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Griffith Main Drain J and Mirrool Creek Flood Study

Reference: R.N20024.001.05.docx
Date: February 2015
Final Report

Griffith Main Drain J and Mirrool Creek Flood Study

Prepared for:	Griffith City Council
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Synopsis:	**Final Report for Griffith Main Drain J Flood Study covering the development and calibration of computer models, establishment of design flood behaviour and flood mapping.**	

REVISION/CHECKING HISTORY

Revision Number	Date	Checked by		Issued by	
0	12/12/13	DJL		DJL	
1	19/05/14	DJL		DJL	
2	02/07/14	DJL		DJL	
3	11/09/14	DJL		DJL	
4	03/10/14	DJL		DJL	
5	27/02/14	DJL		DJL	

DISTRIBUTION

Destination	Revision										
	0	1	2	3	4	5	6	7	8	9	10
Griffith City Council	1e	1e	1e	1e	1e	1e					
BMT WBM File	1e	1e	1e	1e	1e	1e					
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Executive Summary

Introduction

Significant contributions to floodplain risk management within the Main Drain J catchment have already been undertaken through the completion of the Griffith Flood Study (Patterson Britton & Partners, 2006) and the Griffith Floodplain Risk Management Study and Plan (Worley Parsons, 2011).

Following the completion of the study the Riverina region suffered from some of the worst flooding in recorded history. During the March 2012 flood event the community of Yenda was severely impacted. The source of flooding in Yenda was from Mirrool Creek flood waters overtopping the irrigation infrastructure and spilling into the catchment of Main Drain J. The existing Floodplain Risk Management Study had only considered flooding from runoff within the Main Drain J catchment and not from external sources. A review of the Study was therefore required to investigate the implications of flood contributions from Mirrool Creek.

BMT WBM was commissioned by Council in early 2013 to undertake a review of the Griffith Floodplain Risk Management Study and Plan, with consideration of flooding from Mirrool Creek. A requirement of the study brief was to convert the existing Main Drain J catchment hydraulic model from RMA-2 to TUFLOW. Having undertaken this process the results from the two models were compared to confirm their consistency. However, significant differences were found between the existing flood modelling and the TUFLOW results. The observations of flooding during the March 2012 event were more consistent with the updated modelling than those of the existing flood study.

In order to fully understand the differences in the model outputs and to have confidence in the model moving forward in the Floodplain Risk Management process, it was necessary to undertake a full model calibration process. The scope of works undertaken was far beyond a simple model conversion and review. It was therefore appropriate that a flood study report be produced to properly document the model development and calibration process. This essentially provides for updated Griffith Main Drain J Flood Study.

Study Objectives

The primary objective of the Flood Study is to define the flood behaviour within the Main Drain J catchment through the establishment of appropriate numerical models. This includes flood flow contributions from Mirrool Creek, as experienced during the March 2012 flood event. The study has produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Undertaking a community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain risk management process;
- Development and calibration of appropriate hydrologic and hydraulic models;

- Determination of design flood conditions for a range of design event including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and extreme flood event;
- Hydraulic categorisation of the floodplain to guide future floodplain management;
- Produce interim flood planning area extents pending completion of the Floodplain Risk Management Plan;
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping; and
- Identification of key issues for consideration during the floodplain risk management process.

The principal outcome of the flood study is the understanding of flood behaviour in the catchments and in particular design flood information that will underpin subsequent floodplain risk management activities. The Floodplain Risk Management Study (the next stage of the study) will evaluate management options for the floodplain in respect of both existing and future developments, leading to the formal adoption by Council of a Floodplain Risk Management Plan for the floodplain.

Study Area Description

The Main Drain J study catchment totals an area of around 550km^2 and incorporates the city of Griffith, the communities of Yenda, Bilbul, Beelbangera, Yoogali and Hanwood and numerous agricultural properties.

The western slopes of the Cocoparra Range and eastern slopes of the McPhersons Range drain to a naturally occurring topographic depression, situated in the locality of Myall Park. The flat fertile land between Yenda and Hanwood would have formed part of the broader Mirrool Creek floodplain.

Substantial irrigation supply and drainage infrastructure has modified the natural drainage of the catchment. The principal drainage channel for the catchment is Main Drain J, which extends from Yenda, through Bilbul and Yoogali, before discharging to Mirrool Creek some 14km to the west of Griffith. The DC North and DC 'T' now drain the topographic depression of Myall Park, connecting through to Main Drain J via Beelbangera and Yoogali.

