NORTHWEST RAPID TRANSIT

PROJECT INTEGRATED MANAGEMENT SYSTEM

STORMWATER AND FLOODING MANAGEMENT PLAN

FOR

SYDNEY METRO NORTHWEST OPERATIONS, TRAINS and SYSTEMS PPP

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Stormwater and Flooding Management Plan Approval Records

Approval Record

FUNCTION	POSITION	NAME	SIGNATURE	DATE
Prepared by	IJV Flooding and Drainage Engineer	Jeffrey Mail		16/08/17
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Reviewed by	Peter Monsted	Environment Manager		17/8/17
Approved by	IJV Director	David Jackson		17/8/17.

Amendment Record

Changes made to this document since its last revision, which affect its scope or sense, are marked in the right margin by a vertical bar (|).

DATE	REV	AMENDMENT DESCRIPTION	BY	INITIALS
10/12/2014	A	Prepared for Phase 1 Works	Cameron Newling	CN
11/05/2017	B	Updated to include Phase 2 Works.	Jeffrey Mail Cameron Newling	CN/JM
11/08/2017	C	Updated to address comments from TfNSW	Cameron Newling	CN

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1 Introduction

This *Stormwater and Flooding Management Plan* (SFMP) outlines the stormwater and flooding management arrangements by which Northwest Rapid Transit (NRT), in partnership with Transport for NSW (TfNSW), is delivering the Operations, Trains and Systems (OTS) Public Private Partnership (PPP) component of the North West Rail Link (NWRL) Project. This plan has been prepared based on the assessments completed as part of the detailed design process.

NOTE: In June 2015, TfNSW changed the project's name to Sydney Metro Northwest (SMNW) (from the North West Rail Link) to reflect its role in Sydney's new railway network. Any references to the North West Rail Link in this plan can be assumed to be referring to the Sydney Metro Northwest. Similarly, the Rapid Transit Rail Facility (RTRF) is now known as the Sydney Metro Trains Facility (SMTF).

1.1 OTS PPP

Sydney Metro is Australia's largest public transport project. Sydney Metro Northwest, formerly known as the North West Rail Link, is the first stage of Sydney's new fully-automated metro system and will open to customers in the first half of 2019.

Stage 2, Sydney Metro City & Southwest, will extend metro rail under Sydney Harbour, through the CBD and southwest to Bankstown.

The $8.3 billion Sydney Metro Northwest will deliver eight new railway stations and 4,000 commuter car parking spaces to Sydney's growing North West. Services will start with a train every four minutes in the peak. The project also includes the upgrade and conversion of five existing railway stations to metro standards.

The OTS contract is a 15-year PPP project – the largest in the history of New South Wales as well as the largest of the three delivery contracts for Sydney Metro Northwest.

Northwest Rapid Transit is delivering Sydney's new generation metro trains; building the new stations and car parks; installing tracks, signalling, mechanical and electrical systems; building and operating the RTRF at Tallawong Road; upgrading and converting the railway between Epping to Chatswood to rapid transit standards; and operating Sydney Metro Northwest – including all maintenance work.

1.2 Purpose and Application

This SFMP describes how NRT will manage stormwater and flooding issues during Phase 1 and Phase 2 of the delivery of the OTS contract.

Figure 1 below illustrates the delineation of the Phase 1, ECRL Conversion and Phase 2 of the OTS Works.

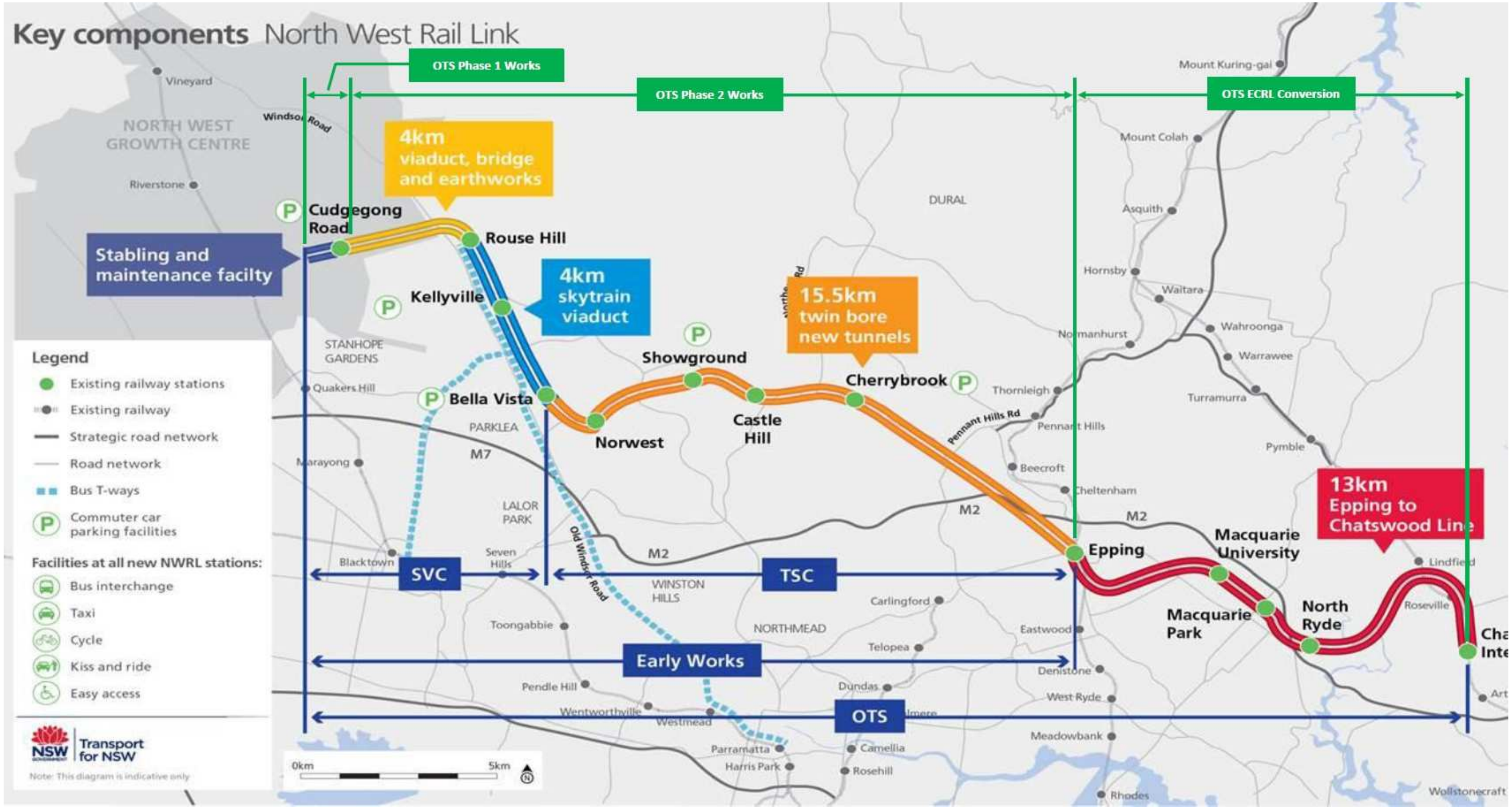


Figure 1 Schematic of NWRL OTS Phase 1, ECRL and Phase 2 Works

1.2.1 Phase 1 Works

In summary NWRL OTS Phase 1 covers the works associated with the delivery of the RTRF and the Cudgegong Road Precinct Enabling Works, being the works west of Cudgegong Road and including the initial earth works in the vicinity of Cudgegong Road Station – see Figure 2 below.

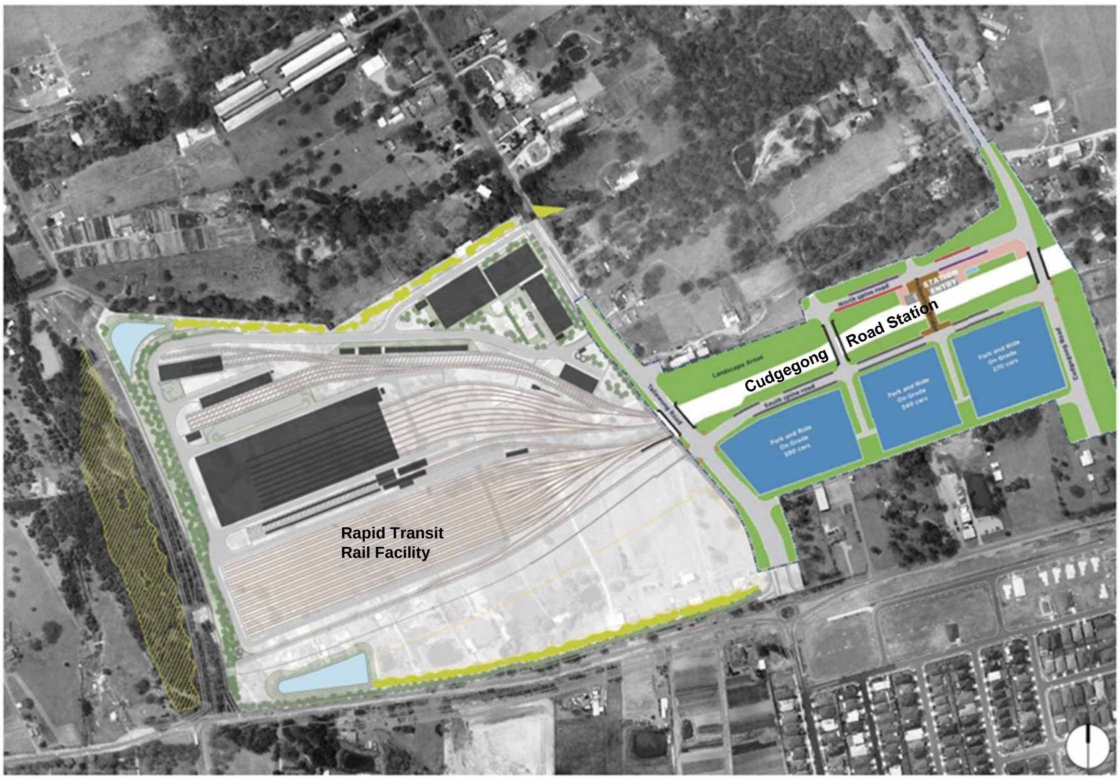


Figure 2 Indicative Layout of NWRL OTS Phase 1 Site: RTRF and Cudgegong Road Station

1.2.2 Phase 2 Works

Phase 2 Works refer to the construction of:

- New railway stations and precincts at Rouse Hill, Kellyville, Bella Vista, Norwest, Showground, Castle Hill and Cherrybrook (connecting to the Phase 1 works to the west and ECRL conversion works to the south-east. These works include the major civil construction work areas, including but not limited to the seven stations sites and six sites associated with the above rail corridor from Bella Vista to the Phase 1 work areas.
- Services facilities at Cheltenham and Epping
- Rail infrastructure and systems
- Infrastructure such as road works, pedestrian/cycle facilities, landscaping associated with construction of precincts and stations.

The scope of Phase 2 Works is illustrated in Figure 3 below.

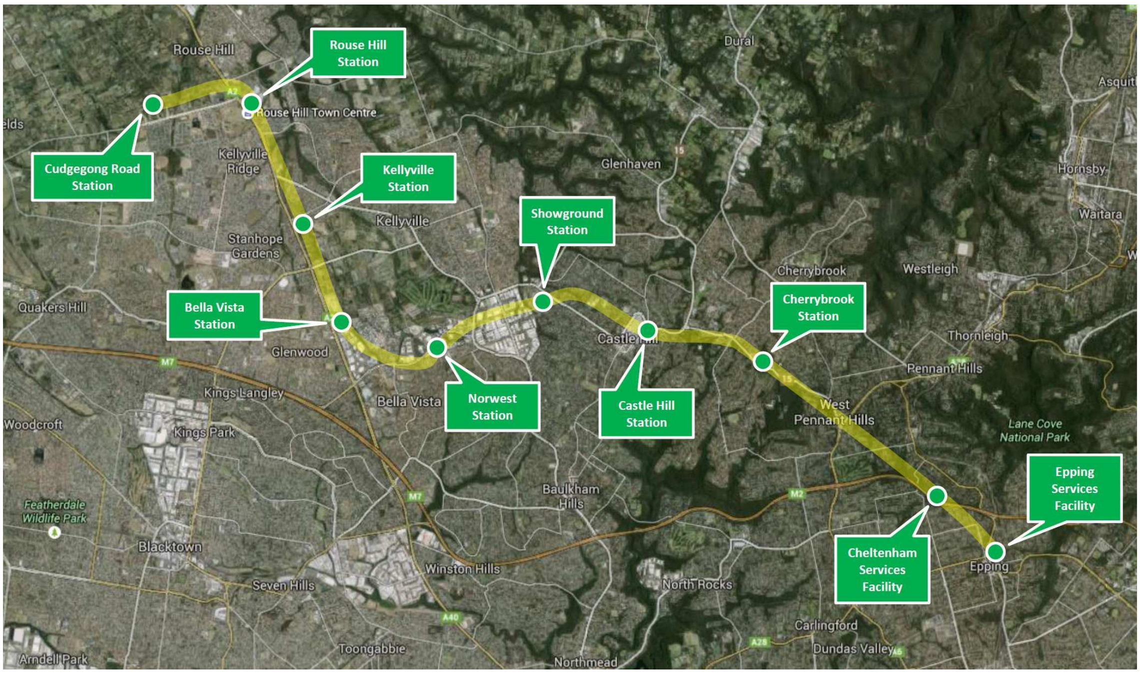


Figure 3 Indicative NWRL OTS Phase 2 Works Area

1.3 Requirements

This SFMP addresses the following requirements:

- Project Planning Approval – Rapid Transit Rail Facility (ref SSI-5931) – All Conditions applicable to Phase 1 NWRL OTS works.
- Project Planning Approval (and Modification 20 May 14) – NWRL Stage 2 – Stations, Rail Infrastructure & Systems (SSI-5414) – applicable to Phase 1 and Phase 2 NWRL OTS works, as defined in Staging Report
- Applicable Environmental Management Measures from Project EISs:
  - Environmental Impact Statement 2 (EIS2) and Submissions Report (including NWRL Stage 2 Stations, Rail Infrastructure and Systems (2012/3)
  - Environmental Impact Statement and Submissions Report – Tallawong Road, Rouse Hill Rapid Transit Rail Facility (JBA 2013)
- NWRL Construction Environmental Management Framework (Rev 1.4)
- Applicable Legislative Obligations.

The Compliance Matrix in Annexure B details how the SFMP complies with the requirements of the applicable Conditions of Approval (CoA) requiring the Plan to be prepared, consulted and approved. Annexure B provides a comprehensive list of compliance requirements, environmental documents and the contract documents. Additional detail on compliance management is also contained in Section 2.2.

1.4 NRT Environmental Management System

In accordance with the OTS Project Deed, Exhibit 1, Scope and Performance Requirements, Section 5.2, NRT must implement and maintain an effective Management System, which addresses all its obligations under the Deed.

The Management Systems must seamlessly integrate all NRT's systems and processes, including those related to rail safety and rail accreditation quality, environmental, sustainability, health and safety and they must accommodate, coordinate and give effect to the Project Plans.

Details of NRT's Integrated Management System including the integrated relationship of the SFMP with the other Project Plans and with the delivery Core Processes are contained in the Project Management Plan. As improvements are made to the processes and systems, these will be reflected in updates to the relevant Project Plans. All elements of the Integrated Management System will reside on Aconex as controlled copies. An intranet will contain a front page to the Integrated Management System with links between documents, processes and forms utilising the Aconex search engine.

1.5 Update and Ongoing Development

NRT will undertake the ongoing development, amendment and updating of the SFMP to ensure it remains consistent with Project priorities, risk management, client requirements and Project objectives, taking into account:

- The status and progress of NRT's activities
- Changes in the design, delivery and operations processes and conditions
- Lessons learnt during delivery and operations
- Changes in other related Project Plans
- Requirements and matters not covered by the existing Project Plans
- Changes to Plans resulting from any comments from the OTS Independent Certifier
- Changes to Project Plans as directed by TfNSW's Representative under the Deed.
- Changes to scope of works
- New areas included into NRT's brief.

1.6 Agency and Stakeholder Consultation

The Minister's Condition of Approval requires that the SFMP be prepared in consultation with the following stakeholders:

- Department of Strategies and Land Release
- Office of Environment and Heritage
- Blacktown City Council
- The Hills Shire Council

- Hornsby Shire Council

Annexure A details the consultation and relevant comments on this plan.

2 Legal and Other Requirements

2.1 Relevant Legislation

The key legislation relevant to stormwater and flooding management includes:

- *Environmental Planning and Assessment Act 1979* (EP&A Act)
- *Protection of the Environment Operations Act 1997* (POEO Act)
- *Water Management Act 2000* (WM Act)

Refer to the Construction Environmental Management Plan for details of relevant legislation.

2.2 Compliance Requirements

Relevant requirements from the CoA are summarised in the Compliance Matrix in Annexure B.

All compliance requirements associated with this sub plan including the Revised Environmental Management and Mitigation Measures from the NWRL Project Environmental impact assessments that are pertinent to this sub plan are tracked and reported via the compliance tracking program developed in accordance with CoA D5((a)-(h)).

2.2.1 Compliance with Conditions of Approval

Project Planning CoA C7 (RTRF Approval SSI-5931) and C33 (OTS Approval SSI-5414) states that the State Significant Infrastructure (SSI) shall be designed, to the extent that it is feasible and reasonable, to not worsen existing flood characteristics in the vicinity of the SSI. A definition of flood characteristics is provided in the condition and is included in the compliance matrix in Annexure B of this Plan.

Reasonable and feasible is defined below as the planning approval:

"Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context. Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements."

Hydrologic and hydraulic modelling completed for EIS 2 and the RTRF EIS predicted no significant impacts on existing flood characteristics in the vicinity of the Phase 1 works, even with the assumption of no mitigation measures being implemented during the construction phase (associated with construction sites and temporary infrastructure).

For Phase 2 works, compliance with CoA C33 will be achieved for the OTS works with mitigation measures in place.

Any mitigation and management measures identified in this report have been modelled in detail as part of the Design process.

2.3 Relevant Guidelines

2.3.1 Floodplain Development Manual

The NSW Government's Floodplain Development Manual – the Management of Flood Liable Land (2005) is concerned with the management of the consequences of flooding as they relate to the human occupation of urban and rural developments. The manual outlines the floodplain risk management process and assigns roles and responsibilities for the various stakeholders.

This Plan has been prepared in accordance with this manual. Results of modelling and mitigation are summarised in Section 7 and emergency response contained in Section 8.

2.3.2 Australian Rainfall and Runoff – Volume 1

Prepared by Engineers Australia, Australian Rainfall and Runoff – A Guide to Flood Estimation (2001) was written to "provide Australian designers with the best available information on design flood estimation". It contains procedures for estimating stormwater runoff for a range of catchments and rainfall events and design methods for urban stormwater drainage systems.

According to the document, for good water management, Master Planning should take into account:

- Hydrological and hydraulic processes
- Land capabilities
- Present and future land uses
- Public attitudes and concerns
- Environmental matters
- Costs and finances
- Legal obligations and other aspects.

2.3.3 Managing Urban Stormwater: Soils and Construction

Managing Urban Stormwater – Soils and Construction (4th edition, March 2004) are guidelines produced by Landcom to help mitigate the impacts of land disturbance activities on landforms and receiving waters by focusing on the removal of suspended solids in stormwater runoff from construction sites.

3 Roles and Responsibilities

The roles and responsibilities of key NRT Personnel with respect to heritage are as follows:

Table 1 Roles and Responsibilities

Project Director	Manage the delivery of the Project including overseeing implementation of stormwater and flood management Act as Contractor's Representative
Environment Manager	Oversee the implementation of all stormwater and flooding management initiatives
Environmental Planning and Approvals Manager	Assist in preparation of this plan and coordinate input from specialist consultants Review plan for compliance with relevant approvals
Design Manager	Oversee hydrological analysis and incorporation of required mitigation measures into the Design
Sustainability Manager	Coordinate the implementation of the sustainability strategy including assessment of potential impacts on climate change
Construction Manager Site Superintendent	Ensure compliance with this Plan Implement required controls
Environment Coordinators / Senior Environment Coordinator	Assist the Construction Managers in implementing this Plan Manage review and continual improvement of this Plan Inspecting and reporting on compliance Monitor weather forecasts and communicate the potential for flood events that may occur Provide advice on mitigation measures during flood events
Project Engineer	Assist the Construction Managers in implementing this Plan
Specialist Consultant	Hydrological analysis and design

3.1 Hydrological Specialist

NRT Infrastructure Joint Venture (IJV) has been engaged to provide expert advice which has been incorporated into this Plan.

The following key hydrological personnel have been involved in the preparation of this report.

- David Bannigan – Principal Water Resources Engineer
- Anton Kandiah – Principal Drainage Engineer
- Jeffery Mail – IJV Flooding and Drainage Engineer

Relevant CV / certification documentation vitae of the above persons demonstrating their experience are attached in Annexure E.

4 Aspects and Potential Impacts

The key aspects and potential impacts associated with overall management of stormwater and flooding during the delivery of Phase 1 and Phase 2 Works are listed in Table 2.

These are the key identified risks for the overall management of stormwater and flooding during the OTS Works.

Table 2 Summary of Overall Aspects and Potential Impacts

Aspects	Potential impacts/opportunities	Risk level for OTS Works (qualitative) (L=low, M=Med, H=High)
Flooding during extreme rainfall from adjacent waterways	• Overland flows/flooding from adjacent rivers/creeks during extreme rainfall events entering the worksites	M
Direct heavy rainfall on the site	• Flooding of excavations • Overtopping of sediment basins • Erosion and sedimentation	H
Localised flow paths causing nuisance flooding on the worksite	• Restricted access to areas • Erosion and sedimentation • Safety issues	M
Alterations to in-stream flow arrangements	• Some watercourses would be directly affected	L

5 Previous Assessments

Chapter 18 Surface Water of EIS 2 (AECOM 2012) contains a detailed assessment of the potential flooding impacts around the OTS Works. The findings from this assessment are provided in the sections below.

5.1 Epping Service Facility

EIS 2 provides the following flood findings at the Epping Service Facility:

- Probable Maximum Flood (PMF) flood level is 78.8 mAHD.
- Facility entry points are located above the PMF level and so the risk of mainstream flooding is low.
- Facility is located outside the PMF extent and so, apart from appropriate drainage design, no additional flood mitigation measures are required.

5.2 Cheltenham Service Facility

EIS 2 provides the following flood findings at the Cheltenham Service Facility:

- PMF flood level is not applicable – local drainage only.
- Facility is located outside the floodplain.
- Portal is located outside the PMF extent and as a result, apart from appropriate drainage design, no additional flood mitigation measures are required.

5.3 Cherrybrook Precinct

EIS 2 provides the following flood findings at the Cherrybrook precinct:

- The station and broader precinct is not affected by mainstream flooding. However, a local overland flowpath runs south to north across the site. Castle Hill Road lies to the south of the site. Flows in excess of the road drainage system capacity will collect at the low point adjacent to Glenhope Road. Some of these flows will enter the station precinct and travel south along the existing depression that runs through the centre of the site.
- Overland flow through the site in the PMF is estimated to be $1.7m^3/s$.
- Without appropriate site grading and drainage measures there is the potential for overflows from Castle Hill Road to enter the precinct and flood the station.
- Design of site grading and local drainage system within the station precinct to provide for the diversion of overland flows around the station opening.
- System to be designed to convey the PMF without ingress into the station, with appropriate allowance for drainage system blockage.
- Runoff draining to and through the site will be discharged into the natural depression at the north west corner of the site. This will be incorporated into the precinct design.

- Site grading and precinct layout designed to manage overland flows along roadways and landscaped areas.

5.4 Castle Hill Precinct

EIS 2 provides the following flood findings at the Castle Hill precinct:

- Station is located at the top of the catchment and therefore flood impacts are not anticipated.
- Apart from appropriate drainage design, no additional flood mitigation measures are required.
- Drainage design would include station entries at a minimum 0.3m above local ground elevations.
- Apart from appropriate drainage design and surface grading to cater for local overland flows no additional floodplain management measures are required.

5.5 Showground Precinct

EIS 2 provides the following flood findings at the Showground precinct:

- Station has been located above the PMF level for Cattai Creek flooding.
- The broader precinct is located outside the 100 year ARI flood extents. However, the southwest corner of the precinct is flood affected in the PMF. The area affected is confined to an access road and a small section of the multi-level carpark building. Access to the station off Carrington Road is outside the PMF extent.
- Station located outside the PMF extent.
- Drainage design would include station entries being a minimum 0.3m above local ground elevations.
- Western access road, adjacent to Cattai Creek, to be designed to manage flood impacts on Carrington Road and surrounding development.

5.6 Norwest Precinct

EIS 2 provides the following flood findings at the Norwest precinct:

- Station precinct is located adjacent to Norwest Boulevard, west of Strangers Creek. Preliminary hydraulic assessment has been carried out to determine the PMF level in Strangers Creek at Norwest Boulevard based on the conservative assumption of all runoff in the PMF flowing overland across the road.
- The station is located above the PMF level for Strangers Creek flooding. However, a minor tributary to Strangers Creek runs north along Brookhollow Avenue (along the western boundary to the station site).
- The PMF flow along Brookhollow Avenue is estimated to be 9.1m^3/s with a depth of 0.6m.

- Station located outside the PMF extent for mainstream flooding. Local overland flows along Brookhollow Avenue to be managed by elevating western entry points to the station a minimum 0.6m above road level or providing surface grading to cater for overland flows in the PMF.
- Otherwise, station entries shall generally be set a minimum 0.3m above local ground elevations.
- Buildings and entry points to station to be located 0.6m above Brookhollow Road or surface grading within precinct designed to manage overland flows through the site.

5.7 Bella Vista Precinct

EIS 2 provides the following flood findings at the Bella Vista precinct:

- The station and broader precinct is located above the PMF level for Elizabeth Macarthur Creek flooding.
- Immediately north of Bella Vista Station is a 700m long cutting that falls to a low point away from the station thus presents minimal risk of overland flows entering the station.
- Station located outside the PMF extent.
- Appropriate drainage design shall include setting of station entries a minimum 0.3m above local ground elevations.
- Apart from appropriate drainage design and surface grading to cater for local overland flows no additional floodplain management measures are required.

5.8 Kellyville Precinct

EIS 2 provides the following flood findings at the Kellyville precinct:

- The station is located above the PMF level for Elizabeth Macarthur Creek flooding.
- A small proportion of broader precinct along the eastern edge is affected by 100 year ARI flooding. The area affected is largely confined to proposed access road. A larger proportion of the precinct, including the area of carpark north of Samantha Riley Drive, is located within the PMF extent. Access to station from Old Windsor Road is outside the PMF extent.
- Station is located outside the PMF extent and so, apart from appropriate drainage design, no additional flood mitigation measures are required.
- Any filling within the floodplain associated with the construction of access roads or car parking to be designed to manage impacts on the surrounding development. Impacts on Old Windsor Road would be managed up to the PMF.

5.9 Rouse Hill Precinct

EIS 2 provides the following flood findings at the Rouse Hill precinct:

- Under the current viaduct design Rouse Hill Station is an elevated scheme, located above the PMF level.
- Located north of Caddies Creek Tributary 3 the precinct would be susceptible to inundation from flows that overtop Windsor Road at the Tributary 3 culverts. Previous hydraulic studies undertaken for the Windsor Road Transitway Project (Maunsell 2005a and 2005b) show that the Tributary 3 culvert crossing has in excess of a 100 year ARI capacity. Consequently, aside from runoff from the local drainage network, the precinct is not expected to be affected by flooding up to the 100 year ARI event. Access to station off Windsor Road is located outside the PMF extent. However, the rail service facility is located within the PMF extents.
- Station is located outside the PMF extent and so, apart from appropriate drainage design, no additional flood mitigation measures are required.
- Critical infrastructure within the facility to be designed above the PMF level.
- Precinct works within the floodplain would be designed to manage impacts on Windsor Road.

5.10 Cudgegong Road Precinct

Technical Paper 7 of EIS 2 – Surface Water and Hydrology (AECOM 2012) contained a detailed assessment of the potential flooding impacts around the Cudgegong Road Precinct. The conclusions from this assessment are provided below:

- The Station is located above the PMF level and so the risk of flooding from Second Ponds Creek is low.
- The existing site is largely undeveloped and contains a number of drainage lines and depressions that currently convey overland flows through the site.
- The Station is located outside the PMF extent and so, apart from appropriate drainage design, no additional flood mitigation measures are required.
- Apart from appropriate drainage design and surface grading to cater for local overland flows no additional broader floodplain management measures are required.

5.11 RTRF

Appendix G of the RTRF EIS – Soils, Surface Water and Hydrology Impact Assessment (SLR 2013) contained a detailed assessment of the potential flooding impacts at the RTRF. The conclusions from this assessment are provided below:

- During construction, earthworks, clearing and installation of outlet pipes from the detention basins along the western boundary of the proposed RTRF site will encroach into lands affected by the PMF and 100 year ARI flood. As the works would only be temporary and on the outer extent of the floodplain, there is considered to be negligible impact on downstream flooding or loss of floodplain storage and no further mitigation is required
- The indicative layout plan for the proposed RTRF shows two stormwater detention basins along the western site boundary with a combined water surface footprint of 5400m^2. These basins are situated outside the 100 year ARI flood extent but are

within the PMF floodplain. The edge of northern basin embankment and toe of the northern basin batter encroach within the PMF floodplain.

- Stormwater detention basin embankments are completely outside the 100 year ARI extent, which is the design standard for new development, and will not impact on downstream flooding.
- The basin embankments encroach on the PMF flood extent but the associated impacts will not affect design standard flooding.
- All other development and retaining walls are outside of the floodplain.

5.12 Corridor Works

Flooding was not assessed in this area in the EIS.

6 Flooding Assessment

6.1 Epping Precinct

6.1.1 Existing Catchment

The Epping Service Facility is immediately adjacent a tributary of Devlins Creek which has previously been concrete lined. To eliminate the risk of flood water entering underground structures, the entry threshold levels for the buildings and underground structures were set above modelled flood levels to prevent the ingress of flood water for all events up to and including the Probable Maximum Flood (PMF).

The design of the Maintenance Parking Area and site drainage infrastructure has been carried out to ensure overland flows from local catchments do not impact the buildings and underground structures for all rainfall events up to and including the Probable Maximum Precipitation (PMP).

6.1.2 Methodology

Modelling for the Epping Service Facility was carried out using the HEC-RAS software package. The model originally developed by AECOM for the EIS was verified and adopted for the determination of flood levels in the vicinity of the site buildings. The PMF level of 78.7m AHD has been adopted as the minimum level acceptable for any opening to buildings and underground structures.

The drainage infrastructure for the Epping Service Facility has been designed using the 12d analysis software for the 20yr ARI rainfall event in accordance with Hornsby Shire Council requirements. In addition to the consideration of flood hazard to people and vehicles in the 100yr ARI event, the grading of car parks and the provision of overland flowpaths has been made to convey runoff from the PMP rainfall event with no impact to the buildings and underground structures.

Modelled Scenarios

The following modelling scenarios were undertaken as part of the design development:

- Existing Scenario
- Proposed Scenario (Existing terrain + NWRL infrastructure)
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall).
- Ultimate Catchment Development conditions
- Additional Climate Change sensitivity analyses.

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipate with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchments affecting the Tributary was undertaken using Watershed Bound Network Model (WBNM) software to calculate the 100 year and PMF peak discharges.

Throughout the design phase, the peak storm events were identified and the corresponding peak hydrographs were extracted from the WBNM model and applied to the HEC-RAS hydraulic model of Epping Service Facility.

The events modelled to inform design development included:

- 100 year ARI, 120min duration
- 100 year ARI, 120min duration +10% Climate Change
- 100 year ARI, 120min duration +20% Climate Change
- 100 year ARI, 120min duration +30% Climate Change
- PMF, 30min duration.

The model parameters adopted are shown in Table 3.

The hydrological model makes no allowance for re-use of surface runoff water on site. The drainage system has been designed such that runoff entering the piped system is discharged through an on-site detention structure via grassed swales to the existing drainage system.

Hydraulic Modelling

The HEC-RAS hydraulic model applied the peak discharge results from the hydrologic model to the Devlins Creek Tributary topography. Classification of the topography with Manning's 'n' values was carried out in reference to the existing surface roughness and the proposed finished surface roughness assessment, and typical values are listed in the table below. Obstructions to the flow were based on inspections of aerial photography and detailed survey information.

Table 3 Adopted Manning's 'n' Values – Epping

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

The maintenance parking area and local catchment areas adjacent Beecroft Road were modelled in DRAINS in order to determine appropriate threshold levels for building and underground structure openings. The drainage infrastructure design from 12d was exported to DRAINS and the PMF peak discharge values for the local catchments were derived using the Generalised Short Duration Method.

6.2 Cheltenham Precinct

6.2.1 Existing Catchment

The Cheltenham Service Facility is located in the vicinity of a tributary of Devlin's Creek, however is not impacted by mainstream flooding. Although there is no mainstream flooding issue at the site, modelling was undertaken during design of the carpark and site drainage infrastructure to ensure overland flows from local catchments do not impact the buildings and underground structures for all rainfall events up to and including the PMP.

6.2.2 Methodology

Modelling during the design development has included the driveway modifications, the hardstand pavement and associated drainage infrastructure.

The drainage infrastructure for the Cheltenham Service Facility has been designed using 12d analysis software for the 20yr ARI rainfall event in accordance with Hornsby Shire Council requirements. In addition to the drainage consideration of flood hazard to people and vehicles.

Modelled Scenarios

The following modelling scenarios were undertaken in TUFLOW as part of the design development:

Proposed Scenario (Existing terrain + NWRL infrastructure) In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involves;

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event;
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchments affecting the site was undertaken using DRAINS software to calculate the 100 year and PMF peak discharges. The 100 year ARI rainfall intensities were sourced from the HSC supplied data, whilst values for the PMP were derived using the Generalised Short Duration Method.

The events which yielded the worst case overland flow situation included:

- PMF, 15min duration
- 100 year ARI, 15min duration.
- 100 year ARI, 15min duration +10% climate change
- 100 year ARI, 15min duration +20% climate change
- 100 year ARI, 15min duration +30% climate change

Hydraulic Modelling

A one and two-dimensional (1D2D) TUFLOW hydraulic model has been developed to represent the overland flow paths through the carpark and surrounding areas to determine overland flow levels, depths and velocities within and adjacent to the service facility site.

The following inputs and assumptions have been adopted as part of the civil design works:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, including pipes, bridges and culverts.
- A 0.5 m x 0.5 m grid was utilised in the model.
- Inflow hydrographs generated from the DRAINS hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 1D2D hydraulic model.
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. Selected locations had relatively constant flow cross sections, with boundaries perpendicular to the flow direction. General landscape grading extracted from the detailed survey information provided the surface slope applied at these boundaries.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 4 below.

Table 4 Adopted Manning's 'n' Values – Cheltenham

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022

Material/Surface Regions	Manning's 'n' value
Roads	0.013

6.3 Cherrybrook Precinct

A TUFLOW model has been developed for the precinct and surrounding roads. This model has been used to determine the extent of inundation from overland flow paths traversing the site and also to determine design flood levels. Options for the piped drainage were developed using 12d drainage design software and run through the flood model to ensure flood protection of the NWRL in all events up to and including the PMF.

6.3.1 Existing Catchment

Under existing conditions the piped drainage system along Castle Hill Road discharges into the station site opposite to Glenhope Road and is conveyed along an overland flow path that runs south to north across the site.

6.3.2 Methodology

Modelled Scenarios

During design development the Probable Maximum Flood scenario has been modelled using TUFLOW. The model configuration consisted of the existing terrain and pipe network, supplemented with the design changes to surface levels and the introduction of design formal drainage infrastructure.

Consideration of Climate Change;

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved the adoption of a 10% increase in design rainfall intensities for events up to the 100 year ARI event.

Potential increases in rainfall intensities have been addressed as part of the hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change. The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchment affecting the station was undertaken using DRAINS software to calculate the PMF peak discharge.

During the design development phase, the peak storm events were identified and the corresponding peak hydrographs were extracted from the DRAINS model and applied to the TUFLOW hydraulic model.

Hydraulic Modelling

A combined 1-dimensional/2-dimensional TUFLOW hydraulic model has been established to represent the flood affected areas adjacent to the station precinct and determine flood levels, depths and velocities within and adjacent to the Cherrybrook station precinct.

The following inputs and assumptions have been adopted as part of the analysis:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey and road design triangulations developed as part of the civil works;
- A 0.5 m x 0.5 m grid was utilised in the model;
- Inflow hydrographs generated from the DRAINS modelling were applied to the upstream boundaries and to individual catchment areas within the TUFLOW model extents;
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied at a series of downstream boundary locations within the model;
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model;
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 5 below.
- The existing network of pits and pipes has been incorporated into the model using ESTRY, the 1-dimensional component of TUFLOW 1D/2D modelling. Existing pipe and pit data was extracted from the Council supplied database of stormwater infrastructure combine with detailed survey 'as built' information. Proposed drainage pits and pipes as designed in the 12d software package were detailed for the proposed scenario

Table 5 - Adopted Manning's N values

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125

Material/Surface Regions	Manning's 'n' value
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

6.4 Castle Hill Precinct

6.4.1 Existing Catchment

The site is located in the upper reaches of the Cattai Creek catchment and is not subject to mainstream flooding. There are no significant flow paths traversing the site however the adjacent road reserves experience local overland flow paths in rainfall events exceeding the 10yr ARI of the existing pit and pipe system. These upstream catchments consist predominantly of road pavements, with low and medium density residential and commercial areas also contributing.

The local overland flow paths in McMullen Ave, Old Northern Road and Old Castle Hill Road affect the site in terms of the flood levels of overland flows within the road reserves. The proposed infrastructure has been assessed against flooding from these local flow paths to ensure the project receives the required protection against flood inundation.

6.4.2 Methodology

Modelled Scenarios

During design development the Probable Maximum Flood scenario has been modelled using TUFLOW. The model configuration consisted of the existing terrain and pipe network, supplemented with the design changes to surface levels and the introduction of design formal drainage infrastructure.

Consideration of Climate Change

Potential increases in rainfall intensities have been addressed as part of the drainage design carried out through design development. In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change involves:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event;
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the drainage design carried out during design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchment affecting the station was undertaken using DRAINS software to calculate the PMF peak discharge. During design development the peak storm event was identified and the corresponding peak hydrograph extracted from the DRAINS model and applied to the TUFLOW hydraulic model.

Hydraulic Modelling

A 1 and 2-dimensional (1D2D) TUFLOW hydraulic model has been developed to represent the overland flow paths through the station and surrounding roads to determine flood levels, depths and velocities within and adjacent to the station precinct. The following inputs and assumptions have been adopted as part of the design development:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, including pipes, bridges and culverts;
- A 0.5m x 0.5m grid was utilised in the model;
- Inflow hydrographs generated from the DRAINS hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 1D2D hydraulic models;
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. Selected locations had relatively constant flow cross sections, with boundaries perpendicular to the flow direction. Road grades extracted from the detailed survey information provided the surface slope applied at these boundaries;
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model;
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 6

Table 6 - Mannings N values

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

6.5 Showground Precinct

6.5.1 Project and Catchment Description

The Showground precinct is immediately adjacent Cattai Creek which is densely vegetated with steep banks on either side.

To eliminate the risk of flood water entering underground structures, the entry threshold levels for the buildings and underground structures were generally set above modelled flood levels or protected with raised ground levels to prevent the ingress of flood water for all events up to and including the Probable Maximum Flood (PMF).

The design of the car park and site drainage infrastructure has been carried out to ensure overland flows from local catchments do not impact the buildings and underground structures for all rainfall events up to and including the Probable Maximum Precipitation (PMP).

6.5.2 Methodology

Modelling for the Showground Facility was carried out using the HEC-RAS software package. The model originally developed by AECOM for the EIS was verified and adopted for the determination of flood levels in the vicinity of the site buildings and precinct roads.

The drainage infrastructure for the Showground precinct has been designed using the 12d analysis software for the 10yr ARI rainfall event in accordance with the Hills Shire Council requirements.

