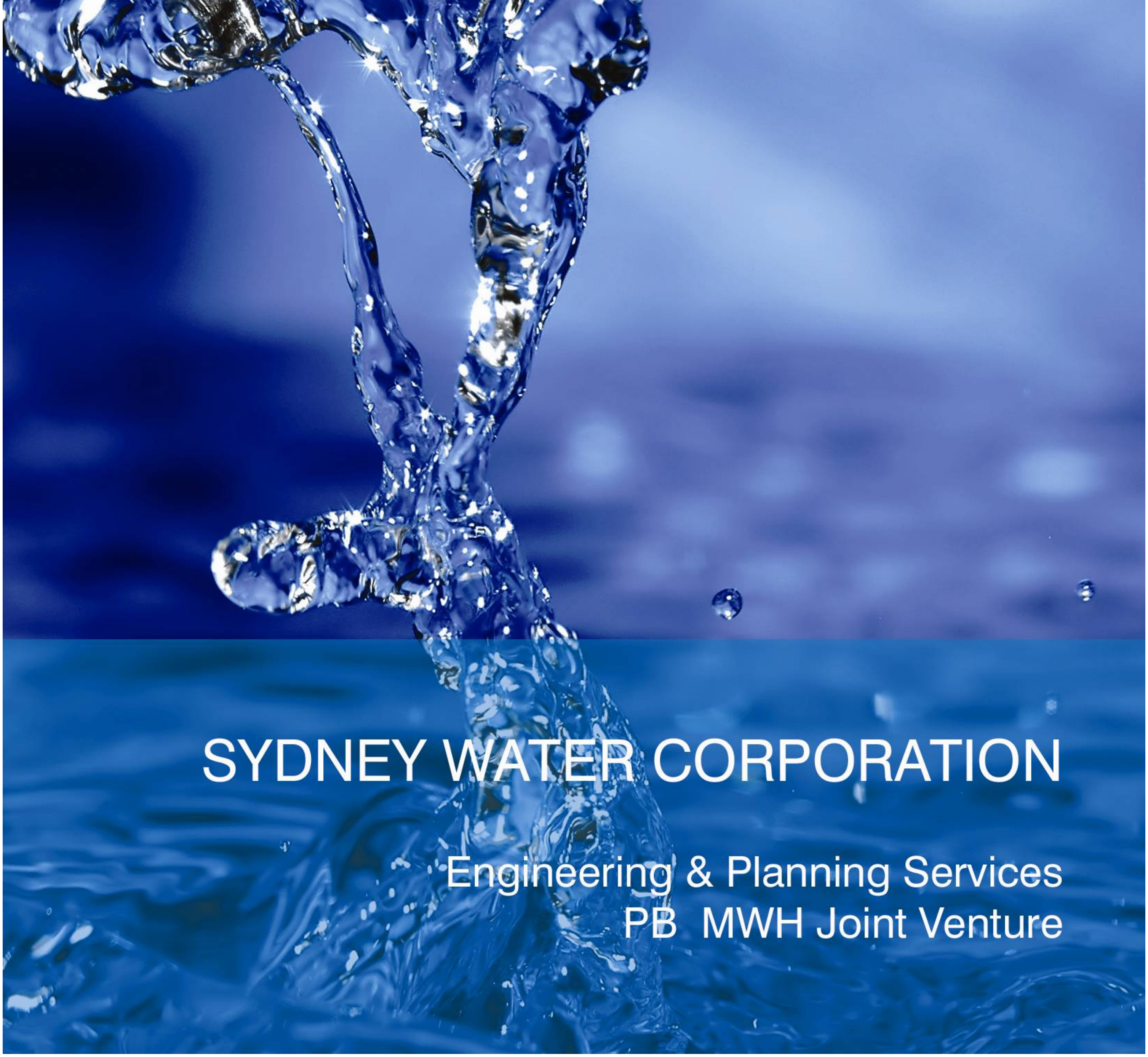

COOKS RIVER FLOOD STUDY

24203-040

FEBRUARY 2009

MWH+PB
ENGINEERING + PLANNING SERVICES

REVISION SCHEDULE

REV. NO.	DATE	DESCRIPTION	PREPARED BY	REVIEWED BY	APPROVED BY
1.0	26/2/09	Final Report	Kate Stephens	Craig Bearsley Stephen Lees	Karen Lancaster

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EXECUTIVE SUMMARY

Sydney Water is responsible for the management of significant stormwater assets, including a substantial portion of the Cooks River and Alexandra Canal. The banks of the lower and middle reaches of both the Cooks River and the Alexandra Canal consist of concrete, masonry, or steel sheet pile walls. Some of the upper reaches have been entirely replaced with concrete trapezoidal channel sections. Many of the walls that were constructed during, and in the years following the Great Depression (1929-1930), are now deteriorating and require renewal or replacement. Instead of replacing the existing concrete walls with new concrete walls in the reaches for which it is responsible, Sydney Water plans to investigate the feasibility of naturalising those sections of the river to improve their aesthetic and environmental values.

The assessment of the bank naturalisation options will include an assessment of impacts on flooding within the Cooks River Catchment. To achieve this, a comprehensive flood study of the Cooks River has taken place to determine the baseline flooding conditions and enable estimates to be made of the flood impacts associated with the naturalisation options. The flood study will also enable all organisations and stakeholders within the catchment to make floodplain management decisions using consistent and comprehensive flooding information.

Flood behaviour within the Cooks River catchment has been investigated previously. The first major flood study in the catchment was completed in 1985 by the NSW Public Works Department. This was then reviewed and the modelling updated during preparation of the Cooks River Floodplain Management Study in 1994 (Webb McKeown & Associates Pty Ltd, 1994). This flood study differs from previous studies in that it uses the latest in two-dimensional (2D) hydraulic modelling techniques and airborne laser scanning topographic survey data. It also provides sufficiently detailed and accurate flood information to support investigations into the feasibility of naturalising some sections of the currently concrete, masonry or steel lined reaches of the Cooks River.

It is anticipated that information from this flood study would be used by councils as the basis for implementing the Floodplain Risk Management process described in the Floodplain Development Manual (NSW Government 2005).

This study has developed a hydrologic model and a hydraulic model of the Cooks River catchment. The hydrologic model was developed using the Watershed Bounded Network Model (WBNM) software program and was used to estimate flood flows within the Cooks River and its tributaries. The hydraulic model was developed using the two-dimensional hydraulic modelling software, TUFLOW. This model simulates hydraulic behaviour within waterways and across their floodplains.

Detailed flood extent maps have been produced so the results of the model can be easily interpreted. These show flood inundation extents for the 2, 20, and 100 year average recurrence interval (ARI) design events and the probable maximum flood (PMF). An assessment of the impacts of climate change on flooding during a 100 year ARI event has also been made and the results are presented with the mapping. The mapping shows that there are numerous properties affected by flooding during the 100 year ARI flood event along the Cooks River. Flood depth and velocity mapping has also been completed for the 100 year ARI event so likely flood hazards can be assessed.

In conjunction with this flood study, the Cooks River TUFLOW model will be used for hydraulic assessments of the bank naturalisation options. These assessments will be reported separately.

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COOKS RIVER FLOOD STUDY

FIGURES

TABLES

APPENDICES

GLOSSARY

Airborne Laser Scanning (ALS) or Lidar	ALS or Lidar (Light Detection and Ranging) are laser scanning methods of gaining land survey. ALS involves laser scanning of both ground and non-ground features and produces raw data in the form of spot levels across the survey area. The survey method works by measuring distance to the ground from the instrument (located on an aircraft) using a laser light. The time taken for the laser beam to hit the ground surface and return to the instrument is measured and the distance calculated based on the speed of light.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see average recurrence interval).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur, on average, once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
Bathymetric survey	Topographical survey of the bed/ floor of a water body.
Bathymetry	The study of water depths.
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Digital Elevation Model (DEM)	A digital representation of ground surface topography or terrain. It is also widely know as a digital terrain model (DTM).
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences, excluding tsunami.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood event (see PMF). Flood prone land is synonymous with flood liable land.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this study, the hazard is flooding which has the potential to cause damage to the community.
Hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or flood level at any particular location varies with time during a flood.
Hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
m/s	metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second. A unit of measurement for flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Model	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable Maximum Precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Velocity	The term used to describe the speed of floodwaters, usually in m/s (metres per second).
Water surface profile	A graph showing the flood level at any given location along a watercourse at a particular time.

Note: Glossary definitions based on the NSW Government, Floodplain Development Manual, 2005.

1. INTRODUCTION

1.1 BACKGROUND

Sydney Water is responsible for the management of significant stormwater assets, including a substantial portion of the Cooks River and Alexandra Canal. The banks of the lower and middle reaches of both the Cooks River and the Alexandra Canal largely consist of concrete, masonry or steel sheet pile walls. Some of the upper reaches have been entirely replaced with concrete trapezoidal channel sections. Many of the walls that were constructed during and in the years following the Great Depression (1929-1930) are now deteriorating and require renewal or replacement. Instead of replacing the existing concrete walls with new concrete walls in the reaches for which it is responsible, Sydney Water plans to investigate the feasibility of naturalising those sections of the river to improve the aesthetic and environmental value.

The Cooks River Foreshore Working Group (CRFWG), comprising representatives from local councils, state agencies and other stakeholders within the catchment, plays a key role in coordinating efforts to improve the health and amenity of the Cooks River. Plans to naturalise sections of the Cooks River will be developed with due recognition of the value that the community places on waterways such as the Cooks River.

The assessment of the bank naturalisation options will include assessment of the resulting impacts on flooding along the Cooks River. This requires a comprehensive flood study (including detailed hydraulic modelling) of the Cooks River to understand the baseline flooding conditions and make estimates of flood impacts associated with the naturalisation options. This flood study will also enable all organisations and stakeholders within the catchment to make floodplain management decisions using consistent and comprehensive flooding information. It is anticipated councils will use information from this flood study as the basis for implementing the Floodplain Risk Management process described in the Floodplain Development Manual (NSW Government 2005).

The models developed in this flood study will be used for hydraulic assessments of the bank naturalisation options developed through the Bank Naturalisation Plan. These assessments will be reported separately.

1.2 CATCHMENT OVERVIEW

The Cooks River Catchment is located south-west of Sydney with flows discharging to Botany Bay at Tempe, adjacent to and immediately south of Sydney Airport. The catchment area is approximately 102 km^2 and covers portions of 13 local government areas. The catchment has been extensively developed, with many reaches severely altered by developments, and the channel constrained or diverted from its original alignment.

The Cooks River has two major tributaries: Alexandra Canal and Wolli Creek. Bardwell Creek forms a tributary of Wolli Creek. Smaller tributaries of the Cooks River include Muddy Creek, Cup and Saucer Creek and Coxs Creek. There are also several unnamed stormwater channels that discharge into the Cooks River. A catchment plan is shown in Figure 1-1.

Much of the main channel of the Cooks River is concrete lined, as is Alexandra Canal and many of the Cooks River's tributaries. Wolli Creek and Bardwell Creek are largely natural waterways.

Legend	
Rivers and creeks	
Major roads	
Rail Line	
Catchment boundary	
LGA boundaries	

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Client: SYDNEY WATER		Designed: GK	Date: Feb, 09
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1.3 STUDY OBJECTIVES

This study's objectives are to:

- Develop a hydrologic model for the Cooks River catchment.
- Develop a hydraulic model for the Cooks River and its significant tributaries (Alexandra Canal and Wolli Creek).
- Develop an understanding of existing flood behavior within the catchment during the 2 year, 20 year, 100 year average recurrence interval (ARI) and probable maximum flood (PMF) design events.
- Use the model to estimate potential climate change flood impacts within the catchment.

1.4 AVAILABLE DATA

The following data was obtained and used for this study:

- Airborne laser scanning (ALS or LiDAR) of the catchment topography. The survey was flown in 2007 and obtained from AAM Hatch.
- Bathymetric survey — the survey was commissioned by Sydney Water for this study. It included the Cooks River from its entrance to Botany Bay to just upstream of Burwood Road; Alexandra Canal from its junction with the Cooks River to Huntley Street; and Wolli Creek from its junction with the Cooks River to Turrella Weir.
- Ocean tide peak level data — various tide levels were reported within the 1994 Flood Study. These included:
  - the highest recorded tide level of 1.45 m Australian Height Datum (AHD), which is considered to have an ARI of approximately 100 years; and
  - the High Water Spring Solstice Tide (HHWSS), which occurs once or twice per year, was reported to peak at about 1.1 m AHD.
- Tidal curve data — six-minute sea level prediction data for Botany Bay was obtained from the Bureau of Meteorology's National Tidal Centre.
- Historic flood data — data on historic peak flood levels recorded at various locations throughout the catchment are reported in the 1994 Flood Study based on a Compendium of Data prepared during 1983 (WMA, 1994).
- Historic rainfall data — historic rainfall data used within the WBNM modelling from the 1994 Flood Study was made available for this study (from WMA modelling data).
- Surveyed cross-sections of the Cooks River and crossing structures details obtained from the RUBICON model developed for the 1994 Flood Study (WMA 1994).
- Cadastral data — cadastral information in GIS format for the entire the catchment was supplied by Sydney Water.
- Aerial Photography — aerial photographs of the catchment were supplied by Sydney Water.
- Work as executed drawings for the Hume Highway Bridge, Pemberton St (now Centenary Drive) and Bexley Road Bridge were obtained from the NSW Roads and Traffic Authority (RTA).
- Work as executed drawings for Wardell Road Bridge, Foord Avenue Footbridge, Church Street Footbridge, Hartill Law Avenue Bridge and the Homer Street Bridge (approaches only) were obtained from Canterbury City Council.
- Photographs of the Cooks River, crossings and in river structures — photographs taken during Bathymetric Survey (March 2008), supplied by Sydney Water.
- Photographs and site notes recorded by Parsons Brinckerhoff (PB) staff, May 2008.

1.5 STUDY LIMITATIONS

The focus of this study is to assess flood behaviour within the Cooks River, Wolli Creek and Alexandra Canal. The following limitations should be noted when using this study:

- Flood information within minor tributaries of the Cooks River (all waterways outside of the extent of the one-dimensional (1D) component of the hydraulic modelling as detailed in Section 4.2) are not accurately defined in this study. If accurate flood information is required for any of these tributaries a more detailed assessment should be carried out.
- Detailed bathymetric data was available for the area from the mouth of the Cooks River to just upstream of Burwood Road, Alexandra Canal, and Wolli Creek from the Cooks River junction to Turrella Weir. Outside of this area the channel has been defined in the model based on cross-sections obtained from the RUBICON model developed for the 1994 flood study or based on the ALS data beyond the 1994 study extents. These data sources give a less accurate definition of the channel geometry than bathymetric data obtained for this study.
- No detailed survey information was available for structures crossing Alexandra Canal. Assumptions have been made in modelling these structures based on site inspection.
- Blockage of structures by debris during flood events has not been taken into account in this study. However, blockage may be an important consideration and should be taken into account in future floodplain management studies in the catchment.

In deciding on this approach, a number of references were reviewed (of note “Causes and Effects of Culvert Blockage During Large Storm Events", E.H. Rigby et al. (2002)). This study found that (for Wollongong) structures with openings of 6m or less have high likelihood of blockage (i.e. almost 60% of culverts with less then 6 m opening will be more than 90% blocked, and the average degree of blocking is 80% blocked). No structure with an opening larger then 6 m was fully blocked (average degree of blockage 10%).The study also looked at catchment factors affecting blockage (for example, land use, stream type, material type, contributing catchment area, blockage of upstream culverts) and found no strong relationship between these factors and culvert blockage. Stream slope was reported as having the strongest influence (with steeper streams having greater level of blockage). Blockage was mainly found to result from:

- sediment from bed and banks
- floating vegetation; and
- urban materials (fences, cars, shopping trolleys, sheds etc).

While noting the above, it is also noted that the Cooks River Catchment is quite different from those catchments studied in Wollongong, making it difficult to directly compare. Structures on the lower reaches of the Cooks River and Alexandra Canal generally have openings larger than 6 m, which are considered unlikely to block. Structures on the upper reaches of the Cooks River do have smaller openings, but as these reaches are generally concrete-lined channels within a highly urbanised environment that has a low debris load, they are considered unlikely to result in a high degree of blockage. Wolli Creek does have some structures that could be subject to blockage, but because the watercourse is flatter the risk of them blocking is considerably lower than those within watercourses studies in Wollongong. Within the Cooks River catchment there are very few areas of dense vegetation, which further reduces the likelihood of debris and blockage.

Catchment-specific reports on structure blockage were not available for this study and collation of such data through eyewitness interviews was beyond this study’s scope.

2. PREVIOUS STUDIES

In developing an understanding of flood behaviour within the Cooks River Catchment, previous studies of the Cooks River have been obtained and reviewed. The main studies, and supporting models that have been reviewed, are discussed below.

2.1 COOKS RIVER BANK NATURALISATION DATA COMPILATION, WEBB MCKEOWN & ASSOCIATES PTY LTD, SEPTEMBER 2007

Sydney Water commissioned this study, as part of the initial stages of investigating the feasibility of naturalising the banks of the Cooks River. Its objective was to gauge the level of interest from stakeholders within the Cooks River catchment in a catchment-wide flood study, and to identify how much data was available for such a flood study. The study also presented three hydraulic modelling options to help assess the flood impacts of bank naturalisation. The options considered were:

1. Upgrade of the existing 1D RUBICON model of the Cooks River, Wolli Creek and Alexandra Canal established for the 1994 Flood Plain Management Study (see Section 2.2).

2. Development of a new 2D model of the same extents covered by the existing 1D RUBICON model.

3. Develop a 2D model of the entire Cooks River catchment, including all major tributaries.

The study reported that overall there is interest from catchment stakeholders in a catchment-wide flood study and a willingness to assist in the project. It identified that limited existing data would be available that would be useful for the study. Options 2 and 3 would require detailed flood plain survey (either ALS or photogrammetry), which would make these options considerably more costly than Option 1. It was noted, however, that a 2D model would be far better at assessing the impacts associated with bank naturalisation than a 1D model, as it would provide greater definition of the overbank flooding regime and ultimately be a more useful tool in floodplain management.

2.2 COOKS RIVER FLOODPLAIN MANAGEMENT STUDY, WEBB MCKEOWN & ASSOCIATES PTY LTD, 1994

Marrickville Council and Canterbury City Council jointly commissioned a floodplain management study of the Cooks River in 1994. The study involved both a revision of the previous flood study for the catchment (prepared by Public Works Department (PWD) in 1985) and the development and assessment of floodplain management options for the catchment. A hydrological model, which used the Watershed Bounded Network Model (WBNM), and a 1D hydraulic model using RUBICON, were developed for the flood study.

The WBNM model represented the catchment with 45 sub-catchments. The model estimated flows for the 20, 50, 100 year average recurrence interval (ARI) design storm events, as well as an extreme storm event. Although no stream flow records were available to calibrate the WBNM model, rainfall records associated with historic flood events were input into the WBNM model to generate catchment flow hydrographs for these storm events to calibrate the hydraulic model.

The 1D hydraulic modelling software package RUBICON was used to develop a hydraulic model of the catchment. The model represented the extent of the Cooks River from the entrance at Botany Bay to Water Street and also included three tributaries of the Cooks River; Alexandra Canal, Wolli Creek (up to Bexley Road), Shea's Creek and Muddy Creek.

Flood levels in the Cooks River are influenced by both catchment runoff and Botany Bay tide levels. As part of the study, an assessment was made of the relative influence of the two factors on the 100 year ARI flood levels. It was found that downstream of the Princes Highway, 100 year ARI flood levels were primarily influenced by the tidal level in Botany Bay, while upstream of the Princes Highway it was catchment flows.

The model was calibrated using data collected from floods within the catchment during November 1961 and March 1983. Data collected from flood events during February 1956, March 1958, and June 1964 were used to verify the model.

This study also involved a flood damages assessment, an assessment of flood mitigation strategies and an assessment of flood management options.

Data from the models developed for the 1994 study have been used, where appropriate, in this flood study. The WBNM hydrologic model of the Cooks River required redeveloping because it is incompatible with current versions of the WBNM software due to its age. The model redevelopment has also ensured the hydrologic representation of the Cooks River catchment is accurate and based on best available current information. Improved information includes current survey (obtained ALS) and other updated geospatial data sets (including aerial photography). The updated model was conceptualised to represent the catchment break up in a similar manner to the 1994 model. This has enabled the two models to be compared as part of the hydrological assessment.

Due to limited stream flow data being available, it was not possible to directly calibrate the model. Instead, it has been semi-calibrated through a process of comparing modelled flows during historic flood events to flows generated for these events with the WBNM model developed for the 1994 study. Model parameters were adjusted within typical ranges until these flows closely match. Full details of the hydrological investigations during this study and comparisons with the 1994 Flood Management Study WBNM model are covered in Section 3.

Details of cross-sections of the Cooks River used in the RUBICON model developed for the 1994 study have been extracted from the provided RUBICON input files. These have been used to develop the TUFLOW model in areas where the ALS and bathymetric survey have not adequately defined the channel. In the upper sections of the Cooks River and its tributaries, where there was no new bathymetric survey, the RUBICON cross-section and structure data has been used in conjunction with ALS data to develop the TUFLOW model. Data relating to tidal levels presented within the 1994 study have been used to develop the hydraulic model. Full details of hydraulic model development and 1994 Flood Management Study RUBICON model use are presented in Section 4.

2.3 COOKS RIVER FLOOD STUDY, PUBLIC WORKS DEPARTMENT, FEBRUARY 1985

This study estimated flood levels for the 100, 50 and 20 year ARI events for the Cooks River between Brighton Avenue at Campsie and the Alexandra Canal junction. It also estimated flood levels for Wolli Creek up to Bardwell Creek. The models were calibrated to data recorded from the 1961 flood event and verified against data from 1956, 1964 and 1983 flood events.

Design flows reported in the 1985 flood study were within 10% of the flows estimated for the 1994 study. Design flood levels were estimated to be 0.2 m higher at Tempe and 0.7 m lower at Brighton Avenue in the 1994 study than in the 1985 study.

This study was subsequently superseded by the Cooks River Floodplain Management Study (WMA, 1994).

3. HYDROLOGY

3.1 MODEL OVERVIEW

A hydrologic model of the Cooks River catchment was developed using the Watershed Bounded Network Model (WBNM) software program. WBNM has been used extensively across Sydney and NSW for urban and rural flood investigations and was also used for the Cooks River Floodplain Management Study (WMA, 1994).

WBNM is an event-based hydrologic model that calculates flood hydrographs from either recorded storm rainfall hyetographs or design storm rainfall parameters. The catchment is represented in the model as a series of sub-catchments for which factors affecting runoff, such as land use (proportion of pervious versus impervious land surfaces), rainfall losses, and routing of runoff both through the catchment and through channels, are defined. Details of how WBNM was used to represent the Cooks River catchment are provided below.

The model of the Cooks River developed for this study was used to estimate flow generated from the catchment during the 2 year, 20 year, 100 year Average Recurrence Interval (ARI) design storm events and the Probable Maximum Precipitation (PMP) design event. The model was also used to assess the change in 100 year ARI design flows that may result from the impacts of climate change.

3.2 HYDROLOGIC MODEL SET-UP

3.2.1 CATCHMENT PARAMETERS

The Cooks River catchment has a total area of 102 km^2 upstream of Botany Bay. The catchment was divided into 44 sub-catchments to enable greater definition of catchment parameters within the WBNM model. The breakdown and location of each sub-catchment is illustrated in Figure 3-1.

Catchment parameters, such as sub-catchment areas, land use, percentage imperviousness, sub-catchment links and channel definition within the catchment, were defined using the digital elevation model (DEM) developed from the supplied ALS data and bathymetric survey, aerial photography, and knowledge of the catchment. Details of catchment parameters adopted for each sub-catchment are shown in Figure 3-1.

The percentage impervious assigned to each sub-catchment was determined based on cadastral data and aerial photography. Each land use was assigned a percentage impervious value, as shown in Table 3-1. The proportion of each land use within each sub-catchment was then assessed and the overall sub-catchment percent impervious value determined.

Table 3-1: Percentage impervious by land use

LAND USE	PERCENTAGE IMPERVIOUS
Residential	60%
Commercial	90%
Open space	5%

Rivers and creeks
Subcatchments

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PDF File: 2114299N_2001a_Cooks_River_Hydrologic_model_layout.pdf

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Values adopted to represent initial and continuing losses were based on recommendations within Australian Rainfall and Runoff (2001) and the XP-RAFTS manual (XP Software, 2000). Adopted loss values are detailed in Table 3-2.

Table 3-2: Adopted loss values

	INITIAL LOSS (mm)	CONTINUING LOSS (mm/hr)
Pervious areas	10	2.5
Impervious areas	1.5	0

Catchment lag parameters and stream lag factors were adopted based on recommendations within *WBNM Theory* (Boyd et al, 2007). The lag parameter for all sub-catchments was adopted as 1.6 and the impervious lag factor as 0.1. Stream lag factors of 0.33 and 1 were adopted for concrete-lined channels and natural channels respectively.

3.2.2 RAINFALL INTENSITY FREQUENCY DURATION PARAMETERS

Rainfall Intensity Frequency Duration (IFD) parameters were obtained for a central location within the catchment from Australian Rainfall and Runoff, Volume 2 (Engineers Australia 1987, 2001). The IFD parameters adopted for this study, and input into the WBNM model developed for the Cooks River catchment, are shown in Table 3-3.

Table 3-3: Cooks River catchment IFD parameters

VARIABLE	SYMBOL	VALUE
Rainfall intensity (mm/hr) (2 year ARI; 1 hour storm duration)	${}^{2}I_{1}$	39.35
Rainfall intensity (mm/hr) (2 year ARI; 12 hour storm duration)	${}^{2}I_{12}$	7.75
Rainfall intensity (mm/hr) (2 year ARI; 72 hour storm duration)	${}^{2}I_{72}$	2.40
Rainfall intensity (mm/hr) (50 year ARI; 1 hour storm duration)	${}^{50}I_{1}$	83.75
Rainfall intensity (mm/hr) (50 year ARI; 12 hour storm duration)	${}^{50}I_{12}$	15.80
Rainfall intensity (mm/hr) (50 year ARI; 72 hour storm duration)	${}^{50}I_{72}$	4.81
Average coefficient of skewness	G	0
Geographical factor (2 year ARI)	F2	4.29
Geographical factor (50 year ARI)	F50	15.88

3.2.3 PMP CALCULATION

Probable Maximum Precipitation (PMP) storms were calculated within WBNM based on the procedures outlined in *The Estimation of Probable Maximum Precipitation in Australia: generalised short duration method* (Bureau of Meteorology, 2003). Input parameters entered into WBNM to determine the PMP are listed in Table 3-4. The moisture adjustment factor was determined from Figure 3 in *The estimation of probable maximum precipitation in Australia: generalised short duration method* (Bureau of Meteorology, 2003). An elevation adjustment factor of one (1) was adopted as the elevation of the site is below 1500 mAHD. The roughness parameter used in PMP calculations is a measure of how steep the catchment is, which was determined based on the DEM of the catchment developed from the ALS data.

Table 3-4: PMP parameters

PARAMETER	VALUE
Moisture adjustment factor	0.70
Elevation adjustment factor	1
Percentage defined as 'rough'	0%

3.2.4 CLIMATE CHANGE

Climate change is predicted to result in increased rainfall intensities and rises in sea levels, both of which will have a significant influence on flood behaviour within the catchment.

CSIRO is studying rainfall intensities in Sydney and surrounding areas with a view to estimating rainfall intensities for a range of recurrence intervals under current climatic conditions (1960-2000), and under increased greenhouse gas concentrations expected in 2030 and 2070. The study involves the dynamic downscaling of outputs from the relatively coarse global climate models to the much finer spatial and temporal scales required to model stormwater runoff in small urban catchments. The downscaling will be combined with a statistical model that will allow rainfall intensities to be estimated at ungauged sites and for a range of recurrence intervals. The project has been guided and financially supported by Sydney Water and other regional state authorities. As definitive results are yet to be obtained they cannot provide input to the Cooks River Flood Study at this stage.

Current advice on how to incorporate potential impacts of climate change into the flood study process is provided in *Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC, 2007).* This guideline recommends sensitivity analyses looking at low, mid and high sea level rises (0.18, 0.55 and 0.91 m), in combination with low, mid and high level rainfall intensity increases to assess changes in flood behaviour.

In line with the DECC guideline, rainfall intensities for the 100 year ARI event within the WBNM model were increased by 10%, 20% and 30% in a series of model runs to assess a range of potential climate change scenarios. Peak flows estimated for each of these three scenarios are documented in Section 3.4.3 below.

3.3 MODEL CALIBRATION

Model calibration involves adjusting one or more of the model parameters in order to match observed or measured data. No measured stream flow data are available to directly calibrate the WBNM Cooks River model. The WBNM model of the Cooks River catchment developed during the 1994 Flood Study (WMA, 1994) was calibrated in conjunction with the hydraulic model, due to the lack of stream flow data. Rainfall records, as used in the 1994 modelling, were made available to PB for this study, as were the previous hydrologic and hydraulic models.

Calibration during the 1994 flood study was based on rainfall records and water level data recorded during storm events in November 1961 and March 1983 (WMA, 1994). Based on reported details, it appears the 1994 study achieved a good calibration of the models to recorded flood levels. However, there was little discussion included in the 1994 flood study report about calibration of flows; most discussion about model calibration related to hydraulic modelling.

The WBNM model of the Cooks River developed during this study was semi-calibrated by running the November 1961 and the March 1983 storm events through the model and comparing the estimated flows to the flows generated for these events during the 1994 study. Key parameters (including continuing loss rates and catchment lag parameters) within the model were adjusted until flows generated closely matched the 1994 study modelled flows. The hydrologic model developed during the 1994 study was compared with the current model during the calibration process to enable a clear understanding of differences in estimated flows. A summary of the model comparison and calibration is provided in Table 3-5. Further details of the calibration results and plots comparing outputs at several locations within the catchment are provided in Appendix A. Refer to Figure 3-1 for sub-catchment locations.

Table 3-5: Cooks River WBNM model comparison & and calibration summary

	WMA MODEL (1994 STUDY)	PB MODEL (CURRENT STUDY)
Model set-up		
Number of sub-catchments	45	44
Total catchment area modelled	99 km^2	102 km^2
Total impervious percent	48%	56 %
Model output		
Sub-catchment CR8		
Peak flow	306.6 m^3/s (Nov 61) 114.6 m^3/s (Mar 83)	357.7 m^3/s (Nov 61) 146.7 m^3/s (Mar 83)
Total volume	4542 ML (Nov 61) 2828 ML (Mar 83)	4793 ML (Nov 61) 2798 ML (Mar 83)
Sub-catchment WC5		
Peak flow	65.4 m^3/s (Nov 61) 91.3 m^3/s (Mar 83)	78.7 m^3/s (Nov 61) 132.3 m^3/s (Mar 83)

	WMA MODEL (1994 STUDY)	PB MODEL (CURRENT STUDY)
Total volume	2057 ML (Nov 61) 1382 ML (Mar 83)	2228 ML (Nov 61) 1407 ML (Mar 83)
Sub-catchment AC5		
Peak flow	78.0 m^3/s (Nov 61) 77.9 m^3/s (Mar 83)	68.9 m^3/s (Nov 61) 93.2 m^3/s (Mar 83)
Total volume	1838 ML (Nov 61) 1121 ML (Mar 83)	1573 ML (Nov 61) 1012 ML (Mar 83)

Table 3-5 above and plots in Appendix A indicate that the hydrologic model developed for this study is producing hydrographs that have higher peaks at most locations throughout the catchment than those from the 1994 study. The exception to this is for the Alexandra Canal catchment. Despite the differences in the peaks, the volume of the hydrographs is similar, which is an important characteristic.

The differences noted between the models are due to factors such as improved catchment definition, differences in percentage imperviousness and more detailed definition of catchment lag parameters. Greater definition of the rainfall throughout the catchment was also applied during the current study for both the November 1961 and the March 1983 events. Further differences in the model results arise as a result of the version of the WBNM used. Since 1994, the WBNM model has been substantially upgraded for representation of urban catchments. Major improvements have included the ability to provide more definition to pervious and impervious surfaces by allowing variation in rainfall losses and lag parameters (Boyd *et al*, 1999). Such differences have been noted when comparing the current model to the model developed for the 1994 study.

Overall, the model developed for the current study has a higher percentage of impervious surfaces. Also, greater definition to lag parameters has been applied, meaning that lag parameters applied to impervious surfaces are lower then those applied to pervious surfaces. These factors will generate higher peak flows.

The Alexandra Canal sub-catchments, however, have been defined to have slightly lower percentage impervious values in the current study than the 1994 study; hence the lower peaks being seen at this location during the November 1961 event. It is noted, however, that an increase in peak flow resulted from the current model for the March 1983 event. This is due to a difference in the way rainfall has been distributed over the Alexandra Canal catchment during this event. The current study has a slightly higher rainfall than the 1994 model over the Alexandra Canal catchment, due to additional rain gauge data that was not included during the 1994 study.

Overall, given the differences in the two models, the results from the current study are comparable to the results from the 1994 study. The model is therefore deemed to be calibrated as best as possible.

3.4 MODEL RESULTS

3.4.1 CRITICAL DURATION

The Cooks River WBNM model was run for a range of standard durations (from 15 minutes to 12 hours) for the 100 year ARI design event. The duration resulting in the maximum peak discharge at the catchment outlet for the 100 year ARI was adopted as the critical duration. It was found that the two-hour duration storm event was critical for this catchment. This correlates with what was found during the 1994 study (WMA, 1994).

The critical duration for the Wolli Creek and Alexandra Canal sub-catchments was also assessed to provide a comparison to the greater Cooks River catchment. The two-hour duration storm event was also found to be the critical for each of these sub-catchments.

3.4.2 PEAK FLOWS

Peak flows estimated by the WBNM model of the Cooks River catchment at crucial locations that a) represent the major tributaries within the catchment and b) where catchment flows will be entered into the hydraulic model (TUFLOW) developed for the Cooks River catchment, are listed in Table 3-6.

