and abutments, and at any new stormwater outlets discharging to the major watercourses. This should be detailed at a later design stage.

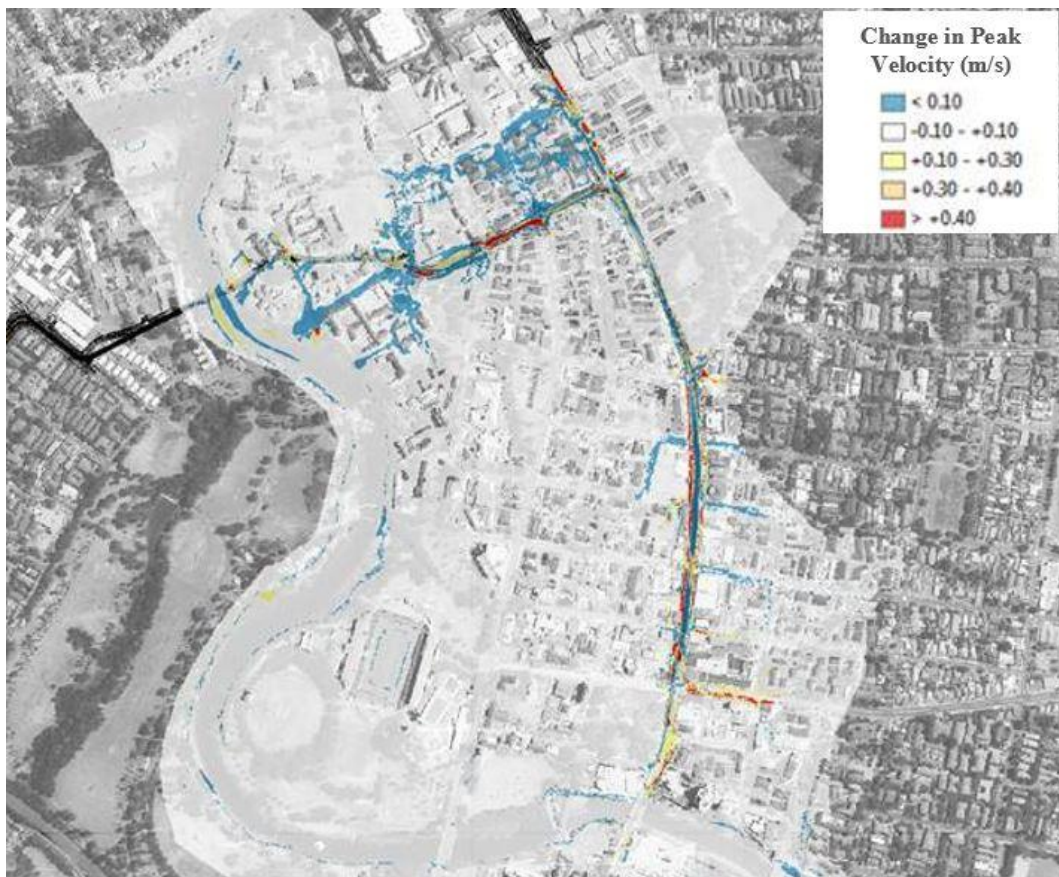


Figure 45 1% AEP Peak Velocity Changes (North Parramatta): Existing vs Post-Construction (North Parramatta TUFLOW model)

With regards to overland flow areas, changes in peak flow velocity along the proposed PLR alignment are seen as a result of the inevitable change in road geometry. However, these changes are minimal and not likely to result in potential scour or erosion along the largely impermeable corridor.

9.3.4 Hydraulic Categorisation and Hazard

The post-construction preliminary hydraulic categorisation for the 1% AEP event is shown in Map 9.37. Impacts of the proposed scheme on the hydraulic categorisation for the areas listed in section 7.2 are outlined below:

- The only impacts of the PLR project to existing floodway areas within water courses are the placement of piers for two proposed bridge structures:
 - North Parramatta Bridge at Cumberland Hospital
 - James Ruse Drive Bridge.
- For both structures above, the piers have been positioned to minimise the hydraulic losses through the structure. There are no significant increases in the floodway areas resulting from either proposed structure.
 - For the proposed North Parramatta Bridge at Cumberland Hospital, the 1% AEP impact mapping illustrates that any afflux greater than +10mm is contained within the existing river banks and that there are no adverse impacts to sensitive receptors resulting from the proposed bridge pier being positioned in the floodway.
 - For the proposed James Ruse Drive Bridge, the 1% AEP impact mapping illustrates that there is no substantial increase in peak water levels resulting from the inclusion of the bridge. The location of the bridge piers within the floodway is considered acceptable on the grounds that there is no change to the existing hydraulic categorisation or peak water levels in the 1% AEP event.
- Tramway Avenue/Arthur Street intersection – proposed embankment between this intersection and the new James Ruse Drive Bridge is located within an existing area of flood storage, however this does not result in any adverse impacts on peak water levels in the 1% AEP event.
- Factory Street/Church Street - there is a reduction in the floodway area along the overland flow path between the Factory Street/Church Street intersection and Cumberland Hospital. This is due to a redistribution of flow created by the design road/rail TIN, and upgrades to the stormwater drainage included in the concept design.
- Church Street/Ross Street - There is a reduction in the area classified as flood storage at sag point near the Church Street/Ross Street intersection due to the inclusion of the design road/rail TIN.
- Victoria Road - There is an increase in the extent of overland flow classified as floodway on the southern edge of the Victoria Road corridor, however this could be mitigated with appropriate stormwater design.
- Macquarie Street - Both the sag points in Macquarie Street (see section 7.1.3), which are flood storage areas under existing conditions, are shown to be flood fringe areas in the post-construction case, due to stormwater upgrades specified as part of the scheme design.
- There is no change to the hydraulic categorisation for the area adjacent to the Carlingford T6 Railway line through Camellia resulting from the PLR project.

Based on the above assessment, the PLR Project is considered compatible with the hydraulic characterisation as it will not materially change the existing characterisation.

The impacts of the PLR project on hydraulic hazard are shown in Maps 9.38 – 9.43. In general, the impact of the PLR project to the hydraulic hazard is negligible. Changes in hydraulic hazard classification shown in the maps are limited to within the project corridor, and are generally a function of where there have been changes made to existing surface levels in the road/rail design TIN. Exceptions to the above are:

- Tramway Avenue/Arthur Street intersection -The formalised flood storage area proposed as part of the scheme design results in the hazard increasing from either low/transition to high within the extent of the flood storage area. This is due to the peak depth within the flood storage area exceeding 1m, and therefore automatically placing the flood storage area within the high hazard category under the Floodplain Development Manual Classification. As the increase in hazard is limited to the storage itself, this increase in hazard could be mitigated by fencing off the flood storage area to prevent public access to this area.
- Tramway Avenue and James Ruse Drive - There is an increase in the hazard categorisation on the fringes of the 1% AEP flood extent in Tramway Avenue and James Ruse Drive. This is a result of changes to the ground levels created by the project works. In both areas, areas of increased hazard classification is offset by areas which show a reduction.
- Leamington Road - There is an increase in hazard classification against the Carlingford Line railway embankment. This is a result of a widening of the embankment and limitations of the TUFLOW GPU model. It is anticipated that this area of increased hydraulic hazard can be reduced or removed in future design stages.
- The detention basin to the north of Carlingford Railway Station should be reviewed for change in hydraulic hazard following the incorporation of stormwater into the flood modelling.

As noted in Section 7.3, the only high hazard area in the 1% AEP event passed through by the PLR project is the section between Alfred Street and James Ruse Drive. Given that a light rail stop is proposed within this section, hazard was also reviewed in this location for the 5% AEP event. The proposed stop location is located outside the high hazard flood zone for the 5% AEP event. Furthermore, depths of flooding for the approach alignment in this event are such that light rail operations would have already ceased on this section of the line prior to the stop becoming a high hazard area (refer outline operational strategy in section 10.3.3.3).

Based on the above, compatibility with hydraulic hazard and changes to hydraulic hazard associated with the project are anticipated to be managed through appropriate design and operational mitigation measures.

9.3.5 Probable Maximum Flood

9.3.5.1 General

The impact of the PLR project on the probable maximum flood is relatively small. The majority of the alignment is severely inundated during the PMF event under existing conditions. As such, changes in road levels along the PLR corridor have minimal impact on peak flood levels in the PMF event. Map 9.62 illustrates the extent of the PMF in the post-construction scenario. Mapping should be viewed in the context of the TUFLOW GPU model approach i.e. that bridges (existing and proposed) and stormwater have not been explicitly modelled.

The following areas have been subject to further review in relation to flood impact in a PMF event:

- Filling of the stabling and maintenance facility site
- Impact to existing critical or sensitive facilities (in line with guidance in *Planning Circular PS07-003* as outlined in section 3.2.2).

9.3.5.2 Stabling and Maintenance Facility

The impact of raising ground levels by approximately 2m at the proposed stabling and maintenance facility is shown in Figure 46 (note that the area inside the “Depot fill region” only shows an afflux because the ground has been raised compared to existing levels).

It can be seen that there is a localised afflux of greater than +100mm within the Grand Avenue and Colquhoun Street road reserves. A maximum increase in peak water level of approximately +400mm occurs near the north-western corner of the proposed stabling and maintenance facility. There is a small section in the adjacent site to the south of the proposed stabling and maintenance facility where the afflux is predicted to be greater than +100mm. The increase in peak water levels in the post-construction case extends between the northern end of the site and over the PLR alignment to Parramatta River, although the increase is generally less the +100mm north of Grand Avenue. To the east of the proposed site, decreases in peak water levels are predicted.

Further design development to address impacts within the road reserve would be undertaken during detailed design, including assessment of detailed stabling and maintenance facility grading plans, stormwater drainage within the facility and stormwater mitigation measures within affected roads.

Note that the PMF post-construction scenario only incorporates changes as a result of the PLR project and does not assume any further developments within the Camellia Precinct. It is understood that future development within the Camellia Precinct may involve raising existing ground levels, and cumulative impacts and coordinate stormwater strategies would need be considered in conjunction with relevant stakeholders in future stages of design.

