APPENDIX A
BACKGROUND TO DEVELOPMENT OF
WOLLI CREEK FLOOD MODELS

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Page No.

FIGURES
(BOUND IN VOLUME 2)

A1. SYNOPSIS

This Appendix provides background to the development of the hydrologic and hydraulic computer models that were developed to define flooding behaviour along the reach of Wolli Creek which runs along the southern side of the M5 East Motorway between King Georges Road and Bexley Road.

The hydrologic model relied upon for the present investigation was originally developed during the detailed design of the M5 East Motorway and more recently updated as part of the early planning for the New M5 project and more recently as part of the King Georges Road Interchange Upgrade (KGRIU) project which forms part of the broader WestConnex project.

The hydraulic models that were developed as part of the detailed design of the M5 East Motorway (HEC-2 and XP-EXTRAN) were not used as part of the more recent investigations. Rather, a two-dimensional modelling approach was adopted using the TUFLOW software. A separate HEC-RAS model was also developed of Wolli Creek and one of its tributaries, the results of which were used to define the upper envelope of potential flooding in the vicinity of the proposed tunnel portals.

A2. WOLLI CREEK RAFTS MODEL

A2.1 Background to hydrologic model development

Wolli Creek catchment has a history of flooding which had been investigated in several detailed flood studies undertaken in the last 25 years. The most recent investigations were undertaken by Willing and Partners (WP) for the design of the M5 East Motorway project and used a hydrologic catchment model based on the RAFTS approach (refer reports entitled "*M5 East Motorway – Preliminary Design Report for Hydraulic and Water Quality Concepts (King Georges Road to Bexley Road"* (WP, 1999) and *"M5 East Project Report on Flood Risk Assessment"* (WP,2000)).

In RAFTS, the catchment is sub-divided into a number of sub-catchments and connected to represent the layout of the drainage system. Rainfall on each sub-catchment is adjusted to allow for infiltration and other losses. The resulting sub-area rainfall-excess is converted into a hydrograph and progressively added to runoff from the other areas in the drainage system, with the combined flow being routed through the system to the outlet.

In addition to rainfall losses, the model requires other parameters relating to the time of travel of the floodwave through the drainage system. Ideally these parameters are derived by calibrating the model to historic storm events and using the calibrated model for the estimation of design flood events. However, there are no historic streamflow data available for Wolli Creek and consequently, WP used values which had been adopted in flood investigations in the Sydney region.

Two RAFTS models were developed by WP during the detailed design of the original M5 East Motorway project. The first was used to generate discharge hydrographs for design storms up to 500 year ARI (**WP RAFTS Model**), whilst the second was used to generate discharge hydrographs for the PMF (**WP PMF RAFTS Model**).[1] **Figure A2.1** shows the layout of the WP RAFTS Model.

[1] It is noted that the structure of the WP PMF RAFTS Model differs from that of the WP RAFTS Model. The reasons for these structural differences are not known.

The structure of the WP RAFTS Model was reviewed and was considered appropriate for adoption in this present study, with the exception that the lag time in the concrete lined section of channel which runs between Kingsgrove Road and Bexley Road was adjusted based on the results of the TUFLOW modelling (refer **Section A2.3.2** for details).

A2.2 Design storms

A2.2.1 Rainfall intensity

Design storms of return periods between 1 in 20 and 1 in 200 years were derived from Australian Rainfall & Runoff (ARR) (Institution of Engineers Australia (IEAust), 1998) for storm durations ranging between 30 and 180 minutes.

A2.2.2 Areal reduction factors

The rainfalls derived using the processes outlined in IEAust, 1998 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.

For this present study, IEAust, 1998 indicates that for a catchment area of 11.5 square kilometres, an ARF value of about 0.98 should be applied to design rainfalls. However, a value of 1 was selected for design purposes, in keeping with the approach adopted for the larger Cooks River catchment (refer **Appendix B** of this technical working paper for details).

A2.2.3 Temporal patterns

Temporal patterns for various zones in Australia are presented in IEAust, 1998. These patterns are used in the conversion of a design rainfall depth with a specific ARI into a design flood of the same frequency. Patterns of average variability are assumed to provide the desired conversion. The patterns may be used for ARIs up to 500 years where the design rainfall data is extrapolated to this ARI.

A2.3 RAFTS model parameters

A2.3.1 Rainfall losses

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 and combines them at the catchment outlet.

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 1.5 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 100 year ARI design storm event. The results showed that the peak discharge was not particularly sensitive to pervious initial loss, because about 50 per cent of the total catchment surface is impervious.

Loss values adopted for design flood estimation are shown in **Table A2.1**.