Table 3-6: Cooks River peak flows

LOCATION	2 YEAR ARI (m^3/s)	20 YEAR ARI (m^3/s)	100 YEAR ARI (m^3/s)	PMP (m^3/s)
Cooks River upper catchment (CR5 outflow)	65.7	134.3	180.7	448.7
Coxs Creek — discharge to Cooks River (CC6 outflow)	76.8	153.4	204.3	472.0
Cup & Saucer Creek — discharge to Cooks River (CSC2 outflow)	43.9	86.8	115.3	272.1
Wolli Creek upper catchment (WC5 outflow)	85.2	174.0	234.8	598.3
Bardwell Creek (BC2 outflow)	35.5	70.5	94.3	279.1
Wolli Creek — discharge to Cooks River (WC7 outflow)	123.3	254.7	348.9	1031.7
Muddy Creek – discharge to Cooks River (MC2 outflow)	55.7	109.3	145.4	364.0
Alexandra Canal upper catchment (AC5 inflow)	82.9	161.9	213.9	469.1

LOCATION	2 YEAR ARI (m^3/s)	20 YEAR ARI (m^3/s)	100 YEAR ARI (m^3/s)	PMP (m^3/s)
Alexandra Canal — discharge to Cooks River (AC5 outflow)	106.7	213.3	286.1	761.6
Cooks River — discharge to Botany Bay (CR19 outflow)	546.7	1151.1	1596.4	5049.3

3.4.3 CLIMATE CHANGE RESULTS

Peak flows estimated for the three climate change scenarios assessed (10%, 20% and 30% increase in rainfall intensity for the 100 year ARI event) are presented in Table 3-7 below. Results of the assessment are presented for the same crucial locations as in Section 3.4.2 above.

Table 3-7: Peak flows — climate change

LOCATION	PEAK FLOWS (m^3/s)		
	100 YEAR ARI (10% INCREASE IN RAINFALL INTENSITY)	100 YEAR ARI (20% INCREASE IN RAINFALL INTENSITY)	100 YEAR ARI (30% INCREASE IN RAINFALL INTENSITY)
Cooks River upper catchment (CR5 outflow)	202.4 (12% increase in flow)	224.3 (24% increase in flow)	246.6 (36% increase in flow)
Coxs Creek — discharge to Cooks River (CC6 outflow)	228.1 (12% increase in flow)	252.3 (23% increase in flow)	276.6 (35% increase in flow)
Cup and Saucer Creek — discharge to Cooks River (CSC2 outflow)	128.7 (12% increase in flow)	142.2 (23% increase in flow)	155.8 (35% increase in flow)
Wolli Creek upper catchment (WC5 outflow)	263.0 (12% increase in flow)	291.6 (24% increase in flow)	320.6 (37% increase in flow)
Bardwell Creek (BC2 outflow)	105.5 (12% increase in flow)	116.8 (24% increase in flow)	128.2 (36% increase in flow)
Wolli Creek upper catchment (WC7 outflow)	391.4 (12% increase in flow)	434.6 (25% increase in flow)	478.3 (37% increase in flow)
Muddy Creek (MC2 outflow)	162.3 (12% increase in flow)	179.3 (23% increase in flow)	196.6 (35% increase in flow)
Alexandra Canal upper catchment (AC5 inflow)	238.3 (11% increase in flow)	262.9 (23% increase in flow)	287.7 (35% increase in flow)

LOCATION	PEAK FLOWS (m^3/s)		
	100 YEAR ARI (10% INCREASE IN RAINFALL INTENSITY)	100 YEAR ARI (20% INCREASE IN RAINFALL INTENSITY)	100 YEAR ARI (30% INCREASE IN RAINFALL INTENSITY)
Alexandra Canal – discharge to Cooks River (AC5 outflow)	320.1 (12% increase in flow)	354.7 (24% increase in flow)	389.6 (36% increase in flow)
Cooks River — discharge to Botany Bay (CR19 outflow)	1794.9 (12% increase in flow)	1995.4 (25% increase in flow)	2199.0 (38% increase in flow)

4. HYDRAULICS

4.1 MODEL OVERVIEW

A hydraulic model of the Cooks River Catchment was developed using the two-dimensional hydraulic modelling software, TUFLOW. TUFLOW is an implicit finite difference model that is specifically orientated towards establishing flow patterns in coastal waters, estuaries, rivers, floodplains and urban areas. The software has the ability to dynamically link to the one dimensional (1D) network hydrodynamic modelling program ESTRY, meaning that both the two-dimensional (2D) and one-dimensional (1D) domains are combined to form one model. This has the advantage of increased resolution and accuracy for in-channel flows, which are essentially 1D in nature, while still accurately modelling the complex floodplain flows and their interaction with channel flows.

The model was used to simulate flood behaviour within river channels and across floodplains for a range of storm events.

4.2 HYDRAULIC MODEL DEVELOPMENT

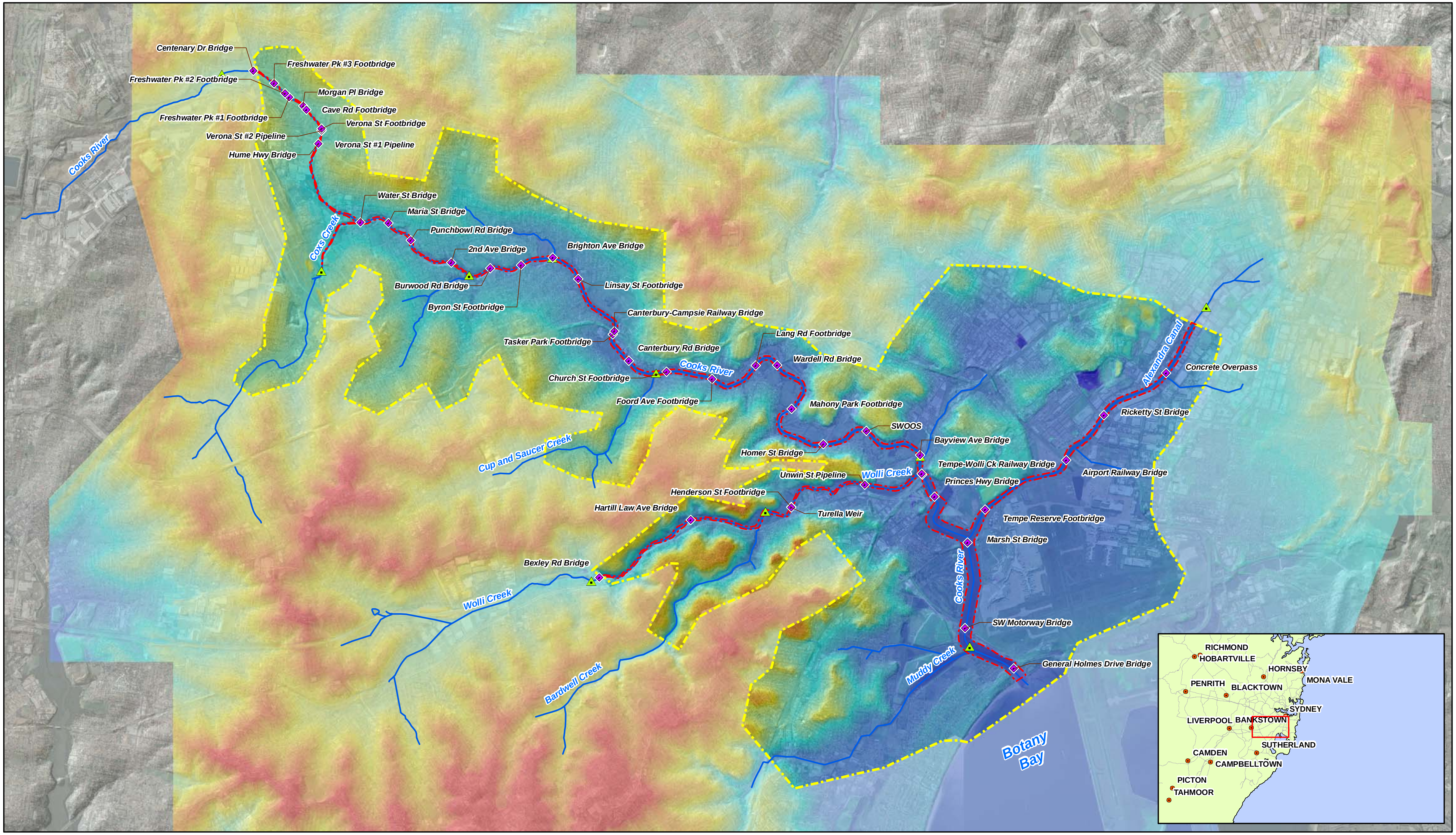
4.2.1 MODEL EXTENT

The Cooks River TUFLOW model was developed to represent the Cooks River, Alexandra Canal, Wolli Creek and their respective floodplains. The extent of the model is illustrated in Figure 4-1.

Detailed 1D modelling has been applied to the following watercourses:

- Cooks River: from Botany Bay to Centennial Drive
- Alexandra Canal: from its junction with the Cooks River to Huntley Street
- Wolli Creek: from its junction with the Cooks River to Bexley Road
- Coxs Creek, from its junction with the Cooks River to Cosgrove Road, was also modelled using 1D model components (note that this was originally outside the scope of the study and was done to resolve model instability issues in this area).

The floodplains of these watercourse and other tributaries within the catchment were modelled within the 2D domain. Tributaries within the 2D domain include Cup and Saucer Creek, Muddy Creek, and Bardwell Creek. Flooding along these tributaries, and Coxs Creek, has only been considered as a result of backwater flooding from the Cooks River, Alexandra Canal and Wolli Creek. Localised flooding impacts on these smaller watercourses were not considered as part of this flood study as hydrologic model inputs from these smaller watercourses was represented as a point source at the confluence with the Cooks River.



- Structures
- Flow input
- Rivers and creeks
- 1d Model Extent
- 2d Model extent

Elevation (mAHD)

High : 76.7

Low : -15.3

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2002a_Cooks_River_Hydraulic_model_extent.pdf

0 1 2 Kms

Title: Hydraulic Model Extents		PARSONS BRINCKERHOFF			
		Datum:	GDA94 / Zone 56	Scale:	1:45,000
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2002a_Cooks_River_Hydraulic_model_extent.mxd		DWG. No:	2114299N_2002	Fig. No.	4-1

4.2.2 TWO-DIMENSIONAL (2D) MODEL DOMAIN

Grid definition

The 2D domain within a TUFLOW model is defined based on a network of square cells, know as the grid. The resolution of the grid (cell size) adopted for the Cooks River model was 7 m by 7 m. This resolution was selected to provide adequate definition to floodplain features while keeping model run and processing times reasonable.

Each grid cell was assigned an elevation based on the Digital Elevation Model (DEM) developed from Airborne Laser Scanning (ALS) and the bathymetric survey. The following refinements were made to the DEM levels assigned to grid cells:

- ***Botany Bay***: levels were based on ALS as no bathymetric survey was conducted of the bay. The ALS had picked up the water surface only as ALS is not capable of penetrating through water. Therefore, the elevations within Botany Bay were manually lowered within the TUFLOW model to the lowest level recorded by the bathymetric survey at the downstream end of the Cooks River.
- ***Training walls at mouth of Cooks River***: filtering of the ALS data before production of the DEM resulted in the elevation detail of some features higher than their immediate surrounds being removed from the data. This occurred with the training walls at the mouth of the Cooks River. The levels of the cells over these walls were manually raised to reflect their true level.
- ***'Gully Lines'***: TUFLOW 'gully lines' were defined in the model to provide greater definition to the stream bed profiles of the tributaries not included in the 1D modelling domain. This allowed for required adjustments where the 7x7 m grid did not clearly define flow paths. Gully lines were defined for Cup and Saucer Creek, Bardwell Creek, Muddy Creek, the unnamed channels which join the Cooks River at Third Avenue, Campsie and at Brighton Avenue, Croydon Park, and Sydney Water's Western Channel and Eastern Channel (which run along the western and the eastern side of Mackey Park, respectively). Gully line levels were based on ALS data.
- ***South Western Ocean Outfall System (SWOOS)****:* filtering of the ALS data before the DEM's production resulted in elevation detail of the SWOOS being removed from the data. The levels of the cells over this pipeline were manually raised to reflect its true level within the floodplain.
- Rail line near Thompson Street Turrella: a section of the rail line between Wolli Creek and Turrella was filtered out of the ALS data. Levels of the cells over the rail line in this location were raised to reflect true levels.
- Road embankments: a number of road embankments throughout the catchment were also filtered out of the ALS data in developing the DEM. These included Centenary Drive in the vicinity of Cooks River at the upstream extent of the model, Bexley Road in the vicinity of Wolli Creek at the upstream extent of the model, Marsh Street near Kogarah Golf Course, and an area near the entrance to the M5 East Tunnel.
- Levees: these were filtered out of the ALS data in developing the DEM along the Cooks River at a few locations, including Canterbury Racecourse, an area near Kogarah Golf Course, and a reach along Tempe Reserve. Cells along these levees were raised to ensure the levees were appropriately represented within the model.

Manning's roughness

The Manning's roughness value is one of the principle parameters that affects modelled flow within the floodplain, and is dependent on the ground profile and the type of cover. There is generally a direct correlation between ground cover and land use. Land use within the floodplain was defined based on cadastral data and aerial photographs provided by Sydney Water. The cadastral data was used to group land use within categories as defined in Table 4-1. Manning's n values were assigned to each land use to define the associated roughness of the area. The Manning's n values were assigned based on typical values documented in a variety of reference texts, plus understanding of the catchment and previous experience in the development of similar models.

Table 4-1: Floodplain Manning's n values

LAND USE	MANNING'S N
Roads	0.015
Airport	0.020
Open space/parkland	0.040
Dense vegetation	0.070
Creek/waterways	0.030
Botany Bay	0.020
Residential*	0.300*
Industrial*	0.300*

* *The manning's roughness value for residential and industrial land use are set much higher than the actual manning's roughness of the surfaces present in these areas. This is a hydraulic modelling approach used to represent the buildings in these areas that have been filtered out of the DEM. By applying this approach flow through residential areas is severely restricted as it would be if the buildings were present in the model, however flood plain storage volume (including that which occurs within buildings) is still correctly accounted for.*

Hydraulic floodplain structures

Major floodplain culverts and openings not correctly represented by the DEM were manually input into the TUFLOW model. Floodplain structures were defined in the TUFLOW model at two locations within the Cooks River floodplain by applying flow constrictions at the corresponding 2D cells.

The opening under the Canterbury-Campsie rail line embankment where Broughton Street passes under the rail line was modelled in this manner; as were the arched floodplain openings under the SWOOS in Wanstead Reserve as it crosses the southern floodplain of the Cooks River.

4.2.3 ONE-DIMENSIONAL (1D) MODEL DOMAIN

Channel definition

The ESTRY 1D domain within the TUFLOW model is used to model flow within the watercourses through of a network of channels (representing the conveyance of flows) and nodes (representing the storage within the network). The 1D ESTRY model requires channel cross section input similar to most other commonly used 1D models.

Cross-sections were located at approximately 100 m intervals along each watercourse, based on best available data. Three data sources were available for the generation of channel cross-sections; the selection of data source for a given cross-section was dependent on availability at a location within catchment. The three data sources (listed in order of preference) and areas where each was adopted are as follows:

Bathymetric Survey (2008)

The bathymetric survey was used to define cross-sections where available (Alexandra Canal, Wolli Creek from Cooks River to Turrella Weir, and the Cooks River from Botany Bay to just upstream of Burwood Road). This survey data is considered the most accurate of the survey data available for this study.

WMA Flood Study Survey (1977–1994)

Cross-section data extracted from the RUBICON model developed during the 1994 flood study (WMA, 1994) was used for areas outside the bathymetric survey limits, which were included in the 1994 study (Wolli Creek from Turrella Weir to Bexley Road and the Cooks River from Burwood Road to Water Street). The cross-sections used in the 1994 study were defined based on field channel survey data obtained from earlier Department of Public Works studies and supplementary data obtained specifically for the 1994 study. These sections provided greater channel definition in locations where the ALS data is limited due to interference from vegetation and water within the channel.

Airborne Laser Scanning (ALS) (2007)

The upper reach of the Cooks River modelled within this study (between Water Street and Centennial Drive) was not covered by the 2008 bathymetric survey or by any earlier modelling studies, so a detailed survey was not available. However, this area was reasonably well defined by the ALS data due to minimal vegetation cover and the channel type (mainly concrete channel which at the time of survey had very little water in it). In the absence of better data the ALS was therefore used to define cross-sections within this area. The cross-sections produced were checked against work as executed drawings, which were available for some sections of the upper Cooks River. The ALS was also used to define Coxs Creek channel sections from its junction with the Cooks River to Cosgrove Road.

Hydraulic watercourse structures

A total of 41 structures were included in the Cooks River TUFLOW model. These included road bridges, rail bridges, foot bridges, and pipelines that cross the Cooks River, Alexandra Canal and Wolli Creek. Details of each structure were sourced from survey drawings, listed in Section 1.4, representation of the structures in the 1994 RUBICON model and details recorded during site investigations (PB, May 2008).

Detailed bridge head loss was calculated for 19 structures (based on procedures outlined in Waterway Design Manual, AUSTROADS, 1994). A small average bridge loss was used for a further 10 bridges that have no in-river piers. A further seven of the bridge structures were represented in TUFLOW as box culverts due to their hydraulic shape. Average bridge losses were assumed for the final five minor bridge structures due to lack of available data.

Manning's roughness

Manning's roughness values within the channel were adopted based on site assessment and photographs, and checked against values reported in Chow (1959) and other reference texts. Values adopted for various reaches within the model are documented in Table 4-2. Variation in Manning's n across the channel was applied in locations where there is dense vegetation/ mangroves growing on the banks.

Table 4-2: Channel Manning's n

RIVER REACH	CHANNEL DESCRIPTION	MANNING'S N[1]
Cooks River (Centennial Drive to Morgan Place)	Rehabilitated channel section — naturalised banks and bed	0.04
Cooks River (Morgan Place to Brighton Avenue	Concrete channel (good condition)	0.015
Cooks River (Brighton Avenue to SWOOS)	Concrete channel, some sediment and gravel, slight variation in channel bed	0.022
Cooks River (SWOOS to Botany Bay)	Sheet pile banks, sediment and small rocks/gravel on bed	0.025
Wolli Creek	Vegetated channel	0.04
Alexandra Canal	Concrete banks, sediment and small rocks on bed	0.025

1. Manning's n of 0.04 was applied to all densely vegetated channel banks

4.2.4 BOUNDARY CONDITIONS

4.2.4.1 FLOW INPUTS

Flow hydrographs were defined at appropriate locations within the 1D network. The hydrographs were extracted from the WBNM hydrologic catchment model developed for this study. Flow hydrographs were applied at the following locations (as shown on Figure 4-1):

- upstream extent of the model on Cooks River (WBNM catchment CR5);
- Coxs Creek junction with Cooks River (WBNM catchment CC6);
- Cup and Saucer Creek junction with Cooks River (WBNM catchment CSC2);
- Muddy Creek junction with Cooks River (WBNM catchment MC2 & MC3);

- upstream extent of the model on Wolli Creek (WBNM catchment WC5);
- Bardwell Creek junction with Wolli Creek (WBNM Catchment BC2);
- upstream extent of the model on Alexandra Canal (WBNM Catchment AC5 inflow); and
- inflows from unnamed tributaries at their junction with Cooks River (WBNM sub-catchments CR9, CR10, CR12 and CR16).

Lateral inflows were also applied to the 1D model to represent flow from the following WBNM modelled sub-catchments:

- CR6
- CR7
- CR8
- CR11
- CR13
- CR14
- CR17
- CR18
- CR19
- WC6
- WC7
- AC5

Hydrographs were defined for the 2 year, 20 year and 100 year ARI events and the PMP storm event. A climate change event was also used, based on the estimated mid-range impacts (20% increase in rainfall intensity).

4.2.4.2 TIDE DETAILS

As the Cooks River discharges to Botany Bay, flood behaviour within the catchment is influenced by both runoff generated within the catchment and tide levels in Botany Bay. For the 1994 flood study, a range of tidal and fluvial events were investigated to assess the relative influence of the two factors on 100 year ARI flood levels within the catchment (WMA, 1994). The study found that downstream of the Princes Highway, flood levels were mainly influenced by tide levels in Botany Bay, while upstream of the Princes Highway they were mainly a factor of streamflow.

The High High Water Spring Solstice (HHWSS) tide level (peak of 1.1 m AHD) was adopted as the downstream boundary in this study for all fluvial flood events modelled, including the 100 year ARI fluvial flood event and the PMF. It was also used during the modelling for the 1994 flood study (WMA, 1994). This tidal downstream boundary was set as a fixed water level for the duration of the fluvial model runs.

Tidal flooding, resulting from the 100 year ARI tide level, was also modelled, in conjunction with a 2 year ARI fluvial event. Tidal Hydraulics of Botany Bay, Water Research Laboratory (WRL), Volume 1, 1980, states that the highest recorded tide within Botany Bay was 1.45 m AHD on 25 May 1974, recorded at the end of the AOR Jetty at Kurnell, and that this tide is considered to have an annual exceedance probability (AEP) of 1% (100 year ARI)[1]. Further discussions with WRL during assessing boundary conditions for use in this study indicated there have been no further studies, or updating of existing studies, in Botany Bay since the 1980 study (Brett Miller, pers com, January 2009).

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[1] Definitions of the terms AEP and ARI are provided in the glossary. For ARIs of greater then 10 years, the AEP is very closely approximated as the reciprocal of the AEP. The relationship between the two terms (with ARI expressed in years) can be expressed as (Bureau of Meterorology, 2006):

$$AEP = 1 - \exp\left(\frac{-1}{ARI}\right).$$

Large flood events in the catchment are likely to be associated with strong southerly or south-easterly winds. During the May 1974 event, wind stress effects of 0.2 m were determined to have occurred based on water level records around Brisbane Water (PWD, 1976). Brisbane Water and Botany Bay were compared during the 1994 Flood Study, and based on this assessment it was decided that a wind stress effect of between 0.2 m to 0.3 m at the entrance to the Cooks River could be expected (WBM, 1994). This study has used a wind stress effect of 0.25 m, as it represents the midpoint of the expected range.

A conservative estimate of the 1% AEP water level at the Cooks River entrance can be found by adopting the 1.45 m AHD level at Kurnell and then adding 0.25 m for storm-related effects to the downstream boundary at the Cooks River entrance. This is the methodology used for the Cooks River Flood Study to identify the 100 year ARI tidal flood event level. The 100 year ARI tide level in Botany Bay was therefore adopted as 1.7 m AHD. A tidal curve for Botany Bay was defined based on six-minute sea level predictions obtained from the Bureau of Meteorology's National Tidal Centre. This curve was shifted to match peak levels adopted (1.7 mAHD), and to ensure that the peak of the 2 year ARI fluvial hydrograph and the tide curve aligned to represent a worst case scenario.

4.2.4.3 CLIMATE CHANGE TIDAL ASSESSMENT

Given that the flooding within the lower reaches of the Cooks River is influenced by tide levels, it is expected that rises in sea level predicted to result from climate change will alter flood levels in the lower Cooks River and extend the tidal influence upstream. At this stage, there is considerable uncertainty regarding sea levels over the next century. Over the past decade, global mean sea level has been rising at about 3.2 mm per year based on satellite data. By 2100, beyond which sea level projections become very uncertain, the range of possible sea level rise is 0.18 m to 0.91 m, with 0.55 m as the mid-range value. The NSW Government has not yet provided firm guidance on what sea level rise to use for planning and development control. The NSW Department of Environment and Climate Change (DECC) *Floodplain Risk Management Guideline: Practical Consideration of Climate Change (DECC, 2007)* recommends sensitivity analyses with sea level rises of 0.18, 0.55 and 0.91 m. In line with that guideline, mid-level climate change ocean impacts were assessed for the Cooks River by increasing tide levels by 0.55 m. This is consistent with the latest 2007 report of the Inter-governmental Panel on Climate Change, which projected a sea level rise of approximately 0.6 m by 2100.

4.2.5 INITIAL CONDITIONS

Throughout the 1D domain, the initial water level was set to be the same as the peak tide level in Botany Bay and was used for all model runs.

Within the 2D domain, the initial water level was also defined to be at the tide level to create a stable model. In some locations within the 2D domain, the initial water level was defined based on the lowest point within the DEM in that vicinity to ensure that the catchment was dry at the start of the modelling run.

4.3 MODEL CALIBRATION

As discussed in Section 3.3 above, the hydrologic model used for this study was semi-calibrated using rainfall data from the November 1961 and the March 1983 storm events and flow hydrographs developed from hydrologic modelling during the 1994 Flood Study (WMA, 1994). These semi-calibrated flows were used in conjunction with flood level data recorded during both of these events in calibration of the Cooks River TUFLOW model.

The recorded flood level data used in the calibration was based on data within the compendium of data that was completed before the 1985 flood study, as reported in the 1994 Flood Study (WMA, 1994). This data consists of observed levels during the November 1961 and March 1983 events, both from council survey and residential interviews.

These two events were used to calibrate the model as they had the most flood level information and the best available rainfall data.

The flood level profile for the November 1961 event, from the TUFLOW model, is shown in Figure 4-2 along with the observed levels recorded during this event. The figure shows that at some locations during this event more than one flood level was recorded/observed. This is not uncommon and reflects the error that is inherent in recording levels during flood conditions. The modelled profile shows a relatively good fit to the recorded data. Generally, the modelled values are slightly lower then the recorded values. The largest difference between modelled and recorded levels is seen at Unwins Bridge. During the 1994 flood study, it was also noted that the modelling could not match the recorded data at this location and it was reported that the recorded level at Unwins Bridge was inconsistent with other observed levels and is possibly in error (WMA, 1994). The similarity of our findings supports this hypothesis.

The difference between the recorded data and the modelled levels at each location is noted in Table 4-3. The model represents existing conditions within the Cooks River catchment. Data is not available to provide a detailed understanding of changes in the catchment between 1961 and now. The difference in flood level may be due to numerous factors, including clearing/reduced mangrove vegetation since 1961, reduced levels of sedimentation within the channel (possibly due to dredging activities or better control of sediment runoff from the catchment), recording errors/inaccuracies or changes in catchment land surfaces.

The flood level profile for the March 1983 event, from the TUFLOW model, is shown in Figure 4-3 along with the observed levels recorded during this event. The modelled profile follows a similar pattern in the recorded data; however, the modelled levels are consistently 0.40– 0.45 m higher than recorded levels. The difference between the recorded data and the modelled levels at each location is noted in Table 4-3. As noted above, the model represents existing conditions within the Cooks River catchment. The difference in flood levels seen in the calibration events may be the result of numerous factors, including additional growth of mangrove vegetation on the banks of the main channel, increased sedimentation within the channel, recording errors/inaccuracies or changes in catchment land surfaces (e.g. due to increases urbanisation).

Table 4-3: Difference between modelled and recorded peak levels

LOCATION OF RECORDED DATA	NOVEMBER 1961 EVENT	MARCH 1983 EVENT
Unwins Bridge (Bayview Avenue)	- 0.87 m	+ 0.41 m
Illawarra Rd (Homer St)	- 0.14 m	+ 0.42 m
Wardell Rd	- 0.02m (below low end of recorded range)	No data
Church St	No data	+ 0.45 m
Canterbury Rd	Within recorded range	+ 0.13m (above high end of recorded range)
Brighton Ave	+ 0.78 m	+ 0.40 m

Note: + indicates model results are higher than recorded data; — indicates model results are lower than recorded data

It is noted that explanations of differences between recorded and modelled flood levels for the two calibration events may appear contradictory to some degree. However, the time between the 1961 event and the 1983 event, and between both events and the present, is sufficient to enable fluctuations of mangrove growth, sedimentation, and other changes within the catchment. The model results fall slightly below the recorded data for the November 1961 event and slightly high for the March 1983 event. Given the above discussion, the level of calibration achieved by the model is considered appropriate for the purposes of this study.

The modelling results for the 100 year ARI design event from the current study have also been compared to the results from the 1994 study so as to understand the potential impacts to adopted design flood levels due to differences in results between the two studies. Details of this assessment are provided in Section 4.5, below.

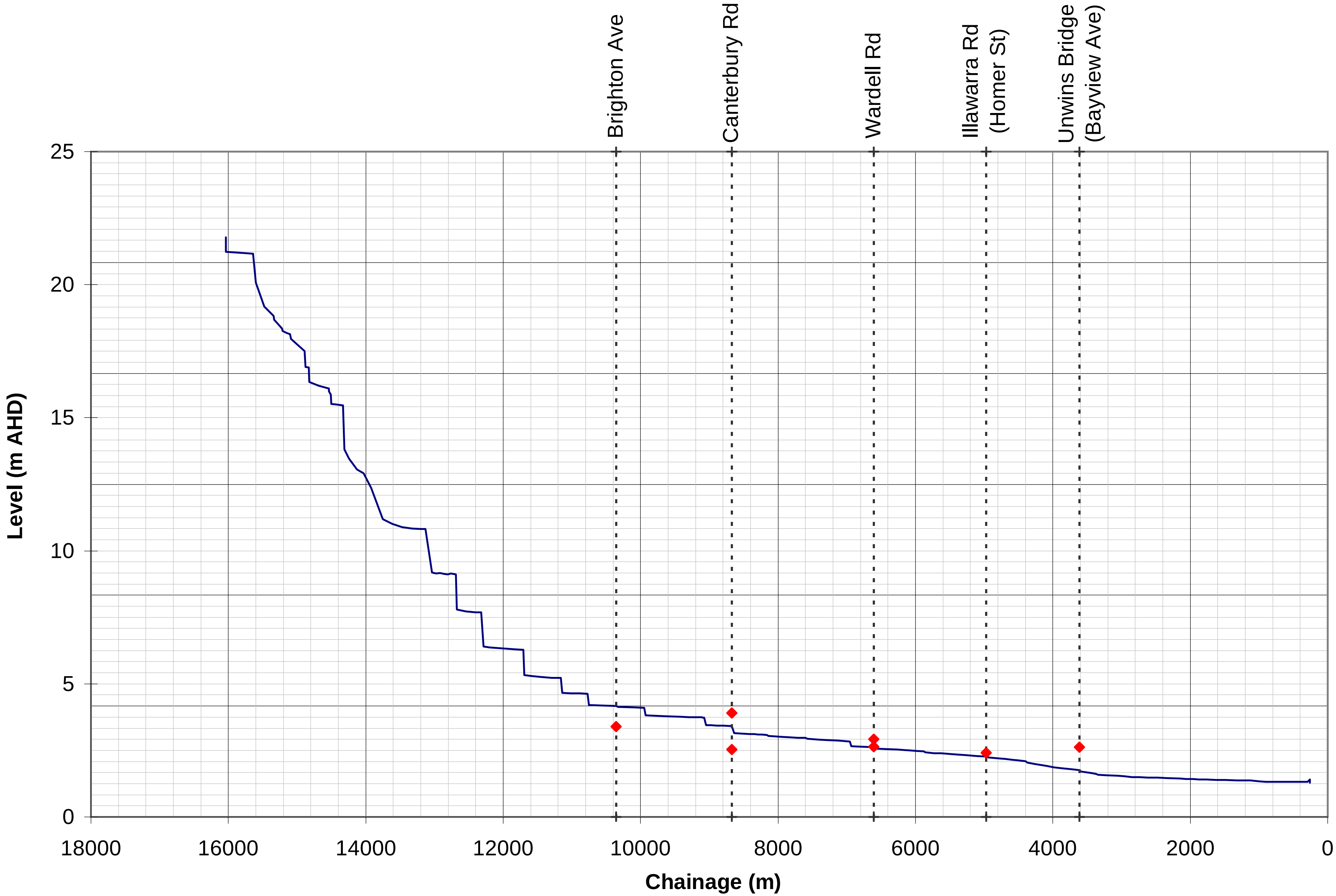

Figure 4-2 Cooks River Flood Profile November 1961

Modelled Water Profile
Calibration Data

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N
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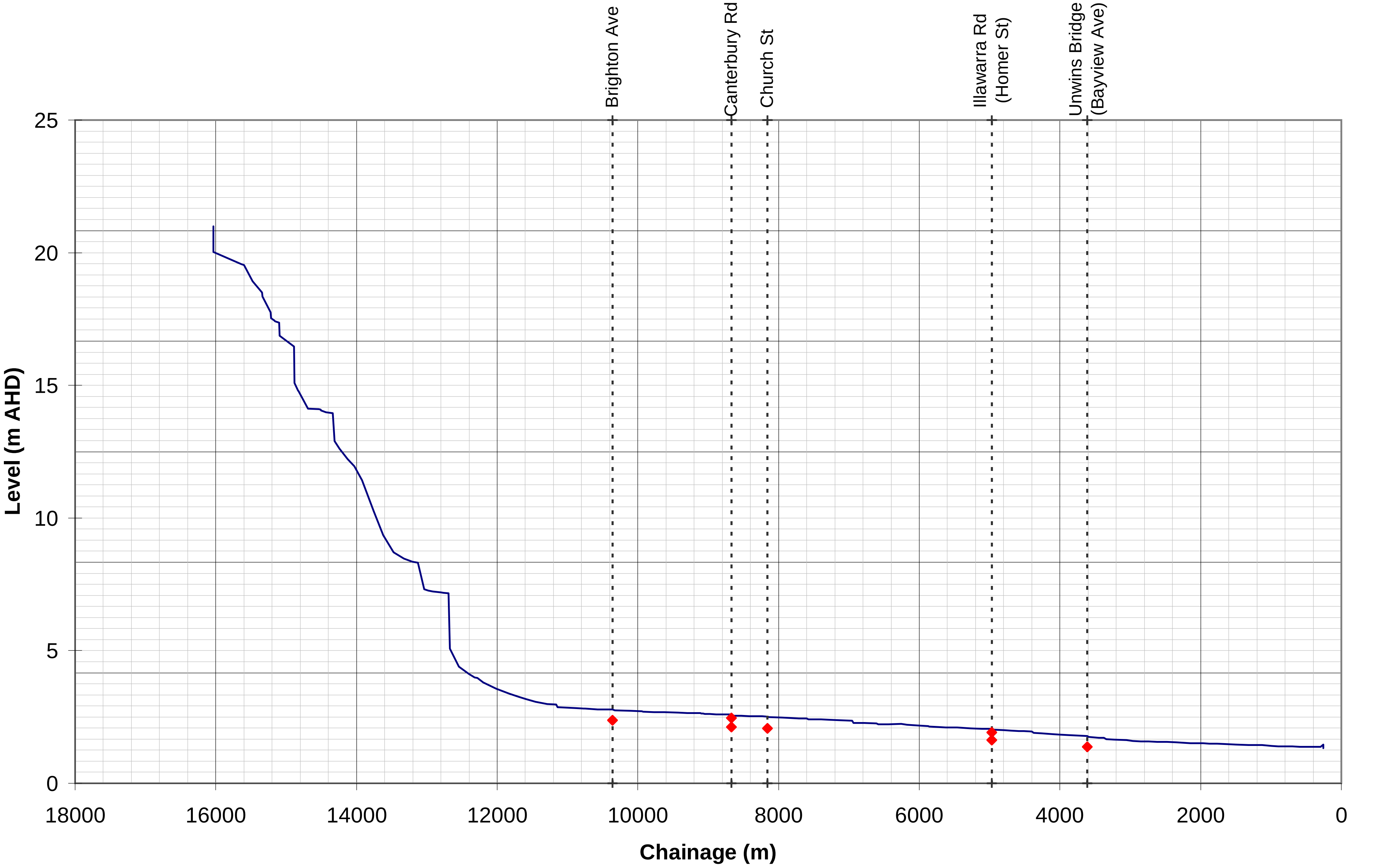

Figure 4-3 Cooks River Flood Profile March 1983

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N
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4.4 MODELLED DESIGN EVENTS

The Cooks River TUFLOW model was used to assess flood behaviour during the 2 year, 20 year, 100 year ARI and Probable Maximum Flood design storm events. As the Cooks River discharges to Botany Bay, a tidal flooding event was also assessed. Two climate change scenarios were also modelled; one assessing the impacts of increased rainfall intensity and the other to model impacts of predicted sea level rise. Details of flows and tide data used for each event are provided in Table 4-4. Details of flow inputs, sea levels adopted for the tidal magnitude, and discussion of climate change predictions is provided in Section 4.2.4, above. As noted in Section 1.5 above, blockage has not been modelled. This assumption should be considered in any future floodplain management studies within the catchment.

