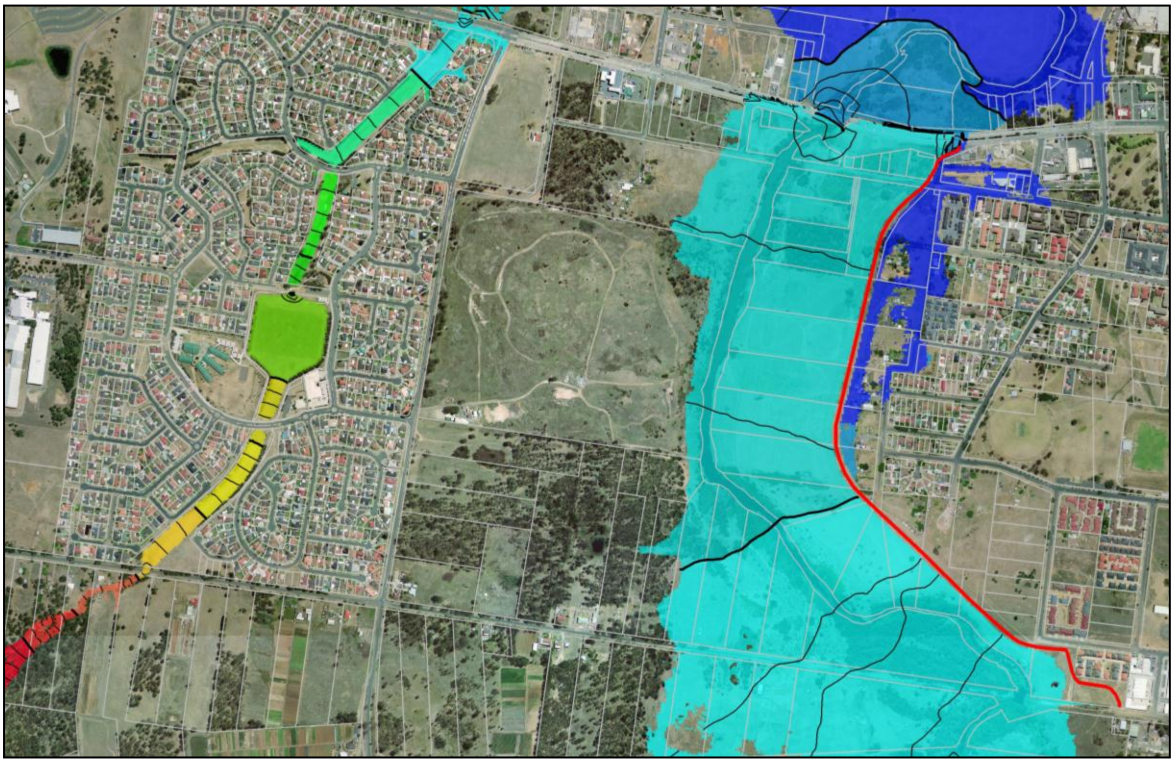
PENRITH CITY COUNCIL IN ASSOCIATION WITH
LIVERPOOL, BLACKTOWN AND FAIRFIELD CITY COUNCILS

UPDATED SOUTH CREEK FLOOD STUDY

Volume 1 – Report Text and Appendices



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PROJECT: 301015-00727 - UPDATED SOUTH CREEK FLOOD STUDY

REV	DESCRIPTION	AUTHOR	REVIEWER	WORLEY-PARSONS APPROVAL	DATE
1	**Draft Report – Issued for Client Review**	RG / CRT	CRT		12/4/2013
2	**Final Draft Report**	RG / CRT	CRT		31/8/2013
3	**Exhibition Draft Report** (Incorporating final comments)	RG / CRT	CRT		8/5/2014
4	**Final Report (*Volume 1 and 2*)**	RG / CRT	CRT	AThomas	30/1/2015

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The Updated South Creek Flood Study was prepared by WorleyParsons Services Pty Ltd on behalf of Penrith City Council, acting in association with Liverpool, Blacktown and Fairfield City Councils. Penrith, Liverpool, Blacktown and Fairfield City Councils have prepared this document with the technical guidance and financial assistance from the New South Wales Government through its Floodplain Management Program.

The Study is the culmination of many months of investigation, analysis and flood modelling, which has been supported by valuable contributions from the Office of Environment & Heritage, and representatives from Penrith, Liverpool, Blacktown and Fairfield City Councils.

FOREWORD

The State Government's Flood Policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. Policy and practice are defined in the Government's Floodplain Development Manual (*2005*).

Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in the discharge of their floodplain risk management responsibilities.

The Policy provides for technical and financial support by the State Government through the following four sequential stages:

STAGES OF FLOODPLAIN RISK MANAGEMENT

STAGE	DESCRIPTION
1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of Plan	Results in construction of flood mitigation works to protect existing development and the application of environmental and planning controls to ensure that new development is compatible with the hazard.

Penrith City Council commenced this process in 2005, when it formed the Technical Working Group for the South Creek Flood Study. The Technical Working Group, which comprises members from Penrith City Council, Blacktown City Council, Liverpool City Council and Fairfield City Council, with the technical and financial support of the NSW Governments Floodplain Management Program, has proceeded with the floodplain management process by engaging consultants to prepare an updated Flood Study for the South Creek catchment.

The Updated Flood Study represents the first of the four stages in the process shown above. It has been prepared to assist Council and the community to understand and define the existing flood behaviour.

The modelling developed for the Updated Flood Study will subsequently be used to assess potential flood damage reduction options and future development scenarios.

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NOTE: *Figures are documented in Volume 2 of the Updated South Creek Flood Study*

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GLOSSARY

Australia Height Datum (AHD)	National survey datum corresponding approximately to mean sea level
catchment	The catchment at a particular point is the area of land which drains to that point.
design floor level	The minimum *(lowest)* floor level specified for a building.
design flood	A hypothetical flood representing a specific likelihood of occurrence *(for example the 100 year recurrence flood or 1% annual exceedance probability flood)*. The design flood may comprise two or more single source dominated floods.
development	Existing or proposed works which may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow, which is a measure of how fast the water is moving. Rather, it is a measure of how much water is moving. Discharge and flow are interchangeable terms.
effective warning time	The available time that a community has from receiving a flood warning to when the flood reaches them.
flood	Above average river or creek flows which overtop banks and inundate floodplains.
flooding	The State Emergency Service uses the following definitions in flood warnings: ▪ **Minor flooding**: causes inconvenience such as closing of minor roads and the submergence of low level bridges. ▪ **Moderate flooding**: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered. ▪ **Major flooding**: extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas flooded.
flood behaviour	The pattern/characteristics/nature of a flood. The flood behaviour is often presented in terms of the peak average velocity of floodwaters and the peak water level at a particular location.
flood awareness	An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warning promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.
flood frequency analysis	An analysis of historical flood records to determine estimates of design flood flows.

flood fringe	Land which may be affected by flooding but is not designated as a floodway or flood storage.
flood hazard	The potential threat to property or persons due to flooding.
flood level	The height or elevation of flood waters relative to a datum *(typically the Australian Height Datum)*. Also referred to as "stage".
floodplain	Land adjacent to a river or creek which is periodically inundated due to floods up to the Probable Maximum Flood event. Floodplains are a natural formation created by the deposition of sediment during floods.
flood planning levels (FPL)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPL's may be appropriate for different categories of land-use and for emergency services planning. The concept of FPL's supersedes the "standard flood event" referred to in the 1986 edition of the *'Floodplain Development Manual'*. **FPL's do not define the extent of flood prone land, and floodplain management plans must always consider that there is flood prone land above the area defined by an adopted FPL.**
flood proofing	Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb.
floodplain management	The coordinated management of the risks associated with human activities that occur on the floodplain.
flood source	The source of the flood waters. In this study South Creek, Ropes Creek and Kemps Creek form the primary sources of floodwaters. The minor tributaries that also contribute are Thompsons, Badgerys, Cosgroves, Blaxland, Claremont and Werrington Creek. Floodwaters along each of these tributaries originates as runoff from rainfall falling over each respective catchment.
flood storages	Floodplain areas which are important for the temporary storage of flood waters during a flood.
freeboard	A factor of safety usually expressed as a height above the flood standard. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
high hazard	Danger to life and limb; evacuation difficult; potential for structural damage, high social disruption and economic losses.
historical flood	A flood which has actually occurred.
hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems.

hydrograph	A graph showing how a river or creek's discharge changes with time.
hydrology	The term given to the study of the rainfall-runoff process in catchments.
low hazard	Flood depths and velocities are sufficiently low that people and their possessions can be evacuated.
management plan	A clear and concise document, normally containing diagrams and maps, describing a series of actions which will allow an area to be managed in a co-ordinated manner to achieve defined objectives.
peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event.
probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
probability	A statistical measure of the likely frequency or occurrence of flooding.
runoff	The amount of rainfall from a catchment which actually ends up as flowing water in the river or creek.
stage	See flood level.
stage hydrograph	A graph of water level over time.
velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, ie. the average velocity across the whole river or creek section.

1. INTRODUCTION

South Creek is a tributary of the Hawkesbury River that drains a 414 km^2 catchment in western Sydney. As shown in **Figure 1.1**, the South Creek catchment is extends from its headwaters near Narellan in the south, to its confluence with the Hawkesbury River near Windsor. South Creek generally flows from south to north through the catchment with the commercial centres of Penrith and Blacktown located to the west and east, respectively. Large areas of the catchment have been urbanised particularly in the vicinity of these commercial centres.

This flood study covers the South Creek catchment extending from Bringelly Road in the south to the Blacktown/Richmond Road Bridge crossing in the north. The total study area is about 240 km^2 and lies within the Hawkesbury, Penrith, Blacktown, Liverpool and Fairfield Local Government Areas (*LGAs*).

Ropes and Kemps Creeks are major tributaries of South Creek (*refer* **Figure 1.1**). Minor tributaries include Werrington, Claremont, Blaxland, Cosgroves, Badgerys and Thompsons Creeks.

Flooding of South Creek typically occurs as a result of local catchment runoff breaking out of the main channel and spilling across the adjoining floodplain. However, the lower reaches of South Creek also serve as a large flood storage area during major flooding of the Hawkesbury-Nepean River system. As a result, floodwaters can 'back-up' along South Creek from its confluence with the Hawkesbury River, leading to inundation of areas of the South Creek floodplain to beyond the area that would typically be flooded in local catchment events.

Two major flood events occurred in the South Creek catchment in the 1980s. The August 1986 flood and the April 1988 flood are two of the largest floods to have occurred in the catchment since European settlement. The 1988 flood was in the order of a 100 year recurrence flood within South Creek. The 1986 flood is considered to be in the order of the 100 year recurrence flood within Ropes Creek. Other significant floods occurred in 1867, 1956, 1961 and 1978.

In 1990, the NSW Department of Water Resources completed a flood study for the South Creek catchment. The study involved the development of hydrologic and hydraulic computer models and their application to define flood behaviour across the floodplains of South Creek and its tributaries. The results from this modelling are documented in a report titled, *'Flood Study Report, South Creek'* (*1990*), which hereafter is referred to as the *'1990 Flood Study'*.

Flood discharges throughout the South Creek catchment were determined using a hydrologic model that was developed using the RAFTS software package. The RAFTS model was calibrated and verified against discharges that were recorded during the August 1986 and April 1988 floods. As part of the current study, this same RAFTS model has been updated to be consistent with the latest version of XP-RAFTS software.

Flood characteristics for the South Creek system were defined using the MIKE-11 and HEC-2 modelling software packages. A one-dimensional MIKE-11 unsteady flow model was developed for South Creek and the lower reaches of its primary tributaries, including Ropes, Badgerys and Kemps Creeks.

HEC-2 steady-state models were developed to model the upper reaches of the primary tributaries and the secondary tributaries of South Creek, including Werrington, Claremont, Blaxland, Cosgroves, and Rileys Creeks. The MIKE-11 and HEC-2 models were also calibrated to available flood level data recorded during the 1986 and 1988 floods.

The MIKE-11 and HEC-2 models were subsequently used to simulate the design 100 year ARI event. Peak design 100 year ARI flood levels were predicted at each of the cross-sections that had been used to develop the hydraulic models.

A floodplain management study was subsequently completed by Willing & Partners in 1991. The findings of this study are documented in the *'South Creek Floodplain Management Study'* (*1991*).

Liverpool City Council also completed Floodplain Management Plans for those sections of South Creek and its major tributaries (*Thompson's and Kemps Creeks*) that fall within the Liverpool City Council LGA. The aim of these studies was to bring together all past, current and proposed future activities related to flood risk. The findings of these investigations are documented in two reports titled, *'South Creek Floodplain Risk Management Study and Plan'* (*2004*) and *'Austral Floodplain Risk Management Study and Plan'* (*2003*).

Since completion of the 1990 Flood Study, there have been many changes occur across the South Creek catchment. These changes include the implementation of a number of measures recommended in the South Creek Floodplain Management Study, including works upstream of Elizabeth Drive, at Overett Avenue, and at South St Marys. Major development of the ADI site at St Marys and small areas on the fringe of Erskine Park has also occurred. Changes have also occurred to areas of the floodplain including the construction of levees and earthworks that have the potential to alter flooding patterns.

In recognition of these changes, Penrith City Council, in conjunction with Blacktown City Council, Fairfield City Council and Liverpool City Council, engaged Patterson Britton & Partners (*now WorleyParsons*) to update the hydrologic and hydraulic models that had been developed as part of the previous studies. The objective was to update or replace the existing hydrologic and hydrodynamic models so that contemporary tools are made available for the assessment of flood conditions across the South Creek catchment. These tools could then be used to simulate flooding of the South Creek system for a range of standard design floods and thereby provide more reliable estimates of planning flood levels for each local government area. The new flood models will also assist any future floodplain management study that may be undertaken to assess options for reducing existing flood damages or in providing guidance to regional planning.

Accordingly, a two-dimensional hydrodynamic model of the South Creek system has been developed using the RMA-2 software package. The model is based on the latest topographic data for the catchment, which was derived from Light Detection and Ranging (LiDAR) data that was gathered for the entire South Creek floodplain between 2002 and 2006. The model has been used to simulate the full range of design floods, including the Probable Maximum Flood. This report documents the findings from the modelling investigations, including details on flows, flood levels, flood depths, flow velocities, and provisional hydraulic and hazard categories for current catchment and floodplain conditions.

2. STUDY METHODOLOGY

2.1 GENERAL

Floodplain risk management in New South Wales generally follows guidelines established in the NSW Government's *'Floodplain Development Manual'* (*2005*). The Manual outlines the steps involved in the process and the activities required to be undertaken to successfully develop a Floodplain Risk Management Plan for flood affected areas.

A description of the inter-relationship between the various stages involved in the preparation of a Floodplain Risk Management Plan is provided in the flow chart shown overleaf. This flow chart also shows the link between the various outcomes of the studies involved in the floodplain risk management process and the implementation of measures to reduce flood damages (*both planning and structural*).

The formulation and implementation of floodplain risk management plans is the cornerstone of the Government's *Flood Prone Land Policy*. The primary objective of the *Flood Prone Land Policy* is to reduce the impacts of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding.

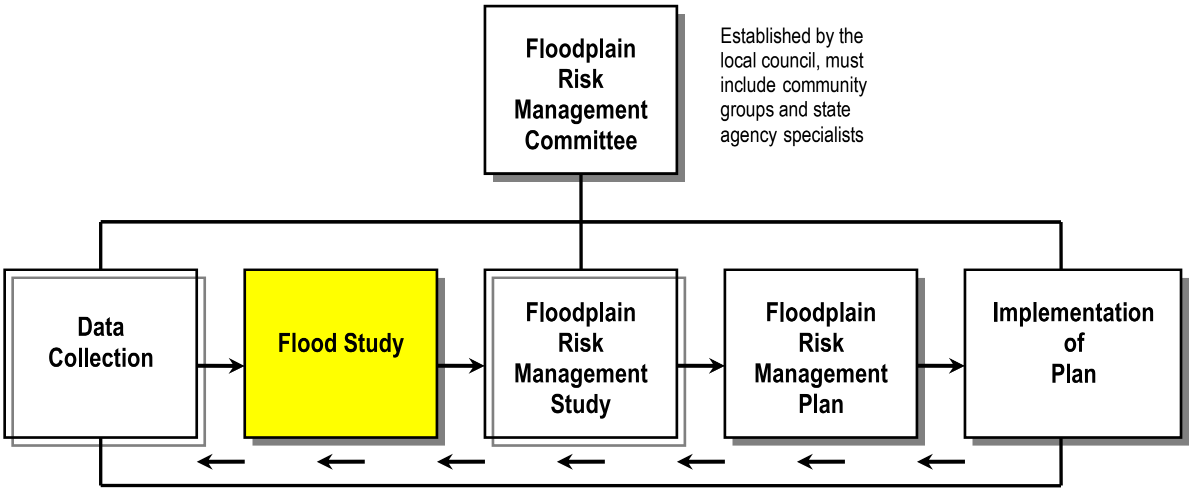
In this regard, the Policy recognises:

- that flood prone land is a valuable resource that should not be sterilised by unnecessarily precluding its development; and.
- that if all applications for development on flood prone land are assessed according to rigid and prescriptive criteria, some proposals may be unjustifiably disallowed or restricted, and equally, quite inappropriate proposals could be approved (*NSW Government, 2005*).

One of the key steps involved in formulating a floodplain risk management plan is the recognition, definition and quantification of the principal factors associated with flooding. This information is presented in a Flood Study, which becomes a baseline document summarising flood related data which can be used to resolve floodplain risk management issues.

Penrith City Council initiated the process for the South Creek by commissioning this study.

The aim of the *study* is to produce information on flood flows, velocities, levels, flood extents, and hydraulic and hazard category mapping for a range of flood events under existing floodplain and catchment conditions.



Established by the local council, must include community groups and state agency specialists

Compilation of existing data and collection of additional data. Usually undertaken by consultants appointed by the council.

Defines the nature and extent of the flood problem, in technical rather than map form. Usually undertaken by consultants appointed by the council.

Determines options in consideration of social, ecological and economic factors relating to flood risk. Usually undertaken by consultants appointed by the council.

Preferred options publicly exhibited and subject to revision in light of responses. Formally approved by the council after public exhibition and any necessary revisions due to public comments.

Flood, response and property modification measures including mitigation works, planning controls, flood warnings, flood readiness and response plans, environmental rehabilitation, ongoing data collection and monitoring.

Source: *'Floodplain Development Manual'* (*2005*)

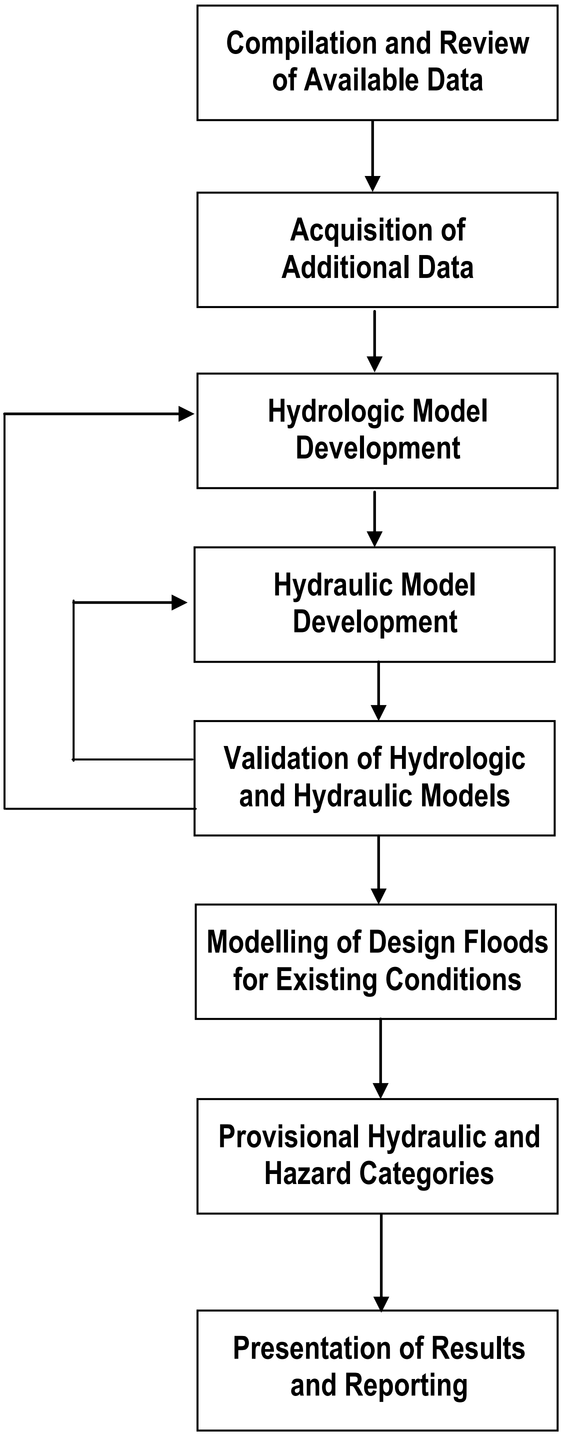
2.2 ADOPTED APPROACH

The general approach and methodology employed to achieve the study objectives involved:

- compilation and review of available information, including previously completed flood studies, streamflow gauge records, rainfall records, topographic mapping of the floodplain, hydrographic surveys of creek channels and details of bridge crossings;
- site inspections to establish catchment roughness, slope, and land-use, and to identify additional survey needs and critical hydraulic controls such as bridges and weirs;
- the collection of historical flood information, including records of peak flood levels for historical floods (*such as occurred in 1986 and 1988*);
- the development of a computer based hydrologic model to simulate the transfer of rainfall into runoff and its concentration in streams during the flood;
- the development of a computer based hydraulic model to simulate the movement of floodwaters through the lower reaches of the floodplain, generally downstream of tidal limits of all streams;
- validation of the models against results from the 1990 Flood Study; and,

- the determination of peak water levels, flood flows, depths and flow velocities along South Creek and its tributaries for the 20, 50, 100, 200 and 500 year ARI floods and the Probable Maximum Flood (*PMF*).

The flow chart shown below outlines the key steps and the sequence of work that has been undertaken in preparing this Flood Study.



2.3 COMPUTER MODELS

Computer models are the most reliable cost-effective tools available to simulate flood behaviour in rivers and streams. Two types of computer models were developed as part of the Flood Study for use in assessing and quantifying flooding characteristics within the South Creek catchment. These are:

- a hydrologic model, covering the entire area of the South Creek catchment and that of its tributaries; and,
- a hydraulic model, extending downstream of Bringelly Road along South Creek, and along its major tributaries Kemps, Ropes, Thompson, Badgerys, Blaxland, Cosgroves, Werrington and Claremont Creeks.

The **hydrologic model** simulates catchment runoff following a particular rainfall event. The main outputs from the hydrologic model are discharge hydrographs which define the quantity of runoff as well as the rate of rise, timing and magnitude of peak discharges resulting from the rainfall event. The discharge hydrographs are utilised as inputs into the hydraulic model.

The **hydraulic model** simulates the passage of floodwater along waterway reaches and across floodplain areas. The hydraulic model calculates key flooding characteristics such as flood levels, flow velocities, floodwater depths and flood hazard at selected points of interest throughout the study area.

Information on the topography and characteristics of the catchments, and the watercourses and their floodplains, is built into the models. For each historic flood, data on rainfall, flood levels and river flows can be used to simulate and validate (*calibrate and verify*) the models.

Development of the computer models involves:

- discretisation of the catchment, creek, floodplain, etc;
- incorporation of physical characteristics (*catchment areas, creek cross-sections, etc.*);
- setting up of hydrologic and hydraulic databases (*rainfall, creek flows, flood levels*) for historic events;
- calibration to one or more historic floods (*calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values*); and,
- verification to one or more other historic floods (*verification is a check on the model's performance without adjustment of parameters*).

Once model development is complete, it may then be used for:

- establishing design flood conditions;
- setting flood standards for planning, so that future land-use is controlled to minimise potential losses/damage due to flooding;
- developing flood hazard mapping;

- hydraulic categorisation of the floodplain; that is, delineating floodway, flood storage and flood fringe;
- assessment and quantification of the impacts of climate change on design flood characteristics; and,
- the modelling of “what-if” management scenarios to assess the hydraulic impacts of structural mitigation measures; e.g., changes to a bridge structure to reduce upstream bridge afflux or the potential benefits of constructing a levee.

3. REVIEW OF AVAILABLE DATA

3.1 AVAILABLE DATA

A range of data is required to develop a flood model and for that model to be applied to simulate flood behaviour. Typically, contours of the land surface and cross-sections of the river and creek system are required to represent the floodplain topography and channel bathymetry. Details of critical hydraulic controls such as bridges and roadway embankments also need to be defined as they can influence flood behaviour. In addition, surface roughness parameters are required to reflect the influence that land features may have on the way floodwaters travel overland. These are usually based on consideration of vegetation density and soil type.

Calibration and verification of the model requires the collection of stream flows and flood level information for calibration and verification for a series of historic floods. Design flood simulation requires that the peak flows entering the modelled area have been established. This requires hydrologic modelling to be undertaken to determine design discharges for the creek.

The data for this study has been obtained from a number of sources including:

- Penrith City Council (PCC);
- Fairfield City Council (FCC);
- Blacktown City Council (BCC);
- Liverpool City Council (LCC); and,
- the Office of Environment & Heritage (*OEH*).

Survey data for the study area was obtained from a number of previous investigations. This was supplemented by topographic information that was generated specifically for the current study.

A detailed description of the available data is provided in the following sections.

3.2 PREVIOUS INVESTIGATIONS

A number of previous hydrologic and hydraulic investigations have been undertaken to examine the nature and extent of flooding along South Creek. These include the following reports:

- *'Flood Study Report, South Creek' (Department of Water Resources, 1990*)
- *'South Creek Floodplain Management Study'* (*Willing and Partners Pty Ltd, 1991*)
- *'ADI St Mary's Watercycle & Soil Management Study, Final Study Report'* (*Sinclair Knight Merz, 1998*)
- *'Austral Floodplain Risk Management Study and Plan'* (*Perrens Consultants, 2003*)
- *'South Creek Floodplain Risk Management Study and Plan'* (*Bewsher Consulting, 2004*)

These reports include flood related data that was useful for this study. A brief synopsis of each is presented in the following sections.

3.2.1 Flood Study Report South Creek (*NSW Department of Water Resources, July 1990*)

This report (*referred to hereafter as the "1990 Flood Study"*) was prepared by the NSW Department of Water Resources for the South Creek catchment. The primary objective of the study was to revise the earlier South Creek Flood Study based on data from severe flooding in August 1986 and April 1988. In addition, plans to undertake large scale development in western Sydney resulted in the need for the hydrologic and hydraulic modelling for South Creek to be updated.

The report details the historic flood behaviour within the catchment and specifies historic flood levels at key locations in the area. These historic flood levels are listed in **Table 1**.

Flood discharges throughout the South Creek catchment were determined through the development of a RAFTS hydrologic model. The RAFTS model was calibrated and validated against the August 1986 and April 1988 events. The model was simulated for the 100 year recurrence event only.

Table 1 HISTORIC FLOOD LEVELS FROM THE 1990 SOUTH CREEK FLOOD STUDY

LOCATION	PEAK FLOOD LEVEL (*mAHD*)					
	1867	1956	1961	1978	1986	1988
Elizabeth Drive	-	43.0	-	42.0	42.7	43.3
Mandalong Stud	-	32.9	-	32.0	-	32.5
F4 Freeway	-	-	-	-	-	26.9
Great Western Highway	24.5	-	24.0	24.4	24.4	24.7
Richmond Road	-	13.5	14.8	14.5	11.2	12.7
Windsor	19.7	13.8	15.0	14.5	11.4	12.8

Flood characteristics for South Creek and its floodplain was defined using MIKE 11 and HEC-2 software. A MIKE 11 one-dimensional unsteady flow model was developed to model South Creek and the lower reaches of the primary tributaries including Ropes, Badgerys and Kemps Creeks. A HEC-2 steady-state model was created to model the upper reaches of the primary tributaries and other tributaries of South Creek such as Werrington, Claremont, Blaxland, Cosgroves, and Rileys Creeks. The hydraulic models were calibrated to the 1986 and 1988 flood events.

The hydraulic models were only simulated for the 100 year recurrence event. The 100 year recurrence flow hydrographs were defined using results generated from the RAFTS hydrologic model of the South Creek catchment. A Hawkesbury River water level of 17 mAHD was used as the tailwater condition in the MIKE 11 model.

The report outlines the design flood behaviour for the 100 year recurrence event. This data includes peak flood levels, flow velocities and flows at each of the cross-sections within the hydraulic models. The peak 100 year recurrence flood levels determined as part of the study are shown in Table 2 for key locations within the study area.

Table 2 DESIGN 100 YEAR RECURRENCE FLOOD LEVELS FOR SOUTH CREEK FROM THE 1990 SOUTH CREEK FLOOD STUDY

LOCATION	PEAK FLOOD LEVEL (*mAHD*)
Upstream of Richmond Road	17.0
Stony Creek Road	17.0
Ropes Creek Confluence	18.9
Downstream Main Western Railway	23.5
Upstream Great Western Highway	25.4
Upstream F4 Freeway	28.5
Upstream Elizabeth Drive	43.2
Upstream Bringelly Road	59.3
Downstream Camden Valley Way	90.5

3.2.2 South Creek Floodplain Management Study (*Willing & Partners, Feb 1991*)

This report documents the Floodplain Management Study carried out by Willing and Partners Pty Ltd for the South Creek catchment. The study quantifies the extent and impacts of flooding in the study area and determines the effects of proposed urban development on flood behaviour. Works and measures aimed at reducing the impact of flooding and water quality issues within the catchment have also been assessed as part of the study.

Hydrologic and hydraulic analyses were undertaken using the RAFTS, MIKE 11 and HEC-2 models developed by the DWR as part of the 1990 Flood Study (*refer* **Section 2.2.5**). The hydraulic analysis was extended to include the 20 and 50 year recurrence events and the PMF (*based on Bulletin 51 and Nepean Catchment PMP*). The Hawkesbury River water levels used as the tailwater levels for the modelling are shown in **Table 3**.

Table 3 HAWKESBURY RIVER TAILWATER LEVELS FROM THE *'SOUTH CREEK FLOODPLAIN MANAGEMENT STUDY'*

AVERAGE RECURRENCE INTERVAL (*YEARS*)	TAILWATER LEVEL (*mAHD*)
20	13.8
50	15.9
100	17.5
PMF	22.2

Investigations undertaken as part of the study also involved the estimation of the hydraulic categories for South Creek and its tributaries for the 100 year recurrence event. The extent of the floodway was determined based on the results of the hydraulic modelling and using the encroachment approach.

Flood damages were assessed by the Centre for Resource and Environmental Studies (*CRES*) at the Australian National University (*ANU*) using ANUFLOOD software. This software was used to assess direct and indirect tangible damages. The total damage within the study area as a result of the 100 year recurrence flood was estimated to be $6.6M at 1990 prices.

A range of flood mitigation works and measures were investigated for the catchment and evaluated in terms of their relative benefits and costs. A number of measures were recommended as a result of the analyses. These included a levee at Overett Avenue, with channel enlargement and a bypass floodway, bridge waterway enlargements at Bringelly Road and Elizabeth Drive and a levee at Victor Avenue with a compensating bypass floodway, which have all been implemented.

Water quality analyses were also carried out to establish the water quality conditions in the South Creek catchment and the likely impacts of urban development on water quality within the study area. A number of water quality measures were proposed as part of the study.

3.2.3 ADI St Mary's Watercycle & Soil Management Study, Final Study Report (*Sinclair knight Merz, August 1998*) (*Including Addendum – Verification of Flood Level Impacts on the Revised Filling Line, 1999*)

Sinclair Knight Merz undertook this study to address matters relating to water cycle and soil management to support the Regional Environmental Plan for the ADI St Marys site. The site is located at the downstream end of the South Creek catchment, with approximately 3 river kilometres of the creek passing through the site between the northern and southern site boundaries. The site ultimately discharges to South Creek and Stony Creek. The study addresses both site specific and mainstream flooding issues for South Creek.

A RAFTS model was developed for the site to determine the peak flow rates for three scenarios, including existing conditions, proposed conditions without flow mitigation and proposed conditions with flow mitigation. Peak site discharges were determined for the 2, 5, 10, 20, 50 and 100 year recurrence events. Twelve (*12*) detention basins were proposed to ensure no net increase in the peak discharges for the 2 to 100 year recurrence events due to the development.

A hydraulic assessment of flood behaviour in South Creek was conducted in 1997 to determine the impact of the proposed development within the ADI site. The assessment was undertaken using the MIKE11 model developed for the *'Flood Study Report South Creek'* (*DWR, 1990*).

However, additional cross sections were incorporated within the model in order to provide a more reliable assessment of the flood behaviour across the site and the impacts associated with proposed filling for the site development.

The flood behaviour along South Creek was assessed for a range of design flood events, including the 20, 50 and 100 year recurrence events and the PMF. The flood event 20% greater than 100 year recurrence event was also investigated. The 100 year recurrence event for the study corresponds to the 100 year catchment event for South Creek and the 5 year recurrence event in the Hawkesbury River.

The results of this assessment are documented in the document *'ADI St Marys Redevelopment – Flood Levels Assessment for Filling within the Floodplain of South Creek'* (*Sinclair Knight Merz, April 1997*). The peak flood levels determined in the study are shown in **Tables 5** and **6** for key locations along South Creek and Ropes Creek, respectively.

Table 4 SIMULATED FLOOD LEVELS FOR SOUTH CREEK FROM THE *'ADI St Mary's Watercycle & Soil Management Study, Final Study Report'* (*1998*)

LOCATION	PEAK FLOOD LEVEL (*mAHD*)	
	PMF	100 Year ARI Event
Dunheved Road	25.97	22.56
Upstream Extent of the ADI Site	24.59	20.63
30 metres Upstream of Munitions Road Bridge	23.95	19.76
50 metres Downstream of Munitions Road Bridge	23.68	19.60
Downstream Extent of the ADI Site	23.21	18.09

Table 5 SIMULATED 100 YEAR RECURRENCE FLOOD LEVELS FOR ROPES CREEK FROM THE *'ADI ST MARY'S WATERCYCLE & SOIL MANAGEMENT STUDY, FINAL STUDY REPORT'* (*1998*)

LOCATION	PEAK 100 YEAR RECURRENCE FLOOD LEVEL (*mAHD*)
Upstream of St Marys STP	20.26
Downstream of St Marys STP	19.79
30 metres Upstream of Munitions Road Bridge	19.70
50 metres Downstream of Munitions Road Bridge	19.27
Confluence with South Creek	18.92

The MIKE 11 model was used to simulate flood levels and response times on the floodplain with the proposed development (filling plus replacement of Munitions Road Bridge). The Munitions Road Bridge has been removed since 1991 Study however, the approach embankments remain in place.

3.2.4 Austral Floodplain Risk Management Study and Plan, Review and Finalisation (*Perrens Consultants, September 2003*)

This study covers the Kemps Creek catchment within the Liverpool LGA and was carried out by Perrens Consultants as part of the *'South Creek Floodplain Risk Management Study and Plan For the Liverpool Local Government Area'* (*Bewsher Consulting Pty Ltd, 2004*)

The study area includes the Austral-Kemps Creek area between Elizabeth Drive and Bringelly Road and a small portion of the Bonds Creek catchment upstream of the Hume Highway which lies within Liverpool LGA.

A RAFTS model was developed for Kemps and Bonds Creeks and used to estimate flows under existing conditions for the 1, 5, 20 and 100 year recurrence events and the PMF (*based on Bulletin 51*).

A HEC-2 steady-state hydraulic model was developed to define the flood behaviour along Kemps and Bonds Creeks. Cross-sections for the model were extracted from photogrammetric survey of the study area and major hydraulic controls were defined by field survey. The results from the 1990 and 1991 studies were used to define boundary conditions. Peak flood levels from the simulation of the HEC-2 model are shown in **Tables 6** and **7** for Kemps and Bonds Creeks, respectively.

Table 6 SIMULATED FLOOD LEVELS FOR KEMPS CREEK FROM THE '*AUSTRAL FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN, REVIEW AND FINALISATION*'

LOCATION	PEAK FLOOD LEVEL (*mAHD*)			
	PMF	100 Year ARI Event	20 Year ARI Event	5 Year ARI Event
Elizabeth Drive	47.5	46.5	46.1	45.9
Gurner Avenue	56.1	55.2	55.0	54.9
Fifteenth Avenue	57.8	56.9	56.7	56.6
Twelfth Avenue	60.6	60.1	60.1	60.1
Bringelly Road	74.3	74.0	73.9	73.9

Table 7 SIMULATED FLOOD LEVELS FOR BONDS CREEK FROM THE '*AUSTRAL FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN, REVIEW AND FINALISATION*'

LOCATION	PEAK FLOOD LEVEL (*mAHD*)			
	PMF	100 Year ARI Event	20 Year ARI Event	5 Year ARI Event
Confluence with Kemps Creek	59.0	58.1	58.0	57.7
Tenth Avenue	63.1	62.4	62.2	61.7
Ninth Avenue	64.6	64.0	63.9	63.7
Fourth Avenue	66.0	65.1	64.4	64.1
Eighth Avenue	66.8	66.1	65.9	65.2
Seventh Avenue	67.9	67.1	66.9	66.5
Confluence with Scalabrini Creek	68.6	67.8	67.7	67.3
Edmondson Avenue	69.1	68.5	68.3	67.7
Sixth Avenue	69.9	69.2	69.0	68.8
Fifth Avenue	72.0	71.3	71.2	71.2
Bringelly Road	74.4	73.8	73.3	73.3
Cowpasture Road	78.7	78.4	78.0	77.5
Hume Highway	79.7	79.4	79.0	78.9
Denham Court Road	86.7	86.2	86.1	86.1

Provisional hydraulic and hazard categories were determined based on the 100 year recurrence event. Flood damages were also estimated for the Austral area, with the damage costs resulting from a 100 year recurrence flood determined to be $8.37M and the AAD estimated to be $1.8M.

3.2.5 South Creek Floodplain Risk Management Study and Plan for the Liverpool Local Government Area (*Bewsher Consulting Pty Ltd, December 2004*)

This report details the floodplain risk management study and plan undertaken by Bewsher Consulting, in association with Don Fox Planning. The study covers the South Creek and Thompsons Creek floodplains that lie within the Liverpool LGA.

As part of this study, Bewsher Consulting Pty Ltd made modifications to a MIKE 11 sub-model developed in the mid 1990's. This sub-model extends from 2.5 kilometres downstream of Elizabeth Drive to just downstream of Bringelly Road.

The MIKE 11 sub-model was originally developed for a number of studies that were undertaken in 1994 to 1997 to examine the flood mitigation options for the Overett and Victor Avenue areas in more detail. The hydrologic and hydraulic analyses undertaken as part of these studies were based on the RAFTS and MIKE 11 models from the *'South Creek Floodplain Management Study'* (*1991*). The sub-model of South Creek was created from the 1991 MIKE 11 model and incorporates greater topographic detail through the addition of cross-sections in the Overett and Victor Avenue areas.

The flood mitigation works that were completed in the late 1990's in response to the 1986 and 1988 floods, as recommended in *'South Creek Floodplain Management Study'* (*1991*) were also incorporated within the sub-model, including:

- a new bridge under Elizabeth Drive about 150m east of the main South Creek crossing; and,
- about 500m of floodway channel between Overett Avenue and north of Elizabeth Drive.

As part of this study, the model was updated to include the new two-lane road bridge was built by the Roads and Traffic Authority (*RTA*) over the main South Creek crossing of Elizabeth Drive. These works were completed in 1996 as part of the RTA's proposed future upgrade of Elizabeth Drive.

The model was also modified to incorporate Thompsons Creek and extend the upstream extent of the model to about 800 metres upstream of Bringelly Road. The model developed for this floodplain management study is referred to as the *'2003 MIKE 11 model'* and represented the best available information for the South Creek and Thompsons Creek floodplains within the Liverpool LGA.

The *'2003 MIKE 11 model'* was used to simulate the 5, 20, 50 and 100 year recurrence events and the PMF. The simulated flood levels at key locations along South Creek and Thompsons Creek are presented in **Tables 8** and **9**, respectively.

Table 8 SIMULATED FLOOD LEVELS FOR SOUTH CREEK FROM THE '*SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY*'

LOCATION	PEAK FLOOD LEVEL (*mAHD*)				
	PMF	100 Year ARI Event	50 Year ARI Event	20 Year ARIe Event	5 Year ARI Event
Upstream of Bringelly Road	60.28	59.30	59.01	58.55	57.96
Downstream of Bringelly Road	59.60	58.27	58.18	58.04	57.80
Confluence with Thompsons Creek	54.79	53.31	53.20	53.03	52.75
Upstream of Elizabeth Drive	44.42	42.64	42.49	42.21	41.80
Downstream of Elizabeth Drive	44.16	42.61	42.47	42.20	41.79
South Creek Dam	39.89	38.61	38.51	38.31	37.84

Table 9 SIMULATED FLOOD LEVELS FOR THOMPSONS CREEK FROM THE '*SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY*'

LOCATION	PEAK FLOOD LEVEL (*mAHD*)				
	PMF	100 Year ARI Event	50 Year ARI Event	20 Year ARI Event	5 Year ARI Event
Downstream of The Northern Road	70.43	69.77	69.68	69.58	-
Just upstream of The Retreat	59.41	58.9	58.87	58.81	-
250m upstream of Confluence with South Creek	54.25	52.88	52.78	52.65	-

The study involved the definition of flood hazards and hydraulic categories within the study area. The hydraulic floodway limit was determined based on the encroachment approach.

The impacts and the costs of flooding in the study were also determined using the results of the MIKE 11 model. The flood damages resulting from a 100 year recurrence event in the study area were estimated to be $3.1M and the Average Annual Damages (*AAD*) were calculated as $420,000 (*in 2004 dollars*).

3.3 SUMMARY OF AVAILABLE DATA

As part of the data collection and review phase for this study, all available survey along South Creek and its tributaries, and across the broader floodplain was compiled. This involved the review of the survey data that was collected for the previous studies within the study area that are detailed in *Section 2.2*. In particular, it involved the extraction of cross-sectional data from the MIKE-11 and HEC-2 hydraulic modelling undertaken for the *'Flood Study Report, South Creek'* (*1990*).

A summary of the extent of available survey data is presented in **Figure 3.1**.

3.3.1 Topographic / Hydrographic Data

Details of the topography of the study area can be interpreted from the following sources:

- Digital Elevation Model (*DEM*) data for the floodplain developed from Airborne Laser Scanning (*ALS*) data for the study area;
- DEM data developed from site specific survey;
- Previously surveyed cross-sections collected for the 1985 and 1990 Flood Studies; and,
- 1:25,000 series topographic maps published by the Central Mapping Authority;

These data sources are described in the following sections.

Airborne Laser Scanning Data

Airborne Laser Scanning (*ALS*) data is available for the entire study area. This ALS data comprises very large data sets that contain thousands of points defining the existing ground surface elevations within the study area. The latest ALS data available includes:

- ALS data collected within the Penrith LGA in 2003;
- ALS data collected within the Blacktown LGA in May 2006;
- ALS data collected within the Fairfield LGA in 2005; and,
- ALS data collected within the Liverpool LGA in 2005.

The extent of the available ALS data sets are shown in **Figure 3.1**.

ALS procedures are unable to penetrate through water, and do not typically include hydrographic features important for flood modelling, such as the bathymetry of streams that carry water under normal flow conditions.

However, South Creek and its tributaries did not carry significant flow during the periods when the ALS data was collected. Moreover, the definition of the creek beds and banks was compared to the surveyed cross-sections collected for the 1990 Flood Study and it was determined that the ALS data adequately defined the bed and banks within the study area. Accordingly, the ALS data has been used to define the channel and floodplain for the South Creek system within the study area.

Site Specific Survey

Site specific survey was provided for the Twin Creeks development along Cosgroves Creek. The survey collected in early 2005 by North Western Surveys Pty Ltd defined finished surface elevations for those parts of the development intended for residential development as well as for the Twin Creeks Golf Course.

The Twin Creeks survey data was overlayed against the ALS data gathered for the Penrith LGA in order to update the topographic information; i.e., the Twin Creeks development occurred post collection of the ALS data for the Penrith LGA (*2003*).

Surveyed Cross-sections from the 1990 Flood Study

A total of 480 cross-sections from 1990/1991 study covering South Creek and its tributaries.

1:25,000 Series Topographic Mapping

The 1:25,000 series topographic mapping covering the study area includes:

- Penrith *9030-3N*;
- Warragamba *9030-3S*;
- Prospect *9030-2N*;
- Riverstone *9030-1S*; and,
- Camden *9029-4N*.

The 1:25,000 series topographic maps shows many of the floodplain and geomorphic features, as well as indicators of vegetation cover and density. Contours are shown relative to Australian Height Datum (*AHD*) at 10 meter intervals.

3.3.2 Historic Flood Levels

Flood levels from the August 1986 and April 1988 floods were identified at many road crossings of South and Ropes Creeks as part of the 1990 Flood Study. However, very little data is available for the minor tributaries of South Creek as few houses were sited near the creeks at the time of these flood events.

The available historic flood levels within the study area have been extracted from the 1990 Flood Study and are listed in **Tables 10** and **11** for South and Ropes Creeks, respectively. The historic flood levels are also shown graphically in **Figures 3.2** and **3.3**.

Work undertaken for the 1990 Flood Study determined that the 1988 flood was approximately equivalent to the design 100 year recurrence event. That is, predicted peak 100 year recurrence flood levels generated from the MIKE 11 modelling undertaken for the 1990 study, are similar to those recorded along South Creek during the 1988 flood. The recorded data also shows that the 1986 flood in Ropes Creek had a magnitude approximately equal to that of the design 100 year recurrence flood.

Hence, the 1986 and 1988 flood marks are representative of the 100 year recurrence flood levels in Ropes and South Creek, respectively.

Table 10 1986 AND 1988 HISTORIC FLOOD MARKS ALONG SOUTH CREEK

LOCATION	RECORDED 1986 FLOOD LEVEL	RECORDED 1988 FLOOD LEVEL
Bringelly Road – Downstream	-	57.59
Victor Avenue	48.56	49.1
Overett Avenue	-	43.41
Elizabeth Drive – Upstream	42.73	43.33
Elizabeth Drive – Downstream	42.06	42.66
Warragamba Pipeline	-	33.67
Luddenham Road, St Clair	29.5	29.8
F4 Freeway Crossing	-	26.94
Saddington Street, St Clair	24.36	25.24
Great Western Highway	24.43	24.73
Main Western Railway	-	22.89
Dunheved Road, Dunheved	21.14	21.25
Eighth Avenue, Shanes Park	16.92	16.74
Stony Creek Road	13.27	13.4
Richmond Road	11.24	12.7

Table 11 1986 AND 1988 HISTORIC FLOOD MARKS ALONG ROPES CREEK

LOCATION	RECORDED 1986 FLOOD LEVEL	RECORDED 1988 FLOOD LEVEL
Debrincat Ave, Tregear	28.38	28.45
Forresters Road, Dunheved	24.42	24.5
Main Western Railway	33.47	32.37
Great Western Highway	36.15	35.66
M4 Motorway	41.68	41.53
Warragamba Pipeline	-	54.04

4. HYDROLOGIC MODELLING

4.1 HYDROLOGIC MODEL DEVELOPMENT

The hydrologic modelling for this study is based on the previous RAFTS (*Runoff Analysis and Flow Training Simulation*) hydrologic modelling (*Version 2.56, 1991*) that was developed by the Department of Water Resources for the *'South Creek Flood Study'* (*1990*). As part of this study, the RAFTS model of the South Creek catchment has been updated to *Version 6.52* (*2005*) XP-RAFTS.

The XP-RAFTS software package can be used to develop a deterministic runoff routing model that simulates catchment runoff processes by incorporating a number of common catchment parameters into its calculation procedures. It is recognised in *'Australian Rainfall and Runoff – A guide to Flood Estimation'* (*1998*), as one of the available tools for use in flood routing within Australian catchments.

XP-RAFTS was chosen for this investigation because it has the following attributes:

- it can account for spatial and temporal variations in storm rainfalls across a catchment;
- it can accommodate variations in catchment characteristics;
- it can be used to estimate discharge hydrographs at any location within a catchment; and,
- it has been widely used across eastern NSW and therefore, where suitable calibration data is not available, the results from modelling of other similar catchments can be used as a guide in the determination of model parameters.

4.1.1 RAFTS Model Developed for 1990 Flood Study

A RAFTS hydrologic model of the South Creek catchment was developed as part of the 1990 Flood Study. The downstream extent of the model was defined as Richmond Road (*refer* **Figure 1.1**).

The South Creek catchment was delineated into 76 sub-catchments based on 1:4,000 and 1:10,000 orthophoto mapping for the area that was available at the time the model was developed.

The RAFTS model was originally developed for the 1990 Flood Study using a range of physical characteristics of the catchment in the early 1990's. The parameters determined for each sub catchment include total area, average slope, percentage impervious area and roughness. The model also accounts for initial and continuing rainfall losses and routes the rainfall excess through the catchment.

Surveyed cross-sections of the creeks were used in the channel routing component of RAFTS. Basins were incorporated within the model to represent the South and Kemps Creek dams. Conceptual basins were also included along Ropes Creek to model the backwater storage effects of the numerous road crossings.

The 1986 and 1988 floods were used to calibrate the RAFTS model. The August 1986 flood was used as the calibration event for the Ropes Creek catchment, whilst the remainder of the catchment was calibrated to the April 1988 flood. This variation was required because the 1986 flood was significantly greater in Ropes Creek than in South Creek and subsequently, there was a greater amount of data available for the model calibration.

Calibration of the model was undertaken by adjusting the ‘BX’ multiplier to obtain good correlation between the peak discharge, time of peak, flood volume and hydrograph shape with the recorded data. The initial and continuing losses were also adjusted to improve the fit of the simulated hydrograph with the recorded hydrograph. A ‘BX’ factor of 1.3 was ultimately used for the modelling.

4.1.2 Development of the XP-RAFTS Model for this Study

The XP-RAFTS model of the South Creek catchment developed for the 1990 Flood Study has been updated from the 1991 version of the software (*Version 2.56*) to the latest version of XP-RAFTS (*Version 6.52*).

As part of the current study, the sub-catchment delineation and break-up was compared against the latest topographic data available for the study area to determine whether the sub-catchment boundaries required adjustments. Some further refinement of sub-catchments was undertaken in order to improve the inter-relationship between the XP-RAFTS model and the RMA-2 hydraulic flood model. This improved the interconnectivity between the hydrologic and hydraulic models and made possible the creation of additional localised inflows within the RMA-2 model.

The XP-RAFTS model sub-catchment delineation is shown in **Figure 4.1**. Sub-catchments refined as part of this study (*i.e., post the 1990 Flood Study*) included sub-catchments along Thompson, Cosgroves, Blaxland, Claremont, Werrington and Ropes Creek (*refer green shaded catchments on* **Figure 4.1**).

The adopted roughness parameters for each sub-catchment were also reviewed against aerial photography in order to determine any changes in vegetation and/or floodplain development that may have occurred since 1990. This process was undertaken to ensure the model was updated to reliably reflect the changes in land use and any developments that may have occurred since 1990. The XP-RAFTS model is therefore considered to reflect catchment conditions up to the year 2007, which reflects the year of the aerial photography that had been adopted as a guide to the model updates.

A summary of the adopted sub catchment parameters is provided in **Appendix A**.

4.1.3 Adopted RAFTS Model Structure & Parameters

The RAFTS model was developed based on the sub catchment break-up shown in **Figure 4.1**. The node and link arrangement shown in **Figure 4.1** were created to provide the pathways for rainfall excess to be “routed” through each of the tributary sub catchments. The amount of rainfall excess and “routing” relationships between catchments were governed largely by the adopted loss parameters and lag times, respectively.

The adopted Intensity-Frequency-Duration (*IFD*) data, loss parameters and lag times for floodwater distribution between nodes is discussed in the following.

IFD Parameters

Intensity-Frequency-Duration (*IFD*) data was developed for the study catchment according to the standard procedures outlined in Chapter 2 of '*Australian Rainfall & Runoff – A Guide to Flood Estimation*' (*1987*). Due to the significant spatial extent of the study area, across which numerous local catchments and tributaries apply, a total of nine (*9*) different IFDs were adopted. Each IFD reflected a specific location within the study area and was applied to those catchments located nearest to it.

The design IFD data for the study area is summarised in **Table 12** below.

Table 12 ADOPTED DESIGN INTENSITY-FREQUENCY-DURATION (*IFD*) DATA

LOCATION	GEOGRAPHICAL FACTORS		IFD COEFFICIENTS (*mm/hr*)					
	F_2	F_{50}	${}^{2}I_{1}$	${}^{2}I_{12}$	${}^{2}I_{72}$	${}^{50}I_{1}$	${}^{50}I_{12}$	${}^{50}I_{72}$
Narellan	4.29	15.8	31.6	6.0	1.80	60.9	12.0	4.0
Bringelly	4.29	15.8	30.0	6.1	1.88	59.3	12.3	4.0
Elizabeth Drive	4.29	15.8	30.0	6.15	1.90	59.3	12.3	4.1
Badgerys Creek	4.29	15.8	30.0	6.46	1.93	59.1	12.6	4.2
Glenfield	4.29	15.8	35.0	7.0	2.25	65.0	15.0	4.7
Mt Vernon	4.29	15.8	31.3	6.2	1.9	59.4	12.6	4.15
Penrith	4.29	15.8	30.0	6.8	1.97	59.7	12.9	4.7
St Marys	4.29	15.8	30.0	6.42	1.86	59.1	12.8	4.4
Riverstone	4.29	15.8	30.0	6.5	1.92	59.2	13.0	4.5

Rainfall Loss Model

In a typical rainfall event, not all of the rainfall that falls onto the catchment is converted to runoff. Depending on the prevailing 'wetness conditions' of the catchment at the commencement of the storm (*i.e., the antecedent wetness conditions*), some of the rainfall may be lost to the groundwater system through infiltration into the soil, or may be intercepted by vegetation and stored. This component of the overall rainfall is considered to be 'lost' from the system and does not contribute to the catchment runoff.

To account for rainfall losses of this nature, a rainfall loss model can be incorporated within the RAFTS hydrologic model. For this study, the ***Initial-Continuing Loss Model*** was used to simulate rainfall losses across the catchment.

This model assumes that a specified amount of rainfall (*e.g., 10 mm*) is lost from the system to simulate initial catchment wetting when no runoff is produced, and that further losses occur at a specified rate per hour (*e.g., 1.0 mm/hr*). These further losses are referred to as continuing losses which aim to account for infiltration once the catchment is saturated.

Both the initial and continuing losses are effectively deducted from the total rainfall over the catchment, thereby leaving the remaining rainfall to be distributed through the watershed as runoff.

As no definitive loss rate data is available for the catchment of South Creek and it's tributaries, the adopted rainfall loss rates were based on data contained in the 1990 Flood Study. As the loss rates had been determined following calibration to the 1986 and 1988 floods, and no further significant floods have occurred since, it is considered appropriate to adopt the loss rates for this study.

The adopted loss rates are listed in **Appendix A** as **Table A1**.

Lag Parameters

XP-RAFTS allows the lag between sub-catchments to be determined through the use of either a '*lagging link*' or a '*routing link*'. The lagging link requires users to input the travel time (*in minutes*) for the peak flow to travel the length of the reach; i.e., from one sub-catchment to another. The lag is determined outside of the RAFTS model, typically through the application of standard methods such as the Rational Method or Bransby Williams methods.

A routing link requires input of typical channel cross-section details such as the reach length, manning's n values, slope and channel dimensions. This input information is used by RAFTS to estimate the average velocity along the channel and the resulting travel time or lag. The 1990 Flood Study model adopted the routing link option.

A summary of the adopted lag parameters and resulting average velocities and lag times are listed in **Appendix A** as **Table A2** for each link in the updated hydrologic model.

4.2 HYDROLOGIC MODEL VALIDATION

The validation of the updated XP-RAFTS model was based on a comparison between the peak discharge and hydrograph shape produced by the RAFTS model developed for the 1990 Flood Study and the results of the latest XP-RAFTS model.

In order to undertake validation of the model, the updated XP-RAFTS model was used to simulate the 100 year ARI storm with a critical storm duration of 36 hours. It was considered appropriate to undertake the validation based on the 36 hour duration alone given it was the critical storm duration for South Creek and the majority of it's tributaries; i.e., at the downstream model extent (*Richmond Road*).

Results were extracted from this simulation in the form of peak flow rates and flow hydrographs at key locations throughout the study area and locations corresponding to inflows for the 1990 MIKE-11 hydraulic model. A comparison of the peak flows predicted by the updated XP-RAFTS model and the 1990 Flood Study model are shown in **Table 13** for key locations along South Creek.

Table 13 COMPARISON OF COMPUTED PEAK DISCHARGES ALONG SOUTH CREEK

LOCATION	UPDATED RAFTS NODE (*refer **Figure 4.1***)	100 YEAR ARI PEAK DISCHARGE (*m^3/s*)		DIFFERENCE
		Updated RAFTS Model (*This Study*)	1990 Flood Study RAFTS Model	
Upstream of Bringelly Road	1.08	312	299	+ 4.3%
U/S of Elizabeth Drive	1.13	479	434	+ 10.4%
Upstream of Western Motorway (*M4*)	1.23	1,164	1,119	+ 4.0%
Upstream of Great Western Highway	1.25D	1,175	1,122	+ 4.7%
Upstream of Railway Line	1.27D	1,193	1,139	+ 4.7%
Ropes Creek Confluence	1.34D	1,370	1,287	+ 6.4%
Upstream of Stony Creek Road	1.37	1,387	1,317	+ 5.3%
Upstream of Richmond Road	1.39D	1,433	1,365	+ 5.0%
			AVERAGE DIFFERENCE	**+ 5.6%**

As shown in **Table 13**, the average difference in peak flows along South Creek is 5.6%, with a maximum difference of 10.4% predicted to occur upstream of Elizabeth Drive. Differences of this magnitude are expected provided sub-catchment delineations and impervious percentages were reviewed as part of this study.

A complete comparison of peak flow discharges along South Creek and its Tributaries is included in **Appendix B** as **Table B1**. The complete comparison has been expanded to include the 2003 and 2004 Floodplain Risk Management Studies prepared for Liverpool City Council covering Kemps Creek, and South and Thompsons Creeks, respectively (*refer* **Section 3.2**).

Hydrographs exported from the updated XP-RAFTS model were also found to match closely the MIKE-11 input hydrographs, in terms of both peak flow and hydrograph shape. Although some differences are evident, these were minimal and expected given the model updates undertaken as part of this study. Examples of the hydrograph comparisons are provided in **Appendix B** for South, Ropes, Badgerys, Blaxland and Kemps Creeks as **Figures B1** to **B5**.

Therefore, the analysis confirmed that the updated XP-RAFTS model is producing similar results to the original RAFTS model used in the 1990 Flood Study and in subsequent studies.

4.3 HYDROLOGIC MODEL SENSITIVITY ANALYSIS

A sensitivity analysis was undertaken to assess the sensitivity of the RAFTS hydrologic model to variations in key parameters including adopted loss rates. The sensitivity analysis was based on consideration of the design 100 year recurrence storm for the full range of critical durations; i.e., 2, 9 and 36 hours.

The sensitivity analysis was completed by reducing the adopted initial and continuing loss rates and assessing the impact that these modifications had on peak flows at key locations throughout the study area. This was undertaken for three scenarios designed to test the impacts of a significant reduction in the continuing loss rate independently, initial losses independently and a combined scenario testing reduced initial and continuing losses combined. The three adopted scenarios are summarised as:

- Scenario 1 – All initial losses for all catchments reduced to zero;
- Scenario 2 – All continuing losses for all catchments reduced to zero; and,
- Scenario 3 – All initial and continuing losses reduced to zero for all catchments; i.e., Scenario 1 and Scenario 2 combined.

The results for the sensitivity analysis for each scenario is summarised in **Table 14** for key locations within the study area. The complete results of the sensitivity analysis are included as **Tables C1** to **C3** of **Appendix C**.

Table 14 SUMMARY OF XP-RAFTS SENSITIVITY ANALYSIS AT KEY LOCATIONS ALONG SOUTH CREEK (36hr STORM DURATION)

LOCATION	UPDATED RAFTS NODE (*refer* **Figure 4.1**)	100 YEAR ARI PEAK DISCHARGE (*m³/s*)			
		BASE CASE	SENSITIVITY SCENARIO		
			1	2	3
Upstream of Bringelly Road	1.08	312	312	328	328
U/S of Elizabeth Drive	1.13	479	480	505	506
Upstream of Western Motorway (*M4*)	1.23	1,164	1,174	1,243	1,252
Upstream of Great Western Highway	1.25D	1,175	1,186	1,255	1,265
Upstream of Railway Line	1.27D	1,193	1,204	1,275	1,285
Ropes Creek Confluence	1.34D	1,370	1,389	1,472	1,489
Upstream of Stony Creek Road	1.37	1,387	1,411	1,494	1,516
Upstream of Richmond Road	1.39D	1,433	1,464	1,547	1,577

The results presented in **Table 14** indicate that the RAFTS model is less sensitive to reductions in initial losses compared to reduced continuing losses. Scenario 1 results in a maximum increase in peak flow of 31 m^3/s which occurs at the downstream limits of the model at Richmond Road, node 1.39D. This represents an increase of no more than 2.2%.

Reductions in the continuing loss rate, Scenario 2, results in a maximum increase in peak flow of 114 m^3/s. Similarly with Scenario 1, this maximum occurs at the downstream limit of the hydrologic model (*refer* **Table 14**) and is representative of an increase of up to 8%.

The combined scenario, Scenario 3, results in a maximum peak flow increase of 144 m^3/s which is approximately 10% greater than the base case scenario. The increase is not considered to be excessive given the '*severe*' nature of the scenario; i.e., whereby initial losses are reduced by up to 32.5 mm and continuing losses reduced to zero. This is representative of a 'worst-case' scenario where the entire catchment is made impervious.

Acknowledging that the sensitivity analysis is testing a '*worst case*' scenario, the results presented in this analysis show that the RAFTS hydrologic model is not overly sensitive to variations in the adopted loss rates. This suggests that the catchment hydrology will not be expected to change substantially as further development of the catchment and floodplain intensifies.

5. HYDRODYNAMIC MODEL DEVELOPMENT

The RMA-2 software was employed to develop a two-dimensional hydrodynamic model of the floodplains of South Creek and its tributaries.

A two-dimensional model is required to update the flood modelling tools that are currently available for the South Creek system. These existing tools comprise a MIKE-11, one-dimensional model of South Creek and its primary tributaries, and HEC-2 models of the secondary tributaries. These tools have become superseded by two-dimensional modelling software which can provide more reliable modelling results when combined with suitable topographic data.

The two-dimensional modelling software also provides greater flexibility in the assessment of potential development proposals and/or potential flood damage reduction measures.

RMA-2 is a fully two dimensional finite element model developed by Resource Management Associates and Prof. Ian King from the University of New South Wales. RMA-2 was chosen for this investigation over other hydrodynamic modelling software because it has the following attributes:

(i) RMA-2 is a fully two dimensional, dynamic, finite element model. Hence, it allows for overland flow and storage to be modelled within the floodplain and ensures that the interaction between mainstream and overbank flows is reliably simulated.

(ii) RMA-2 uses finite element methods to solve 2D depth averaged equations for turbulent energy losses, friction losses and horizontal momentum transfer. Therefore, it offers significant benefits over the more traditional finite difference techniques.

(iii) RMA-2 uses a variable grid geometry employing elements with irregular and curved boundaries which can be modified as required without the need for regeneration of the entire grid. This enables topographic features or hydraulic controls of any shape to be reliably represented within the model.

(iv) RMA-2 permits the simulation of floodplain elements that wet and dry during the analysis period.

A major advantage of using RMA-2 over traditional finite difference models is that the model resolution can be varied to cover regions of particular interest, or regions particularly affecting flood behaviour; *e.g., around urban areas*. It is also relatively simple to adjust the model network to incorporate structural flood mitigation works, such as channel modifications or levees, as may be required for the future Floodplain Risk Management Study that is to be prepared for South Creek and its tributaries in the future.

RMA-2 also provides the flexibility to allow Council to investigate options that could be implemented to reduce flood damages and to assess future development scenarios. Hence, it is appropriately suited to being adapted to support any revisiting of the Floodplain Risk Management Study in accordance with the process outlined in **Section 2**.

Development of the computer flood model was carried out over several stages that addressed the different processes of flood hydrology (*conversion of rainfall to runoff*) and flood hydraulics (*the routing of runoff*). The methodology that was employed to develop the flood model involved the following:

- Preparation of the Digital Elevation Model (DEM) using the ALS data provided by each Council as well as site specific survey data.
- Network mesh development by picking up the definition of South Creek and its tributaries followed by the addition of floodplains, major roadways and levees.
- Validation of the flood model to historic floods and the 1990 Flood Study.

5.1 PREPARATION OF THE DIGITAL ELEVATION MODEL (DEM)

Airborne Laser Scanning (*ALS*) data is available for the entire study area. This ALS data comprises very large data sets that contain thousands of points defining the existing ground surface elevations within the study area. The latest available data includes:

- ALS data collected within the Penrith LGA in 2002;
- ALS data collected within the Blacktown LGA in May 2006;
- ALS data collected within the Fairfield LGA in 2005; and,
- ALS data collected within the Liverpool LGA in 2005.

The extent of the available ALS data sets are shown in **Figure 3.1**.

These ALS data-sets were combined to form a digital elevation model (*DEM*) of the entire South Creek floodplain within the study area. The DEM is required as a base for development of the two-dimensional hydrodynamic model.

As the ALS data for each LGA within the study area was provided in “raw” data format, it was necessary to process the data to make it suitable for use in the development of the RMA-2 hydrodynamic model and for flood extent mapping in the later stages of the project.

The ALS data comprised very large data sets. Accordingly, it has been “clipped” and “thinned” to make it more manageable. The ALS data from outside the extents of the study area has been clipped and the data thinned to remove survey data points where there is little variation in topography. This created a “processed ALS data set” from which a triangular irregular network (*TIN*) of the study area was developed. This TIN forms the Digital Elevation Model (*DEM*) for the study area.

The resulting DEM covers the floodplain within the study area and essentially forms a complete 3D representation of the terrain of the entire river channel and floodplain of South Creek and its tributaries.

ALS procedures are unable to penetrate through water, and do not typically include hydrographic features important for flood modelling, such as the bathymetry of streams that carry water under normal flow conditions. However, South Creek and its tributaries did not carry significant flow during the periods when the ALS data was collected. In that regard, the data is considered more than adequate for the purposes of the study.

Moreover, the definition of the creek beds and banks was compared to the surveyed cross-sections collected for the 1990 Flood Study and it was determined that the ALS data adequately defines the creek bed and banks within the study area. Accordingly, the ALS data has been used to define the channel and floodplain for the South Creek system within the study area.

The DEM was also updated to include Work-As-Executed survey that had been gathered following completion of the bulk earthworks for the Twin Creeks development along Cosgroves Creek. This 'site specific' DEM was overlayed against the ALS DEM to overwrite the now out-dated topographic elevations.

5.2 NETWORK MESH DEVELOPMENT

RMA-2 is a finite element model that represents topographic features via a network or geometric shapes (*i.e., triangles, squares and rectangles*). The geometric shapes are joined together to form a finite element mesh that covers the entire study area.

The RMA-2 model mesh was developed to extend over the entire creek and floodplain of South Creek and its tributaries within the study area. The layout of the RMA-2 hydraulic model that was developed for this study is shown in **Figure 5.1**. The upstream extents of the model was defined by:

- downstream limit – 200 metres downstream of the Richmond Road bridge crossing of South Creek;
- South Creek – Bringelly Road;
- Ropes Creek – Capital Hill Drive;
- Kemps Creek – Bringelly Road;
- Werrington Creek – downstream of William Street Footbridge;
- Cosgroves Creek – Approximately 5.8 km upstream of the South Creek confluence;
- Claremont Creek – Approximately 1.3 km upstream of the Caddens Road;
- Blaxland Creek – Approximately 3.2 km upstream of the South Creek confluence;
- Badgerys Creek – Badgerys Creek Road; and,
- Thompsons Creek – downstream of the Northern Road.

As shown in **Figure 5.1**, the downstream limit of the model is set at approximately 200 metres downstream of the Richmond Road.

Main channel and overbank roughness' were estimated for the study area from aerial photograph analysis and field observations of channel and floodplain vegetation density. The adopted roughness values were determined by comparing vegetation density and soil types observed in the field, with standard photographic records of stream and floodplain conditions for which roughness values are documented. This approach in combination with the fine network mesh of the hydraulic model allows for a high degree of discretisation of roughnesses across channels and floodplain areas.

The geometry of bridge crossings and major culverts along South Creek and its tributaries were defined in the model geometry by '*picking-up*' in detail the extents and elevations of key features such as embankments and approach and wingwall abutments. These bridge features were defined were available on detailed design drawings and/or survey that had been made available at the study commencement. Where detailed information was not available bridge waterway openings were defined based on a combined analysis of the ALS data and available aerial photography.

Roughness parameters in the vicinity of the bridge under croft and along culverts were set to represent the energy and friction losses that would have been caused by the presence of bridge piers and the bridge deck (*for those cases where the bridge capacity was exceeded and the deck became submerged*).

The levees within the study area, the Werrington Road levee and St Marys Earthen and Concrete Levee, were modelled in RMA-2 as a '*levee structure*' with the crests of the levees assigned based on the available ALS data. This approach is traditionally preferred for locations where sub-surface flows are found to inundate '*low lying*' areas that have no physically connecting flow path due to its reliability in completely blocking the passage of any minor sub-surface flows.

Although this was found to be problematic originally and as such was incorporated, this approach is no longer considered to be an issue following recent advancements to the RMA-2 software and modelling approaches/parameters.

The elevations within the creek system and across the floodplain have been assigned based on the DEM developed for the study.

5.3 HYDRODYNAMIC MODEL SET-UP

As discussed, initial estimates of floodplain and river channel roughness parameters were based on aerial photograph analysis and field inspections. In order to validate the roughness parameters, it is necessary to calibrate the hydraulic model to replicate historic flood events. Calibration involves the adjustment of parameters (*typically roughness coefficients*) until simulated flood levels "agree" with known historic flood levels.

The RMA-2 flood model that has been developed for this study has not been calibrated against historic floods. The Project Brief specified that the model only needed to be validated against predicted peak flood levels generated for the 100 year ARI flood using the MIKE-11 and HEC-2 modelling that was developed for the 1990 Flood Study.

The results of more recent studies such as the South Creek Floodplain Risk Management Study (*2004*) and Austral Floodplain Risk Management Study (*2005*) have also been taken into consideration as part of the validation process.

The MIKE-11 and HEC-2 models used for each of the studies were calibrated to available recorded flood levels for the 1986 and 1988 events, which are the largest events to have occurred in the catchment over the last 60 years. The calibration was undertaken by varying the Manning's "n" values used for the modelling within reasonable bounds.

5.3.1 Model Boundary Conditions

Upstream Boundary Conditions

The upstream boundary conditions for the hydraulic model are provided by the discharge hydrographs generated from the XP-RAFTS hydrologic modelling that has been updated for the study.

The upstream boundary conditions correspond to the location of inflows into the creek system (*i.e., flows into South, Ropes, Kemps, Werrington, Claremont, Blaxland, Cosgroves, Badgerys and Thompsons Creeks*). The XP-RAFTS model nodes corresponding to these inflows are listed in **Table 15**. The locations of each of the XP-RAFTS model sub-catchments are shown in **Figure 4.1**.

Table 15 UPSTREAM BOUNDARY CONDITIONS FOR THE RMA-2 MODEL

TRIBUTARY	LOCATION	RAFTS MODEL NODE (*refer* **Figure 4.1**)	100 YEAR ARI PEAK INFLOWS (m^3/s)	CRITICAL DURATION
South Creek	Bringelly Road	1.08	312	36 hours
Ropes Creek	Capitol Hill Drive	20.00	53	36 hours
Kemps Creek	Bringelly Road	9.00	33	36 hours
Werrington Creek	William St Footbridge	18.00	141	2 hours
Claremont Creek	1.3km U/S Caddens St	16.00	33	9 hours
Blaxland Creek	-	14.01	102	36 hours
Cosgroves Creek	-	12.02	93	36 hours
Badgerys Creek	Badgerys Creek Rd	5.00	53	36 hours
Thompsons Creek	D/S of the Northern Road	4.00	38	9 hours

Local inflows were also incorporated within the RMA-2 model to incorporate runoff generated by rainfall on sub-catchments located within the extents of the model. In total 53 local catchment inflows were used for each design simulation.

The locations of all upstream and local catchment inflows into the RMA-2 model are shown on **Figure 5.2**. The RMA-2 network mesh and RAFTS sub-catchment is overlayed for reference.

Downstream Boundary Conditions

In addition to upstream boundary conditions, downstream boundary conditions must also be specified. The downstream boundary conditions are typically specified by a known time-varying water surface elevation.

The downstream boundary condition for this study assumes the concurrence of flooding along the Hawkesbury-Nepean River and South Creek. Therefore, levels in the lower reaches of the study area, in the vicinity of Richmond Road, are dominated under this scenario by backwater flooding from the Hawkesbury-Nepean River.

In that regard, the design simulations adopted a downstream boundary condition reflective of a similar design ARI Hawkesbury-Nepean River flood level. Notwithstanding, each design scenario was also run with lower tailwater scenarios. This was required in order to ensure the full range of modelling results were simulated with and without downstream constraints.

The downstream boundary conditions adopted for this study are outlined in **Table 16**.

Table 16 ADOPTED DOWNSTREAM BOUNDARY CONDITIONS / HAWKESBURY RIVER DESIGN LEVELS

AVERAGE RECURRENCE INTERVAL (*YEARS*)	HAWKESBURY-NEPEAN FLOOD LEVEL AT RICHMOND ROAD (*mAHD*)
20	13.7
50	15.7
100	17.3
200	18.7
500	20.2
Probable Maximum Flood	26.4

The peak flood levels documented in **Table 16** were extracted from flood modelling results using the Rubicon flood model of the Hawkesbury-Nepean system. This modelling was undertaken for the Public Works Department in 1999 as part of the *'Warragamba Dam Auxiliary Spillway EIS Flood* Study', which was prepared by Webb McKeown & Associates (*now WMA Water*).

5.3.2 Channel and Floodplain Roughness

Calibration and verification of the hydrodynamic model was undertaken by adjusting the roughness parameter values assigned to each RMA-2 *element type* until a good correlation was achieved with simulated flood levels determined from the MIKE-11 and HEC-RAS modelling. Element types were delineated to 'pick up' distinct variations in hydraulic roughness across the river and floodplain.

The adopted hydrodynamic model roughness values are listed in **Table 17** for each element type. These adopted roughness values are all within acceptable ranges for the density and type of vegetation encountered within the South Creek system.

Table 17 ADOPTED RMA-2 ELEMENT ROUGHNESS VALUES

RMA-2 MODEL ELEMENT TYPE	DESCRIPTION	ROUGHNESS PARAMETER VALUE
1	Moderately vegetated creek channel	0.10
2	Heavily vegetated creek channel	0.12
3	Grassed floodplain and sparse trees	0.05
4	Floodplain with moderate coverage of trees	0.08
5	Floodplain with dense trees	0.12
6	Urban Floodplain	0.04
7	Industrial Development	0.09
8	Roadways	0.015

5.4 HYDRODYNAMIC MODEL VALIDATION

The RMA-2 model was used to simulate the 2, 9 and 36 hour duration, 100 year ARI floods. The results from these simulations were used to prepare design 100 year ARI flood water surface profiles for South Creek and its tributaries. The design 100 year ARI water surface profiles for the validation simulations were based on the design envelope of the following simulations:

- 36hr critical duration 100 year ARI flood for the entire study area; and
- 100 year ARI flood with critical durations specific to tributaries; i.e., Werrington (*2 hr*), Thompsons (9 *hr*) and Claremont Creeks (*9 hr*).