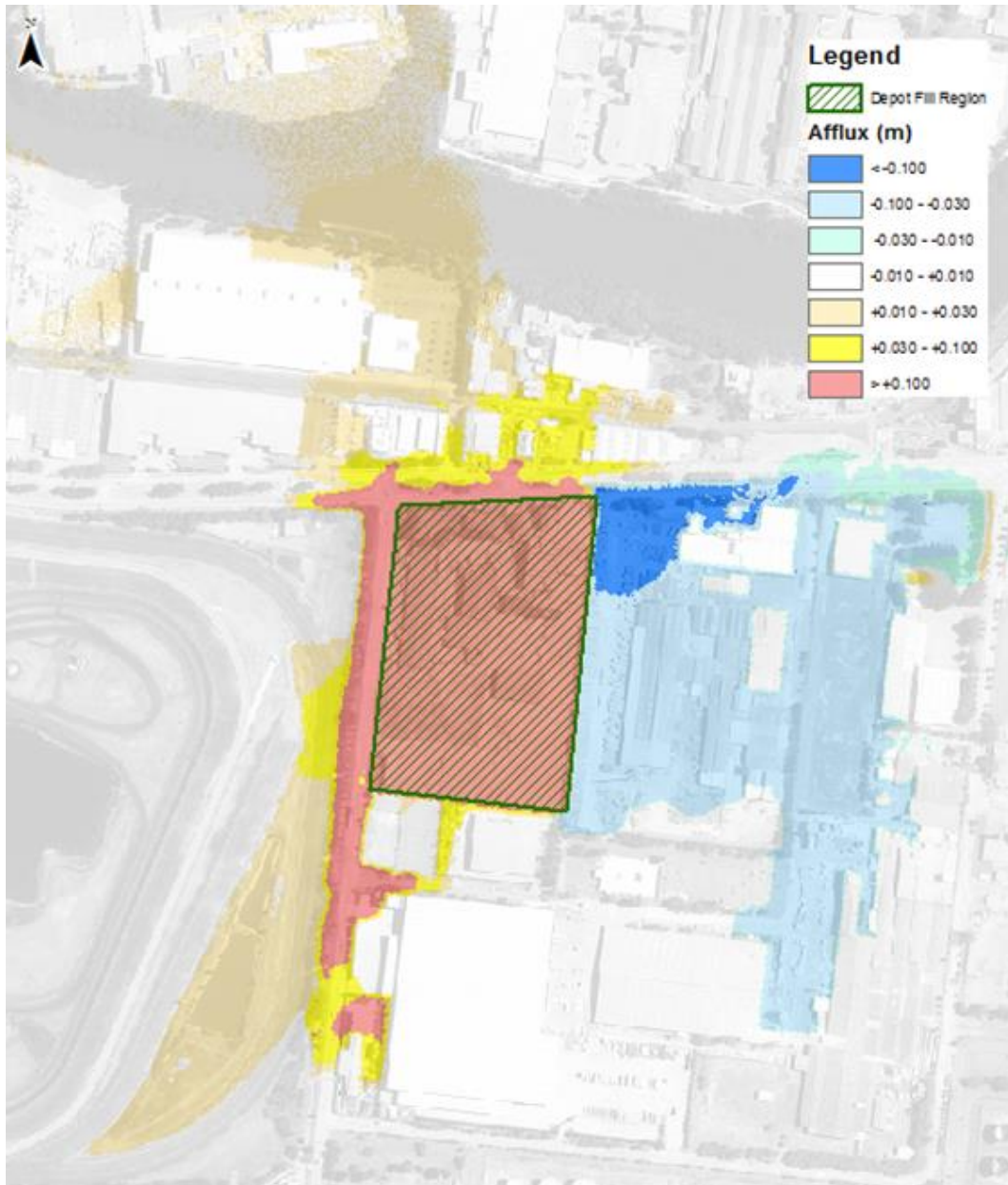


Figure 46 Impact of Stabling and Maintenance Facility Fill on PMF Peak Water Level

9.3.5.3 Impact on Existing Critical or Sensitive Facilities

A review of impacts in the PMF event associated with the PLR project has been undertaken for existing critical facilities.

The following facilities were identified that may be considered critical or sensitive:

- Westmead Hospital
- Children's Hospital at Westmead
- Cumberland Hospital (west)
- WSU Westmead

- Sydney West Area Health Service
- Parramatta North Public School
- Parramatta Police Station
- WSU Parramatta City Campus
- Parramatta Town Hall
- Arthur Phillip High School
- Parramatta Public School
- Barrack Lane Substation
- Rowland Hassall School
- Sydney Water Sewer Pump Station 67
- WSU Rydalmere

No significant adverse impacts were identified for a PMF event. Results for the PMF event are to be considered broadly indicative only given the method of assessment, and require confirmation through detailed modelling in future project design stages. Future modelling would be required to assess impact of new bridges in the PMF event.

9.3.5.4 Bridge Impacts

Given the overland flow only assessment methodology for the PMF, impact of the North Parramatta, Vineyard Creek and James Ruse Drive bridges could not be quantitatively assessed. This should be undertaken during future design stages.

9.3.6 Climate Change Sensitivity

Climate change scenarios were assessed for the 0.2EY and 1% AEP events to determine the long term flood impacts of the PLR project. The assessment was carried out for both the lower bound and upper bound climate change scenarios as specified in section 6.1.

The impact of climate change on the PLR project in the 0.2EY event is shown in Maps 9.44 – 9.49. These maps represent the impact of climate change on light rail operability.

The impacts of the PLR project in each climate change scenario for the 1% AEP event can be seen in Maps 9.50 – 9.61.

A summary of the impacts of the project incorporating climate change for each precinct in the 1% AEP and 0.2EY events is given below.

9.3.6.1 Westmead Precinct

Although peak depths in the road corridors increase under both climate change scenarios, the proposed PLR alignment through the Westmead Precinct is shown to remain operable under climate change conditions in the 0.2EY event.

There are no additional areas within the Westmead Precinct (with respect to overland flow) that are adversely impacted by the PLR project under the lower or upper bound climate change scenarios relative to the baseline comparison in the 1% AEP event. The afflux upstream of the proposed North Parramatta Bridge would be increased by approximately +15mm in the upper bound climate change scenario (up to a total of +55mm noting afflux for the baseline proposed case). However, as with the baseline comparison, this impact remains within the banks of the Parramatta River and does not impact any sensitive receptors.

9.3.6.2 Parramatta North Precinct

Additional flood impacts on the PLR project under the climate change scenarios in the 0.2EY event relative to the existing baseline comparison occur at the following locations:

- Cumberland Hospital near the roundabout south of the oval – the proposed alignment is predicted to be inundated through the sag to a depth of approximately 200mm under the lower bound climate change scenario, and up to approximately 280mm under the upper bound climate change scenario. This inundation over the alignment would be for a period of 15–30 minutes for both scenarios. This impact could potentially be mitigated with upgrades to the proposed scheme stormwater design, in addition to that already incorporated into the concept design
- Localised sag just south of the intersection of Church Street and Ross Street – the proposed PLR alignment is predicted to be inundated by up to 120mm under the upper bound climate change scenario. This would be for a duration of 10-15 minutes.

There are no additional areas within the Parramatta North Precinct that are adversely impacted by the PLR project under the lower or upper bound climate change scenarios relative to the baseline comparison in the 1% AEP event.

9.3.6.3 Parramatta CBD Precinct

Additional flood impacts on the PLR project under the climate change scenarios relative to the existing baseline comparison occur at the following locations:

- Macquarie Street near Harris Street stop – increased depths over the track are predicted within the sag point of up to a total depth of approximately 80mm in the 0.2 EY upper bound climate change scenario. Whilst the increase in depth relative to the baseline scheme design is approximately 30mm, the upper bound climate change scenario shows a considerably larger area of the alignment being impacted than in the post-construction case without climate change.
- George Street adjacent to Queen’s Wharf Reserve (between Harris Street and Purchase Street) is shown to be inundated under both climate change scenarios in the 1% AEP event. It should be noted that for the lower bound climate change scenario, George Street is not inundated under existing conditions in the 1% AEP event.

There are no additional areas within the Parramatta CBD Precinct that are adversely impacted by the PLR project under the lower or upper bound climate change scenarios relative to the baseline comparison in the 1% AEP event.

9.3.6.4 Rosehill and Camellia Precinct

Additional flood impacts on the PLR project under the climate change scenarios relative to the existing baseline comparison occur at the following locations:

- Tramway Avenue stop – the 0.2EY upper bound climate change event results in the stop being inundated to a depth of 300mm, whereas it remains dry under the proposed scheme baseline. The western part of the stop is shown to still be dry under the upper bound climate change scenario
- Tramway Avenue/Arthur Street intersection – the sag point through this intersection is predicted to be inundated to a depth of up to approximately 320mm in the 0.2EY lower bound climate change event. This ponding would occur for a duration of 3-5 hours. Under the lower bound climate change scenario, ponding within the sag remains separated from flooding in the Clay Cliff Creek. In the 0.2EY upper bound climate change scenario, flooding from Clay Cliff Creek begins to interact with flooding in the sag and results in peak depths of approximately 900mm. This ponding would occur for a duration greater than 5 hours.

The section of the project along the existing Sandown Line, remains free of flooding in the 0.2EY under both climate change scenarios.

Impacts of the PLR project on the Rosehill and Camellia Precinct are similar under the lower or upper bound climate change conditions relative to baseline comparison in the 1% AEP event. A slight increase in afflux in both climate change scenarios is seen in an area on the western side of the Carlingford line embankment (near the Carlingford junction) under the climate change scenarios. In the upper bound climate change scenario, the predicted afflux due to the PLR project is approximately +20mm (compared to <+10mm in the baseline comparison).

9.3.6.5 Carlingford Precinct

The proposed PLR alignment through the Carlingford Precinct is shown to remain operable under climate change conditions in the 0.2EY event, although the peak depths in the road corridors increase under both climate change scenarios.

For the upper bound climate change scenario in the 1% AEP event, the peak water level in Vineyard Creek does not overtop the proposed embankment structure, as it does under existing conditions. Nonetheless the operation of the light rail may be impacted under the upper bound climate change scenario as water is shown to encroach on the track.