TABLE A2.1
DESIGN LOSS VALUES

Type of Surface	Initial Loss (mm)	Continuing Loss (mm/h)
Pervious Areas	20	1.5
Impervious Areas	1.5	0

A2.3.2 Routing parameters

During the early phases of the study it was found that the travel times in the WP RAFTS Model for the reach of Wolli Creek between Kingsgrove Road and Bexley Road were too long when compared to the results of the TUFLOW hydraulic model. The lag times in the WP RAFTS Model were therefore reduced based on an average flow velocity in the modelled reach of channel of 3 metres per second (**Adjusted RAFTS Models**). **Figure A2.2** shows the relative timing of the discharge hydrograph which was generated by the Adjusted RAFTS Models and after it was routed through the TUFLOW hydraulic model.
Similar to the WP RAFTS Model, a Bx factor of 1.0 was incorporated in the Adjusted RAFTS Models.

A2.3.3 Surface roughness parameters

The WP RAFTS model developed as part of the detailed design of the original M5 East Motorway project contained Manning's n surface roughness values of 0.025 and 0.035 for the impervious and pervious portions of the catchment, respectively. No changes were made to these values as part of the present investigation.

A2.4 Probable maximum precipitation

The flooding investigations that were undertaken as part of the detailed design of the original M5 East Motorway project derived estimates of probable maximum precipitation (PMP) based on the Generalised Short Duration Method (GSDM) as described in *Bulletin 53: The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method* (Bureau of Meteorology (BOM, 1994). In 2003, BoM issued an update of Bulletin 53 which incorporated a revised method of spatial distribution of rainfall and updated moisture factors (*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* - BoM, 2003).

For the KGRIU project (*King Georges Road Interchange Upgrade Flooding and Drainage Investigation* – Lyall & Associates (L&A), 2014), estimates of probable maximum precipitation (PMP) were derived using the methodology prescribed in BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 6 hours.

The steps involved in assessing revised PMP estimates for the Wolli Creek catchment are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data, but modified in the light of Australian experience.
- Derive storm hyetographs using the temporal distribution contained in Bulletin 53, which is based on pluviographic traces recorded in major Australian storms.

No PMP ellipses are presented WP, 1999 and WP, 2000. It was therefore necessary to rely on the input data that is contained in the WP PMP RAFTS Model for assigning revised PMP rainfall depths to the sub-catchments in the model. In addition to updating the PMP depth estimates in the model (**Adjusted WP PMF RAFTS Model**), the lag time in several of the model links was also adjusted as described in **Section A2.3.2**.

A2.5 Design discharge hydrographs

The Adjusted WP PMF RAFTS Model was run with the parameters given in **Annexure A** to obtain design hydrographs for input to the TUFLOW hydraulic model. **Table A2.2** at the end of this chapter gives peak flows at key locations along the main arm of Wolli Creek and at inflow points to the TUFLOW hydraulic model for design storms with ARI's of 20 and 100 years, as well as the PMF.

For comparative purposes, peak flow estimates for the PMF event based on the methodology set out in BoM, 1994 are also presented in **Table A2.2**. The revised methodology of BoM, 2003 for deriving PMP estimates led to a 5 per cent increase at Kingsgrove Road, and about a 9 per cent increase at Bexley Road in the peak flow estimate for the PMF event. The peak flows on Wolli Creek between Beverly Hills Park and Bexley Road range between 3.5 and 3.7 times the magnitude of the 100 year ARI peak. These values are at the lower limit of expected values for small urbanised catchments.

Discharge hydrographs generated by the Adjusted RAFTS Model may be compared with the TUFLOW discharge hydrographs, which are also shown on **Figure A2.2**. The estimates of peak overland flow discharge derived by TUFLOW are less than those derived by RAFTS. This difference is attributed to the attenuating effects of the storage which is present on the floodplain and which is incorporated into the two-dimensional model domain of TUFLOW, but is not specifically modelled by RAFTS.

Given the uncertainties associated with the background to the development of the WP PMF RAFTS Model, leading to the possible underestimation of peak flows, it is recommended that a new hydrologic model be developed and used to derive discharge hydrographs and peak flow estimates for the PMF event as part of the detailed design of the New M5 project.[2]

[2] This recommendation did not apply to the detailed design of the KGRIU project as it is located on land which lies above the PMF.

TABLE A2.2
SUMMARY OF PEAK FLOWS
(m^3/s)

Location	TUFLOW Inflow Hydrograph Identifier(1)	Design Storm Event (year ARI)			PMF	
		20(4)	100(4)	200(4)	BOM, 1994(2)	BOM, 2003(3)
King Georges Road	WC01	6.5	8.6	10	22	23
Kirrang Street	WC02	6.4	8.4	9.8	19	20
Canterbury Golf Course	WC03	46	62	74	157	164
Rosebank Avenue	WC04	6.3	8.2	9.7	19	20
Amtree Street	WC05	5.9	7.8	9.3	19	20
Beverly Hills Park	WC06	116	156	185	534	561
Garema Circuit	WC07	5.1	6.9	8.2	17	18
	WC08	0.6	0.8	0.9	1.7	1.8
Smith Reserve	WC09	21	27	32	64	67
West of Forrester Street	WC10	0.7	0.9	1.1	2.1	2.2
Forrester Street	WC11	0.7	0.9	1.1	2.1	2.2
Sheffield Street	WC12	0.4	0.5	0.5	1.0	1.1
Richland Street	WC13	9.9	13	16	34	35
Kingsgrove Road	-	186	250	297	836	875
Kingsgrove Memorial Reserve	WC14	24	32	38	72	76
West of Arinya Street	WC15	2.0	2.7	3.2	5.9	6.1
Arinya Street	WC16	1.9	2.4	2.8	4.8	5.0
Pangee Street	WC17	3.4	4.5	5.2	9.2	9.7
Giraween Street	-	198	267	317	883	937(4)
Bobadah Street	WC18	3.1	4.0	4.7	8.2	8.6
South of Beaconsfield Avenue	WC19	1.2	1.5	1.8	3.1	3.2
Gilchrist Park	WC20	14	18	22	43	45
Bexley Road	WC21	14	18	23	43	45
Kingsgrove Avenue Reserve	-	208	282	334	930	1010(4)
Bexley Road	-	210	285	337	938	1022(4)