Simulation of the tributary based and 36 hour 100 year scenarios separately was necessary in order to ensure the timing differences between the 2 and 9 hour hydrograph inflows would not reduce the peak flow along South Creek (*where the 36 hour duration flood applied*). Therefore, two simulations were run for the 100 year recurrence flood adopting the peak inflows / upstream boundary conditions shown in **Table 15**.

The results from the validation simulations were extracted and compared against the peak 100 year ARI flood levels documented as part of the 1990 Flood Study Report, 2003 Austral Floodplain Risk Management Study and the 2004 South Creek Floodplain Risk Management Study, where applicable. The comparison was undertaken as part of the process for “validating” the RMA-2 model.

The extent and location of the MIKE-11 and HEC-2 cross-sections were digitised from the plans developed for the 1990 and 2004 studies. The digitised cross-sections were superimposed over the RMA-2 network to determine the position of each cross-section relative to the RMA-2 network and the chainage along the centreline of each creek.

The design 100 year ARI flood profiles for the validation scenario are presented in **Figures 5.3** to **5.9**. Figures **5.3** to **5.6** show a comparison between the results from the MIKE-11 and the RMA-2 modelling along South Creek. **Figures 5.7** to **5.9** show comparisons between the RMA-2 and MIKE-11 or HEC-2 results along Ropes Creek. Key locations along South and Ropes Creek are marked on each of the WSP plots.

A comparison to the recorded 1986 and 1988 flood levels with the 100 year ARI flood levels generated using the RMA-2 and MIKE-11 models for South and Ropes Creek is also presented on the water surface profiles provided in **Figures 5.3** to **5.6** for South Creek, and **Figure 5.7** to **5.9** for Ropes Creek.

Tables D1 to **D10** in **Appendix D** also list peak flood levels generated by each of the MIKE-11, HEC-2 and RMA-2 models, as well as the difference between these levels, at key locations throughout the study area. The tables are provided a comparison of peak 100 year recurrence flood levels along South, Werrington, Claremont, Blaxland, Cosgroves, Badgerys, Kemps and Thompsons Creeks.

5.5 DISCUSSION OF VALIDATION RESULTS

5.5.1 Comparison of Peak 100 year ARI Flood Levels

The results for South Creek show a reasonably good match between the water surface profiles generated by the MIKE-11 and RMA-2 models.

The comparison shows that the RMA-2 modelling results are on average higher than those predicted during previous studies. As shown in **Figures 5.4** to **5.6**, the RMA-2 modelling results appear to follow quite closely the gradient of the MIKE-11 profile. Where differences occur these are typically within 0.2 to 0.3 metres. Although there are locations where RMA-2 predicts levels that are over 0.3 metres higher, these locations are localised and can be explained by differences in modelling approach and topographic data (*refer* **Figure 5.4** *to* **5.6**).

Table D1 of **Appendix D** shows that the average difference between the RMA-2 and MIKE-11 modelling results is 0.30 metres. This is based on the comparison of flood levels at thirty nine key locations throughout the study area.

Table D1 also compares the RMA-2 results to updated MIKE-11 modelling that was undertaken for the 2004 South Creek Floodplain Risk Management Study. The comparison to this more recent study incorporating more recent topographic data shows that the average difference is reduced to 0.27 metres.

Flood levels predicted by the RMA-2 model are similarly higher along Ropes Creek with differences typically ranging between 0.2 to 0.3 metres. As shown in **Figure 5.8** and **Figure 5.9**, the RMA-2 and MIKE-11 / HEC-2 water surface profiles are generally in agreement. **Table D8** of **Appendix D** indicates an average difference of 0.23 metres based on flood level comparisons at twenty one key locations.

Table 18 provides a summary of the average flood level differences documented in **Table D1** to **D8** for South Creek and its tributaries.

Overall, there is good correlation between the peak 100 year ARI flood levels produced by the MIKE-11 and HEC-2 models for the 1990 Flood Study and those predicted by the RMA-2 model for the tributaries of South Creek. Major differences can be accounted for by the more accurate definition of the channels and floodplain topography made possible by the previously unavailable ALS data.

Table 18 SUMMARY OF RMA-2 LEVEL DIFFERENCES

TRIBUTARY	AVERAGE 100 YEAR ARI LEVEL DIFFERENCE (*m*)		
	South Creek Flood Study (1990)	Austral FPRMS (2004)	South Creek FPRMS (2004)
South Creek	0.30	/	0.27
Thompsons Creek	0.38	/	0.27
Kemps Creek	0.25	0.21	/
Ropes Creek	0.25	/	/
Badgerys Creek	0.32	/	/
Cosgroves Creek	0.10	/	/
Claremont Creek	0.34	/	/
Werrington Creek	0.10	/	/

5.5.2 Peak Flow Comparison

A comparison between the peak 100 year ARI flows in the RMA-2 model and corresponding peak flows generated by the MIKE-11 model (*as documented in Appendix 1 of the 'South Creek Flood Study' (1990)* has also been undertaken. These comparisons have been made at strategic locations along the length of South Creek.

Detailed comparisons of flow hydrographs generated by the MIKE-11 and RMA-2 models have been undertaken as part of the hydrodynamic model validation process. The comparisons have been based on hydrographs generated at points along South Creek during the design 100 year ARI flood.

Plots showing these comparisons are contained within **Appendix E**. The peak flows routed through each model to the Richmond Road crossing shown in **Table 19**.

Table 19 PEAK 100 YEAR ARI FLOWS FROM THE MIKE-11 AND RMA-2 MODELS AT RICHMOND ROAD

MODEL	PEAK FLOWS ($m^{3/s}$)
MIKE-11	1,365
RMA-2	1,370

The close correlation between peak flows generated at the downstream end of both models serves to provide further evidence of the effective validation of the RMA-2 model. Based on the assumption that the MIKE 11 model has been suitably calibrated, this correlation indicates that continuity of flow is being maintained within the RMA-2 model and that the peak flows throughout the model are similar to those generated by the MIKE-11 model.

However, based on an analysis of the hydrograph shape throughout the system (*refer* **Appendix E**), it can be concluded that the RMA-2 model is routing the flow through the system slightly more efficiently than the MIKE-11 model.

5.5.3 Check of Continuity of Flow

The volume of floodwater in the XP-RAFTS, MIKE-11 and RMA-2 models has been established. For the XP-RAFTS model, the flow volume in the model was determined by calculating the area under the discharge hydrographs at the outlet of the model.

Similarly, we extracted the discharge hydrograph at the downstream boundary of the MIKE-11 model of South Creek developed for the 1990 flood study and calculated the area under the hydrograph to determine the volume of floodwater within the model.

The volume within the RMA-2 model was determined using the *waterRIDE FLOOD MANAGER*^{TM} software.

The calculated floodwater volumes within the models are listed in **Table 20**.

Table 20 FLOODWATER VOLUMES FROM THE RAFTS, MIKE-11 AND RMA-2 MODELS

MODEL	FLOODWATER VOLUME FOR THE 100 year ARI flood (m^3)
XP-RAFTS	8.7×10^7
MIKE-11	7.4×10^7
RMA-2	8.3×10^7

This comparison demonstrates that mass is being conserved in the RMA-2 model. Furthermore, the comparison confirms that there is no loss of flow from the model and indicates that the RMA-2 model can reliably be used to simulate flood processes in the South Creek valley.

5.5.4 Review of Predicted Affluxes at Major Crossings

Affluxes at major bridge crossings throughout the study area were calculated by applying Bradley's Method (*1978*). This allowed those affluxes predicted by the RMA-2 model to be validated to ensure the hydraulics at major bridge crossings were reliably reflected in the model results.

The Bradley's Method calculations for six (*6*) major bridge crossings along both South Creek and Ropes Creek are included as **Appendix L**. The results indicate that the RMA-2 model predicts affluxes that are within 100 mm to 200 mm for all six (*6*) bridge crossings. This suggests that the affluxes predicted by the RMA-2 model are reliable.

5.6 SENSITIVITY ANALYSES

Sensitivity testing was undertaken for the RMA-2 flood model to establish the potential for changes in flood level predictions to occur due to changes to a range of model parameters and inputs. The following three sensitivity tests were adopted:

- Roughness Parameters (*+/- 20%)*
- Inflow Boundary Conditions; and
- Potential Bridge Blockage Scenarios

The impact of climate change was not considered as part of the flood study investigations, however it is understood that it will be investigated as part of any subsequent floodplain risk management studies.

The results of the sensitivity analysis of the RMA-2 flood model is discussed in the following.

5.6.1 Roughness Parameters

Sensitivity testing was undertaken for the RMA-2 flood model in order to establish the sensitivity of peak flood level predictions to the adopted roughness parameters. The sensitivity analysis was based on increasing and decreasing model roughness coefficients by 20% and assessing the impact that these alterations had on peak flood level estimates across the study area.

The results of the roughness testing are summarised in **Tables F1** to **F8** of **Appendix F**.

The results indicate that flood level predictions are most sensitive to the decrease in roughness parameters with peak flood level predictions consistently changing by a greater magnitude than for the increased roughness scenario. This was found to be the case for South Creek and each of the tributaries.

Table 21 shows the average difference in flood levels that resulted from the +/- 20% roughness scenarios.

Table 21 AVERAGE 100 YEAR ARI FLOOD LEVEL DIFFERENCE DUE TO +/- 20% ROUGHNESS SCENARIOS

TRIBUTARY	AVERAGE 100 YEAR ARI LEVEL DIFFERENCE (*m*)	
	- 20% ROUGHNESS	+ 20% ROUGHNESS
South Creek	- 0.16	0.14
Thompsons Creek	- 0.11	0.10
Kemps Creek	- 0.14	0.10
Ropes Creek	- 0.15	0.12
Badgerys Creek	- 0.11	0.09
Cosgroves Creek	- 0.11	0.10
Claremont Creek	- 0.16	0.13
Werrington Creek	- 0.17	0.14

5.6.2 Inflow Boundary Conditions

The sensitivity analysis undertaken for the XP-RAFTS model established that reductions to the adopted initial and continuing loss rates (*to zero*) would only have the potential to increase peak flows by up to 10.3% at Richmond Road. The magnitude of this increase was reduced for locations further upstream with increases of only 4.9% predicted at Bringelly Road (*refer* **Appendix C** *and* **Section 4.3**).

Taking the XP-RAFTS sensitivity results into consideration it was considered appropriate to compare the 100 year and 200 year recurrence floods as a sensitivity scenario. Peak flows for the 200 year recurrence flood are approximately 15% higher at Richmond Road and up to 9% higher at the Bringelly Road crossing of South Creek. Accordingly, the 200 year recurrence flood would provide a conservative sensitivity scenario.

A comparison of 100 year and 200 year recurrence flood levels along South Creek at key locations is included in **Table 22**.

Table 22 indicates that a 9% to 15% (*at the upstream and downstream limits of the RMA-2 model, respectively*) increase in the adopted 100 year recurrence inflows could have the potential to result in increased flood levels of up to 0.5 metres. On average however increases would be much lower typically between 0.1 to 0.2 metres throughout the study area.

Table 22 COMPARISON OF 100 AND 200 YEAR FLOOD LEVELS FOR KEY LOCATIONS ALONG SOUTH CREEK

LOCATIONS ALONG SOUTH CREEK	FLOOD LEVEL (*mAHD*)		
	100 YEAR ARI FLOOD	200 YEAR ARI FLOOD (+ *9 to 15% Flow*)	DIFF (m)
Bringelly Road	58.8	58.9	+ 0.1
Confluence with Thompsons Creek	53.3	53.4	+ 0.1
Upstream Elizabeth Drive	42.9	43.0	+ 0.1
Upstream South Creek Dam	38.1	38.15	+ 0.05
Upstream Sydney Water Pipeline	33.8	33.9	+ 0.1
Upstream Western Motorway (*M4*)	28.5	28.7	+ 0.2
Upstream Great Western Highway	25.7	25.9	+ 0.2
Upstream Railway Line	23.9	24.1	+ 0.2
Upstream Dunheved Road	22.6	22.8	+ 0.2
Confluence with Ropes Creek	18.8	19.3	+ 0.5
Upstream Stony Creek Road	17.4	17.7	+ 0.3

5.6.3 Potential for Blockage of Bridges

During significant flooding scenarios there is the potential for the conveyance capacity of bridges and culverts to be reduced due to blockages caused by accumulated debris. In recognition of this, a sensitivity scenario was adopted which tested the impact of a 30% blockage scenario on a number of key bridges along South and Ropes Creek.

The following bridges were included as part of this sensitivity scenario.

- Elizabeth Drive main and relief floodway bridge crossings over South Creek
- Western Motorway (*M4*) bridge and culvert crossing over South Creek
- Great Western Highway bridge and culvert crossing over South Creek
- Western Motorway (*M4*) bridge crossing over Ropes Creek
- Great Western Highway bridge crossing over Ropes Creek
- Railway bridge crossing over Ropes Creek

The predicted impact of the bridge blockages on peak 100 year recurrence flood levels are shown **Figure 5.10** and **Figure 5.11**.

As shown in **Figure 5.10**, the 30% blockage of the main bridge crossing and the relief floodway bridge crossing along Elizabeth Drive would be predicted to cause a maximum flood level increase of 0.35 metres at the peak of the 100 year recurrence flood. This maximum increase occurs immediately upstream of the relief floodway bridge. Elsewhere, flood level increases are lower typically not exceeding 0.15 metres. The impact of the 30% bridge blockage is not predicted to extent more than 50 metres upstream of Overett Avenue.

Figure 5.11 shows the predicted impacts of the 30% blockages on the remaining bridges along South and Ropes Creeks. Along Ropes Creek, the largest flood level increase of 0.48 metres is predicted to occur upstream of the Western Motorway (*M4*) crossing. This increase is substantially larger than the 0.3 metre and 0.35 metre flood level increases that are predicted to occur upstream of the Great Western Highway and Railway Line crossings, respectively.

As shown in **Figure 5.11**, the 30% blockage of the Western Motorway (*M4*) bridge crossing over South Creek is predicted to cause a flood level increase of up to 0.55 metres. This maximum increase occurs immediately upstream of the bridge crossing. The blockage is predicted to cause flood level increases as far upstream as Luddenham Road; a distance of approximately 3.5 kilometres.

Figure 5.11 also shows substantial flood level increases upstream of the Great Western Highway bridge and culvert crossing. The increased flood levels of up to 0.38 metres would be predicted to extent as far upstream as the Western Motorway (*M4*).

It is noted that the above assessment represents only a preliminary blockage analysis for the study area. It may be appropriate to undertake a more detailed blockage analysis as part of the Floodplain Risk Management Study during which all bridges and culverts could be assessed, and for higher blockage factors such as 50%, as adopted by Liverpool City Council.

5.7 ESTIMATED RMA-2 MODEL ACCURACY

The perceived accuracy to which the RMA-2 model is able to predict flood levels is inferred based on the outcomes of the model calibration/verification, sensitivity analysis, the input data, and the convergence parameters adopted for each simulation. Consideration of each of these items is typically required to reliably assess the confidence level that could be assigned to the flood model predictions.

Although consideration of each of the above is ideal, it does tend to result in an overly complicated approach. Accordingly, it is suggested as an alternative approach that the model accuracy be defined based on the maximum range of flood level differences predicted through the sensitivity analysis. This is considered appropriate given the conservative approach adopted to assess the impacts of varying inflows and roughness parameters.

Based on this approach it is predicted that the South Creek RMA-2 flood model has a confidence level for peak flood level predictions of +/- 0.20 metres.

Although sensitivity analysis was also undertaken to assess the impacts on levels due to a 30% blockage at key bridge crossings, this sensitivity analysis is very much dependant on localised conditions and as such it is difficult to justify these results as a reflection of the overall model confidence limits. For this reason the sensitivity analysis of bridge blockage scenarios has been disregarded from the determination of the estimated model accuracy.

6. DESIGN FLOOD ESTIMATION

6.1 GENERAL

Design floods are hypothetical floods that are commonly used for planning and floodplain risk management investigations. Design floods are based on statistical analysis of rainfall and flood records and are defined by their probability of occurrence. For example, a 100 year recurrence flood is the best estimate of a flood that will likely occur on average, once in every one hundred years.

Design floods can also be expressed by their probability of occurring in a given year. For example the 100 year recurrence flood can also be expressed as the 1% Annual Exceedance Probability (*AEP*) flood. That is, there is a 1% chance of the 100 year recurrence flood occurring in any given year.

It should be noted that there is no guarantee that the design 100 year recurrence flood will occur just once in a one hundred year period. It may occur more than once, or at no time at all in the one hundred year period. This is because the design floods are based upon a statistical 'average'.

The computer models identified in **Sections 4** and **5** were used to derive design flood estimates for the 20, 50, 100, 200 and 500 year recurrence floods as well as an Extreme Flood. The procedures employed in deriving these design floods are outlined in the following sections.

6.2 HYDROLOGY

6.2.1 Design Flood Simulations

The RAFTS hydrologic model described in **Section 4** was used to simulate runoff from the catchment for design storm conditions. The design storm conditions were based on rainfall intensities and temporal patterns for the study area, which were derived using standard procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (*1987*) (*ARR 87*). The design storm rainfall data was generated by applying the principles of rainfall intensity estimation described in Chapter 2 of ARR 87.

Due to the large catchment area, spatially varying intensity-frequency-duration data were adopted across the catchment of South Creek and its tributaries. Design temporal patterns outlined in ARR 87 were also applied. These temporal patterns specify the variation in rainfall intensity over the duration of the design storms.

A range of storm durations were first considered to establish the critical storm duration for the catchment. The critical storm duration was assumed to correspond to the duration that generated the maximum peak discharge at the inflow locations to the hydraulic model and at the downstream limits of each tributary (*refer* **Figure 5.2**).

A critical storm duration of 36 hours was determined to be appropriate for South, Kemps, Ropes, Blaxland, Cosgroves and Badgerys Creeks. Critical storm durations of 9 hours were determined for Thompsons and Claremont Creek.

A 2 hour critical storm duration was found to apply to Werrington Creek. These critical storm durations were in accordance with the findings of the 1990 Flood Study.

Discharge hydrographs were generated for locations throughout the catchment for a range of flood frequencies using the appropriate critical durations and the appropriate rainfall intensities and design temporal patterns. The design flood frequencies considered for this study include the 20, 50, 100, 200 and 500 year recurrence events.

An estimate of the Probable Maximum Precipitation (*PMP*) for this study was adopted based on investigations undertaken for the 1991 South Creek Floodplain Management Study as required by the study brief. The 1991 Study derived a PMP estimate based on procedures outlined in '*The Estimation of Probable Maximum Precipitation in Australia for Short Durations and Small Areas – Bulletin 51*' (*Bureau of Meteorology, 1984*) and information contained in '*Interim Generalised PMP Estimates for the Catchment of Nepean Dam*' (*Hydrometeorological Advisory Service, 1988*).

In simulating the Probable Maximum Flood (*PMF*), the six hour PMP storm duration was found to be critical for the catchment as a whole. This is consistent with the findings of the 1991 Study.

6.2.2 Hydrologic Modelling Results

Design discharge hydrographs determined using the RAFTS hydrologic model were used to define inflows into the RMA-2 hydrodynamic model.

A summary of the peak discharges for each tributary inflow is provided in **Table 23**. The peak discharges are referenced to the RAFTS model node numbers which are shown in **Figure 4.1**. For example, the peak discharge along Ropes Creek at the upstream extent of the RMA-2 model corresponds to the listed discharges in **Table 23** for RAFTS model node number **20.00**.

A complete listing of results generated by the RAFTS hydrologic model for each of the design events is provided in **Appendix G**. Copies of the design discharge hydrographs derived at the upstream extent of each of the tributaries are included within **Appendix H**.

Review of the peak design inflows listed in **Table 23** shows an anomaly in the magnitudes of design inflows for Werrington Creek whereby the peak flow for the 500 year recurrence flood exceeds that for the Probable Maximum Flood. This occurs due to a single rainfall duration of 6 hours being adopted for the Probable Maximum Flood for the entire catchment (*which reflects the critical duration for the PMF*) and not a specific tributary based duration as had been adopted for simulation of the 500 year recurrence flood. This anomaly only occurs along Werrington Creek as it is the only tributary with a critical duration of less than 9 hours.

Table 23 PEAK DESIGN INFLOWS FOR THE SOUTH CREEK RMA-2 FLOOD MODEL

TRIBUTARY	RAFTS MODEL NODE NUMBER[1]	STORM DURATION (hours)	PEAK DISCHARGE[2] (m³/s)					
			PMP	500 Year ARI	200 Year ARI	100 Year ARI	50 Year ARI	20 Year ARI
South Creek	1.08	36		403	349	312	272	237
		6	1,135					
Ropes Creek	20.00	36		69	59	53	46	41
		6	188					
Kemps Creek	9.00	36		44	38	33	29	26
		6	125					
Werrington Creek	18.00	36		74	64	57	50	44
		6	176					
		2		181	158	141	125	111
Claremont Creek	16.00	36		40	34	30	26	23
		9		44	38	33	28	23
		6	100					
Blaxland Creek	14.01	36		133	115	102	89	77
		6	353					
Cosgroves Creek	12.02	36		120	104	93	82	71
		6	324					
Badgerys Creek	5.00	36		69	60	53	46	40
		6	192					
Thompsons Creek	4.00	36		40	34	30	27	24
		9		50	43	38	33	28
		6	113					

1. *For node and catchment locations refer to **Figure 4.1***
2. *Peak discharges listed do not necessarily occur simultaneously.*

6.2.3 Comparison of Design Flows with Previous Studies

As discussed in **Section 4.1.1**, flood modelling undertaken for the 1990 flood study was based on hydrology and peak flows predicted using a RAFTS-XP model developed specifically for that study.

Although the RAFTS model was coarser with fewer sub-catchments, it was calibrated and verified during the course of that study and would therefore, be expected to generate a reasonable estimate of design flood discharges.

A comparison of the peak discharges determined by the 1990 RAFTS-XP hydrologic model and the revised RAFTS-XP hydrologic model is shown in **Table 24**. The comparison has been undertaken for upstream and downstream limits of South Creek and each of its tributaries. Peak discharges have been extracted from Appendix A of the 1991 Floodplain Management Study.

As shown in **Table 24**, the peak discharges predicted by the updated XP-RAFTS hydrologic model are generally within 5-10% of those predicted by the 1990 RAFTS model for the 20 and 100 year recurrence floods.

The greatest differences of up to 34% and 24% in peak flows is shown to occur along Werrington Creek and Claremont Creek, respectively (*refer* **Table 24**). These differences are have occurred as an outcome of the incorporation of greater sub-catchment refinement and following a review of catchment parameters; i.e., percentage imperviousness, catchment slope etc. Accordingly, the peak discharges determined for this study are considered to be more reliable.

Comparison of peak discharges for the PMF shows differences typically ranging between 10 to 20%. An exception to this occurs for the Badgerys Creek catchment where the updated XP-RAFTS model is predicting discharges that are approximately 30% less at the South Creek confluence (*downstream extent*).

The differences in peak discharges for the PMF are attributed to the 1990 RAFTS model adopting reduced initial and continuing losses specifically for simulation of the PMF event. For the updated assessment loss parameters have been maintained for all design events. This change in adopted loss parameters is attributed to the 10-30% differences in peak discharges shown in **Table 24** for the PMF event.

Table 24 COMPARISON WITH PEAK DISCHARGES DETERMINED FOR THE 1990 FLOOD STUDY

TRIBUTARY	RAFTS MODEL NODE NUMBER[1]	PEAK DISCHARGE[2] (m^3/s)					
		20 Year ARI		100 Year ARI		Probable Maximum Flood	
		1991 FPMS	RMA-2 (2013)	1991 FPMS	RMA-2 (2013)	1991 FPMS	RMA-2 (2013)
South Creek Upstream	1.08	216	237	300	312	1,207	1,135
South Creek Downstream	1.39D	791	1,015	1,365	1,433	4,724	4,209
Ropes Creek Upstream	20.00	/	41	/	53	/	188
Ropes Creek Downstream	20.11	153	199	254	260	802	689
Kemps Creek Upstream	9.00	26	26	40	33	145	125
Kemps Creek Downstream	9.08D	195	221	316	298	1,263	1,057
Werrington Creek Upstream	18.00	/	111	93	141	/	176
Werrington Creek Downstream	18.01	95	128	133	168	273	266
Claremont Creek Upstream	16.00	23	23	41	33	109	100
Claremont Creek Downstream	16.02	48	45	72	65	219	201
Blaxland Creek Upstream	14.01	/	77	102	102	/	353
Blaxland Creek Downstream	14.02	99	97	129	129	515	440
Cosgroves Creek Upstream	12.02	/	71	90	93	/	324
Cosgroves Creek Downstream	12.03	95	95	121	124	488	431
Badgerys Creek Upstream	5.00	43	40	74	53	234	192
Badgerys Creek Downstream	5.04	93	102	151	138	643	480
Thompsons Creek Upstream	4.00	/	28	30	38	/	113
Thompsons Creek Downstream	4.02	44	54	71	74	251	233

1. *For node and catchment locations refer to **Figure 4.1***
2. *Peak discharges adopted in the 1990 and 1991 Studies taken from Appendix A in the 1991 South Creek Floodplain Management Study Report*
3. *Peak discharges listed do not necessarily occur simultaneously*

6.3 HYDRAULICS

6.3.1 Design Flood Simulations

The RMA-2 hydrodynamic model that was developed for the project was used to simulate flood behaviour across the South Creek floodplain and its tributaries. The model was used to simulate each of the design 20, 50, 100, 200 and 500 year recurrence flood events, and the Probable Maximum Flood (*PMF*). The design simulations were based on a range of boundary condition data which is described in the following sections.

Catchment Runoff

Upstream boundary conditions were defined for each design flood based on the inflow hydrographs generated using the RAFTS hydrologic model (*refer* **Table 23** *and* **Appendix G** *and* **Appendix H**). For example, design 100 year ARI flood discharge hydrographs for creek inflows were extracted from the RAFTS hydrologic model output and used to define the rate of flow into the area covered by the flood model.

A total of ten (*10*) continuity line inflows were adopted to input flows into the upstream extents of the flood model along the South, Werrington, Claremont, Blaxland, Cosgroves, Badgerys, Thompsons, Kemps, Bonds and Ropes Creeks. A further fifty three (*53*) local element inflows were specified throughout the model network allowing localised flows to be input into the hydraulic model. These local element inflows were representative of sub-catchments defined in the RAFTS hydrologic model.

The locations of all upstream boundary inflows and local element inflows are shown in **Figure 5.2**.

Tailwater Levels

As already stated, peak flood levels within the lower reaches of the South Creek are strongly influenced by flood levels along the Hawkesbury-Nepean at times of concurrent flooding. Accordingly, it is difficult to establish a ‘typical’ design flood due to the various combinations of catchment runoff conditions and downstream boundary conditions that could potentially occur in isolation or concurrently. That is, no two floods are exactly the same and it is difficult to define an ‘average’ design flood.

For this study, the downstream boundary conditions that were adopted for simulation of the 20, 50, 100, 200 and 500 year recurrence floods and the Probable Maximum Flood (*PMF*) were extracted from Rubicon flood modelling results for the Hawkesbury-Nepean system. The Rubicon modelling was undertaken for the Public Works Department in 1999 as part of the ‘*Warragamba Dam Auxiliary Spillway EIS Flood Study*’ prepared by Webb McKeown.

The Hawkesbury-Nepean flood levels adopted as downstream boundary conditions for the design modelling scenarios are shown in **Table 25.**

Table 25 ADOPTED DOWNSTREAM BOUNDARY CONDITIONS (*LEVELS*) FOR DESIGN SIMULATIONS

AVERAGE RECURRENCE INTERVAL (ARI)	**HAWKESBURY-NEPEAN LEVEL** (mAHD)	**COMMENT**
Probable Maximum Flood	**26.4**	Adopted for simulation of the design Probable Maximum Flood
500 years	**20.2**	Adopted for simulation of the design 500 year ARI flood
200 years	**18.7**	Adopted for simulation of the design 200 year ARI flood
100 years	**17.3**	Adopted for simulation of the design 100 year ARI flood
50 years	**15.7**	Adopted for simulation of the design 50 year ARI flood
20 years	**13.7**	Adopted for simulation of the design 20 year ARI flood

6.3.2 Results and Discussion

Peak Flood Levels

Peak flood level estimates were extracted from the hydrodynamic modelling results and were used to generate peak water surface profiles for each of the design events. The design flood water surface profiles generated are presented in **Figure 6.1** to **6.15**.

As discussed in **Section 6.2.4**, each design catchment event was simulated in conjunction with their corresponding downstream boundary conditions. For example, the 100 year ARI flood was simulated with the design 100 year ARI Hawkesbury River tailwater level of 17.3 mAHD (*refer* **Section 6.2.4** *and* **Table 25**).

A summary of the applicable WSP Figure for each tributary is outlined below:

- South Creek – Water Surface Profile **Figures 6.1** to **6.4**;
- Ropes Creek – Water Surface Profile **Figures 6.5** to **6.7**;
- Kemps Creek – Water Surface Profile **Figures 6.8** to **6.9**;
- Werrington Creek – Water Surface Profile **Figure 6.10**;
- Claremont Creek – Water Surface Profile **Figure 6.11**;
- Blaxland Creek – Water Surface Profile **Figure 6.12**;
- Cosgroves Creek – Water Surface Profile **Figure 6.13**;
- Badgerys Creek – Water Surface Profile **Figure 6.14**; and,
- Thompsons Creek – Water Surface Profile **Figure 6.15**.

Peak flood levels for the full range of design events at a number of key locations throughout the study area are also provided in **Table I1** of **Appendix I** for South Creek. Peak flood levels at key locations along Ropes, Kemps, Werrington, Claremont, Blaxland, Cosgroves, Badgerys and Thompsons Creek are provided in **Table I2** to **Table I8** of **Appendix I**.

Assessment of the Influence of Hawkesbury-Nepean Flooding

The design water surface profiles presented in **Figures 6.1** to **6.15** illustrate the influence of elevated flood levels from the Hawkesbury Nepean River on design flood levels along the lower reaches of South Creek and to a lesser extent Ropes, Werrington and Claremont Creek. Although the backwater impacts on flood levels are evident it is difficult to ascertain directly from these results the distance to which flood levels are influenced by the adopted Hawkesbury-Nepean flood levels along each creek system.

For the above reason, each design event was also simulated in isolation of any concurrent flooding along the Hawkesbury-Nepean River. These '*local catchment*' flood scenarios assume uniform and steady flow at the downstream extent of the steady area free from any backwater influences. These local catchment tailwater levels were determined by applying normal-depth calculations based on the predicted peak discharge, for each respective event, and the local floodplain topography.

The downstream tailwater levels that have been adopted for simulation of each local catchment flood scenario are documented in **Table 26**. A comparison with each respective Hawkesbury River tailwater level is also included.

Table 26 ADOPTED 'LOCAL CATCHMENT' DOWNSTREAM BOUNDARY CONDITIONS (*LEVELS*)

AVERAGE RECURRENCE INTERVAL (ARI)	LOCAL CATCHMENT TAILWATER LEVEL (mAHD)	HAWKESBURY-NEPEAN TAILWATER LEVEL (mAHD)	LEVEL DIFFERENCE (m)
PMF	**12.3**	26.4	14.1
500 years	**9.5**	20.2	10.7
200 years	**9.0**	18.7	9.7
100 years	**8.6**	17.3	8.7
50 years	**8.3**	15.7	7.4
20 years	**7.9**	13.7	5.8

Further to the '*local catchment*' simulations, a number of additional modelling scenarios were simulated for each design event adopting reduced magnitudes of Hawkesbury-Nepean River flooding as downstream boundary conditions. For example, the 100 year recurrence flood was simulated with a 5, 10 and 20 year recurrence Hawkesbury-Nepean River tailwater scenario; in addition to the standard 100 year recurrence Hawkesbury-Nepean River tailwater scenario.

The water surface profile generated from each of these simulations is shown in **Figures 6.16** to **6.21**.

As shown in **Figures 6.16** to **6.20**, the upstream extent to which South Creek flood levels are impacted by downstream boundary conditions varies substantially depending on the elevations of the adopted boundary conditions. In that regard, the extent of upstream influence appears to fall between Mayo Road and Dunheved Road for the majority of scenarios.

As shown in **Figure 6.21**, adoption of the Hawkesbury-Nepean Probable Maximum Flood level of 26.4 mAHD results in level difference as far upstream as the Western Motorway (*M4*). This '*worst-case*' scenario is over-exaggerated however due to the Hawkesbury-Nepean Probable Maximum Flood resulting in backwater flooding as far upstream as the Main Western Railway; i.e., without the concurrence of any local catchment flooding.

Extent of Inundation

The predicted extent of inundation across the floodplain of the study area for the 20, 100 and 200 year recurrence floods and the Probable Maximum Flood (*with concurrent flooding along the Hawkesbury River of same magnitude; i.e., 20 year ARI inflows with 20 year ARI Hawkesbury River tailwater conditions*) has been extracted from the modelling results and are presented in **Figures 6.22** to **6.89**. The study area has been split up into seventeen (*17*) extents in order to ensure sufficient detail can be seen for all locations. **Plate 1** on the following page provides an overview of the seventeen (*17*) extents.

Figures 6.22 to **6.89** shows that a substantial proportion of the study area is at risk of flooding during events up to and including the Probable Maximum Flood.

At the peak of the 100 year ARI flood, the majority of inundation occurs across undeveloped areas of floodplain. This is particularly the case in the upper reaches of the catchment where development is quite sparse and generally of a '*rural*' nature. Inundation of developed land is predicted around parts of Kemps Creek (*refer* **Figures 6.41**, **6.49**, **6.50**), Werrington (*refer* **Figure 6.46**), St Marys (*refer* **Figures 6.45, 6.46**) and Oxley Park (*refer* **Figure 6.54**) at the peak of the 100 year recurrence flood; amongst other areas.

As shown in **Figure 6.48**, significant inundation is also predicted to occur along the lower floodplain areas of South Creek (*downstream of Munitions Road and the Ropes Creek Confluence*). Unlike further upstream, inundation along these lower extents is dominated by the Hawkesbury-Nepean peak 100 year recurrence flood level of 17.3 mAHD.

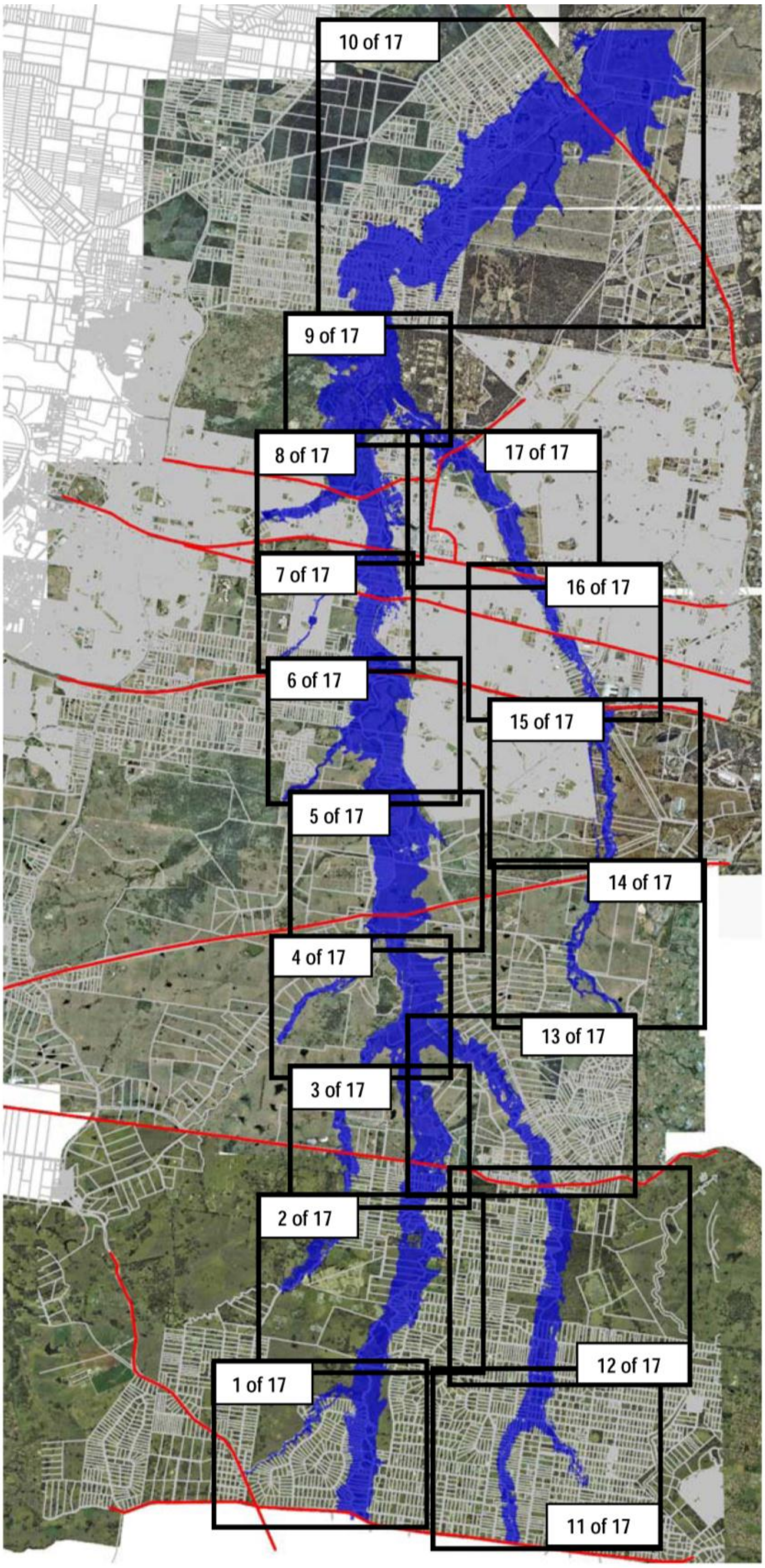


PLATE 1 OVERVIEW OF FIGURE EXTENTS FOR DESIGN MODELLING RESULTS

Floodwater Depths

Peak floodwater depths were extracted from the modelling results for the 20, 100 and 200 year ARI floods and are presented in **Figures 6.89** to **6.106**, **Figures 6.107** to **6.123**, and **Figures 6.124** to **6.140**, respectively (*i.e., seventeen (17) figures for each design event*). Floodwater depth mapping was also extracted for the Probable Maximum Flood and is shown in **Figures 6.141** to **6.157**.

These figures indicate that in major floods, floodwater depths of over 1 metre occur over the vast majority of the floodplain.

Flow Velocities

Peak floodwater flow velocities for the adopted design 20, 100 and 200 year recurrence floods are superimposed over the floodwater depth plots shown in **Figures 6.89** to **6.140** as velocity vectors. These figures indicate that the peak flow velocities are largest within the main channel of South Creek and its tributaries.

During the 100 year ARI flood, the peak in-channel velocities within South Creek upstream of Elizabeth Drive typically range between 0.8 and 1.0 m/s. In-channel velocities are similar along Badgerys Creek upstream of Elizabeth Drive, and typically lower ranging between 0.6 and 0.8 m/s along Kemps Creek and Thompsons Creek.

Between Elizabeth Drive and the Western Motorway (*M4*) in-channel velocities along South, Badgerys, Kemps and Cosgroves Creeks are slightly higher ranging between 0.8 to 1.2 m/s. Average velocities along South Creek are predicted to steadily increase with distance downstream due to the increase in peak discharges conveyed within the channel. Tributaries such as Cosgroves Creek experience comparable average in-channel velocities despite much lower discharges due to the steeper channels and narrower floodplains.

Upstream of Dunheved Road in-channel velocities typically range between 0.9 to 1.2 m/s along South Creek. Between Dunheved Road and South Creek Road, average velocities are slightly lower typically ranging between 0.6 and 1.1 m/s. The decrease in velocities is attributed largely to the greater distribution of floodwaters resulting in a wider floodplain characterised by generally slower moving floodwaters.

Downstream of South Creek Road and Stony Creek Road, in-channel and floodplain velocities are reduced significantly due to the influence of the elevated Hawkesbury-Nepean flood levels. During the 100 year recurrence flood, peak velocities are not predicted to exceed 0.5 m/s downstream of Stony Creek Road.

Flow velocities along Ropes Creek are generally uniform ranging between 0.5 and 1.0 m/s across much of the floodplain and in-channel areas.

Peak floodwater flow velocities for the Probable Maximum Flood are shown as velocity vectors superimposed on floodwater depth mapping contained on **Figures 6.141** to **6.157**.

7. FLOOD INTELLIGENCE DATA

The preceding sections have established that there is a significant risk of flooding throughout the South Creek floodplain and that of its tributaries. The severity of this risk is sensitive to a raft of factors such as the available response times and rate of rise of floodwaters, depths and velocities across areas of inundation and evacuation routes, and the availability of suitable evacuation paths for occupants of the floodplain to evacuate to higher ground.

Each of these factors are important inputs that are commonly required to populate a flood intelligence database that can be used for the effective planning of emergency response procedures. These factors are discussed in the following sections for a number of locations/evacuation routes that are likely to be of interest to the State Emergency Services (*SES*).

7.1 FLOOD LAG / RATE OF RISE

Peak flood flows are predicted to enter the upper reaches of the study area (*Bringelly Road crossing of South Creek*) approximately 20 hours after the commencement of a storm event that will cause major flooding; that is, following a storm event of about 36 hour duration.

From Bringelly Road, the flood wave takes a further 2.5 hours to propagate downstream to Elizabeth Drive and a further 2 to 3 hours to reach the Western Motorway Crossing.

Predicted flood lag times at various locations along South Creek are presented in **Table 27**. Lag times along Ropes and Kemps Creeks are shown in **Table 28**.

Table 27 PREDICTED LAG TIMES FOR THE 100 YEAR ARI FLOOD ALONG SOUTH CREEK

DESCRIPTION OF LOCATION	TIME OF PEAK FLOOD LEVEL (*hours after start of design storm*)*
Bringelly Road Crossing	20.0
Confluence with Thompsons Creek	21.0
Elizabeth Drive Crossing	22.5
Warragamba Pipeline	23.5
Luddenham Road, St Clair	24.0
Western Motorway (*M4*)	25.0
Great Western Highway	26.0
Main Western Railway	26.0

Dunheved Road, Dunheved	26.5
Munitions Road	27.0
Ropes Creek Confluence	27.5
Eighth Avenue, Shanes Park	27.5
Stony Creek Road	27.5
Richmond Road	28.0

** Critical Rainfall duration over South Creek Catchments is 36 hours.*

Table 28 PREDICTED LAG TIMES FOR THE 100 YEAR ARI FLOOD ALONG ROPES AND KEMPS CREEKS

DESCRIPTION OF LOCATION	TIME OF PEAK FLOOD LEVEL (*hours after start of design storm*)*
LOCATIONS ALONG ROPES CREEK	
Capitol Hill Drive Crossing	19.0
Warragamba Pipeline	20.0
M4 Motorway	21.0
Great Western Highway	21.5
Main Western Railway	22.0
Debrincat Ave, Tregear	22.0
Forresters Road, Dunheved	22.5
LOCATIONS ALONG KEMPS CREEK	
Bringelly Road Bridge Crossing	19.5
Confluence with Bonds Creek	20.0
Gurner Avenue	20.5
Elizabeth Drive Bridge Crossing	21.0
Kemps Creek Dam	22.5

** Critical Rainfall duration over Ropes and Kemps Creek Catchments is 36 hours.*

7.2 FLOODING AT MAJOR HYDRAULIC CONTROLS

Throughout the study area there are numerous roadways and railway lines which act as major hydraulic controls to flooding. In most cases, these hydraulic controls are characterised by an elevated roadway or carriageway, with bridges and/or culverts constructed to permit the passage of flow during normal conditions and during times of flood.

Many of the roadways and railway lines within the study area are predicted to experience some inundation during the adopted design flood scenarios. In order to better understand which roadways and railway lines are most susceptible to flooding, it is beneficial to assess the duration of, and depths to which, each roadway is predicted to be inundated to for each design event. This information could be used to assist emergency personnel in evaluating potential evacuation routes, or could be used to inform engineers which roadways or bridges would most benefit an upgrade.

The performance of the following major road and railway crossings has been assessed as part of these Flood Study investigations and is provided in **Appendix J**:

- Elizabeth Drive crossing of South Creek (*refer* **Figure J1** *and* **J2**);
- Western Motorway (*M4*) crossing of South Creek (*refer* **Figure J3** *and* **J4**);
- Great Western Highway crossing of South Creek (*refer* **Figure J5** *and* **J6**);
- Railway Line crossing of South Creek (*refer* **Figure J7** *and* **J8**);
- Dunheved (*Christie*) Road crossing of South Creek (*refer* **Figure J9** *and* **J10**);
- Western Motorway (*M4*) crossing of Ropes Creek (*refer* **Figure J11** *and* **J12**);
- Great Western Highway crossing of Ropes Creek (*refer* **Figure J13** *and* **J14**);
- Railway Line crossing of Ropes Creek (*refer* **Figure J15** *and* **J16**);
- Debrincat Avenue crossing of Ropes Creek (*refer* **Figure J17** *and* **J18**);
- Elizabeth Drive crossing of Kemps Creek (*refer* **Figure J19** *and* **J20**); and
- Elizabeth Drive crossing of Badgerys Creek (*refer* **Figure J21** *and* **J22**);

As shown in **Figures J1** to **J22** in **Appendix J**, all of the road and railway crossings are predicted to experience some inundation during flood events up to and including the Probable Maximum Flood.

The Dunheved (*Christie*) Road crossing of South Creek is predicted to experience inundation most frequently with floodwaters overtopping the roadway by up to 0.9 metres at the peak of the design 20 year recurrence flood (*refer* **Figure J9** *and* **J10**). The Elizabeth Drive crossings of Kemps and Badgerys Creeks are also predicted to experience substantial flooding with up to 0.3 metres and 0.1 metres predicted across the road surfaces at the peak of the 20 year recurrence flood, respectively (*refer* **Figure J19** *to* **J22**).

The Western Motorway (*M4*) and Railway Line crossings of Ropes Creek are predicted to experience the least flooding with the Motorway and Railway Line remaining flood free during floods up to and including the 500 year recurrence flood (*refer* **Figure J11** *to* **J12** *and* **Figure J15** *to* **J16**).

It is envisaged that the figures provided in **Appendix J** could be added to the SES's flood intelligence database.

In viewing **Figures J1** to **J22** it is worth noting that the flood level information has been extracted at the locations along each crossing where upstream levels were highest. This location was in most cases found to lie along the floodplain outside of the main channel. For this reason the flood levels shown in **Figures J1** to **J22** will not match those documented in **Appendix I** which were extracted within the channel; and therefore will in all cases be lower.

7.3 FLOODING AT MAJOR HYDRAULIC CONTROLS

A number of flood mitigation works have been constructed within the study area in order to improve localised flood conditions. The following works have been implemented since completion of the '*South Creek Flood Study Report*' in 1990:

- Relief floodway channel and bridge crossing along Elizabeth Drive at Kemps Creek;
- St Marys earthen and concrete levee;
- Werrington Road levee at Werrington; and
- Earthen levee with flood flap at Werrington.

The performance of each of these flood mitigation works is discussed below.

Relief Floodway Channel and Bridge Crossing, Kemps Creek

Flooding along South Creek upstream of the Elizabeth Drive at Kemps Creek has been an area of concern since the 1990s. In that regard, floodplain management options in the form of bank shaping of the South Creek channel had been examined and constructed in the 1990s.

Although these works would have improved the flooding problem, all studies since their implementation, namely the '*South Creek Floodplain Risk Management Study and Plan*' (*2004*), have again highlighted that the flood problem remains. As an outcome, the Floodplain Risk Management Study investigated and recommended that a combination of the following mitigation works be implemented:

- Voluntary purchase of the three western-most dwellings along Overett Avenue (*nearest South Creek*);
- Construction of a relief floodway to the West of Overett Avenue; and
- Construction of an additional bridge over Elizabeth Drive plus associated connecting floodway upstream and downstream of the bridge.

All of the above recommendations have since been implemented and as such have been incorporated into the RMA-2 flood model developed as part of this study. Therefore, the benefits to flooding (*i.e., in terms of reduced flood levels*) upstream of Elizabeth Drive is included in the modelling results discussed and presented in this report.

Without simulation of a pre-mitigation scenario using the RMA-2 model, it is difficult to reliably assess the performance of the mitigation works. Comparison of the RMA-2 results to the superseded HEC-RAS and MIKE-11 model results is considered misleading and prone to misunderstanding due to the substantial differences in modelling approaches (*1D to 2D*) in combination with the significant differences in topographic data available at the time each model was developed. For these reasons it is not reliable to assess the performance of the mitigation works based on a comparison of the RMA-2 results to previous model results.

In recognition of the above, an alternate approach was adopted for which the performance of the mitigation works were assessed by assuming that the levels upstream of Elizabeth Drive could be directly related to the increased '*total*' conveyance capacity afforded by the additional floodway bridge. In that regard, the existing conditions rating curve that had been developed for the crossing (*refer* **Figure K1** *of* **Appendix K**) was used to estimate upstream flood levels when the flood flows through the additional floodway bridge were subtracted from the '*total*' conveyance capacity of the crossing.

The peak discharge conveyed by the relief floodway bridge according to the RMA-2 flood model results are shown in **Table 29** below for each of the design events.

Table 29 PEAK DISCHARGES CONVEYED THROUGH THE RELIEF FLOODWAY BRIDGE ALONG ELIZABETH DRIVE

DESIGN FLOOD (*ARI*)	**DISCHARGE THROUGH RELIEF FLOODWAY BRIDGE** (m^3/s)	**PERCENTAGE OF TOTAL FLOW**
20	128	35%
50	140	32%
100	157	31%
200	187	32%
500	207	32%
PMF	320	19%

The performance of the mitigation works through application of this comparative approach is shown in **Figure K1** of **Appendix K**.

As shown in **Figure K1**, the mitigation works are estimated to reduce flood levels upstream of Elizabeth Drive by up to 0.3 metres for the full range of design flood scenarios. The greatest reduction in flood level of 0.3 metres occurs at the peak of the 20 year recurrence flood for which the additional floodway bridge conveys up to 35% of the total flow (*refer* **Table 29**).

The mitigation works are also predicted to have reduced the frequency of inundation across Elizabeth Drive with overtopping occurring at the peak of the 20 year recurrence flood for the pre-mitigation scenario and not for existing conditions (*refer* **Figure K1**). This reflects the additional flows that would have previously been forced through the main bridge opening or which would have discharged over Elizabeth Drive.

St Marys Earthen & Concrete Levee

A levee has been constructed along the western floodplain of South Creek to protect both residential and commercial/industrial properties upstream of the Great Western Highway at St Marys. The combined earthen and concrete levee is approximately 1,700 metres in length. The concrete component is minimal spanning approximately 60 metres of the northern most section of the levee where it '*meets*' the upstream embankment of the Great Western Highway.

As shown in **Figure K2**, the levee crest elevations vary between 28.2 mAHD to 25.6 mAHD from the upstream (*southern*) end to the downstream (*northern*) end of the levee, respectively. Comparison of crest elevations to the RMA-2 model results indicates that the levee would not be overtopped during floods up to and including the 100 year recurrence flood. The model results also indicate that the levee has the least freeboard available at the downstream limits where it adjoins the Great Western Highway (*refer* **Figure K2**).

A Water Surface Profile (*WSP*) along the earthen and concrete components of the St Marys Levee is shown in **Figure K3**. **Figure K3** supports the tables on **Figure K2**, on which the concrete component of the levee is most vulnerable to overtopping. The profile also indicates that the levee would have zero freeboard along part of the concrete component of the levee at the peak of the 100 year recurrence flood, and would be overtopped for a localised extent for events greater than the 100 year recurrence flood (*refer* **Figure K2**).

To assess the performance of the St Marys levee it is necessary to evaluate the level of protection it provides to the residential and commercial/industrial properties to the east. This assessment is however '*muddied*' by the presence of a singular cell box culvert across the Great Western Highway, which allows floodwaters to discharge in an upstream direction to inundate properties protected by the St Marys Levee. This results in properties being potentially inundated by backwater flooding prior to any overtopping of the levee occurring.

The function of this culvert cell is summarised in **Figure K4**.

The performance of the St Marys Levee is presented below in **Table 30** based on an analysis of peak flood levels to the east and west of the levee.

Table 30 PEAK FLOOD LEVELS TO THE EAST AND WEST OF THE ST MARYS LEVEE

DESIGN FLOOD (*ARI*)	**PEAK FLOOD LEVELS** (*mAHD*)		
	TO THE EAST (*Protected Area*)	**TO THE WEST** (*Along St Marys Levee*)	**LEVEL REDUCTION** (*m*)
20	24.00	24.5 - 26.75	0.50 – 2.75
50	24.20	24.75 - 27.05	0.55 – 2.85
100	24.40	25.00 - 27.30	0.60 – 2.90
200	24.65	25.20 – 27.60	0.55 – 2.95
500	25.10	25.70 – 27.85	0.60 – 2.75
PMF	27.10 - 28.20	27.00 – 28.90	0.10 – 0.60

Based on the flood level analysis to the east and west of the levee shown in **Table 30**, it is evident that the levee reduces flood levels to the east by between 0.55 to 2.90 metres, on average. Some flooding, albeit only minor, is still experienced in floods up to and including the 100 year recurrence flood due solely to the singular cell culvert (*refer* **Figure K4**) allowing floodwater to back-up behind the levee. The greatest reduction in flood level occurs to the south (*upstream extent of the levee*) where the backwater flooding is insufficient to cause any inundation.

The RMA-2 results and the flood level comparison in **Table 30** indicates that if the culvert were blocked, or a flood gate were installed, then no inundation of the land east of the culvert would occur for floods up to and including the 100 year recurrence flood. Although this would prevent floodwaters entering from South Creek, some localised flooding could potentially still occur due to the build-up of overland flows from localised rainfall.

Installation of a flood gate would therefore substantially increase the performance of the levee and as a result should be considered as a potential structural measure as part of any future Floodplain Management Study. An upgrade of the concrete component to match the elevations and freeboard available along the earthen component is also recommended for consideration.

Werrington Road Levee

Werrington Road at Werrington has been constructed with an elevated roadway to act as a flood protection levee for the residential properties located to the west. In that regard, the levee has been designed to protect the suburb of Werrington from floodwaters originating along South Creek to the west.

The alignment of the Werrington Road levee is shown in **Figure K5**.

As shown, crest elevations along the Werrington Road levee range between 23.5 mAHD to 23.15 mAHD, with the lowest point occurring approximately 100 metres south of the Dunheved Road roundabout. The RMA-2 model results indicate that the levee will not be overtopped during floods up to and including the 200 year recurrence flood. As shown in **Figure K5**, a maximum freeboard of 0.10 metres is predicted to be available at the peak of a 200 year recurrence flood. Between 0.15 and 0.35 metres freeboard is predicted to be available at the peak of the 100 year recurrence flood.

The RMA-2 model results indicate that the Werrington Road levee will prevent inundation of properties at Werrington during South Creek flooding up to and including the design 200 year recurrence flood. Although the levee is predicted to be overtopped at the peak of the 500 year recurrence flood, the levee would still prevent significant inundation of Werrington by limiting the volume of flow entering; i.e., since the levee would not be overtopped by more than 0.30 metres. In that regard, the RMA-2 model results indicate that flood levels would not exceed 22.45 mAHD within Werrington, which reflects a drop in flood level of between 0.9 and 1.35 metres compared to peak 500 year recurrence levels along South Creek (*refer* **Figure K5** *and* **Figure K6**).

This benefit of reduced flood levels is still predicted to occur during the Probable Maximum Flood, albeit to a lesser magnitude. This is to be expected given the increased depths to which floodwaters would overtop the Werrington Road levee (*refer* **Figure K5**). In that regard, **Figure K6** indicates a peak flood level of 24.2 mAHD within Werrington at the peak of the Probable Maximum Flood, a reduction of up to 0.7 metres when compared to South Creek flood levels.

Werrington Earthen Levee and Flap Gate

An earthen levee was also constructed downstream of Werrington to protect residential properties from backwater flooding from Werrington Creek and South Creek. The earthen Levee shown in **Figure K7** spans a length of approximately 230 metres, '*meeting*' the Dunheved Road embankment at its northern end.

A culvert and flap gate had also been constructed along the earthen levee as shown in **Figure K7**. The culvert had been constructed to allow overland flows that would be generated from rainfall falling on the catchment upstream of the earthen levee (*to the east*) to discharge downstream naturally to Werrington Creek. This was required to prevent flows from building-up against the upstream side of the levee. The flap gate was installed to prevent elevated Werrington Creek and South Creek flood levels backing-up through the culvert inundating those residential properties protected by the levee.

As shown in **Figure K7**, the earthen levee has been constructed with a crest elevation of approximately 22.30 mAHD. At 22.30 mAHD the crest elevation is sufficient to prevent overtopping of the levee during design floods up to and including the 500 year recurrence flood. The freeboard available at the peak of each design flood is also shown on **Figure K7**.

As indicated on **Figure K7**, inundation of Werrington can occur from a number of scenarios associated with overtopping of either the Werrington Road levee to the east, the earthen levee to the west, or even failure of the flap gate also to the west. For the first two of these scenarios the modelling has indicated that no inundation will occur at Werrington during floods up to and including the 200 year recurrence flood. That is, both the Werrington Road Levee and earthen levee will not be overtopped.

Inundation of Werrington is predicted to begin to occur at the peak of the 500 year recurrence flood as flood levels along South Creek to the east become sufficiently high to overtop the Werrington Road Levee. This results in floodwaters spilling into Werrington where they are predicted to fill up behind the earthen levee due to the inflows exceeding the capacity of the culvert system (*i.e., the floodwaters flowing into Werrington would exceed the outflow capacity of the culvert*). As shown in **Figure K7**, this is predicted to result in a peak 500 year recurrence flood level within Werrington of 22.45 mAHD. The flood level is predicted to increase to 24.20 mAHD at the peak of the Probable Maximum Flood.

Figure K7 also indicates peak flood levels that are predicted within Werrington for a scenario assuming failure of the flap gate. A peak 100 year recurrence flood level of 21.70 mAHD is predicted within Werrington for this failure scenario.

Please note that this failure scenario has only been considered as a '*worst-case*' scenario and as such does not reflect the existing conditions or base case scenario on which all design flood simulations have been based. Accordingly, all design flood simulations have assumed that the flap gate would operate as designed.

8. HAZARD AND HYDRAULIC CATEGORIES

8.1 GENERAL

The personal danger and physical property damage caused by a flood varies both in time and place across the floodplain. Accordingly, the variability of flood patterns across the floodplain over the full range of floods, needs to be understood by flood prone landholders and by floodplain risk managers.

Representation of the variability of flood hazard across the floodplain provides floodplain risk managers with a tool to assess the existing flood risk and to determine the suitability of land use and future development. The hazard associated with a flood is represented by the static and dynamic energy of the flow, which is in essence, the depth and velocity of the floodwaters. Therefore, the flood hazard at a particular location within the floodplain, is a function of the velocity and depth of the floodwaters at that location.

The NSW Government's *'Floodplain Development Manual'* (*2005*), characterises hazards associated with flooding into a combination of three hydraulic categories and two hazard categories. Hazard categories are broken down into high and low hazard for each hydraulic category as follows:

- Low Hazard – Flood Fringe
- Low Hazard – Flood Storage
- Low Hazard – Floodway
- High Hazard – Flood Fringe
- High Hazard – Flood Storage
- High Hazard - Floodway

As a result, the manual effectively divides hazard into two categories, namely, high and low. An interpretation of the hazard at a particular site can be established from **Figure L1** and **L2** on the following page, which have been taken directly from the manual.

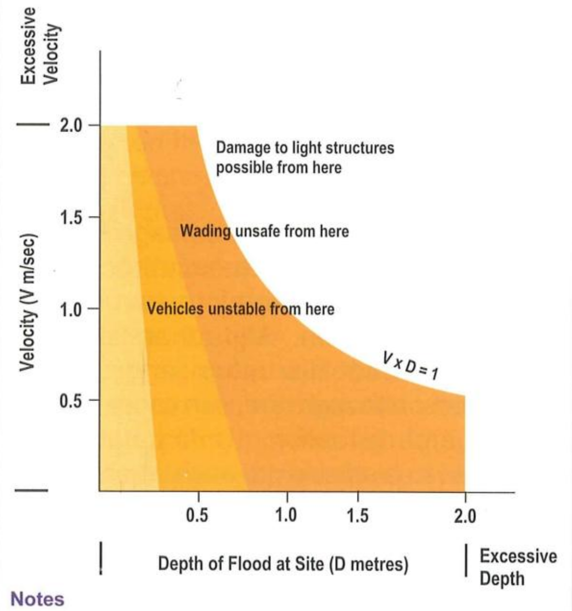
The first of these graphs shows approximate relationships between the depth and velocity of floodwaters and resulting hazard. This relationship has been used to define the provisional low and high hazard categories represented in the second of these plots.

8.2 FLOOD HAZARD

8.2.1 Adopted Provisional Hazard Categorisation

As shown in the **Figures L1** and **L2**, flood hazard is a measure of the degree of difficulty that pedestrians, cars and other vehicles will have in egressing flooded areas, and the likely damage to property and infrastructure. At low hazard, passenger cars and pedestrians (*adults*) are able to move out of a flooded area. At high hazard, wading becomes unsafe, cars are immobilised and damage to light timber-framed houses would occur.

Flood hazard is categorised according to a combination of the flow velocity and the depth of floodwater. The categories are defined by lower and upper bound values for the product of flow velocity and floodwater depth.

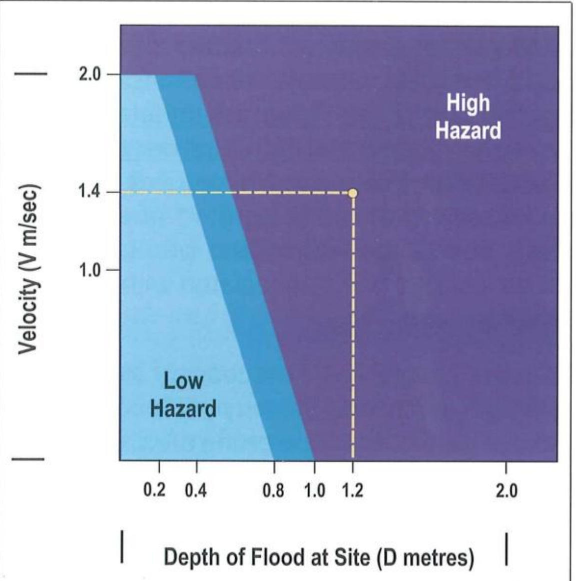


Notes

1. At velocities in excess of 2.0 m/s, the stability of foundations and poles can be affected by scour. Also, grass and earth surfaces begin to scour and can become rough and unstable
2. The velocity of floodwaters passing between buildings can produce a hazard, which may not be apparent if only the average velocity is considered. For instance, the velocity of floodwaters in a model test has risen from an average of 1 m/sec to 3 m/sec between houses.
3. Vehicle instability is initially by buoyancy.
4. At floodwater depths in excess of 2.0 meters and even at low velocities, there can be damage to light-framed buildings from water pressure, flotation and debris impact.

Derived from laboratory testing and flood conditions which caused damage.

FIGURE L1 - Velocity & Depth Relationships



Notes

The degree of hazard may be either -

- reduced by establishment of an effective flood evacuation procedure.
- increased if evacuation difficulties exist.

In the transition zone highlight by the median colour, the degree of hazard is dependant on site conditions and the nature of the proposed development.

Example:

If the depth of flood water is **1.2 m**
and the velocity of floodwater is **1.4 m/sec**
then the provisional hazard is **high**

FIGURE L2 - Provisional Hydraulic Hazard Categories

Spatial and temporal distributions of flow, velocity and water level determined from the computer modelling undertaken as part of this study, were used to determine the flood hazard along the floodplain of South and its tributaries. Interpretation of this data indicates that for large events like the 100 year recurrence flood, the majority of flooded land would fall within the high hazard category defined in the *'Floodplain Development Manual'* (*2005*).

Hence, for the purpose of understanding how the flood hazard affects existing development and areas of potential future development, it is useful to further subdivide areas falling within the high hazard category, into High Hazard, Very High Hazard and Extreme Hazard.

Similarly, the low hazard category defined in the manual has been subdivided to create a Low Hazard and a Medium Hazard category.

A summary of the criteria adopted for each hazard category is listed in **Table 31** and also presented in the coloured hazard chart shown as **Plate 2**.

Table 31 ADOPTED HAZARD CRITERIA

HAZARD CATEGORY	CRITERIA
Low	Depth (*d*) < 0.4 m & velocity (*v*) < 0.5 m/s
Medium	exceeding Low criteria, and $d \leq 0.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 0.5$
High	exceeding Medium criteria, and $d \leq 1.8$ m, $v \leq 3.0$ m/s, and $v \times d \leq 1.5$
Very High	exceeding High criteria, and 0.5 m/s < velocity < 4 m/s & $v \times d \leq 2.5$
Extreme	exceeding Very High criteria and v > 4 m/s

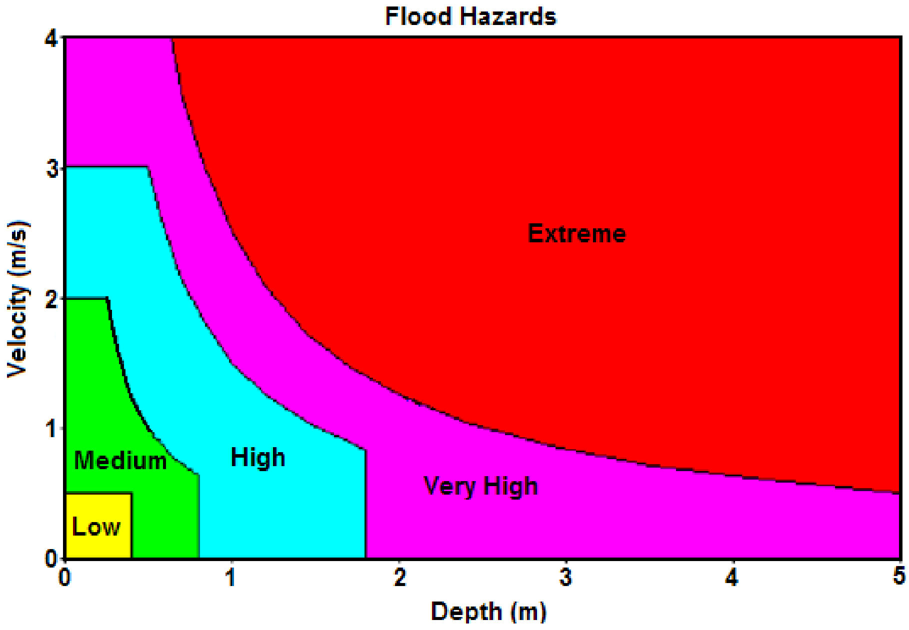


PLATE 2 PROVISIONAL FLOOD HAZARD CHART

8.2.2 Provisional Flood Hazard

The criteria presented in **Table 31** were used to develop provisional hazard mapping for the floodplain of South Creek and its tributaries. Results from the flood modelling that was undertaken for this study were combined with the hazard category criteria listed in **Table 31** to generate the flood hazard mapping.

Provisional flood hazard mapping generated for the 100 year ARI flood is presented in **Figures 7.1** to **7.17**.

The mapping indicates substantial differences in floodplain hazards throughout the study area. Hazards are typically higher within the lower reaches of the study area where depths are significant due to the elevated flood levels from the concurrent Hawkesbury-Nepean 100 year recurrence flood. Within these lower reaches the majority of floodplain areas are categorised as high to very high hazard *(refer* **Figure 7.9** *and* **7.10**).

Within the upper reaches of South Creek (*between Bringelly Road and South Creek Dam*) floodplain areas are typically categorised as medium to high hazard. Downstream of South Creek Dam the floodplain is typically classified as high to very high hazard.

As shown in **Figures 7.1** to **7.17**, flood hazards along the tributaries are typically lower than those predicted along South Creek. In that regard, floodplain areas along Thompsons, Kemps, Ropes, Badgerys, Cosgroves, Blaxland, Claremont and Werrington Creeks are generally within the low to medium hazard categories with the exception of localised areas of high hazard.

The hazard represented in this mapping is provisional only. This is because it is based only on an interpretation of the flood hydraulics and does not reflect the effects of other factors that influence hazard (*see clause L6 to Appendix L of the Floodplain Development Manual*). For example, access to an otherwise low hazard area may be through a high hazard area and this may present an unacceptable risk to life and limb and as such the provisional low hazard area may be changed to high hazard.

Accordingly, modification of the hazard mapping presented in **Figures 7.1** to **7.17** will be required as part of investigations that will need to be undertaken in the future to develop / prepare an updated Floodplain Risk Management Plan for the South Creek and its tributaries.

8.3 HYDRAULIC CATEGORIES

8.3.1 Adopted Hydraulic Categorisation

The NSW Government's *'Floodplain Development Manual'* (*2005*) also characterises flood prone areas according to the hydraulic categories presented in **Table 32**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour.

Table 32 HYDRAULIC CATEGORY CRITERIA

HYDRAULIC CATEGORY	DESCRIPTION
FLOODWAY	• those areas where a significant volume of water flows during floods • often aligned with obvious natural channels • they are areas that, even if only partially blocked, would cause a significant increase in flood levels and/or a significant redistribution of flood flow, which may in turn adversely affect other areas • they are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
FLOOD STORAGE	• those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood • If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. • Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.
FLOOD FRINGE	▪ the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. ▪ Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Unlike for the hazard categorisation outlined on the previous page, the *'Floodplain Development Manual'* (*2005*) does not provide explicit quantitative criteria for defining hydraulic categories. This is because the extent of floodway, flood storage and flood fringe areas is largely dependent on the geomorphic characteristics of the floodplain in question.

Although there are no specific procedures for identifying or determining hydraulic categories, a rigorous methodology involving several stages of analytical analysis in conjunction with flood modelling has been developed by Thomas & Golaszewski (*2012*). This methodology has been applied with success to similar floodplains in NSW and has been shown to provide a robust procedure for defining floodway extent.

Most recently, this methodology was applied to the Lower Hastings River floodplain as part of investigations for the *'Hastings Floodplain Risk Management Study*' (*2012*), the Lower Camden Haven River floodplain as part of investigations for the *'Camden Haven Flood Study*' (*2013*) and also as part of investigations for the '*Griffith Floodplain Risk Management Study*' (*2012*).

The hydraulic category mapping that was prepared for South Creek and its tributaries as part of the Updated South Creek Flood Study investigations is shown in **Figures 7.18** to **7.34**.

The following sections describe the methodology that was employed to determine the hydraulic category mapping.

8.3.2 Adopted Methodology for Determination of Floodway Corridors

The adopted methodology for determination of hydraulic categories for the floodplain of South Creek and its tributaries involved several stages of assessment that relied on rigorous analytical analysis of all available hydraulic, topographic, cadastral and geomorphic data-sets. The analysis also involved testing of hydraulic parameters and flood modelling to simulate the impact of encroachment on initial and revised estimates of floodway corridors.

Once the detailed investigations to determine the extents of floodway corridors were completed, an analytical assessment was also undertaken to determine the extent of flood storage and flood fringe areas. Each of these hydraulic categories was then combined to develop hydraulic category mapping for the study area which can be incorporated into future mapping layers linked to Council's Local Environmental Plan.

A detailed breakdown of the methodology applied to determine the hydraulic category mapping is outlined in the following sections.

Stage 1 – Determination of Preliminary Floodway Extent

A preliminary floodway extent was firstly determined based on an assessment of aerial photography, topographic data and existing 100 year ARI flood modelling results. Determination of this extent or "line" considered the following:

- the location of flood storages that are readily identifiable from aerial photography;
- the location and potential impact of hydraulic controls and geomorphic features that could influence floodwater movement and flood characteristics (*e.g., velocity*);
- mapping of contours of 'velocity-depth' product (*V x D*); and,
- mapping of the variation in peak flow velocity.

Because of the complex nature of flooding along South Creek and its tributaries and the varied floodplain types encountered across the study area, establishment of a standard set of criteria was not considered appropriate for the determination of all floodway extents. For example, definition of the floodway extent based on a single target value for velocity or velocity-depth product (*V x D*) would limit the reliability of the investigation findings.

Accordingly, to ensure the assessment of floodway extent was completed reliably, the study area was divided into numerous precincts to enable assessment on a '*local*' scale.

A set of interactive flood maps was produced for each of these precincts to show key hydraulic data including the variation in V x D, peak flow velocities and peak flood depths. The results of modeling of the design 100 year ARI flood were used as the benchmark for the analysis.

The interactive flood maps were used to identify areas of the floodplain representing:

- high depth and high velocities; i.e., high V x D (*generally considered floodway*);
- high depth and low velocities (*generally considered flood storage*); and,
- low depth and low velocity (*generally considered flood fringe*).

In this regard, a typical "first pass" assessment of floodway extents was undertaken to identify areas where the velocity-depth product is greater than 1.0 m^2/s and where flow velocities are greater than 0.5 m/s. The alignment of significant flow paths across the floodplain (*i.e., potential flood runners*), as inferred by the velocity and V x D contour mapping, was also considered in determining the preliminary floodway extents.

The Preliminary Floodway Extent was further verified by comparison with mapping of the width of the floodplain that would be required to convey 80% of the peak flow. Trial analyses for this project and similar floodplain risk management studies have shown a good correlation between the transitions in velocity-depth product contour mapping, geomorphic characteristics and the width of the floodplain that conveys about 80% of the flood flow. A discussion of this criteria and its appropriateness for defining floodway extent is provided in Thomas et al (*2012*).

The width occupied by 80% of the flow was readily determined for any location within the lower reaches of the floodplain using the *Flow Extraction* tool within waterRIDE^{TM}. This width was then used to verify and adjust the Preliminary Floodway Extent and generate Adopted Preliminary Floodway Extent Mapping.

Through mapping of the floodplain extent required to convey 80% of the flood flow it became evident that no one value of velocity-depth could be adopted for the entire study area. This was perhaps most evident when investigating the floodway extents along the tributaries where velocity-depth products of as low as 0.6 m^2/s where found to be representative of the floodway corridor. Along South Creek appropriate velocity-depth products were found to vary between the upper and lower extents of the study area; generally increasing towards the lower reaches.

Due consideration was also given to the full range of design flood events; that is, the assessment was not solely reliant on hydraulic data for the 100 year ARI event. Particular attention was paid to identifying floodways that could emerge during flooding of the magnitude of the 200 year ARI event and during a Probable Maximum Flood.

Due consideration was also given to varying tailwater level scenarios in order to reliably assess the floodway corridor for the lower reaches of South Creek. This was required in order to reduce the influence of backwater flooding from the Hawkesbury River which caused floodwaters to "back-up" along the South Creek system. Three reduced tailwater level scenarios were adopted with the results for each being assessed individually via application of the Stage 1 criteria.

The following tailwater scenarios were selected:

- 10 year ARI Hawkesbury TWL of 12.2 mAHD;
- 5 year ARI Hawkesbury TWL of 10.8 mAHD; and,
- Nominal TWL of 7.5 mAHD (*assumed to be less than 5 year ARI*).

