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 relied upon for the present investigation were originally developed as part of a series of flooding investigations that were undertaken for the New M5 Motorway 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 (**Cooks River RAFTS Model**) and a DRAINS model of the Alexandra Canal catchment (**Alexandra Canal DRAINS Model**). The hydraulic model was developed using the TUFLOW software (**Cooks River TUFLOW Model**).

This annexure also includes a comparison of the results of the present investigation with those of previous studies as well as those derived using the procedures set out in ARR 2016.

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 A1** shows the sub-catchments which comprised the Cooks River RAFTS Model.

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 processes 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 kilometres 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 A2.2**). 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 are shown in **Table A2.1**.

TABLE A2.1
COOKS RIVER RAFTS MODEL - DESIGN LOSS VALUES

Type of Surface	Initial Loss (mm)	Continuing Loss (mm/h)
Pervious Areas	10	2.5
Impervious Areas	2	0

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 A2**). 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 A2.2**). After consideration a velocity of two metres per second was adopted for design.

A2.4 Design discharge hydrographs

Figure A3 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 A2.2 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 Corporation (SWC) 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 A2.2**, 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.

TABLE A2.2
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 (SWC 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 DRAINS MODEL

A3.1 Background to Hydrologic Model Development

As part of a series of flooding investigations for the New M5 Motorway and associated projects it was necessary to develop an understanding of the magnitude of flow in Sheas Creek (the major contributor to flow in Alexandra Canal), as well as the minor lateral drainage lines which discharge to the canal along its length. Rather than further sub-divide the Cooks River RAFTS Model, a separate DRAINS model was developed of the catchments which contribute flow to Alexandra Canal.

For the purpose of the present investigation the Alexandra Canal DRAINS Model was updated in order to provide inflow hydrographs to the Lower Cooks River TUFLOW Model, which was extended in order to more accurately define the depth and extent of inundation in the vicinity of the project. The update of the Alexandra Canal DRAINS Model involved the following:

- 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 A4**.
- The sub-catchments that cover the suburbs of Mascot, Rosebery and Eastlakes were revised using details contained in a DRAINS model that was developed as part of the *Mascot, Rosebery and Eastlakes Flood Study* (WMAwater 2015) for the City of Botany Bay (now part of Bayside Council). The sub-catchments that were revised are denoted "**Mascot, Rosebery and Eastlakes sub-catchments**" on **Figure A4**.
- 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 A4**.

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 DRAINS Model Parameters

Table A3.1 provides a summary of the adopted loss parameters for the various sub-catchments that comprise the Alexandra Canal 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 were based on those contained in the DRAINS model 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.

A3.4 Design Discharge Hydrographs

Figure A3 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.

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

A4. LOWER COOKS RIVER TUFLOW MODEL

A4.1 Background to Hydraulic Model Development

The hydraulic model relied upon for the present investigation was originally developed as part of a series of flooding investigations that were undertaken for the WestConnex New M5 (New M5) and associated projects (LA 2015). For the purpose of the present investigation the following changes were made to the structure of the Lower Cooks River TUFLOW Model to include details of recent projects and to improve the definition of flooding behaviour in the vicinity of the project:

- Details of a new bridge which has recently been constructed across Alexandra Canal downstream of the Port Botany Rail Line were incorporated in the Lower Cooks River TUFLOW Model using detailed design drawings and models obtained during the preparation of LA 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 A5** 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 provided by Marrickville Council (now part of Inner West Council).

- The model was extended to include the portion of the catchment that covers the suburbs of Mascot, Rosebery and Eastlakes using details contained in a TUFLOW model that was originally developed as part of the *Mascot, Rosebery and Eastlakes Flood Study* (WMAwater 2015) for the City of Botany Bay (now part of Bayside Council). This detail was added to the model in order to more accurately define the depth and extent of inundation in the vicinity of Qantas Drive and the area along the eastern bank of Alexandra Canal upstream of the Port Botany Rail Line. **Figure A.5** shows the layout and extent of the updated 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.

- 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.

- 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 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.

A4.2 Sources of Topographic Data

Figure A.5 shows the various sources of topographic data available to construct the Lower Cooks River 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-WMH Joint Venture study of Cooks River catchment in 2009 (SWC, 2009)
- A hydrographic survey of the lower reaches of Cooks River and Alexandra Canal; provided by Roads and Maritime
- 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 project corridor and its immediate vicinity. 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 Lower Cooks TUFLOW Model is shown on **Figure A.5**. Both the floodplain and stream beds of 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 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.

Earlier versions of the Lower Cooks River TUFLOW Model incorporated a five metre grid. However, later studies required a nested grid to be developed which covered Alexandra Canal. The latest version of the model comprises a two metre grid which covers areas that are affected by flooding along Alexandra Canal and a six metre grid which covers the remainder of the two-dimensional model domain. 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 Upstream Boundary

Discharge hydrographs generated by the Cooks River RAFTS Model were applied at the external TUFLOW model boundary while discharge hydrographs generated by the Alexandra Canal DRAINS Model were applied as both external TUFLOW model boundary and internal point source and region inflows. The location of inflow boundaries are shown on **Figure A.5**.

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 *Flood Risk Management Guideline: Modelling the Interaction of Catchment Flooding and Oceanic Inundation in Coastal Waterways* (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. The impact of the project on flooding behaviour in Alexandra Canal under scenario iii) has also been assessed in order to determine the extent of impacts in the absence of an elevated tailwater.

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[4]	PMF	1% AEP storm tide [1.70 m AHD]

Notes:

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 mm 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 hydraulic roughness values adopted for design purposes.

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
River bed	0.025
Well Maintained Grassed Cover e.g. sporting oval	0.03
Grass or Lawns	0.045
Macrophytes (river bank)	0.06
Trees	0.08
Fenced Properties	1.0
Buildings	10

A4.5 Sensitivity analyses

A4.5.1 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 (refer **Table A4.3**) on flood behaviour during a 1% AEP event. The assessment found that peak 1% AEP flood levels are generally increased in the range 0.05 to 0.1 metres along Alexandra Canal.

A4.5.2 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 6.2.4** of this report.

A4.5.3 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 6.2.3** of this report.

A4.6. Comparison with results using ARR 2016

A4.6.1 General

As noted in **Section A3,** the Alexandra Canal DRAINS model used to generated inflow hydrographs to the TUFLOW model within the Alexandra Canal catchment was based on design storms that were derived using the procedures set out in ARR 1987. While an update of ARR was released in 2016 (i.e. ARR 2016) the document is currently in 'draft for industry consultation'.

Given the potentially imminent release of a final revision of ARR 2016, a comparison has been made with ARR 1987 in order to assess potential changes to flood behaviour in the vicinity of the project.

A4.6.2 Assessment Approach

Separate DRAINS models were developed using the procedures in ARR 1987 and ARR 2016 in order to generate discharge hydrographs which were then applied as inflows to the 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 2016. 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 2016. **Table A4.4** over the page shows that ARR 1987 design rainfall depths are 23 per cent higher than corresponding ARR 2016 values for a storm duration of 120 minutes, which is also similar to the differences in rainfall depths for other durations between 30 and 180 minutes.
2. The design rainfalls were then converted into rainfall hyetographs using the temporal patterns presented in ARR 1987 and ARR 2016. While ARR 1987 prescribes a single temporal pattern for each storm duration, ARR 2016 requires an analysis of 10 temporal patterns for each storm duration. The application of these ten temporal patterns to the Lower Cooks River TUFLOW Model is discussed further under Task 4.

3. While ARR 2016 recommends the use of a new urban loss model, clear guidance on the application of the new model is relatively limited, while the paper entitled *Applying ARR 2016 to Stormwater Drainage Design* (Kus et al 2018) has identified 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 2016. 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 use of 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 2016.
4. The Lower Cooks River 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 2016 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 2016 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 2016	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.

A4.6.3 Summary of Key Findings

Figure A.6 (4 sheets) shows the impact that the application of ARR 2016 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 2016 design storms would result in a reduction in peak flood levels by a maximum of 0.1 metre along the section of Alexandra Canal to the south (downstream) of Coward Street; Airport Drive where it runs between Arrivals Court and Qantas Drive; and the northwestern portion of Sydney Airport. Larger reductions in peak flood levels, typically by a maximum of 0.2 metres would occur in the northeastern portion of Sydney Airport; Qantas Drive at the Robey Street intersection; and an area of land to the east of the Cooks River Intermodal Terminal.

A4.7 Comparison with Results of Previous Studies

Table A4.5 over the page compares peak 1% AEP flood levels derived using the Lower Cooks River TUFLOW Model that was used for the present investigation with results presented in the *Sydney Airport Flood Study* (AECOM 2018), the *Cooks River Flood Study* (Sydney Water 2009) and the *Hydrology Model Development Report – Cooks River Flood Modelling* (Aurecon Jacobs Joint Venture (AJJV), 2016).

Comparison of the results from the Lower Cooks River TUFLOW Model with the previous studies shows that:

- Peak flood levels along the Cooks River (refer Locations L01 to L03 shown on **Figure A.5**) and Alexandra Canal (Locations L04 and L05) are typically within 0.1 to 0.2 metres of the results presented in AECOM 2018. The greatest difference occurs on the Cooks River at the Princes Highway where the peak flood level in Table 13 of AECOM 2018 is 0.3 metres higher than the corresponding result from the Lower Cooks River TUFLOW Model. This is likely to be attributable to the upstream boundary in the AECOM, 2018 flood model being located at the Princes Highway, which would affect the modelled flood behaviour at this location.
- Peak flood levels along the eastern overbank of Alexandra Canal (Locations L07 to L09) are within 0.1 to 0.2 metres of the results presented in AECOM 2018.
- The peak flood level in Sydney Airport at the northern pond (2.05 m AHD) matches closely with the peak flood level presented in AECOM 2018 (2.0 m AHD).
- The peak flood level at the western end of Ewan Street (Location L10) is 0.5 metres lower than the result presented in AECOM 2018, which 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 L11) 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.
- Both the Lower Cooks River TUFLOW Model and AECOM 2018 produce peak flood levels on the Cooks River at Marsh Street (Location L02), as well as the lower reach of Alexandra Canal (Location L05) that are higher than the corresponding results from SW, 2009. This is likely to be attributable to the approach adopted to model the main channel of the Cooks River. While a two-dimensional modelling approach was adopted in the Lower Cooks River 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 Marsh Street.

The peak flood level at the downstream end of the Cooks River (Location L01) is within 0.1 metres of the results presented in both AECOM 2018 and SW 2009 which indicates that the adopted boundary conditions within each study has only a minor impact on peak flood levels.

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

Location		Lower Cooks River TUFLOW Model(2)	AECOM 2018(3,4)	SW 2009(4)
I.D.(1)	Description			
L01	Cooks River at General Holmes Drive	1.8	1.7 *[-0.1]*	1.8 *[0.0]*
L02	Cooks River at Marsh Street	2.3	2.1 *[-0.2]*	2.0 *[-0.3]*
L03	Cooks River at Princes Highway	3.0	3.3 *[0.3]*	2.2 *[-0.8]*
L04	Alexandra Canal at Canal Road	2.6	2.5 *[-0.1]*	2.7 *[0.1]*
L05	Alexandra Canal at Nigel Love Bridge	2.5	2.5 *[0.0]*	2.2 *[-0.3]*
L06	Sydney Airport at Northern Pond	2.05	2.0 *[-0.05]*	Not reported
L07	Coward Street, southern overbank of Alexandra Canal	2.5	2.4 *[-0.1]*	2.2 *[-0.3]*
L08	Ricketty Street, southern overbank of Alexandra Canal	2.6	2.4 *[-0.2]*	2.5 *[-0.1]*
L09	Gardeners Road, southern overbank of Alexandra Canal	3.3	3.2 *[-0.1]*	2.7 *[-0.6]*
L10	Ewan Street, north of Port Botany Rail Line	5.1	5.6 *[0.5]*	Not reported
L11	O'Riordan Street Underpass at the Port Botany Rail Line	5.1	5.2 *[0.1]*	Not reported

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

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

(3) Peak flood levels are taken from Table 13 of AECOM 2018 with the exception of Location L06 which was taken from Table 17 of AECOM 2018.

(4) Values in brackets show the relative difference in peak flood level between the previous study and the Lower Cooks River 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 Lower Cooks River TUFLOW Model.

A4.8 Adjustments made to the structure of the Cooks River TUFLOW Model to reflect construction conditions

The following adjustments were made to the structure of the Cooks River TUFLOW Model in order to undertake a preliminary assessment of the potential impact the construction of the project would have on flooding behaviour:

- **St Peters interchange connection work area (WA1)** - The footprint of the St Peters interchange connection compound (C1) was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow, with the exception of a five to ten metres wide corridor along its western boundary which would be required to construct a drainage channel as part of the operational works.
- **Eastern bridges work area (WA2)** - The footprint of the Eastern bridge compound (C2) was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works (such as site offices, sheds, and workshops, stored materials and fencing around its perimeter).

  The full extent of the proposed earthworks associated with the Terminal links component of the project was incorporated into the flood model in order to reflect a likely worst case scenario for construction staging. The proposed transverse drainage structures and drainage channels were also included on the basis that these flood mitigation works would need to be installed prior to the construction of the raised roadway.
- **Western bridges work area (WA3)** - The full extent of the proposed earthworks associated with the Terminal 1 connection to the north of Alexandra Canal was incorporated into the flood model in order to reflect a likely worst case scenario for construction staging.
- **Qantas Drive work area (WA4)** - The footprint of the Qantas Drive compound (C4) was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works (such as site offices, sheds and stored materials).

  The footprint of the section of Qantas Drive bridge compound (C8) to the south of Northern pond 2, including the crane pad adjacent to the Qantas Drive bridge, was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works.

  In the flood model a 20 per cent blockage factor was applied to the area below the crane pad adjacent to the terminal link road within Qantas Drive bridge compound (C8) in order to reflect the obstruction to flow caused by the piers to support the steel working platform. It was assumed that the steel working platform would be located above the 1% AEP flood level.

  The full extent of the proposed road works along Qantas Drive was incorporated into the flood model in order to reflect a likely worst case scenario for construction staging. The proposed upgrade to the existing drainage was also included on the basis that these works would need to be installed prior to the proposed road widening to control runoff through the construction site. The modelled arrangement is shown on **Figure 6.1**, sheets 2 and 4.

- **Terminals 2/3 access work area (WA5)** - The full extent of the proposed earthworks associated with the Terminal 2/3 access was incorporated into the flood model in order to reflect a likely worst case scenario for construction staging. The proposed upgrade to the existing drainage was also included on the basis that these works would need to be installed prior to the proposed road works in order to control runoff through the construction site. The modelled arrangement is shown on **Figure 6.1**, sheet 4.
- **Airport drive work area (WA6)** - The footprint of the Terminal 1 connection bridge compound (C6) was nominally raised above the 1% AEP flood level in the flood model in order to represent a complete obstruction to flow and thus represent a worse case of potential flood impacts due to obstructions caused by the site works (such as site offices and sheds).

  The full extent of the proposed earthworks associated with the Terminal 1 access to the south of Alexandra Canal was incorporated into the flood model in order to reflect a likely worst case scenario for construction staging. The proposed upgrade to the existing drainage was also included on the basis that these works would need to be installed prior to the proposed road works in order to control runoff through the construction site. The modelled arrangement is shown on **Figure 6.1**, sheet 3.

A4.9 Adjustments made to the structure of the Cooks River TUFLOW Model to reflect operation conditions

The following adjustments were made to the structure of the Cooks River 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 DRAINS Model representing pre-project conditions was modified by adjusting sub-catchment boundaries based on the layout of the proposed pavement drainage network, 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 Lower Cooks River TUFLOW Model were adjusted using a 3D model of the road, earthworks and active transport facilities that was developed as part of the concept design for the project.
- The superstructures of the proposed Terminal 1 connection bridge, Freight terminal bridge, Qantas Drive bridge and Terminal link bridge were modelled as layered flow constriction shapes to reflect the obstruction that they would have on flow in Alexandra Canal.[1]
- The drainage system in the Lower Cooks River TUFLOW Model was modified to reflect the details of the concept drainage design, which included:
  - a drainage line to control runoff from the Cooks River Intermodal Terminal (the drainage line, which would comprise a series of channels connected by culverts where it crosses the road embankments is denoted **'Flood Relief Channel'** on **Figure 6.1**, sheet 2);

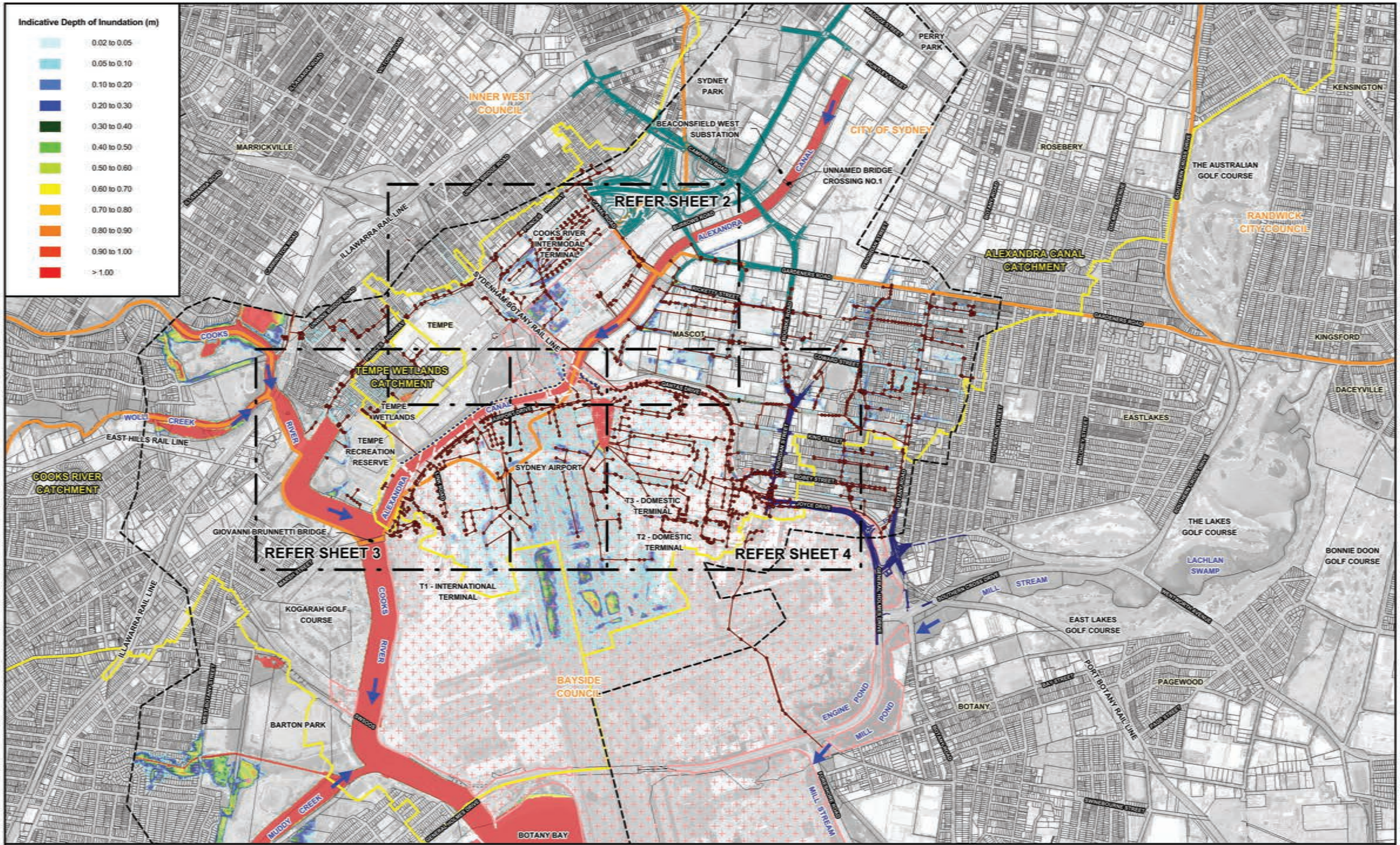
[1] While the superstructures of the four proposed bridges that cross Alexandra Canal were incorporated into the TUFLOW model, it was subsequently found that only the soffit of the bridge superstructure at Terminal link bridge would be submerged during a PMF, whereby the peak flood level would be a maximum of 0.1 m above the soffit of the bridge.

  - a series of drainage channels which would control runoff from the section of new motorway to the south of the Port Botany Rail Line, the outlets of which would be located along the western bank of Alexandra Canal; and
  - a proposed pavement drainage network to control runoff from the upgraded sections of Airport Drive and Qantas Drive.

- An additional drainage structure comprising two off 3000 mm wide by 1500 mm high box culverts was added along the eastern side of the southern approach to Terminal 1 connection bridge in order to offset the removal of floodplain storage caused by the raised road levels in this area.
- An additional transverse drainage structure comprising a single 1050 mm diameter pipe was added to drain the low point on the northern side of Airport Drive – Qantas Drive Link Road, to the west of Alexandra Canal.
- Ground levels along the southern bank of Alexandra Canal were adjusted to reflect the barrier wall that is proposed along the edge of the shared user path where it runs below Qantas Drive bridge and Terminal link bridge.
- A lumped approach was adopted for modelling the pavement drainage network that is proposed for the new sections of motorway to the west of Alexandra Canal, whereby inflows were injected into the Lower Cooks River TUFLOW Model at the outlet of each pavement drainage line. This approach was considered appropriate as unlike Airport Drive and Qantas Drive the pavement drainage systems for the new sections of motorway will be separate from the upstream drainage system.

Table 6.1 and **Figure 6.1** (4 sheets) show the key features of the project which were incorporated in the TUFLOW model representing post-project conditions.

ANNEXURE B
ADDITIONAL FIGURES SHOWING FLOOD MODEL RESULTS



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.

Lyall & Associates

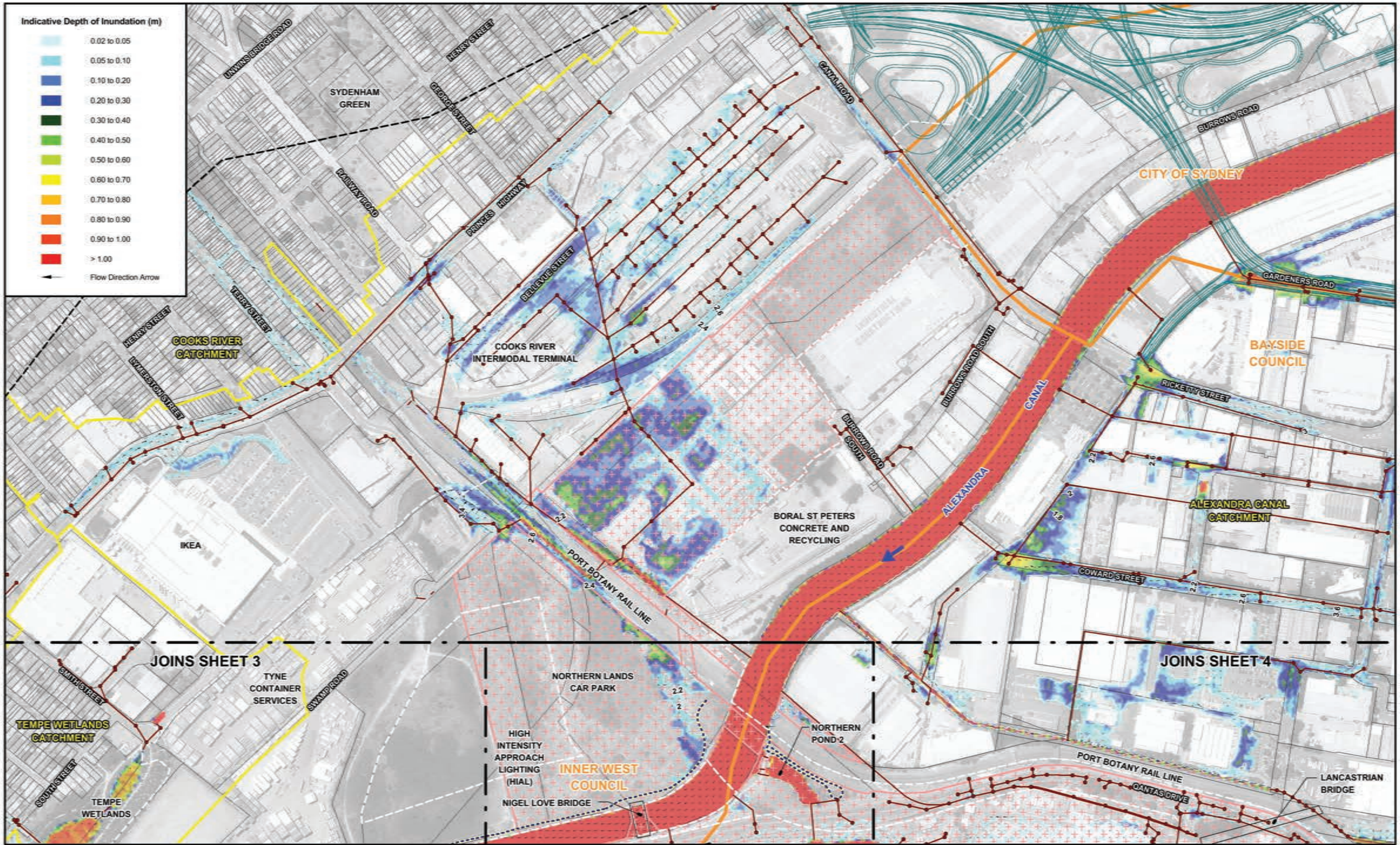
LEGEND

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

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 1 of 4)

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

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.