In addition to the consideration of flood hazard to people and vehicles in the 100yr ARI event, the grading of car parks and the provision of overland flowpaths has been made to convey runoff from the PMP rainfall event with no impact to the buildings and underground structures.

Modelled Scenarios

The following modelling scenarios were undertaken as part of the design development:

- Existing Scenario;
- Proposed Scenario (Existing terrain + NWRL infrastructure);
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall); and
- Additional climate change sensitivity analyses

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involves:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event;
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipate with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchments affecting Cattai Creek was undertaken using WBNM software to calculate the 100 year and PMF peak discharges.

The events modelled included:

- 100 year ARI, 120 min duration;
- 100 year ARI, 120 min duration +10% Climate Change;
- 100 year ARI, 120 min duration +20% Climate Change;
- 100 year ARI, 120 min duration +30% Climate Change;
- PMF, 30 min duration;

Hydraulic Modelling

The HEC-RAS hydraulic model applied the peak discharge results from the hydrologic model to the Cattai Creek topography. Classification of the topography with mannings 'n' values was carried out in reference to the existing surface roughness and the proposed finished surface roughness assessment, and typical values are listed in the table below. Obstructions to the flow were based on inspections of aerial photography and detailed survey information.

6.6 Norwest Precinct

6.6.1 Existing Catchment

The Norwest station precinct sits within the Norwest employment area characterised by large commercial buildings, extensive parking areas and road networks. Two upper tributaries flow in a northerly direction from the wider Norwest catchment, joining to become Strangers Creek approximately 500 m to the north of the proposed Norwest station. Strangers Creek is a tributary of Cattai Creek. The station precinct is not affected by mainstream flooding of Strangers Creek.

Norwest station is sited in a natural topographic valley prone to localised flash flooding. The station is affected by localised flooding from a small upstream catchment, approximately 6.5 hectares in size which drains along Brookhollow Avenue and Norwest Boulevard.

Proposed NWRL Infrastructure and Flooding Considerations

Norwest Station will be an underground station and consequently must be protected from the entry of flood waters in a Probable Maximum Flood (PMF). In a PMF, Flood waters will be conveyed along Brookhollow Avenue and west into Norwest Boulevard toward Strangers Creek predominantly along the road carriageways. The station entrance lift access and underpass entrance will be set above the PMF level to prevent water ingress.

6.6.2 Methodology

Modelled Scenarios

The following modelling scenarios were undertaken as part of the design development:

- Existing Scenario;
- Proposed Scenario (Existing terrain + NWRL infrastructure); and
- Climate Change Scenarios

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved;

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event;
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the drainage design development with all elements of the civil works designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis of the local catchment affecting the station was undertaken using DRAINS software to calculate the 100 year and PMF peak discharges.

The peak storm events were identified and the corresponding peak hydrographs were extracted from the DRAINS model and applied to the TUFLOW hydraulic model of Brookhollow Avenue and Norwest Boulevard. The events modelled through design development included:

- 100 year ARI, 15min duration +10% Climate Change
- 100 year ARI, 5min duration +10% Climate Change
- PMF, 15min duration

Hydraulic Modelling

A 2-dimensional TUFLOW hydraulic model has been established to represent the flood affected areas adjacent to the station precinct and determine flood levels, depths and velocities within and adjacent to Norwest station.

The following inputs and assumptions have been adopted as part of the design works:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey and road design triangulations developed as part of the civil works;
- A 0.5 m x 0.5 m grid was utilised in the model;
- Inflow hydrographs generated from the DRAINS modelling were applied to the upstream boundaries of the TUFLOW model;
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied at a series of downstream boundary locations within the model;
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model;

- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 7 below.

Table 7 Adopted Manning's 'n' Values – Norwest

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

6.7 Bella Vista Precinct

6.7.1 Existing Catchment

The Station precinct is located adjacent to Elizabeth Macarthur Creek in the Caddies Creek catchment. The catchment area upstream of Brighton Drive is 44 hectares and comprises a mixture of residential and commercial development. Between Brighton Drive and Balmoral Road, the catchment of Elizabeth Macarthur Creek increases to 104 hectares. The lower reaches of the catchment to Balmoral Road are largely undeveloped but future development has been planned as part of the North West Growth Centres.

The EIS identified flooding extents for Elizabeth Macarthur Creek in the vicinity of the BLV Station precinct which showed that the site is generally clear of the Probable Maximum Flood (PMF) extent. However encroachment into the eastern site boundary from the creek area adjacent can be observed. The proposed works would be located outside the PMF flood extent with the exception of the Celebration Drive extension which may encroach into the PMF flood extent. The current flood modelling undertaken for the proposed condition also confirms the EIS results.

A local crest exists in the catchment area between Windsor Road and the station resulting in an upstream catchment contributing overland flows towards the station area. The localised flooding resulting from short burst storms of high intensity due to the small catchment size is addressed through additional TUFLOW modelling.

6.7.2 Modelled Scenarios

The following modelling scenarios were undertaken during design development:

- Existing Scenario
- Proposed Scenario (Existing terrain + NWRL infrastructure)
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall).
- Ultimate Catchment Development conditions
- Additional Climate Change sensitivity analyses.

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis was undertaken using the WBNM software.

A validation of the existing WBNM models obtained from the approved EIS study (AECOM, 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the Caddies Creek catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results have therefore been deemed appropriate for use at this precinct. The events modelled for design development included;

- 100 year ARI, 120min duration
- 100 year ARI, 120min duration +10% Climate Change

- PMF, 60min duration

Aside from the adjusted impervious fraction (based on the revised catchment delineation), WBNM model parameters have remained as modelled in the EIS (AECOM 2012) study.

They are as shown in Table 8.

Table 8 Adopted Design Parameters – Bella Vista

Design Parameter	Parameter Value
Lag Parameter 'C'	1.3
Pervious Area Initial Loss	5 mm for design events up to 100 year ARI 0 mm/h for PMF event
Pervious Area Continuing Loss	2.5 mm for design events up to 100 year ARI 0 mm/h for PMF event

To assess the project impacts, the NWRL works were incorporated into the WBNM model through changes to the impervious percentages in the model to reflect the changes within the rail precinct and rail corridor.

Hydraulic Modelling

A 1 and 2-dimensional (1D2D) TUFLOW hydraulic model has been established to represent the creek and floodplain at Elizabeth Macarthur Creek and determine flood levels, depths and velocities within and adjacent to the Bella Vista precinct.

The following inputs and assumptions have been adopted as part of the design development;

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, including pipes, bridges and culverts.
- A 3m x 3m grid was utilised in the model.
- Inflow hydrographs generated from the revised WBNM hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 1D2D hydraulic model.
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. A slope of 1% was adopted.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Major culvert structures have been modelled in this TUFLOW model, levels and culvert dimensions have been confirmed via detailed survey where available.

- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 9.

Table 9 Adopted Manning's 'n' Values – Bella Vista

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

A separate TUFLOW model for the station and surrounds was also developed to simulate the flooding regime of the PMF to ensure the civil works provide adequate protection to the station and the tunnel. This model is also a combined 1-dimensional 2-dimensional model incorporating the drainage network of pits and pipes throughout the BLV precinct. This hydraulic analysis was performed for the interim and ultimate design stages.

6.8 Kellyville Precinct

6.8.1 Existing Catchment

Kellyville station and precinct is located within the Elizabeth Macarthur Creek catchment. The precinct is adjacent to the creek, which runs in a northerly direction parallel with Old Windsor Road. Elizabeth Macarthur Creek flows through a culvert beneath Memorial Avenue, east of the proposed Kellyville precinct. The creek then flows to the north towards Caddies Creek beyond the beyond the Kellyville site.

The Elizabeth Macarthur Creek catchment currently consists of low, medium density residential and mixed use/commercial areas. It is estimated that the current catchment area of approximately 220 hectares has an impervious percentage of approximately 30%, with this expected to increase significantly in the future.

There are no significant catchments upstream of the Kellyville precinct contributing overland flows through the site. Thus the flooding impacts are limited to local runoff from the precinct area and from the Elizabeth Macarthur creek floodway only.

The boundaries of the Kellyville Precinct works include approximately 9 hectares of land between Old Windsor Road and Elizabeth Macarthur Creek in the locality of Kellyville. The increased impervious area arising from the NWRL proposal would potentially result in increased frequency and magnitude of stormwater discharge leaving the site. However wider area water-cycle management mitigates stormwater impacts of developments in the catchment.

The EIS identified that a small portion of the Kellyville precinct is affected by the 100 year ARI flood in Elizabeth Macarthur Creek with a larger proportion affected in the PMF. The modelling indicates that flood affectation is limited to a relatively small area adjacent the eastern batter slope of the precinct. These impacts are not considered to be significant in terms of their reach and influence on flood hazards in the surrounding area.

6.8.2 Modelled Scenarios

Modelling for Kellyville Station was carried out using the TUFLOW model developed by AECOM for the EIS, verified and adopted for the determination of flood levels in the vicinity of the site buildings and precinct roads.

The drainage infrastructure for the station has been designed using the 12d analysis software for the 10yr ARI rainfall event in accordance with the Hills Shire Council requirements.

In addition to the consideration of flood hazard to people and vehicles in the 100yr ARI event, the grading of car parks and the provision of overland flow paths has been made to convey runoff from the PMP rainfall event with no impact to the buildings and underground structures

The following modelling scenarios were undertaken as part of the design phase:

- Existing Scenario;

- Proposed Scenario (Existing terrain + NWRL infrastructure); and

- Climate Change Scenarios.

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis was undertaken using the WBNM software.

A validation of the existing WBNM models obtained from the approved EIS study (AECOM 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the Elizabeth Macarthur Creek catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results. Checking of hydrological parameters was carried out and loss factors confirmed for all input hydrological data for the hydraulic modelling.

Some minor amendments have been made to the original catchment delineation to enable closer inspection of the flow regime where overland flow paths from the subject site meet the main creek flows. Based on the minor changes made to a small number of sub-catchment areas, revised flow rates have now been adopted within the Elizabeth Macarthur wider catchment.

The peak storm events were identified and the corresponding peak hydrographs were extracted from the updated WBNM model and applied to the TUFLOW hydraulic model of Elizabeth Macarthur Creek.

The events modelled for the design development included:

- 100 year ARI, 120min duration
- 100 year ARI, 120min duration +10% Climate Change
- PMF, 60min duration.

Aside from the adjusted impervious fraction (based on the revised catchment delineation), WBNM model parameters have remained as modelled in the EIS (AECOM 2012) study.

They are as shown in Table 10.

Table 10 Adopted Design Parameters – Kellyville

Design Parameter	Parameter Value
Lag Parameter 'C'	1.3
Pervious Area Initial Loss	5 mm for design events up to 100 year ARI 0 mm/h for PMF event

Design Parameter	Parameter Value
Pervious Area Continuing Loss	2.5 mm for design events up to 100 year ARI 0 mm/h for PMF event

To assess the project impacts, the NWRL works were incorporated into the WBNM model through changes to the impervious percentages in the model to reflect the changes within the rail precinct and rail corridor.

Hydraulic Modelling

A 1 and 2-dimensional (1D2D) TUFLOW hydraulic model has been established to represent the creek and floodplain at Elizabeth Macarthur Creek and determine flood levels, depths and velocities within and adjacent to the Bella Vista precinct.

The following inputs and assumptions have been adopted as part of the design development:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, including pipes, bridges and culverts.
- A 3m x 3m grid was utilised in the model.
- Inflow hydrographs generated from the revised WBNM hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 1D2D hydraulic model.
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. A slope of 1% was adopted.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Major culvert structures have been modelled in this TUFLOW model, levels and culvert dimensions have been confirmed via detailed survey where available.
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 11.

Table 11 Adopted Manning's 'n' Values – Kellyville

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2

Material/Surface Regions	Manning's 'n' value
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

6.9 Rouse Hill Precinct

6.9.1 Existing Catchment

Rouse Hill station and precinct is located within the Caddies Creek catchment on a small crest adjacent Windsor Road. This location on the crest results in a stormwater discharge north to Rouse Hill Drive, and to the south into Tributary 3 of Caddies Creek.

The wider Caddies Creek Tributary 3 and Rouse Hill Drive catchment currently consists of undeveloped open spaces, medium density residential areas and mixed use/commercial areas.

It is estimated that the current catchment area has an impervious percentage of approximately 12% where draining to Tributary 3, and approximately 8% draining to Rouse Hill Drive.

Proposed NWRL Infrastructure and Flooding Considerations

The EIS identified that the Rouse hill site is clear of the 100 year flood in Tributary 3 of Caddies Creek, but will experience some inundation from the southern boundary in the PMF.

The boundaries of the Rouse Hill station and precinct works include approximately 2.6 hectares of land to the east of Windsor Road adjacent the Rouse Hill Town Centre. No increase in impervious area will arise from the NWRL construction since the site consists of 90% existing impervious areas.

The upstream catchments draining to Tributary 3 of Caddies Creek is unlikely to experience an increase in impervious areas in the future, with the open area across Windsor Road reserved for use as the crematorium. North of Schofields Rd, an undeveloped area currently occupied in part by a shale quarry is zoned for future medium density residential.

6.9.2 Methodology

Modelled Scenarios

The following modelling scenarios were investigated through the detailed design phases:

- Existing Scenario;

- Proposed Scenario (Existing terrain + RTRF infrastructure);

- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall);

- Ultimate Catchment Development conditions;

- Additional Climate Change sensitivity analyses.

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis was undertaken using the WBNM software for the catchment draining to Caddies Creek Tributary 3.

A validation of the existing WBNM models obtained from the approved EIS study (AECOM, 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the Caddies Creek Tributary 3 catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results. Checking of hydrological parameters was carried out and loss factors confirmed for all input hydrological data for the hydraulic modelling.

The upstream catchments contributing overland flows to the Rouse Hill Drive corridor have been analysed using Drains software. The analysis included single catchments contributing overland flows to the Windsor Road/Rouse Hill Drive intersection and does not include and flow links/channel routing.

WBNM Hydrological Model

The design peak storm events identified in the AECOM WBNM model and the corresponding peak hydrographs applied to the HEC-RAS model were adopted as the base input hydrological data for Tributary 3 of Caddies Creek. The worst case events selected for hydraulic modelling included;

- 100 year ARI, 120min duration;

- 100 year ARI, 120min duration +10% Climate Change;

- 100 year ARI, 120min duration +20% Climate Change;

- 100 year ARI, 120min duration +30% Climate Change;

- PMF, 15 min duration

Aside from the adjusted impervious fraction (based on the revised catchment delineation), WBNM model parameters have remained as modelled in the EIS (AECOM 2012) study. They are as Table 12 below.

Table 12 Adopted Design Parameters – Rouse Hill

Design Parameter	Parameter Value
Lag Parameter ‘C’	1.3
Pervious Area Initial Loss	5 mm for design events up to 100 year ARI 0 mm/h for PMF event
Pervious Area Continuing Loss	2.5 mm for design events up to 100 year ARI 0 mm/h for PMF event

DRAINS Hydrological Model

Hydrologic analysis of the local catchment affecting the Rouse Hill Drive corridor was undertaken using DRAINS software to calculate the 100 year and PMF peak discharges.

The peak storm events were identified and the corresponding peak hydrographs were extracted from the DRAINS model and applied to the TUFLOW hydraulic model of Rouse Hill station and precinct. The events modelled for the analysis included:

- 100 year ARI, 25min duration;

- 100 year ARI, 25min duration +10% Climate Change;

- 100 year ARI, 25min duration +20% Climate Change;

- 100 year ARI, 25min duration +30% Climate Change;

- PMF, 15min dur

PMF sensitivity checking of the Ultimate scenario incorporating the future land use of the currently undeveloped upstream catchment to the north-west of the site has indicated no major concerns for the operation of the NWRL. The 100 year runoff from the above site in the developed scenario is anticipated to be attenuated back to the existing 100 year event as to not worsen overland flow conditions at Windsor Road.

Hydraulic Modelling

A 1 and 2-dimensional (1D2D) TUFLOW hydraulic model has been developed to represent the overland flow paths through the station precinct and surrounding areas to determine overland flow levels, depths and velocities within and adjacent to the station site. The following inputs and assumptions have been adopted as part of the civil design works:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, including pipes, bridges and culverts.
- A 0.5 m x 0.5 m grid was utilised in the model.
- Inflow hydrographs generated from the DRAINS hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 12D hydraulic model.
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. Selected locations had relatively constant flow cross sections, with boundaries perpendicular to the flow direction.
- Road/Tributary invert grades extracted from the detailed survey information provided the surface slope applied at these boundaries.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Major culvert structures under Rouse Hill Drive have been modelled in this TUFLOW model, levels and culvert dimensions have been confirmed via detailed survey where available.

6.10 Cudgegong Road Precinct

6.10.1 Design Development

The concept design was based on the results of modelling by AECOM which showed that the project would not be impacted by the 100 year ARI flood and Probable Maximum Flood (PMF) in Second Ponds Creek.

During design development a new TUFLOW model has been developed for Second Ponds Creek. This model has been used to determine design flood levels for Second

Ponds Creek which is the receiving waterway for the Cudgegong Road Station OTS works.

6.10.2 Methodology

Modelled Scenarios

The following modelling scenarios were undertaken during design development:

- Existing Scenario
- Proposed Scenario (Existing terrain + NWRL infrastructure)
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall).
- Ultimate Catchment Development conditions
- Additional Climate Change sensitivity analyses.

Consideration of Climate Change

In accordance with the Northwest Rail Link Hydrology and Drainage Report prepared for the reference design, and recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on stormwater involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the drainage design development with all elements of the civil works designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project.

Hydrology

Hydrologic analysis was undertaken using the WBNM software.

A validation of the existing WBNM models obtained from the approved EIS study (AECOM 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the Second Ponds Creek catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results have therefore been deemed appropriate for use at this precinct.

During detailed design, the peak storm events were identified and the corresponding peak hydrographs were extracted from the WBNM models and applied to the TUFLOW hydraulic model of Second Ponds Creek. The events modelled for design development included:

- 100 year ARI, 120 min duration
- 100 year ARI, 120 min duration +10% Climate Change
- PMF, 45min duration.

All WBNM parameters have remained as modelled in the EIS AECOM (2012) study; these are shown in Table 13.

Table 13 Adopted Design Parameters – Cudgegong Road

Design Parameter	Parameter Value
Lag Parameter 'C'	1.3
Pervious Area Initial Loss	5 mm for design events up to 100 year ARI 0 mm/h for PMF event
Pervious Area Continuing Loss	2.5 mm for design events up to 100 year ARI 0 mm/h for PMF event

To assess the project impacts, the NWRL works were incorporated into the WBNM model through changes to the impervious percentages in the model, to reflect the changes within the rail precinct and rail corridor.

Hydraulic Modelling

A 2-dimensional TUFLOW hydraulic model has been established to represent the creek and floodplain at Second Ponds Creek and determine flood levels, depths and velocities within and adjacent to the Cudgegong Road station precinct and rail line.

The following inputs and modelling assumptions have been adopted in the hydraulic model;

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey and road design triangulations (Schofields Road design) provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, most notably the Schofields Road bridge crossing of Second Ponds Creek (including abutments) in the vicinity of the station precinct.
- A 2m x 2m grid was utilised in the model.
- Inflow hydrographs generated from the revised WBNM hydrologic modelling were applied to the upstream boundaries of the TUFLOW model. This approach applies to the existing and proposed scenarios whereby the hydrologic model handles losses and runoff generation leaving the routing of runoff and determination of flood levels to the 1D2D hydraulic model.

- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. A slope of 1% was adopted.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Flow constriction cells have been applied to model the bridge piers across Schofields Road.
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces.
- To assess the project impacts, the post NWRL WBNM discharges were input to the TUFLOW model. The effect of the SVC works was also included at Second Ponds Creek rail crossing through the use of elevated terrain model levels in the TUFLOW model to represent abutment finished surface levels.
- Bridge piers have been modelled using flow constriction cells, a method which employs an empirical value for flow constriction calibrated against other methods of modelling creek flow regimes. In this case HEC-RAS modelling was used to calibrate the empirical value of cell flow constriction incorporated into the TUFLOW model.

6.11 RTRF

6.11.1 Design Development

The concept design was based on the results of modelling by AECOM which showed that the project would not be impacted by the 100 year ARI flood and would be minimally impacted by the Probable Maximum Flood (PMF) in First Ponds Creek.

For the detailed design, a new TUFLOW model has been developed for First Ponds Creek and this model has been used to determine design flood levels for the RTRF Site and to assess the project impacts.

Two detention basins have been proposed with a combined volume of 12,750 m^3 which has been specified as minimum volume in the project EIS.

6.11.2 Methodology

Modelled Scenarios

The following modelling scenarios were undertaken as part of the design development:

- Existing Scenario
- Proposed Scenario (Existing terrain + NWRL infrastructure)
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall).
- Ultimate Catchment Development conditions
- Additional Climate Change sensitivity analyses.

Consideration of Climate Change

In accordance with the recommended procedures set out in DECCW's Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydraulic modelling carried out during drainage design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

The design has been carried out to best practice with regard to climate change, informed in part by the DECC Guidelines on the Practical Consideration of Climate Change. The Delivery Phase Sustainability Management Plan (NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B) risk assessment which is detailed in Section 4.1, Table 34 details the Adaption Actions which have been incorporated through detail design of the OTS project. The Plan NWRLOTS-NRT-PRD-PM-PLN-000818 - Appendix B and Adaption Actions contained within it have been reviewed and certified as meeting all the requirements of the OTS Deed, with the OTS Independent Certifier's Project Plan certificate being issued 27 March 2015.

Hydrology

Hydrologic analysis was undertaken using the WBNM software.

A validation of the existing WBNM models obtained from the approved EIS study (AECOM 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the First Ponds Creek catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results. Some minor amendments have been made to the original catchment delineation due to the newly constructed Schofields Road upgrade. Based on the minor changes made to a small number of sub-catchment areas, revised flow rates have now been adopted within the First Ponds Creek wider catchment.

During design development, the peak storm events were identified and the corresponding peak hydrographs were extracted from the updated WBNM model and applied to the TUFLOW hydraulic model of First Ponds Creek. The events modelled included:

- 100 year ARI, 120min duration
- 100 year ARI, 120min duration +10% Climate Change
- PMF, 45min duration.

Aside from the adjusted impervious fraction (based on the revised catchment delineation), WBNM model parameters have remained as modelled in the EIS (AECOM 2012) study. They are as shown in Table 14 below.

Table 14 Adopted Design Parameters – RTRF

Design Parameter	Parameter Value
Lag Parameter 'C'	1.3
Pervious Area Initial Loss	5 mm for design events up to 100 year ARI 0 mm/h for PMF event
Pervious Area Continuing Loss	2.5 mm for design events up to 100 year ARI 0 mm/h for PMF event

To assess the project impacts, the NWRL works were incorporated into the WBNM model through changes to the impervious percentages in the model to reflect the changes within the rail precinct and rail corridor.

Hydraulic Modelling

A 2-dimensional TUFLOW hydraulic model has been established to represent the creek and floodplain at First Ponds Creek and determine flood levels, depths and velocities within and adjacent to the RTRF facility.

The following inputs and assumptions have been adopted as part of the detailed design works:

- The TUFLOW digital terrain model has been based on aerial laser survey data (ALS), and supplemented with detailed topographical survey and road design triangulations (Schofields Road design) provided by TfNSW. Additional detailed survey data has been obtained to define hydraulic structures, most notably the Schofields Road bridge crossing of First Ponds Creek (including abutments) in the vicinity of the station precinct.
- A 2 m x 2 m grid was utilised in the model.
- Inflow hydrographs generated from the revised WBNM hydrologic modelling were applied to the upstream boundaries of the TUFLOW model.
- A rating curve (stage-discharge relationship) based on the local hydraulic gradient was applied as the downstream boundary condition of the model. A slope of 1% was adopted.
- Losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model.
- Major culvert structures have been modelled in this TUFLOW model, most notably the Gordon Road culvert. Invert levels and culvert dimensions have been confirmed via site inspection and detailed survey.
- Flow constriction cells have been applied to model the bridge piers across Schofields Road.
- Detention basins have been incorporated in the TUFLOW model.
- Manning's 'n' roughness coefficients were applied to regions within the catchment based on the bed resistance of material/natural surfaces. The values adopted are shown in Table 15 below.

Table 15 Adopted Manning's 'n' Values – RTRF

Material/Surface Regions	Manning's 'n' value
Water Surface	0.035
Buildings	0.2
Asphalt/Parking Areas	0.013
Light Vegetation	0.05
Dense Vegetation	0.12
Residential Areas	0.125
Train Lines	0.015
Unsealed Roads	0.022
Roads	0.013

To assess the project impacts, the post NWRL WBNM discharges were input to the TUFLOW model.

6.12 Corridor Works

6.12.1 Existing Catchment

The corridor works are located within the Caddies and Elizabeth Macarthur Creek catchments and comprise segments of shared path located between Bella Vista and Rouse Hill Stations. The proposed shared path route crosses a number of watercourses including Caddies Creek Tributaries 3 and 4 and Elizabeth Macarthur Creek, just upstream of the confluence with Caddies Creek.

The Elizabeth Macarthur Creek catchment currently consists of low, medium density residential and mixed use/commercial areas. It is estimated that the current catchment area of approximately 220 hectares has an impervious percentage of approximately 30%, with this expected to increase significantly in the future.

The boundaries of the Bella Vista Precinct works include approximately 14 hectares of land between Old Windsor Road and Elizabeth Macarthur Creek in the localities of Bella Vista and Kellyville. The Kellyville Precinct works include approximately 9 hectares of land between Old Windsor Road and Elizabeth Macarthur Creek in the locality of Kellyville.

The increased impervious area arising from the NWRL proposal would potentially result in increased frequency and magnitude of stormwater discharge leaving these sites. However wider area water-cycle management implemented by Sydney Water

Corporation (SWC) mitigates the stormwater impacts of developments in the catchment.

The EIS has not addressed flood risk for the Corridor Works package specifically as this is a new works package developed in detailed design phase. The shared path has been located generally clear of the 100 year flood extent for Elizabeth Macarthur Creek, with the exception of crossings and drainage elements discharging flows of a smaller design ARI than those of major floods.

6.12.2 Methodology

Modelled Scenarios

The following modelling scenarios were undertaken as part of the design development;

- Existing Scenario;
- Proposed Scenario (Existing terrain + NWRL infrastructure); and
- Climate Change Scenario (Proposed Scenario +10% Additional Rainfall).
- Climate Change Scenario (Proposed Scenario +20% Additional Rainfall).
- Climate Change Scenario (Proposed Scenario +30% Additional Rainfall).

Consideration of Climate Change

In accordance with the recommended procedures set out in the DECCW – Guidelines on Practical Considerations of Climate Change (2007), the adopted approach to manage the potential impacts of climate change on flooding involved:

- Adopting a 10% increase in design rainfall intensities for events up to the 100 year ARI event;
- Undertaking sensitivity analyses for increases in rainfall intensity of 20% and 30% to identify areas of the project that may be sensitive to further potential increases in design rainfall intensities.

Potential increases in rainfall intensities have been addressed as part of the hydrologic and hydraulic modelling carried out during design development. All elements of the civil works including the pit and pipe stormwater network have been designed in accordance with the approach above, adopting the increased rainfall intensity anticipated with climate change.

Hydrology

Hydrologic analysis was undertaken using WBNM software. A validation of the existing WBNM models obtained from the approved EIS study (AECOM, 2012) has been undertaken to confirm the results of the previously approved study. An analysis of the Elizabeth Macarthur Creek catchment was found to show similar characteristics to that of the approved EIS model and the AECOM WBNM results. Checking of hydrological parameters was carried out and loss factors confirmed for all input hydrological data for the hydraulic modelling.

Some minor amendments have been made to the original catchment delineation at the Bella Vista precinct to enable closer inspection of the flow regime where site overland flow paths meet the main creek flows. Based on the minor changes made to a small number of subcatchment areas, revised flow rates have now been adopted within the Elizabeth Macarthur wider catchment.

Peak storm events were identified and the corresponding peak hydrographs were extracted from the WBNM models and applied to the TUFLOW hydraulic model of Caddies Creek.

The events modelled during design development included:

- 100 year ARI, 120min duration;
- 100 year ARI, 120min duration +10% Climate Change;
- 100 year ARI, 120min duration +20% Climate Change;
- 100 year ARI, 120min duration +30% Climate Change;
- PMF, 45min duration

Hydraulic Modelling

A 2-dimensional TUFLOW hydraulic model was established by AECOM for the EIS Surface Water and Hydrology Studies to assess flood levels in Caddies Creek and tributaries including Elizabeth Macarthur Creek.

The AECOM TUFLOW model forming the basis of the flood assessment documented in the EIS was reviewed and updated with the adopted rail alignment and pier arrangements throughout the SVC package design development.

This model has been further updated and now includes the wider NWRL project precincts including Bella Vista Station and Kellyville Station, and the corridor works package including the shared user path and Rouse Hill Traction Substation.

The following inputs and assumptions have been adopted:

- A 3 m x 3 m grid was utilised in the model;
- Inflow hydrographs generated from the WBNM hydrologic modelling were applied TUFLOW model;
- Infiltration losses have been applied through the hydrological model and therefore not incorporated in the hydraulic TUFLOW model

7 Flood Impacts and Mitigation

7.1 Permanent Works

Table 16 Permanent Works Flood Impacts and Mitigation

Site Name	Potential Flooding Impacts	Required Flood Mitigation
Epping Precinct	The flood models developed have been used to quantify flood behaviour in the vicinity of the Epping Service Facility site under existing and proposed conditions. The outcomes of these models allows for informed design decisions relating to the development of the civil works and on the management of flood risks and impacts. The assessment has included consideration of climate change impacts as well as flood behaviour in events greater than the 100 year ARI event. See Figure 12 and Figure 13. **Flood Extents** The Epping Service Facility is located outside of the 100 year ARI flood extent, but does encroach into the PMF extent. **Flood Level Impacts** 100 year event In the 100 year event there is no change in flood level from the existing to the proposed scenarios. No areas experience a change in flood level in excess of the 50 mm limit on afflux in this flood event. PMF Potential increases in flood levels in the Devlin's Creek Tributary of up to 300 mm are anticipated during the PMF event. This increase in level does not contribute any significant increase in flooded areas (and thus hazard) due to the relatively steep topography adjacent the tributary. Areas immediately upstream of the site, experience the increase in levels up to the potential maximum of 300 mm, with areas downstream experiencing a drop in flood level during the PMF event. **Time of inundation** The project does not impact the time of inundation experienced in the Devlin's Creek Tributary.	The Epping Service Facility works are outside the 100 year event flood extents in the adjacent tributary, resulting in no impacts during these flood events. Building threshold levels are outside the extents of the PMF event and have the required freeboard to 100 year flood event levels. Local drainage infrastructure for the maintenance parking area adjacent to Beecroft Rd has been designed in accordance with the relevant standards to manage local overland flows including the 100year and PMF storm events. The worst case PMF event was used to determine the building entry levels for the service facility

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	There are no elements of the design below the 100 year ARI flood level and therefore no impact on the flow regime in a 100 year flood event. **Potential for Soil Scour** There is no increase in velocity experienced within the Devlin's Creek Tributary in a 100 year event as a result of the project works. The Project does not impact the potential for soil erosion or scouring in the Tributary.	
Cheltenham Precinct	The TUFLOW model developed for the site has been used to quantify overland flow behaviour in the vicinity of the Cheltenham Service Facility under proposed conditions. The outcomes from this modelling allowed for informed design decisions relating to the development of the works and on the management of flood risks and impacts. All openings to the Service facility are located 0.3m above the 100 year ARI flow path levels and above all flow paths during the PMF. The assessment has included consideration of climate change impacts as well as flood behaviour in events greater than the 100 year ARI event. See Figure 14 and Figure 15. **Flood Extents** The Cheltenham Service Facility is located outside of the mainstream 100 year ARI flood and PMF extents. **Flood Level Impacts** As the Cheltenham Service Facility is located outside of the mainstream flood extents, changes to the site do not result in flood level impacts to mainstream flooding.	The Cheltenham Service Facility works impact on local flow paths only and will have no major effect on mainstream flooding conditions. Building threshold levels are outside the extents of the PMF event and have the required freeboard to 100 year flood event levels.
Cherrybrook Precinct	The flood models developed for the site have been used to quantify flood behaviour in the vicinity of the Cherrybrook station site under proposed conditions. The outcomes of the modelling allows for informed design decisions relating to the development of the works and on the management of flood risks and impacts. The proposed scenario flood extents for the PMF event is shown in Figure 16. **Flood Extents** Local overland flows from site catchments and the surrounding roads travel down Precinct Street A from the east and west, meeting at the road low point outside the main entrance to the station. The cross section of Precinct Street A has been optimised such that overland flows are directed to the northern kerb of the street and during rainfall events in excess of the design capacity of the piped	The openings to underground structures have been identified and designed to be above the PMF level, with an additional requirement that such openings be 300 mm above the adjacent ground levels. The Cherrybrook Station and precinct works impact on local flow paths only and have no effect on mainstream flooding conditions. Station threshold levels are outside the extents of the PMF event and thus underground parts of the NWRL are protected from the ingress of water.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	drainage infrastructure flows spill through the northern pedestrian access. **Flood Level Impacts** The NWRL at Cherrybrook station does not negatively affect overland flows in the existing road network. At the low point in Castle Hill Road the drainage amenity is improved with the introduction of the piped drainage infrastructure, and the resulting ponding during extreme events shall be reduced. New flow paths are created in Precinct Street A which do not correlate with any quantifiable flow path in the existing scenario.	
Castle Hill Precinct	The flood model developed during design development has been used to quantify flood behaviour in the vicinity of the Castle Hill station site under proposed conditions. The outcomes of the modelling allowed for informed design decisions relating to the design development and on the management of flood risks and impacts. See Figure 17. **Flood Extents** The flood extents in the Castle Hill Station area are shown in the figure below. Overland flows from the site catchments are split between Old Northern Road and Old Castle Hill Road. The flow carrying capacity of these road reserves is such that in the event of a PMF, overland flows are directed longitudinally away from the station entrance. The overland flow experienced in McMullen Ave is a result of the upstream catchment of Old Northern Road. This flow passes the site without having an effect on the NWRL service building entry located off McMullen Ave. The driveway associated with this service building has been designed to direct overland flows from site catchments toward a new swale, to be provided along the boundary of the site, carrying flows downstream toward McMullen Ave. **Flood Level Impacts** The openings to underground structures have been identified and designed to be above the PMF level, with an additional requirement that such openings be 300 mm above the adjacent ground levels. The following figures reveal the critical architectural locations in determining the appropriate building threshold levels to design for the PMF.	The Castle Hill Station and precinct works impact on local flow paths only and have no effect on mainstream flooding conditions. Station threshold levels are above the levels of the PMF event and thus underground parts of the NWRL are protected from the ingress of water.
Showground Precinct	The flood models developed have been used to quantify flood behaviour in the vicinity of the Showground precinct site under existing and proposed conditions. The outcomes of these models allows for informed design decisions relating to the development of the design and on the management of flood risks and impacts. The assessment has included consideration of climate	The Showground precinct works impact on PMF flood behaviour only and will have no major effect on mainstream flooding conditions. Building threshold levels are outside the extents of the

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	change impacts as well as flood behaviour in events greater than the 100 year ARI event. **Flood Extents** Figure 18 and Figure 19 indicate the flooding extents for the scenarios modelled in the hydraulic analysis. **100 year** The Showground precinct is located outside of the 100 year ARI flood extent so no changes to the flooding regime in Cattai Creek is observed as a result of the project works. **PMF** The PMF scenario inundation across the precinct street is limited to the road reserve. Protection of the carpark and buildings beyond the road reserve is achieved by maintaining the standard cross-section of the Precinct Street through the area of inundation. **Flood Level Impacts** The provision of the detention basin for the attenuation of the proposed scenario runoff ensures that there is no increase in peak flows reaching Cattai Creek. All project works are located outside the extents of the 100 year flood, with no negative impacts influencing flood levels. Potential changes in flood levels in Cattai Creek during the PMF event are limited to areas immediately adjacent PMF inundation of precinct roads. These potential increases in level do not contribute any increase in flooded area due to the relatively steep topography adjacent the tributary. **Time of inundation** As the Showground Station precinct is located outside of the mainstream flood extents in the 100 year flood, changes to the site do not result in time of inundation impacts to mainstream flooding. **Potential for Soil Scour** The project does not have a significant impact on existing flooding regimes in terms of time of inundation or velocity as indicated by the modelling results as the profile of the water level curve against time does not change significantly in the 100year modelling from existing to proposed scenarios.	PMF event and have the required freeboard to 100 year flood event levels.
Norwest Precinct	The flood models developed have been used to quantify flood behaviour in the vicinity of the Norwest station site under existing and proposed conditions. The outcomes of these models allows for informed design decisions relating to the development of the works and on the	The Norwest Station and precinct works impact on local flow paths only and have no effect on mainstream flooding conditions. Station threshold levels are outside the extents of the PMF event

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	management of flood risks and impacts. See Figure 20 and Figure 21. The assessment has included consideration of climate change impacts as well as flood behaviour in events greater than the 100 year ARI event. **Time of Inundation and Velocity** Through the assessment of flooding at the site it has been determined that the worst case flooding occurs during shorter storms of high intensity. The duration of the inundation across the site in these worst case storms is approximately 25 minutes, with the changes due to construction of the NWRL having no significant impact on the time of inundation or maximum velocities experienced in the area. The flow hydrographs indicate a typical section across Brookhollow Ave experiences a slight shortening in time of inundation under proposed conditions. The nature of flash flooding is such that inundation is not extended, with flows quickly dispersing further downstream. For longer duration storms a similar trend to that from the worst case storm can be observed. The slight changes to the flow rates experienced across the model result in no significant change in velocities through the major flow paths. Typical sections of both Brookhollow Avenue and Norwest Boulevard are generally widened, with the crossfall not becoming significantly greater in the proposed scenario. As a result of these changes in cross section to the two major flow paths, the velocities experienced are not increased **Flood Extents** The existing scenario flood extents for the 100 year ARI and PMF events are shown and The 100 year ARI climate change (+10% rainfall intensity) and PMF flood extents in relation to the proposed site are shown. Under existing conditions the 100 year flood event flows from the upstream catchments spread across both carriageways of Norwest Boulevard. The proposed changes to the road grading and widening of Norwest Boulevard results in the proposed scenario 100 year flood events from the upstream catchments being limited to the carriageway adjacent the future station only. To the north of Norwest Boulevard, it can be observed in the 100 year existing scenario results that spilling of overland flow paths occurs into the commercial precinct. Through changes made to the road cross section the flows become limited within the road reserve of Norwest Boulevard, in line with the major flow principles documented in Austroads. The main station entrance is located outside of the PMF flood extent. The final positions of the entrance thresholds to the Norwest Boulevard pedestrian underpass have been confirmed and care has been taken to ensure they are not impacted upon by the PMF flood extent on the	and have the required freeboard to 100 year flood event levels. Changes to flood affectation outside the conformance limits of 50 mm occur for the PMF event. These changes are due to the significant changes to the grading through Norwest Boulevard and Brookhollow Avenue road reserves. Whilst the limits to affectation are not met where grading changes occur within the road reserve, the limits are satisfied for flooded areas encroaching on surrounding properties.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	northern side of the Norwest Boulevard. The openings to underground structures have been identified and designed to be above the PMF level, with an additional requirement that such openings be 300mm above the adjacent ground levels. **Flood Level Impacts** For 100 year events the figure in Annexure F.2 shows differences in flood levels between the existing and proposed models greater than 50 mm. The blue coloured areas show improved or reduced flood levels (greater than 50 mm difference), whereas the red and orange areas show increases in flood levels of greater than 50mm. The results show that flows are generally contained within the Brookhollow Avenue and Norwest Boulevard carriageways, with the exception of slight overtopping of some access driveways to the commercial developments to the north of the station in the PMF event. Changes to the flooding levels along Brookhollow and Norwest Boulevard are, in isolated areas, outside the 100 year project limits of 50mm. These areas are limited to the road reserve and have been assessed in terms of the flood hazard exposure to pedestrians and vehicles along with the considerations of building floor levels detailed in Austroads guidelines. Ponding of water does not occur in the vicinity of the Norwest precinct and the ponding limitations suggested in Austroads are not valid for the reasonable uniform overland flow channels in the road reserves. Throughout design development, extensive investigation into mitigation options for flood levels occurred. The designers concluded that no feasible and reasonable option is available to eliminate these flood level impacts. This approach was verified through the independent certifier and TfNSW by way of technical workshops. Refer Annexure F.2.	
Bella Vista Precinct	The hydrologic and hydraulic models have been used to quantify the flood behaviour in the vicinity of the BLV Station precinct under existing, proposed and ultimate conditions. The outcomes of these models allowed for informed design decisions relating to the development and the management of flood risks and impacts. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event, i.e. PMF event. See Figure 22 to Figure 25 **Flood Extents** The flood depth and afflux outputs from TUFLOW for the existing and the proposed conditions	The development of a TUFLOW model and full 1D/2D flooding analysis of the design indicates that the formal drainage infrastructure and associated earthworks can achieve the water cycle management targets without worsening flood characteristics on site and in the vicinity. Local ponding and overland flow provisions have been assessed through modelling using TUFLOW. The designed civil works, and additionally the future ‘ultimate’ case have been analysed and