The preliminary floodway corridors determined for each tailwater level scenario were found to not vary significantly with maximum variations in extent of typically less than 50 metres. The preliminary floodway corridor that had been determined based on the 7.5 mAHD tailwater level was adopted for encroachment testing.

This methodology was applied to generate a “Preliminary” Floodway Extent and is referred to as the Stage 1 Assessment.

Stage 2 – Encroachment Testing of Adopted Preliminary Floodway Extent

The Adopted Preliminary Floodway Extent mapping was tested and verified on a precinct by precinct basis by selective encroachment analyses.

The analyses involved flood modelling of ‘encroachment’ scenarios for each individual precinct to test whether the ‘Stage 1’ floodway corridor was sufficiently sized to convey a significant proportion of total flood volume. A floodway corridor was considered sufficiently sized if the encroachment testing did not lead to increases in 100 year ARI flood level of more than 100 mm.

Flood level difference mapping was prepared for each iteration of the modelling and the alignment of the preliminary floodway extent was adjusted where necessary; i.e., where flood level increases were found to be significant. Adjustment of the preliminary floodway extent was undertaken by re-applying the Stage 1 methodology. Areas that required the most attention were locations where the floodway boundary was not readily apparent from velocity or V x D contour mapping.

This iterative approach led to the development of a Refined Floodway Alignment.

Stage 3 – Final Encroachment Testing

The Refined Floodway Alignment was re-tested as part of a final round of encroachment testing. As part of these tests, further encroachment simulations were undertaken for a number of precincts which had been determined specifically as requiring further investigation.

Following completion of the final ‘precinct by precinct’ encroachment simulations a final encroachment simulation was run which tested the complete Refined Floodway Alignment.

Following review of the complete encroachment scenario and incorporation of minor modifications, the Refined Floodway Alignment was determined to satisfy the adopted floodway criteria.

8.3.3 Adopted Methodology for Determining Flood Storage and Flood Fringe

Following determination of those areas of the floodplain categorised as floodway, investigations were focused towards identifying the remaining hydraulic categories, namely flood storage and flood fringe. As outlined in the NSW *'Floodplain Development Manual'* (*2005*), flood storage and flood fringe make up the remainder of the floodplain outside of the floodway corridor.

Flood storage areas are typically defined as those flood prone areas that afford significant temporary storage of floodwaters during a major flood. If filled or obstructed (*through the construction of levees or road embankments*) the reduction in storage would be expected to result in a commensurate increase in flood levels in nearby areas. The remaining flood prone areas not classified as floodway or flood storage are termed flood fringe.

In order to determine the boundary between flood storage and flood fringe, the variation in peak flood depths and velocities in areas outside of the floodway extent was mapped to identify areas inundated to depths of up to 0.3 metres and velocities of up to 1.0 m/sec. A depth of 0.3 metres was selected as it is considered to be the transitionary point up to which flood conditions become hazardous to people and vehicles and up to which any future development proposals would require substantial earthworks (*i.e., floodplain filling to elevate finished floor levels to meet Council requirements*).

In terms of the South Creek floodplain and that of its tributaries, peak depths below 0.3 metres are also considered to correspond to areas where negligible flow is conveyed and represent a relatively small proportion of storage for floodwaters. This is further supported by an assessment of peak 100 year recurrence velocities, where concurrent mapping of both criteria showed velocities were less than 1.0 m/sec at all locations where depths are predicted to be less than 0.3 metres.

In accordance with the Floodplain Development Manual (*2005*), this represents areas which are unlikely to have any significant impact on the pattern of floodwater distribution through a creek and floodplain system and associated flood levels.

Accordingly, the boundary between flood storage and flood fringe was defined by a peak 100 year ARI flood depth of 0.3 metres and peak velocities of up to 1.0 m/sec. Accordingly, the velocity-depth product for flood fringe areas is less than 0.3 m^2/sec.

Flood storage and flood fringe mapping for the floodplains of South Creek and its tributaries is presented as **Figures 7.18** to **7.34**.

9. REFERENCES

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10. APPENDICES

APPENDIX A

UPDATED RAFTS MODEL PARAMETERS

TABLE A1: RAFTS MODEL CATCHMENT PARAMETERS

Node	Catchment	Total Area (ha)	Slope (%)	Impervious (%)	Pervious 'n'	Initial Loss (mm)	Continuing Loss (mm/hr)
1.00	A	500.0	0.83	0.2	0.025	35.9	0.94
1.01	A	372.0	0.96	0.2	0.025	35.9	0.94
1.02	A	421.0	0.88	1.2	0.025	35.9	0.94
1.03	A	693.0	0.73	0.3	0.025	35.9	0.94
1.04	A	307.0	0.50	0.4	0.025	35.9	0.94
1.05D	A	0.1	0.10	0	0.025	0	0
1.06	A	13.0	0.31	0	0.025	35.9	0.94
1.07D	A	0.1	0.10	0	0.02	0	0
1.08	A	491.0	0.71	1.5	0.025	35.9	0.94
1.09	A	740.0	0.76	1.4	0.025	35.9	0.94
1.10	A	102.0	0.81	1	0.025	35.9	0.94
1.11D	A	0.1	0.10	0	0.02	0	0
1.12	A	505.0	0.67	1.2	0.025	35.9	0.94
1.13	A	942.0	0.26	1.6	0.025	35.9	0.94
1.14	A	416.0	0.57	1.2	0.025	37.1	0.94
1.15	A	369.0	0.15	0	0.025	37.1	0.94
1.16D	A	0.1	0.10	0	0.02	0	0
1.17	A	609.0	0.53	0.6	0.025	37.1	0.94
1.18D	A	0.1	0.10	0	0.02	0	0
1.19	A	985.0	0.31	6.6	0.025	37.1	0.94
	B	90.0	0.31	75	0.025	1	0
1.20D	A	0.1	0.10	0	0.02	0	0
1.21	A	122.0	0.78	1	0.025	37.1	0.94
	B	21.0	0.78	75	0.025	1	0
1.22D	A	0.1	0.10	0	0.02	0	0
1.23	A	220.0	0.73	1	0.025	37.1	0.94
	B	342.0	0.73	75	0.025	1	0
1.24	A	205.0	0.56	3	0.025	37.1	0.94
1.25D	A	0.1	0.10	0	0.02	0	0
1.26	A	123.0	0.70	1	0.025	36.6	0.94
	B	53.0	0.70	99	0.025	1	0
1.27D	A	0.1	0.10	0	0.02	0	0
1.28D	A	0.1	0.10	0	0.02	0	0
1.29	A	204.0	0.39	1	0.025	36.6	0.94
	B	65.0	0.39	99	0.025	1	0
1.30D	A	0.1	0.10	0	0.02	0	0
1.31	A	591.0	0.66	16	0.025	36.6	0.94
1.32	A	514.0	0.65	4	0.025	36.6	0.94
	B	54.0	0.65	75	0.025	1	0
1.33	A	20.0	0.42	4	0.025	36.6	0.94
1.34D	A	0.1	0.10	0	0.02	0	0
1.35	A	692.0	0.46	3.4	0.025	36.6	0.94
1.36D	A	0.1	0.10	0	0.02	0	0
1.37	A	477.0	0.76	1.8	0.025	36.6	0.94
1.38	A	856.0	0.36	3	0.025	36.6	0.94
1.39D	A	0.1	0.10	0	0.025	0	0
1.40	A	292.0	0.53	0.3	0.025	36.6	0.94
2.00	A	625.0	1.04	0.2	0.025	35.9	0.94
2.01	A	726.0	0.71	0.5	0.025	35.9	0.94
3.00	A	443.0	0.93	0.3	0.025	35.9	0.94
3.01	A	580.0	0.85	1.5	0.025	35.9	0.94
3.02	A	473.0	0.63	1.5	0.025	35.9	0.94
4.00	A	480.0	1.18	1	0.025	15	0
4.01	A	330.0	0.57	0.6	0.025	15	0
4.02	A	224.0	0.57	0.6	0.025	15	0.94
5.00	A	980.0	0.55	1.2	0.025	37.1	0.94
5.01	A	745.0	0.67	1.9	0.025	37.1	0.94
5.02	A	309.0	0.52	3.3	0.025	37.1	0.94
5.03D	A	0.1	0.10	0	0.02	0	0
5.04	A	303.0	0.41	0.2	0.025	37.1	0.94
6.00	A	369.0	0.75	1.6	0.025	37.1	0.94
7.00	A	569.0	0.68	2.8	0.025	33.9	0.94
8.00	A	1031.0	0.56	2.4	0.025	33.9	0.94
8.01D	A	0.1	0.10	0	0.02	0	0

8.02	A	290.0	0.63	4	0.025	33.9	0.94
9.00	A	583.0	0.70	2	0.025	33.9	0.94
9.01	A	534.0	0.58	2.4	0.025	33.9	0.94
Jtn9.02	A	0.1	0.10	0	0.02	0	0
9.03	A	1007.0	0.35	4	0.025	33.9	0.94
9.04D	A	0.1	0.10	0	0.02	0	0
9.05	A	234.0	1.18	1.6	0.025	33.9	0.94
9.06	A	910.0	0.25	1.9	0.025	33.9	0.94
9.07	A	102.0	0.65	0.3	0.025	33.9	0.94
9.08D	A	0.1	0.10	0	0.02	0	0
10.00	A	721.0	0.62	3.1	0.025	33.9	0.94
11.00	A	385.0	0.84	1.1	0.025	37.1	0.94
12.00	A	780.0	0.83	1.4	0.025	37.1	0.94
12.01	A	0.1	0.10	0	0.025	0	0
12.02	A	380.0	0.40	0.6	0.025	37.1	0.94
12.03	A	595.0	0.40	0.6	0.025	37.1	0.94
13.00	A	614.0	0.66	0.1	0.025	37.1	0.94
13.01	A	677.0	0.56	0.6	0.025	37.1	0.94
14.00	A	1150.0	0.62	1.5	0.025	37.1	0.94
14.01	A	660.0	0.52	0.5	0.025	37.1	0.94
14.02	A	500.0	0.52	0.5	0.025	37.1	0.94
15.00	A	68.0	0.93	1	0.025	37.1	0.94
	B	127.0	0.93	99	0.025	1	0
15.01	A	141.0	0.74	1	0.025	37.1	0.94
	B	172.0	0.74	99	0.025	1	0
16.00	A	445.0	0.74	4	0.025	36.6	0.94
16.01	A	182.0	0.68	10	0.025	15	0.94
	B	60.0	0.68	75	0.025	1	0
16.02	A	136.0	0.68	10	0.025	1	0
	B	90.0	0.68	80	0.025	0	0
17.00	A	103.0	0.72	1	0.025	36.6	0.94
	B	155.0	0.72	99	0.025	1	0
18.00	A	375.0	0.71	1	0.025	5	0.94
	B	405.0	0.71	95	0.025	1	0
18.01	A	184.0	0.71	1	0.025	15	0.94
	B	208.0	0.71	95	0.025	1	0
19.00	A	200.0	0.76	1	0.025	36.6	0.94
	B	151.0	0.76	99	0.025	1	0
20.00	A	891.0	0.67	3.2	0.025	32.6	0.94
20.01	A	449.7	0.44	0	0.025	32.6	0.94
	B	10.2	0.42	100	0.025	1	0
20.02D	A	0.0	0.00	0	0.025	0	0
20.03	A	332.1	0.56	1	0.025	32.6	0.94
20.04	A	441.0	0.47	2	0.025	32.6	0.94
	B	0.0	0.00	1	0.001	0	0
20.04b	A	274.0	0.47	2	0.025	32.6	0.94
	B	0.0	0.00	1	0.001	0	0
20.05D	A	0.1	0.10	0	0.02	0	0
20.06	A	119.0	1.26	1	0.025	32.6	0.94
	B	97.0	1.26	75	0.025	0	0
20.07	A	118.0	0.82	1	0.025	32.6	0.94
	B	323.0	0.82	75	0.025	1	0
20.08	A	353.0	0.88	1	0.025	32.6	0.94
	B	235.0	0.88	99	0.025	1	0
20.09	A	238.0	1.25	1	0.025	32.6	0.94
	B	158.0	1.25	99	0.025	1	0
20.10	A	255.0	0.75	1	0.025	36.6	0.94
	B	110.0	0.75	99	0.025	1	0
20.11	A	207.0	0.60	10	0.025	36.6	0.94
21.00	A	105.0	0.67	1	0.025	32.6	0.94
	B	131.0	0.67	75	0.025	1	0
22.00	A	547.0	0.68	17	0.025	36.6	0.94
23.00	A	608.0	0.48	1	0.025	36.6	0.94
	B	441.0	0.48	99	0.025	1	0
23.01	A	1025.0	0.41	7	0.025	36.6	0.94
	Total Area:	41387.14					

TABLE A2: RAFTS MODEL ROUTING LINK PARAMETERS

Link	Total Link Length [m]	Right Manning's n [n value]	Central Manning's n [n value]	Left Manning's n [n value]	Slope [%/100]	Avg. Channel Velocity [m/s]	Lag [min]
1.00 - 1.01 (L1.00)	1765.0	0.0	0.08	0.04	0.0059	0.583	50
1.01 - 1.02 (L1.01)	1828.0	0.0	0.08	0.04	0.0061	1.25	24
1.02 - 1.03 (L1.02)	1445.0	0.0	0.08	0.04	0.0047	0.81	30
1.03 - 1.04 (L1.03)	2310.0	0.0	0.07	0.04	0.0038	0.637	60
1.04 - 1.05D (L1.04)		0.1	0.04	0.07			
2.00 - 2.01 (L2.00)	2060.0	0.1	0.15	0.05	0.0053	0.398	86
1.05D - 1.06 (L1.05)	525.0	0.0	0.07	0.04	0.0049	0.808	11
1.06 - 1.07D (L1.06)		0.1	0.04	0.07			
3.00 - 3.01 (L3.00)	2850.0	0.1	0.15	0.05	0.0043	0.445	107
3.01 - 3.02 (L3.01)	3340.0	0.1	0.08	0.09	0.0037	0.592	94
3.02 - 1.07D (L3.02)		0.1	0.04	0.07			
1.07D - 1.08 (L1.07)	1050.0	0.0	0.07	0.045	0.0036	0.99	18
1.08 - 1.09 (L1.08)	1360.0	0.0	0.07	0.045	0.0043	0.978	23
1.09 - 1.10 (L1.09)	1095.0	0.0	0.07	0.035	0.0034	1.03	18
1.10 - 1.11D (L1.10)		0.1	0.04	0.07			
4.00 - 4.01 (L4.00)	2020.0	0.0	0.10	0.04	0.0044	0.768	44
1.11D - 1.12 (L1.11)	1360.0	0.0	0.07	0.035	0.0019	0.78	29
1.12 - 1.13 (L1.12)	3845.0	0.0	0.08	0.045	0.0022	0.806	80
1.13 - 1.14 (L1.13)	2000.0	0.0	0.05	0.035	0.0003	0.499	67
1.14 - 1.15 (L1.14)		0.1	0.04	0.07			
5.00 - 5.01 (L5.00)	2100.0	0.1	0.12	0.06	0.0025	0.456	77
5.01 - 5.02 (L5.01)	2920.0	0.1	0.12	0.06	0.0038	0.624	78
5.02 - 5.03D (L5.02)		0.1	0.04	0.07			
6.00 - 5.03D (L6.00)		0.1	0.04	0.07			
5.03D - 5.04 (L5.03)	2920.0	0.1	0.11	0.05	0.0009	0.441	110
5.04 - 1.15 (L5.04)		0.1	0.04	0.07			
1.15 - 1.16D (L1.15)		0.1	0.04	0.07			
9.00 - 9.01 (L9.00)	3600.0	0.1	0.08	0.06	0.0046	0.447	134
9.01 - Jtn9.02 (L9.01)		0.1	0.04	0.07			
8.00 - 8.01D (L8.00)		0.1	0.04	0.07			
7.00 - 8.01D (L7.00)		0.1	0.04	0.07			
8.01D - 8.02 (L8.01)	2700.0	0.1	0.08	0.06	0.0036	0.583	77
8.02 - Jtn9.02 (L8.02)		0.1	0.04	0.07			
Jtn9.02 - 9.03 (L9.02)	4180.0	0.0	0.12	0.045	0.0022	0.566	123
9.03 - 9.04D (L9.03)		0.1	0.04	0.07			
10.00 - 9.04D (L10.00)		0.1	0.04	0.07			
9.04D - 9.05 (L9.04)	800.0	0.0	0.12	0.045	0.0025	0.686	19
9.05 - 9.06 (L9.05)	4960.0	0.0	0.05	0.035	0.0006	0.617	134
9.06 - 9.07 (L9.06)		0.1	0.04	0.07			
9.07 - 9.08D (L9.07)		0.1	0.04	0.07			
9.08D - 1.16D (L9.08)	1400.0	0.1	0.07	0.05	0.0013	0.285	82
1.16D - 1.17 (L1.16)	1900.0	0.0	0.04	0.035	0.0013	1.31	24
1.17 - 1.18D (L1.17)		0.1	0.04	0.07			
11.00 - 12.01 (L11.00)		0.1	0.04	0.07			
12.00 - 12.01 (L12.00)		0.1	0.04	0.07			
12.01 - 12.02 (L12.01)	3000.0	0.0	0.09	0.035	0.0034	0.695	72
12.03 - 1.18D (L12.02)		0.1	0.04	0.07			
1.18D - 1.19 (L1.18)	4340.0	0.0	0.05	0.035	0.0012	0.997	73
1.19 - 1.20D (L1.19)		0.1	0.04	0.07			
13.00 - 13.01 (L13.00)	5040.0	0.0	0.12	0.035	0.005	0.584	144
13.01 - 1.20D (L13.01)		0.1	0.04	0.07			
1.20D - 1.21 (L1.20)	1640.0	0.0	0.05	0.03	0.0007	1.04	26
1.21 - 1.22D (L1.21)		0.1	0.04	0.07			
14.00 - 14.01 (L14.00)	2500.0	0.0	0.12	0.035	0.0035	0.646	64
14.02 - 1.22D (L14.01)		0.1	0.04	0.07			
1.22D - 1.23 (L1.22)	1440.0	0.0	0.05	0.03	0.0007	0.705	34
1.23 - 1.24 (L1.23)	1590.0	0.0	0.05	0.035	0.0011	1.3	20
1.24 - 1.25D (L1.24)	500.0	0.0	0.04	0.03	0.0005	0.911	9
15.00 - 15.01 (L15.00)	2120.0	0.0	0.05	0.045	0.0048	0.493	72

15.01 - 1.25D (L15.01)		0.1	0.04	0.07			
1.25D - 1.26 (L1.25)	900.0	0.0	0.04	0.03	0.0005	0.863	17
1.26 - 1.27D (L1.26)		0.1	0.04	0.07			
16.00 - 16.01 (L16.00)	2200.0	0.1	0.04	0.06	0.0048	1.71	21
1.27D - 1.28D (L1.27)	750.0	0.0	0.04	0.03	0.0014	1.36	9
17.00 - 1.28D (L17.00)	1600.0	0.1	0.05	0.05	0.0083	1.55	17
1.28D - 1.29 (L1.28)	640.0	0.0	0.04	0.03	0.0014	1.36	8
1.29 - 1.30D (L1.29)		0.1	0.04	0.07			
18.01 - 1.30D (L18.00)		0.1	0.04	0.07			
1.30D - 1.31 (L1.30)	2720.0	0.0	0.07	0.045	0.0019	1.19	38
1.31 - 1.32 (L1.31)	750.0	0.0	0.07	0.045	0.0031	1.42	9
19.00 - 1.32 (L19.00)	3620.0	0.1	0.04	0.06	0.0052	1.71	35
1.32 - 1.33 (L1.32)	600.0	0.0	0.07	0.045	0.0003	0.763	13
1.33 - 1.34D (L1.33)		0.1	0.04	0.07			
20.03 - 20.04 (L20.01)	1100.0	0.0	0.06	0.035	0.0032	1.61	11
21.00 - 20.05D (L21.00)		0.1	0.04	0.07			
20.05D - 20.06 (L20.03)	500.0	0.0	0.15	0.035	0.0033	0.576	14
20.06 - 20.07 (L20.04)	1950.0	0.0	0.06	0.035	0.0022	1.34	24
20.07 - 20.08 (L20.05)	1300.0	0.0	0.06	0.045	0.0027	0.942	23
20.08 - 20.09 (L20.06)	1600.0	0.1	0.18	0.06	0.0023	0.536	50
20.09 - 20.10 (L20.07)	1950.0	0.1	0.18	0.06	0.0015	0.603	54
20.10 - 20.11 (L20.08)	2810.0	0.1	0.02	0.07	0.0033	4.47	10
20.11 - 1.34D (L20.09)		0.1	0.04	0.07			
1.34D - 1.35 (L1.34)	2910.0	0.1	0.07	0.06	0.0003	0.456	106
1.35 - 1.36D (L1.35)		0.1	0.04	0.07			
22.00 - 1.36D (L22.00)		0.1	0.04	0.07			
1.36D - 1.37 (L1.36)	1300.0	0.1	0.07	0.06	0.0008	0.821	26
1.37 - 1.38 (L1.37)	2470.0	0.0	0.05	0.045	0.0007	1.1	37
1.38 - 1.39D (L1.38)		0.1	0.04	0.07			
23.00 - 23.01 (L23.00)	5110.0	0.0	0.06	0.045	0.0041	0.659	129
23.01 - 1.39D (L23.01)		0.1	0.04	0.07			
1.39D - 1.40 (L1.39)	1980.0	0.0	0.04	0.03	0.0003	1.02	32
20.00 - 20.01 (L32)	2250.0	0.0	0.08	0.04		1.1	34
20.02D - 20.03 (L33B)	2800.0	0.0	0.08	0.04		1.32	35
20.01 - 20.02D (LDummy)		0.1	0.04	0.07			
12.02 - 12.03 (link1)	4200.0	0.0	0.09	0.035		0.761	92
14.01 - 14.02 (link2)	2540.0	0.0	0.12	0.035		0.759	56
18.00 - 18.01 (L 18.01)	2200.0	0.0	0.05	0.035		1.74	21
16.01 - 16.02 (link3)	2200.0	0.1	0.04	0.06		1.95	19
16.02 - 1.27D (link4)		0.1	0.04	0.07			
20.04 - 20.04b (link7)	2100.0	0.0	0.06	0.035	0.0032	1.35	26
20.04b - 20.05D (link8)		0.1	0.04	0.07			
2.01 - 1.06 (link9)		0.1	0.04	0.07			
4.01 - 4.02 (link10)	2020.0	0.0	0.10	0.04	0.0044	0.851	40
4.02 - 1.11D (link11)		0.1	0.04	0.07			

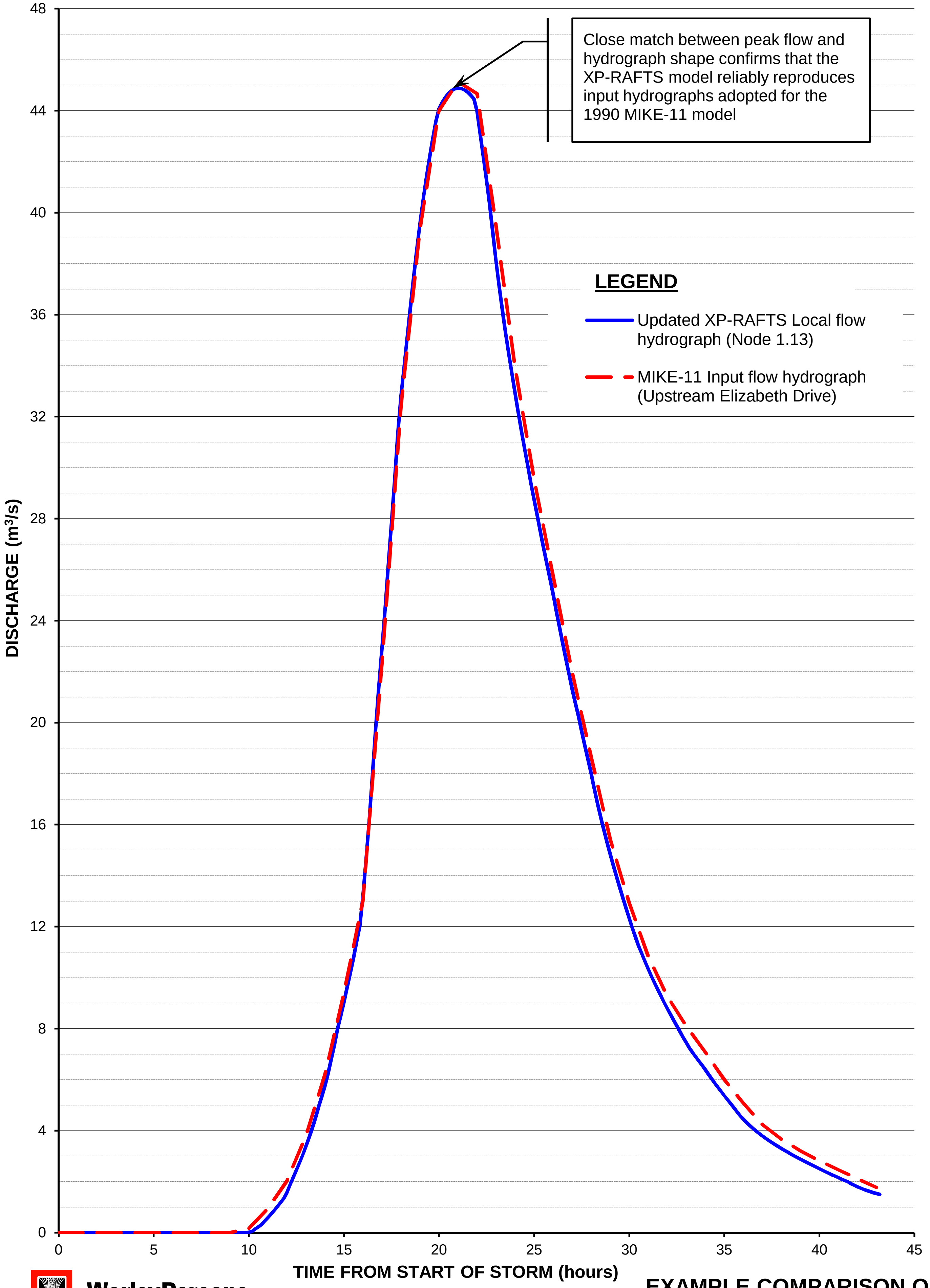
APPENDIX B

COMPARISON OF COMPUTED DISCHARGES (RAFTS)

TABLE B1 COMPARISON OF 100 YEAR COMPUTED PEAK DISCHARGES FOR SOUTH CREEK AND ITS TRIBUTARIES

	NODE	**100 YEAR ARI PEAK DISCHARGE** (m3/s)					
		2013 Updated Flood Study		1990 Flood Study (DWR)	1991 South Creek FPRMS (DWR)	2004 South Creek FPRMS (LCC)	2003 Austral FPRMS (LCC)
SOUTH CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Bringelly Road / U/S Extent of RMA-2 Model	1.08	312	N.A	299	300	299	N.A
D/S of Confluence with Thompson Creek / Fifteenth Ave	1.10	354	N.A	/	328	328	N.A
U/S of 15th Avenue	/	/	N.A	381	379	/	N.A
U/S of Elizabeth Drive	1.13	479	N.A	434	433	433	N.A
Confluence with Badgerys Creek / U/S South Creek Dam	1.14	492	N.A	448	444	444	N.A
U/S Sydney Water Pipeline	1.17	942	N.A	988	983	N.A	N.A
Confluence with Blaxland Creek	1.18D	1027	N.A	/	1041	N.A	N.A
U/S of Western Motorway (M4)	1.23	1164	N.A	1119	1116	N.A	N.A
U/S of Great Western Highway	1.25D	1175	N.A	1122	1116	N.A	N.A
U/S of Railway Line	1.27D	1193	N.A	1139	1115	N.A	N.A
U/S of Ropes Creek Confluence	1.33	1243	N.A	/	/	N.A	N.A
D/S of Ropes Creek Confluence	1.34D	1370	N.A	1287	1277	N.A	N.A
U/S of Stoney Creek Road	1.37	1387	N.A	1317	1295	N.A	N.A
U/S of Richmond Road	1.39D	1433	N.A	1328	1328	N.A	N.A
KEMPS CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Bringelly Road / U/S Extent of RMA-2 Model	9.00	33	N.A	40	40	N.A	/
U/S 15th Ave	9.02D	168	N.A	193	183	N.A	/
U/S Elizabeth Drive	9.05	262	N.A	270	259	N.A	307
U/S Kemps Creek Dam	9.08D	298	N.A	316	316	N.A	/
ROPES CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Capital Hill Drive / U/S Extent of RMA-2 Model	20.00	53	N.A	/	/	N.A	N.A
U/S Sydney Water Pipeline	20.03	98	N.A	97	/	N.A	N.A
U/S Western Motorway (M4)l	20.06	164	N.A	162	162	N.A	N.A
U/S Great Western Highway	20.07	187	N.A	185	184	N.A	N.A
U/S Railway Line	20.08	219	N.A	215	/	N.A	N.A
U/S Debrincat Avenue	20.09	235	N.A	232	232	N.A	N.A
U/S Forrester Road	20.10	251	N.A	249	249	N.A	N.A
U/S of Confluence with South Creek	20.11	260 *	N.A	252 *	254 *	N.A	N.A
BADGERYS CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Extent of RMA-2 Model / Badgerys Creek Rd	5.00	53	N.A	74	53	N.A	N.A
U/S Green Street	5.01	92	N.A	95	/	N.A	N.A
Upstream Elizabeth Drive	5.03D	126	N.A	112	126	N.A	N.A
At Confluence with South Creek	5.04	138	N.A	151	151	N.A	N.A
THOMPSON CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Northern Rd / U/S Extent of RMA-2 Model	4.00	30	38	30	/	/	N.A
U/S of Confluence with South Creek	4.02	62	74	71	67	67	N.A
COSGROVES CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Extent of RMA-2 Model	12.02	93	N.A	90	/	N.A	N.A
U/S of Confluence with South Creek	12.03	123	N.A	129	129	N.A	N.A
BLAXLAND CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Extent of RMA-2 Model	14.01	102	N.A	102	/	N.A	N.A
U/S of Confluence with South Creek	14.02	129	N.A	129	129	N.A	N.A
CLAREMONT CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S Western Motorway (M4) / U/S Extent of RMA-2 Model	16.00	30	33	35	/	N.A	N.A
U/S Sunflower Drive	16.01	47	51	61	/	N.A	N.A
U/S Confluence with South Creek	16.02	62	65	72	72	N.A	N.A
WERRINGTON CREEK		(36 hr Duration)	(2, 9 hr Durations)				
U/S William St Footbridge / U/S Extent of RMA-2 Model	18.00	57	141	93	/	N.A	N.A
U/S Forrester Road / Confluence with South Creek	18.01	85	167	133	125	N.A	N.A

FIGURE B1



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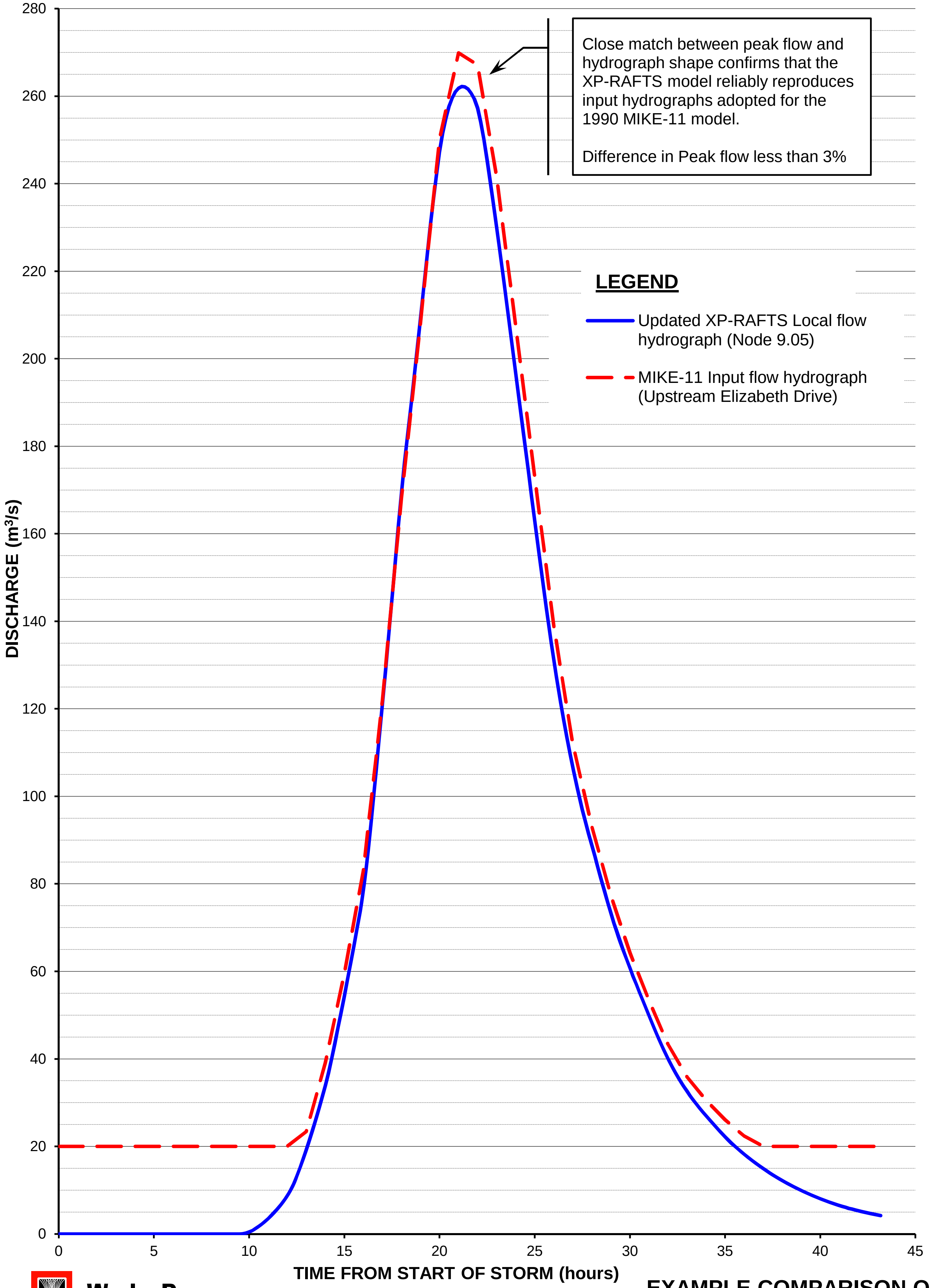
6033rg130118_Hydrograph Comparison.xls

EXAMPLE COMPARISON OF DISCHARGE HYDROGRAPHS FROM XP-RAFTS AND MIKE-11 INPUT FOR SOUTH CREEK SUB-CATCHMENT 1.13

FIGURE B2



Close match between peak flow and hydrograph shape confirms that the XP-RAFTS model reliably reproduces input hydrographs adopted for the 1990 MIKE-11 model.

Difference in Peak flow less than 3%

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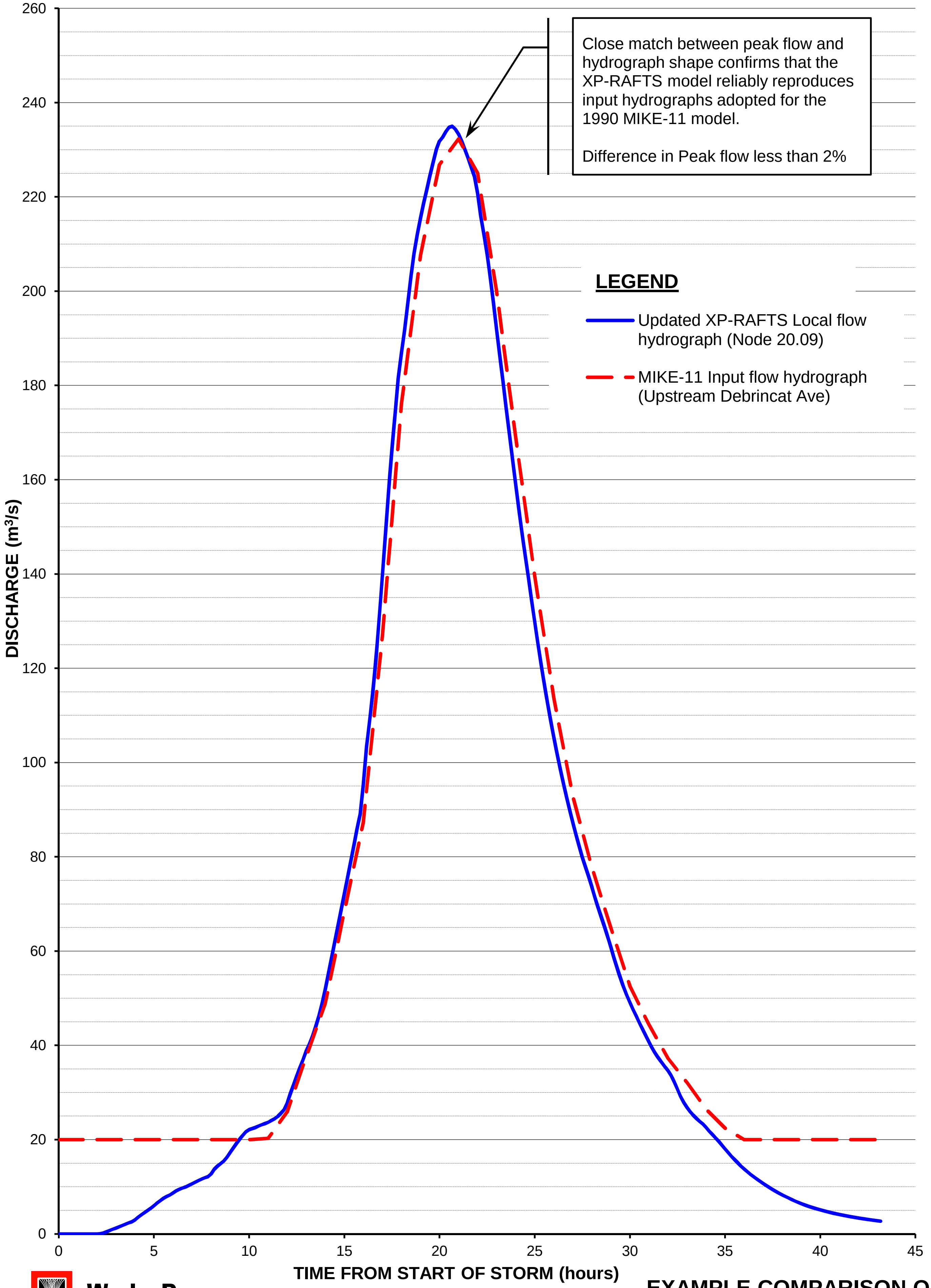
EXAMPLE COMPARISON OF DISCHARGE HYDROGRAPHS FROM XP-RAFTS AND MIKE-11 INPUT FOR KEMPS CREEK SUB-CATCHMENT 9.05



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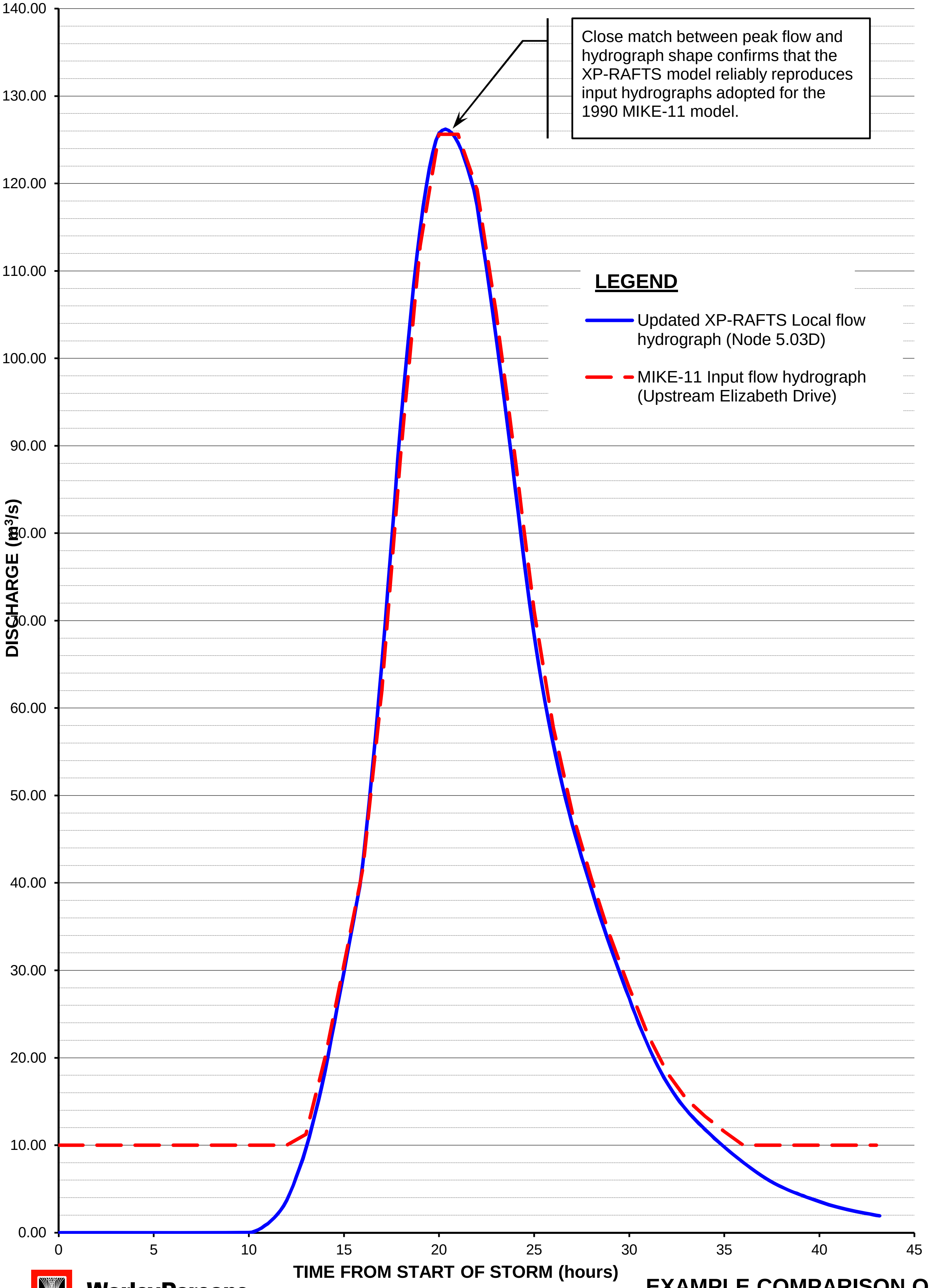
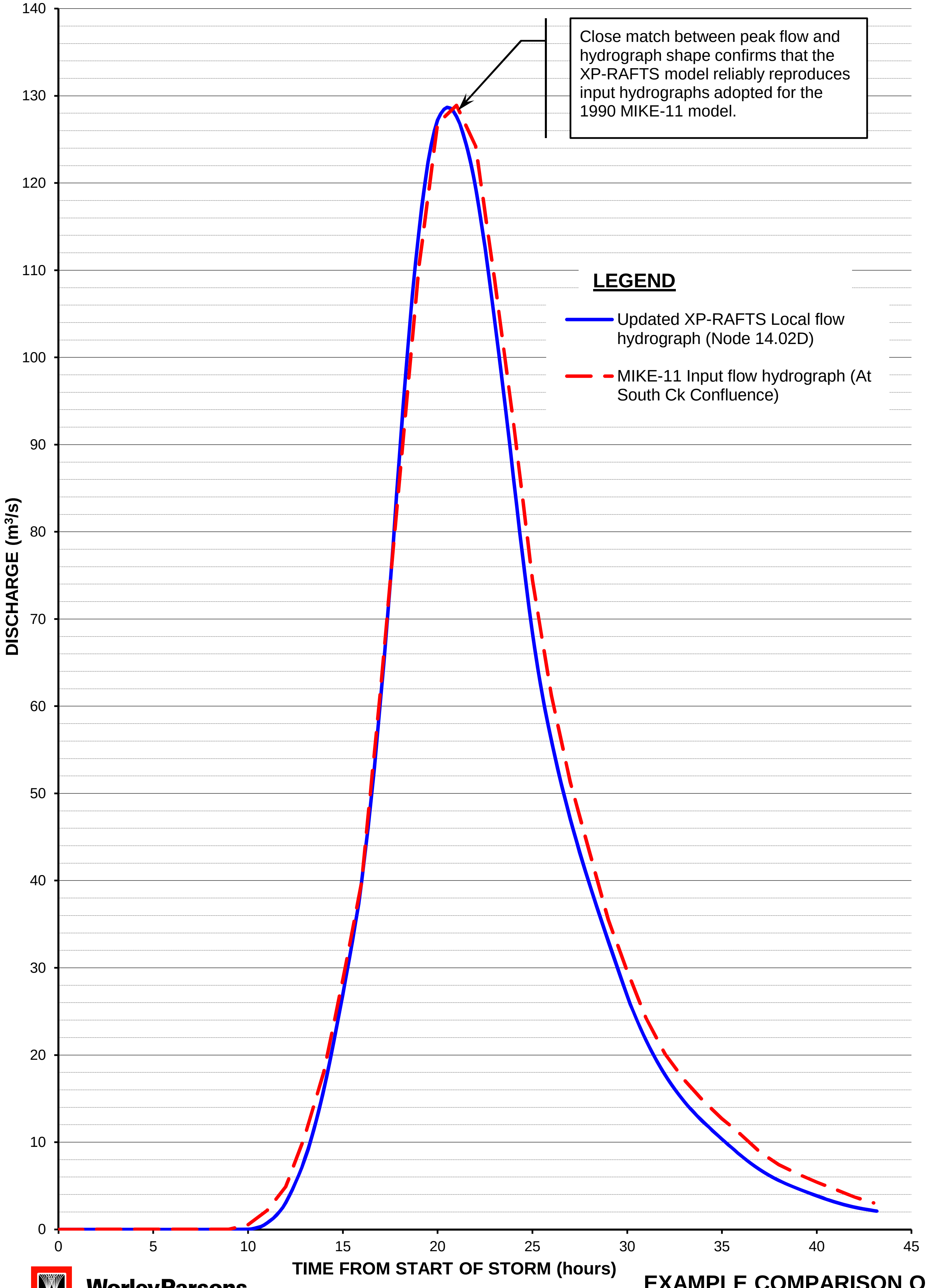
EXAMPLE COMPARISON OF DISCHARGE HYDROGRAPHS FROM XP-RAFTS AND MIKE-11 INPUT FOR ROPES CREEK SUB-CATCHMENT 20.09



Close match between peak flow and hydrograph shape confirms that the XP-RAFTS model reliably reproduces input hydrographs adopted for the 1990 MIKE-11 model.

EXAMPLE COMPARISON OF DISCHARGE HYDROGRAPHS FROM XP-RAFTS AND MIKE-11 INPUT FOR BADGERYS CREEK SUB-CATCHMENT 5.03D



Close match between peak flow and hydrograph shape confirms that the XP-RAFTS model reliably reproduces input hydrographs adopted for the 1990 MIKE-11 model.

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EXAMPLE COMPARISON OF DISCHARGE HYDROGRAPHS FROM XP-RAFTS AND MIKE-11 INPUT FOR BLAXLAND CREEK SUB-CATCHMENT 14.02D

APPENDIX C

RAFTS SENSITIVITY ANALYSIS

TABLE C1 - ADOPTED SCENARIOS FOR TESTING OF THE HYDROLOGIC MODEL

ID	DESCRIPTION
Scenario 1	Initial losses reduced to zero for all catchments (pervious and impervious)
Scenario 2	Continuing losses reduced to zero for all catchments (pervious and impervious)
Scenario 3	Initial and continuing losses reduced to zero for all catchments (Combination of Scenario 1 & 2)

TABLE C2 - XP-RAFTS SENSITIVITY ANALYSIS (36hr CRITICAL DURATION)______(1 of 3)

RAFTS NODE	BASE CASE	SCENARIO 1			SCENARIO 2			SCENARIO 3		
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF
1	29	29	0	0.0	31	1	4.9	31	1	4.9
1.01	51	51	0	0.1	53	3	5.0	53	3	5.0
1.02	75	75	0	0.0	79	4	4.9	79	4	5.0
1.03	114	114	0	0.1	120	6	4.9	120	6	5.0
1.04	130	130	0	0.1	137	7	5.0	137	7	5.1
1.06	207	207	0	0.1	218	11	5.1	218	11	5.2
1.08	312	312	0	0.1	328	16	5.2	328	17	5.3
1.09	350	350	0	0.1	368	19	5.3	369	19	5.4
1.1	354	354	0	0.1	373	19	5.4	373	19	5.5
1.12	436	437	1	0.1	460	23	5.4	460	24	5.5
1.13	479	480	1	0.3	505	26	5.5	506	27	5.7
1.14	493	494	1	0.3	520	28	5.6	521	29	5.9
1.15	641	643	2	0.4	677	37	5.7	679	39	6.0
1.17	943	947	5	0.5	1000	57	6.1	1004	61	6.5
1.19	1048	1055	7	0.7	1115	67	6.4	1121	73	7.0
1.21	1087	1095	8	0.7	1159	72	6.6	1166	79	7.2
1.23	1164	1174	10	0.9	1243	79	6.8	1252	88	7.6
1.24	1167	1177	11	0.9	1246	79	6.8	1256	89	7.6
1.26	1178	1188	11	0.9	1258	80	6.8	1267	90	7.6
1.29	1202	1214	11	0.9	1285	83	6.9	1295	93	7.7
1.31	1228	1241	12	1.0	1315	86	7.0	1326	97	7.9
1.32	1243	1256	13	1.0	1332	89	7.1	1343	100	8.0
1.33	1243	1256	13	1.0	1332	89	7.1	1343	100	8.1
1.35	1376	1398	22	1.6	1480	104	7.6	1500	124	9.0
1.37	1388	1411	23	1.7	1494	107	7.7	1516	128	9.2
1.38	1400	1425	25	1.8	1509	109	7.8	1532	133	9.5
1.4	1435	1469	34	2.4	1551	115	8.0	1583	148	10.3
2	37	37	0	0.0	39	2	4.9	39	2	5.0
2.01	77	77	0	0.0	81	4	5.0	81	4	5.0
3	27	27	0	0.0	28	1	4.7	28	1	4.8
3.01	58	58	0	0.0	61	3	4.8	61	3	4.9
3.02	80	80	0	0.1	84	4	5.3	84	4	5.4

NOTE: *Refer **Figure 5** for locations of XP-RAFTS sub-catchments*

TABLE C2 - XP-RAFTS SENSITIVITY ANALYSIS (36hr CRITICAL DURATION)______Continued (2 of 3)

RAFTS NODE	BASE CASE	SCENARIO 1			SCENARIO 2			SCENARIO 3		
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF
4.00	30	30	0	0.0	32	1	4.7	32	1	4.7
4.01	49	49	0	0.0	51	2	4.8	51	2	4.8
4.02	62	62	0	0.0	64	3	4.8	64	3	4.8
5.00	53	53	0	0.3	56	3	5.4	56	3	5.7
5.01	92	93	1	0.6	97	5	5.5	98	5	5.9
5.02	107	108	1	0.7	113	6	5.6	113	7	6.2
5.04	138	140	1	1.0	146	8	5.9	148	9	6.8
6.00	23	23	0	0.0	24	1	4.6	24	1	4.6
7.00	33	33	0	0.0	35	2	4.9	35	2	4.9
8.00	56	56	0	0.1	59	3	5.2	59	3	5.3
8.02	104	105	0	0.2	110	5	5.2	110	6	5.4
9.00	34	34	0	0.0	35	2	5.0	35	2	5.0
9.01	63	63	0	0.1	66	3	5.1	67	3	5.2
9.03	216	217	0	0.2	228	12	5.4	229	12	5.6
9.05	262	263	1	0.2	277	15	5.6	277	15	5.8
9.06	295	296	1	0.4	313	18	6.2	314	19	6.6
9.07	298	299	1	0.4	316	19	6.3	317	20	6.6
10.00	43	43	0	0.0	45	2	4.7	45	2	4.8
11.00	24	24	0	0.0	26	1	4.5	26	1	4.5
12.00	47	47	0	0.1	49	2	4.7	49	2	4.8
12.01	71	71	0	0.0	75	3	4.6	75	3	4.7
12.02	93	93	0	0.1	97	4	4.7	97	4	4.8
12.03	124	124	0	0.2	130	6	5.0	130	6	5.1
13.00	36	36	0	0.1	38	2	4.8	38	2	4.9
13.01	73	73	0	0.3	77	4	5.5	77	4	5.8
14.00	66	66	0	0.2	69	3	5.0	69	3	5.1
14.01	102	102	0	0.3	107	5	5.2	108	6	5.5
14.02	129	129	0	0.3	135	7	5.3	136	7	5.5
15.00	15	15	0	0.0	16	0	1.2	16	0	1.2
15.01	38	38	0	0.0	38	1	1.7	38	1	1.7
16.00	30	30	0	0.0	31	1	4.3	31	1	4.3
16.01	47	47	0	0.0	48	2	4.0	49	2	4.0
16.02	63	63	0	0.0	65	2	3.0	65	2	3.0
17.00	20	20	0	0.0	20	0	1.6	20	0	1.6
18.00	57	57	0	0.0	58	1	2.0	58	1	2.0
18.01	85	85	0	0.0	86	2	2.0	86	2	2.0
19.00	27	27	0	0.0	28	1	2.2	28	1	2.2
20.00	53	53	0	0.0	55	3	4.9	55	3	4.9
20.01	79	79	0	0.1	83	4	4.9	83	4	4.9
20.03	98	98	0	0.1	103	5	4.9	103	5	5.0
20.04	124	124	0	0.1	130	6	4.9	130	6	4.9
20.06	164	165	0	0.2	172	7	4.5	172	8	4.6
20.07	187	188	0	0.2	195	8	4.1	195	8	4.2
20.08	219	219	0	0.2	227	9	3.9	228	9	4.1
20.09	235	235	1	0.2	244	9	3.7	244	9	3.9
20.10	251	251	1	0.2	260	9	3.6	260	9	3.8
20.11	260	261	1	0.2	269	9	3.6	270	10	3.8

NOTE: *Refer* ***Figure 5*** *for locations of XP-RAFTS sub-catchments*

TABLE C2 - XP-RAFTS SENSITIVITY ANALYSIS (36hr CRITICAL DURATION)______Continued (3 of 3)

RAFTS NODE	BASE CASE	SCENARIO 1			SCENARIO 2			SCENARIO 3		
	Peak Flow (m^3/s)	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF
21	18	18	0	0.0	18	0	1.8	18	0	1.8
22	41	41	0	0.0	43	2	3.7	43	2	3.7
23	68	68	0	0.7	70	2	3.0	70	2	3.7
23.01	128	128	1	0.5	133	5	3.9	133	5	4.3
1.05D	130	130	0	0.1	137	7	5.0	137	7	5.1
1.07D	286	286	0	0.1	301	15	5.2	301	15	5.3
1.11D	412	412	1	0.1	434	22	5.3	434	22	5.4
1.16D	928	933	5	0.5	983	55	6.0	987	59	6.4
1.18D	1027	1033	6	0.6	1091	65	6.3	1096	70	6.8
1.20D	1086	1094	8	0.7	1157	71	6.6	1164	78	7.2
1.22D	1156	1166	10	0.9	1236	80	6.9	1244	88	7.6
1.25D	1175	1186	11	0.9	1255	80	6.8	1265	90	7.6
1.27D	1193	1204	11	0.9	1275	82	6.9	1285	92	7.7
1.28D	1198	1209	11	0.9	1280	82	6.9	1290	92	7.7
1.30D	1223	1234	12	0.9	1307	85	6.9	1318	95	7.8
1.34D	1370	1389	20	1.4	1472	102	7.5	1489	120	8.7
1.36D	1383	1405	22	1.6	1488	106	7.6	1509	126	9.1
1.39D	1433	1464	31	2.1	1547	114	8.0	1577	144	10.1
20.02D	79	79	0	0.1	83	4	4.9	83	4	4.9
20.04b	140	140	0	0.1	147	7	4.8	147	7	4.9
20.05D	153	153	0	0.1	160	7	4.6	160	7	4.7
5.03D	126	127	1	0.9	133	7	5.6	134	8	6.4
8.01D	88	89	0	0.1	93	5	5.1	93	5	5.2
9.04D	252	253	1	0.2	266	14	5.5	267	14	5.7
9.08D	298	299	1	0.4	316	19	6.3	317	20	6.6
Jtn9.02	168	168	0	0.2	176	9	5.2	177	9	5.3

NOTE: *Refer **Figure 5** for locations of XP-RAFTS sub-catchments*

TABLE C3 - XP-RAFTS SENSITIVITY ANALYSIS (TRIBUTARY BASED CRITICAL DURATIONS)

RAFTS NODE	BASE CASE	SCENARIO 1			SCENARIO 2			SCENARIO 3		
	Peak Flow (m3/s)	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF	Peak Flow (m^3/s)	DIFF (m^3/s)	% DIFF
4	38.3	38.7	0.4	1.0	39.9	1.6	1.0	40.3	2	5.2
4.01	59.9	60.8	0.9	1.5	62.5	2.6	1.5	63.4	3.5	5.8
4.02	74	75.1	1.1	1.5	77.2	3.2	1.5	78.4	4.4	5.9
16	32.6	35.6	3	9.2	34	1.4	9.2	37.1	4.5	13.8
16.01	51.3	57.1	5.8	11.3	53.2	1.9	11.3	59.1	7.8	15.2
16.02	64.7	70.8	6.1	9.4	66.5	1.8	9.4	72.8	8.1	12.5
18	141.4	143.2	1.8	1.3	141.5	0.1	1.3	143.4	2	1.4
18.01	167.8	173.1	5.3	3.2	168.1	0.3	3.2	173.5	5.7	3.4

NOTE: *Refer **Figure 5** for locations of XP-RAFTS sub-catchments*

APPENDIX D

COMPARISON OF 100 YEAR ARI FLOOD LEVELS (RMA-2 WITH PREVIOUS STUDIES)

TABLE D1 COMPARISON OF 100 YEAR LEVELS ALONG SOUTH CREEK TO PREVIOUS STUDIES

	KEY LOCATIONS ALONG SOUTH CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)		South Creek FPRMS (2004)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
SOUTH CREEK	Downstream Bringelly Road	58.8	58.3	0.50	58.27	0.53
	Bellfield Avenue	57.6	57.1	0.50	57.05	0.55
	Confluence with Thompsons Creek	53.3	/	/	53.31	-0.01
	Fifteenth Avenue	51.3	51.5	-0.20	51.46	-0.16
	Watts Road	49.8	49.9	-0.10	49.87	-0.07
	Victor Avenue	48.9	48.9	0.00	49.11	-0.21
	Overett Avenue	43.6	43.9	-0.30	43.36	0.24
	Upstream Elizabeth Drive	42.9	43.2	-0.30	42.64	0.26
	Downstream Elizabeth Drive	42.8	42.6	0.20	42.61	0.19
	Upstream End of South Creek Dam	38.1	38.6	-0.50	38.61	-0.51
	Bailey Bridge	35.3	35.1	0.20	/	/
	Upstream Sydney Water Pipeline	33.8	33.9	-0.10	/	/
	Downstream Sydney Water Pipeline	33.7	33.7	0.00	/	/
	Patons Lane	32.3	31.6	0.67	/	/
	150 metres Upstream Luddenham Road	30.1	30.1	0.00	/	/
	300 metres Downstream Luddenham Road	30.1	29.6	0.50	/	/
	Upstream Motorway (M4)	28.5	28.5	0.00	/	/
	Dowsntream Motorway (M4)	27.7	27.4	0.30	/	/
	Wilson Street	26.4	26.1	0.33	/	/
	Saddington Street	26.1	25.6	0.50	/	/
	Upstream Great Western Highway	25.7	25.4	0.30	/	/
	Downstream Great Western Highway	24.8	24.6	0.20	/	/
	Upstream Main Western Railway	23.9	23.5	0.40	/	/
	Downstream Main Western Railway	23.8	23.4	0.40	/	/
	Upstream Dunheved Road	22.6	22.6	0.00	/	/
	Downstream Dubheved Road	22.3	22.5	-0.20	/	/
	Upstream Links Road Railway	20.5	20.6	-0.10	/	/
	Dowsntream Links Road Railway	20.5	20.0	0.50	/	/
	Upstream Munitions Road	19.7	19.8	-0.10	/	/
	Downstream Munitions Road	19.6	19.6	0.00	/	/
	Ropes Creek Confluence	18.4	18.9	-0.50	/	/
	Seventh Avenue	18.1	17.2	0.90	/	/
	End of South Creek Road	17.6	17.0	0.60	/	/
	Mayo Road	17.5	17.0	0.50	/	/
	Stoney Creek Road	17.4	17.0	0.40	/	/
	Upstream Richmond Road	17.3	17.0	0.30	/	/
			Average Difference -	0.30	Average Difference -	0.27

TABLE D2 COMPARISON OF 100 YEAR LEVELS ALONG COSGROVES CREEK TO PREVIOUS STUDIES

	KEY LOCATIONS ALONG COSGROVES CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
COSGROVES CREEK	Upstream Private Bridge (Upstream Twin Creeks)	38.8	38.9	-0.10
	Downstream Private Bridge (Upstream Twin Creeks)	38.8	38.9	-0.10
	Upstream Twin Creek Drive	34.6	/	/
	Downstream Twin Creeks Drive	34.4	/	/
			Average Difference -	0.10

TABLE D3 COMPARISON OF 100 YEAR LEVELS ALONG THOMPSONS CREEK TO PREVIOUS STUDIES

	KEY LOCATIONS ALONG THOMPSONS CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)		South Creek FPRMS (2004)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
THOMPSONS CREEK	Downstream Northern Road	69.5	69.8	-0.30	69.77	-0.27
	Kelvin Park Drive	64.4	/	/	64.46	-0.06
	120 metres Upstream The Retreat	59.7	/	/	59.07	0.63
	Upstream The Retreat Road	59.2	58.9	0.30	58.90	0.30
	Dowsntream The Retreat Road	59.1	58.6	0.50	58.80	0.30
	250 m U/S of South Creek	53.4	53.0	0.40	53.10	0.30
	At Confluence with South Creek	53.3	/	/	53.31	-0.01
			Average Difference -	0.38	Average Difference -	0.27

TABLE D4 COMPARISON OF 100 YEAR LEVELS ALONG KEMPS CREEK TO PREVIOUS STUDIES

	KEY LOCATIONS ALONG KEMPS CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)		Austral FPRMS (2003)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
KEMPS CREEK	Downstream Bringelly Road	74.3	74.0	0.30	74.00	0.30
	Little Street	67.7	68.2	-0.50	/	/
	East of Devonshire Road	63.9	63.3	0.60	/	/
	Twelfth Avenue	60.2	59.6	0.60	60.10	0.10
	Fourteenth Avenue	58.4	58.0	0.40	58.10	0.30
	Upstream Fifteenth Avenue	57.4	57.4	0.00	57.50	-0.10
	Dowsntream Fifteenth Avenue	57.2	57.3	-0.10	56.90	0.30
	Upstream Gurner Avenue	55.4	55.4	0.00	55.30	0.10
	Downstream Gurner Avenue	55.3	55.3	0.00	/	/
	East of Tavistock Road	50.3	50.2	0.10	/	/
	Upstream Cross Street	48.1	48.3	-0.20	/	/
	Upstream Elizabeth Drive	47.7	47.6	0.10	47.70	0.00
	Downstream Elizabeth Drive	46.7	46.6	0.10	46.50	0.20
	Adjacent to Kerrs Road	43.7	43.4	0.30	/	/
	Upstream End of Kemps Creek Dam	38.6	38.7	-0.10	/	/
	At Confluence with South Creek	35.6	35.1	0.50	/	/
			Average Difference -	0.24	Average Difference -	0.18

TABLE D5 **COMPARISON OF 100 YEAR LEVELS ALONG BADGERYS CREEK TO PREVIOUS STUDIES**

	KEY LOCATIONS ALONG BADGERYS CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
BADGERYS CREEK	Downstream Badgerys Creek Road	58.9	58.2	0.70
	East of Green Street	55.4	55.3	0.10
	East of Leggo Street	53.6	53.9	-0.30
	Upstream Pitt Street	50.6	50.8	-0.20
	Downstream Pitt Street	50.5	50.8	-0.30
	Upstream Elizabeth Drive	46.5	46.6	-0.10
	Downstream Elizabeth Drive	46.2	46.4	-0.20
	At Confluence with South Creek	37.9	38.6	-0.70
			Average Difference -	0.32

TABLE D6 **COMPARISON OF 100 YEAR LEVELS ALONG CLAREMONT CREEK TO PREVIOUS STUDIES**

	KEY LOCATIONS ALONG CLAREMONT CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
CLAREMONT CREEK	Downstream Castle Road	39.0	39.1	-0.10
	Upstream Caddens Road	34.1	35.2	-1.10
	Downstream Caddens Road	33.9	35.1	-1.20
	Apex Trotting Track	/	33.3	/
	Upstream O'Connel Street	30.5	30.3	0.20
	Downstream O'Connel Street	29.9	29.9	0.00
	Upstream Sunflower Drive	28.5	28.8	-0.30
	Downstream Sunflower Drive	28.2	28.0	0.20
	Upstream Great Western Highway	26.9	26.9	0.00
	Downstream Great Western Highway	26.2	26.3	-0.10
	Upstream Werrington Road	24.2	23.8	0.38
	Downstream Werrington Road	24.2	23.8	0.38
	At Confluence with South Creek	23.9	23.8	0.10
			Average Difference -	0.34

TABLE D7 **COMPARISON OF 100 YEAR LEVELS ALONG WERRINGTON CREEK TO PREVIOUS STUDIES**

	KEY LOCATIONS ALONG WERRINGTON CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
WERRINGTON CREEK	William Street Footbridge	29.4	29.5	-0.10
	Upstream Burton Street	27.8	28.0	-0.20
	Downstream Burton Street	27.6	27.8	-0.20
	Upstream John Oxley Drive	25.0	24.8	0.20
	Downstream John Oxley Drive	24.7	24.8	-0.10
	40m Upstream Dunheved Road	21.7	21.7	0.00
			Average Difference -	0.10

TABLE D8 COMPARISON OF 100 YEAR LEVELS ALONG ROPES CREEK TO PREVIOUS STUDIES

	KEY LOCATIONS ALONG ROPES CREEK	Updated South Creek Flood Study (2013)	South Creek Flood Study (1990)	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
ROPES CREEK	Downstream Capital Hill Drive	69.1	/	
	Upstream Sydney Water Pipeline	54.0	53.8	0.20
	Downstream Sydney Water Pipeline	53.9	53.8	0.10
	Upstream Motorway (M4)	42.5	41.9	0.60
	Dowsntream Motorway (M4)	41.9	41.8	0.10
	Upstream Carlisle Avenue	39.2	39.4	-0.20
	Downstream Carlisle Avenue	39.2	39.3	-0.10
	Upstream Great Western Highway	36.7	36.1	0.60
	Downstream Great Western Highway	36.3	36.0	0.30
	Upstream Durham Street	33.7	33.3	0.40
	Downstream Durham Street	33.5	33.2	0.30
	Upstream Main Western Railway	32.9	32.7	0.20
	Downstream Main Western Railway	32.7	32.7	0.00
	Downstream Debrincat Avenue	28.6	28.6	0.00
	Upstream Forresters Road	24.7	24.7	0.00
	Downstream Forresters Road	24.5	24.6	-0.10
	Upstream Munitions Railway / Ropes Crossing Boulevard	23.7	23.9	-0.20
	Downstream Munitions Railway / Ropes Crossing Bouleva	23.4	22.7	0.70
	Upstream Munitions Road	19.4	19.7	-0.30
	Downstream Munitions Road	19.4	19.3	0.10
	At Confluence with South Creek	18.4	18.9	-0.50
			Average Difference -	0.25

APPENDIX E

COMPARISON OF RMA-2 AND MIKE-11 HYDROGRAPHS

FIGURE E1

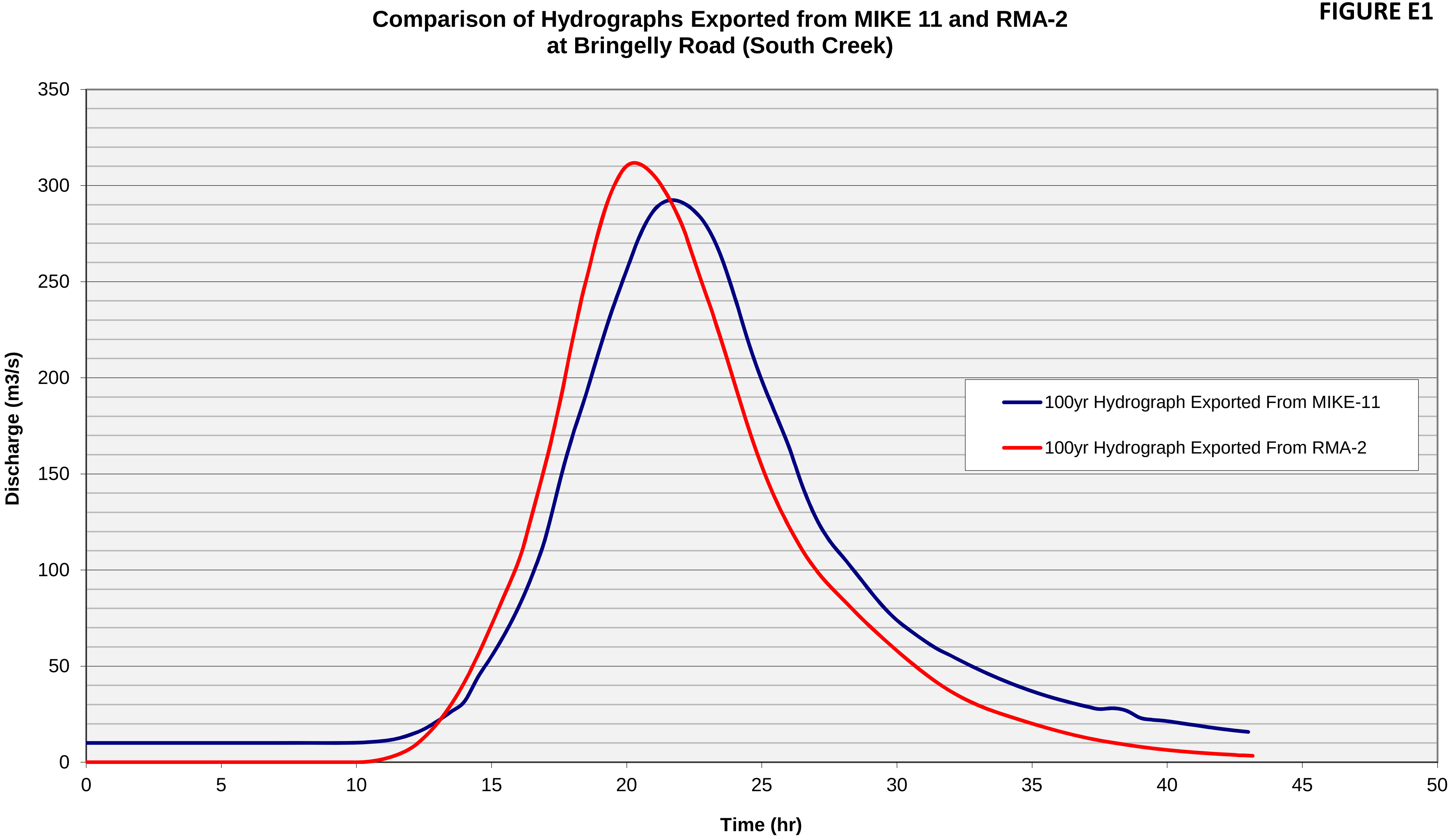
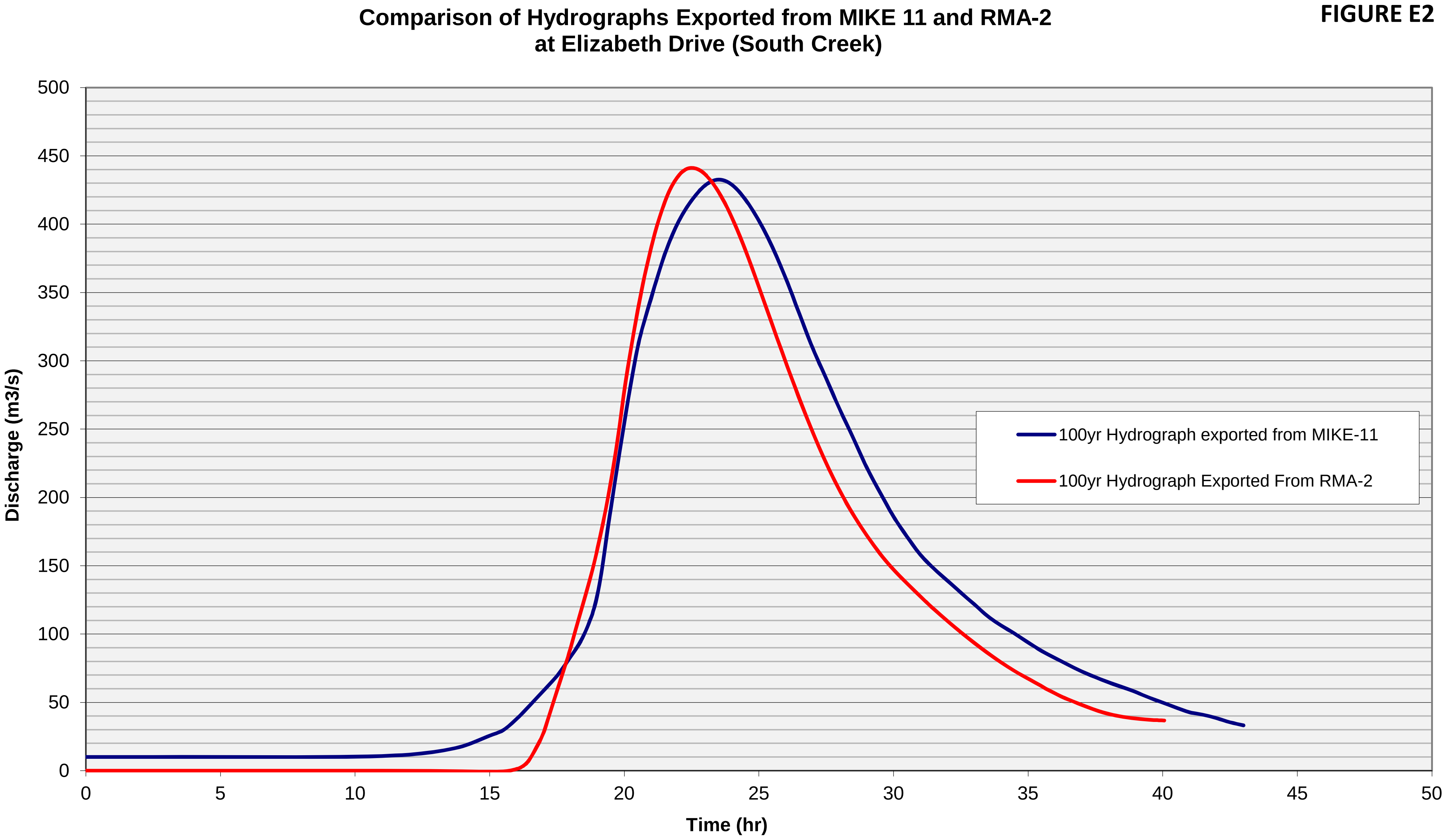

