ANNEXURE A
BACKGROUND TO THE DEVELOPMENT OF FLOOD MODELS

TABLE OF CONTENTS

Page No.

FIGURES
(located at the end of this annexure)

A1. OVERVIEW

This annexure provides background to the development of the hydrologic and hydraulic computer models that were developed to define flood behaviour in the vicinity of the project.

The hydrologic and hydraulic models that were relied upon for the present investigation were originally developed as part of the following previous studies:

- A series of flooding investigations that were undertaken for the WestConnex New M5 Motorway (New M5) and associated projects which were previously documented in the *WestConnex New M5 EIS Technical Working Paper: Flooding* (Lyall and Associates(L&A) 2015).

  The hydrologic models that were developed as part of these earlier investigations included a RAFTS model of the Cooks River catchment and a DRAINS model of the Alexandra Canal catchment. A hydraulic model was developed of the lower Cooks River and Alexandra Canal floodplain using the TUFLOW software.

- The *Mascot, Rosebery and Eastlakes Flood Study*[1] (WMAwater 2015) that was carried out on behalf of the City of Botany Bay (now Bayside Council).

  As part of WMAwater 2015 two separate but overlapping models were developed covering:

  - the suburbs of Mascot, Rosebery and Eastlakes within the Alexandra Canal and Mill Stream catchments
  - the main arm of Mill Stream and the suburb of Pagewood within the Mill Stream catchment.

  Hydrologic models were developed using the DRAINS software, while hydraulic models were developed using the TUFLOW software.

For the purpose of the present investigation the DRAINS models from the previous studies were combined and updated in the vicinity of the rail corridor, while the TUFLOW models were spliced together to remove the influence of adopted boundary conditions on modelled flood behaviour in the vicinity of the rail corridor.

This annexure also includes a comparison of the results of the present investigation with those of previous studies, as well as a comparison of model inputs and parameters using the procedures set out in ARR 2019.

A2. COOKS RIVER RAFTS MODEL

A2.1 Background to hydrologic model development

The Cooks River catchment was divided into 44 sub-catchments using available GIS based two metre contour data. Data such as sub-catchment land use and percentage imperviousness of the surfaces due to urbanisation were developed from the underlying aerial photography. **Figure A.1** shows the sub-catchments which comprised the Cooks River RAFTS model.

[1] While the flood study by WMAwater was entitled “Mascot, Rosebery and Eastlakes” it also covered the Mill Stream catchment.

A2.2 Design storms

Design storms for intensities between 50% and 0.2% AEP were derived from ARR 1987 for storm durations ranging between one hour and six hours. The design rainfall depths were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987.

The rainfalls derived using the procedures outlined in ARR 1987 are applicable strictly to a point. In the case of a large catchment of over tens of square kilometres, it is not realistic to assume that the same rainfall intensity can be maintained over a large area. An areal reduction factor (ARF) is typically applied to obtain an intensity that is applicable over the entire area.

The ARF data contained in ARR 1987 were originally published by the US National Weather Service in 1980 and were derived from recorded storm data in the Chicago area. The paper entitled *Derivation of Areal Reduction Factors for Design Rainfalls in Victoria* (Siriwardene and Weinmann 1996) presents the findings of research undertaken by the Cooperative Research Centre for Catchment Hydrology (CRCCH) for deriving ARF's in an Australian setting. Siriwardena and Weinmann 1996 undertook this analysis for Victorian catchments for a range of catchments from 1 to 10,000 square kilometres in area and storm durations from 18 to 120 hours. The conclusion of this investigation was that ARF's were related to rainfall frequency and that the values in ARR should be reduced by 5-8 per cent for storm durations in this range.

The paper entitled *A Hydroinformatic Approach to the Development of Areal Reduction Factors* (Catchlove and Ball 2003) presents the findings of a study on the 112 square kilometre catchment of the Upper Parramatta River where the records at eight pluviometers were analysed. The key finding of this investigation was that for storm durations in excess of two hours, the best estimate of ARF for this catchment was one. Application of relationships derived by ARR 1987 and CRCCH gave similar results for the Upper Parramatta River catchment because the variations for different exceedance probabilities for a small catchment of this size are minimal. In practice, adoption of a single ARF unrelated to frequency is more appropriate.

For the present investigation, ARR 1987 indicates that a value of 0.85 could have been adopted for the ARF on the Cooks River catchment as an appropriate value for the two hour storm duration found to be critical on this catchment. However, a value of one was selected for design purposes, in keeping with the more recent results of Catchlove and Ball 2003.

Estimates of probable maximum precipitation (PMP) were derived using the Generalised Short Duration Method (GSDM) as described in The *Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (BoM 2003). This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 square kilometres in area and storm durations up to six hours.

A2.3 RAFTS model parameters

RAFTS requires losses to be applied to storm rainfall to determine the depth of surface runoff, as well as information on the time of travel of the flood wave through the catchment.

Infiltration losses are of two types: initial loss arising from water which is held in depressions which must be filled before runoff commences, and a continuing loss rate which depends on the type of soil and the duration of the storm event. The split catchment option was used for estimating hydrographs from each sub-catchment. This option separately models runoff from the pervious and impervious portions of the sub-catchment.

Losses from the impervious portion of the catchment are subject to less uncertainty resulting from antecedent rainfall conditions than from the pervious portion. Values of two millimetres for initial loss and zero continuing loss were adopted for impervious surfaces. The response of the model to initial losses from the pervious portion ranging between zero and 20 millimetres was tested for the 1% AEP two hour critical storm (**Figure A.2**). The results showed that the peak discharge was not particularly sensitive to pervious initial loss. This is because about 50 per cent of the total catchment surface was impervious. Loss values adopted for design flood estimation comprised the following:

- Pervious areas - 10 millimetres initial loss and 2.5 millimetres per hour continuing loss
- Impervious areas - 2 millimetres initial loss and 0 millimetres per hour continuing loss

A simple lagging of the ordinates was adopted to describe the translation of the discharge hydrograph generated at each sub-catchment outlet along the various links to the next downstream sub-catchment. This approach required specifying a velocity of the flow along the link. The sensitivity of the results to assumed velocities ranging between one and three metres per second was tested for the 1% AEP critical storm (**Figure A.2**). The one metre per second velocity resulted in peak discharges that were much smaller than peaks estimated in any of the other studies of flooding on the Cooks River (**Table A2.1**). After consideration a velocity of two metres per second was adopted for design.

A2.4 Design discharge hydrographs

Figure A.3 shows design discharge hydrographs that were adopted for input at the upstream boundaries of the Cooks River TUFLOW Model. The peaks of the PMF are between two and four times those of the 1% AEP flood, depending on location. The PMF is the largest flood that could reasonably be expected to occur and is generally considered to have a return period between 1 in 10^5 and 1 in 10^6 years.

Table A2.1 compares peak discharges derived from both the present and previous investigations. The peak discharges derived from the Cooks River RAFTS model as part of the present investigation are given in column B of the table. The peaks derived from the Cooks River TUFLOW Model are given in column C. The differences between the peak flows at each of the locations represent the routing effects of channel and floodplain storage which are incorporated in the TUFLOW analysis but which are not modelled by RAFTS. The effects of storage are represented by a reduction in peak flow at the outlet for TUFLOW when compared with the RAFTS result.

The *Sydney Airport Flood Study* (AECOM 2018), the *Cooks River Flood Study* (Sydney Water (SW) 2009) and the *Cooks River Floodplain Management Study* (Webb, McKeown and Associates (WMA) 1994) (refer peak flows given in columns D, E and F of **Table A2.1**, respectively) used the WBNM hydrologic modelling software. WBNM is a rainfall-runoff hydrologic model similar to RAFTS and would be expected to give similar results, provided that the model layout and adopted parameters were similar.

The peak flow in the Cooks River at Botany Bay derived by the Cooks River RAFTS model is within 10 per cent of the peak flow estimates presented in AECOM 2018 and SW 2009 but is 30 per cent greater than the peak flow estimate presented in WMA 1994.

TABLE A2.1
PEAK DISCHARGES
1% AEP
(cubic metres per second)

Location [A]	Cooks River RAFTS Model [B]	Lower Cooks River TUFLOW Model [C]	Sydney Airport Flood Study (AECOM 2018) [D]	Cooks River Flood Study (SW 2009) [E]	Cooks River Floodplain Management Study (WMA 1994) [F]
Wolli Creek at SWSOOS Crossing	431	430	356	348	290
Alexandra Canal Discharge to Cooks River	353	203	325	286	160
Muddy Creek Discharge to Cooks River	262	178	177	145	150
Cooks River Outfall to Botany Bay	1440	1145	1557	1596	1010

A3. ALEXANDRA CANAL AND MILL STREAM DRAINS MODEL

A3.1 Background to Hydrologic Model Development

For the purpose of the present investigation the DRAINS models that were developed as part of previous studies were combined and updated in order to provide inflow hydrographs to the combined TUFLOW model (**Alexandra Canal and Mill Stream DRAINS model**). **Figure A.4** shows the layout of the following sub-catchments that comprise the Alexandra Canal and Mill Stream DRAINS model:

- The sub-catchments draining to Alexandra Canal upstream of Campbell Road were based on the DRAINS model that was developed as part of L&A 2015 (denoted "**Upper Alexandra Canal sub-catchments**" on **Figure A.4**).
- The sub-catchments to the west of Alexandra Canal between the Cooks River and Canal Road, including those draining to Tempe Wetlands, were revised using GIS based details of the pit and pipe drainage system obtained from Marrickville Council (now part of Inner West Council). The sub-catchments that were revised are denoted **"Tempe sub-catchments"** on **Figure A.4**.
- The sub-catchments that cover the suburbs of Mascot, Rosebery and Eastlakes were based on a DRAINS model that was developed as part of WMAwater 2015 (denoted "**Mascot, Rosebery and Eastlakes sub-catchments**" on **Figure A.4**).
- The sub-catchments that cover Sydney Airport, including a portion of the Mill Stream catchment, were revised using pit and pipe survey provided by Sydney Airport Corporation, as well as details contained in the *Sydney Airport Flood Study* (AECOM 2018). The sub-catchments that were revised are denoted "**Sydney Airport sub-catchments**" on **Figure A.4**.
- The sub-catchments that cover the lower reach of Mill Stream were based on a DRAINS model that was developed as part of WMAwater 2015. The sub-catchments were revised and extended to cover the full extent of the catchment draining to Mill Stream at Foreshore Road. The sub-catchments that were revised are denoted "**Mill Stream sub-catchments**" on **Figure A.4**.
- The sub-catchments that cover the suburb of Pagewood were based on a DRAINS model that was developed as part of WMAwater 2015 (denoted "**Pagewood sub-catchments**" on **Figure A.4**).

A3.2 Design storms

Design storms for intensities between 50% and 0.2% AEP were derived using the procedures set out in ARR 1987, while estimates of the PMP were derived using the GSDM as described in BoM 2003. The approach adopted was the same as that described in **Section A2.2** for the Cooks River RAFTS model.

A3.3 Model Parameters

Table A3.1 provides a summary of the adopted loss parameters for the various sub-catchments that comprise the Alexandra Canal and Mill Stream DRAINS model for the purpose of design flood estimation. The adopted loss parameters in the Upper Alexandra Canal sub-catchments were based on tuning of that portion of the model to the flows given in *Sheas Creek Flood Study* (Webb, McKeown and Associates (WMA), 1991). The adopted loss parameters for the Mascot, Rosebery and Eastlakes sub-catchments and the Mill Stream and Pagewood sub-catchments were based on those contained in the DRAINS model that was developed as part of WMAwater 2015, while the adopted loss parameters for the Tempe and Sydney Airport catchments were based on typical values for highly modified urbanised catchments.

TABLE A3.1
ALEXANDRA CANAL DRAINS MODEL - DESIGN LOSS VALUES

Sub-catchments	Initial Loss (mm)		Soil Type	Antecedent Moisture Content
	Paved areas	Grassed areas		
Upper Alexandra Canal	2	20	2	3
Tempe	1	5	3	3
Mascot, Rosebery and Eastlakes	1	5	1	3
Sydney Airport	1	5	3	3
Mill Stream and Pagewood	1	5	1	3

A3.4 Design Discharge Hydrographs

Figure A.3 shows the design discharge hydrographs that were applied to the upstream boundary of the TUFLOW model on Sheas Creek. The peak 1% AEP flow generated by the Alexandra Canal DRAINS model at the location where Sheas Creek discharges to Alexandra Canal of 162 cubic metres per second compares closely with the peak flow of 160 cubic metres per second given in *Sheas Creek Flood Study* (Webb, McKeown and Associates (WMA), 1991) at the same location.

A4. COMBINED TUFLOW MODEL

A4.1 Background to Hydraulic Model Development

The hydraulic model relied upon for the present investigation was based on the following three separate but overlapping models covering:

- The main arms of the Cooks River and Alexandra Canal that was developed as part of L&A 2015 (**Lower Cooks River TUFLOW model**).
- The suburbs of Mascot, Rosebery and Eastlakes that was developed as part of WMAwater 2015 (**MRE TUFLOW model**).
- The lower reach of Mill Stream and the suburb of Pagewood that was developed as part of WMAwater 2015 (**MS TUFLOW model**).

For the purpose of the present investigation the three models were spliced together to better define the interaction of flow between the adjoining catchments and to remove the influence of adopted boundary conditions on modelled flood behaviour in the vicinity of the rail corridor (combined TUFLOW model). The following changes were also made to the structure of the combined TUFLOW model to include details of recent projects and to improve the definition of flood behaviour in the vicinity of the rail corridor:

- Ground elevations and details of the drainage system in the vicinity of the project were updated based on detailed road and drainage design models for the Airport North and Airport East projects. It was noted that the majority of the recently constructed works in the vicinity of O'Riordan Street for the Airport East project will be adjusted once the Airport North project is completed. **Figure A.4** shows the extent of the Airport East and Airport North projects.
- The combined TUFLOW model was extended in the vicinity of Sydney Airport and Foreshore Road to assess the full extent of flooding in the vicinity of the project corridor.
- Details of the bridge crossing over Mill Stream at the rail corridor were updated based on detailed ground survey. A layered flow constriction shape was used to apply a form loss across the entire bridge waterway to account for hydraulic losses associated with the piers. A form loss coefficient of 0.2 was calculated using the procedure set out in *Hydraulics of Bridge and Waterways* (Bradley 1978) while pier and waterway dimensions were obtained from the ground survey.
- The model was updated to incorporate details of the work-as-executed road and drainage designs of the recent upgrades to the road network within Sydney Airport at Robey Street and O'Riordan Street. **Figure A.4** shows the extent of the Sydney Airport road upgrades that were incorporated into the model.
- The layout of the drainage system within Sydney Airport was updated based on a review of pit and pipe survey provided by Sydney Airport Corporation, as well as details contained in AECOM 2018.
- Details of a new bridge which has recently been constructed across Alexandra Canal downstream of the Botany Rail Line were incorporated in the combined TUFLOW model using detailed design drawings and models obtained during the preparation of L&A 2015. Natural surface levels were also raised on the northern side of the canal adjacent to the new bridge to reflect finished surface levels associated with a then planned and since

constructed vehicle storage area. **Figure A.5**, sheet 1 shows the approximate extent of the works which have been denoted as the "**Nigel Love Bridge and Northern Lands carpark**".

- Details of the local drainage system that controls runoff from the catchment to the west of Alexandra Canal between the Cooks River and Canal Road were incorporated into the model in order to more accurately define the nature of local catchment flooding in this area. Details of the drainage system were obtained from GIS based pit and pipe data that were provided by Marrickville Council (now part of Inner West Council).

- Two new bridge crossings that are currently being constructed across Alexandra Canal upstream of the Port Botany Rail Line as part of the New M5 project were incorporated in the model using design drawings and road models provided by Roads and Maritime. Natural surface levels were also adjusted on either side of the canal adjacent to the new bridges to reflect finished surface levels associated with the road works. For the purpose of the present investigation it was assumed that the discharge of runoff into the canal from the St Peters Interchange (which is currently under construction as part of the New M5 project to the north of Canal Road) will be the same as pre- New M5 conditions. **Figure A.4** shows the extent of the New M5 project and the location of the St Peters Interchange.

A4.2 Sources of Topographic Data

Figure A.5 (2 sheets) shows the various sources of topographic data that were available to construct the combined TUFLOW model. The data included:

- Cross sections of the streams which had been included in the TUFLOW model developed for Sydney Water by the PB-MWH Joint Venture study of Cooks River catchment in 2009 (SW 2009)
- A hydrographic survey provided by MSW Roads and Maritime Services of the lower reaches of Cooks River and Alexandra Canal
- Detailed ground survey along the road reserve of Marsh Street west of the Cooks River
- Details of the various bridge crossings provided by Roads and Maritime
- LiDAR survey data provided by Roads and Maritime to define natural surface levels on the floodplain
- Levels along the shoreline based on LiDAR survey provided by Roads and Maritime which were used in conjunction with estimated depths of Botany Bay to extend the model into the bay below the Cooks River outlet
- Grid elevations in the model were updated using detailed ground survey along the rail corridor and its immediate vicinity, including the road corridor of Qantas Drive. The detailed ground survey was also used to update the layout of the drainage system along Qantas Drive and Airport Drive.