Table 4-4: Cooks River model event simulations

DESIGN EVENT	FLUVIAL MAGNITUDE	TIDAL MAGNITUDE
2 year ARI	2 year ARI	HHWSS*
20 year ARI	20 year ARI	HHWSS
100 year ARI - combines results from two model runs		
▪ 100 year ARI (fluvial)	100 year ARI	HHWSS
▪ 100 year ARI (tidal)	2 year ARI	100 year ARI
PMF	PMF	HHWSS
100 year ARI climate change scenario - combines results from two model runs:		
▪ 100 year ARI climate change (fluvial)	100 year ARI + 20% rainfall intensity	HHWSS + 0.55m
▪ 100 year ARI climate change (tidal)	2 year ARI	100 year ARI + 0.55m

*HHWSS = High Water Spring Solstice tide

The 100 year ARI flood profile adopted for the catchment was developed by combining the 100 year ARI (fluvial) event with the 100 year ARI (tidal) event. The higher of the two resulting flood levels was adopted throughout the catchment using GIS to overlay the two flood layers. This resulted in using the 100 year ARI (tidal) event for lower reaches of the catchment while the 100 year ARI (fluvial) event was adopted for higher reaches.

A similar approach was applied to develop the 100 year ARI climate change flood profile for the catchment. The flood levels resulting from the 100 year ARI climate change (fluvial) and the 100 year ARI climate change (tidal) scenarios were overlaid and combined by adopting the higher flood level of the two scenarios throughout the catchment.

4.5 MODEL RESULTS

Results of each of the five modelled events listed in Table 4-4 above are presented in flood extent maps in Appendix B. It should be noted that the flood inundation extents shown on minor tributaries (i.e. all watercourses except for the Cooks River, Alexandra Canal and Wolli Creek) is the result of backwater effects of the major modelled watercourses and does not take account of local flows.

From the aerial photograph in the background of this mapping, the properties within the catchment that are flood-affected can be seen. For the reaches of the Cooks River downstream of Brighton Avenue, the 100 year ARI flood extent mapping shows similar results in terms of affected properties to those seen in the results presented in Figure 21 and Figure 22 of the Cooks River Floodplain Management Study (WMA, 1994). Properties affected within the reaches upstream of Brighton Avenue were not assessed during the 1994 study. Notable areas where properties are affected by the 100 year ARI flood event include properties in the vicinity of:

- Bay Street, Tempe (Figure B-20)
- Carrington Road and Thornley, Marrickville (Figure B-18)
- Bankside Avenue to Bamboo Avenue, Earlwood (Figure B-18)
- Illawarra Road/Wharf Street Marrickville (Figure B-18)
- Riverview Road to Flinders Road, Earlwood (Figure B-17)
- Riverside Crescent, Dulwich Hill (Figure B-17)
- Lang Road Earlwood (Figure B-17)
- Tennent Parade, Hurlstone Park (Figure B-17)
- Hurlstone Avenue, Hurlstone Park (Figure B-17)
- Waterside Crescent, Earlwood (Figure B-17)
- Charles Street, Canterbury (Figure B-17)
- Phillips Avenue, Canterbury (Figure B-17)
- Between Bellombi Street and Adam Street, Campsie (Figure B-16)
- Byron Street, Campsie (Figure B-16)
- Fifth Avenue, Campsie (Figure B-16)
- Walsh Avenue, Croydon Park (Figure B-16)
- Water Street, Belfield (Figure B-16)
- Cave Road to Morgan Place, Strathfield (Figure B-15)
- Augusta Street Strathfield (Figure B-15); and
- Ada Avenue, Strathfield (Figure B-15).

Further details of model results for the 100 year ARI event are presented as maps of flood velocity and flood depth in Appendix C.

The flood level results for the 100 year ARI event have also been compared to the results presented within the Floodplain Management Study (WMA, 1994). The flood profile from the TUFLOW model for the 100 year ARI event is shown in Figure 4-4 along with flood levels as reported in the 1994 report. This figure shows that for much of the Cooks River, flood levels estimated in the 1994 study closely match the modelling results for this study. In the area around Brighton Avenue and Burwood Road, the current flood study estimates higher water levels than during the 1994 study. This may be due to more accurate survey being available for this study (this is within the extent of the bathymetric survey), different modelling techniques, or factors such as increased sedimentation within the channel.

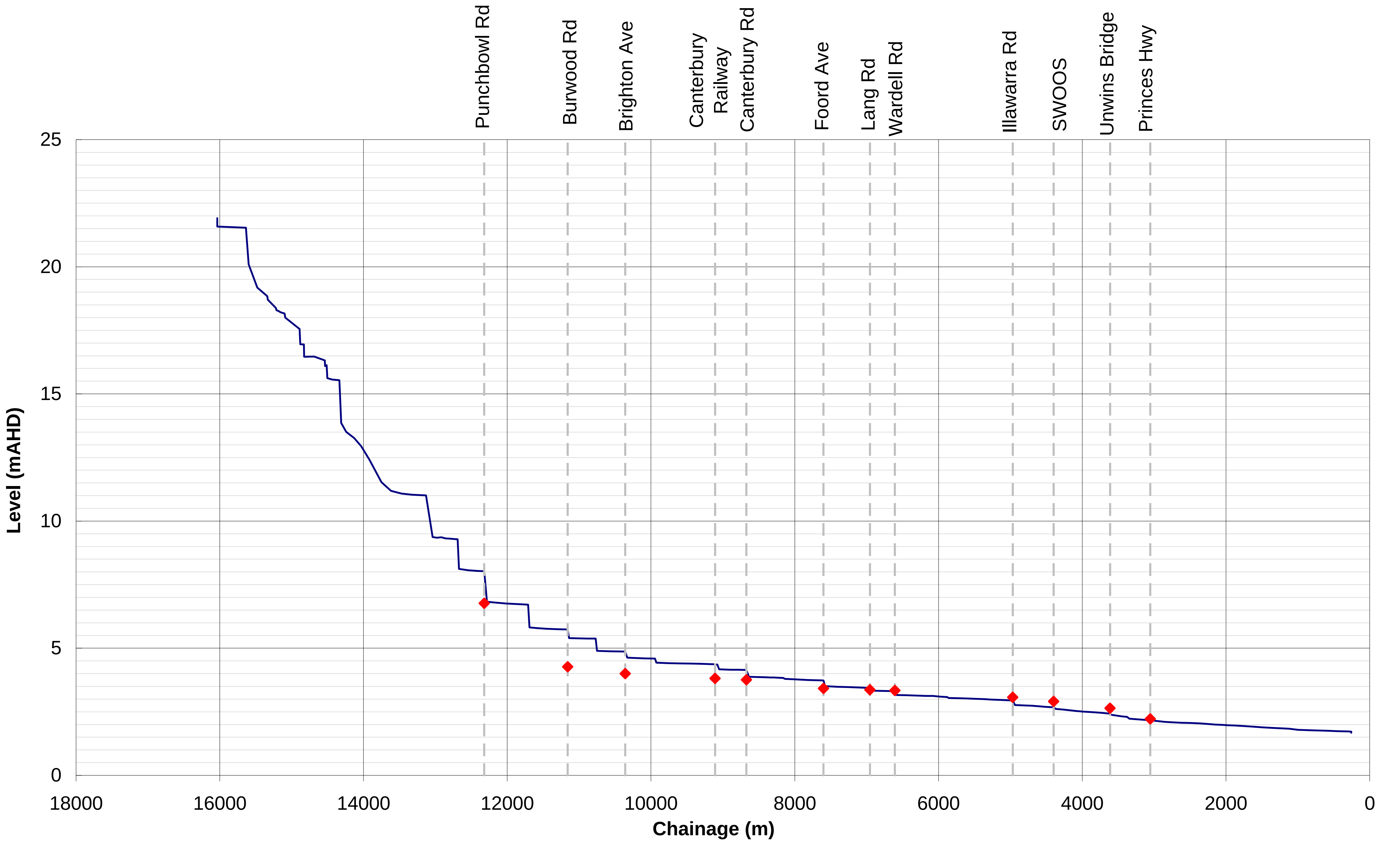

Figure 4-4: Cooks River 100 year ARI Flood Profile

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N

Max Water Level
1994 Floodplain Management Study 100 year ARI Levels

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The flood profile along the Cooks River for each of the design events modelled (2, 20, 100 year ARI, 100 year ARI climate change, and PMF) are shown in Figure 4-5. Details of flood level at a number of structures crossing the Cooks River are provided in Table 4-5.

Table 4-5: Cooks River Design Flood Levels

STRUCTURE	FLOOD LEVEL (mAHD)				
	2 YEAR ARI	20 YEAR ARI	100 YEAR ARI	100 YEAR ARI CLIMATE CHANGE	PMF
General Holmes Drive	1.29	1.54	1.73	2.34	2.78
Marsh Street	1.41	1.76	2.00	2.41	3.19
Princes Highway	1.49	1.89	2.16	2.55	3.46
Tempe - Wolli Creek Railway	1.57	2.01	2.30	2.67	5.24
SWOOS	1.82	2.34	2.67	3.20	6.14
Illawarra Road	1.93	2.49	2.94	3.50	6.25
Wardell Road	2.16	2.87	3.32	3.88	6.45
Lang Road	2.28	3.02	3.43	3.96	6.51
Foord Avenue	2.37	3.12	3.73	4.25	6.75
Canterbury Road	2.53	3.46	4.14	4.75	7.25
Canterbury Railway	2.59	3.72	4.37	4.92	7.61
Brighton Avenue	2.73	4.05	4.87	5.38	7.89
Burwood Road	2.92	4.83	5.74	6.34	8.60
Punchbowl Road	3.97	6.29	8.03	8.50	10.44
Water Street	7.30	8.78	9.37	9.74	11.71
Hume Highway	14.14	15.13	15.54	15.84	17.42
Morgan Place	16.62	17.37	17.55	17.79	18.73

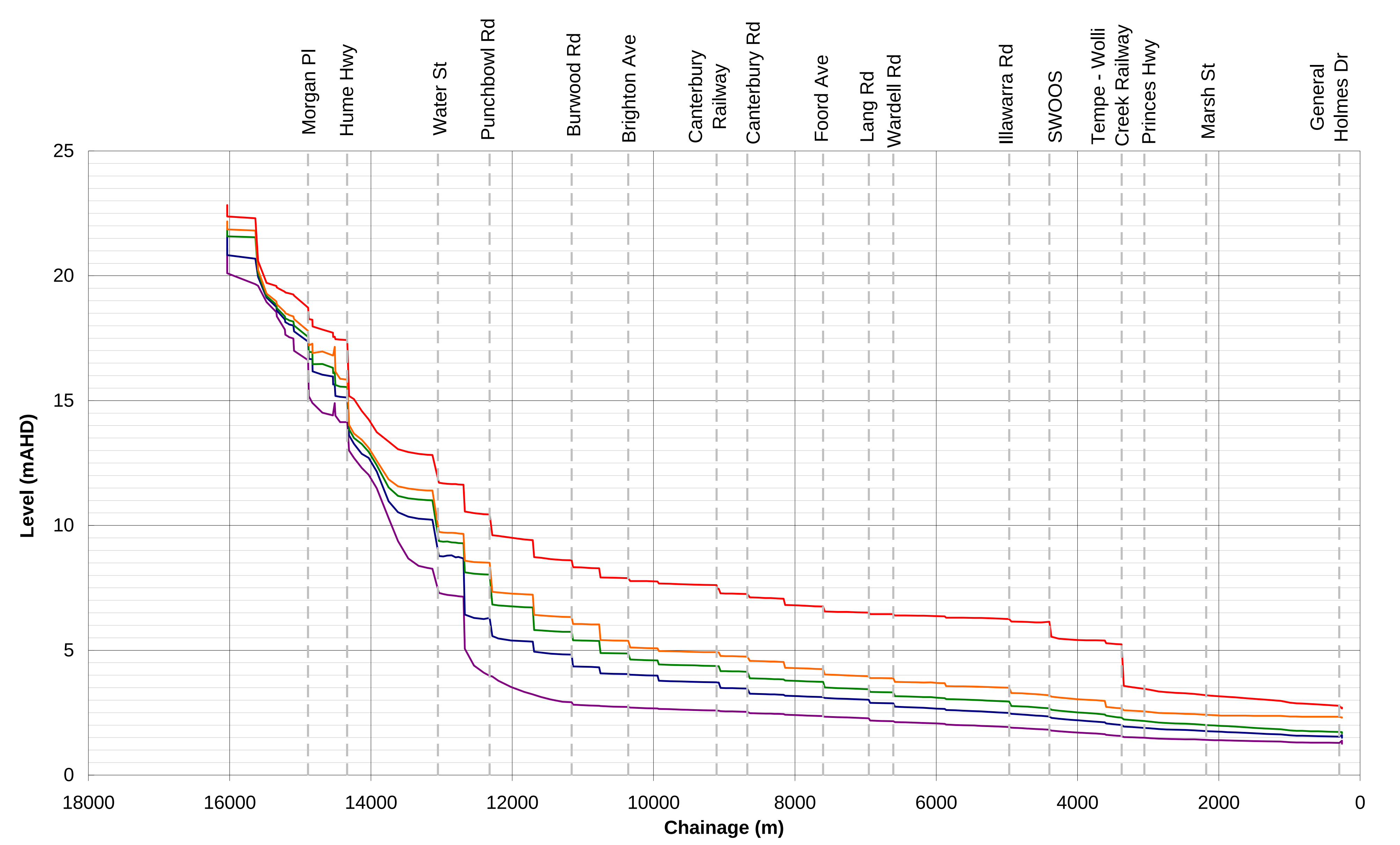

Figure 4-5: Cooks River Design Event Flood Profiles

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N

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5. CONCLUSIONS

This flood study provides an updated understanding of flood behaviour within the Cooks River catchment. This will enable all organisations and stakeholders within the catchment to make decisions using consistent and comprehensive flooding information. It will also provide a baseline to assess proposed bank naturalisation options along the Cooks River.

The models developed during this study will be used to provide an assessment of the hydraulic impacts of proposed bank naturalisation options. This will assist in ensuring that bank naturalisation along the Cooks River does not adversely change flood levels at properties within the catchment.

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APPENDIX A

HYDROLOGIC MODEL CALIBRATION

The following charts show the comparison of flows used in the 1994 hydraulic model (WMA) and the flows produced by the current WBNM model for the November 1961 (iWBNM 1961) and the March 1983 (iWBNM 1983) storm events at four locations within the Cooks River catchment (CR8, WC5, AC5, and MC2).

HYDROLOGIC MODEL CALIBRATION

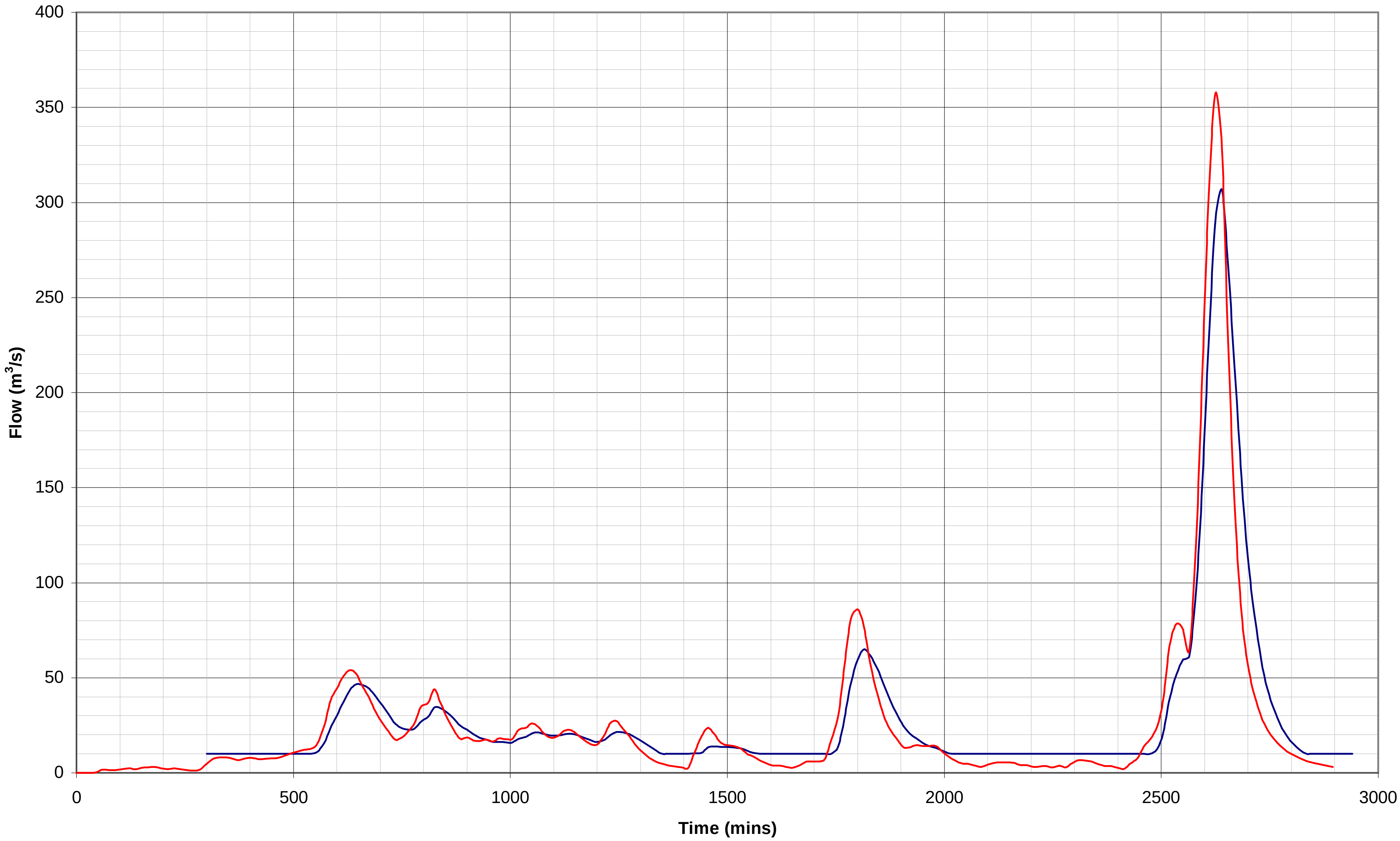

Figure A-1: Cooks River (CR8) Nov 1961

Project: Cooks River Flood Study

Client: Sydney Water

Project Number: 2114299N

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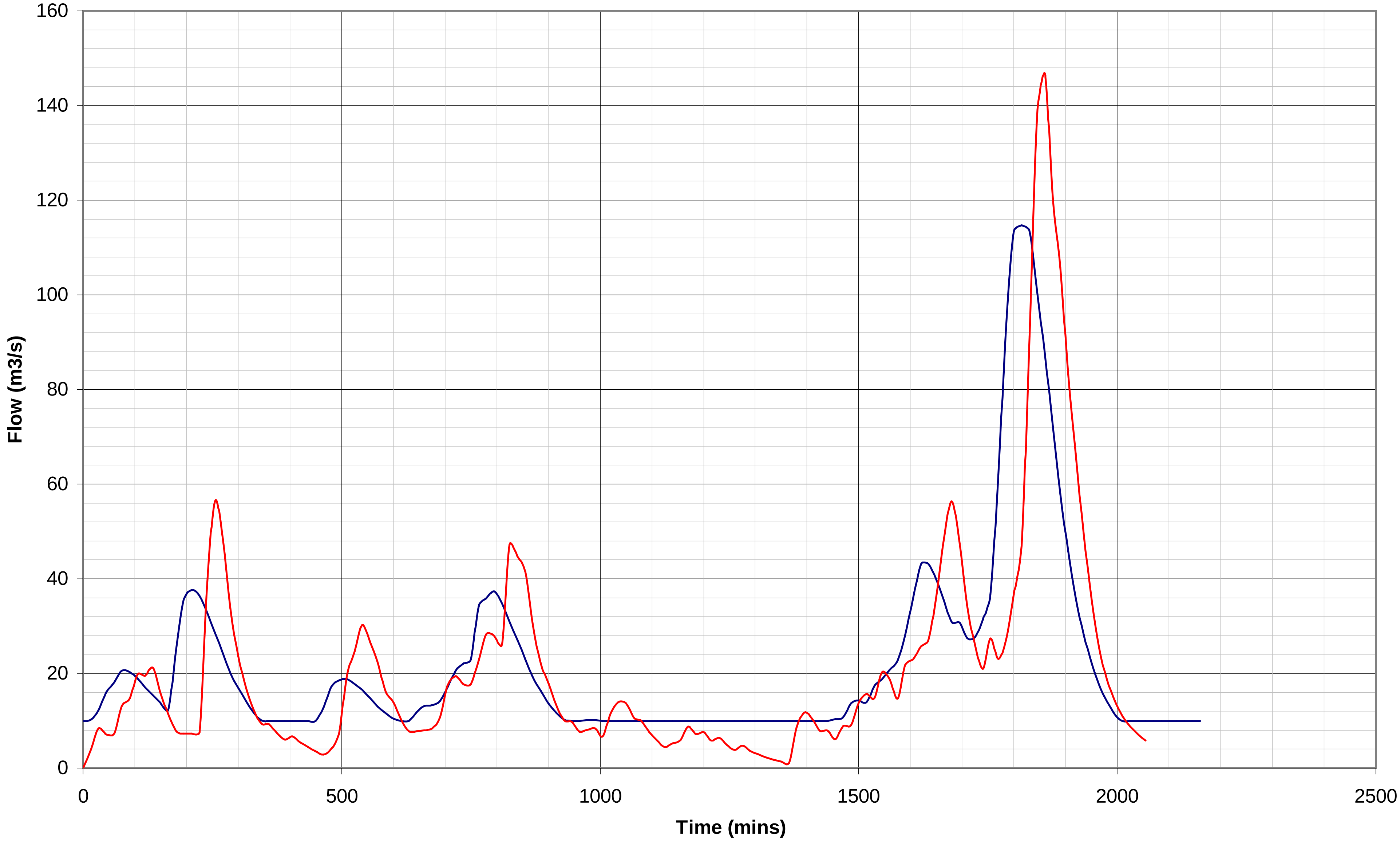

Figure A-2: Cooks River (CR8) Mar 1983

WMA (1994) Model - QCOOKS
CURRENT MODEL - CR8 (top)

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N

File Path: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\05_WrkPapers\Technical\01 Hydrology\WBNM\calibration assessment\WBNM calibration 07.xls

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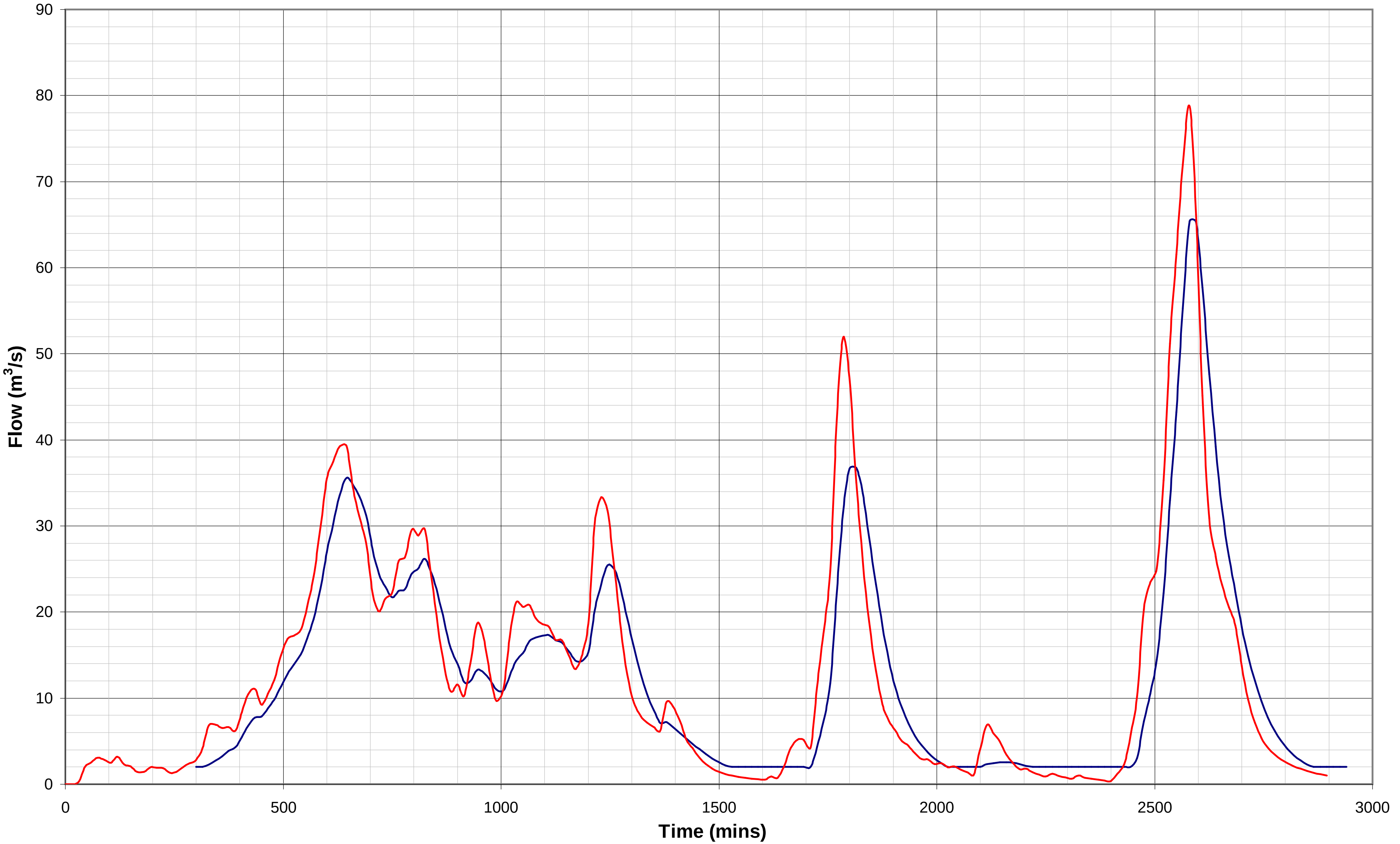

Figure A-3: Wolli Creek (WC5) Nov 1961

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N
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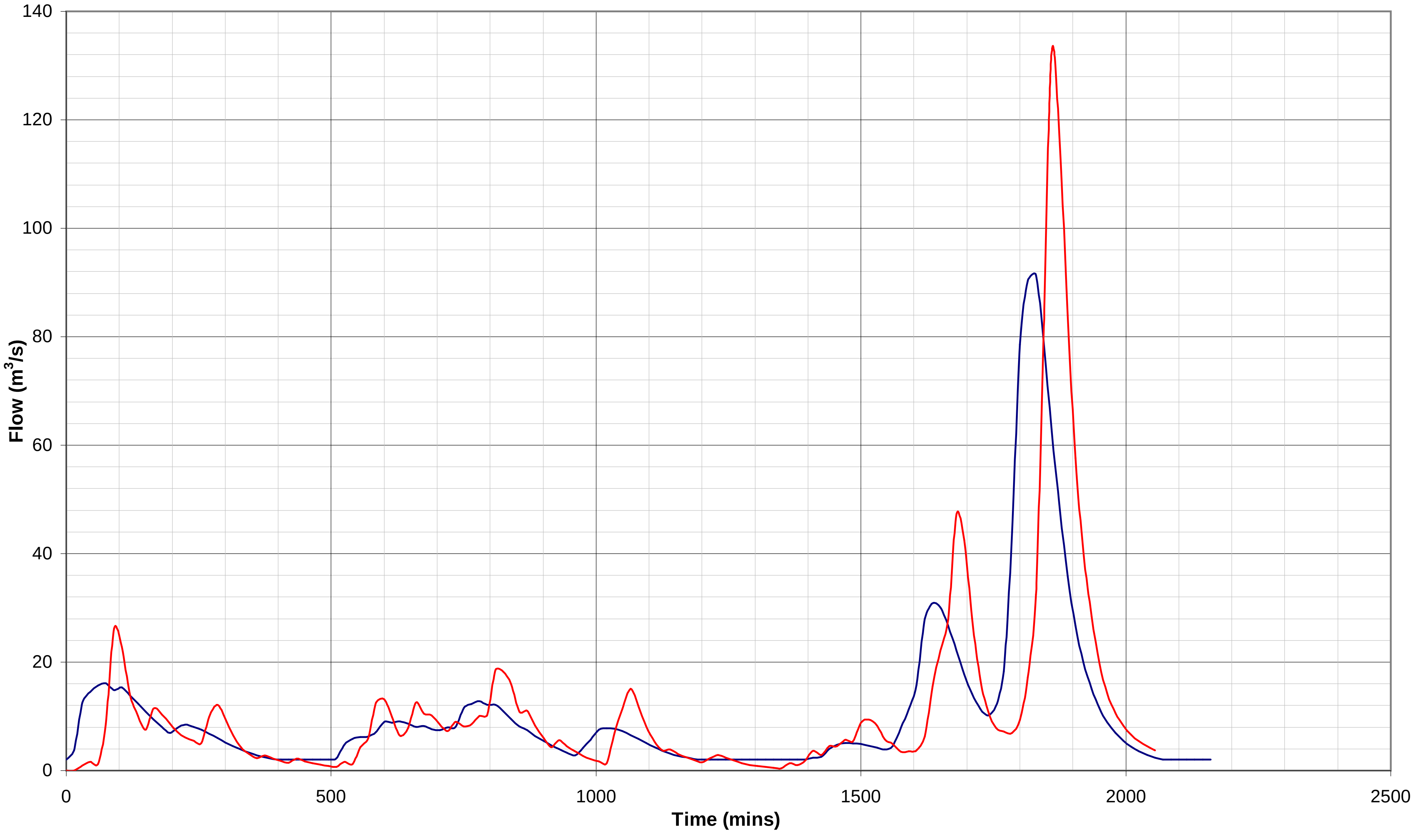

Figure A-4: Wolli Creek (WC5) Mar 1983

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N
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WMA (1994) MODEL - QWOLLI
CURRENT MODEL - WC5 (Q outflow)

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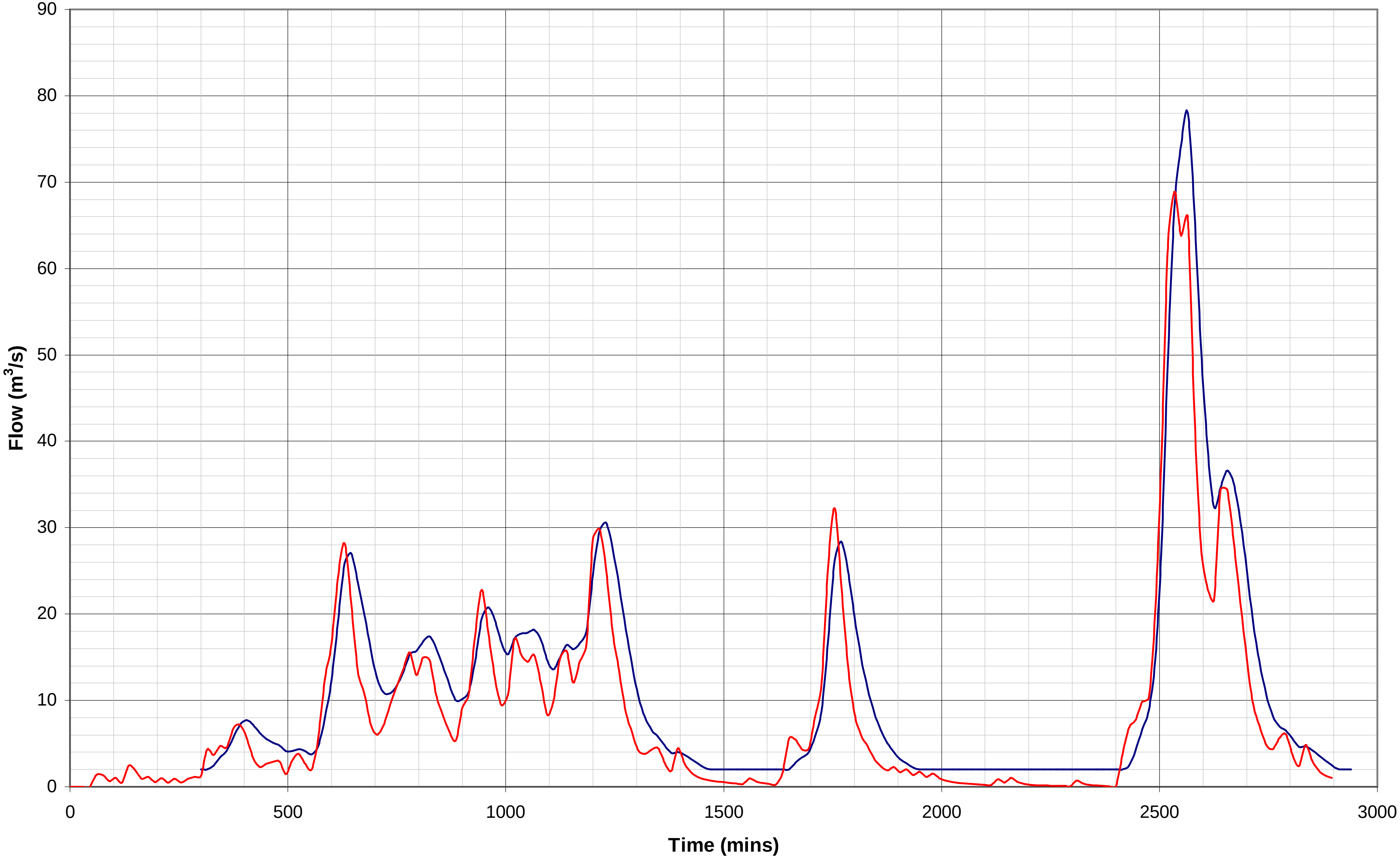