Comparison of Hydrographs Exported from MIKE 11 and RMA-2
at Bringelly Road (South Creek)
Discharge (m3/s)
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
Time (hr)
100yr Hydrograph Exported From MIKE-11
100yr Hydrograph Exported From RMA-2

FIGURE E2



Comparison of Hydrographs Exported from MIKE 11 and RMA-2
at Elizabeth Drive (South Creek)
Discharge (m3/s)
500
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
35
40
45
50
Time (hr)
100yr Hydrograph exported from MIKE-11
100yr Hydrograph Exported From RMA-2

FIGURE E3

Comparison of Hydrographs Exported from MIKE 11 and RMA-2
at Warragamba Pipeline (South Creek)

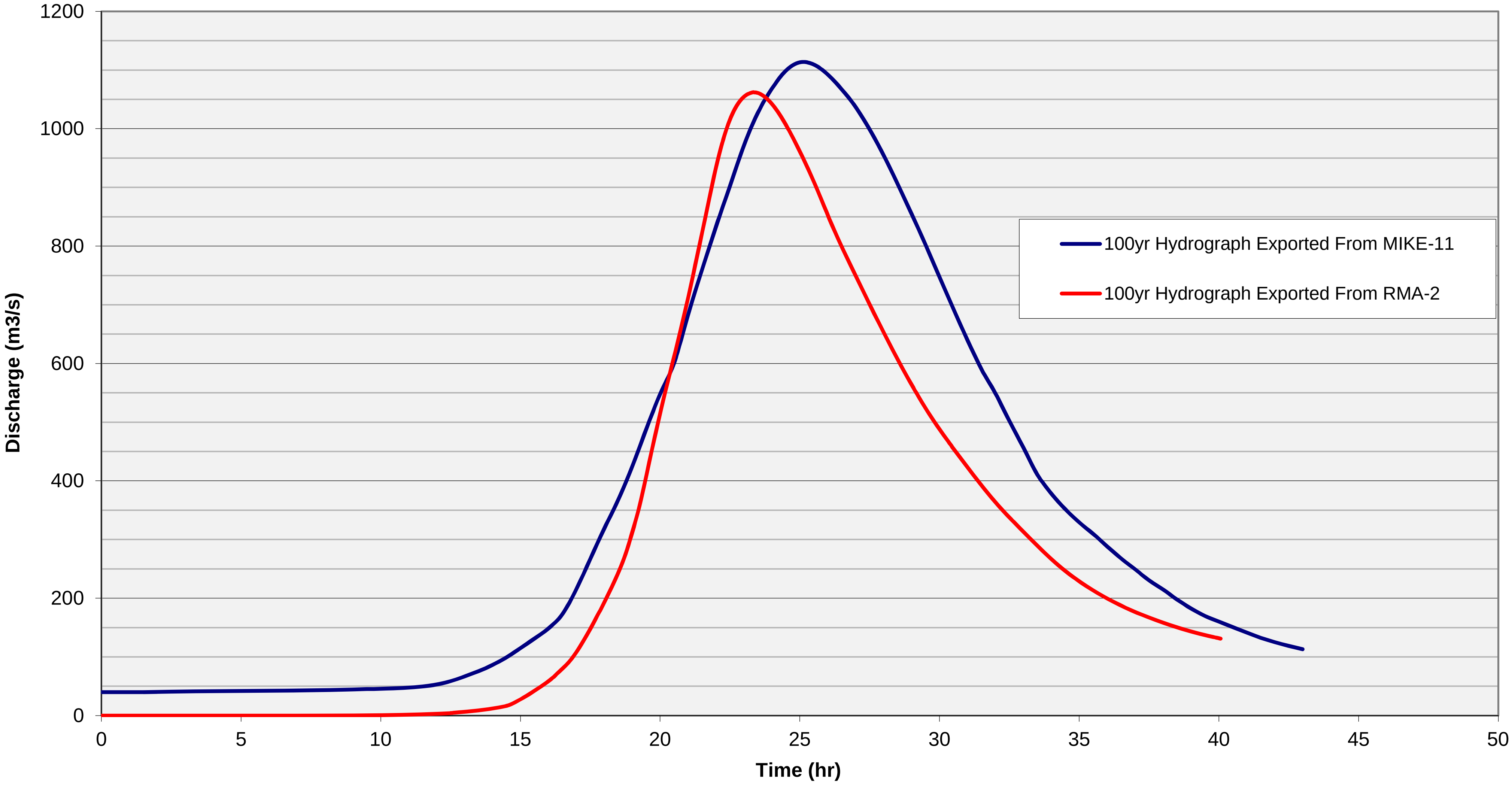


FIGURE E4

Comparison of Hydrographs Exported from MIKE 11 and RMA-2 at M4 Motorway (South Creek)

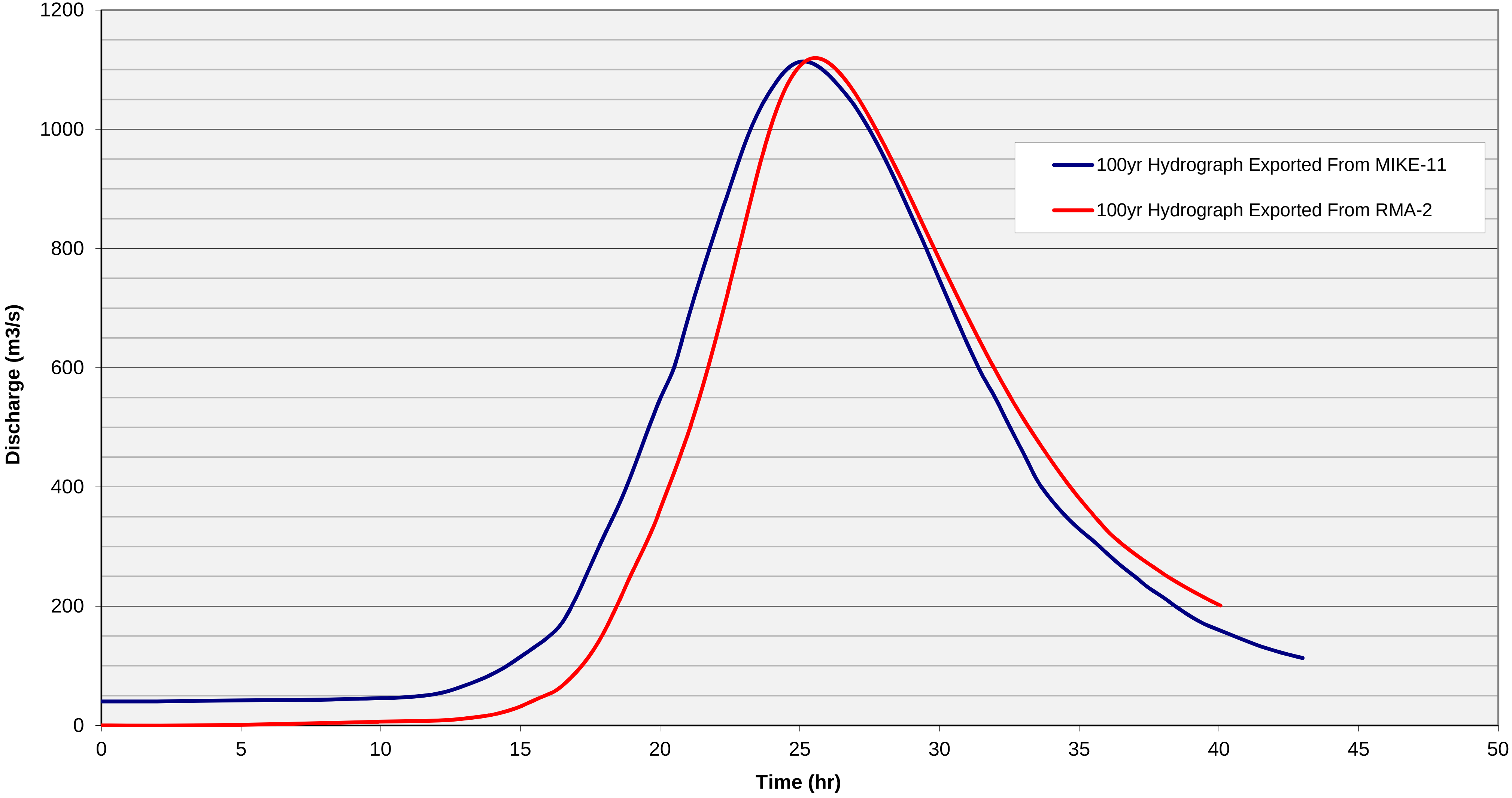
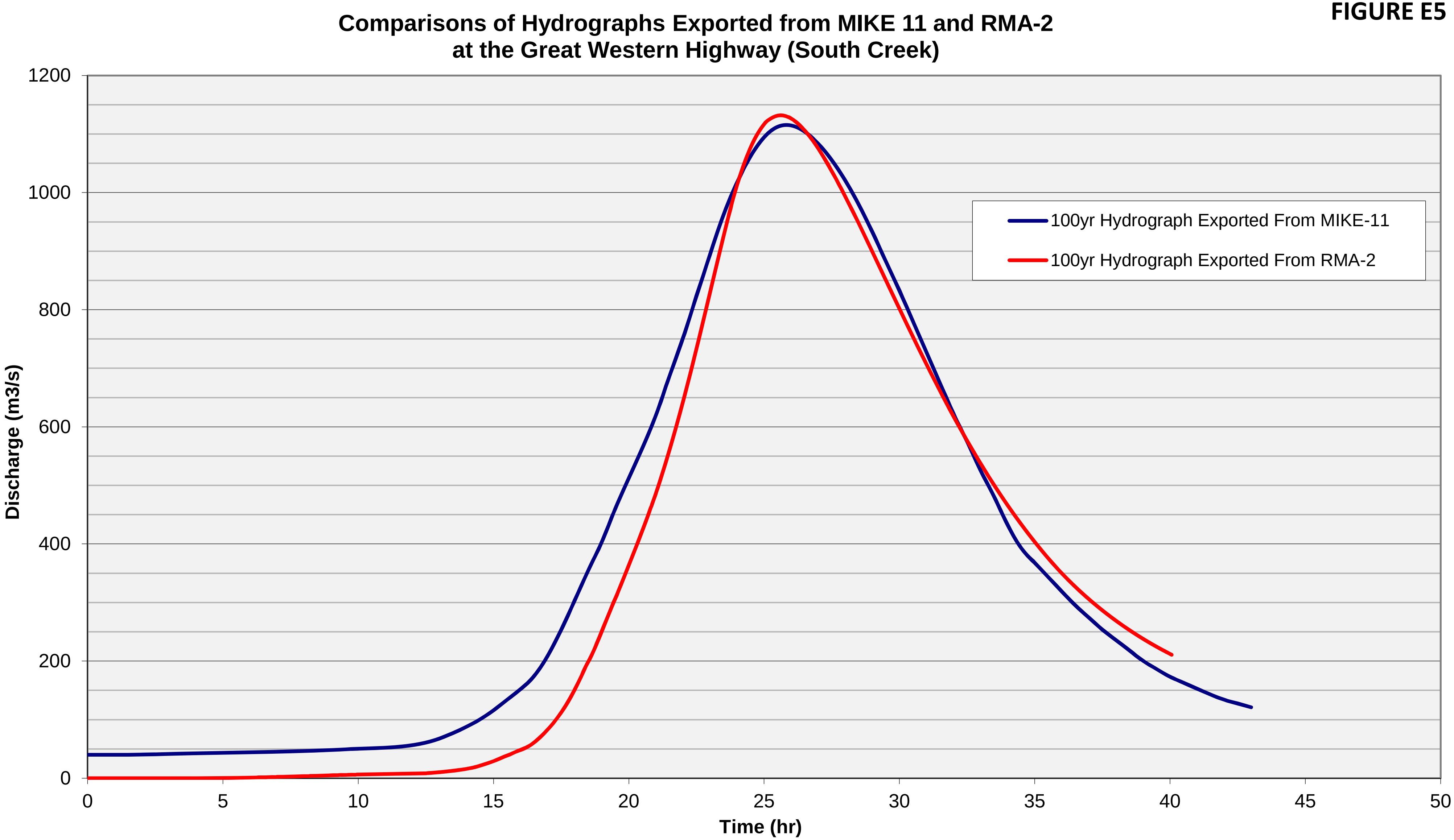


FIGURE E5


Comparisons of Hydrographs Exported from MIKE 11 and RMA-2
at the Great Western Highway (South Creek)
Discharge (m3/s)
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
40
45
50
Time (hr)
100yr Hydrograph Exported From MIKE-11
100yr Hydrograph Exported From RMA-2

Comparison of Hydrographs Exported from MIKE 11 and RMA-2 at the South & Ropes Creek Confluence (South Creek)

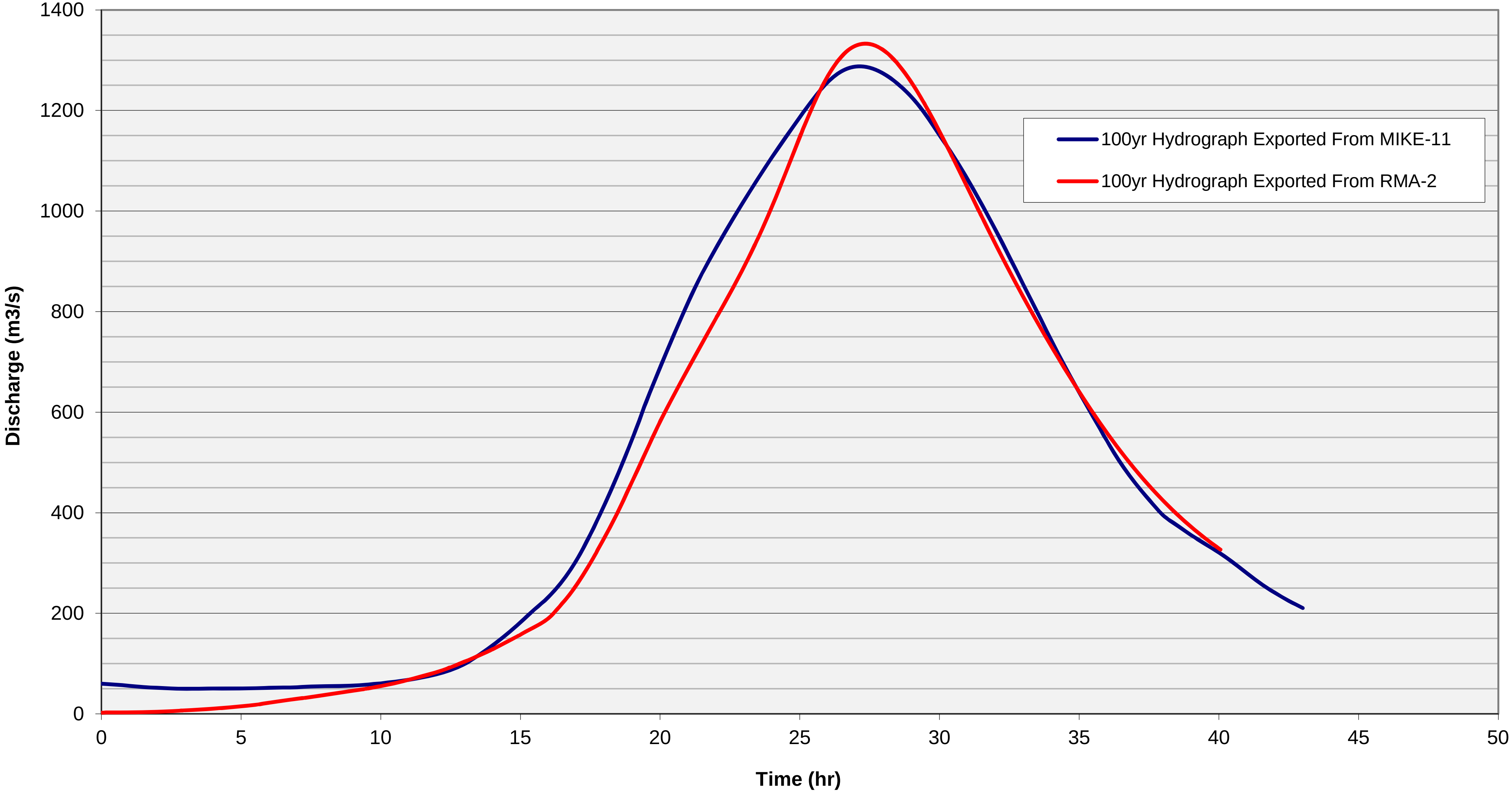
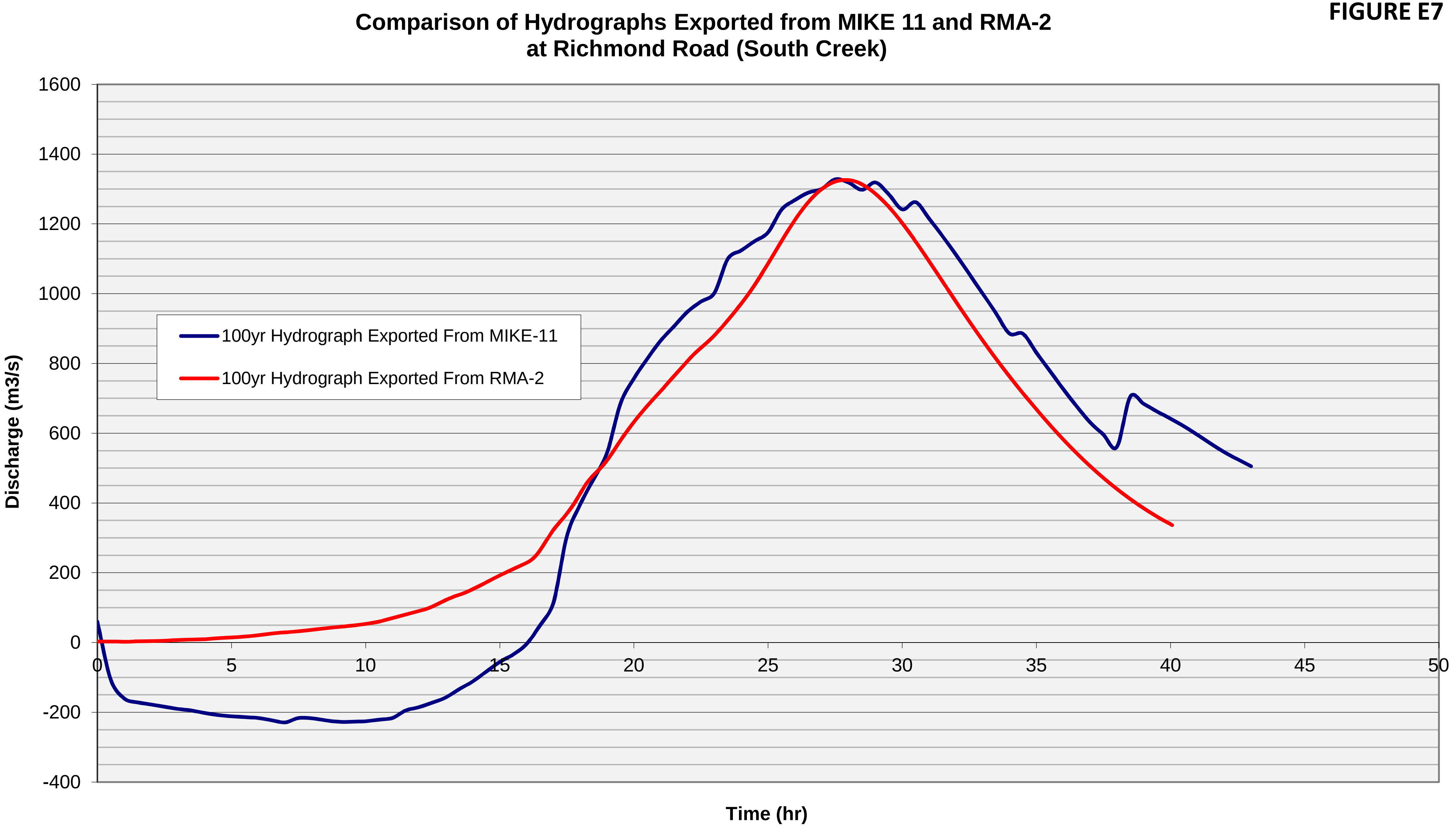


FIGURE E7


Comparison of Hydrographs Exported from MIKE 11 and RMA-2
at Richmond Road (South Creek)
Discharge (m3/s)
1600
1400
1200
1000
800
600
400
200
0
-200
-400
0
5
10
15
20
25
30
35
40
45
50
Time (hr)
100yr Hydrograph Exported From MIKE-11
100yr Hydrograph Exported From RMA-2

APPENDIX F

RMA-2 SENSITIVITY ANALYSIS

TABLE F1　　RESULTS OF SENSITIVITY ANALYSIS ALONG SOUTH CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG SOUTH CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
SOUTH CREEK	Downstream Bringelly Road	58.8	58.6	-0.20	58.96	0.16
	Bellfield Avenue	57.6	57.45	-0.15	57.73	0.13
	Confluence with Thompsons Creek	53.3	53.18	-0.12	53.41	0.11
	Fifteenth Avenue	51.3	51.16	-0.14	51.43	0.13
	Watts Road	49.8	49.67	-0.13	49.92	0.12
	Victor Avenue	48.9	48.78	-0.12	49.01	0.11
	Overett Avenue	43.6	43.43	-0.17	43.74	0.14
	Upstream Elizabeth Drive	42.9	42.75	-0.15	43.02	0.12
	Downstream Elizabeth Drive	42.8	42.68	-0.12	42.90	0.10
	Upstream End of South Creek Dam	38.1	37.99	-0.11	38.19	0.09
	Bailey Bridge	35.3	35.04	-0.26	35.51	0.21
	Upstream Sydney Water Pipeline	33.8	33.65	-0.15	33.93	0.13
	Downstream Sydney Water Pipeline	33.7	33.56	-0.14	33.83	0.13
	Patons Lane	32.3	32.09	-0.18	32.42	0.15
	150 metres Upstream Luddenham Road	30.1	29.90	-0.20	30.27	0.17
	300 metres Downstream Luddenham Road	30.1	29.89	-0.21	30.28	0.18
	Upstream Motorway (M4)	28.5	28.22	-0.28	28.69	0.19
	Dowsntream Motorway (M4)	27.7	27.43	-0.27	27.91	0.21
	Wilson Street	26.4	26.24	-0.19	26.61	0.18
	Saddington Street	26.1	25.95	-0.15	26.24	0.14
	Upstream Great Western Highway	25.7	25.56	-0.14	25.84	0.14
	Downstream Great Western Highway	24.8	24.58	-0.22	24.99	0.19
	Upstream Main Western Railway	23.9	23.71	-0.19	24.07	0.17
	Downstream Main Western Railway	23.8	23.58	-0.22	23.97	0.17
	Upstream Dunheved Road	22.6	22.43	-0.17	22.74	0.14
	Downstream Dubheved Road	22.3	22.15	-0.15	22.43	0.13
	Upstream Links Road Railway	20.5	20.31	-0.19	20.65	0.15
	Dowsntream Links Road Railway	20.5	20.32	-0.18	20.65	0.15
	Upstream Munitions Road	19.7	19.53	-0.17	19.85	0.15
	Downstream Munitions Road	19.6	19.34	-0.22	19.75	0.19
	Ropes Creek Confluence	18.4	18.22	-0.18	18.56	0.16
	Seventh Avenue	18.1	17.97	-0.13	18.21	0.11
	End of South Creek Road	17.6	17.54	-0.06	17.66	0.06
	Mayo Road	17.5	17.47	-0.03	17.53	0.03
	Stoney Creek Road	17.4	17.39	-0.01	17.41	0.01
	Upstream Richmond Road	17.3	17.30	0.00	17.30	0.00
			Average Difference -	-0.16	Average Difference -	0.14

TABLE F2 RESULTS OF SENSITIVITY ANALYSIS ALONG COSGROVES CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG COSGROVES CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
COSGROVES CREEK	Upstream Private Bridge (Upstream Twin Creeks)	38.8	38.71	-0.09	38.88	0.08
	Downstream Private Bridge (Upstream Twin Creeks)	38.8	38.71	-0.09	38.88	0.08
	Upstream Twin Creek Drive	34.6	34.44	-0.16	34.74	0.14
	Downstream Twin Creeks Drive	34.4	34.29	-0.11	34.50	0.10
			Average Difference -	-0.11	Average Difference -	0.10

TABLE F3 RESULTS OF SENSITIVITY ANALYSIS ALONG THOMPSONS CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG THOMPSONS CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
THOMPSONS CREEK	Downstream Northern Road	69.5	69.20	-0.30	69.64	0.14
	Kelvin Park Drive	64.4	64.25	-0.15	64.52	0.12
	120 metres Upstream The Retreat	59.7	59.60	-0.10	59.77	0.07
	Upstream The Retreat Road	59.2	59.10	-0.10	59.27	0.07
	Dowsntream The Retreat Road	59.1	59.00	-0.10	59.16	0.06
	250 m U/S of South Creek	53.4	53.30	-0.10	53.49	0.09
	At Confluence with South Creek	53.3	53.18	-0.12	53.41	0.11
			Average Difference -	-0.14	Average Difference -	0.09

TABLE F4 RESULTS OF SENSITIVITY ANALYSIS ALONG KEMPS CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG KEMPS CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
KEMPS CREEK	Downstream Bringelly Road	74.3	74.23	-0.07	74.36	0.06
	Little Street	67.7	67.62	-0.08	67.77	0.07
	East of Devonshire Road	63.9	63.80	-0.10	63.99	0.09
	Twelfth Avenue	60.2	60.13	-0.07	60.26	0.06
	Fourteenth Avenue	58.4	58.30	-0.10	58.48	0.08
	Upstream Fifteenth Avenue	57.4	57.32	-0.08	57.47	0.07
	Dowsntream Fifteenth Avenue	57.2	57.13	-0.07	57.26	0.06
	Upstream Gurner Avenue	55.4	55.30	-0.10	55.48	0.08
	Downstream Gurner Avenue	55.3	55.20	-0.10	55.39	0.09
	East of Tavistock Road	50.3	50.19	-0.11	50.40	0.10
	Upstream Cross Street	48.1	47.94	-0.16	48.24	0.14
	Upstream Elizabeth Drive	47.7	47.59	-0.11	47.80	0.10
	Downstream Elizabeth Drive	46.7	46.53	-0.17	46.84	0.14
	Adjacent to Kerrs Road	43.7	43.51	-0.19	43.85	0.15
	Upstream End of Kemps Creek Dam	38.6	38.49	-0.11	38.70	0.10
	At Confluence with South Creek	35.6	35.34	-0.26	35.81	0.21
			Average Difference -	-0.12	Average Difference -	0.10

TABLE F5 RESULTS OF SENSITIVITY ANALYSIS ALONG BADGERYS CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG BADGERYS CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
BADGERYS CREEK	Downstream Badgerys Creek Road	58.9	58.76	-0.14	59.03	0.13
	East of Green Street	55.4	55.31	-0.09	55.47	0.07
	East of Leggo Street	53.6	53.51	-0.09	53.68	0.08
	Upstream Pitt Street	50.6	50.47	-0.13	50.71	0.11
	Downstream Pitt Street	50.5	50.37	-0.13	50.61	0.11
	Upstream Elizabeth Drive	46.5	46.38	-0.12	46.58	0.08
	Downstream Elizabeth Drive	46.2	46.11	-0.09	46.27	0.07
	At Confluence with South Creek	37.9	37.82	-0.08	37.98	0.08
			Average Difference -	-0.11	Average Difference -	0.09

TABLE F6 RESULTS OF SENSITIVITY ANALYSIS ALONG CLAREMONT CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG CLAREMONT CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
CLAREMONT CREEK	Downstream Castle Road	39.0	38.86	-0.14	39.12	0.12
	Upstream Caddens Road	34.1	33.99	-0.11	34.20	0.10
	Downstream Caddens Road	33.9	33.78	-0.12	34.02	0.12
	Upstream O'Connel Street	30.5	30.38	-0.12	30.61	0.11
	Downstream O'Connel Street	29.9	29.62	-0.28	30.05	0.15
	Upstream Sunflower Drive	28.5	28.33	-0.17	28.63	0.13
	Downstream Sunflower Drive	28.2	28.04	-0.16	28.33	0.13
	Upstream Great Western Highway	26.9	26.80	-0.10	26.97	0.07
	Downstream Great Western Highway	26.2	26.08	-0.12	26.29	0.09
	Upstream Werrington Road	24.2	23.98	-0.20	24.35	0.17
	Downstream Werrington Road	24.2	23.98	-0.20	24.35	0.17
	At Confluence with South Creek	23.9	23.71	-0.19	24.07	0.17
			Average Difference -	-0.16	Average Difference -	0.13

TABLE F7 RESULTS OF SENSITIVITY ANALYSIS ALONG WERRINGTON CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG WERRINGTON CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)	100yr ARI Levels (*mAHD*)	Level Difference (*metres*)
WERRINGTON CREEK	William Street Footbridge	29.4	29.19	-0.21	29.57	0.17
	Upstream Burton Street	27.8	27.69	-0.11	27.89	0.09
	Downstream Burton Street	27.6	27.49	-0.11	27.69	0.09
	Upstream John Oxley Drive	25.0	24.73	-0.27	25.22	0.22
	Downstream John Oxley Drive	24.7	24.49	-0.21	24.87	0.17
	40m Upstream Dunheved Road	21.7	21.58	-0.12	21.81	0.11
			Average Difference -	-0.17	Average Difference -	0.14

TABLE F8 RESULTS OF SENSITIVITY ANALYSIS ALONG ROPES CREEK (ROUGHNESS VALUES)

	KEY LOCATIONS ALONG ROPES CREEK	BASE CASE	- 20% ROUGHNESS		+ 20% ROUGHNESS	
		100yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD)*	Level Difference (*metres*)	100yr ARI Levels (*mAHD)*	Level Difference (*metres*)
ROPES CREEK	Downstream Capital Hill Drive	69.1	68.96	-0.14	69.17	0.07
	Upstream Sydney Water Pipeline	54.0	53.93	-0.07	54.06	0.06
	Downstream Sydney Water Pipeline	53.9	53.84	-0.06	53.95	0.05
	Upstream Motorway (M4)	42.5	42.26	-0.24	42.71	0.21
	Dowsntream Motorway (M4)	41.9	41.74	-0.16	42.04	0.14
	Upstream Carlisle Avenue	39.2	39.01	-0.19	39.36	0.16
	Downstream Carlisle Avenue	39.2	39.02	-0.18	39.35	0.15
	Upstream Great Western Highway	36.7	36.52	-0.18	36.86	0.16
	Downstream Great Western Highway	36.3	36.12	-0.18	36.46	0.16
	Upstream Durham Street	33.7	33.58	-0.12	33.80	0.10
	Downstream Durham Street	33.5	33.35	-0.15	33.62	0.12
	Upstream Main Western Railway	32.9	32.74	-0.16	33.04	0.14
	Downstream Main Western Railway	32.7	32.58	-0.12	32.78	0.08
	Downstream Debrincat Avenue	28.6	28.52	-0.08	28.67	0.07
	Upstream Forresters Road	24.7	24.60	-0.10	24.78	0.08
	Downstream Forresters Road	24.5	24.40	-0.10	24.58	0.08
	Upstream Munitions Railway / Ropes Crossing Boulevard	23.7	23.56	-0.14	23.79	0.09
	Downstream Munitions Railway / Ropes Crossing Bouleva	23.4	23.26	-0.14	23.49	0.09
	Upstream Munitions Road	19.4	19.23	-0.17	19.55	0.15
	Downstream Munitions Road	19.4	19.19	-0.21	19.58	0.18
	At Confluence with South Creek	18.4	18.22	-0.18	18.56	0.16
			Average Difference -	-0.15	Average Difference -	0.12

APPENDIX G

RAFTS MODEL OUTPUT FOR DESIGN FLOOD EVENTS

##

Modelling Results for 20 yr ARI Storm (36 Hour Storm Duration)

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 20
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)	(%)	(%)								
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342	1
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0	1.001
9	583	0	0.7	0	2	0	0.025	0	1.012	0	2
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	2.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	3
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	4
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	3.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	3.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	2.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	5
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	2.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	2.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	2.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.008
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	6
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	6.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	6.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	6.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	6.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	6.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	7
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	7.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	6.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	8
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	8.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	8.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	6.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	6.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	6.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	6.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	6.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	6.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	10
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	10
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	10
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	11
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	10
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	10
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	6.015
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.009
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	2.01
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	12
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	13
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	12
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	12
12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	12
1.18D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.011
1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033	2.012
13	614	0	0.66	0	0.1	0	0.025	0	1.166	0	14
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0	14

1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.013
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306	2.014
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0	15
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0	15
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0	15
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.015
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349	2.016
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0	2.017
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505	16
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663	16
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.018
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369	2.019
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.02
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636	18
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.021
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055	2.022
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	19
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	19
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.023
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0	2.024
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611	20
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547	2.025
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0	2.026
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855	21
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0	22
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199	22
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0	22
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0	22
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001	22
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001	22
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	21
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533	21
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235	21
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715	21
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488	21
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522	21.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0	21.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.027
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0	2.028
22	547	0	0.68	0	17	0	0.025	0	0.5623	0	23
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.029
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0	2.03
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0	2.031
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.002
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0	1.003

Link	Average	Initial Loss		Cont. Loss		Excess Rain		Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
(mm/h)	(mm/h)		(mm)		(mm/h)		(mm)	(m^3/s)	Peak	mins
23	5.704	36.6	1	0.94	0	147.89	204.34	50.301	1080	0
23.01	5.704	36.6	0	0.94	0	147.89	0	94.843	1180	0
9	5.289	33.9	0	0.94	0	135.8	0	25.76	1170	0
9.01	5.367	33.9	0	0.94	0	138.47	0	48.228	1210	0
8	5.289	33.9	0	0.94	0	135.8	0	42.61	1200	0
7	5.289	33.9	0	0.94	0	135.8	0	25.336	1160	0
8.01D	0.01	0	0	0	0	0.36	0	67.617	1200	0
8.02	5.518	33.9	0	0.94	0	143.66	0	79.078	1230	0
Jtn9.02	0.01	0	0	0	0	0.36	0	127.13	1220	0
9.03	5.518	33.9	0	0.94	0	143.66	0	163.4	1320	0
10	5.518	33.9	0	0.94	0	143.66	0	32.916	1180	0
9.04D	0.01	0	0	0	0	0.36	0	190.15	1310	0
9.05	5.518	33.9	0	0.94	0	143.66	0	197.41	1320	0
9.06	5.518	33.9	0	0.94	0	143.66	0	219.74	1430	10
9.07	5.44	33.9	0	0.94	0	141.02	0	221.43	1440	10
9.08D	0.01	0	0	0	0	0.36	0	221.33	1460	0
1	5.289	35.9	0	0.94	0	134.09	0	22.338	1160	0
1.01	5.289	35.9	0	0.94	0	134.09	0	38.789	1180	0
1.02	5.289	35.9	0	0.94	0	134.09	0	57.524	1180	0
1.03	5.292	35.9	0	0.94	0	134.19	0	87.32	1200	0
1.04	5.292	35.9	0	0.94	0	134.19	0	99.111	1240	0
1.05D	0.01	0	0	0	0	0.36	0	99.111	1240	0

2	5.292	35.9	0	0.94	0	134.19	0	28.429	1150	0
2.01	5.292	35.9	0	0.94	0	134.19	0	59.113	1200	0
1.06	5.367	35.9	0	0.94	0	136.73	0	156.92	1230	0
3	5.289	35.9	0	0.94	0	134.09	0	20.347	1130	0
3.01	5.289	35.9	0	0.94	0	134.09	0	45.144	1200	0
3.02	5.289	35.9	0	0.94	0	134.09	0	61.855	1270	0
1.07D	0.01	0	0	0	0	0.36	0	218.1	1240	0
1.08	5.367	35.9	0	0.94	0	136.73	0	237.38	1250	0
1.09	5.367	35.9	0	0.94	0	136.73	0	266.31	1260	0
1.1	5.367	35.9	0	0.94	0	136.73	0	269.37	1280	0
4	5.367	15	0	0.94	0	154.02	0	23.534	1110	0
4.01	5.367	15	0	0.94	0	154.02	0	38.034	1160	0
4.02	5.367	15	0	0.94	0	154.02	0	47.849	1200	0
1.11D	0.01	0	0	0	0	0.36	0	313.27	1270	0
1.12	5.367	35.9	0	0.94	0	136.73	0	331.58	1280	0
1.13	5.44	35.9	0	0.94	0	139.33	0	362.74	1330	0
1.14	5.44	37.1	0	0.94	0	138.29	0	371.43	1380	70
5	5.367	37.1	0	0.94	0	135.68	0	40.237	1210	0
5.01	5.367	37.1	0	0.94	0	135.68	0	69.315	1240	0
5.02	5.44	37.1	0	0.94	0	138.29	0	79.934	1290	0
6	5.578	37.1	0	0.94	0	143.07	0	17.994	1130	0
5.03D	0.01	0	0	0	0	0.36	0	93.844	1280	0
5.04	5.44	37.1	0	0.94	0	138.29	0	101.85	1370	20
1.15	5.44	37.1	0	0.94	0	138.29	0	480.6	1440	5
1.16D	0.01	0	0	0	0	0.36	0	699.11	1470	0
1.17	5.44	37.1	0	0.94	0	138.29	0	709.11	1480	0
11	5.578	37.1	0	0.94	0	143.07	0	18.935	1120	0
12	5.578	37.1	0	0.94	0	143.07	0	36.516	1170	0
12.01	0.01	0	0	0	0	0.36	0	55.179	1150	0
12.02	5.578	37.1	0	0.94	0	143.07	0	71.416	1210	0
12.03	5.578	37.1	0	0.94	0	143.07	0	94.496	1290	0
1.18D	0.01	0	0	0	0	0.36	0	772.61	1470	0
1.19	5.655	37.1	1	0.94	0	145.78	202.58	784.86	1540	0
13	5.578	37.1	0	0.94	0	143.07	0	27.854	1200	0
13.01	5.578	37.1	0	0.94	0	143.07	0	54.834	1260	0
1.20D	0.01	0	0	0	0	0.36	0	811.13	1540	0
1.21	5.655	37.1	1	0.94	0	145.78	202.58	811.38	1550	0
14	5.578	37.1	0	0.94	0	143.07	0	50.061	1210	0
14.01	5.578	37.1	0	0.94	0	143.07	0	77.298	1240	0
14.02	5.578	37.1	0	0.94	0	143.07	0	97.072	1270	0
1.22D	0.01	0	0	0	0	0.36	0	859.42	1540	0
1.23	5.655	37.1	1	0.94	0	145.78	202.58	863.46	1570	0
1.24	5.704	37.1	0	0.94	0	147.39	0	864.94	1590	0
15	5.655	37.1	1	0.94	0	145.78	202.58	12.127	1080	0
15.01	5.655	37.1	1	0.94	0	145.78	202.58	29.568	1080	0
1.25D	0.01	0	0	0	0	0.36	0	869.89	1590	0
1.26	5.704	36.6	1	0.94	0	147.89	204.34	870.95	1610	0
16	5.704	36.6	0	0.94	0	147.89	0	22.706	1120	0
16.01	5.704	15	1	0.94	0	165.89	204.34	35.526	1100	0
16.02	5.704	1	0	0	0	204.34	205.34	47.976	1100	0
1.27D	0.01	0	0	0	0	0.36	0	880.53	1610	0
17	5.655	36.6	1	0.94	0	146.14	202.58	15.507	1080	0
1.28D	0.01	0	0	0	0	0.36	0	882.82	1610	0
1.29	5.704	36.6	1	0.94	0	147.89	204.34	885.79	1620	0
18	5.704	5	1	0.94	0	172.97	204.34	43.886	1080	0
18.01	5.704	15	1	0.94	0	165.89	204.34	65.458	1080	0
1.30D	0.01	0	0	0	0	0.36	0	897.35	1620	0
1.31	5.704	36.6	0	0.94	0	147.89	0	899.14	1650	0
19	5.967	36.6	1	0.94	0	156.99	213.8	20.989	1080	0
1.32	5.704	36.6	1	0.94	0	147.89	204.34	907.56	1660	0
1.33	5.704	36.6	0	0.94	0	147.89	0	907.45	1670	0
21	5.655	32.6	1	0.94	0	149.52	202.58	13.966	1080	0
20	5.518	32.6	0	0.94	0	144.8	0	40.639	1180	0
20.01	5.518	32.6	1	0.94	0	144.8	197.66	60.483	1200	0
20.02D	0.01	0	0	0	0	0.36	0	60.483	1200	0
20.03	5.518	32.6	0	0.94	0	144.8	0	75.232	1210	0
20.04	5.655	32.6	0	0.94	0	149.52	203.58	95.324	1210	0
20.04b	5.655	32.6	0	0.94	0	149.52	203.58	107.5	1220	0
20.05D	0.01	0	0	0	0	0.36	0	117.76	1200	0
20.06	5.655	32.6	1	0.94	0	149.52	202.58	126.45	1210	0
20.07	5.655	32.6	1	0.94	0	149.52	202.58	144.04	1210	0
20.08	5.655	32.6	1	0.94	0	149.52	202.58	167.69	1210	0
20.09	5.704	32.6	1	0.94	0	151.11	204.34	179.91	1270	0
20.1	5.704	36.6	1	0.94	0	147.89	204.34	191.76	1310	0
20.11	5.704	36.6	0	0.94	0	147.89	0	198.58	1320	0
1.34D	0.01	0	0	0	0	0.36	0	984.21	1650	0
1.35	5.704	36.6	0	0.94	0	147.89	0	984.98	1730	0
22	5.704	36.6	0	0.94	0	147.89	0	31.783	1090	0
1.36D	0.01	0	0	0	0	0.36	0	988.07	1730	0
1.37	5.704	36.6	0	0.94	0	147.89	0	990.46	1750	0
1.38	5.704	36.6	0	0.94	0	147.89	0	996.49	1770	0
1.39D	0.01	0	0	0	0	0.36	0	1014.8	1770	0
1.4	5.822	36.6	0	0.94	0	151.93	0	1015	1790	0

##

Modelling Results for 20 yr ARI Storm (Critical Duration Tribs)

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 20
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)	(%)	(%)								
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	1
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	1.001
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17

Link	Average	Initial Loss		Cont. Loss		Excess Rain		Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
(mm/h)	(mm/h)	(mm)		(mm/h)		(mm)		(m^3/s)	Peak	mins
18	33.122	5	1	0.94	0	59.52	65.244	110.85	42	0
18.01	33.122	15	1	0.94	0	49.708	65.244	128.05	52	0
4	12.541	15	0	0.94	0	90.884	0	28.257	356	0
4.01	12.541	15	0	0.94	0	90.884	0	44.045	392	0
4.02	12.541	15	0	0.94	0	90.884	0	53.987	422	0
16	13.013	36.6	0	0.94	0	74.935	0	22.275	390	0
16.01	13.013	15	1	0.94	0	95.094	116.11	35.128	362	0
16.02	13.013	1	0	0	0	116.11	205.34	44.889	362	0

##

Modelling Results for 50 yr ARI Storm (36 Hour Storm Duration)

##

Results for period from 0:00 0 1/ Jan-11
to 19:20.0 2/ Jan-11

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 50
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)	(%)	(%)								
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342	1
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0	1.001
9	583	0	0.7	0	2	0	0.025	0	1.012	0	2
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	2.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	3
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	4
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	3.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	3.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	2.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	5
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	2.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	2.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	2.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.008
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	6
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	6.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	6.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	6.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	6.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	6.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	7
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	7.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	6.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	8
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	8.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	8.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	6.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	6.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	6.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	6.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	6.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	6.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	10
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	10
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	10
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	11
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	10
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	10
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	6.015
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.009
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	2.01
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	12
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	13
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	12
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	12

12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	12
1.18D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.011
1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033	2.012
13	614	0	0.66	0	0.1	0	0.025	0	1.166	0	14
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0	14
1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.013
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306	2.014
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0	15
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0	15
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0	15
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.015
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349	2.016
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0	2.017
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505	16
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663	16
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.018
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369	2.019
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.02
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636	18
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.021
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055	2.022
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	19
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	19
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.023
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0	2.024
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611	20
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547	2.025
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0	2.026
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855	21
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0	22
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199	22
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0	22
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0	22
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001	22
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001	22
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	21
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533	21
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235	21
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715	21
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488	21
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522	21.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0	21.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.027
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0	2.028
22	547	0	0.68	0	17	0	0.025	0	0.5623	0	23
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.029
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0	2.03
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0	2.031
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.002
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0	1.003

Link Label (mm/h)	Average Intensity (mm/h)	Initial Loss #1	#2	Cont. Loss #1	#2	Excess Rain #1	#2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
		(mm)		(mm/h)		(mm)				
23	6.841	36.6	1	0.94	0	186.93	245.27	58.912	1080	0
23.01	6.841	36.6	0	0.94	0	186.93	0	110.87	1170	0
9	6.298	33.9	0	0.94	0	170.24	0	29.439	1160	0
9.01	6.363	33.9	0	0.94	0	172.46	0	55.35	1200	0
8	6.298	33.9	0	0.94	0	170.24	0	49.181	1200	0
7	6.298	33.9	0	0.94	0	170.24	0	28.94	1150	0
8.01D	0.01	0	0	0	0	0.36	0	77.544	1190	0
8.02	6.567	33.9	0	0.94	0	179.63	0	91.3	1210	0
Jtn9.02	0.01	0	0	0	0	0.36	0	146.64	1210	0
9.03	6.567	33.9	0	0.94	0	179.63	0	189.11	1300	0
10	6.567	33.9	0	0.94	0	179.63	0	37.602	1170	0
9.04D	0.01	0	0	0	0	0.36	0	220.35	1290	0
9.05	6.567	33.9	0	0.94	0	179.63	0	229.02	1300	0
9.06	6.567	33.9	0	0.94	0	179.63	0	256.73	1420	10
9.07	6.456	33.9	0	0.94	0	175.8	0	258.99	1420	10
9.08D	0.01	0	0	0	0	0.36	0	258.93	1440	0
1	6.298	35.9	0	0.94	0	168.61	0	25.53	1150	0
1.01	6.298	35.9	0	0.94	0	168.61	0	44.389	1160	0
1.02	6.298	35.9	0	0.94	0	168.61	0	65.887	1160	0
1.03	6.298	35.9	0	0.94	0	168.61	0	100.01	1190	0
1.04	6.298	35.9	0	0.94	0	168.61	0	114.06	1230	0

1.05D	0.01	0	0	0	0	0.36	0	114.06	1230	0
2	6.298	35.9	0	0.94	0	168.61	0	32.409	1130	0
2.01	6.298	35.9	0	0.94	0	168.61	0	67.673	1200	0
1.06	6.363	35.9	0	0.94	0	170.77	0	180.92	1220	0
3	6.298	35.9	0	0.94	0	168.61	0	23.247	1130	0
3.01	6.298	35.9	0	0.94	0	168.61	0	51.101	1200	0
3.02	6.298	35.9	0	0.94	0	168.61	0	70.14	1270	0
1.07D	0.01	0	0	0	0	0.36	0	249.82	1230	0
1.08	6.363	35.9	0	0.94	0	170.77	0	272.39	1230	0
1.09	6.363	35.9	0	0.94	0	170.77	0	305.76	1250	0
1.1	6.363	35.9	0	0.94	0	170.77	0	309.5	1260	0
4	6.363	15	0	0.94	0	188.54	0	26.529	1100	0
4.01	6.363	15	0	0.94	0	188.54	0	43.009	1160	0
4.02	6.363	15	0	0.94	0	188.54	0	54.157	1190	0
1.11D	0.01	0	0	0	0	0.36	0	360.18	1250	0
1.12	6.363	35.9	0	0.94	0	170.77	0	381.62	1270	0
1.13	6.456	35.9	0	0.94	0	174.11	0	418.98	1320	0
1.14	6.456	37.1	0	0.94	0	173.07	0	430.08	1360	70
5	6.363	37.1	0	0.94	0	169.76	0	46.428	1200	0
5.01	6.363	37.1	0	0.94	0	169.76	0	80.671	1210	0
5.02	6.456	37.1	0	0.94	0	173.07	0	93.269	1270	0
6	6.613	37.1	0	0.94	0	178.57	0	20.438	1120	0
5.03D	0.01	0	0	0	0	0.36	0	109.94	1250	0
5.04	6.456	37.1	0	0.94	0	173.07	0	119.88	1340	20
1.15	6.456	37.1	0	0.94	0	173.07	0	559.14	1420	5
1.16D	0.01	0	0	0	0	0.36	0	805.6	1460	0
1.17	6.456	37.1	0	0.94	0	173.07	0	818.13	1470	0
11	6.613	37.1	0	0.94	0	178.57	0	21.489	1120	0
12	6.613	37.1	0	0.94	0	178.57	0	41.493	1150	0
12.01	0.01	0	0	0	0	0.36	0	62.756	1140	0
12.02	6.613	37.1	0	0.94	0	178.57	0	81.639	1200	0
12.03	6.613	37.1	0	0.94	0	178.57	0	108.58	1270	0
1.18D	0.01	0	0	0	0	0.36	0	891.39	1460	0
1.19	6.746	37.1	1	0.94	0	183.18	241.85	909.25	1530	0
13	6.613	37.1	0	0.94	0	178.57	0	31.753	1190	0
13.01	6.613	37.1	0	0.94	0	178.57	0	63.334	1230	0
1.20D	0.01	0	0	0	0	0.36	0	941.57	1520	0
1.21	6.746	37.1	1	0.94	0	183.18	241.85	942.27	1540	0
14	6.613	37.1	0	0.94	0	178.57	0	57.724	1200	0
14.01	6.613	37.1	0	0.94	0	178.57	0	89.259	1230	0
14.02	6.613	37.1	0	0.94	0	178.57	0	112.5	1250	0
1.22D	0.01	0	0	0	0	0.36	0	1000.7	1520	0
1.23	6.746	37.1	1	0.94	0	183.18	241.85	1007.1	1550	0
1.24	6.841	37.1	0	0.94	0	186.58	0	1009.4	1560	0
15	6.746	37.1	1	0.94	0	183.18	241.85	13.545	1080	0
15.01	6.746	37.1	1	0.94	0	183.18	241.85	33.229	1080	0
1.25D	0.01	0	0	0	0	0.36	0	1016.6	1570	0
1.26	6.841	36.6	1	0.94	0	186.93	245.27	1018.2	1580	0
16	6.841	36.6	0	0.94	0	186.93	0	25.998	1110	0
16.01	6.841	15	1	0.94	0	205.55	245.27	40.653	1100	0
16.02	6.841	1	0	0	0	245.27	246.27	54.924	1090	0
1.27D	0.01	0	0	0	0	0.36	0	1031.6	1580	0
17	6.746	36.6	1	0.94	0	183.68	241.85	17.369	1080	0
1.28D	0.01	0	0	0	0	0.36	0	1034.9	1590	0
1.29	6.841	36.6	1	0.94	0	186.93	245.27	1039.1	1590	0
18	6.841	5	1	0.94	0	212.89	245.27	49.852	1080	0
18.01	6.841	15	1	0.94	0	205.55	245.27	74.352	1080	0
1.30D	0.01	0	0	0	0	0.36	0	1055.9	1590	0
1.31	6.841	36.6	0	0.94	0	186.93	0	1059.9	1620	0
19	7.134	36.6	1	0.94	0	197.29	255.81	23.776	1080	0
1.32	6.841	36.6	1	0.94	0	186.93	245.27	1071.7	1630	0
1.33	6.841	36.6	0	0.94	0	186.93	0	1071.6	1640	0
21	6.746	32.6	1	0.94	0	187.05	241.85	15.665	1080	0
20	6.567	32.6	0	0.94	0	180.78	0	46.33	1170	0
20.01	6.567	32.6	1	0.94	0	180.78	235.41	69.064	1190	0
20.02D	0.01	0	0	0	0	0.36	0	69.064	1190	0
20.03	6.567	32.6	0	0.94	0	180.78	0	86.098	1200	0
20.04	6.746	32.6	0	0.94	0	187.05	242.85	109.22	1200	0
20.04b	6.746	32.6	0	0.94	0	187.05	242.85	122.91	1210	0
20.05D	0.01	0	0	0	0	0.36	0	134.7	1200	0
20.06	6.746	32.6	1	0.94	0	187.05	241.85	144.67	1210	0
20.07	6.746	32.6	1	0.94	0	187.05	241.85	165.09	1210	0
20.08	6.746	32.6	1	0.94	0	187.05	241.85	192.57	1210	0
20.09	6.841	32.6	1	0.94	0	190.46	245.27	207.31	1250	0
20.1	6.841	36.6	1	0.94	0	186.93	245.27	221.15	1290	0
20.11	6.841	36.6	0	0.94	0	186.93	0	229.25	1300	0
1.34D	0.01	0	0	0	0	0.36	0	1174	1610	0
1.35	6.841	36.6	0	0.94	0	186.93	0	1178.2	1690	0
22	6.841	36.6	0	0.94	0	186.93	0	36.031	1090	0
1.36D	0.01	0	0	0	0	0.36	0	1183.7	1690	0
1.37	6.841	36.6	0	0.94	0	186.93	0	1186.9	1710	0
1.38	6.841	36.6	0	0.94	0	186.93	0	1195.8	1730	0
1.39D	0.01	0	0	0	0	0.36	0	1222.3	1730	0
1.4	6.976	36.6	0	0.94	0	191.79	0	1223.9	1750	0

###

Modelling Results for 50 yr ARI Storm (Trib)

###

Results for period from 0:00 0 1/ Jan-11
to 19:20.0 2/ Jan-11

###

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 50
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)	(%)	(%)								
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	1
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	1.001
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17

Link	Average	Initial Loss		Cont. Loss		Excess Rain		Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
(mm/h)	(mm/h)	(mm)		(mm/h)		(mm)		(m^3/s)	Peak	mins
18	38.869	5	1	0.94	0	70.984	76.738	125.4	42	0
18.01	38.869	15	1	0.94	0	61.172	76.738	147.46	50	0
4	14.769	15	0	0.94	0	110.66	0	33.185	340	0
4.01	14.769	15	0	0.94	0	110.66	0	52.202	388	0
4.02	14.769	15	0	0.94	0	110.66	0	64.23	414	0
16	15.293	36.6	0	0.94	0	95.164	0	27.778	376	0
16.01	15.293	15	1	0.94	0	115.33	136.63	43.65	360	0
16.02	15.293	1	0	0	0	136.63	246.27	55.3	356	0

##

Modelling Results for 100 yr ARI Storm (36 Hour Storm Duration)

##

Results for period from 0: 0.0 1/ 1/2011
to 19:20.0 2/ 1/2011

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 100
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	1
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	1.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	1.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	1.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	1.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	2
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	2.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	1.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	3
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	3.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	3.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	1.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	1.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	1.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	1.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	4
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	4.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	4.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	1.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	1.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	1.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	1.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	5
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	5.001
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	5.002
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	6
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	5.003
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	5.004
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	1.015
9	583	0	0.7	0	2	0	0.025	0	1.012	0	7
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	7.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	8
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	9
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	8.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	8.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	7.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	7.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	10
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	7.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	7.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	7.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	7.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	7.008
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	1.016
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	1.017
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	11
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	12
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	11
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	11
12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	11
1.18D	0.1		0		0		0	0	0.0241	0	1.018

1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033		1.019
13	614	0		0		0		0	1.166	0		13
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0		13
1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.02
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306		1.021
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0		14
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0		14
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0		14
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.022
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349		1.023
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0		1.024
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505		15
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663		15
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.025
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369		1.026
16	445	0	0.74	0	4	0	0.025	0	0.7848	0		16
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565		16
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646		16
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.027
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636		17
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.028
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055		1.029
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114		18
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788		18
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.03
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0		1.031
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611		19
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547		1.032
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0		1.033
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855		20
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0		21
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199		21
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0		21
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0		21
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001		21
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001		21
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		20
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533		20
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235		20
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715		20
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488		20
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522		20.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0		20.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.034
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0		1.035
22	547	0	0.68	0	17	0	0.025	0	0.5623	0		22
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0		1.036
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0		1.037
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0		1.038
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342		23
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0		23
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0		1.039
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0		1.04

Link Label (mm/h)	Average Intensity (mm/h)	#1	Initial Loss #2 (mm)	#1	Cont. Loss #2 (mm/h)	#1	Excess Rain #2 (mm)	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
1	7.076	35.9	0	0.94	0	195.84	0	29.123	1140	0
1.01	7.076	35.9	0	0.94	0	195.84	0	50.776	1150	0
1.02	7.076	35.9	0	0.94	0	195.84	0	75.372	1160	0
1.03	7.073	35.9	0	0.94	0	195.75	0	114.24	1180	0
1.04	7.073	35.9	0	0.94	0	195.75	0	130.4	1220	0
1.05D	0.01	0	0	0	0	0.36	0	130.4	1220	0
2	7.073	35.9	0	0.94	0	195.75	0	37.019	1120	0
2.01	7.073	35.9	0	0.94	0	195.75	0	76.804	1200	0
1.06	7.128	35.9	0	0.94	0	197.62	0	207.12	1210	0
3	7.076	35.9	0	0.94	0	195.84	0	26.521	1120	0
3.01	7.076	35.9	0	0.94	0	195.84	0	57.951	1200	0
3.02	7.076	35.9	0	0.94	0	195.84	0	80.023	1250	0
1.07D	0.01	0	0	0	0	0.36	0	285.88	1220	0
1.08	7.128	35.9	0	0.94	0	197.62	0	311.76	1230	0
1.09	7.128	35.9	0	0.94	0	197.62	0	349.74	1240	0
1.1	7.128	35.9	0	0.94	0	197.62	0	353.98	1250	0
4	7.128	15	0	0.94	0	215.7	0	30.171	1100	0
4.01	7.128	15	0	0.94	0	215.7	0	48.877	1150	0
4.02	7.128	15	0	0.94	0	215.7	0	61.523	1180	0
1.11D	0.01	0	0	0	0	0.36	0	411.63	1240	0

1.12	7.128	35.9	0	0.94	0	197.62	0	436.22	1260	0
1.13	7.236	35.9	0	0.94	0	201.53	0	479.09	1300	0
1.14	7.236	37.1	0	0.94	0	200.48	0	492.62	1340	70
5	7.128	37.1	0	0.94	0	196.58	0	53.048	1200	0
5.01	7.128	37.1	0	0.94	0	196.58	0	92.427	1210	0
5.02	7.236	37.1	0	0.94	0	200.48	0	106.88	1260	0
6	7.408	37.1	0	0.94	0	206.48	0	23.263	1120	0
5.03D	0.01	0	0	0	0	0.36	0	126.22	1230	0
5.04	7.236	37.1	0	0.94	0	200.48	0	138.16	1330	20
1.15	7.236	37.1	0	0.94	0	200.48	0	640.89	1400	5
9	7.076	33.9	0	0.94	0	197.61	0	33.573	1150	0
9.01	7.128	33.9	0	0.94	0	199.46	0	63.24	1200	0
8	7.076	33.9	0	0.94	0	197.61	0	56.219	1200	0
7	7.076	33.9	0	0.94	0	197.61	0	32.995	1140	0
8.01D	0.01	0	0	0	0	0.36	0	88.444	1180	0
8.02	7.374	33.9	0	0.94	0	208.17	0	104.38	1210	0
Jtn9.02	0.01	0	0	0	0	0.36	0	167.57	1200	0
9.03	7.374	33.9	0	0.94	0	208.17	0	216.43	1290	0
10	7.374	33.9	0	0.94	0	208.17	0	42.812	1160	0
9.04D	0.01	0	0	0	0	0.36	0	252.19	1270	0
9.05	7.374	33.9	0	0.94	0	208.17	0	262.21	1280	0
9.06	7.374	33.9	0	0.94	0	208.17	0	294.87	1390	10
9.07	7.236	33.9	0	0.94	0	203.21	0	297.72	1400	10
9.08D	0.01	0	0	0	0	0.36	0	297.64	1420	0
1.16D	0.01	0	0	0	0	0.36	0	927.91	1440	0
1.17	7.236	37.1	0	0.94	0	200.48	0	942.7	1460	0
11	7.408	37.1	0	0.94	0	206.48	0	24.441	1110	0
12	7.408	37.1	0	0.94	0	206.48	0	47.168	1140	0
12.01	0.01	0	0	0	0	0.36	0	71.434	1130	0
12.02	7.408	37.1	0	0.94	0	206.48	0	92.827	1190	0
12.03	7.408	37.1	0	0.94	0	206.48	0	123.72	1250	0
1.18D	0.01	0	0	0	0	0.36	0	1026.6	1450	0
1.19	7.588	37.1	1	0.94	0	212.79	272.15	1047.8	1510	0
13	7.408	37.1	0	0.94	0	206.48	0	36.078	1170	0
13.01	7.408	37.1	0	0.94	0	206.48	0	72.586	1210	0
1.20D	0.01	0	0	0	0	0.36	0	1086	1500	0
1.21	7.588	37.1	1	0.94	0	212.79	272.15	1086.9	1520	0
14	7.408	37.1	0	0.94	0	206.48	0	65.774	1200	0
14.01	7.408	37.1	0	0.94	0	206.48	0	102.04	1210	0
14.02	7.408	37.1	0	0.94	0	206.48	0	128.67	1240	0
1.22D	0.01	0	0	0	0	0.36	0	1156.2	1500	0
1.23	7.588	37.1	1	0.94	0	212.79	272.15	1163.8	1530	0
1.24	7.722	37.1	0	0.94	0	217.61	0	1166.9	1540	0
15	7.588	37.1	1	0.94	0	212.79	272.15	15.322	1080	0
15.01	7.588	37.1	1	0.94	0	212.79	272.15	37.688	1080	0
1.25D	0.01	0	0	0	0	0.36	0	1175.1	1550	0
1.26	7.722	36.6	1	0.94	0	218.06	276.98	1177.5	1560	0
16	7.722	36.6	0	0.94	0	218.06	0	29.796	1110	0
16.01	7.722	15	1	0.94	0	236.73	276.98	46.62	1090	0
16.02	7.722	1	0	0	0	276.98	277.98	62.843	1090	0
1.27D	0.01	0	0	0	0	0.36	0	1193.3	1560	0
17	7.588	36.6	1	0.94	0	213.29	272.15	19.681	1080	0
1.28D	0.01	0	0	0	0	0.36	0	1197.5	1560	0
1.29	7.722	36.6	1	0.94	0	218.06	276.98	1202.4	1570	0
18	7.722	5	1	0.94	0	244.38	276.98	56.614	1080	0
18.01	7.722	15	1	0.94	0	236.73	276.98	84.694	1080	0
1.30D	0.01	0	0	0	0	0.36	0	1222.8	1560	0
1.31	7.722	36.6	0	0.94	0	218.06	0	1228.3	1590	0
19	8.036	36.6	1	0.94	0	229.19	288.28	27.053	1080	0
1.32	7.722	36.6	1	0.94	0	218.06	276.98	1243	1600	0
1.33	7.722	36.6	0	0.94	0	218.06	0	1242.9	1610	0
21	7.588	32.6	1	0.94	0	216.82	272.15	17.768	1080	0
20	7.374	32.6	0	0.94	0	209.32	0	52.793	1160	0
20.01	7.374	32.6	1	0.94	0	209.32	264.48	78.741	1190	0
20.02D	0.01	0	0	0	0	0.36	0	78.741	1190	0
20.03	7.374	32.6	0	0.94	0	209.32	0	98.032	1200	0
20.04	7.588	32.6	0	0.94	0	216.82	273.15	124.36	1200	0
20.04b	7.588	32.6	0	0.94	0	216.82	273.15	139.87	1210	0
20.05D	0.01	0	0	0	0	0.36	0	153.18	1200	0
20.06	7.588	32.6	1	0.94	0	216.82	272.15	164.45	1200	0
20.07	7.588	32.6	1	0.94	0	216.82	272.15	187.46	1210	0
20.08	7.588	32.6	1	0.94	0	216.82	272.15	218.55	1210	0
20.09	7.722	32.6	1	0.94	0	221.64	276.98	234.95	1250	0
20.1	7.722	36.6	1	0.94	0	218.06	276.98	250.67	1280	0
20.11	7.722	36.6	0	0.94	0	218.06	0	260.05	1280	0
1.34D	0.01	0	0	0	0	0.36	0	1369.7	1580	0
1.35	7.722	36.6	0	0.94	0	218.06	0	1376	1650	0
22	7.722	36.6	0	0.94	0	218.06	0	41.232	1080	0
1.36D	0.01	0	0	0	0	0.36	0	1382.9	1650	0
1.37	7.722	36.6	0	0.94	0	218.06	0	1387.5	1680	0
1.38	7.722	36.6	0	0.94	0	218.06	0	1399.6	1700	0
23	7.722	36.6	1	0.94	0	218.06	276.98	67.871	1080	0
23.01	7.722	36.6	0	0.94	0	218.06	0	127.61	1170	0
1.39D	0.01	0	0	0	0	0.36	0	1433	1690	0
1.4	7.87	36.6	0	0.94	0	223.28	0	1435.4	1710	0

##

Modelling Results for 100 yr ARI Storm (Tribn)

##

Results for period from 0: 0.0 1/ 1/2011
to 19:20.0 2/ 1/2011

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 100
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	1
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	1.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	1.002
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	16
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	16
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	16
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	18
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	18

Link Label (mm/h)	Average Intensity (mm/h)	Initial Loss		Cont. Loss		Excess Rain		Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
		#1	#2	#1	#2	#1	#2			
		(mm)		(mm/h)		(mm)				
4	16.47	15	0	0.94	0	125.84	0	38.261	332	0
4.01	16.47	15	0	0.94	0	125.84	0	59.937	380	0
4.02	16.47	15	0	0.94	0	125.84	0	73.965	408	0
16	17.03	36.6	0	0.94	0	110.69	0	32.606	362	0
16.01	17.03	15	1	0.94	0	130.85	152.27	51.285	350	0
16.02	17.03	1	0	0	0	152.27	277.98	64.656	352	0
18	43.244	5	1	0.94	0	79.733	85.488	141.36	42	0
18.01	43.244	15	1	0.94	0	69.921	85.488	167.83	50	0

##

Modelling Results for 200 yr ARI Storm (36 Hour Storm Duration)

##

Results for period from 0: 0.0 1/ 1/2011
to 19:20.0 2/ 1/2011

##

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 200
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342	1
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0	1.001
9	583	0	0.7	0	2	0	0.025	0	1.012	0	2
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	2.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	3
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	4
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	3.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	3.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	2.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	5
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	2.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	2.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	2.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.008
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	6
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	6.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	6.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	6.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	6.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	6.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	7
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	7.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	6.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	8
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	8.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	8.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	6.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	6.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	6.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	6.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	6.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	6.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	10
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	10
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	10
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	11
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	10
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	10
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	6.015
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.009
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	2.01
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	12
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	13
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	12
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	12

12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	12
1.18D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.011
1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033	2.012
13	614	0	0.66	0	0.1	0	0.025	0	1.166	0	14
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0	14
1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.013
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306	2.014
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0	15
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0	15
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0	15
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.015
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349	2.016
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0	2.017
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505	16
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663	16
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.018
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369	2.019
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.02
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636	18
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.021
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055	2.022
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	19
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	19
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.023
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0	2.024
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611	20
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547	2.025
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0	2.026
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855	21
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0	22
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199	22
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0	22
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0	22
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001	22
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001	22
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	21
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533	21
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235	21
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715	21
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488	21
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522	21.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0	21.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.027
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0	2.028
22	547	0	0.68	0	17	0	0.025	0	0.5623	0	23
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.029
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0	2.03
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0	2.031
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.002
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0	1.003

Link	Average	Initial Loss		Cont. Loss		Excess Rain		Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
(mm/h)	(mm/h)	(mm)		(mm/h)		(mm)		(m^3/s)	Peak	mins
23	8.627	36.6	1	0.94	0	250.15	309.56	77.201	1080	0
23.01	8.627	36.6	0	0.94	0	250.15	0	144.71	1160	0
9	7.872	33.9	0	0.94	0	225.72	0	37.871	1140	0
9.01	7.908	33.9	0	0.94	0	227.02	0	71.319	1200	0
8	7.872	33.9	0	0.94	0	225.72	0	63.384	1200	0
7	7.872	33.9	0	0.94	0	225.72	0	37.229	1130	0
8.01D	0.01	0	0	0	0	0.36	0	99.649	1170	0
8.02	8.2	33.9	0	0.94	0	237.36	0	117.78	1200	0
Jtn9.02	0.01	0	0	0	0	0.36	0	189.1	1200	0
9.03	8.2	33.9	0	0.94	0	237.36	0	244.55	1280	0
10	8.2	33.9	0	0.94	0	237.36	0	48.205	1150	0
9.04D	0.01	0	0	0	0	0.36	0	285.51	1260	0
9.05	8.2	33.9	0	0.94	0	237.36	0	296.98	1270	0
9.06	8.2	33.9	0	0.94	0	237.36	0	336.47	1370	10
9.07	8.033	33.9	0	0.94	0	231.53	0	339.93	1380	10
9.08D	0.01	0	0	0	0	0.36	0	339.85	1400	0
1	7.872	35.9	0	0.94	0	224.04	0	32.814	1130	0
1.01	7.872	35.9	0	0.94	0	224.04	0	57.343	1150	0
1.02	7.872	35.9	0	0.94	0	224.04	0	85.06	1150	0
1.03	7.865	35.9	0	0.94	0	223.8	0	128.82	1170	0
1.04	7.865	35.9	0	0.94	0	223.8	0	147.16	1210	0
1.05D	0.01	0	0	0	0	0.36	0	147.16	1210	0

2	7.865	35.9	0	0.94	0	223.8	0	41.788	1110	0
2.01	7.865	35.9	0	0.94	0	223.8	0	86.52	1200	0
1.06	7.908	35.9	0	0.94	0	225.18	0	233.83	1210	0
3	7.872	35.9	0	0.94	0	224.04	0	29.863	1120	0
3.01	7.872	35.9	0	0.94	0	224.04	0	63.27	1210	0
3.02	7.872	35.9	0	0.94	0	224.04	0	87.606	1260	0
1.07D	0.01	0	0	0	0	0.36	0	320.05	1210	0
1.08	7.908	35.9	0	0.94	0	225.18	0	349.17	1220	0
1.09	7.908	35.9	0	0.94	0	225.18	0	392.41	1230	0
1.1	7.908	35.9	0	0.94	0	225.18	0	397.13	1240	0
4	7.908	15	0	0.94	0	243.41	0	34.026	1090	0
4.01	7.908	15	0	0.94	0	243.41	0	54.902	1150	0
4.02	7.908	15	0	0.94	0	243.41	0	69.124	1180	0
1.11D	0.01	0	0	0	0	0.36	0	461.93	1230	0
1.12	7.908	35.9	0	0.94	0	225.18	0	489.9	1250	0
1.13	8.033	35.9	0	0.94	0	229.68	0	538.54	1290	0
1.14	8.033	37.1	0	0.94	0	228.64	0	555.08	1330	70
5	7.908	37.1	0	0.94	0	224.13	0	59.77	1200	0
5.01	7.908	37.1	0	0.94	0	224.13	0	104.22	1210	0
5.02	8.033	37.1	0	0.94	0	228.64	0	120.57	1250	0
6	8.218	37.1	0	0.94	0	235.12	0	26.113	1110	0
5.03D	0.01	0	0	0	0	0.36	0	142.64	1220	0
5.04	8.033	37.1	0	0.94	0	228.64	0	156.72	1320	20
1.15	8.033	37.1	0	0.94	0	228.64	0	722.64	1390	5
1.16D	0.01	0	0	0	0	0.36	0	1051.7	1430	0
1.17	8.033	37.1	0	0.94	0	228.64	0	1069.3	1440	0
11	8.218	37.1	0	0.94	0	235.12	0	27.443	1110	0
12	8.218	37.1	0	0.94	0	235.12	0	53.007	1140	0
12.01	0.01	0	0	0	0	0.36	0	80.233	1130	0
12.02	8.218	37.1	0	0.94	0	235.12	0	104.25	1190	0
12.03	8.218	37.1	0	0.94	0	235.12	0	139.15	1240	0
1.18D	0.01	0	0	0	0	0.36	0	1166.4	1430	0
1.19	8.45	37.1	1	0.94	0	243.44	303.18	1191.2	1490	0
13	8.218	37.1	0	0.94	0	235.12	0	40.481	1170	0
13.01	8.218	37.1	0	0.94	0	235.12	0	82.278	1210	0
1.20D	0.01	0	0	0	0	0.36	0	1236.1	1480	0
1.21	8.45	37.1	1	0.94	0	243.44	303.18	1237.4	1490	0
14	8.218	37.1	0	0.94	0	235.12	0	73.848	1200	0
14.01	8.218	37.1	0	0.94	0	235.12	0	115.01	1210	0
14.02	8.218	37.1	0	0.94	0	235.12	0	144.98	1230	0
1.22D	0.01	0	0	0	0	0.36	0	1319.5	1480	0
1.23	8.45	37.1	1	0.94	0	243.44	303.18	1326.8	1510	0
1.24	8.627	37.1	0	0.94	0	249.65	0	1330.5	1520	0
15	8.45	37.1	1	0.94	0	243.44	303.18	17.108	1080	0
15.01	8.45	37.1	1	0.94	0	243.44	303.18	42.293	1080	0
1.25D	0.01	0	0	0	0	0.36	0	1339.8	1520	0
1.26	8.627	36.6	1	0.94	0	250.15	309.56	1342.5	1540	0
16	8.627	36.6	0	0.94	0	250.15	0	33.794	1100	0
16.01	8.627	15	1	0.94	0	268.95	309.56	52.974	1090	0
16.02	8.627	1	0	0	0	309.56	310.56	71.166	1090	0
1.27D	0.01	0	0	0	0	0.36	0	1361.1	1530	0
17	8.45	36.6	1	0.94	0	243.79	303.18	22.061	1080	0
1.28D	0.01	0	0	0	0	0.36	0	1365.8	1540	0
1.29	8.627	36.6	1	0.94	0	250.15	309.56	1371.4	1540	0
18	8.627	5	1	0.94	0	276.74	309.56	63.678	1080	0
18.01	8.627	15	1	0.94	0	268.95	309.56	95.282	1080	0
1.30D	0.01	0	0	0	0	0.36	0	1395.2	1540	0
1.31	8.627	36.6	0	0.94	0	250.15	0	1402.5	1570	0
19	8.961	36.6	1	0.94	0	261.99	321.58	30.454	1080	0
1.32	8.627	36.6	1	0.94	0	250.15	309.56	1419.8	1580	0
1.33	8.627	36.6	0	0.94	0	250.15	0	1419.9	1580	0
21	8.45	32.6	1	0.94	0	247.47	303.18	19.935	1080	0
20	8.2	32.6	0	0.94	0	238.51	0	59.461	1150	0
20.01	8.2	32.6	1	0.94	0	238.51	294.2	88.671	1180	0
20.02D	0.01	0	0	0	0	0.36	0	88.671	1180	0
20.03	8.2	32.6	0	0.94	0	238.51	0	110.46	1190	0
20.04	8.45	32.6	0	0.94	0	247.47	304.18	140.04	1200	0
20.04b	8.45	32.6	0	0.94	0	247.47	304.18	157.41	1210	0
20.05D	0.01	0	0	0	0	0.36	0	172.29	1200	0
20.06	8.45	32.6	1	0.94	0	247.47	303.18	184.93	1200	0
20.07	8.45	32.6	1	0.94	0	247.47	303.18	210.58	1210	0
20.08	8.45	32.6	1	0.94	0	247.47	303.18	245.56	1210	0
20.09	8.627	32.6	1	0.94	0	253.68	309.56	262.5	1260	0
20.1	8.627	36.6	1	0.94	0	250.15	309.56	280.05	1290	0
20.11	8.627	36.6	0	0.94	0	250.15	0	290.3	1300	0
1.34D	0.01	0	0	0	0	0.36	0	1571	1550	0
1.35	8.627	36.6	0	0.94	0	250.15	0	1578.8	1620	0
22	8.627	36.6	0	0.94	0	250.15	0	46.485	1080	0
1.36D	0.01	0	0	0	0	0.36	0	1587.1	1620	0
1.37	8.627	36.6	0	0.94	0	250.15	0	1593.1	1640	0
1.38	8.627	36.6	0	0.94	0	250.15	0	1608.4	1660	0
1.39D	0.01	0	0	0	0	0.36	0	1648.9	1650	0
1.4	8.788	36.6	0	0.94	0	255.8	0	1652.7	1670	0

```
####################################################################################
Modelling Results for 200 yr ARI Storm (trib)
####################################################################################

Results for period from  0: 0.0  1/ 1/2011
         to 19:20.0  2/ 1/2011
####################################################################################

          ROUTING INCREMENT (MINS)                =         10
          STORM DURATION (MINS)                   =         2160
          RETURN PERIOD (YRS)                     =         200
          BX                                      =         1.3
          TOTAL OF FIRST SUB-AREAS (ha)           =         37888.96
          TOTAL OF SECOND SUB-AREAS (ha)          =         3498.17
          TOTAL OF ALL SUB-AREAS (ha)             =         41387.13


  SUMMARY OF CATCHMENT AND RAINFALL DATA
   Link     Catch.     Area          % Slope          % Impervious            Pern                 B             Link
   Label      #1        #2        #1        #2        #1        #2        #1        #2        #1        #2       No.
                  (ha)                (%)                  (%)
         4       480         0      1.18         0         1         0     0.025         0    0.7369         0         4
      4.01       330         0      0.57         0       0.6         0     0.025         0    0.8878         0     4.001
      4.02       224         0      0.57         0       0.6         0     0.025         0    0.7258         0     4.002
        16       445         0      0.74         0         4         0     0.025         0    0.7848         0        16
     16.01       182        60      0.68      0.68        10        75     0.025     0.025    0.4055    0.0565        16
     16.02       136        90      0.68      0.68        10        80     0.025     0.025    0.3485    0.0646        16
        18       375       405      0.71      0.71         1        95     0.025     0.025    0.8351    0.1114        18
     18.01       184       208      0.71      0.71         1        95     0.025     0.025    0.5767    0.0788        18


Link      Average        Initial Loss        Cont. Loss          Excess Rain    Peak      Time      Link
Label     Intensity #1        #2        #1        #2        #1        #2        Inflow    to        Lag
(mm/h)    (mm/h)           (mm)               (mm/h)               (mm)         (m^3/s)   Peak      mins
         4    18.198        15         0      0.94         0    141.29         0    43.103       334         0
      4.01    18.198        15         0      0.94         0    141.29         0    67.724       376         0
      4.02    18.198        15         0      0.94         0    141.29         0    83.706       402         0
        16    18.793      36.6         0      0.94         0    126.43         0      37.6       360         0
     16.01    18.793        15         1      0.94         0    146.62    168.14    59.304       346         0
     16.02    18.793         1         0         0         0    168.14    310.56    74.462       350         0
      1.29     8.627      36.6         1      0.94         0    250.19    309.56    1308.5      1556         0
        18    47.677         5         1      0.94         0    88.568    94.354    158.13        40         0
     18.01    47.677        15         1      0.94         0    78.756    94.354     188.9        50         0
```