A4.3 TUFLOW Model Layout

The layout of the combined TUFLOW model is shown on **Figure A.5**. Both the floodplain and stream beds of Mill Stream, Alexandra Canal and the lower reaches of the Cooks River and Wolli Creek were modelled as a grid of two-dimensional elements. The grid levels comprising the stream beds of Alexandra Canal and the lower reaches of the Cooks River and Wolli Creek were interpolated from the cross sections shown on **Figure A.5** in areas where there was no hydrographic survey.

All of the features which influence the passage of flow on the floodplain were included in the model. An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive and it is not practicable to use a mesh of very fine elements without incurring very long times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

The model comprises a two metre grid which covers areas that are affected by flooding along Alexandra Canal and Mill Stream and a six metre grid which covers the portion of the two-dimensional model domain along the main arm of the Cooks River. Ridge and gully lines were added to the model where the grid spacing was considered too coarse to accurately represent important topographic features which influence the passage of overland flow, such as road centrelines and footpaths. It was important that the model recognised the ability of roads to capture overland flow and act as floodways.

The footprints of a large number of individual buildings were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow whilst maintaining a correct estimate of floodplain storage in the model. It was not practicable to model the individual fences surrounding the many allotments in the study area. They comprised many varieties (brick, paling, colorbond, etc) of various degrees of permeability and resistance to flow. It was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways.

A4.4 TUFLOW Model Boundary Conditions

A4.4.1 Inflow Boundaries

Discharge hydrographs were applied to the following external inflow boundaries, the locations of which are shown on **Figure A.5**:

- Five discharge hydrographs were derived from the Cooks River RAFTS model and enter the model along the main arm of the Cooks River and a series of tributaries to its west (refer inflow boundary location identifiers **CR1** to **CR5** on **Figure A.5**).
- A discharge hydrograph was derived from the Alexandra Canal and Mill Stream DRAINS model and applied to the main arm of Alexandra Canal upstream of Maddox Street (refer inflow boundary location identifier **AC1** on **Figure A.5**)
- Eight discharge hydrographs were obtained from the MS TUFLOW model and enter the model along Gardeners Road (refer inflow boundary location identifiers **KC1** to **KC8** on **Figure A.5**). The hydrographs, which were contained in the MS TUFLOW model, were originally developed as part of the _Kensington – Centennial Park Flood Study_ (WMAwater, 2013), the downstream limit of which is located at Gardeners Road.
- Two discharge hydrographs from the Pagewood catchment were derived from the Alexandra Canal and Mill Stream DRAINS model. These inflows enter the model along its eastern boundary, either side of Wentworth Avenue (refer inflow boundary location identifiers **PW1** and **PW2** on **Figure A.5**, sheet 1).

- Three inflow hydrographs from the Daceyville/Astrolabe Park catchment were derived from the Alexandra Canal and Mill Stream DRAINS model. These inflows enter the model along the eastern side of the Eastlake Golf Club (refer inflow boundary location identifiers **DA1** to **DA4** on **Figure A.5**, sheet 1).

For consistency with the approach adopted in WMA, 2015, the MRE and MS sections of the combined TUFLOW model were run using inflow boundaries that were derived using:

- a two hour storm for internal inflow boundaries within the MRE section of the model
- a two hour storm for external inflow boundaries from the Daceyville/Astrolabe Park catchment
- a 25 minute storm for external inflow boundaries from the Pagewood catchment within the MS section of the model
- a nine hour storm for internal inflow boundaries along the main arm of Mill Stream
- a one hour storm embedded within a 12 hour storm for external inflow boundaries along Gardeners Road, which were originally developed as part of WMAwater, 2013
- a two hour storm for internal inflow boundaries for urbanised areas to the east and west of the main arm of Mill Stream.

A two hour storm was found to be critical for maximising peak flood levels in the Lower Cooks River section of the model, including areas in the vicinity of the rail corridor, and was therefore adopted in the combined TUFLOW model. This also provided consistency in inflow boundaries with the adjoining MRE section of the model.

A4.4.2 Storm Tides at Botany Bay

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

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

- A default tidal hydrograph which has a peak RL 2.6 metres AHD for the 1 in 100 year event; or 2.3 metres AHD for the 5% AEP event. This default option is acknowledged by DECCW as providing a *conservatively high estimate* of tides for these types of entrances. Results achieved with these levels have been determined in the present investigation, but are only presented as a *sensitivity study*.
- A detailed site-specific analysis of elevated water levels at the ocean boundary. The analysis should include contributions to the water levels such as tides, storm surge wind and wave set up. The analysis should examine the duration of high tidal levels, as well as their potential coincidence with catchment flooding. This approach requires a more

detailed consideration of historic tides and the entrance characteristics, but provides information which is more directly relevant to a particular entrance. It has been adopted for *design purposes* in the present investigation.

A4.4.4 Consideration of Historic Storm Tides

The Highest Astronomical Tide (HAT) level recorded in Botany Bay was 1.45 metres AHD on 25 May 1974. This level was recorded at Kurnell and was considered to have an AEP of 1 per cent. In the WMA 1994 investigation an allowance of 0.25 metres was adopted for additional storm related components such as wind stress and wave action, yielding a peak of 1.7 metres AHD at the Cooks River entrance. By comparison the High High Water Solstice Spring (HHWSS) tide which occurs once or twice a year has a peak of about 1.02 metres AHD.

Peak storm tide levels for events with AEP's of 20% and 5% were derived by adding 0.25 metres to design still water levels for Fort Denison which are given in *Fort Denison Sea Level Rise Vulnerability Study* (Department of Environment and Climate Change (DECC) 2008), while the upper limit of ocean flooding (referred to herein as an "extreme ocean flood event" and assigned a probability of 1 in 10,000 AEP) was determined by extrapolation of the data presented in DECC 2008.

Table A4.1 sets out the peak tide levels that were adopted for design flood modelling. Tidal hydrographs were generated with the peak levels for application to the downstream boundary of the TUFLOW model.

TABLE A4.1
ADOPTED PEAK STORM TIDE LEVELS IN BOTANY BAY

Storm Tide Event	Peak Storm Tide Level (metres AHD)
Normal Tide	0.63
HHWSS	1.02
20% AEP(1)	1.57
5% AEP(1)	1.63
1% AEP(2)	1.70
Extreme	1.85

1. Derived by adding 0.25 m to the values presented in DECCW, 2010.
2. Source: WMA 1994.

A4.4.3 Envelope Scenarios for Determining Flood Levels in Cooks River

In accordance with the *Floodplain Risk Management Guideline: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (Office of Environment and Heritage (OEH), 2015), the derivation of 1% AEP flood levels in the tidal zone of the Cooks River and Alexandra Canal required consideration of the interaction of catchment and ocean flooding for the following scenarios:

i. 5% AEP catchment flooding coincident with a 1 in 100 year ocean flooding (peak water level of RL 1.70 m AHD).

ii. 1% AEP catchment flooding coincident with a 1 in 20 year ocean flooding (peak water level of RL 1.63 m AHD).

iii. 1% AEP catchment flooding coincident with a normal tidal cycle.

For the purpose of the present investigation, scenario ii) was adopted for defining 1% AEP flooding patterns in the vicinity of the project as this combination of local catchment and ocean tide conditions is critical for maximising peak flood levels in the middle and upper reaches of Alexandra Canal.

In addition to the above, flooding conditions arising as a result of floods other than the 1% AEP event were also assessed. **Table A4.2** sets out the combinations of coincident catchment and ocean flooding conditions that were adopted for the present investigation.

TABLE A4.2
ADOPTED COINCIDENT CATCHMENT AND OCEAN FLOODING CONDITIONS

Design Flood	Local Catchment Flood	Downstream Boundary Condition in Botany Bay(1)
50% AEP	50% AEP	HHWSS [1.02 m AHD]
20% AEP	20% AEP	HHWSS [1.02 m AHD]
10% AEP	10% AEP	20% AEP storm tide [1.57 m AHD]
5% AEP	5% AEP	20% AEP storm tide [1.57 m AHD]
2% AEP	2% AEP	5% AEP storm tide [1.63 m AHD]
1% AEP	1% AEP	5% AEP storm tide [1.63 m AHD]
	1% AEP	Normal tide cycle [0.63 m AHD]
Probable Maximum Flood	PMF	1% AEP storm tide [1.70 m AHD]

1. Values in [ ] relate to adopted peak storm tide level.

A4.5 TUFLOW Model Parameters

A4.5.1 General

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

A4.5.2 Channel Roughness

There are very limited historic flood level data available in the lower reaches of the Cooks River and Alexandra Canal to assist with the calibration of the model for roughness. Channel roughness values were estimated from site inspection, past experience and values contained in the engineering literature.

Initial runs of the TUFLOW model were carried out with channel roughness values of 0.025 and 0.03, with the latter value resulting in peak flood levels about 200 millimetres higher than the former. After consideration a value of 0.025 was adopted for assessment purposes.

A4.5.3 Floodplain Roughness

The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline and kerb elevations, allowed an accurate assessment of their conveyance capacity to be made. Similarly the high value of roughness adopted for buildings recognised that they completely blocked the flow but were capable of storing water when flooded.

A4.5.4 Design Roughness Values

Table A4.3 summarises the ‘best estimate’ hydraulic roughness values that were adopted for design purposes.

A4.6 Sensitivity analyses

A4.6.1 Sensitivity of flood behaviour to increase in hydraulic roughness

A sensitivity analysis was undertaken to assess the impact of a 20 per cent increase in the ‘best estimate’ values of hydraulic roughness on flood behaviour during a 1% AEP event. The assessment found that peak 1% AEP flood levels are generally increased in the range 0.02 to 0.1 metres in the vicinity of the rail corridor. The main exception is along the northern side of the rail corridor to the west of General Holmes Drive where peak flood levels are reduced by 0.4 metres. This is due to the attenuating effects that an increase in hydraulic roughness has on the rate of overland flow that collects at the lowpoint in Baxter Road to the north of the rail corridor.

A4.6.2 Increases in design rainfall intensities and tailwater levels

An assessment of the impact that a potential increase in rainfall intensities and tailwater levels as a result of future climate change would have on flood behaviour in the vicinity of the project is presented in **Section 5.2.3** of this report.

A4.6.3 Partial blockage of hydraulic structures

An assessment of the impact that a partial blockage of major hydraulic structures would have on flood behaviour in the vicinity of the project is provided in **Section 5.2.4** of this report.

TABLE A4.3
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Surface Treatment	Manning's n Value
Concrete lined channels	0.015
Asphalt or concrete road surface	0.02
Rail corridor	0.025
River and canal bed	0.025
Well Maintained Grassed Cover e.g. sporting oval	0.03
Grass or Lawns	0.045
In bank area of Mill Stream, including Botany Wetlands	0.045
Macrophytes (river bank)	0.06
Trees	0.08
Fenced Properties	1.0
Buildings	10

A4.7. Comparison with procedures in ARR 2019

A4.7.1 General

As noted in **Section A3,** the DRAINS model used to generate inflow hydrographs to the TUFLOW model within the Alexandra Canal and Mill Stream catchments was based on design storms that were derived using the procedures set out in ARR 1987, which is also consistent with the approach adopted for previous studies within the study area.

Given the recent release of ARR 2019, an assessment has been made of the potential changes that the adoption of the procedures set out in ARR 2019 would have on predicted flood behaviour.

For the purpose of the comparison, an assessment has been made of changes in flood behaviour within the Alexandra Canal catchment only. The main inflows to the Mill Stream catchment are from the catchment upstream of Gardeners Road, which are based on a series of discharge hydrographs that were originally developed as part of the *Kensington – Centennial Park Flood Study* (WMAwater 2013). A comparison of flood behaviour in the Mill Stream catchment would require that the flood model that was developed as part of WMAwater 2013 be rerun using the procedures set out in ARR 2019, a task that is beyond the scope of the present investigation. The conclusions drawn from the comparison of flood behaviour within the Alexandra Canal catchment would also be applicable to the Mill Stream catchment.

A4.7.2 Assessment Approach

Separate DRAINS models were developed using the procedures in ARR 1987 and ARR 2019 in order to generate discharge hydrographs which were then applied as inflows to a TUFLOW model of the Alexandra Canal catchment and lower Cooks River (**Lower Cooks River TUFLOW model**). This involved the following tasks:

1. Rainfall depths for a 1% AEP event were derived for a storm duration of two hours using the procedures outlined in ARR 1987 and ARR 2019. The two hour storm had been found to be critical for maximising peak flood levels in the vicinity of the project based on ARR 1987 and therefore, for the purpose of the comparison was also adopted for ARR 2019. **Table A4.4** over the page shows that ARR 1987 design rainfall depths are 23 per cent higher than corresponding ARR 2019 values for a storm duration of two hours, which is also similar to the differences in rainfall depths for other durations between 30 minutes and three hours.
2. The design rainfalls were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987 and ARR 2019. While ARR 1987 prescribes a single temporal pattern for each storm duration, ARR 2019 requires an analysis of 10 temporal patterns for each storm duration. The application of these ten temporal patterns to the TUFLOW Model is discussed further under Task 4.
3. While ARR 2019 recommends the use of a new urban loss model, the paper entitled *Applying ARR 2016 to Stormwater Drainage Design* (Kus et al 2018) has identified some shortcomings of the approach in its present form. For these reasons, the loss models and parameters established in the hydrologic models for ARR 1987 were also adopted for ARR 2019. The new guidelines recommend the division of impervious areas into directly and indirectly connected impervious areas, with losses applied to the indirectly connected area closer to the values for rural pervious areas. On this basis the adoption of the ARR 1987 loss models and parameters is likely to produce a higher peak flow estimate in comparison to the new urban loss model recommended in ARR 2019.
4. The TUFLOW Model was run for a 1% AEP design event for a storm duration of two hours using the inflow hydrographs generated from the DRAINS models. While ARR 2019 recommends that ten temporal patterns for each storm duration are run through the hydrologic model in order to select the pattern that produces a peak flow estimate that is closest to the mean, this approach is not practical for investigations where the hydrologic model is being used to generate inflow hydrographs to a hydrodynamic model which is then used to assess flood behaviour at multiple locations across a study area (such as the present investigation). For this reason, the assessment of flood behaviour using ARR 2019 involved the generation of discharge hydrographs for all ten temporal patterns which were then applied to the Lower Cooks River TUFLOW Model. A representative set of water surface elevations and depths were then developed based on the median values which were derived by running the ten temporal patterns.

TABLE A4.4
COMPARISON OF 1% AEP DESIGN RAINFALL DEPTHS (mm)

Storm duration (minutes)	ARR 1987	ARR 2019	DIfference[(1)]
30	67	55	-18%
60	95	71	-25%
120	120	93	-23%
180	138	109	-21%

1. A positive value represents an increase and conversely a negative value represents a decrease relative to ARR 1987 design rainfall depths.

A4.7.3 Summary of Key Findings

Figure A.6 (2 sheets) shows the impact that the application of ARR 2019 has on flood behaviour in terms of changes in peak flood levels and the extent of inundation during a 1% AEP storm.

The adoption of ARR 2019 design storms would result in a reduction in peak flood levels by a maximum of 0.1 metres along the section of Alexandra Canal where it is crossed by the Botany Line. Larger reductions in peak flood levels, typically by a maximum of 0.2 metres would occur in the vicinity of the rail corridor at the western end of Ewan Street and at the Robey Street and O'Riordan Street Underpasses.

A4.8 Comparison with Results of Previous Studies

Table A4.5 at the end of this chapter compares peak 1% AEP flood levels derived using the combined TUFLOW model that was used for the present investigation with results presented in the *Mascot, Rosebery and Eastlakes Flood Study* (WMAwater 2015), the *Sydney Airport Flood Study* (AECOM 2018), and the *Cooks River Flood Study* (Sydney Water 2009).