Figure A-5: Alexandra Canal (AC5) Nov 1961

Project: Cooks River Flood Study
Client: Sydney Water
Project Number: 2114299N
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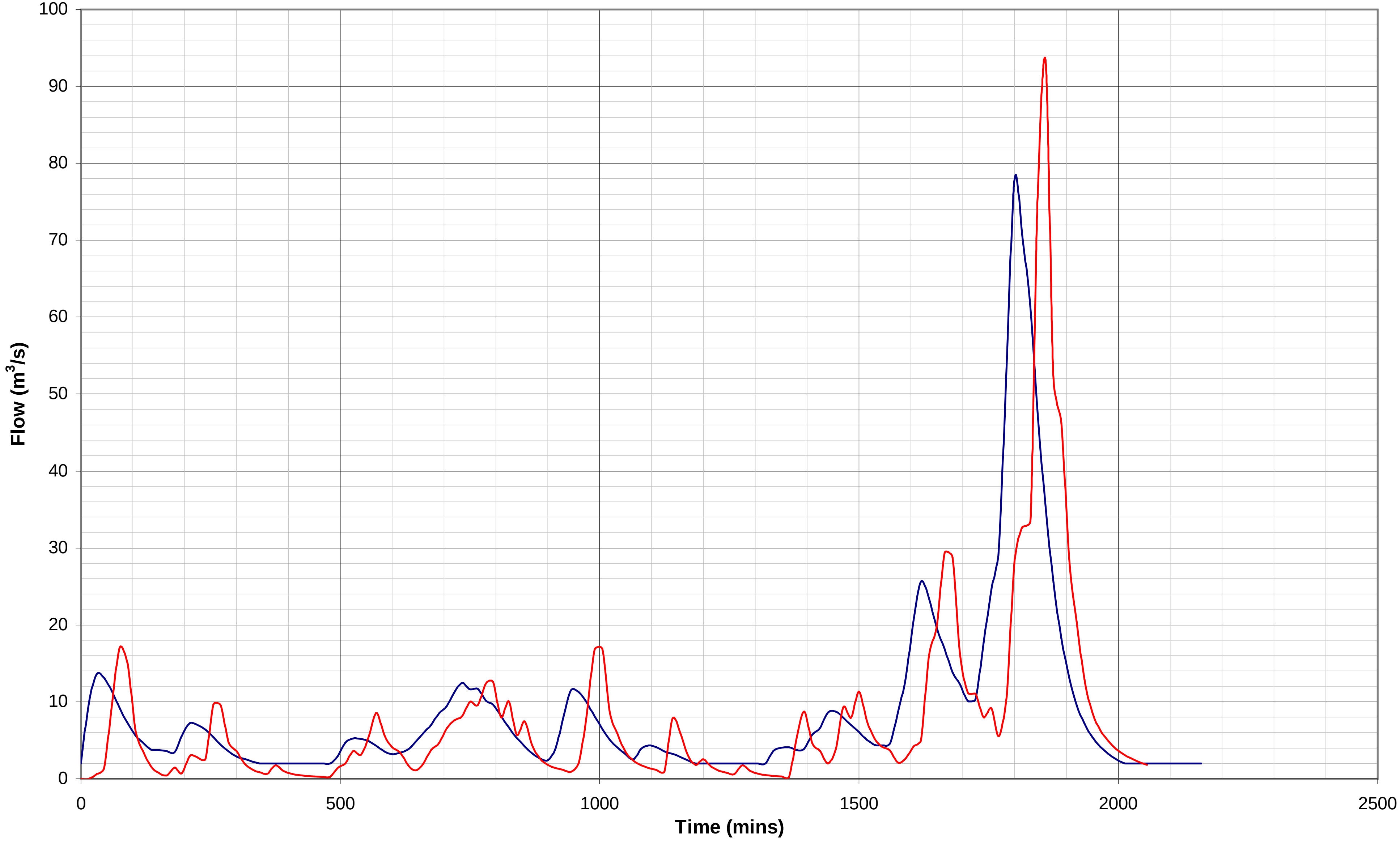

Figure A-6: Alexandra Canal (AC5) Mar 1983

Project: Cooks River Flood Study

Client: Sydney Water

Project Number: 2114299N

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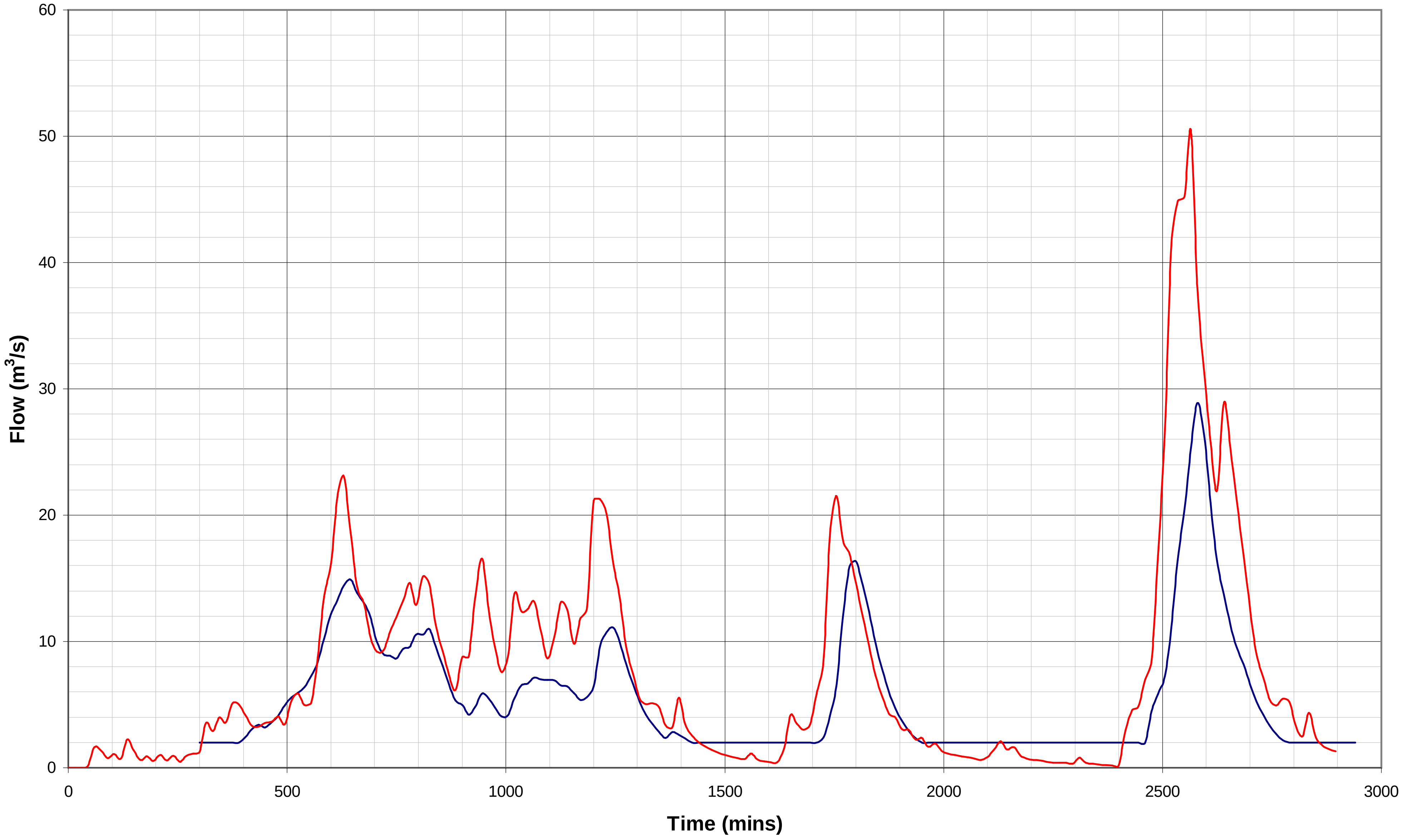

Figure A-7: Muddy Creek (MC2) Nov 1961

Project: Cooks River Flood Study

Client: Sydney Water

Project Number: 2114299N

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WMA (1994) MODEL - QMUDDY

CURRENT MODEL - MC2 (Q outflow)

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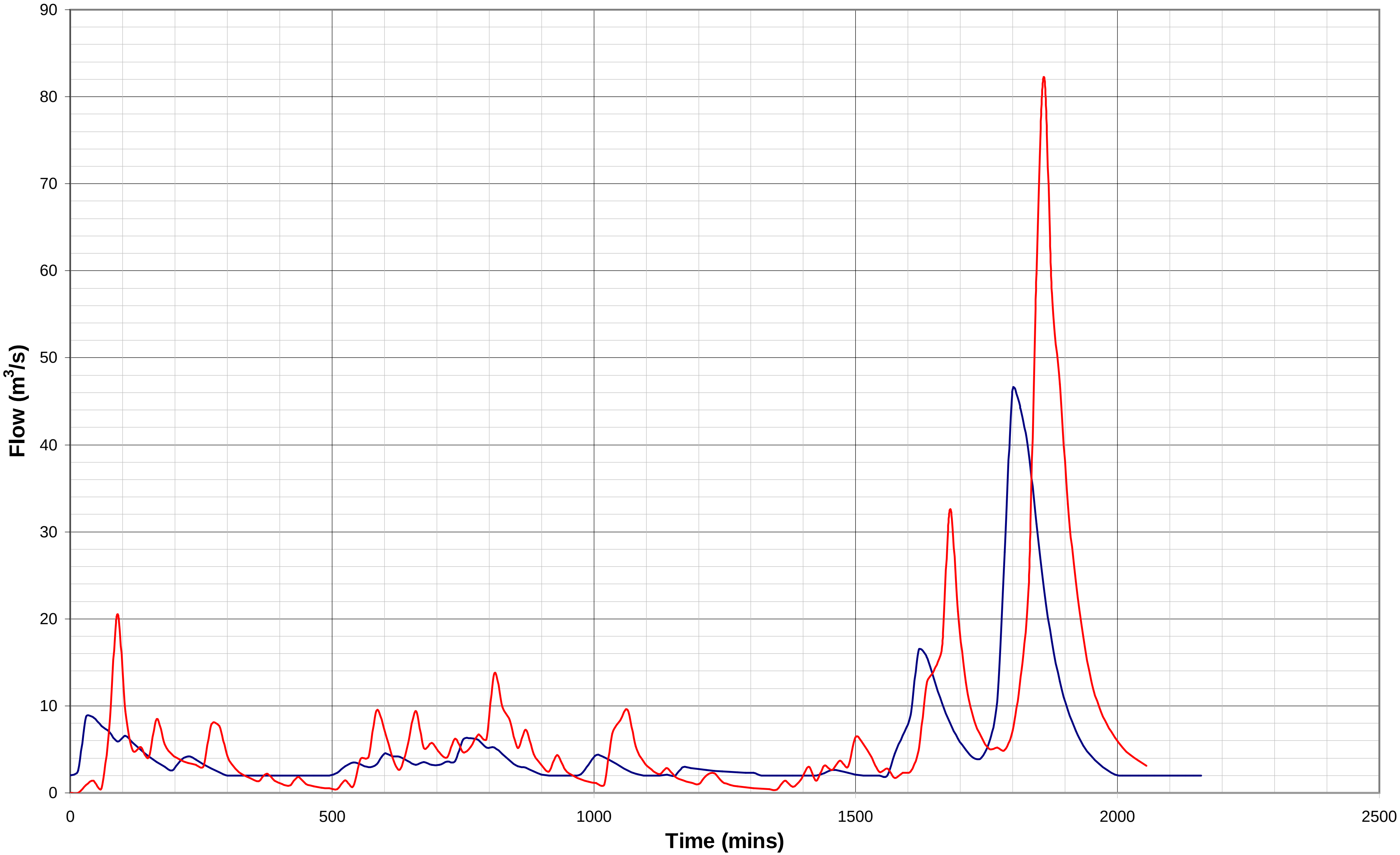

Figure A-8: Muddy Creek (MC2) Mar 1983

Project: Cooks River Flood Study

Client: Sydney Water

Project Number: 2114299N

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WMA (1994) MODEL - QMUDDY

CURRENT MODEL - MC2 (Q outflow)

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APPENDIX B

FLOOD EXTENT MAPPING

FLOOD EXTENT MAPPING

Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- 2 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2003a_Cooks_River_Flood_extents_2yr_Sheet1.pdf

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Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\2114299N_2003a_Cooks_River_Flood_extents_2yr_Sheet1.mxd	DWG. No:	2114299N_2003a	Fig. No.	B-1

Flood level (mAHD)

0.1 m interval

0.5 m interval

2 year ARI flood extent

LGA boundaries

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PDF File: 2114299N_2003b_Cooks_River_Flood_extents_2yr_Sheet2.pdf

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Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
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Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- 2 year ARI flood extent
- LGA boundaries

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Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
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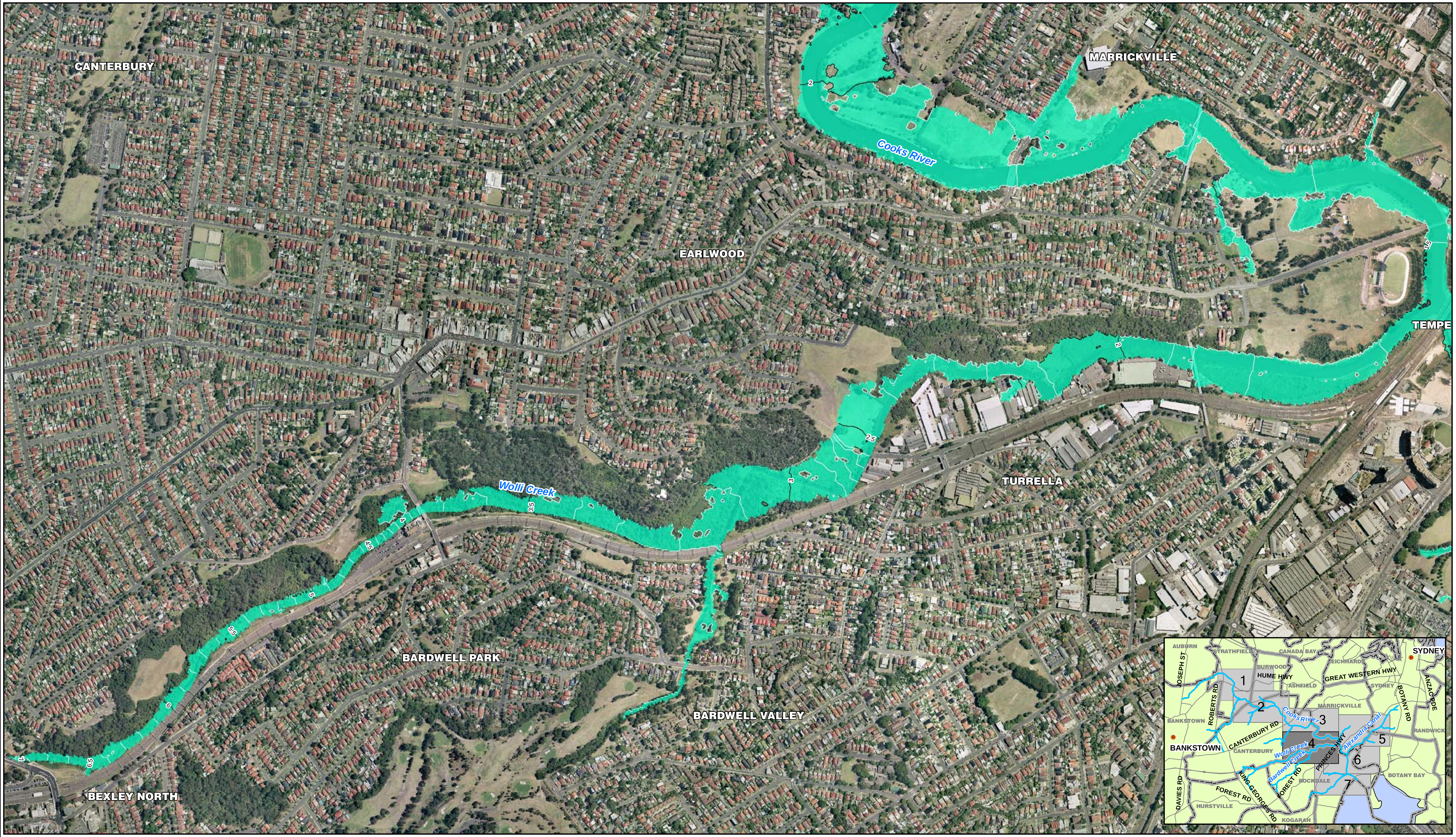

Flood level (mAHD)

0.1 m interval

0.5 m interval

2 year ARI flood extent

LGA boundaries

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0 250 500 Metres

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Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- 2 year ARI flood extent
- LGA boundaries

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0 250 500 Metres

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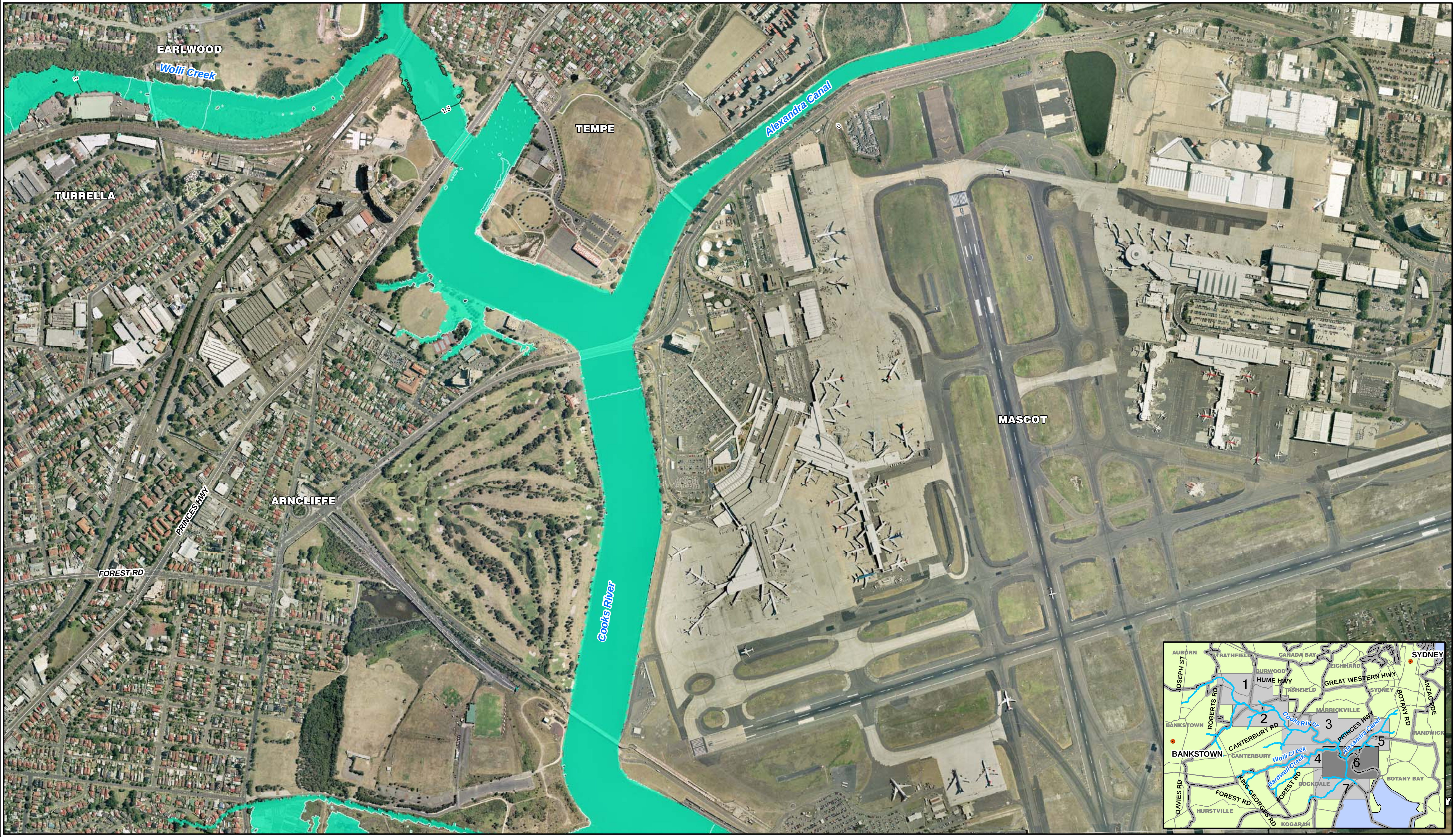
Client: SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N Layout Size: A3	Checked: KS	Date: Feb, 09	
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GISProjects\ArcView\2114299N_2003e_Cooks_River_Flood_extents_2yr_Sheet5.mxd	DWG. No: 2114299N_2003e	Fig. No. B-5	



Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- 2 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2003f_Cooks_River_Flood_extents_2yr_Sheet6.pdf

0 250 500 Metres

Title: Flood Extent Mapping 2 year ARI Sheet 6 of 7	PARSONS BRINCKERHOFF / Sydney WATER		
	Datum: GDA94 / Zone 56	Scale: 1:10,000	
Project: Cooks River Flood Study	Drawn: GK	Date: Oct, 08	
Client: SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2003f_Cooks_River_Flood_extents_2yr_Sheet6.mxd	DWG. No: 2114299N_2003f	Fig. No. B-6	

Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- 2 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

PDF File: 2114299N_2003g_Cooks_River_Flood_extents_2yr_Sheet7.pdf

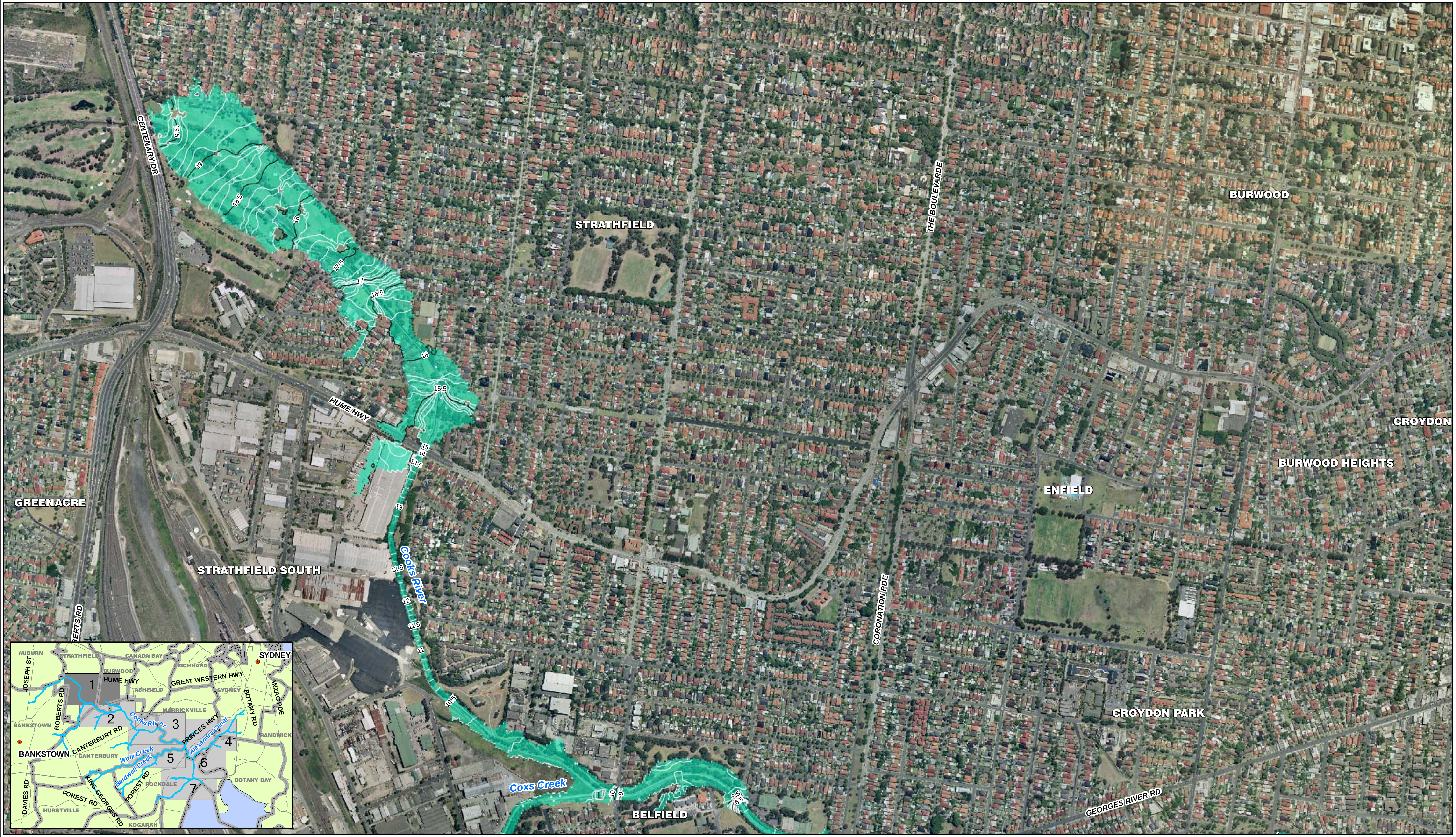
0 250 500 Metres

Title: Flood Extent Mapping
2 year ARI
Sheet 7 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Project: Cooks River Flood Study		Datum: GDA94 / Zone 56		Scale: 1:10,000	
		Drawn: GK		Date: Oct, 08	
Client: SYDNEY WATER		Designed: GK		Date: Oct, 08	
Proj. No. 2114299N	Layout Size: A3	Checked: KS		Date: Feb, 09	
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\ 2114299N_2003g_Cooks_River_Flood_extents_2yr_Sheet7.mxd		DWG. No: 2114299N_2003g		Fig. No. B-7	



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2004a_Cooks_River_Flood_extents_20yr_Sheet1.pdf

0 250 500 Metres

Title:	Flood Extent Mapping 20 year ARI Sheet 1 of 7		PARSONS BRINCKERHOFF / Sydney WATER		
			Datum: GDA94 / Zone 56		Scale: 1:10,000
Project:	Cooks River Flood Study		Drawn: GK		Date: Oct, 08
Client:	SYDNEY WATER		Designed: GK		Date: Oct, 08
Proj. No.	2114299N	Layout Size: A3	Checked: KS		Date: Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\ 2114299N_2004a_Cooks_River_Flood_extents_20yr_Sheet1.mxd		DWG. No: 2114299N_2004a		Fig. No. B-8

Flood level (mAHD)

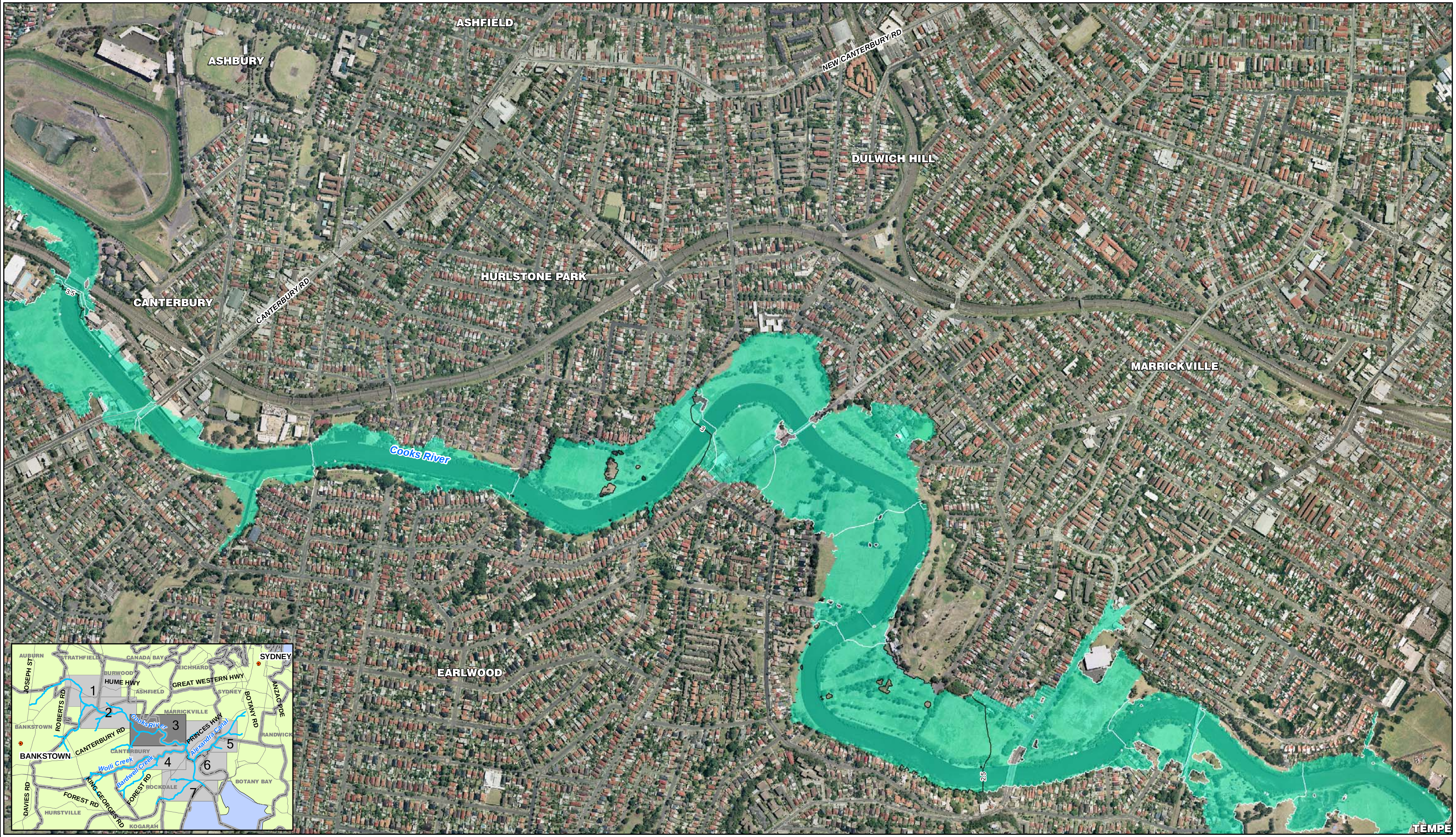
- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2004b_Cooks_River_Flood_extents_20yr_Sheet2.pdf

0 250 500 Metres

Title: Flood Extent Mapping 20 year ARI Sheet 2 of 7	PARSONS BRINCKERHOFF / Sydney WATER		
	Datum: GDA94 / Zone 56	Scale: 1:10,000	
Project: Cooks River Flood Study	Drawn: GK	Date: Oct, 08	
Client: SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N — Layout Size: A3	Checked: KS	Date: Feb, 09	
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2004b_Cooks_River_Flood_extents_20yr_Sheet2.mxd	DWG. No: 2114299N_2004b	Fig. No. B-9	



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

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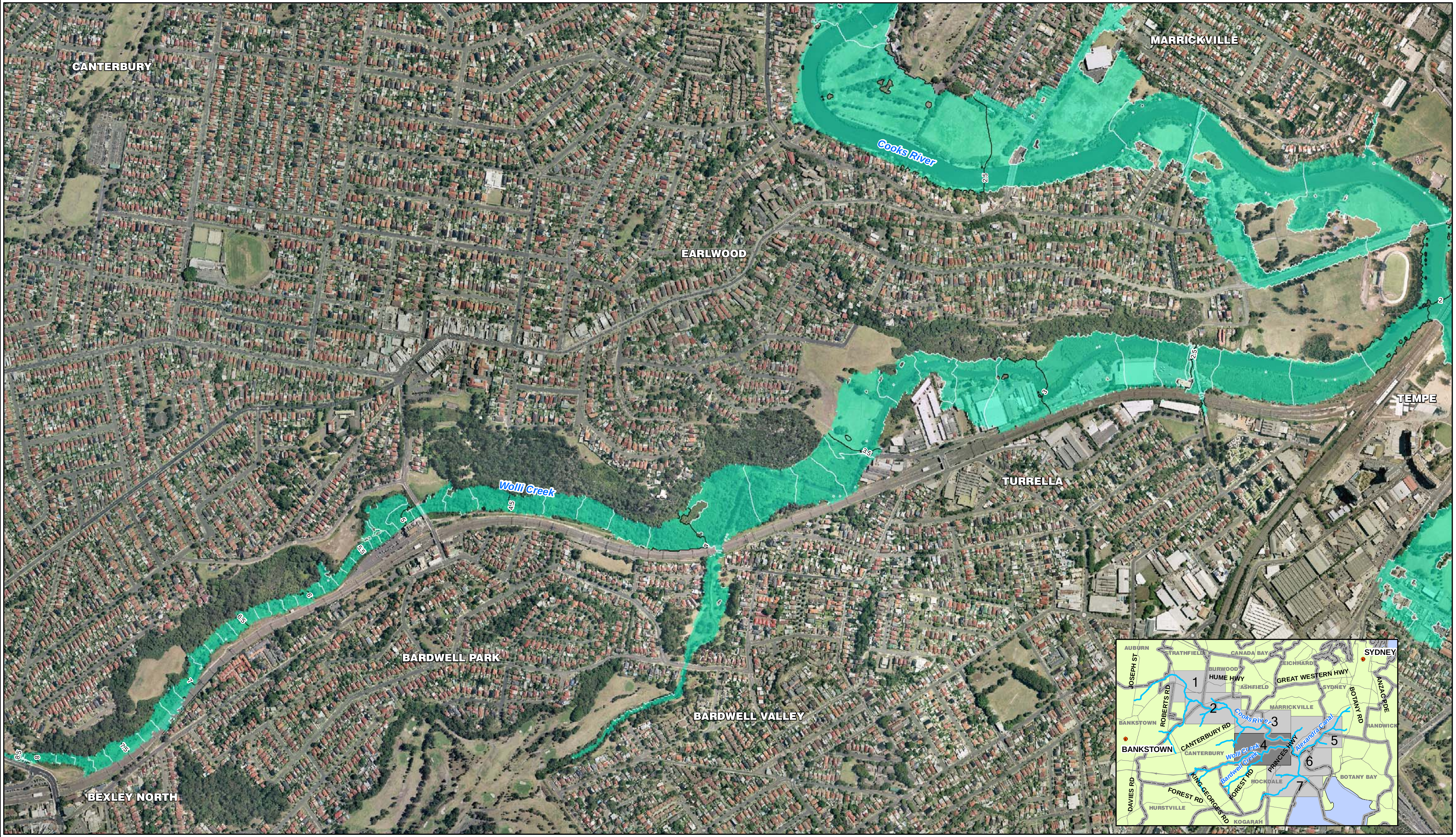
PDF File: 2114299N_2004c_Cooks_River_Flood_extents_20yr_Sheet3.pdf