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	(incl. climate change +10% rainfall intensity) are provided in the figures referenced above. TUFLOW outputs show that the station and the tunnel are protected during PMF event from external catchments for Scenario 1 and Scenario 2. The local catchments modelling for Scenario 1 and Scenario 2 also indicate that overland flows from narrow catchments adjacent the excavated corridor, i.e. the terrace areas, enter the rail formation during PMF event. These flows will be captured by pipes and pipe network constructed part of SVC works. The figures also show up to 800mm ponding depth in the table drain west of the path way reduces to 400mm along the eastern side of the pathway. This ponding is contained by a barrier kerb provided along the eastern side of the path way. Whilst flood depths in the drainage channel adjacent the access footpath in Scenario 1 conditions range up to 800mm, it should be noted that the PMF event is an extreme flood and the focus of safety to people and vehicles in such an event is on the ability to evacuate to higher ground rather than assessment of ponded volumes and associated velocities of flows. The pit and pipe network is schematically shown on the figures for Scenario 2 is to provide information on the sources of localised ponding and the direction of formal drainage elements. The discharge location of this ponding in Scenario 1 is through the drainage channel adjacent the footpath drains towards the south and in Scenario 2 predominantly through the formal drainage network, with excess overland flows escape through Precinct Street D over the bridge. **Flood Level Impacts** The flood impact maps shown above indicate that the flooding impacts (afflux) in the 100 year ARI is generally in accordance with the project requirements of 50 mm in the 100 year ARI event. The areas shown highlighted in the PMF afflux results do not indicate increased levels to neighbouring properties or additional areas of adjacent properties exposed to flood waters. This is considered to be an appropriate outcome in the management of flood hazards in the vicinity. **Time of Inundation and Potential for Scour** The project does not have a significant impact on existing flooding regimes in terms of time of inundation or velocity.	determined not to pose significant risk of flood waters entering the station and underground facilities.
Kellyville Precinct	The hydrologic and hydraulic models have been used to quantify flood behaviour in the vicinity of the Kellyville precinct under existing and proposed conditions. The results of these models allows for informed design decisions relating to the development of the works and on the management of	The Kellyville station is located outside the100yr ARI and PMF flood extents for Elizabeth Macarthur Creek. However these flood events

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	flood risks and impacts. See Figure 26 to Figure 29. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event. **Cumulative Affects in Elizabeth Macarthur Creek** The presence of multiple NWRL sites adjacent Elizabeth Macarthur Creek has the potential to have effects on the major event flow regimes in excess of the affects observed through investigation of a single site in isolation. For this reason the Elizabeth Macarthur Creek hydraulic model has incorporated the upstream and downstream sites in the analysis of the Kellyville precinct to ensure these possible cumulative effects are designed for. **Flood Extents** The existing scenario flood extents for the 100 year ARI and PMF events are shown the figures referenced above. **Flood Level Impacts** The impact of the NWRL project on existing flood levels for the 100 year ARI and PMF is shown on and respectively. The orange areas highlighted indicate areas in which the water level afflux exceeds the 50 mm limit imposed by the design requirements in the 100 year ARI event. The blue areas show where flooding conditions are reduced by greater than 50 mm. The figures show the PMF flood affectation for Elizabeth Macarthur Creek. As discussed in the 100year afflux results above, flood levels adjacent the precinct road reserve are impacted by changes to the ground surface associated with precinct works. The area towards the northern end of the carpark site highlighted orange indicates the overland flows as they spread across from Old Windsor Road toward the fringe of the mainstream flooding. The areas shown highlighted in the PMF afflux results do not indicate increased levels to neighbouring properties or additional areas of adjacent properties exposed to flood waters. This is considered to be an appropriate outcome in the management of flood hazards in the vicinity.	impact on the precinct road reserves and future development sites. The development of a TUFLOW model and full 1D/2D flooding analysis of the design indicates that the formal drainage infrastructure and associated earthworks can achieve the water cycle management targets without worsening flood characteristics for neighbouring sites
Rouse Hill Precinct	The hydrologic and hydraulic models have been used to quantify flood behaviour in the vicinity of the Rouse hill station and precinct under existing and proposed conditions. The results of these models allows for informed design decisions relating to the development of the civil works and on the management of flood risks and impacts. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event. Checks have been carried out to ensure that the threshold of all entrances to structures is a minimum of 300mm above the adjacent finished ground level and that both the PMF and Q100 flood events	The Rouse Hill Station precinct is located outside the 100 year ARI flood extent for Caddies Creek Tributary 3. The PMF event however does impact on the site works with overland flow paths from upstream catchments passing through the Rouse Hill Station precinct. Floor levels of the proposed structures have been designed in accordance with

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	have no impact on any station structure or building entrance. See Figure 30 and Figure 31. **Flood Extents** The figures show the 100 year ARI, and 100 year ARI including climate change flood extents for the existing and proposed scenarios respectively in relation to the proposed Rouse Hill Station precinct. The results show that Windsor Road at White Hart Drive is not overtopped in a 100 year ARI event, and flows are confined to the channel downstream. Overland flows from upstream catchments cross Windsor Road at Rouse Hill Drive in the 100 year event. The flood extents shown below indicate that flows area directed to the north-west along the northern verge of Rouse Hill Drive. The major culvert underneath the Windsor Road/Rouse Hill Drive intersection discharges to the open channel in the median between the carriageways of Rouse Hill Drive downstream of the site. **Flood Level Impacts** The impact of the NWRL project on existing flood levels for the 100 year ARI is shown on the figure in Annexure F.3. The orange areas highlighted indicate areas in which the water level afflux exceeds the 50 mm limit imposed by the design requirements in the 100 year ARI event. The blue areas show where flooding conditions are reduced by greater than 50 mm. The area shown orange within the Windsor Road left turn lane to Rouse Hill Drive reflects changes in the wider verge area adjacent Windsor Road. To accommodate an extension of the T-way through to a new turning facility car park, the left turn lane off Windsor Road has been realigned adjacent the through traffic. The associated change in kerb position causes the local peak in overland flows crossing the verge to occur at the new kerb position rather than the verge. This results in the 'shift' of peak flow levels from the highlighted blue area to the area highlighted orange. This area outside the project limits of afflux is not considered to pose additional flood hazard to people and vehicles as it is just a lateral movement of a local overland flow crest with the relocation of the kerb line. The area shown red within the T-way driveway reflects a significant change in ground level. Runoff in this area is not increased in volume or concentrated into unsafe flow paths. Throughout design development, extensive investigation into mitigation options for flood levels occurred. The designers concluded that no feasible and reasonable option is available to eliminate these flood level impacts. This approach was verified through the independent certifier and TfNSW by way of technical workshops. Refer Annexure F.3. **PMF** The precinct experiences overland flows from the upstream catchments in the PMF event. Flows	the project requirements such that the PMF flood event will not cause flooding of the NWRL.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	cross Windsor Road and enter the site from the west which creates a significant flow path southbound within the T-way road reserve. As indicated in the figures all service buildings part of the NWRL at Rouse Hill Station have floor levels above the PMF, preventing overland flows within the T-way from entering the NWRL structures. However, landscaped areas to the south of the station structures will experience shallow overland flows from the Tway road reserve as flow paths continue downstream towards White Hart Drive and beyond to the Tributary. **Major Flood Escape Routes** The precinct experiences overland flows from the upstream catchments rather than rising inundation from the creeks downstream of the site. As a result the period of high flood hazards in the vicinity is relatively short. In the event of major floods, sheltering in place at Rouse Hill Station or Rouse Hill Town Centre is an appropriately safe approach. Regional escape routes north and south along Windsor Road are not significantly impacted as a result of the NWRL project.	
Cudgegong Road Precinct	The developed models have been used to quantify flood behaviour in the vicinity of the Cudgegong Road Station precinct under existing and proposed conditions. The outcomes of these models allows for informed design decisions relating to the design development and on the management of flood risks and impacts. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event. **Flood Extents** The 100 year ARI climate change (+10% rainfall intensity) and PMF flood extents in relation to the proposed site are shown on Figure 4 and Figure 5 below. **Flood Level Impacts** The impact of the NWRL project on existing flood levels for the 100 year ARI and PMF is shown on Figure 6 and Figure 7 respectively. Shown through the colour scale is the mathematical difference in flood level from the proposed scenario relative to the existing scenario. Levels which experience a change within the flood tolerance of the SPR (less than 50mm) are greyed out to provide greater clarity and highlight areas of greater impact. The orange areas shown in the Figure 6 indicate areas in which the water level afflux exceeds the 50mm limit imposed by the design requirements in the 100 year ARI event. The blue areas show where flooding conditions are reduced by greater than 50mm. The area of reduction to the south of the site is associated with existing overland flow paths which will be captured by formal drainage structures in the proposed scenario. The discharge of these flows is then to Second Ponds Creek by means of the designed channels. No significant areas of increase are indicated in the figure indicating adjustments to the discharge	The Cudgegong Road Station precinct is located outside the PMF flood extent for Second Ponds Creek. A number of regional detention basins are located within the Second Ponds Creek catchment. These basins have been designed to offset increases in runoff that would arise from future development. The EIS notes that the NWRL project has been allowed for in the design of these regional basins and no additional detention facilities are required.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	locations are not considered to introduce any additional flood risk.	
RTRF	The developed models have been used to quantify flood behaviour in the vicinity of the RTRF under existing and proposed conditions. The outcomes of these models allows for informed design decisions relating to the development of the works and on the management of flood risks and impacts. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event. **Flood Extents** The 100 year ARI climate change (+10% rainfall intensity) and PMF flood extents in relation to the proposed site are shown on Figure 8 and Figure 9 **Flood Level Impacts** The impact of the NWRL project on existing flood levels for the 100 year ARI is shown on Figure 8 below. Shown through the colour scale is the mathematical difference in flood level from the proposed scenario relative to the existing scenario. To assist in identifying the areas of interest and for general clarity all areas where the impacts to flood levels are within the SPR tolerance of 50mm have been greyed out. The orange areas indicate areas in which the water level afflux exceeds the 50mm limit imposed by the design requirements in the 100 year ARI event. The blue areas show where flooding conditions are reduced by greater than 50mm. The area shown yellow/orange downstream of the southern basin is a result of two aspects of the southern basin design coordinated with Council: • Routing stormwater discharge from the development site south of the NWRL site to First Ponds Creek via the southern basin rather than the existing Schofields Road drainage channel moves this discharge point further downstream than in the existing scenario. • The alignment of the discharge control structure and channel has been carried out to Council's preferred arrangement. The discharge is directed at the future Hambledon Road extension culvert, adjacent the south western corner of the NWRL site. Whilst these orange coloured areas indicate areas of non-conformance with the requirements of the NWRL project, the basin design has been carried out in consultation with Blacktown City Council, the authority for water cycle management in the area. Council has indicated that this area of afflux within the First Ponds Creek floodway is not considered to increase flood hazards significantly and would be acceptable to them considering the benefits through management of the NWRL site in conjunction with the upstream future development site. Figure 11 shows the PMF flood affectation within First Ponds Creek. This map shows differences in flood levels between the existing and proposed models.	The RTRF is located outside the PMF flood extent for First Ponds Creek. The PMF event does impact on the site boundaries at both the north-west and south-west corners of the wider precinct near the proposed detention basins. The increased impervious area arising from the RTRF proposal would potentially result in increased frequency and magnitude of stormwater discharge leaving the site. Detention basins are included in the RTRF to mitigate stormwater impacts by providing attenuation of runoff.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
Corridor Works	The hydrologic and hydraulic models have been used to quantify flood behaviour in the vicinity of the corridor works under existing and proposed conditions. The results of these models allowed for informed design decisions relating to the development of the civil works and on the management of flood risks and impacts. The assessment has included consideration of climate change impacts and also flood behaviour in events greater than the 100 year ARI event. The presence of multiple NWRL sites adjacent Elizabeth Macarthur Creek has the potential to have effects on the major event flow regimes in excess of the affects observed through investigation of a single site in isolation. For this reason the Elizabeth Macarthur Creek hydraulic model has incorporated the precinct sites in the analysis of the corridor works to ensure these possible cumulative effects are designed for. See Figure 32 to Figure 37. **Flood Extents** a) Shared User Path bridge The existing scenario flood extents for the 100 year ARI and PMF events are on the figures referenced above. b) Rouse Hill Substation The existing scenario flood extents for the 100 year ARI and PMF events are shown in figures referenced above. **Level Impacts** The impact of the NWRL project on existing flood levels for the 100 year ARI and PMF are shown on the figures. a) Shared User Path Bridge The highlighted areas shown orange in the 100 year are a result of the shared path embankments traversing the overbank areas of Elizabeth Macarthur Creek acting as an obstruction across the floodway. The impact of the shared path has been reduced through the provision of culverts under the shared path at local depressions. These areas remaining highlighted do not conform with the project afflux limit of 50mm. The definition of 'feasible and reasonable' forms a key role in the determination of an appropriate flooding outcome for elements of the project particularly sensitive to flooding. This definition was provided in the infrastructure approval document which lists conditions from the Minister for Planning and Infrastructure (C33). See Annexure F for a discussion of this result.	The civil works have been located outside the 100 year event flood extents as much as possible resulting in no significant impacts to flood behaviour during 100 year flood events. Local drainage infrastructure for the Traction Substation and Shared User Path has been designed in accordance with the relevant standards to manage local overland flows including the 100 year ARI and PMF storm events

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	During a PMF event the residential areas experiencing inundation would be evacuated due to the significant flood risk to people. This design outcome is considered reasonable as there is no increase in the total number of dwellings to be evacuated in a PMF. **Rouse Hill Traction Substation** As can be observed in the 100 year ARI afflux result there are no significant areas where flood levels are in exceedance of the project tolerance of 50mm. The works for the Traction Substation are generally clear of the 100 year flood extent and thus have little effect on the flood behaviour. During a PMF event there are changes to flooding behaviour which are closely associated with the changes in finished surface levels within the pavement areas of the Traction Substation access road and adjacent shared user path. The pavement levels are raised relative to the existing levels in these areas which contribute to higher flood levels in a PMF as flood waters traverse a higher ground level. This change in flood level is not considered to pose additional risk to people and vehicles in a PMF event as these pavements do not form part of any emergency egress routes. **Time of inundation** The project does not impact the time of inundation experienced in the Elizabeth Macarthur Creek system. As discussed above the only elements of the design affecting 100 year ARI flood behaviour are isolated in overbank areas and therefore no impact is made on the conveyance of the creek or time of inundation. **Potential for Soil Scour** There is no increase in velocity experienced within Elizabeth Macarthur Creek in a 100 year event as a result of the project works. The Project does not impact the potential for soil erosion or scouring in the creek system.	

7.2 Temporary Works

Table 17 below details the flooding impacts on temporary works. Due to the fact that the work areas are predicted to be mostly outside of the PMF extent areas, flooding would not be considered to be a significant issue.

Table 17 Temporary Works Flood Impacts and Mitigation

Site Name	Potential Flooding Impacts	Required Flood Mitigation
Epping Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Devlins Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures
Cheltenham Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Devlins Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Cherrybrook Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated

Site Name	Potential Flooding Impacts	Required Flood Mitigation
		within the excavation before being discharged.
	Overland flows from Pyes Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Castle Hill Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Cattai Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Showground Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Cattai Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Norwest Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Strangers Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
Bella Vista Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Elizabeth Macarthur Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Kellyville Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Elizabeth Macarthur Creek onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Rouse Hill Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the construction worksite.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Caddies Creek (and its tributaries) onto the work site.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
Cudgegong Road Precinct	Direct rainfall on work areas causing erosion and sediment loss.	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.

Site Name	Potential Flooding Impacts	Required Flood Mitigation
	Direct rainfall flooding the excavation for the station footprint and rail cutting to Tallawong Road.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from Second Ponds Creek are unlikely to cause any impacts as the PMF flood levels would not encroach onto the work site.	None required.
RTRF	Direct rainfall on work areas causing erosion and sediment loss	Refer to the Soil and Water Management Plan and Primary ERSED plan for details of mitigation measures.
	Direct rainfall flooding the excavation cutting from Tallawong Road. The rest of the site is generally cut to fill works so accumulation of water is not considered to be a significant issue.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged.
	Overland flows from First Ponds Creek are unlikely to cause any impacts as the PMF flood levels would not encroach onto the work site, aside from a small portion in the south west corner.	Construction material stockpiles are to be kept outside of the PMF flood extent. Construction machinery and equipment is also to be kept out of the PMF floodplain at these sites.
Corridor	Overland flows from Elizabeth Macarthur Creek onto the work site.	Diversion bunds would be built on the upside of excavations to divert water where practical. Accumulated water would be pumped to sediment basins for treatment, or would be treated within the excavation before being discharged Construction material stockpiles are to be kept outside of the PMF flood extent. Construction machinery and equipment is also to be kept out of the PMF floodplain at these sites

8 Flood Emergency Response Plan

8.1 Overview

In addition to the management measures integrated into the design as set out in previous sections, the following management measures will also be implemented.

8.2 Design of Sediment Basins

The work sites have been designed to convey stormwater runoff to sediment basins through a series of above ground overland flow paths and below ground pipe networks.

In accordance with the Construction Soil and Water Management Plan (CSWMP), sediment basins will be used as the primary end-of-line control for all construction worksites. These have been sized in accordance with standard Blue Book requirements. See the Primary Erosion and Sediment Control Plan for further detail.

8.3 Monitoring of Rainfall

Monitoring of rainfall will be undertaken in accordance with the Construction Air Quality Management Plan.

A project weather station/s will be utilised where practical to collect and distribute real-time observations and up-to-date forecasts for wind, temperature, humidity and precipitation.

Onsite weather data will be supplemented with daily weather conditions and forecasts obtained from the Bureau of Meteorology website (http://www.bom.gov.au). In the absence of electronic meteorological information, the Site Supervisor, Site Engineers and Environment Coordinator will monitor and interpret local wind conditions onsite against the Beaufort Wind Scale.

The following action and alarm levels are proposed for the sites

Category 1: Action – 24.6mm for the 80th percentile sediment basin(s) and 32.2mm for the 85th percentile sediment basin(s) of rainfall is expected over a 5 day period (or less). Sediment ponds to be prepared in accordance with the Construction Soil and Water Management Plan.

Category 2: Alarm – When rainfall is expected to be greater than that predicted in Category 1 and would have the potential for sediment basins to overtop, and excavations to become inundated with water.

8.4 Site Inspections

In accordance with the Construction Environmental Management Plan (CEMP) environmental inspections will be undertaken weekly as a minimum and more frequently as determined. The inspections will identify actions that are to be closed out by the Construction Team within agreed timeframes.

In addition, NRT Site Supervisors, as part of their daily duties will conduct formal inspections of the sites, including subcontractor works.

8.5 Flood Response

As noted in Section 7, most of the work areas are located outside of the PMF level therefore the risk of impacts from overland flooding is very low.

8.5.1 Additional Site Inspections

In accordance with the Construction Soil and Water Management Plan an Environmental Inspection Form is to be completed immediately following significant rainfall (i.e. > 10 mm/ 24h). This will be undertaken by the Environment Coordinator and/ or Site Supervisor. Actions and timeframe for completion will be agreed with the Construction Team. Safety consideration will also be a factor in determining if it is safe to complete the action during significant rainfall.

8.6 Responding During a Flood

8.6.1 General

The following general requirements will be implemented:

- Construction equipment (or excess material) would be removed from waterway or flood prone areas.
- Temporary levees or bunds would be strategically placed to contain potential flooding impacts resulting from any temporary works on the floodplain and minimise the risk to surrounding properties which might otherwise be affected.
- Stockpile sites would be generally located outside the 20 year ARI flood. The exact level of flood immunity provided to stockpile sites would depend on the duration of stockpiling operations, the type of material stored and the nature of the downstream waterway or any other specified requirements.

8.6.2 Monitoring of Water Levels Inside Excavations

In respect of each excavation the water levels would be monitored if there is a risk of inundation and safety issues. Submersible pumps would be available to pump water from these areas.

8.6.3 Emergency Response

In the event of an emergency the requirements set out in the Emergency Management Plan (ERP) will be implemented.

8.6.4 Evacuations

In the event of a flood emergency the internal evacuation requirements set out in the Emergency Response Plan (ERP) for each zone will be implemented.

Personnel will gather at the designated marshalling areas at each construction site, in accordance with the ERP.

From this point the Site Superintendent is to use the available information at hand (including flood evacuation orders from SES) to decide if evacuation from the site is required.

8.7 Remediation Works

8.7.1 Dewatering of Excavations

Where water has been captured in excavations, the process for de-watering may include a combination of options such as the treatment of water within the excavation, the processing of the water in the water treatment plants or the removal of water to a licenced facility. Water will not be directly discharged from the premise after a flood event without prior testing and treatment (where required).

8.7.2 Discharge of Sediment Basins

Water discharge from sediment basins within the sites will be undertaken in accordance with the Construction Soil and Water Management Plan and it will be a requirement to ensure that sufficient storage capacity is available in the event of wet weather.

8.7.3 Sediment Controls

Sediments controls would be reinstated where damaged as a result of flooding.

9 Conclusions

Suitable drainage design has been completed for the OTS civil works, which will manage the impacts of stormwater discharge from the completed works.

A Construction Soil and Water Management Plan has been developed to provide appropriate measures for erosion and sediment control during the construction works.

Flood modelling investigations have shown that the potential impact of the OTS on flooding are within the acceptable limits provided by the Minister's Conditions of Approval (CoA) (no greater than 50mm for a 100 year ARI), or can otherwise be appropriately justified; with no feasible and reasonable option to eliminate minor area not within the limits.

Implementation of the mitigation works detailed in Section 7 and the Flood Emergency Response Plan set out in Section 8 will provide the necessary measures to minimise the potential impacts of flooding and stormwater drainage during and after construction of the OTS works.

10 Training, Reporting and Review

10.1 Training

All personnel working on the site will undertake a site induction, which will provide initial training on various environmental aspects including issues around managing stormwater and flood risks.

Additional training will be provided to the workforce during toolbox talks when high amounts of rainfall are forecast.

10.2 Compliance and Reporting

Monitoring and inspection will be recorded on the Weekly Environmental Inspection Form. The weekly environmental inspection form will be used as an instrument to record the weather conditions, the construction activities and comments about stormwater and flood controls

Typical Compliance records would consist of:

- Inspections undertaken in relation to stormwater and flood management measures
- Weekly Environmental Inspection forms
- Toolbox training records
- Records of any meteorological condition monitoring
- Records of any management measures implemented as a result of rainfall and flooding
- Records of inspections undertaken.

Results and outcomes of inspections, monitoring and auditing will be reported internally on a monthly basis. Six-monthly construction compliance reports will be prepared to report on compliance with the Project Approval.

10.3 Review and Improvement

A non-conformance is an action or omission that does not conform to the requirements of this Plan or any legal and other requirements. Any member of the project team or the Environmental Representative can identify a non-conformance or opportunity for improvement. The CEMP identifies the process for identifying, reporting, recoding and reviewing non-conformances. This will ensure continual improvement.

The processes described in the CEMP may result in the need to update or revise this Plan. This will occur as needed. This Plan will be audited within six months of the commencement of construction and thereafter as per the CEMP. The Plan shall be reviewed and updated based on the findings of the audit.

Annexure A Stakeholder Consultation Feedback

Condition of Approval SSI-5931	Condition of Approval SSI-5414	Document	Agency Consultation	Status	Comments	NRT Response
Phase 1						
C8	C34	Stormwater and Flooding Management Plan	OEH	Submitted for review	No response received after 4 weeks.	N/A
			Blacktown City Council	Submitted for review	No response received after 4 weeks.	N/A
			Department Strategies and Land Release	Submitted for review	No response received after 4 weeks.	N/A
Phase 2						
N/A	C34	Stormwater and Flooding Management Plan	OEH	Submitted for review	No response received after 4 weeks.	N/A
			Blacktown City Council	Submitted for review	No response received after 4 weeks.	N/A
			The Hills Shire Council	Submitted for review	No response received after 4 weeks.	N/A
			Hornsby Shire Council	Submitted for review	No response received after 4 weeks.	N/A
			Department Strategies and Land Release	Response received 14 Oct 2015	Department Strategies and Land Release notes that reference is made to assessing the potential impact of the proposed extension of Hambledon Road in later design stages. The alignment of the road will be defined in the final Riverstone East ILP. The Riverstone East Precinct Plan includes land require for drainage infrastructure to support future urban development within the Precinct, and outside of the RTRF. Detailed drainage considerations in this regard will be reviewed by Blacktown City Council and they suggest direct consultation with Council if this hasn't occurred.	Noted

Annexure B Stormwater and Flooding Management Measures and Compliance Matrix

	Measure	Timing	Requirement	Responsibility	Reference
Project Conditions of Approval – Plan Requirements					
	A Stormwater and Flooding Management Plan(s) shall be prepared in consultation with the Department (Strategies and Land Release), OEH, and relevant Councils during detailed design of the SSI and prior to construction, or as otherwise agreed by the Director General. The Plan shall identify actions to ensure that the SSI addresses existing flooding characteristics within the vicinity of the SSI for a full range of flood sizes up to and including the probable maximum flood. The Plan(s) shall be prepared by appropriately qualified person(s) and facilitate a holistic approach to detailed hydrologic assessment and stormwater management, which gives consideration to the cumulative impacts of the SSI associated with its construction and operation, and shall include but not be limited to:	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	This Plan Annexure A Section 3.1 Section 6
	(a) the design of temporary works, compensatory and management measures that would be implemented during construction to not worsen, to the extent that it is feasible and reasonable, existing and known future flooding characteristics;	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 7.2
	(b) the identification of flood risks to the SSI and adjoining areas, including the consideration of local and regional drainage catchment assessments, strategies and guidelines; and climate change implications on rainfall and drainage characteristics	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 5 Section 6 Section 7
	(c) the design and layout of each station precinct and rail service facility to not worsen, to the extent that is feasible and reasonable, existing and known future flooding characteristics;	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 5 Section 6 Section 7
	(d) Identification of design and mitigation measures that would be implemented to protect proposed construction and operational activities and not worsen existing flooding characteristics, including soil erosion and scouring. Design of mitigation measures should consider more frequent floods besides flood of design; and	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 7

	Measure	Timing	Requirement	Responsibility	Reference
	e) identify flood risk, potential for inflows, potential consequences and required mitigation measures for each tunnel entrance;	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 6 Section 7
	(f) specific information related to flood risk in larger floods (for example PMF) and the incorporation of management measures in the flood emergency response planning required under condition F4.	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 7 Annexure C Annexure D Section 8
	For surface components of the SSI located on floodplains, flood impacts shall be confirmed in accordance with the Floodplain Development Manual (2005), and other relevant NSW Government Guidelines.	Before Construction	OTS Approval SSI-5414 CoA C34	Design Manager Hydrological Specialist	Section 2.3.1
	A Stormwater and Flooding Management Plan shall be prepared in consultation with the Department (Strategies and Land Release), OEH and Blacktown City Council during detailed design of the SSI and prior to construction, or as otherwise agreed by the Director General. The Plan shall identify actions to ensure that the SSI addresses existing flooding characteristics within the vicinity of the SSI for a full range of flood sizes, up to and including Probable Maximum Flood. The Plan shall be prepared by an appropriately qualified person(s) and facilitate a holistic approach to detailed hydrologic assessment and stormwater management, which gives consideration to the cumulative of the SSI allocation with its construction and operation and, shall include but not be limited to:	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	This Plan Annexure A Section 3.1
	(a) the design of the permanent works of the SSI to not worsen, to the extent that it is feasible and reasonable, existing and known future flooding characteristics.	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 7.1 Annexure F
	(b) the design of temporary works, compensatory and management measures to not worsen existing and known future flooding characteristics	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 7.2
	(c) the identification of flood risks to the SSI and adjoining areas, including the consideration of local drainage catchment assessments, strategies and guidelines;	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological	Section 5 Section 6

	Measure	Timing	Requirement	Responsibility	Reference
	and climate change implications on rainfall and drainage characteristics;			Specialist	Section 7
	d) the identification 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. Design of mitigation measures should consider more frequent floods besides flood of design;	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 7
	e) the identification of drainage system upgrades; and	Before & during Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 6 Section 7
	(f) the preparation of a flood/emergency management plan.	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 8
	For components of the SSI located on floodplains, flood impacts shall be confirmed in accordance with the Floodplain Development Manual (2005), and other relevant NSW Government Guidelines."	Before Construction	RTRF Approval SSI-5931 CoA C8	Design Manager Hydrological Specialist	Section 2.3.1
Project Approval – Specific Conditions					
	The SSI shall be designed, to the extent that it is feasible and reasonable, to not worsen existing flood characteristics in the vicinity of the SSI. Not worsen is defined as: (a) a maximum increase flood levels of 50mm in a 100 year Average Recurrence Interval (ARI) flood event; and (b) a maximum increase in time of inundation of one hour in a 100 year ARI flood event; and (c) any increase in flow velocity in a 100 year ARI flood event should not increase the potential for soil erosion and scouring.		OTS Approval SSI-5414 CoA C33	Design Manager	Section 2.2.1 Annexure F
	The SSI shall be designed, to the extent that is feasible and reasonable, to not worsen existing flooding characteristics in the vicinity of the SSI. Not worsen is defined as: (a) a maximum increase in flood levels of 50 mm in a 1 in 100 year Average		RTRF Approval SSI-5931 CoA C7	Design Manager	Section 2.2.1 Section 7.1

	Measure	Timing	Requirement	Responsibility	Reference
	Recurrence Interval (ARI) rainfall event; and (b) a maximum increase in inundation time of one hour in a 1 in 100 year ARI rainfall event; (c) any increase in flow velocity in a 100 year ARI event should not increase the potential for soil erosion and scouring; and (d) the Proponent shall design and construct stormwater detention basins to maintain pre-development peak flows in First Ponds Creek, with a minimum volume of 12,750m3 stormwater detention capacity on the site, unless otherwise agreed by the Director-General.				Section 6.11.1
EIS Revised Environmental Mitigation Measures					
	Entries to below ground stations would be located above the PMF level for mainstream flooding and local measures provided to manage the ingress of runoff from local overland flooding up to the PMF.		EIS 2 REMM OpSW5	Design Manager	Section 6.1, 6.2, 6.7, 7
	The stabling facility would be located above the 100 year ARI flood level.		EIS 2 REMM OpSW6 RTRF REMM OpSW6		Section 7.1 Annexure C Annexure D
	Tunnel entries would be located above the PMF level for mainstream flooding and local measures provided to manage the ingress of runoff from local overland flooding up to the PMF.		EIS 2 REMM OpSW7		Section 6.1, 6.2, 6.7, 7.1
	The rail line would be located above the 100 year ARI flood level to provide an appropriate level of flood immunity.		EIS 2 REMM OpSW8		Section 7.1 Annexure C Annexure D
	Entries to below ground services facilities would be located above the PMF level for mainstream flooding and local measures provided to manage the ingress of runoff from local overland flooding up to the PMP.		EIS 2 REMM OpSW9		Section 6.1, 6.2, 6.7, 7
	Critical rail system infrastructure such as substations and sectioning huts would be located at a suitable level above the 100 year ARI peak flood level to protect against		EIS 2 REMM OpSW10		Section 7.1 Annexure C

Measure	Timing	Requirement	Responsibility	Reference
mainstream and local overland flooding.				Annexure D Annexure E
Development within the floodplain would be designed to minimise adverse impacts on adjacent development for flooding up to the 100 year ARI event. And would be designed to maintain the operation of key evacuation routes, minimise impacts on critical infrastructure and flood hazard for flooding up to the PMF.		EIS 2 REMM OpSW11 RTRF REMM OpSW11		Section 7.1 Annexure C Annexure D
Local drainage systems and overland flowpaths at all precincts would be designed to provide appropriate flood immunity to the precincts and minimise the risk of ingress of floodwaters to the underground stations.		EIS 2 REMM OpSW13		Section 7.1
Water quality treatment measures (including a combination of swales, bioretention systems, water quality basins, gross pollutant traps) would be integrated into the drainage system to mitigate impacts to waterways.		EIS 2 REMM OpSW14 RTRF EMM OpSW14		Section 7.1
A holistic approach to water quality and stormwater management would be adopted that incorporates Water Sensitive Urban Design principles to minimise impacts on the existing hydrologic regime. Such measures would include: • Managing total runoff volumes through the use of rainwater tanks and measures that promote stormwater infiltration. • Minimising increases in peak flows through the use of detention and retention measures as appropriate. • Preserving and enhancing the amenity of waterways by maintaining or providing natural vegetated measures. • Treating stormwater through a range of at source and end point measures that are integrated with the urban landscape.		EIS 2 REMM OpSW15 RTRF REMM OpSW15		Section 7.1
Construction equipment (or excess material) would be removed from waterway or flood prone areas if wet weather is approaching and at the completion of each day's work activity. The extent of the flood prone area would be defined during detailed construction planning.		EIS 2 REMM SW3 RTRF REMM SW3		Section 7
Temporary levees or bunds would be strategically placed to contain potential flooding		EIS 2 REMM SW4		Section 7

	Measure	Timing	Requirement	Responsibility	Reference
	impacts resulting from any temporary works on the floodplain and minimise the risk to surrounding properties which might otherwise be affected.				
	Entries to tunnel excavations would be protected against flooding by locating openings outside flood prone areas, local bunding and / or appropriate drainage.		EIS 2 REMM SW5		Section 6.1, 6.2, 6.7, 7.2
	The flood standard adopted at each tunnel entry during Stage 2 construction would need to be developed taking into consideration the duration of construction, the magnitude of inflows and the potential risks to the project works and personal safety.		EIS 2 REMM SW6		Section 6.1, 6.2, 6.7, 7.2
	Stockpile sites would be generally located outside the 20 year ARI flood. The exact level of flood immunity provided to stockpile sites would depend on the duration of stockpiling operations, the type of material stored and the nature of the downstream waterway or any other specified requirements. This would be defined during detailed construction planning.		EIS 2 REMM SW12		Section 7.2
	Inspection of water quality mitigation controls (eg sediment fences, sediment basins) would be carried out regularly and following significant rainfall to detect any breach in performance.		EIS 2 REMM SW44 RTRF REMM SW44		Section 8.4 Section 8.7
	A stormwater management plan that identifies the appropriate design standards for flood mitigation based on the duration of construction, proposed activities and flood risks would be developed for each construction site. The plan would develop procedures to ensure that threats to human safety and damage to infrastructure are not exacerbated during the construction period.		EIS 2 REMM SW45 RTRF REMM SW45		This Plan

Annexure C Flood Maps – Phase 1 Works

Cudgegong Road Precinct

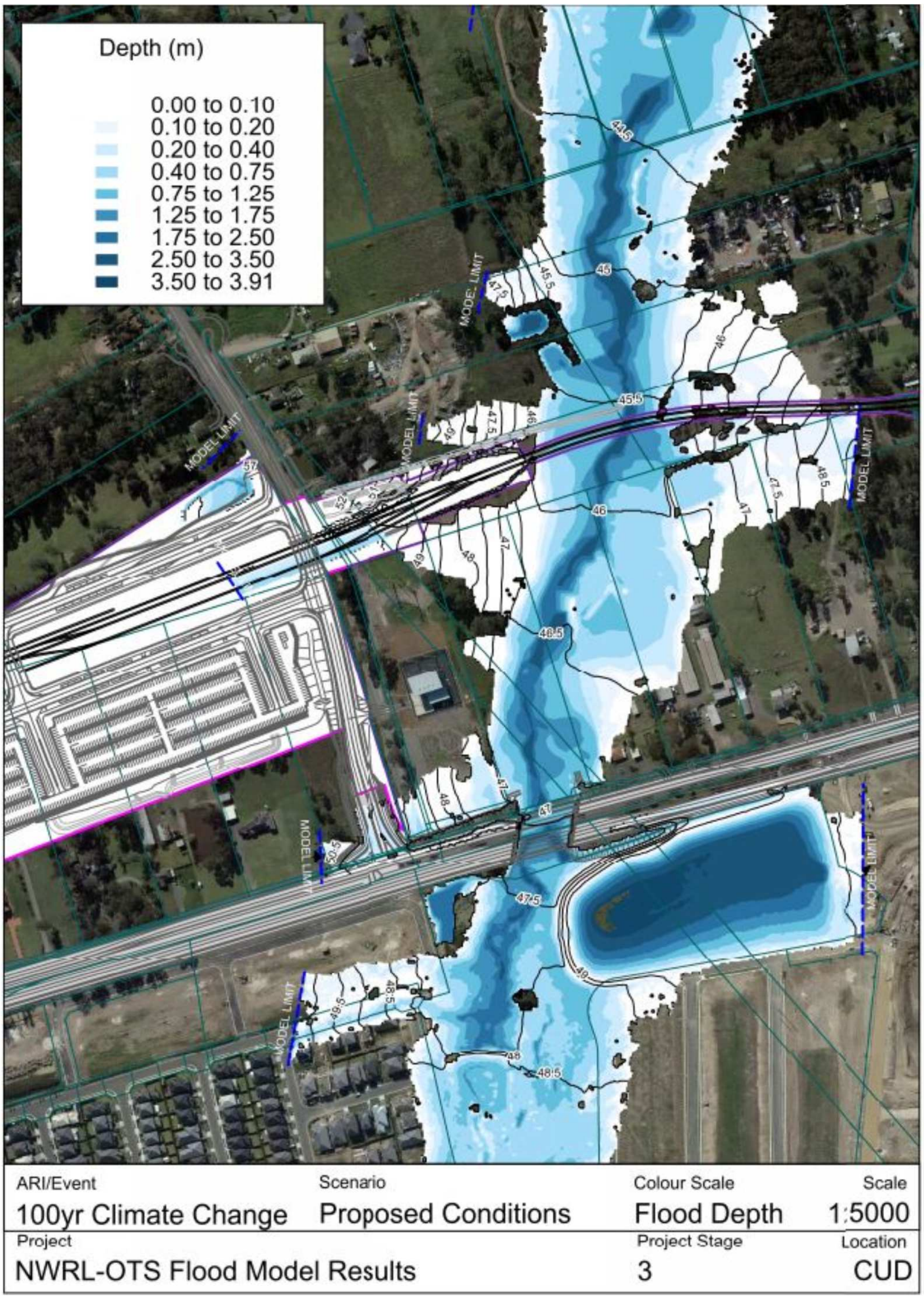


Figure 4 Cudgegong Road 100 year ARI Climate Change (+10% Rainfall Intensity) Flood Extents