Comparison of the results from the combined TUFLOW model with the previous studies shows that:

- The peak 1% AEP flood level in Alexandra Canal at Nigel Love Bridge (Location L01) matches closely with the result presented in AECOM 2018.
- Both the combined TUFLOW model and AECOM 2018 produce peak flood levels on Alexandra Canal (**Location L01**) that are higher than the corresponding result from SW, 2009. This is likely to be attributable to the approach adopted to model the main channel of the Cooks River and Alexandra Canal. While a two-dimensional modelling approach was adopted in the combined TUFLOW model and AECOM 2018, a one-dimensional modelling approach was adopted in SW 2009. The latter approach is likely to underestimate the hydraulic losses associated with the bends in the Cooks River over the reach downstream of its confluence with Alexandra Canal.
- The peak 1% AEP flood level in Sydney Airport at the northern pond (**Location L02**) matches closely with the peak flood level presented in AECOM 2018.
- The peak 1% AEP flood level at the western end of Ewan Street (**Location L03**) is 0.2 metres lower than the result presented in WMAwater 2015 and 0.5 metres lower than the result presented in AECOM 2018. The higher peak flood level estimate in AECOM 2018 is likely to be attributable to the AECOM, 2018 flood model not containing details of the piped drainage system that controls runoff in Ewan Street.

- The peak flood level in O'Riordan Street (**Location L04**) matches closely with the result presented in WMAwater 2015 and is 0.1 metres lower than the result presented in AECOM 2018. The slightly higher peak flood level from AECOM 2018 is likely to be attributable to its flood model containing limited details of the drainage system upstream of the O'Riordan Street Underpass.
- The peak 1% AEP flood level in Baxter Road (**Location L05**) is 0.6 metres lower than the result presented in WMAwater 2015 and 1.3 metres lower than the result presented in AECOM 2018. The higher peak flood level estimate in WMAwater 2015 is likely to be influenced by boundary condition assumptions in Ascot Drain, which forms the downstream limit of the model used to define flood behaviour in Baxter Road. The higher peak flood level estimate in AECOM 2018 is likely to be attributable to the AECOM, 2018 flood model not containing details of the piped drainage system that controls runoff in Baxter Road.
- Peak 1% AEP flood levels in Mill Stream (**Locations L06** and **L07**) and in Bay Street and Banksia Street (**Locations L08** and **L09**) match closely with the results presented in WMAwater 2015.

A4.9 Adjustments made to the structure of the combined TUFLOW model to reflect operational conditions

The following adjustments were made to the structure of the combined TUFLOW model in order to assess the impact the operation of the project would have on flood behaviour and to also assess the flood risks to the project:

- The Alexandra Canal and Mill Stream DRAINS model representing pre-project conditions was modified by adjusting sub-catchment boundaries based on the layout of the proposed rail drainage, as were catchment characteristics such as percentage impervious based on the increase in impervious area that is attributable to the project.
- Ground elevations in the combined TUFLOW model were adjusted using a 3D model of the rail duplication and associated earthworks that was developed as part of the concept design for the project.
- The piers and superstructure of the proposed Mill Stream bridge were modelled as a layered flow constriction shape to reflect the obstruction that it would have on flow in Mill Stream.
- The drainage system in the combined TUFLOW model was modified to reflect the details of the concept drainage design, which included:
  - a drainage line to control runoff from the section of rail corridor and adjoining portion of Eastlake golf course to the east of Mill Stream;
  - a series of drainage channels which would control runoff from the section of rail corridor between Mill Stream and Banksia Street; and
  - a series of modified or new drainage outlets to control runoff from the rail corridor that would discharge into the downstream drainage systems (denoted **DO1** to **DO14** on **Figure 5.3**, sheets 2 and 3 in this report.

Table 5.2 and **Figure 5.3** (3 sheets) in this report show the key features of the project which were incorporated in the TUFLOW model representing post-project conditions.

TABLE A4.5
PEAK 1% AEP FLOOD LEVELS - COMPARISON OF RESULTS WITH PREVIOUS STUDIES

Location		Combined TUFLOW model(2)	WMAwater 2015(3)	AECOM 2018(4)	SW 2009(3)
I.D.(1)	Description				
L01	Alexandra Canal at Nigel Love Bridge	2.5	Not reported	2.5 _[0.0]_	2.2 _[-0.3]_
L02	Sydney Airport at Northern Pond	2.05	Not reported	2.0 _[-0.05]_	Not reported
L03	Ewan Street, north of the Botany Line	5.1	5.3 _[0.2]_	5.6 _[0.5]_	Not reported
L04	O'Riordan Street Underpass at the Botany Line	5.1	5.1 _[0.0]_	5.2 _[0.1]_	Not reported
L05	Baxter Road, west of Botany Road	5.4	6.0 _[0.6]_	6.7 _[1.3]_	Not reported
L06	Mill Stream immediately upstream of Botany Road	4.2	4.2 _[0.0]_	Not reported	Not reported
L07	Mill Stream, about 400 m upstream of the Botany Line	7.3	7.2 _[-0.1]_	Not reported	Not reported
L08	Bay Street, north of the Botany Line	8.9	8.9 _[0.0]_	Not reported	Not reported
L09	Banksia Street, north of the Botany Line	9.8	9.9 _[0.1]_	Not reported	Not reported

(1) Refer to **Figure A.5** (2 sheets) for Location I.Ds.

(2) Results are based on a 1% AEP local catchment flood coincident with a 5% AEP storm tide.

(3) Values in brackets show the relative difference in peak flood level between the previous study and the combined TUFLOW model. A positive value represents a higher value, while conversely a negative value represents a lower value from the previous study when compared to the combined TUFLOW model.

(4) Peak flood levels are taken from Table 13 of AECOM 2018 with the exception of Location L02 which was taken from Table 17 of AECOM 2018.

A5. REFERENCES

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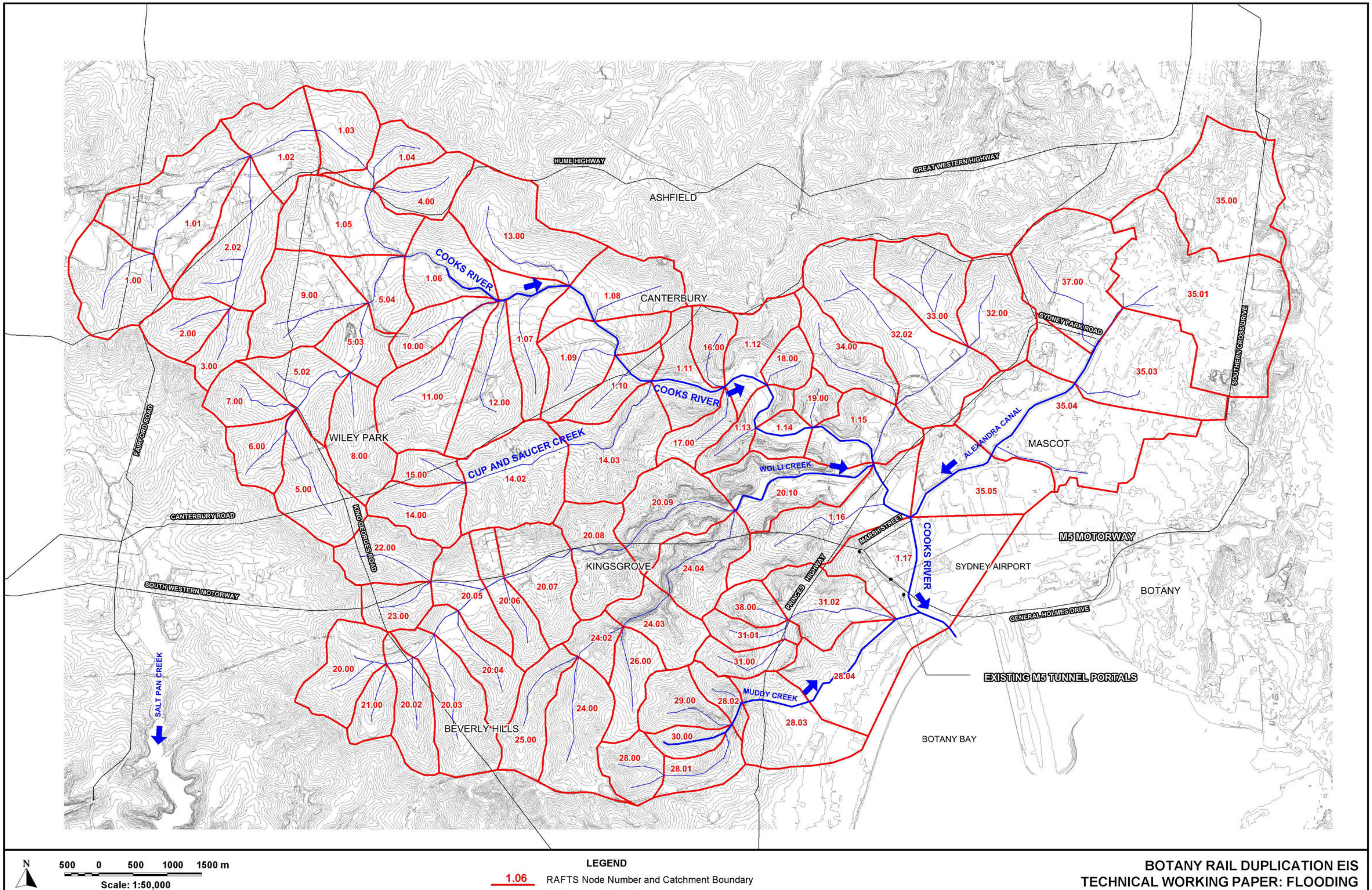
WMAwater, 2015. *Mascot, Rosebery and Eastlakes Flood Study*.



LEGEND

1.06 RAFTS Node Number and Catchment Boundary

Watercourse/Flowpath

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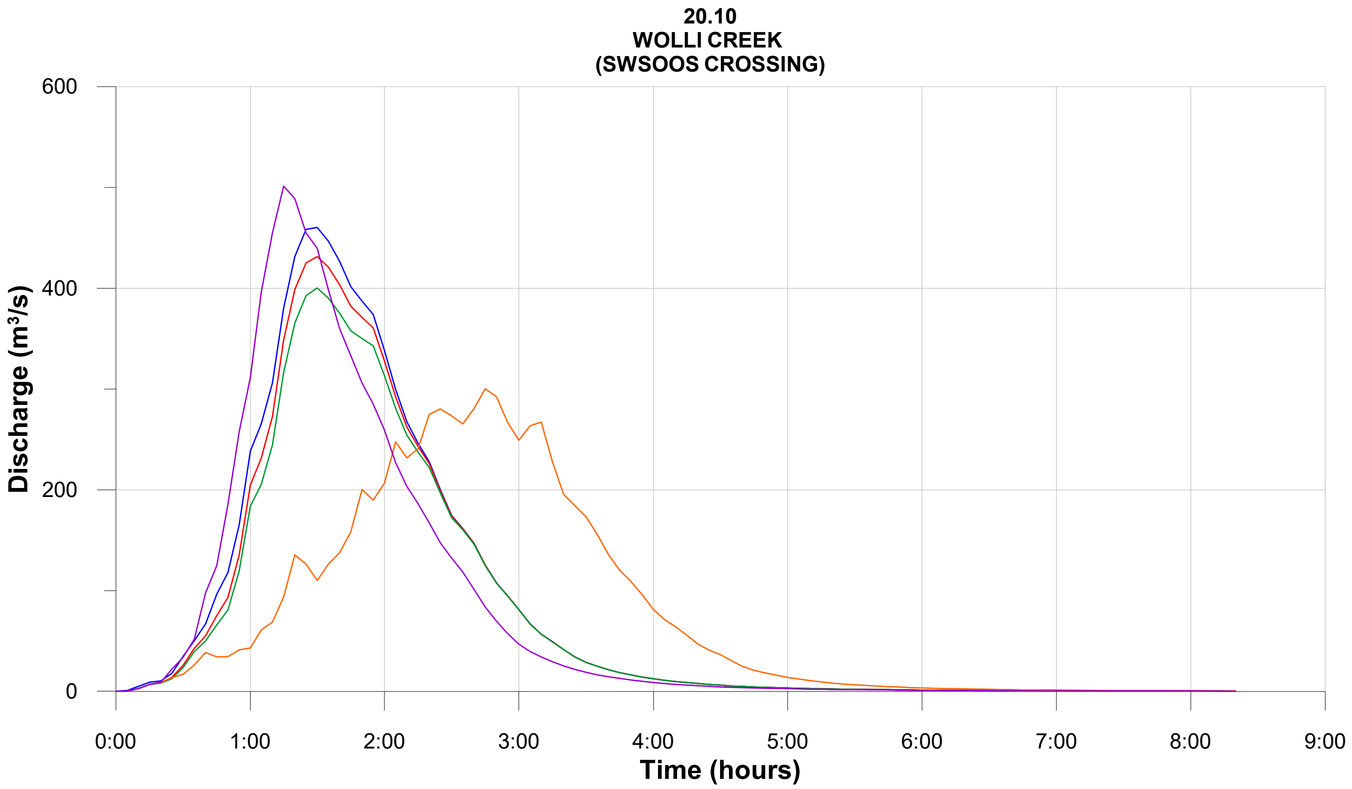
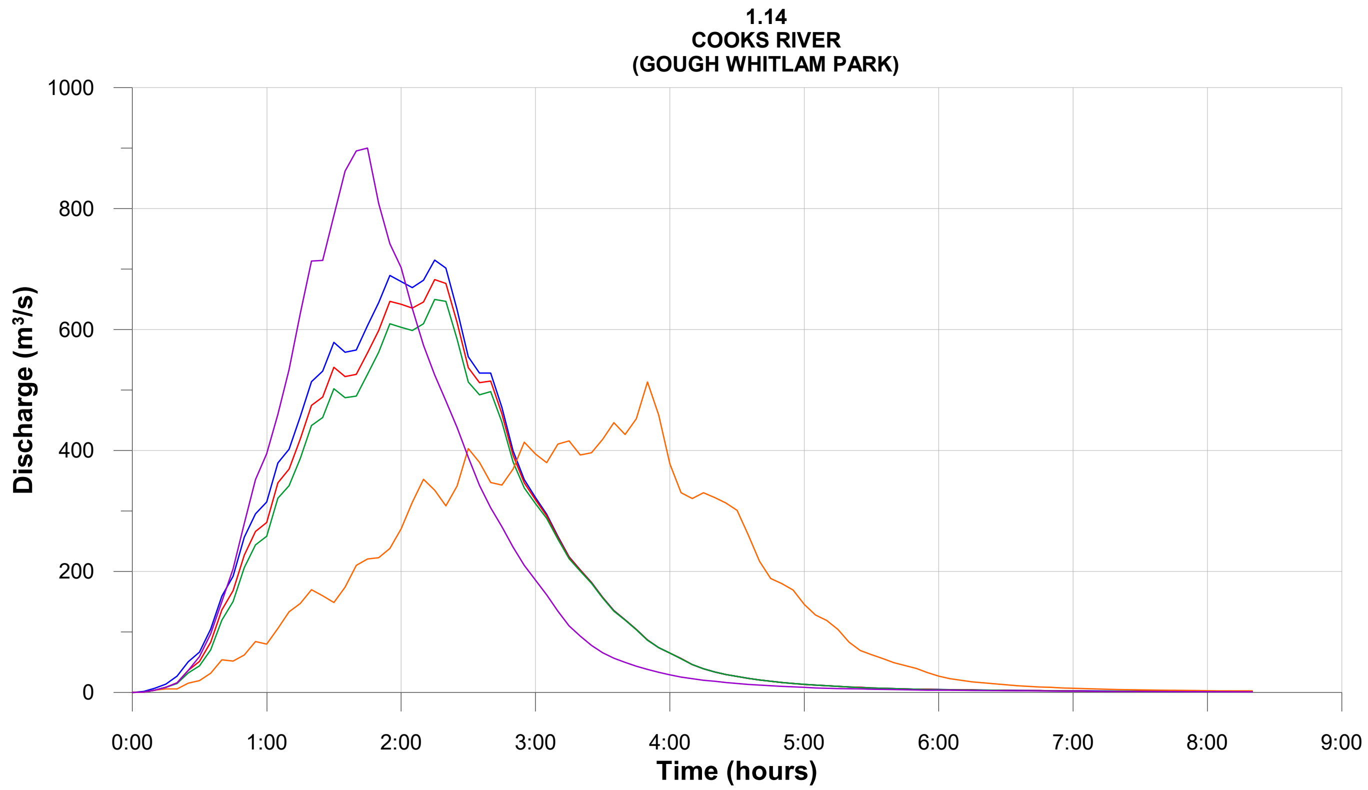
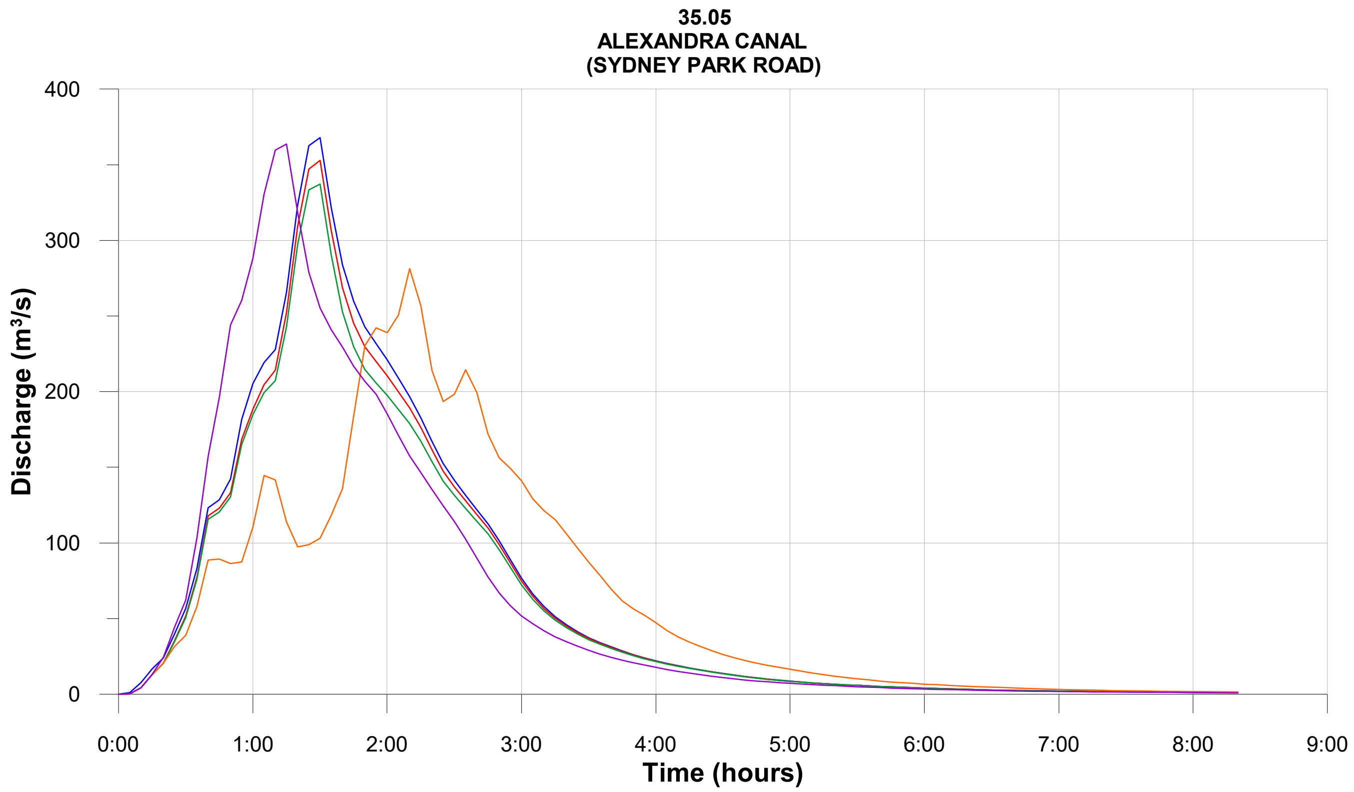
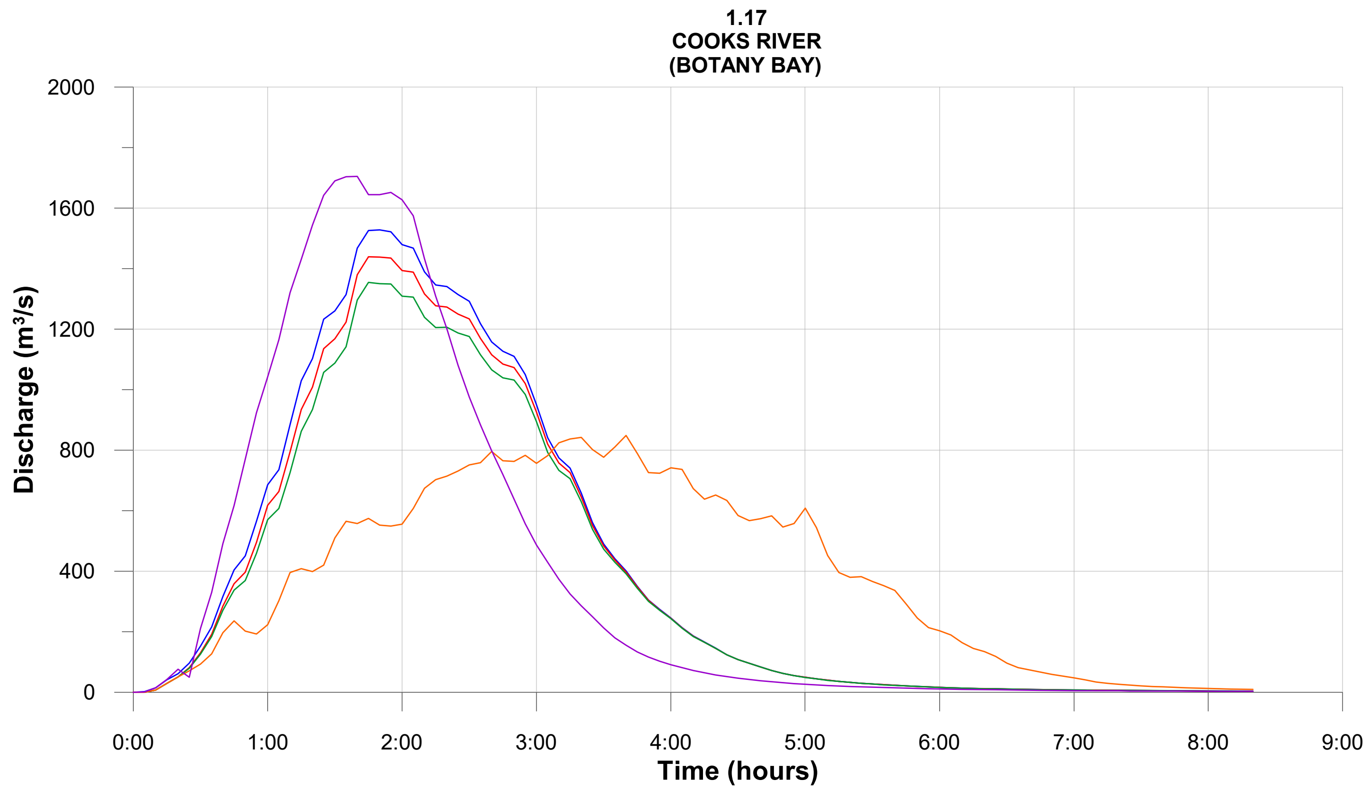
Figure A.1