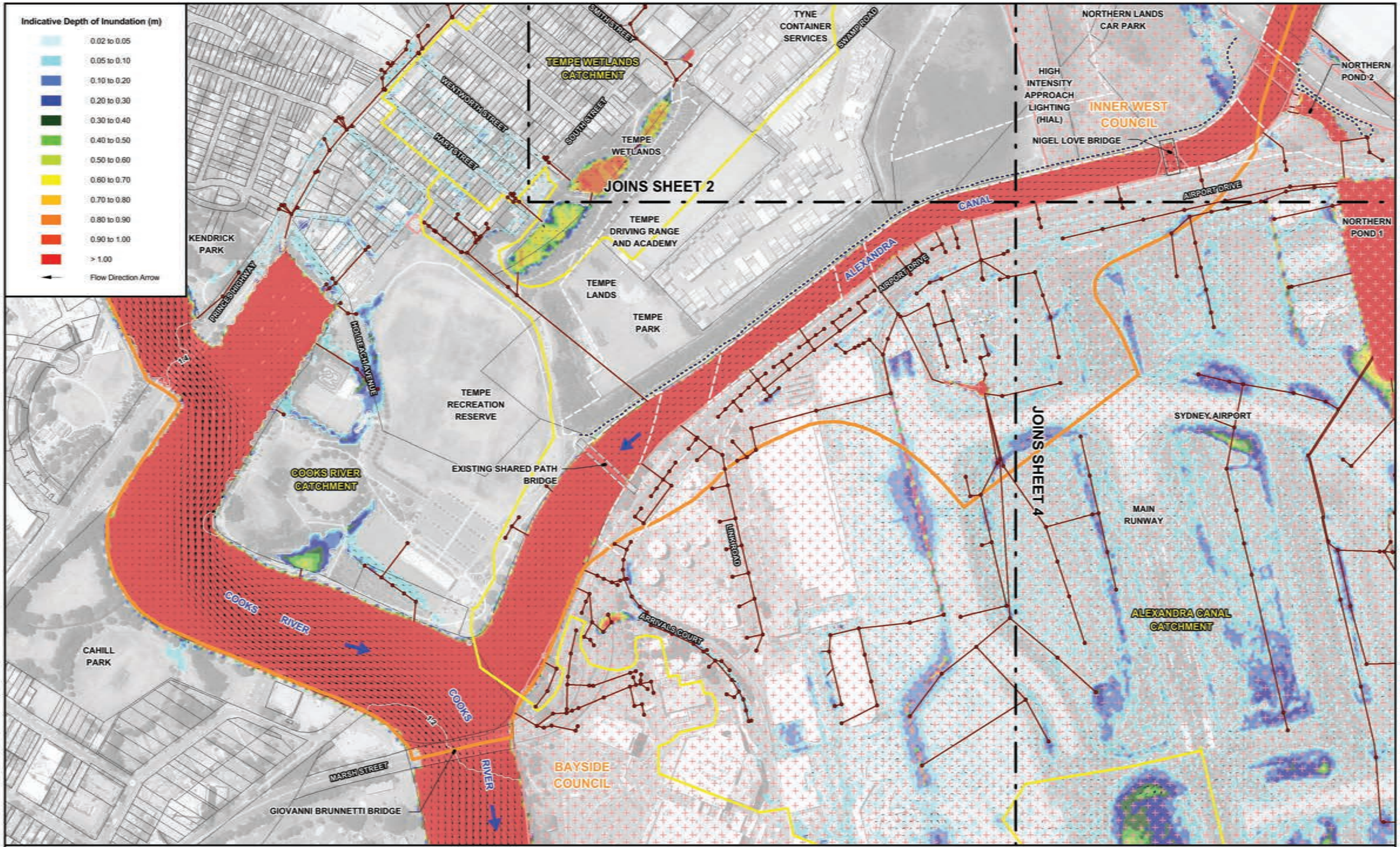
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.4 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 2 of 4)

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

Lyall & Associates

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.

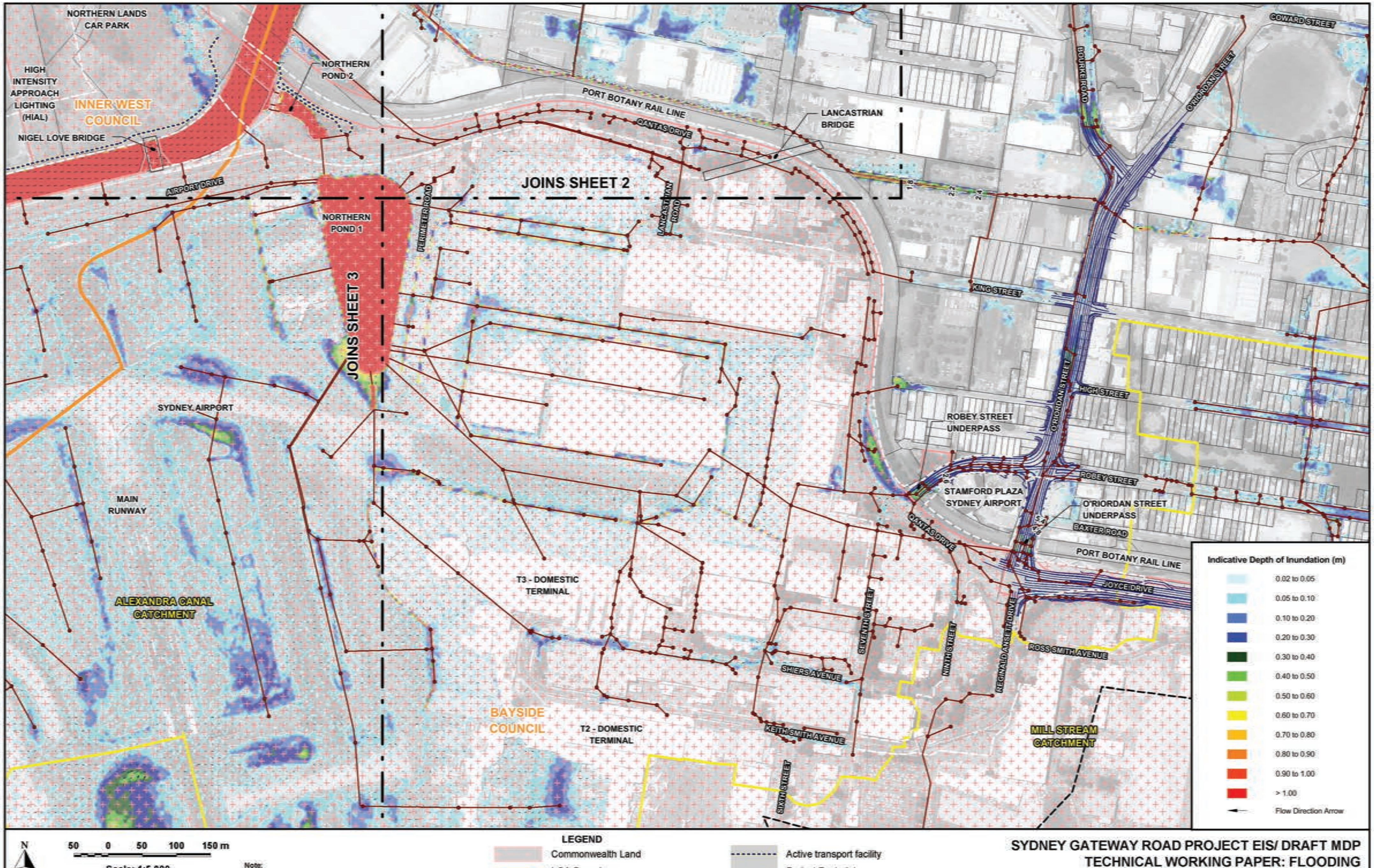
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.4 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 3 of 4)

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.

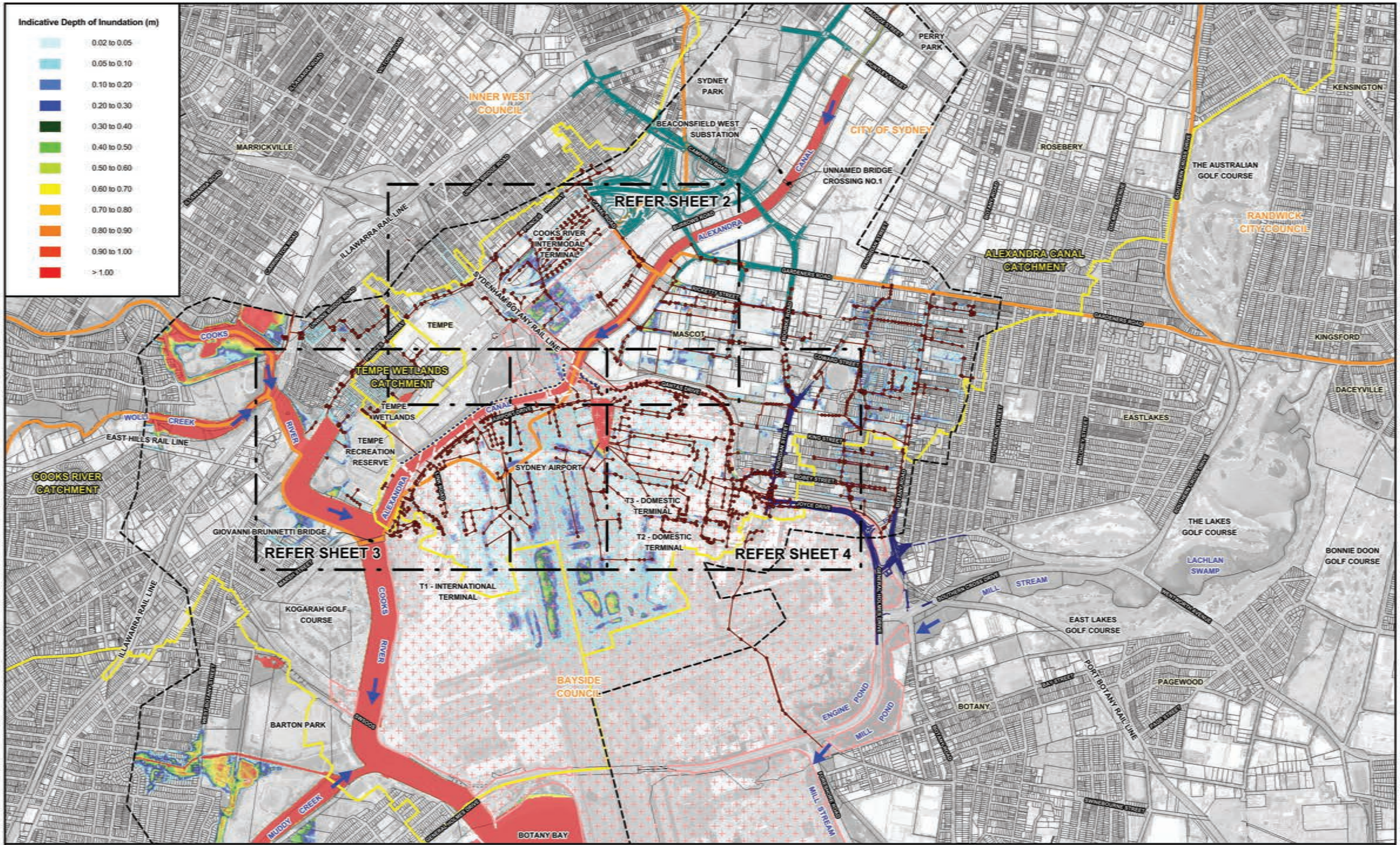
LEGEND
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.1
(Sheet 4 of 4)

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



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.

LEGEND

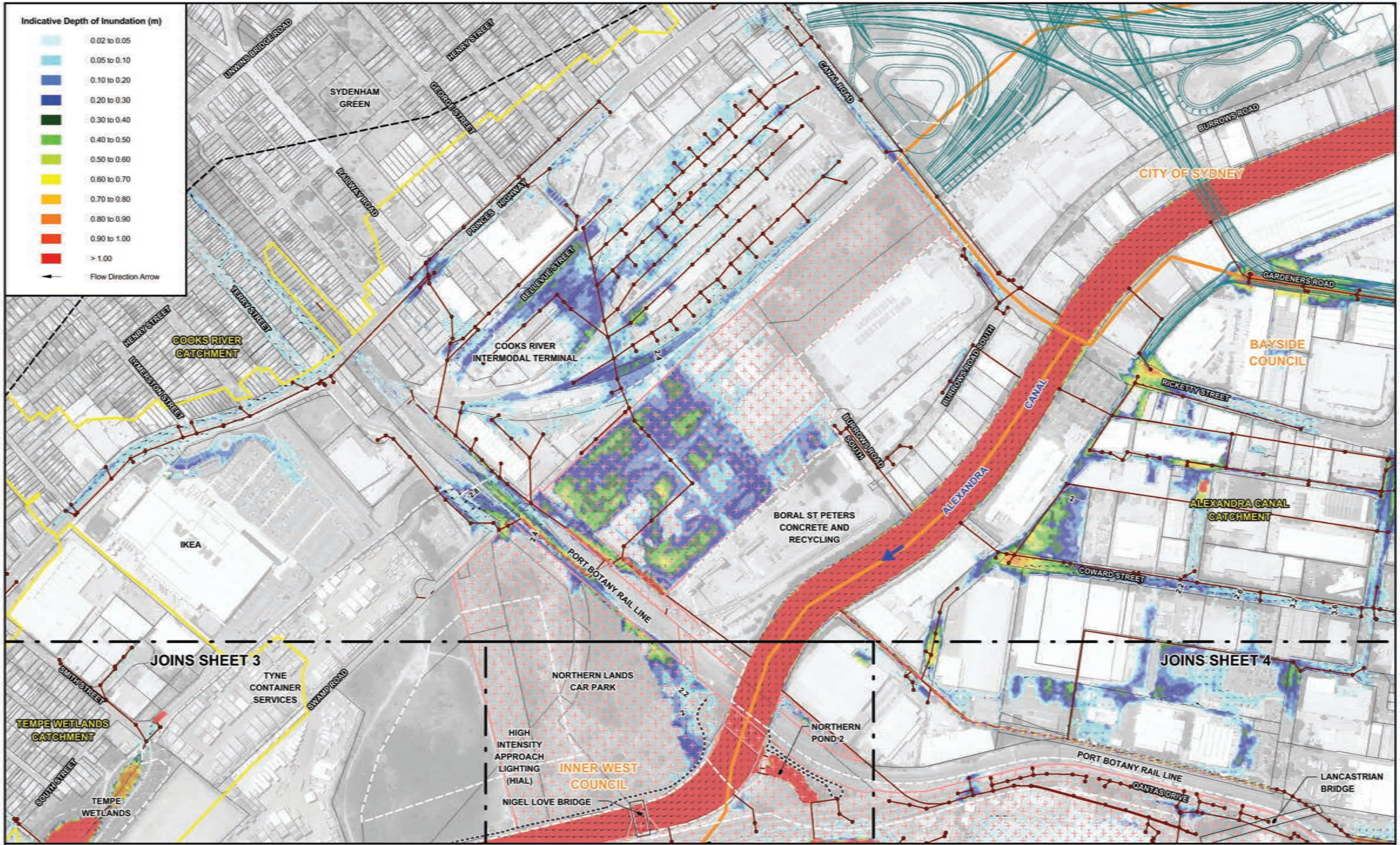
- Two-Dimensional Model Boundary
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 1 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 20% 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.

Lyall & Associates

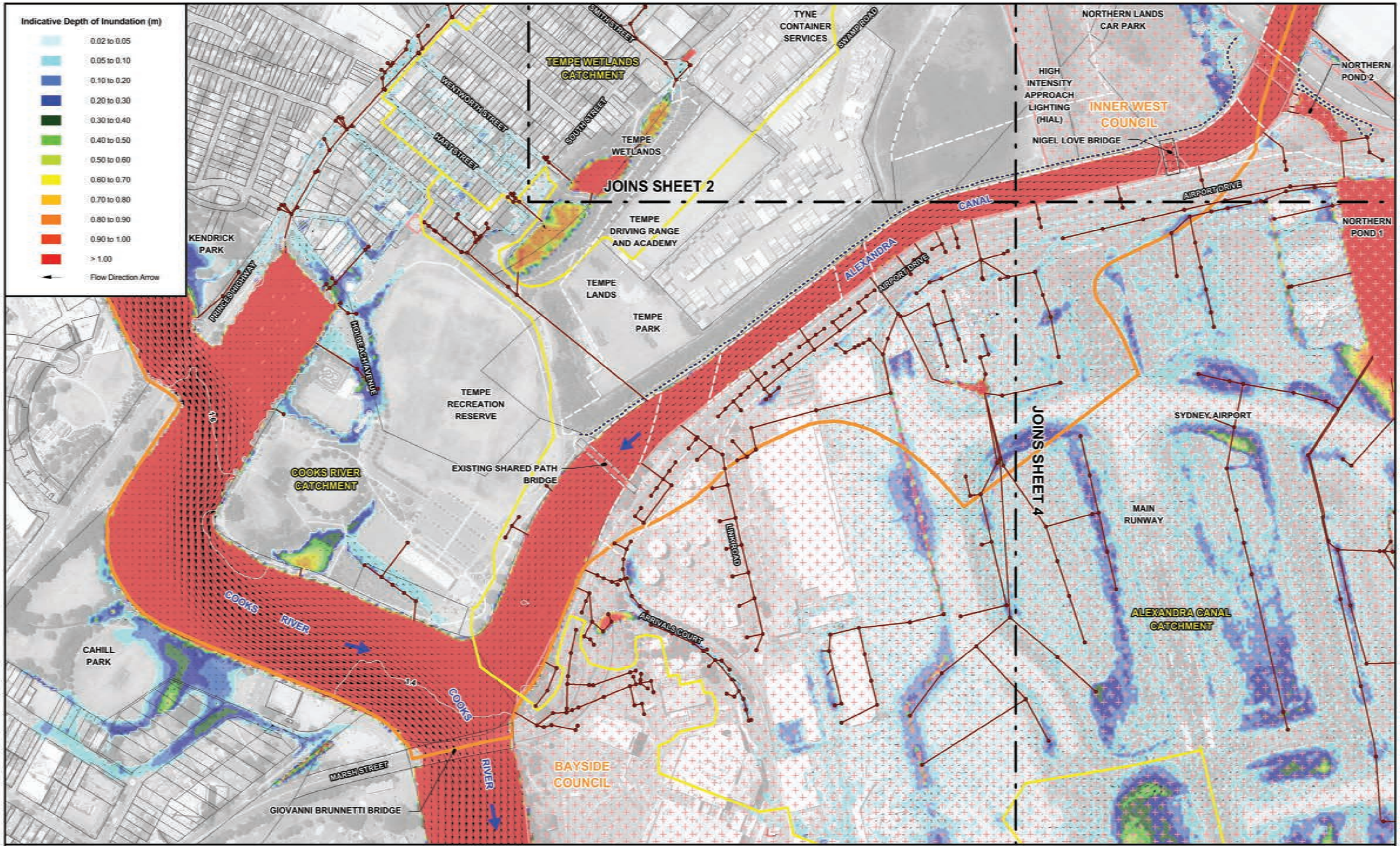
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 2 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 20% 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.

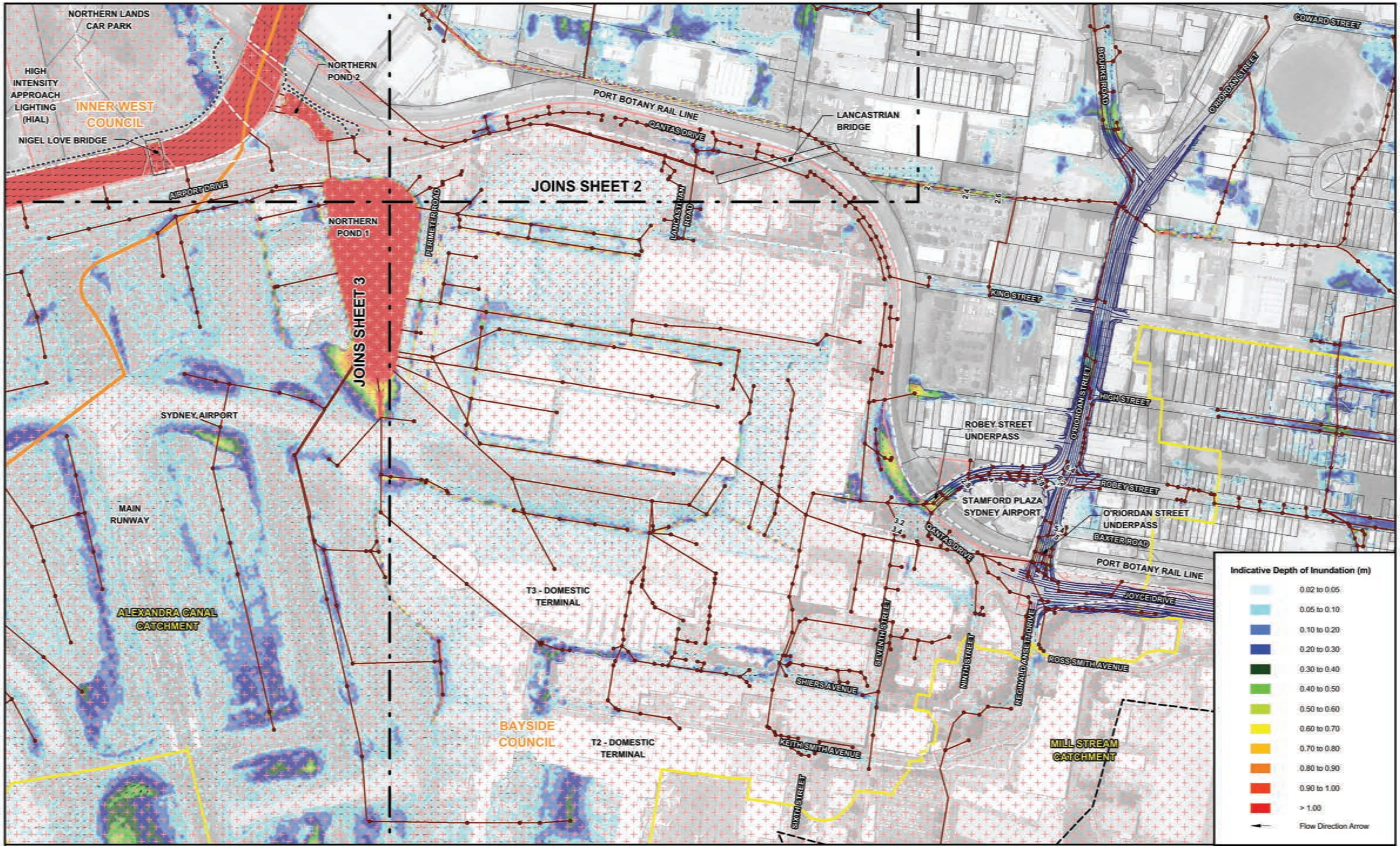
Lyall & Associates

LEGEND
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 3 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 20% 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.