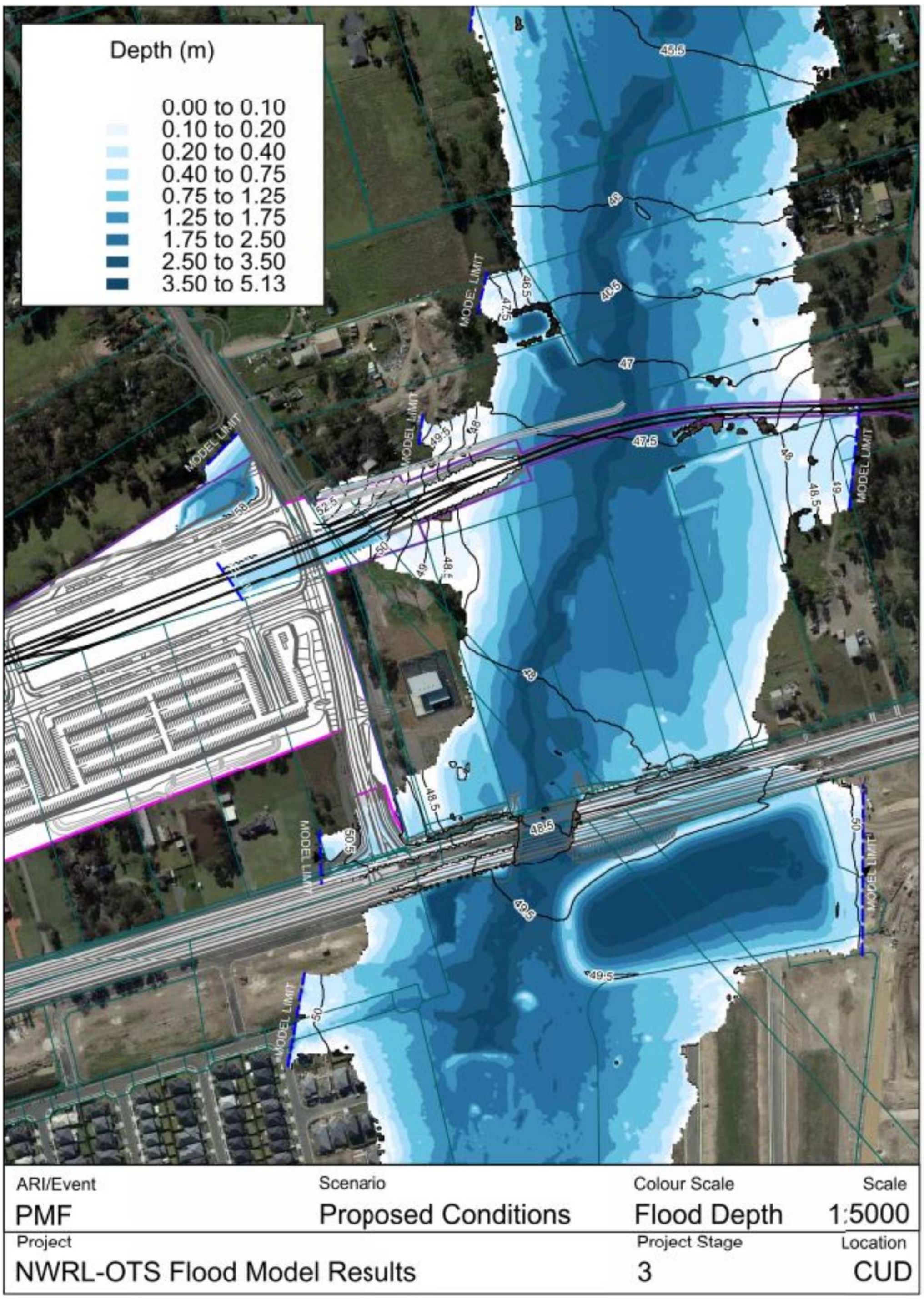


Figure 5 Cudgegong Road PMF Flood Extents

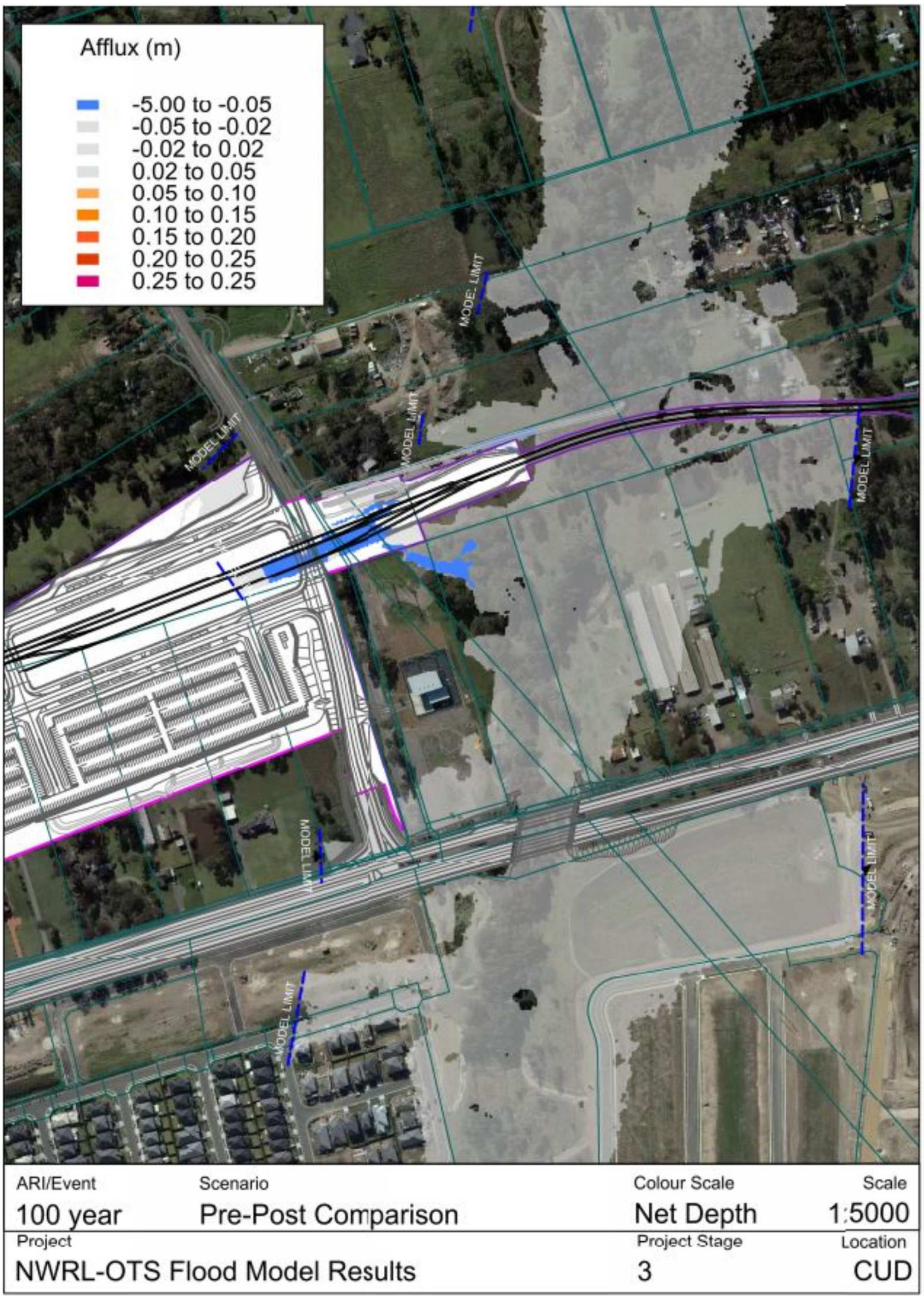


Figure 6 Cudgegong Road 100 year ARI Flood Impacts – Second Ponds Creek

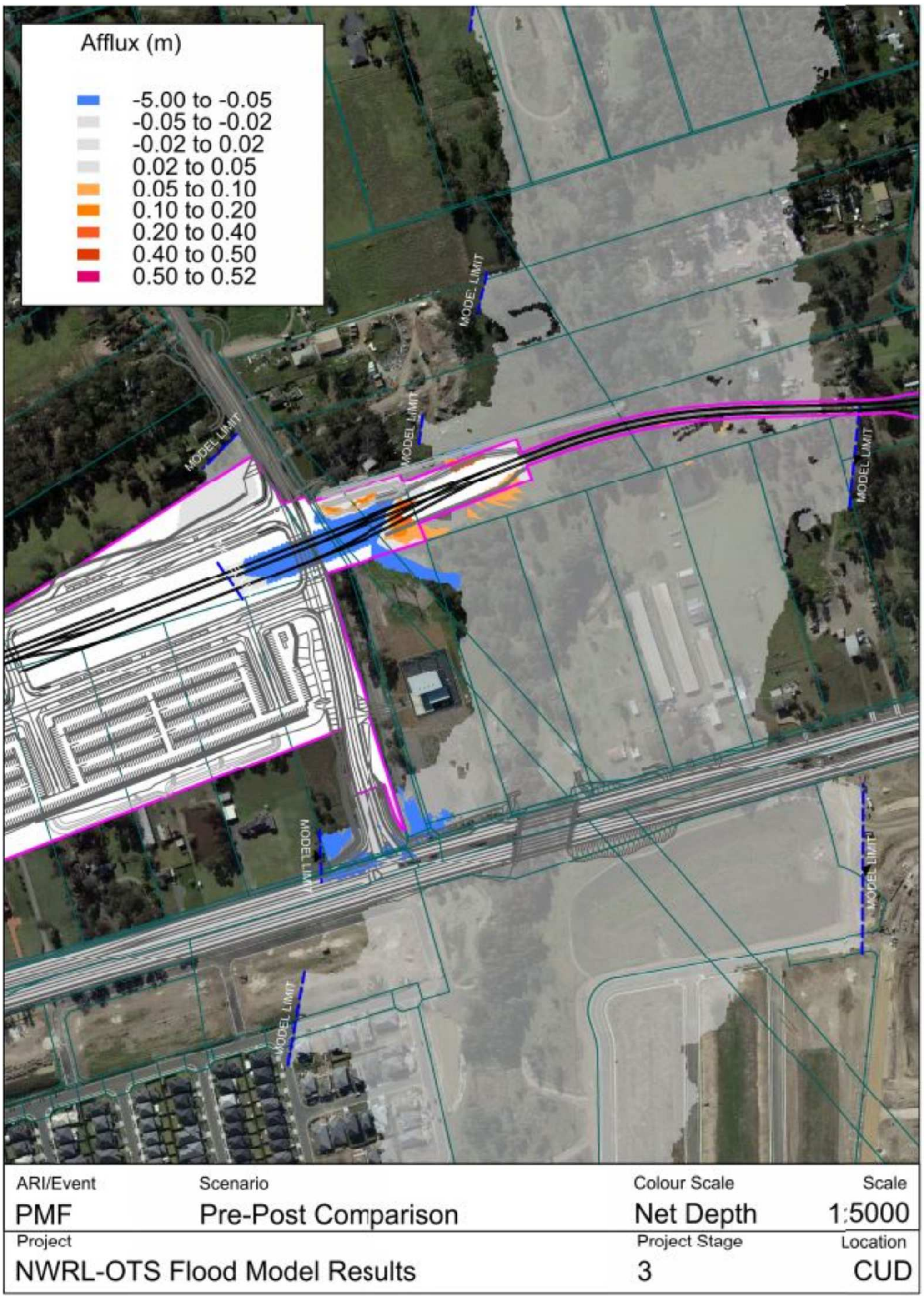


Figure 7 Cudgegong Road PMF Flood Impacts – Second Ponds Creek

RTRF Precinct

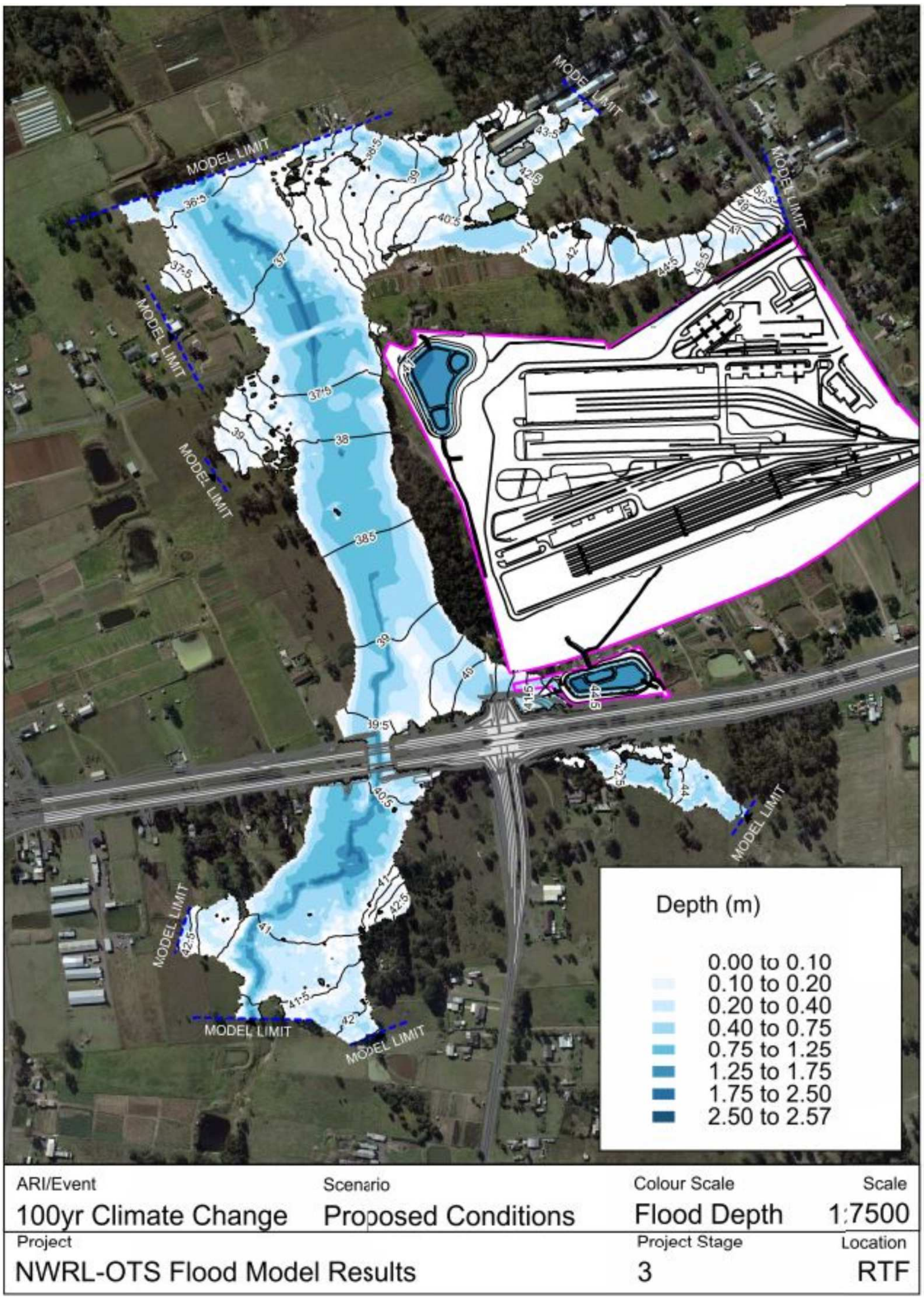


Figure 8 RTRF 100 year ARI Climate Change (+10% Rainfall Intensity) Flood Extents

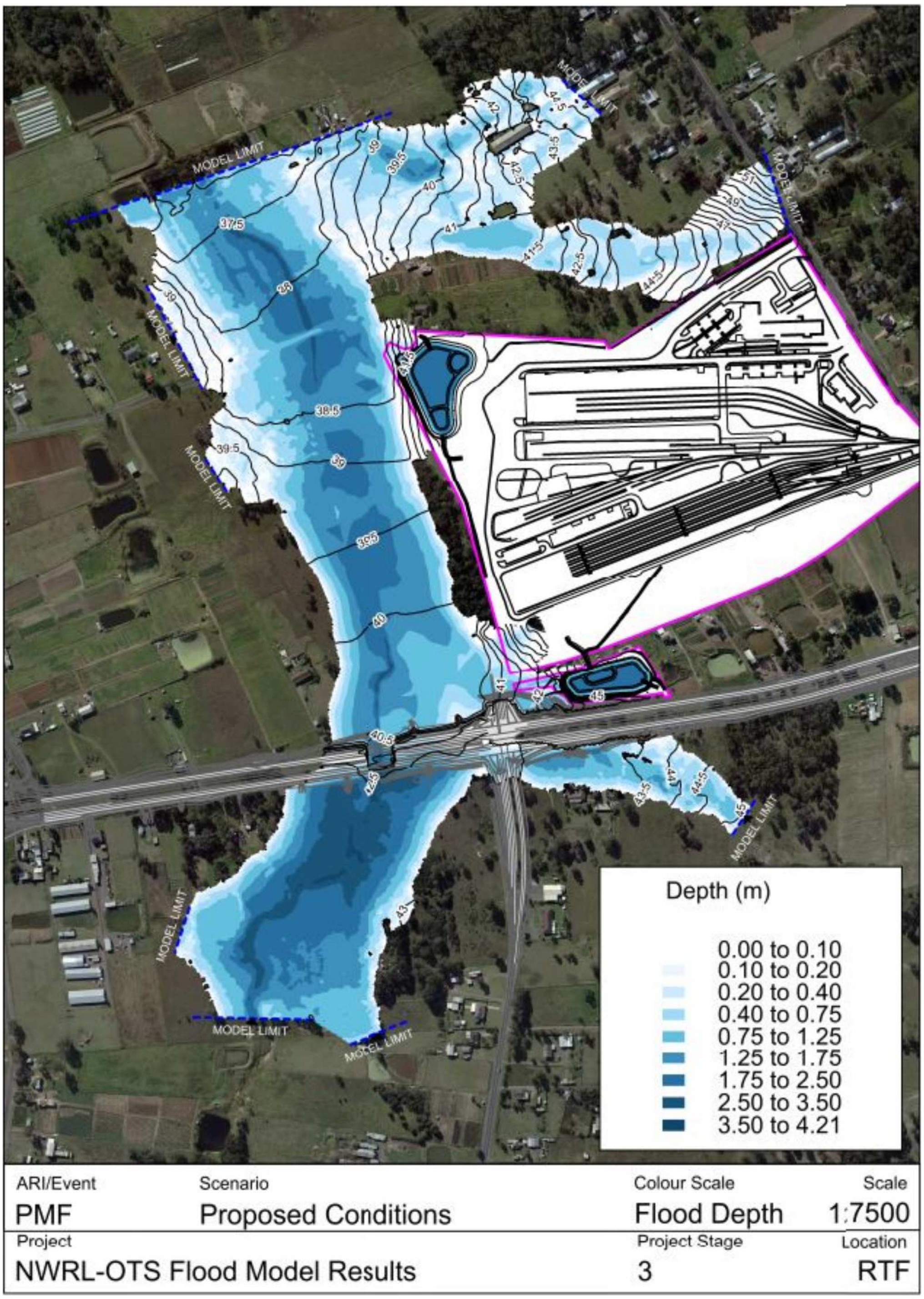


Figure 9 RTRF PMF Flood Extents

Figure 10 RTRF 100 year ARI Flood Impacts

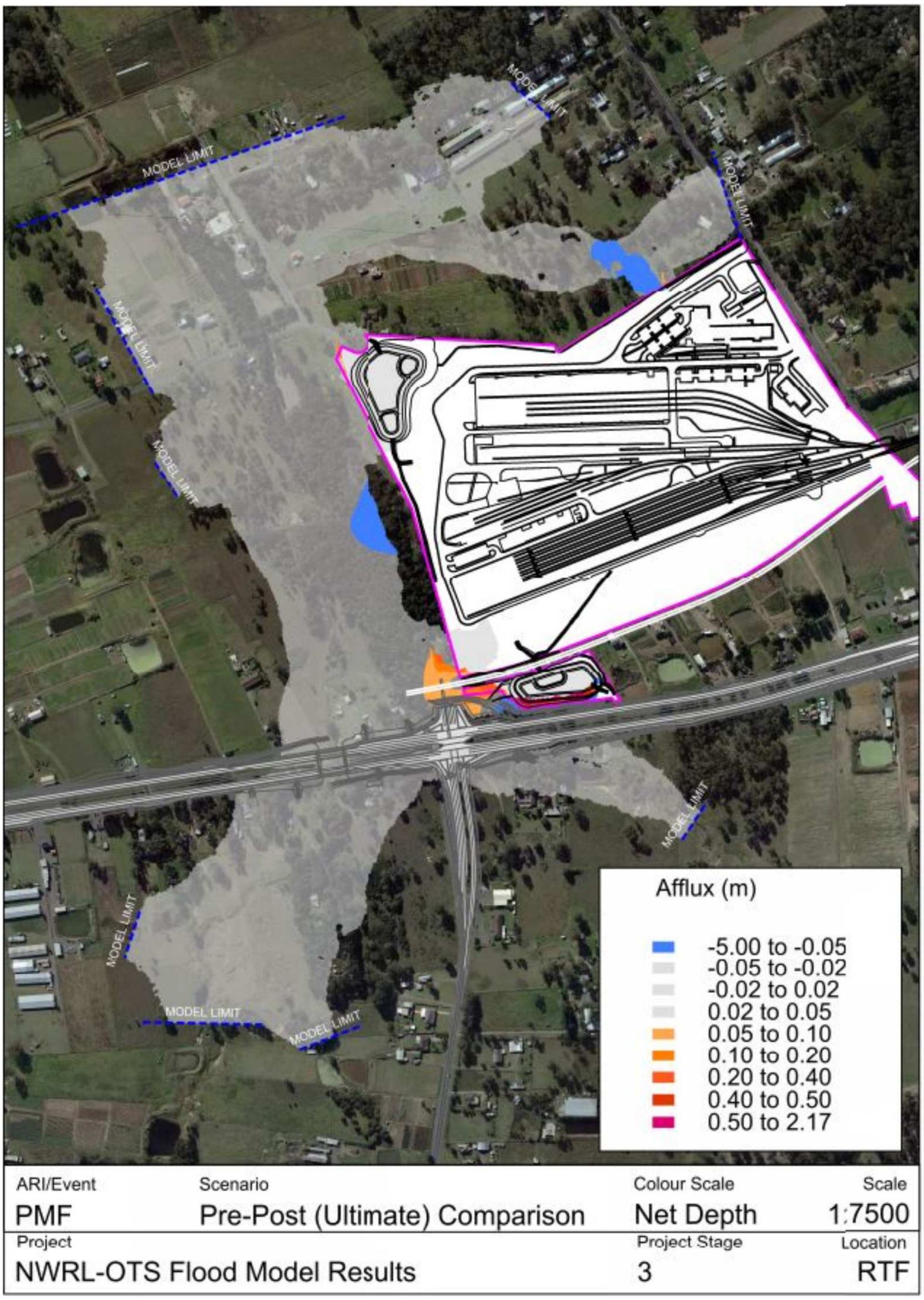


Figure 11 RTRF PMF Flood Impacts

Annexure D Flood Maps – Phase 2 Works

Epping Precinct

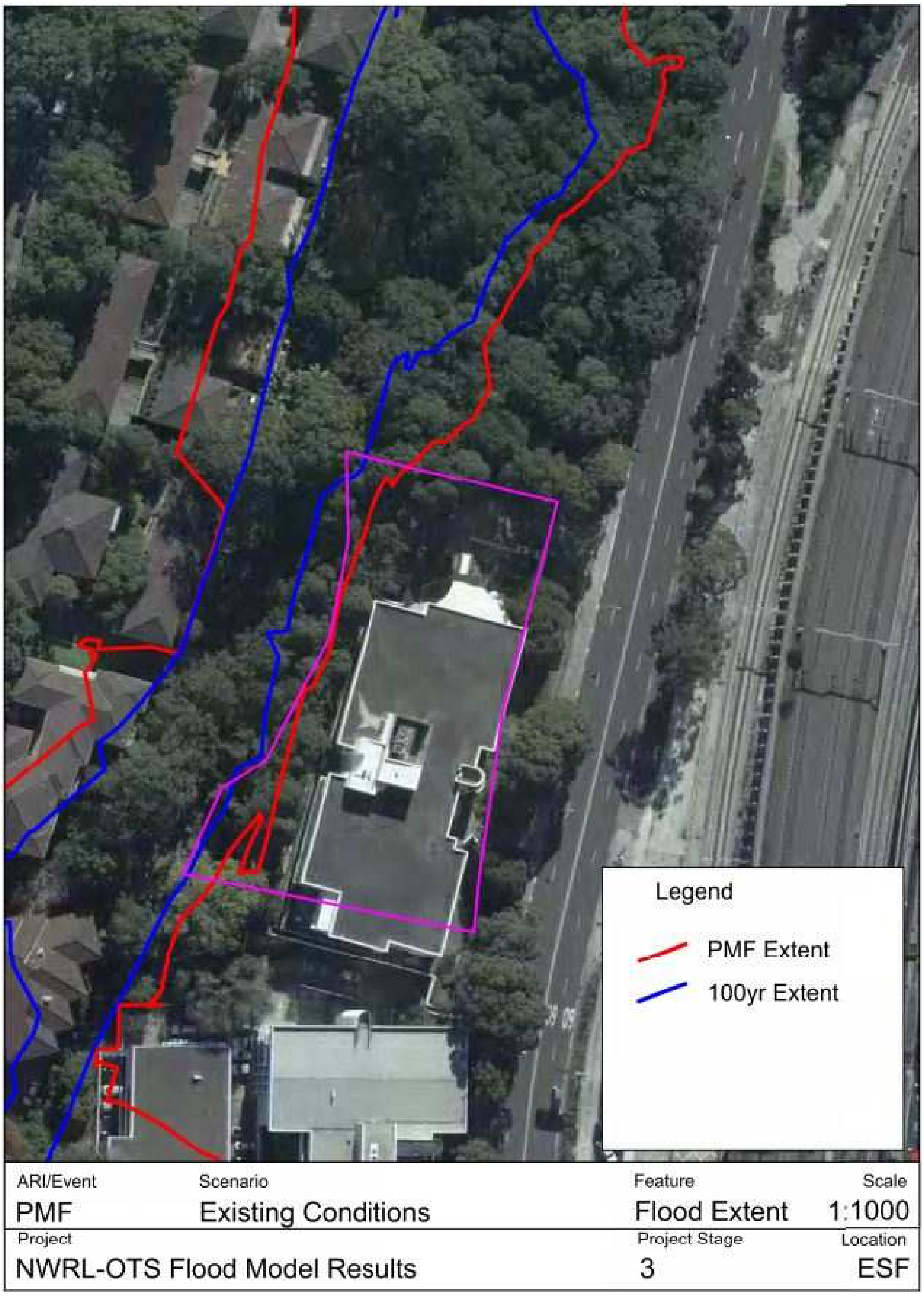


Figure 12 Epping Flood Extents under Existing Conditions (PMF and 100 year)

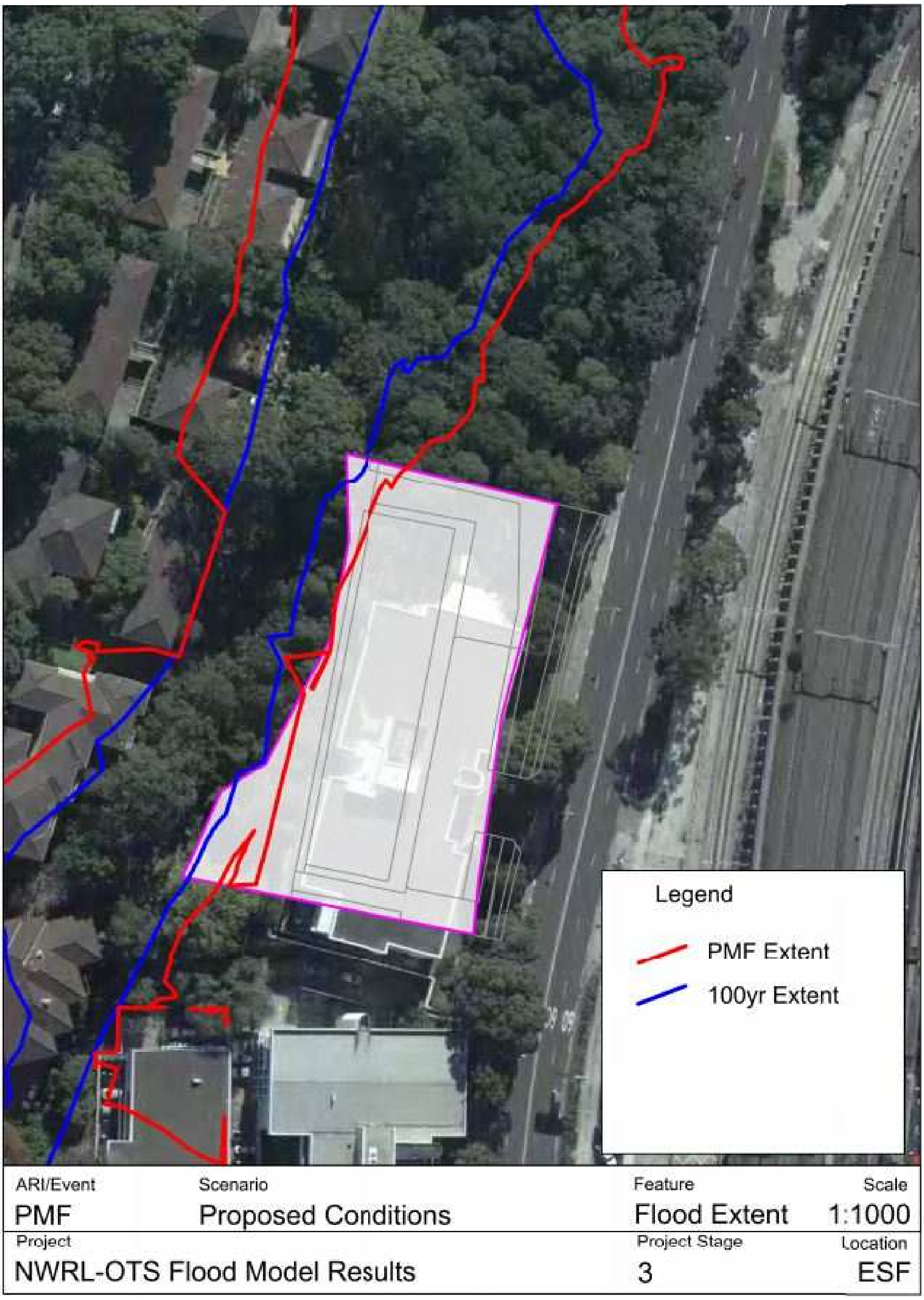
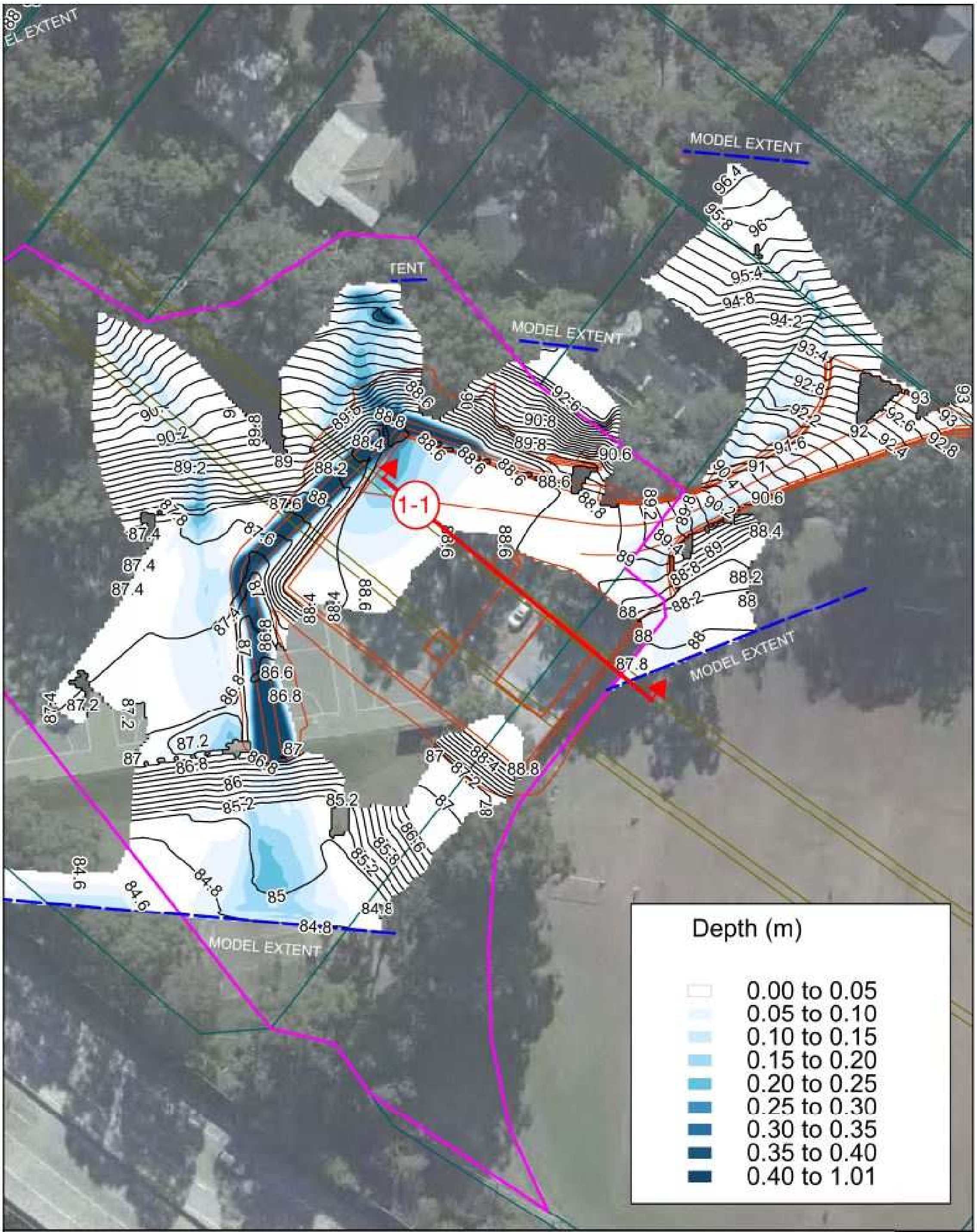


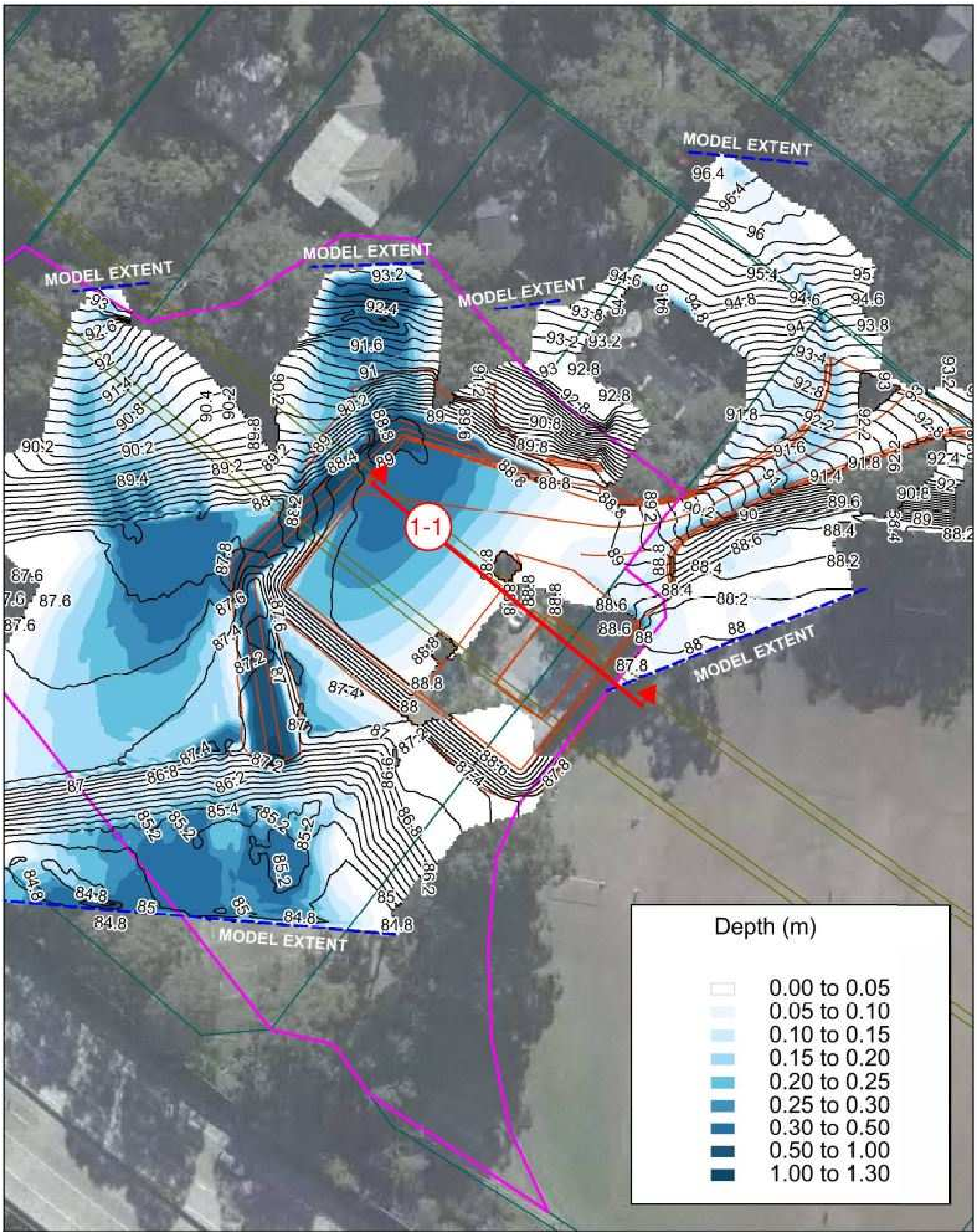
Figure 13 Epping Flood Extents under Proposed Conditions (PMF and 100 year including Climate Change)

Cheltenham Precinct



ARI/Event	Scenario	Colour Scale	Scale
100 year	Proposed Scenario	Flood Depth	1:750
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	CSF

Figure 14 Cheltenham 100 year ARI Flood Extents



ARI/Event	Scenario	Colour Scale	Scale
PMF	Proposed Scenario	Flood Depth	1:750
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	CSF