Impacts of the PLR project under climate change conditions relative to the existing baseline comparison occur at the following locations:

- Vineyard Creek Bridge – Afflux in Vineyard Creek upstream of the bridge is up to approximately +40mm under the upper bound climate change scenario. This is the result of the rail embankment being raised in the post-construction case relative to the existing, such that flow no longer overtops the embankment as it does under existing conditions. Note that the bridge over Vineyard Creek has not been explicitly modelled in the Carlingford TUFLOW GPU model and further assessment is required to confirm project impacts at this location.
- Carlingford stop – The reduction in peak water level noted in the baseline post-construction case has reduced to < -10mm under the upper bound climate change scenario.

For the remainder of the Carlingford Precinct there are no additional areas adversely impacted by the PLR project under the lower or upper bound climate change scenarios relative to the baseline comparison in the 1% AEP event.

9.3.7 Off-Alignment Roadworks

In addition to the road and traffic changes identified along the project alignment, a series of additional road and traffic changes would be required to manage the significant interactions between the proposed road alterations associated with the project and the consequences this would have on the operation of the surrounding road network. These would include works such as:

- Line-marking and signage changes
- Signalisation of intersections, or modification to existing signal arrangements
- Provision of additional lanes or turning lanes, including kerb adjustments
- Removal of on-street parking.

Typically, these works involve negligible change to existing longitudinal road grading and hence negligible change to flooding and overland flow. Where the proposed works include providing additional lanes, this may necessitate kerb and drainage adjustments and changes to road cross falls, which would potentially affect local overland flow paths.

Given the early stage of design, only 2D layout plans are available for the assessment of flood impacts from off-alignment works. Therefore, flood modelling to quantitatively assess the impact of these works could not be undertaken as part of this assessment, and would be required during subsequent design. However, given the local and minor nature of the majority of these works, it is considered appropriate to provide a qualitative assessment of potential impacts based on review of existing flood behaviour. This is provided in Table 26.

Table 26 Assessment of Off-Alignment Roadworks Impacts

Location and Description of Works	Current Flood Behaviour	Potential Impact
Parramatta North Precinct		
<p><u>Works north of Factory Street:</u></p> <ul style="list-style-type: none"> • Modification of an existing signalised intersection at Barney Street and Church Street. Two lanes west-bound to be provided in Barney Street. • Provision of a new signalised intersection at Board Street and Church Street with double left hand turning lane from Board Street to Church Street. Two lanes east-bound to be provided in Board Street • Line marking along Barney Street (between Church Street and O’Connell Street) to allow for traffic lanes eastbound and two traffic lanes westbound • Removal of existing on –street parking along Board Street and Barney Street between Church Street and O’Connell Street • Provision of four traffic lanes on O’Connell Street from Factory Street to Board Street, including kerb adjustments where required • Provision of new traffic signals at O’Connell Street and Barney Street • Provision of four traffic lanes and strip widening of O’Connell Street from Factory Street to Board Street 	<p>Area is not subject to mainstream flooding in the PMF Event (in areas where flood model coverage is available).</p> <p>Not fully covered by current model.</p> <p>Moderate overland flows within Church Street and O’Connell Street between Factory and Dunlop streets (up to 250mm in 1% AEP) with some overland flow onto adjacent properties.</p> <p>Although overland flow information is not available for the following areas, there is potential for overland flow issues / flooding at Church Street / Board Street, and Board Street / O’Connell Street intersections. This is inferred from general limitations of existing stormwater infrastructure observed within PLR TUFLOW model extents, and contributing catchment draining to these locations from upstream, with potential tailwater constraints not currently available.</p>	<p>Overland flows would shift laterally to the match the new kerb lines. Current 3D design alignment model covers a portion of this area, and indicates some transfer of overland flow may occur from the PLR project.</p> <p>Potential re-distribution of overland flows through and around intersections</p> <p>In addition to the above, areas that may be prone to potential impact are as follows:</p> <p>Church Street / Board Street intersection – Removal of central median may result in change of overland flow behaviour at this intersection, which should be determined by hydraulic modelling during subsequent design stages.</p> <p>Board Street / O’Connell Street sag – Should super-elevation be introduced, there is the potential to exacerbate existing flooding should it exist, with stormwater potentially draining within traffic lanes due to central median proposed.</p> <p>O’Connell Street – Formalised kerb and gutter may concentrate flow path along western gutter, as opposed to existing flow paths being potentially wider.</p>

Location and Description of Works	Current Flood Behaviour	Potential Impact
<p><u>Works South of Factory Street</u></p> <ul style="list-style-type: none"> • Provision of four traffic lanes on O’Connell Street between Factory Street and Albert Streets, including kerb adjustments (where required) • Removal of on–street parking along O’Connell Street between Factory Street and Albert Street • Modification to the current Albert Street/O’Connell intersection including traffic signal adjustments • Provision of new traffic signals at the intersection of Fennell Street and / O’Connell Street 	<p>Area is not subject to mainstream flooding in the PMF Event.</p> <p>Existing flood depths along O’Connell Street between Factory and Albert Streets are typically <0.1m for the 1% AEP event, and therefore are generally contained within the kerb. Greater definition to be provided in these areas through incorporation of off-alignment topographical survey.</p> <p>Existing flood depths along Albert Street between O’Connell and Church Streets are typically less than 0.2m depth in the 1% AEP, with no transfer across the road crown. Greater definition to be provided with incorporation of off-alignment topographical survey into existing base case model.</p> <p>Gutter flow along eastern carriageway between Albert Street and Fennell Road up to 0.2m in 0.2 EY event. Greater resolution to be provided by incorporation of off-alignment topographical survey.</p> <p>Gutter flow along eastern carriageway between Grose Street and Victoria Road up to 0.2m in 0.2 EY event. Greater resolution to be provided by incorporation of off-alignment topographical survey.</p>	<p>Works to O’Connell Street involve minimal change to existing kerb lines and therefore flood impacts are likely to be negligible.</p> <p>Works to Albert Street involve widening and realigning the intersection with Church Street. Overland flows would shift laterally to the match the new kerb lines and there is the potential that grading of this intersection could result in some additional flows into Albert Street, the impact of which within the road corridor would need to be determined by hydraulic modelling. Proposed footpath extensions for traffic calming could result in trapped low points for stormwater.</p> <p>Potential re-distribution of overland flows through and around intersections</p>

Location and Description of Works	Current Flood Behaviour	Potential Impact
<p><u>Works South of Factory Street</u></p> <ul style="list-style-type: none"> • Upgrade of the existing O’Connell Street/Victoria Road intersection including provision of a dual left turn lane (southbound) and widening of Victoria Road (southern kerb) • Albert Street / Trott Street intersection • Albert Street / Church Street / Pennant Hills Road intersection • O’Connell Street / Fennell Street intersection • Ross Street / O’Connell Street intersection • O’Connell Street / George Street intersection • Victoria Road / Villiers Street intersection 	<p>Area is not subject to mainstream flooding in the PMF Event.</p> <p>Existing flood depths along Victoria Road are typically up to 0.1m depth in the 1% AEP event, with depths up to 0.2m occurring at the intersection with O’Connell Street, noting overtopping the crown of Victoria Road. Note that greater definition could be provided through incorporation of topographical survey.</p>	<p>Proposed works would widen Victoria Road at the intersection with Factory Street. Overland flows would shift laterally to the match the new kerb lines but the works are unlikely to change flood behaviour outside the road corridor or alter flood depths within the corridor. There would be an opportunity to improve gutter flow widths at the intersection as part of the works.</p> <p>Line marking and signage works on Market and Marsden Streets would not impact flooding.</p>

Location and Description of Works	Current Flood Behaviour	Potential Impact
Parramatta CBD Precinct		
<ul style="list-style-type: none"> • Reconfiguration of George Street between O’Connell Street and Harris Street to allow for bi-directional traffic movements, including removal of some parking • Future proofing of George Street kerb to allow for cycle ways (outside scope of current project) • Remove heritage light rail tracks and re-profile street cross fall to allow for truck and tall vehicle movements (where required) • Signal adjustments and line marking at Marsden Street, Smith Street, Charles Street and Harris Street to allow bi-directional flow • Reconfigure line marking, signposts and signal phasing on Marsden Street to facilitate eastbound traffic to access George Street and Macquarie Street • Macquarie Street / O’Connell Street intersection • Macquarie Street / Marsden Street intersection 	<p>Area is subject to mainstream flooding in the PMF Event, but is outside the mainstream 1% AEP extent.</p> <p>Existing flood depths along George Street due to overland flow range up to 0.35m in the 1% AEP event, with greatest depths occurring between Smith and Charles Street. Considerable gutter flows for 0.2 EY also.</p> <p>Existing flood depths along O’Connell Street due to overland flow range up to 0.8m in the 1% AEP event (at Macquarie Street intersection), with greatest depths occurring between Smith and Charles Street.</p> <p>Existing flood depths along Macquarie Street (between O’Connell Street and Marsden Street) greater than 1.0m in the 1% AEP, with considerable depths (up to 0.8m) in 0.2 EY event also.</p>	<p>Proposed works result in minimal change to existing kerb positions and re-profiling is not expected to result in change to flood behaviour outside the road corridor or alter flood depths within the corridor.</p> <p>Potential loss of flood storage due to proposed footpath widening to be determined in subsequent design stages.</p> <p>Potential trapped low point at Marsden Street / Macquarie Street intersection due to footpath widening.</p>

9.3.8 Emergency Management

The PLR project would have a relatively minor impact on hydraulic categorisation and hydraulic hazard, as discussed in section 9.3.4. Afflux that results as a consequence of the proposed works is not expected to impede trafficability of the road network in the 1% AEP and more frequent events. The PLR would not affect the existing “shelter in place” strategy outlined in the DISPLAN. Existing CBD areas that have a Flood Emergency Response classification of “rising road access” within the *Draft Update of Parramatta Floodplain Risk Management Plans, Molino Stewart, 2016* would remain unaltered by the project. Therefore, the PLR is not predicted to alter existing community emergency management arrangements for flooding.

PLR will require a strategy for managing operations during flood conditions. An outline strategy is provided in section 10.3.3.3.

Noting the requirement of the SEARs to discuss the potential impacts of the development on the existing emergency management arrangements, meetings were held with the relevant stakeholders as below.

9.3.8.1 Consultation with CoP

Several meetings with City of Parramatta have been held throughout the Definition Design stage of the Parramatta Light Rail project. Workshops presenting the existing flood conditions, the EIS stormwater / flood management proposals, and PLR operational intent in flood events were held on:

- 6th June 2017
- 15th June 2017
- 27th June 2017

It is the intent to continue consultation with City of Parramatta Council throughout subsequent stages of the PLR project, including ongoing discussion on the impacts that the development may have upon existing community emergency management arrangements for flooding.