LEGEND

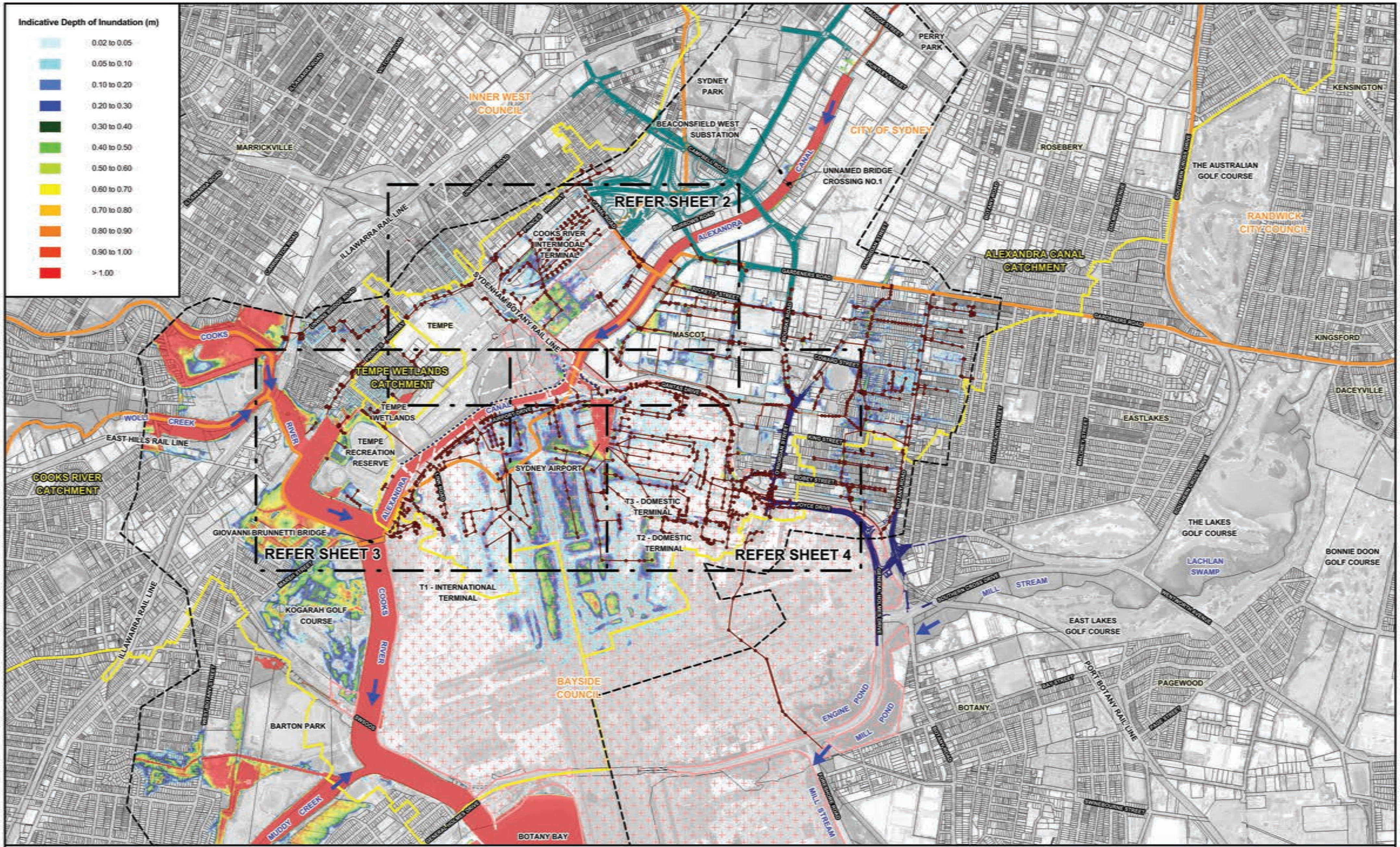
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.2
(Sheet 4 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
PRE-PROJECT CONDITIONS - 20% 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

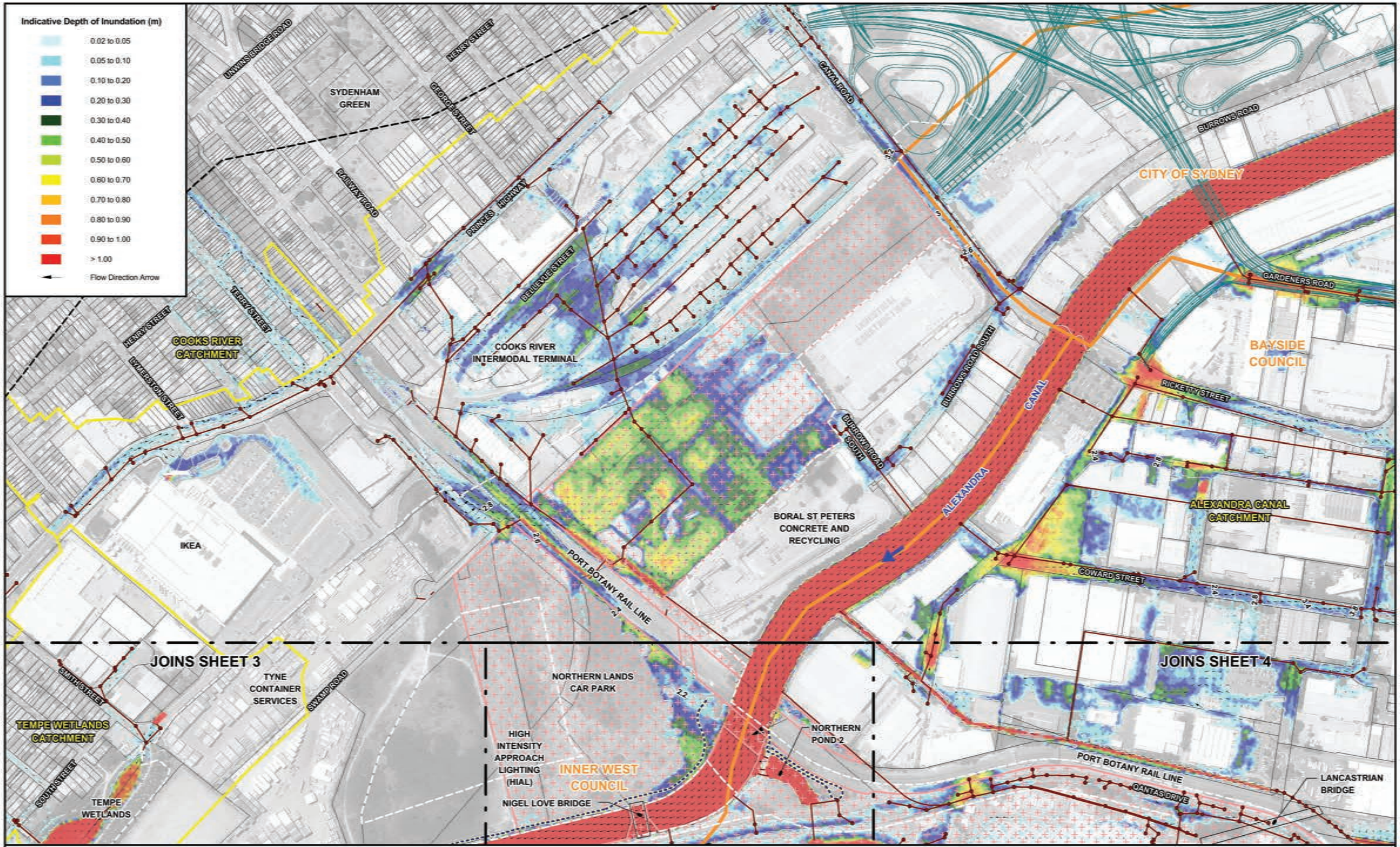
- Two-Dimensional Model Boundary
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 1 of 4)

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.

Lyall & Associates

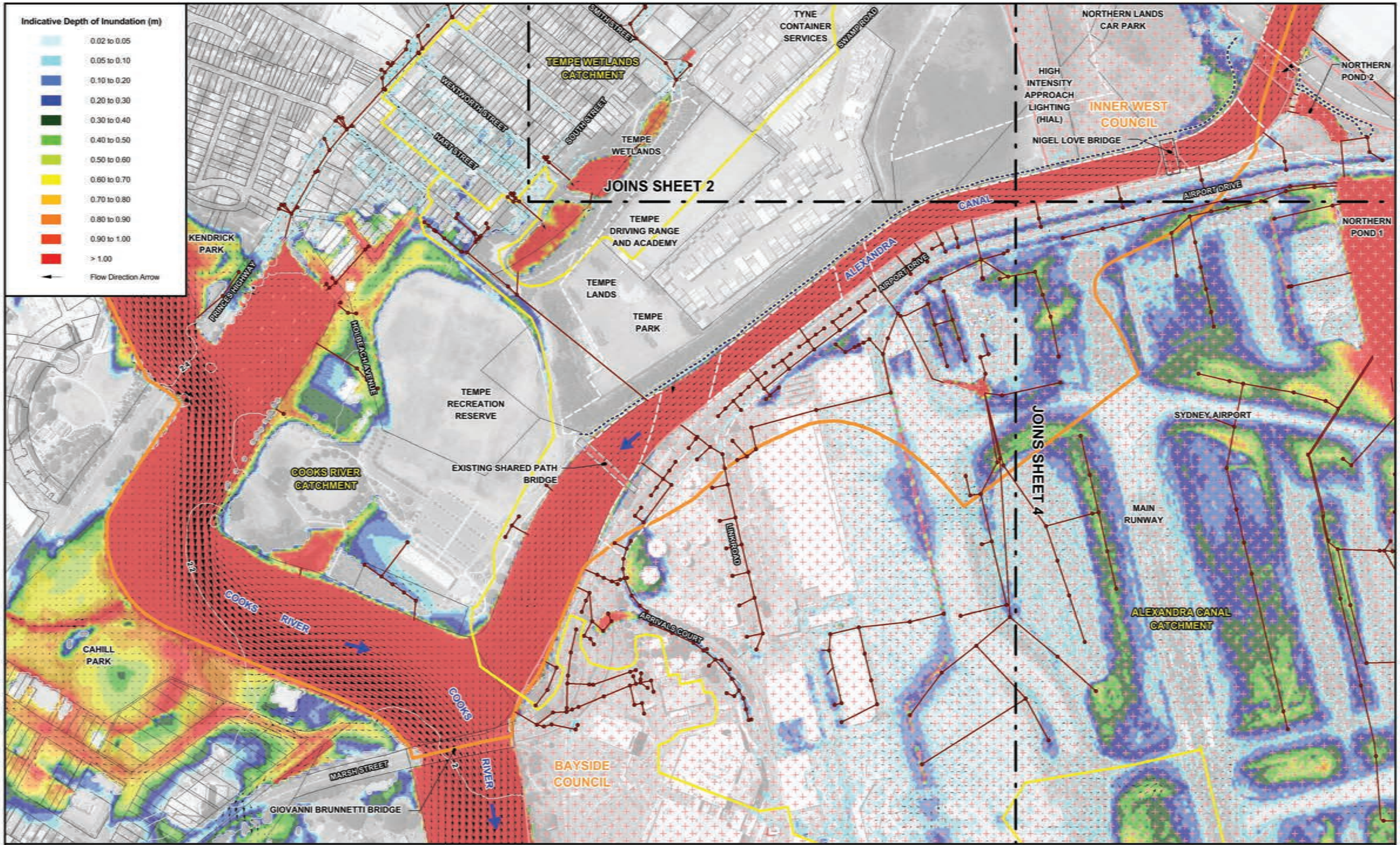
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 2 of 4)

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.

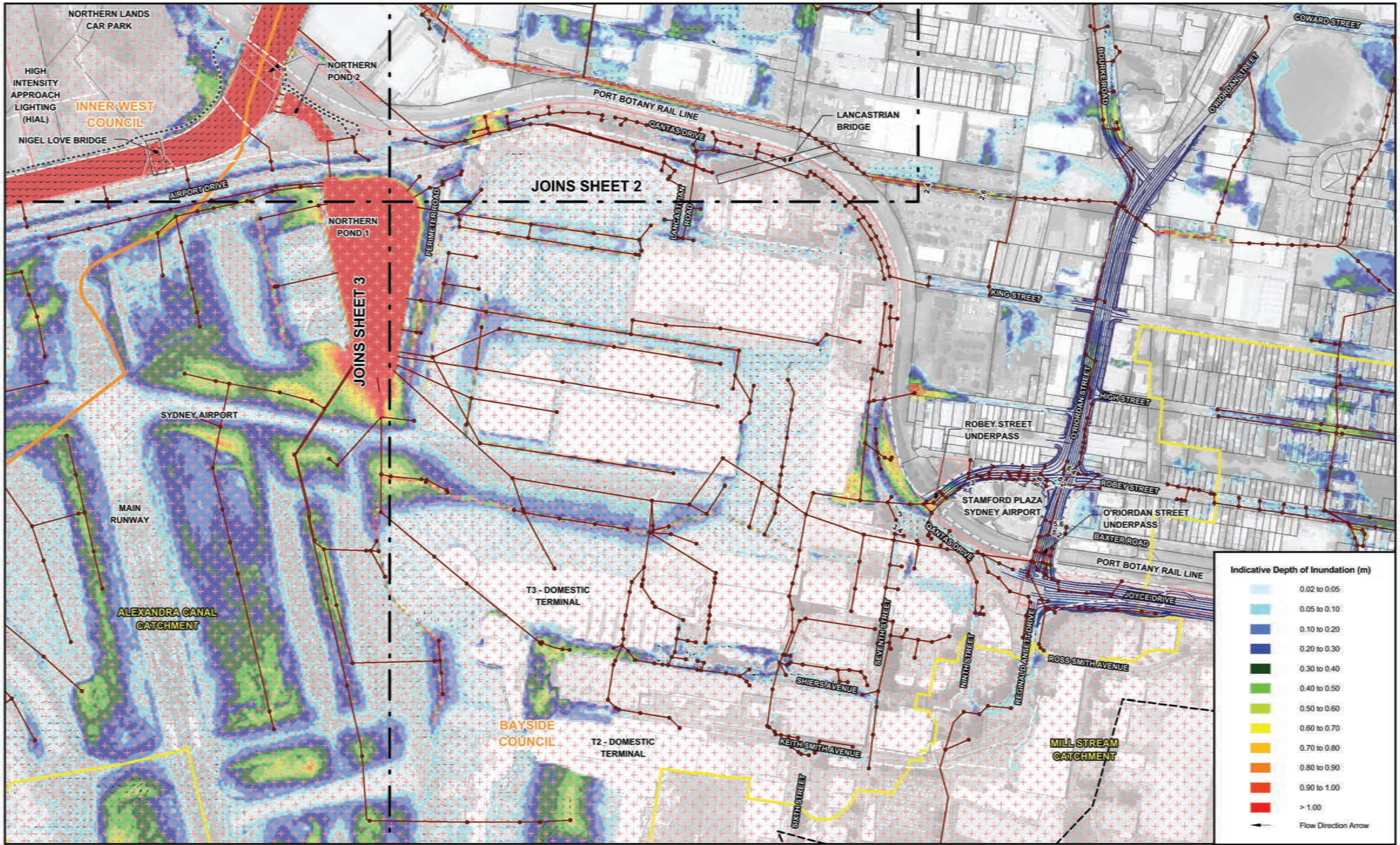
Lyall & Associates

LEGEND
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 3 of 4)

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

LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

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.

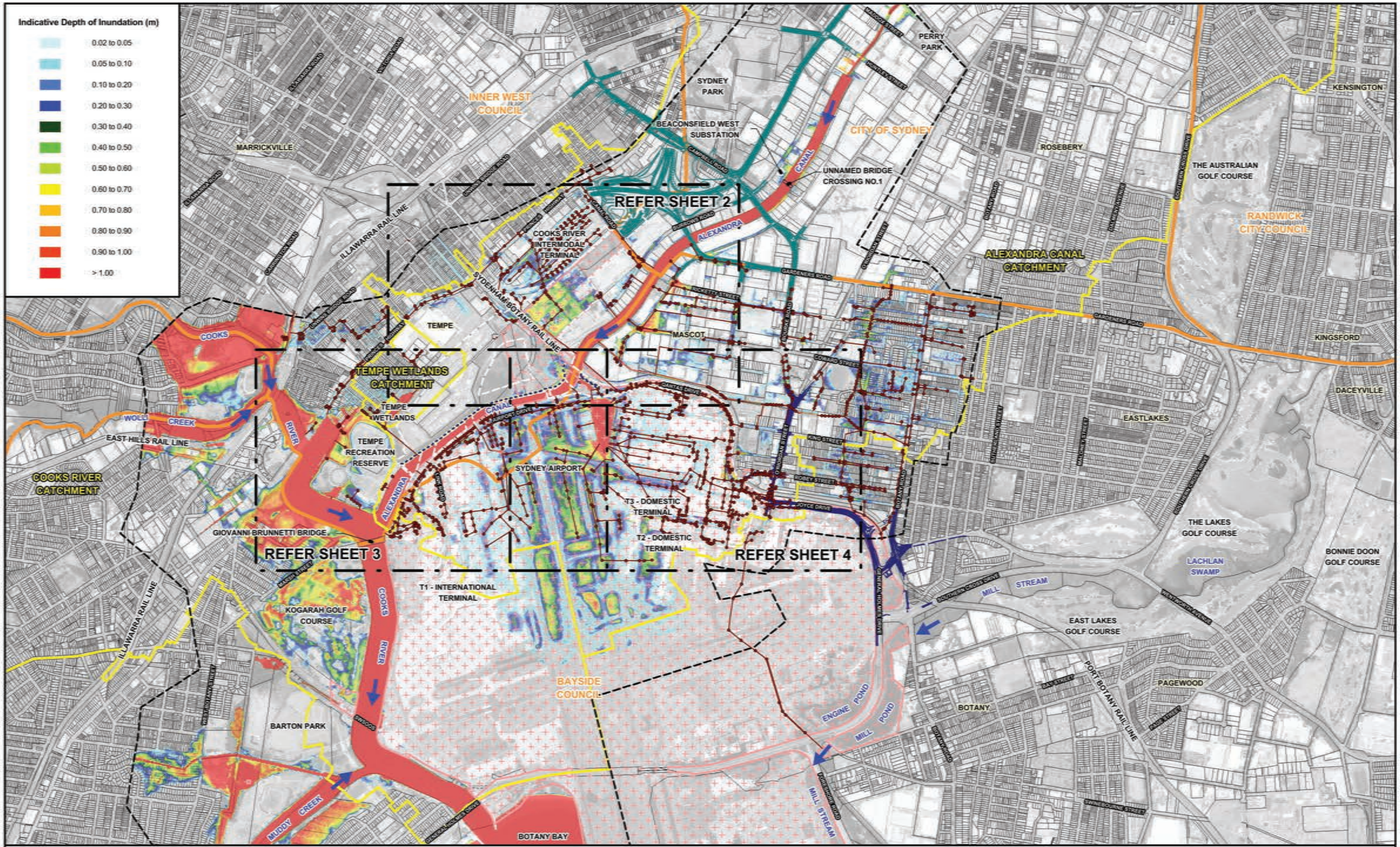
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.3
(Sheet 4 of 4)

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

Lyall & Associates

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.

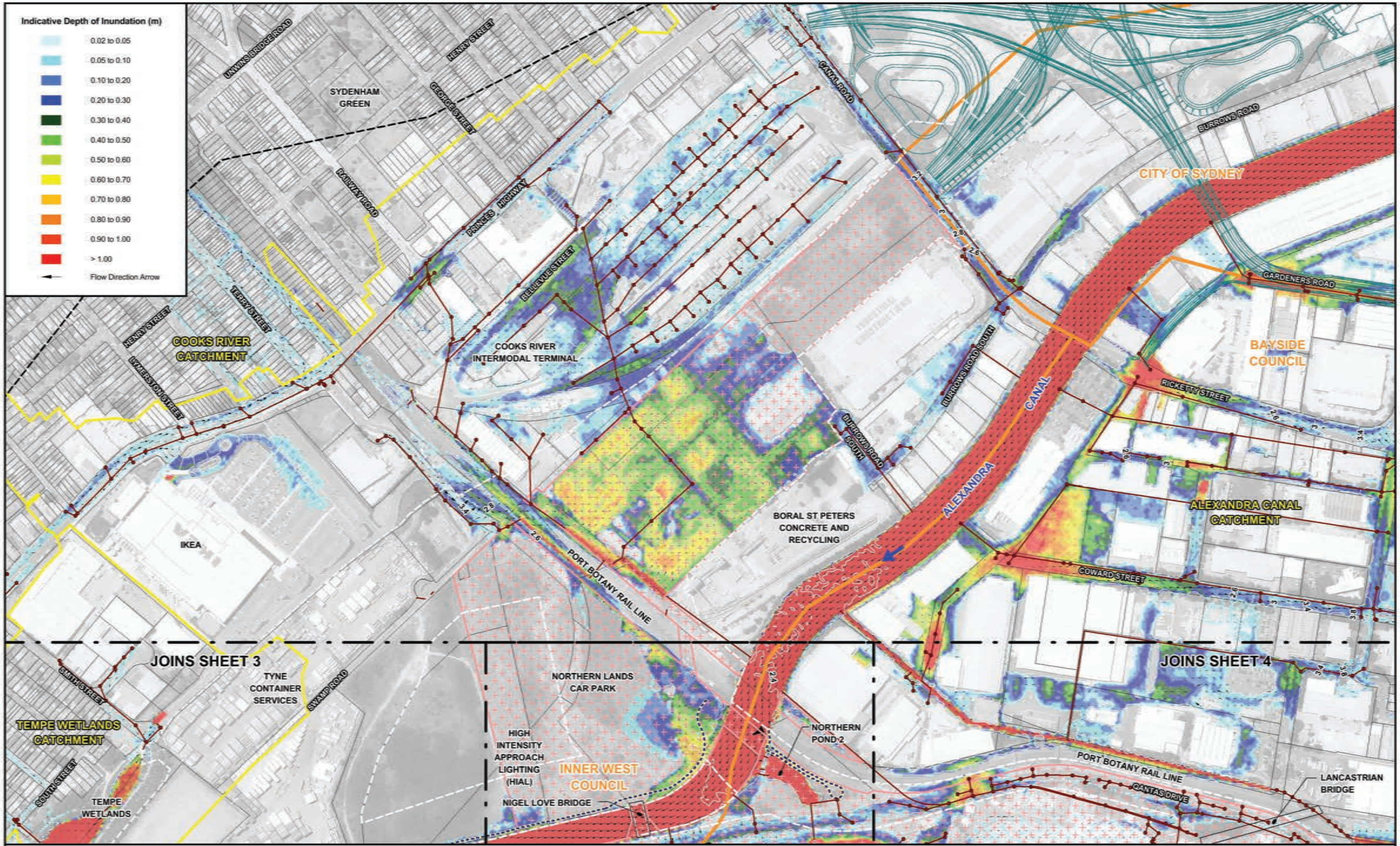
LEGEND

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

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 1 of 4)

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

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.

Lyall & Associates

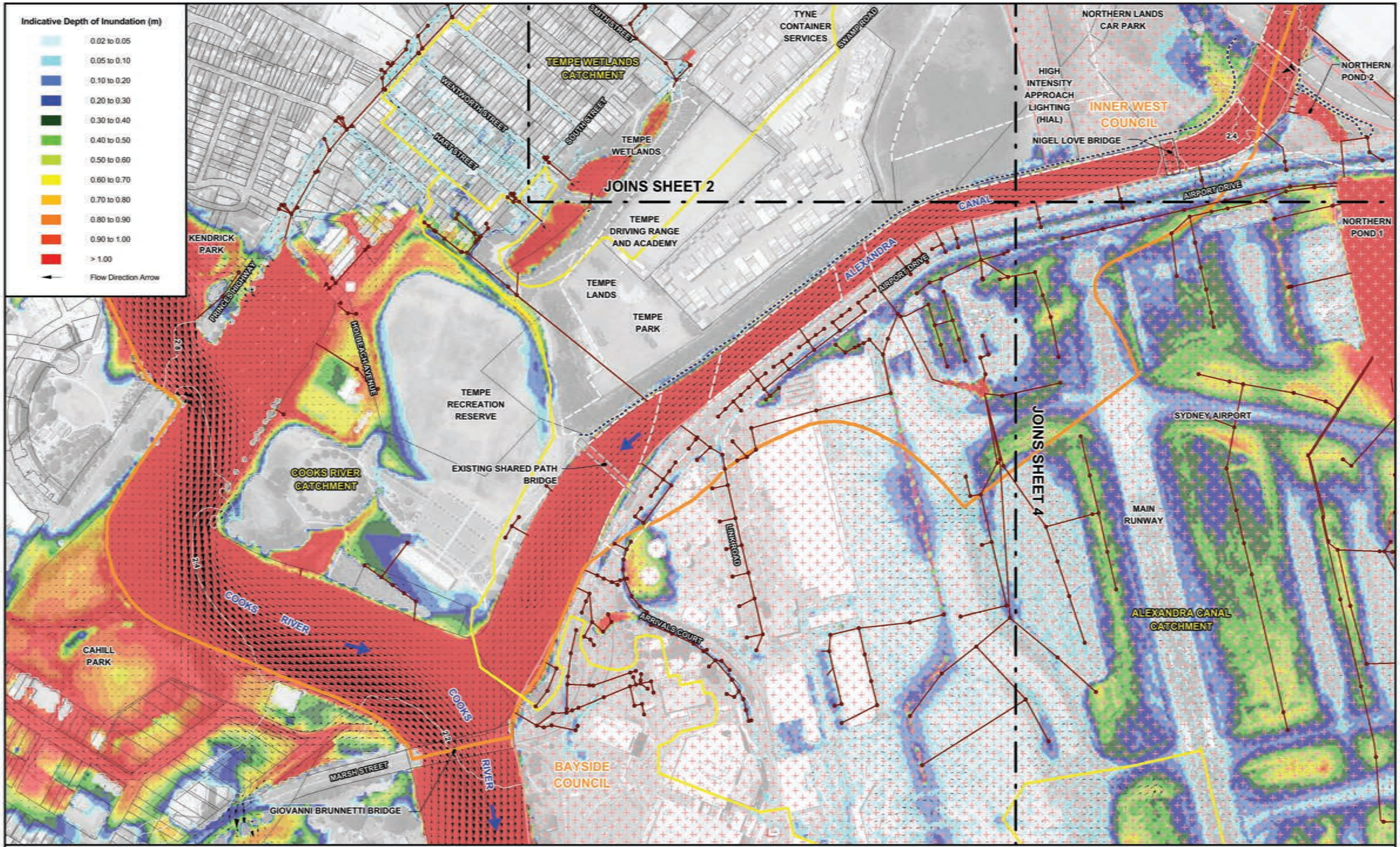
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 2 of 4)