Figure 15 Cheltenham PMF Flood Extents

Cherrybrook Precinct

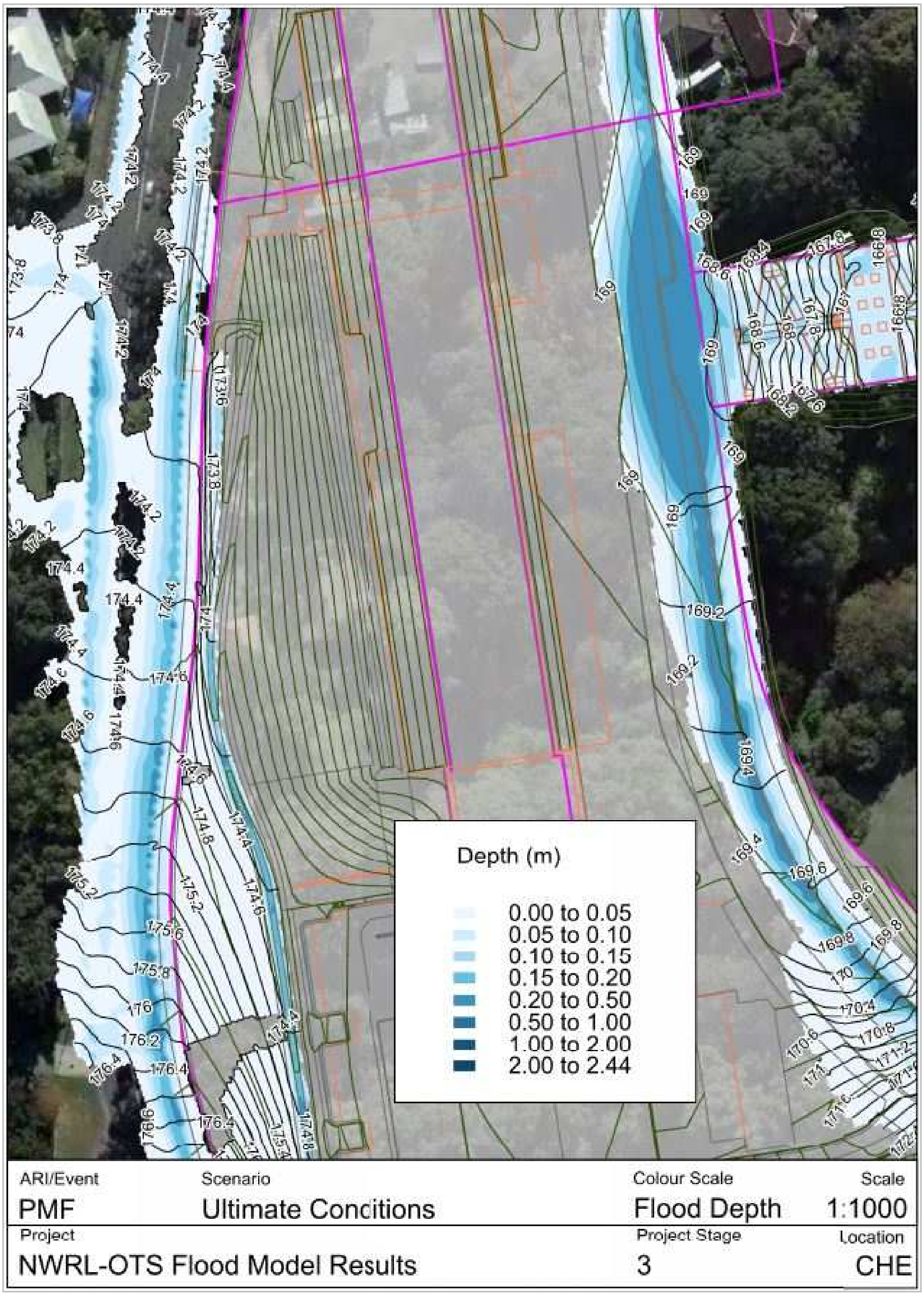


Figure 16 Cherrybrook PMF Flood Extents

Castle Hill Precinct

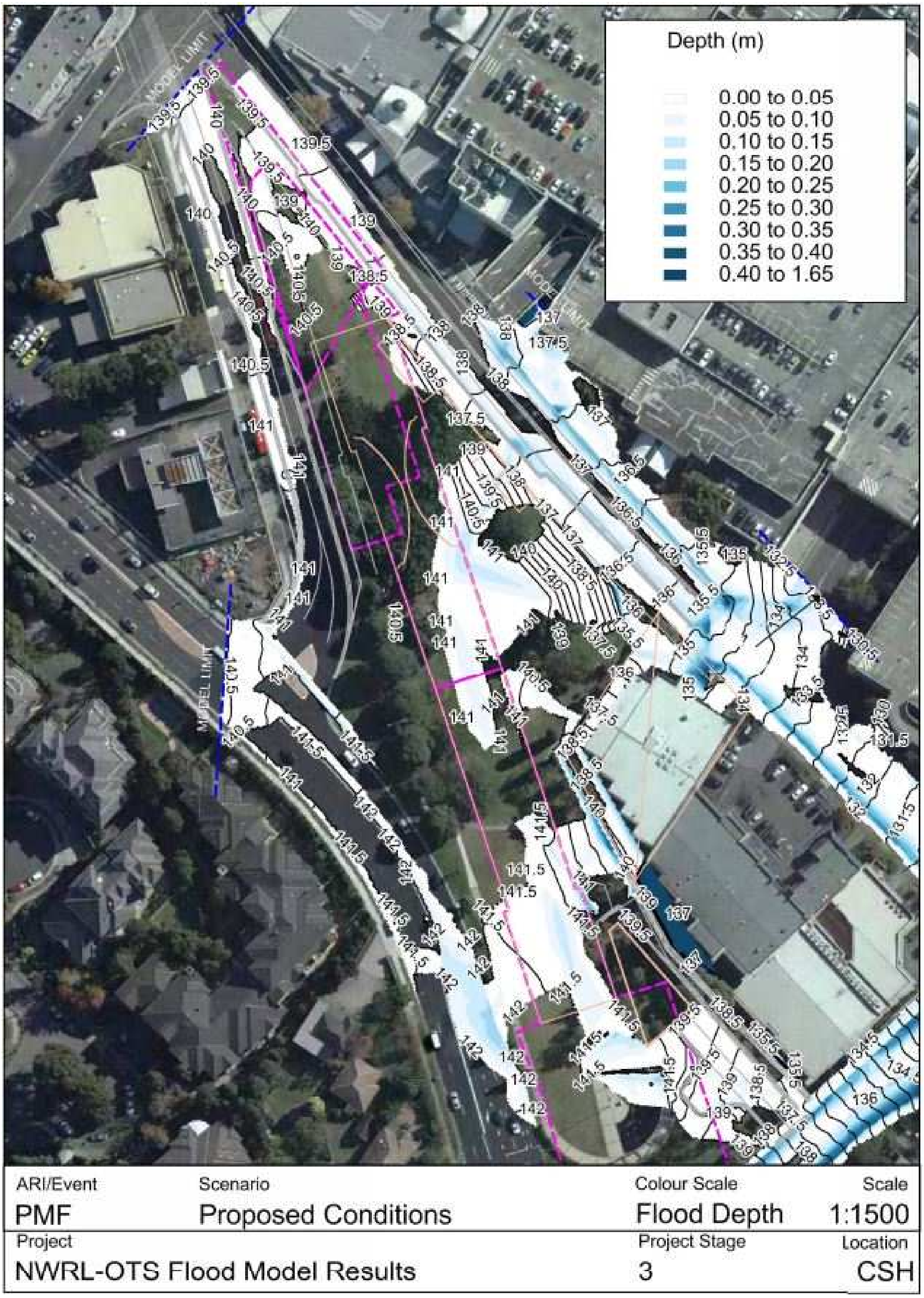


Figure 17 Castle Hill PMF Flood Extents

Showground Precinct

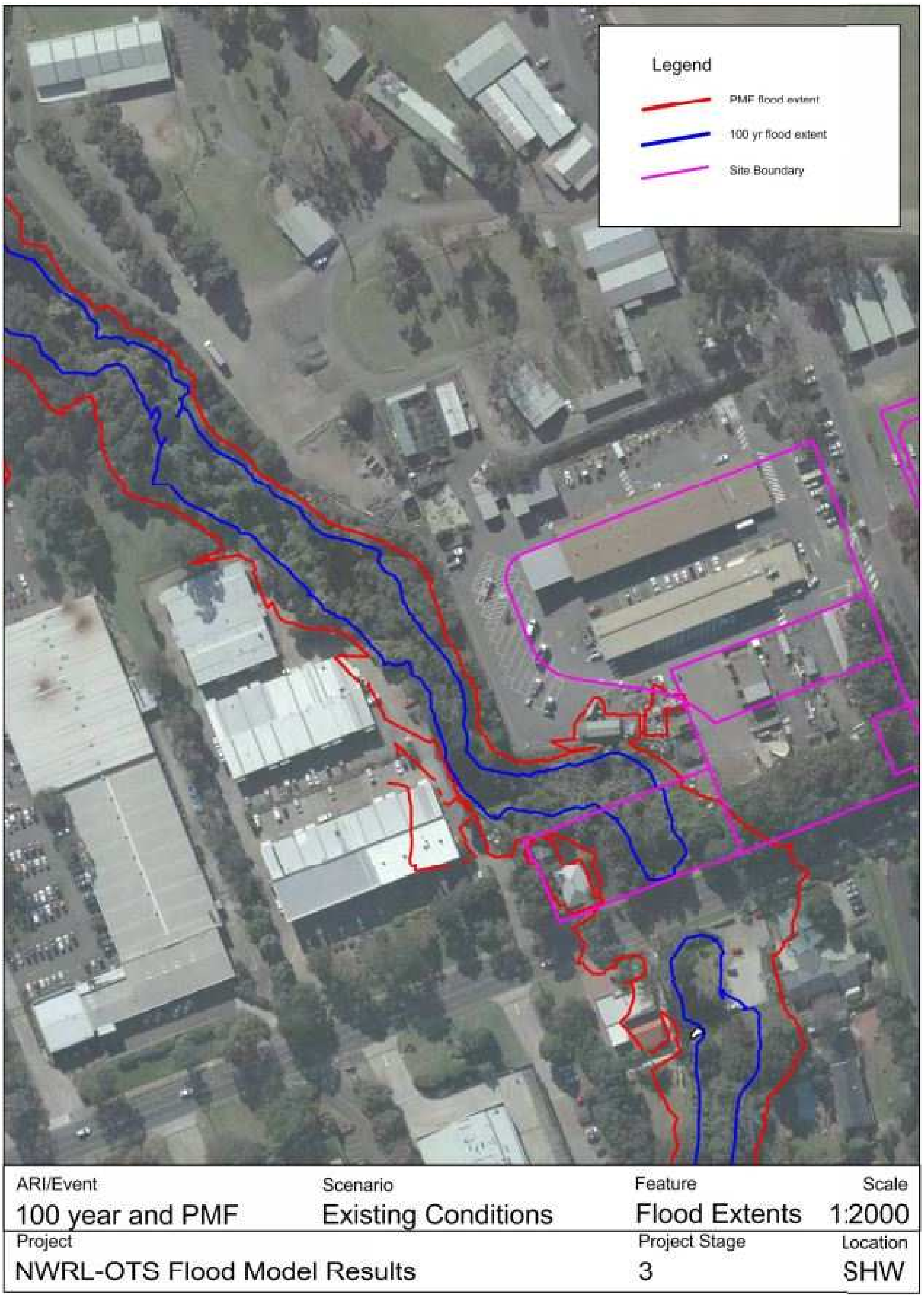


Figure 18 Showground Existing 100 year ARI and PMF Flood Extents

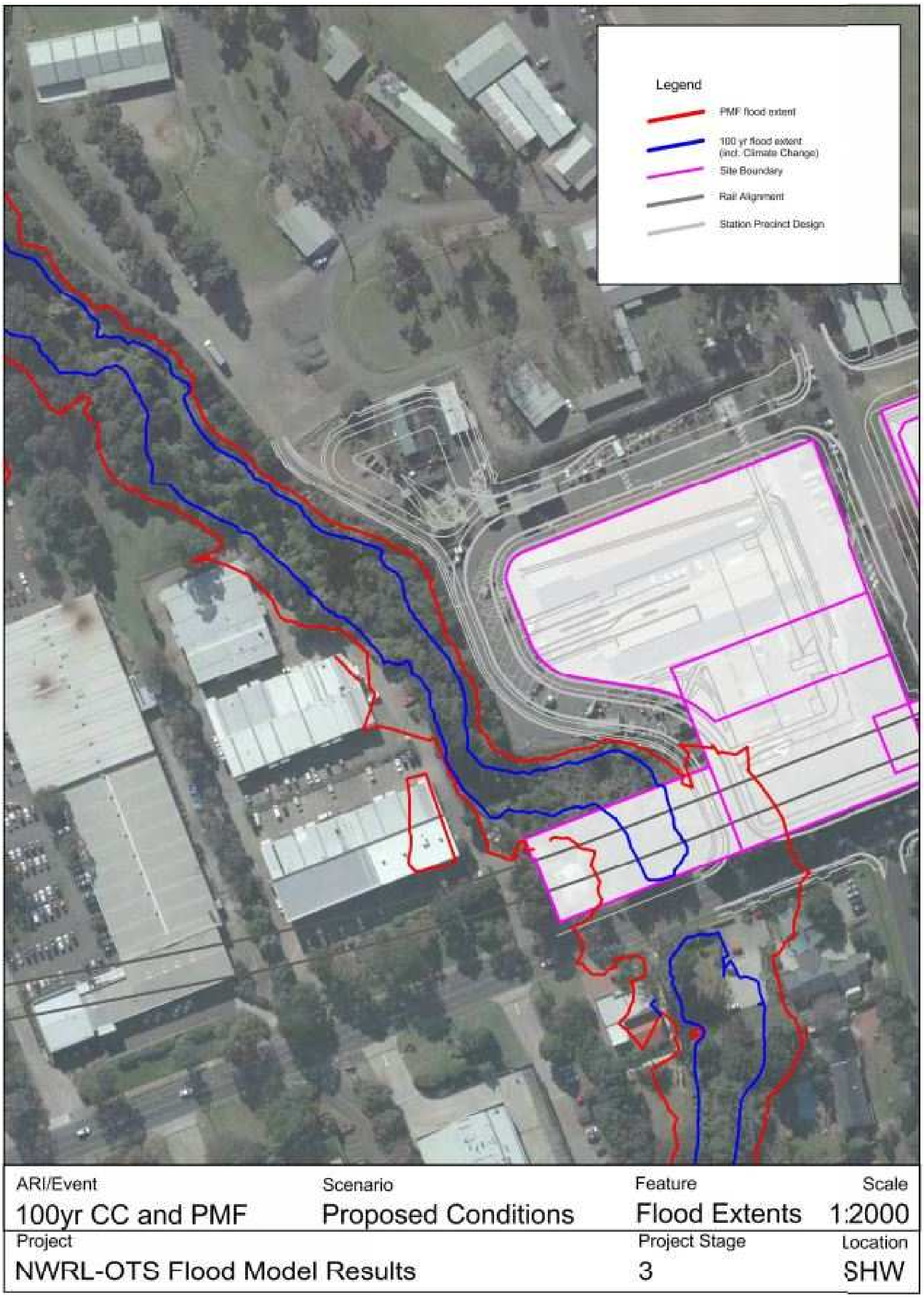


Figure 19 Showground Proposed 100yrCC and PMF Flood Extents

.

Norwest Precinct

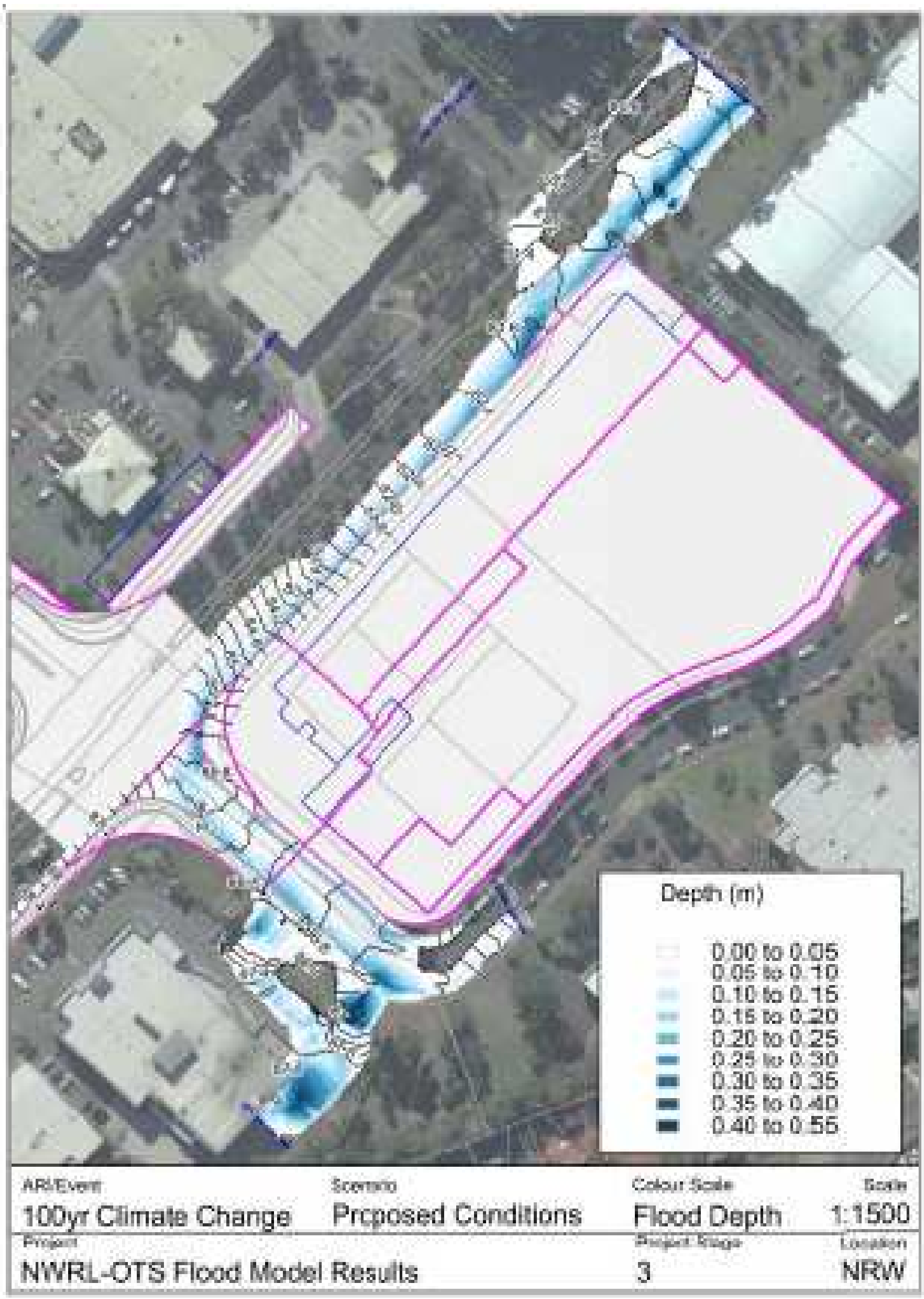


Figure 20 Norwest 100 year ARI Flood Extents

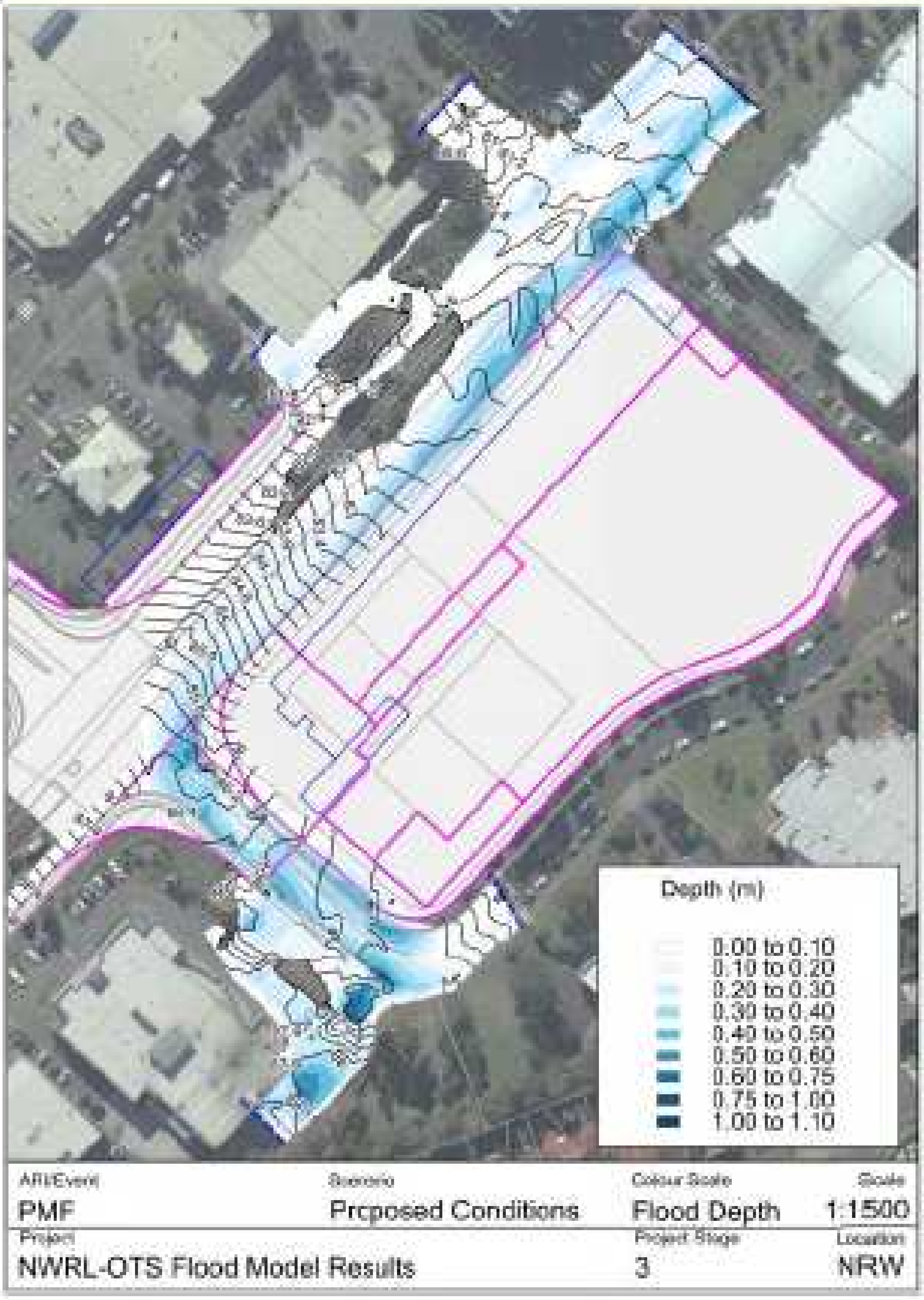


Figure 21 Norwest PMF Flood Extents

Bella Vista Precinct

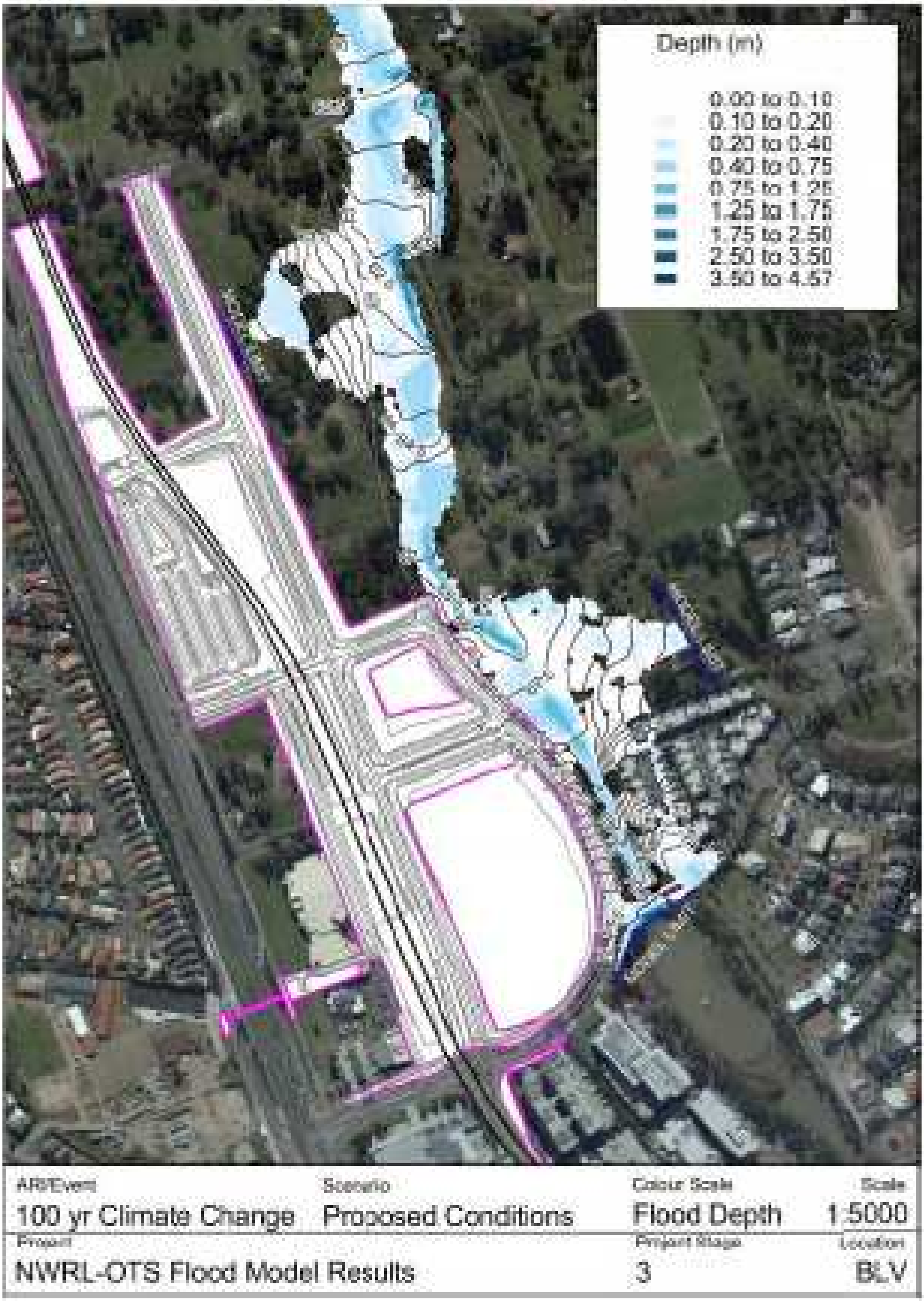


Figure 22 Bella Vista 100 year ARI Flood Extents

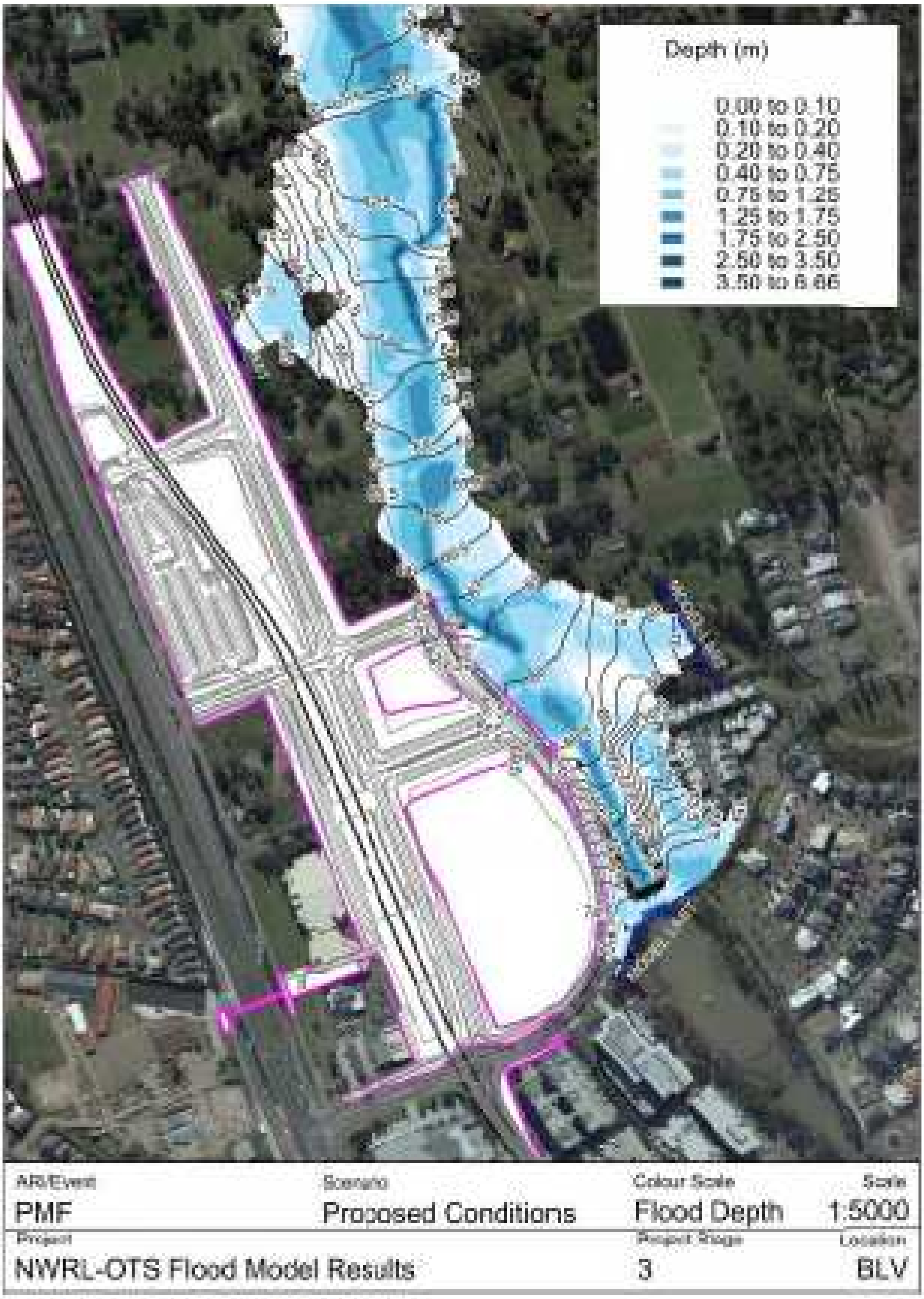


Figure A1.17 - PMF Extents. Proposed condition

Figure 23 Bella Vista PMF Flood Extents

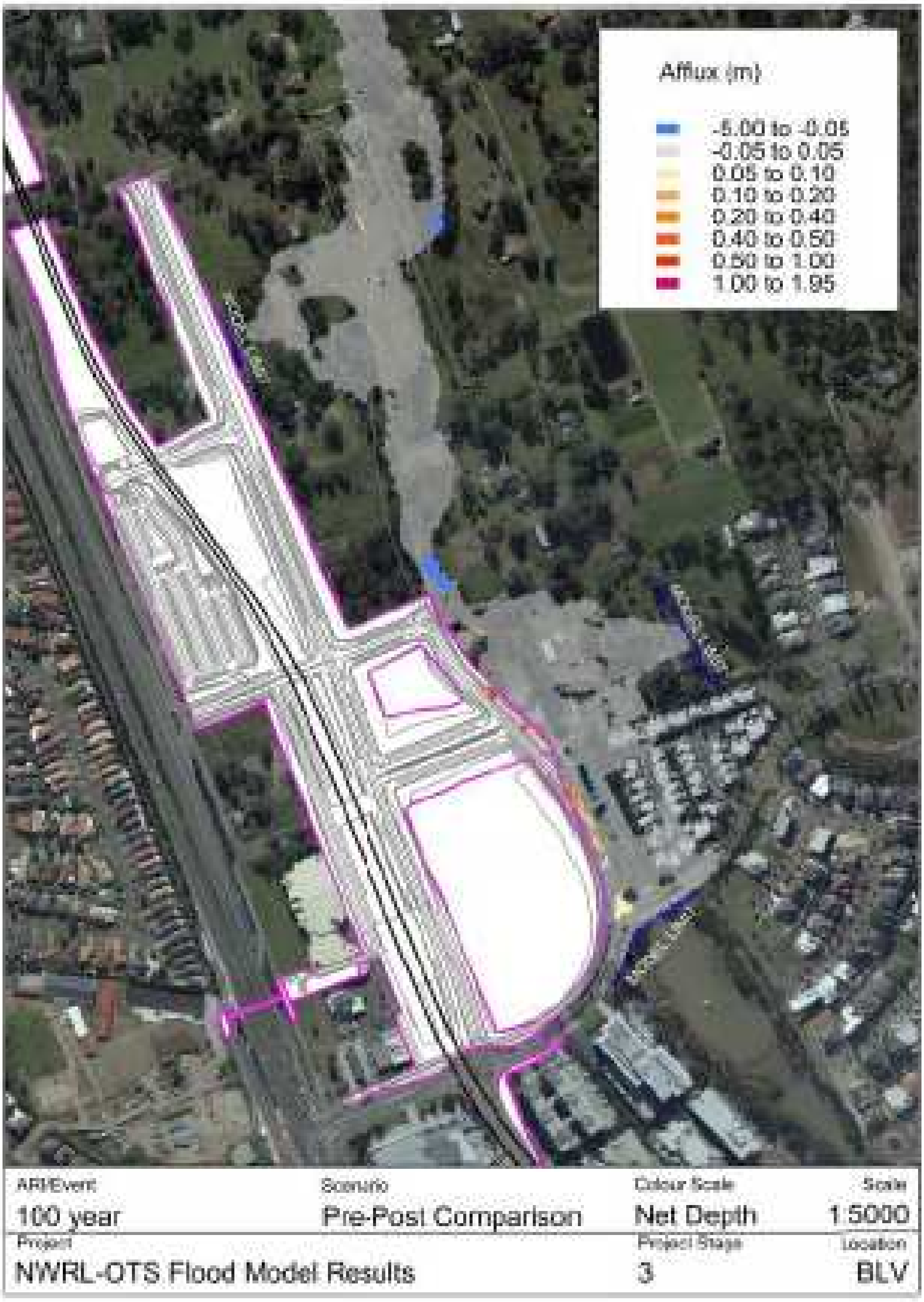


Figure 24 Bella Vista 100 year ARI Flood Impacts

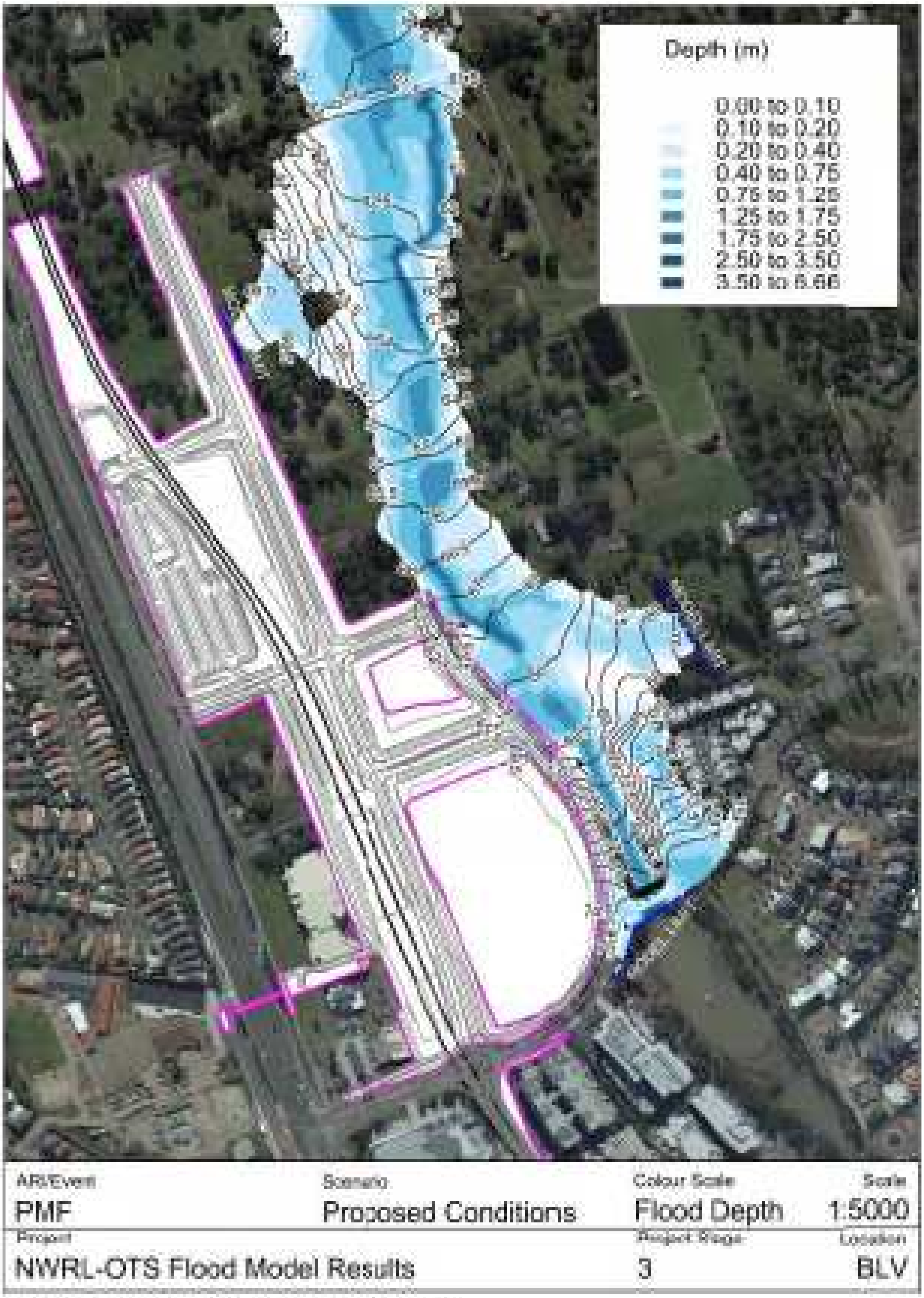
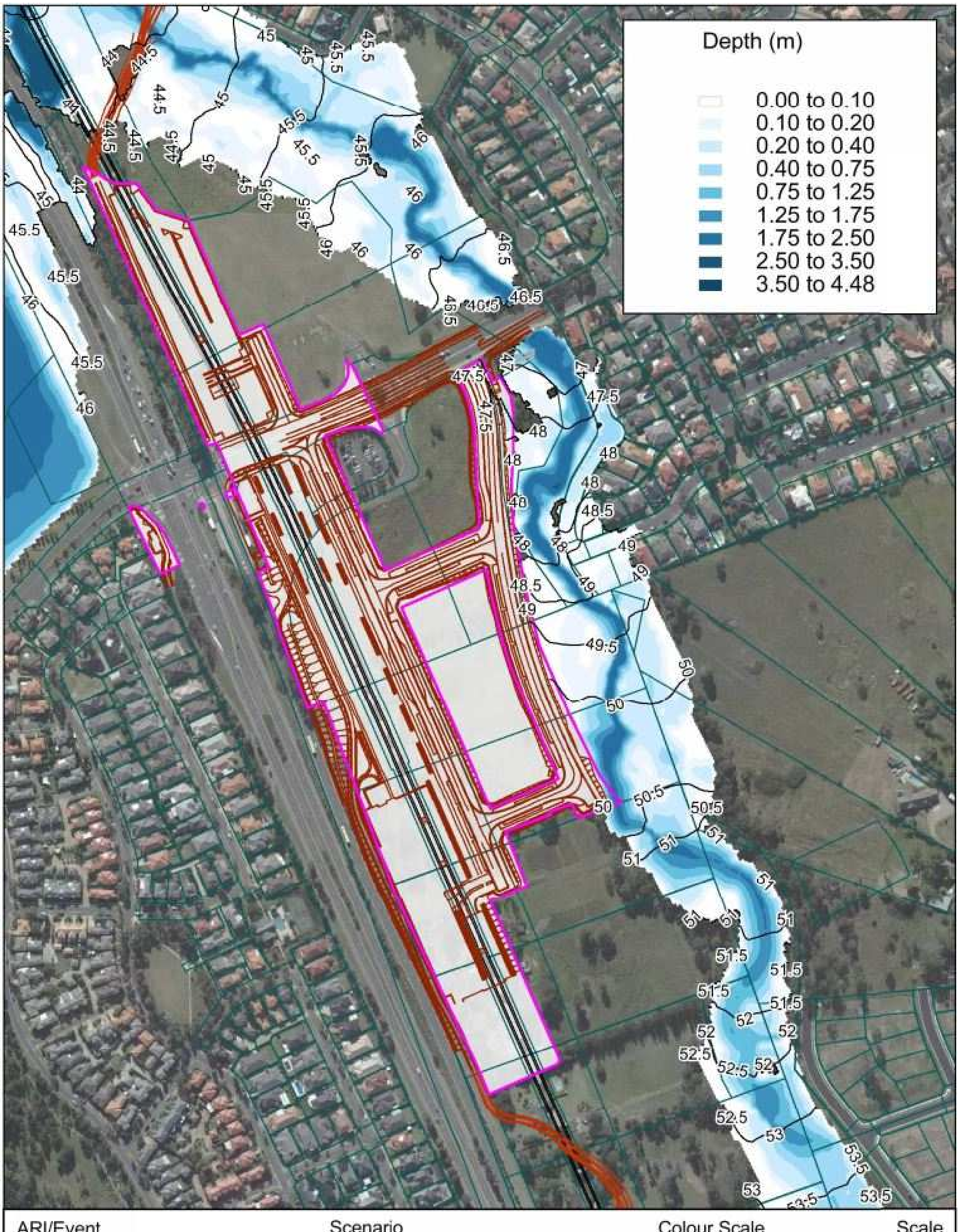