1. Refer **Figure A3.1** for location of TUFLOW model inflow boundaries.
2. Peak flows presented for PMP rainfall depths for 60 minute storm duration.
3. Unless otherwise noted, critical PMP storm is of 60 minutes duration.
4. Peak flows are for critical storm of 90 minutes duration.

A3. WOLLI CREEK TUFLOW MODEL

A3.1 Background to TUFLOW model development

Previous studies undertaken during the investigation and design of the M5 East Motorway used the HEC-2 (WP, 1995) and XP-EXTRAN (WP, 2000) software packages to define flooding behaviour along the main arm of Wolli Creek. Since the preparation of these earlier studies, more sophisticated modelling techniques have been developed which more accurately simulate the passage of a flood wave through the drainage system.

For the purpose of the present investigation, the TUFLOW software was used to convert the design discharge hydrographs generated by the WP RAFTS Model and the Adjusted WP PMF RAFTS Model into two-dimensional (in plan) flooding patterns.

A3.2 The TUFLOW modelling approach

TUFLOW solves the equations of flow at each point of a rectangular grid system which represent overland flow on the floodplain and along streets. The choice of grid point spacing depends on the need to accurately represent features on the floodplain which influence hydraulic behaviour and flow patterns (e.g. buildings, streets, changes in channel and floodplain dimensions, hydraulic structures which influence flow patterns, etc).

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

Pipe drainage and channel systems can be modelled as one-dimensional elements embedded in the larger two-dimensional domain which typically represents the wider floodplain. Flows are able to move between the one and two-dimensional elements of the model depending on the capacity characteristics of the drainage system being modelled.

A3.3 TUFLOW model setup

A3.3.1 Model structure

The layout of the TUFLOW model developed as part of the present investigation (**Wolli Creek TUFLOW Model**) is shown on **Figures A3.1** (2 Sheets). All of the features which influence the passage of flow were included in the TUFLOW model which comprises piped reaches on the main arms, cross drainage pipes, open channels which are modelled by cross sections normal to the direction of flow, as well as overland flow which is modelled by the rectangular grid. **Table A3.1** over the page gives details of the M5 East Motorway transverse drainage structures that were incorporated in the TUFLOW model.

In addition to the transverse drainage structures listed in **Table A3.1**, flood relief is also provided via the Karingal Street, Arinya Street and Lundy Avenue underpasses, details of which were also incorporated in the TUFLOW model.

Discharge hydrographs from the RAFTS sub-catchments were added as distributed flow at the model boundaries and at internal locations identified in **Figure A3.1**.

TABLE A3.1
DETAILS OF M5 EAST MOTORWAY TRANSVERSE DRAINAGE STRUCTURES INCORPORATED INTO TUFLOW MODEL

Transverse Drainage Structure Identifier(1)	Dimensions (mm)(2)	Invert Level (metres AHD)	
		Inlet on Northern Side of Motorway Corridor	Outlet to Wolli Creek
XD1	2 off 4200 x 1800 RCBC's	21.6	21.18
XD1A	1 off 1050 RCP	20.56	20.33
XD2	2 off 1200 RCP's	26.11	20.10
XD3	2 off 1200 RCP's	24.25	18.63
XD4	1 off 1800 RCP	20.25	15.88
XD5	1 off 1050 RCP	20.00	15.36
XD6	1 off 1050 RCP	15.90	15.03
XD7	1 off 1050 RCP	14.97	14.84
XD8	1 off 1050 RCP	14.80	13.81
XD9	2 off 2100 x 1800 RCBC's	13.87	13.57
XD10	1 off 1500 RCP	13.20	11.17
XD11	1 off 1350 RCP	11.55	10.50
XD12	1 off 1500 RCP	13.55	10.13
XD13	1 off 1500 RCP	14.57	9.51
XD14	1 off 1050 RCP	18.60	7.33
XD15	1 off 2400 RCP	5.63	5.21

1. Refer **Figure A3.1** for location of transverse drainage structures.
2. RCBC = Reinforced Concrete Box Culvert RCP = Reinforced Concrete Pipe

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.