9.3.8.2 Consultation with NSW State Emergency Services

Transport for NSW held a meeting with NSW SES (Region Controller and Deputy Region Controller for Sydney Western Region) on Thursday 29th June 2017.

During this meeting, Transport for NSW provided SES with an overview of the project, the existing flood conditions, the flood management proposals, and the outline strategy for the intended operational response measures in flood events.

It is the intent to continue consultation throughout the subsequent stages of the PLR project in relation to integrating with existing or future proposed emergency management arrangements.

10 Management of Potential Impacts

10.1 General Requirements

A Flood Management Strategy (FMS) would be prepared for flood affected land as a result of the PLR project prior to construction. The strategy would demonstrate how the project achieves the Performance Criteria outlined in section 8.2. The Strategy would include but not be limited to:

- 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.
- The identification of 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.
- Identification of drainage system upgrades.
- The preparation of a flood/emergency management plan, for both the construction phase and post-construction.

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

The following sections outline measures which would be considered during preparation of the FMS in relation to construction and operational impacts.

10.2 Management of Construction Impacts

10.2.1 Management of flood risk to construction activities

Considering the duration of construction activities, the FMS would need to identify a suitable level of flood protection to be provided to construction works.

Construction activities would need to be planned and designed to:

- Limit works in high flood risk areas
- Where works are unavoidable in high flood risk area, limit the duration of works
- Direct overland flows either through or around work in a controlled manner.

The FMS would need to identify:

- Procedures to be adopted by the contractor to monitor weather conditions, communicate with emergency services personnel including the SES and disseminate warnings and instructions to construction personnel in the event of an approaching flood event.

- How damage to construction facilities and equipment would be managed, such as movement of construction equipment and materials to flood-free areas in advance of a flood event.
- How risks to construction personnel would be managed, including:
 - Threshold levels above which evacuation of sites would be instructed.
 - Safe evacuation routes that would be available during a flood event.
- How risk or damage to facilities/equipment would be managed given the fast response nature of the catchment, as effective warning time would be limited.

10.2.2 Management of flood impact

A detailed assessment of impacts from construction activities and details and procedures to manage adverse impacts would need to be carried out as part of development of the FMS with detailed site layouts and staging diagrams. For sites where potential flood impact is identified, detailed assessment would include a floor level survey of potentially impacted properties in order to quantify impact and identify appropriate mitigation.

Management of flood impacts would include:

- Staging of works to minimise temporary works within high flood risk area
- Directing overland flows either through or around work in a manner that maintains, as much as possible, existing flow directions and distribution
- Removal of construction materials and equipment from flood risk areas as soon as possible following completion of works and, if identified in the FMS, following warning of an approaching flood event
- Providing temporary flood protection to properties identified as being at risk of adverse impacts.

10.2.2.1 Site Compounds

Stockpile sites would be located outside areas of frequent inundation, with acceptable level of flood risk depending on the duration of use.

Potential mitigation measures at each compound location are addressed in Table 27.

10.2.2.2 Bridge Construction

The following measures would be adopted for construction of new bridges/modification of new bridges over waterways:

- Maximising use of pre cast elements to minimise construction works within the floodplain
- Minimising temporary formwork requirements and removal of formwork as soon as possible after completion of each work stage

- Minimising temporary structures required within the waterway
- Staging works to minimise the duration of construction activities within the waterway.

Potential mitigation measures at each bridge location are addressed in Table 27.

10.2.2.3 General Alignment Works

For general light rail alignment and road modification works, the FMS would need to include details of:

- How overland flows would be managed during each construction stage
- The nature of construction hoardings/barriers that are proposed to be used along the linear worksite and how these impact overland flows, including but not limited to consideration of any reduced overland flow capacity in the roadways
- Measures to be adopted to manage impacts, which may include:
 - Staging of works to minimise impacts
 - Allowing permeability of the worksite to allow controlled overland flows through the site
 - Removal of temporary barriers in the event of a flood warning being issued
 - Providing temporary flood protection to properties identified as being at risk of adverse flood impacts.

10.2.3 Key sites

Table 27 contains a list of measures which could be implemented in order to mitigate construction related impacts on flooding behaviour at proposed construction compounds, bridges or bridge modification sites and the stabling and maintenance facility. These measures are to be considered as additional to the general measures identified in the previous sections.

Table 27 Summary of potential construction phase mitigation measures - key sites

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
Westmead Precinct		
Westmead Station construction compound	Not affected by mainstream flooding (lies outside PMF extent) or major overland flow	No additional measures expected to be required.
Hawkesbury Road construction compound	Not affected by mainstream flooding (lies outside PMF extent). Overland flow along Hawkesbury Road ponds in the sag adjacent the site, but does not encroach on the site for the 1% AEP event.	No additional measures expected to be required.

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
North Parramatta Bridge construction	<p>Construction of the new bridge would involve works within Parramatta River and within the floodplain.</p> <p>Potential impacts include:</p> <ul style="list-style-type: none"> • Obstruction of the waterway by temporary scaffolding/falsework. • Obstruction of the waterway through temporary access for central pier piling works. 	<p>As the cantilevered structure would be primarily constructed of precast materials and would be craned into place, impacts associated with temporary falsework are expected to be minimised.</p> <p>Minimise time for which temporary access to new central pier is required.</p> <p>As per section 10.2.2.2.</p>
Parramatta North Precinct		
Parramatta North construction compound	<p>Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling.</p> <p>Not subject to major overland flows.</p>	<p>No additional measures expected to be required.</p>
Factory Street construction compound	<p>Not affected by mainstream flooding (lies outside PMF extent) or major overland flow. Overland flows in adjacent streets do not exceed 100mm depth in 1% AEP event.</p>	<p>No additional measures expected to be required.</p>
Fennell Street construction compound	<p>Not affected by mainstream flooding (lies outside PMF extent) or major overland flow. Overland flows in adjacent streets do not exceed 100mm depth in 1% AEP event.</p>	<p>No additional measures expected to be required.</p>
Parramatta CBD Precinct		
O'Connell Street construction compound	<p>Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling.</p> <p>Overland flows in adjacent streets do not overtop the kerb in 1% AEP event.</p>	<p>No additional measures expected to be required.</p>
Barrack Lane construction compound	<p>Located outside the 1% AEP mainstream flood extent, but within Parramatta River PMF extent from CoP modelling.</p> <p>Overland flows in the adjacent street (Barrack Lane) do not exceed 100mm depth in a 1% AEP event. Existing site is also elevated 0.5-1.0m above existing gutter level.</p>	<p>No additional measures expected to be required.</p>

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
Rosehill and Camellia Precinct		
Alfred Street construction compound	The eastern boundary of the site appears to have local trapped sags for the 0.2EY and 20% AEP events. The site is affected by Clay Cliff creek flooding in a 1% AEP events, with depths ranging up to 400mm.	Provision of an overland flow path along the eastern boundary to maintain existing overland flow direction. Review of impacts through flood modelling in detailed design once construction site layout is developed, and subsequent development of further mitigation measures if required.
Clay Cliff Creek/James Ruse Drive Bridge	<p>Construction works within the floodplain for events including the 0.2EY and upwards.</p> <p>Access to and from Arthur Street would be affected by flooding of the street network in a 0.2EY event. This would limit evacuation of the site during a flood event.</p> <p>Site (excluding the Clay Cliff Creek culvert) is classified as high flood hazard east of Clay Cliff Creek for events beyond a 5% AEP event. This would be a safety risk to personnel.</p> <p>Depending on the proposed structures/storage on the site, limited obstruction of floodwaters may occur.</p>	<p>There are no bridge supports within Clay Cliff Creek and as such construction works within Clay Cliff Creek would be limited to removal of existing Sydney Water maintenance ramp and construction of new ramp.</p> <p>Demolition of the existing pedestrian and utilities bridge is expected to be carried out without accessing Clay Cliff Creek.</p> <p>Detailed site planning to allow a setback from the edge of Clay Cliff Creek for any stored material to minimise flood risk to construction and minimise sediment/materials being washed into the Creek.</p> <p>Early construction of stormwater upgrade works in Tramway Avenue may improve accessibility to and from the site in 0.2EY event.</p> <p>Flood emergency procedures to be established for the site, including communication of early warnings from SES/CoP of potential flood events. Procedures may include evacuation of the site, or shelter in place measures.</p> <p>Review of flood risk and impacts through flood modelling in detailed design once construction site layout is developed, and subsequent development of further mitigation measures if required.</p> <p>Other measures as per section 10.2.2.2.</p>

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
Stabling and maintenance facility	<p>Located outside the 1% AEP flood extent, but within the PMF flood extent.</p> <p>Not subject to major overland flows.</p> <p>Potential impacts include:</p> <ul style="list-style-type: none"> • Obstruction of overland flow due to construction works. • Sediment/pollutant transport during site filling. 	<p>No additional measures expected to be required to manage impacts.</p> <p>Management of sediment/pollutant transport would be through on-site construction phase stormwater and erosion controls.</p>
Parramatta River Bridge South construction compound	<p>The site is impacted by flooding from the Parramatta River in a 5% AEP event, with depths ranging up to 0.6m.</p> <p>While this site is not impacted for the 0.2EY event, the culvert below the rail corridor which is the proposed site access would be impassable for this event.</p> <p>The site is classified as high hazard for the 1% AEP event, however the culvert below the rail corridor is high hazard for the 0.2EY event and above.</p>	<p>Review of flood risk and impacts through flood modelling in detailed design once construction site layout is developed, in particular:</p> <ul style="list-style-type: none"> • Safe emergency egress routes from the site. • Subsequent development of further mitigation measures if required.
Parramatta River Bridge modification	<p>Construction of the new bridge is unlikely to involve works temporary works within the river, but may cause impact through:</p> <ul style="list-style-type: none"> • Obstruction of overbank flooding due to construction works to abutments/end spans; • Obstruction of high flood events due to formwork on the bridge for construction of the cantilevered active transport link • Sediment/pollutant transport during site filling. 	<p>As per section 10.2.2.2.</p> <p>Flood emergency procedures to be established for the site, including communication of early warnings from SES/CoP of potential flood events.</p> <p>Review of flood risk and impacts in detailed design once construction staging is developed.</p> <p>Subsequent development of further mitigation measures if required.</p>
Parramatta River Bridge North construction compound	<p>Located outside the 1% AEP mainstream flood extent, but partially within Parramatta River PMF extent from CoP modelling.</p>	<p>No additional measures expected to be required to manage flood impact.</p> <p>May require site-specific measures to manage transport of sediment/materials into Parramatta River due to proximity to river.</p>