###

Modelling Results for 500 yr ARI Storm (36 Hour Storm Duration)

###

Results for period from 0: 0.0 1/ 1/2011
to 19:20.0 2/ 1/2011

###

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 2160
RETURN PERIOD (YRS) = 500
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342	1
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0	1.001
9	583	0	0.7	0	2	0	0.025	0	1.012	0	2
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	2.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	3
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	4
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	3.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	3.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	2.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	5
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	2.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	2.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	2.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.008
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	6
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	6.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	6.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	6.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	6.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	6.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	7
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	7.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	6.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	8
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	8.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	8.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	6.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	6.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	6.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	6.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	6.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	6.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	10
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	10
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	10
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	11
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	10
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	10
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	6.015
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.009
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	2.01
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	12
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	13
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	12
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	12

12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	12
1.18D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.011
1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033	2.012
13	614	0	0.66	0	0.1	0	0.025	0	1.166	0	14
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0	14
1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.013
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306	2.014
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0	15
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0	15
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0	15
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.015
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349	2.016
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0	2.017
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505	16
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663	16
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.018
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369	2.019
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.02
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636	18
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.021
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055	2.022
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	19
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	19
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.023
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0	2.024
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611	20
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547	2.025
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0	2.026
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855	21
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0	22
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199	22
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0	22
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0	22
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001	22
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001	22
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	21
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533	21
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235	21
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715	21
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488	21
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522	21.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0	21.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.027
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0	2.028
22	547	0	0.68	0	17	0	0.025	0	0.5623	0	23
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.029
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0	2.03
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0	2.031
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.002
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0	1.003

Link	Average		Initial Loss		Cont. Loss		Excess Rain	Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
(mm/h)	(mm/h)		(mm)		(mm/h)		(mm)	(m^3/s)	Peak	mins
23	9.867	36.6	1	0.94	0	294.24	354.21	89.621	1080	0
23.01	9.867	36.6	0	0.94	0	294.24	0	168.23	1160	0
9	8.956	33.9	0	0.94	0	264.23	0	43.823	1130	0
9.01	8.968	33.9	0	0.94	0	264.65	0	82.262	1190	0
8	8.956	33.9	0	0.94	0	264.23	0	73.045	1190	0
7	8.956	33.9	0	0.94	0	264.23	0	43.086	1120	0
8.01D	0.01	0	0	0	0	0.36	0	114.99	1160	0
8.02	9.325	33.9	0	0.94	0	277.48	0	136.11	1190	0
Jtn9.02	0.01	0	0	0	0	0.36	0	218.38	1190	0
9.03	9.325	33.9	0	0.94	0	277.48	0	282.84	1260	0
10	9.325	33.9	0	0.94	0	277.48	0	55.628	1140	0
9.04D	0.01	0	0	0	0	0.36	0	330.98	1250	0
9.05	9.325	33.9	0	0.94	0	277.48	0	344.5	1250	0
9.06	9.325	33.9	0	0.94	0	277.48	0	391.9	1360	10
9.07	9.117	33.9	0	0.94	0	270	0	396.1	1360	10
9.08D	0.01	0	0	0	0	0.36	0	396.03	1380	0
1	8.956	35.9	0	0.94	0	262.54	0	37.988	1120	0
1.01	8.956	35.9	0	0.94	0	262.54	0	66.523	1140	0
1.02	8.956	35.9	0	0.94	0	262.54	0	98.464	1150	0
1.03	8.945	35.9	0	0.94	0	262.12	0	148.87	1160	0
1.04	8.945	35.9	0	0.94	0	262.12	0	170.23	1200	0
1.05D	0.01	0	0	0	0	0.36	0	170.23	1200	0
2	8.945	35.9	0	0.94	0	262.12	0	48.347	1110	0
2.01	8.945	35.9	0	0.94	0	262.12	0	99.648	1190	0
1.06	8.968	35.9	0	0.94	0	262.96	0	270.35	1200	0
3	8.956	35.9	0	0.94	0	262.54	0	34.544	1110	0
3.01	8.956	35.9	0	0.94	0	262.54	0	72.686	1210	0

3.02	8.956	35.9	0	0.94	0	262.54	0	100.7	1250	0
1.07D	0.01	0	0	0	0	0.36	0	369.9	1210	0
1.08	8.968	35.9	0	0.94	0	262.96	0	403.27	1210	0
1.09	8.968	35.9	0	0.94	0	262.96	0	453.24	1220	0
1.1	8.968	35.9	0	0.94	0	262.96	0	458.82	1240	0
4	8.968	15	0	0.94	0	281.2	0	39.503	1090	0
4.01	8.968	15	0	0.94	0	281.2	0	63.427	1140	0
4.02	8.968	15	0	0.94	0	281.2	0	79.777	1170	0
1.11D	0.01	0	0	0	0	0.36	0	533.25	1230	0
1.12	8.968	35.9	0	0.94	0	262.96	0	565.4	1240	0
1.13	9.117	35.9	0	0.94	0	268.15	0	621.98	1280	0
1.14	9.117	37.1	0	0.94	0	267.11	0	641.96	1320	70
5	8.968	37.1	0	0.94	0	261.76	0	68.825	1200	0
5.01	8.968	37.1	0	0.94	0	261.76	0	120.46	1200	0
5.02	9.117	37.1	0	0.94	0	267.11	0	139.58	1240	0
6	9.319	37.1	0	0.94	0	274.21	0	30.045	1110	0
5.03D	0.01	0	0	0	0	0.36	0	165.53	1210	0
5.04	9.117	37.1	0	0.94	0	267.11	0	181.57	1300	20
1.15	9.117	37.1	0	0.94	0	267.11	0	835.76	1380	5
1.16D	0.01	0	0	0	0	0.36	0	1221.9	1410	0
1.17	9.117	37.1	0	0.94	0	267.11	0	1243.1	1430	0
11	9.319	37.1	0	0.94	0	274.21	0	31.595	1100	0
12	9.319	37.1	0	0.94	0	274.21	0	61.024	1130	0
12.01	0.01	0	0	0	0	0.36	0	92.341	1120	0
12.02	9.319	37.1	0	0.94	0	274.21	0	119.94	1180	0
12.03	9.319	37.1	0	0.94	0	274.21	0	160.56	1230	0
1.18D	0.01	0	0	0	0	0.36	0	1357.1	1410	0
1.19	9.626	37.1	1	0.94	0	285.25	345.54	1386.1	1470	0
13	9.319	37.1	0	0.94	0	274.21	0	46.534	1160	0
13.01	9.319	37.1	0	0.94	0	274.21	0	95.06	1210	0
1.20D	0.01	0	0	0	0	0.36	0	1440.1	1460	0
1.21	9.626	37.1	1	0.94	0	285.25	345.54	1441.9	1470	0
14	9.319	37.1	0	0.94	0	274.21	0	84.842	1190	0
14.01	9.319	37.1	0	0.94	0	274.21	0	132.54	1210	0
14.02	9.319	37.1	0	0.94	0	274.21	0	167.21	1220	0
1.22D	0.01	0	0	0	0	0.36	0	1540	1460	0
1.23	9.626	37.1	1	0.94	0	285.25	345.54	1548.9	1480	0
1.24	9.867	37.1	0	0.94	0	293.74	0	1553.2	1500	0
15	9.626	37.1	1	0.94	0	285.25	345.54	19.574	1080	0
15.01	9.626	37.1	1	0.94	0	285.25	345.54	48.642	1080	0
1.25D	0.01	0	0	0	0	0.36	0	1564.5	1500	0
1.26	9.867	36.6	1	0.94	0	294.24	354.21	1567.7	1510	0
16	9.867	36.6	0	0.94	0	294.24	0	39.628	1090	0
16.01	9.867	15	1	0.94	0	313.18	354.21	61.913	1090	0
16.02	9.867	1	0	0	0	354.21	355.21	82.908	1090	0
1.27D	0.01	0	0	0	0	0.36	0	1589.8	1510	0
17	9.626	36.6	1	0.94	0	285.62	345.54	25.258	1080	0
1.28D	0.01	0	0	0	0	0.36	0	1595.1	1520	0
1.29	9.867	36.6	1	0.94	0	294.24	354.21	1602.2	1520	0
18	9.867	5	1	0.94	0	321.14	354.21	73.527	1080	0
18.01	9.867	15	1	0.94	0	313.18	354.21	110.01	1080	0
1.30D	0.01	0	0	0	0	0.36	0	1630	1520	0
1.31	9.867	36.6	0	0.94	0	294.24	0	1638.8	1550	0
19	10.225	36.6	1	0.94	0	306.96	367.11	35.181	1080	0
1.32	9.867	36.6	1	0.94	0	294.24	354.21	1659.9	1550	0
1.33	9.867	36.6	0	0.94	0	294.24	0	1660	1560	0
21	9.626	32.6	1	0.94	0	289.28	345.54	22.85	1080	0
20	9.325	32.6	0	0.94	0	278.62	0	68.602	1140	0
20.01	9.325	32.6	1	0.94	0	278.62	334.7	102.26	1170	0
20.02D	0.01	0	0	0	0	0.36	0	102.26	1170	0
20.03	9.325	32.6	0	0.94	0	278.62	0	127.48	1180	0
20.04	9.626	32.6	0	0.94	0	289.28	346.54	161.62	1190	0
20.04b	9.626	32.6	0	0.94	0	289.28	346.54	181.02	1220	0
20.05D	0.01	0	0	0	0	0.36	0	197.35	1210	0
20.06	9.626	32.6	1	0.94	0	289.28	345.54	211.65	1210	0
20.07	9.626	32.6	1	0.94	0	289.28	345.54	240.03	1210	0
20.08	9.626	32.6	1	0.94	0	289.28	345.54	278.57	1210	0
20.09	9.867	32.6	1	0.94	0	297.93	354.21	297.76	1260	0
20.1	9.867	36.6	1	0.94	0	294.24	354.21	316.93	1320	0
20.11	9.867	36.6	0	0.94	0	294.24	0	328.24	1320	0
1.34D	0.01	0	0	0	0	0.36	0	1857.2	1520	0
1.35	9.867	36.6	0	0.94	0	294.24	0	1870.6	1580	0
22	9.867	36.6	0	0.94	0	294.24	0	53.76	1080	0
1.36D	0.01	0	0	0	0	0.36	0	1881	1580	0
1.37	9.867	36.6	0	0.94	0	294.24	0	1889.8	1600	0
1.38	9.867	36.6	0	0.94	0	294.24	0	1909.5	1620	0
1.39D	0.01	0	0	0	0	0.36	0	1960.6	1610	0
1.4	10.045	36.6	0	0.94	0	300.65	0	1966	1620	0

```
##########################################################################################
Modelling Results for 500 yr ARI Storm (Trib)
##########################################################################################

Results for period from  0: 0.0  1/ 1/2011
          to 19:20.0  2/ 1/2011
##########################################################################################


          ROUTING INCREMENT (MINS)                      =          10
          STORM DURATION (MINS)                         =          2160
          RETURN PERIOD (YRS)                           =          500
          BX                                            =          1.3
          TOTAL OF FIRST SUB-AREAS (ha)                 =          37888.96
          TOTAL OF SECOND SUB-AREAS (ha)                =          3498.17
          TOTAL OF ALL SUB-AREAS (ha)                   =          41387.13


  SUMMARY OF CATCHMENT AND RAINFALL DATA
   Link     Catch.      Area           % Slope            % Impervious           Pern                  B               Link
  Label       #1         #2         #1         #2         #1         #2         #1         #2         #1         #2       No.
                  (ha)                   (%)                   (%)
        4        480          0       1.18          0          1          0      0.025          0     0.7369          0          4
     4.01        330          0       0.57          0        0.6          0      0.025          0     0.8878          0      4.001
     4.02        224          0       0.57          0        0.6          0      0.025          0     0.7258          0      4.002
       16        445          0       0.74          0          4          0      0.025          0     0.7848          0         16
    16.01        182         60       0.68       0.68         10         75      0.025      0.025     0.4055     0.0565         16
    16.02        136         90       0.68       0.68         10         80      0.025      0.025     0.3485     0.0646         16
       18        375        405       0.71       0.71          1         95      0.025      0.025     0.8351     0.1114         18
    18.01        184        208       0.71       0.71          1         95      0.025      0.025     0.5767     0.0788         18


Link       Average           Initial Loss                Cont. Loss               Excess Rain        Peak       Time       Link
Label      Intensity   #1         #2         #1         #2         #1         #2         Inflow     to         Lag
(mm/h)     (mm/h)           (mm)                  (mm/h)                   (mm)           (m^3/s)    Peak       mins
        4     20.536         15          0       0.94          0     162.24          0     49.522        332          0
     4.01     20.536         15          0       0.94          0     162.24          0     77.962        374          0
     4.02     20.536         15          0       0.94          0     162.24          0     96.508        396          0
       16     21.175       36.6          0       0.94          0     147.61          0     44.124        352          0
    16.01     21.175         15          1       0.94          0     167.99     189.58     70.157        340          0
    16.02     21.175          1          0          0          0     189.58     355.21     87.593        348          0
       18     53.662          5          1       0.94          0     100.54     106.32     180.81         40          0
    18.01     53.662         15          1       0.94          0     90.727     106.32     215.14         50          0
```

###

Modelling Results for the PMF Storm (6 Hour Storm Duration)

###

Results for period from 0: 0.0 1/ 1/2011
to 19:20.0 2/ 1/2011

###

ROUTING INCREMENT (MINS) = 10
STORM DURATION (MINS) = 360
RETURN PERIOD (YRS) = 10000
BX = 1.3
TOTAL OF FIRST SUB-AREAS (ha) = 37888.96
TOTAL OF SECOND SUB-AREAS (ha) = 3498.17
TOTAL OF ALL SUB-AREAS (ha) = 41387.13

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch.	Area	% Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
23	608	441	0.48	0.48	1	99	0.025	0.025	1.305	0.1342	1
23.01	1025	0	0.41	0	7	0	0.025	0	1.438	0	1.001
9	583	0	0.7	0	2	0	0.025	0	1.012	0	2
9.01	534	0	0.58	0	2.4	0	0.025	0	1.043	0	2.001
8	1031	0	0.56	0	2.4	0	0.025	0	1.495	0	3
7	569	0	0.68	0	2.8	0	0.025	0	0.9791	0	4
8.01D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	3.001
8.02	290	0	0.63	0	4	0	0.025	0	0.6807	0	3.002
Jtn9.02	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.002
9.03	1007	0	0.35	0	4	0	0.025	0	1.743	0	2.003
10	721	0	0.62	0	3.1	0	0.025	0	1.144	0	5
9.04D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.004
9.05	234	0	1.18	0	1.6	0	0.025	0	0.4938	0	2.005
9.06	910	0	0.25	0	1.9	0	0.025	0	2.141	0	2.006
9.07	102	0	0.65	0	0.3	0	0.025	0	0.4578	0	2.007
9.08D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.008
1	500	0	0.83	0	0.2	0	0.025	0	0.9303	0	6
1.01	372	0	0.96	0	0.2	0	0.025	0	0.7419	0	6.001
1.02	421	0	0.88	0	1.2	0	0.025	0	0.7897	0	6.002
1.03	693	0	0.73	0	0.3	0	0.025	0	1.17	0	6.003
1.04	307	0	0.5	0	0.4	0	0.025	0	0.9212	0	6.004
1.05D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	6.005
2	625	0	1.04	0	0.2	0	0.025	0	0.9336	0	7
2.01	726	0	0.71	0	0.5	0	0.025	0	1.204	0	7.001
1.06	13	0	0.31	0	0	0	0.025	0	0.2301	0	6.006
3	443	0	0.93	0	0.3	0	0.025	0	0.8216	0	8
3.01	580	0	0.85	0	1.5	0	0.025	0	0.9365	0	8.001
3.02	473	0	0.63	0	1.5	0	0.025	0	0.9781	0	8.002
1.07D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.007
1.08	491	0	0.71	0	1.5	0	0.025	0	0.9395	0	6.008
1.09	740	0	0.76	0	1.4	0	0.025	0	1.129	0	6.009
1.1	102	0	0.81	0	1	0	0.025	0	0.3973	0	6.01
4	480	0	1.18	0	1	0	0.025	0	0.7369	0	9
4.01	330	0	0.57	0	0.6	0	0.025	0	0.8878	0	9.001
4.02	224	0	0.57	0	0.6	0	0.025	0	0.7258	0	9.002
1.11D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	6.011
1.12	505	0	0.67	0	1.2	0	0.025	0	0.9946	0	6.012
1.13	942	0	0.26	0	1.6	0	0.025	0	2.166	0	6.013
1.14	416	0	0.57	0	1.2	0	0.025	0	0.9747	0	6.014
5	980	0	0.55	0	1.2	0	0.025	0	1.549	0	10
5.01	745	0	0.67	0	1.9	0	0.025	0	1.18	0	10
5.02	309	0	0.52	0	3.3	0	0.025	0	0.7975	0	10
6	369	0	0.75	0	1.6	0	0.025	0	0.7845	0	11
5.03D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	10
5.04	303	0	0.41	0	0.2	0	0.025	0	1.019	0	10
1.15	369	0	0.15	0	0	0	0.025	0	1.882	0	6.015
1.16D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.009
1.17	609	0	0.53	0	0.6	0	0.025	0	1.266	0	2.01
11	385	0	0.84	0	1.1	0	0.025	0	0.775	0	12
12	780	0	0.83	0	1.4	0	0.025	0	1.11	0	13
12.01	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	12
12.02	380	0	0.4	0	0.6	0	0.025	0	1.14	0	12

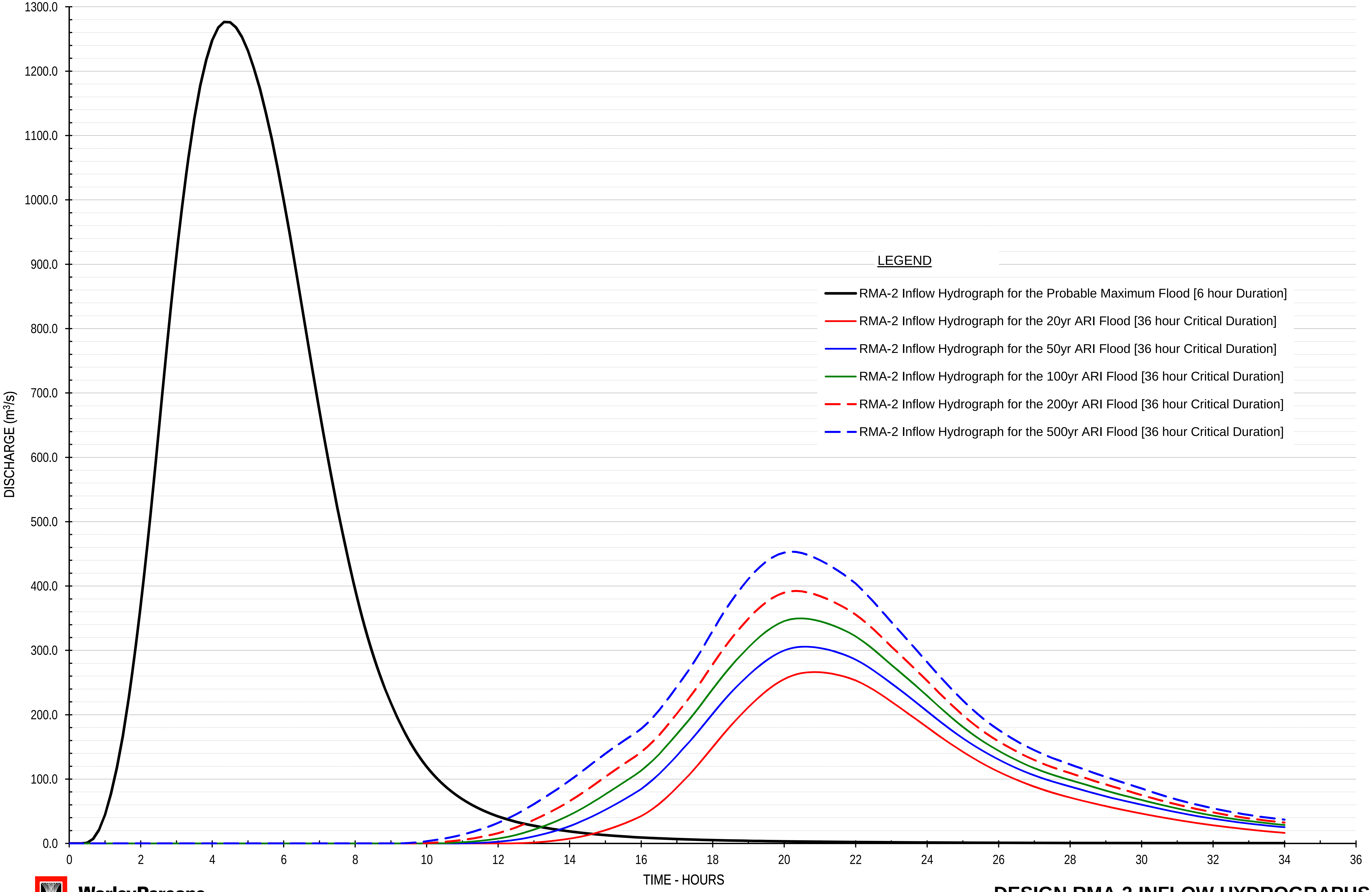
12.03	595	0	0.4	0	0.6	0	0.025	0	1.439	0	12
1.18D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.011
1.19	985	90	0.31	0.31	6.6	75	0.025	0.025	1.646	0.1033	2.012
13	614	0	0.66	0	0.1	0	0.025	0	1.166	0	14
13.01	677	0	0.56	0	0.6	0	0.025	0	1.301	0	14
1.20D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.013
1.21	122	21	0.78	0.78	1	75	0.025	0.025	0.4444	0.0306	2.014
14	1150	0	0.62	0	1.5	0	0.025	0	1.564	0	15
14.01	660	0	0.52	0	0.5	0	0.025	0	1.338	0	15
14.02	500	0	0.52	0	0.5	0	0.025	0	1.158	0	15
1.22D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.015
1.23	220	342	0.73	0.73	1	75	0.025	0.025	0.6242	0.1349	2.016
1.24	205	0	0.56	0	3	0	0.025	0	0.6289	0	2.017
15	68	127	0.93	0.93	1	99	0.025	0.025	0.3004	0.0505	16
15.01	141	172	0.74	0.74	1	99	0.025	0.025	0.4919	0.0663	16
1.25D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.018
1.26	123	53	0.7	0.7	1	99	0.025	0.025	0.4711	0.0369	2.019
16	445	0	0.74	0	4	0	0.025	0	0.7848	0	17
16.01	182	60	0.68	0.68	10	75	0.025	0.025	0.4055	0.0565	17
16.02	136	90	0.68	0.68	10	80	0.025	0.025	0.3485	0.0646	17
1.27D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.02
17	103	155	0.72	0.72	1	99	0.025	0.025	0.4235	0.0636	18
1.28D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.021
1.29	204	65	0.39	0.39	1	99	0.025	0.025	0.8205	0.055	2.022
18	375	405	0.71	0.71	1	95	0.025	0.025	0.8351	0.1114	19
18.01	184	208	0.71	0.71	1	95	0.025	0.025	0.5767	0.0788	19
1.30D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.023
1.31	591	0	0.66	0	16	0	0.025	0	0.6143	0	2.024
19	200	151	0.76	0.76	1	99	0.025	0.025	0.5822	0.0611	20
1.32	514	54	0.65	0.65	4	75	0.025	0.025	0.9025	0.0547	2.025
1.33	20	0	0.42	0	4	0	0.025	0	0.2074	0	2.026
21	105	131	0.67	0.67	1	75	0.025	0.025	0.4434	0.0855	21
20	891	0	0.67	0	3.2	0	0.025	0	1.224	0	22
20.01	449.73	10.17	0.44	0.42	0	100	0.025	0.025	1.219	0.0199	22
20.02D	0.00001	0	0.001	0	0	0	0.025	0	0.0027	0	22
20.03	332.14	0	0.56	0	1	0	0.025	0	0.8826	0	22
20.04	441	0.00001	0.47	0.001	2	1	0.025	0.001	1.067	0.0001	22
20.04b	274	0.00001	0.47	0.001	2	1	0.025	0.001	0.8336	0.0001	22
20.05D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	21
20.06	119	97	1.26	1.26	1	75	0.025	0.025	0.3453	0.0533	21
20.07	118	323	0.82	0.82	1	75	0.025	0.025	0.426	0.1235	21
20.08	353	235	0.88	0.88	1	99	0.025	0.025	0.7271	0.0715	21
20.09	238	158	1.25	1.25	1	99	0.025	0.025	0.4972	0.0488	21
20.1	255	110	0.75	0.75	1	99	0.025	0.025	0.6649	0.0522	21.01
20.11	207	0	0.6	0	10	0	0.025	0	0.4615	0	21.01
1.34D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.027
1.35	692	0	0.46	0	3.4	0	0.025	0	1.283	0	2.028
22	547	0	0.68	0	17	0	0.025	0	0.5623	0	23
1.36D	0.1	0	0.1	0	0	0	0.02	0	0.0241	0	2.029
1.37	477	0	0.76	0	1.8	0	0.025	0	0.8828	0	2.03
1.38	856	0	0.36	0	3	0	0.025	0	1.648	0	2.031
1.39D	0.1	0	0.1	0	0	0	0.025	0	0.0322	0	1.002
1.4	292	0	0.53	0	0.3	0	0.025	0	0.8758	0	1.003

Link Label (mm/h)	Average Intensity (mm/h)	Initial Loss #1	#2 (mm)	#1	Cont. Loss #2 (mm/h)	#1	Excess Rain #2 (mm)	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
23	67.5	36.6	1	0.94	0	363.23	404	203.29	250	0
23.01	67.5	36.6	0	0.94	0	363.23	0	404.12	260	0
9	67.5	33.9	0	0.94	0	365.93	0	125	210	0
9.01	67.5	33.9	0	0.94	0	365.93	0	232.76	250	0
8	67.5	33.9	0	0.94	0	365.93	0	206.67	250	0
7	67.5	33.9	0	0.94	0	365.93	0	123.04	210	0
8.01D	67.5	0	0	0	0	405	0	325.46	240	0
8.02	67.5	33.9	0	0.94	0	365.93	0	379.74	260	0
Jtn9.02	67.5	0	0	0	0	405	0	612.34	260	0
9.03	67.5	33.9	0	0.94	0	365.93	0	781.34	300	0
10	67.5	33.9	0	0.94	0	365.93	0	151.85	220	0
9.04D	67.5	0	0	0	0	405	0	911.11	290	0
9.05	67.5	33.9	0	0.94	0	365.93	0	947.13	300	0
9.06	67.5	33.9	0	0.94	0	365.93	0	1048.7	370	10
9.07	67.5	33.9	0	0.94	0	365.93	0	1057.3	380	10
9.08D	67.5	0	0	0	0	405	0	1055.3	390	0
1	67.5	35.9	0	0.94	0	363.93	0	108.28	210	0
1.01	67.5	35.9	0	0.94	0	363.93	0	188.79	220	0
1.02	67.5	35.9	0	0.94	0	363.93	0	277.68	230	0
1.03	67.5	35.9	0	0.94	0	363.93	0	421.29	240	0
1.04	67.5	35.9	0	0.94	0	363.93	0	483.07	260	0
1.05D	67.5	0	0	0	0	405	0	483.09	260	0
2	67.5	35.9	0	0.94	0	363.93	0	137.76	200	0
2.01	67.5	35.9	0	0.94	0	363.93	0	285.66	250	0
1.06	67.5	35.9	0	0.94	0	363.93	0	769.29	260	0
3	67.5	35.9	0	0.94	0	363.93	0	98.804	190	0
3.01	67.5	35.9	0	0.94	0	363.93	0	207.95	260	0

3.02	67.5	35.9	0	0.94	0	363.93	0	283.53	300	0
1.07D	67.5	0	0	0	0	405	0	1040.2	260	0
1.08	67.5	35.9	0	0.94	0	363.93	0	1135.2	270	0
1.09	67.5	35.9	0	0.94	0	363.93	0	1276.3	270	0
1.1	67.5	35.9	0	0.94	0	363.93	0	1292.7	280	0
4	67.5	15	0	0.94	0	384.52	0	113.27	170	0
4.01	67.5	15	0	0.94	0	384.52	0	184.88	200	0
4.02	67.5	15	0	0.94	0	384.52	0	233.48	220	0
1.11D	67.5	0	0	0	0	405	0	1504	280	0
1.12	67.5	35.9	0	0.94	0	363.93	0	1594.7	280	0
1.13	67.5	35.9	0	0.94	0	363.93	0	1714.1	330	0
1.14	67.5	37.1	0	0.94	0	362.73	0	1749.2	360	70
5	67.5	37.1	0	0.94	0	362.73	0	191.55	260	0
5.01	67.5	37.1	0	0.94	0	362.73	0	329.37	270	0
5.02	67.5	37.1	0	0.94	0	362.73	0	379.44	300	0
6	67.5	37.1	0	0.94	0	362.73	0	81.703	190	0
5.03D	67.5	0	0	0	0	405	0	444.22	290	0
5.04	67.5	37.1	0	0.94	0	362.73	0	480.45	340	20
1.15	67.5	37.1	0	0.94	0	362.73	0	2223.9	420	5
1.16D	67.5	0	0	0	0	405	0	3249.6	440	0
1.17	67.5	37.1	0	0.94	0	362.73	0	3274.8	450	0
11	67.5	37.1	0	0.94	0	362.73	0	86.083	190	0
12	67.5	37.1	0	0.94	0	362.73	0	166.17	220	0
12.01	67.5	0	0	0	0	405	0	250.81	210	0
12.02	67.5	37.1	0	0.94	0	362.73	0	324.44	250	0
12.03	67.5	37.1	0	0.94	0	362.73	0	431.46	290	0
1.18D	67.5	0	0	0	0	405	0	3486.3	450	0
1.19	67.5	37.1	1	0.94	0	362.73	404	3498.3	490	0
13	67.5	37.1	0	0.94	0	362.73	0	126.26	240	0
13.01	67.5	37.1	0	0.94	0	362.73	0	252.32	280	0
1.20D	67.5	0	0	0	0	405	0	3582	480	0
1.21	67.5	37.1	1	0.94	0	362.73	404	3577.5	490	0
14	67.5	37.1	0	0.94	0	362.73	0	227.76	250	0
14.01	67.5	37.1	0	0.94	0	362.73	0	352.85	270	0
14.02	67.5	37.1	0	0.94	0	362.73	0	440.08	290	0
1.22D	67.5	0	0	0	0	405	0	3736.4	490	0
1.23	67.5	37.1	1	0.94	0	362.73	404	3726.5	500	0
1.24	67.5	37.1	0	0.94	0	362.73	0	3724.2	520	0
15	67.5	37.1	1	0.94	0	362.73	404	47.481	140	0
15.01	67.5	37.1	1	0.94	0	362.73	404	119.17	150	0
1.25D	67.5	0	0	0	0	405	0	3727.2	520	0
1.26	67.5	36.6	1	0.94	0	363.23	404	3725.6	530	0
16	67.5	36.6	0	0.94	0	363.23	0	100.48	190	0
16.01	67.5	15	1	0.94	0	384.52	404	154.33	190	0
16.02	67.5	1	0	0	0	404	405	200.72	210	0
1.27D	67.5	0	0	0	0	405	0	3738.4	530	0
17	67.5	36.6	1	0.94	0	363.23	404	60.806	150	0
1.28D	67.5	0	0	0	0	405	0	3738.2	530	0
1.29	67.5	36.6	1	0.94	0	363.23	404	3742.5	540	0
18	67.5	5	1	0.94	0	394.36	404	176.37	180	0
18.01	67.5	15	1	0.94	0	384.52	404	265.98	170	0
1.30D	67.5	0	0	0	0	405	0	3752.4	540	0
1.31	67.5	36.6	0	0.94	0	363.23	0	3738.4	560	0
19	67.5	36.6	1	0.94	0	363.23	404	79.841	180	0
1.32	67.5	36.6	1	0.94	0	363.23	404	3747.1	560	0
1.33	67.5	36.6	0	0.94	0	363.23	0	3745.8	570	0
21	67.5	32.6	1	0.94	0	367.07	404	55.428	150	0
20	67.5	32.6	0	0.94	0	367.07	0	187.84	220	0
20.01	67.5	32.6	1	0.94	0	367.07	404	278.34	250	0
20.02D	67.5	0	0	0	0	405	0	278.34	250	0
20.03	67.5	32.6	0	0.94	0	367.07	0	346.84	250	0
20.04	67.5	32.6	0	0.94	0	367.07	405	434.78	260	0
20.04b	67.5	32.6	0	0.94	0	367.07	405	483.82	280	0
20.05D	67.5	0	0	0	0	405	0	521.41	280	0
20.06	67.5	32.6	1	0.94	0	367.07	404	555.32	270	0
20.07	67.5	32.6	1	0.94	0	367.07	404	617.33	290	0
20.08	67.5	32.6	1	0.94	0	367.07	404	697.68	300	0
20.09	67.5	32.6	1	0.94	0	367.07	404	668.04	360	0
20.1	67.5	36.6	1	0.94	0	363.23	404	680.78	380	0
20.11	67.5	36.6	0	0.94	0	363.23	0	689.41	400	0
1.34D	67.5	0	0	0	0	405	0	4220.3	550	0
1.35	67.5	36.6	0	0.94	0	363.23	0	4189.2	600	0
22	67.5	36.6	0	0.94	0	363.23	0	133.56	150	0
1.36D	67.5	0	0	0	0	405	0	4190.9	600	0
1.37	67.5	36.6	0	0.94	0	363.23	0	4185.7	620	0
1.38	67.5	36.6	0	0.94	0	363.23	0	4183.6	650	0
1.39D	67.5	0	0	0	0	405	0	4208.7	650	0
1.4	67.5	36.6	0	0.94	0	363.23	0	4201	660	0

APPENDIX H

DESIGN RMA-2 INFLOW HYDROGRAPHS



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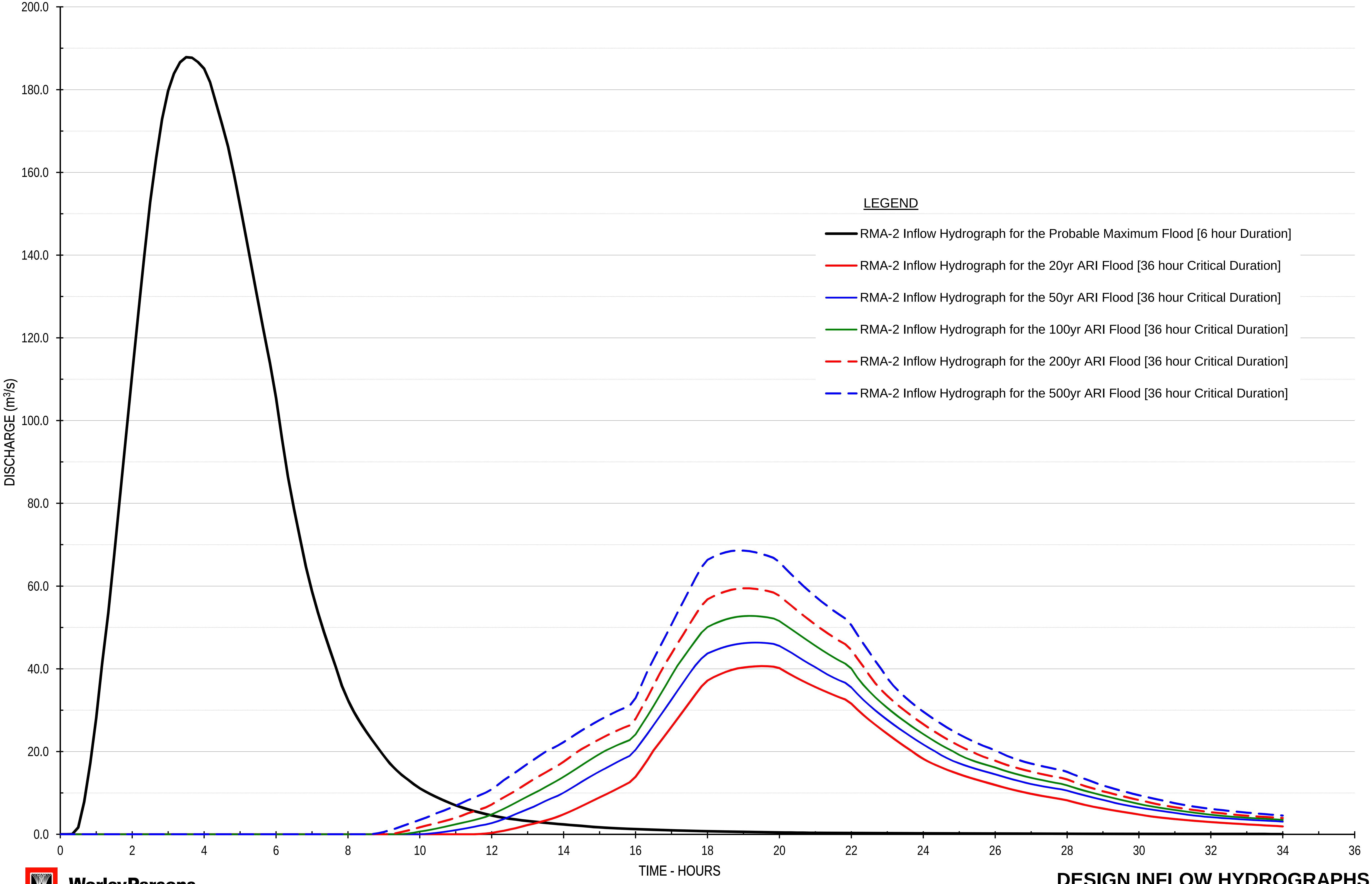
DESIGN RMA-2 INFLOW HYDROGRAPHS FOR SOUTH CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL

FIGURE H2



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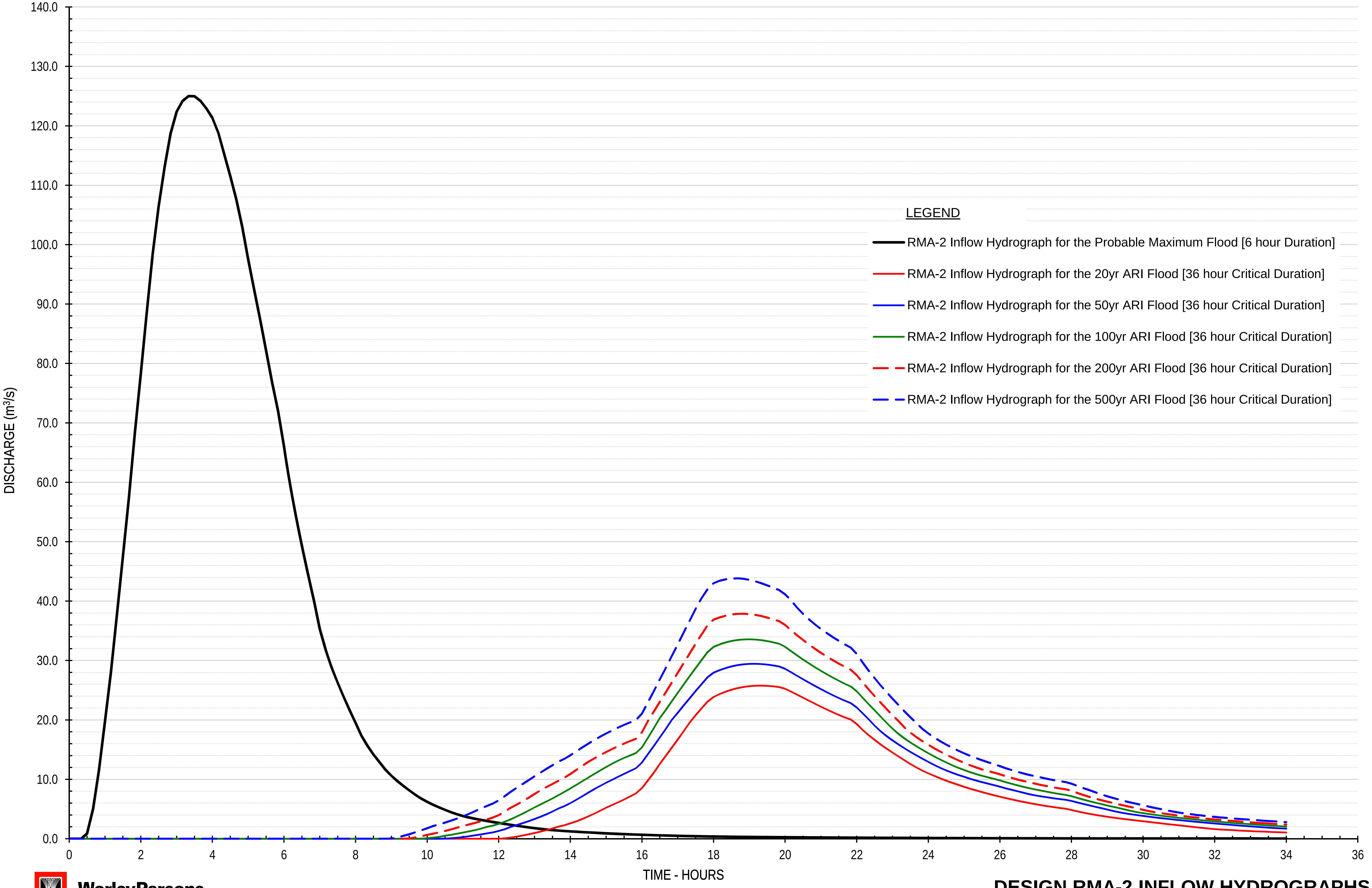
DESIGN INFLOW HYDROGRAPHS FOR ROPES CREEK AT UPSTREAM EXTENT OF RMA-2 MODEL



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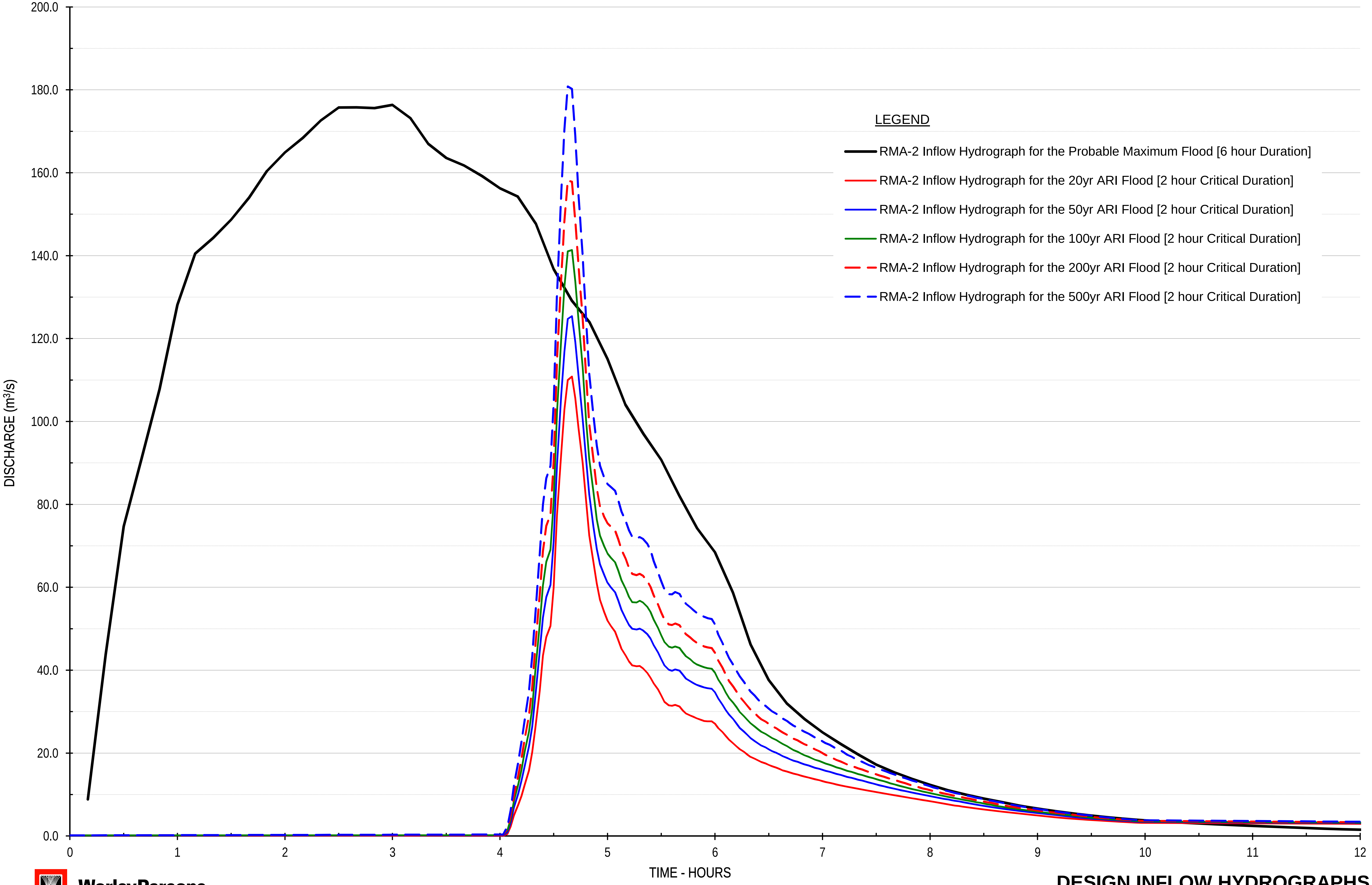
DESIGN RMA-2 INFLOW HYDROGRAPHS FOR KEMPS CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL



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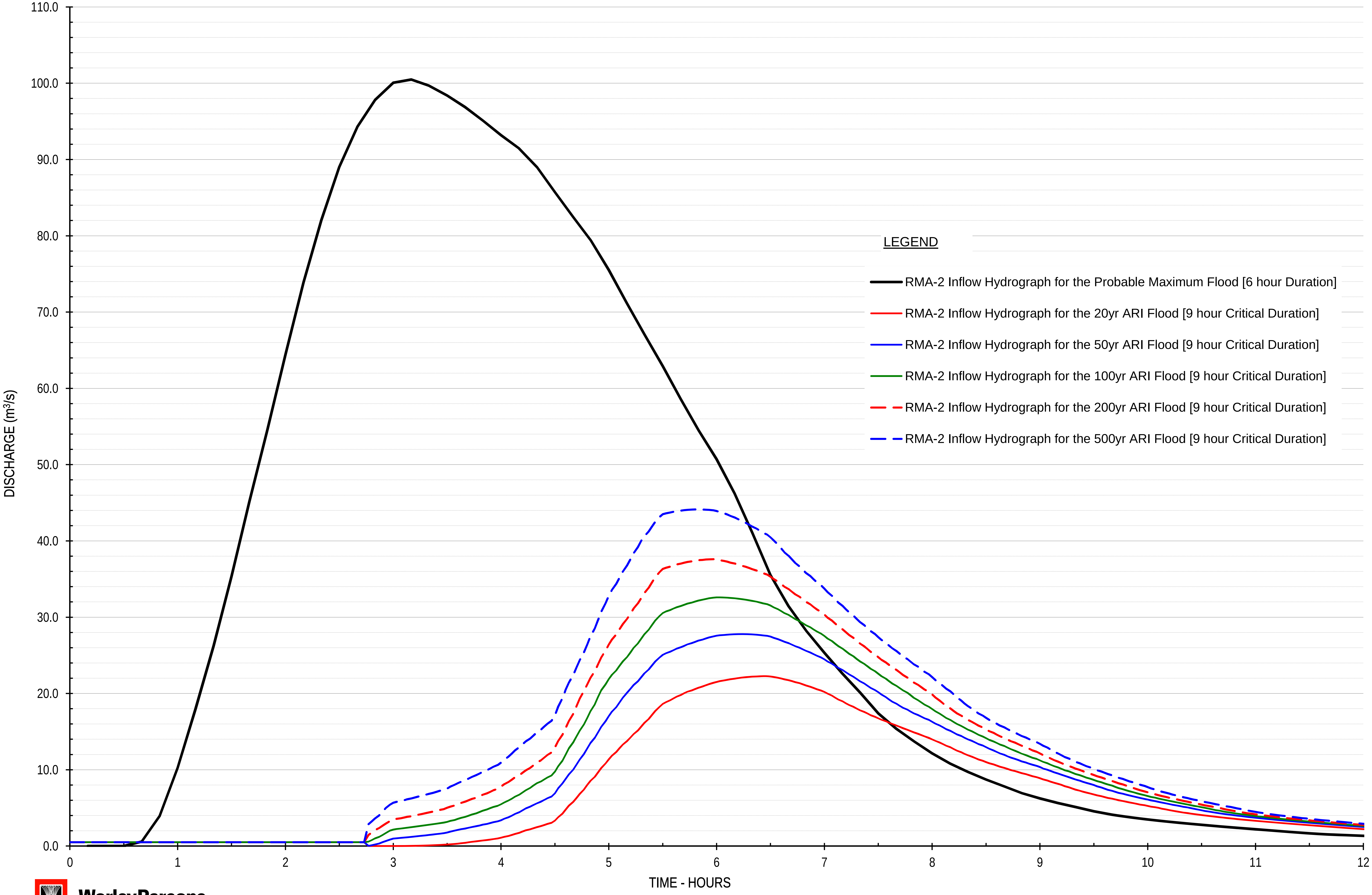
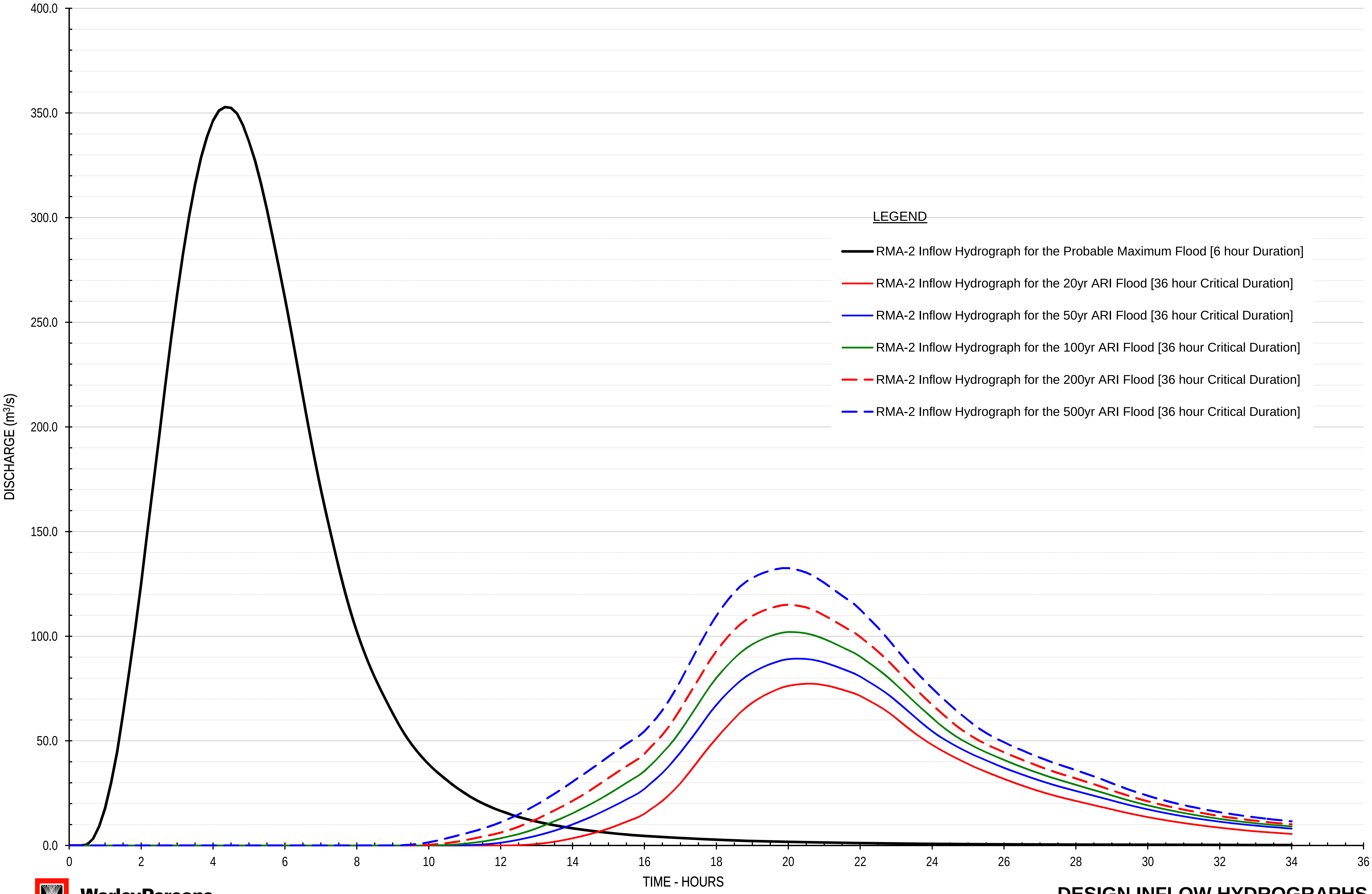
DESIGN INFLOW HYDROGRAPHS
FOR WERRINGTON CREEK
AT UPSTREAM EXTENT OF RMA-2 MODEL



DESIGN INFLOW HYDROGRAPHS FOR CLAREMONT CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL



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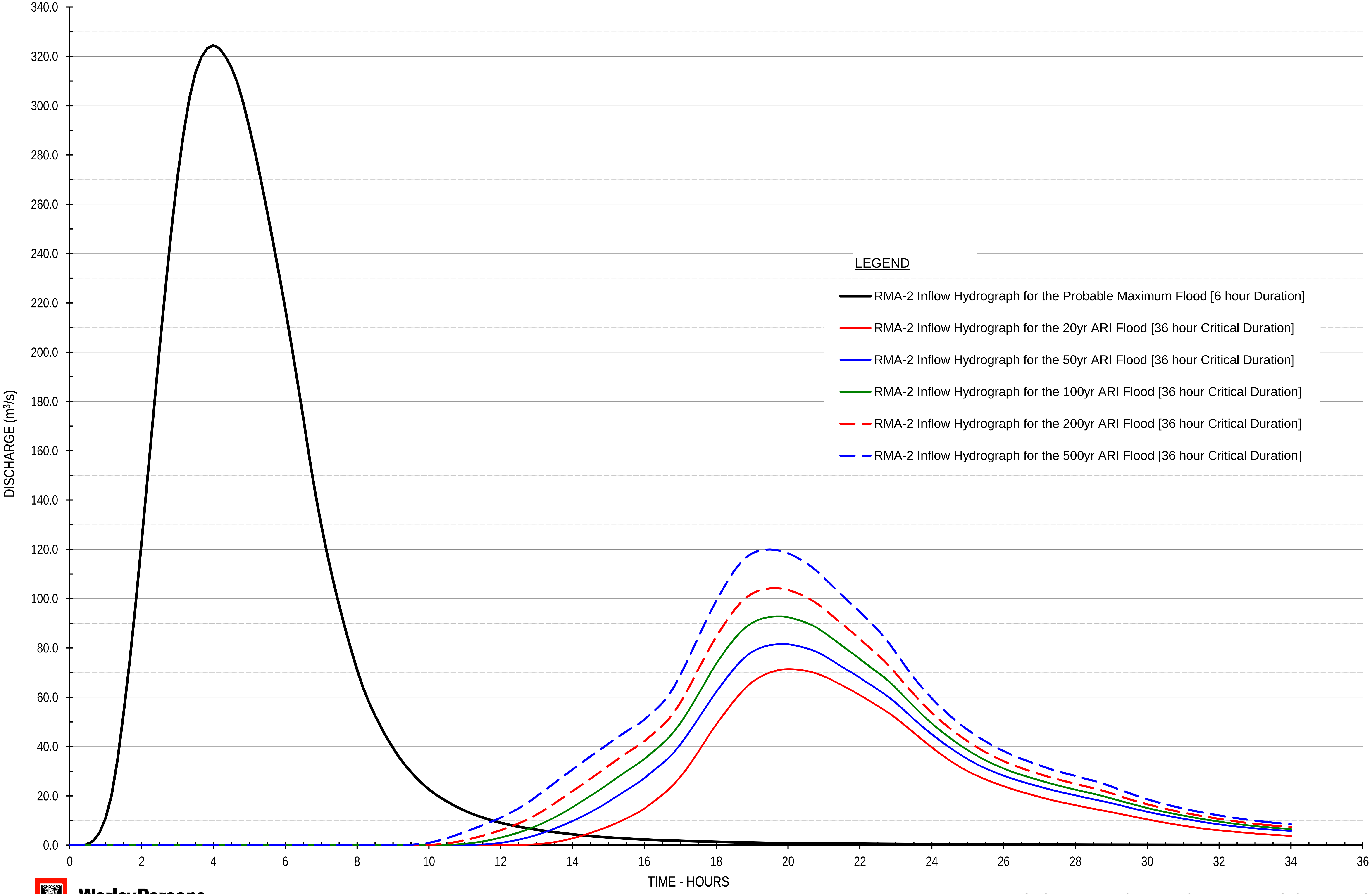
DESIGN INFLOW HYDROGRAPHS FOR BLAXLAND CREEK AT UPSTREAM EXTENT OF RMA-2 MODEL



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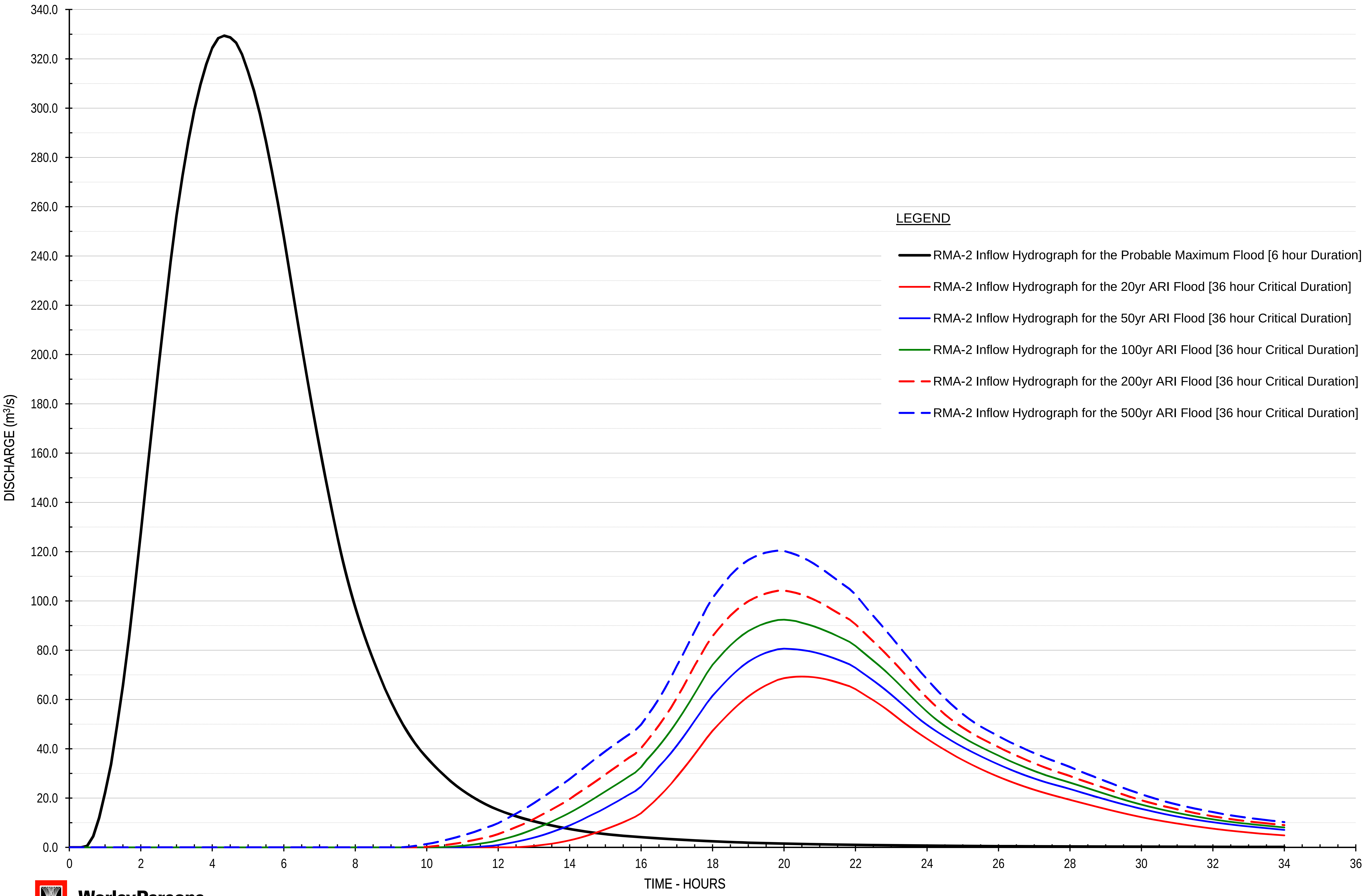
DESIGN RMA-2 INFLOW HYDROGRAPHS FOR COSGROVE CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL



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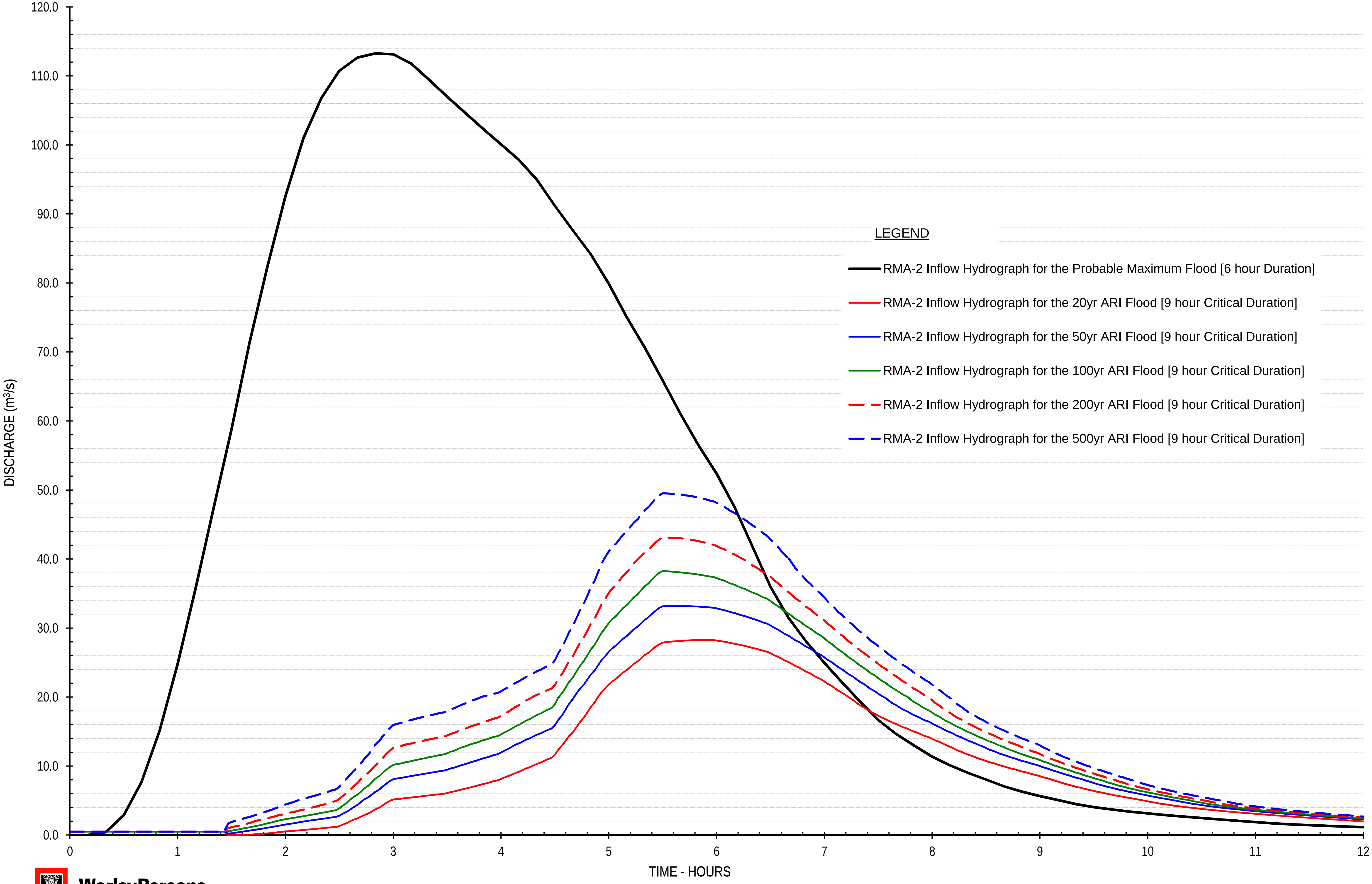
DESIGN RMA-2 INFLOW HYDROGRAPHS FOR BADGERYS CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL



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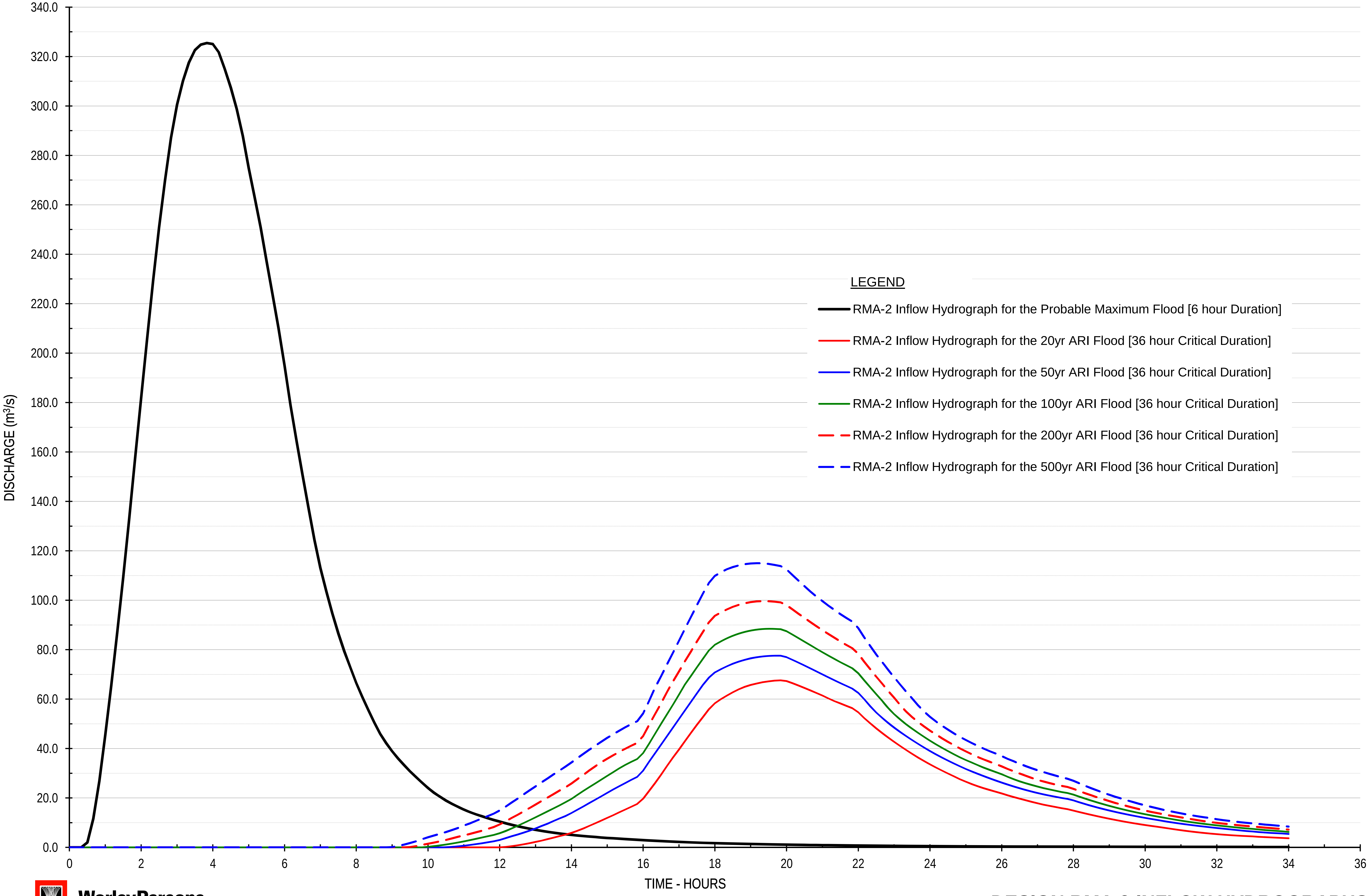
DESIGN RMA-2 INFLOW HYDROGRAPHS FOR THOMPSON CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL



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DESIGN RMA-2 INFLOW HYDROGRAPHS FOR BONDS CREEK AT THE UPSTREAM EXTENT OF THE RMA-2 MODEL

Table H1 PEAKS FLOWS ALONG SOUTH CREEK EXTRACTED FROM RMA-2 MODEL RESULTS

KEY LOCATIONS ALONG SOUTH CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Bringelly Road Upstream	266	305	350	392	453	1276
Bringelly Road Dowsntream	262	303	344	389	452	1268
Confluence with Thompsons Creek	310	355	410	455	520	1485
Opposite Fifteenth Avenue	310	355	410	455	520	1485
Opposite Victor Avenue	330	380	430	480	560	1540
Opposite Overett Avenue	330	380	430	480	560	1540
Elizabeth Drive Upstream	350	390	450	520	600	1680
Elizabeth Drive Dowsntream	350	390	450	520	600	1680
Upstream extent of South Creek Dam	360	410	485	535	625	1725
Confluence with Badgerys Creek	385 *	420 *	440 *	470 *	510 *	1400 *
Sydney Water Pipeline Upstream	720	860	1015	1140	1330	3450
Sydney Water Pipeline Downstream	735	870	1020	1145	1350	3465
Luddenham Road	735	870	1020	1145	1350	3465
Confluence with Blaxland Creek	800	950	1110	1280	1540	3690
Motorway (M4)	805	970	1125	1300	1565	3700
Great Western Highway	805	980	1145	1310	1520	3750
The Kingsway	810	980	1150	1315	1550	3750
Main Western Railway / Confluence with Claremont Creek	810	980	1150	1315	1555	2900 **
Dunheved Road	800	980	1150	1315	1555	2600 **
Links Road Railway	820	1040	1200	1380	1570	3750
Munitions Road	630 ^	870 ^	960 ^	1080 ^	1100 ^	3750
Downstream of Confluence with Ropes Creek	890	1110	1290	1510	1835	4070
Eighth Avenue Bridge	900	1110	1290	1510	1835	4070
Stoney Creek Raod	880	1080	1290	1520	1810	4020
Richmond Road	890	1110	1320	1550	1840	4060

* Cross-section taken downstream of location where South Creek flows divert to Kemps Creek (*refer* Figures *for localised flood conditions*)

** Cross-section taken downstream of location where South Creek flows divert to Werrington Creek (*refer* Figures *for localised flood conditions*)

^ Cross-section taken downstream of location where South Creek flows divert towards Ropes Creek (*refer* Figures *for localised flood conditions*)

^^ Cross-section taken at location where South Creek & Ropes Creek flows act together. Accordingly, the flow represents the total flow along both Creeks (*refer* Figures *for localised flood conditions*)