COOKS RIVER RAFTS MODEL LAYOUT









LEGEND

INITIAL LOSS (mm)	VELOCITY (m/s)
0	2
10	2
20	2
10	1
10	3

NOTE:

RESULTS APPLY FOR 2 HOUR CRITICAL STORM.

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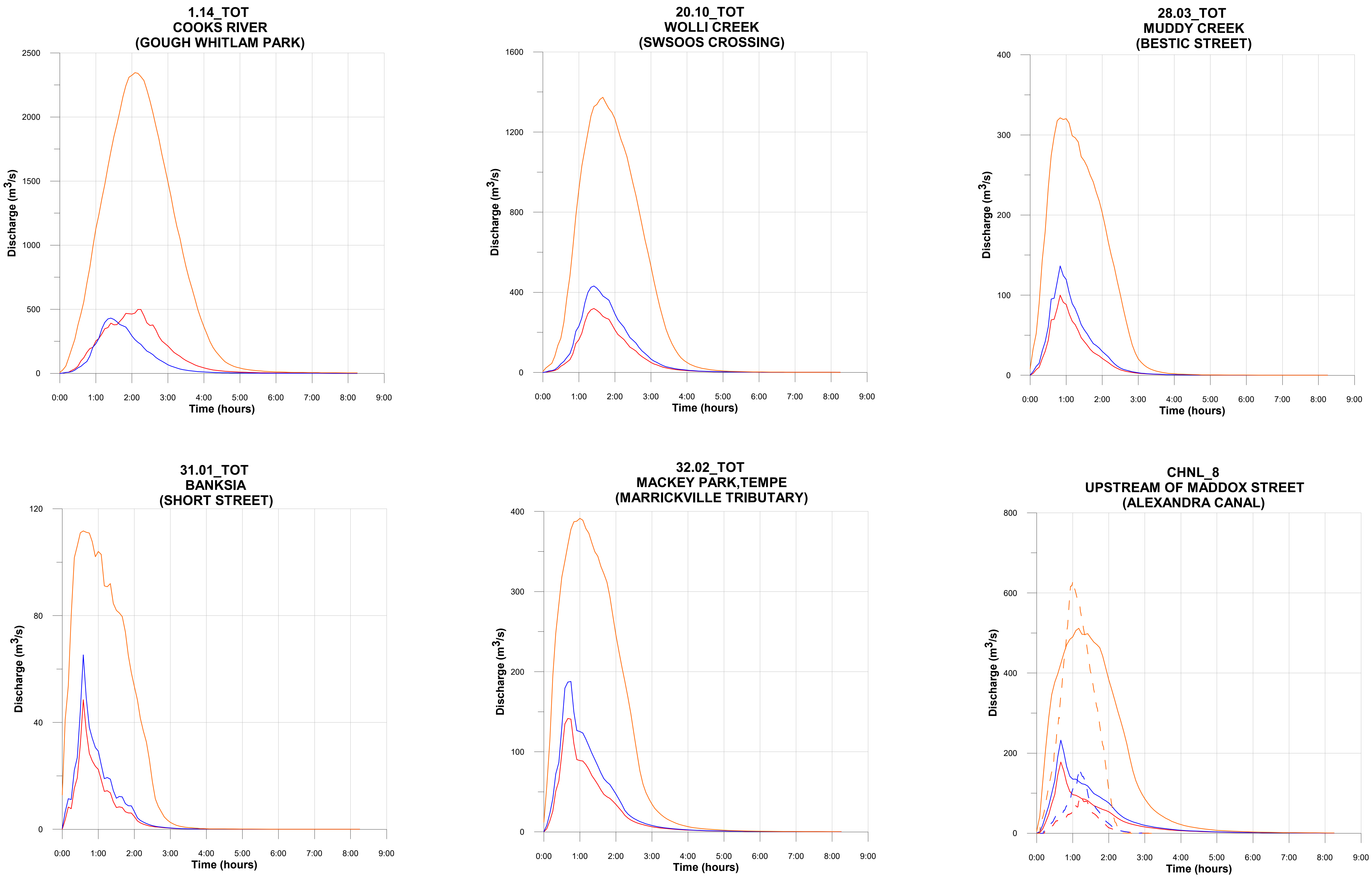
Figure A.2

SENSITIVITY STUDY - 1% AEP
RAFTS DISCHARGE HYDROGRAPHS



LEGEND

Cooks River RAFTS Model	Alexandra Canal DRAINS Model	
solid orange line	dashed orange line	PMF
solid blue line	dashed blue line	1% AEP
solid red line	dashed red line	5% AEP

NOTE:

UNLESS OTHERWISE NOTED, FLOWS WERE DERIVED BY RAFTS AND APPLIED AS BOUNDARY CONITIONS TO TUFLOW.

CRITICAL DURATION FOR 5%, 1%, 0.5% AND 0.2% AEP STORMS IS 2 HOURS. CRITICAL DURATION FOR PMF IS 2.5 HOURS.

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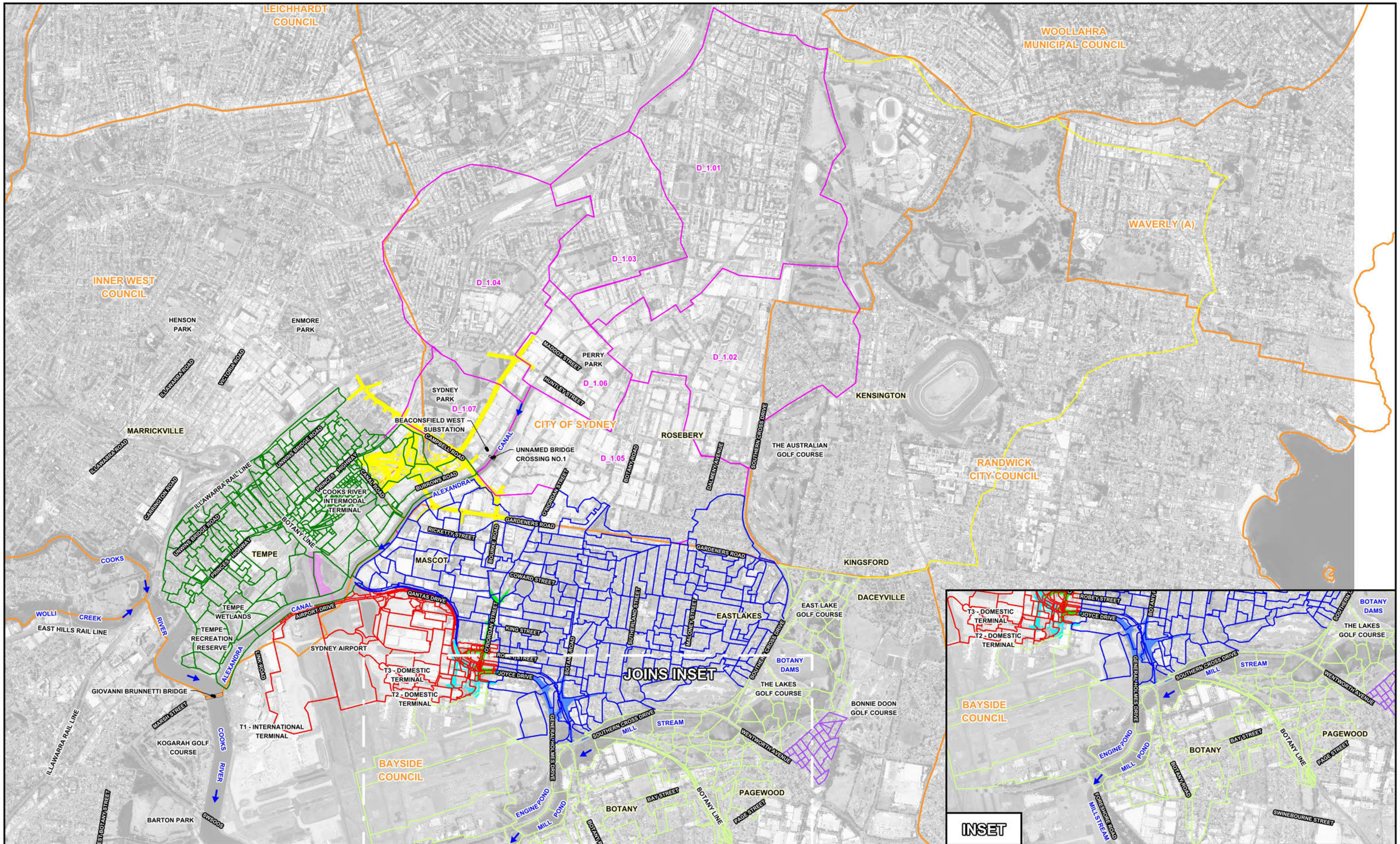
Figure A.3

DESIGN DISCHARGE HYDROGRAPHS
COOKS RIVER AND TRIBUTARIES



N

300 0 300 600 900 m

Scale: 1:30,000

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LEGEND

- LGA Boundary
- WestConnex New M5 Design
- Airport North Road Upgrade
- Airport East Road Upgrade
- SACL Projects Road Upgrade
- Approximate footprint of Nigel Cove Bridge and Northerns Lands Carpark
- D_1.01 Upper Alexandra Canal Sub-Catchment Boundary and Identifier
- Tempe Sub-Catchment Boundary
- Mascot, Rosebery and Eastlakes Sub-Catchment Boundary
- Sydney Airport Sub-Catchment Boundary
- Mill Stream Sub-Catchment Boundary
- Pagewood Sub-Catchment Boundary
- Gardeners Road East Catchment Boundary