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

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

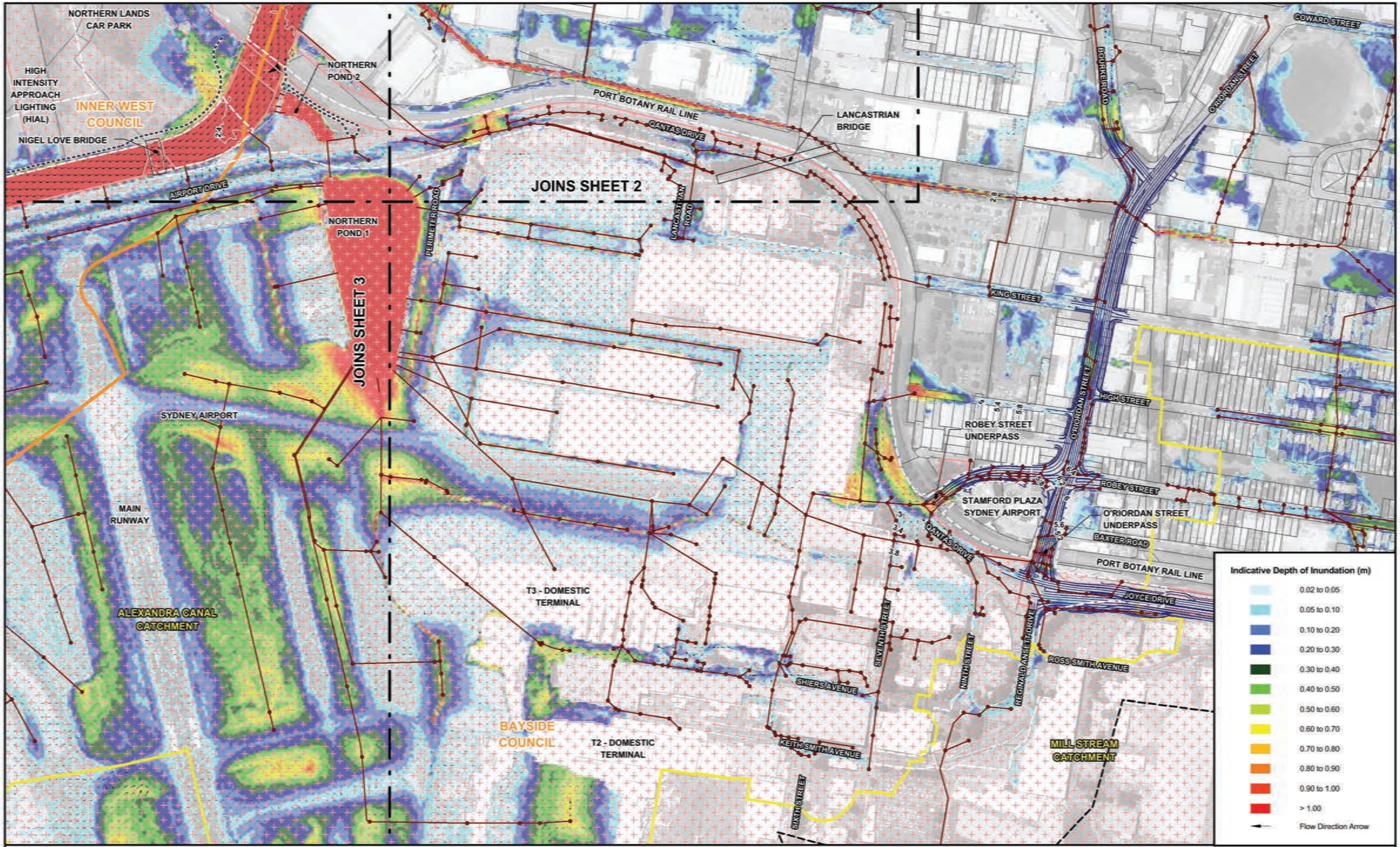
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 3 of 4)

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

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

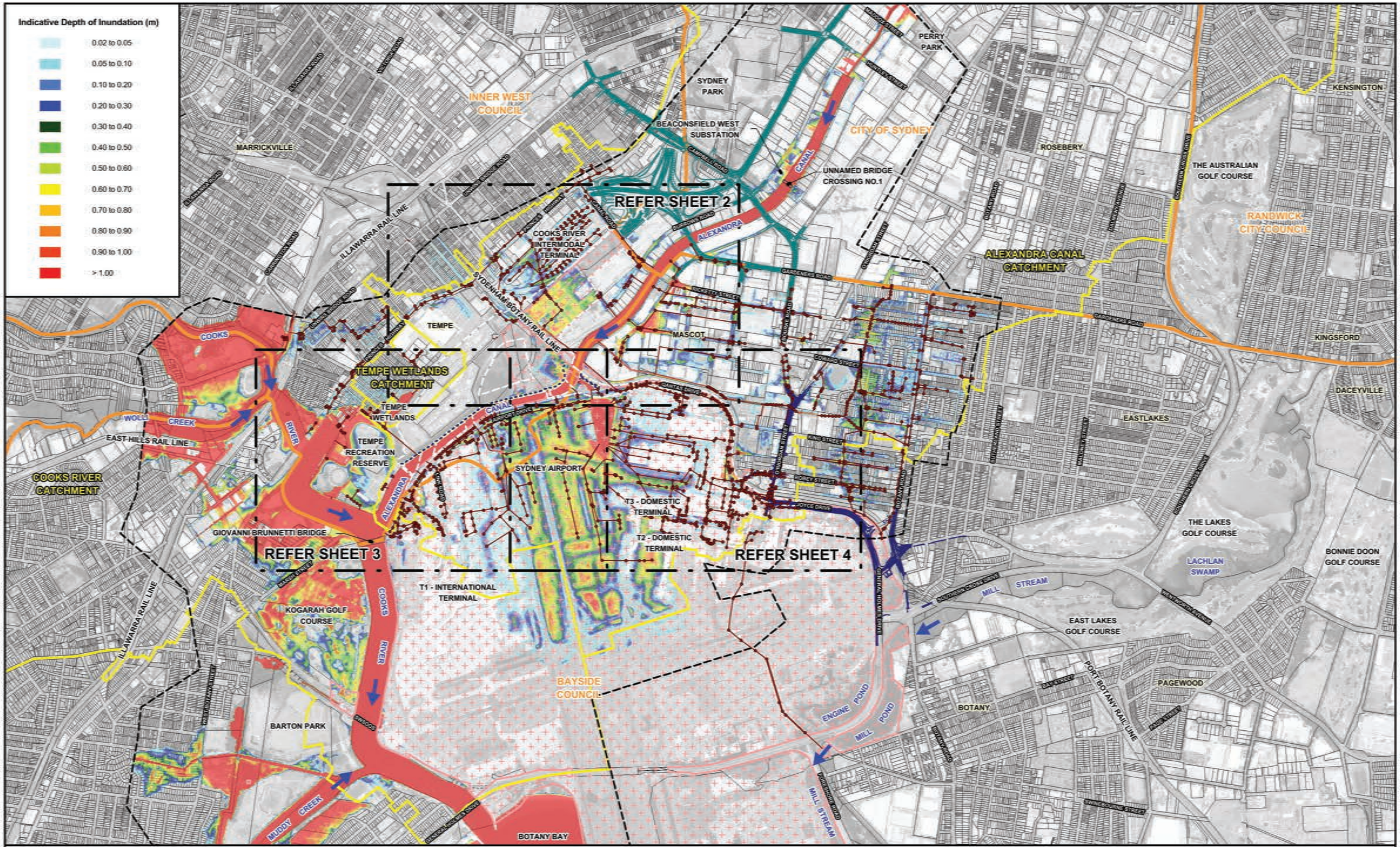
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.4
(Sheet 4 of 4)

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

Lyall & Associates

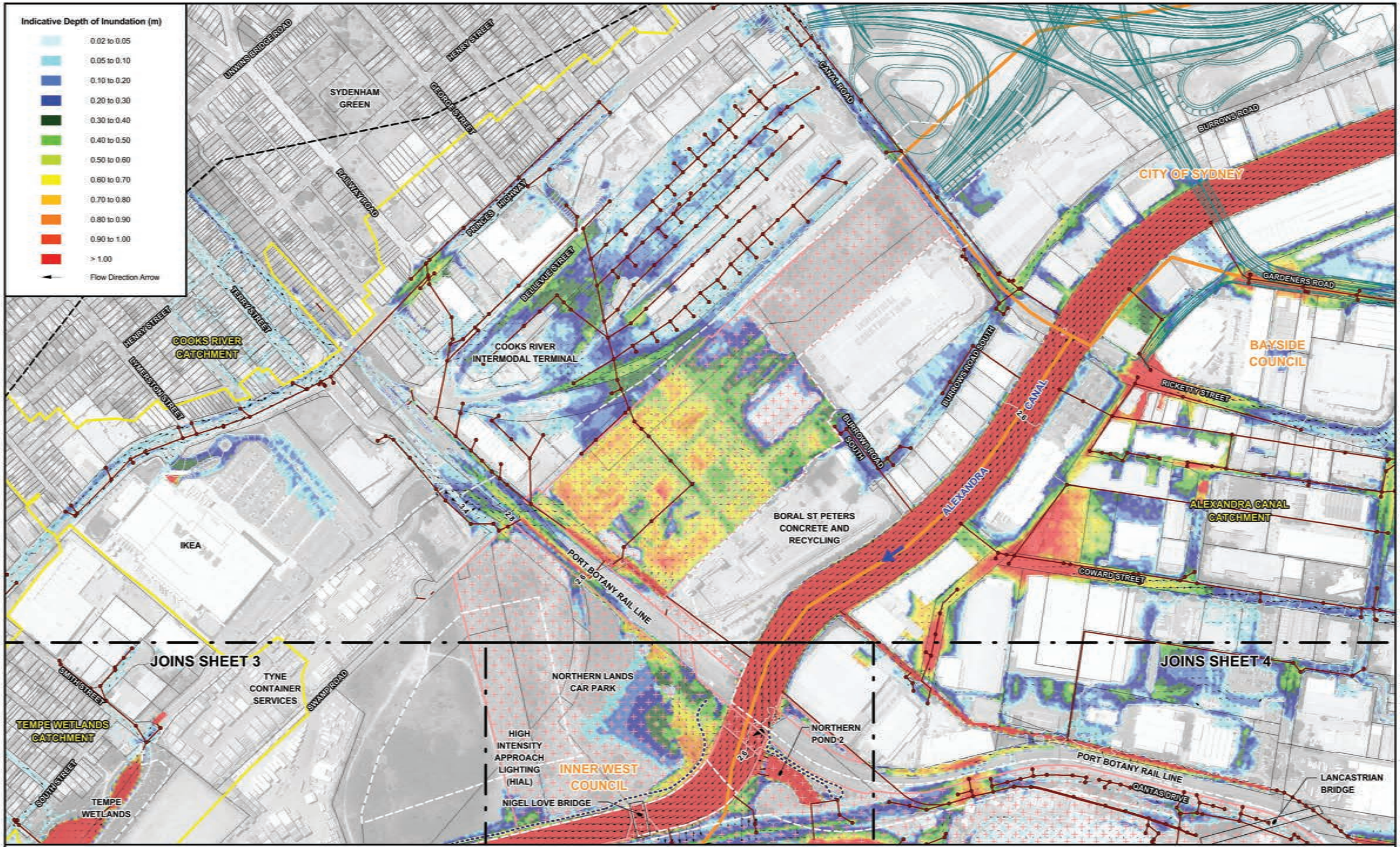
LEGEND

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

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 1 of 4)

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:

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.

Lyall & Associates

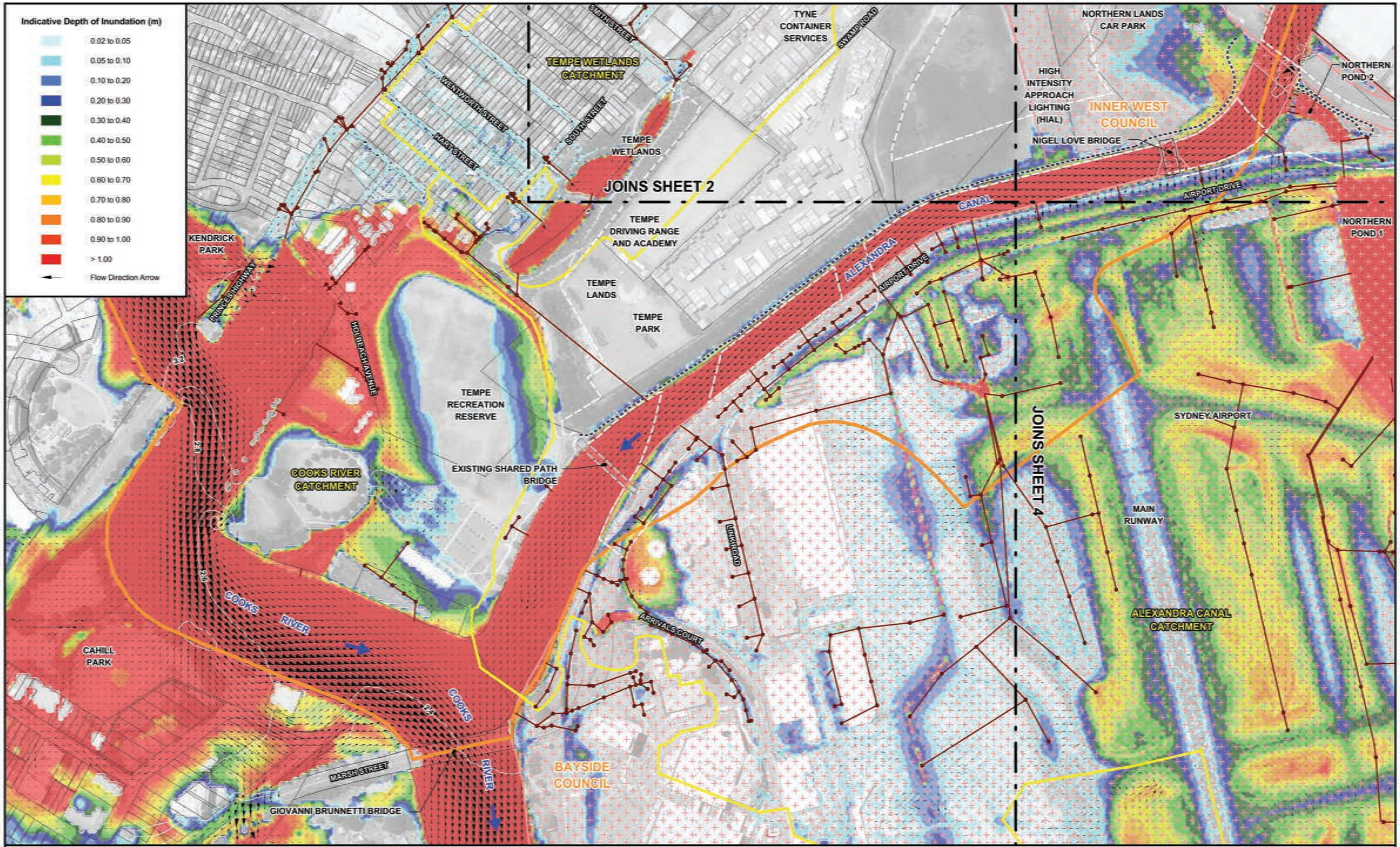
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 2 of 4)

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

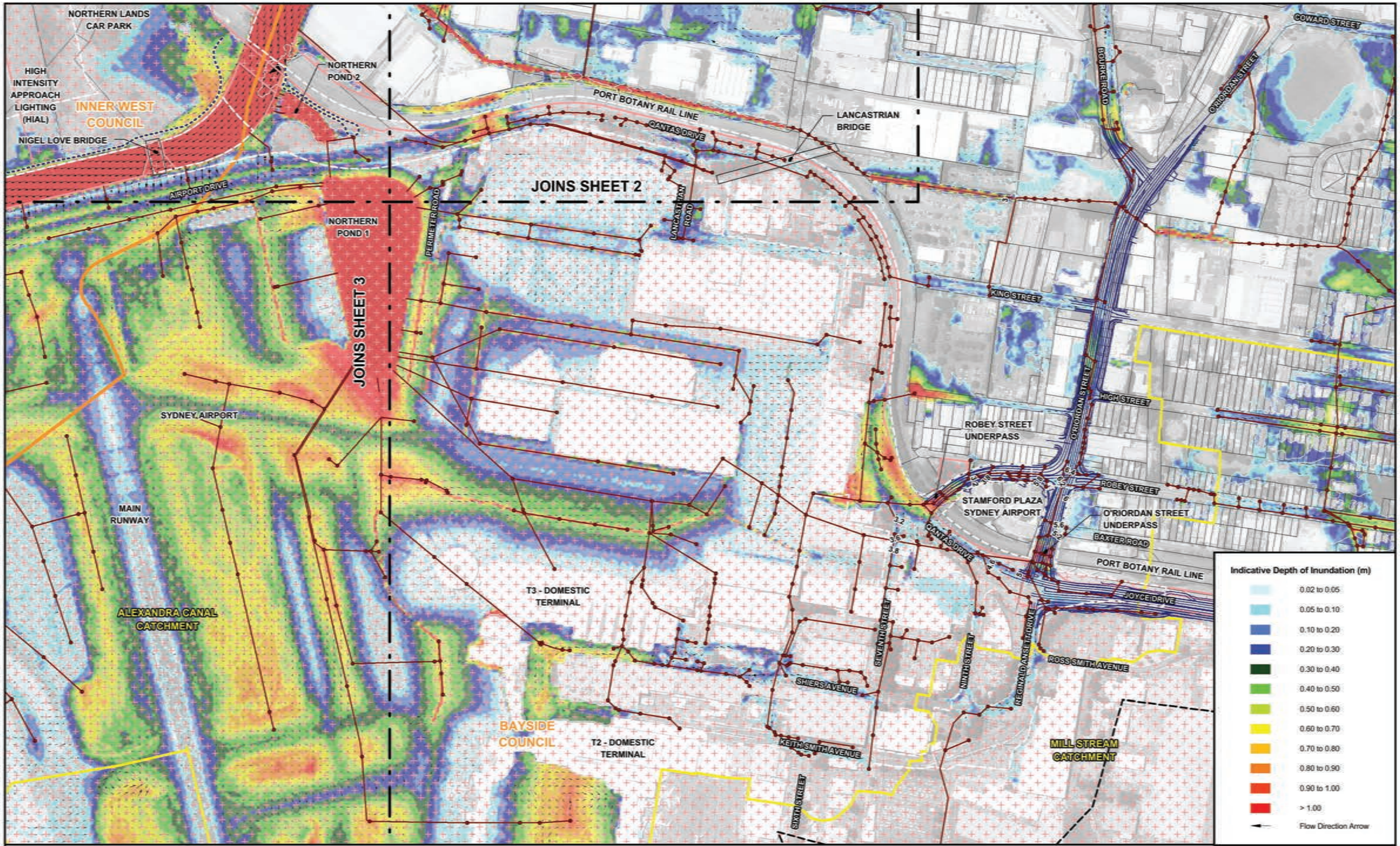
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.6 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 3 of 4)

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

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.

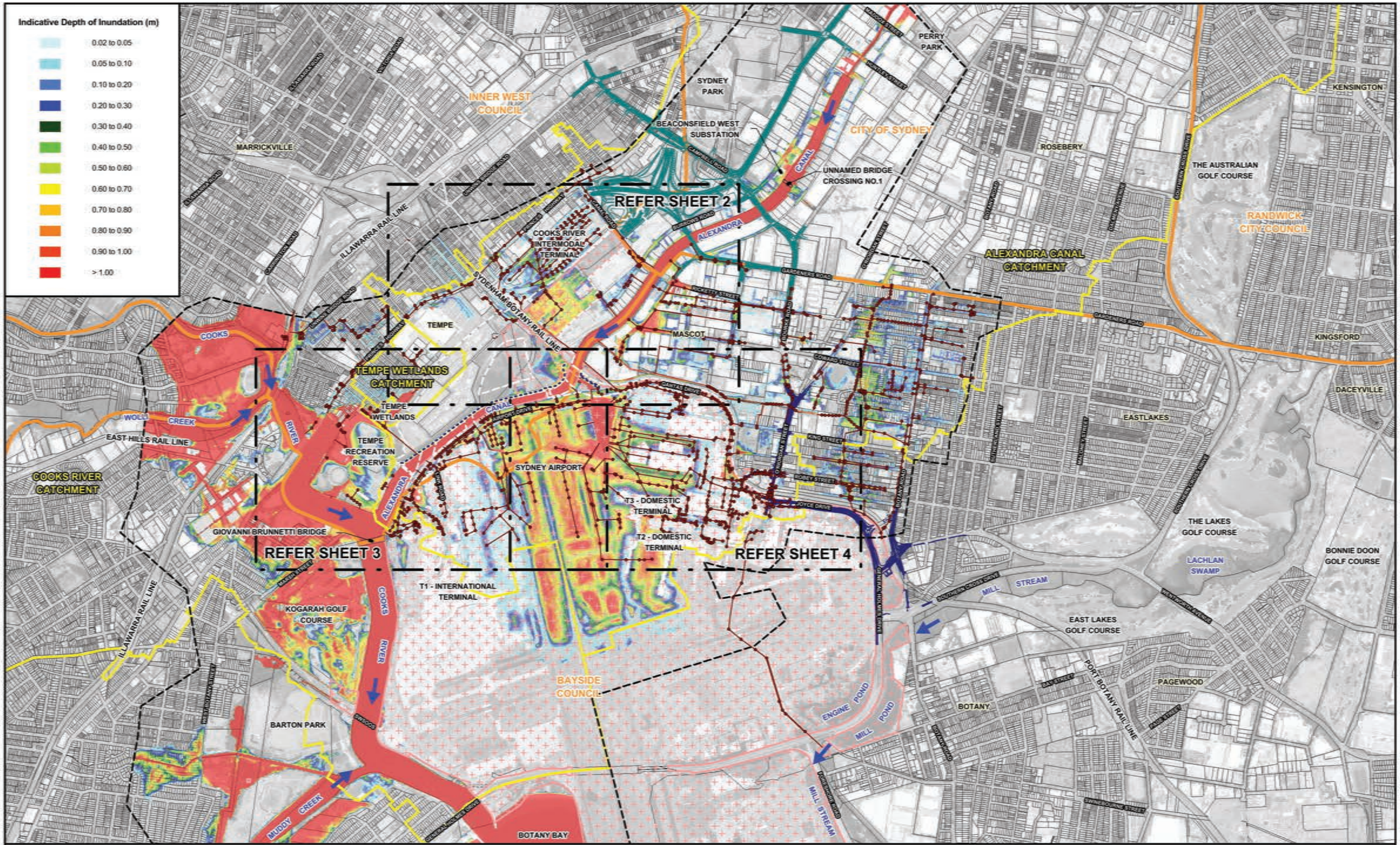
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 26 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.5
(Sheet 4 of 4)

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

Lyall & Associates

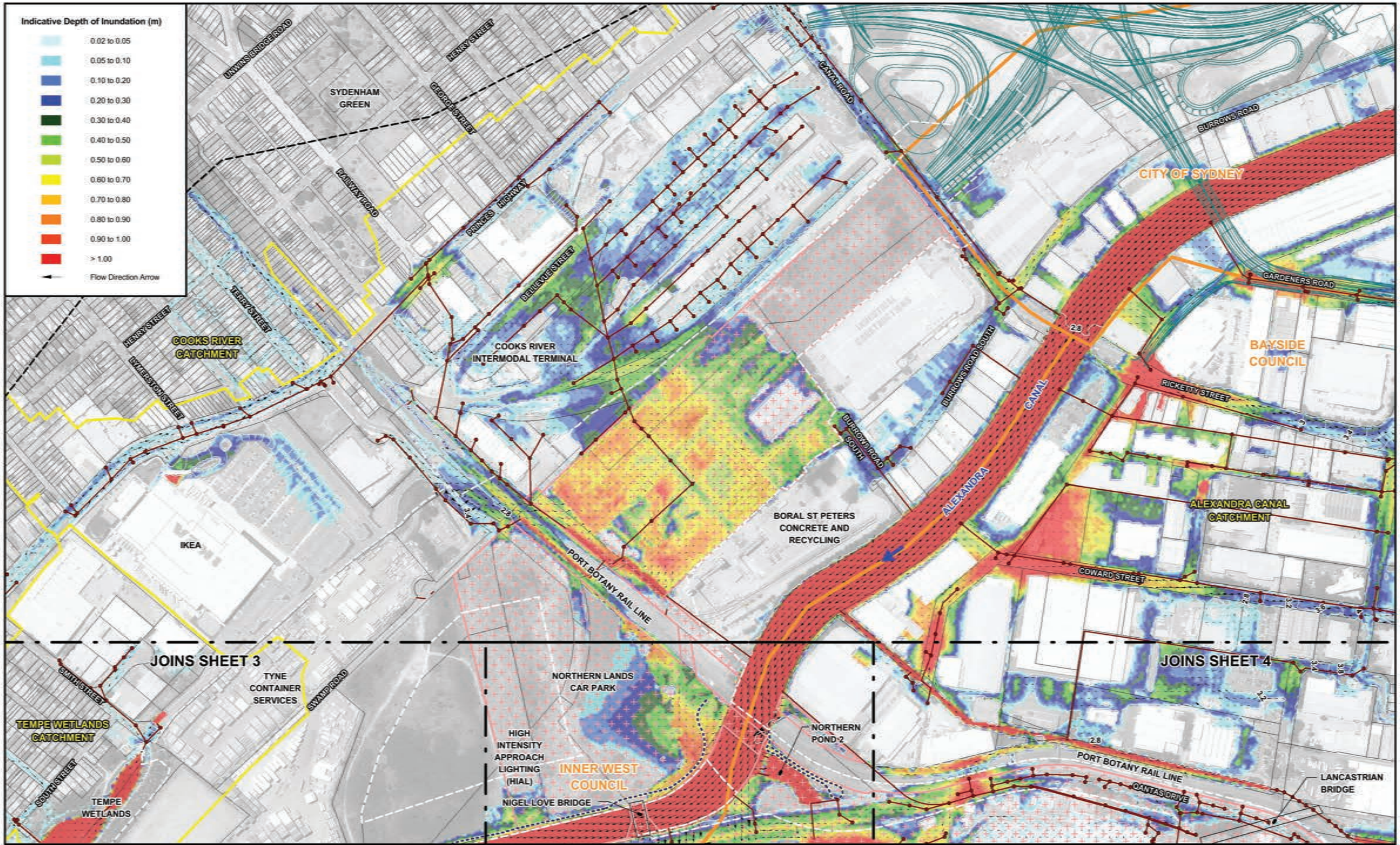
LEGEND

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

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.6
(Sheet 1 of 4)

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

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.