After initial model testing, a 2 metre grid spacing was found to provide the appropriate balance between the need to define features on the floodplain versus model run times. Grid elevations were based on available LiDAR survey data. 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 located in the two-dimensional model domain 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.

A3.3.2 Model parameters

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths, as well as for the cross sections representing the geometric characteristics of the creek between King Georges Road and Bexley Road. 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”. Flow in the piped system also requires an estimate of hydraulic roughness.

There are no historic flood level data available to assist with the tuning of the model for roughness. Assessment of Manning’s n values for the cross sections comprising the concrete lined and unlined sections of Wolli Creek was relatively straightforward. Cross sections taken normal to the direction of flow have traditionally been used for one-dimensional modelling of waterways and there are numerous previous studies and references in the engineering literature relating various types of surfaces to hydraulic roughness.

Table A3.2 over the page presents the “best estimate” of hydraulic roughness values adopted for design purposes. 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.

A3.4 Sensitivity of flood behaviour to increase in hydraulic roughness

Figure A3.2 shows the difference in peak flood levels (i.e. the “afflux”) for the 100 year ARI storm resulting from an assumed 20 per cent increase in hydraulic roughness compared to the “best estimate” values given in **Table A3.2** over the page. The afflux is given in colour coded increments in metres. The figure also identifies areas where land is rendered flood free, or where additional areas of land are flooded.

There will be only a minor increase in peak 100 year ARI flood levels along the northern side of the motorway corridor in the vicinity of the inlet to transverse drainage structure XD1, while peak 100 year ARI flood levels south of the corridor will be increased generally in the range 0-200 millimetres upstream and in the range 0-300 millimetres downstream of Kingsgrove Road.

TABLE A3.2
"BEST ESTIMATE" OF HYDRAULIC ROUGHNESS VALUES
ADOPTED FOR TUFLOW MODELLING

Surface Treatment	Manning's n Value
Concrete channel	0.015
Asphalt or concrete road surface	0.02
Well Maintained Grassed Cover e.g. sporting oval	0.03
Unlined channel/Flow over Road Impeded by Handrail	0.05
Grass/Lawns/Macrophytes	0.06
Trees	0.08
Creek bank	0.10
Fences Houses	1
Buildings	10

A3.5 Adjustments made to the structure of the Wolli Creek TUFLOW Model to reflect post-construction conditions

The following adjustments were made to the structure of the Wolli Creek TUFLOW Model in order to assess the impact the project would have on flooding behaviour and to also assess the flood risks to the project:

- The 3D concept design model for the project was spliced with the available LiDAR survey data.
- A new 1 off 3000 x 2400 RCBC was incorporated in the model to replace a section of the existing concrete lined channel upstream of cross drainage structures XD1.
- The existing section of concrete lined channel downstream of the new length of 3000 x 2400 RCBC was realigned.
- Cross drainage structures XD1 and XD2 were extended on the upstream (northern) side of the motorway.
- Cross drainage structures XD3 and XD4 were replaced with realigned sections of reinforced concrete pipes which ranged in diameter between 1500 and 1800 millimetres.
- The blocking effects of the Bexley Road South motorway operations complex were incorporated in the model by raising natural surface levels above the peak PMF level.
- Finished surface levels were raised along the northern side of the motorway to prevent the ingress of floodwater to the new tunnel portals.

Figure 1.2 (Sheets 1 and 2) show the key features of the project which were incorporated in the TUFLOW model representing post-construction conditions.

A4. WOLLI CREEK HEC-RAS MODEL

A4.1 Background to HEC-RAS model development

While the results of the TUFLOW model described in **Chapter A3** were generally relied upon for assessing the impact the road works will have on flooding behaviour, the results of running a HEC-RAS model which was developed of the main arm of Wolli Creek downstream of Kingsgrove Road (**Wolli Creek HEC-RAS Model**) were used to define the upper envelope of flooding along this reach of the creek. The upper envelope of flooding was defined as the elevation of the energy grade line for the PMF event.

This approach provided a conservative estimate of the potential height to which water levels could rise in the vicinity of the existing tunnel portals and takes account of the presence of wave action in the flow.

A4.2 The HEC-RAS modelling approach

HEC-RAS is a one-dimensional hydraulic modelling package developed by the Hydrologic Engineering Centre of the US Army Corps of Engineers and has seen widespread application in Australia in recent years.

HEC-RAS is capable of undertaking single model runs of “mixed flow” where the flow is a mix of the sub-critical and super-critical flow regimes, such as is the case in the concrete lined section of channel on Wolli Creek. Mixed flow occurs, with high velocity supercritical flow occurring in the channel and a hydraulic jump forming upstream of many of the local road crossings.

The momentum equation of open channel flow is solved numerically between user defined grid arrangements (typically, cross sections of the stream channel and its overbanks) for given boundary conditions. Typically, a peak discharge comprises the upstream boundary and the downstream boundary is either a rating curve (stage versus discharge relationship) or the assumption of uniform flow (friction slope equals the bed slope of the stream).