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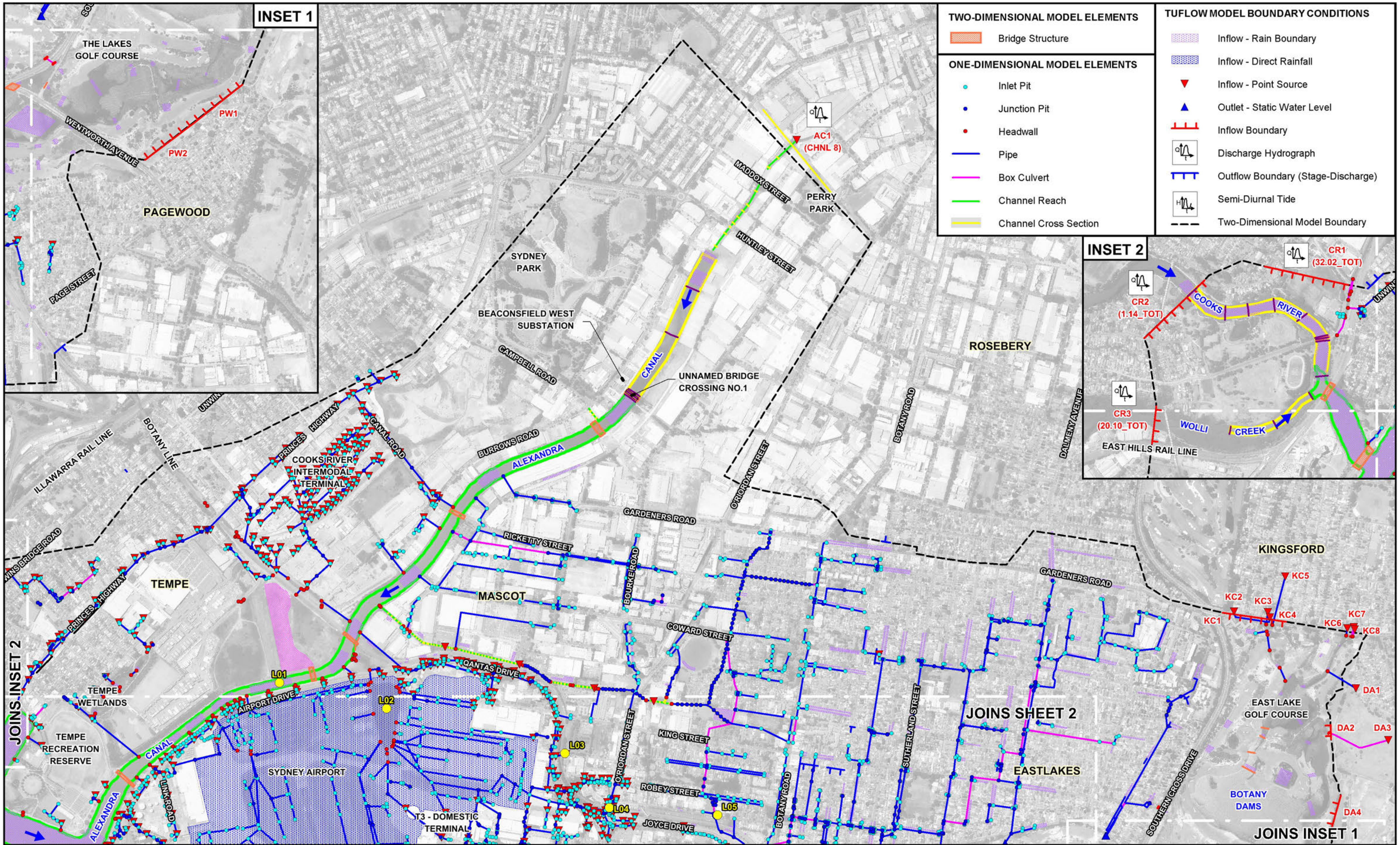
Figure A.4

ALEXANDRA CANAL AND MILL STREAM DRAINS MODEL LAYOUT



N

150 0 150 300 400 m

Scale: 1:15,000

LEGEND

Approximate Footprint of Nigel Love Bridge and Northern Lands Carpark

Riverbed Interpolated from Cross Sections used in TUFLOW Model Supplied by Sydney Water

Cross Sections from Sydney Water TUFLOW Model

Hydrographic Survey Provided By RMS

Bed Levels in Botany Bay based on Lidar Survey Levels Along the Shoreline and Estimated Depths in the Bay

L01 Peak Flood Level Location and Identifier

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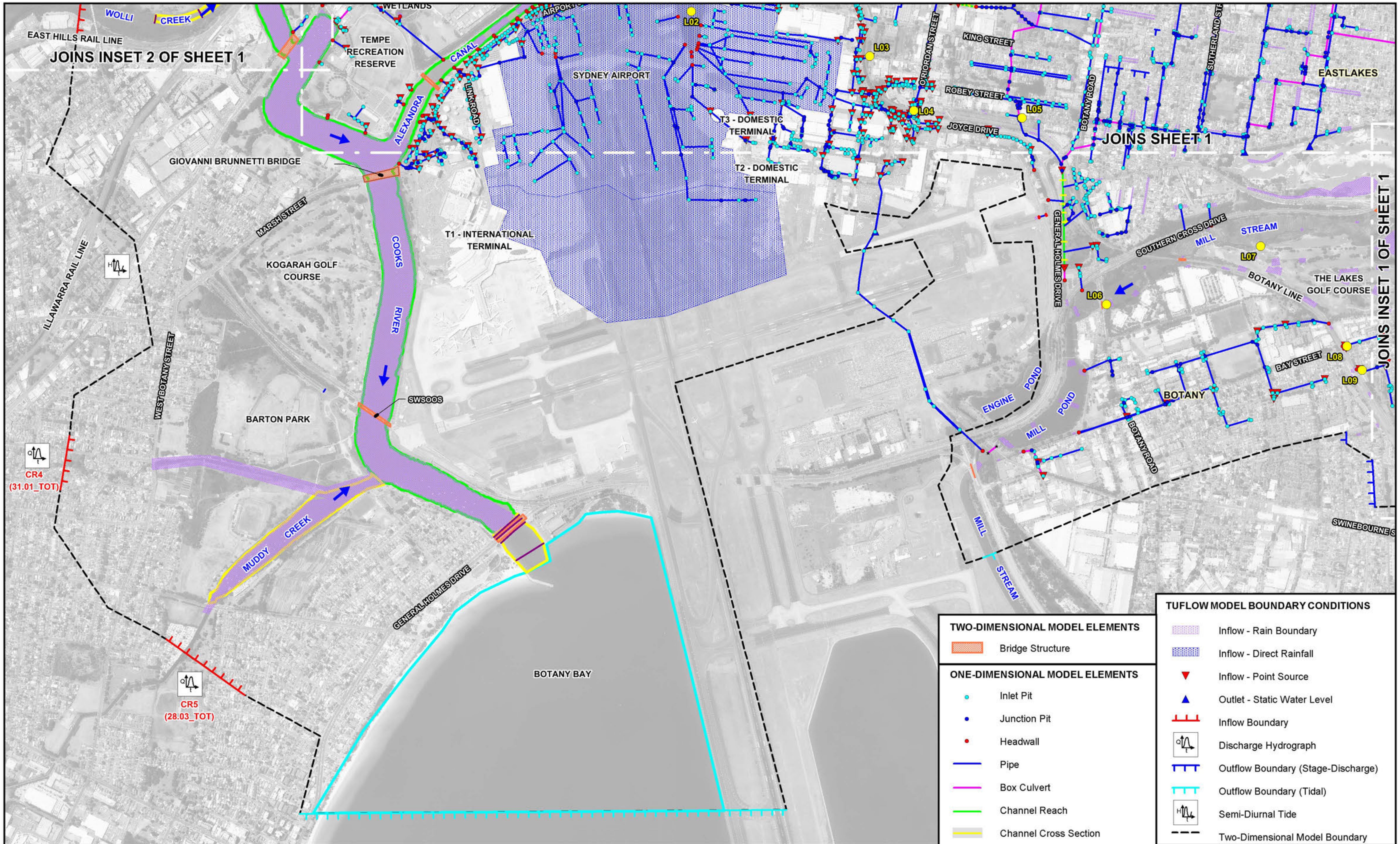
Figure A.5
(Sheet 1 of 2)

COMBINED TUFLOW MODEL LAYOUT



N

150 0 150 300 400 m

Scale: 1:15,000

LEGEND

- Riverbed Interpolated from Cross Sections used in TUFLOW Model Supplied by Sydney Water
- Cross Sections from Sydney Water TUFLOW Model
- Hydrographic Survey Provided By RMS
- Bed Levels in Botany Bay based on Lidar Survey Levels Along the Shoreline and Estimated Depths in the Bay
- L01 Peak Flood Level Location and Identifier

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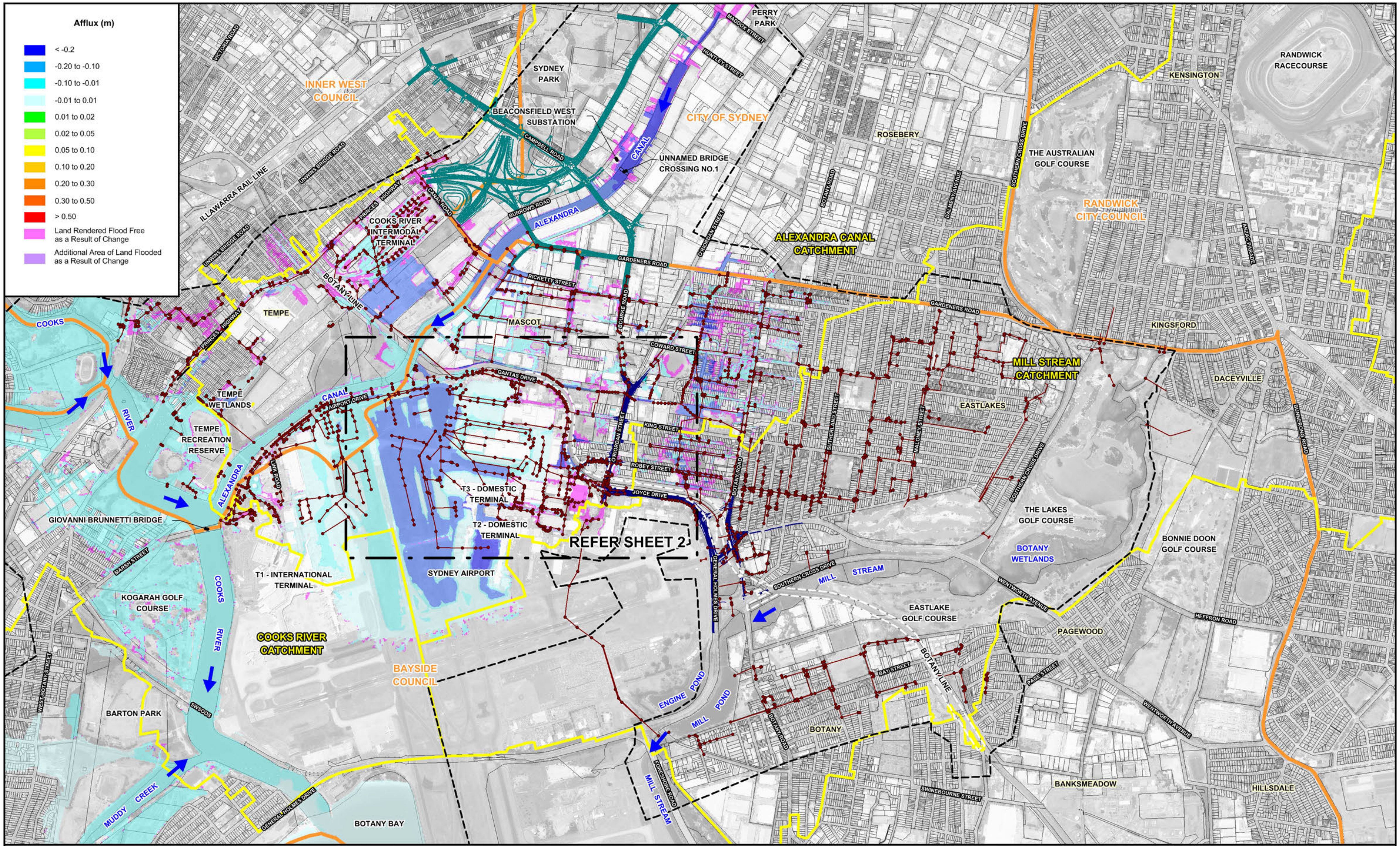
Figure A.5
(Sheet 2 of 2)

COMBINED TUFLOW MODEL LAYOUT



N

200 0 200 400 600 m

Scale: 1:20,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

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LEGEND

- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

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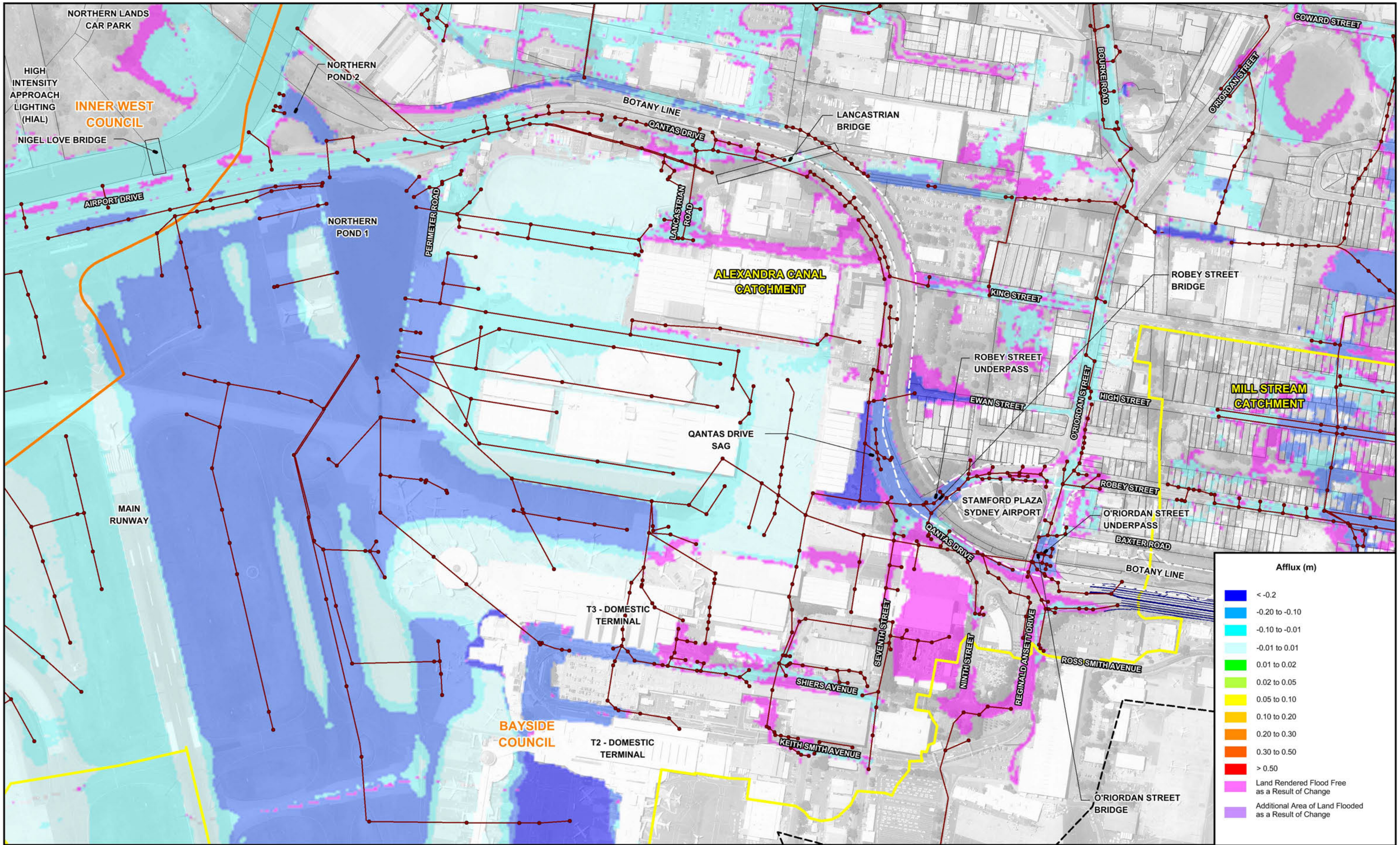
Figure A.6
(Sheet 1 of 2)

DIFFERENCE IN FLOOD BEHAVIOUR IN ALEXANDRA CANAL CATCHMENT - ARR 2019 MINUS ARR 1987
PRE-PROJECT CONDITIONS - 1% AEP EVENT



LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- LGA Boundary

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
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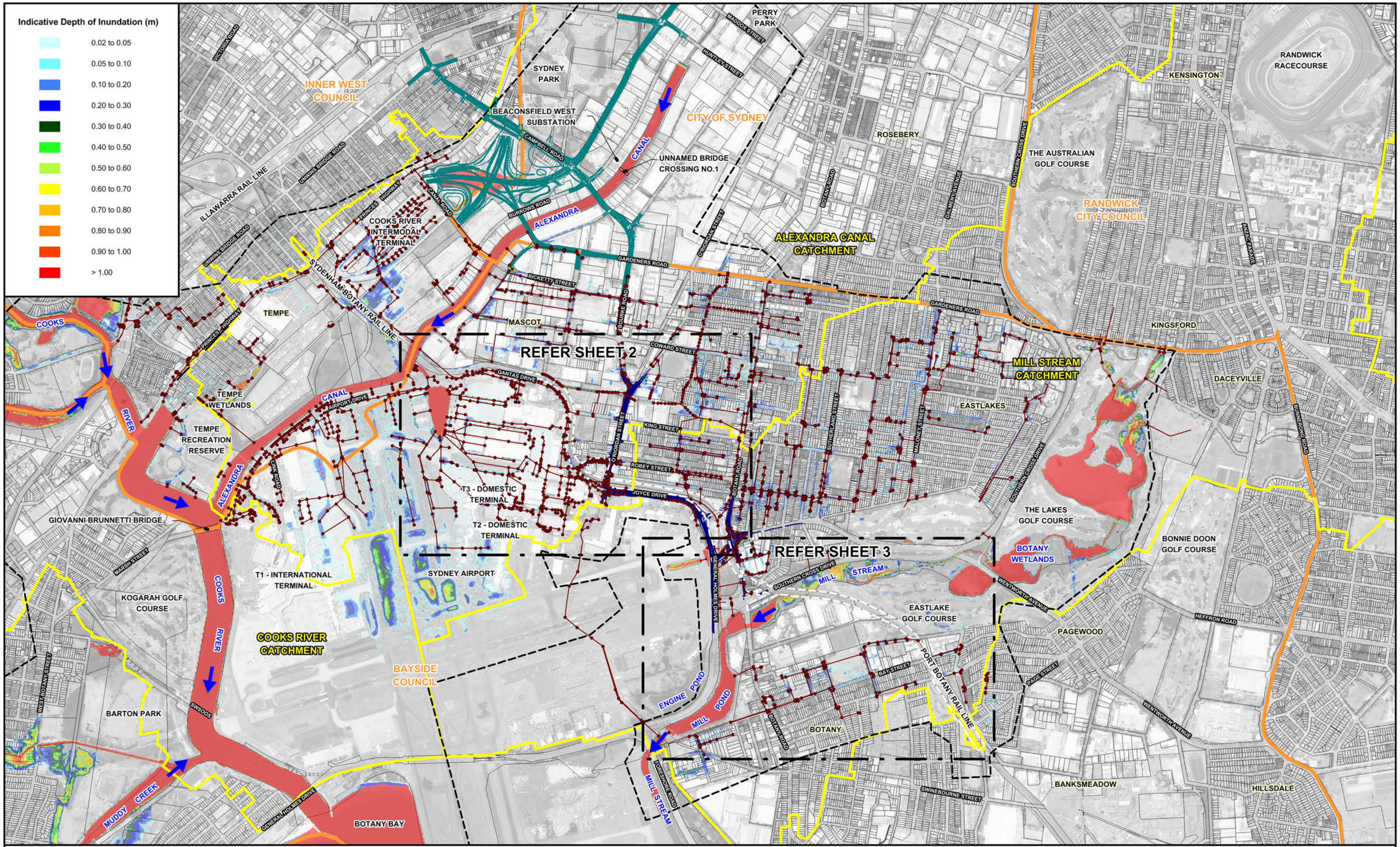
Figure A.6
(Sheet 2 of 2)

DIFFERENCE IN FLOOD BEHAVIOUR IN ALEXANDRA CANAL CATCHMENT - ARR 2019 MINUS ARR 1987
PRE-PROJECT CONDITIONS - 1% AEP EVENT

ANNEXURE B
ADDITIONAL FIGURES SHOWING FLOOD MODEL RESULTS



200 0 200 400 600 m

Scale: 1:20,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

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BOTANY RAIL DUPLICATION EIS
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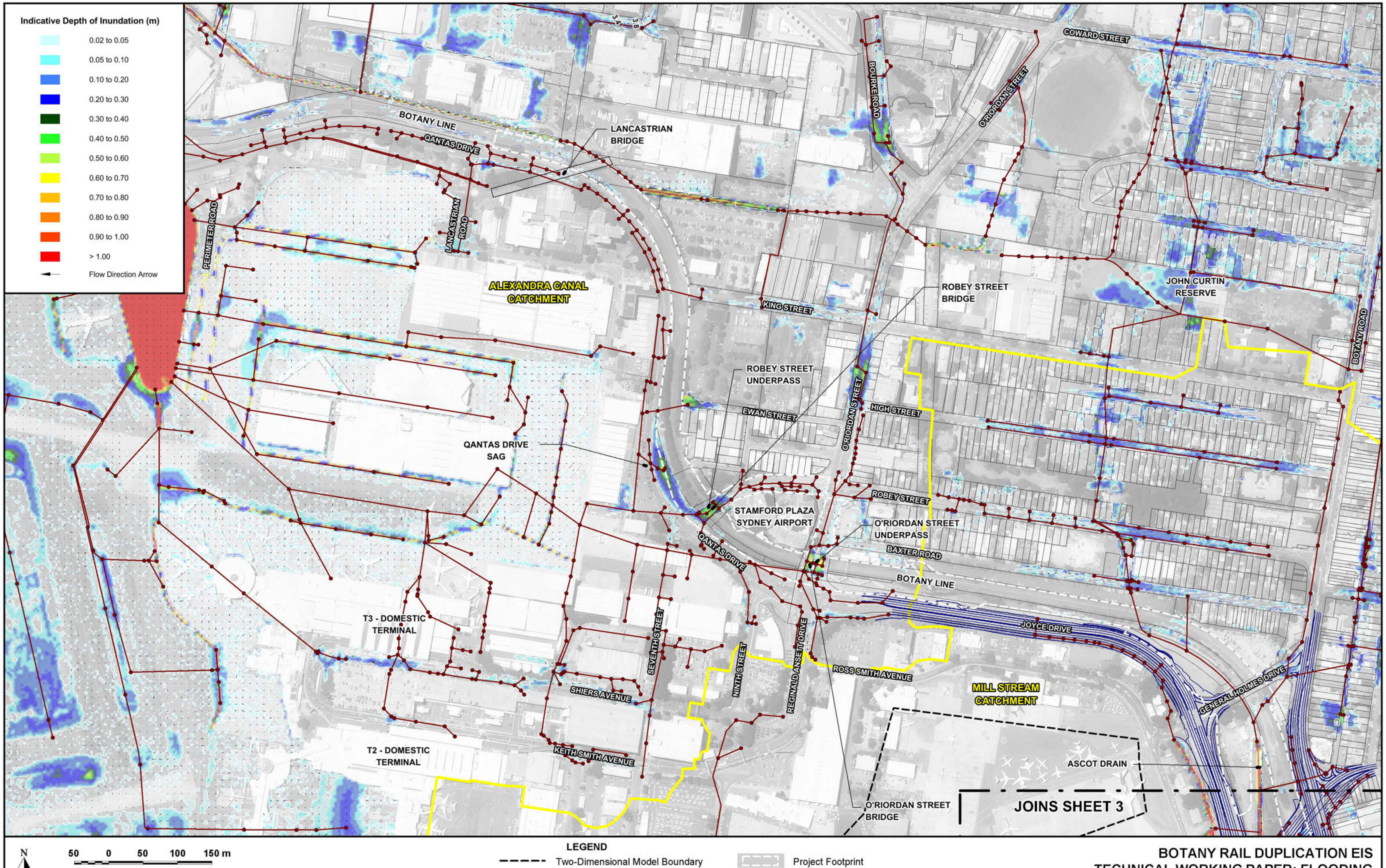
Figure B.1
(Sheet 1 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 50% AEP EVENT



Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 14.2 Water Surface Elevation Contours

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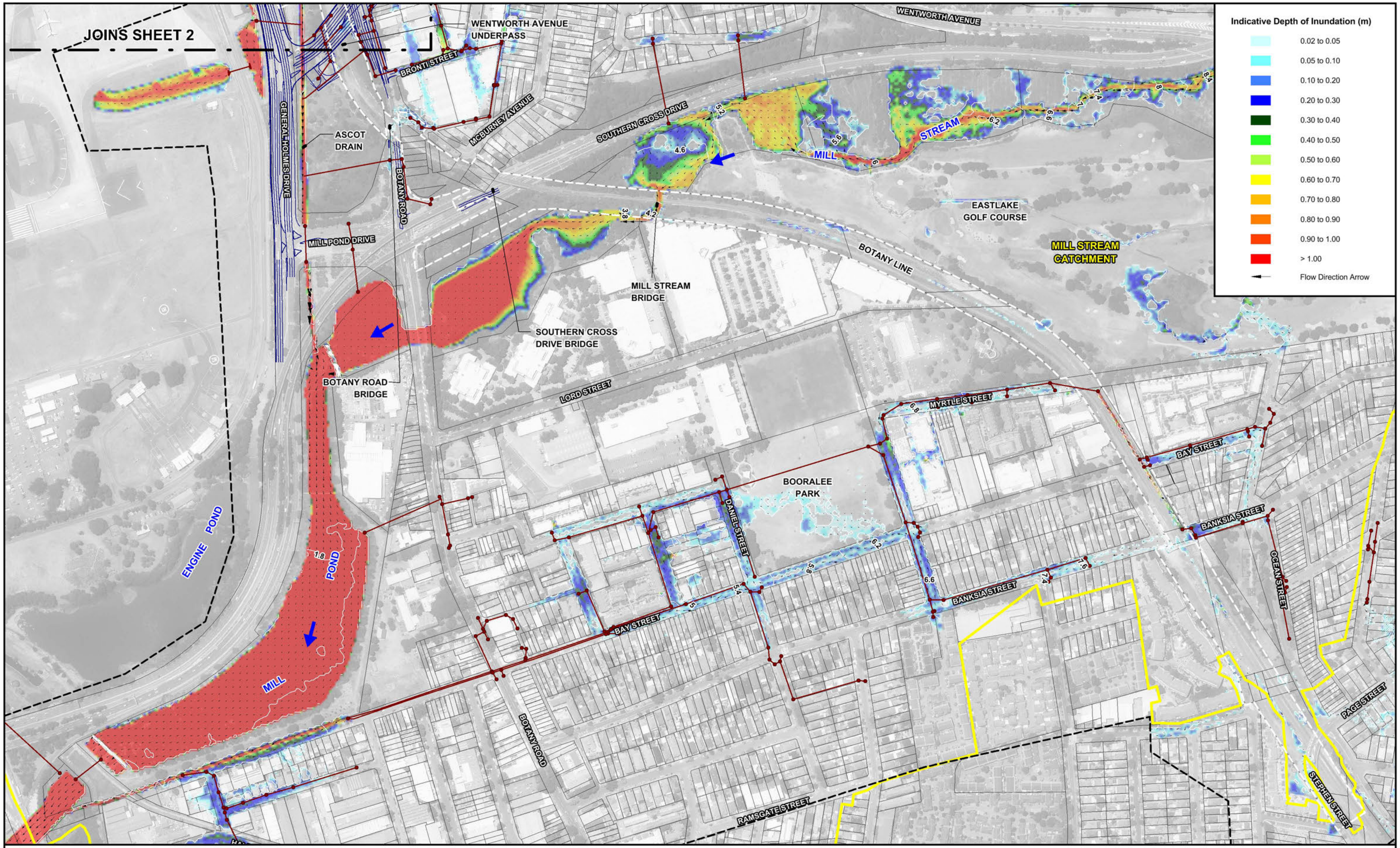
BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 2 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 50% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

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Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

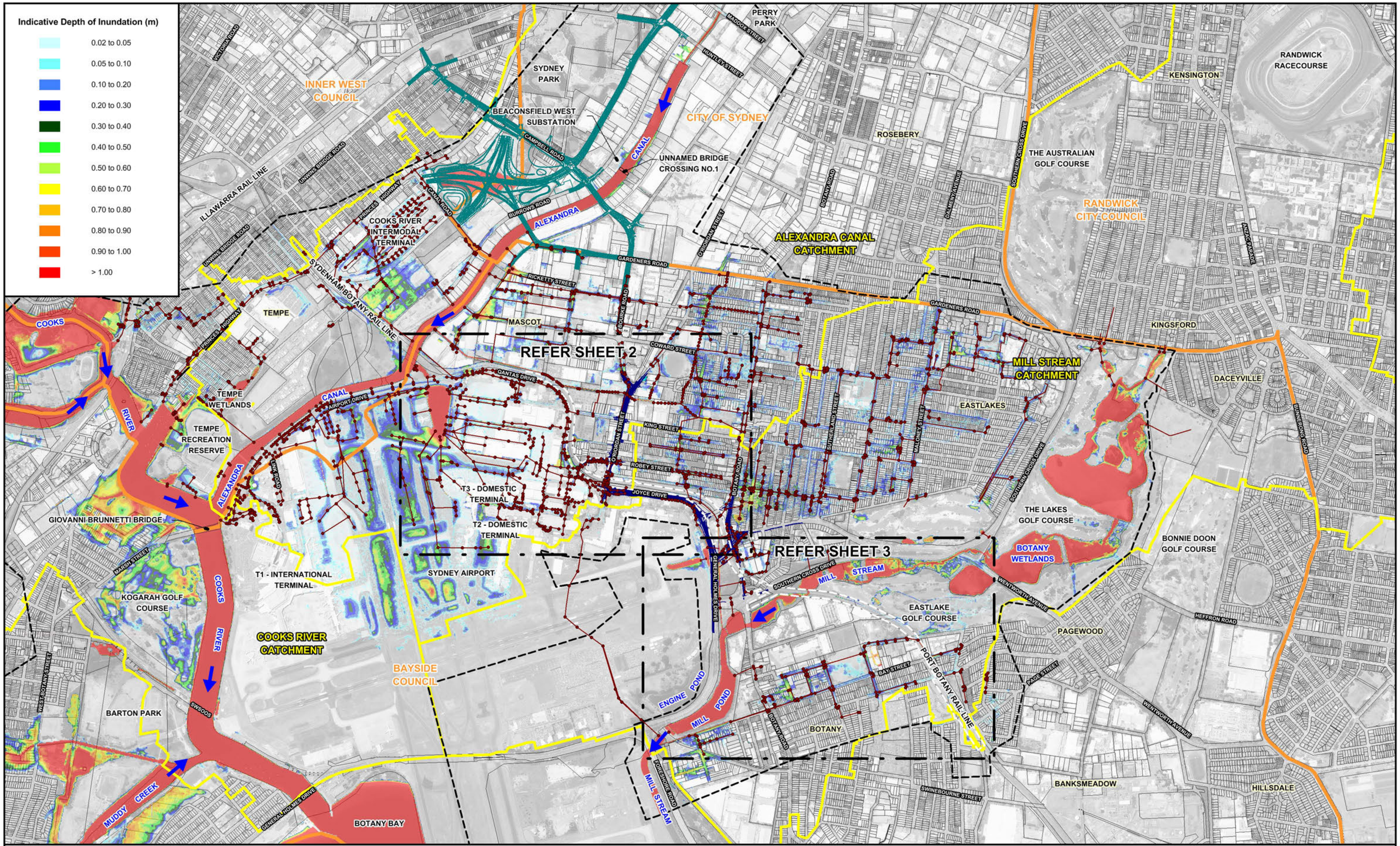
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 14.2 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 3 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 50% AEP EVENT



200 0 200 400 600 m

Scale: 1:20,000

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

LEGEND
- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

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BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 1 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 5% AEP EVENT

50 0 50 100 150 m

Scale: 1:5,000

Note:

The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

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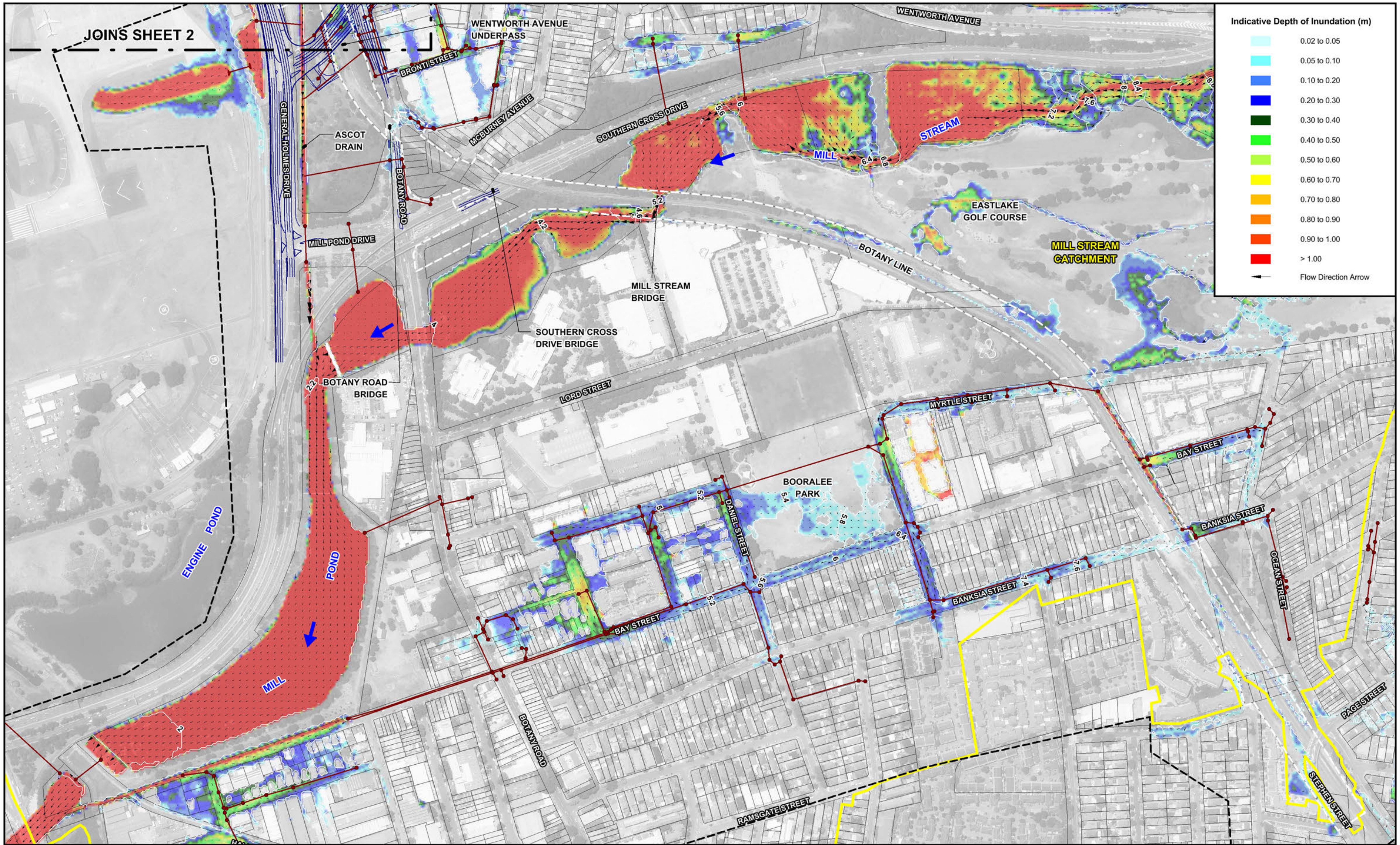
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 2.6 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 2 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 5% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Note:
The ground surface model incorporated in TUFLOW is based on LiDAR survey which has been sampled on a 2m (min.) grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.

Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

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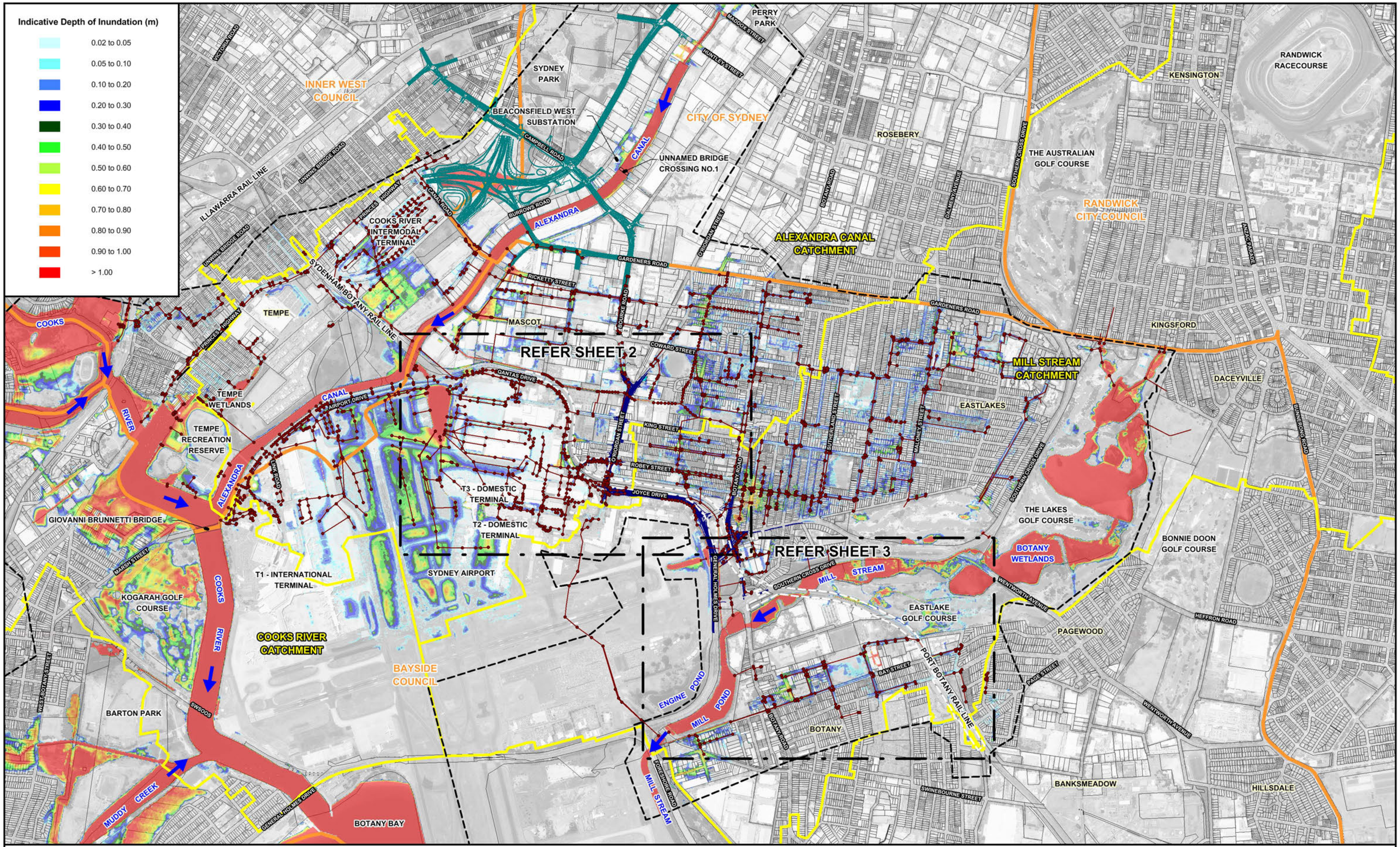
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 2.6 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 3 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 5% AEP EVENT



N

200 0 200 400 600 m

Scale: 1:20,000

Note:

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Lyall & Associates

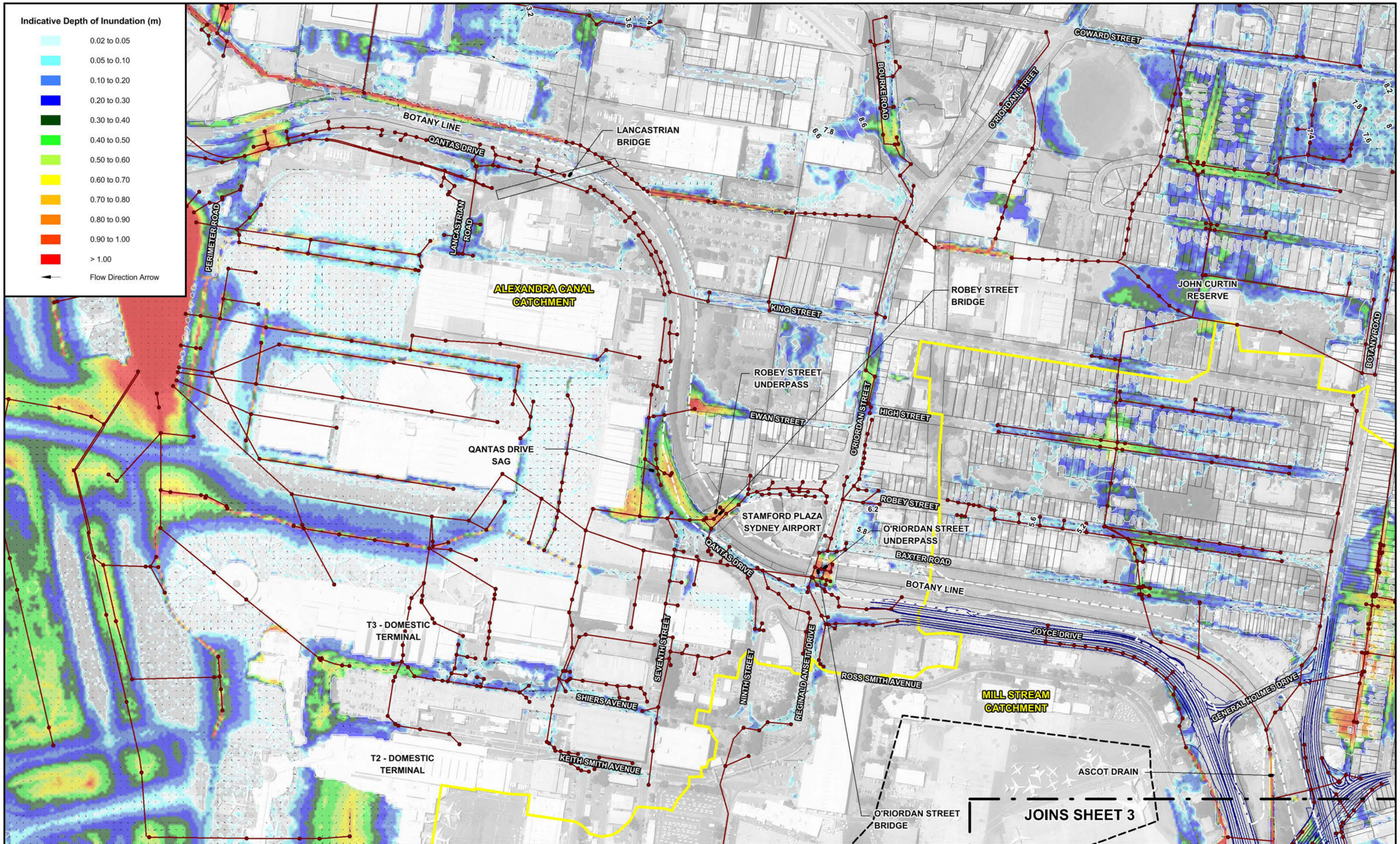
LEGEND

- Two-Dimensional Model Boundary
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 1 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 2% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

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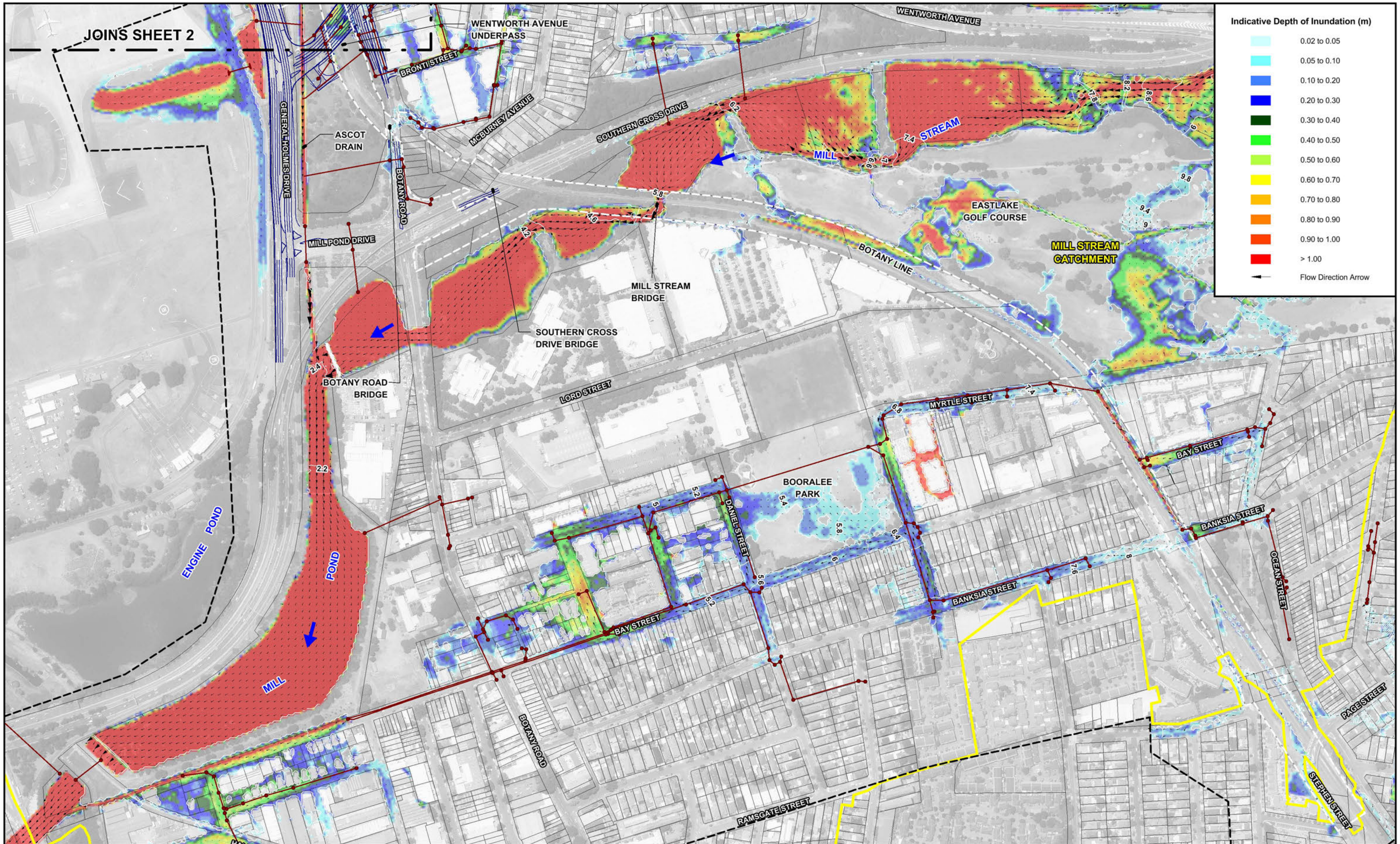
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 2.6 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 2 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 2% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

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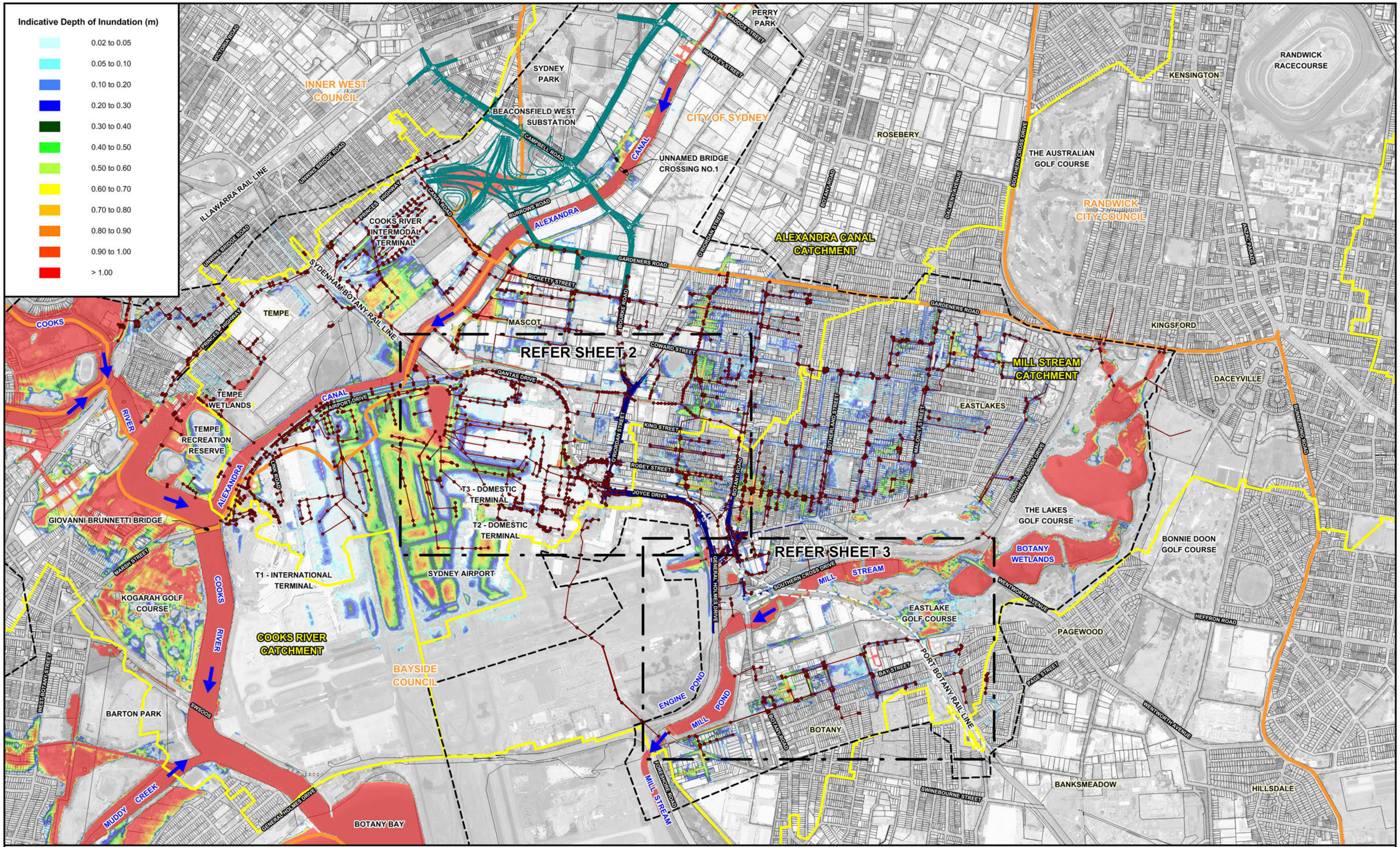
BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 3 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 2% AEP EVENT