0 250 500 Metres

Title: Flood Extent Mapping 20 year ARI Sheet 3 of 7		PARSONS BRINCKERHOFF / Sydney WATER			
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2004c_Cooks_River_Flood_extents_20yr_Sheet3.mxd		DWG. No:	2114299N_2004c	Fig. No.	B-10



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2004d_Cooks_River_Flood_extents_20yr_Sheet4.pdf

0 250 500 Metres

Title: Flood Extent Mapping 20 year ARI Sheet 4 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2004d_Cooks_River_Flood_extents_20yr_Sheet4.mxd		DWG. No: 2114299N_2004d	Fig. No. B-11

Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

PDF File: 2114299N_2004e_Cooks_River_Flood_extents_20yr_Sheet5.pdf

0 250 500 Metres

Title: Flood Extent Mapping
20 year ARI
Sheet 5 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Datum:	GDA94 / Zone 56	Scale:	1:10,000
Drawn:	GK	Date:	Oct, 08
Designed:	GK	Date:	Oct, 08
Checked:	KS	Date:	Feb, 09
DWG. No:	2114299N_2004e	Fig. No.	B-12

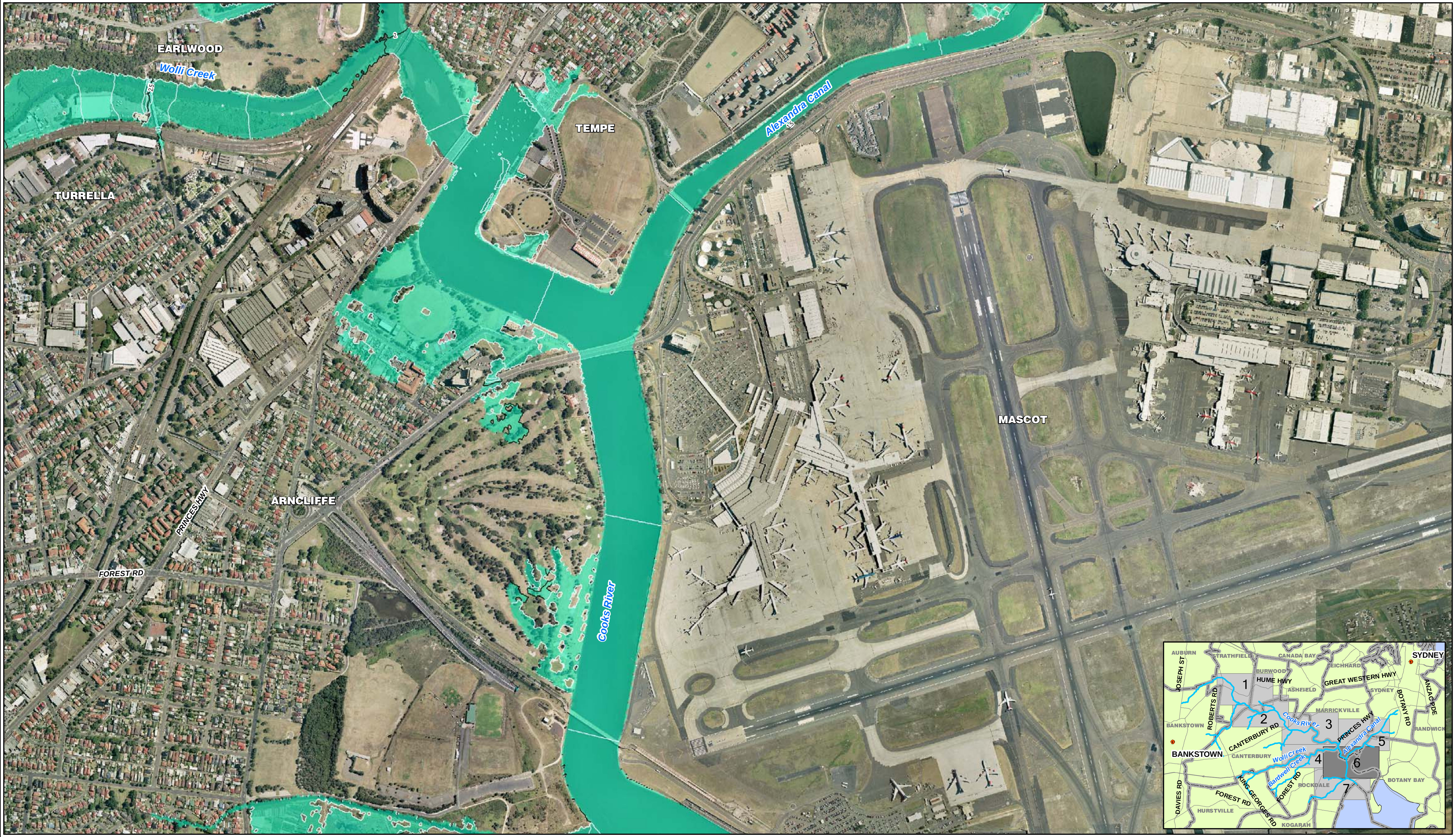
Project: Cooks River Flood Study

Client: SYDNEY WATER

Proj. No. 2114299N

Layout Size: A3

GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\2114299N_2004e_Cooks_River_Flood_extents_20yr_Sheet5.mxd



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2004f_Cooks_River_Flood_extents_20yr_Sheet6.pdf

0 250 500 Metres

Title: Flood Extent Mapping 20 year ARI Sheet 6 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2004f_Cooks_River_Flood_extents_20yr_Sheet6.mxd		DWG. No: 2114299N_2004f	Fig. No. B-13

Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 20 year ARI flood extent
- LGA boundaries

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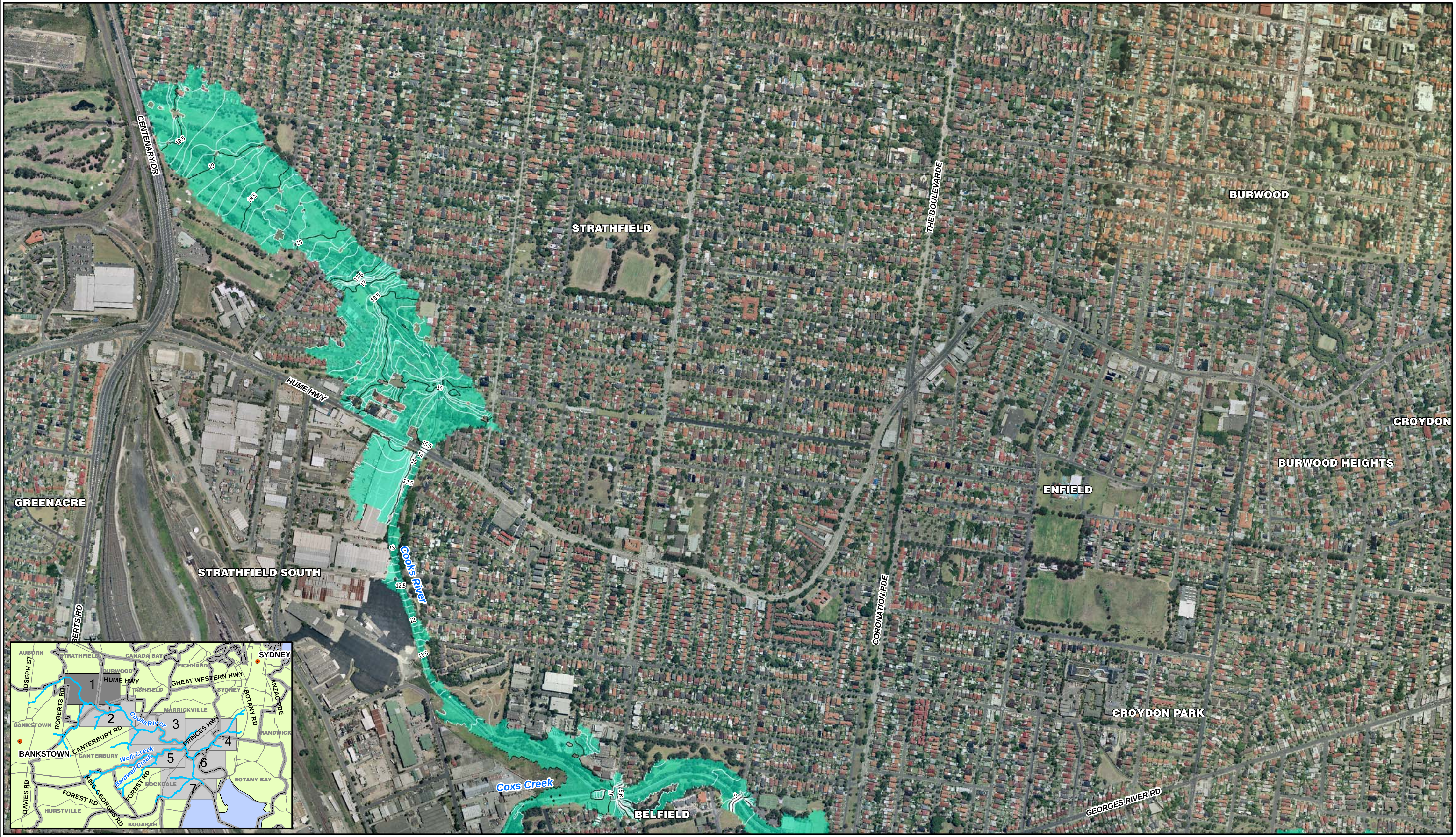
PDF File: 2114299N_2004g_Cooks_River_Flood_extents_20yr_Sheet7.pdf

0 250 500 Metres

Title: Flood Extent Mapping 20 year ARI Sheet 7 of 7		PARSONS BRINCKERHOFF / Sydney WATER			
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2004g_Cooks_River_Flood_extents_20yr_Sheet7.mxd	DWG. No:	2114299N_2004g	Fig. No.	B-14



Flood level (mAHD)

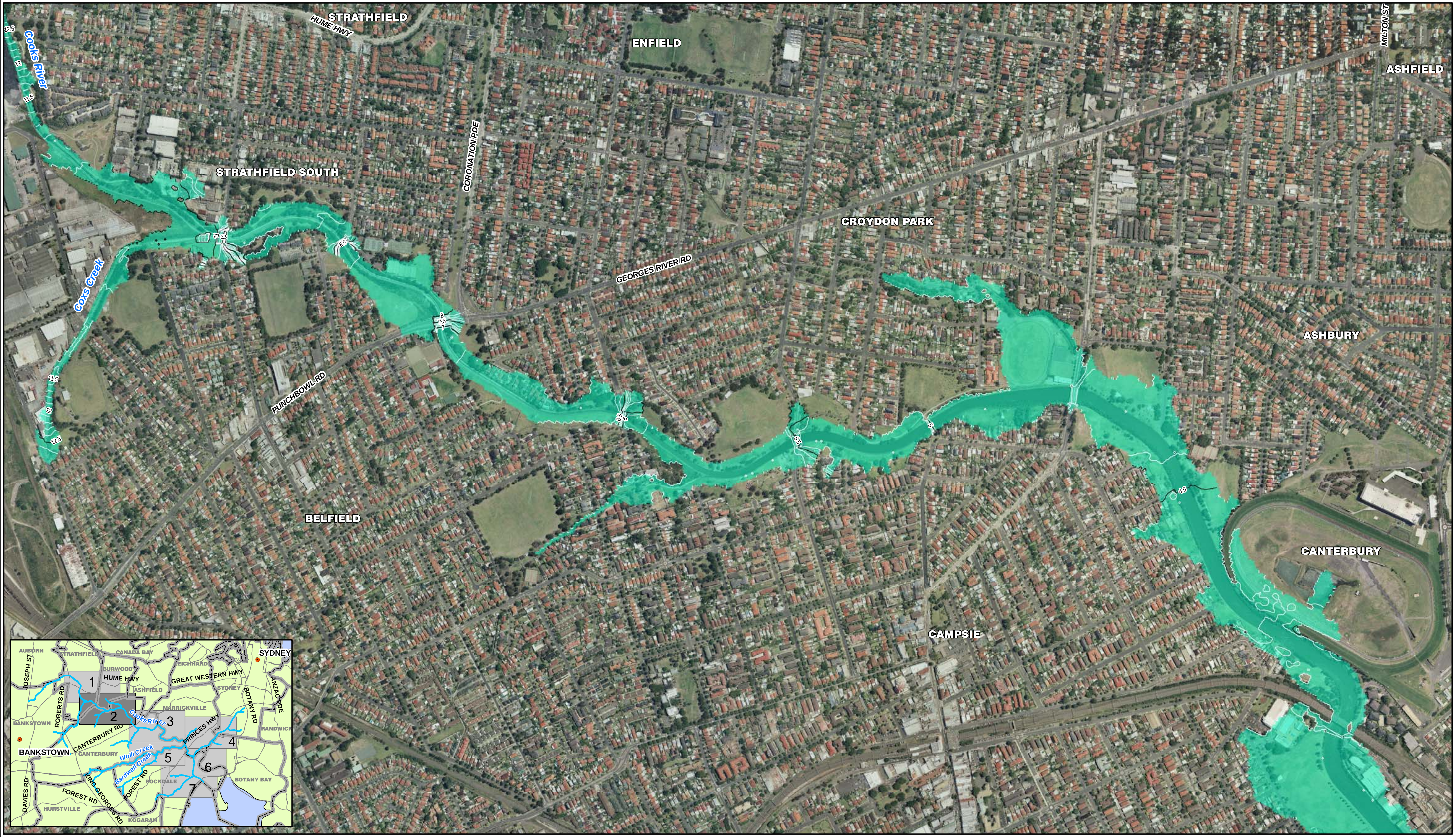
- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

PDF File: 2114299N_2005a_Cooks_River_Flood_extents_100yr_Sheet1.pdf

0 250 500 Metres

Title: Flood Extent Mapping 100 year ARI Sheet 1 of 7		PARSONS BRINCKERHOFF		Sydney WATER	
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\2114299N_2005a_Cooks_River_Flood_extents_100yr_Sheet1.mxd	DWG. No:	2114299N_2005a	Fig. No.	B-15



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

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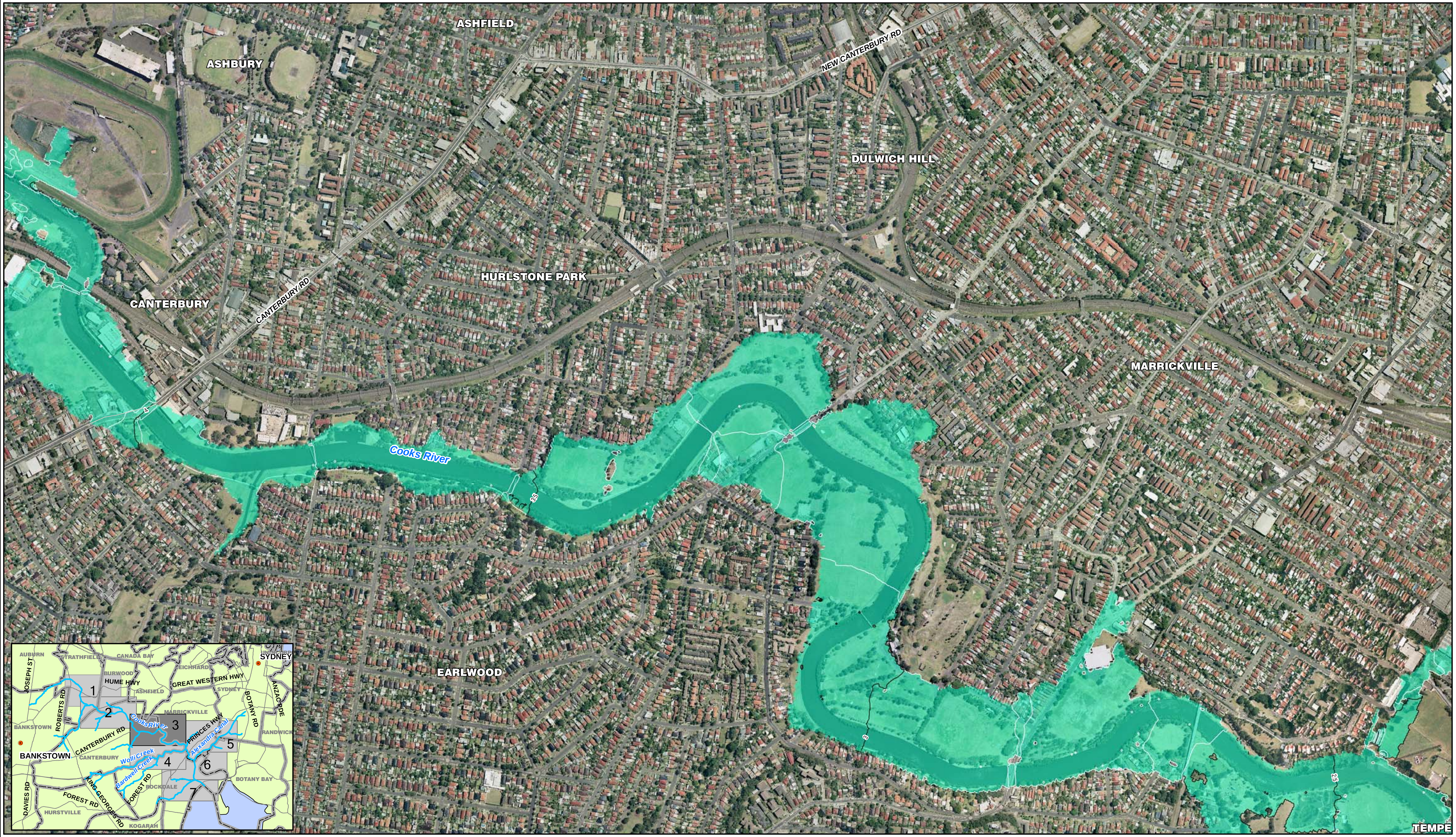
PDF File: 2114299N_2005b_Cooks_River_Flood_extents_100yr_Sheet2.pdf

0 250 500 Metres

Title: Flood Extent Mapping 100 year ARI Sheet 2 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2005b_Cooks_River_Flood_extents_100yr_Sheet2.mxd		DWG. No: 2114299N_2005b	Fig. No. B-16



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2005c_Cooks_River_Flood_extents_100yr_Sheet3.pdf

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Title: Flood Extent Mapping 100 year ARI Sheet 3 of 7		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
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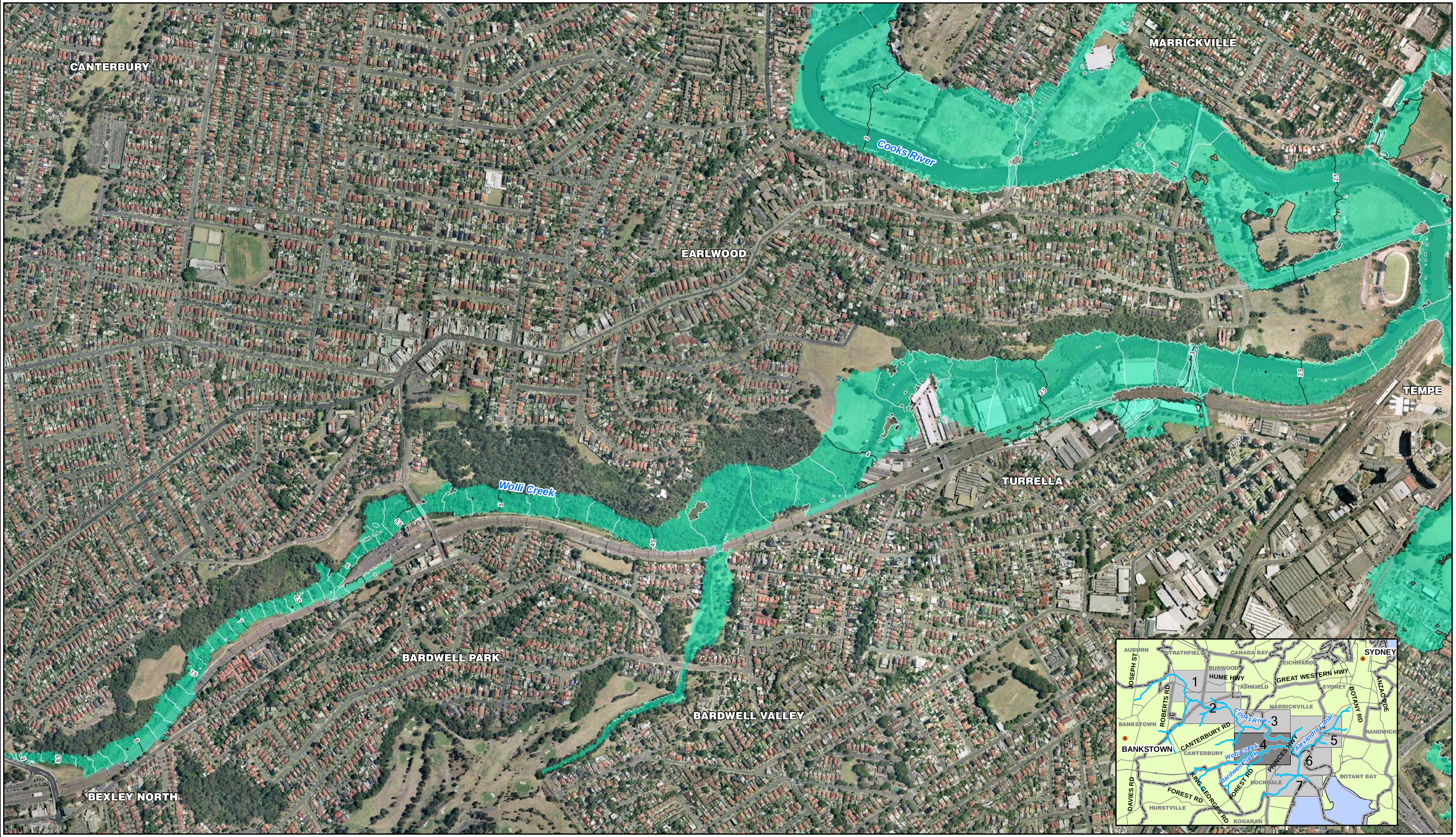

Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2005d_Cooks_River_Flood_extents_100yr_Sheet4.pdf

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Title: Flood Extent Mapping 100 year ARI Sheet 4 of 7		PARSONS BRINCKERHOFF		Sydney WATER	
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
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Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2005e_Cooks_River_Flood_extents_100yr_Sheet5.pdf

0 250 500 Metres

Title: Flood Extent Mapping 100 year ARI Sheet 5 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
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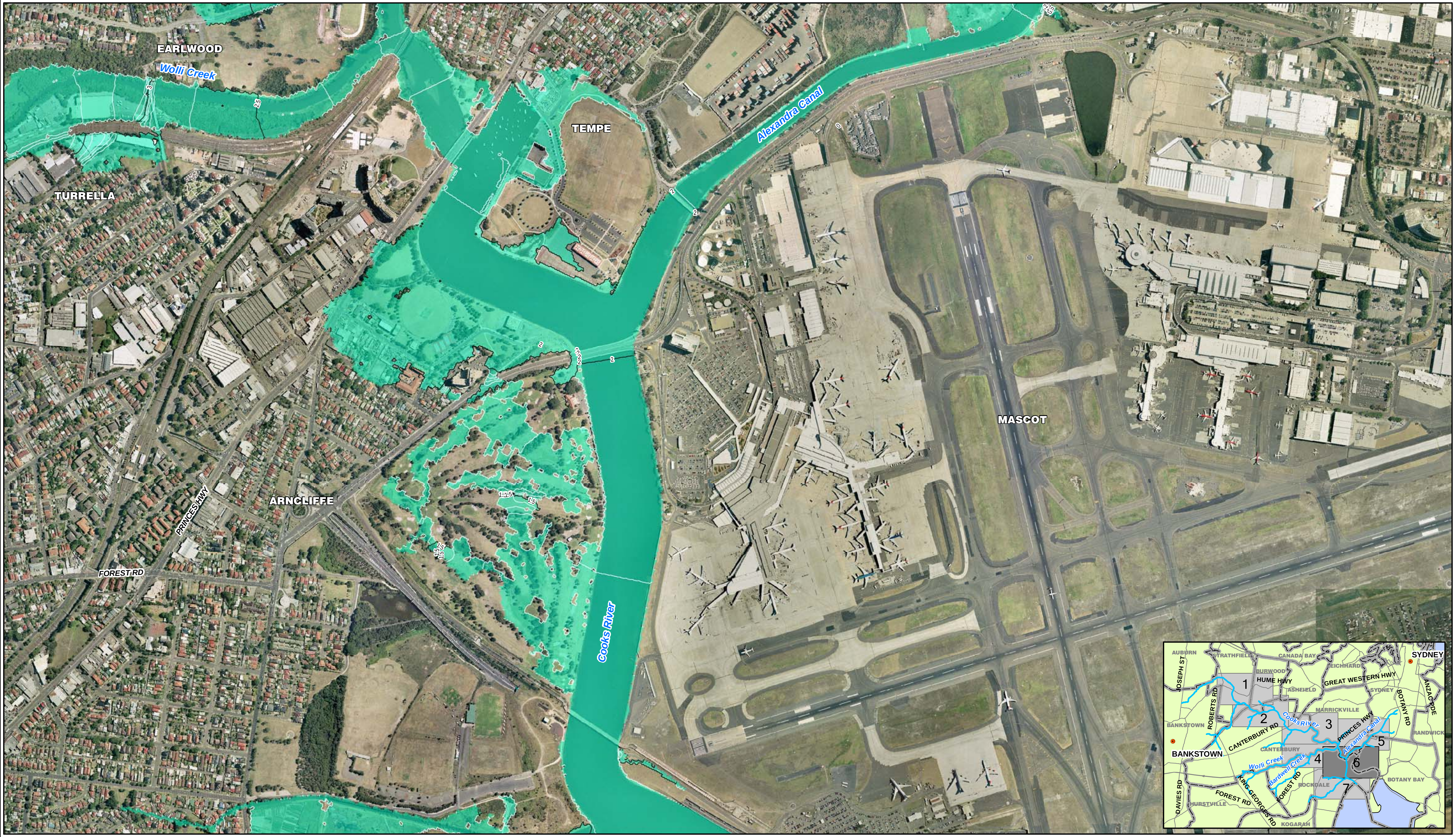

Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2005f_Cooks_River_Flood_extents_100yr_Sheet6.pdf

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Title: Flood Extent Mapping 100 year ARI Sheet 6 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2005f_Cooks_River_Flood_extents_100yr_Sheet6.mxd		DWG. No: 2114299N_2005f	Fig. No. B-20

Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- 100 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2005g_Cooks_River_Flood_extents_100yr_Sheet7.pdf

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Title: Flood Extent Mapping 100 year ARI Sheet 7 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
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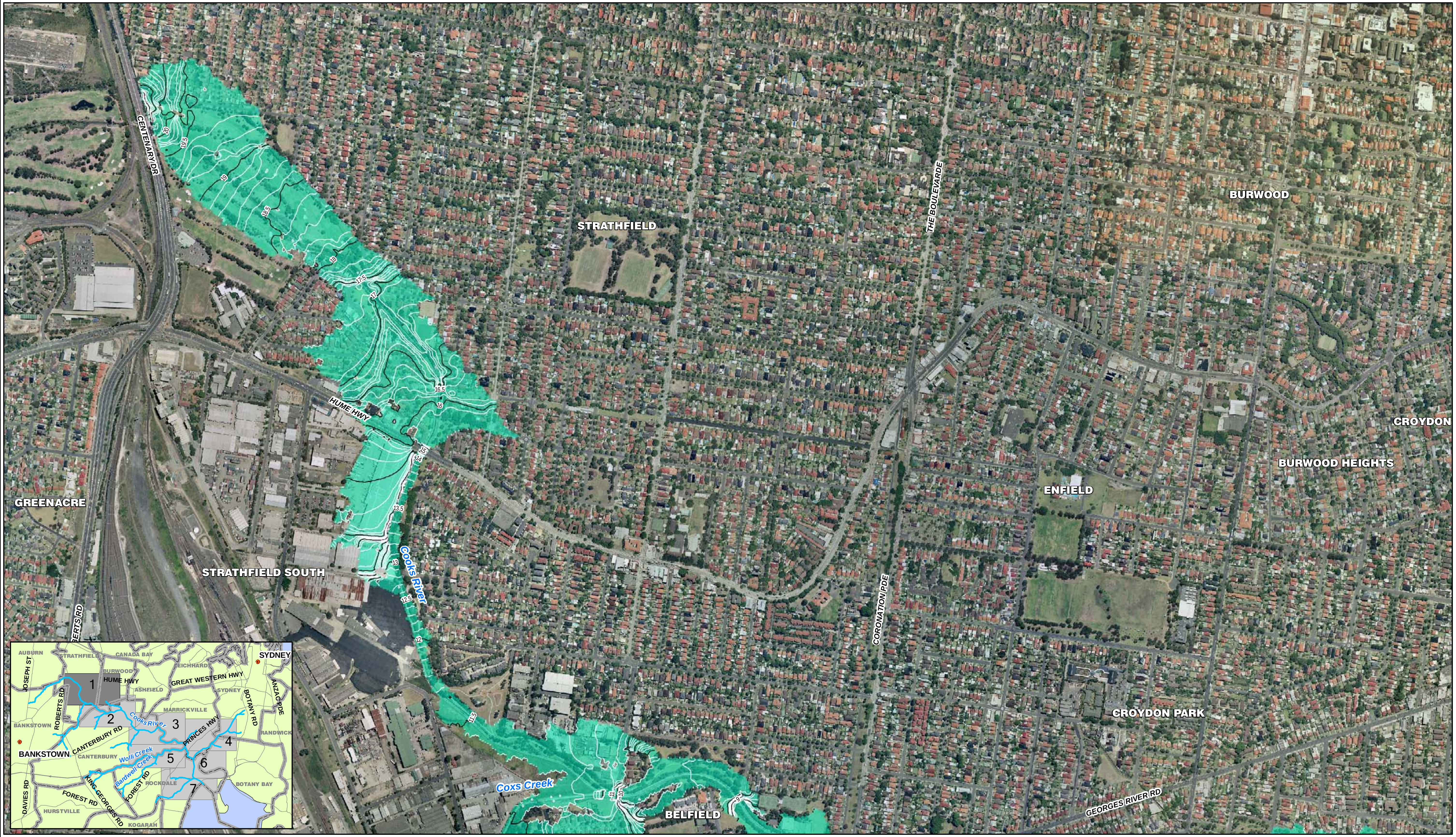

Flood level (mAHD)

0.1 m intervals

0.5 m intervals

Climate Change 100 year ARI flood extent

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006a_Cooks_River_Flood_extents_CC_100yr_Sheet1.pdf

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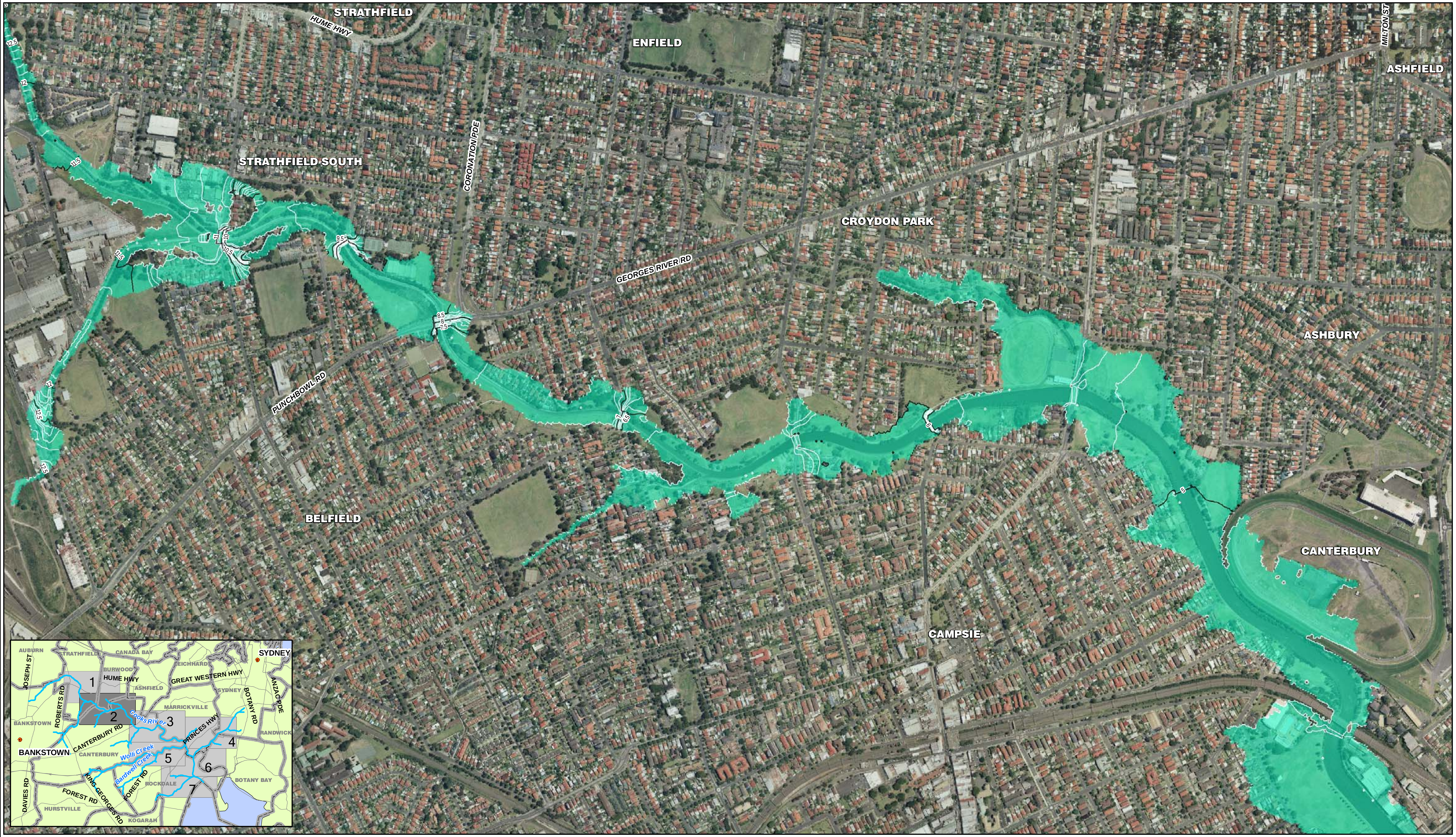
Title: Flood Extent Mapping Climate Change 100 year ARI Sheet 1 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006a_Cooks_River_Flood_extents_CC_100yr_Sheet1.mxd		DWG. No: 2114299N_2006a	Fig. No. B-22



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- Climate Change 100 year ARI flood extent
- LGA boundaries