Figure A1.17 - PMF Extents. Proposed condition

Figure 25 Bella Vista PMF Flood Impacts

Kellyville Precinct



ARI/Event	Scenario	Colour Scale	Scale
100yr Climate Change	Proposed Conditions	Flood Depth	1:4000
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	KVE

Figure 26 Kellyville 100 year ARI Flood Extents

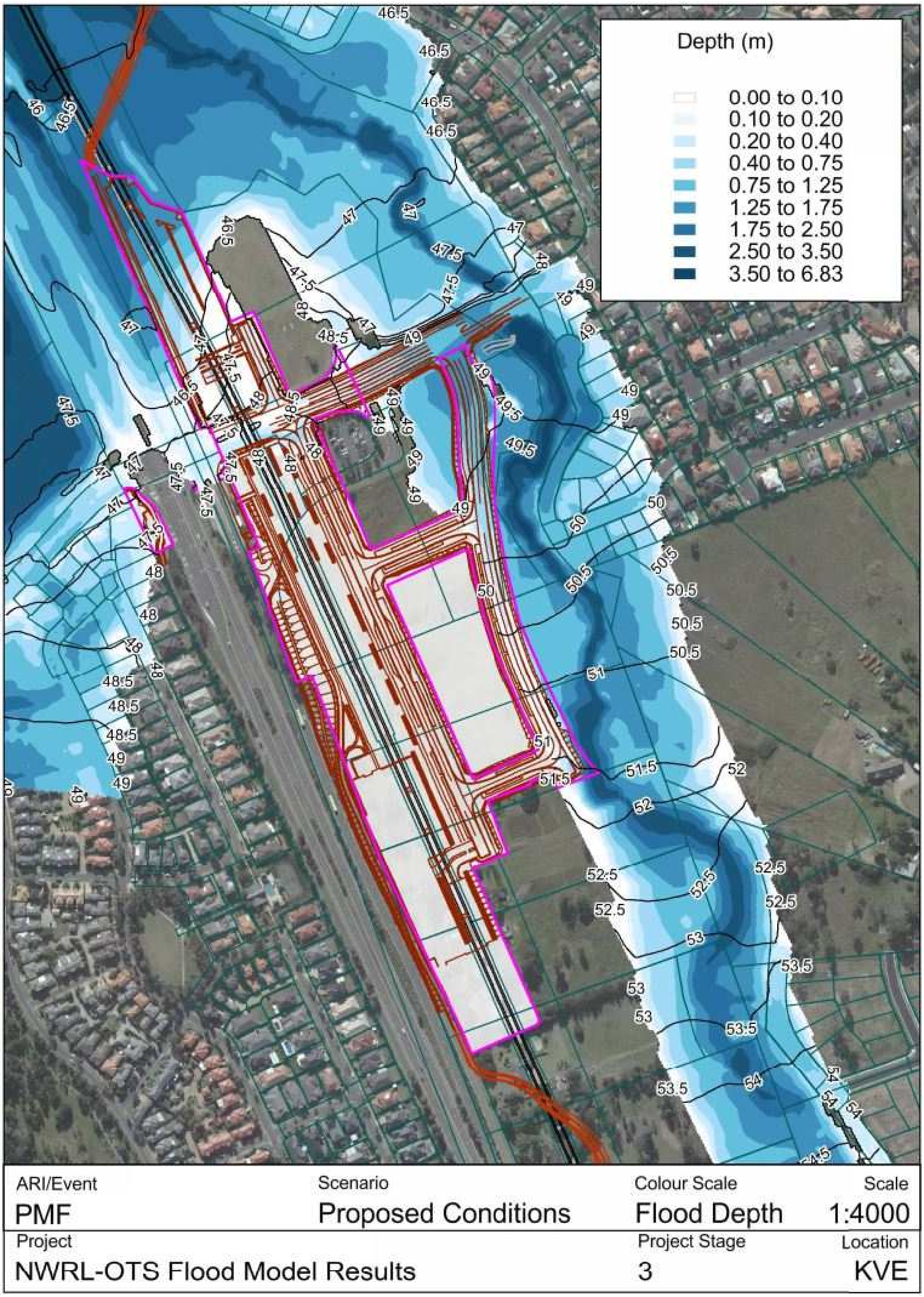
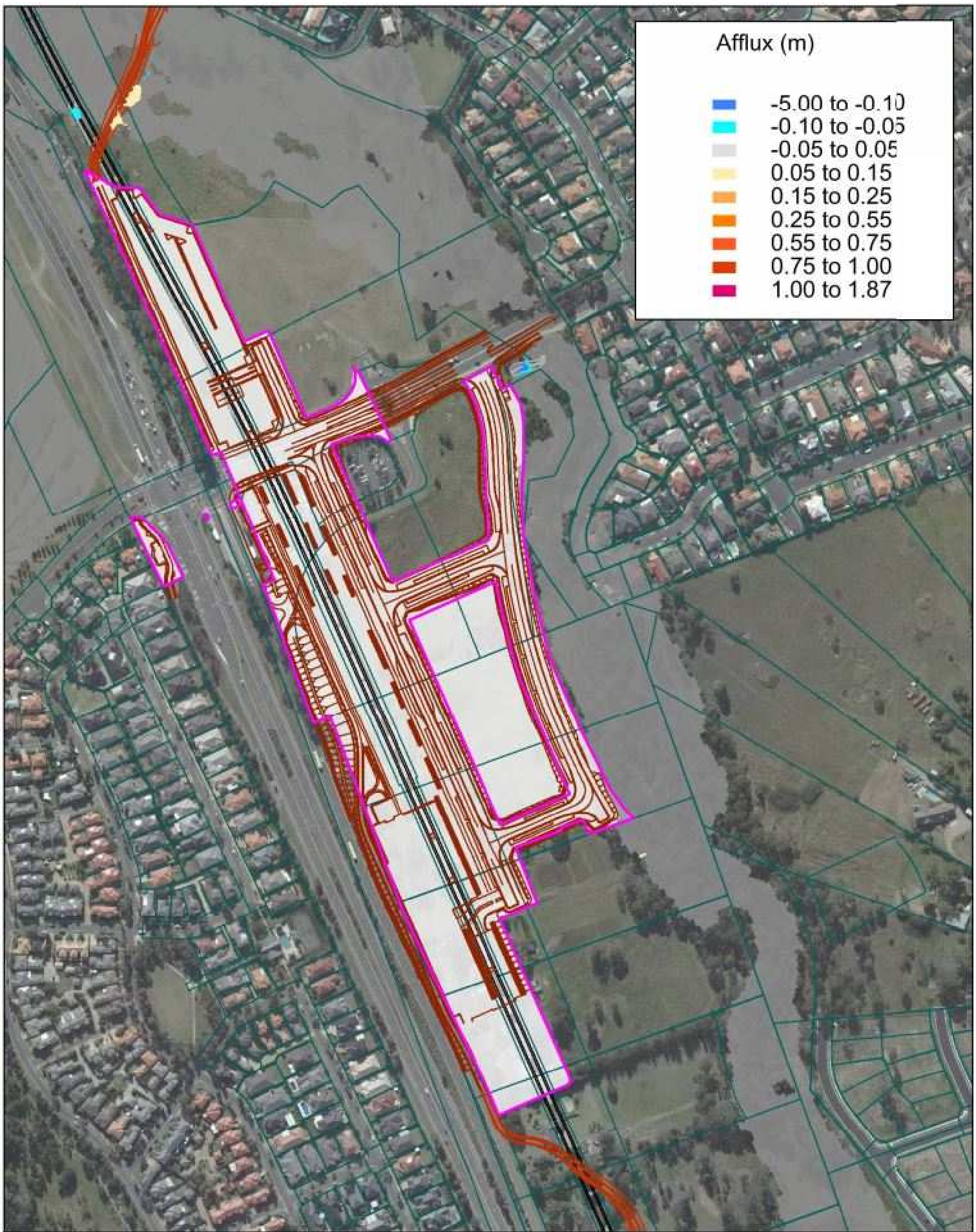


Figure 27 Kellyville PMF Flood Extents



ARI/Event	Scenario	Colour Scale	Scale
100 year ARI	Pre-Post Comparison	Net Depth	1:4000
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	KVE

Figure 28 Kellyville 100 year ARI Flood Impacts

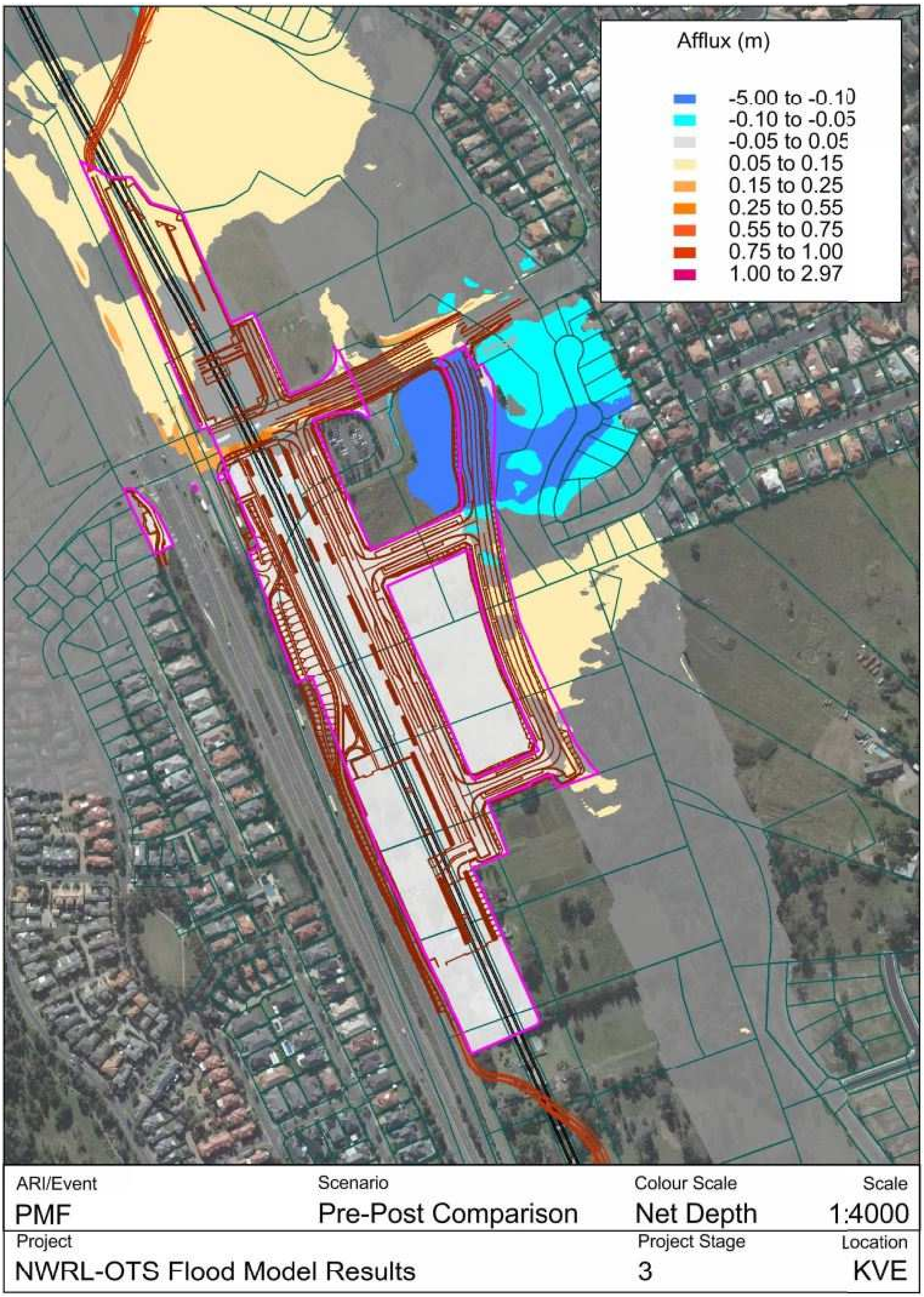


Figure 29 Kellyville PMF Flood Impacts

Rouse Hill Precinct

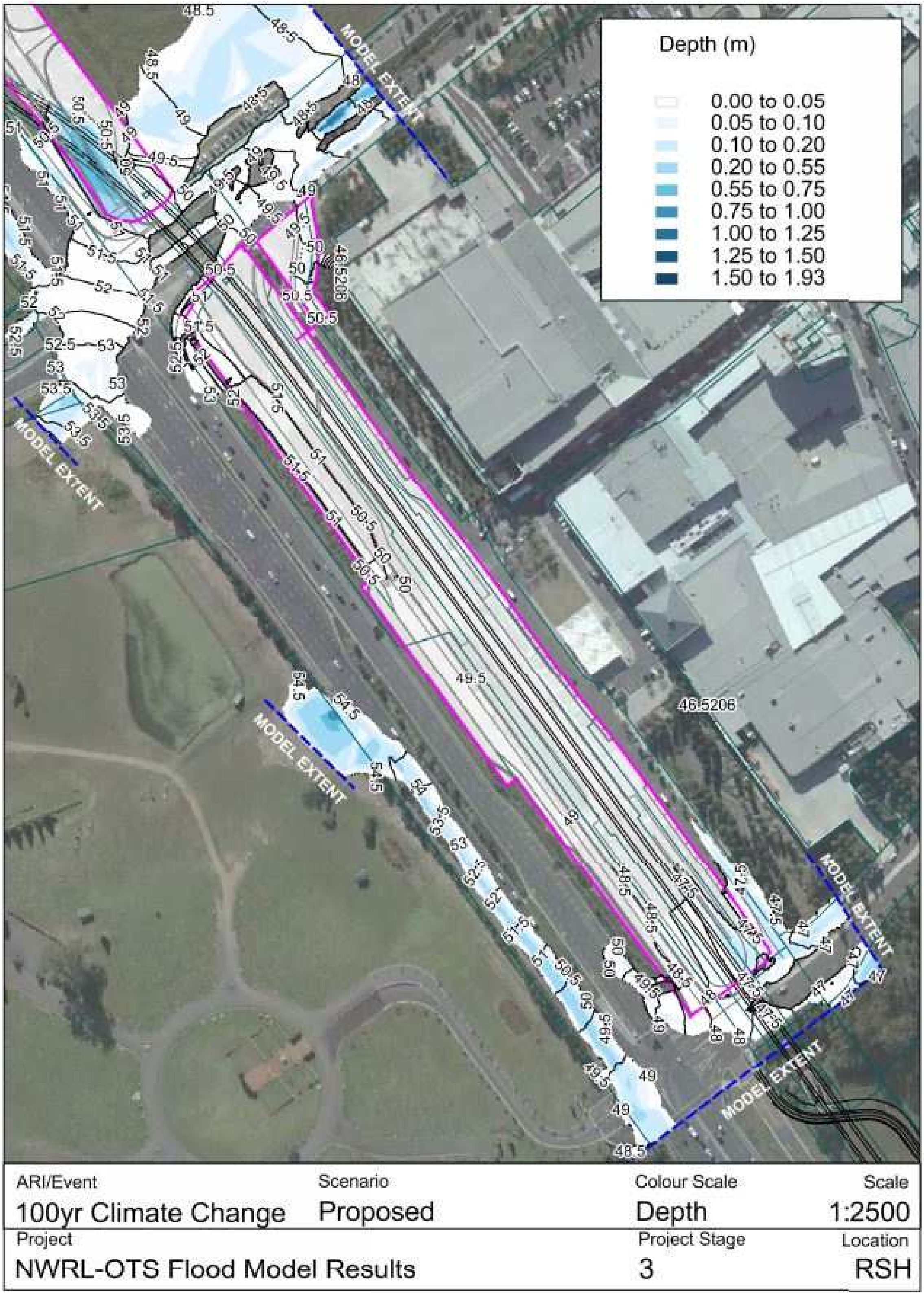
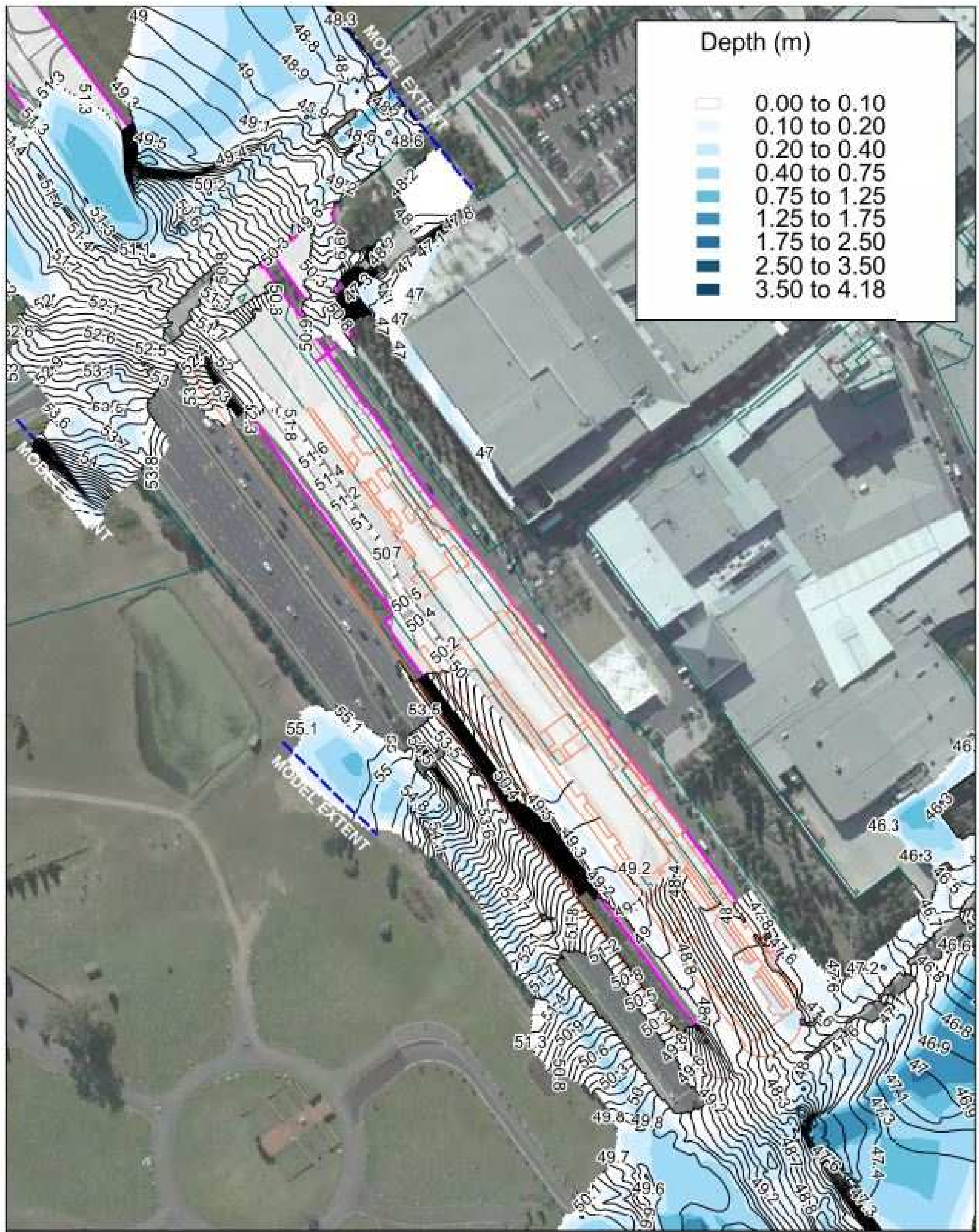


Figure 30 Rouse Hill 100 year ARI) Flood Extents



ARI/Event	Scenario	Colour Scale	Scale
PMF	Proposed Conditions	Depth	1:2500
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	RSH

Figure 31 Rouse Hill PMF Flood Extents

Corridor

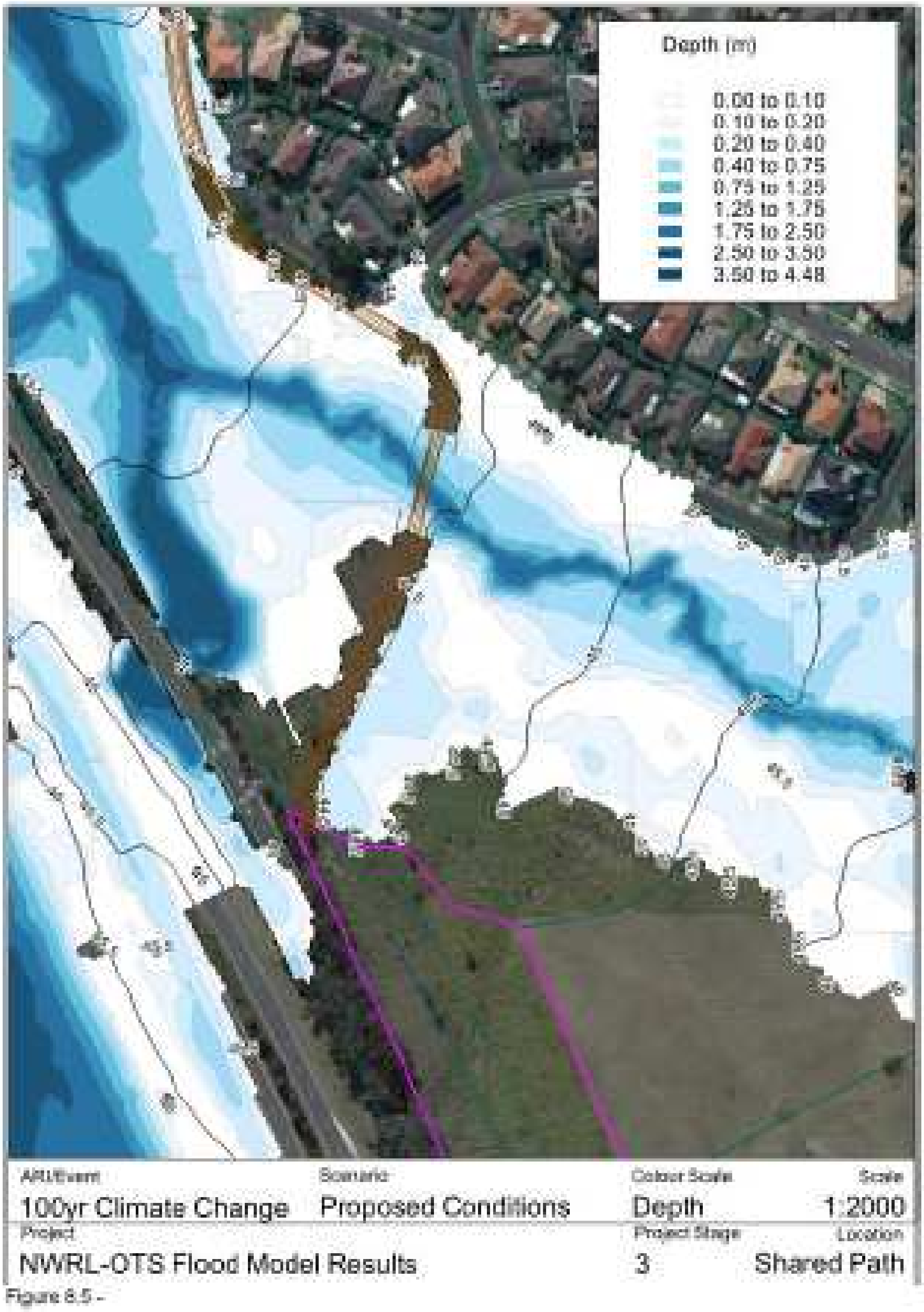
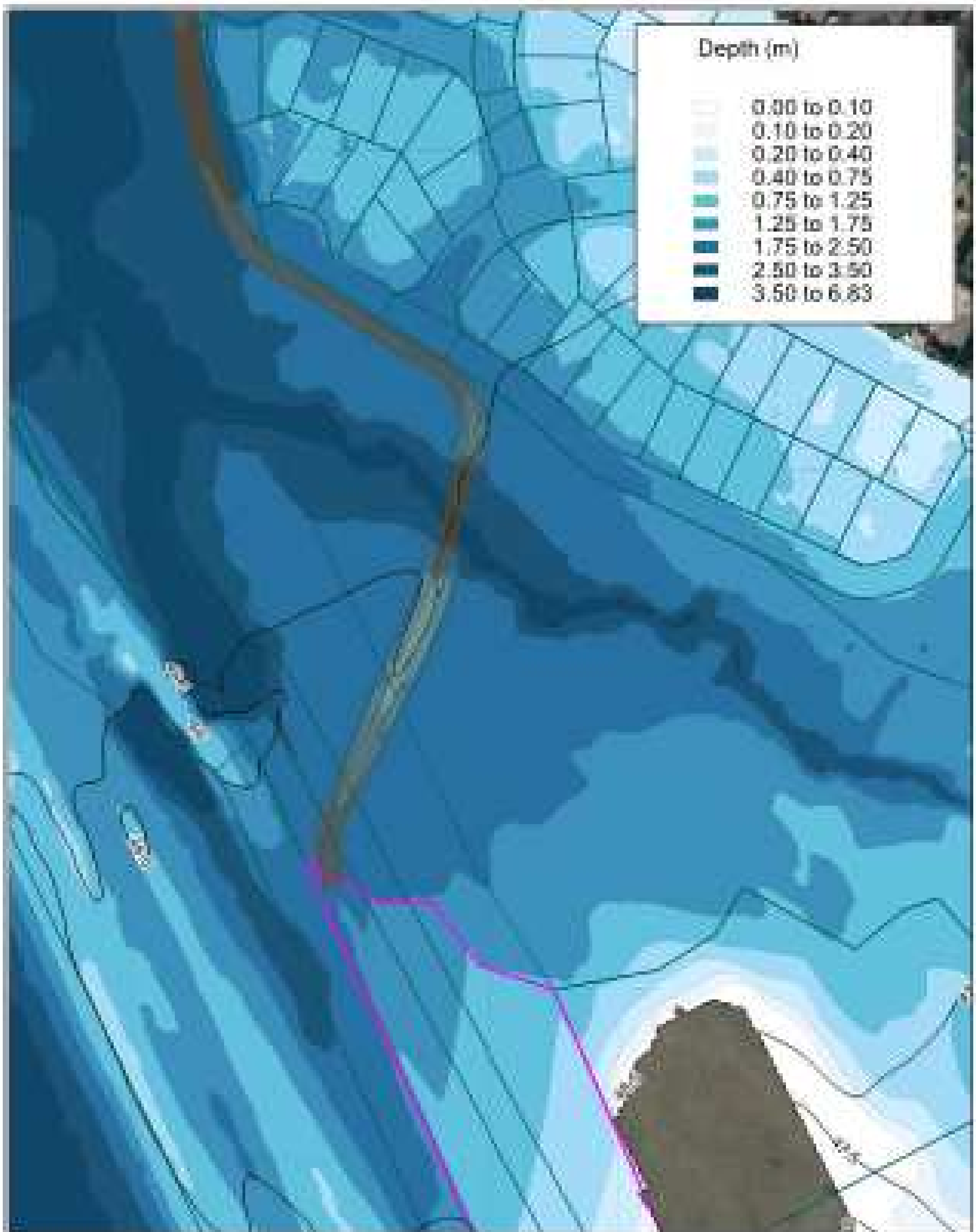


Figure 32 - Corridor 100yr Flood Extents



ARI/Event	Scenario	Colour Scale	Scale
PMF	Proposed Conditions	Depth	1:2000
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	Shared Path

Figure 8.5 -

Figure 33 - Corridor PMF Extents

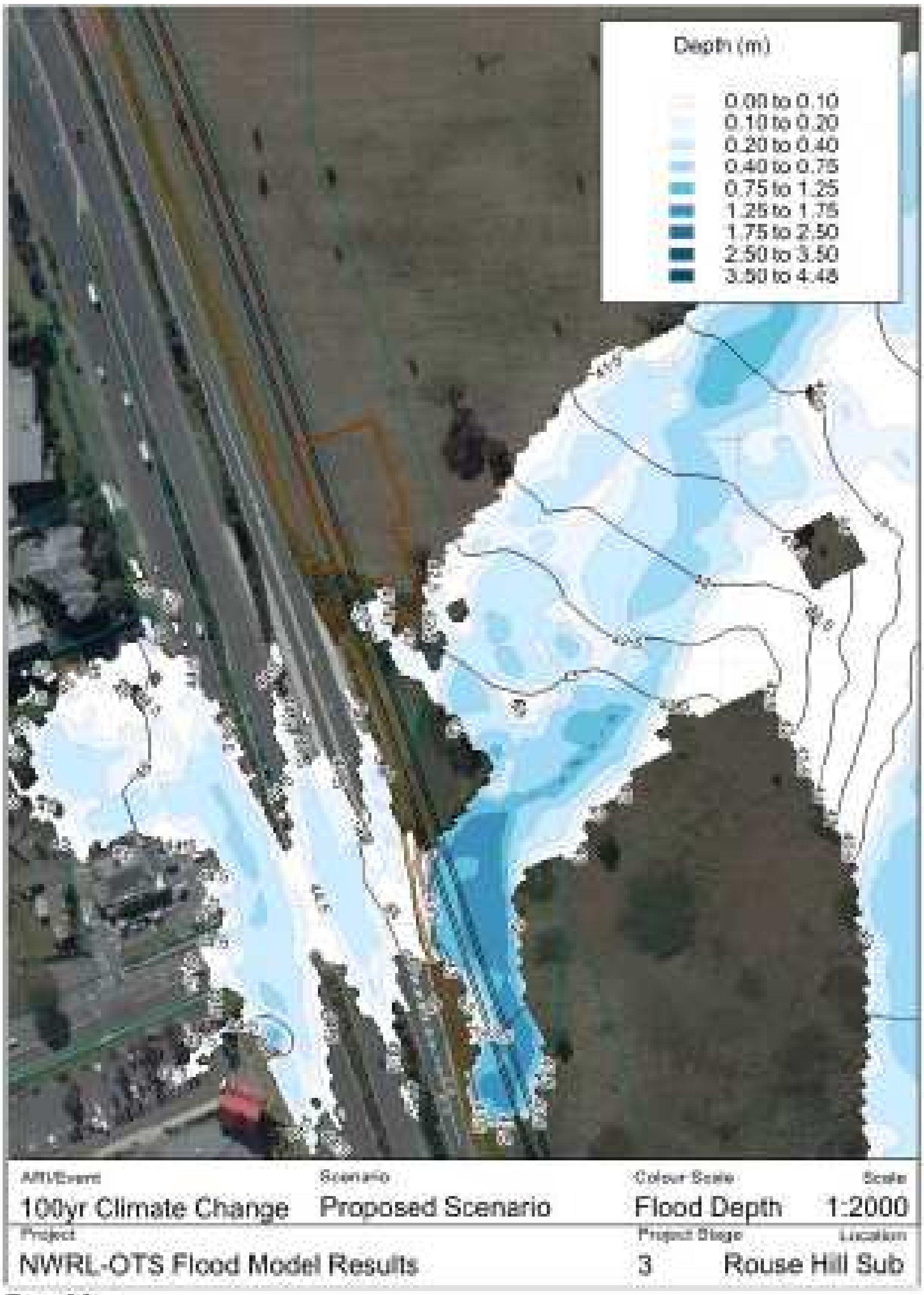


Figure 8.9 -

Figure 34 – 100yr Climate Change Flood Extents

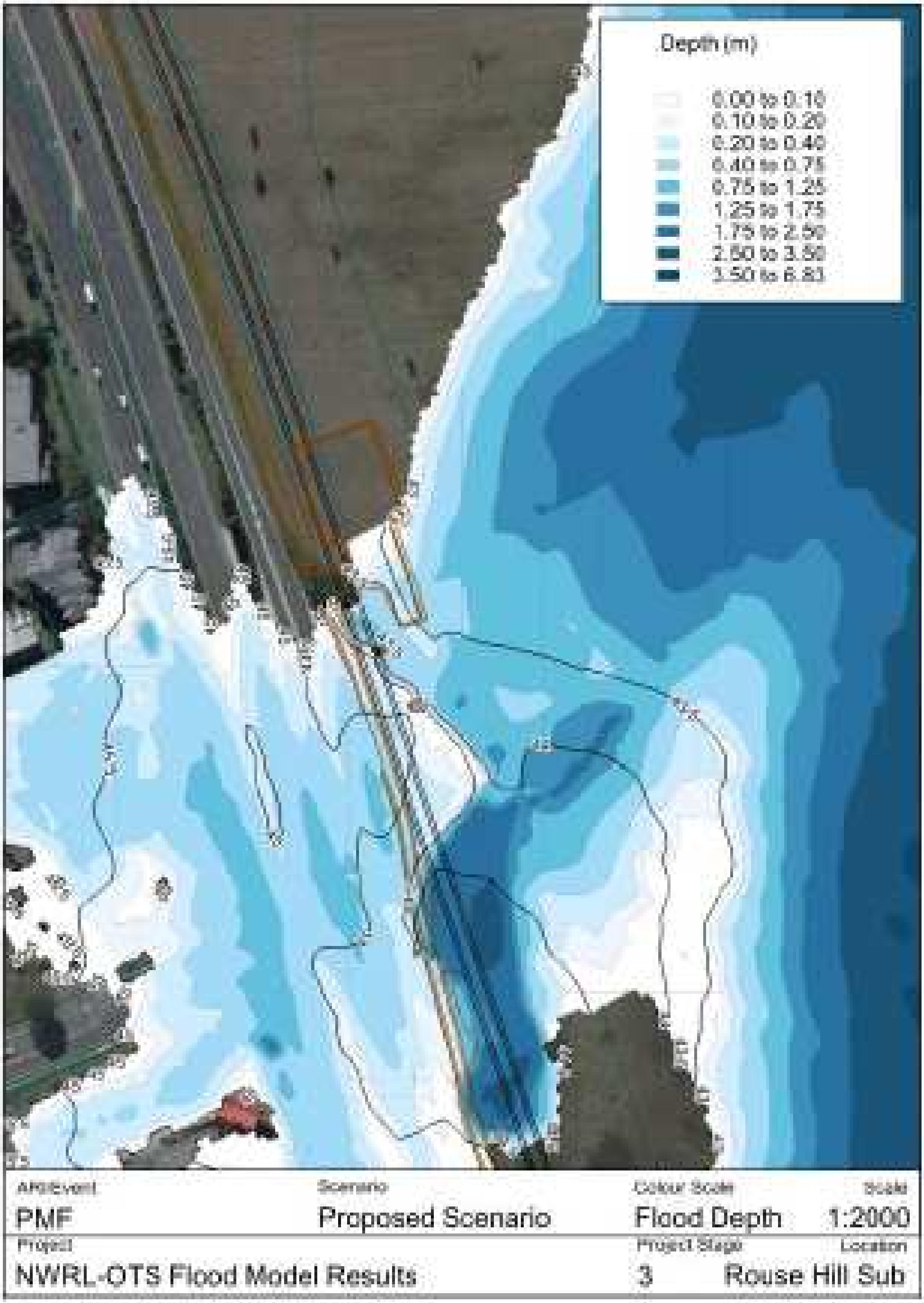


Figure 35 - Corridor Substation PMF

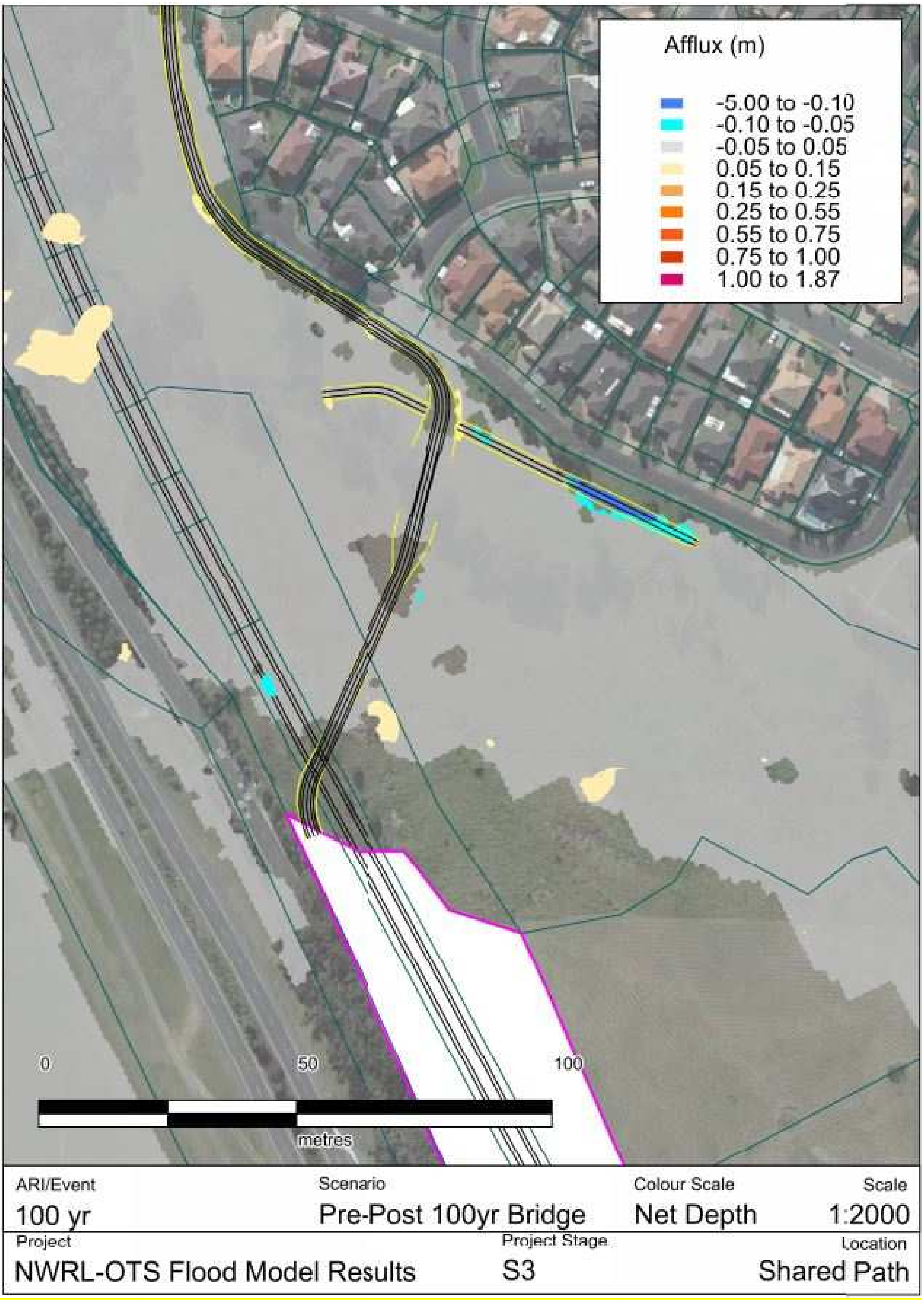


Figure 36 - Corridor Bridge 100 yr Impacts

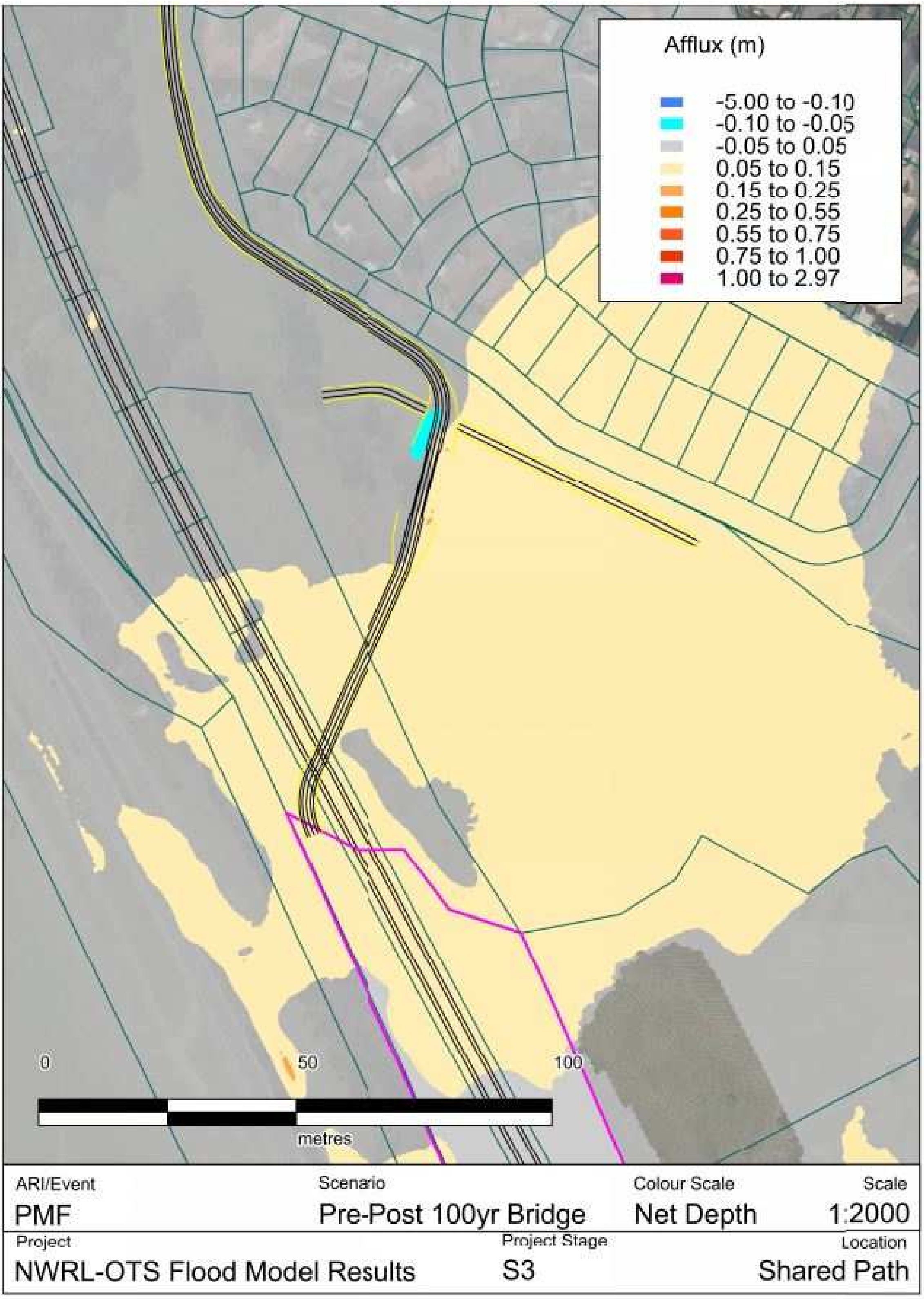


Figure 37 - Corridor Bridge PMF Impacts

Annexure E Curricula Vitae

David Bannigan

Principal Water Resources Engineer

QUALIFICATIONS

- Master of Engineering Science (Water Engineering), University of New South Wales, 1997.
- Bachelor of Engineering, University of New South Wales, 1988
- Member, Institution of Engineers Australia

KEY SKILLS AND COMPETENCIES

- Project Management
- Team leadership.
- Strategic planning and staff development
- Detailed knowledge of Environmental Legislation
- Design of drainage infrastructure for urban, commercial and industrial developments
- Water supply and water balance modelling
- Hydropower Studies
- Water Sensitive Urban Design
- Dam Safety reviews
- Dam spillway adequacy studies
- Flood modelling and flood risk assessment
- Design of environmental mitigation measures.