Lyall & Associates

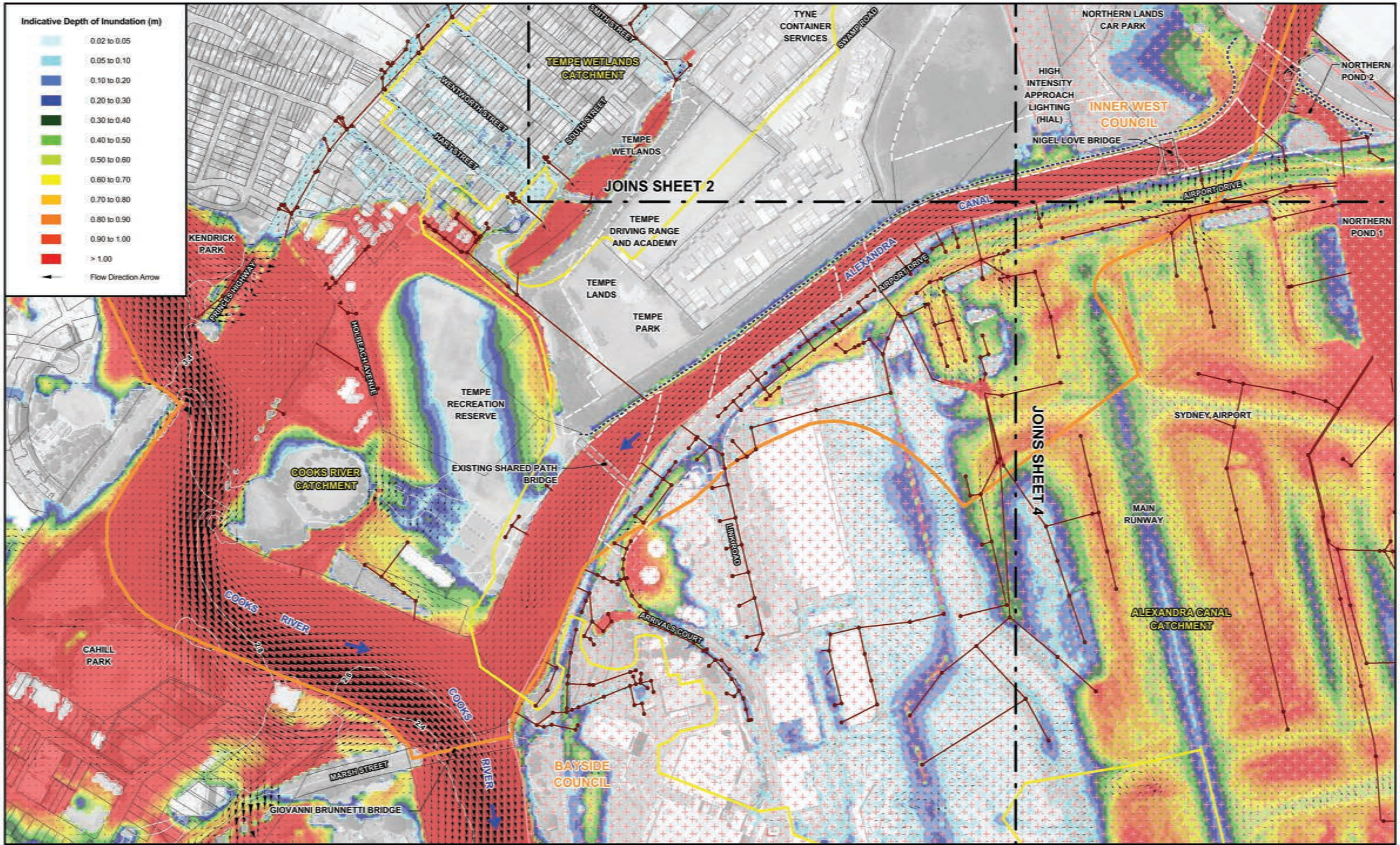
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.8 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.6
(Sheet 2 of 4)

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

Lyall & Associates

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.

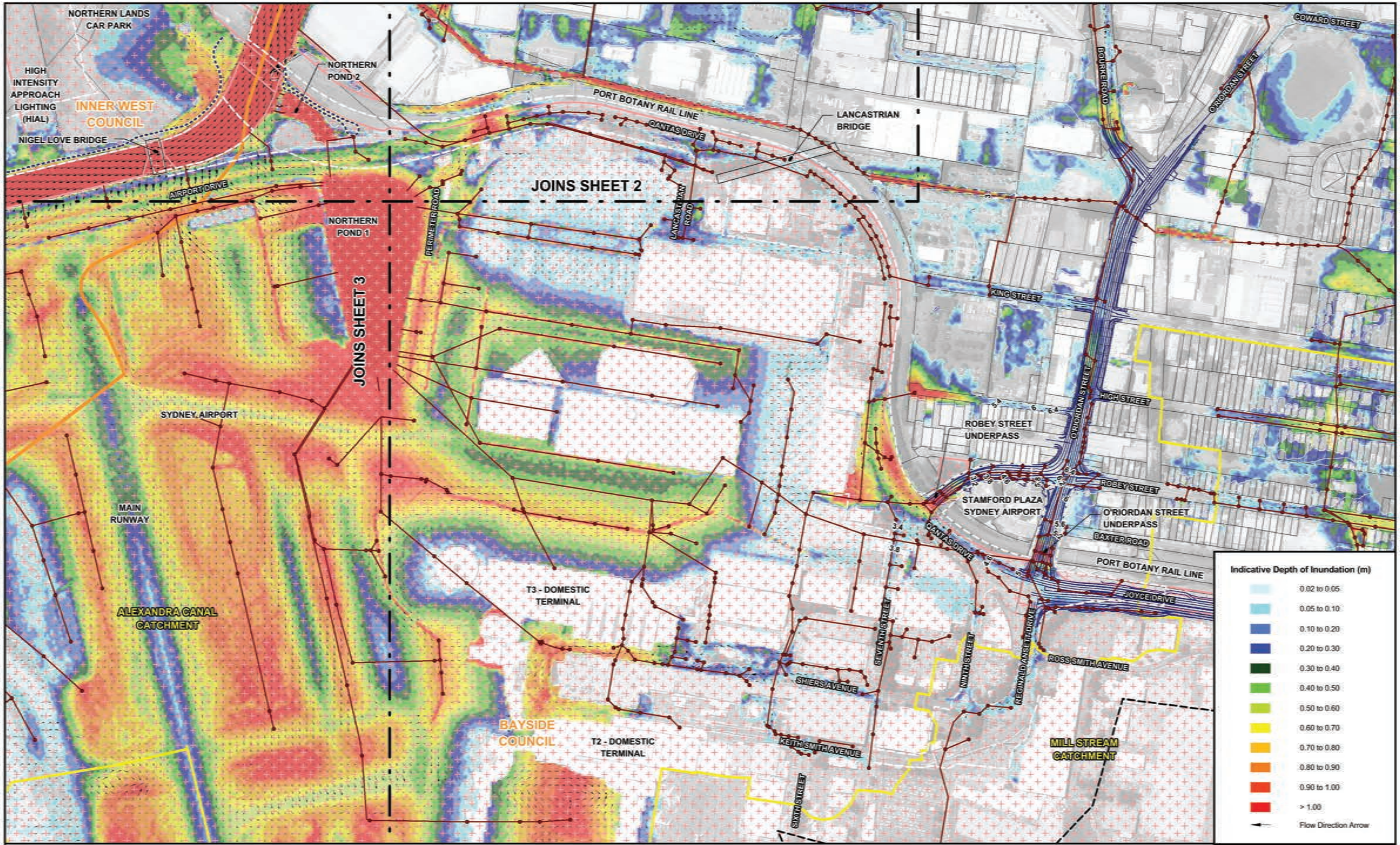
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.8 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.6
(Sheet 3 of 4)

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

Lyall & Associates

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.

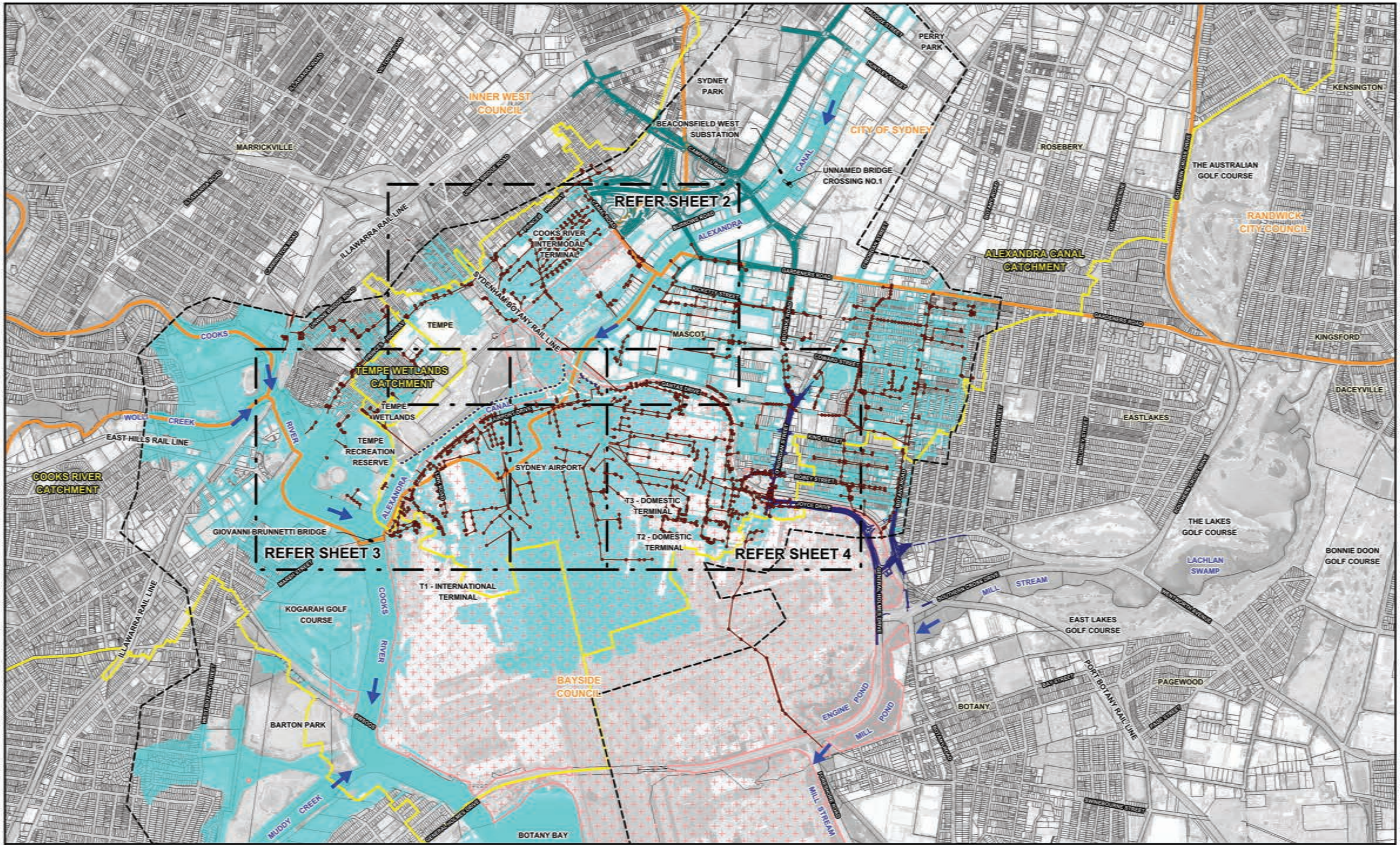
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- 2.8 Water Surface Elevation Contours
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.6
(Sheet 4 of 4)

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



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.

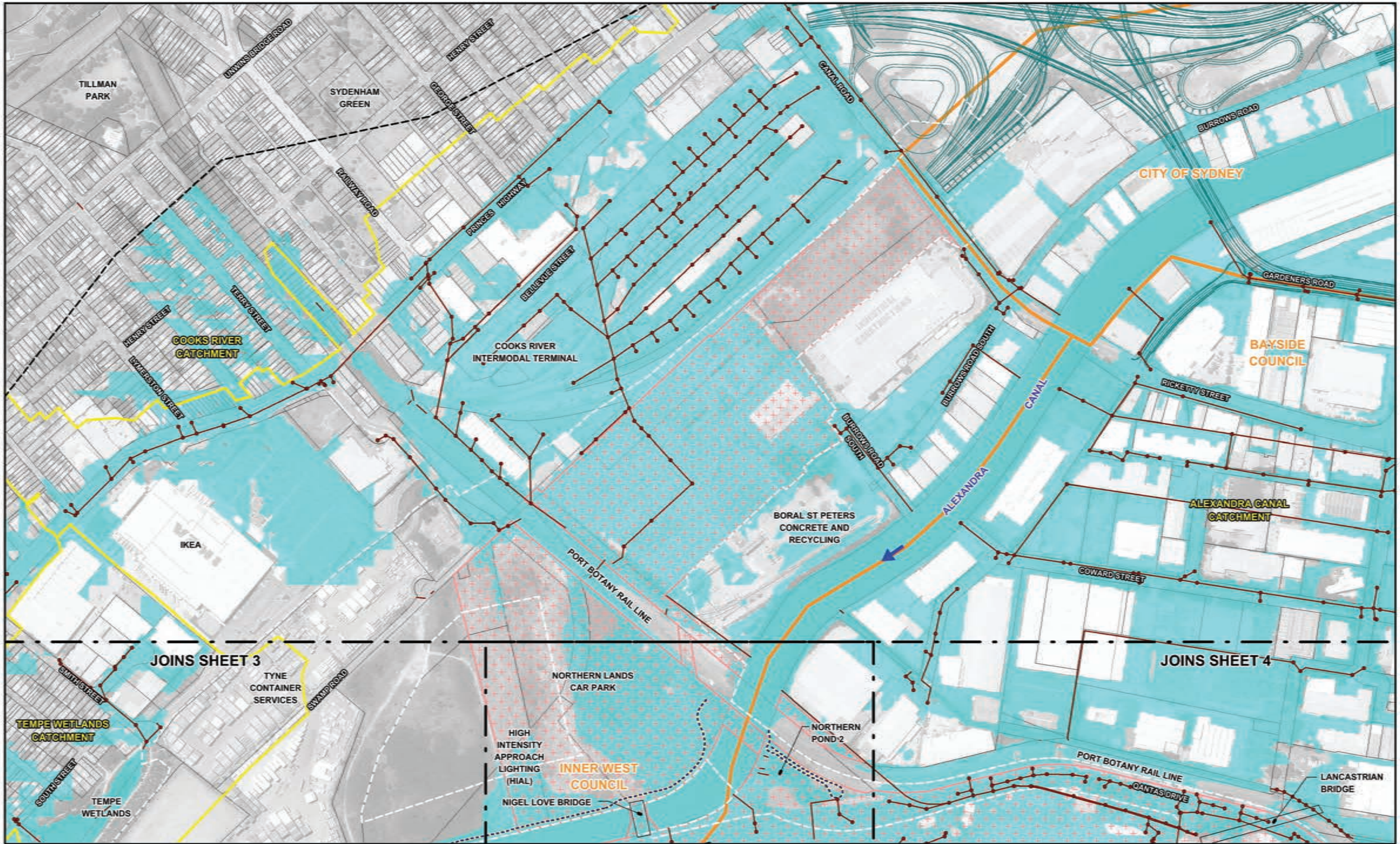
LEGEND

- Two-Dimensional Model Boundary
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works
- Flood Planning Area

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.7
(Sheet 1 of 4)

FLOOD PLANNING AREA
PRE-PROJECT CONDITIONS - 1% AEP EVENT



LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- New M5 Surface Road Works
- Flood Planning Area

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.

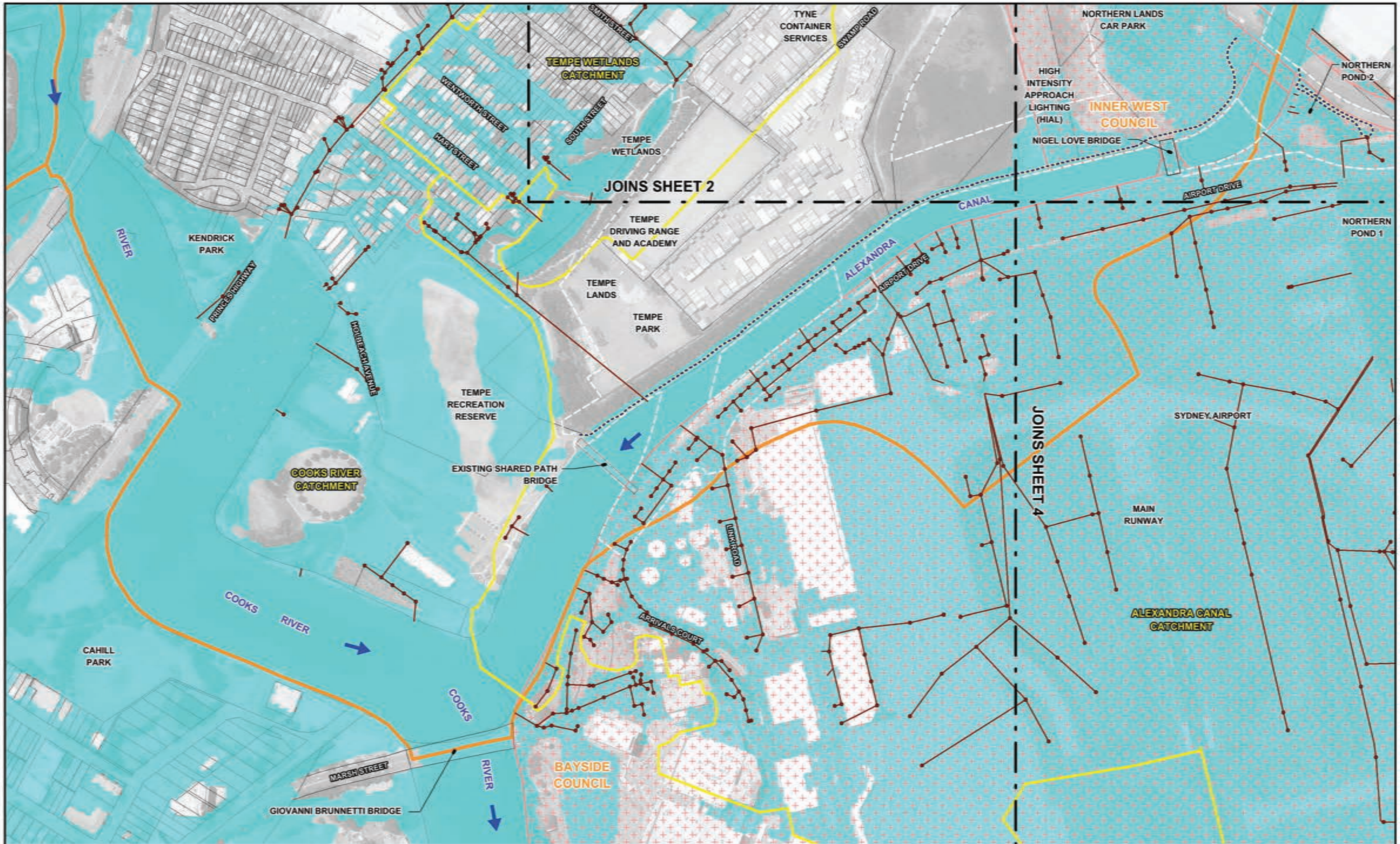
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.7
(Sheet 2 of 4)

FLOOD PLANNING AREA
PRE-PROJECT CONDITIONS - 1% 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.

LEGEND

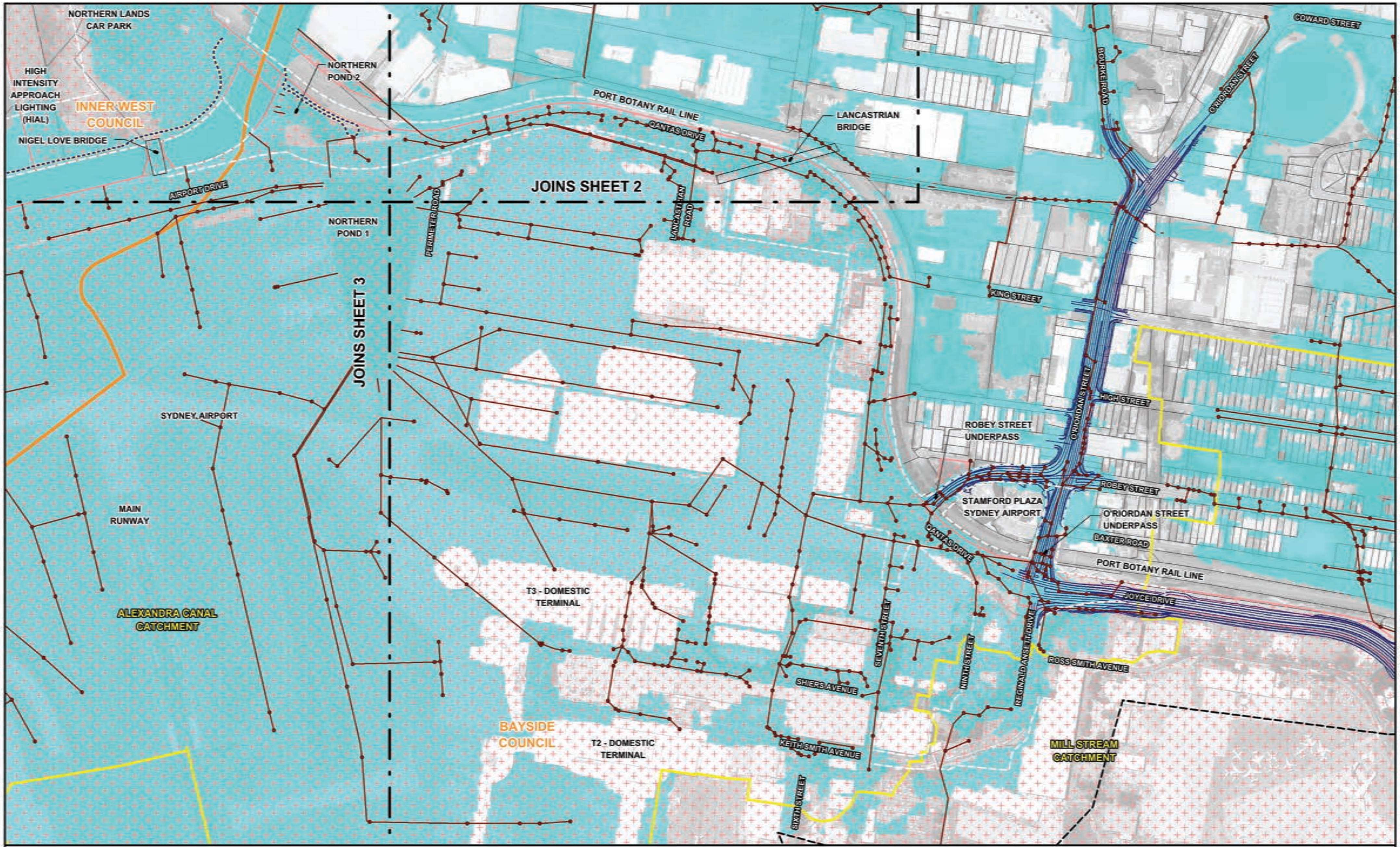
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- Flood Planning Area

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.7
(Sheet 3 of 4)

FLOOD PLANNING AREA
PRE-PROJECT CONDITIONS - 1% 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.

LEGEND

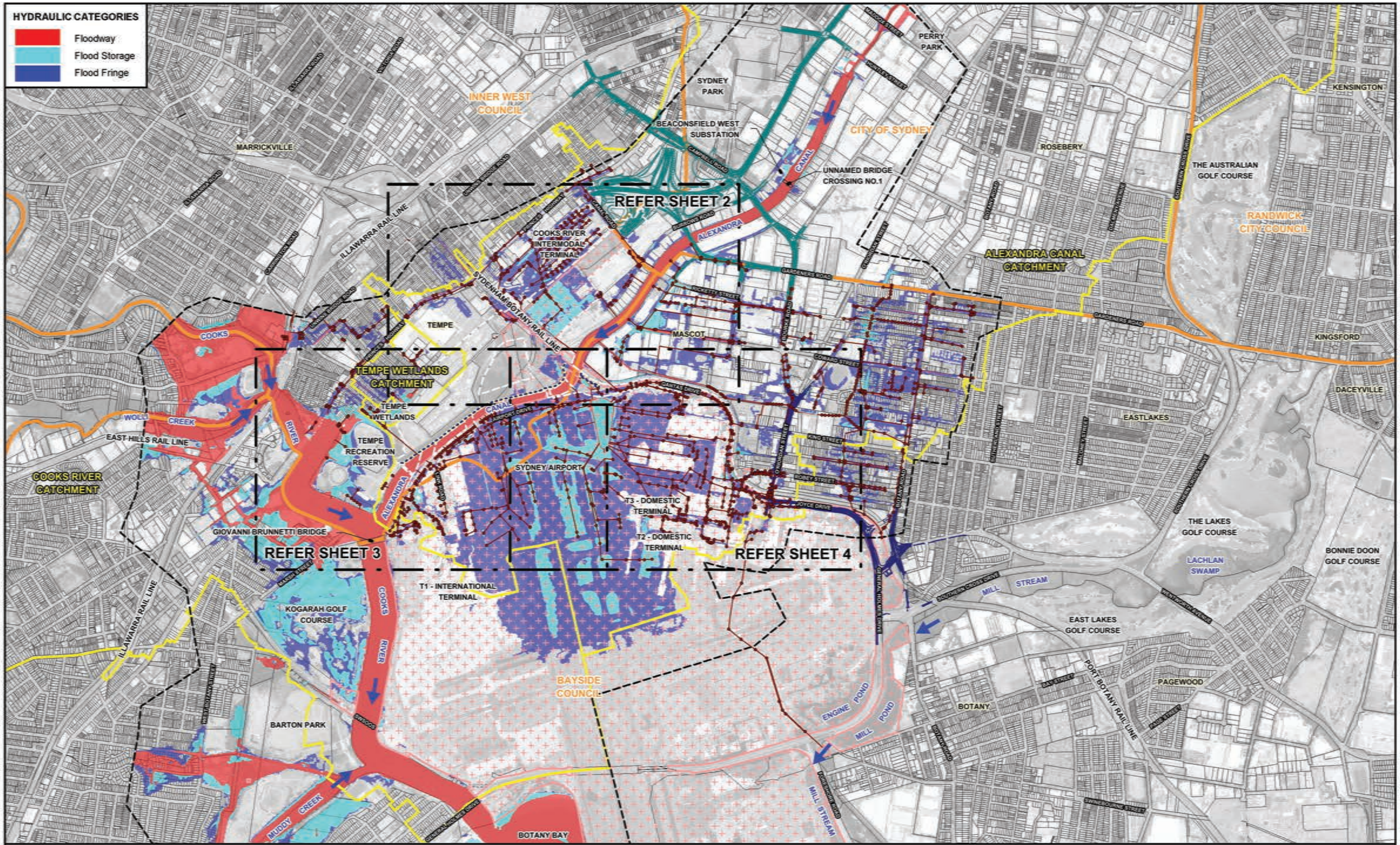
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- New M5 Surface Road Works
- Flood Planning Area

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.7
(Sheet 4 of 4)

FLOOD PLANNING AREA
PRE-PROJECT CONDITIONS - 1% AEP EVENT



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.