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
Carlingford Precinct		
Vineyard Creek construction compound	<p>As the site is immediately adjacent the creek, it is partially affected by flooding for the 5% AEP event and above. Flood depths range up to 0.5-1.0m in the 1% AEP event in close proximity to the creek.</p> <p>Access from the site to Railway Street is not affected in the 1% AEP.</p> <p>Overbank flooding from Vineyard Creek may result in sediment/materials being washed into the Creek.</p> <p>Depending on the proposed structures/storage on the site, limited obstruction of floodwaters may occur.</p>	<p>Detailed site planning to minimise use of flood affected portion of the site.</p> <p>Review of flood risk and impacts through flood modelling in detailed design once construction site layout is developed, and subsequent development of further mitigation measures if required.</p>
Vineyard Creek bridge construction	<p>Construction of the new bridge would involve works within Vineyard Creek and on and adjacent to the steep river embankments.</p> <p>Piling rig would require access to the creek to install piles for the central pier. This may necessitate temporary access within the Creek.</p>	<p>As per section 10.2.2.2.</p> <p>Detailed site planning to minimise use of flood affected portion of the site.</p> <p>Review of flood risk and impacts in detailed design once construction methodology and staging is developed, and subsequent development of further mitigation measures if required.</p>
Rydalmere Station (west) construction compound	<p>The site is not affected by mainstream flooding from Vineyard Creek in the 1% AEP event, and is not affected by major overland flows</p>	<p>No additional measures expected to be required.</p>
Rydalmere Station (east) construction compound	<p>The site is not affected by mainstream flooding from Vineyard Creek in the 1% AEP event, and is not affected by major overland flows.</p>	<p>No additional measures expected to be required.</p>
Dundas Station construction compound	<p>The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.</p>	<p>No additional measures expected to be required.</p>
Kissing Point Road construction compound	<p>The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.</p>	<p>No additional measures expected to be required.</p>

Location/Activity	Flood Risk/Potential Impact	Potential Mitigation Measures*
Adderton Road construction compound	The site is not affected by mainstream flooding (lies outside PMF event). Overland flow modelling indicates there may be some overland flow to the rear of the site adjacent the rail corridor, but this would be expected to be managed through existing drainage (not modelled) or manageable through proposed drainage.	Review overland flows to confirm they can be managed through existing and/or proposed drainage. No additional measures expected to be required.
Telopea Station construction compound	The site is not affected by mainstream flooding (lies outside PMF event), and is not affected by major overland flows.	No additional measures expected to be required.
Carlingford Station construction compound	This site is not affected by mainstream flooding (lies outside PMF event). The southern boundary of the site is within an existing stormwater detention area and as such is inundated in a 0.2EY event and above by up to 1m. Other than the area within 10-20m of the boundary, the site is unaffected by the 1% AEP. Access from either the commuter carpark or Boundary Road would be unaffected in the 1% AEP.	Detailed site planning to avoid or minimise impact to detention area.

* It is assumed all sites would adopt appropriate management of soil and erosion in accordance with *Managing Urban Stormwater, Soils and Construction* (The “Blue Book”), and would have a suitably detailed Construction phase Environmental Management Plan (CEMP).

10.3 Management of Post-Construction Impacts

10.3.1 Overview

This flood assessment has provided an understanding of flood risk to the PLR project infrastructure and operations, and potential impacts on existing flood behaviour associated with the project.

Mitigation measures which could be implemented in order to manage risks and impacts to meet the Performance Requirements identified in section 8.2 are outlined in the following section.

10.3.2 Flood Model Development

The flood model would be made available to delivery contractors to further refine and develop both representation of existing flood behaviour, predicted impacts and mitigation measures. This work would be carried out in accordance with the performance criteria and drainage principles previously outlined, and in consultation with stakeholder including but not limited to CoP, Sydney Water, NSW Health and Urban Growth. Specific areas of model development for both the existing and PLR project models are outlined below.

Existing Case Model

- Incorporation of additional topographical survey received for off-alignment works areas
- Incorporation of stormwater survey commissioned by PLR that has not yet been received to confirm the existing network
- Incorporation of pit inlet rating curves following confirmation of alignment, pipe sizes, pit types etc.
- Commissioning of additional survey (topographical, stormwater and/or CCTV) in those areas identified where there is less knowledge of existing conditions (e.g. Westmead hospital, Parramatta North Development, Camellia, Carlingford Line)
- Acquisition and incorporation of updated LiDAR information, to more accurately represent current development and land use
- Incorporation of bridge survey for bridges currently represented using MIKE 11 model information
- Additional sensitivity testing, e.g.:
 - Lumped sub-catchment hydrology
 - Building representation
 - Impact of blockage on pits
 - Impact of blockage of major hydraulic structures
- Incorporation of any new information that may become available from the CoP flood study currently underway, for example updated bathymetry

Proposed Case Model

- Incorporation of additions/modifications to the baseline model elements noted above
- Review any constraints in providing stormwater infrastructure solutions that were not known at the time of this assessment e.g. utility constraints, contaminated land etc.
- Integrated development of the model with road, rail and urban design packages to minimise impacts on flood behaviour (e.g. at Arthur Street/Tramway Avenue)

- Interfacing with other construction projects along the alignment
- Detailed flood modelling of bridges across the project, in particular:
 - Development of a detailed flood model for the Vineyard Creek bridge
 - Scour assessments for North Parramatta, Vineyard Creek and James Ruse Drive bridge piers and abutments
 - Flood modelling for the 0.05% AEP (1 in 2000 year ARI) event and PMF event for the North Parramatta, Vineyard Creek and James Ruse Drive bridges, for the purposes of bridge design and impact assessment
- Incorporation of proposed grading and stormwater design for the Parramatta North Development as designed by Urban Growth
- Consideration of cumulative impacts, for example proposed upgrade of James Ruse Drive by Roads and Maritime.

10.3.3 Flood risk

10.3.3.1 Alignment

The PLR post-construction flood model has demonstrated, to the extent feasible with the level of current baseline information and PLR alignment design, that it is likely to be hydraulically feasible to enable operability of the PLR in the 0.2EY event through site-specific stormwater drainage measures at locations with existing flood risk.

The final level of stormwater upgrade required from an operational performance perspective would depend on detailed flood modelling, road and rail alignment design and light rail vehicle selection.

Future flood and drainage modelling would also need to address:

- Future-proofing drainage located beneath the light rail hazard zone, including assessment of flood risk and flood impact of upgrading existing capacity within the corridor prior to the construction of corresponding downstream upgrades by others. This may result in the need to temporarily throttle flows back to existing levels through orifice plates or similar until downstream upgrades are constructed.
- Design of appropriate inlets with capacity to achieve the required hydraulic performance of the pipe infrastructure, including consideration of appropriate blockage factors.
- Quantifying what additional drainage would be required to achieve operational objectives in the 0.2EY event inclusive of predicted climate change.

10.3.3.2 Key PLR Infrastructure

As noted in section 9.2.1.2, the stabling and maintenance facility (including operational control centre) has immunity for the 1% AEP flood level with greater

than 500mm freeboard. All proposed traction power substations would be provided with immunity for the 1% AEP with limited elevation above surrounding levels. Further mitigation is not anticipated to be required based on modelling carried out to date, although review is recommended following future updates to the flood models and PLR design.

Final locations of the rail points and associated communications equipment, as well as communications equipment to be located at stops would be carried out in detailed design. As noted in section 9.2.1.2, points and point machines would be required to be designed and rated for submergence to the extent identified by flood modelling. Preliminary review of point locations and stop locations indicates that communications cabinets can be located outside 1% AEP flood extents or feasibly elevated above the 1% AEP, with the exception of Tramway Avenue stop. As the equipment needs to be located at the stop, recommended mitigation measure at this location include:

- Elevation of the equipment as much as is feasible
- Modelling intermediate events between the 5% AEP and 1% AEP to establish the design event at which the equipment would be affected
- Retention of additional spare communications equipment at the stabling and maintenance facility to allow prompt replacement in the event of failure due to flooding
- Ensuring that the communications network for the wider PLR is not reliant on operability of the equipment at this location.

10.3.3.3 Operational Response During Flooding

A concept strategy for operational response during flooding has been developed by the PLR Operations Technical Advisor. The strategy was based on predicted flood depths and assuming that light rail vehicles can traverse flood depths of up to 50mm under normal operations and up to 80mm at specific locations with restricted speeds. This strategy would be subject to further development and consultation as PLR design progresses. An outline of the strategy is provided below.

Operational management of flooding was divided into three scenarios

- Scenario 1 – Flooding below 50mm
- Scenario 2 – Flooding above 50mm but below 80mm
- Scenario 3 – Flooding above 80mm

A process map for management of flood events under the three scenarios is provided as Figure 47.