Table H2 PEAKS FLOWS ALONG ROPES CREEK EXTRACTED FROM RMA-2 MODEL RESULTS

KEY LOCATIONS ALONG ROPES CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Capitol Hill Drive	40	46	52	59	68	187
Sydney Water Pipeline	70	80	92	103	120	338
Lenore Drive	92	106	118	138	155	415
Motorway (M4)	124	142	160	180	210	540
Carlisle Avenue	115	135	150	175	210	520
Great Western Highway	135	155	175	200	220	580
Main Western Railway	152	178	205	228	260	615
Debrincat Avenue	155	188	210	242	280	635
Forrester Road	160	190	215	245	285	650
Ropes Crossing Boulevard	170	200	235	255	305	670
Confluence with South Creek	890 *	1110 *	1290 *	1510 *	1835 *	4070 *

* At Ropes Creek confluence with South Creek flows act together with no distinguishable floodplain seperation (*refer* Figures *for localised flood conditions*)

Table H3 **PEAKS FLOWS ALONG KEMPS CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG KEMPS CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Bringelly Road (U/S and D/S) *	25	29	33	70	43	122
Twelfth Ave	25	29	33	70	43	120
Fifteenth Ave	125	145	165	185	210	610
Gurner Ave	125	145	165	185	210	610
Elizabeth Drive (U/S and D/S) *	190	220	255	290	335	925
Upstream End of Kemps Creek Dam	220	245	290	330	380	1,010
Upstream Confluence with South Creek	260	360	440	560	680	2,300

Table H4 **PEAKS FLOWS ALONG BONDS CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG BONDS CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Ninth Ave	65	75	85	95	112	320
Tenth Ave	65	75	85	95	112	320

Table H5 **PEAKS FLOWS ALONG THOMPSONS CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG THOMPSONS CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Downstream of Northern Road	26	30	36	42	47	105
The Retreat Road	42	49	55	64	74	174
Confluence with South Creek	52	60	69	82	94	225

Table H6 **PEAKS FLOWS ALONG BADGERYS CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG BADGERYS CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Badgerys Creek Road	68	80	90	102	115	320
Elizabeth Drive	68	80	90	102	118	330
Confluence with South Creek	98	115	135	155	180	480

Table H7 **PEAKS FLOWS ALONG COSGROVES CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG COSGROVES CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Twin Creed Drive	70	80	90	102	118	320
Confluence with South Creek	N.A *	N.A *	N.A *	N.A *	N.A *	N.A *

* Flooding conditions dominated by South Creek flows with no differentiation between South/Cosgrove Creek flows (*refer* Figures *for localised flood conditions*)

Table H8 **PEAKS FLOWS ALONG BLAXLAND CREEK EXTRACTED FROM RMA-2 MODEL RESULTS**

KEY LOCATIONS ALONG BLAXLAND CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Upstream Confluence with South Creek	N.A *	N.A *	N.A *	N.A *	N.A *	N.A *

* Flooding conditions dominated by South Creek flows with no differentiation between South/Blaxland Creek flows (*refer* Figures *for localised flood conditions*)

Table H9 PEAKS FLOWS ALONG CLAREMONT CREEK EXTRACTED FROM RMA-2 MODEL RESULTS

KEY LOCATIONS ALONG CLAREMONT CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
Downstream of Motorway (M4)	20	26	32	36	43	95
Castle Road	20	25	30	35	42	94
Caddens Road	20	25	30	35	42	94
Sunflower Drive (*South*)	20	25	30	35	42	94
Sunflower Drive (*North*)	32	42	47	55	68	145
Great Western Highway (U/S and D/S) *	32	42	45	55	68	145
Werrington Road	32	42	45	55	65	150 *
Confluence with South Creek	N.A *	N.A *	N.A *	N.A *	N.A *	N.A *

* Flooding conditions dominated by South Creek flows with no differentiation between South/Cosgroves Creek flows (*refer* Figures *for localised flood conditions*)

Table H10 PEAKS FLOWS ALONG WERRINGTON CREEK EXTRACTED FROM RMA-2 MODEL RESULTS

KEY LOCATIONS ALONG WERRINGTON CREEK	PEAK FLOWS BASED ON RMA-2 FLOOD MODEL RESULTS (m3/s)					
	20yr ARI Flows	50yr ARI Flows	100yr ARI Flows	200yr ARI Flows	500yr ARI Flows	PMF Flows
William Street Footbridge	110	125	140	155	180	175
Burton Street	85	105	120	140	150	145
John Oxley Drive	85	105	120	140	160	160
Dunheved Road	95	105	130	145	160	780 *
Confluence with South Creek	N.A *	N.A *	N.A *	N.A *	N.A *	N.A *

* Flooding conditions dominated by South Creek flows with no differentiation between South/Werrington Creek flows (*refer* Figures *for localised flood conditions*)

APPENDIX I

RMA-2 DESIGN FLOOD LEVELS

TABLE I1 DESIGN FLOOD LEVELS ALONG SOUTH CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
SOUTH CREEK	Downstream Bringelly Road	58.6	59.0	58.8	59.3	59.4	60.1
	Bellfield Avenue	57.4	57.5	57.6	57.7	57.8	58.8
	Confluence with Thompsons Creek	53.1	53.2	53.3	53.4	53.5	54.4
	Fifteenth Avenue	51.1	51.2	51.3	51.4	51.5	52.7
	Watts Road	49.6	49.7	49.8	49.9	50.0	51.0
	Victor Avenue	47.8	48.8	48.9	49.0	49.1	50.0
	Overett Avenue	43.3	43.5	43.6	43.7	43.8	44.9
	Upstream Elizabeth Drive	42.6	42.8	42.9	43.0	43.1	44.0
	Downstream Elizabeth Drive	42.6	42.7	42.8	42.9	43.0	43.8
	Upstream End of South Creek Dam	37.8	37.9	38.1	38.1	38.2	39.4
	Bailey Bridge	34.9	35.0	35.3	35.3	35.6	37.1
	Upstream Sydney Water Pipeline	33.5	33.6	33.8	33.9	34.0	35.3
	Downstream Sydney Water Pipeline	33.4	33.6	33.7	33.9	34.0	35.3
	Patons Lane	31.9	32.1	32.3	32.4	32.6	33.8
	150 metres Upstream Luddenham Road	29.6	30.2	30.1	30.5	30.8	32.3
	300 metres Downstream Luddenham Road	29.6	29.9	30.1	30.3	30.6	32.1
	Upstream Motorway (M4)	27.6	28.1	28.5	28.8	29.0	30.3
	Dowsnstream Motorway (M4)	27.0	27.4	27.7	27.9	28.1	29.4
	Wilson Street	25.8	26.2	26.4	26.7	26.9	28.1
	Saddington Street	25.6	25.9	26.1	26.3	26.6	27.8
	Upstream Great Western Highway	25.2	25.5	25.7	26.0	26.2	27.5
	Downstream Great Western Highway	24.5	24.8	24.8	25.2	25.4	27.3
	Upstream Main Western Railway	23.3	23.6	23.9	24.1	24.4	27.0
	Downstream Main Western Railway	23.3	23.6	23.8	24.1	24.3	26.9
	Upstream Dunheved Road	22.1	22.4	22.6	22.8	23.1	26.7
	Downstream Dunheved Road	21.9	22.1	22.3	22.5	22.7	26.7
	Upstream Links Road Railway	19.9	20.2	20.5	20.7	21.3	26.6
	Dowsntream Links Road Railway	19.9	20.2	20.4	20.7	21.3	26.6
	Upstream Munitions Road	19.1	19.4	19.7	20.1	21.0	26.6
	Downstream Munitions Road	18.9	19.3	19.6	20.0	20.9	26.6
	Ropes Creek Confluence	17.7	18.0	18.4	19.1	20.5	26.5
	Seventh Avenue	17.1	17.5	18.1	19.0	20.4	26.5
	End of South Creek Road	16.0	16.6	17.6	18.9	20.3	26.5
	Mayo Road	15.1	16.1	17.5	18.8	20.3	26.4
	Stoney Creek Road	14.2	15.8	17.4	18.7	20.2	26.4
	Upstream Richmond Road	13.8	15.7	17.3	18.7	20.2	26.4

TABLE I2 DESIGN FLOOD LEVELS ALONG COSGROVES CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
COSGROVES CREE	Upstream Private Bridge (Upstream Twin Creeks)	38.5	38.6	38.8	38.9	39.0	39.7
	Downstream Private Bridge (Upstream Twin Creeks)	38.5	38.6	38.8	38.8	39.0	39.7
	Upstream Twin Creek Drive	34.3	34.5	34.6	34.7	34.9	36.0
	Downstream Twin Creeks Drive	34.3	34.3	34.4	34.5	34.6	35.7

TABLE I3 DESIGN FLOOD LEVELS ALONG THOMPSONS CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
THOMPSONS CREEK	Downstream Northern Road	69.1	69.2	69.5	69.6	69.7	70.5
	Kelvin Park Drive	64.2	64.3	64.4	64.5	64.4	65.2
	120 metres Upstream The Retreat	59.6	59.6	59.7	59.8	59.8	60.2
	Upstream The Retreat Road	59.0	59.1	59.2	59.2	59.3	59.6
	Dowsntream The Retreat Road	59.0	59.1	59.1	59.2	59.2	59.5
	250 m U/S of South Creek	53.2	53.4	53.4	53.5	53.6	54.5
	At Confluence with South Creek	53.1	53.2	53.3	53.4	53.5	54.4

TABLE I4 DESIGN FLOOD LEVELS ALONG KEMPS CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
KEMPS CREEK	Downstream Bringelly Road	74.2	74.3	74.3	74.3	74.4	75.0
	Little Street	67.5	67.6	67.7	67.7	67.8	68.2
	East of Devonshire Road	63.8	63.9	63.9	64.0	64.1	64.7
	Twelfth Avenue	60.1	60.2	60.2	60.3	60.3	60.8
	Fourteenth Avenue	58.2	58.3	58.4	58.4	58.5	59.2
	Upstream Fifteenth Avenue	57.2	57.3	57.4	57.4	57.5	58.2
	Dowsntream Fifteenth Avenue	57.1	57.2	57.2	57.3	57.4	57.9
	Upstream Gurner Avenue	55.3	55.3	55.4	55.5	55.5	56.2
	Downstream Gurner Avenue	55.2	55.3	55.3	55.4	55.4	56.2
	East of Tavistock Road	50.2	50.3	50.3	50.4	50.5	51.3
	Upstream Cross Street	47.9	48.0	48.1	48.2	48.4	49.5
	Upstream Elizabeth Drive	47.5	47.6	47.7	47.8	47.9	48.8
	Downstream Elizabeth Drive	46.5	46.6	46.7	46.8	46.9	47.9
	Adjacent to Kerrs Road	43.4	43.6	43.7	43.9	44.0	44.9
	Upstream End of Kemps Creek Dam	38.3	38.4	38.6	38.7	38.8	40.0
	At Confluence with South Creek	35.2	35.4	35.6	35.7	35.9	37.4

TABLE I5 DESIGN FLOOD LEVELS ALONG BADGERYS CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
BADGERYS CREEK	Downstream Badgerys Creek Road	58.7	59.0	58.9	59.3	59.4	60.3
	East of Green Street	55.2	55.3	55.4	55.5	55.6	56.1
	East of Leggo Street	53.4	53.5	53.6	53.6	53.7	54.3
	Upstream Pitt Street	50.3	50.5	50.6	50.7	50.8	51.5
	Downstream Pitt Street	50.3	50.4	50.5	50.6	50.7	51.4
	Upstream Elizabeth Drive	46.3	46.4	46.5	46.6	46.6	47.2
	Downstream Elizabeth Drive	46.1	46.2	46.2	46.3	46.3	46.9
	At Confluence with South Creek	37.4	37.7	37.9	38.0	38.1	38.8

TABLE I6 DESIGN FLOOD LEVELS ALONG CLAREMONT CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
CLAREMONT CREEK	Downstream Castle Road	38.8	38.9	39.0	39.2	39.3	39.8
	Upstream Caddens Road	33.9	34.0	34.1	34.2	34.3	34.6
	Downstream Caddens Road	33.6	33.8	33.9	34.0	34.1	34.5
	Apex Trotting Track						
	Upstream O'Connel Street	30.1	30.3	30.5	30.7	30.8	31.5
	Downstream O'Connel Street	29.5	29.7	29.9	30.0	30.2	30.8
	Upstream Sunflower Drive	28.1	28.3	28.5	28.6	28.7	29.3
	Downstream Sunflower Drive	27.9	28.0	28.2	28.3	28.4	29.0
	Upstream Great Western Highway	26.7	26.8	26.9	27.0	27.1	27.3
	Downstream Great Western Highway	26.0	26.2	26.2	26.3	26.4	27.1
	Upstream Werrington Road	23.7	23.9	24.2	24.4	24.7	27.1
	Downstream Werrington Road	23.6	23.9	24.2	24.4	24.7	27.1
	At Confluence with South Creek	23.3	23.7	23.9	24.2	24.5	27.1

TABLE I7 DESIGN FLOOD LEVELS ALONG WERRINGTON CREEK

	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
WERRINGTON CREEK	William Street Footbridge	29.2	29.3	29.4	29.5	29.6	29.7
	Upstream Burton Street	27.6	27.7	27.8	27.9	28.0	28.1
	Downstream Burton Street	27.4	27.4	27.6	27.6	27.7	27.8
	Upstream John Oxley Drive	24.8	24.9	25.0	25.1	25.2	26.7
	Downstream John Oxley Drive	24.6	24.6	24.7	24.7	24.8	26.7
	40m Upstream Dunheved Road	21.3	21.5	21.7	21.9	22.2	26.7

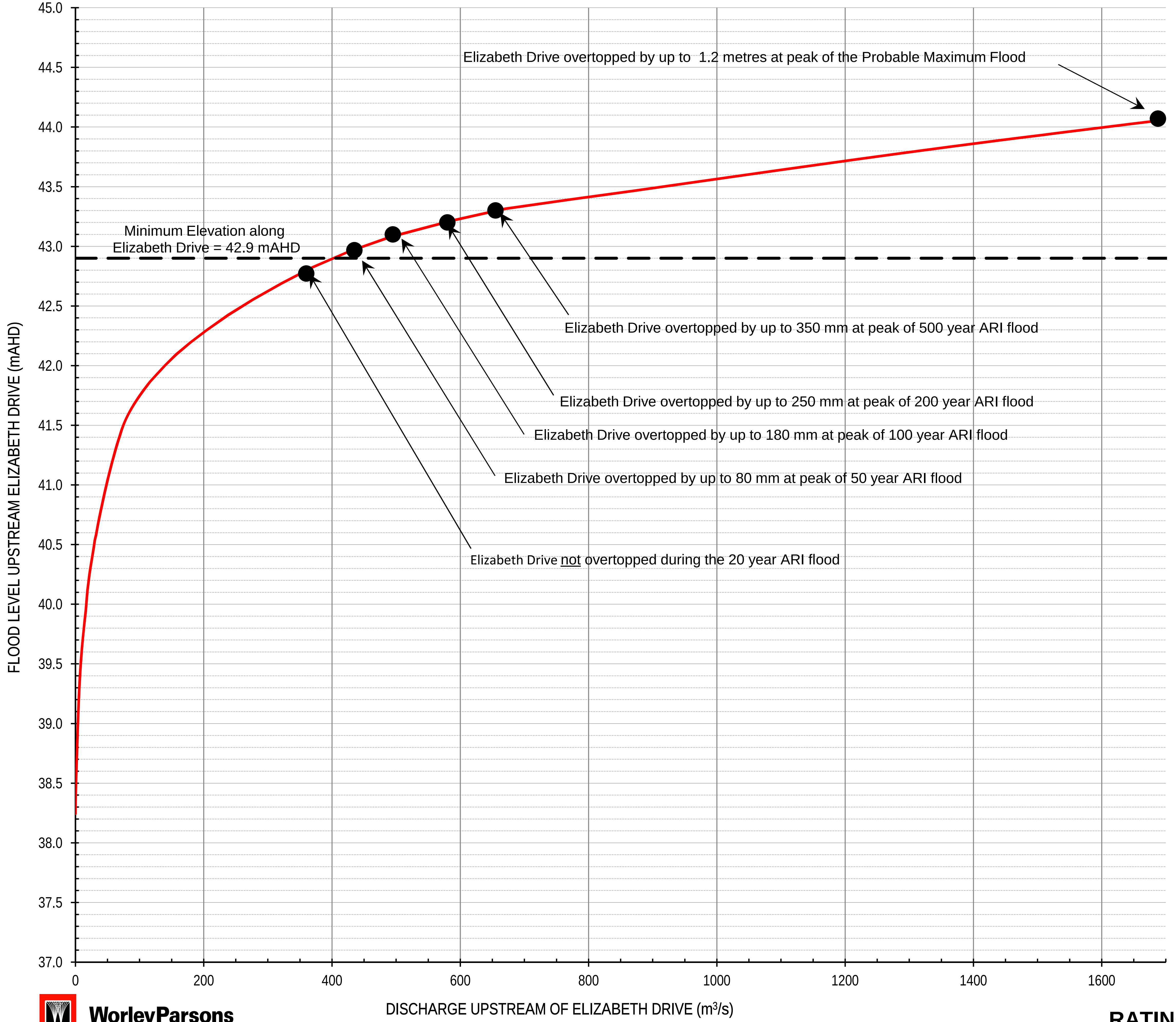
TABLE I8 DESIGN FLOOD LEVELS ALONG ROPES CREEK

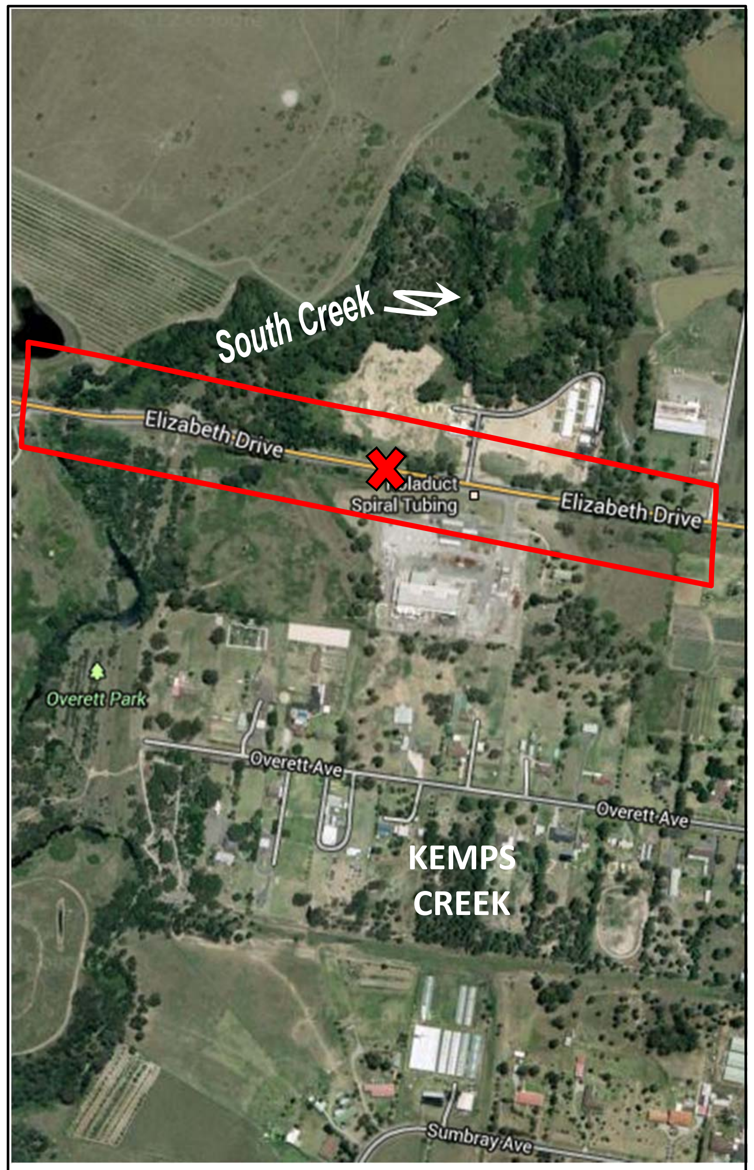
	KEY LOCATIONS ALONG SOUTH CREEK	UPDATED SOUTH CREEK FLOOD STUDY RESULTS (RMA-2)					
		20yr ARI Levels (*mAHD*)	50yr ARI Levels (*mAHD*)	100yr ARI Levels (*mAHD*)	200yr ARI Levels (*mAHD*)	500yr ARI Levels (*mAHD*)	PMF Levels (*mAHD*)
ROPES CREEK	Downstream Capital Hill Drive	68.9	69.0	69.1	69.2	69.3	69.8
	Upstream Sydney Water Pipeline	53.9	54.0	54.0	54.1	54.1	54.5
	Downstream Sydney Water Pipeline	53.8	53.9	53.9	54.0	54.0	54.5
	Upstream Motorway (M4)	42.2	42.3	42.5	42.7	43.0	44.8
	Dowsntream Motorway (M4)	41.7	41.8	41.9	42.1	42.2	43.3
	Upstream Carlisle Avenue	38.9	39.0	39.2	39.4	39.6	40.4
	Downstream Carlisle Avenue	38.9	39.0	39.2	39.3	39.4	40.3
	Upstream Great Western Highway	36.3	36.4	36.7	36.8	36.9	38.0
	Downstream Great Western Highway	36.1	36.2	36.3	36.5	36.7	37.4
	Upstream Durham Street	33.5	33.6	33.7	33.8	33.9	35.1
	Downstream Durham Street	33.3	33.4	33.5	33.7	33.9	35.0
	Upstream Main Western Railway	32.6	32.7	32.9	33.1	33.2	34.6
	Downstream Main Western Railway	32.5	32.6	32.7	32.8	32.9	33.7
	Downstream Debrincat Avenue	28.4	28.5	28.6	28.7	28.8	29.3
	Upstream Forresters Road	24.5	24.6	24.7	24.8	24.8	26.7
	Downstream Forresters Road	24.4	24.5	24.5	24.6	24.7	26.7
	Upstream Ropes Crossing Boulevard	23.4	23.6	23.7	23.7	23.8	26.7
	Downstream Ropes Crossing Boulevard	23.1	23.3	23.4	23.5	23.6	26.6
	Upstream Munitions Road	18.7	19.1	19.4	19.9	20.9	26.6
	Downstream Munitions Road	18.6	19.0	19.4	19.9	20.8	26.6
	At Confluence with South Creek	17.7	18.0	18.4	19.1	20.5	26.5

APPENDIX J

ANALYSIS OF FLOODING AT MAJOR HYDRAULIC CONTROLS

FIGURE J1





Map Source: www.maps.google.com.au

LEGEND:

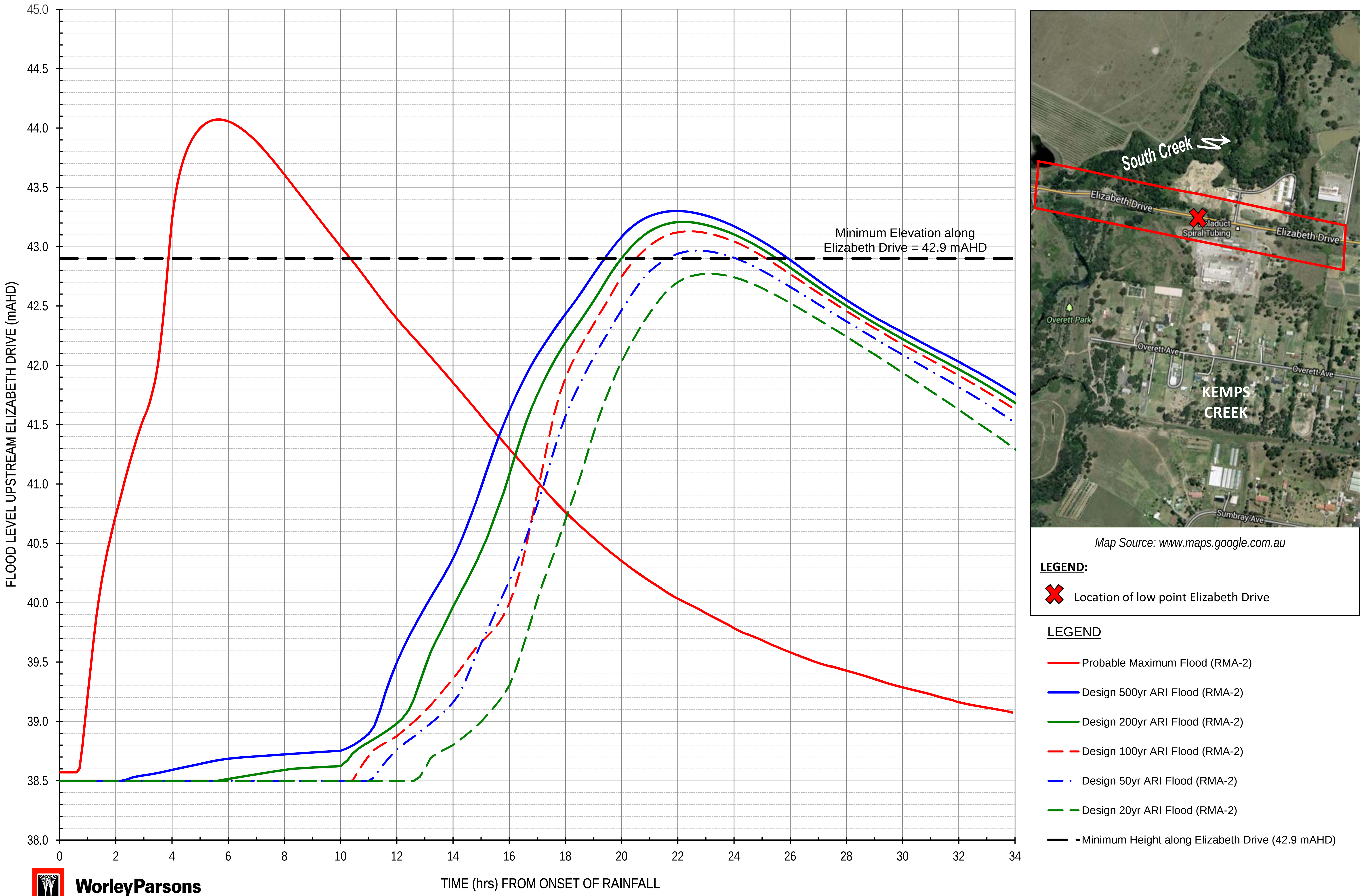
❌ Location of low point along Elizabeth Drive

LEGEND

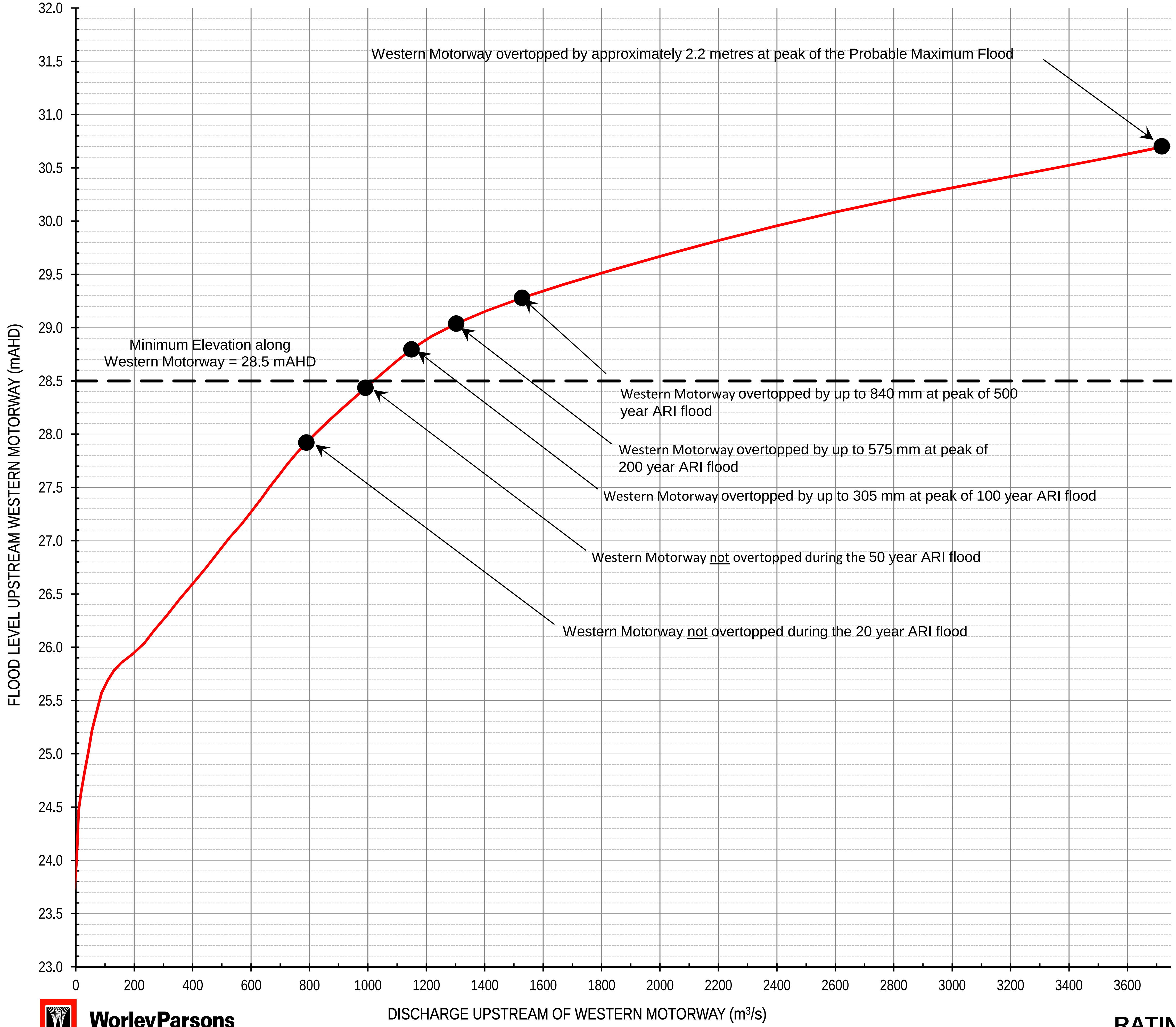
━	Rating Curve for Elizabeth Drive based on RMA-2 modelling of current catchment conditions (South Creek)
━ ━	Minimum Height along Elizabeth Drive (42.9 mAHD)

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR SOUTH CREEK UPSTREAM OF ELIZABETH DRIVE

FIGURE J2



ELIZABETH DRIVE DURING DESIGN FLOODS
(*SOUTH CREEK CROSSING*)



Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point along Western Motorway

LEGEND

🟥 Western Motorway (South Creek) - Rating Curve

– – Minimum elevation along Western Motorway (28.5 mAHD)

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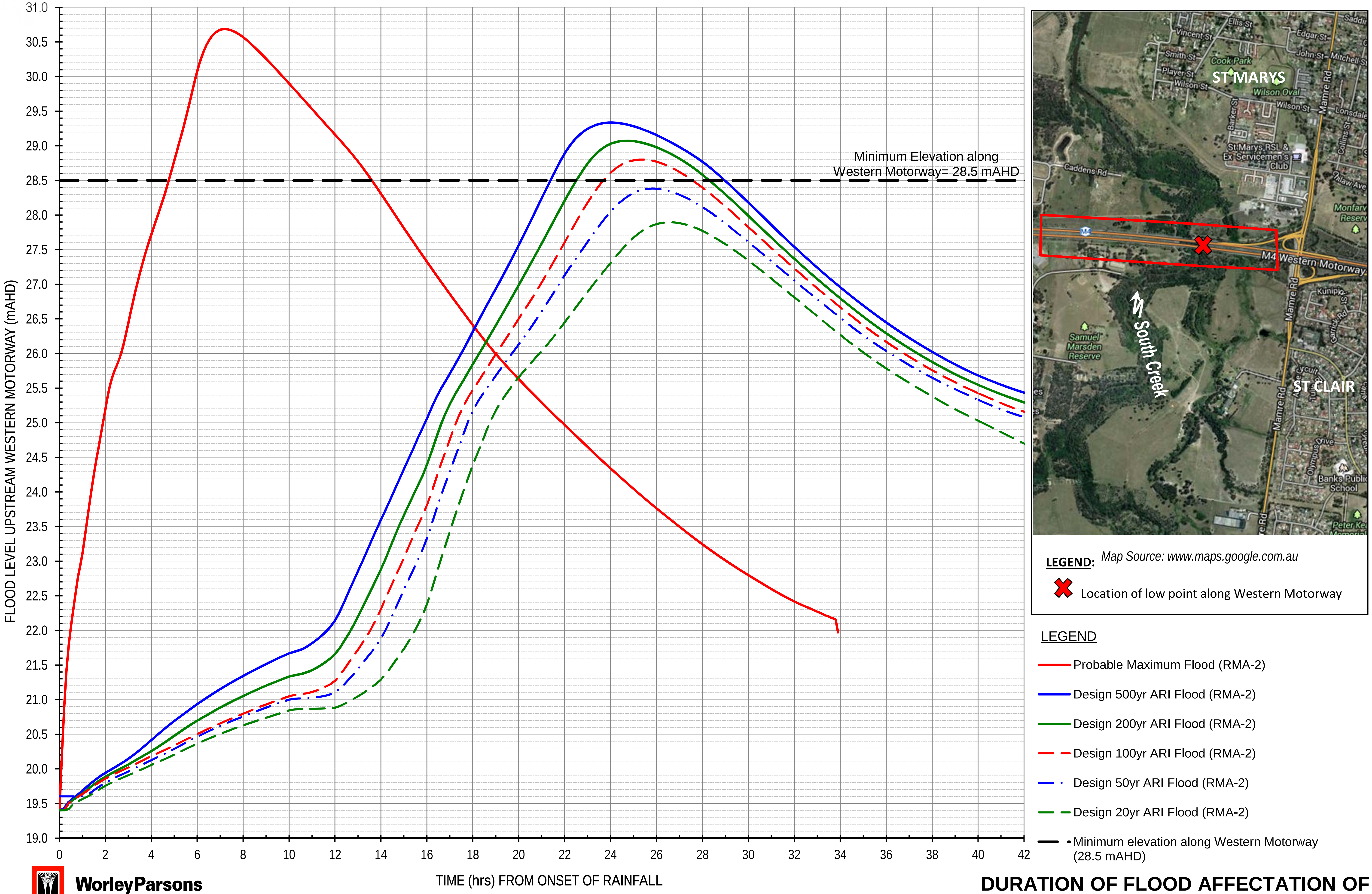
fg6033rg130214-APPENDIX J.xls

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR SOUTH CREEK UPSTREAM OF WESTERN MOTORWAY

FIGURE J4



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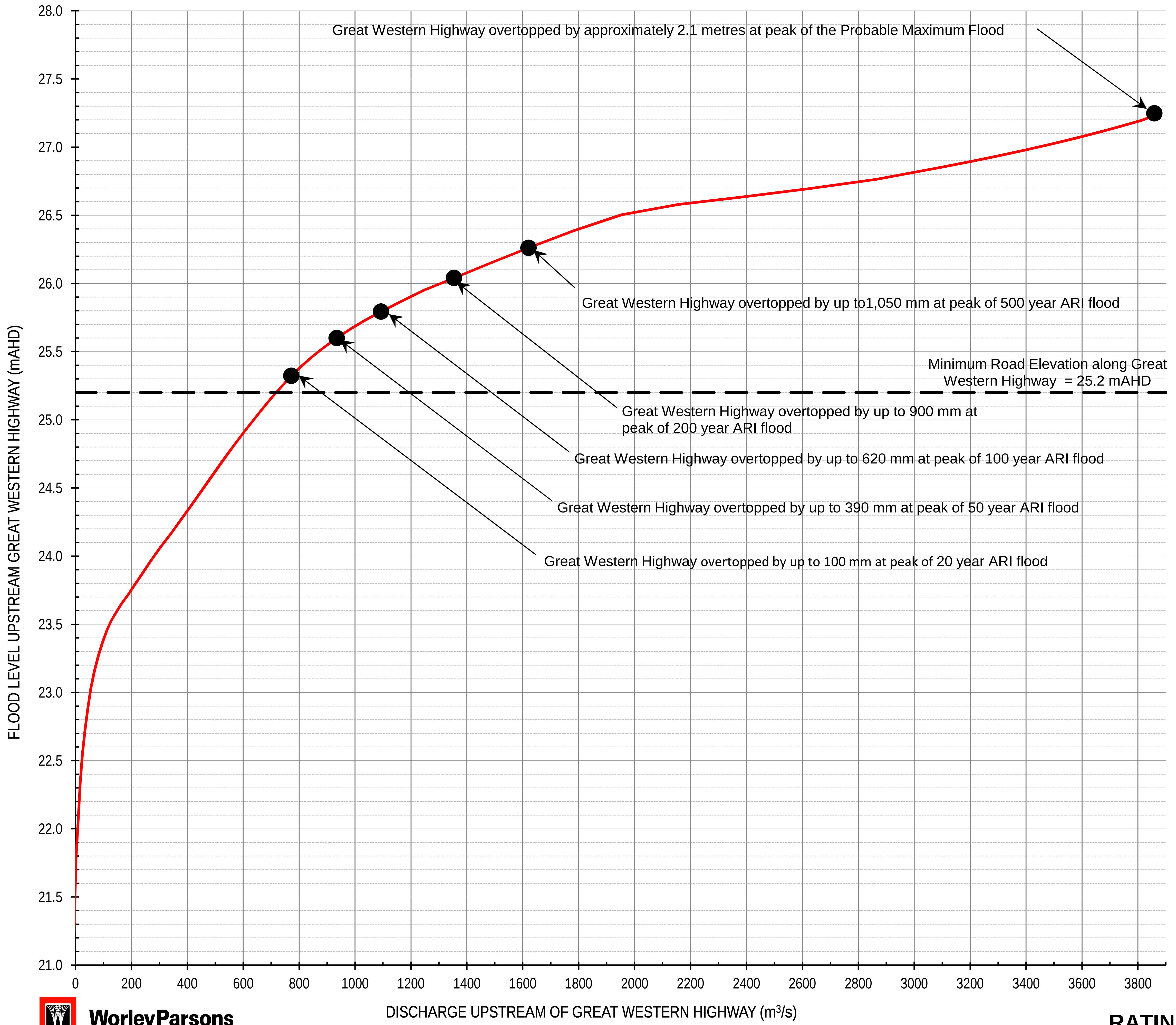
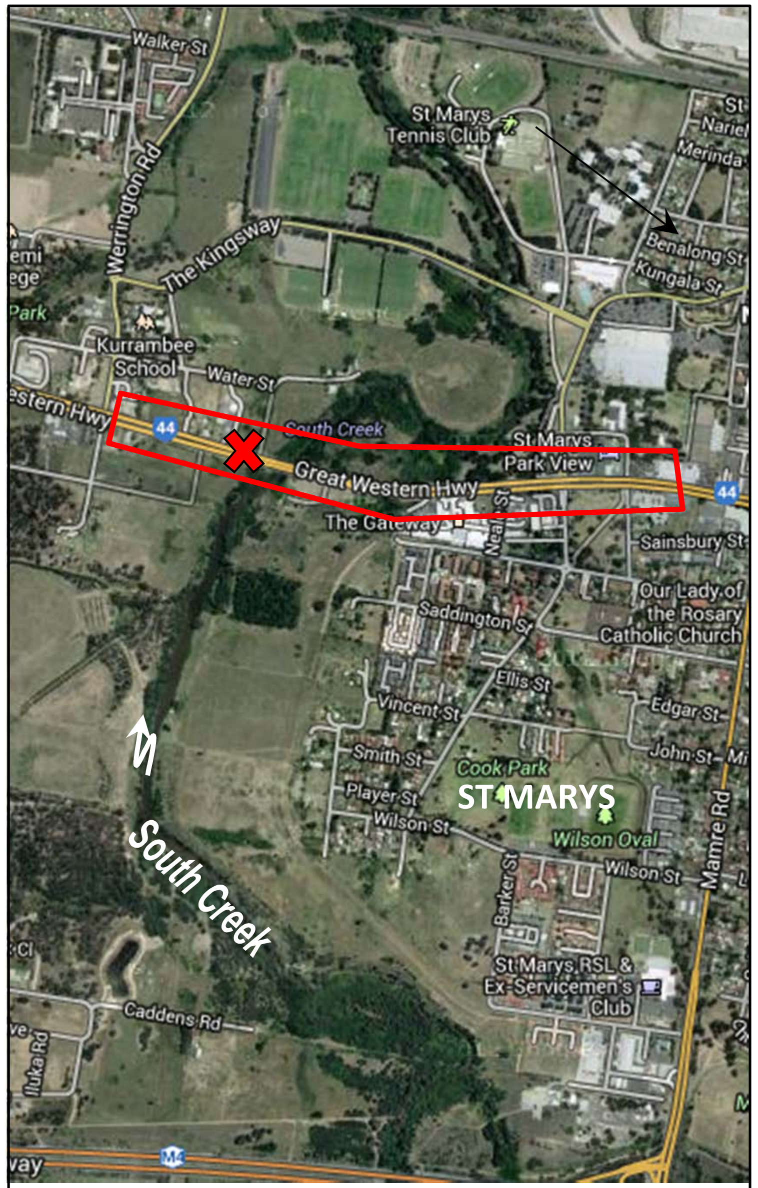
DURATION OF FLOOD AFFECTATION OF WESTERN MOTORWAY DURING DESIGN FLOODS (*SOUTH CREEK CROSSING*)

FIGURE J5





Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point along Great Western Highway

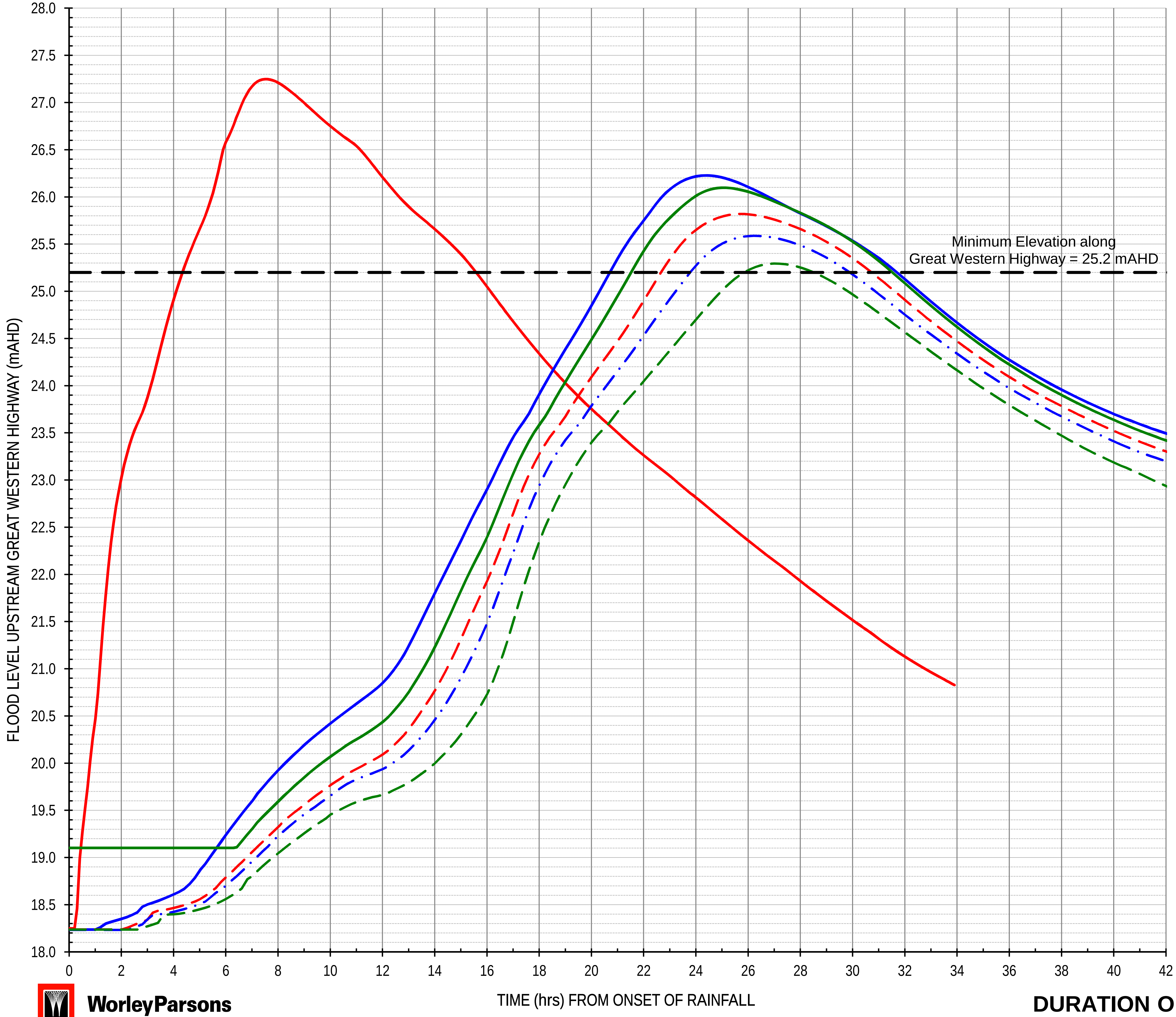
LEGEND

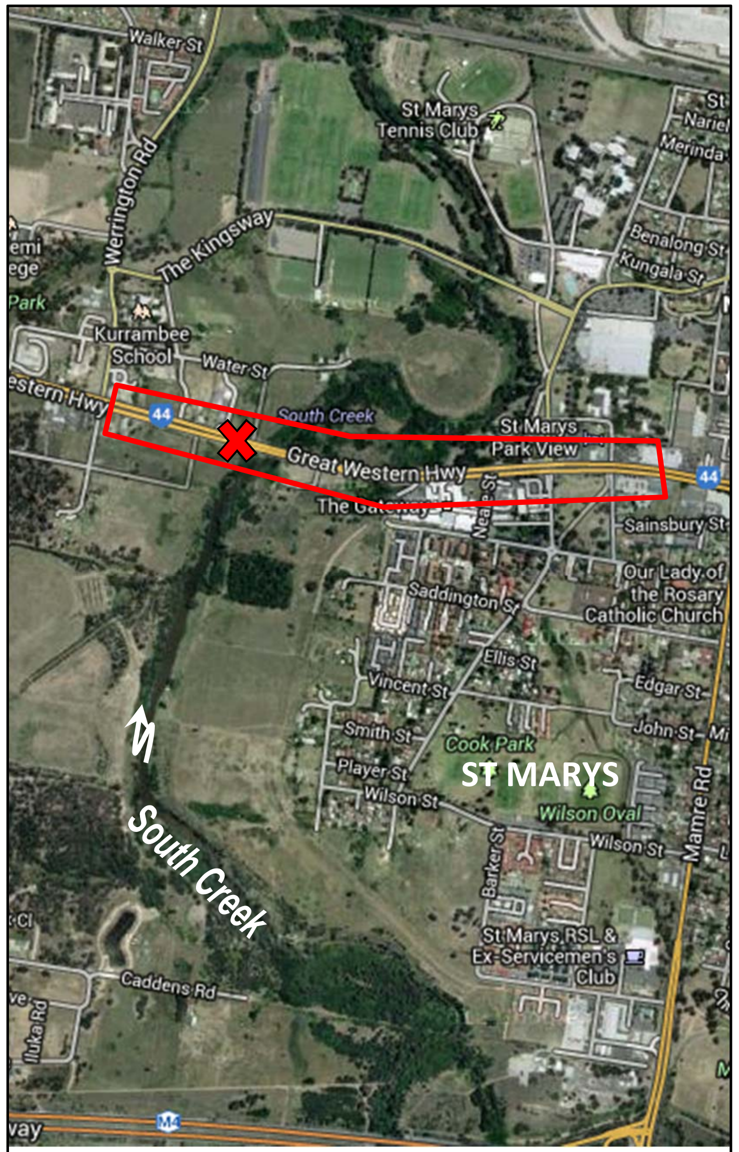
🟥 Great Western Highway (South Creek) - Rating Curve

▬ ▬ Minimum Elevation along Great Western Highway (25.2 mAHD)

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR SOUTH CREEK UPSTREAM OF GREAT WESTERN HIGHWAY

FIGURE J6





Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point along Great Western Highway

LEGEND

- Probable Maximum Flood (RMA-2)
- Design 500yr ARI Flood (RMA-2)
- Design 200yr ARI Flood (RMA-2)
- Design 100yr ARI Flood (RMA-2)
- Design 50yr ARI Flood (RMA-2)
- Design 20yr ARI Flood (RMA-2)
- Minimum Elevation along Great Western Highway (25.2 mAHD)

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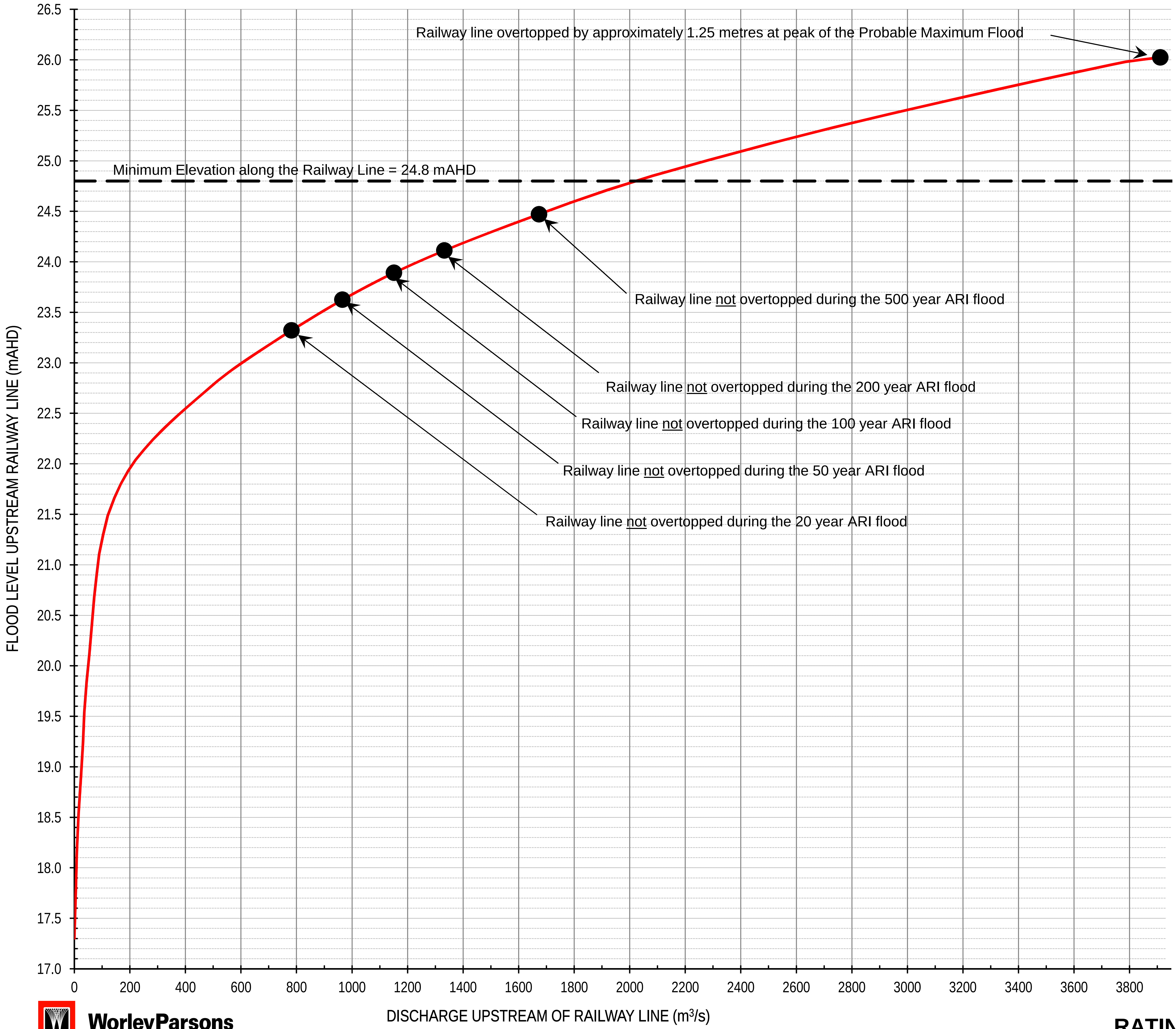
fg6033rg130214-APPENDIX J.xls

DURATION OF FLOOD AFFECTATION OF GREAT WESTERN HIGHWAY DURING DESIGN FLOODS (*SOUTH CREEK CROSSING*)

FIGURE J7



Railway line overtopped by approximately 1.25 metres at peak of the Probable Maximum Flood

Minimum Elevation along the Railway Line = 24.8 mAHD

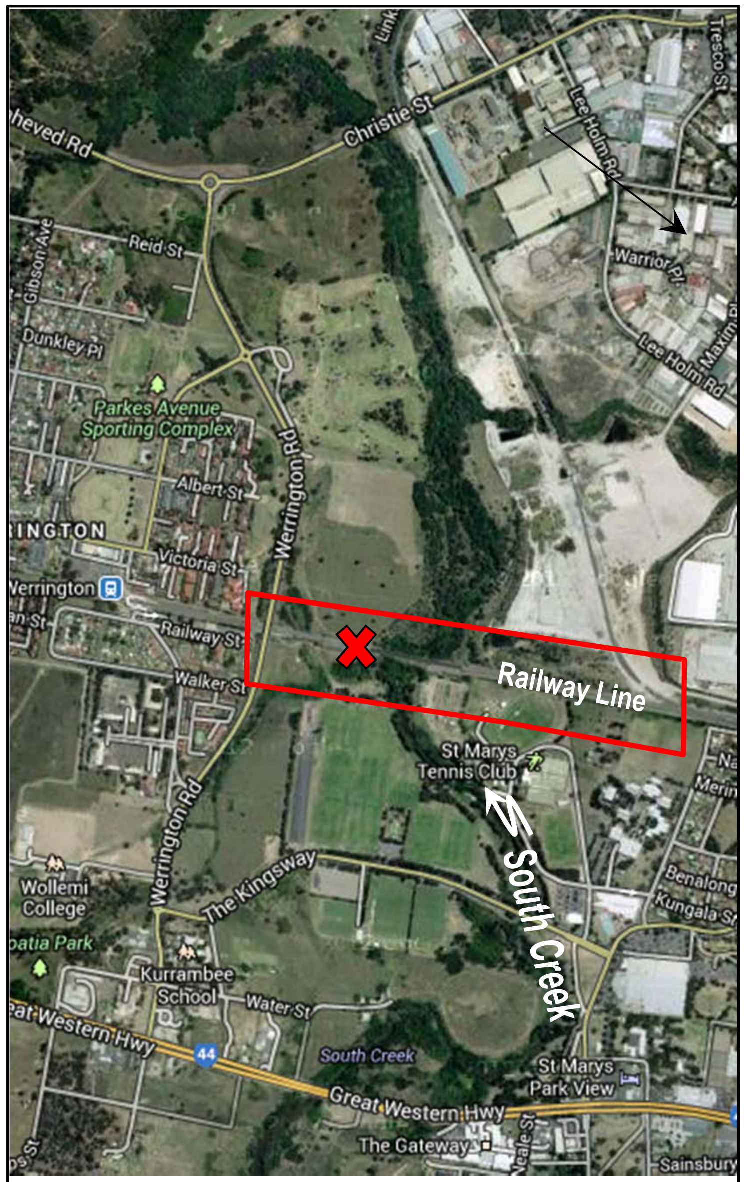
Railway line not overtopped during the 500 year ARI flood

Railway line not overtopped during the 200 year ARI flood

Railway line not overtopped during the 100 year ARI flood

Railway line not overtopped during the 50 year ARI flood

Railway line not overtopped during the 20 year ARI flood



Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point along Railway line

LEGEND

🟥	Railway Line (South Creek) - Rating Curve
— —	Minimum elevation along Railway (24.8 mAHD)

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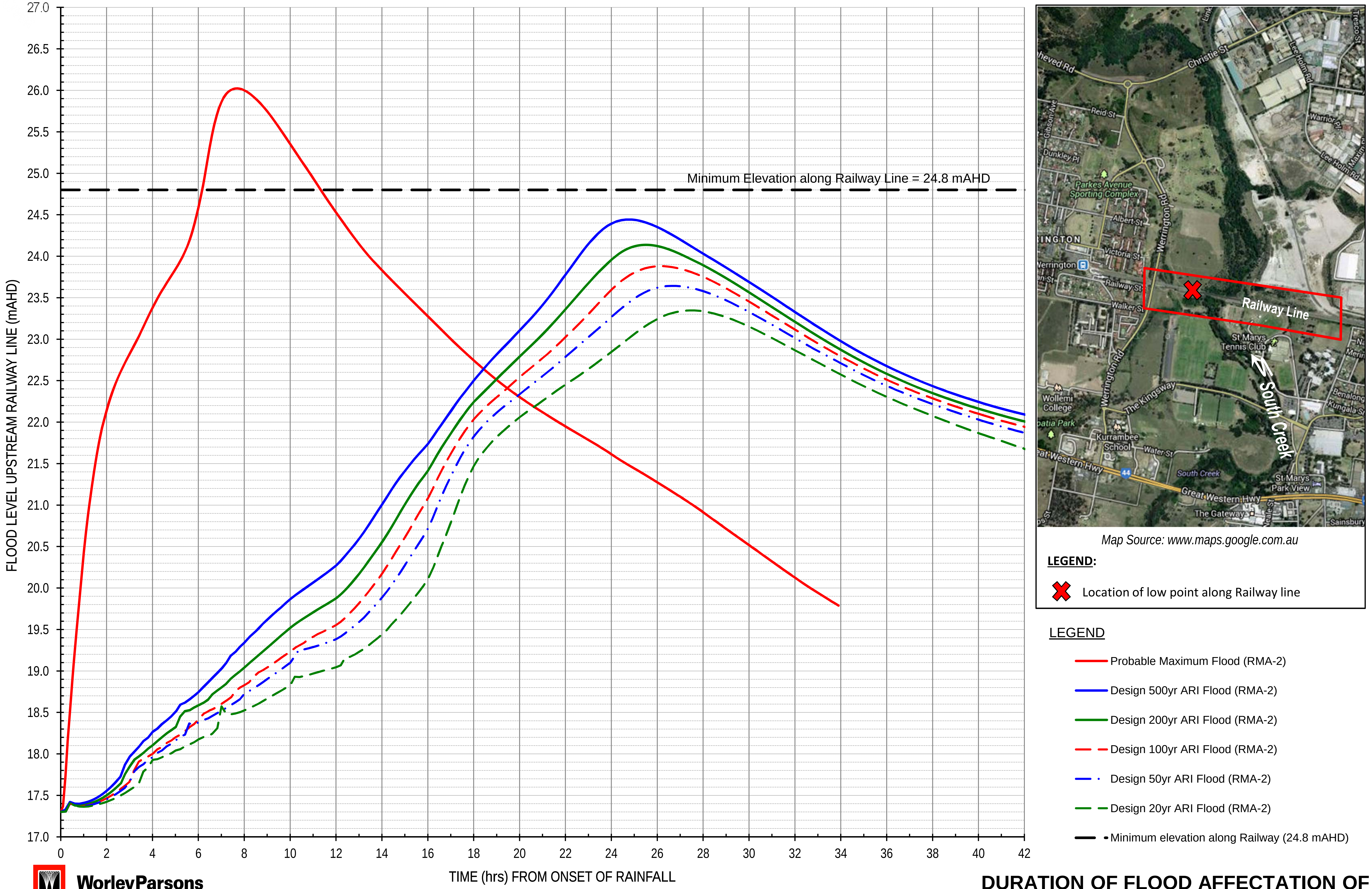
RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR SOUTH CREEK UPSTREAM OF RAILWAY LINE

FIGURE J8



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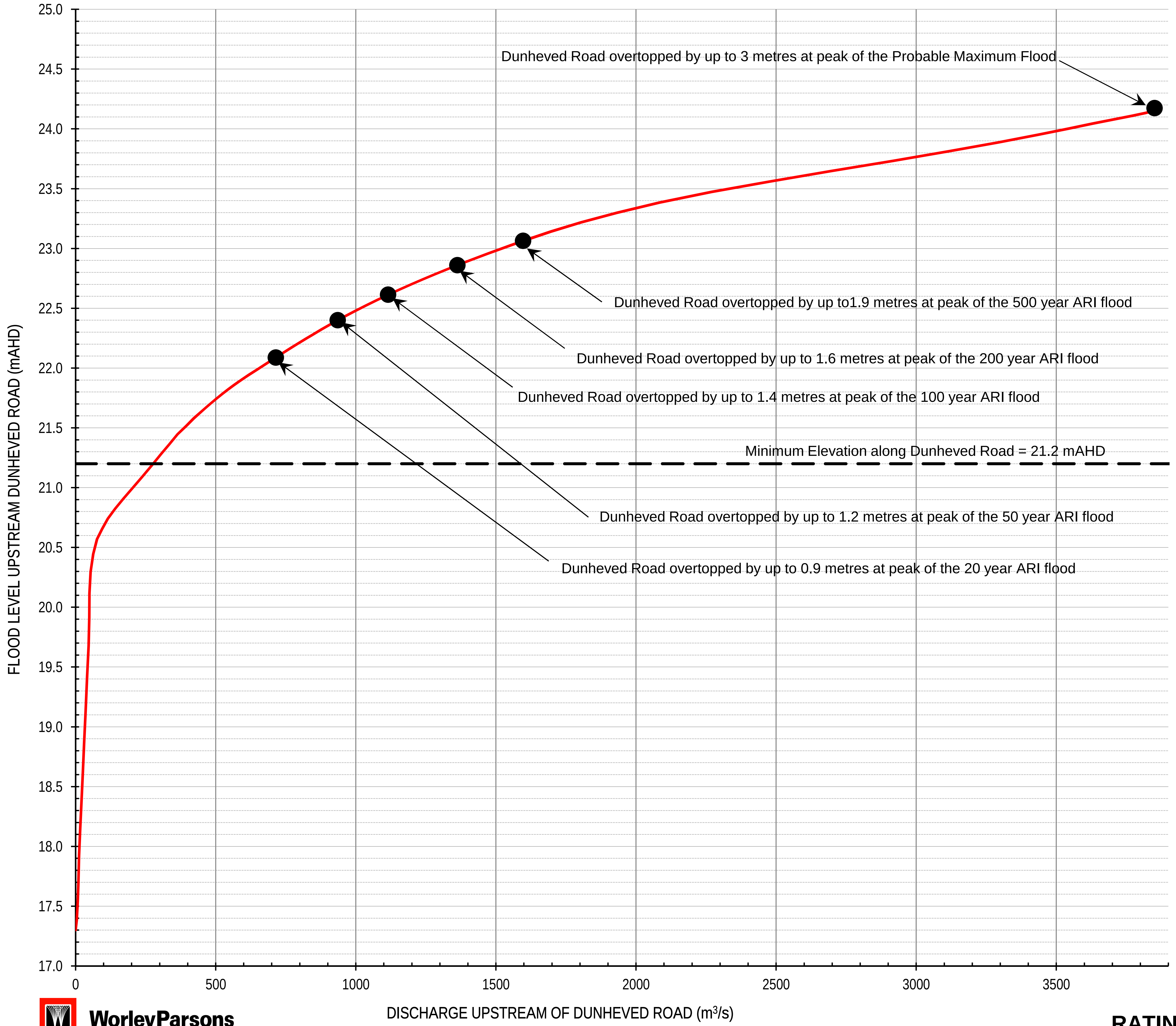
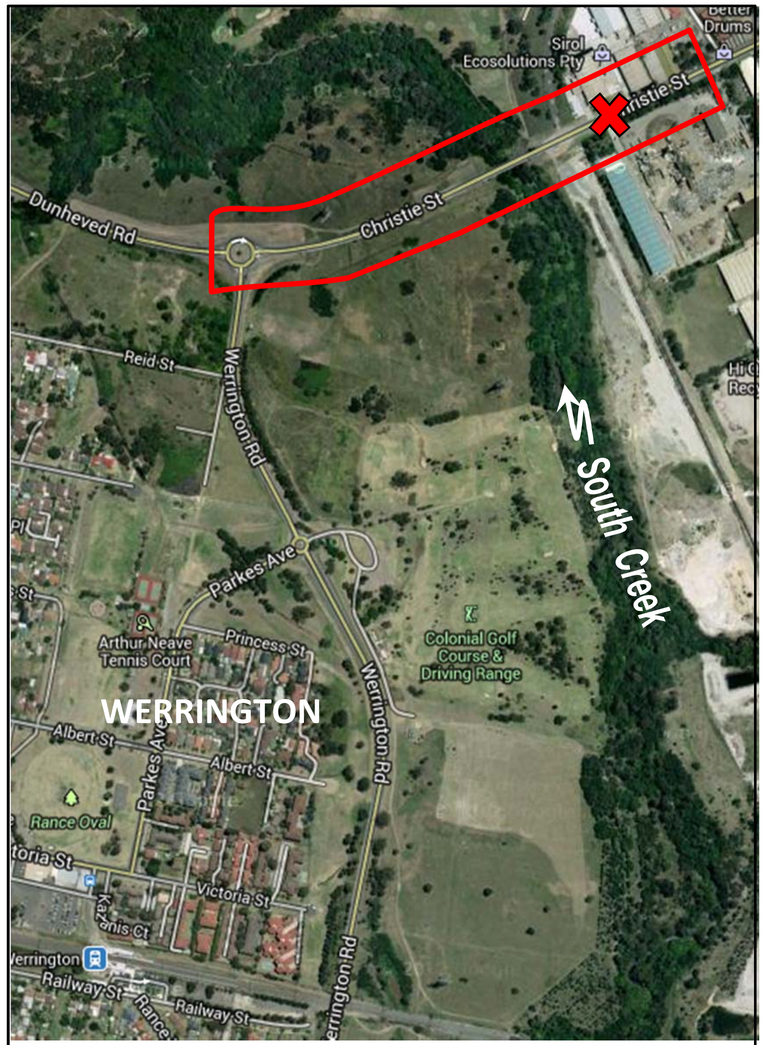
DURATION OF FLOOD AFFECTATION OF RAILWAY LINE DURING DESIGN FLOODS (*SOUTH CREEK CROSSING*)

FIGURE J9





Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point Dunheved Road

LEGEND

— Dunheved Road (South Creek) - Rating Curve

– – Minimum elevation along Dunheved Road (21.2 mAHD)

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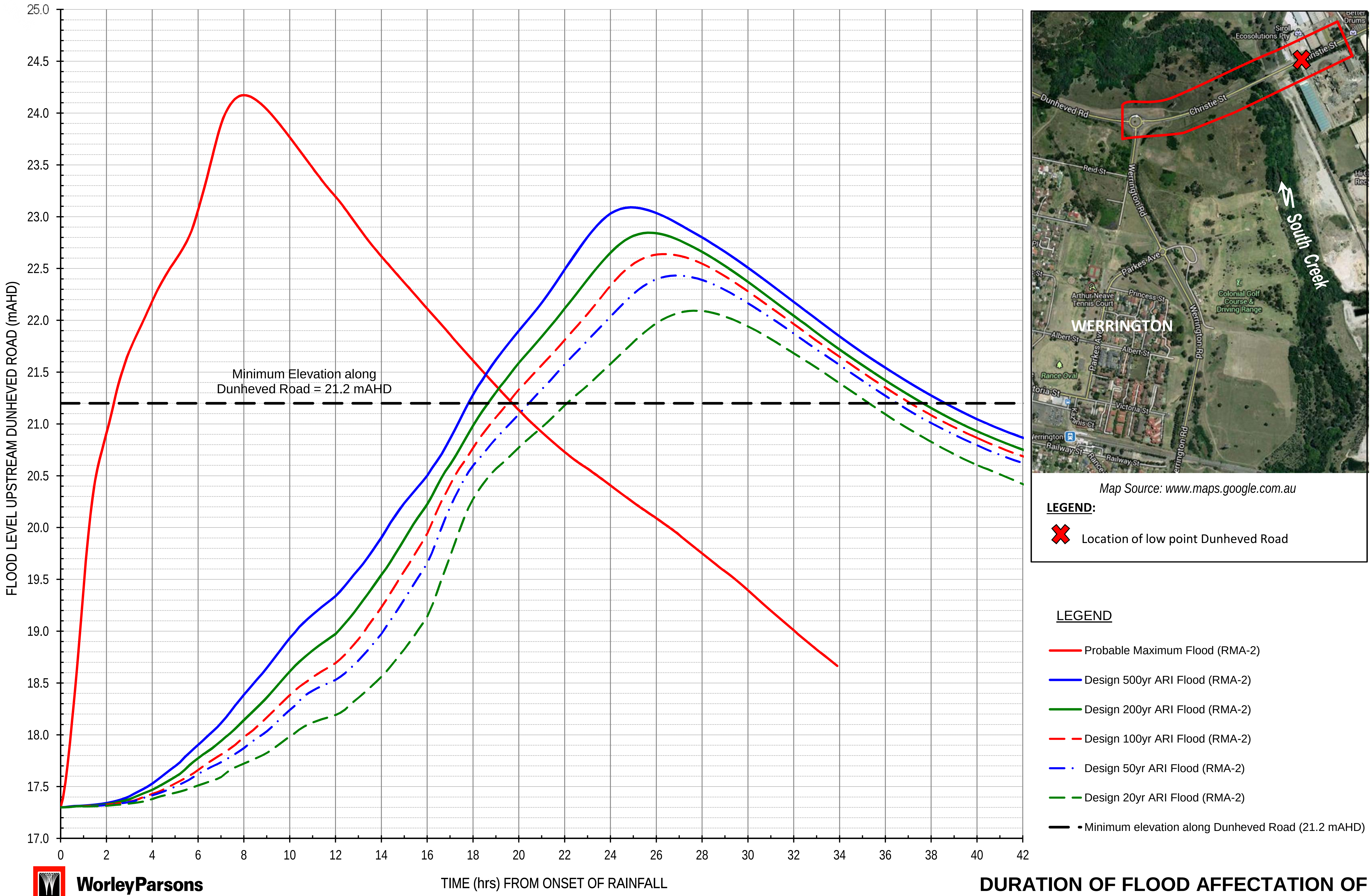
fg6033rg130214-APPENDIX J.xls

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR SOUTH CREEK UPSTREAM DUNHEVED ROAD

FIGURE J10



Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point Dunheved Road

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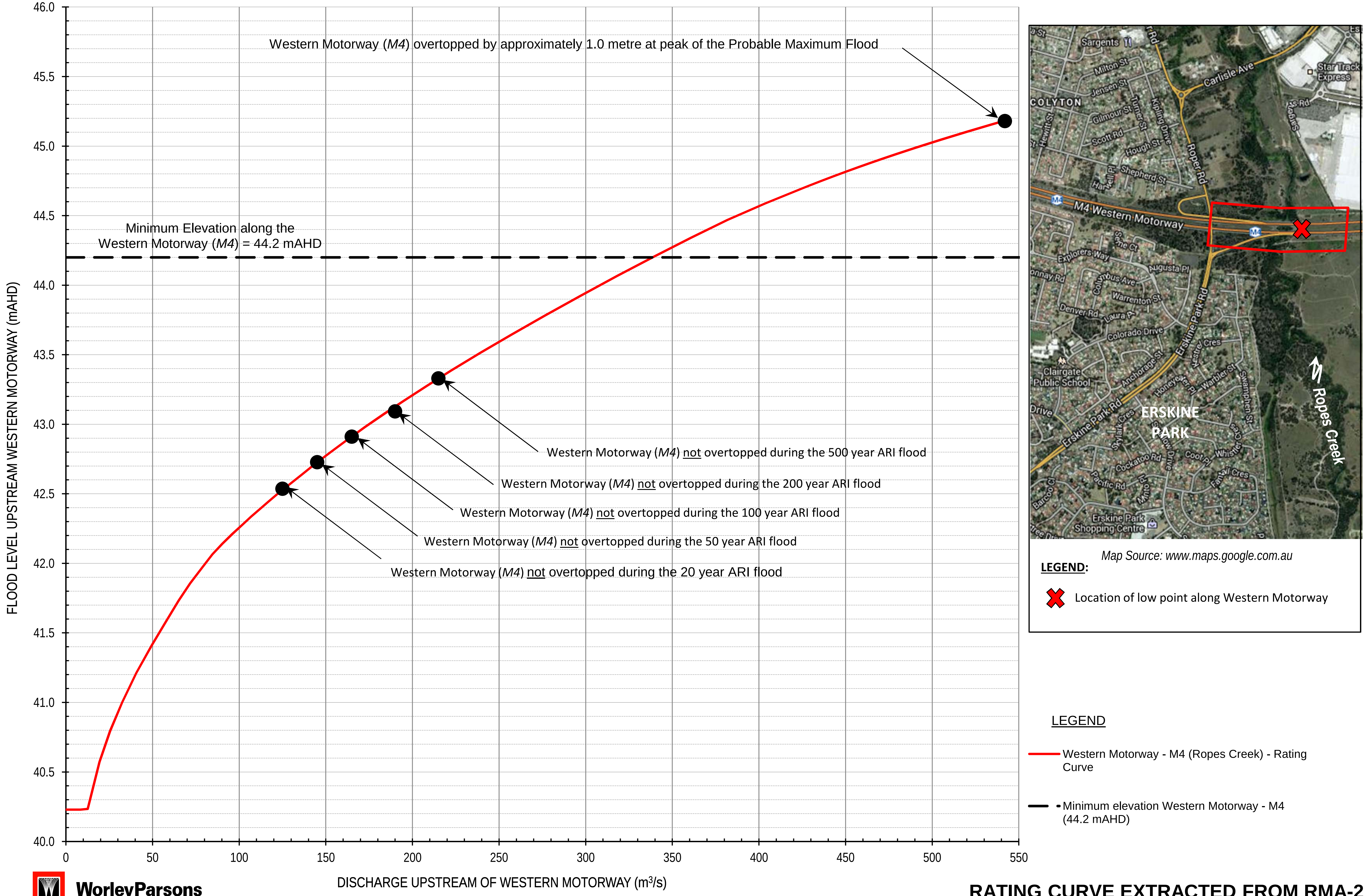
DURATION OF FLOOD AFFECTATION OF DUNHEVED ROAD DURING DESIGN FLOODS (*SOUTH CREEK CROSSING*)

FIGURE J11



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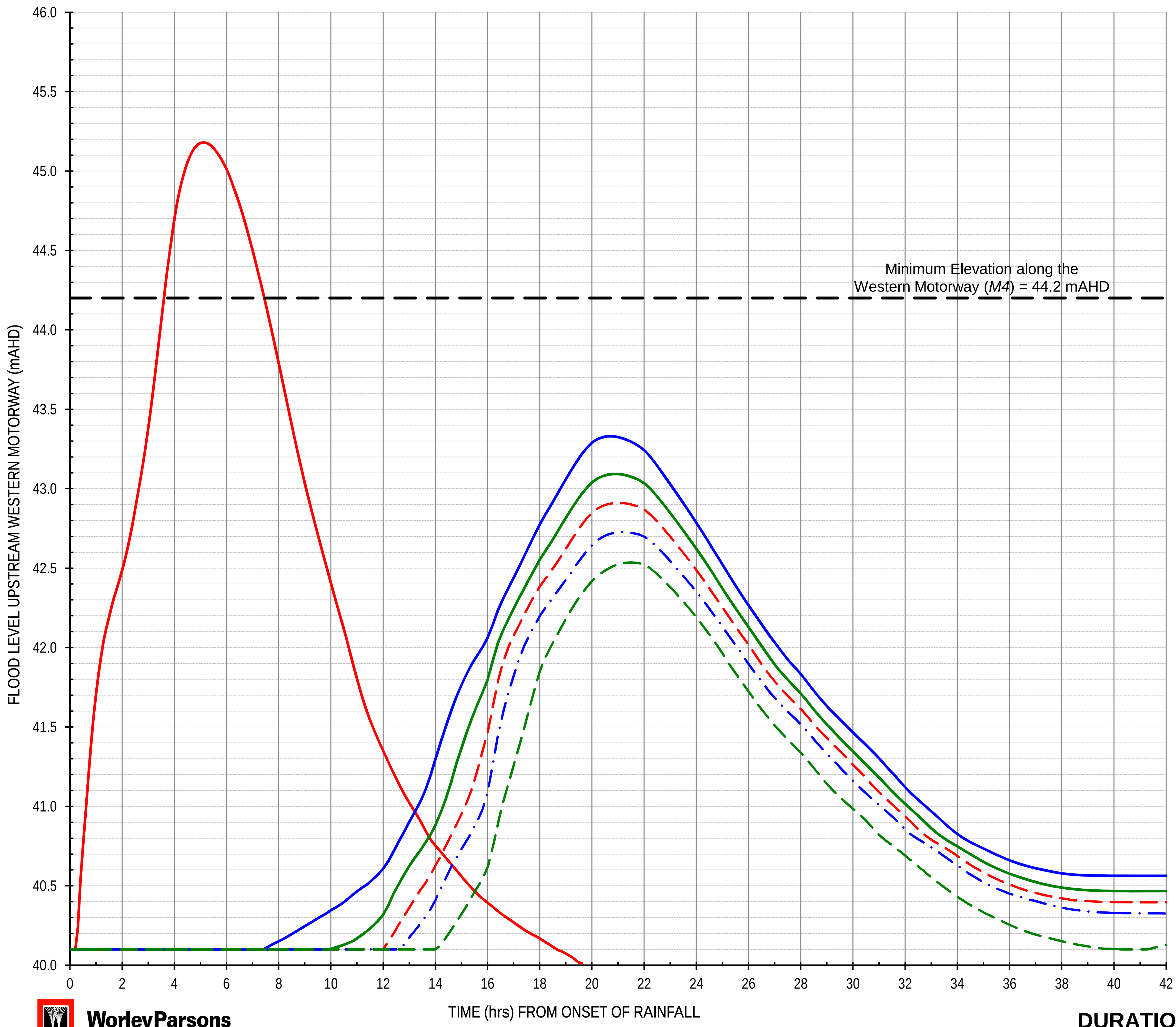
fg6033rg130214-APPENDIX J.xls

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR ROPES CREEK UPSTREAM OF THE WESTERN MOTORWAY (M4)

FIGURE J12



Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point along Western Motorway

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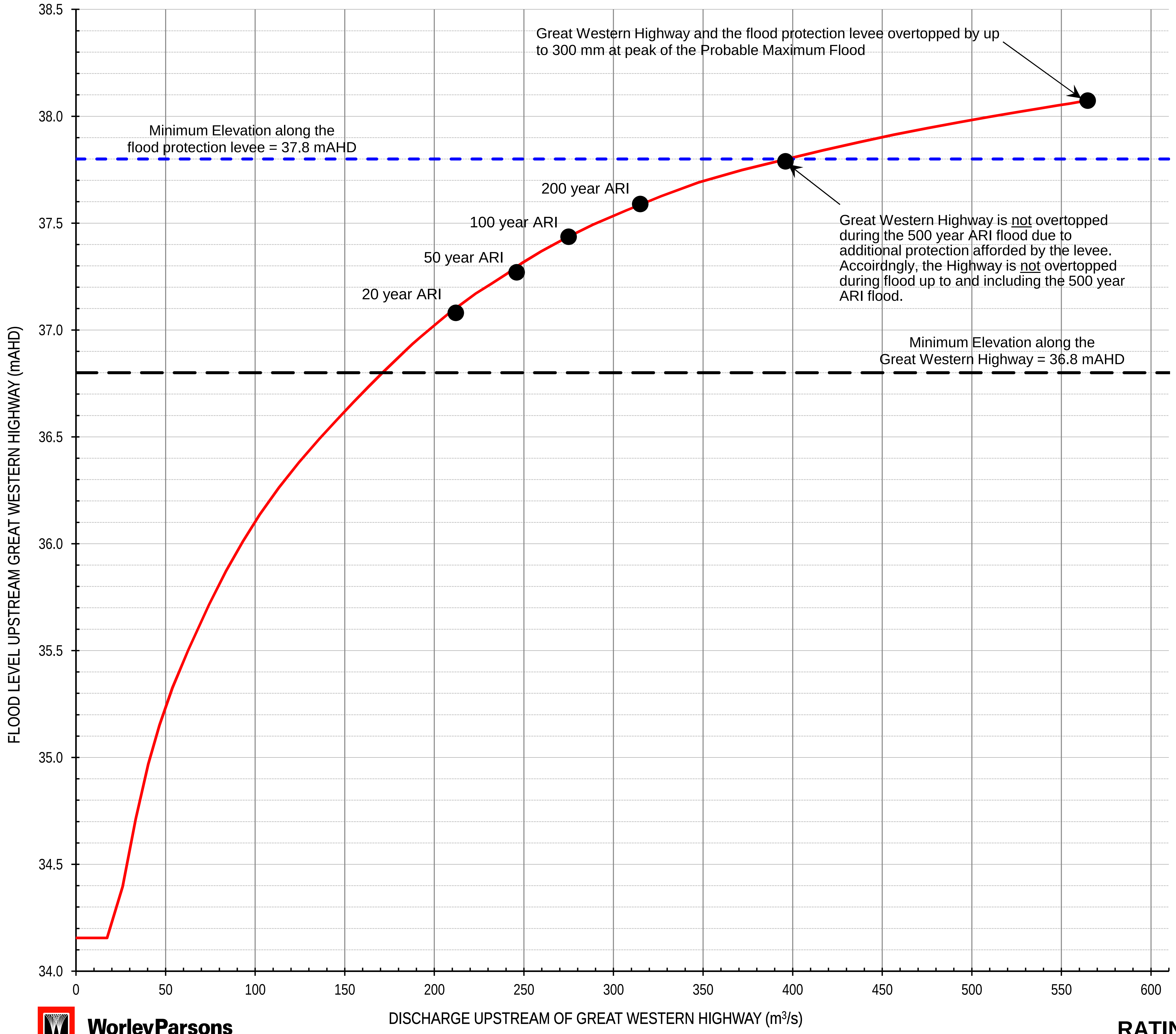
fg6033rg130214-APPENDIX J.xls

DURATION OF FLOOD AFFECTATION OF THE WESTERN MOTORWAY DURING DESIGN FLOODS (*ROPES CREEK CROSSING*)

FIGURE J13



Great Western Highway and the flood protection levee overtopped by up to 300 mm at peak of the Probable Maximum Flood

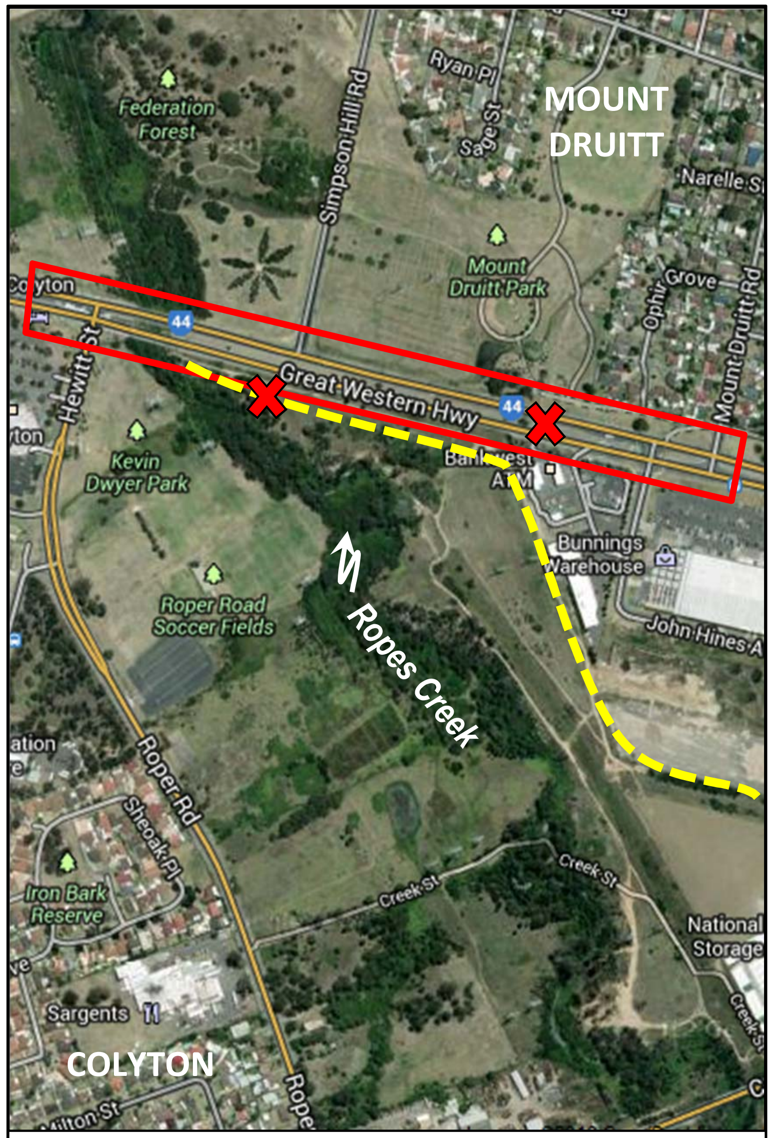
Minimum Elevation along the flood protection levee = 37.8 mAHD

Great Western Highway is not overtopped during the 500 year ARI flood due to additional protection afforded by the levee. Accoirdngly, the Highway is not overtopped during flood up to and including the 500 year ARI flood.