LEGEND

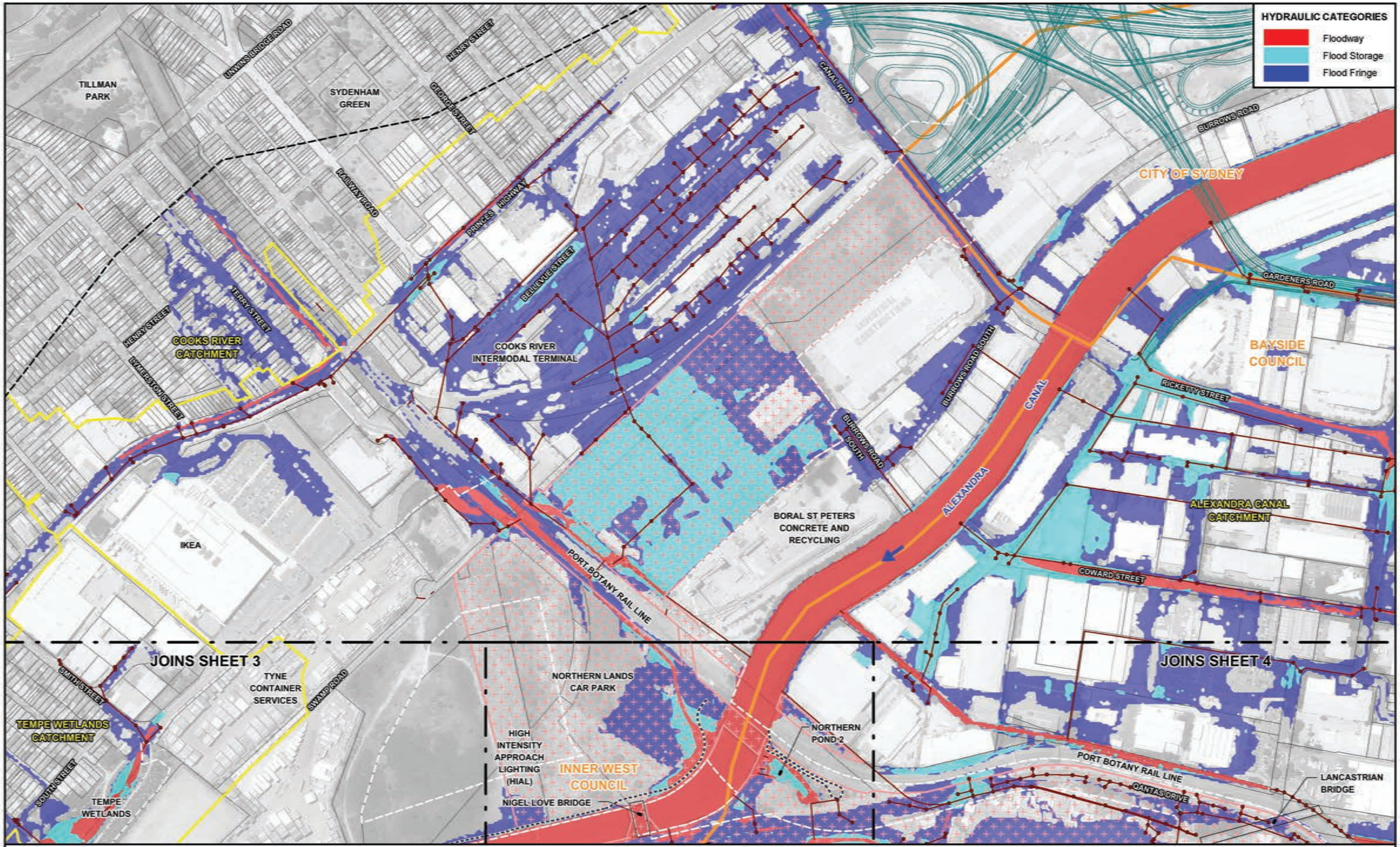
- Two-Dimensional Model Boundary
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Airport North and Airport East Road Works
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.8
(Sheet 1 of 4)

PRELIMINARY HYDRAULIC CATEGORISATION
PRE-PROJECT CONDITIONS - 1% 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.

LEGEND

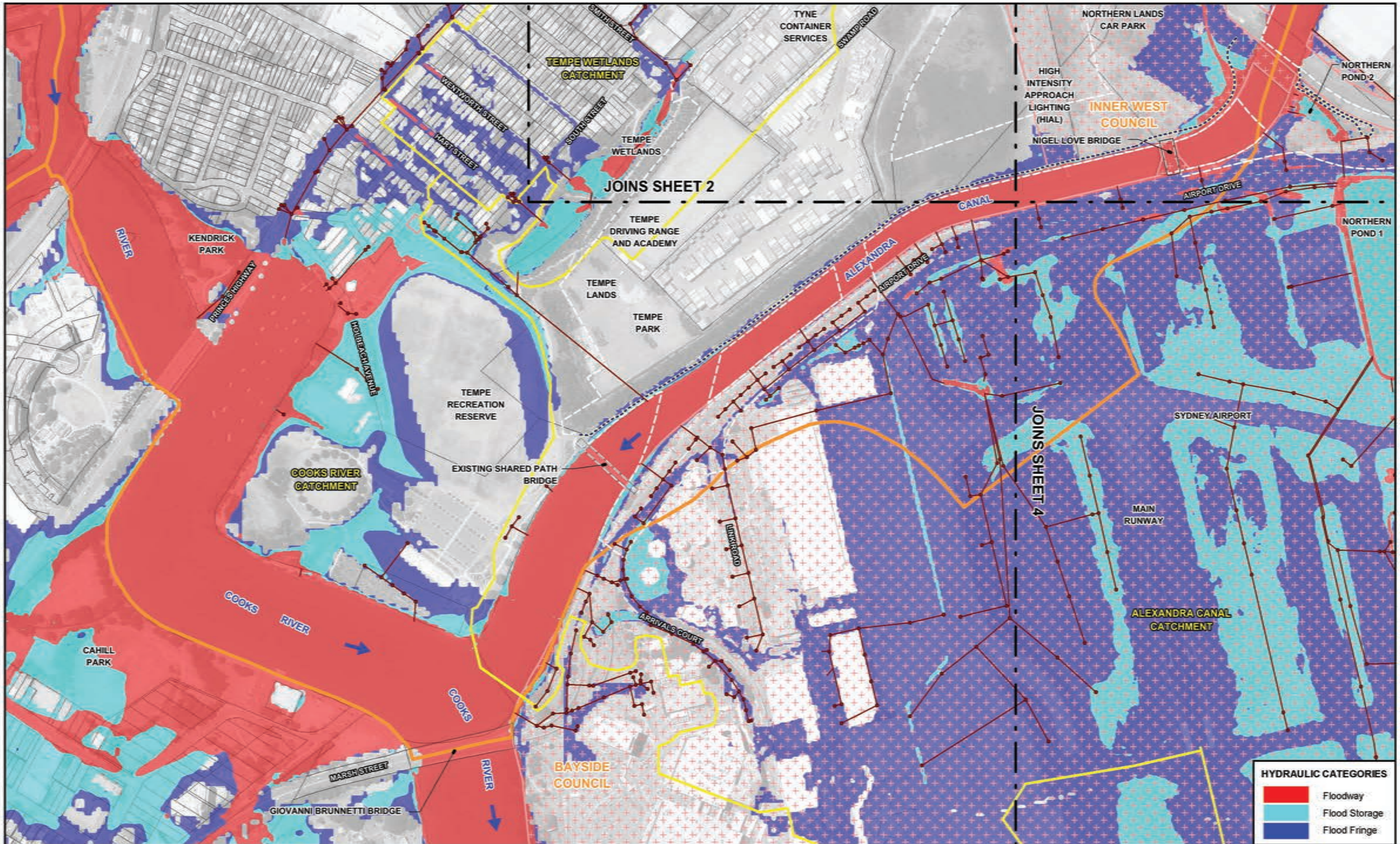
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.8
(Sheet 2 of 4)

PRELIMINARY HYDRAULIC CATEGORISATION
PRE-PROJECT CONDITIONS - 1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

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.

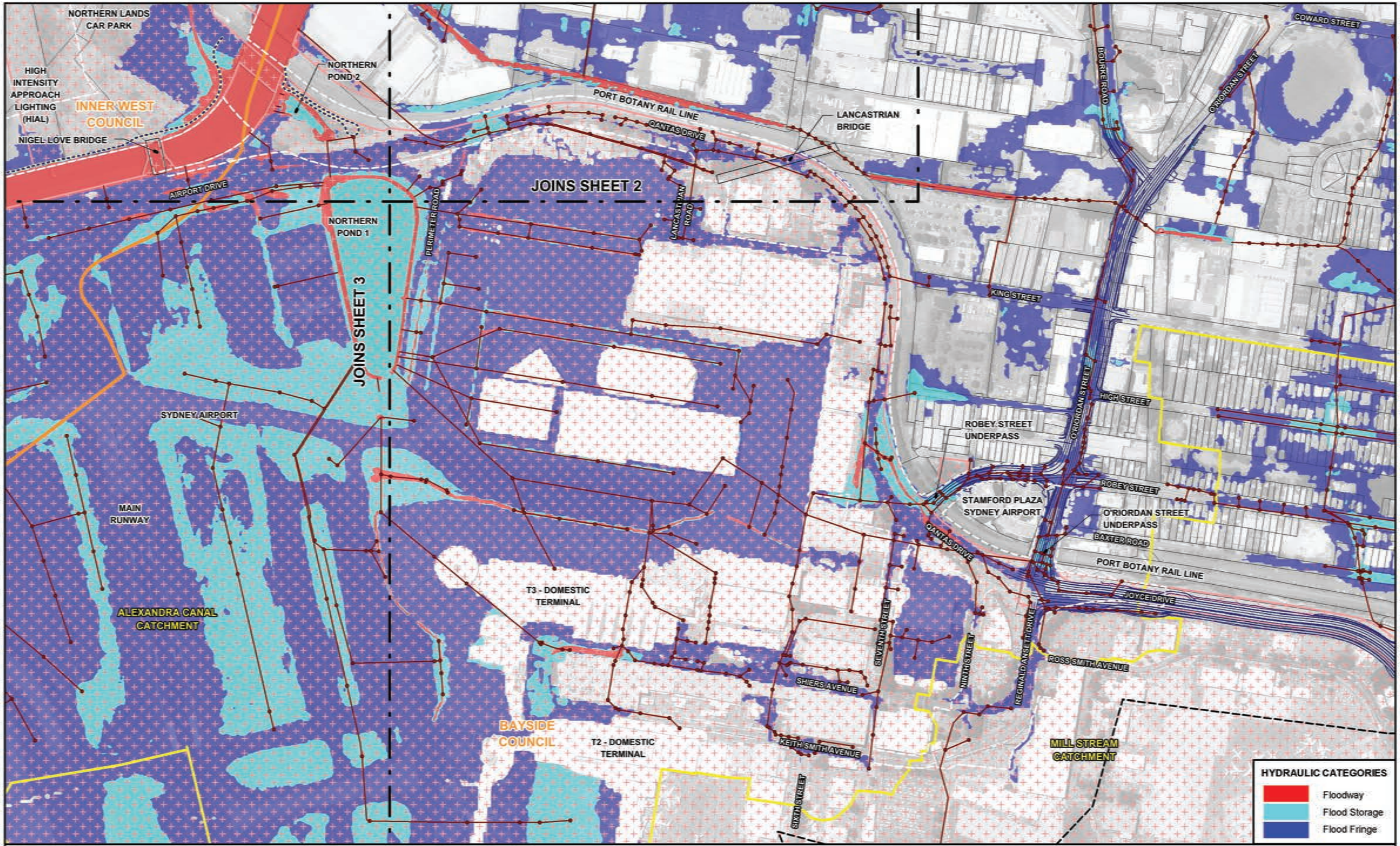
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.8
(Sheet 3 of 4)

PRELIMINARY HYDRAULIC CATEGORISATION
PRE-PROJECT CONDITIONS - 1% 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.

Lyall & Associates

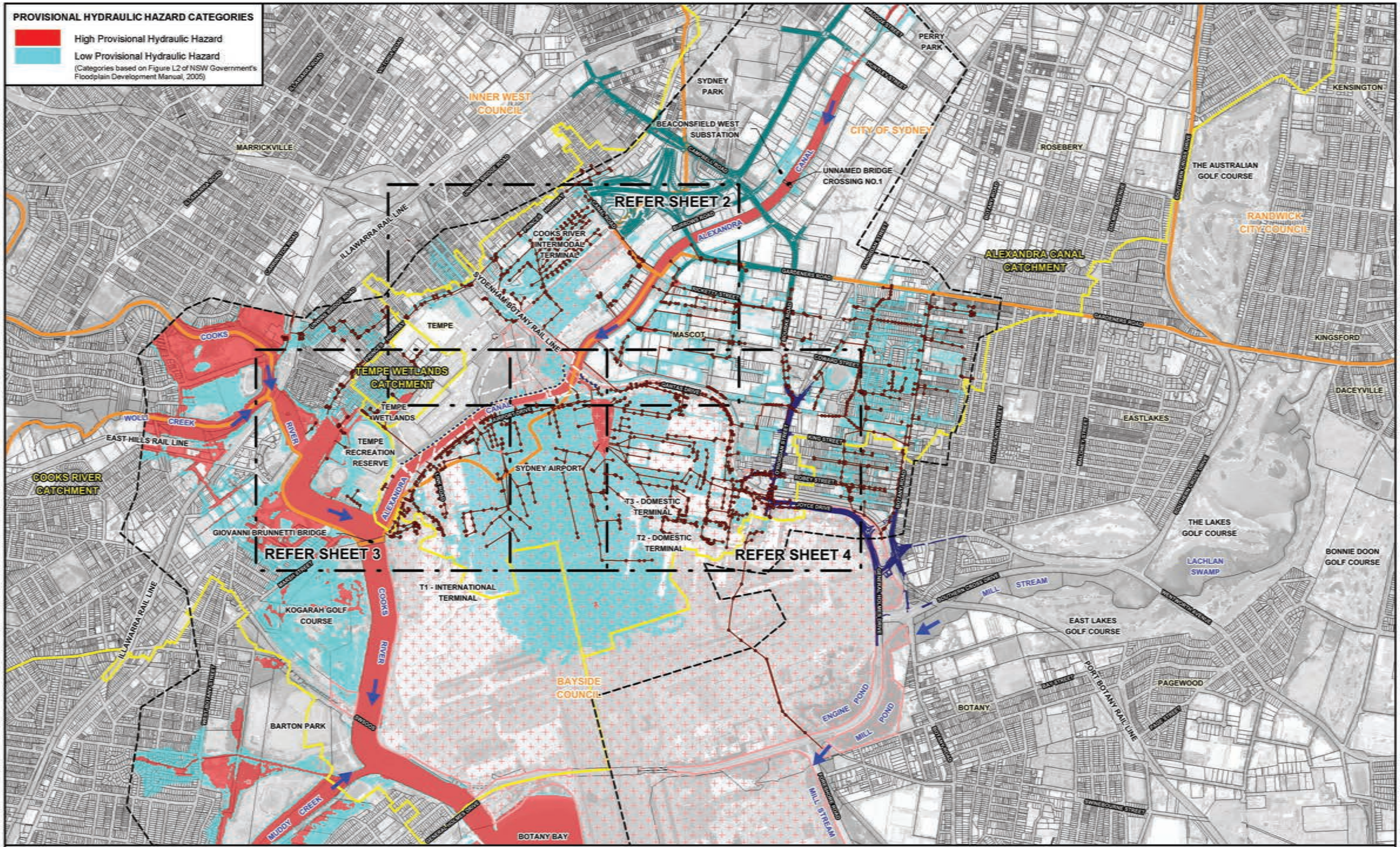
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.8
(Sheet 4 of 4)

PRELIMINARY HYDRAULIC CATEGORISATION
PRE-PROJECT CONDITIONS - 1% AEP EVENT



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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.

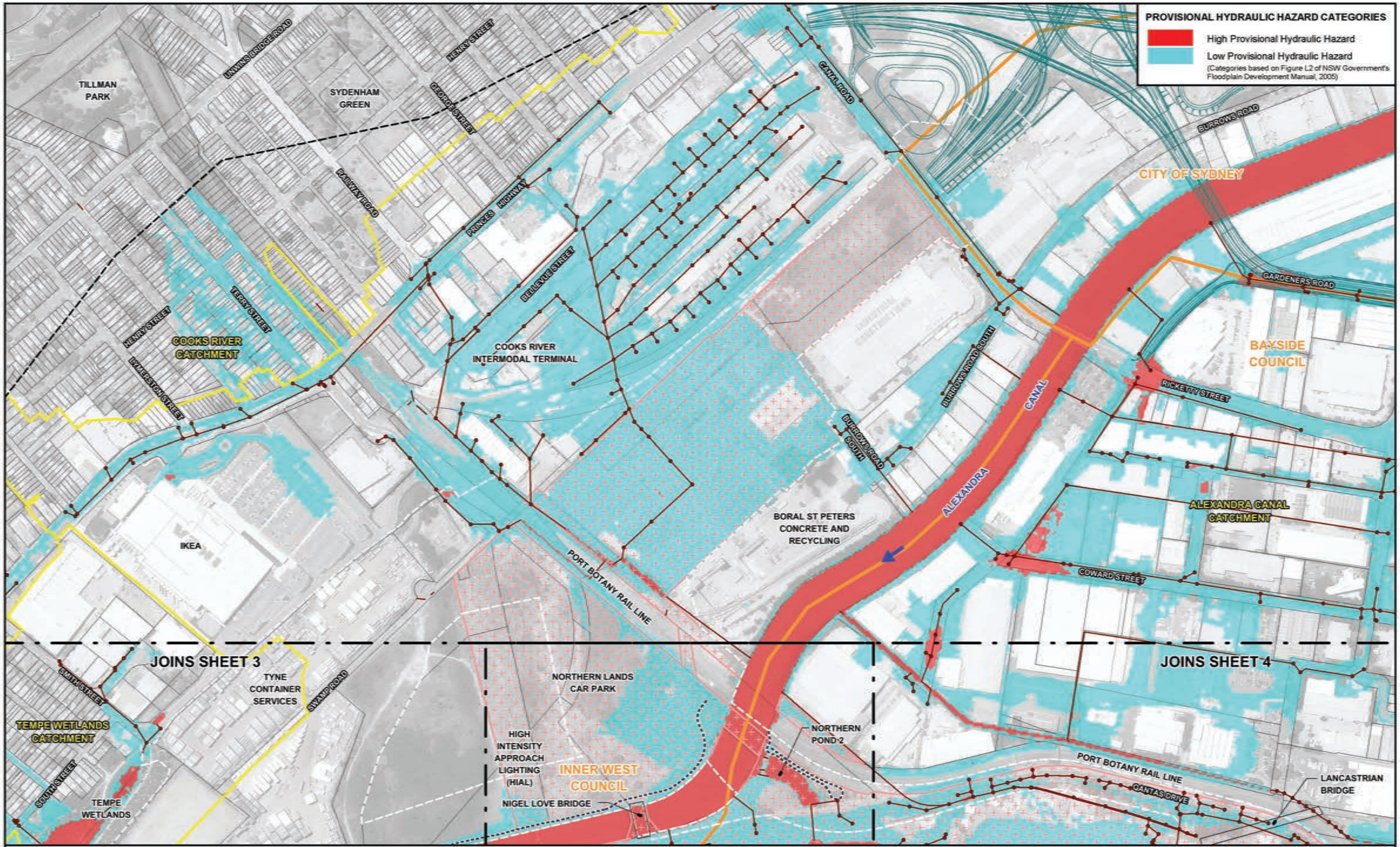
LEGEND

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

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.9
(Sheet 1 of 4)

PROVISIONAL FLOOD HAZARD CATEGORISATION
PRE-PROJECT CONDITIONS - 1% 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.

Lyall & Associates

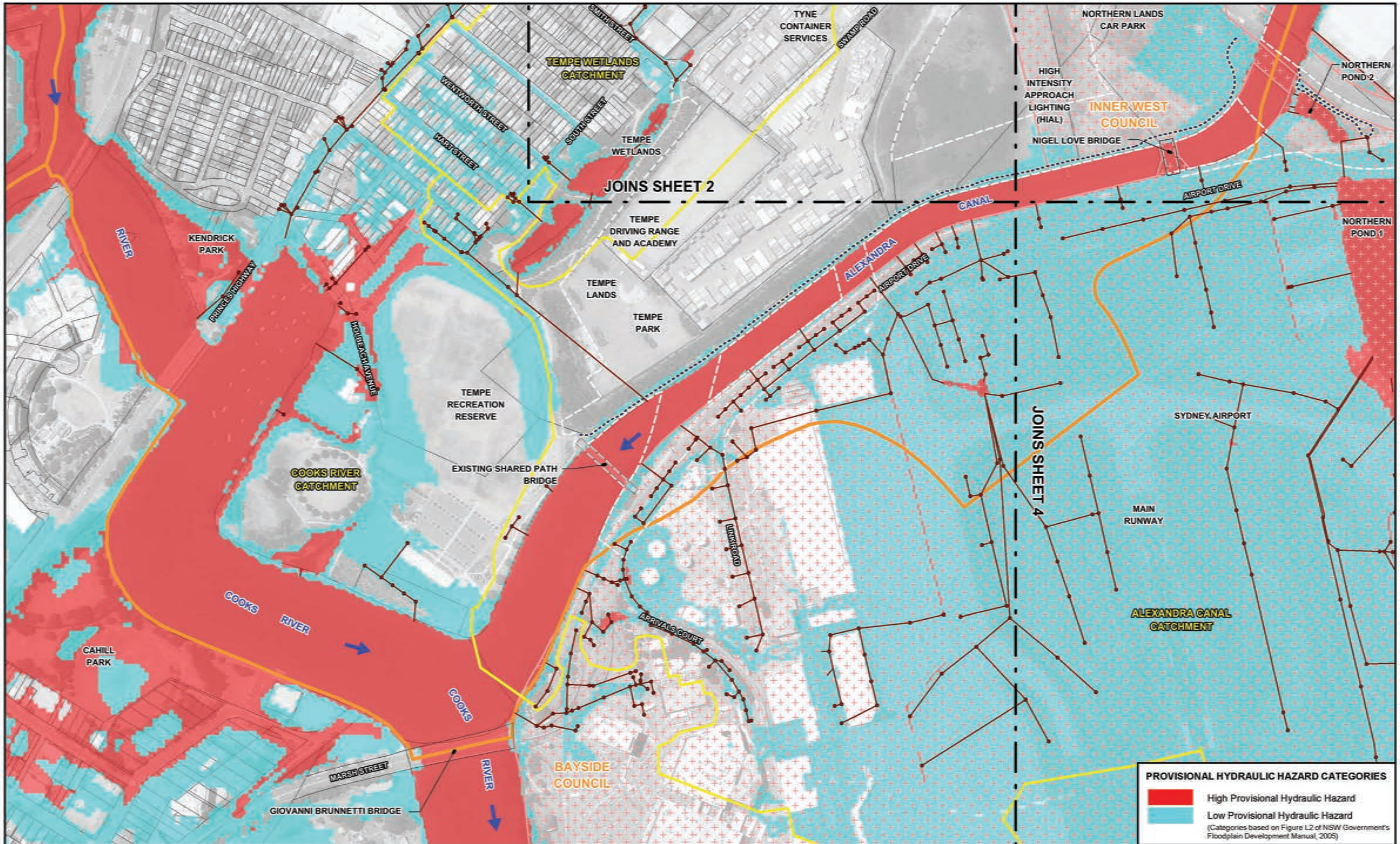
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.9
(Sheet 2 of 4)

PROVISIONAL FLOOD HAZARD CATEGORISATION
PRE-PROJECT CONDITIONS - 1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

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.