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PDF File: 2114299N_2006b_Cooks_River_Flood_extents_CC_100yr_Sheet2.pdf

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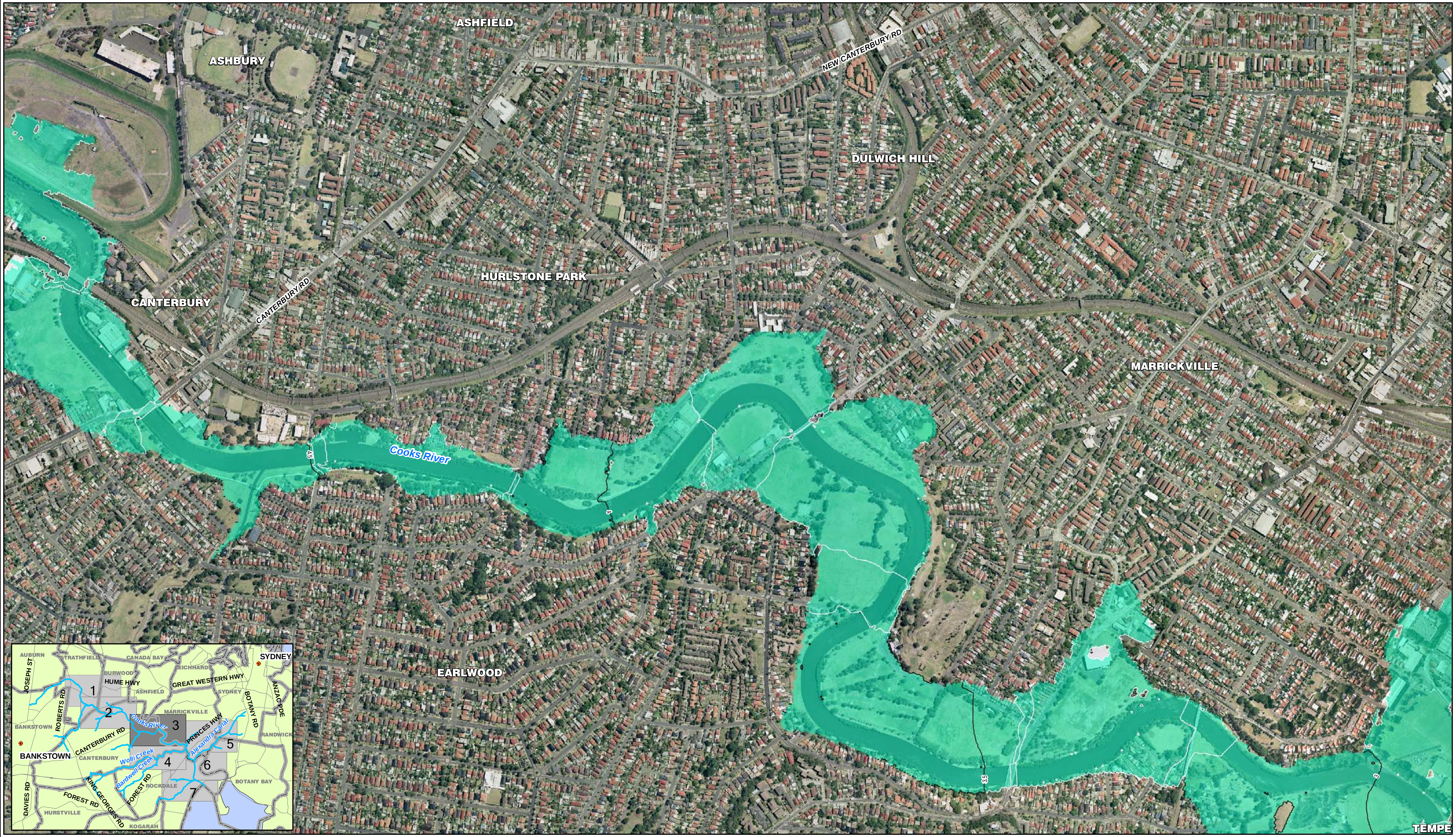
Title:	Flood Extent Mapping Climate Change 100 year ARI Sheet 2 of 7		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000	
Project:	Cooks River Flood Study	Drawn: GK	Date: Oct, 08	
Client:	SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09	
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006b_Cooks_River_Flood_extents_CC_100yr_Sheet2.mxd	DWG. No: 2114299N_2006b	Fig. No. B-23	



Flood level (mAHD)

0.1 m intervals

0.5 m intervals

Climate Change 100 year ARI flood extent

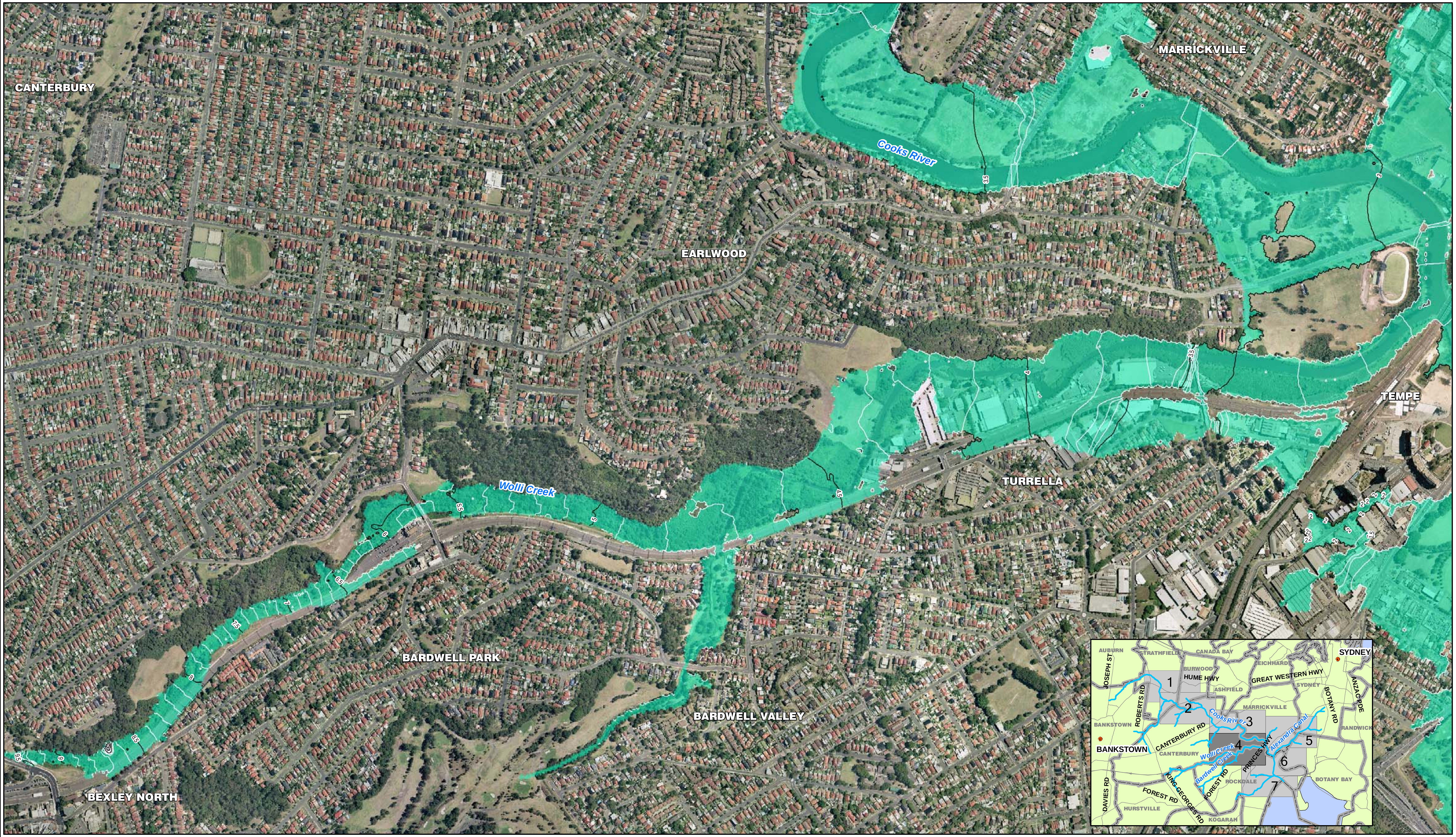
LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006c_Cooks_River_Flood_extents_CC_100yr_Sheet3.pdf

0 250 500 Metres

Title: Flood Extent Mapping Climate Change 100 year ARI Sheet 3 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006c_Cooks_River_Flood_extents_CC_100yr_Sheet3.mxd		DWG. No: 2114299N_2006c	Fig. No. B-24



Flood level (mAHD)

- 0.1 m intervals
- 0.5 m intervals
- Climate Change 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006d_Cooks_River_Flood_extents_CC_100yr_Sheet4.pdf

0 250 500 Metres

Title: Flood Extent Mapping Climate Change 100 year ARI Sheet 4 of 7		PARSONS BRINCKERHOFF / Sydney WATER			
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006d_Cooks_River_Flood_extents_CC_100yr_Sheet4.mxd		DWG. No:	2114299N_2006d	Fig. No.	B-25

Flood level (mAHD)

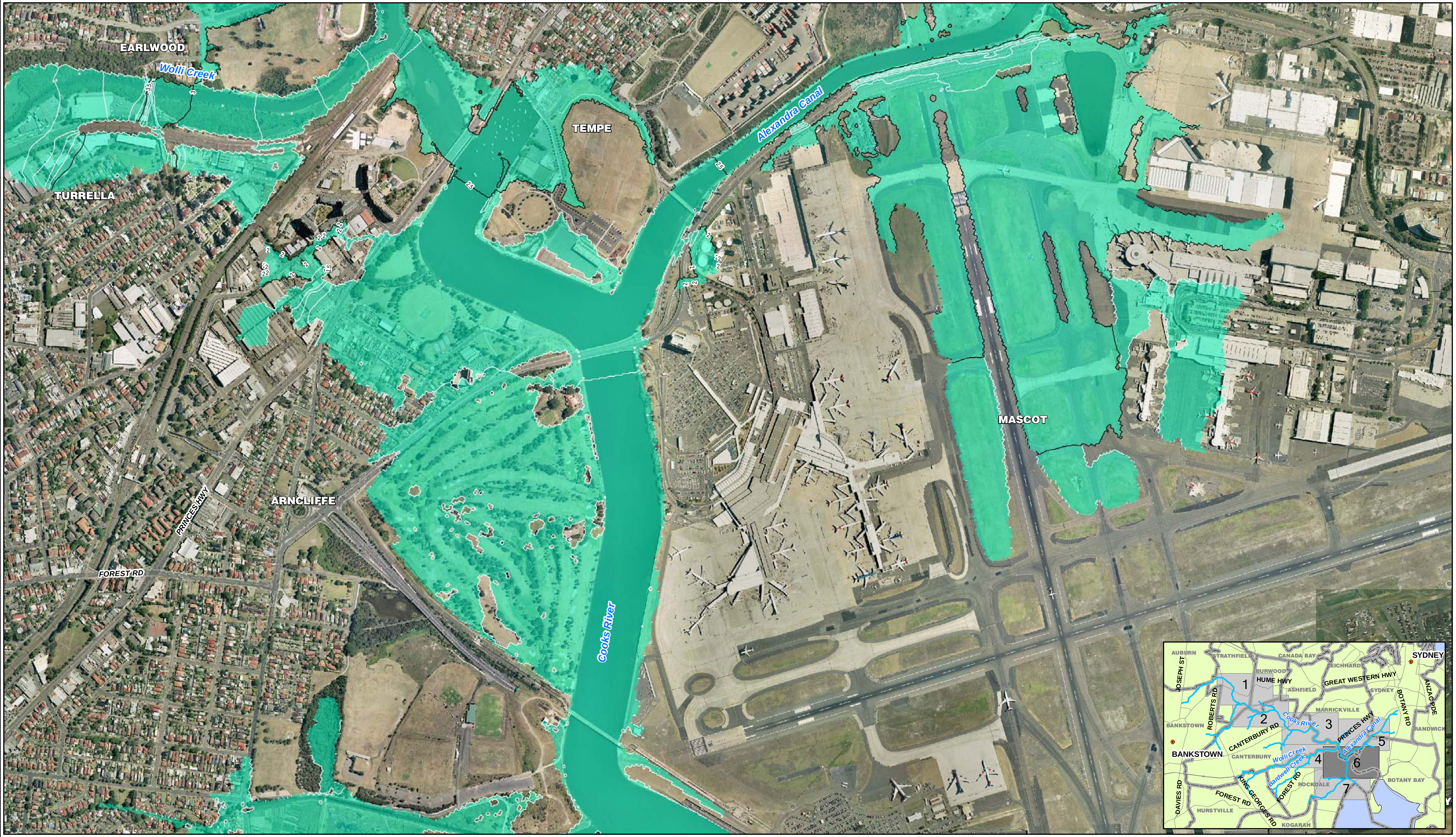
- 0.1 m intervals
- 0.5 m intervals
- Climate Change 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006e_Cooks_River_Flood_extents_CC_100yr_Sheet5.pdf

0 250 500 Metres

Title: Flood Extent Mapping Climate Change 100 year ARI Sheet 5 of 7		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006e_Cooks_River_Flood_extents_CC_100yr_Sheet5.mxd		DWG. No: 2114299N_2006e	Fig. No. B-26



Flood level (mAHD)

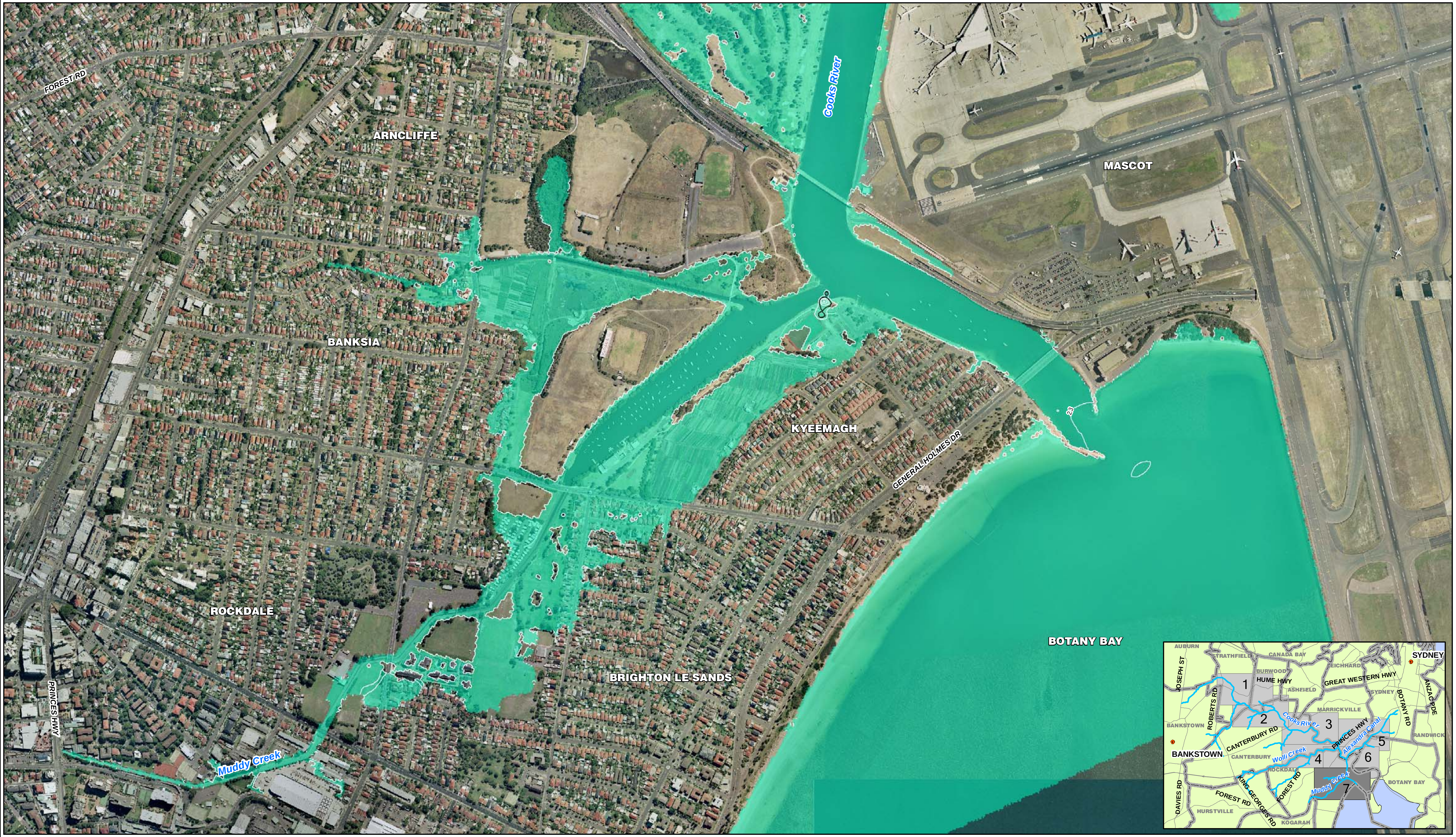
- 0.1 m intervals
- 0.5 m intervals
- Climate Change 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006f_Cooks_River_Flood_extents_CC_100yr_Sheet6.pdf

0 250 500 Metres

Title: Flood Extent Mapping Climate Change 100 year ARI Sheet 6 of 7	PARSONS BRINCKERHOFF / Sydney WATER		
	Datum: GDA94 / Zone 56	Scale: 1:10,000	
Project: Cooks River Flood Study	Drawn: GK	Date: Oct, 08	
Client: SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006f_Cooks_River_Flood_extents_CC_100yr_Sheet6.mxd	DWG. No: 2114299N_2006f	Fig. No. B-27	



Flood level (mAHD)

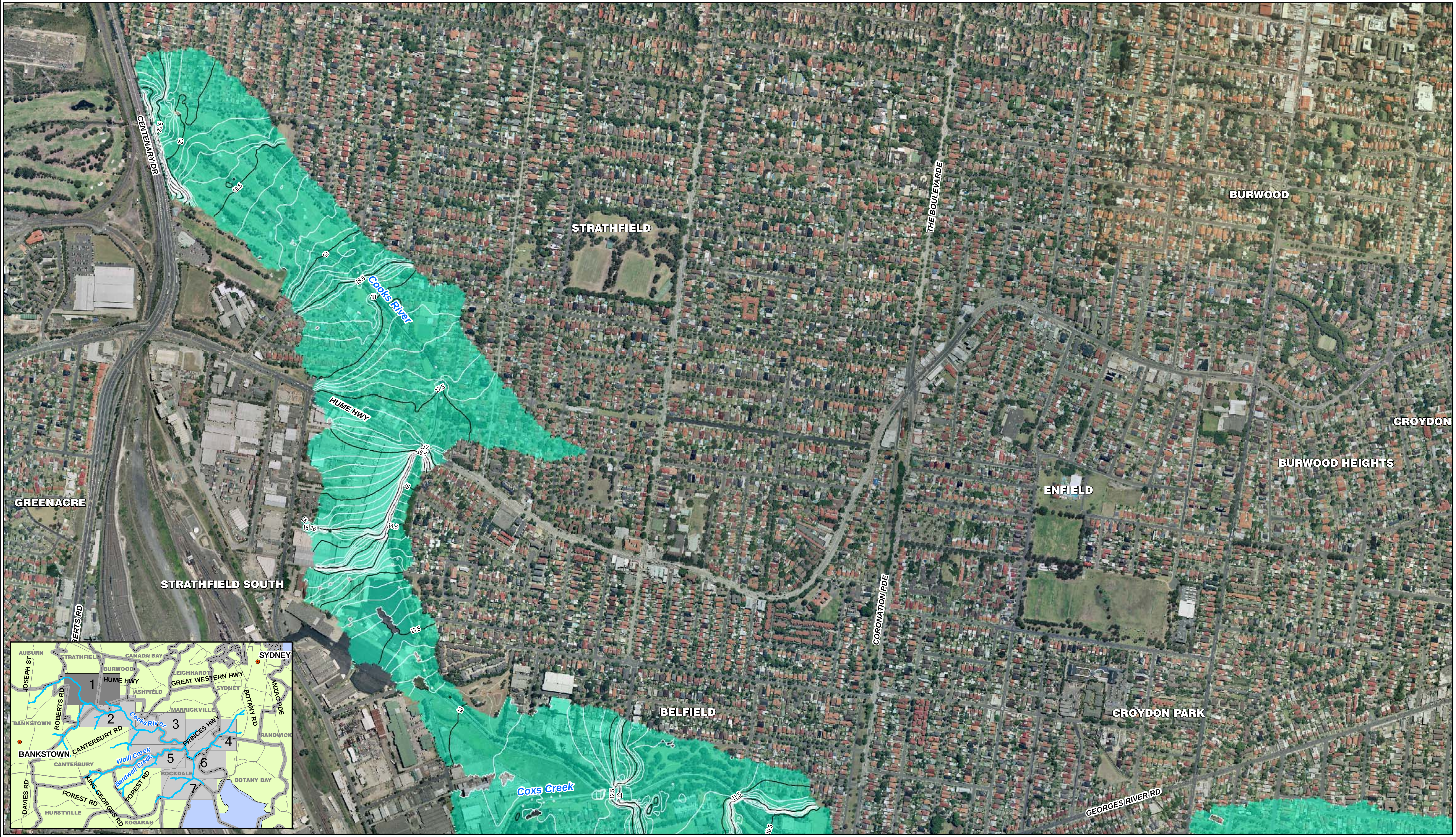
- 0.1 m intervals
- 0.5 m intervals
- Climate Change 100 year ARI flood extent
- LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2006g_Cooks_River_Flood_extents_CC_100yr_Sheet7.pdf

0 250 500 Metres

Title:	Flood Extent Mapping Climate Change 100 year ARI Sheet 7 of 7	PARSONS BRINCKERHOFF / Sydney WATER			
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No.	2114299N — Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2006g_Cooks_River_Flood_extents_CC_100yr_Sheet7.mxd	DWG. No:	2114299N_2006g	Fig. No.	B-28



Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- PMF ARI flood extent***
- LGA boundaries

*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Maps\09Feb

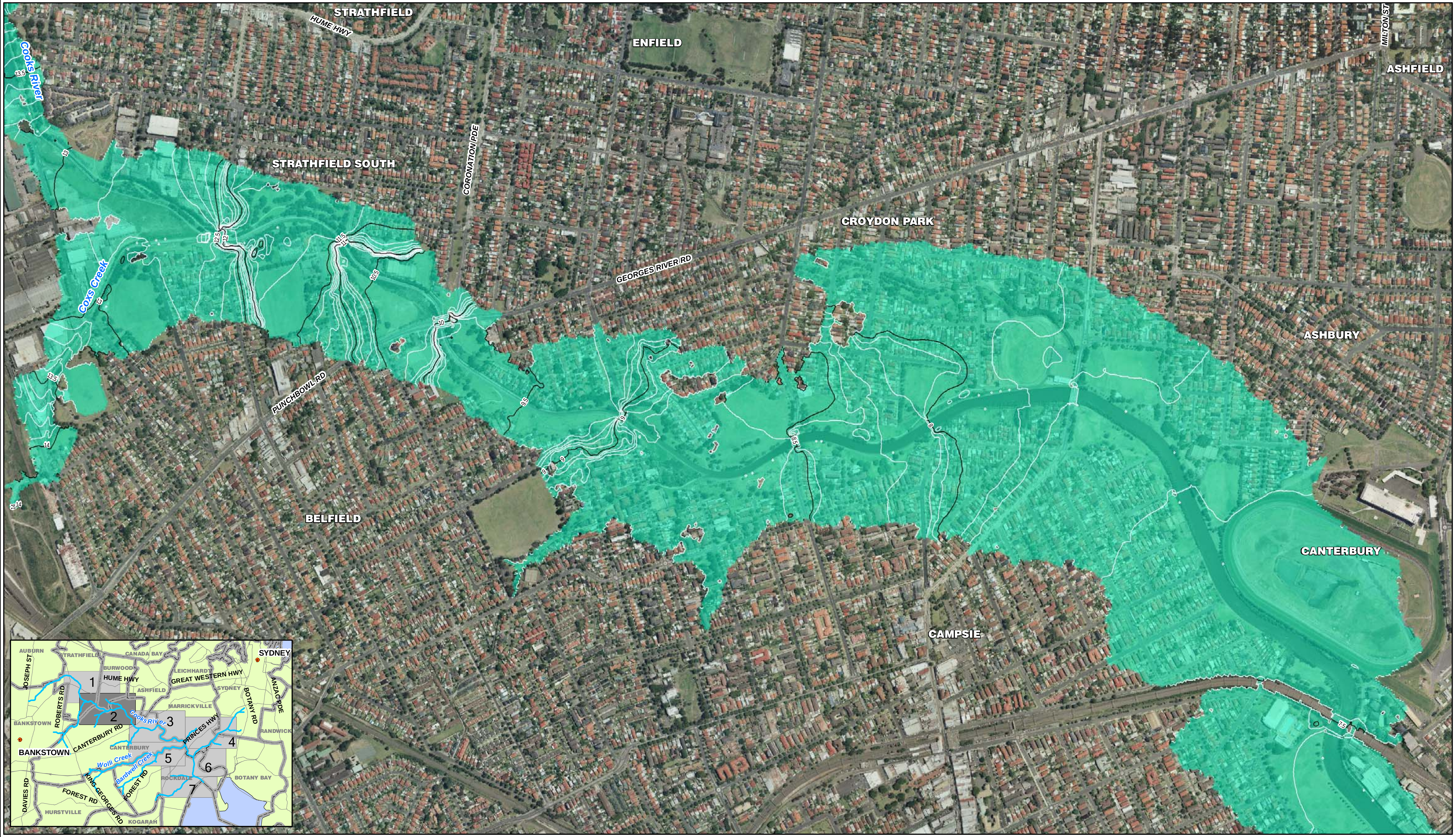
PDF File: 2114299N_2009a_Cooks_River_Flood_extents_PMF_Sheet1.pdf

0 250 500 Metres

Title: Flood Extent Mapping PMF ARI Sheet 1 of 7

PARSONS BRINCKERHOFF | Sydney WATER

Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project: Cooks River Flood Study			
Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER			
Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3		
Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Projects\ArcView\2114299N_2009a_Cooks_River_Flood_extents_PMF_Sheet1.mxd			
DWG. No:	2114299N_2009a	Fig. No.	B-29



Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- PMF ARI flood extent***
- LGA boundaries

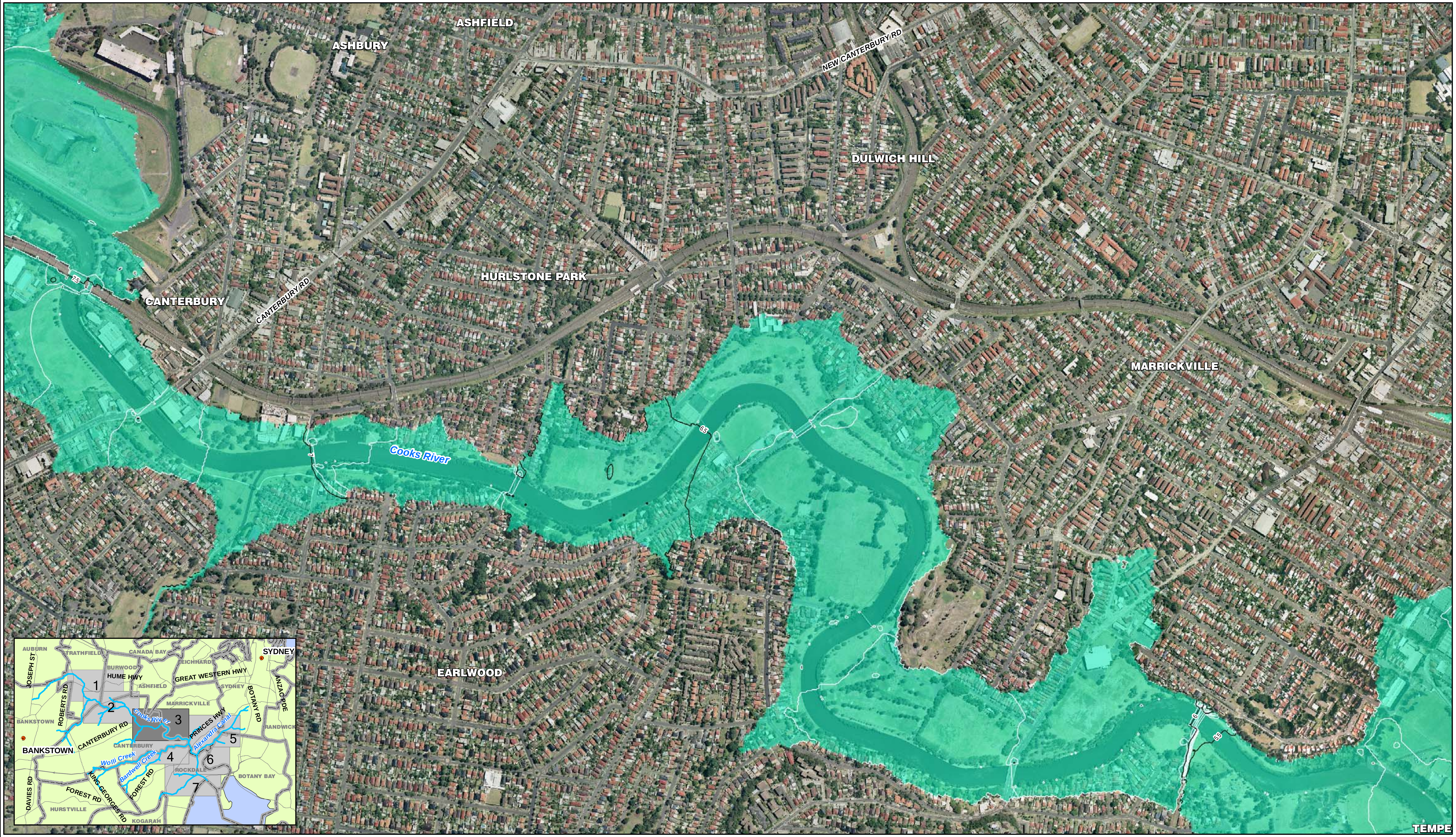
*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2009b_Cooks_River_Flood_extents_PMF_Sheet2.pdf

0 250 500 Metres

Title: Flood Extent Mapping PMF ARI Sheet 2 of 7		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2009b_Cooks_River_Flood_extents_PMF_Sheet2.mxd		DWG. No: 2114299N_2009b	Fig. No. B-30



Flood level (mAHD)

0.1 m interval

0.5 m interval

PMF ARI flood extent***

LGA boundaries

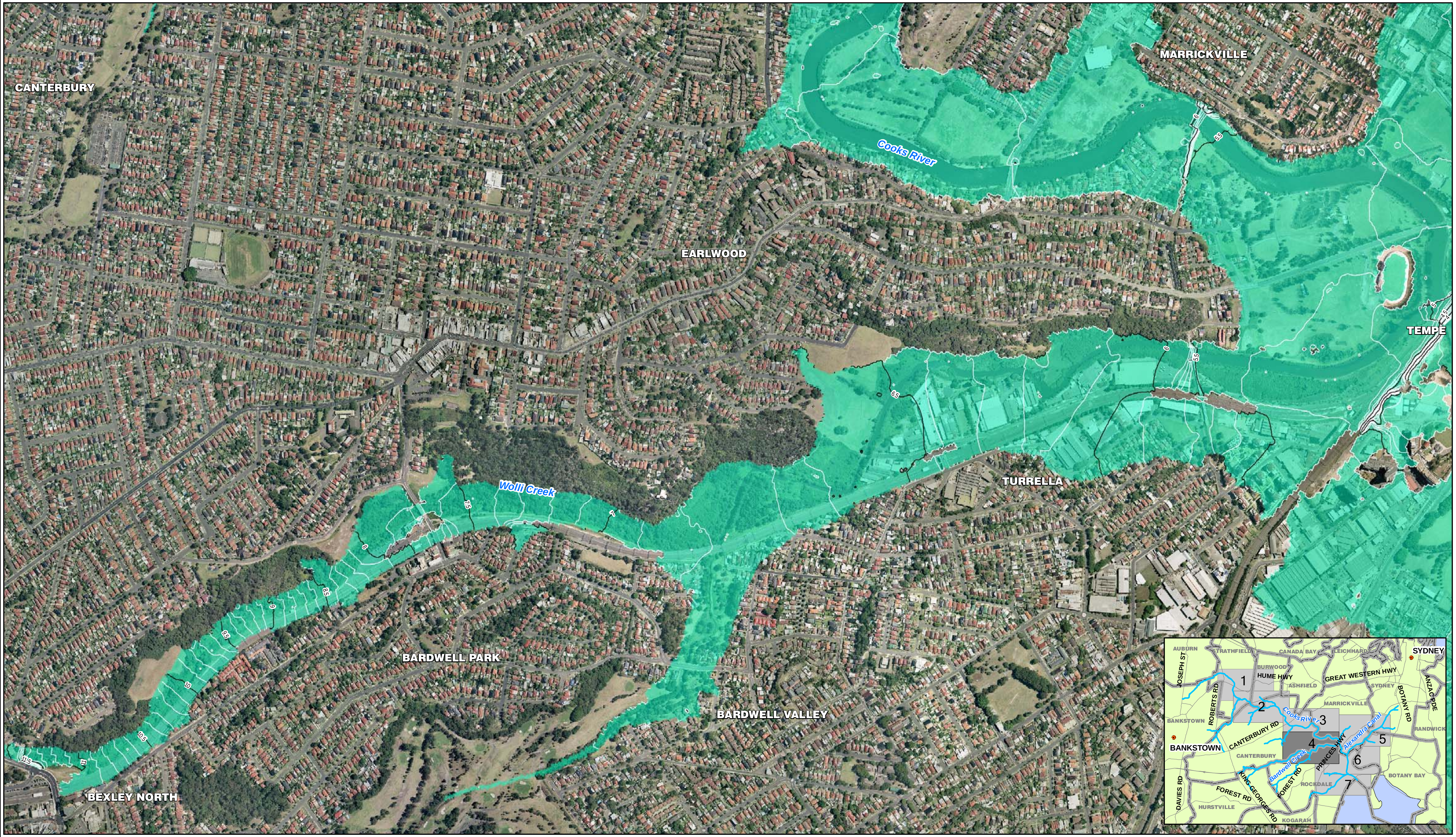
*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2009c_Cooks_River_Flood_extents_PMF_Sheet3.pdf

0 250 500 Metres

Title: **Flood Extent Mapping PMF ARI Sheet 3 of 7**		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2009c_Cooks_River_Flood_extents_PMF_Sheet3.mxd		DWG. No: 2114299N_2009c	Fig. No. B-31