N

200 0 200 400 600 m

Scale: 1:20,000

Note:

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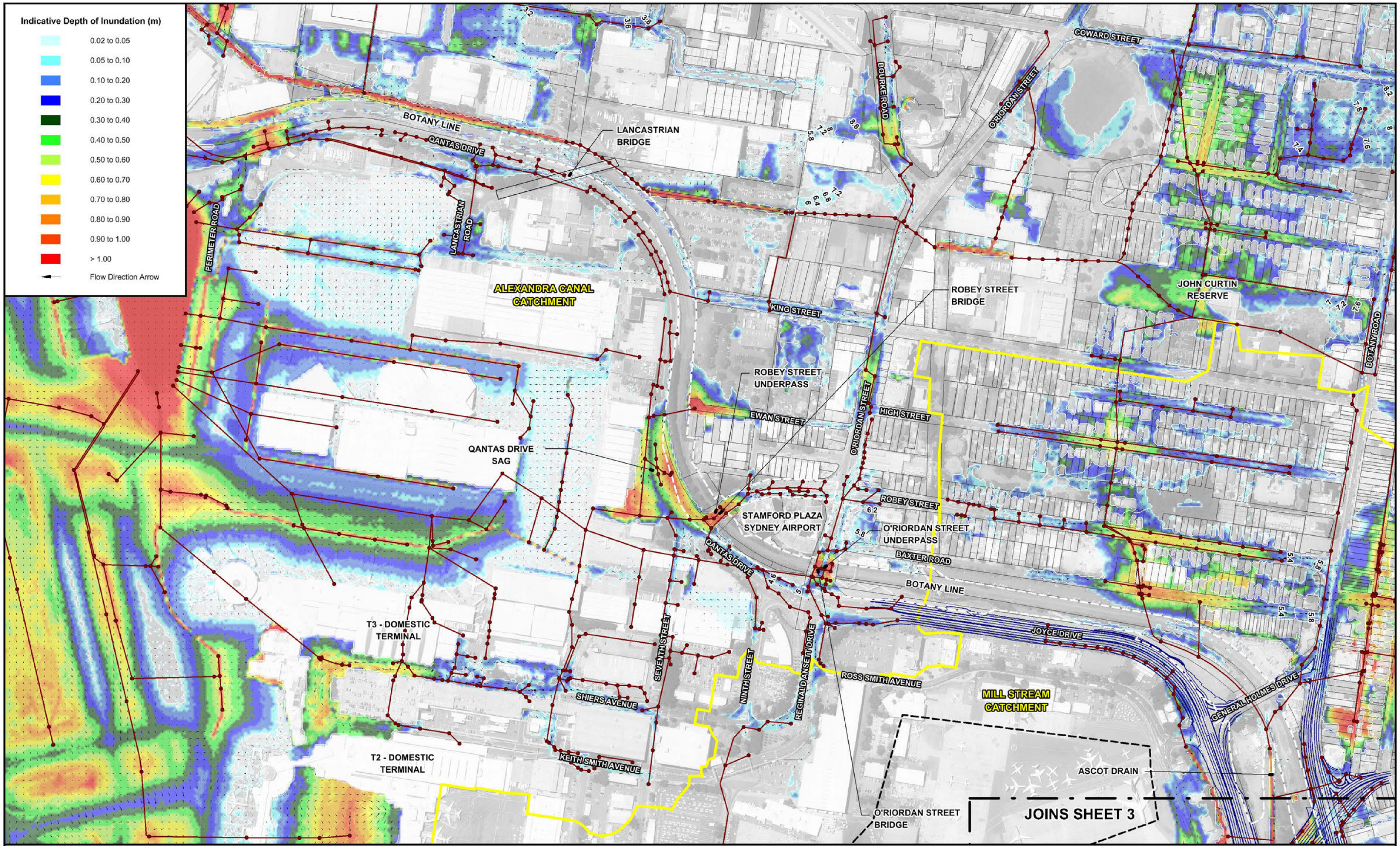
BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 1 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 0.5% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

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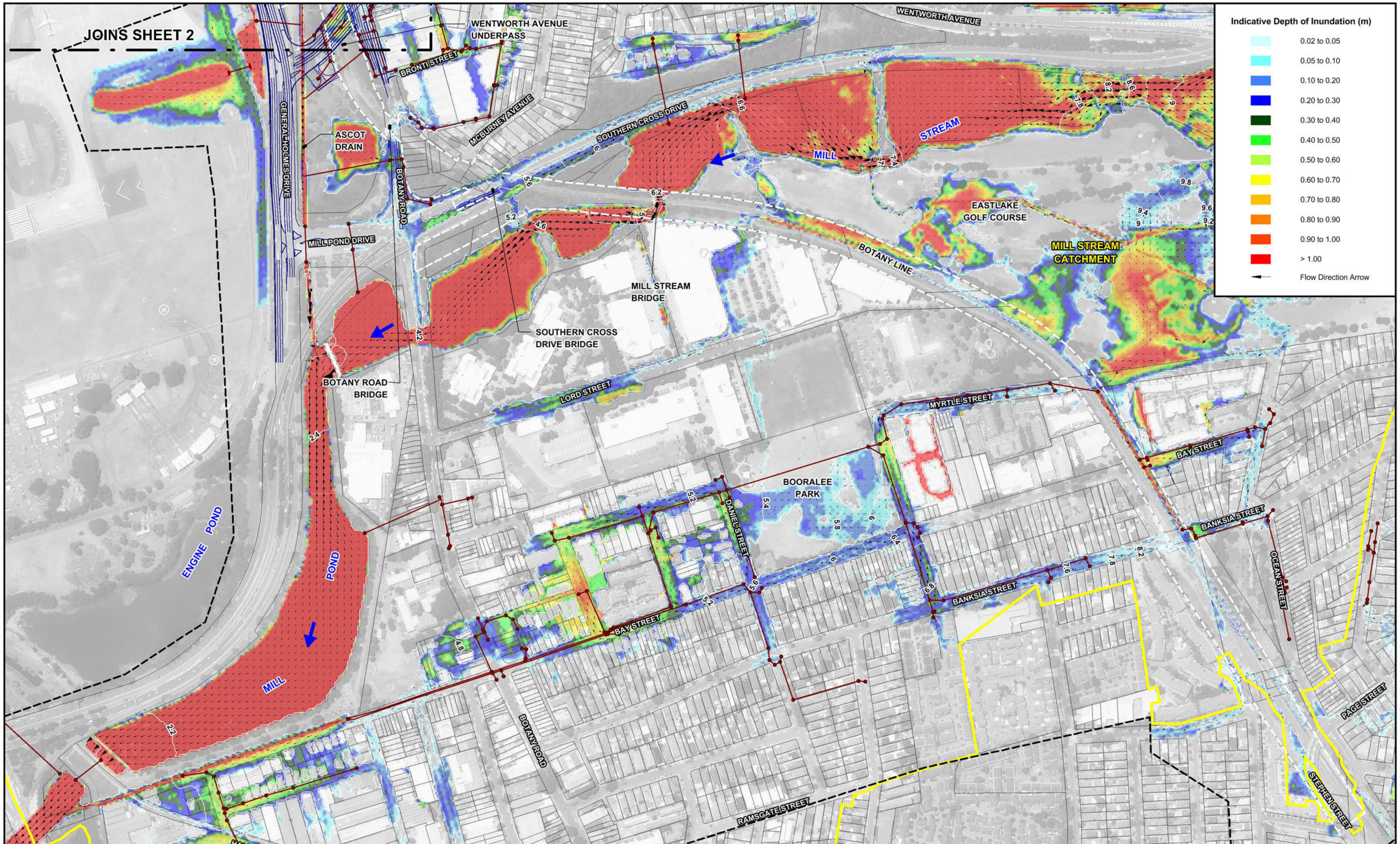
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 2.6 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 2 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 0.5% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Note:

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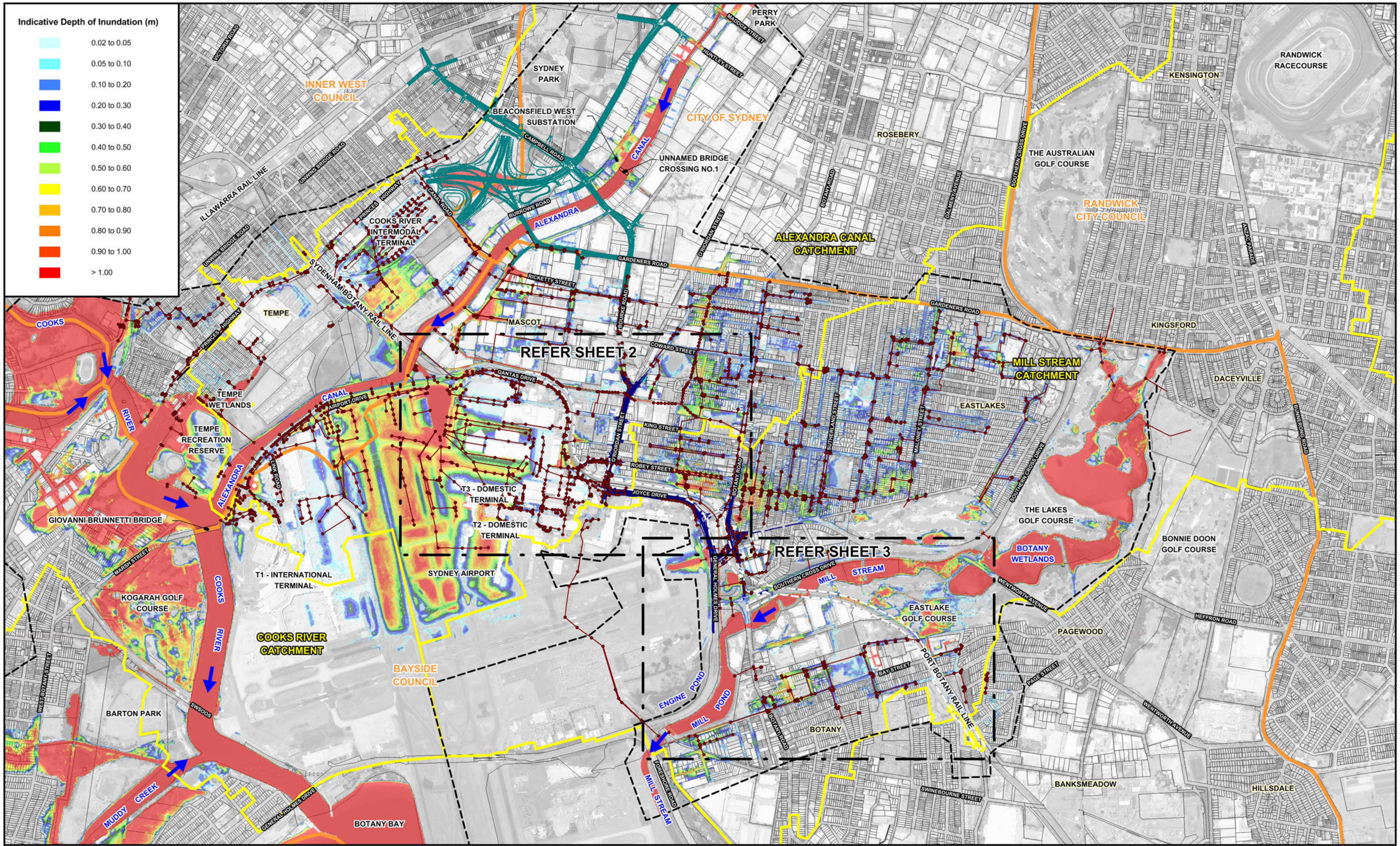
LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
- Existing Drainage System
- Project Footprint
- Airport North and Airport East Road Works
- 2.6 Water Surface Elevation Contours

BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 3 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 0.5% AEP EVENT



N

200 0 200 400 600 m

Scale: 1:20,000

Note:

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LEGEND

- Two-Dimensional Model Boundary
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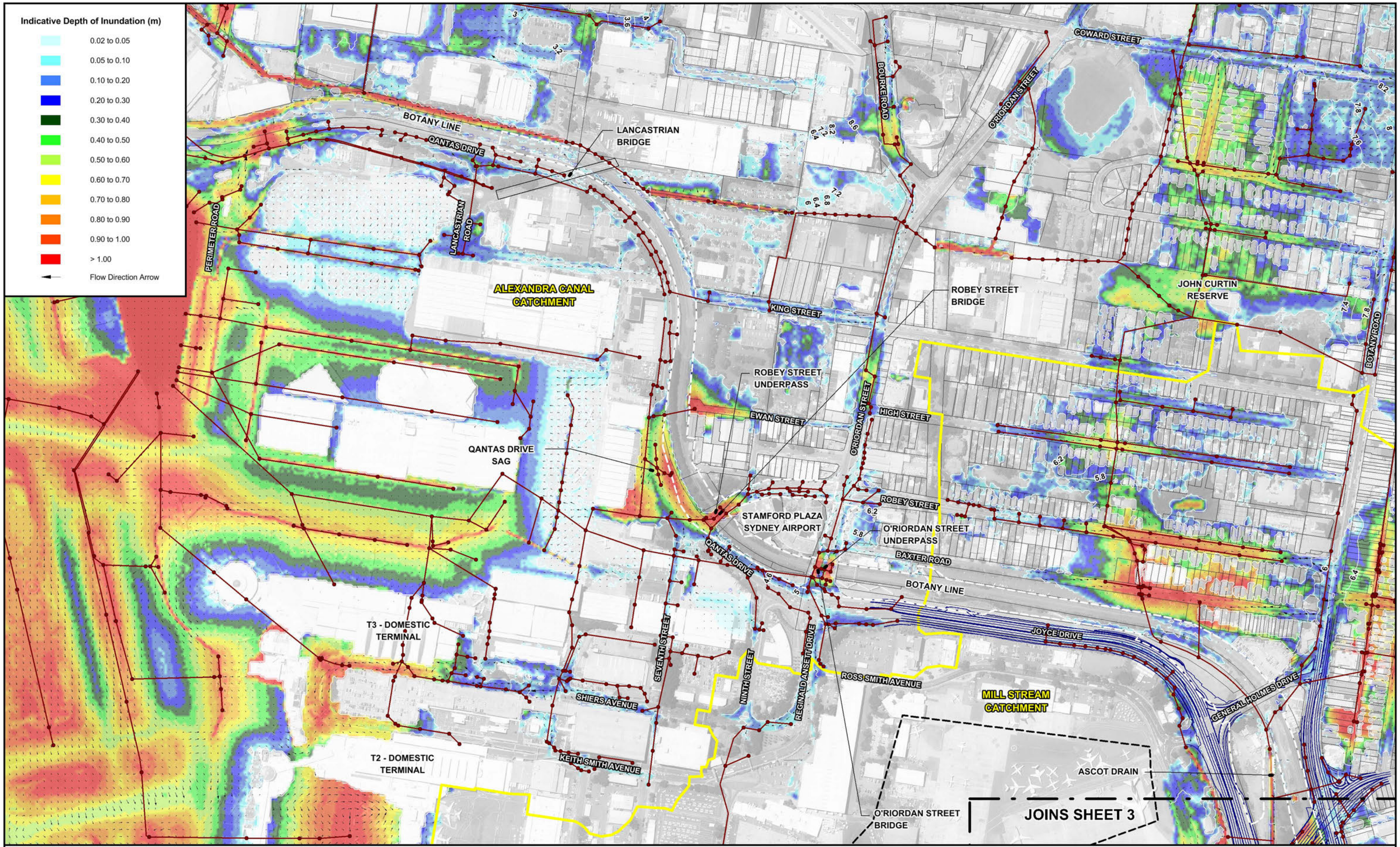
BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 1 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 0.2% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

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LEGEND

- Two-Dimensional Model Boundary
- Catchment Boundary
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- Water Surface Elevation Contours

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BOTANY RAIL DUPLICATION EIS
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 2 of 3)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 0.2% AEP EVENT