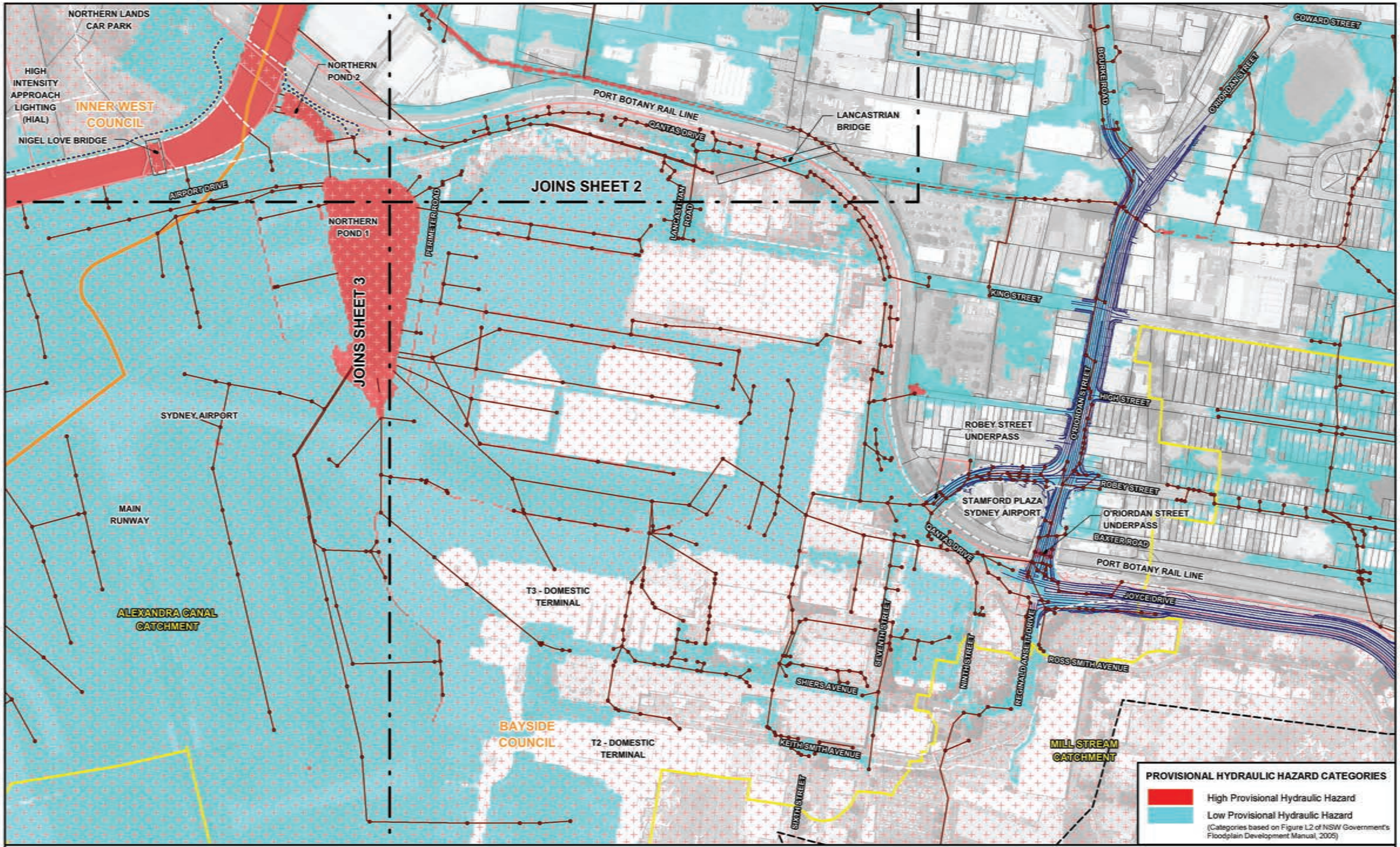
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.9
(Sheet 3 of 4)

PROVISIONAL FLOOD HAZARD CATEGORISATION
PRE-PROJECT CONDITIONS - 1% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

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.

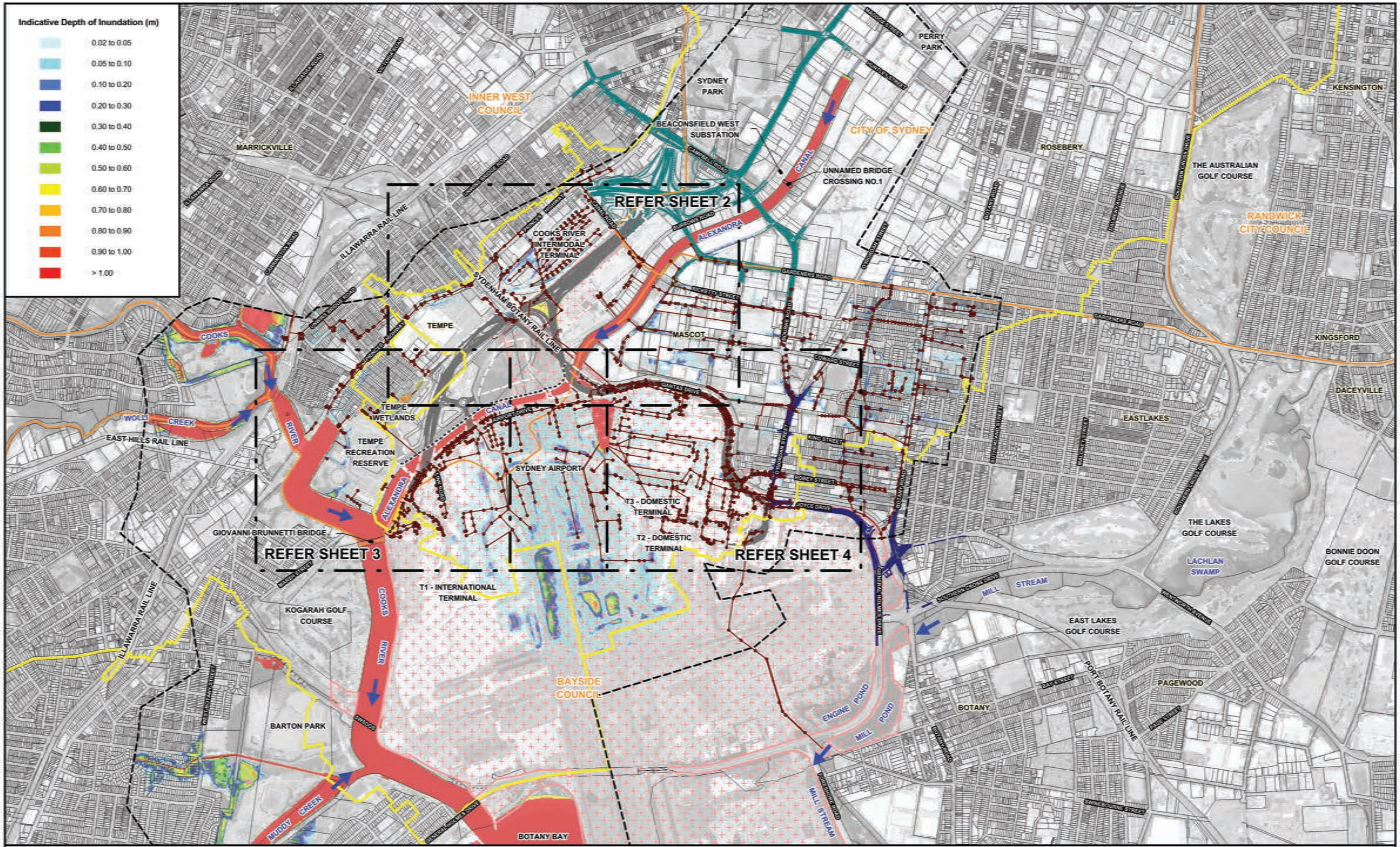
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System
- Active transport facility
- Project Footprint
- Two-Dimensional Model Boundary
- Airport North and Airport East Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.9
(Sheet 4 of 4)

PROVISIONAL FLOOD HAZARD CATEGORISATION
PRE-PROJECT CONDITIONS - 1% 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

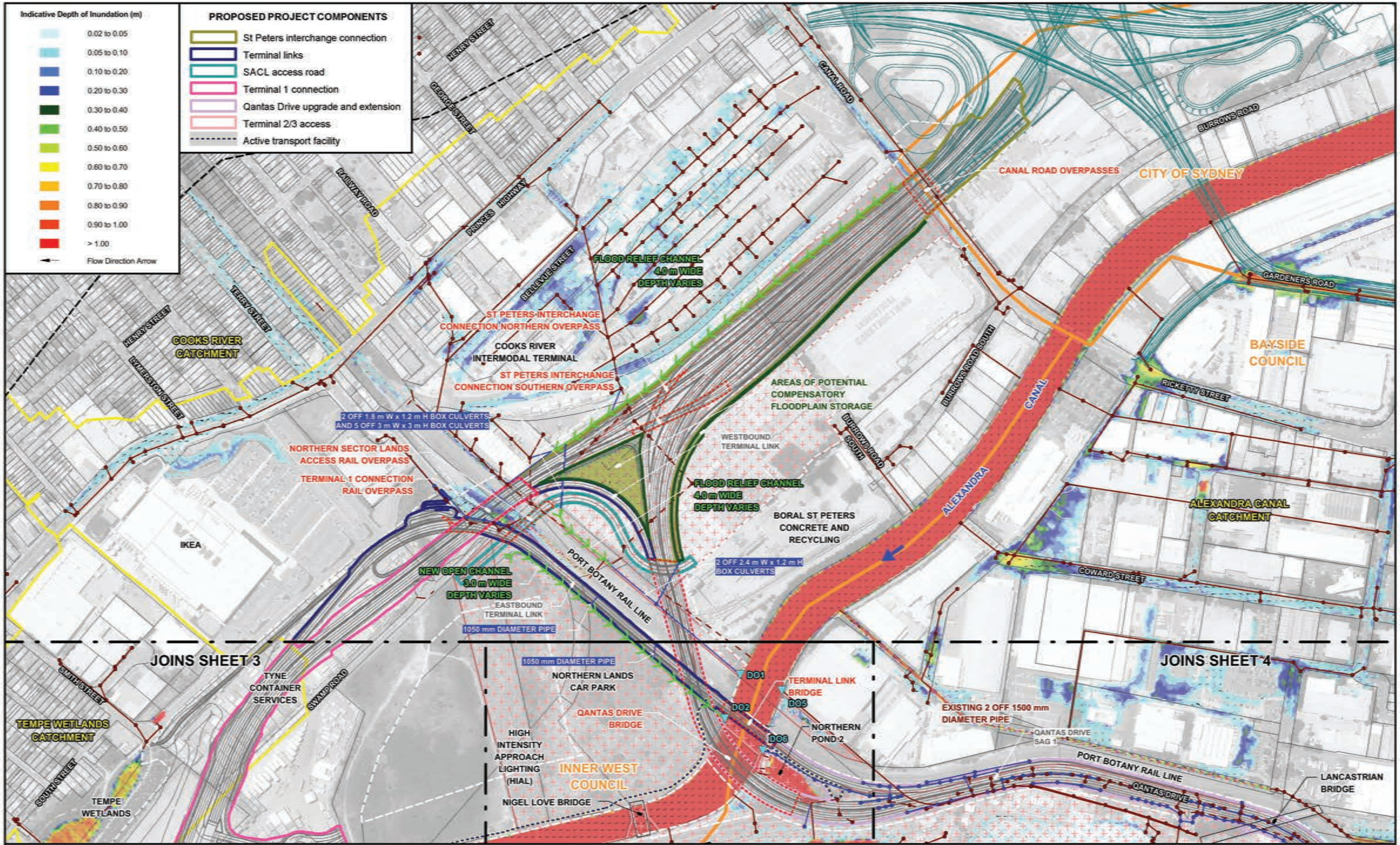
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Modelled Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.10
(Sheet 1 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 50% 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.

Lyall & Associates

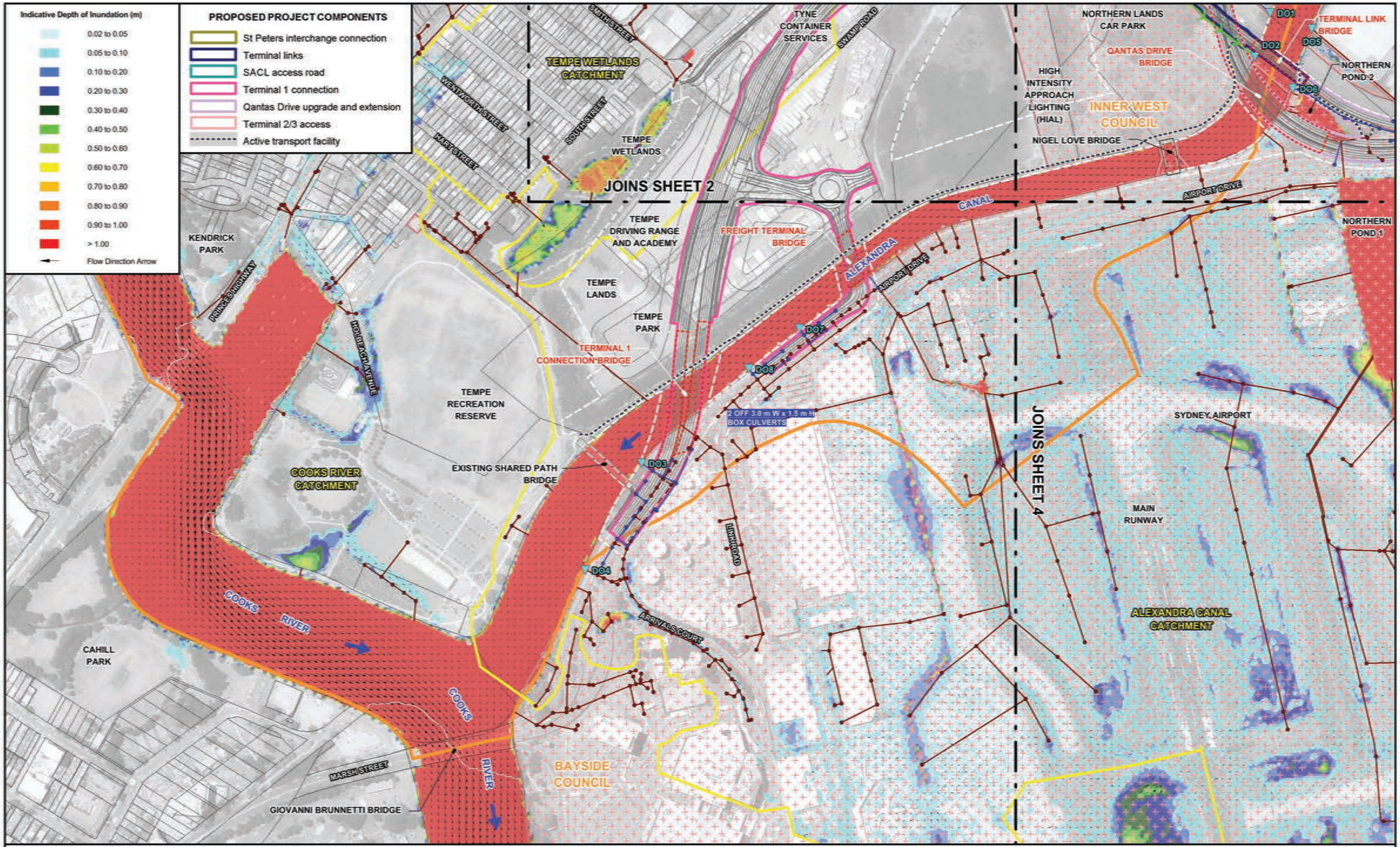
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- New M5 Surface Road Works
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary
- 1.2 Water Surface Elevation Contours

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.10
(Sheet 2 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 50% 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.

Lyall & Associates

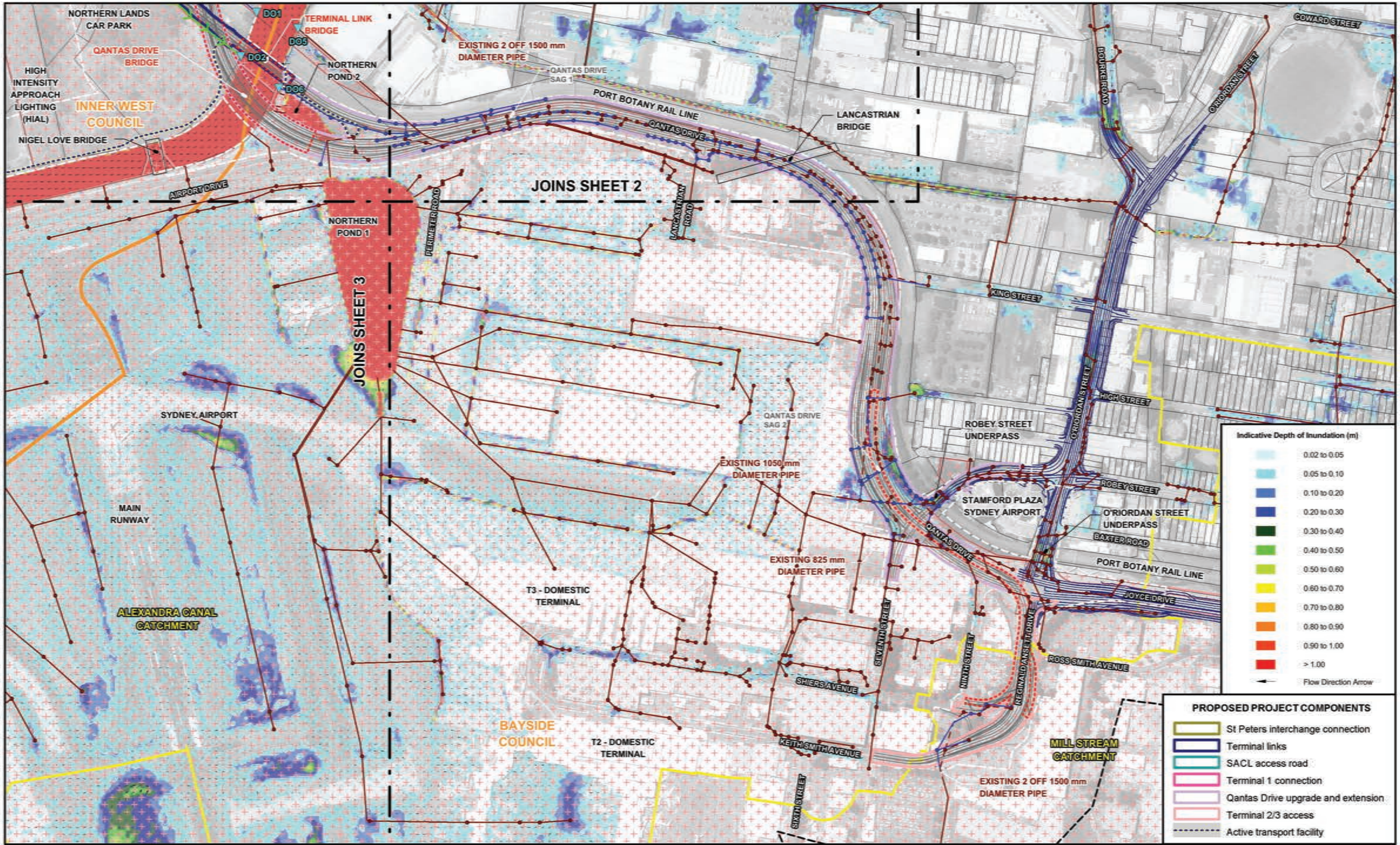
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- Water Surface Elevation Contours
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.10
(Sheet 3 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 50% 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.

Lyall & Associates

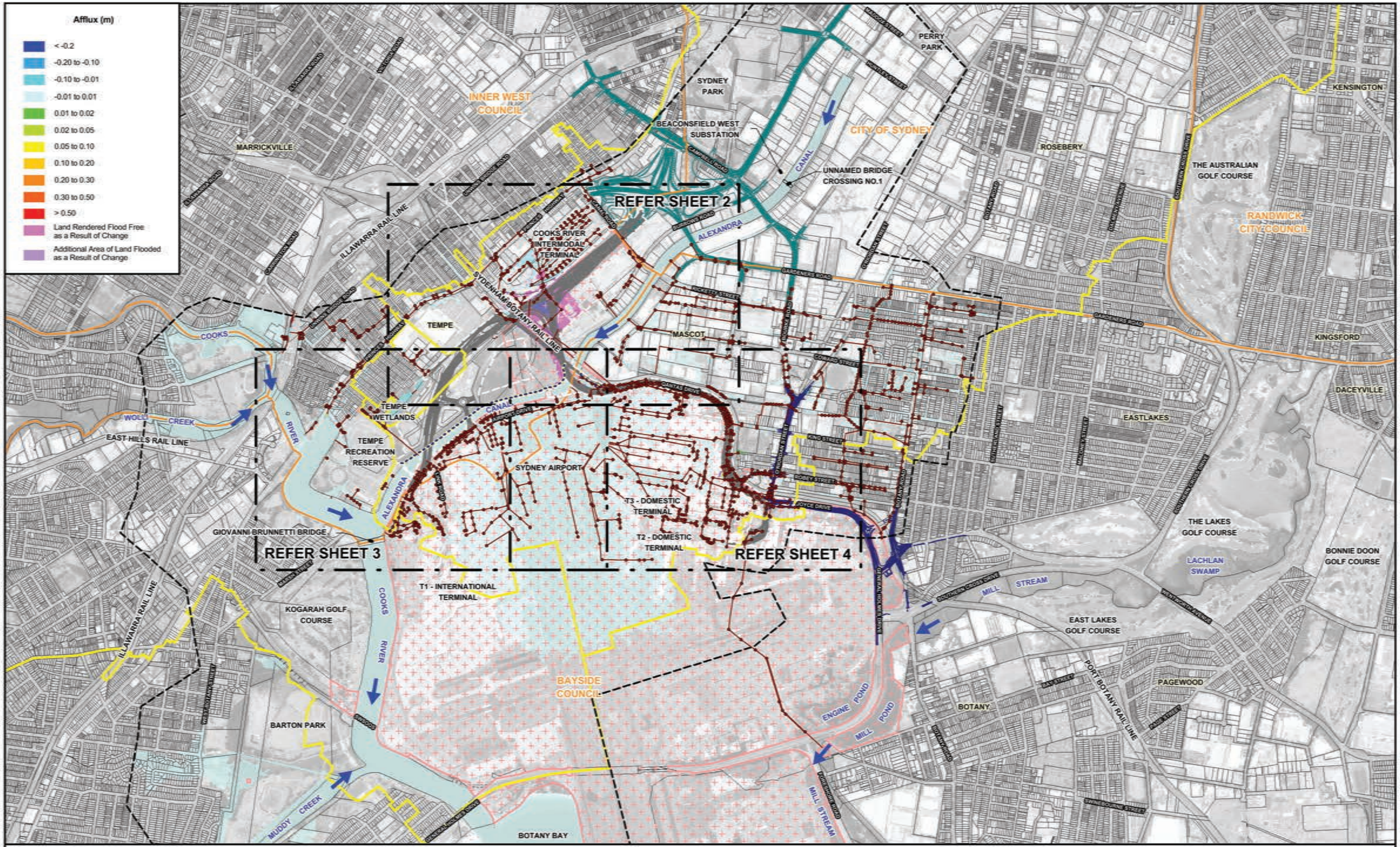
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary
- 1.2 Water Surface Elevation Contours

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.10
(Sheet 4 of 4)

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



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.

LEGEND

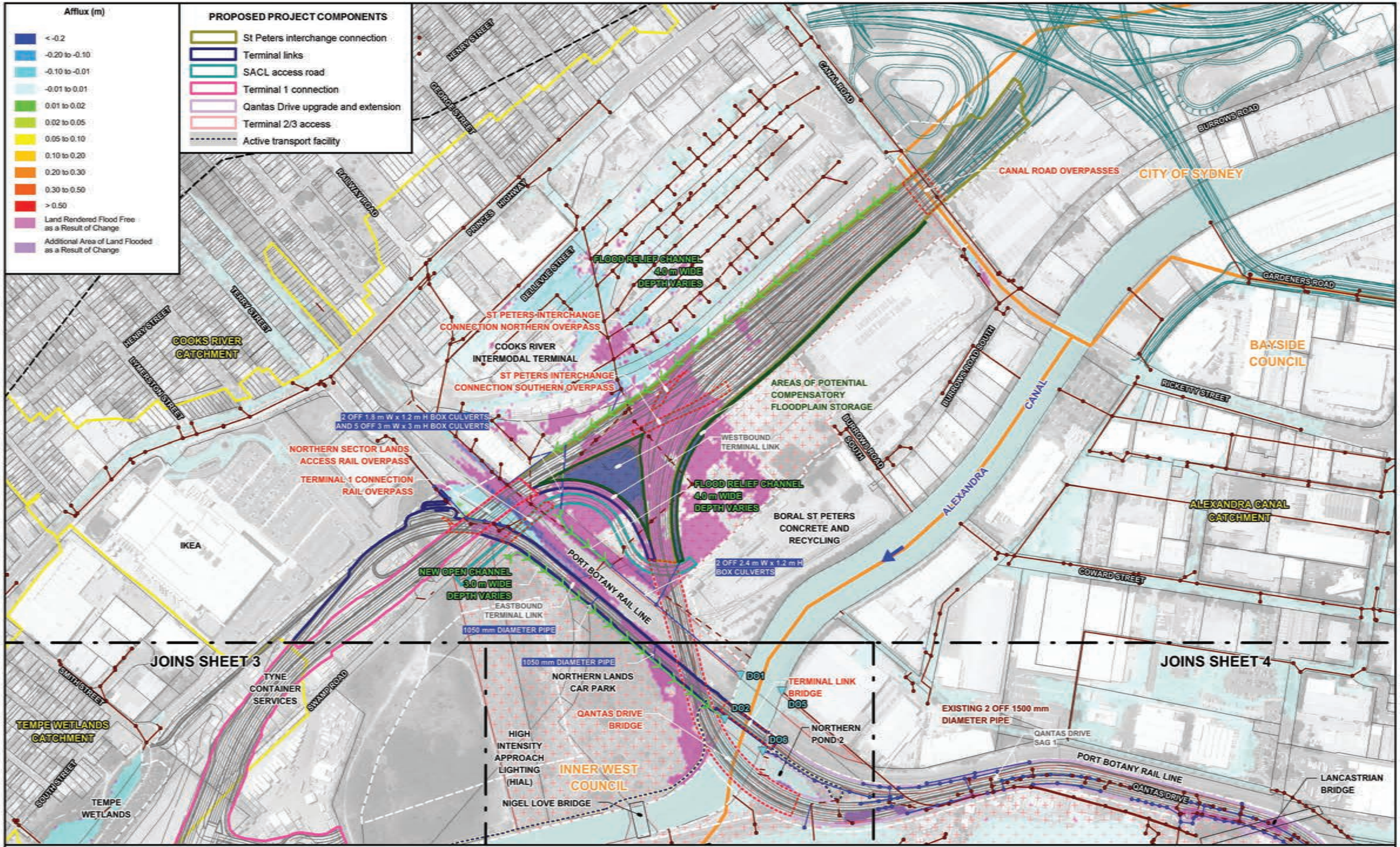
- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Modelled Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- New M5 Surface Road Works

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.11
(Sheet 1 of 4)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
50% 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.