Minimum Elevation along the Great Western Highway = 36.8 mAHD

LEGEND

- Great Western Highway (Ropes Creek) - Rating Curve
- Minimum Height along Great Western Highway (36.8 mAHD)
- Minimum Elevation along Protective Levee - 37.8 mAHD



Map Source: www.maps.google.com.au

LEGEND:

- ✖ Location of low points along Great Western Highway and along the flood protection levee
- ▨ Alignment of flood protection levee

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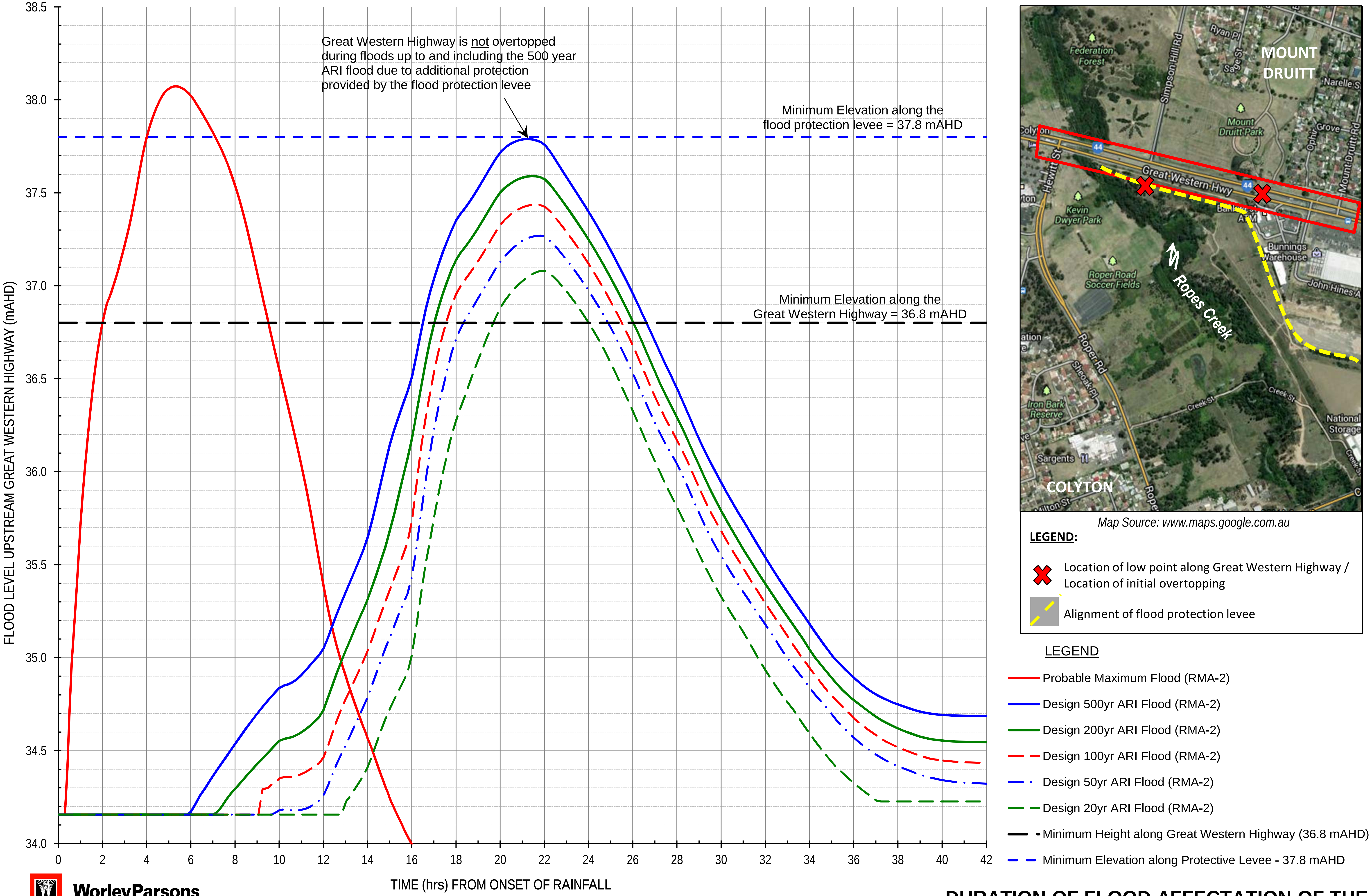
RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR ROPES CREEK UPSTREAM OF THE GREAT WESTERN HIGHWAY

FIGURE J14



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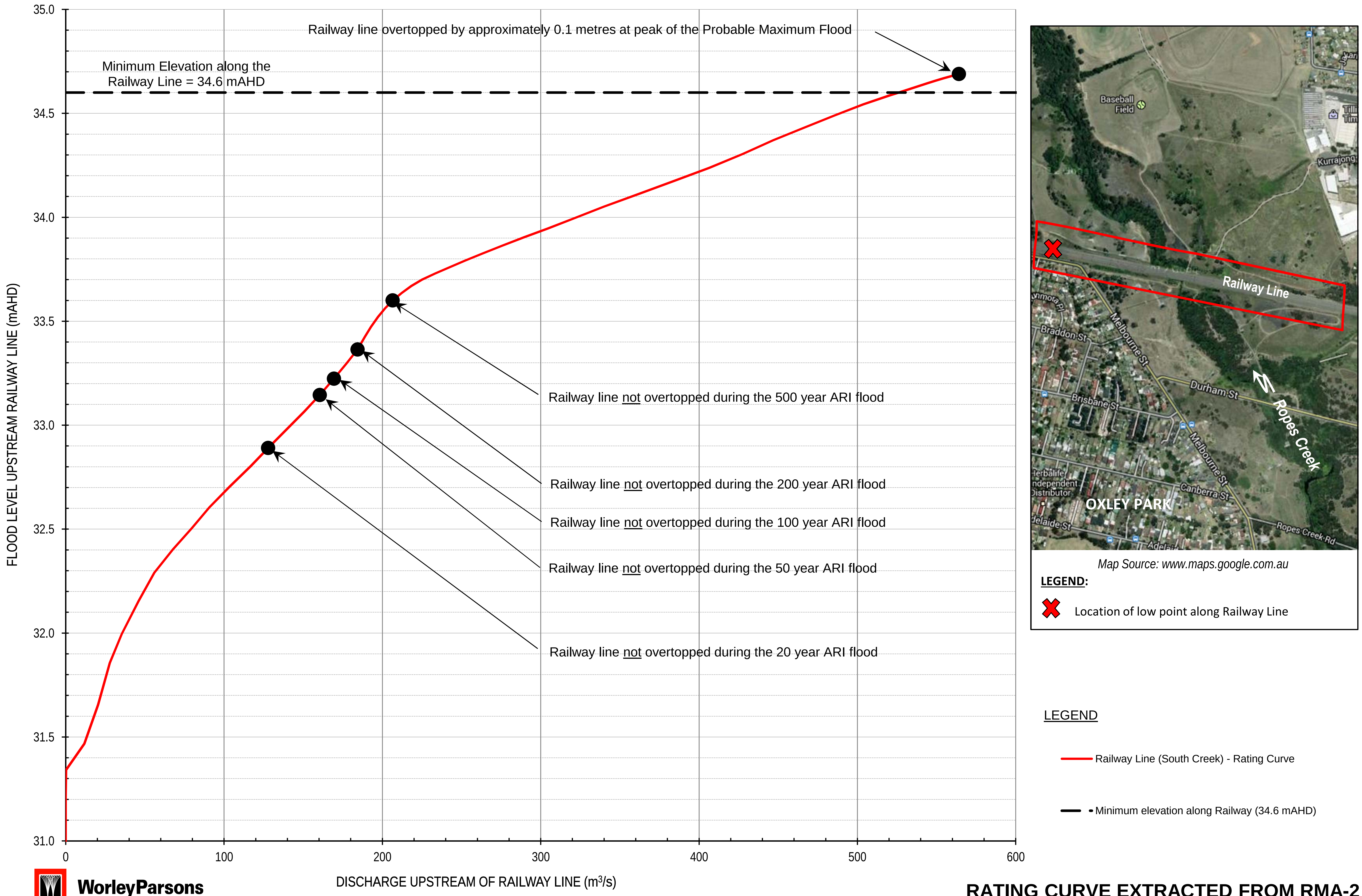
DURATION OF FLOOD AFFECTATION OF THE GREAT WESTERN HIGHWAY DURING DESIGN FLOODS (*ROPES CREEK CROSSING*)

FIGURE J15



Railway line overtopped by approximately 0.1 metres at peak of the Probable Maximum Flood

Minimum Elevation along the Railway Line = 34.6 mAHD

Railway line not overtopped during the 500 year ARI flood

Railway line not overtopped during the 200 year ARI flood

Railway line not overtopped during the 100 year ARI flood

Railway line not overtopped during the 50 year ARI flood

Railway line not overtopped during the 20 year ARI flood

Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point along Railway Line

LEGEND

Railway Line (South Creek) - Rating Curve

Minimum elevation along Railway (34.6 mAHD)

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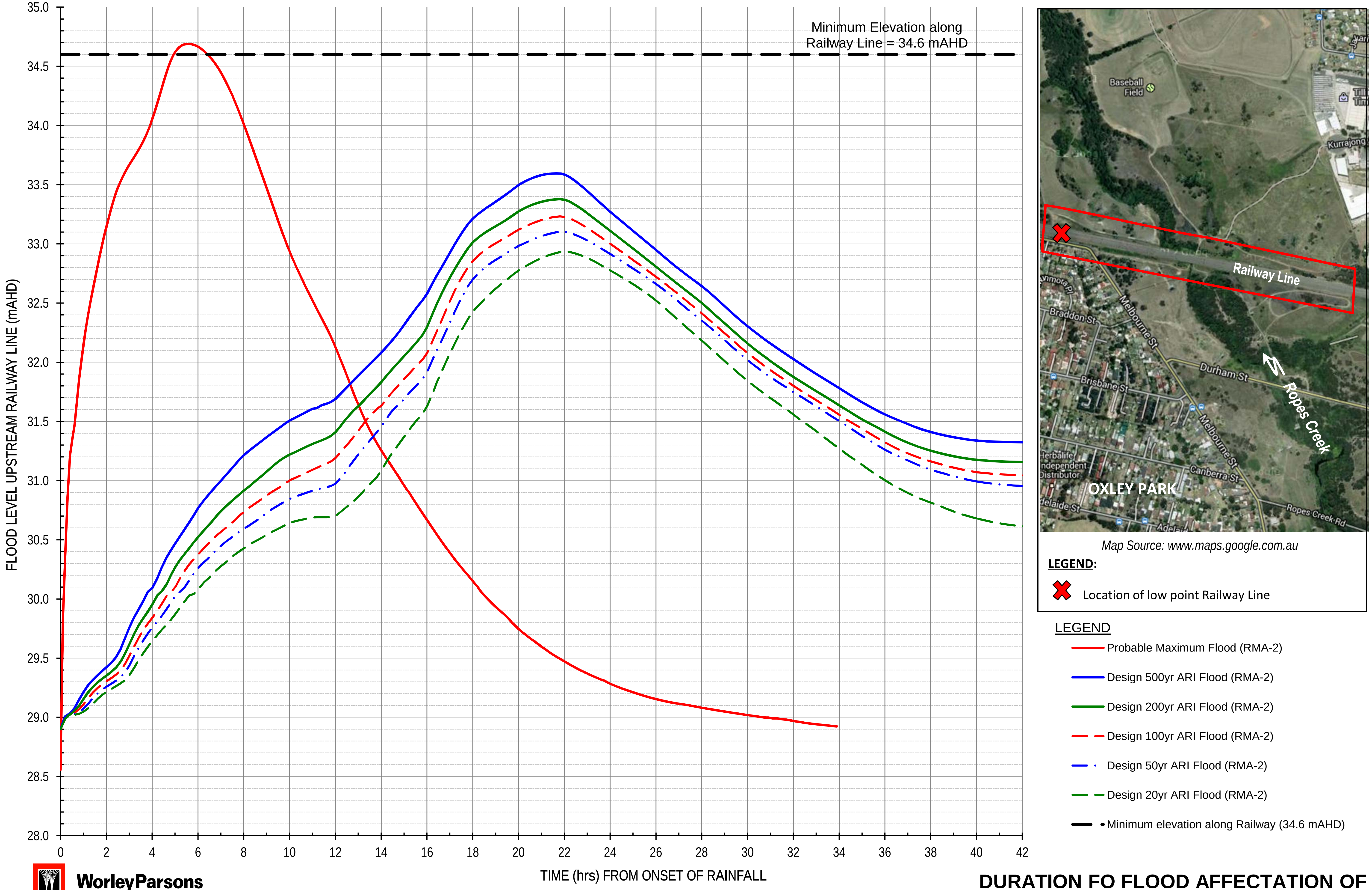
RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR ROPES CREEK UPSTREAM OF RAILWAY LINE

FIGURE J16



Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point Railway Line

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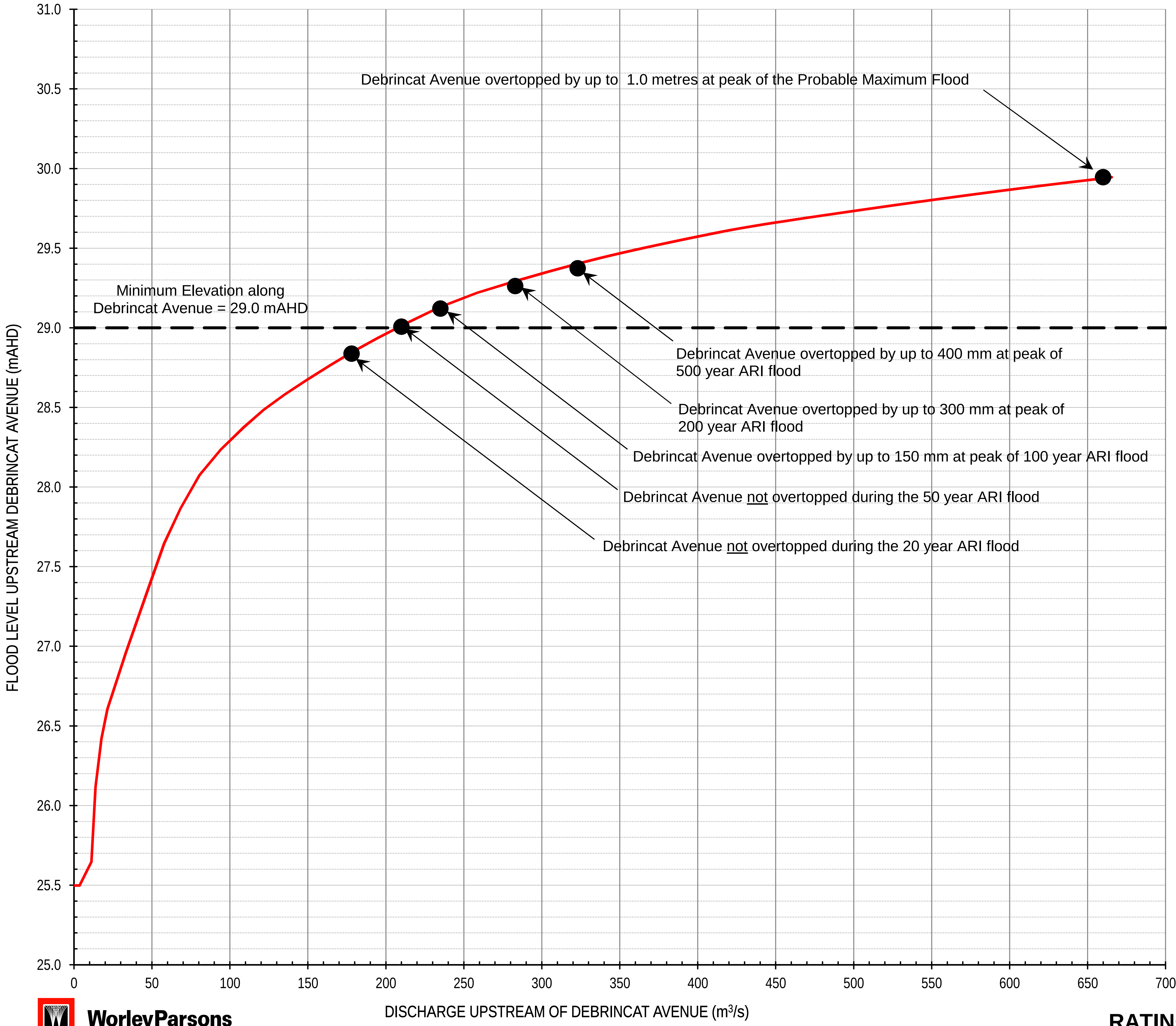
fg6033rg130214-APPENDIX J.xls

DURATION FO FLOOD AFFECTATION OF RAILWAY LINE DURING DESIGN FLOODS (*ROPES CREEK CROSSING*)

FIGURE J17



Debrincat Avenue overtopped by up to 1.0 metres at peak of the Probable Maximum Flood

Minimum Elevation along Debrincat Avenue = 29.0 mAHD

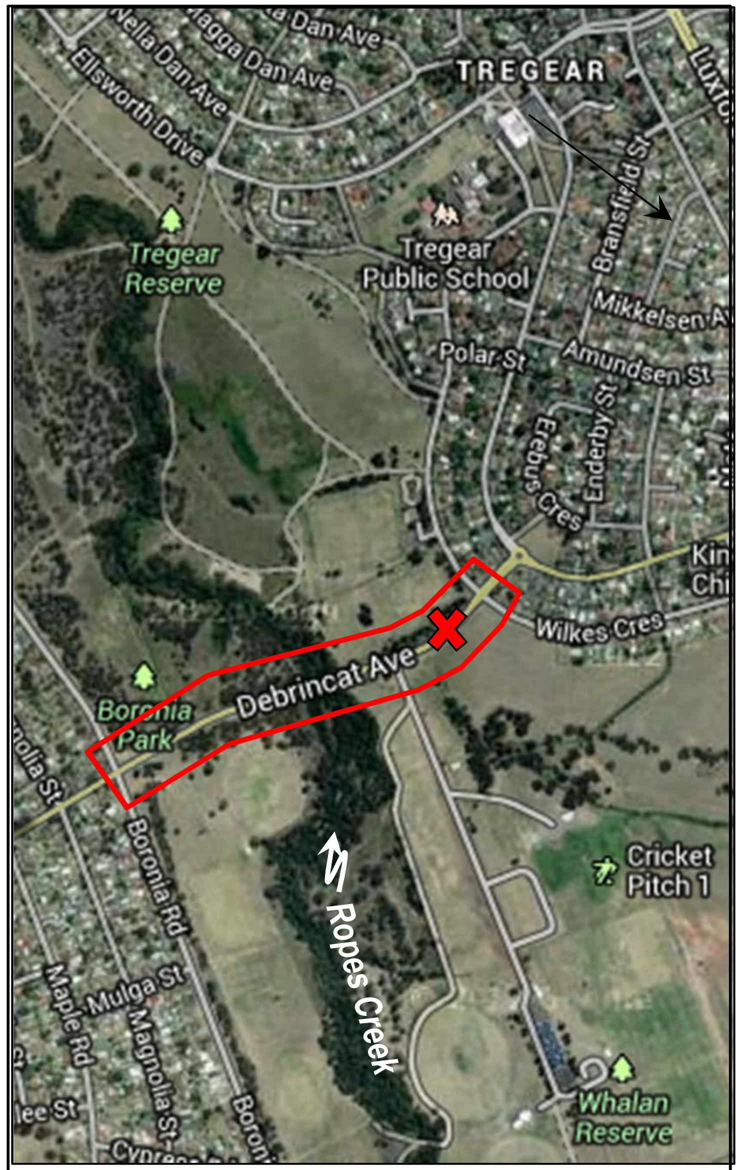
Debrincat Avenue overtopped by up to 400 mm at peak of 500 year ARI flood

Debrincat Avenue overtopped by up to 300 mm at peak of 200 year ARI flood

Debrincat Avenue overtopped by up to 150 mm at peak of 100 year ARI flood

Debrincat Avenue not overtopped during the 50 year ARI flood

Debrincat Avenue not overtopped during the 20 year ARI flood



Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point along Debrincat Avenue

LEGEND

🟥	Debrincat Avenue (Ropes Creek) - Rating Curve
▬ ▪	Minimum elevation along Debrincat Avenue (29.0 mAHD)

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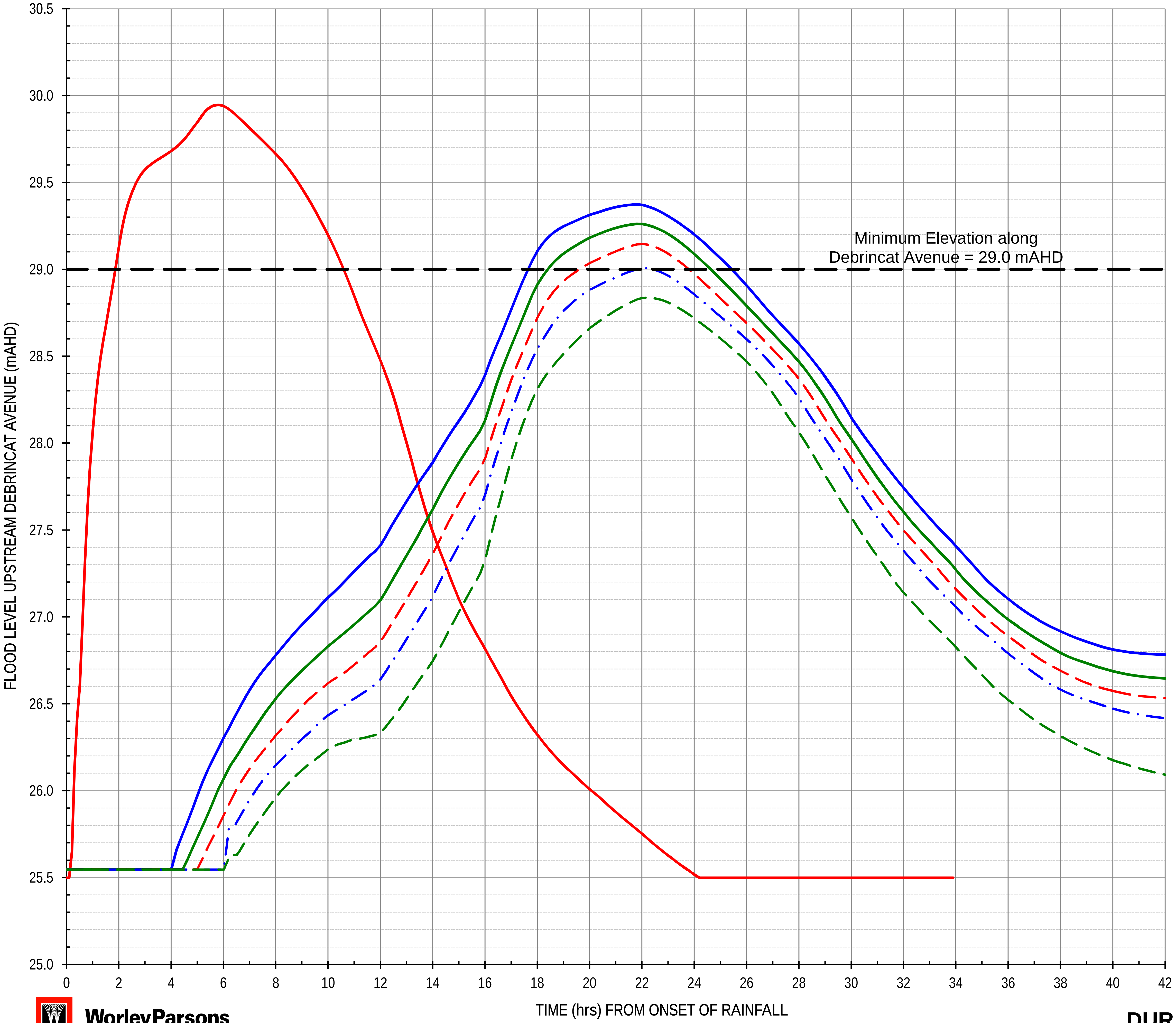
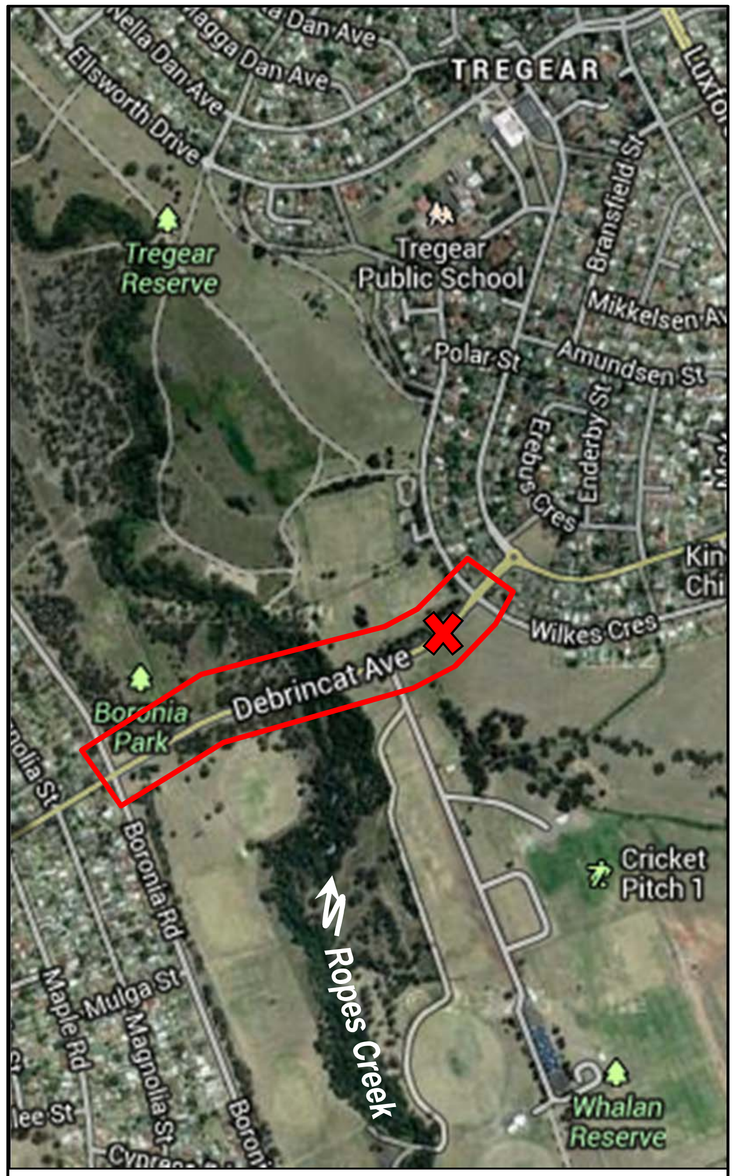
RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR ROPES CREEK UPSTREAM OF DEBRINCAT AVENUE

FIGURE J18



LEGEND

- 🟥 Probable Maximum Flood (RMA-2)
- 🟦 Design 500yr ARI Flood (RMA-2)
- 🟩 Design 200yr ARI Flood (RMA-2)
- Design 100yr ARI Flood (RMA-2)
- Design 50yr ARI Flood (RMA-2)
- Design 20yr ARI Flood (RMA-2)
- Minimum elevation along Debrincat Avenue (29.0 mAHD)



Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point along Debrincat Avenue

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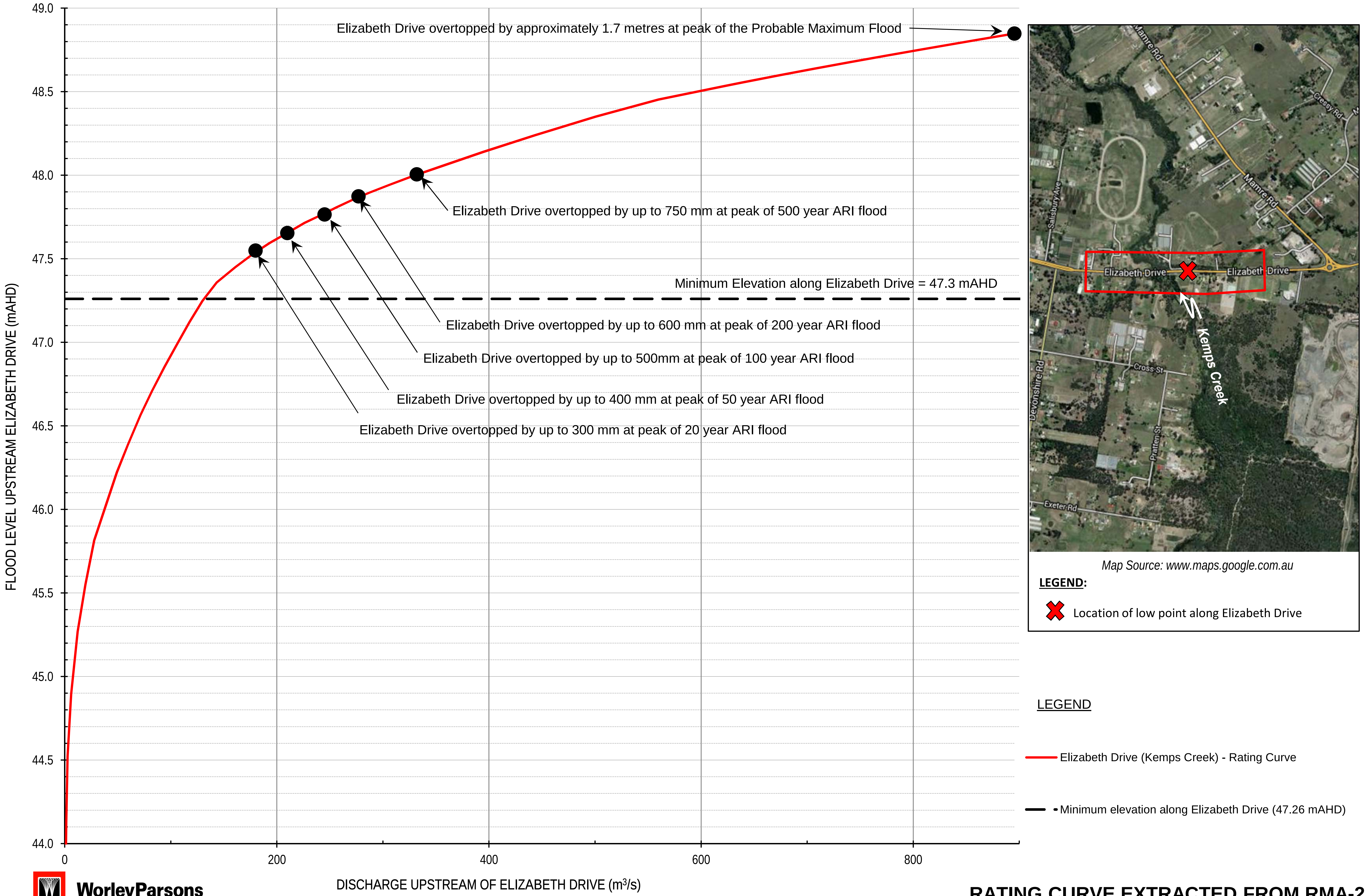
DURATION OF FLOOD AFFECTATION OF DEBRINCAT AVENUE DURING DESIGN FLOODS (*ROPES CREEK CROSSING*)

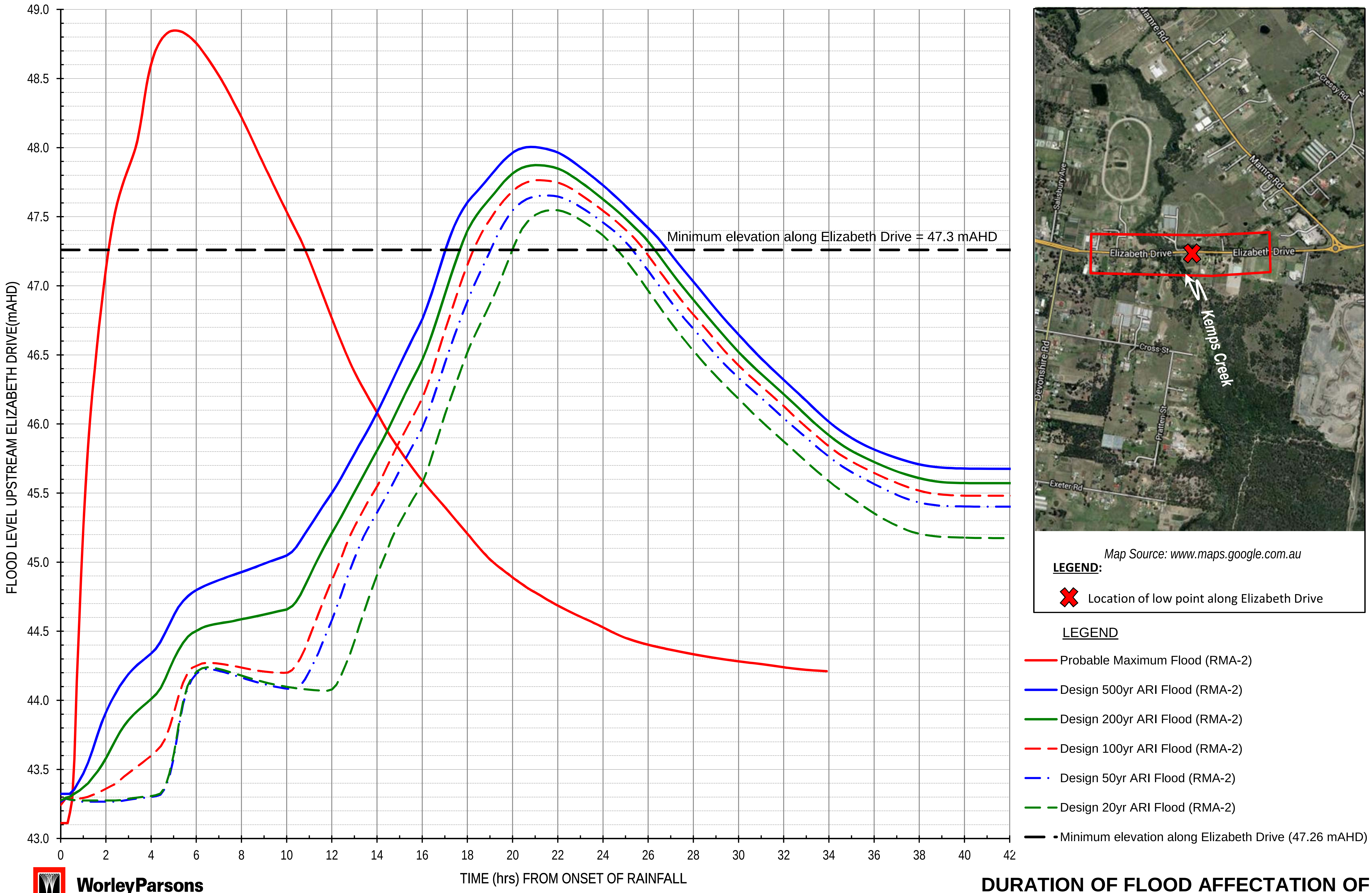
FIGURE J19



Map Source: www.maps.google.com.au

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR KEMPS CREEK UPSTREAM OF ELIZABETH DRIVE

FIGURE J20



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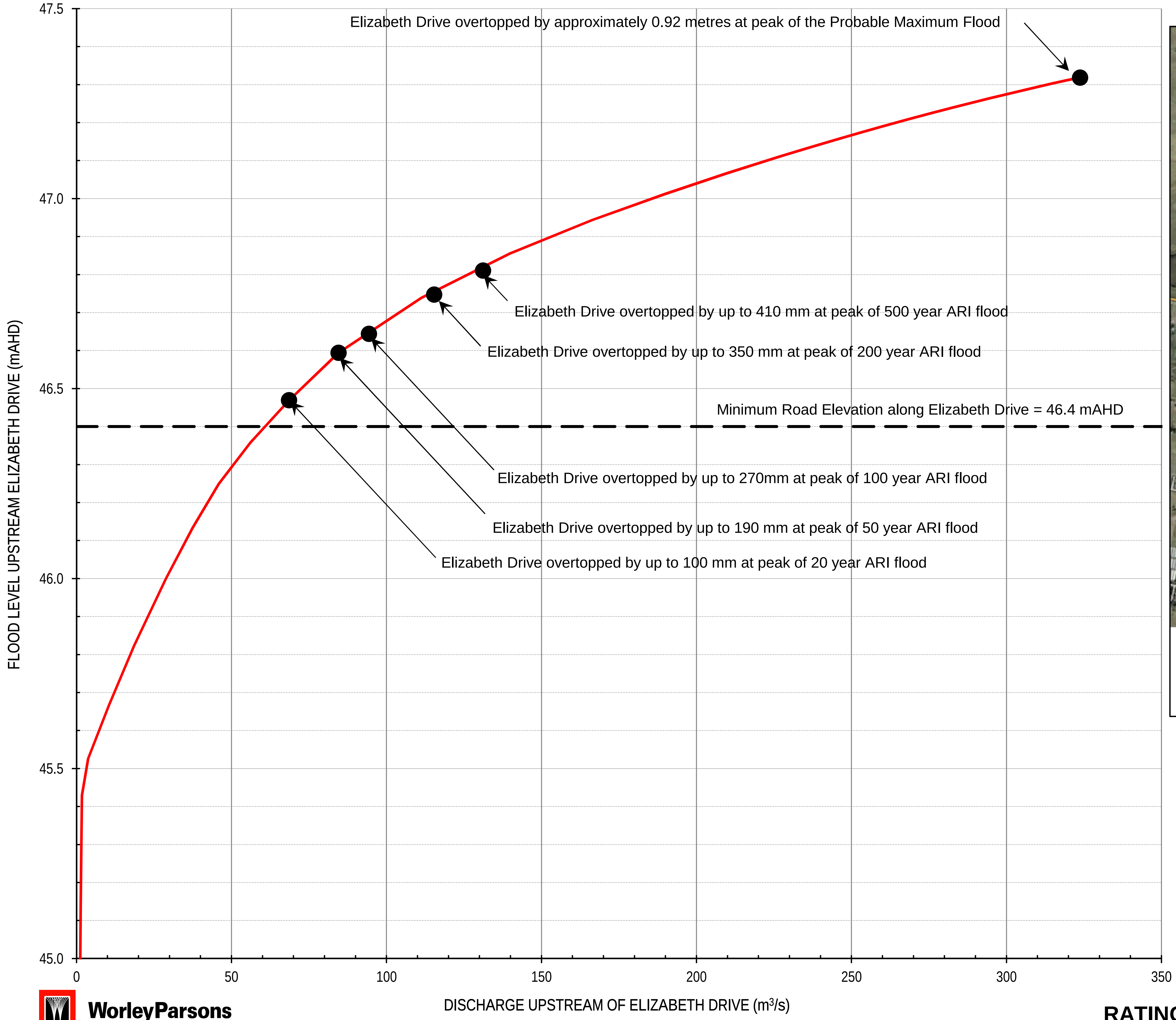
fg6033rg130214-APPENDIX J.xls

DURATION OF FLOOD AFFECTATION OF ELIZABETH DRIVE DURING DESIGN FLOODS (*KEMPS CREEK CROSSING*)



Elizabeth Drive overtopped by approximately 0.92 metres at peak of the Probable Maximum Flood

Elizabeth Drive overtopped by up to 410 mm at peak of 500 year ARI flood

Elizabeth Drive overtopped by up to 350 mm at peak of 200 year ARI flood

Minimum Road Elevation along Elizabeth Drive = 46.4 mAHD

Elizabeth Drive overtopped by up to 270mm at peak of 100 year ARI flood

Elizabeth Drive overtopped by up to 190 mm at peak of 50 year ARI flood

Elizabeth Drive overtopped by up to 100 mm at peak of 20 year ARI flood

Map Source: www.maps.google.com.au

LEGEND:

❌ Location of low point along Elizabeth Drive

LEGEND

🟥 Elizabeth Drive (Badgerys Creek) - Rating Curve

▬ Minimum elevation along Elizabeth Drive (46.40 mAHD)

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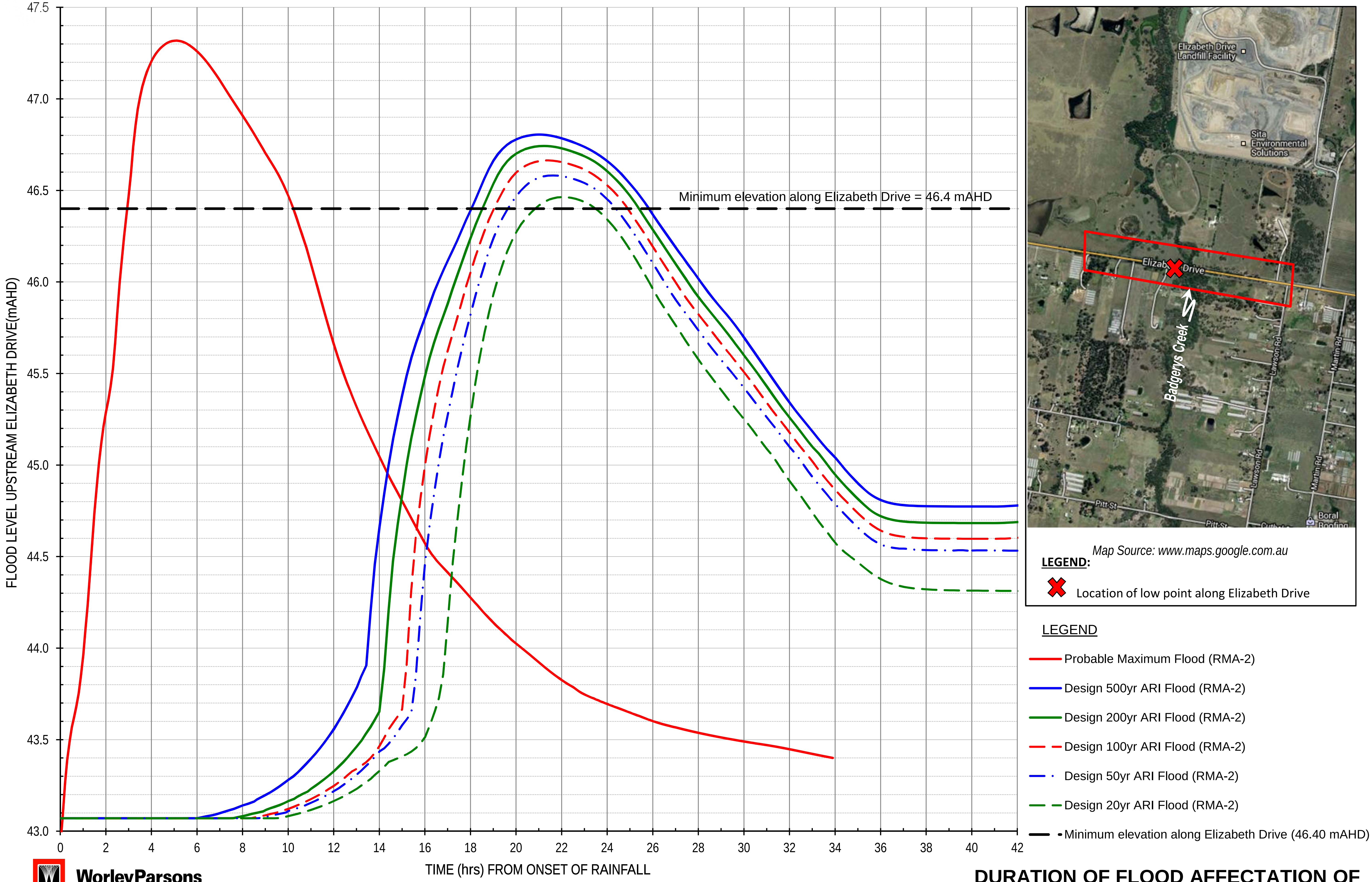
fg6033rg130214-APPENDIX J.xls

RATING CURVE EXTRACTED FROM RMA-2 MODELLING FOR BADGERYS CREEK UPSTREAM OF ELIZABETH DRIVE

FIGURE J22



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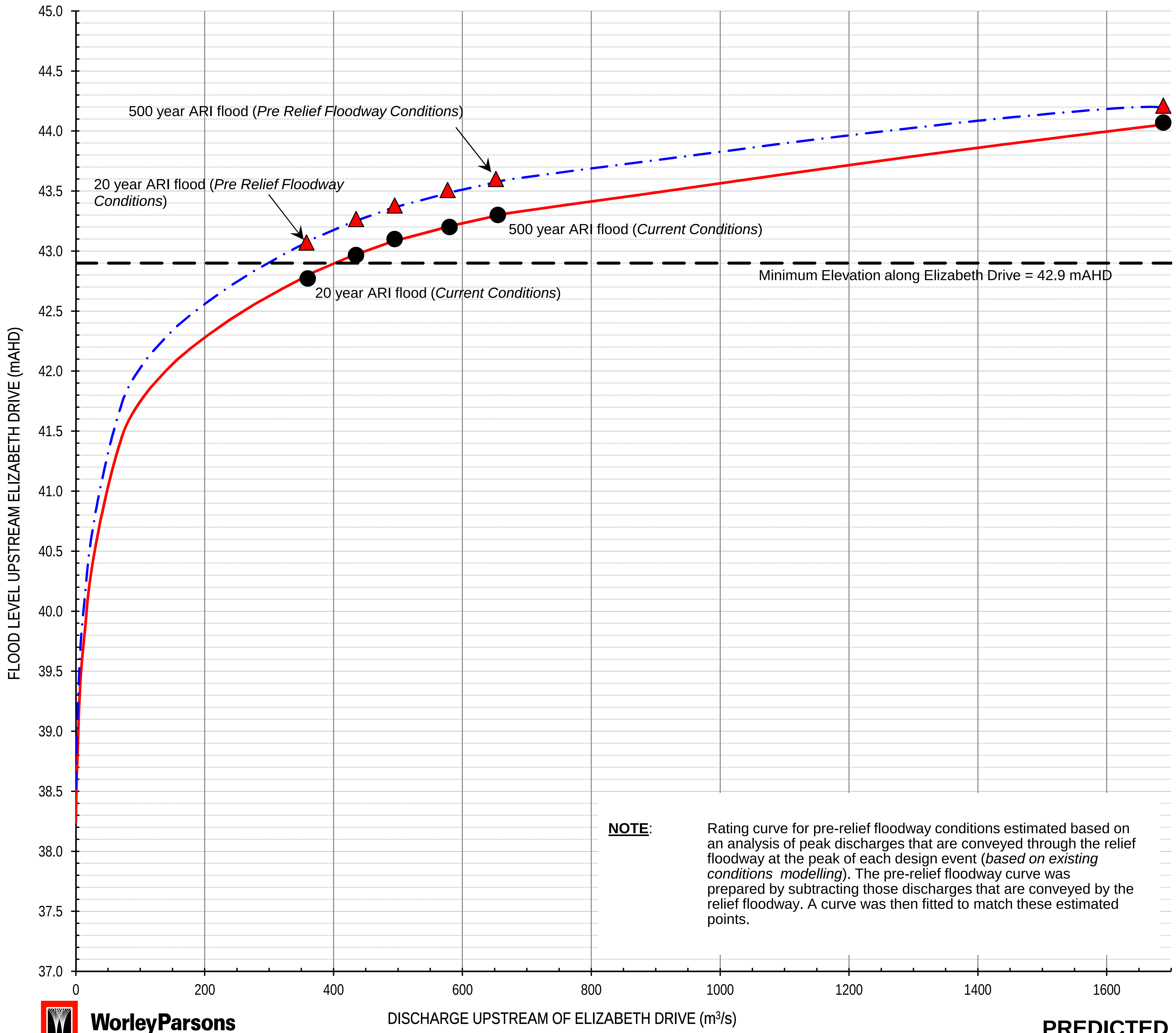
fg6033rg130214-APPENDIX J.xls

DURATION OF FLOOD AFFECTATION OF ELIZABETH DRIVE DURING DESIGN FLOODS (*BADGERYS CREEK CROSSING*)

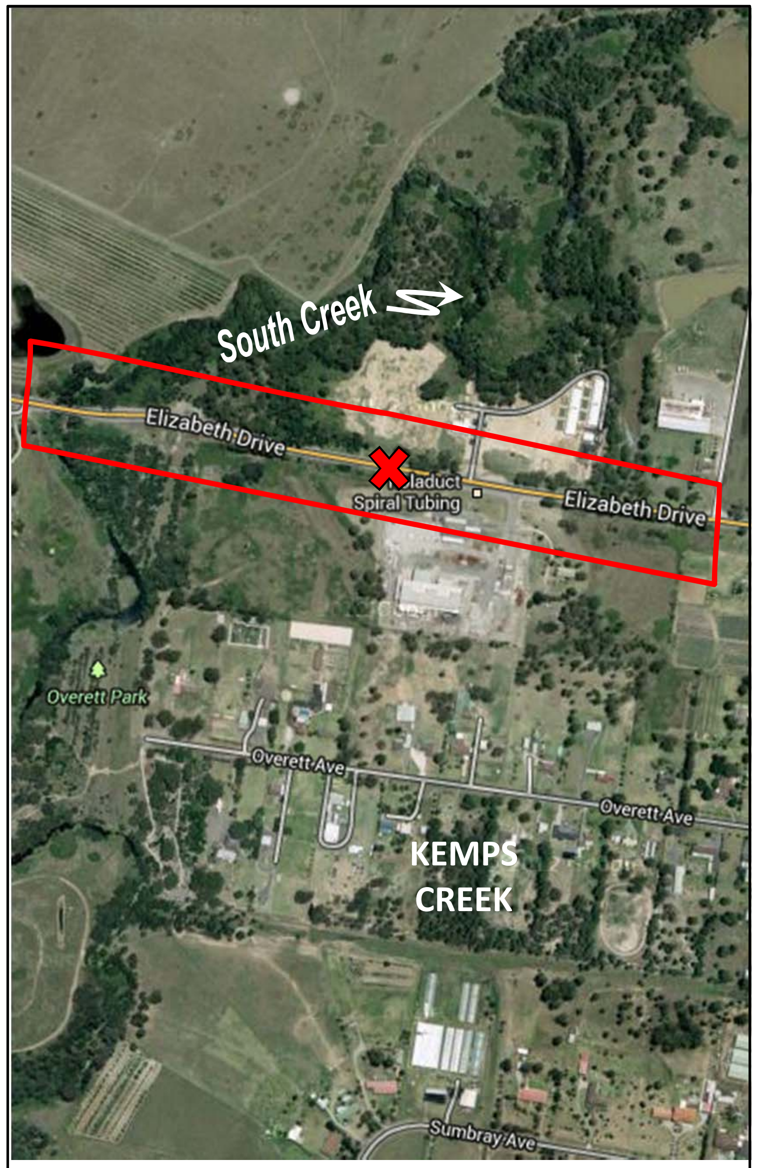
APPENDIX K

ANALYSIS OF FLOODING AT MITIGATIONS WORKS

FIGURE K1



NOTE: Rating curve for pre-relief floodway conditions estimated based on an analysis of peak discharges that are conveyed through the relief floodway at the peak of each design event (*based on existing conditions modelling*). The pre-relief floodway curve was prepared by subtracting those discharges that are conveyed by the relief floodway. A curve was then fitted to match these estimated points.



Map Source: www.maps.google.com.au

LEGEND:

✖ Location of low point along Elizabeth Drive

LEGEND

- Rating Curve for Elizabeth Drive based on RMA-2 modelling of current catchment conditions (South Creek)
- Estimated Rating Curve for Elizabeth Drive without Mitigation Works
- ▲ Predicted Flood Levels without Mitigation Works
- Minimum Height along Elizabeth Drive (42.9 mAHD)

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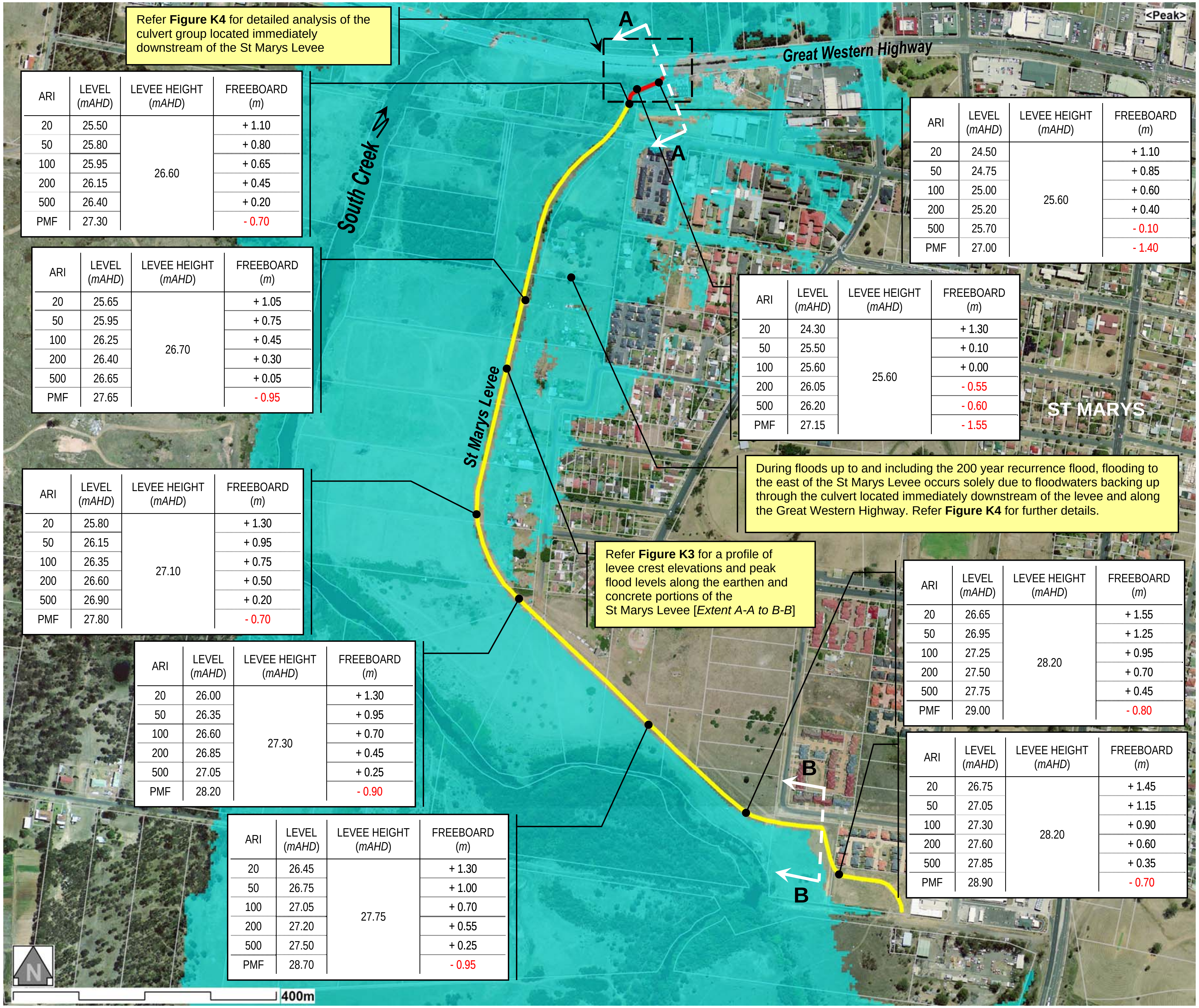
PREDICTED BENEFIT TO FLOODING FOLLOWING CONSTRUCTION OF RELIEF FLOODWAY ALONG ELIZABETH DRIVE (*SOUTH CREEK*)

FIGURE K2



Refer **Figure K4** for detailed analysis of the culvert group located immediately downstream of the St Marys Levee

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	25.50	26.60	+ 1.10
50	25.80		+ 0.80
100	25.95		+ 0.65
200	26.15		+ 0.45
500	26.40		+ 0.20
PMF	27.30		- 0.70

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	25.65	26.70	+ 1.05
50	25.95		+ 0.75
100	26.25		+ 0.45
200	26.40		+ 0.30
500	26.65		+ 0.05
PMF	27.65		- 0.95

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	25.80	27.10	+ 1.30
50	26.15		+ 0.95
100	26.35		+ 0.75
200	26.60		+ 0.50
500	26.90		+ 0.20
PMF	27.80		- 0.70

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	26.00	27.30	+ 1.30
50	26.35		+ 0.95
100	26.60		+ 0.70
200	26.85		+ 0.45
500	27.05		+ 0.25
PMF	28.20		- 0.90

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	26.45	27.75	+ 1.30
50	26.75		+ 1.00
100	27.05		+ 0.70
200	27.20		+ 0.55
500	27.50		+ 0.25
PMF	28.70		- 0.95

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	24.50	25.60	+ 1.10
50	24.75		+ 0.85
100	25.00		+ 0.60
200	25.20		+ 0.40
500	25.70		- 0.10
PMF	27.00		- 1.40

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	24.30	25.60	+ 1.30
50	25.50		+ 0.10
100	25.60		+ 0.00
200	26.05		- 0.55
500	26.20		- 0.60
PMF	27.15		- 1.55

During floods up to and including the 200 year recurrence flood, flooding to the east of the St Marys Levee occurs solely due to floodwaters backing up through the culvert located immediately downstream of the levee and along the Great Western Highway. Refer **Figure K4** for further details.

Refer **Figure K3** for a profile of levee crest elevations and peak flood levels along the earthen and concrete portions of the St Marys Levee *[Extent A-A to B-B]*

ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	26.65	28.20	+ 1.55
50	26.95		+ 1.25
100	27.25		+ 0.95
200	27.50		+ 0.70
500	27.75		+ 0.45
PMF	29.00		- 0.80

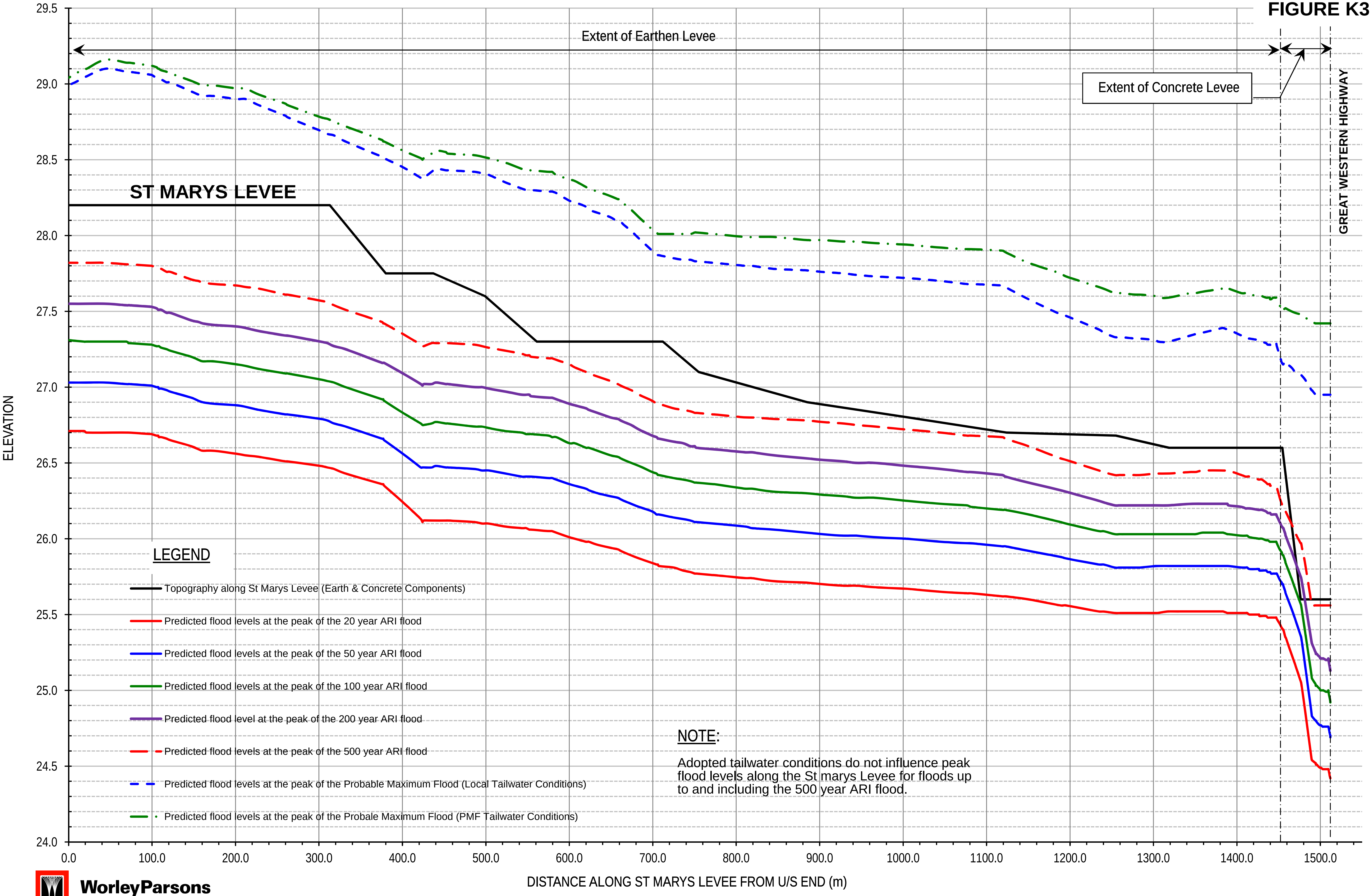
ARI	LEVEL *(mAHD)*	LEVEE HEIGHT *(mAHD)*	FREEBOARD *(m)*
20	26.75	28.20	+ 1.45
50	27.05		+ 1.15
100	27.30		+ 0.90
200	27.60		+ 0.60
500	27.85		+ 0.35
PMF	28.90		- 0.70

LEGEND:

- 🟨 Extent of St Marys Levee constructed as an earthen levee
- 🟥 Extent of St Marys Levee constructed as a concrete levee
- 🟦 Mapped flood extents at the peak of the design 100 year ARI flood

ASSESSMENT OF THE POTENTIAL FOR OVERTOPPING TO OCCUR OF THE ST MARYS LEVEE

FIGURE K3



NOTE:

Adopted tailwater conditions do not influence peak flood levels along the St marys Levee for floods up to and including the 500 year ARI flood.

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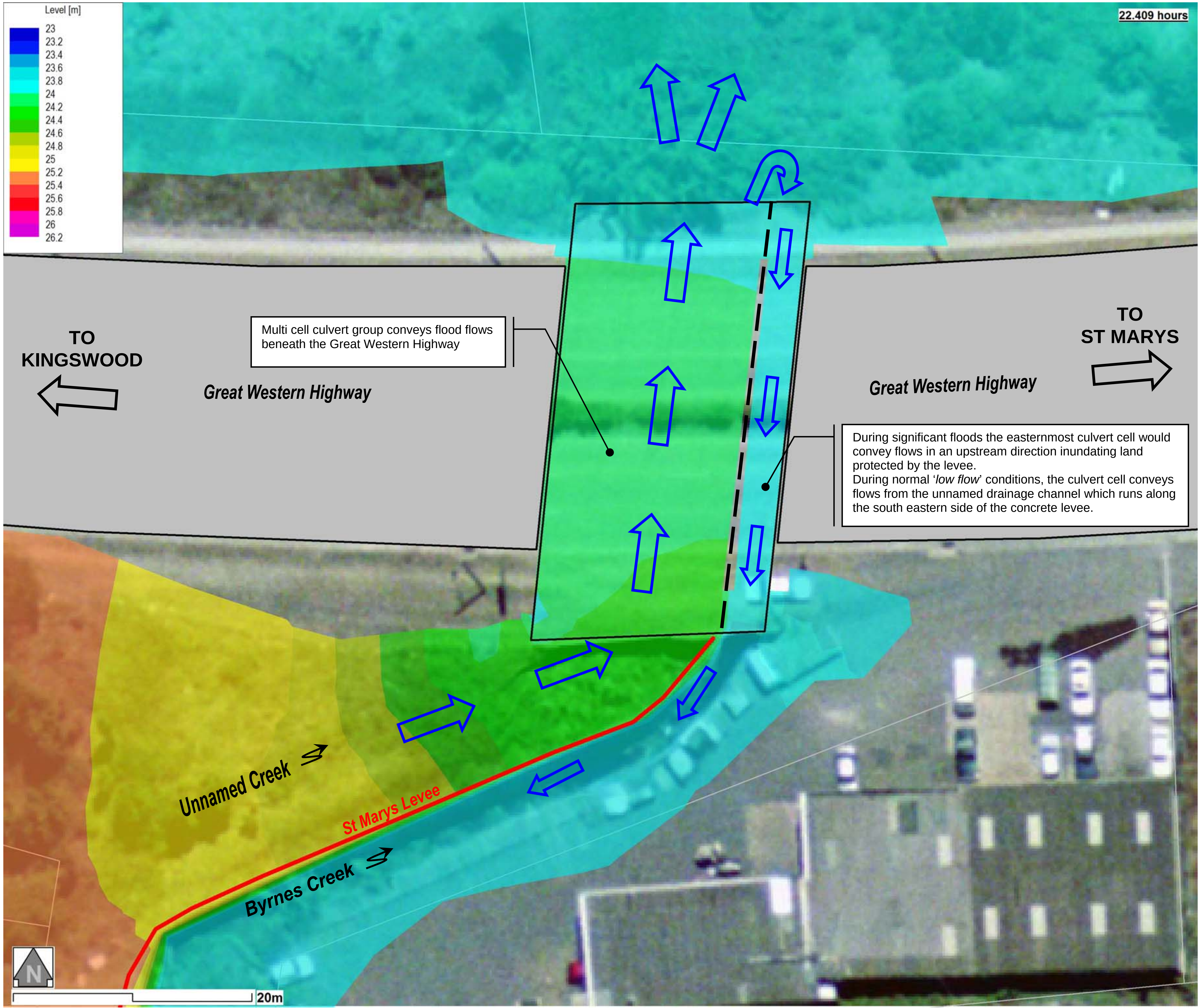
South Creek Flood Study
6033rg131115_Profiles along Levees.xls

DESIGN FLOODWATER SURFACE PROFILES ALONG THE ST MARYS EARTHEN AND CONCRETE LEVEE

FIGURE K4



Multi cell culvert group conveys flood flows beneath the Great Western Highway

During significant floods the easternmost culvert cell would convey flows in an upstream direction inundating land protected by the levee.
During normal '*low flow*' conditions, the culvert cell conveys flows from the unnamed drainage channel which runs along the south eastern side of the concrete levee.