Flood level (mAHD)

0.1 m interval

0.5 m interval

PMF ARI flood extent

LGA boundaries

*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

PDF File: 2114299N_2009d_Cooks_River_Flood_extents_PMF_Sheet4.pdf

0 250 500 Metres

Title:

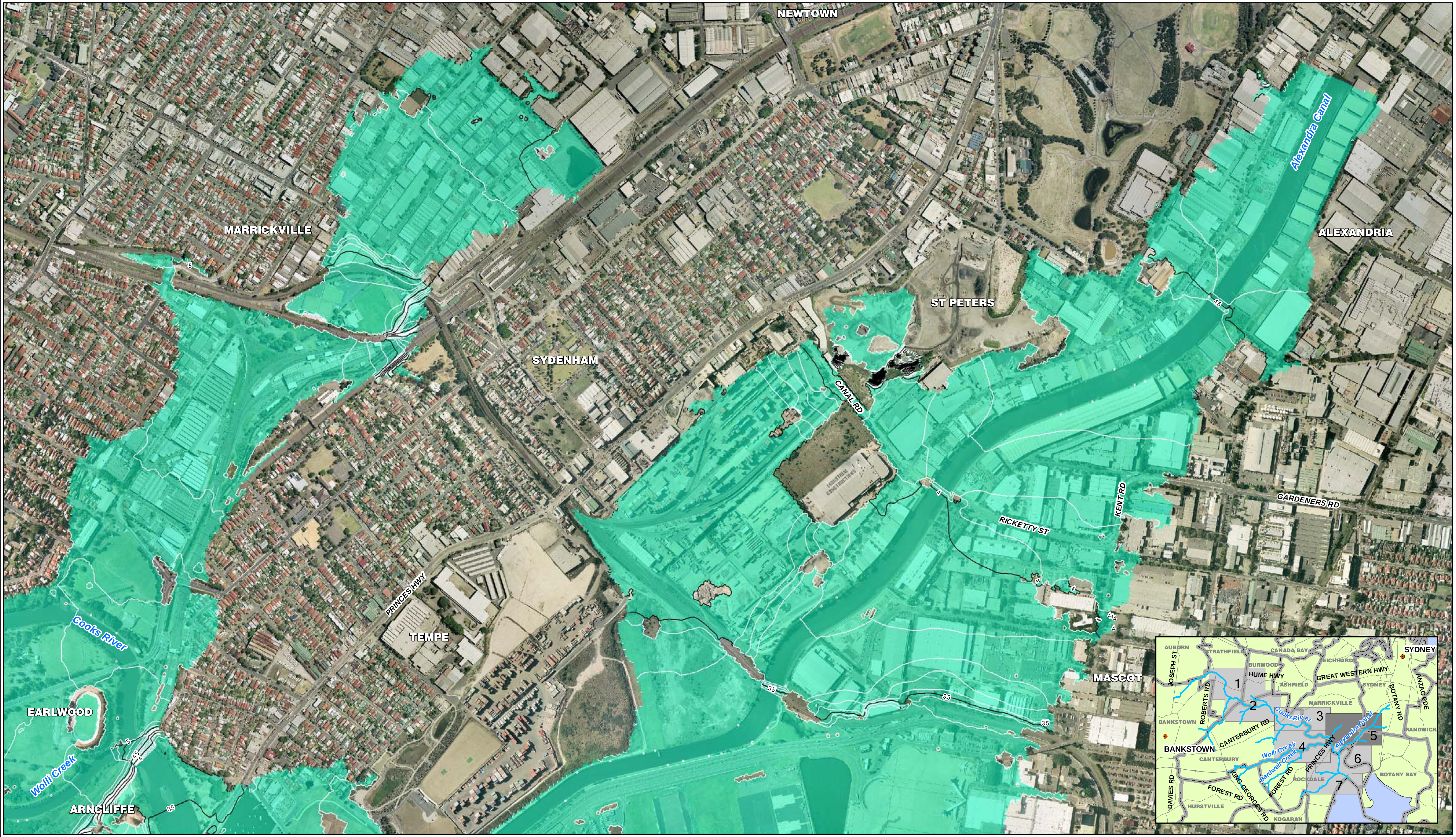
Flood Extent Mapping PMF ARI

Sheet 4 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Project: Cooks River Flood Study		Datum: GDA94 / Zone 56	Scale: 1:10,000
Client: SYDNEY WATER		Drawn: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Designed: GK	Date: Oct, 08
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\2114299N_2009d_Cooks_River_Flood_extents_PMF_Sheet4.mxd		Checked: KS	Date: Feb, 09
		DWG. No: 2114299N_2003d	Fig. No. B-32



Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- PMF ARI flood extent***
- LGA boundaries

*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Maps\09Feb

PDF File: 2114299N_2009e_Cooks_River_Flood_extents_PMF_Sheet5.pdf

0 250 500 Metres

Title:

Flood Extent Mapping
PMF ARI
Sheet 5 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Datum:	GDA94 / Zone 56	Scale:	1:10,000
Drawn:	GK	Date:	Oct, 08
Designed:	GK	Date:	Oct, 08
Checked:	KS	Date:	Feb, 09
DWG. No:	2114299N_2009e	Fig. No.	B-33

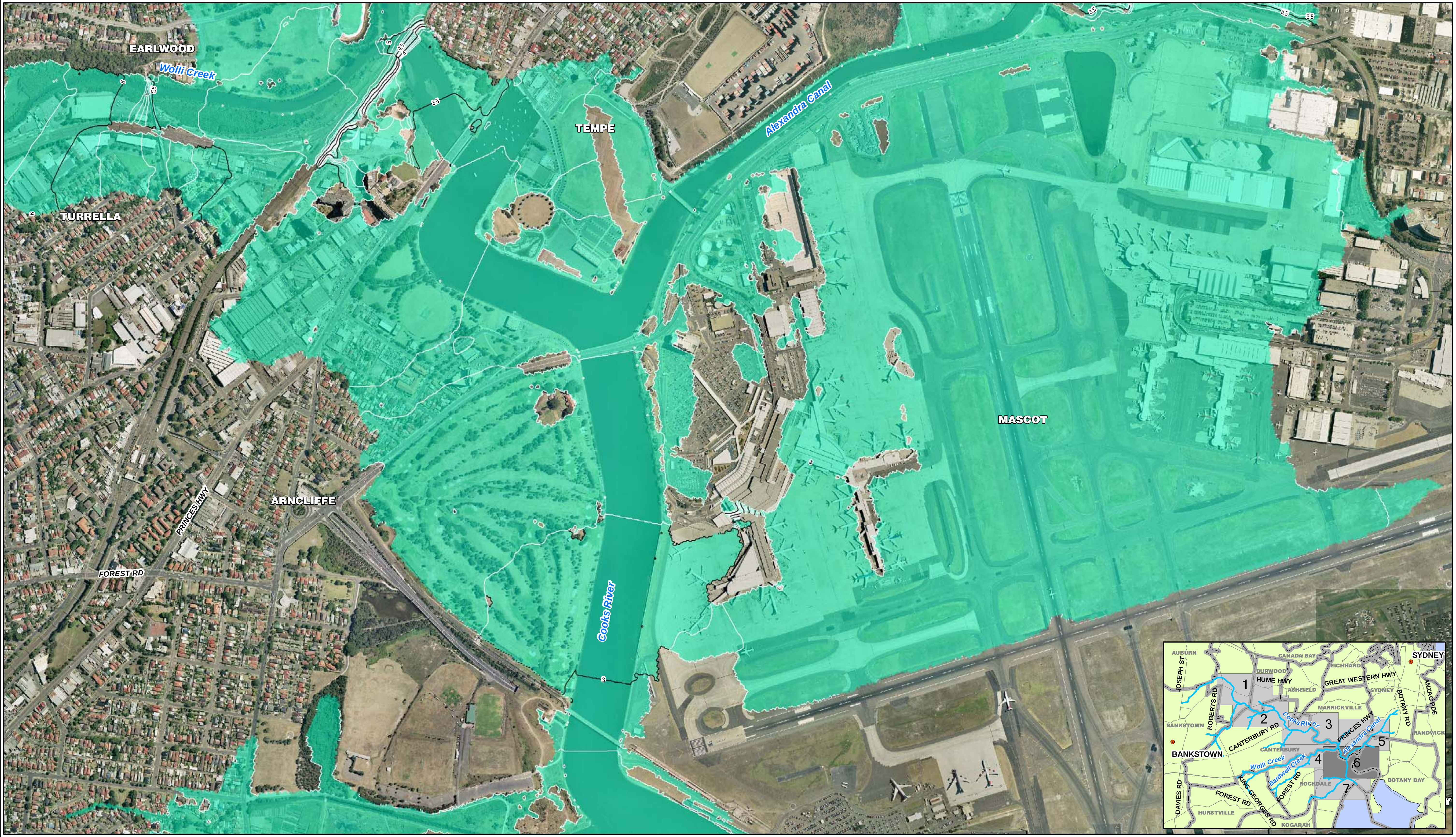
Project: Cooks River Flood Study

Client: SYDNEY WATER

Proj. No. 2114299N

Layout Size: A3

GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Projects\ArcView\2114299N_2009e_Cooks_River_Flood_extents_PMF_Sheet5.mxd



Flood level (mAHD)

0.1 m interval

0.5 m interval

PMF ARI flood extent***

LGA boundaries

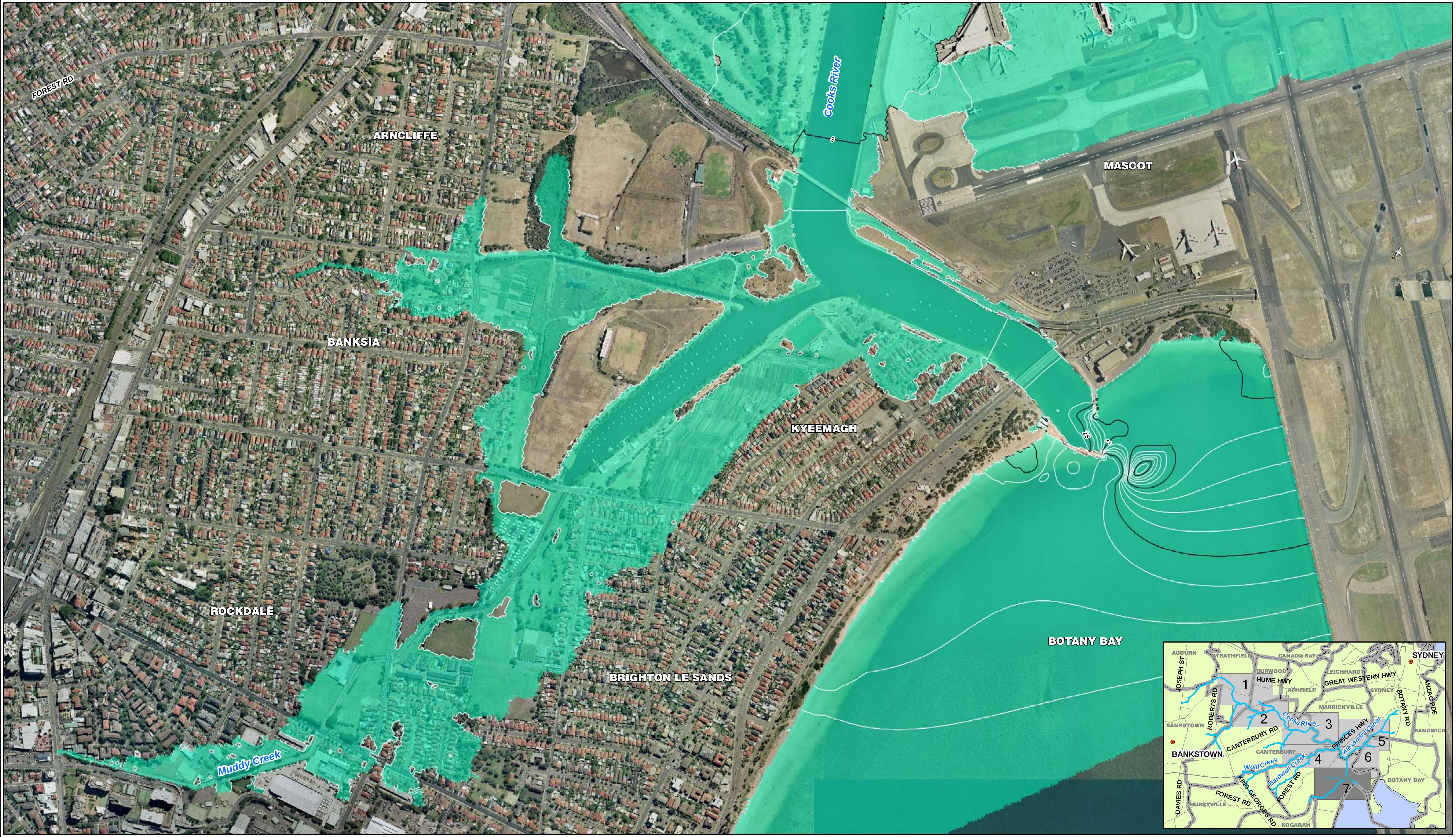
*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2009f_Cooks_River_Flood_extents_PMF_Sheet6.pdf

0 250 500 Metres

Title: Flood Extent Mapping PMF ARI Sheet 6 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2009f_Cooks_River_Flood_extents_PMF_Sheet6.mxd		DWG. No: 2114299N_2009f	Fig. No. B-34



Flood level (mAHD)

- 0.1 m interval
- 0.5 m interval
- PMF ARI flood extent
- LGA boundaries

*** PMF extent shown is indicative only due to the uncertainty inherent in modelling events of this magnitude

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2009g_Cooks_River_Flood_extents_PMF_Sheet7.pdf

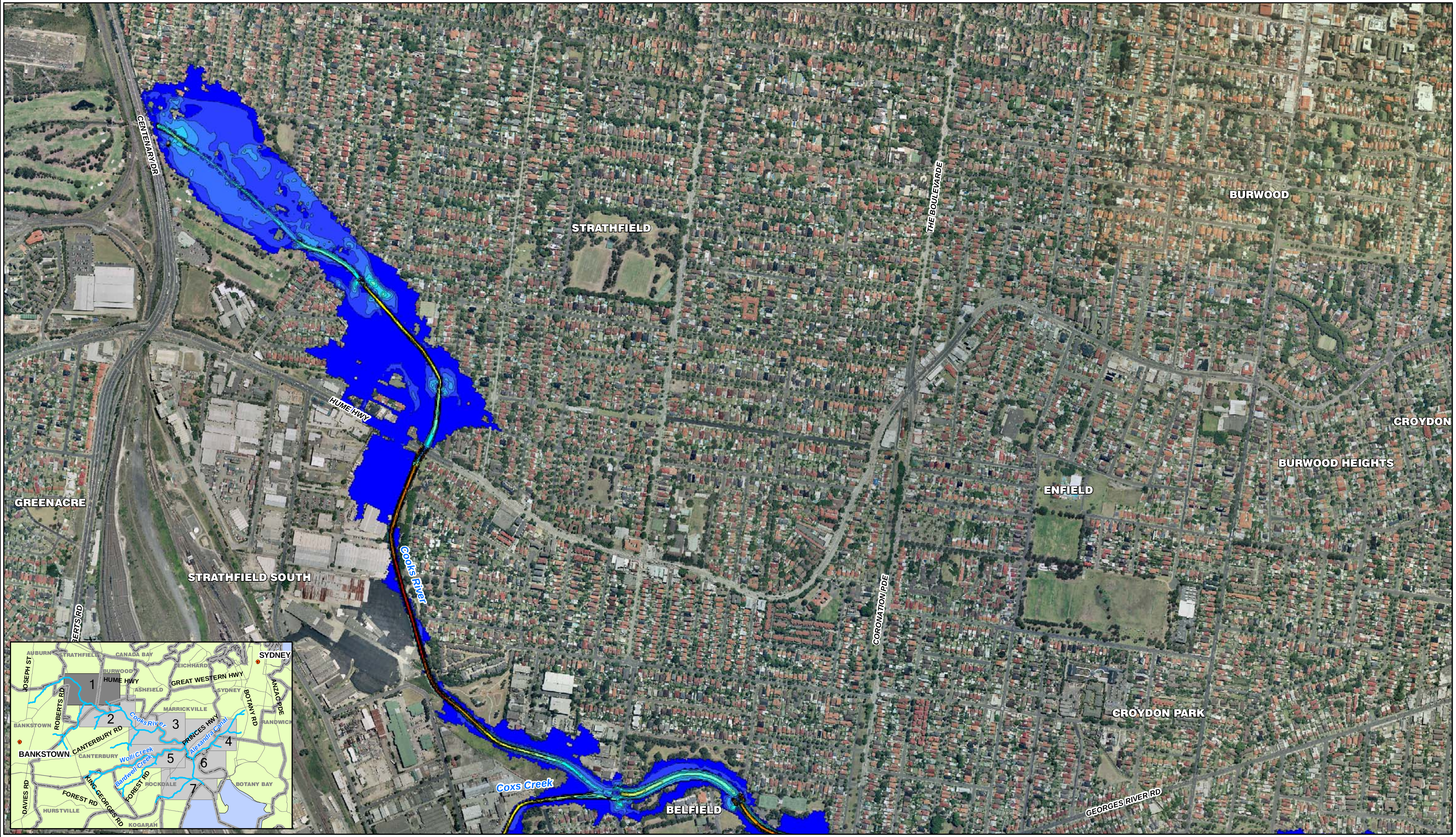
0 250 500 Metres

Title: Flood Extent Mapping PMF ARI Sheet 7 of 7		PARSONS BRINCKERHOFF / Sydney WATER	
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2009g_Cooks_River_Flood_extents_PMF_Sheet7.mxd		DWG. No: 2114299N_2009g	Fig. No. B-35

APPENDIX C

100 YEAR ARI EVENT VELOCITY AND DEPTH MAPPING

FLOOD EXTENT MAPPING



Flood velocity contours (m/s)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Maps\09Feb

PDF File: 2114299N_2008a_Cooks_River_Flood_Velocity_100yr_Sheet1.pdf

Flood Velocity
100 year ARI (m/s)

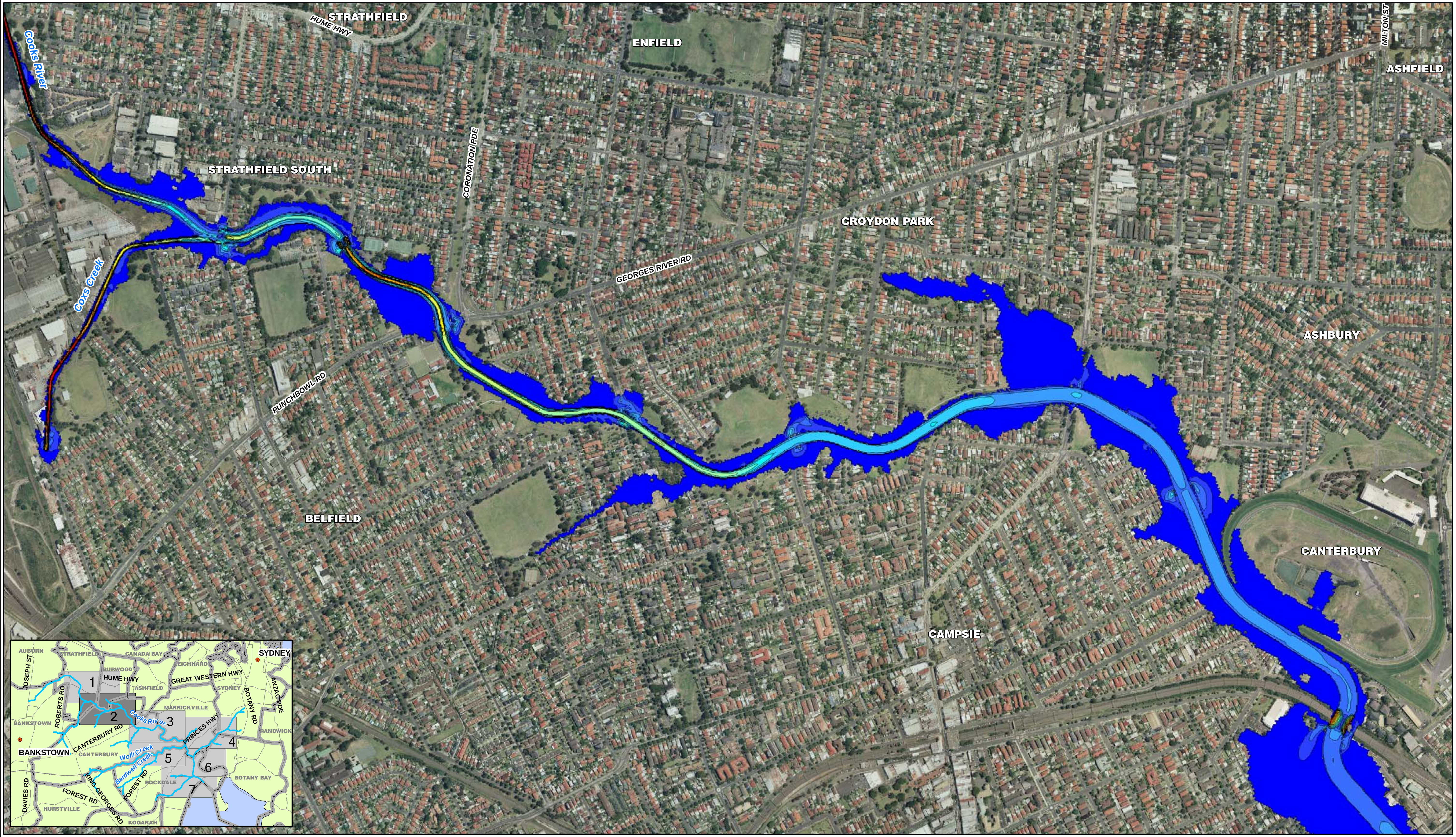
- 0.0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Velocity Mapping
100 year ARI
Sheet 1 of 7

PARSONS BRINCKERHOFF | Sydney WATER

Datum:	GDA94 / Zone 56	Scale:	1:10,000		
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No.	2114299N	Layout Size: A3	Checked: KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Projects\ArcView\2114299N_2008a_Cooks_River_Flood_Velocity_100yr_Sheet1.mxd	DWG. No:	2114299N_2008a	Fig. No.	C-1



Flood velocity contours (m/s)

LGA boundaries

Flood Velocity 100 year ARI (m/s)	
0.0 - 0.5	3.6 - 4.0
0.6 - 1.0	4.1 - 4.5
1.1 - 1.5	4.6 - 5.0
1.6 - 2.0	5.1 - 5.5
2.1 - 2.5	5.6 - 6.0
2.6 - 3.0	6.1 - 6.5
3.1 - 3.5	6.6 - 7.0
	7.1 - 7.5
	7.6 - 8.0

0 250 500 Metres

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2008b_Cooks_River_Flood_Velocity_100yr_Sheet2.pdf

Title:

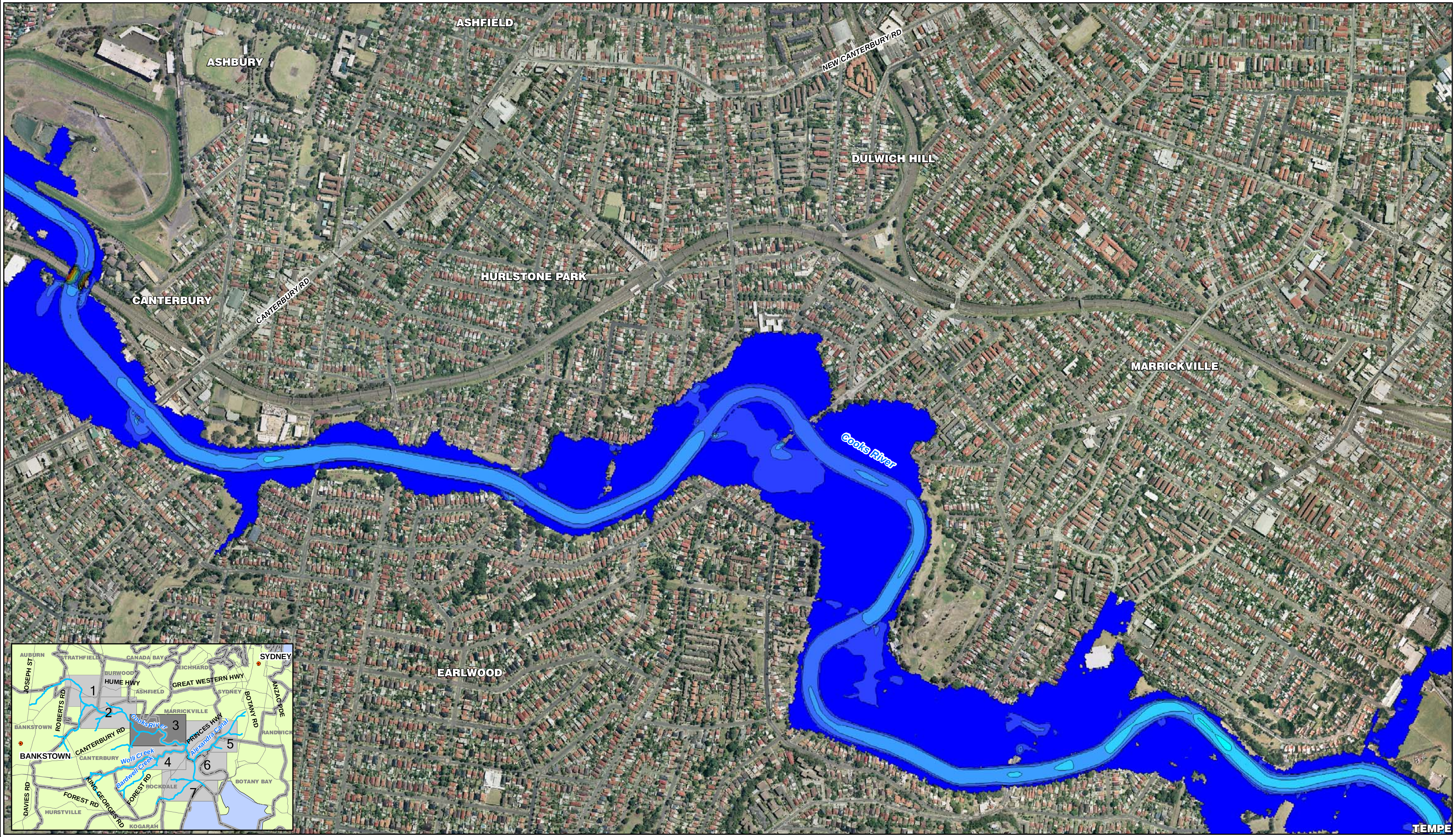
Flood Velocity Mapping 100 year ARI

Sheet 2 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Datum: GDA94 / Zone 56	Scale: 1:10,000		
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2008b_Cooks_River_Flood_Velocity_100yr_Sheet2.mxd		DWG. No: 2114299N_2008b	Fig. No. C-2



Flood velocity contours (m/s)

LGA boundaries

Flood Velocity

100 year ARI (m/s)

- 0.0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

PDF File: 2114299N_2008c_Cooks_River_Flood_Velocity_100yr_Sheet3.pdf

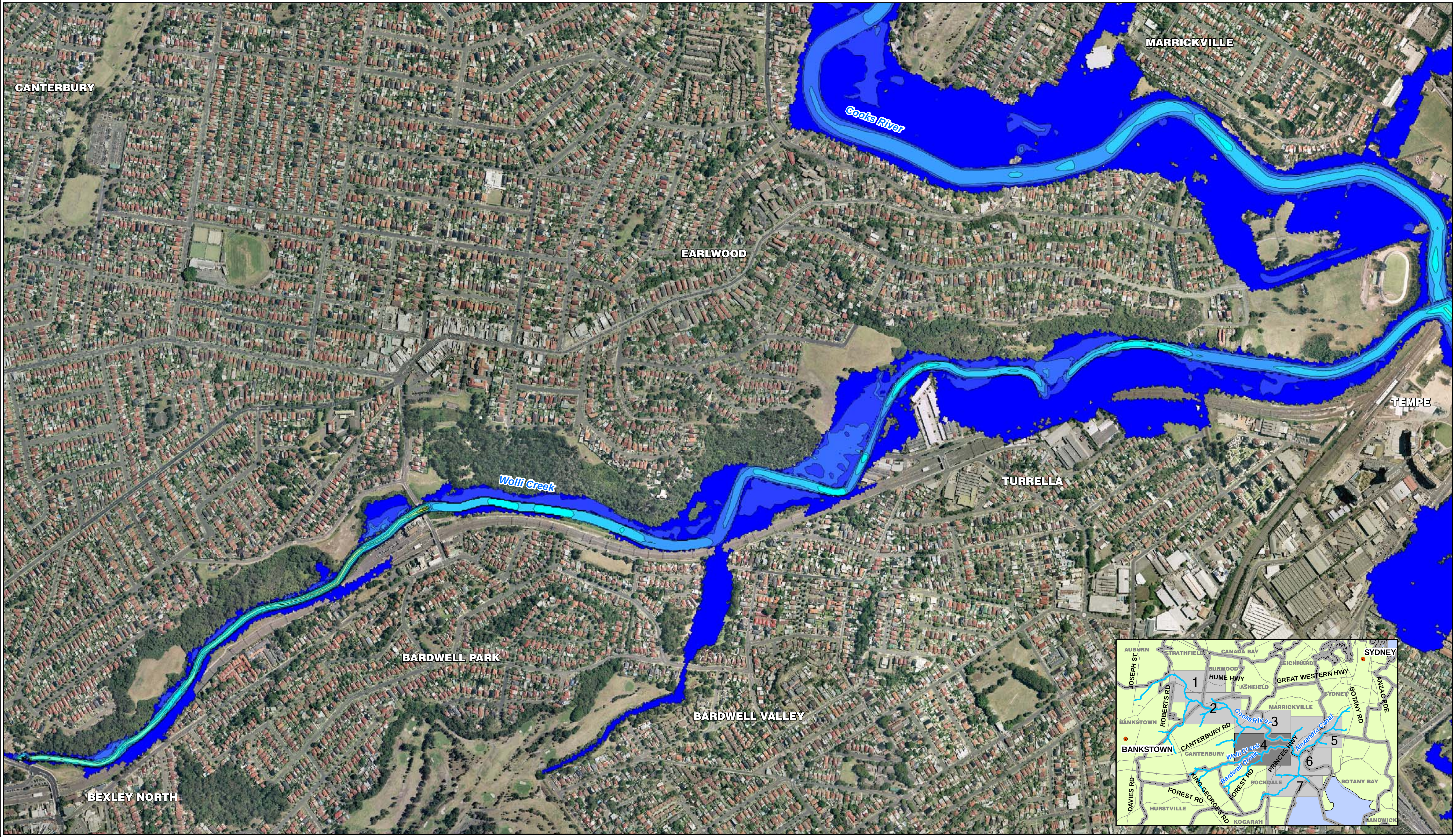
Title:

Flood Velocity Mapping
100 year ARI
Sheet 3 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Project:	Cooks River Flood Study	Datum:	GDA94 / Zone 56	Scale:	1:10,000
Client:	SYDNEY WATER	Drawn:	GK	Date:	Oct, 08
Proj. No.	2114299N Layout Size: A3	Designed:	GK	Date:	Oct, 08
		Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\ 2114299N_2008c_Cooks_River_Flood_Velocity_100yr_Sheet3.mxd	DWG. No:	2114299N_2008c	Fig. No.	C-3



Flood velocity contours (m/s)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Maps\09Feb

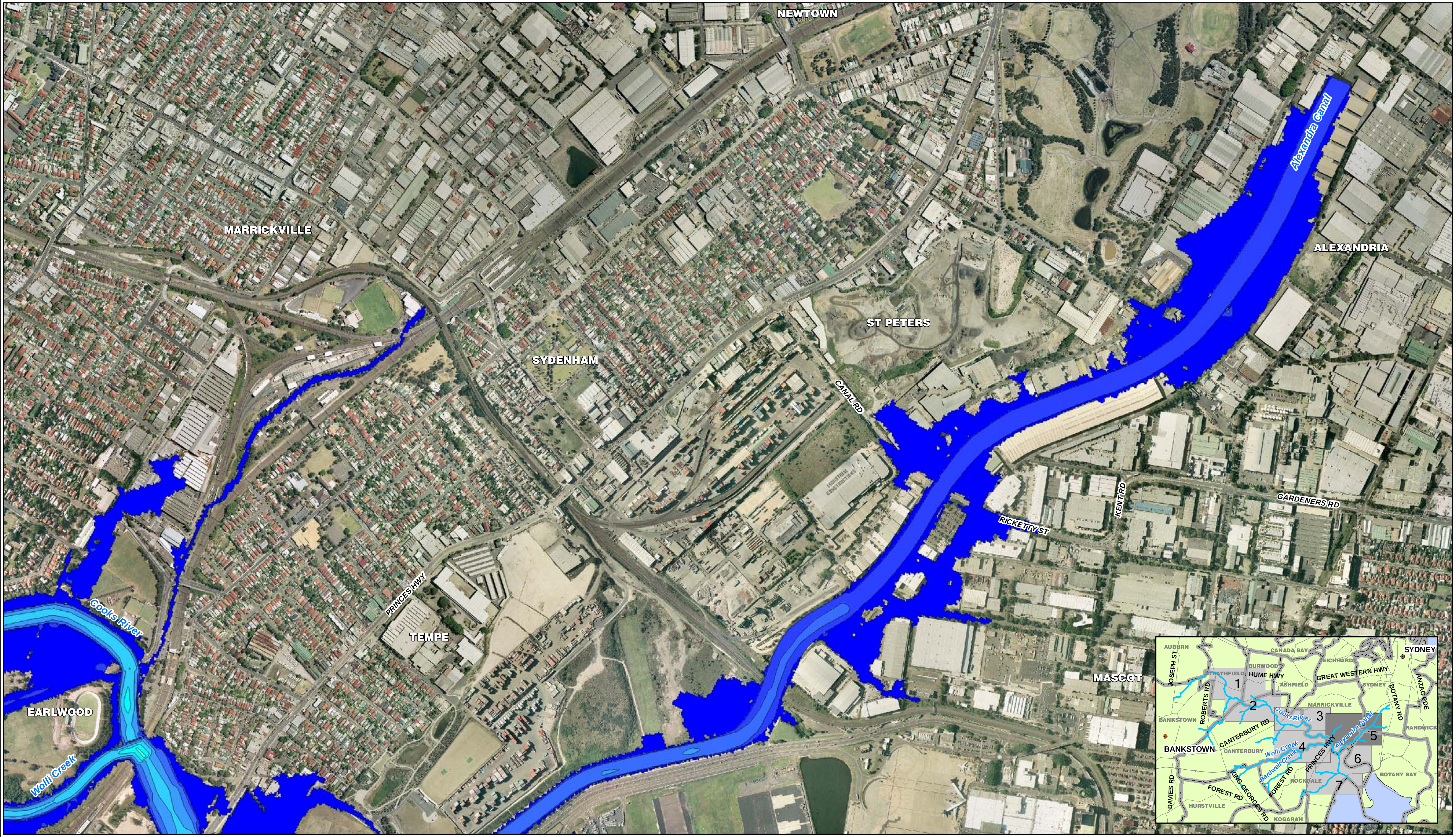
PDF File: 2114299N_2008d_Cooks_River_Flood_Velocity_100yr_Sheet4.pdf