PROFESSIONAL HISTORY

David is a water resources engineering consultant with twenty five years professional experience.

David joined SMEC's water resources group in 1997 and has over the last 16 years worked on major engineering projects in Australia and Asia covering flooding investigations, dam safety reviews, highways, mining, hydropower and water supply investigations.

David's roles within SMEC have included management of the Water Resources teams in NSW and QLD.

RELEVANT EXPERIENCE

Water Management Strategy for 2 X 100 MW Coal Fired Power Station

Project manager for water management study to determine the feasibility of providing water supply of 19,000 m^3/day to a proposed coal fired power station in Kalimantan using mine surface runoff. Study included water balance modelling, flood modelling ,sedimentation assessment and dam safety management.

Bega and Brogo Rivers Flood Study

Project Manager. Flood Study of Bega and Brogo Rivers using RAFTS and TUFLOW models. Study outputs included GIS layers of flood level, velocity, depth and hazard across the floodplain.

Wingecarribee River Flood Study

Project Manager. Flood Study of the Wingecarribee River catchment using RAFTS and TUFLOW models to develop flood maps and GIS layers of flood information for flood planning purposes for the Wingecarribee Shire.

Carroll Causeways Flood Assessment

Project Manager. Two dimensional hydraulic modelling study for RMS to determine appropriate causeway levels and culvert arrangements and to map project impacts on flood levels associated with proposed road upgrades in the Namoi River floodplain at Carroll. Flood behaviour was modelled in TUFLOW

Flood Modelling Investigation, Blackadder Creek Corindi, NSW

Project Director – Review of recent highway safety improvement works for RMS using two dimensional flood modelling to assess impacts of highway works on flood patterns in Corindi River floodplain. Study included detailed flood modelling and community presentations.

WestConnex, M4 Widening Environmental Impact Statement

Client WestConnex Delivery Authority

Team Leader for Hydraulic Studies to assess impact of proposed widening of M4 Motorway from Church Street Parramatta to Homebush Bay Drive in Sydney. Study involved hydrologic data collection, hydrologic and hydraulic modelling for catchments including Duck River, Haslam's Creek and Homebush Bay.

Hydropower Projects - Asia

Lead Hydrologist for various Hydropower Projects. Responsible for assessment of design floods, determination of available water, spillway design floods and reservoir sediment inflows for the following projects:

- Telom HEPP (132 MW) - Detailed Feasibility Study, Malaysia 2013-2014
- Sibundong HEPP (60 MW) – Detailed Feasibility Study, Indonesia 2013
- Jiasa HEPP (270 MW) – Value Engineering, China 2013
- Baram HEPP (1200 MW) – Pre Engineering, Malaysia 2012-2013
- Baleh HEPP (1400 MW) - Pre Engineering, Malaysia 2012-2013
- Limbang 1 and Limbang 2 HEP Detailed Feasibility Studies, Malaysia 2011-2012
- Lawas HEPP Detailed Feasibility Studies, Malaysia 2011-2012
- Batang Gadis HEPP (5 MW), Sumatra Indonesia 2010
- Urumuka HEPP (500 MW)- Expert Review, Papua Indonesia 2010
- Ulu Jelai HEPP (372 MW) Detailed Feasibility and Reservoir Operation Studies, Malaysia 2008, 2012
- Nam Theun 2 HEPP (1070 MW) Detailed Feasibility Studies, Laos 2006

Pacific Highway Upgrade Project

Team leadership and design review roles in the following Pacific Highway Upgrade projects to duplicate the existing Pacific Highway to separated dual carriageway between Sydney and Queensland:

- Oxley Highway to Kempsey – 38 km
- Banora Point Upgrade – 2.5 km
- Ballina Bypass – 11.5 km
- Bonville Upgrade – 9.8 km
- Brunswick Heads to Yelgun – 8.7 km
- Bulahdelah Bypass – 8.5 km
- Karuah Bypass – 10 km
- Raymond Terrace to Karuah – 30 km

Keepit Dam Upgrade Stage 2 Works

Oversaw the design of downstream embankment revetment and road strengthening works to withstand extreme flood downstream recirculation currents predicted by CFD modelling. SMEC was engaged to prepare detailed designs for the raising of the concrete monoliths and main embankment of Keepit Dam, a 45,500 ML capacity dam with a catchment area of 5700 km^2 located in the NSW Namoi River Valley.

Hastings and Wilson Rivers Floodplain and Bridge Modelling Studies

Team leader for development of bridge options for the Pacific Highway Upgrade crossings of the Hastings and Wilson Rivers, with a combined catchment area of 3700 km^2, draining to the Pacific Ocean. Supervised catchment hydrologic studies and hydraulic modelling which included calibration of RAFTS and TUFLOW models to historic events and flood frequency analysis with inclusion of censored data. Carried out climate change sensitivity modelling for a range of sea level and rainfall intensity changes and developed climate change adaptation solutions.

Oxley Creek Flood Modelling - Business Case for Ipswich Motorway Upgrade – Rocklea to Darra, QLD

Lead hydrologist for planning study to prepare business case for preferred option for upgrading of the Ipswich Motorway between Rocklea and Darra. The project has complex flooding and environmental constraints with flooding from both Brisbane River regional floods and Oxley Creek local floods. A TUFLOW model was established for the Oxley Creek flood plain and various highway alignments were tested to determine flood impacts and predicted flood closure times.

Yield Assessment and Development of Decision Support System- Darwin River Dam and Manton Dams, Darwin NT

Project Manager. Darwin River Dam is a key component of the Darwin City water supply. The purpose of the study was to review the available yield from the existing water supply catchment under a range of climate change projections. A multi objective decision support system was developed to assess augmentation options.

Murray Darling Basin Afforestation Study

Project Hydrologist. Study into the potential effects on water yields of expansion of traditional forestry and carbon sequestration plantations in the Murray Darling Basin. The project involved collation and synthesise of current scientific knowledge by interviewing leading scientists and industry experts and using the findings to assess impacts on catchment water balance under several future climate scenarios.

Loudoun Weir Operation Plan, QLD

Hydrologist for development of a water balance model for Loudoun Weir located on the Condamine River in QLD. The model was calibrated to measured streamflow and pumping records and was used to support the development of an operation plan for the weir, incorporating environmental releases through a newly modified fish ladder.

Hume Dam Assessment of Hydrologic Risk

Hydrologic study to prepare calibrated hydrologic models to determine inflow floods for Hume Dam for the assessment of spillway capacity. Hume Dam has a storage volume of 3,040 GL and a catchment area of 15,280 km^2. In the model calibration process, it was necessary to account for snowmelt contributions as well as water transfers from the Snowy Mountains Scheme storages.

Gladstone Water Supply Optimisation and OPEX Study, QLD

Responsible for analysis of Gladstone raw and treated water supply systems for independent economic assessment of water pricing for regulating authority. Simulated pumping and gravity distribution system using WATNET software and determined future distribution system upgrade requirements to meet projected demands

Lae City Institutional Strengthening - Papua New Guinea -

Drainage Specialist providing advice and training on flood design, water quality improvement and asset maintenance as part of an Australian funded project to upgrade 36 km of arterial and industrial roads in Lae City. The project was aimed at strengthening the capacity of the local agencies to undertake future planning of road and drainage requirements.

Dam Failure Impact Assessment – Storm King Dam, QLD

Project manager for dam failure impact assessment for 2100 ML concrete gravity dam in the Southern Downs in QLD. The study involved calibration of hydrologic models, extreme flood estimation and dam break modelling using MIKE 11 software. The flood extent was then mapped and population at risk estimates were determined.

Dam Failure Impact Assessment – Rifle Ck and Leichardt River Dams, Mt Isa QLD

Project Manager for dam failure impact assessments for two dams on the Leichardt River at Mt Isa. Rifle Ck dam is an arch gravity dam impounding 9500 ML located upstream of Mt Isa township. Leichardt River Dam is a concrete faced rock fill dam impounding 103,000 ML. The study involved calibration of hydrologic models, extreme flood modelling and dam break modelling using MIKE 11 over a distance of approximately 300 km to determine population at risk and failure impact on downstream infrastructure. Spillway capacity upgrade requirements were then determined

Appin West Colliery, Surface Water Dams, Douglas Park, NSW

Project Manager for design and construction of 10ML stormwater water settling dam at Appin West Colliery. The dam was designed to regulate the flow of stormwater discharge from the 12 ha pit top catchment through a downstream 30 l/s cartridge filter unit, as part of minewater/stormwater separation works to purify water released to the downstream environmentally sensitive Nepean River basin.

Belongil Creek Flood Study, NSW

Responsible for a flood study of the Belongil Estuary and Byron Bay town centre to determine flood levels and flood risk. Assessed impacts of climate change on flood hazard. through application of increased rainfall intensity, sea level and storm surge. The study area was modelled using TUFLOW software to simulate complex two dimensional flood behaviour.

Liverpool Retarding Basin 100 Remedial And Consequential Hazard Rating Investigation

Project Manager for geotechnical and hydrologic study on 30 ML retarding basin located in a residential development in Cecil Hills, Liverpool. The project involved geotechnical field investigations to assess stability of existing embankment wall resulting in recommendations and a conceptual design to reconstruct the wall and spillway. A dam break study was carried out using MIKE 11 with assessment of downstream consequences, resulting in a recommendation to increase the Flood Consequence Category and to increase the existing spillway capacity.

Burrendong, Burrinjuck and Wyangala Dams, Spillway Gate Malfunction Studies

Project Manager for studies to assess security of three large gated storages in the event of mechanical failure of one or more of the spillway gates during an extreme flood event. Flood inflow hydrographs were routed through the storages for a range of initial drawdown conditions and gate malfunction scenarios. Joint probability methods, which take into account storage drawdown probability at the commencement of flooding, were then used to determine the probabilities of dam overtopping for each gate failure case.

Manton Dam Risk Assessment Study, NT

Lead Hydrologist. The project involved determination of hydrologic risk of overtopping and dam break analysis using MIKE 11 to determine failure consequences along Manton River, downstream of the dam

Namoi River - Carroll to Boggabri Hydraulic Modelling

Numerical modeller responsible for preparing a quasi two dimensional unsteady model of the Namoi River and associated floodplains using a complex MIKE 11 model.. The model covered a 100 km reach of the Namoi River encompassing the towns of Carroll, Gunnedah and Boggabri in central NSW. The modelling will form a future planning tool for DLWC to be used for assessing the influence of existing and future levee banks on flooding patterns.

Nerang River Hydraulic and Water Quality Modelling

Lead Hydrologist. Responsible for hydraulic modelling of the Nerang River Estuary, using a highly detailed MIKE 21 model. The study area included the Nerang River and the numerous man-made Gold Coast canal estates which are hydraulically interconnected with the river. The study purpose was to provide Council with both flooding and water quality models for assessment of future development scenarios. The model calibration was carried out in two stages with one stage focusing on modelling of tidal conditions and the other stage focusing on modelling of flood conditions. The water quality modelling phase of the study was undertaken in conjunction with Asia-Pacific Applied Science Associates. The water quality model consisted of a pollutant export model to model nutrient inputs and an in-stream processes model capable of modelling advection, dispersion and decay processes throughout the estuary.

Glenlyon Dam Safety Review

Hydrologist, responsible for hydrology component of a comprehensive dam safety review for one on South East Queensland's water supply dams which has a storage capacity of approximately 260 GL supplying water to the Inglewood Shire. Tasks included review of spillway capacity and exposure of downstream communities and infrastructure to under dam failure scenarios.

Happy Valley Dam Remedial Works, Adelaide

Hydrologist. Responsible for a dam break assessment and preparation of a Dam Safety Emergency Plan for Happy Valley Reservoir which is part of Adelaide's water supply infrastructure. The dam break assessment utilised Mike 11 software was for a cascading failure of four embankments which included the reservoir, expressway and railway embankments which cross the Field River in Adelaide.

Gold Ridge Mine Haul Road Design, Solomon Islands

Project Manager to undertake the detailed design of a haul road for Gold Ridge Mine, an open cut gold mine producing 100,000 oz of gold per annum. , responsible for detailed design of bulk earthworks, engineered cut and fill embankments in unstable mountainous terrain, hydrologic analysis and design of design of culverts and permanent sediment control works to reduce environmental impacts on receiving waters.

Warragamba Dam – Gate Operation Review

Warragamba Dam impounds approximately 2,000 GL of water and is one of the largest domestic supply dams in the world. The spillway discharge is controlled by 4 radial gates and a single drum gate, operated at the time of the study according to a procedure referred to as H14. SMEC was commissioned to undertake a study of the dam spillway to assess the effectiveness of alternative gate operating procedures based on forecasting of dam inflows in reducing downstream flood damages. Responsible for supervision of computer modelling, further development of existing gate modelling software and preparation of detailed report on study outcomes.

PUBLISHED PUBLICATIONS

Bannigan D.J, Green J, Nandakumar.N, Varley I (2002) "The Effect of Gate Malfunction on the Hydrologic Risk of Dams", Proceedings of 27th Hydrology and Water Resources Symposium, IE Aust Conference, Melbourne, May 2002.

Short S.A, Bannigan D.J, Nichols P.S (1998) "pH Management of Waste Waters or Leachates by Exposure to Coal Washery Discharge", Proceedings of 2nd International Conference on Environmental Management (ICEM2), Australia, 10-13 February

Rigby E.H & Bannigan D.J (1998), "A Review of Factors Influencing Near Coastal Flooding in Hewitts Creek, Wollongong", Proceedings of 2nd International Conference on Environmental Management (ICEM2), Australia

Rigby & Bannigan (1995) "The Embedded Design Storms Concept - A Critical Review" Proc Hydrology 96, IE Aust Conference, Hobart, May 1996.

Rigby, Anger & Bannigan (1995) "Modelling the Hydrology of a Complex Partly Urbanised Catchment" Proc Hydrology 96. IE Aust Conference, Hobart, May 1996.

Anton Kandiah

Principal Engineer

Years of Industry Experience

- 19 Years

Qualifications and Memberships

- MEng
- BEng (Civil) Hons

Key Skills and Competencies

- Managing drainage team
- Providing assistance and directions regarding drainage issues to engineers
- Providing professional advice to drainage related matters

Professional History

Anton is a Principal Engineer with SMEC. He has over 19 year's professional experience in drainage design mainly in storm water drainage for urban and rural highways. Anton has good knowledge of drainage design softwares including DRAINS, XP-Rafts, Hec-Ras, MUSIC and Culvertmaster.

Relevant Project Experience

Pacific Highway Upgrade – Oxley Highway to Kempsey
Drainage Team Leader responsible for the coordination of the drainage drawings in conjunction with the road design and RMS requirements. Responsibilities included drainage design, temporary and permanent water quality design, negotiations with RMS environmental personnel in identifying fauna passages and investigation of flood immunity to fauna culverts, attend coordination meetings with RMS, external verifiers and other authorities as required.

Pacific Highway Upgrade – Sapphire to Woolgoolga
Design Package Manager for the drainage design of 27 km of rural highway, responsible for the coordination of the drainage drawings in conjunction with the road design and RMS requirements.This project required special attention to flooding. Other responsibilities included treatments for culverts on soft soils and water quality meetings with RMS, external verifiers, contractor and other authorities as required.

Pacific Highway Upgrade - Bulahdelah Bypass

Design Package Manager for the drainage design of 8.5 km of rural highway, responsible for the coordination of the drainage drawings in conjunction with the road design and RMS requirements. This project required special attention to flooding, foundation treatments for culverts on soft soils, durability treatments for drainage structures in acid sulphate soils and environmental treatments to culverts and embankments. Other responsibilities included attending coordination meetings with RMS and other authorities as required.

Pacific Highway Upgrade - Ballina Bypass

Independent Verifier (IV) for drainage and water quality packages. Tasks included a review of all drainage related drawings and reports.

Pacific Highway Upgrade - Bonville Upgrade

Design Package Manager for the drainage design of 9.8 km of rural highway, responsible for the coordination of the drainage drawings in conjunction with the road design and RMS requirements. Other responsibilities include attend coordination meetings with RMS, the external verifier and the contractor.

Pacific Highway - Brunswick Heads to Yelgun

Design Package Manager for the drainage design of 9 km of rural highway.
Coordination of the drainage drawings in conjunction with the road design.

Westlink M7

The M7 is a 40km 4-lane divided highway in the west of Sydney. Anton was a Senior Design Engineer and responsible for the design of pavement drainage, transverse drainage and sub-surface on an 8km section of the M7. Design was performed using various computer programs including 12D and DRAINS. Part of Anton's responsibility was the coordination of the drainage design in conjunction with the road and bridge design.

Windsor Road Upgrade between Commercial Road and Mile End Road

Design Package Manager for the drainage design of 1.7 km of road. Responsible for the design of pavement drainage, transverse drainage and sub-surface design. Design performed using various computer programs including 12D and DRAINS. Responsible for the coordination of the drainage drawings in conjunction with the road design and RTA requirements.

Pacific Highway Upgrade, Karuah Bypass

Design Package Manager for the drainage design of 11 km of a 4-lane divided rural highway. Responsible for the design of pavement drainage, sub-surface design. Design performed using various computer programs including 12D and DRAINS. Provided assistance in the design of transverse culverts, pollution control measures, diversion structures.

Old Windsor Road Upgrade

Drainage Engineer for the design of 1.0 km of road including major intersection. Responsible for the design of pavement drainage. Design performed using various computer programs including 12D and DRAINS. Responsible for the coordination of the pavement drainage drawings in conjunction with the road design and preparation of the sub soil drawings in conjunction with design guidelines.

Pacific Highway Upgrade - Karuah to Bulahdelah, Section 3

Drainage Engineer for the design of 12.6 km of 4-lane divided rural highway. Responsible for the design of longitudinal drainage. Design performed using various computer programs including 12D and XP-Rat 2000. Design of transverse drainage, sediment control devices, energy dissipater structures, and bridge hydraulics.

RailCorp Projects

Drainage input to various RailCorp projects including Cockle Creek, Beecroft railway line upgrades in accordance with RailCorp standards.

Annexure F – Reasonable and Feasible

F.1 Corridor Flooding

The definition of ‘feasible and reasonable’ forms a key role in the determination of an appropriate flooding outcome for elements of the project particularly sensitive to flooding. This definition was provided in the same infrastructure approval document which lists conditions from the Minister for Planning and Infrastructure (C33).

Feasible and Reasonable

Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context. Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.

Where requested by the Director General, the Proponent shall provide evidence as to how feasible and reasonable measures were considered and taken into account.

The results of the comparative analysis in the vicinity of the shared user path bridge across Elizabeth Macarthur Creek is shown in the attached figure by means of a colour scale representing afflux in the water surface level. This colour scale highlights areas which do not conform with limit (a) of C33 above. It is the designer’s view that these highlighted areas should not represent a ‘non-conformance’ of the conditions and the justification of this view follows

Mitigation benefits versus cost

It can be seen that the areas which do not conform with the C33 (a) limits are contained within the 0 – 150 mm range of the colour scale. The location of these areas is not within private properties, do not apply to habitable floor levels of any buildings, and are removed from adjacent private properties altogether. The location of these afflux areas within the creek corridor is such that the risk involved with this flooding is to pedestrians/cyclists or to persons carrying out field inspections/maintenance only. This afflux is observed at the peak of the 100 year flood event, which occurs hours after the commencement of the extreme rainfall event. Thus it is not likely that any of these users of the area would still be in the area, rather sheltering somewhere protected from the extreme weather. The potential benefit of mitigating this relatively small area experiencing an increase in flood levels is not considered significant as the presence of people is not likely.

The costs of measures which could alleviate this afflux is unduly high relative to the benefits. Increasing the bridge extent of the crossing such that there are reduced lengths of shared path with batter slopes obstructing the flow could eliminate afflux. The size of a bridge to do this would be greater than 150m, far greater than the proposed 40m structure. The flooded areas highlighted in the attached figure are in the overbank section of the creek rather than the main channel. Here the flows are slower moving and shallower than flows typically found in a channel or swale. This means that culverts or openings to allow these flows to pass the shared path alignment do not achieve a reasonable hydraulic performance relative to their cost of construction. The determining factor on the hydraulic performance of potential culverts here is the tailwater level downstream of the culvert. With the entire overbank areas flooded (and with relatively low velocities) there is no hydraulic grade across potential culverts and therefore the cost of providing sufficient flow capacity for the alleviation of afflux is unreasonable.

Community views and nature and extent of potential improvements

Community expectations around the treatment of creeks as part of Civil works in NSW is that impacts to the existing conditions be limited to the bare minimum in order to carry out construction, and improvement to the quality of vegetation where reinstatement is required. There is a further expectation that the ecological impact be limited. This expectation has ruled out the potential option of creek channel modifications which could potentially increase the flow capacity across the alignment.

Community expectations that the vegetation beneath the SVC structures be maintained requires drainage elements (channels, pits etc) be installed for the direction of minor stormwater flows used for irrigation. These minor drainage elements also introduce isolated areas of afflux in the 100 year peak flood levels. The adopted free-draining method of irrigation is considered to have lower capital and operational costs than piped irrigation systems. The relatively small mitigation benefit of reducing the afflux due to the free-draining irrigation measures does not warrant construction of alternative measures requiring more regular and costly maintenance/operation.

Summary

Throughout design development an iterative process of designing the infrastructure to minimise the effects on flooding and then re-modelling has been implemented. Many iterations of the design has resulted in an outcome where the shared user path bridge confirms to the project requirements whilst having a minimal effect on the flooding regime. The designers consider that a reasonable approach to the development of the final design has resulted in an outcome which satisfies the Minister's C33 conditions.

F.2 Norwest Flooding

The attached technical document summarises the key points in the determination of the significance of flood impacts where the 50mm in 100 year ARI SPR afflux requirements are not met. This document provides the evidence that designers considered all feasible options prior to their determination.

The following list and supporting technical documentation outline the relevant engineering inputs and summarise outcomes from collaborative working sessions to examine the afflux at Norwest and assess the benefits of further mitigating works.

- Current 100yr flooding situation in Norwest Boulevard is inundated road pavement and verge areas:
    - Road pavement – high hazard per NSW Floodplain Development Manual (FDM)
    - Verge area – low hazard (FDM)
- Worst case flooding results from short duration (15 minute) storm
    - Peak flood levels last less than 5 minutes
    - This kind of short term "flash flooding" is typical of major arterial roads where upstream urban areas have pipe systems for the minor storm only (eg 10 year storm event)
- Current design does not comply with the SPR 50mm afflux requirement in isolated areas. This non-conformance is due to the transition of overland flows from the upgraded road reserve cross section back to the existing cross section.
- Three feasible mitigating measures have been developed to satisfy requirements, refer technical documentation for further details
    - 1 – Widen Norwest Boulevard to sag north of station, approx. 125m
    - 2 – Construct dedicated 100yr pipe system, approx. 140m
    - 3 – Construct 45 cubic metre underground flood storage
- Mitigating measures limit the afflux to within the 50mm tolerance from existing water levels:
    - measures do not provide improved water levels relative to the existing case
    - measures do not change or improve hazard classification (FDM)
- Mitigating measures all require/involve:
    - Traffic management for partial closure of Norwest Boulevard for construction
    - Road network delays to the area
    - Program delays
    - Stakeholder input and approvals
- Potential future upgrades to Norwest Boulevard already planned by RMS may well eliminate the issue through a full upgrade of the road reserve, achieving the same outcome as mitigation Option 1 above.

In light of the minimal benefits experienced by implementing these mitigating measures and the above discussion points, the designers have arrived at the conclusion that the construction of any identified measure to be unreasonable. It is therefore proposed that the 50mm afflux criteria be relaxed in these isolated areas.

Technical Documentation

Introduction

The Norwest civil works report identifies areas of afflux which exceed the project limits of 50mm. This RFI collects and presents the following information;

a) Extracts from the civil design report for Norwest Station precinct;
b) Additional design and modelling details provided by the designers;
c) Comments from TfNSW on an earlier RFI submission;
d) Collaborative working sessions with TfNSW

The definition of ‘feasible and reasonable’ forms a key role in the determination of an appropriate flooding outcome for elements of the project particularly sensitive to flooding. This definition was provided in the same infrastructure approval document which lists conditions from the Minister for Planning and Infrastructure (C33). The mitigating measures developed are considered feasible, so this assessment focusses on whether it’s reasonable to carry out any of the measures.

SPR Requirements and The Minister's Conditions

- Extract from Ministers conditions:

“Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context.
Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.
Where requested by the Director General, the Proponent shall provide evidence as to how feasible and reasonable measures were considered and taken into account. “

Comments from earlier RFI submission

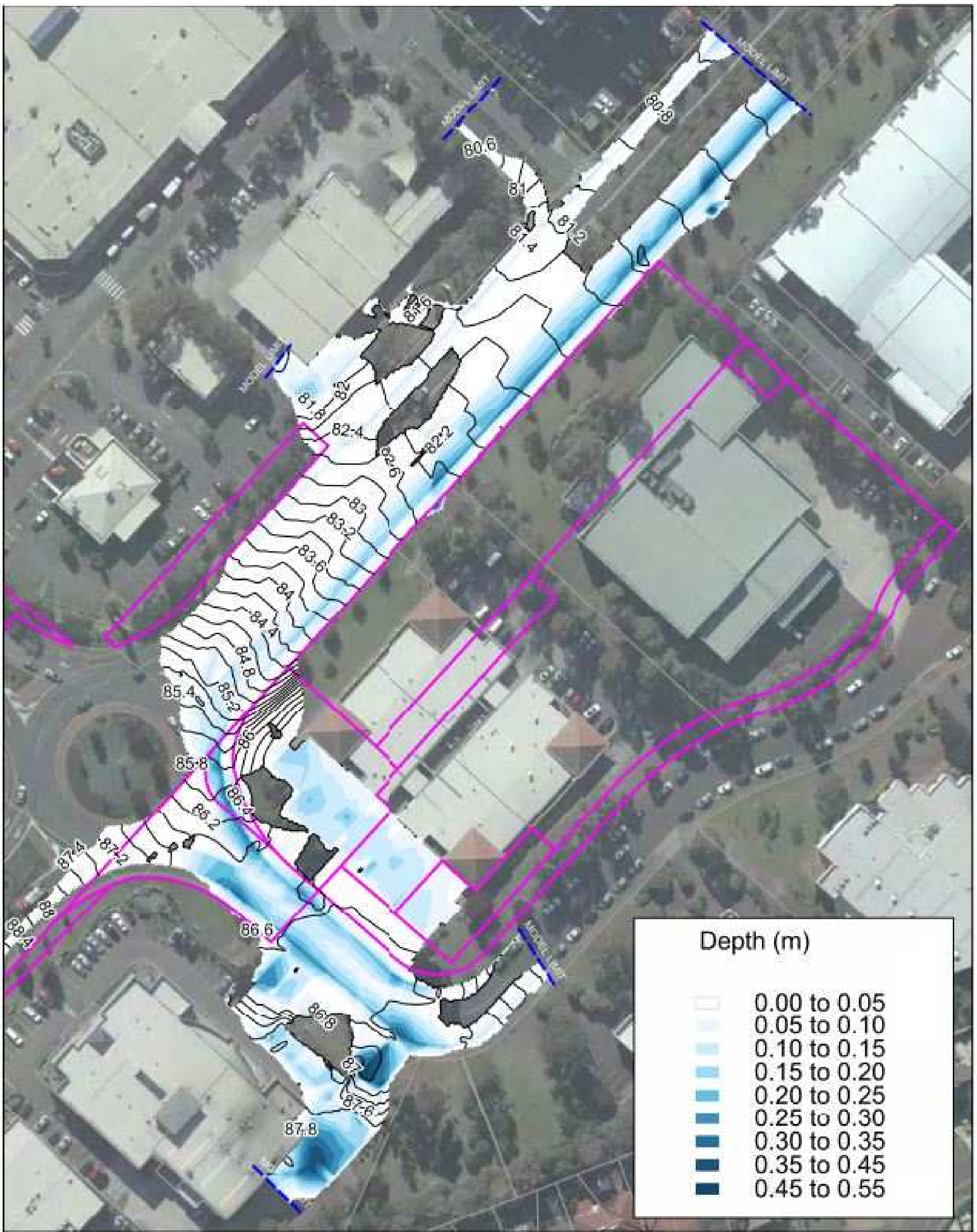
In response to an earlier RFI submission, TfNSW indicated that further details of mitigating measures would be required to assess the benefits of their execution. Subsequently, the three options developed by the designers were discussed in detail during a collaborative session, and comments/discussion points have been summarized in this report.

Modelling Results

- **Wider Flooding Context:**

During the 100yr flood, the existing pit and pipe stormwater network quickly becomes full and ineffective, known as a 'drowned' condition. The road pavement of Norwest Boulevard then becomes inundated by overland flow paths from upstream catchments. The location of these areas is not within private property, do not apply to habitable floor levels of any buildings, and are removed any escape routes for the adjacent private property.

This afflux is observed at the peak of the 100 year flood event, and it is anticipated that pedestrians in the vicinity during a storm of this magnitude will be sheltering in place due to the significant rainfall which triggers as event of this major scale. However, the footpath (verge area) is considered low hazard (FDM) allowing for any pedestrians to move to these areas.

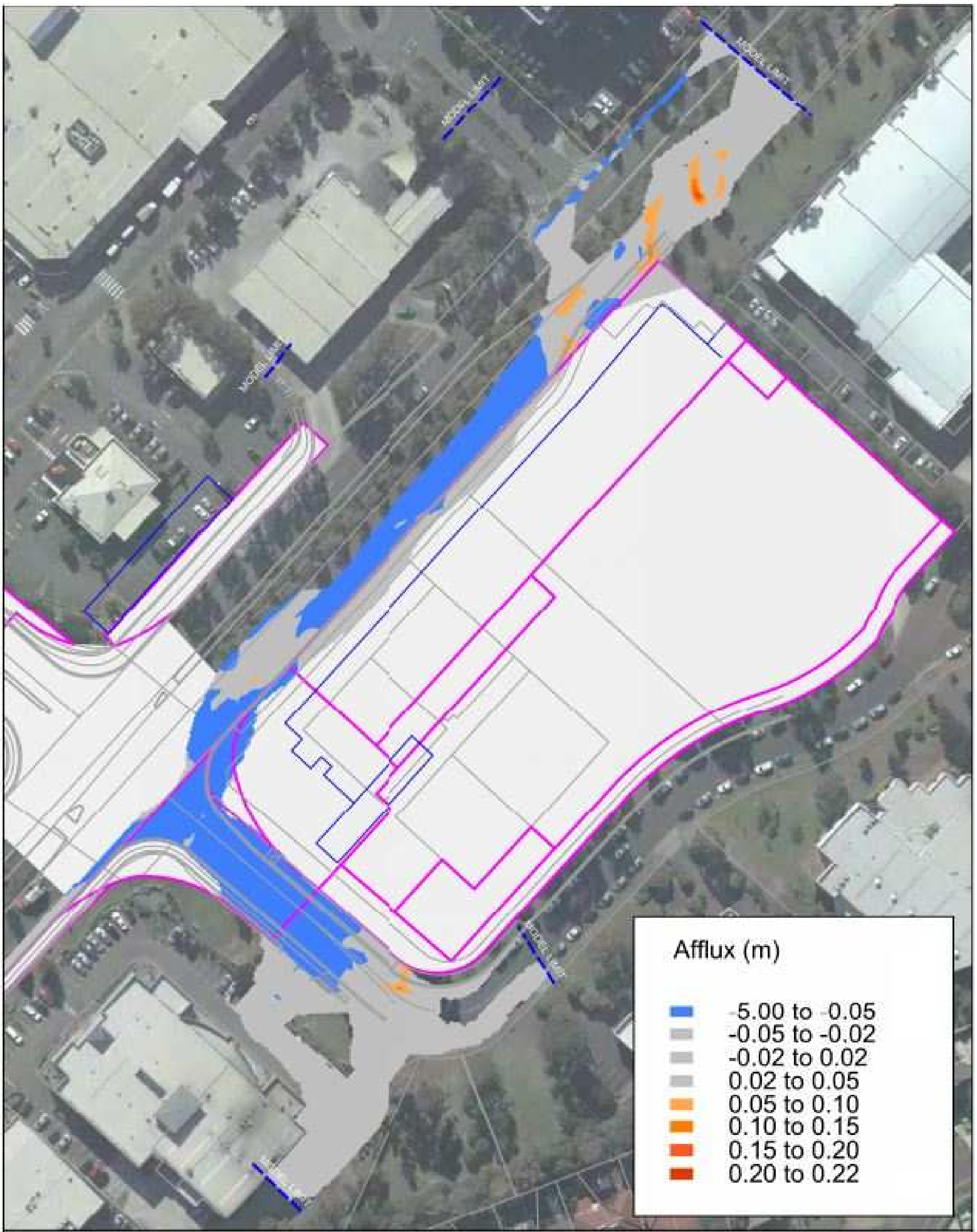


ARI/Event	Scenario	Colour Scale	Scale
100 year	Existing Conditions	Flood Depth	1:1500
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	NRW

- **Area outside project limit:**

The area of concern is at the fringe of the overland flow path inundation of the road reserve. The location of these areas is not within private property, do not apply to habitable floor levels of any buildings, and are removed any escape routes for the adjacent private property. The local crest and trough profile of the water surface is characteristic of the flow path transition between the two different cross section of Norwest Boulevard. This can be observed on the afflux plan, indicated by the alternating areas within and exceeding the limits in the direction of travel along Norwest Boulevard.

This afflux is observed at the peak of the 100 year flood event. This worst case flooding is a result of the 15 minute storm duration, and peak levels last less than 5 minutes before the flooding event has passed. The area of exceeded afflux is within the road pavement area only.



ARI/Event	Scenario	Colour Scale	Scale
100 year	Pre-Post Comparison	Net Depth	1:1500
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	NRW

Potential Mitigating Measures

- Option 1 – Further Norwest Boulevard Upgrade

As the afflux is created by the crest and trough profile at the transition from upgraded road cross section to the existing, the extension of the upgraded cross section along a larger run of Norwest Boulevard to the sag point in the North East could alleviate the afflux issue. The distance to the overland flow discharge point at the road sag location is approx. 125m, however an upgrade would require approx 160m of additional works to the Norwest Boulevard road reserve for an appropriate transition.

To enable this work, RMS approval is required for the closure of part of Norwest Boulevard, with other stakeholder approvals for significant service relocations. Construction traffic management and flow on effects to the road network must be considered.

It is anticipated that Norwest Boulevard will be upgraded by RMS as the NWRL and other developments in the area give rise to the need for a full upgrade of the entire length of Norwest Boulevard in the future.

- Option 2 – Dedicated 100yr Flood Pipe System

To supplement the existing pit and pipe system designed for the minor (10 year) storms with additional infrastructure for the purpose of mitigating major (100 year) flooding, a fully separate system is required. 6 large capacity pits within the verge are required, with an additional dia. 450mm pipe length and minimum. 3 junction pits to the discharge location approx. 140m downstream.

Due to the need to delay the effect of the major storm infrastructure, these works would only perform their intended purpose rarely, at a frequency approaching once every 100 years. The maintenance program for this type of infrastructure presents an additional risk in that the usual trigger of smaller rainfall events will not prompt maintenance activities since the infrastructure will only be effective in the major storm events above Q100.

- Option 3 – Underground Flood Storage:

To eliminate the non-conforming afflux areas, underground storage of floodwater at the peak of the 100 year storm event could result in lower flood levels. It is not possible to accumulate flood water storage over the full duration of the overland flow event as the space underground is limited by services, structural and access requirements. Therefore storage would need to be provided only when the flood is approaching it's peak. This requirement for delayed timing gives rise to the need for inlet pits separate to those constructed in the roadway. To capture the overland flows sufficiently by means of dedicated inlets near the peak of floodwaters, approx. 6 large pits with significant inlet capacities would be required in the Norwest Boulevard road reserve.

The verge space is heavily constrained by services which complicates this option, requiring relocations/modifications and the appropriate stakeholder approvals. To achieve the 45 cubic metre storage volume it is most likely that the underground tank would be located under the road pavement of Norwest Boulevard which triggers the need for approvals and coordination with multiple stakeholders including RMS and service authorities. Considering safety-in-design, an underground structure requiring access from a road pavement is not favourable. This option also shares the special maintenance requirements of option 2 above.

Assessment of Benefits

There are potential benefits only in the case of pedestrians are attempting to travel through already flowing overland flow paths in Norwest Boulevard. It is anticipated that during major storms when the Norwest Boulevard overland flow is occurring, most pedestrians will seek shelter or an alternate route to the North and East via Brookhollow Ave.

These benefits are short lived as the mitigating measures only improve the situation right at the peak of the flooding event. As mentioned above peak levels only last for short durations (less than 5 min) in this worst case flooding.

Summary

Considering the wider inundation of Norwest Boulevard and the rare function of such infrastructure, the potential benefits in terms of the added amenity as a result of eliminating this 50mm afflux is not considered significant enough to warrant construction of these potential mitigating infrastructure options. In light of the SPR requirements being subject to the definitions for feasible and reasonable infrastructure as defined above, it is the designer's view that these highlighted areas should not represent a 'non-conformance' of the conditions.