A4.3 HEC-RAS model setup

A series of cross sections were cut normal to the direction of flow and generally corresponded with the location of the one-dimensional cross sections which were used to define the inbank area of the concrete lined section of channel in TUFLOW. **Figure A4.1** shows the layout of the cross sections which were used as input to the TUFLOW HEC-RAS Model. Manning’s n values similar to those set out in **Table A3.2** were assigned to each cross section in the model.

The HEC-RAS software was used in its “steady state” mode, with only response to the peak discharge being modelled. The synchronisation of peak flows within the drainage system was determined from RAFTS (refer peak flows given in **Table A2.2**).

A5. REFERENCES

Bureau of Meteorology (BoM), 1994. "*Bulletin 53: The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method'*

Bureau of Meteorology (BoM), 2003. *"The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method"*.

Lyall & Associates (L&A), 2014. *"King Georges Road Interchange Upgrade Flooding and Drainage Investigation"*

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FIGURES

SOURCE: WILLING & PARTNERS 2000

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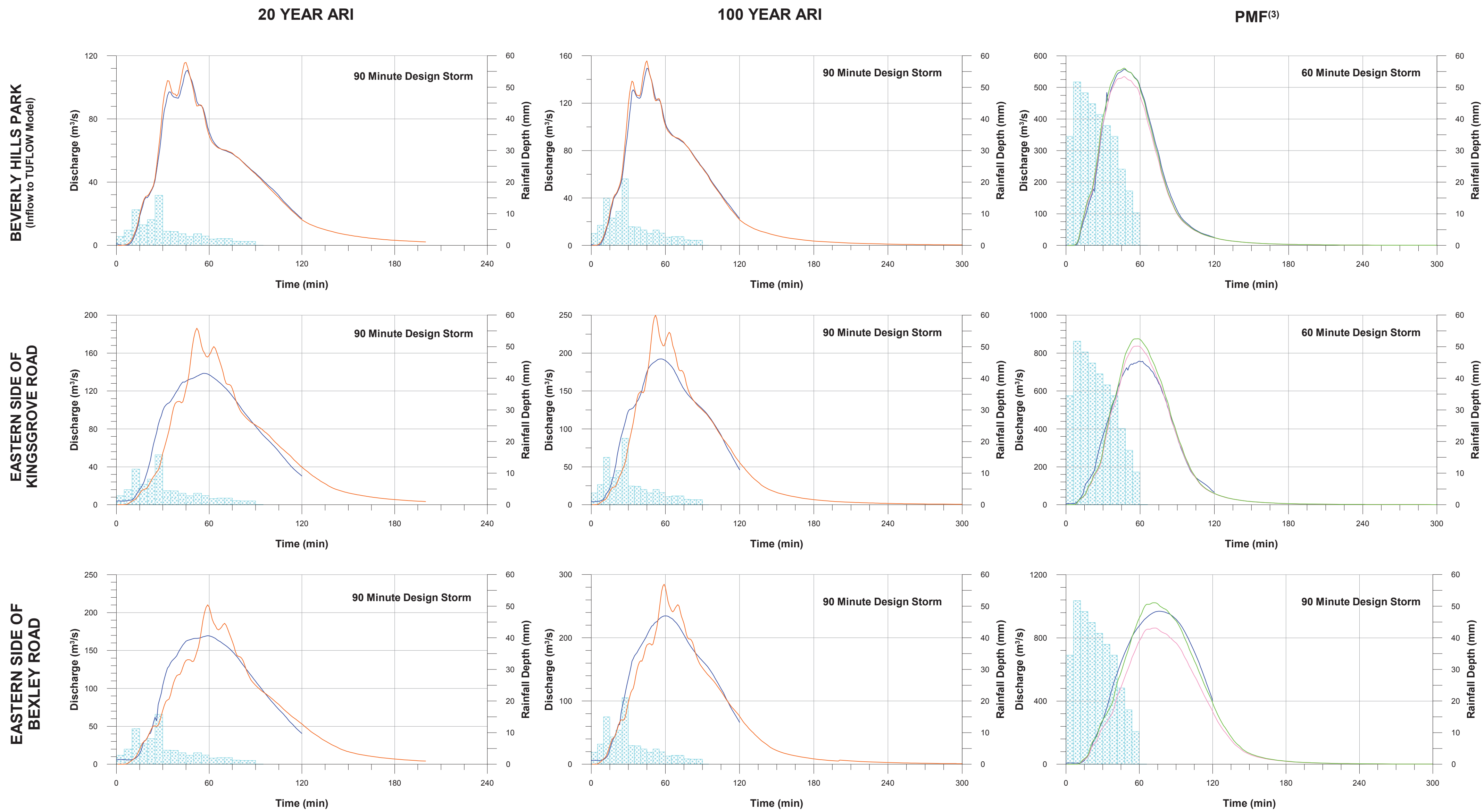
WESTCONNEX NEW M5 EIS
TECHNICAL WORKING PAPER: FLOODING

Figure A2.1

WOLLI CREEK RAFTS MODEL LAYOUT



NOTE:

(1) TUFLOW DISCHARGES FOR KINGSGROVE ROAD ARE THE SUM OF THE FLOW CROSSING KINGSGROVE ROAD TO THE NORTH AND SOUTH OF THE M5 MOTORWAY.