Lyall & Associates

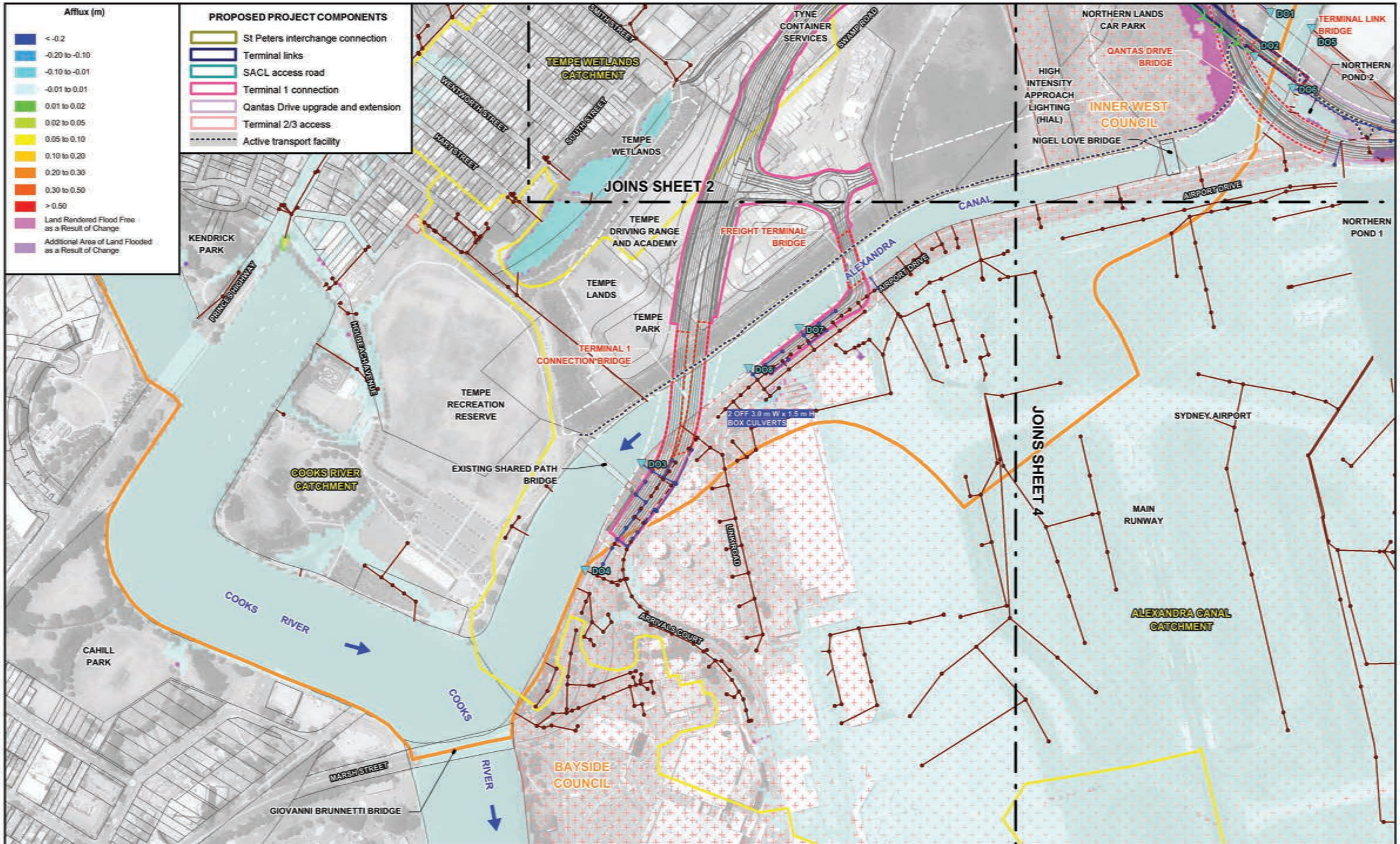
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- New M5 Surface Road Works
- Two-Dimensional Model Boundary
- D05 Drainage Outlet Location and Identifier

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.11
(Sheet 2 of 4)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
50% AEP EVENT



N

50 0 50 100 150 m

Scale: 1:5,000

Lyall & Associates

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.

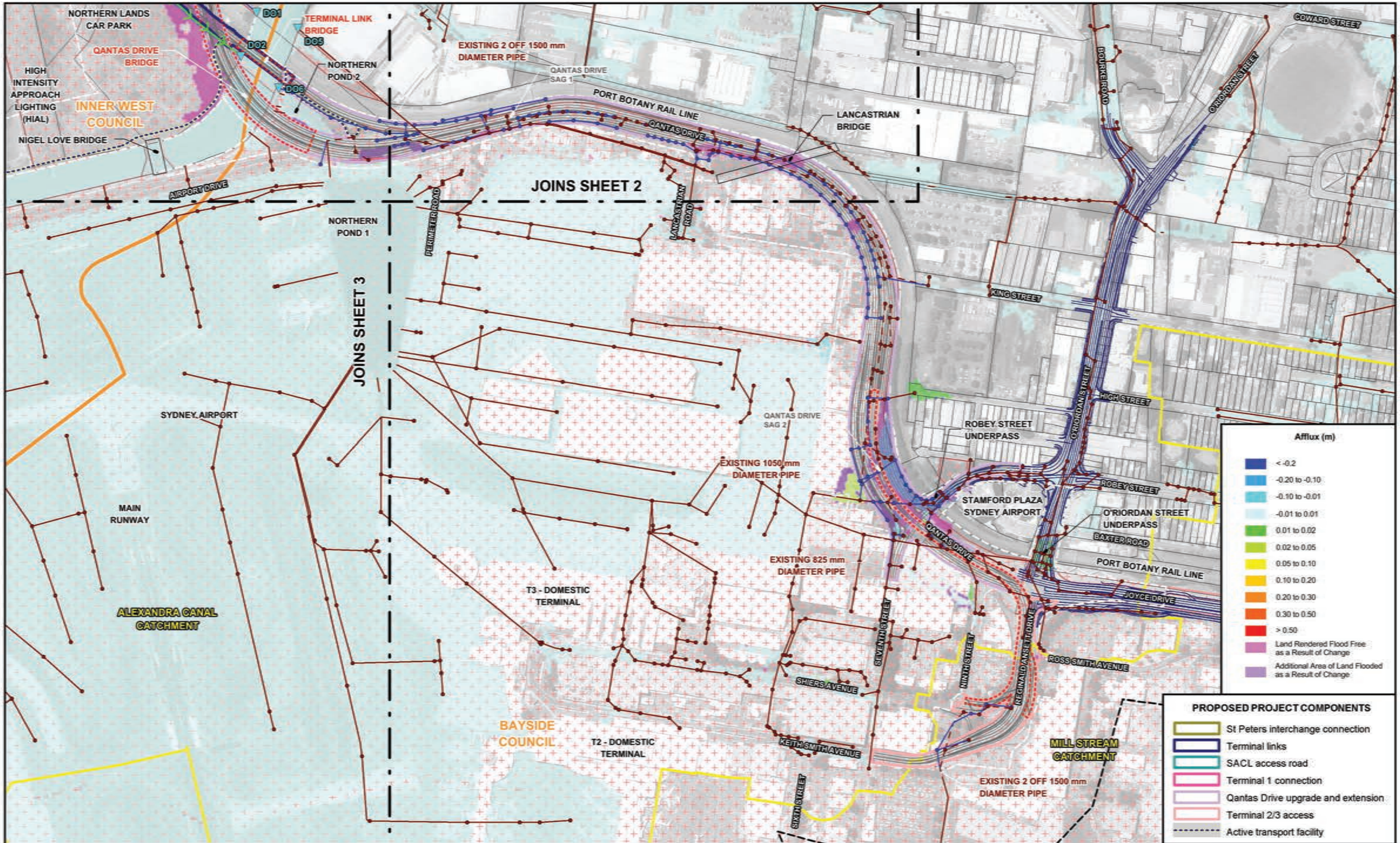
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.11
(Sheet 3 of 4)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
50% AEP EVENT



LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- Two-Dimensional Model Boundary
- DO5 Drainage Outlet Location and Identifier

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.

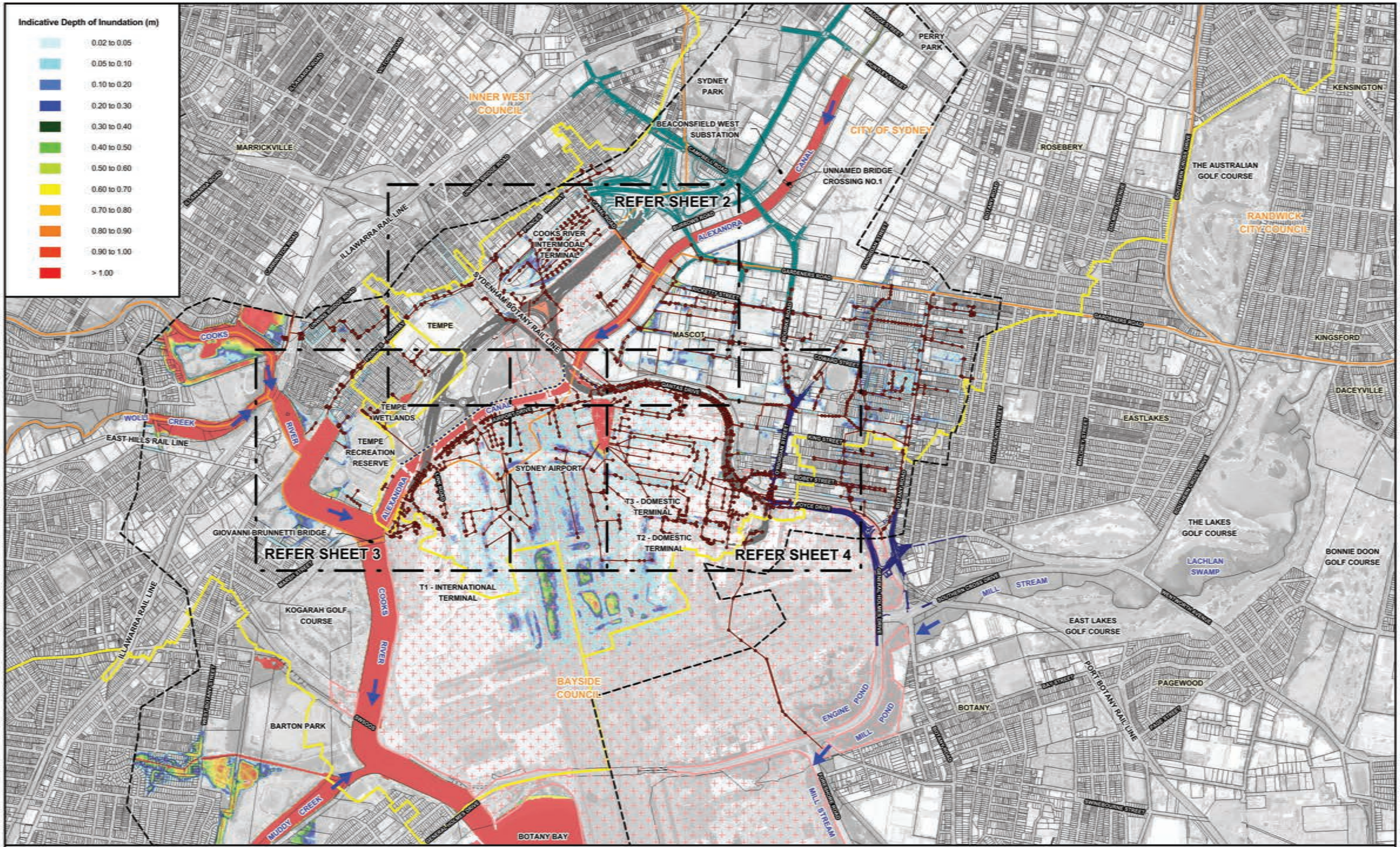
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.

Lyall & Associates

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.11
(Sheet 4 of 4)

IMPACT OF PROJECT OPERATION ON FLOOD BEHAVIOUR
50% AEP EVENT



N

200 0 200 400 600 m

Scale: 1:20,000

Lyall & Associates

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.

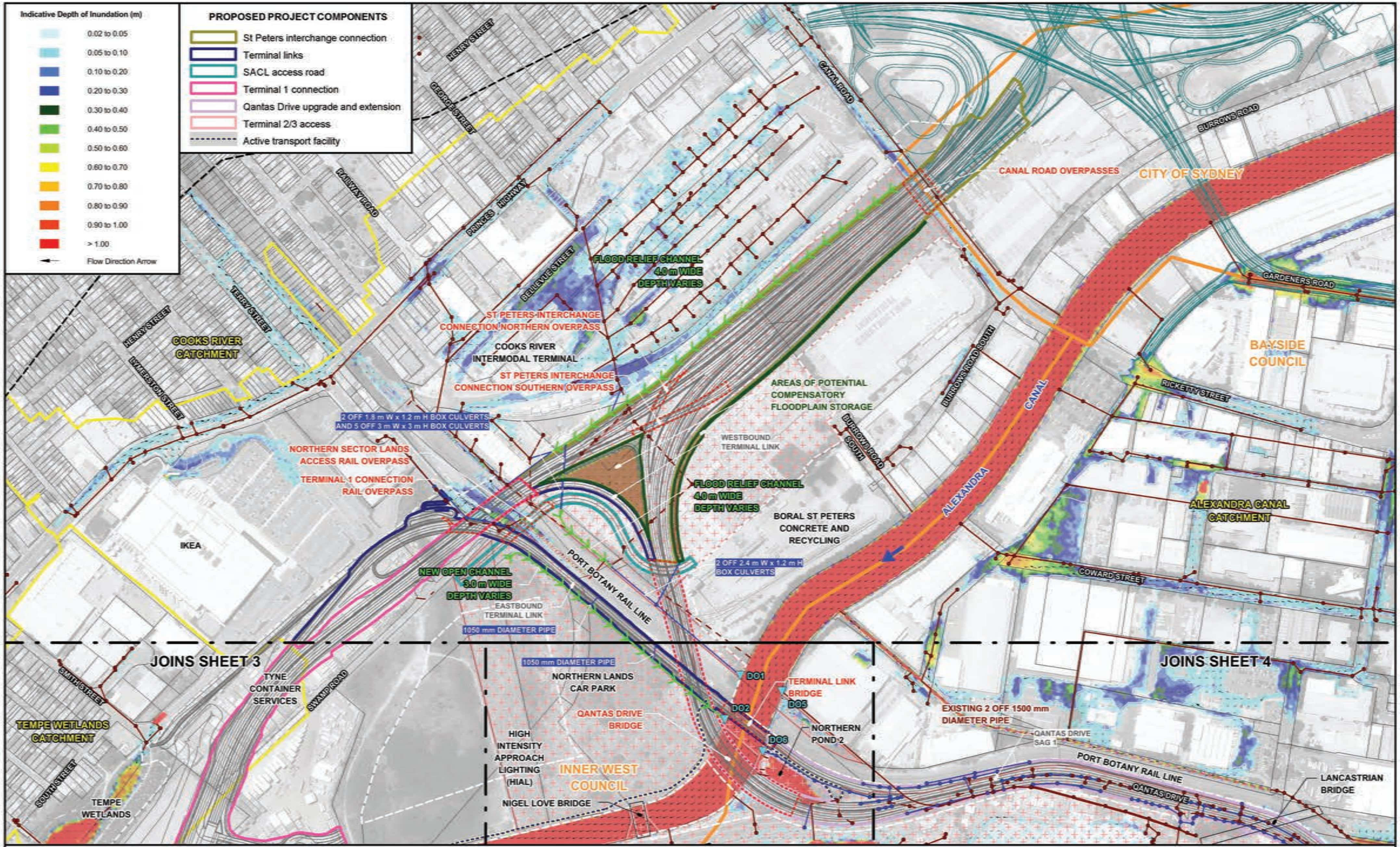
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Modelled Drainage System
- Two-Dimensional Model Boundary
- Active transport facility
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- New M5 Surface Road Works

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.12
(Sheet 1 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 20% 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.

Lyall & Associates

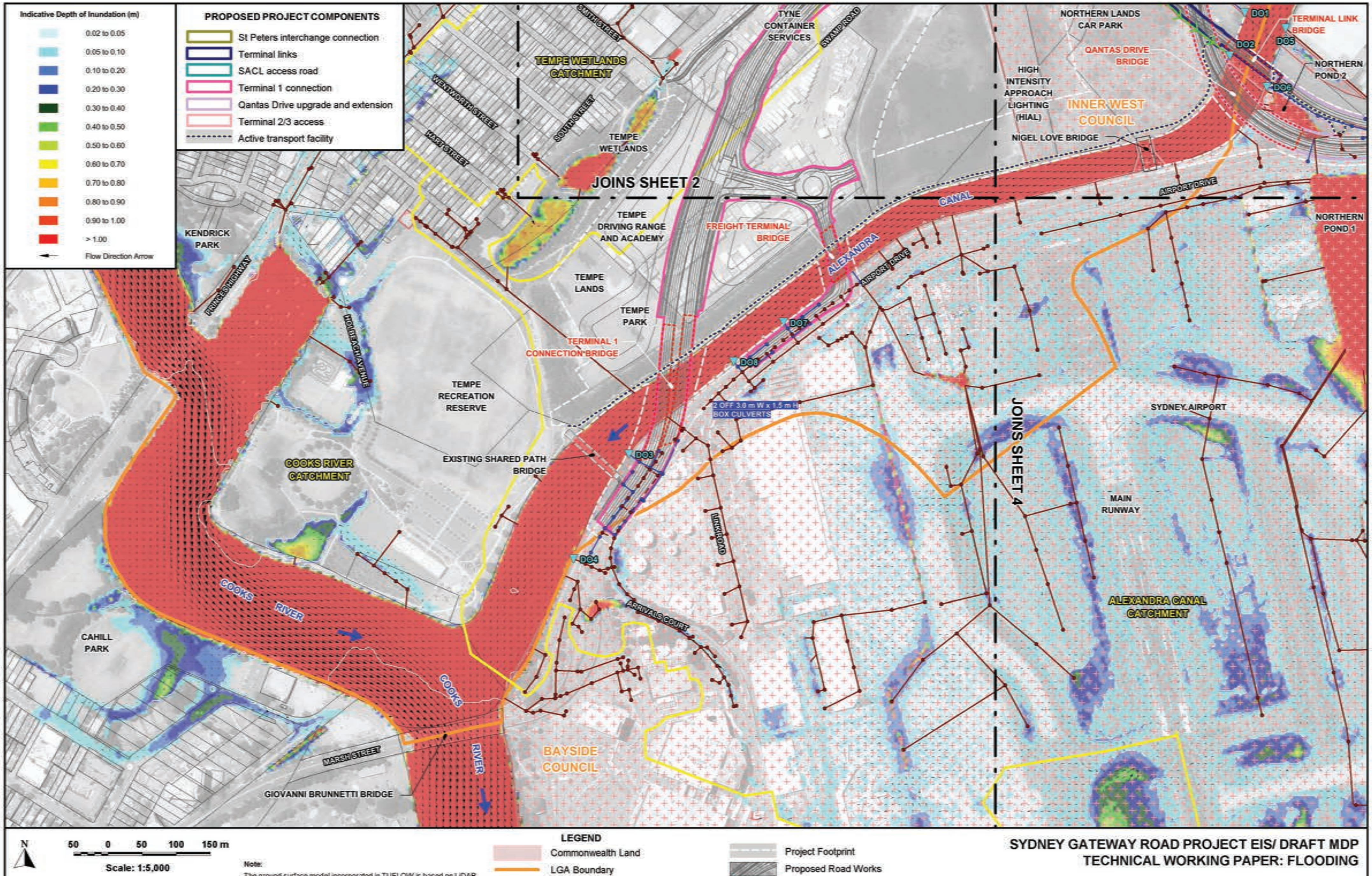
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- New M5 Surface Road Works
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary
- Water Surface Elevation Contours

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.12
(Sheet 2 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 20% 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.

Lyall & Associates

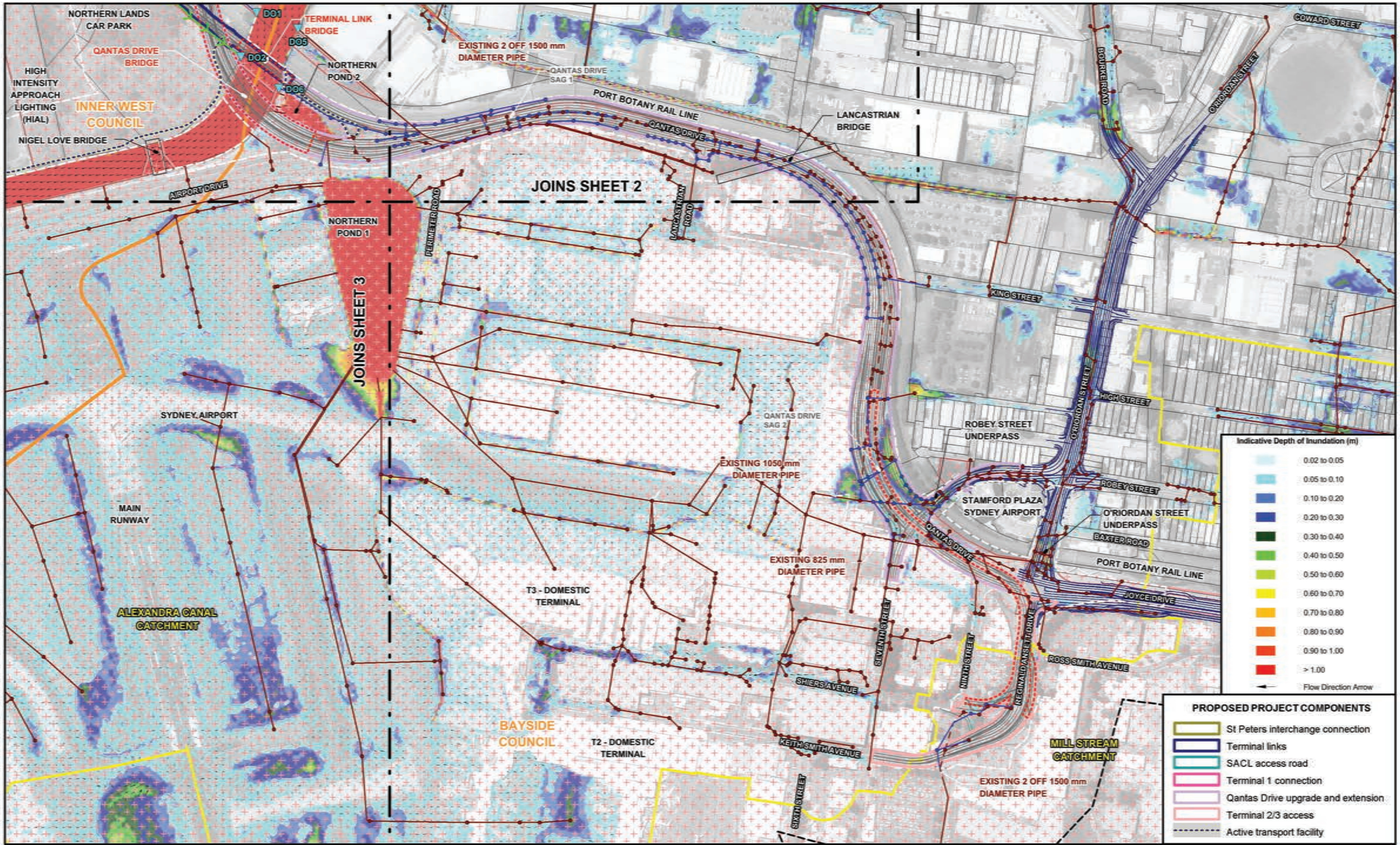
LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- 1.4 Water Surface Elevation Contours
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.12
(Sheet 3 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 20% 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.

Lyall & Associates

LEGEND

- Commonwealth Land
- LGA Boundary
- Catchment Boundary
- Existing Drainage System to Remain
- Existing Drainage System to be Abandoned/Demolished
- Proposed Drainage System
- Project Footprint
- Proposed Road Works
- Airport North and Airport East Road Works
- DO5 Drainage Outlet Location and Identifier
- Two-Dimensional Model Boundary
- Water Surface Elevation Contours

SYDNEY GATEWAY ROAD PROJECT EIS/ DRAFT MDP
TECHNICAL WORKING PAPER: FLOODING

Figure B.12
(Sheet 4 of 4)

PATTERNS OF MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW
OPERATIONAL CONDITIONS - 20% AEP EVENT