Flood Velocity
100 year ARI (m/s)

- 0.0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Velocity Mapping 100 year ARI Sheet 4 of 7	PARSONS BRINCKERHOFF / Sydney WATER		
	Datum: GDA94 / Zone 56	Scale: 1:10,000	
Project: Cooks River Flood Study	Drawn: GK	Date: Oct, 08	
Client: SYDNEY WATER	Designed: GK	Date: Oct, 08	
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_FI\10_GIS\Projects\ArcView\2114299N_2008d_Cooks_River_Flood_Velocity_100yr_Sheet4.mxd	DWG. No: 2114299N_2008d	Fig. No. C-4	



Flood velocity contours (m/s)

LGA boundaries

PDF Address:
J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File:
2114299N_2008e_Cooks_River_Flood_Velocity_100yr_Sheet5.pdf

Flood Velocity
100 year ARI (m/s)

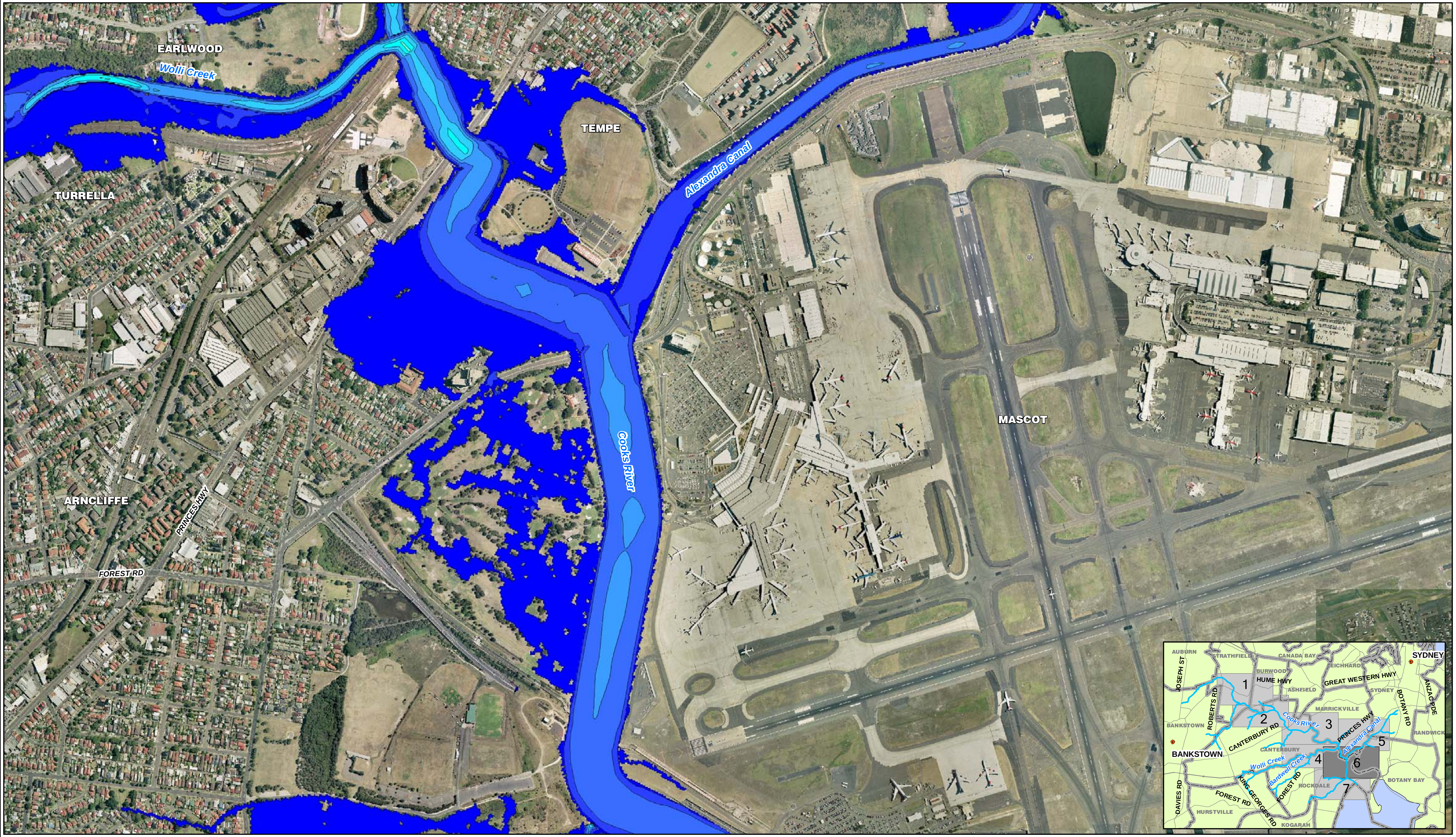
- 0.0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title:

Flood Velocity Mapping
100 year ARI
Sheet 5 of 7

Project: Cooks River Flood Study		Datum: GDA94 / Zone 56	Scale: 1:10,000
Client: SYDNEY WATER		Drawn: GK	Date: Oct, 08
		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2008e_Cooks_River_Flood_Velocity_100yr_Sheet5.mxd		DWG. No: 2114299N_2008e	Fig. No. C-5



Flood velocity contours (m/s)
LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb
PDF File: 2114299N_2008f_Cooks_River_Flood_Velocity_100yr_Sheet6.pdf

Flood Velocity
100 year ARI (m/s)

- 0.0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Velocity Mapping 100 year ARI Sheet 6 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: **GDA94 / Zone 56**	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. **2114299N**	Layout Size: **A3**	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2008f_Cooks_River_Flood_Velocity_100yr_Sheet6.mxd		DWG. No: **2114299N_2008f**	Fig. No. **C-6**

Flood velocity contours (m/s)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Maps\09Feb

PDF File: 2114299N_2008g_Cooks_River_Flood_Velocity_100yr_Sheet7.pdf

Flood Velocity

100 year ARI (m/s)

0.0 - 0.5	3.6 - 4.0
0.6 - 1.0	4.1 - 4.5
1.1 - 1.5	4.6 - 5.0
1.6 - 2.0	5.1 - 5.5
2.1 - 2.5	5.6 - 6.0
2.6 - 3.0	6.1 - 6.5
3.1 - 3.5	6.6 - 7.0
	7.1 - 7.5
	7.6 - 8.0

0 250 500 Metres

Title:

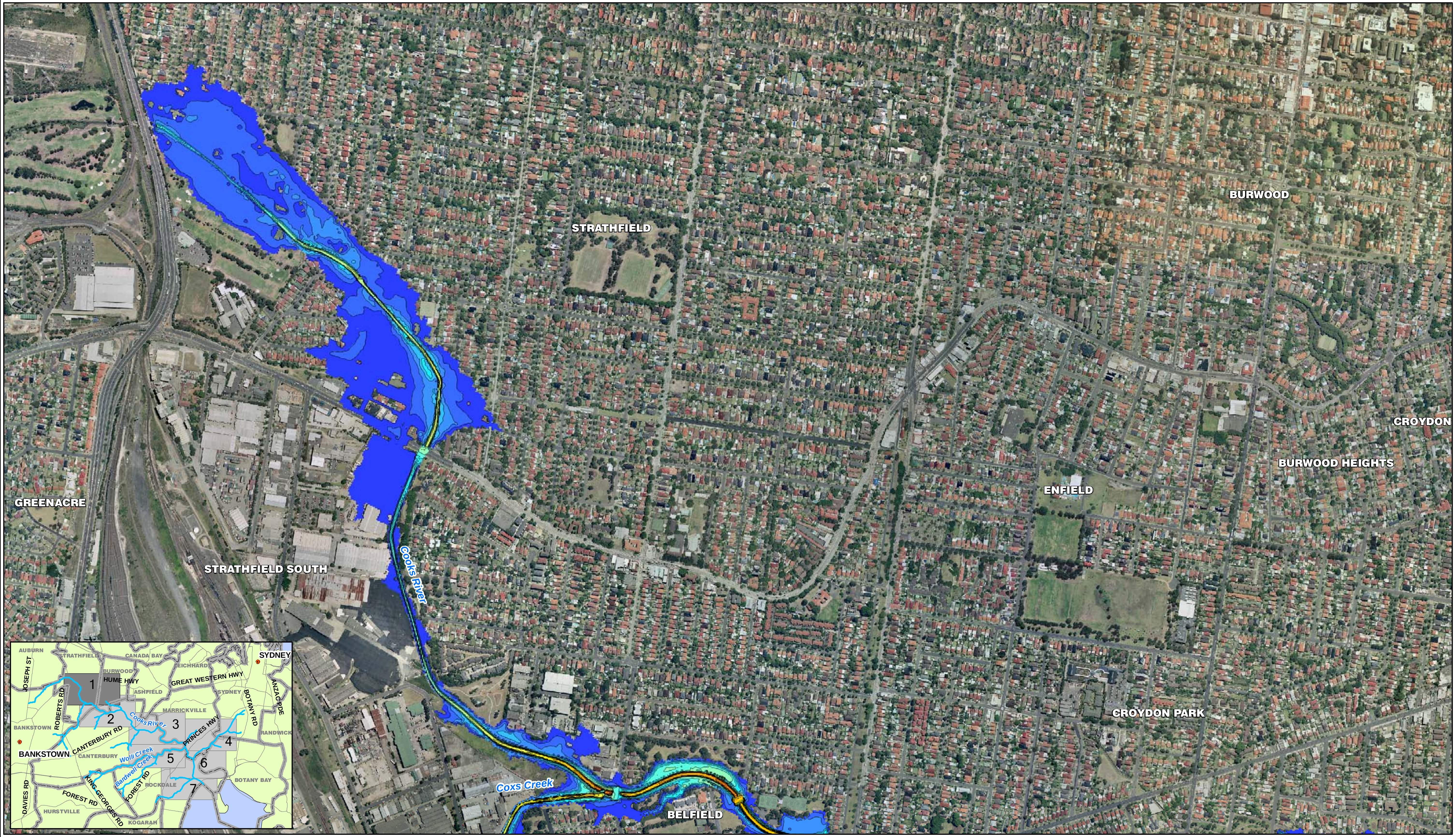
Flood Velocity Mapping 100 year ARI

Sheet 7 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Datum: GDA94 / Zone 56	Scale: 1:10,000		
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Projects\ArcView\2114299N_2008g_Cooks_River_Flood_Velocity_100yr_Sheet7.mxd		DWG. No: 2114299N_2008g	Fig. No. C-7



Flood level (mAHD)
LGA boundaries

Flood Depth 100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

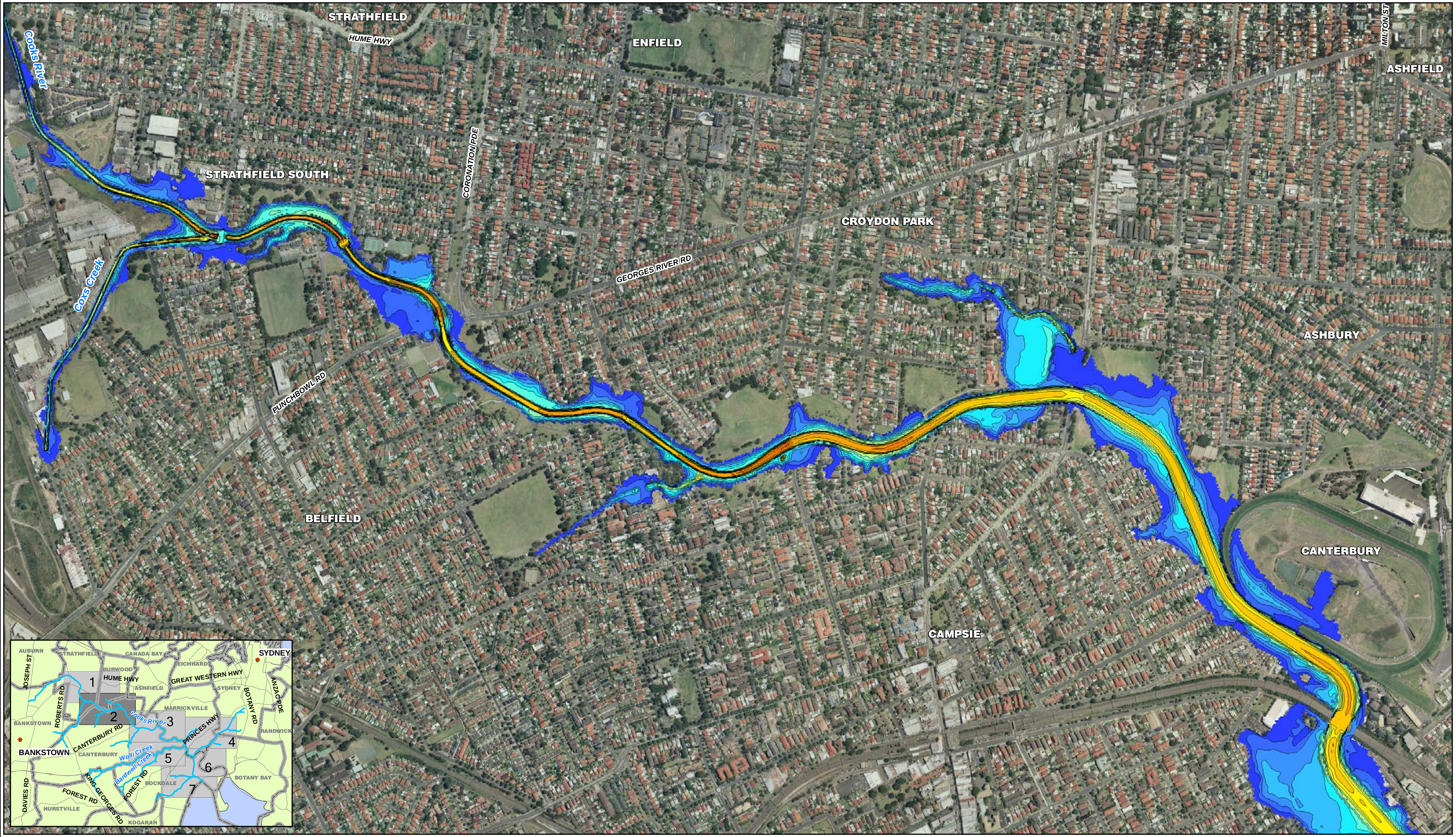
PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Maps\09Feb

PDF File: 2114299N_2007a_Cooks_River_Flood_Depth_100yr_Sheet1.pdf

Title: Flood Depth Mapping
100 year ARI
Sheet 1 of 7

PARSONS BRINCKERHOFF | Sydney WATER

Datum:	GDA94 / Zone 56	Scale:	1:10,000		
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_F\10_GIS\Projects\ArcView\2114299N_2007a_Cooks_River_Flood_Depth_100yr_Sheet1.mxd		DWG. No:	2114299N_2007a	Fig. No.	C-8



Flood level (mAHD)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

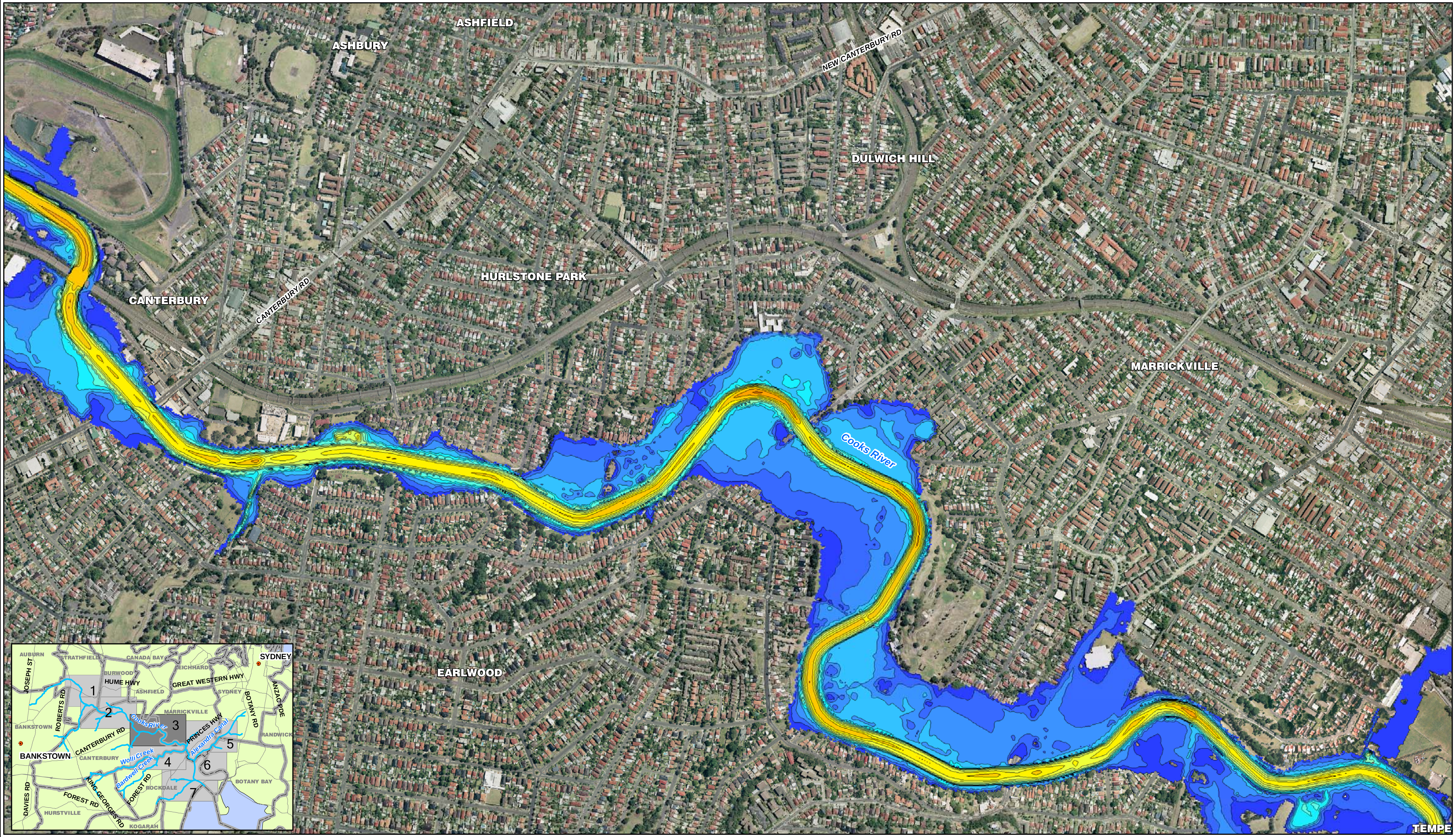
PDF File: 2114299N_2007b_Cooks_River_Flood_Depth_100yr_Sheet2.pdf

Flood Depth 100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Depth Mapping 100 year ARI Sheet 2 of 7		PARSONS BRINCKERHOFF	Sydney WATER
		Datum: GDA94 / Zone 56	Scale: 1:10,000
Project: Cooks River Flood Study		Drawn: GK	Date: Oct, 08
Client: SYDNEY WATER		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007b_Cooks_River_Flood_Depth_100yr_Sheet2.mxd		DWG. No: 2114299N_2007b	Fig. No. C-9



Flood level (mAHD)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2007c_Cooks_River_Flood_extents_100yr_Sheet3.pdf

Flood Depth

100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

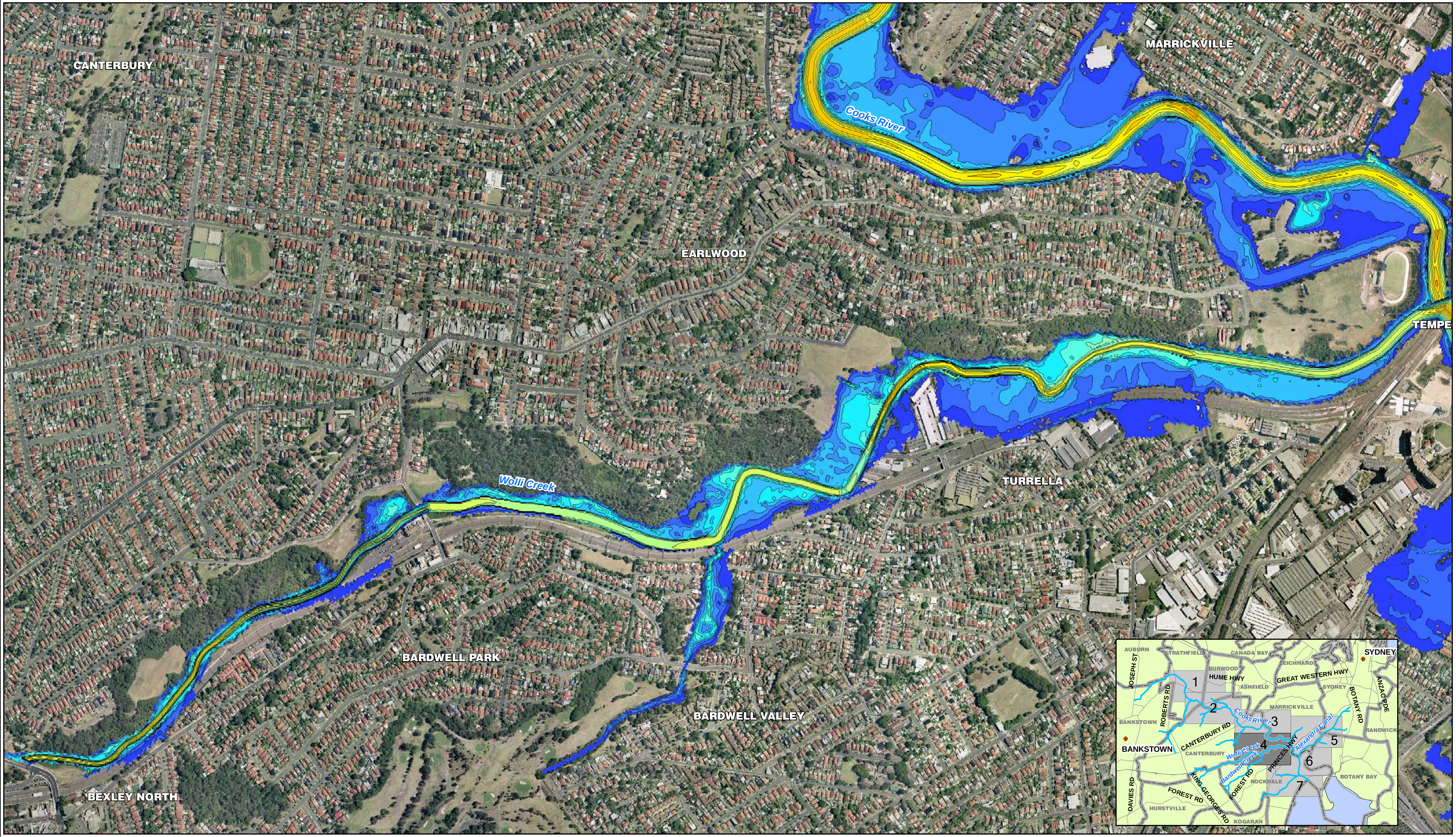
Title:

Flood Depth Mapping
100 year ARI
Sheet 3 of 7

PB PARSONS BRINCKERHOFF

Sydney WATER

Datum:	GDA94 / Zone 56			Scale:	1:10,000
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No.	2114299N	Layout Size: A3	Checked: KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007c_Cooks_River_Flood_Depth_100yr_Sheet3.mxd	DWG. No:	2114299N_2007c	Fig. No.	C-10



Flood level (mAHD)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2007d_Cooks_River_Flood_Depth_100yr_Sheet4.pdf

Flood Depth
100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title:

Flood Depth Mapping
100 year ARI
Sheet 4 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Project: Cooks River Flood Study		Datum: GDA94 / Zone 56	Scale: 1:10,000
Client: SYDNEY WATER		Drawn: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Designed: GK	Date: Oct, 08
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007d_Cooks_River_Flood_Depth_100yr_Sheet4.mxd		Checked: KS	Date: Feb, 09
		DWG. No: 2114299N_2007d	Fig. No. C-11

Flood level (mAHD)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2007e_Cooks_River_Flood_Depth_100yr_Sheet5.pdf

Flood Depth 100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

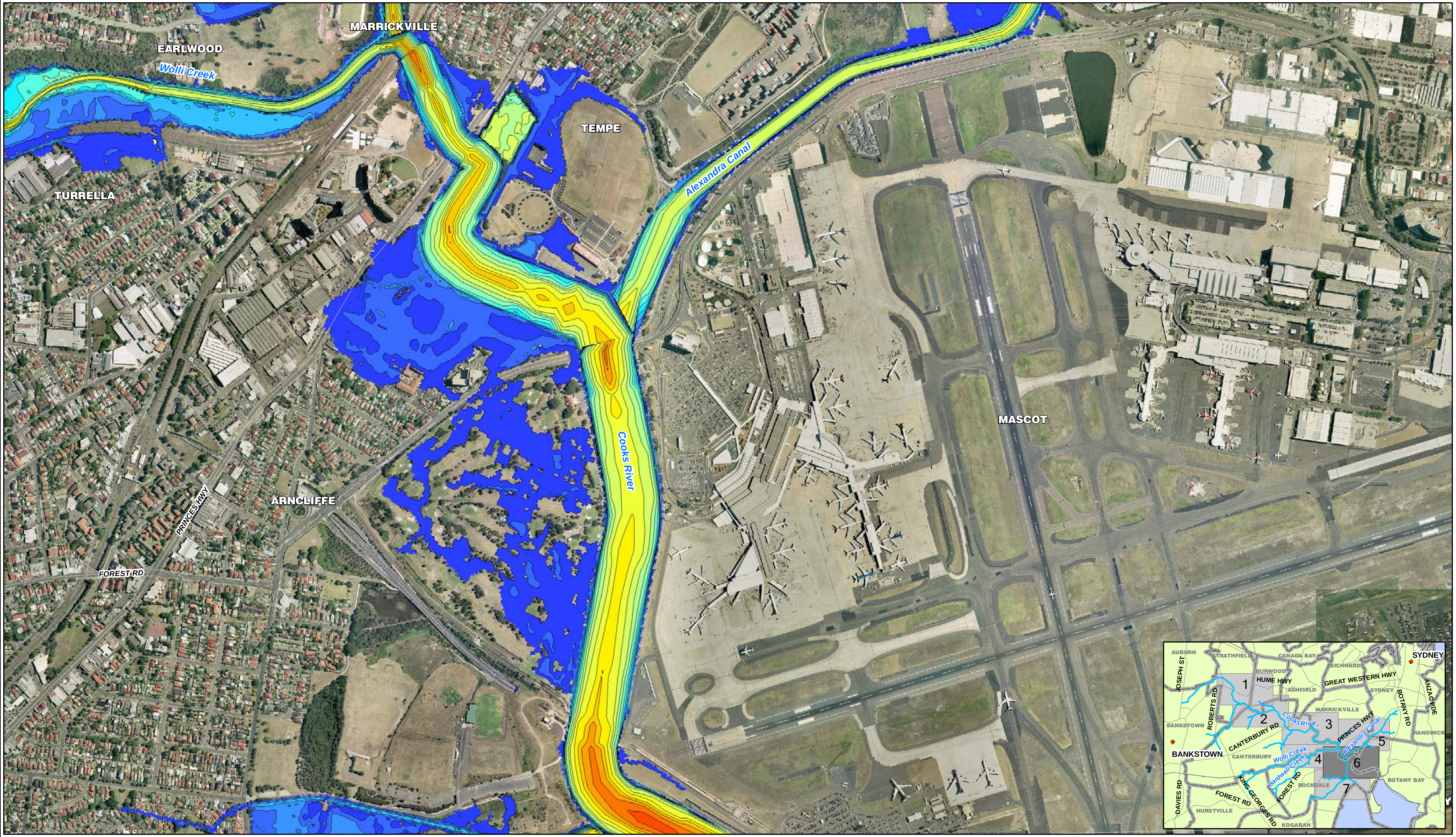
Title:

Flood Depth Mapping
100 year ARI
Sheet 5 of 7

PARSONS BRINCKERHOFF

Sydney WATER

Project: Cooks River Flood Study		Datum: GDA94 / Zone 56	Scale: 1:10,000
Client: SYDNEY WATER		Drawn: GK	Date: Oct, 08
		Designed: GK	Date: Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked: KS	Date: Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007e_Cooks_River_Flood_Depth_100yr_Sheet5.mxd		DWG. No: 2114299N_2007e	Fig. No. C-12



Flood level (mAHD)
LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

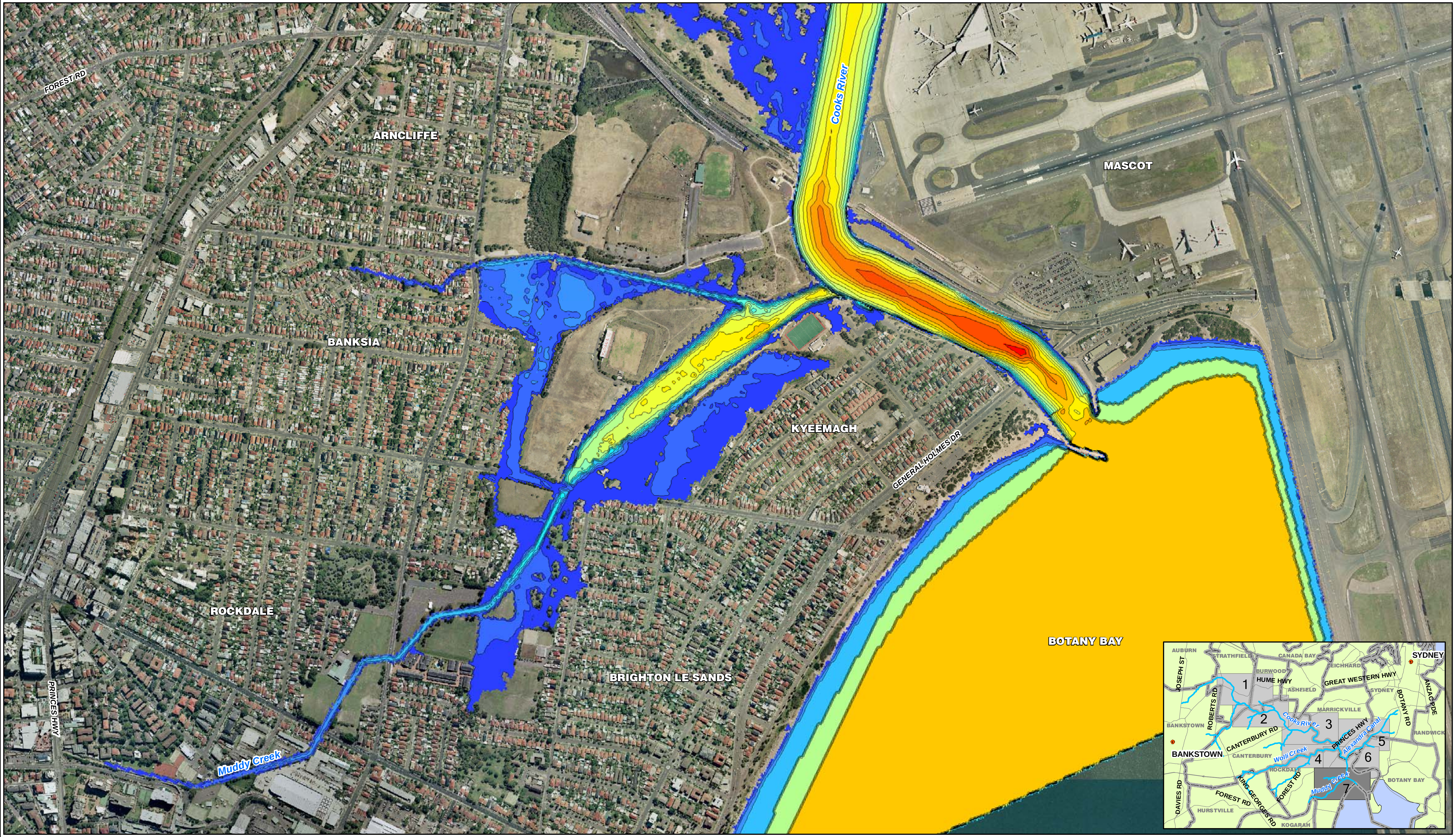
PDF File: 2114299N_2007f_Cooks_River_Flood_Depth_100yr_Sheet6.pdf

Flood Depth
100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Depth Mapping 100 year ARI Sheet 6 of 7		PARSONS BRINCKERHOFF / Sydney WATER			
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project: Cooks River Flood Study		Drawn:	GK	Date:	Oct, 08
Client: SYDNEY WATER		Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007f_Cooks_River_Flood_Depth_100yr_Sheet6.mxd		DWG. No:	2114299N_2007f	Fig. No.	C-13



Flood level (mAHD)

LGA boundaries

PDF Address: J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Maps\09Feb

PDF File: 2114299N_2007g_Cooks_River_Flood_Depth_100yr_Sheet7.pdf

Flood Depth
100 year ARI (m)

- 0 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- 2.6 - 3.0
- 3.1 - 3.5
- 3.6 - 4.0
- 4.1 - 4.5
- 4.6 - 5.0
- 5.1 - 5.5
- 5.6 - 6.0
- 6.1 - 6.5
- 6.6 - 7.0
- 7.1 - 7.5
- 7.6 - 8.0

0 250 500 Metres

Title: Flood Depth Mapping 100 year ARI Sheet 7 of 7		PARSONS BRINCKERHOFF		Sydney WATER	
		Datum:	GDA94 / Zone 56	Scale:	1:10,000
Project:	Cooks River Flood Study	Drawn:	GK	Date:	Oct, 08
Client:	SYDNEY WATER	Designed:	GK	Date:	Oct, 08
Proj. No. 2114299N	Layout Size: A3	Checked:	KS	Date:	Feb, 09
GIS Proj:	J:\A246-WAT\PROJ\2114299N_Cooks_River_Fl\10_GIS\Projects\ArcView\2114299N_2007g_Cooks_River_Flood_Depth_100yr_Sheet7.mxd	DWG. No:	2114299N_2007g	Fig. No.	C-14

APPENDIX D

COOKS RIVER GIS DATA (DVD)