(2) TUFLOW DISCHARGES AT BEVERLY HILLS PARK AND KINGSGROVE ROAD ARE THE SAME IN BOTH PRE- AND POST-UPGRADE CONDITIONS

(3) PMP RAINFALL DEPTHS ONLY SHOWN FOR BoM, 2003.

LEGEND

- Rainfall Depth (mm)
- RAFTS (IEAUST, 1998)
- TUFLOW
- RAFTS (BoM, 1994)
- RAFTS (BoM, 2003)

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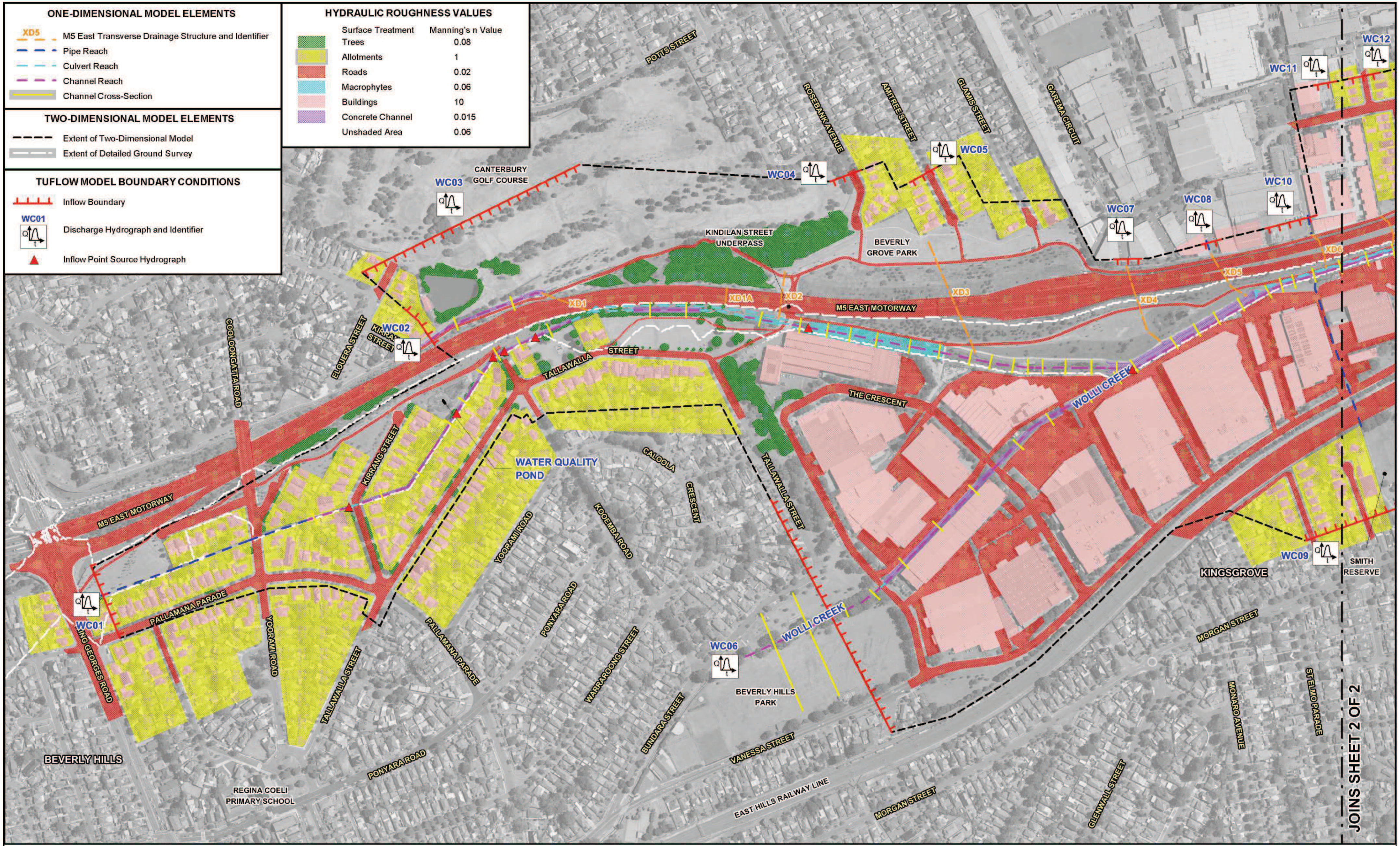
Figure A2.2

DESIGN DISCHARGE HYDROGRAPHS
WOLLI CREEK



N

50 0 50 100 150m

Scale: 1:5,000

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NOTE:

TUFLOW MODEL SHOWN ON THIS FIGURE IS REPRESENTATIVE OF PRESENT DAY CONDITIONS

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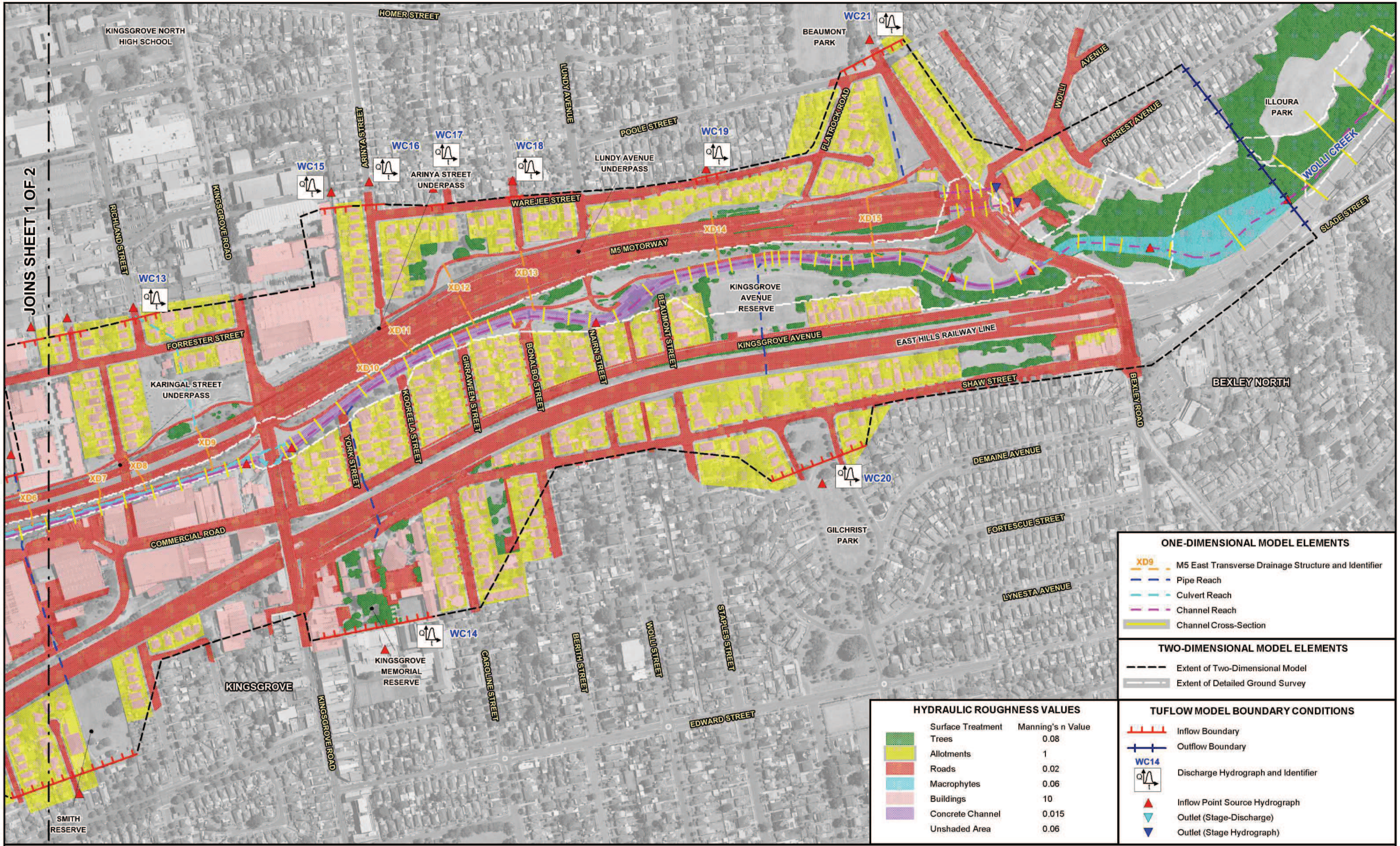
Figure A3.1
(Sheet 1 of 2)

WOLLI CREEK TUFLOW MODEL LAYOUT



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50 0 50 100 150m

Scale: 1:5,000

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NOTE:
TUFLOW MODEL SHOWN ON THIS FIGURE IS REPRESENTATIVE OF PRESENT DAY CONDITIONS

WESTCONNEX NEW M5 EIS
TECHNICAL WORKING PAPER: FLOODING

Figure A3.1
(Sheet 2 of 2)

WOLLI CREEK TUFLOW MODEL LAYOUT

N

50 0 50 100 150 m

Scale: 1:5,000

LEGEND

- TUFLOW Model Extent
- Inflow Boundary
- Existing Motorway Transverse Drainage Structure

NOTE:

THE EXTENTS AND DEPTH OF FLOODING SHOWN WERE DETERMINED FROM AIRBORNE LASER SURVEY DATA AND ARE APPROXIMATE ONLY.

THE INFORMATION SHOWN ON THIS PLAN SHOULD NOT BE USED TO PROVIDE FLOOD ADVICE IN INDIVIDUAL ALLOTMENTS.