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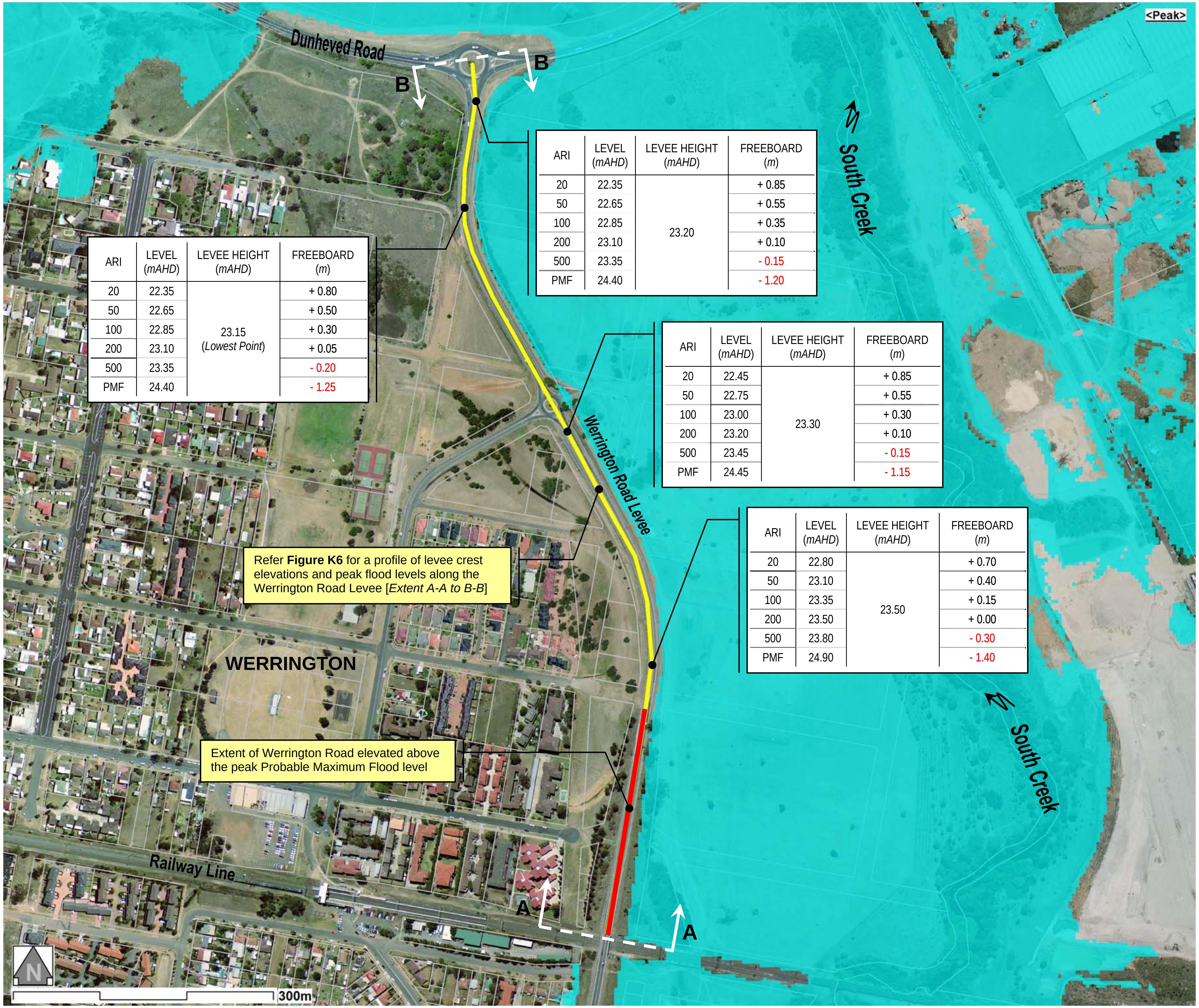
Rp6033- South Creek Flood Study
fg6033rg130613-Fig K4-St Marys Levee 3 of 3 (Culvert Analysis).doc

FUNCTION OF ST MARYS LEVEE AND CULVERT CELL ALONG THE GREAT WESTERN HIGHWAY (*NEAR ST MARYS*)

FIGURE K5



ARI	LEVEL (mAHD)	LEVEE HEIGHT (mAHD)	FREEBOARD (m)
20	22.35	23.20	+ 0.85
50	22.65		+ 0.55
100	22.85		+ 0.35
200	23.10		+ 0.10
500	23.35		- 0.15
PMF	24.40		- 1.20

ARI	LEVEL (mAHD)	LEVEE HEIGHT (mAHD)	FREEBOARD (m)
20	22.35	23.15 (*Lowest Point*)	+ 0.80
50	22.65		+ 0.50
100	22.85		+ 0.30
200	23.10		+ 0.05
500	23.35		- 0.20
PMF	24.40		- 1.25

ARI	LEVEL (mAHD)	LEVEE HEIGHT (mAHD)	FREEBOARD (m)
20	22.45	23.30	+ 0.85
50	22.75		+ 0.55
100	23.00		+ 0.30
200	23.20		+ 0.10
500	23.45		- 0.15
PMF	24.45		- 1.15

ARI	LEVEL (mAHD)	LEVEE HEIGHT (mAHD)	FREEBOARD (m)
20	22.80	23.50	+ 0.70
50	23.10		+ 0.40
100	23.35		+ 0.15
200	23.50		+ 0.00
500	23.80		- 0.30
PMF	24.90		- 1.40

Refer **Figure K6** for a profile of levee crest elevations and peak flood levels along the Werrington Road Levee [*Extent A-A to B-B*]

Extent of Werrington Road elevated above the peak Probable Maximum Flood level

LEGEND:

▨	Extent of Werrington Road Levee
🟦	Mapped flood extents at the peak of the design 100 year ARI flood

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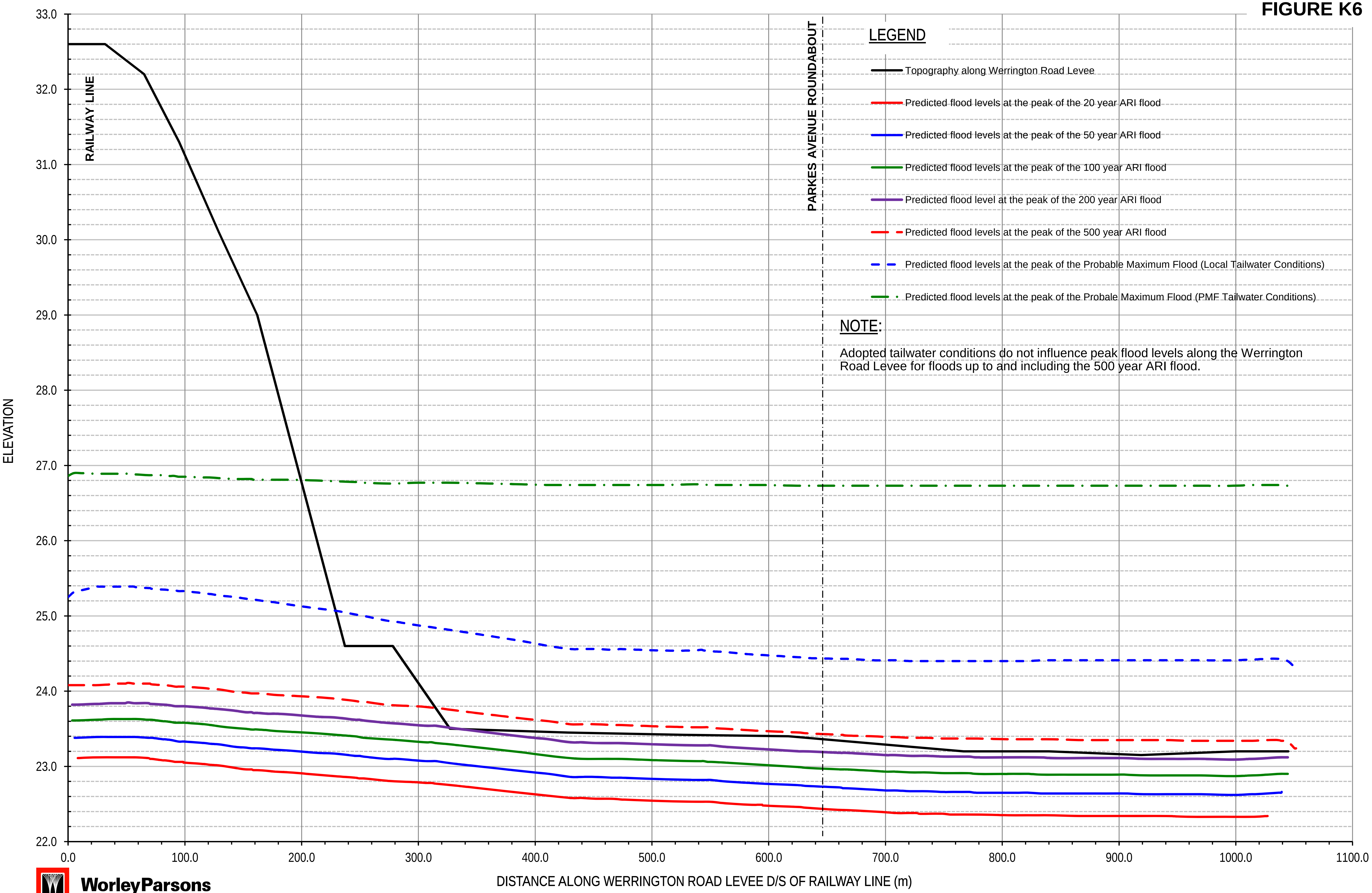
ASSESSMENT OF THE POTENTIAL FOR OVERTOPPING TO OCCUR OF THE WERRINGTON ROAD LEVEE

FIGURE K6



NOTE:

Adopted tailwater conditions do not influence peak flood levels along the Werrington Road Levee for floods up to and including the 500 year ARI flood.

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South Creek Flood Study
6033rg131115_Profiles along Levees.xls

DESIGN FLOODWATER SURFACE PROFILES ALONG THE WERRINGTON ROAD LEVEE

FIGURE K7

ARI	LEVEL (*mAHD*)	LEVEE HEIGHT (*mAHD*)	FREEBOARD (*m*)
20	21.32	22.30	+ 0.98
50	21.52		+ 0.78
100	21.70		+ 0.60
200	21.88		+ 0.42
500	22.15		+ 0.15
PMF	24.15		- 0.85

NOTE:

Peak flood levels extracted along Werrington Creek side of the earthen levee.

LEGEND:

🟥	Extent of Werrington Earthen Levee
🟦	Mapped flood extents at the peak of the design 100 year ARI flood for existing conditions
🟨	Werrington Creek 1% AEP potential flood extent during malfunction of Werrington Earthen Levee – for landuse planning and development control purposes

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ASSESSMENT OF THE POTENTIAL FOR MALFUNCTION OF THE WERRINGTON EARTHEN LEVEE & FLAP GATE

APPENDIX L

BRIDGE AFFLUX CHECK CALCULATIONS

BRIDGE AFFLUX 'CHECK' CALCULATIONS (1 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **M4 Motorway (South Creek) - Western Bridge Opening**

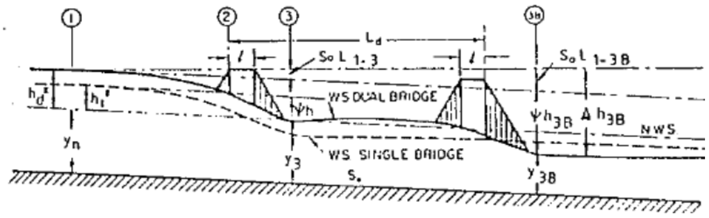
Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref	Calculations	Output

Calculation of afflux for the Western Motorway (M4) bridge crossing of South Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood
Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

K*

The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M =

$$M = \frac{k_{Bridge}}{k_{Total}}$$

Where k = conveyance
From Mannings Eqn

$$k = \frac{ar^{\frac{2}{3}}}{n}$$

From the RMA-2 model

Q for channel LOB	120	**Q for main channel**	550	**Q for channel ROB**	180

k

Therefore M = 0.65

M = 0.65

The value of Kb (the base value) can be read from the figure below

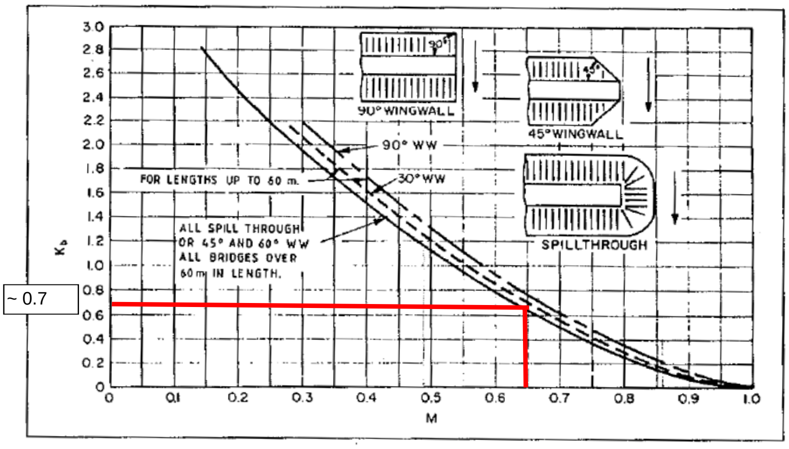


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)

Source: Bradley (1978)

Kb = 0.7

K_b = 0.7

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Ref	Calculations	Output

Kp = Using

$$J = \frac{Ap}{An2}$$

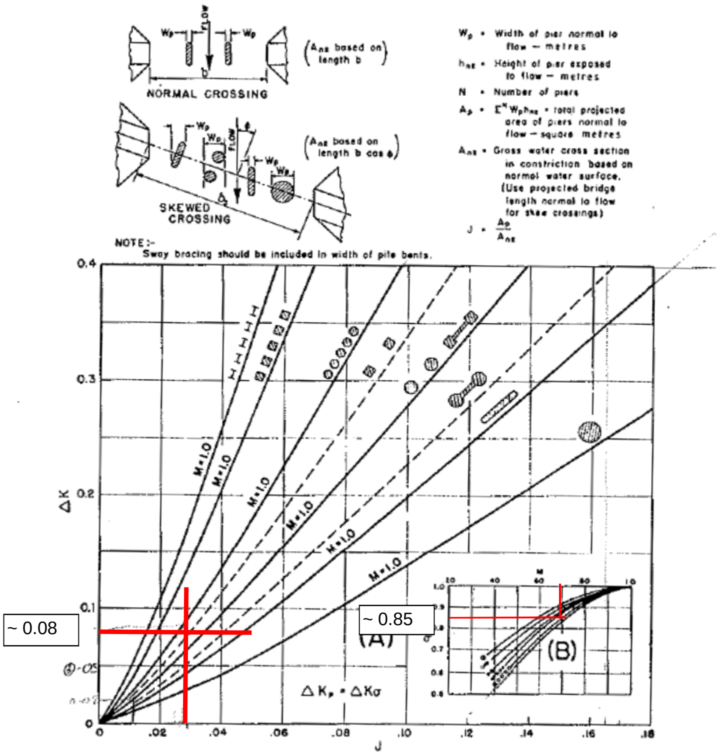
Where Ap = area of piers
assume 2 rows of 400mm square piers
Variable heights
= 2.4 m2

and An2 = Gross water cross section in constriction

75 m2 *Based on length b when normal to flow*

J = 0.03

From the graph below



ΔK	0.8
σ	0.85

ΔKp = σ* ΔK **0.68**

K_p = 0.68

Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

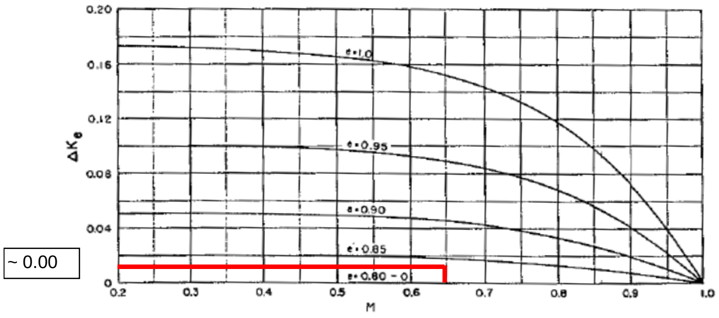
$$e = 1 - \frac{Q_{ROB}}{Q_{LOB}}$$

Since Q ROB = 120.00

Since Q LOB = 180.00 From RMA-2 model

e = 0.33

Greater flow always goes on top of the equation



K_e = 0

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 1.38

K* = 1.38

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **M4 Motorway (South Creek) - Western Bridge Opening**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref	Calculations	Output

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\alpha_1 = \frac{\Sigma qv^2}{QV_1^2}$$

Considering the channel as per

LOB	q =	120	A	206	v =	0.6
Main Channel	q =	550		640	v =	0.9
ROB	q =	180		500	v =	0.4
	Total Q =	850.0	m3/s	1346	Average V =	0.63 m/s

Therefore α 1 **1.4**

α_1 = **1.4**

$\alpha 2$
From Ref 1.

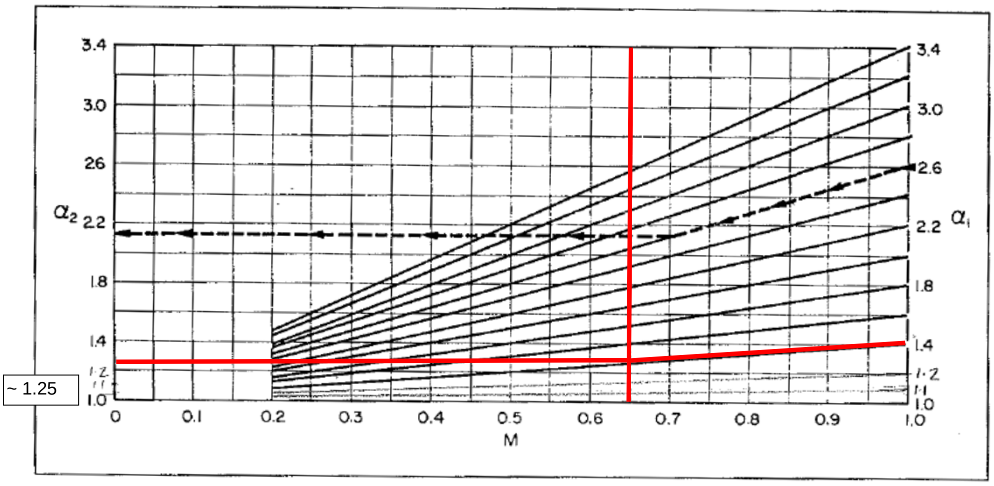


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 = **1.25**

h*1

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.57	m/s	In channel
	An2	540	m2	In channel
	A4	5300	m2	In channel
	A1	6600	m2	In channel
	α 1 =	1.4		
	α 2 =	1.25		
	K* =	1.38		

h*1 = 0.22 m

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**M4 Motorway (South Creek) - Western Bridge Opening**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref	Calculations	Output

h*b

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.57	m/s	In channel
	An2	540	m2	In channel
	A4	5300	m2	In channel
	A1	6600	m2	In channel
	α 1 =	1.4		
	α 2 =	1.25		
	K* =	0.70		

h*b = 0.11 m

Δh

Db	0.55	Refer Figure 5.13
h*3 =	0.091	
b	75.00	width of opening under bridge
y	7.2	A2/b
L (initial) (m)	128	iterate until the same as L_{final}
So ave	0.004	
S_o x L_{1-3}	0.56	

Δh initial **0.87** metres

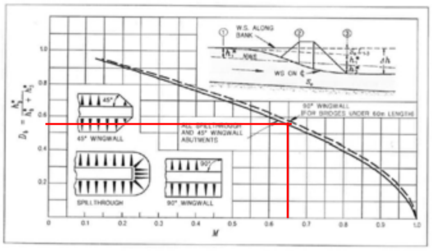


Figure 5.13 Differential Water Level Ratio Base Curves

L*

Δh/y	0.12	
L*/b	0.9	From Figure 5.14
L*	67.5	
L_{1-3} - L*	60	
$L_{1-3\ (final)}$	127.5	

RMA-2 WL Diff 1 metres

Difference **0.13** metres

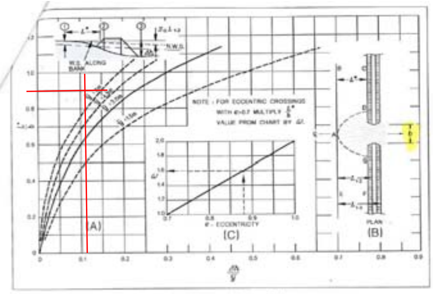


Figure 5.14 Distance to Maximum Backwater

BRIDGE AFFLUX 'CHECK' CALCULATIONS (2 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Great Western Highway (South Creek) Western Opening**

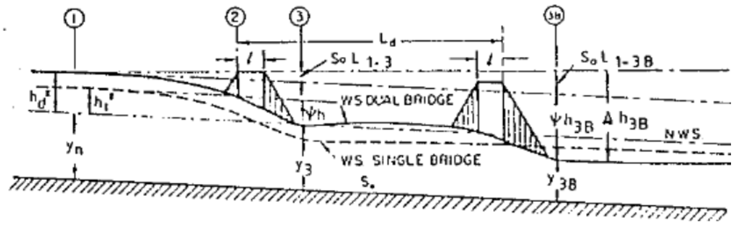
Job Ref: 6033
Calc By: DJB
Checked By: RG
Date: 7/06/2013

Ref | **Calculations** | **Output**

Calculation of afflux for the Great Western Highway bridge crossing of South Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood
Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4} \right]^2 - \left[\frac{A_{n2}}{A_1} \right]^2 \right] \frac{V_{n2}^2}{2g}$$

K*

The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M =

$$M = \frac{k_{Bridge}}{k_{Total}}$$

Where k = conveyance
From Mannings Eqn

$$k = \frac{ar^{\frac{2}{3}}}{n}$$

From the RMA-2 model

Q for channel LOB	45	**Q for main channel**	680	**Q for channel ROB**	125
k	8.0		106.0		54.0

Therefore M = 0.80

M = 0.80

The value of Kb (the base value) can be read from the figure below

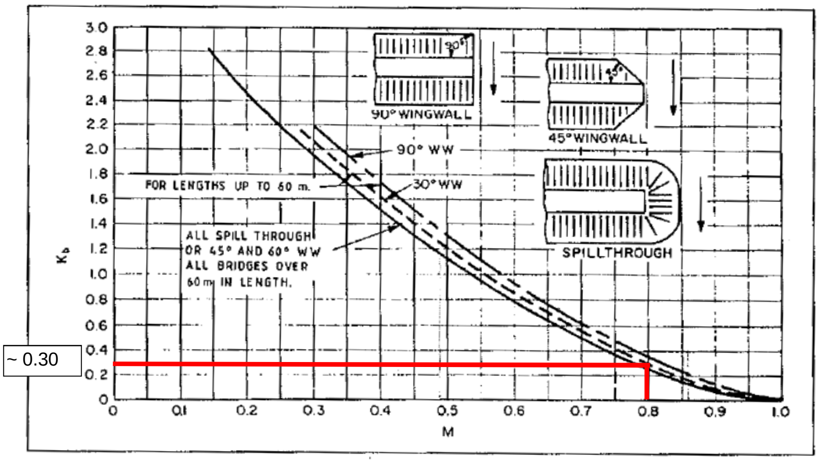


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)

Source: Bradley (1978)

Kb = 0.3

K_b = 0.3

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Great Western Highway (South Creek) Western Opening**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref **Calculations** **Output**

Kp = Using

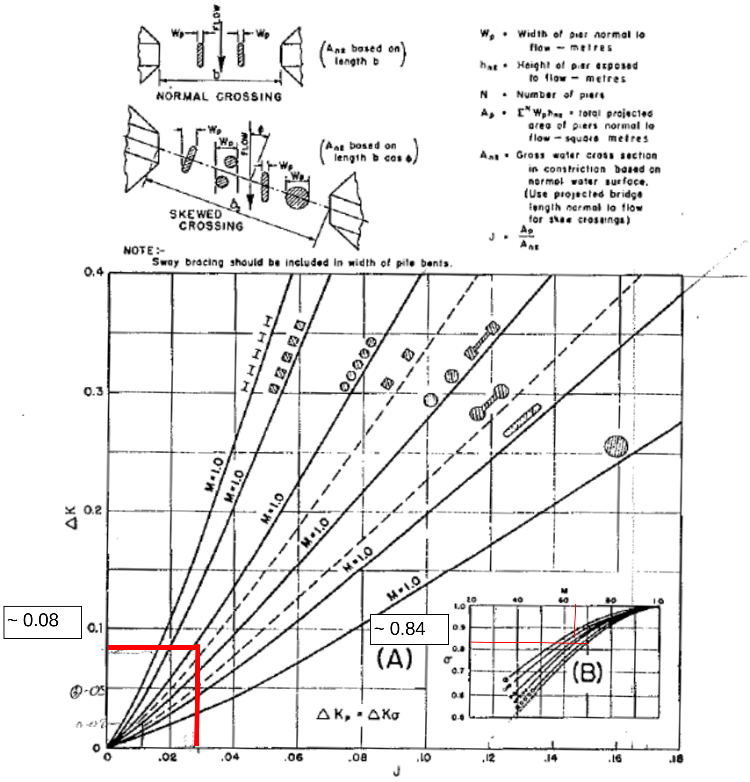
$$J = \frac{Ap}{An2}$$

Where Ap = area of piers
assume 2 rows of 400mm square piers
Variable heights
= 2.4 m2

and An2 = Gross water cross section in constriction
85 m2

J = 0.03

From the graph below



ΔK 0.08
σ 0.84

ΔKp = σ* ΔK **0.07**

K_p = 0.07

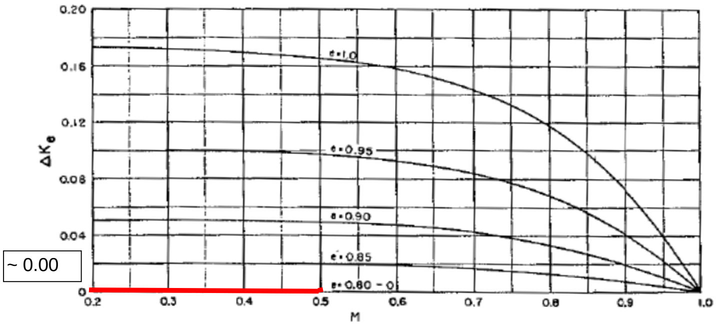
Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

$$e = 1 - \frac{Q_{ROB}}{Q_{LOB}}$$

Since Q ROB = 45.00 Note that ROB and LOB have been reversed so that the smaller number is on top

Since Q LOB = 125.00 From RMA-2 model

e = 0.64



K_e = 0

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 0.37

K* = 0.37

Ref	Calculations	Output

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\alpha_1 = \frac{\Sigma\, qv^2}{QV_1^2}$$

Considering the channel as per

LOB	q =	45	A	120	v =	0.4
Main Channel	q =	680.0		500	v =	1.4
ROB	q =	125.0		200	v =	0.6
	Total Q =	850.0	m3/s	820	Average V =	1.04 m/s

Therefore α 1 **1.4**

α_1 = **1.4**

$\alpha 2$

From Ref 1.

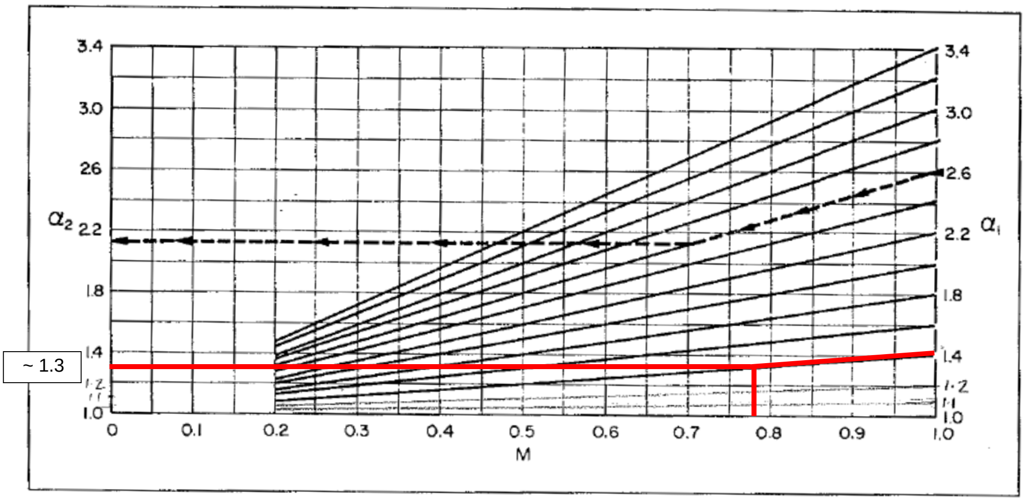


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 = **1.3**

h*1

$$h^*_1 = K^*\,\alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1\left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2\right]\frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.36	m/s	In channel
	An2	450	m2	In channel
	A4	2200	m2	In channel
	A1	2700	m2	In channel
	α 1 =	1.4		
	α 2 =	1.3		
	K* =	0.37		

Inputs above this line completed

h*1 = 0.05 m

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Great Western Highway (South Creek) Western Opening**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref	Calculations	Output

h*b

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.36	m/s	In channel
	An2	450	m2	In channel
	A4	2200	m2	In channel
	A1	2700	m2	In channel
	α 1 =	1.4		
	α 2 =	1.3		
	K* =	0.30		

Inputs above this line completed

h*b = 0.04 m

Δh

Db	0.38	Refer Figure 5.13
h*3 =	0.062	
b	85.00	width of opening under bridge
y	5.3	A2/b
L (initial) (m)	155	iterate until the same as L_{final}
So ave	0.004	
S_o x L_{1-3}	0.69	

Δh initial **0.80** metres

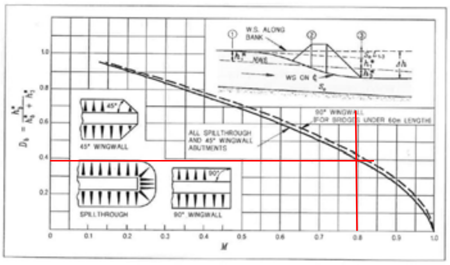


Figure 5.13 Differential Water Level Ratio Base Curves

L*

Δh/y	0.15	
L*/b	0.88	From Figure 5.14
L*	74.8	
L_{1-3} - L*	80	
$L_{1-3\ (final)}$	154.8	

RMA-2 WL Diff 1 metres

Difference **0.20** metres

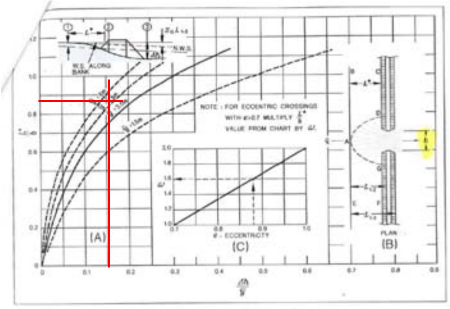


Figure 5.14 Distance to Maximum Backwater

BRIDGE AFFLUX 'CHECK' CALCULATIONS (3 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Railway Bridge Crossing (South Creek) - Eastern Bridge Opening**

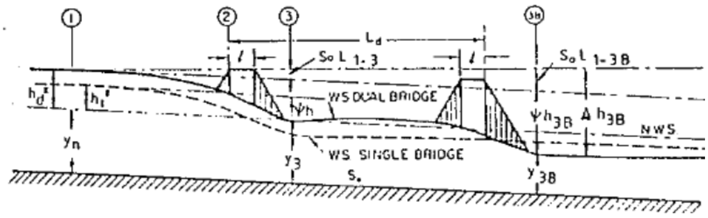
Job Ref: 6033
Calc By: DJB
Checked By: RG
Date: 7/06/2013

Ref | **Calculations** | **Output**

Calculation of afflux for the Railway bridge crossing of South Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood
Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

K*

The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M = $M = \frac{k_{Bridge}}{k_{Total}}$

Where k = conveyance
From Mannings Eqn

$k = \frac{ar^{\frac{2}{3}}}{n}$

From the RMA-2 model

Q for channel LOB 110
Q for main channel 630
Q for channel ROB 70

k

Therefore M = **0.78**

M = 0.78

The value of Kb (the base value) can be read from the figure below

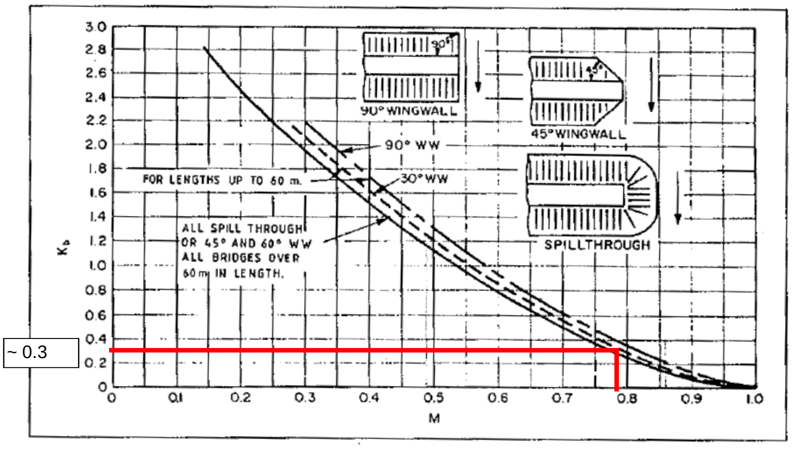


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)
Source: Bradley (1978)

Kb = 0.3

K_b = 0.3

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Railway Bridge Crossing (South Creek) - Eastern Bridge Opening**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref	**Calculations**	**Output**

Kp = Using $J = \dfrac{Ap}{An2}$

Where Ap = area of piers

assume 2 rows of 400mm square piers

Variable heights

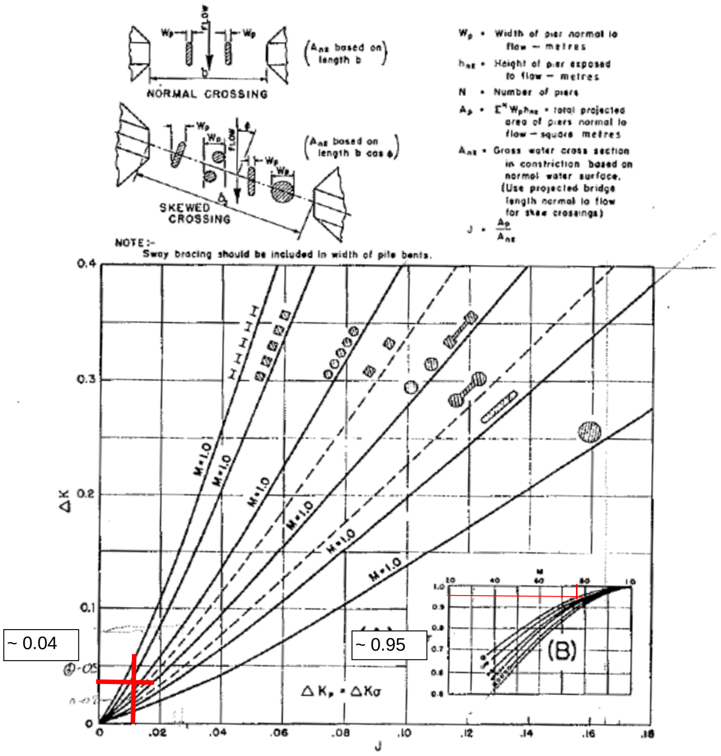
= 2.4 m2

and An2 = Gross water cross section in constriction

220 m2

J = 0.01

From the graph below



ΔK 0.04

σ 0.95

ΔKp = σ* ΔK **0.04**

K_p = 0.04

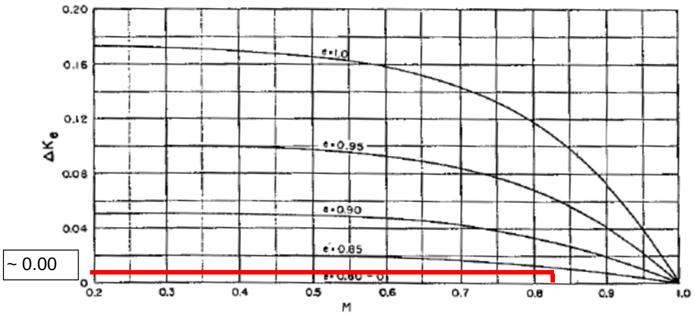
Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

$$\boxed{e = 1 - \frac{Q_{ROB}}{Q_{LOB}}}$$

Since Q ROB = 70.00 Note that ROB and LOB have been reversed so that the smaller number is on top

Since Q LOB = 110.00 From RMA-2 model

e = 0.36



K_e = 0

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 0.34

K* = 0.34

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Railway Bridge Crossing (South Creek) - Eastern Bridge Opening**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref	**Calculations**	**Output**

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\alpha_1 = \frac{\Sigma qv^2}{QV_1^2}$$

Considering the channel as per

LOB	q =	110	A	310	v =	0.4
Main Channel	q =	630.0		1030	v =	0.6
ROB	q =	70.0		230	v =	0.3

Total Q = 810.0 m3/s 1570 Average V = 0.52 m/s

Therefore α 1 **1.2**

α_1 **= 1.2**

$\alpha 2$

From Ref 1.

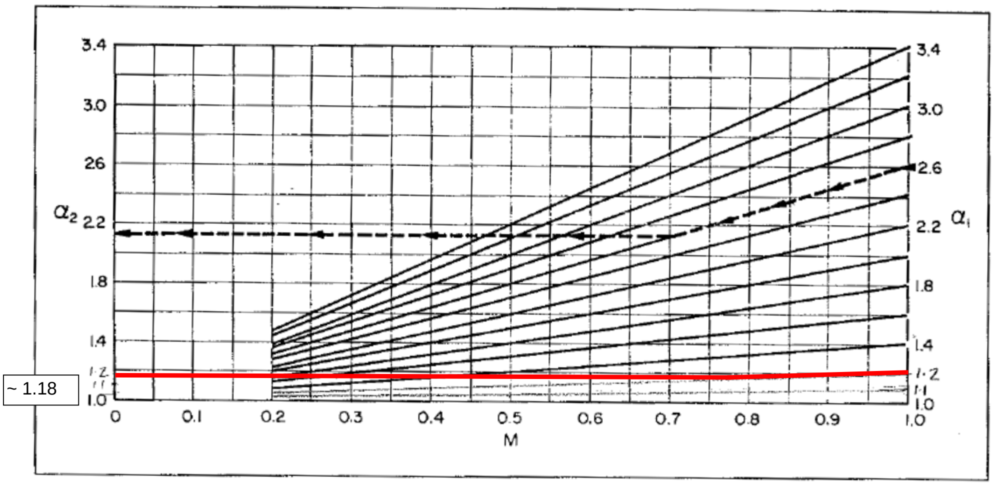


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 **= 1.18**

h*1

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	0.79	m/s	In channel
	An2	1030	m2	In channel
	A4	2200	m2	In channel
	A1	2400	m2	In channel
	α 1 =	1.2		
	α 2 =	1.18		
	K* =	0.34		

h*1 = 0.01 m

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Railway Bridge Crossing (South Creek) - Eastern Bridge Opening**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref	Calculations	Output

h*b

where	g =	9.81	ms/2	
	Vn2 = Q/An2	0.79	m/s	In channel
	An2	1030	m2	In channel
	A4	2200	m2	In channel
	A1	2400	m2	In channel
	α 1 =	1.2		
	α 2 =	1.18		
	K* =	0.30		

h*b = 0.01 m

Δh

Db	0.41	Refer Figure 5.13
h*3 =	0.018	
b	220.00	width of opening under bridge
y	4.7	A2/b
L (initial) (m)	172	iterate until the same as L_{final}
So ave	0.001	
S_o x $L_{1\text{-}3}$	0.25	
Δh initial	**0.28**	metres

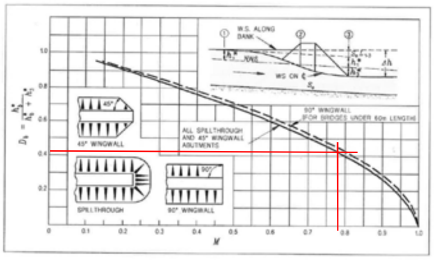


Figure 5.13 Differential Water Level Ratio Base Curves

L*

Δh/y	0.06	
L*/b	0.6	From Figure 5.14
L (initial) (m)	132	
So ave	40	
S_o x $L_{1\text{-}3}$	172	
RMA-2 WL Diff	**0.4**	metres
Difference	**0.12**	metres

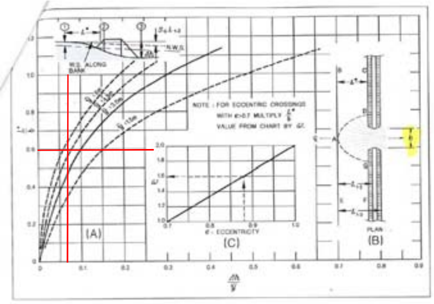


Figure 5.14 Distance to Maximum Backwater

BRIDGE AFFLUX 'CHECK' CALCULATIONS (4 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Western Motorway - M4 (Ropes Creek)**

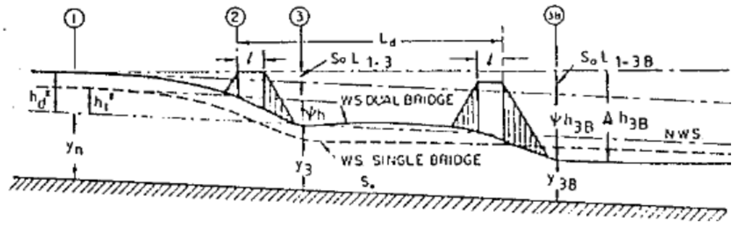
Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref **Calculations** **Output**

Calculation of afflux for the Western Motorway (M4) bridge crossing of Ropes Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood
Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

K* The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M =

$$M = \frac{k_{Bridge}}{k_{Total}}$$

Where k = conveyance
From Mannings Eqn

$$k = \frac{ar^{\frac{2}{3}}}{n}$$

From the RMA-2 model

Q for channel LOB	15	**Q for main channel**	80	**Q for channel ROB**	65

k

Therefore M = **0.50**

M = 0.50

The value of Kb (the base value) can be read from the figure below

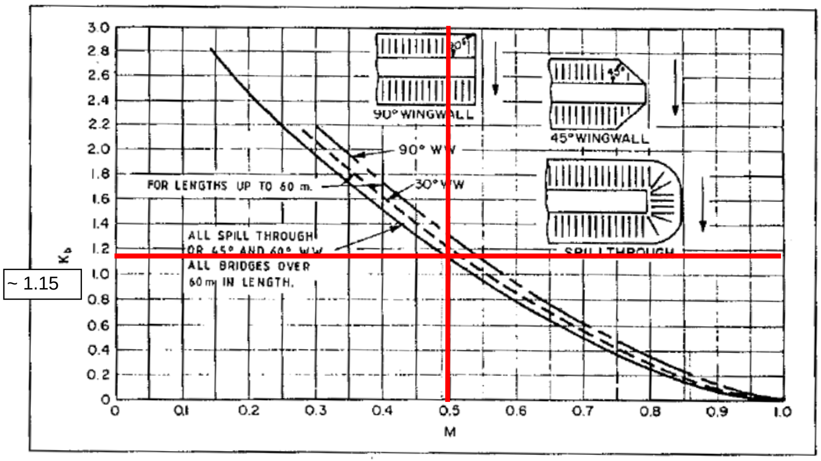


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)
Source: Bradley (1978)

Kb = 1.15

K_b = 1.15

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Western Motorway - M4 (Ropes Creek)**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref | **Calculations** | **Output**

Kp = Using

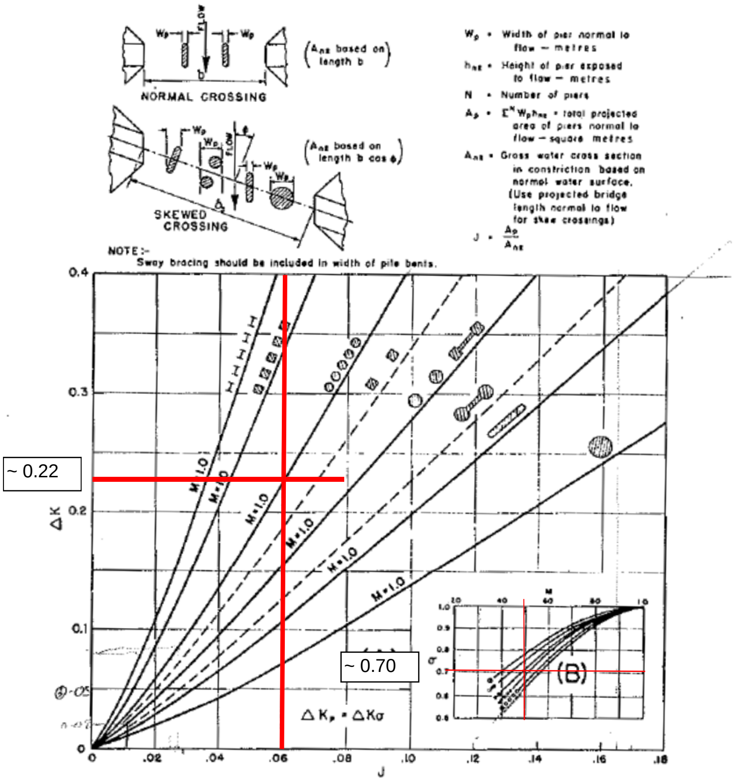
$$J = \frac{Ap}{An2}$$

Where Ap = area of piers
assume 2 rows of 400mm square piers
Variable heights
= 2.4 m2

and An2 = Gross water cross section in constriction
38 m2

J = 0.06

From the graph below



ΔK 0.22
σ 0.7

ΔKp = σ* ΔK **0.15**

K_p = 0.15

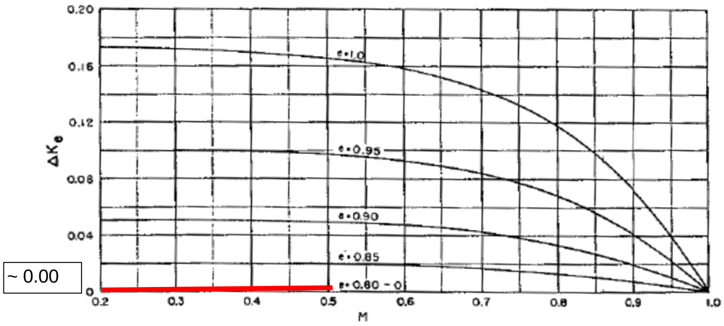
Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

$$e = 1 - \frac{Q_{ROB}}{Q_{LOB}}$$

Since Q ROB = 15.00 Note that ROB and LOB have been reversed so that the smaller number is on top

Since Q LOB = 65.00 From RMA-2 model

e = 0.77



K_e = 0

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 1.30

K* = 1.30

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\alpha_1 = \frac{\Sigma\, qv^2}{QV_1^2}$$

Considering the channel as per

LOB	q =	15	50	v =	0.3
Main Channel	q =	80.0	114	v =	0.7
ROB	q =	65.0	163	v =	0.4

Total Q = 160.0 m3/s 327 Average V = 0.49 m/s

Therefore α 1 **1.3**

α_1 **= 1.3**

$\alpha 2$

From Ref 1.

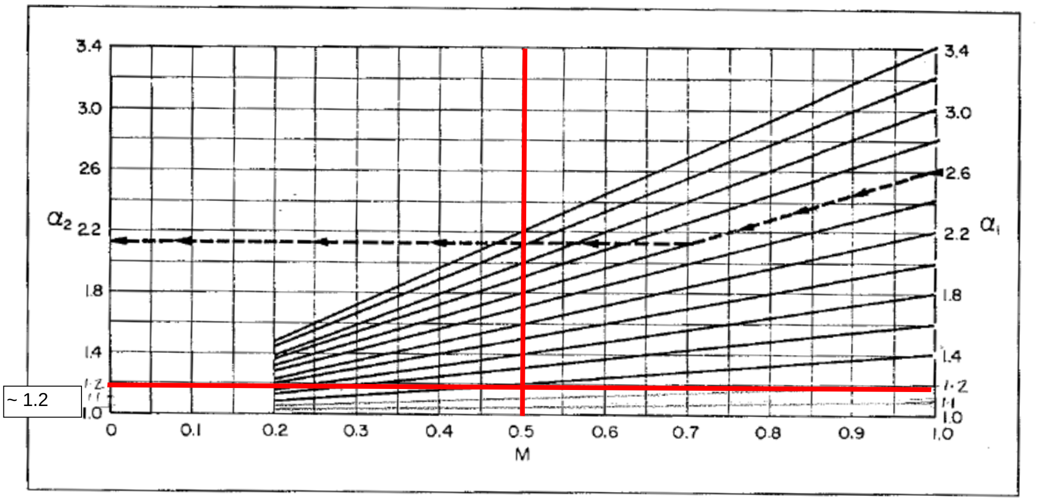


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 **= 1.2**

h*1

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1\left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2\right]\frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	0.94	m/s	In channel
	An2	170	m2	In channel
	A4	620	m2	In channel
	A1	1180	m2	In channel
	α 1 =	1.3		
	α 2 =	1.2		
	K* =	1.30		

h*1 = 0.07 m

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Western Motorway - M4 (Ropes Creek)**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref **Calculations** **Output**

h*b

where				
	g =	9.81	ms/2	
	Vn2 = Q/An2	0.94	m/s	In channel
	An2	170	m2	In channel
	A4	620	m2	In channel
	A1	1180	m2	In channel
	α 1 =	1.3		
	α 2 =	1.2		
	K* =	1.15		

Inputs above this line completed

h*b = 0.07 m

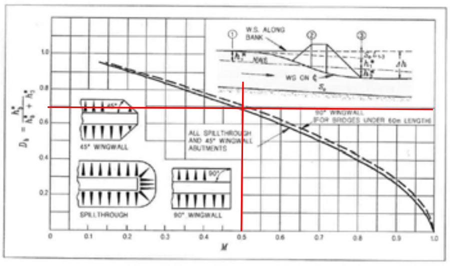


Figure 5.13 Differential Water Level Ratio Base Curves

Δh

Db	0.68	Refer Figure 5.13
h*3 =	0.031	
b	42	width of opening under bridge
y	4.0	A2/b
L (initial) (m)	84	iterate until the same as L_{final}
So ave	0.006	
S_o x L_{1-3}	0.47	
Δh initial	**0.58**	metres

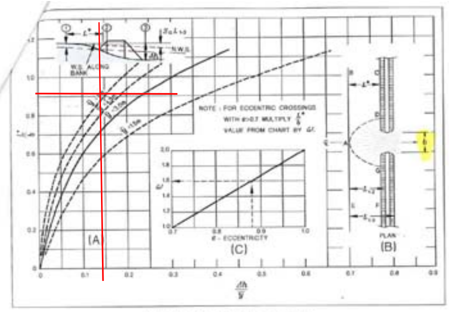


Figure 5.14 Distance to Maximum Backwater

L*

Δh/y	0.14	
L*/b	0.91	From Figure 5.14
L*	38.22	
L1-3 - L*	45	
$L_{1\text{-}3\ (final)}$	83.22	

Backwater Multiplication Factor for Dual Bridges

Multiplication factor based on Figure 1.2 (following page):

L_d	65
l	18
Multipl. Factor	**1.35** From Figure 5.12

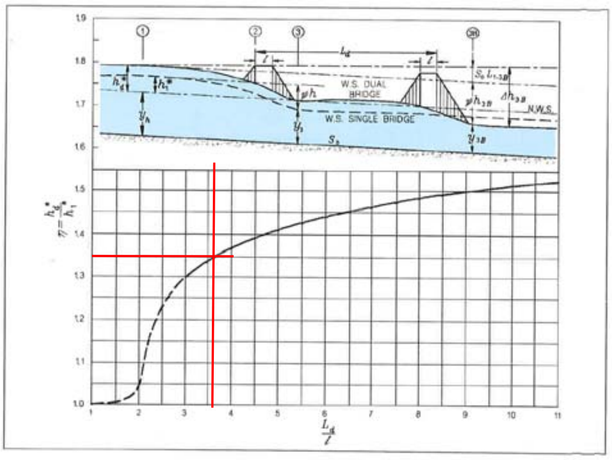


Figure 5.12 Backwater Multiplication Factor for Dual Bridges

Δh

With Dual Bridge Coefficient

Δh final	**0.78**	metres
RMA-2 WL Diff	**0.9**	metres
Difference	**0.12**	metres

BRIDGE AFFLUX 'CHECK' CALCULATIONS (5 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Great Western Highway (Ropes Creek)**

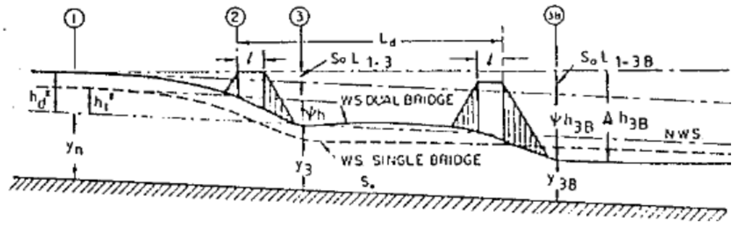
Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref | **Calculations** | **Output**

Calculation of afflux for the Great Western Highway bridge crossing of Ropes Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood
Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4} \right]^2 - \left[\frac{A_{n2}}{A_1} \right]^2 \right] \frac{V_{n2}^2}{2g}$$

K*

The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M =

$$M = \frac{k_{Bridge}}{k_{Total}}$$

Where k = conveyance
From Mannings Eqn

$$k = \frac{ar^{\frac{2}{3}}}{n}$$

From the RMA-2 model

Q for channel LOB	5	**Q for main channel**	155	**Q for channel ROB**	15

k

Therefore M = **0.89**

M = 0.89

The value of Kb (the base value) can be read from the figure below

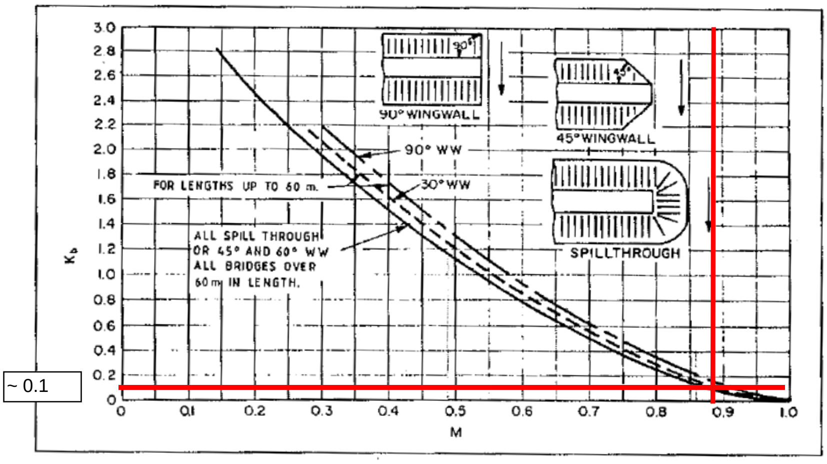


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)
Source: Bradley (1978)

Kb = 0.1

K_b = 0.1

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Great Western Highway (Ropes Creek)**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref **Calculations** **Output**

Kp = Using

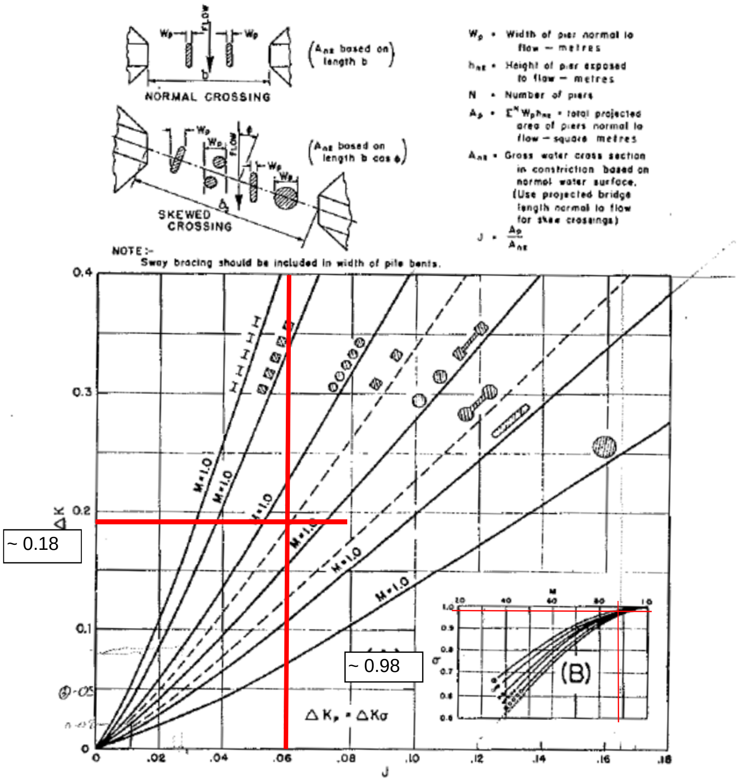
$$J = \frac{Ap}{An2}$$

Where Ap = area of piers
assume 2 rows of 400mm square piers
Variable heights
= 2.4 m2

and An2 = Gross water cross section in constriction
42 m2

J = 0.06

From the graph below



ΔK 0.32
σ 0.98

$\Delta Kp = \sigma * \Delta K$ **0.31**

K_p = 0.31

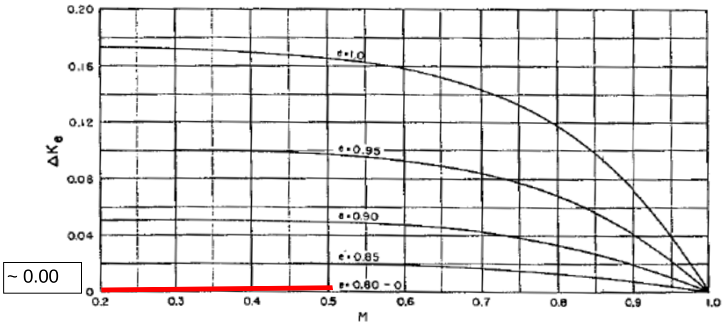
Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

$$e = 1 - \frac{Q_{ROB}}{Q_{LOB}}$$

Since Q ROB = 5.00 Note that ROB and LOB have been reversed so that the smaller number is on top

Since Q LOB = 15.00 From RMA-2 model

e = 0.67



K_e = 0

Ref	**Calculations**	**Output**

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 0.41

K* = 0.41

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\boxed{\alpha_1 = \frac{\Sigma qv^2}{QV_1^2}}$$

Considering the channel as per

LOB	q =	5	13	v =	0.4
Main Channel	q =	155.0	141	v =	1.1
ROB	q =	15.0	25	v =	0.6

Total Q = 175.0 m3/s 178 Average V = 0.98 m/s

Therefore α 1 **1.2**

α_1 **= 1.2**

$\alpha 2$
From Ref 1.

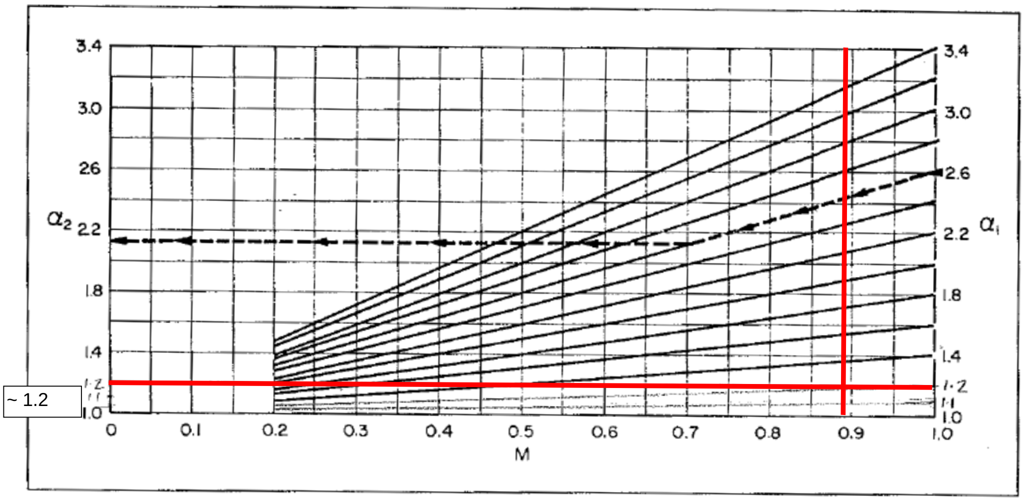


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 **= 1.2**

h*1

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.00	m/s	In channel
	An2	175	m2	In channel
	A4	575	m2	In channel
	A1	535	m2	In channel
	α 1 =	1.2		
	α 2 =	1.2		
	K* =	0.41		

h*1 = 0.02 m

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Great Western Highway (Ropes Creek)**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref **Calculations** **Output**

h*b

where g = 9.81 ms/2

Vn2 = Q/An2 1.00 m/s In channel

An2 175 m2 In channel

A4 575 m2 In channel

A1 535 m2 In channel

α 1 = 1.2

α 2 = 1.2

K* = 0.10

Inputs above this line completed

h*b = 0.01 m

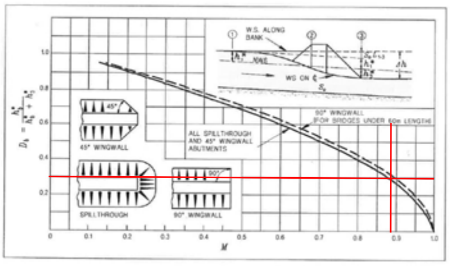


Figure 5.13 Differential Water Level Ratio Base Curves

Δh

Db 0.3 Refer Figure 5.13

h*3 = 0.012

b 42 width of opening under bridge

y 4.2 A2/b

L (initial) (m) 72 iterate until the same as L_{final}

So ave 0.007

S_o x L_{1-3} 0.52

Δh initial 0.56 metres

L*

Δh/y 0.13

L*/b 0.64 From Figure 5.14

L* 26.88

L1-3 - L* 45

$L_{1-3\ (final)}$ 71.88

RMA-2 WL Diff 0.7 metres

Difference 0.14 metres

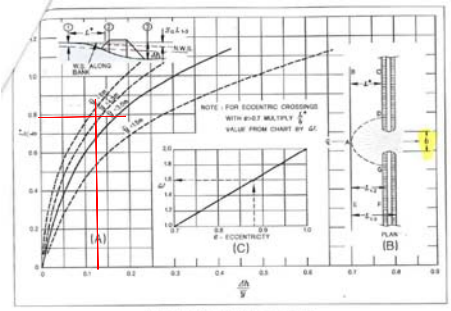


Figure 5.14 Distance to Maximum Backwater

BRIDGE AFFLUX 'CHECK' CALCULATIONS (6 of 6)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Railway Bridge Crossing (Ropes Creek)**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

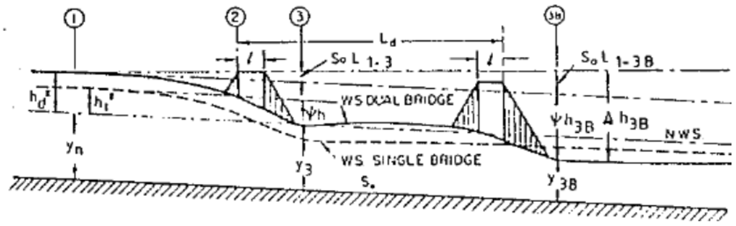
Ref **Calculations** **Output**

Calculation of afflux for the Railway bridge crossing of Ropes Creek for existing topographic conditions

Basis of calculations

This calculation is used to check the validity of the Affluxes predicted by the RMA-2 model at major bridge crossings during the 100 year ARI Flood

Based on the guidelines in Bradley (1987) the following appoximation can be used to estimate the bridge affluxes



To calculate the backwater or Afflux of the existing conditions using Bradleys Method the following formula can be applied

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

K*

The value for K* the total backwater co-efficient is made up of a variety of components, viz

1. Stream constriction as measured by the bridge opening ratio **M**
2. Type of bridge abutment, retaining, spill through etc. **Kb**
3. Number, size, shape orientation of piers in constriction **Kp**
4. Eccentricity or asymetric location of bridge wrt floodplains **Ke**
5. Skew (bridge crosses floodplain at other than 90deg angle **Ks**

This is done through calculating a base value of Kb and adding various emprically derived incremental co-efficients

Firstly calculate the bridge opening ratio (M)

M =

$$M = \frac{k_{Bridge}}{k_{Total}}$$

Where k = conveyance
From Mannings Eqn

$$k = \frac{ar^{\frac{2}{3}}}{n}$$

From the RMA-2 model

Q for channel LOB	65	**Q for main channel**	60	**Q for channel ROB**	75

k

Therefore M = 0.30

M = 0.30

The value of Kb (the base value) can be read from the figure below

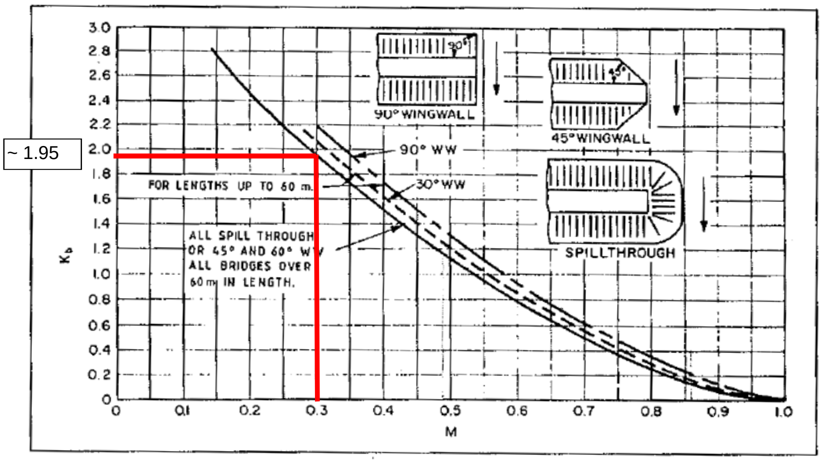


Figure 5.5 Backwater Coefficient Base Curves (Subcritical Flow)

Source: Bradley (1978)

Kb = 1.95

K_b = 1.95

Ref. 1 - Bridge Waterways Hydrology and Design - NAASRA Technical Report (January 1989)

Project: **SOUTH CREEK FLOOD STUDY**
Structure: **Railway Bridge Crossing (Ropes Creek)**

Job Ref:	6033
Calc By:	DJB
Checked By:	RG
Date:	7/06/2013

Ref **Calculations** **Output**

Kp = Using

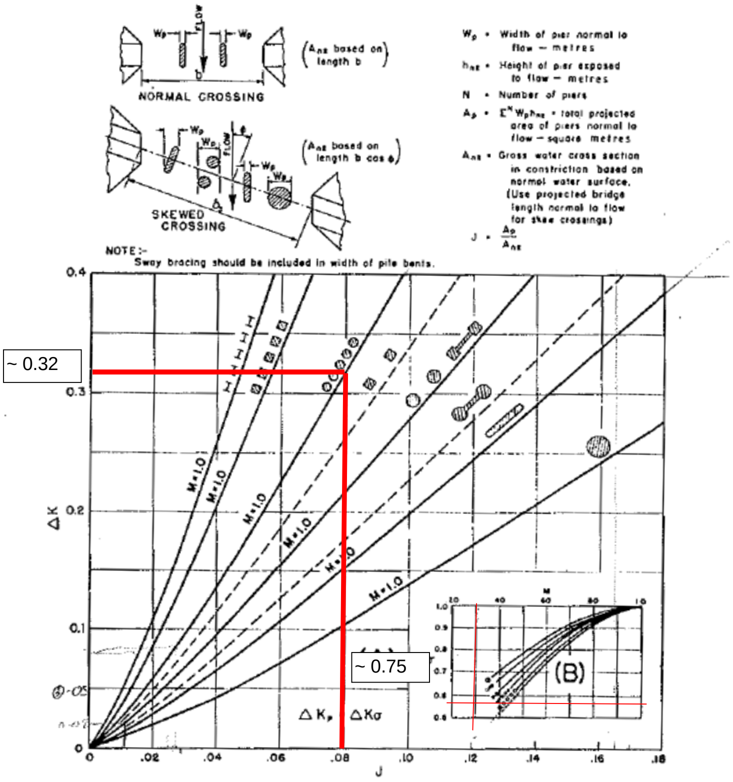
$$\boxed{J = \frac{Ap}{An2}}$$

Where Ap = area of piers
assume 2 rows of 400mm square piers
Variable heights
= 2.4 m2

and An2 = Gross water cross section in constriction
32 m2

J = 0.08

From the graph below



ΔK 0.32
σ 0.55

ΔKp = σ* ΔK **0.18**

K_p = **0.18**

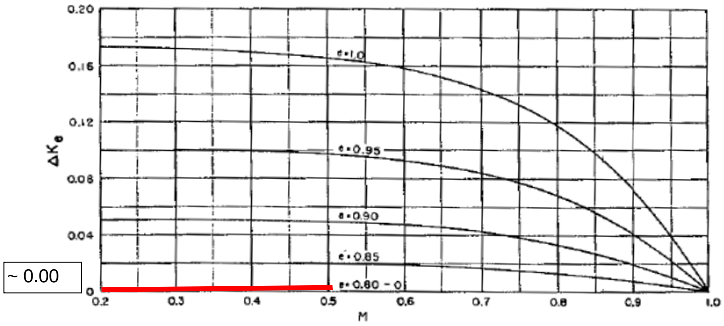
Ke = Eccentricity needs to be considered as flow is not evenly distributed across the floodplain

$$\boxed{e = 1 - \frac{Q_{ROB}}{Q_{LOB}}}$$

Since Q ROB = 65.00 Note that ROB and LOB have been reversed so that the smaller number is on top

Since Q LOB = 75.00 From RMA-2 model

e = 0.13



K_e = 0

Effect of skew is not considered necessary as bridge is at 90 degrees to flow

K* = Kb + Kp + Ke

K* = 2.13

K* = 2.13

$\alpha 1$ **Kinetic Energy Co-efficient**

$$\alpha_1 = \frac{\Sigma\, qv^2}{QV_1^2}$$

Considering the channel as per

LOB	q =	65	A	108	v =	0.6
Main Channel	q =	60.0		92	v =	0.7
ROB	q =	75.0		107	v =	0.7

Total Q = 200.0 m3/s 308 Average V = 0.65 m/s

Therefore α 1 **1.0**

α_1 **= 1.0**

$\alpha 2$

From Ref 1.

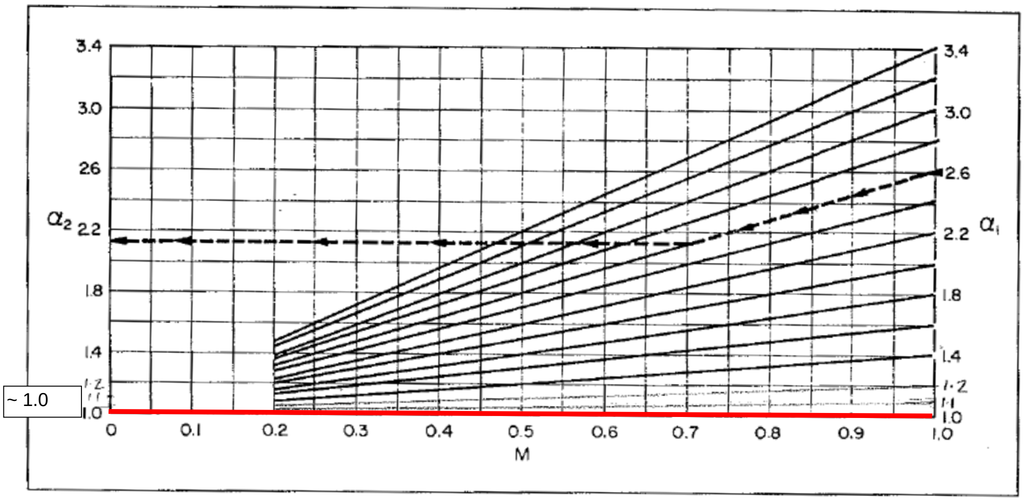


Figure 5.4 Aid for Estimating a_2

Source: Bradley (1978)

α_2 **= 1**

h*1

$$h^*_1 = K^* \alpha_2 \frac{V_{n2}^2}{2g} + \alpha_1 \left[\left[\frac{A_{n2}}{A_4}\right]^2 - \left[\frac{A_{n2}}{A_1}\right]^2 \right] \frac{V_{n2}^2}{2g}$$

where	g =	9.81	ms/2	
	Vn2 = Q/An2	1.33	m/s	In channel
	An2	150	m2	In channel
	A4	690	m2	In channel
	A1	900	m2	In channel
	α 1 =	1.0		
	α 2 =	1		
	K* =	2.13		

h*1 = 0.19 m

Project:	**SOUTH CREEK FLOOD STUDY**	Job Ref:	6033
Structure:	**Railway Bridge Crossing (Ropes Creek)**	Calc By:	DJB
		Checked By:	RG
		Date:	7/06/2013

Ref | **Calculations** | **Output**

h*b

where

g =	9.81	ms/2	
Vn2 = Q/An2	1.33	m/s	In channel
An2	150	m2	In channel
A4	690	m2	In channel
A1	900	m2	In channel
α 1 =	1.0		
α 2 =	1		
K* =	1.95		

Inputs above this line completed

h*b = 0.18 m

Δh

Db	0.82	Refer Figure 5.13
h*3 =	0.039	
b	32	width of opening under bridge
y	4.7	A2/b
L (initial) (m)	71	iterate until the same as L_{final}
So ave	0.005	
S_o x L_{1-3}	0.33	

Δh initial 0.57 metres

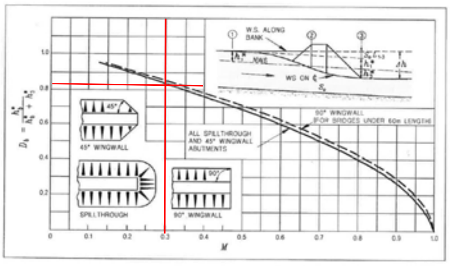


Figure 5.13 Differential Water Level Ratio Base Curves

L*

Δh/y	0.12	
L*/b	0.8	From Figure 5.14
L*	25.6	
L1-3 - L*	45	
$L_{1\text{-}3\ (final)}$	70.6	

RMA-2 WL Diff 0.7 metres

Difference 0.13 metres

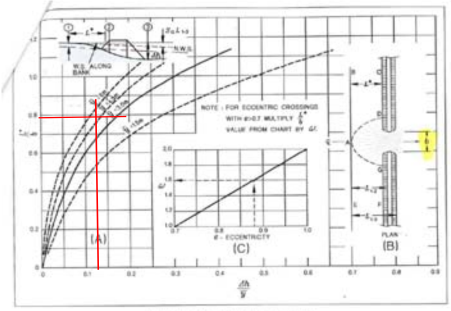


Figure 5.14 Distance to Maximum Backwater