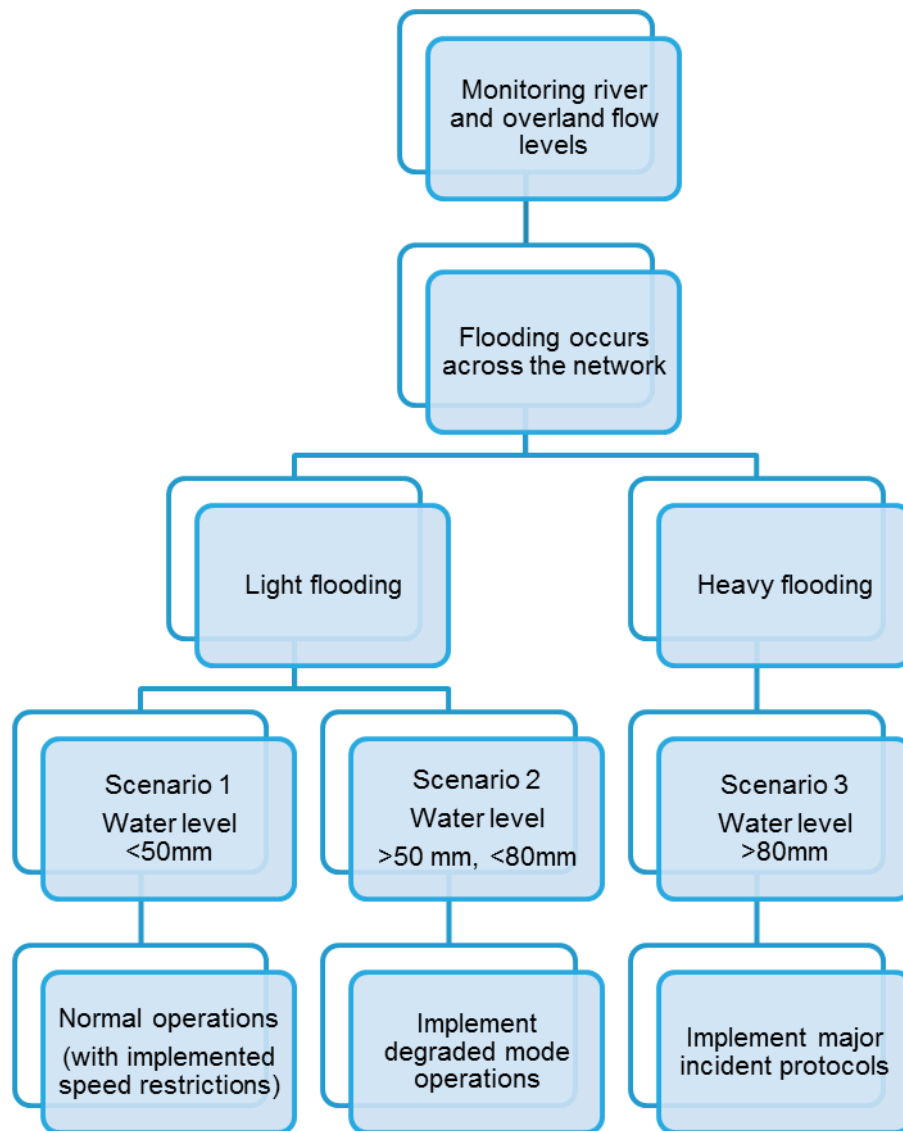


Figure 47 Preliminary Flood Event Process Map

Note: The above figure is a preliminary process map based on the information provided at the time of writing. Detailed mitigation plans would be developed in accordance with PLR requirements.

Scenario 1 – Flood depths below 50mm

Under this scenario, normal operations would continue. Water levels would be monitored by drivers through observation of depth markers along the route and The Operations Control Centre (OCC) would also keep abreast of weather forecasts and warnings from emergency personnel and be prepared to implement degraded mode operations (truncated services) either side of affected areas, if it should be required.

If the weather forecast indicates further heavy rainfall and/or emergency personnel provide warning of a flood event approaching, primary areas of flooding within the CBD may start to cause an extended interruption to normal operations and therefore the OCC should be prepared to implement shuttle services, whereby LRVs continue to operate truncated sections of the network.

Scenario 2 - Water level above 50mm but below 80mm

The OCC would implement degraded mode operations where by LRVs run short services between the following sections:

- Section 1 – Westmead Station stop to Parramatta Square stop
- Section 2 – Parramatta Square stop to Camellia
- Section 3 – Camellia to Carlingford

Temporary speed restrictions would be implemented across areas where water is above the top of the rail but not at the ultimate height to stop services. This strategy is based on the assumption that both the Parramatta Square stop turn backs are still operable and that 12 LRVs would be operating on the network at the same time, with 4 LRVs in each section.

If there is an indication that flood levels will continue to rise, the OCC would inform drivers to prepare for major incident protocols and direct the drivers to carry out the following protocols.

Table 28 Degraded Mode Protocols

From	To	Protocol
Westmead Station stop	Parramatta Square	Proceed to Factory Street and Fennel Street Stops. Disembark passengers (emergency de-tram protocols). Stable vehicles at stops.
Parramatta Square	Westmead Station stop	Proceed to Westmead Station Stop. Disembark passengers (emergency de-tram protocols). Stable vehicles at terminus
Parramatta Square	Camellia	Proceed to stabling and maintenance facility or to Camellia and operate resulting 4 vehicles on the Camellia to Carlingford section.
Camellia	Parramatta Square	Proceed to Prince Alfred Square and Eat Street stops. Disembark passengers. Stable vehicles at stops
Camellia	Carlingford	Continue to operate as normal but with additional two (2) vehicles from Parramatta to Camellia section
Carlingford	Camellia	Continue to Operate as normal but with additional two (2) vehicles from Parramatta to Camellia section

The provision of alternative transport options to major transport interfaces, such as Parramatta Square, Camellia and Westmead, would need to be considered if the relevant roadways are unaffected by flooding. Buses to disperse passengers from stops like Fennel Street, Factory Street, Prince Alfred Square and Eat Street may be considered, depending on the warning time available to enable the arrangement of replacement buses.

Scenario 3 - Water level above 80mm

Operations across the network would cease with the exception of the Camellia to Carlingford section, for which flood depths of this order are not anticipated to occur.

In this scenario, protocols from Scenario 2 would have already been adopted i.e. the OCC would have informed drivers of the suspended service who would, by then, have safely disembarked passengers and stabled vehicles at the positions defined in the degraded operations section above.

In the event that an LRV is unable to reach a stop to disembark passengers, the driver would notify the OCC and determine an appropriate course of actions based on the risks. This may be to park on a section of the route not affected by flooding and instigate an emergency de-tram process. As an example, if a vehicle is travelling between the Harris Street stop and Parramatta Square stop, and Parramatta Interchange becomes impassable, an appropriate area to stable and drop off passengers would be on Macquarie Street, in between Smith Street and Charles Street.

It is expected that as part of the current flood study being carried out by CoP, a review of Flood Emergency Response classification for Parramatta as a whole will be carried out, which will inform PLR operating strategies.

It will also be important to understand in more detail the status and details of the CoP flood warning system, in particular to understand the warning time available for various return period events to inform operating procedures. It is expected that the light rail operator would require a minimum of 15-20 minutes to implement any of the operation scenarios to respond to flooding, which is understood to be within the available warning time expected to be achievable from the CoP flood warning system.

10.3.4 Flood Impact

A detailed flood assessment would be carried out during detailed design to identify impacts, inform the design of mitigation measures and assess the effectiveness of these measures.

Where impacts are predicted, a floor level survey would be carried out to determine whether the PLR would adversely affect flooding to a habitable floor level or basement entrance.

The project would be designed to minimise adverse impacts up to the 1% AEP generally, and up to the PMF for critical infrastructure.

The James Ruse Drive bridge and North Parramatta Bridge would be designed such that soffit (underside of bridge) level achieved 0.5m freeboard above the 1% AEP. Vineyard Creek bridge would be designed such that adverse impacts would be minimised in all events up to the 1% AEP.

Road modifications would be designed to minimise redistribution of overland flows and to not adversely affect existing flood hazard.

Final mitigation measures may include a combination of:

- Flood modification measures – these modify the behaviour of the flood itself by reducing flood levels or velocities, e.g. stormwater drainage improvements, construction of detention basins and flood storage areas
- Property modification measures - these modify either the existing buildings (voluntary house purchase/raising) or future development (through development controls) within the floodplain
- Response modification measures - these actions modify the response of the population to the flood threat, generally through community education or improvements to emergency management.

Based on the preliminary modelling carried out to date, site-specific mitigation measures that would need to be incorporated to address predicted impacts are summarised in Table 29.

It is important to note that, for the impacts discussed in the Carlingford Precinct, the hydraulic modelling carried out did not include pipe networks for both existing and post-construction cases. As such, it is anticipated that inclusion of stormwater networks for both scenarios would give a more realistic and comparative assessment of the impacts caused by the PLR project. Mitigation measures should be reassessed following inclusion of stormwater (where appropriate) in subsequent design stages.

Table 29 Summary of PLR Impacts and Mitigation Measures

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
Westmead Precinct			
East of proposed Westmead stop (Ashley Lane/Central Avenue)	Increase in off-alignment flows to properties between Ashley Lane and Central Avenue, noting water trapped behind buildings. Stormwater drainage issue, not flooding	Removal of building from existing model and redistribution of flows at new stop location.	Provision of drainage at stop, appropriate grading of stop area in detailed design to maintain status quo or addition of appropriate stormwater infrastructure
Car park adjacent to The Westmead Institute of Medical Research	Increase in flood depths within Westmead health precinct.	Function of road widening upstream and redistribution of flows from existing Westmead entrance.	Liaison with HI and integration with proposed Central Acute Services Building design. Potential re-grading and modifications to proposed drainage, noting potential changes to roadworks for new road junction at this location.
Caroline Street	Water trapped behind private property at Caroline Street, noting that buildings are represented as blockages. Not real flooding.	Minor level differences at transition of proposed TIN with existing levels, transferring minimal transfer of flows into property. Water cannot escape grid due to building representation.	More accurate tie in of proposed grading to existing levels
Westmead Hospital car park	Increased flows into private entrance of Westmead Hospital.	Partial Hawkesbury Road widening, and reduced flows into existing Westmead entrances upstream in proposed case	Liaison with HI and integration with proposed Central Acute Services Building design. Potential re-grading and modifications to proposed drainage, noting potential changes to roadworks for new road junction at Helen Street. Consideration of crest to protect entrance should there still be an increase in flows compared to existing.
Cumberland Hospital near North Parramatta Bridge (Western side)	Localised increase in depth outside one property on northern edge of alignment.	Lack of existing drainage information in this area, with minimal increase in level in proposed TIN.	Incorporation of existing drainage survey into this area of the TUFLOW model. Potential grading and drainage modifications through further design development

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
North Parramatta Bridge	Afflux caused by proposed North Parramatta Bridge	Inclusion of new central pier in TUFLOW model resulting in upstream afflux due to higher losses through the proposed structure	Co-ordination with structures team to minimise hydraulic losses through new structure. Afflux shown is contained within the river banks, however TUFLOW model requires further refinement at this location.
North Parramatta Bridge	Impact of proposed bridge in PMF event not currently assessed.	Potential impact to Parramatta River in PMF event.	PMF model to be created and impact to be assessed in future design stage
Parramatta North Precinct			
Road within old Cumberland Hospital	Minor increase in flows to road south of alignment, noting that existing drainage is missing from TUFLOW model in this area, along with minimal topographical survey	Lack of existing drainage and topographical information in this area, along with minor level modifications.	Incorporation of existing drainage survey into this area of the TUFLOW model. Potential grading and drainage modifications through further design development
Cumberland Hospital Oval	Reduced overland flows towards alignment in proposed case modelling	Reductions in flows towards alignment from north is due to changes noted in Factory Street/Church Street item below. Existing drainage is also missing from existing and proposed case TUFLOW models. Flows further reduced due to grading at Fleet Street and O'Connell Street intersections with Factory Street.	Incorporation of existing drainage survey into this area of the TUFLOW model. Incorporation of proposed drainage design for Parramatta North Development for proposed case after liaison with Urban Growth. Potential grading and drainage modifications through further design development.
Factory Street / Church Street	Changes in afflux / flows within Church Street to north of Factory Street / Church Street	Modifications to grading at intersection and inclusion of central median on Church Street resulting in flows continuing to north rather than to west towards PNUT, noting that existing case model only had LiDAR in area to north of Factory Street.	Incorporation of additional topographical survey for existing case model to determine more representative changes in overland flow in proposed case. Grading and drainage modifications to road and rail TIN maintain status quo.