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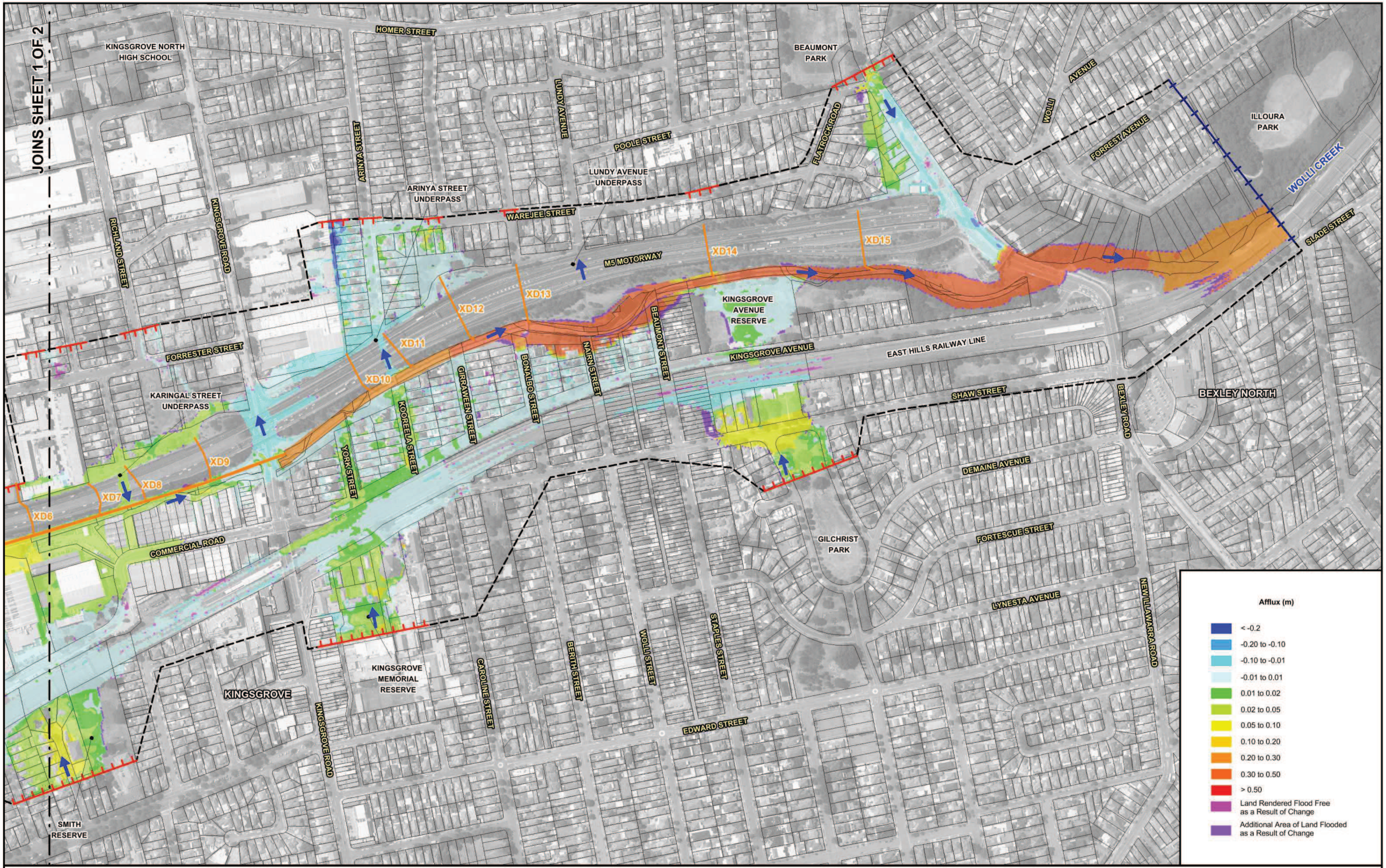
Figure A3.2
Sheet 1 of 2

SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
100 YEAR ARI



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50 0 50 100 150 m

Scale: 1:5,000

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NOTE:

THE EXTENTS AND DEPTH OF FLOODING SHOWN WERE DETERMINED FROM AIRBORNE LASER SURVEY DATA AND ARE APPROXIMATE ONLY.

THE INFORMATION SHOWN ON THIS PLAN SHOULD NOT BE USED TO PROVIDE FLOOD ADVICE IN INDIVIDUAL ALLOTMENTS.

LEGEND

- TUFLOW Model Extent
- Inflow Boundary
- Outlet
- Existing Motorway Transverse Drainage Structure

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Figure A3.2

Sheet 2 of 2

SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES

100 YEAR ARI

LEGEND

43	HEC-RAS River Station Number
	HEC-RAS Cross Section

Lyall & Associates

WESTCONNEX NEW M5 EIS
TECHNICAL WORKING PAPER: FLOODING

Figure A4.1

WOLLI CREEK HEC-RAS MODEL LAYOUT