Decision Matrix:

Mitigating Option	1 – Further Extent of Road Upgrade	2 – Dedicated 100yr Pipe System	3 Underground Flood Storage
Benefit	• Eliminate non-conformance. • Satisfy project SPR without requiring evidence of feasible/reasonable assessment	• Eliminate non-conformance. • Satisfy project SPR without requiring evidence of feasible/reasonable assessment	• Eliminate non-conformance. • Satisfy project SPR without requiring evidence of feasible/reasonable assessment
Minimum additional works	• 160m dual carriageway upgrade	• 6 grated inlet pits in verge • 140m RCP construction with junction pits • Discharge headwall	• 6 grated inlet pits in verge • $45m^3$ tank, likely under road • One-way flap valves to existing storm network
Potential required flow on works	• Construction Traffic modelling • Construction staging	• Construction Traffic modelling • Construction staging	• Construction Traffic modelling • Construction staging
Authority approvals	• RMS lane closure • Electrical (HV) relocation • Likely SWC sewer relocation • Council approval	• RMS lane closure • RMS acceptance of dual pipe systems • Electrical (HV) relocation • Council approval	• RMS lane closure • RMS acceptance of tank under roadway • Electrical (HV) relocation • Council approval • Likely SWC sewer relocation
Negative impacts	• Design and construction delays to project • Pedestrian and vehicle disruption	• Design and construction delays to project • Pedestrian and vehicle disruption	• Design and construction delays to project • Pedestrian and vehicle disruption

	due to construction	due to construction • Maintenance schedule 'off-line' with respect to existing storm network	due to construction • Maintenance schedule 'off-line' with respect to existing storm network • Complex access and maintenance for clean-out
Feasible Yes/No, if No then why?	Yes	Yes	Yes
Reasonable Yes/No, if No then why?	No, • Limited benefits • No hazard improvement from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program	No, • Limited benefits • No hazard improvement from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program	No, • Limited benefits • No hazard improvement from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program • Not favourable due to safety-in-design aspects of roadway tank access

F.3 Rouse Hill Flooding

The attached technical document summarises the key points in the determination of the significance of flood impacts where the 50mm in 100 year ARI SPR afflux requirements are not met. This document provides the evidence that designers considered all feasible options prior to their determination.

The following list and supporting technical documentation outline the relevant engineering inputs and summarise outcomes from collaborative working sessions to examine the afflux at Rouse Hill and assess the benefits of further mitigating works.

- Current worst case 100yr flooding situation in Windsor Road and Rouse Hill Drive is inundated road pavement and verge areas:
    - Road pavement – low hazard per NSW Floodplain Development Manual (FDM) with isolated instances of high hazard along the existing kerb alignment in Rouse Hill Drive
    - Verge area – low hazard (FDM)
- Worst case flooding results from short duration (25 minute) storm
    - Peak flood levels last less than 5 minutes
    - This kind of short term “flash flooding” is typical of major arterial roads where upstream urban areas have pipe systems for the minor storm only (eg 10 year storm event)
- Current design does not comply with the SPR 50mm afflux requirement in isolated areas. This non-conformance is due to the movement of the kerb alignment on the eastern side of Windsor Road. The kerb position is moving to accommodate a changed T-Way bus turnaround arrangement and left turn lane from Windsor Road to Rouse Hill Drive. As a result of the new kerb arrangement, finished surface levels are different from the existing case giving rise to the changes in water surface level.
- Three feasible mitigating measures have been developed in the attempt to satisfy requirements, refer technical documentation for further details
    - 1 – Upsize design pit and pipe system in Windsor Road to accommodate the major (100yr) flow rates with surcharge further down Rouse Hill Drive, approx. 85m
    - 2 – Construct dedicated 100yr pipe system, approx. 160m
    - 3 – Construct 200 cubic metre underground flood storage
    - 4 – Re-design of Windsor Road/Schofields Road/Rouse Hill Drive intersection
- Mitigating measures **DO NOT** limit the afflux to within the 50mm tolerance from existing water levels:
    - measures do not provide improved water levels relative to the existing case
    - measures do not change or improve hazard classification (FDM)
- Mitigating measures all require/involve:
    - Traffic management and lane closures
    - Program delays
    - Stakeholder input and approvals

In light of the minimal benefits experienced by implementing these mitigating measures and the above discussion points, the designers have arrived at the conclusion that the construction of any identified measure to be unreasonable. It is therefore suggested that the 50mm afflux criteria is not applicable (as defined in the minister’s conditions) in these isolated areas.

Technical Documentation

Introduction

The Rouse Hill civil works report identifies areas of afflux which exceed the project limits of 50mm. This RFI collects and presents the following information;

a) Extracts from the civil design report for Rouse Hill Station precinct;
b) Additional design and modelling details provided by the designers;
c) Comments from TfNSW on an earlier RFI submission;
d) Collaborative working sessions with TfNSW

The definition of 'feasible and reasonable' forms a key role in the determination of an appropriate flooding outcome for elements of the project particularly sensitive to flooding. This definition was provided in the same infrastructure approval document which lists conditions from the Minister for Planning and Infrastructure (C33). The mitigating measures developed are considered feasible, so this assessment focusses on whether it's reasonable to carry out any of the measures.

SPR Requirements and The Minister's Conditions

- Extract from Ministers conditions:

"Consideration of best practice taking into account the benefit of proposed measures and their technological and associated operational application in the NSW and Australian context.
Feasible relates to engineering considerations and what is practical to build. Reasonable relates to the application of judgement in arriving at a decision, taking into account mitigation benefits and cost of mitigation versus benefits provided, community views and nature and extent of potential improvements.
Where requested by the Director General, the Proponent shall provide evidence as to how feasible and reasonable measures were considered and taken into account. "

Comments from earlier RFI submission

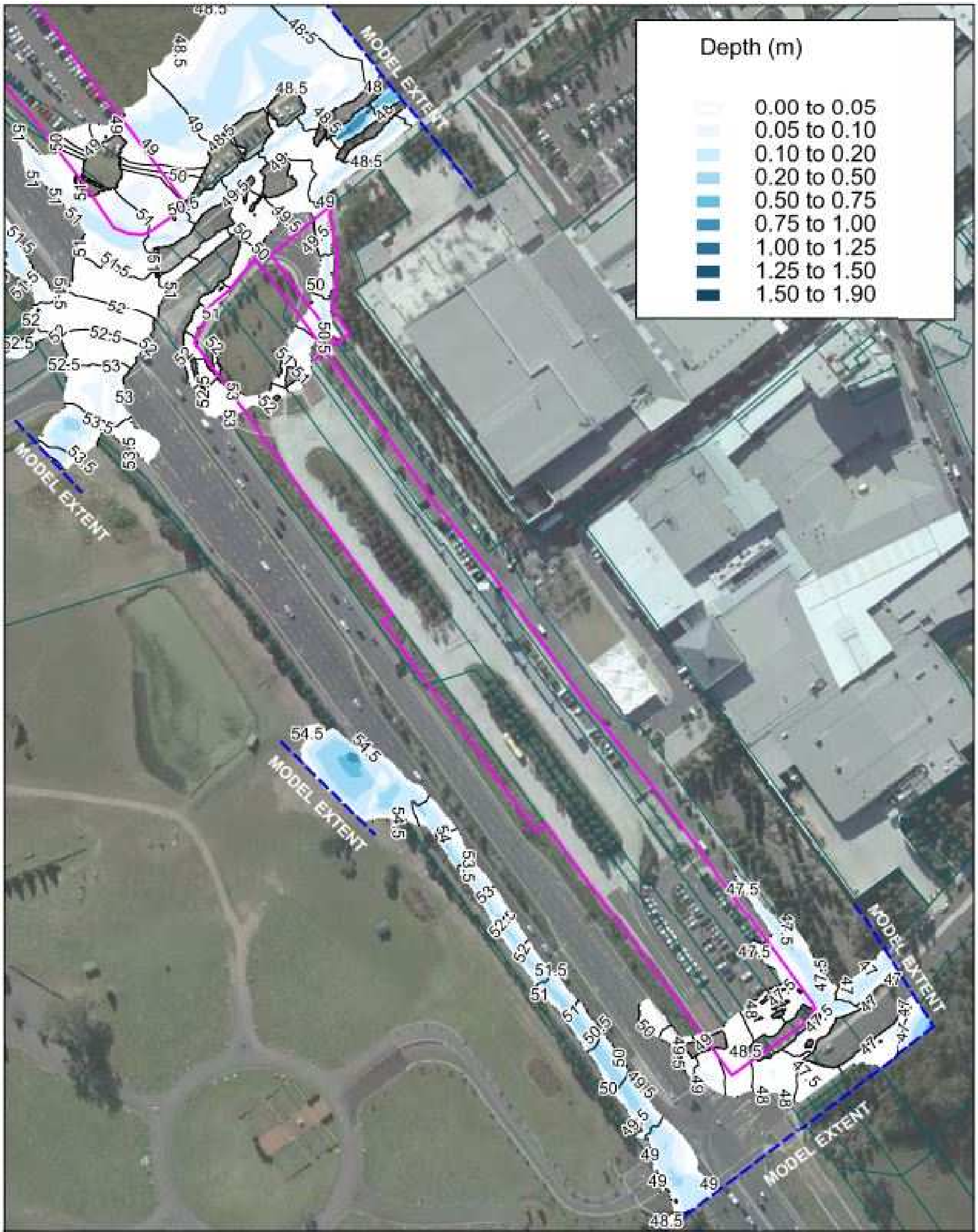
In response to an earlier RFI submission, TfNSW indicated that they are not in a position to 'relax' the deed requirement. This subsequent submission to TfNSW indicates that the DJV considers the design to be in accordance with the deed requirement, given the definitions of feasible and reasonable and their relevance at Rouse Hill, outlined within this document.

A suggestion in the TfNSW response of an afflux mitigating approach centered around the provision of detention for upstream catchments is not considered appropriate. Sydney Water is the managing authority for the catchment and has developed a strategy for the wider management of runoff volumes, peak flows and water quality. Placing development controls on upstream sites over the top of the existing Sydney Water management scheme complicates the management of runoff in the catchment and this additional civil work and associated lifecycle cost for maintenance is not justified as discussed in the flood hazard section in this document.

Modelling Results

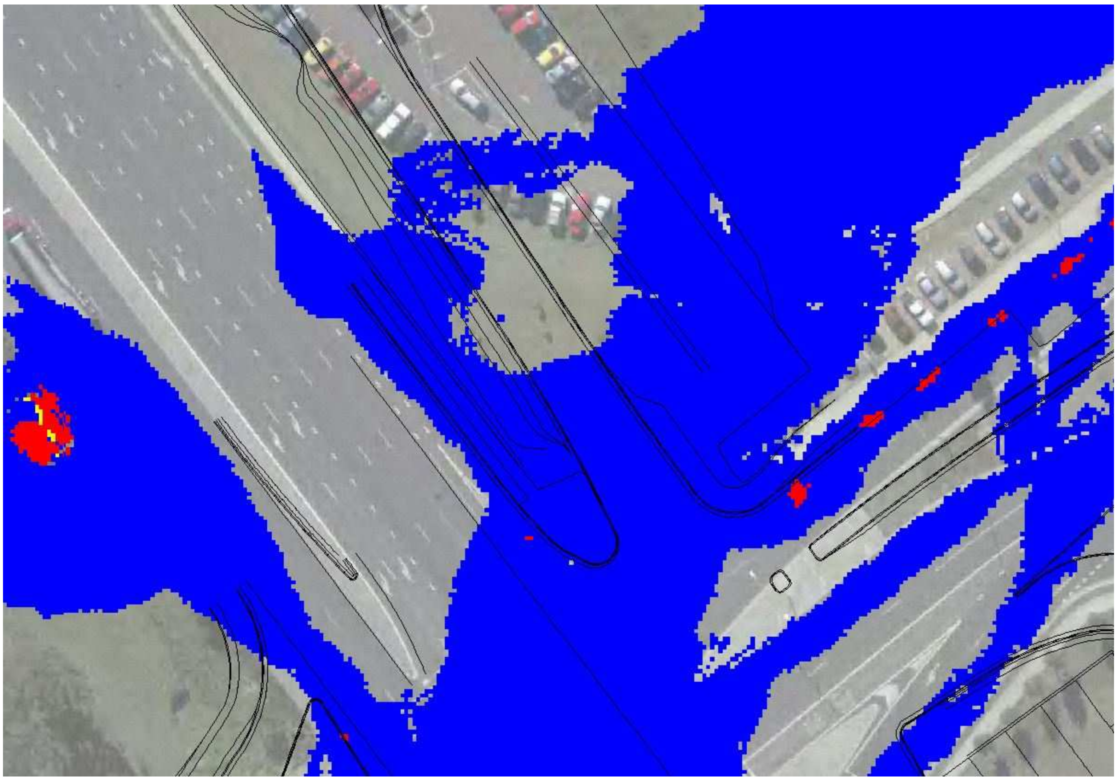
- **Wider Flooding Context:**

During the 100yr flood, the existing pit and pipe stormwater network quickly becomes full and ineffective in draining road pavement water, known as a 'drowned' condition. The road pavement of Windsor Road and Rouse Hill Drive then becomes inundated by overland flow paths from upstream catchments. The location of these inundated areas around intersections and sag point is typical of the wider road network during storms of this magnitude. Whilst the flood hazard category is low (per NSW Floodplain Development Manual 2005) it is anticipated that most pedestrians will seek shelter within the Rouse Hill Station site itself, and avoid the inundated road reserves.



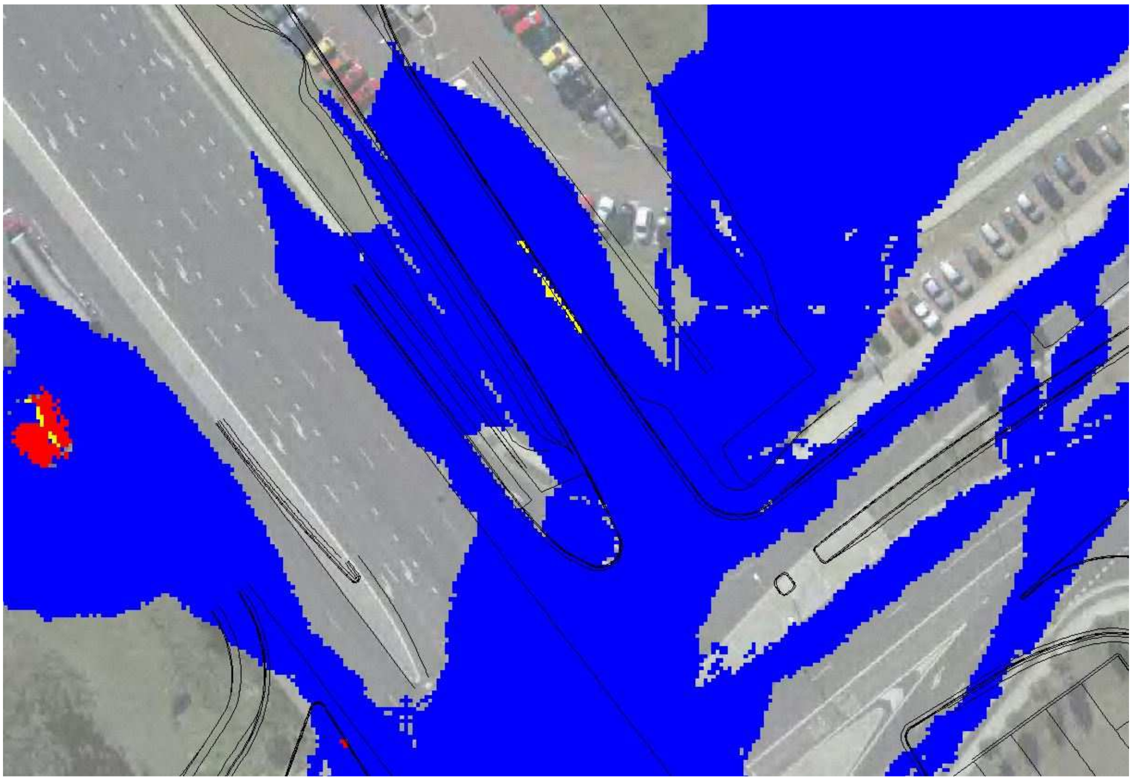
ARI/Event	Scenario	Colour Scale	Scale
100 year	Existing Conditions	Depth	1:2500
Project		Project Stage	Location
NWRL-OTS Flood Model Results		3	RSH

- **100yr Existing flood hazard (with design overlay)**



The blue areas are flood hazard category: low, defined in the NSW Floodplain Development Manual as being safe for pedestrians and vehicles. General drainage design best practice involves limiting the flood hazard to the low category within the road reserve.

- **100yr Proposed flood hazard**



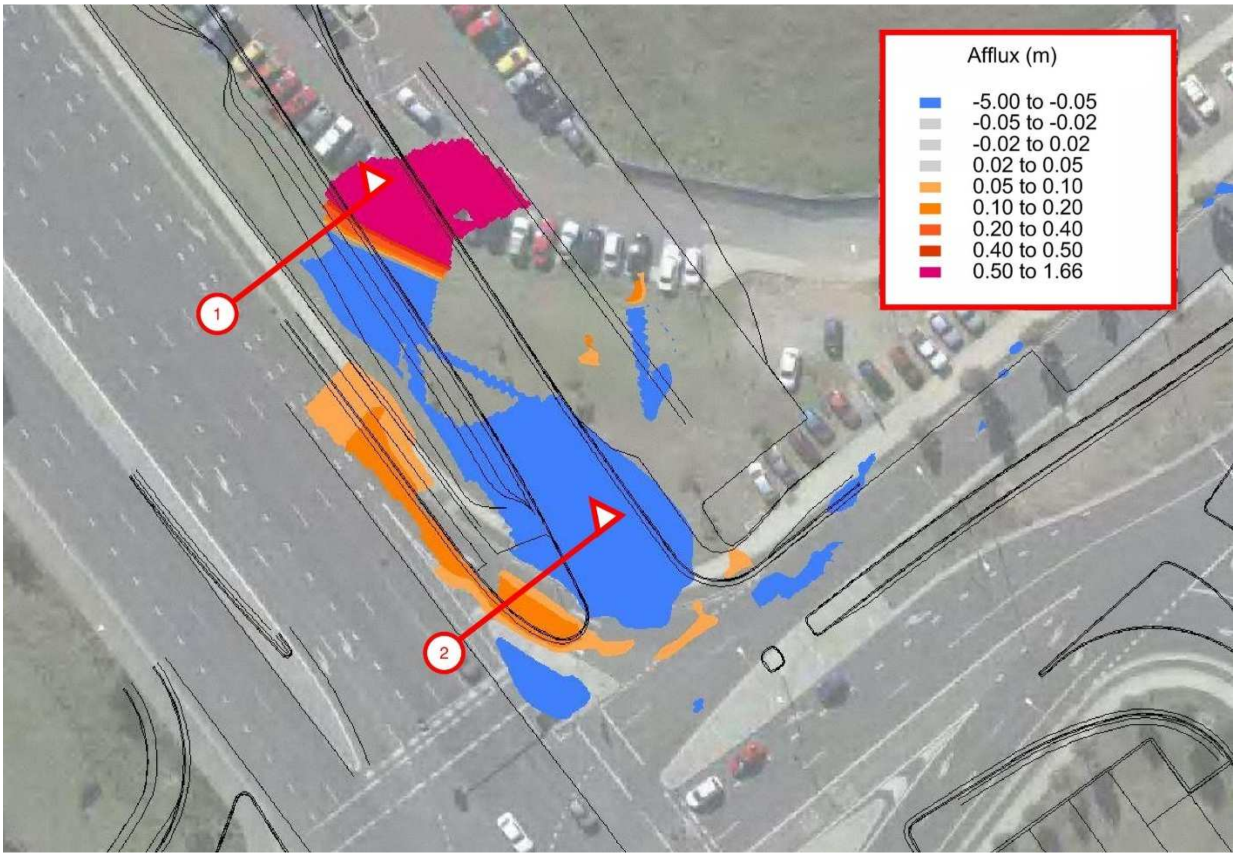
The proposed design maintains this wider flood hazards categorisation within the low category shown above.

- **Area outside project limit:**

The area of concern is a direct result of changes in grading. The changes in the kerb alignment result in new levels along the kerb and gutter profile with respect to the existing kerb and verge grading.

Water level afflux is generally a criteria used to determine the affects of a flood on mainstream flood levels rather than overland flow paths. This worst case flooding involves overland flows in the order of 0.3-0.4m³/s which is fairly typical of a major road reserve.

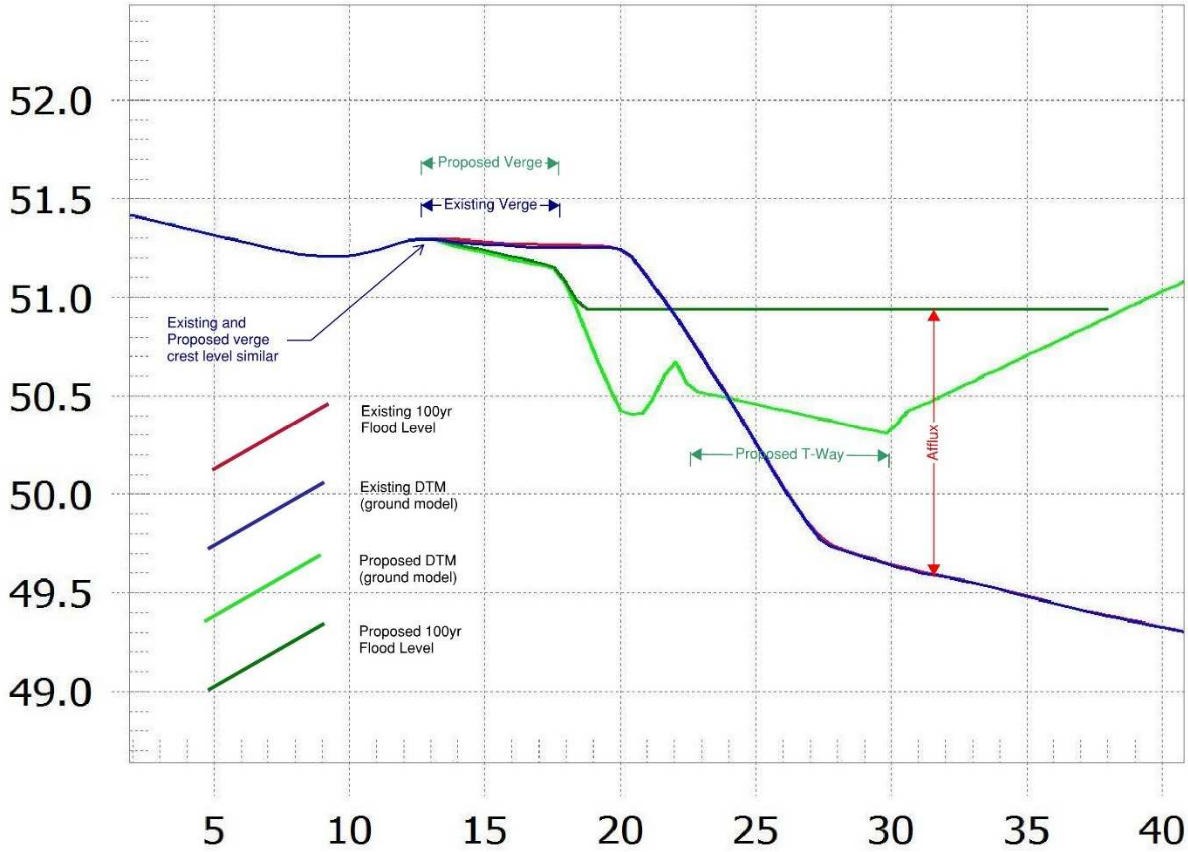
This afflux is observed at the peak of the 100 year flood event. This worst case flooding is a result of the 25 minute storm duration, and peak levels last less than 5 minutes before the flooding event has passed.



The grading changes giving rise to the afflux can be seen in the following two cross sections, indicated on plan in the above screen grab.

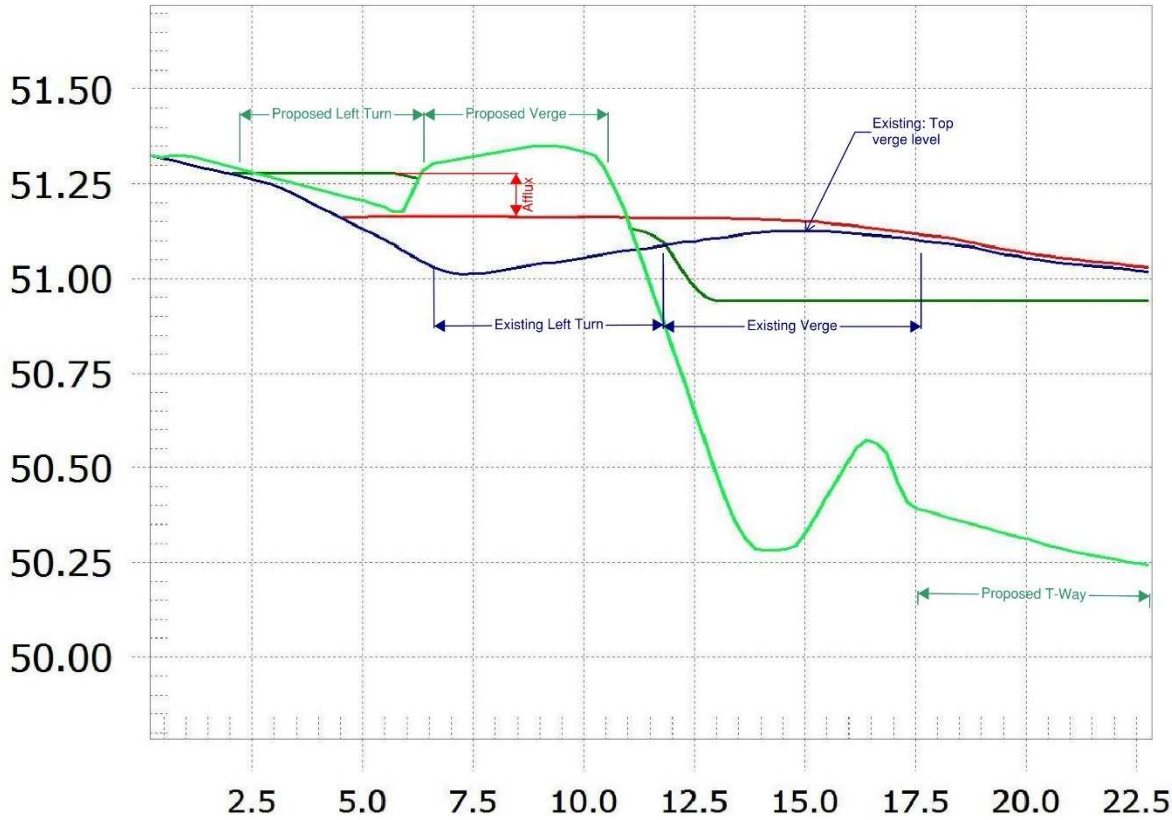
- **100yr Flood Level**

Cross Section 1 (exaggerated vertical scale, m)
The larger area shaded red in the figure above is a result of the new T-Way alignment which traverses an area in the existing scenario of open grass batter slopes and asphalt carpark. The increase in flood levels is show below, resulting from the blue existing profile being raised to the light green road reserve to form the T-Way layover. Finished surface levels here are changed by upwards of 1m relative to the existing ground levels.



Cross Section 2 (exaggerated vertical scale, m)

In this cross section the light green profile of the proposed road design shows the shift in kerb position relative to the existing blue profile. Where overland flow occurs within the road pavement of the new green profile, the elevation is higher than the water surface level in the existing scenario (red line). This indicates that regardless of pit capacity in Windsor Road, the configuration of the intersection to achieve the left turn, through traffic and T-Way movements to RMS design standards inevitably results in afflux.



Potential Mitigating Measures

- Option 1 – Upsize design pit and pipe system in Windsor Road to accommodate the major (100yr) flow rates with surcharge further down Rouse Hill Drive, approx. 85m

This option assumes that the area highlighted in the afflux result as being greater than 50mm can be alleviated by increasing pipe capacity to carry greater flows downstream. The distance to an appropriate downstream pit east of the T-Way intersection is approx. 85m. Doing a sensitivity analysis on the pipe capacity it is evident that with a larger flow capacity, the discharge location downstream experiences greater deterioration in flooding performance than improvements upstream. This observation was repeated when a location further down the proposed drainage system was used for surcharge of additional pipe capacity.

The afflux in Windsor Road is reduced however not back within the 50mm tolerance of the requirement and a similar area outside the 50mm limit remains.

- Option 2 – Dedicated 100yr Flood Pipe System

To supplement the existing pit and pipe system designed for the minor (10 year) storms with additional infrastructure for the purpose of mitigating major (100 year) flooding, a fully separate system is required. 6 large capacity pits within the verge are required, with an additional dia. 450mm pipe length and minimum. 3 junction pits to the discharge location approx. 160m downstream.

The afflux in Windsor Road is reduced however not back within the 50mm tolerance of the requirement and a similar area outside the 50mm limit remains. An increase in water level further down Rouse Hill Drive is associated with the reduction at Windsor Road.

The road reserve of Windsor Road and Rouse Hill Drive are heavily constrained with services. Significant service relocations would be required for a dedicated system with separate alignment to the existing system being modified as part of the design.

- Option 3 – Underground Flood Storage:

To reduce the non-conforming afflux areas, underground storage of floodwater at the peak of the 100 year storm event could result in lower flood levels. As the afflux occurs from early in the storm event due to grading of Windsor road left turn lane, stormwater capture across the full duration of the storm event is required. Approx. 6 dedicated inlet pits would be required in the Windsor Road road reserve.

The verge space is heavily constrained by services which complicates this option, requiring relocations/modifications and the appropriate stakeholder approvals. To achieve the 200 cubic metre storage volume it is most likely that the underground tank would be located under the road pavement of Windsor Road or under the T-Way layover. A Windsor Road location would trigger the need for approvals and coordination with multiple stakeholders including RMS and service authorities. Considering safety-in-design, an underground structure requiring access from a road pavement is not favourable.

The 200 cubic metre volume is still not sufficient to eliminate the afflux over the 50mm limit but is the largest size that could be practically accommodated given the site constraints.

- Option 4 – Intersection re-design

As discussed with Cross Section 2 above, the re-design of the RMS intersection could alleviate the afflux in the road pavement on approach to the Rouse Hill Drive left turn. To maintain design standards and geometry, lowering the pavement in this isolated area would require flow on changes to the longitudinal grading through the intersection. Construction within the intersection would be a disruptive exercise and would almost certainly not be considered reasonable and given approval by RMS.

Assessment of Benefits

There are potential benefits only in the case of pedestrians are attempting to travel through already flowing overland flow paths in Rouse Hill Drive and Windsor Road. It is anticipated that during major storms when the overland flow is occurring, most pedestrians will seek shelter in the dry areas around Rouse Hill Station. However in the figures above it can be seen that the flood hazard category (per NSW FDM) in both the existing and proposed cases are low.

These potential benefits are limited and come at significant capital costs and some with further maintenance concerns. As mentioned above peak levels only last for short durations (less than 5 min) in this worst case flooding.

Summary

The potential benefits in terms of the added amenity as a result of eliminating this 50mm afflux assumes pedestrians will attempt to cross the already flooded Rouse Hill Drive road reserve in a major flood event. In light of the SPR requirements being subject to the definitions for feasible and reasonable infrastructure as defined above, it is the designer's view that these highlighted areas should not represent a 'non-conformance' of the conditions.

Decision Matrix:

Mitigating Option	1 – Upsize design pipe system allowing surcharge downstream	2 – Dedicated 100yr Pipe System	3 Underground Flood Storage	4 Intersection Re-design
Mitigation Benefits	• Reduced flood levels relative to design case.	• Reduced flood levels relative to design case	• Reduced flood levels relative to design case	• Eliminate non-conformance within Windsor Road only • Satisfy project SPR in Windsor Road
Minimum additional works	• 85m pipe size increase, 375mm to 600mm • 4 additional inlet pits in Windsor Road verge	• 4 additional inlet pits in Windsor Road verge • 160m RCP construction with 3 junction pits • Existing headwall modification for additional discharge pipe	• 6 grated inlet pits in verge • 200m³ tank, likely under road or T-Way • One-way flap valves to existing storm network	• Complete longitudinal redesign of Windsor Road Approach to Rouse Hill Drive
Potential required flow on works		• Additional maintenance scheduling offline from regular stormwater assets	• Construction Traffic modelling • Construction staging	• Construction Traffic modelling • Construction staging
Authority	• Council approval	• RMS acceptance of dual	• RMS lane closure	• RMS lane closure

approvals		pipe systems • Electrical (HV) relocation • Council approval	• RMS acceptance of tank under roadway • Electrical (HV) relocation • Council approval • Likely other service relocations and stakeholder consultation	• Staged construction into intersection with Rouse Hill Drive • Council Approval • Service relocations and stakeholder consultation
Negative impacts	• Downstream flooding becomes worse, affects private properties	• Design and construction delays to project • Pedestrian and vehicle disruption due to construction • Maintenance schedule 'off-line' with respect to existing storm network	• Design and construction delays to project • Pedestrian and vehicle disruption due to construction • Maintenance schedule 'off-line' with respect to existing storm network • Complex access and maintenance for clean-out	• Service relocations • Lane closure • Traffic modelling required for construction works
Community Views	• Non-tangible benefits • No increased interruption/inconvenience through construction	• Non-tangible benefits • Slightly increased interruption/inconvenience in construction	• Non-tangible benefits • Significantly increased interruption/inconvenience	• Non-tangible benefits • High levels of increases in interruption/inconvenience
Feasible Yes/No, if No then why?	Yes	Yes	Yes	Yes
Reasonable Yes/No, if No then why?	No, • Limited benefits • No hazard improvement	No, • Limited benefits • No hazard improvement	No, • Limited benefits • No hazard improvement	No, • Limited Benefit • No Hazard improvement

	from existing	from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program	from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program • Not favourable due to safety-in-design aspects of roadway tank access	from existing • Extensive stake holder engagement and multiple stakeholders • Delays to the design and construction program

Annexure G Glossary

Term	Definition
AEC	Areas of Environmental Concern
AHIMS	Aboriginal Heritage Information Management System
AMS	Activity Method Statement
ANZECC	Australian and New Zealand Environment Conservation Council
ARI	Average Recurrence Interval
ARMCANZ	Agriculture and Resources Management Council of Australia and New Zealand
ASS	Acid Sulfate Soil
Blue Book	Managing Urban Stormwater: Soils and Construction (Landcom 2004)
BOM	Bureau of Meteorology
CAQMP	Construction Air Quality Management Plan
CBD	Central Business District
CCAMP	Construction Compounds and Ancillary Facilities Management Plan
CEEC	Critically Endangered Ecological Community
CEMF	Construction Environmental Management Framework
CEMP	Construction Environmental Management Plan

Term	Definition
CFFMP	Construction Flora and Fauna Management Plan
CHMP	Construction Heritage Management Plan
CNVIS	Construction Noise and Vibration Impact Statement
CNVMP	Construction Noise and Vibration Management Plan
CoA	Condition of Approval
CoPC	Contaminants of Potential Concern
CPESC	Certified Professional in Erosion and Sediment Control
CSWMP	Construction Soil and Water Management Plan
DACHA	Darug Aboriginal Cultural Heritage Assessments
DACHi	Darug Aboriginal Land Care Inc.
DCAC	Darug Custodian Aboriginal Corporation
DECC	Department of Environment and Climate Change (now OEH and EPA)
DECCW	Department of Environment, Climate Change and Water (now OEH and EPA)
DLALC	Darkinjung Local Aboriginal Land Council
DLO	Darug Land Observations
DLWC	Department of Land and Water Conservation (now NSW Office of Water)
DP&E	Department of Planning and Environment

Term	Definition
DPI	Department of Primary Industries
DTAC	Darug Tribal Aboriginal Corporation
E&SM	Environment and Sustainability Manager
EC	Environmental Coordinator
ECRL	Epping to Chatswood Rail Link
EEC	Ecologically Endangered Community
EIL	Ecological Investigation Levels
EIS	Environmental Impact Statement
EIS 1	EIS for SSI-5100 – NWRL Early Works and Major Civil Construction Works (Incorporating Staged Infrastructure Modification Assessment)
EIS 2	EIS for SSI-5414 – NWRL works associated with the construction and operation of stations and wider precincts, service facilities, rail infrastructure and systems
EMS	Environmental Management System
EP&A Act	*Environmental Planning and Assessment Act 1979*
EP&A Regulation	Environmental Planning and Assessment Regulation 2000
EPA	Environment Protection Authority
EPBC Act	*Environmental Protection and Biodiversity Conservation Act 1999 (Cth)*
EPL	Environment Protection Licence

Term	Definition
EPM	Environmental Planning and Approvals Manager
ER	Environmental Representative
ERP	Emergency Response Plan
ESCP	Erosion and Sediment Control Plan
GDE	Groundwater Dependant Ecosystems
IC	Independent Certifier
IFD	Intensity-Frequency-Duration
IJV	Infrastructure Joint Venture (of NRT)
ITP	Inspection and Test Plan
JHET	John Holland Event Tracking
JHPL	John Holland Propriety Limited
LCPL	Leighton Contractors Propriety Limited
LOR	Limits of Reporting
MLALC	Metropolitan Local Aboriginal Land Council
NEPM	National Environment Protection Measure
NHMRC	National Health and Medical Research Council
NOW	NSW Office of Water

Term	Definition
NPW Act	*National Parks and Wildlife Act 1974*
NPWS	National Parks and Wildlife Service
NRT	Northwest Rapid Transit
NTU	Nephelometric Turbidity Units
NWRL	North West Rail Link (now Sydney Metro Northwest)
OEH	Office of Environment and Heritage
OpCo	OTS Operating Company
OTS	Operations, Trains and Systems
PAD	Potential Archaeological Deposit
PASS	Potential Acid Sulfate Soil
PIMS	Project Integrated Management System
PIRMP	Pollution Incident Response Management Plan
PMF	Probable Maximum Flood
POEO Act	*Protection of the Environment Operations Act 1997*
PPP	Public Private Partnership
Project	Sydney Metro Northwest OTS Project
Project Approval	Minister for Planning and Infrastructure's Approval for SSI-5414, SSI-5931 and TfNSW's Approval for the ECRL Conversion Works

Term	Definition
RAP	Registered Aboriginal Parties
REF	Review of Environmental Factors
REMM	Revised Environmental Mitigation Measures
RFP	Request for Proposal
RFT	Request for Tender
RMS	Roads and Maritime Services
RTRF	Rapid Transit Rail Facility (now Sydney Metro Trains Facility)
RTRF EIS	EIS for SSI-5931 – Rapid Transit Rail Facility
SDS	Safety Data Sheet
SEP	Site Environment Plan
SEPP	State Environmental Planning Policy
SES	State Emergency Service
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities (now Department of the Environment)
SM	OTS Sustainability Manager
SMP	Spoil Management Plan
SMTF	Sydney Metro Trains Facility (formerly the Rapid Transit Rail Facility)
Spoil	Material generated by excavation into the ground

Term	Definition
SPR	Scope and Performance Requirements
SQERM	Safety, Quality and Environment Risk Management
SSI	State Significant Infrastructure
SVC	Surface and Viaduct Civil Works
SWC	Sydney Water Corporation
SWTC	Scope of Works and Technical Criteria
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids
TfNSW	Transport for New South Wales
TRA	Task Risk Assessment
TSC	Tunnels and Station Civil Works
TSC Act	*Threatened Species Conservation Act 1995*
TSS	Total Suspended Solids
VAMP	Visual Amenity Management Plan
VENM	Virgin Excavated Natural Material – natural material (such as clay, gravel, sand, soil and rock) that is not mixed with any other type of waste and/or has been excavated from areas of land that are not contaminated
WAD	Works Authorisation Deed

Term	Definition
WBNM	Watershed Bound Network Model
WM Act	*Water Management Act 2000*
WMRP	Waste Management and Recycling Plan
WRA	Workplace Risk Assessment
WRAPP	Waste Reduction and Purchasing Policy
WTP	Water Treatment Plant