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
Church Street north of Dunlop Street	Increase in flows to north along Church Street	Lack of survey in existing model for appropriate comparative assessment. Central medians in proposed off-alignment works. Off-alignment drainage works not included in proposed case	Incorporation of additional topographical survey for existing case model to determine more representative changes in overland flow in proposed case. Grading and drainage modifications to road and rail TIN to maintain status quo.
Albert Street / Church Street	Increase in flows into Albert Street from Church Street	Re-grading at intersection resulting in overland flows overtopping footpath and draining towards Albert Street to east.	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure.
Fennell Street	Minor afflux shown at private property on south of Fennell Street intersection with Church Street	Minor level differences at transition of proposed TIN with existing levels, transferring minimal transfer of flows into property. Water cannot escape grid due to building representation.	More accurate tie in of proposed grading to existing levels.
Grose Street	Minor afflux shown at private property on south of Grose Street intersection with Church Street	Minor level differences at transition of proposed TIN with existing levels, transferring minimal transfer of flows into property. Water cannot escape grid due to building representation.	More accurate tie in of proposed grading to existing levels.
Ross Street/Sorrell Street East of Church Street	Increase in flows and afflux in Ross Street to east and west of Church Street	Proposed rail alignment upstream has no crossfall, with pre-concept grading increasing flows towards sag in Ross Street, potentially impacting existing properties	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure
Victoria Road	Increase in flows and afflux in Victoria Road to east of Church Street	Increase in flows towards Ross Street as per above item, and continuation overland to Brickfield Creek from sag	Re-grading of rail alignment and intersections upstream to north to maintain status quo or addition of appropriate stormwater infrastructure
Parramatta CBD Precinct			
Robin Thomas Reserve	Localised increase in depth in park area alongside proposed tracks	Minor increase in levels in proposed rail/road TIN	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
George Street between Harris Street and Purchase Street	Impact to private property to south of proposed alignment.	Increase in design rail/road TIN levels across southern boundary	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure
Rosehill and Camellia Precinct			
George Street between Purchase Street and Alfred Street	Minor increase in levels within private properties to south of alignment	Existing case TUFLOW model had only LiDAR in this location. Design TIN based off LiDAR also.	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure
Alfred Street/Hassall Street	Minor increase in water levels in the 0.2EY south of the alignment	Function of the design TIN at intersection of George Street and Alfred Street redistributing flow away from its existing path	Grading modifications to proposed road and rail TIN to maintain status quo, or addition of appropriate stormwater infrastructure
James Hardie Underpass	Impact to small parcel of land upstream of James Hardie Underpass - only in the 0.2EY	Widening of the Carlingford Line embankment and proposed bridge extension having not being fully incorporated into TUFLOW	Co-ordination with structures team so that existing hydraulic capacity of underpass is maintained
James Ruse Drive Bridge	Afflux caused by proposed James Ruse Drive Bridge	Proposed Bridge being incorporated in TUFLOW model potentially reducing flood storage in Clay Cliff Creek Floodplain area	Co-ordination with structures team to minimise hydraulic losses through new structure. Afflux shown is contained within the river banks, however TUFLOW model requires further refinement at this location.
James Ruse Drive Bridge	Impact of proposed bridge in PMF event not currently assessed.	Potential obstruction to Clay Cliff Creek/Parramatta River floodplain.	PMF model to be created and impact to be assessed in future design stage
Maintenance and Stabling Facility	Increase in peak water level in adjacent road reserves in PMF event.	Filling the site by up to 2m.	Inclusion of detailed site grading and stormwater drainage in future detailed design modelling.

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
Carlingford Precinct			
Rydalmere stop	Newly impacted area adjacent to existing Rydalmere station - depths of up to 0.5 m reported not present in existing case	Widening of existing railway corridor creating new area for water to pond	Grading modifications to proposed rail alignment TIN to maintain status quo and/or addition of appropriate stormwater infrastructure (if necessary)
Dudley Road/Crowgey Street	Reduction in flow due to redistribution of overland flow path. Impacts on water levels in Subiaco Creek	Widening/re-grading of existing railway embankment cutting of existing flow path	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure (if necessary)
Leamington Road pedestrian underpass	Afflux shown on upstream side of Carlingford line embankment	Widening of existing railway corridor - not maintaining hydraulic capacity of existing pedestrian underpass (acting as a culvert for overland flows)	Co-ordination with structures team so that existing hydraulic capacity of underpass is maintained/appropriate stormwater design
Adderton Road north of Kissing Point Road intersection	Increase of peak water level on upstream side of rail alignment	Widening/re-grading of existing railway embankment creating redistribution of flows compared with existing	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure (if necessary)
Winter Street	Increase of peak water level on upstream side of rail alignment	Widening/re-grading of existing railway embankment creating redistribution of flows compared with existing	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure (if necessary)
Marshall Road/Sophie Street intersection	Afflux shown as flow approaches intersection after draining off the railway embankment	Widening/re-grading of existing railway embankment creating redistribution of flows compared with existing	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure (if necessary)
Adderton Road/Homelands Avenue intersection	Afflux shown as flow approaches intersection after draining off the railway embankment	Cess drain modelling as part of proposed rail TIN distributing a larger catchment area to this location than the existing	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure further north up the catchment to maintain status quo
Adderton Road south of Cumberland Highway intersection	Afflux shown as flow approaches intersection after draining off the railway embankment	Cess drain modelling as part of proposed rail TIN distributing a larger catchment area to this location than the existing	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure further north up the catchment to maintain status quo

Location	Description	Potential Cause of Impact	Mitigation requirements/Further design development
Kenny Place	Reduction in peak water level due to redistribution of flow within design TIN (see previous)	Cess drain modelling as part of proposed rail TIN distributing flow away from this location	Grading modifications to proposed rail alignment TIN to maintain status quo or addition of appropriate stormwater infrastructure to discharge to this location and match existing conditions
Carlingford stop	Reduction in water levels in detention basin upstream of rail alignment	Additional storage created from Design TIN	Co-ordination with alignment team so that existing flood storage area is maintained. Behaviour of basin to be further investigated incorporating stormwater
Vineyard Creek Bridge	Bridge impacts not currently modelled due to TUFLOW GPU approach adopted. Minor impact in 1% AEP event may occur due to proposed soffit of bridge being 70mm lower than existing soffit, and existing soffit being inundated in the 5% AEP event (Source: Vineyard Creek flood study)	A lower soffit level than existing for the proposed bridge is inconsistent with the proposed design principles and may impact flood behaviour. Differences in bridge superstructure depth from existing may result in impacts in events for which the bridge soffit is impacted i.e. a 5% AEP event and higher.	Review bridge soffit and match existing level. Development of a 1D/2D model for the bridge and assess in the 1% AEP and PMF event.

10.3.4.1 Off-Alignment Works

Table 26 in section 9.3.7 outlined potential impacts associated with off-alignment roadworks. Only minor potential impacts were identified with the exception of Church Street and O'Connell Street north of Factory Street (already covered within Table 29) and specific mitigation measures are not anticipated to be required. However, impact assessment through flood modelling is recommended during detailed design once 3D alignments are developed, to confirm requirements for mitigation.

11 Summary

This report sets out the outcomes of a preliminary flooding and drainage assessment carried out for the Parramatta Light Rail EIS. The purpose of this report is to identify and assess the hydrology and flooding impacts of the project during both construction and operation. Additionally, this report address flood risks to the PLR infrastructure and operations.

Hydraulic models were developed for the project based on best available information and historic models provided. Notwithstanding the limited information provided, due care and diligence was carried out in developing models to determine existing flooding conditions, and the mechanisms that cause them.

Comparative assessments of baseline model results were made against historical studies and comparison with alternative hydrological methods was carried out. In addition, noting the general uncertainty in hydraulic modelling, a level of sensitivity analysis was carried out appropriate to the level of design development and available information. These processes confirmed the suitability of the models in assessing relative impacts for the PLR project.

To complement modelled results on existing flood depth, hydraulic categorisation and hazard, existing flood risk management plans and emergency management plans were reviewed to understand current flood management procedures within and adjacent to the PLR alignment. Appropriate stakeholders, including CoP and the SES were consulted in relation to emergency flood management.

Having determined the existing hazard and flooding mechanisms, the concept design road and rail alignment was incorporated into the TUFLOW flood models, along with a concept stormwater design, to enable assessment of impacts.

Performance criteria for the PLR project in terms of drainage and flooding were provided in section 8, along with the recommended level of flood protection to each element of the project.

Construction phase flood risks and impacts were qualitatively assessed using baseline flood depths and extents. These are summarised in section 9.1. Construction compounds and worksites with flood risks and potential for flood impact include Alfred Street, James Ruse Drive, Parramatta River Bridge South and Vineyard Creek. Bridge construction and modification generally along the

alignment has the potential to impact flooding. A Flood Management Strategy (FMS) would be prepared to address management of both flood risk and flood impact. Potential mitigation measures for construction phase flood impacts are identified in section 10.2.

Flood risk during the operation phase was assessed for each project element against the recommended level of flood protection previously identified. It was demonstrated that it is likely to be hydraulically feasible to achieve operability for the PLR in a 0.2EY event. It was also demonstrated that achievement of the recommended level of flood protection for the stabling and maintenance facility, traction substations and communications equipment could be achieved with the exception of the communications equipment located on the Tramway Avenue stop platform. An outline of potential operational flood emergency management protocols for the PLR was developed. Flood risk is described in section 9.2 with relevant mitigation measures provided in section 10.3.3.

Flood impact during the operation phase was assessed in the 1% AEP event. While the majority of impacts are contained within the road corridor, minor local impacts outside the road corridor are predicted at various locations. Detailed discussion on impacts is provided in section 9.3.2. It is noted that due to the extent of road network modification, a degree of afflux would occur solely as a consequence of change in road level, without significantly altering flood depth. A risk-based approach should be considered in further assessment.

A review of the peak velocities in Parramatta River was carried out to determine whether the PLR project would be likely to result in any increases to flow velocity in Parramatta River. It was found that the change in velocities as a result of the PLR project were generally minimal relative to the existing velocities in the river. Local changes in velocities were found near the PLR alignment and proposed bridges and would not result in potential for significant erosion and/or scour. Changes in peak flow velocity along the proposed PLR alignment are seen as a result of the inevitable change in road geometry. However, these changes are minimal and not likely to result in potential scour or erosion along the largely impermeable corridor.

The impact of raising levels by approximately 2m at the stabling and maintenance facility site was assessed for the PMF event. Results indicate that localised impacts of up to +400mm would occur within the surrounding road reserve. Further design development to address impacts within the road reserve would be undertaken during detailed design, including assessment of detailed stabling and maintenance facility grading plans, stormwater drainage within the facility and stormwater mitigation measures within affected roads.

Existing critical infrastructure was identified along the alignment, and no significant adverse impacts were identified for a PMF event. Results for the PMF event are to be considered broadly indicative only given the method of assessment, and require confirmation through detailed modelling in future project design stages. Future modelling would be required to assess impact of new bridges in the PMF event.

Change in hydraulic categorisation and provisional flood hazard were assessed. Results indicate that the project would have minimal impact on existing hydraulic

categorisation and flood hazard. The project is therefore considered unlikely to impact existing flood emergency management procedures. The potential impacts of future climate change were also assessed, in accordance with current guidance documents.

General mitigation measures to achieve performance outcomes, as well as specific mitigation measures to address local impacts are identified in section 10.3.4.

The TUFLOW models established for the EIS have been built for the sole purpose of determining existing flood conditions in the vicinity of the light rail alignment and likely impacts of the alignment on flood behaviour. As such, the results should not be used for identifying flood prone or impacted properties, and subsequently notification of Section 149 certificates. The models are considered a suitable base for further model development in subsequent stages of the PLR design. Requirements for the further development of the models are outlined in section 10.3.2.

Appendix A

Maps

- Map 5.1 Catchment Plan
- Map 5.2 Digital Terrain Mapping - Westmead Model
- Map 5.3 Digital Terrain Mapping - North Parramatta Model
- Map 5.4 Digital Terrain Mapping - Parramatta CBD Model
- Map 5.5 Digital Terrain Mapping - Camellia Model
- Map 5.6 Digital Terrain Mapping - Carlingford Model
- Map 5.7 Stormwater Network Mapping - Westmead Model
- Map 5.8 Stormwater Network Mapping - North Parramatta Model
- Map 5.9 Stormwater Network Mapping - Parramatta CBD Model
- Map 5.10 Stormwater Network Mapping - Camellia Model
- Map 5.11 Existing Drainage Performance - Westmead Model
- Map 5.12 Existing Drainage Performance - North Parramatta Model
- Map 5.13 Existing Drainage Performance - Parramatta CBD Model
- Map 5.14 Existing Drainage Performance - Camellia Model
- Map 5.15 1% AEP Existing Critical Storm Duration - Westmead Model
- Map 5.16 1% AEP Existing Critical Storm Duration - North Parramatta Model
- Map 5.17 1% AEP Existing Critical Storm Duration - Parramatta CBD Model
- Map 5.18 1 % AEP Existing Critical Storm Duration - Camellia CBD Model
- Map 5.19 1% AEP Existing Critical Storm Duration - Carlingford Model
- Map 7.1 Existing Peak Flood Depths - 0.2 EY - Westmead Model
- Map 7.2 Existing Peak Flood Depths - 0.2 EY - North Parramatta Model
- Map 7.3 Existing Peak Flood Depths - 0.2 EY - Parramatta CBD Model
- Map 7.4 Existing Peak Flood Depths - 0.2 EY - Camellia Model
- Map 7.5 Existing Peak Flood Depths - 0.2 EY - Carlingford Model - Sheet 1
- Map 7.6 Existing Peak Flood Depths - 0.2 EY - Carlingford Model - Sheet 2
- Map 7.7 Existing Peak Flood Depths - 5% AEP - Westmead Model
- Map 7.8 Existing Peak Flood Depths - 5% AEP - North Parramatta Model
- Map 7.9 Existing Peak Flood Depths - 5% AEP - Parramatta CBD Model
- Map 7.10 Existing Peak Flood Depths - 5% AEP - Camellia Model
- Map 7.11 Existing Peak Flood Depths - 5% AEP - Carlingford Model - Sheet 1
- Map 7.12 Existing Peak Flood Depths - 5% AEP - Carlingford Model - Sheet 2
- Map 7.13 Existing Peak Flood Depths - 1% AEP - Westmead Model
- Map 7.14 Existing Peak Flood Depths - 1% AEP - North Parramatta Model
- Map 7.15 Existing Peak Flood Depths - 1% AEP - Parramatta CBD Model
- Map 7.16 Existing Peak Flood Depths - 1% AEP - Camellia Model
- Map 7.17 Existing Peak Flood Depths - 1% AEP - Carlingford Model - Sheet 1
- Map 7.18 Existing Peak Flood Depths - 1% AEP - Carlingford Model - Sheet 2
- Map 7.19 Existing Hydraulic Categorisation - 1% AEP
- Map 7.20 Existing Hydraulic Hazard - 1% AEP
- Map 7.21 Existing Peak Flood Depths - PMF
- Map 8.1 Concept Stormwater Design - Westmead Model
- Map 8.2 Concept Stormwater Design - North Parramatta Model
- Map 8.3 Concept Stormwater Design - Parramatta CBD Model
- Map 8.4 Concept Stormwater Design - Camellia Model
- Map 8.5 Concept Stormwater Design - Carlingford Model - Sheet 1
- Map 8.6 Concept Stormwater Design - Carlingford Model - Sheet 2
- Map 9.1 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 1
- Map 9.2 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 2
- Map 9.3 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 3

Map 9.4 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 4
Map 9.5 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 5
Map 9.6 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 6
Map 9.7 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 7
Map 9.8 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 8
Map 9.9 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 9
Map 9.10 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 10
Map 9.11 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 11
Map 9.12 PLR Post-Construction Peak Flood Depths - 0.2 EY - Sheet 12
Map 9.13 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 1
Map 9.14 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 2
Map 9.15 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 3
Map 9.16 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 4
Map 9.17 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 5
Map 9.18 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 6
Map 9.19 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 7
Map 9.20 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 8
Map 9.21 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 9
Map 9.22 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 10
Map 9.23 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 11
Map 9.24 PLR Post-Construction Peak Flood Depths - 1% AEP - Sheet 12
Map 9.25 Impact of PLR Project - 1% AEP - Sheet 1
Map 9.26 Impact of PLR Project - 1% AEP - Sheet 2
Map 9.27 Impact of PLR Project - 1% AEP - Sheet 3
Map 9.28 Impact of PLR Project - 1% AEP - Sheet 4
Map 9.29 Impact of PLR Project - 1% AEP - Sheet 5
Map 9.30 Impact of PLR Project - 1% AEP - Sheet 6
Map 9.31 Impact of PLR Project - 1% AEP - Sheet 7
Map 9.32 Impact of PLR Project - 1% AEP - Sheet 8
Map 9.33 Impact of PLR Project - 1% AEP - Sheet 9
Map 9.34 Impact of PLR Project - 1% AEP - Sheet 10
Map 9.35 Impact of PLR Project - 1% AEP - Sheet 11
Map 9.36 Impact of PLR Project - 1% AEP - Sheet 12
Map 9.37 PLR Post-Construction Hydraulic Categorisation - 1% AEP
Map 9.38 Change in Hydraulic Hazard - 1% AEP - Westmead Model
Map 9.39 Change in Hydraulic Hazard - 1% AEP - North Parramatta Model
Map 9.40 Change in Hydraulic Hazard - 1% AEP - Parramatta CBD Model
Map 9.41 Change in Hydraulic Hazard - 1% AEP - Camellia Model
Map 9.42 Change in Hydraulic Hazard - 1% AEP - Carlingford Model - Sheet 1
Map 9.43 Change in Hydraulic Hazard - 1% AEP - Carlingford Model - Sheet 2
Map 9.44 Climate Change Impact on PLR Project - 0.2EY - Westmead Model
Map 9.45 Climate Change Impact on PLR Project - 0.2EY - North Parramatta Model
Map 9.46 Climate Change Impact on PLR Project - 0.2EY - Parramatta CBD Model
Map 9.47 Climate Change Impact on PLR Project - 0.2EY - Camellia Model
Map 9.48 Climate Change Impact on PLR Project - 0.2EY - Carlingford Model
Map 9.49 Climate Change Impact on PLR Project - 0.2EY - Carlingford Model

- Map 9.50 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Westmead Model
- Map 9.51 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - North Parramatta Model
- Map 9.52 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Parramatta CBD Model
- Map 9.53 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Camellia Model
- Map 9.54 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Carlingford Model Sheet 1
- Map 9.55 Impact of PLR Project with Lower Bound Climate Change - 1% AEP - Carlingford Model Sheet 2
- Map 9.56 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Westmead Model
- Map 9.57 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - North Parramatta Model
- Map 9.58 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Parramatta CBD Model
- Map 9.59 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Camellia Model
- Map 9.60 Impact of PLR Project with Upper Bound Climate Change - 1% AEP - Carlingford Model Sheet 1
- Map 9.61 Impact of PLR with Upper Bound Climate Change - 1% AEP - Carlingford Model Sheet 2
- Map 9.62 PLR Post-Construction Peak Flood Depths - PMF