The Mirrool Branch Canal forms the southern limit of the Main Drain J catchment, separating it from the broader Mirrool Creek floodplain. The Mirrool Creek catchment is some 6,500km^2 in area upstream of the East Mirrool Regulator. This catchment area can be divided into two main sub-catchments. Mirrool Creek drains the upland areas around Ariah Park and the Barellan flats to the south of the Griffith-Temora Railway, with a total contributing catchment area of around 2,500km^2. Binya Creek joins Mirrool Creek a few kilometres upstream of the East Mirrool Regulator. It drains the upland areas to the north of Ardlethan, the eastern slopes of the Cocoparra Range and the Barellan flats to the north of the Griffith Temora Railway, with a total contributing catchment area of around 4,000km^2.

The Main Canal is the principal irrigation supply for the region and crosses Mirrool Creek at the East Mirrool Regulator, some 5km to the east of Yenda. The flows of Mirrool Creek are passed under the canal via means of a siphon structure. However, large flood flows on Mirrool Creek exceed the capacity of this structure and cause flood waters to back up behind the Main Canal and Northern Branch Canal. During the March 2012 event this caused flood waters to breach the canal and flow through to Myall Park via Yenda.

There are two main mechanisms governing flood behaviour in the Main Drain J catchment. Runoff from within the catchment produces high flow conditions within the irrigation drainage channels and presents a flood risk to communities such as Yoogali, Hanwood and other areas adjacent to Main Drain J. Significant floods within the Mirrool Creek catchment also present a risk to the community of Yenda, as evidenced by the March 2012 flood. Myall Park can flood from both local catchment runoff and Mirrool Creek flood events.

Historical Flooding

A number of floods have been experienced in the study catchment since European settlement and the construction of the irrigation system in 1912. Major floods are known to have occurred in 1931, 1939, 1956, 1974, 1989 and most recently in 2012.

For the more localised Main Drain J catchment, the March 1989 and March 2012 represent the largest recorded events within the catchment. The March 2012 flood was the largest in recorded history. The continuous rainfall record at Griffith Airport indicates that a total of 147mm fell in a 16-hour period, which is in excess of a 1 in 100-year probability event when compared to the standard design rainfall estimates. A similar rainfall depth was recorded at Yenda, but total rainfall depths reduced to around half of this amount at the eastern edge of the Mirrool Creek catchment. Flooding in Bilbul, Yoogali, Griffith and Hanwood resulted from the local catchment runoff exceeding the capacity of the available drainage. The flood flow from the Mirrool Creek catchment also exceeded the capacity of the siphon structure at the East Mirrool Regulator. This resulted in breaching of the Northern Branch Canal and subsequent flooding of Yenda.

For March 1989, the continuous rainfall record at Hanwood indicates that a total of 103mm fell in a 15-hour period on 14th, which is again of the order of a 1 in 100-year probability event when compared to the standard design rainfall estimates. A rainfall depth of 93mm was recorded at Yenda. Flooding is understood to have occurred in Yenda, Bilbul, Yoogali, Griffith in Hanwood. The partial blockage of the siphon structures at Yenda may have made a significant contribution to the severity of flooding at that location.

In considering major flood events on the broader Mirrool Creek system, the March 2012 event is again noted as the highest event on record. The majority of the rainfall was recorded in the 24-hour period from 6am 3rd March to 6am 4th March. Given the large size of the catchment there is a substantial spatial variability. The highest recorded rainfall depth in the catchment was 165mm at the Barellan Post Office gauge in the middle of the catchment which exceeds the 1 in 100-year probability event rainfall by some margin. Similar totals were recorded at Yanco and Griffith with the south-western part of the catchment in general receiving the highest rainfall totals. The recorded rainfall depths significantly reduce in the upper catchment, with a total of 56mm recorded at the Ariah Park Post Office gauge (representing only a 1 in 5year probability rainfall).

The second largest event in the Mirrool Creek catchment is understood to be June 1931. This event was very different to the high intensity rainfall of March 2012, driven by sustained winter rainfall. Following flooding of Yenda in June 1931 a set of flood gates were installed that allow flow to be released from the Main Canal to Mirrool Creek on the downstream side of the canal. With the exception of March 2012, during flood events since 1931 the escape doors and flood gates have been opened to allow flood waters from Mirrool Creek to flow through the Main Canal to the downstream floodplain. This was the case for the March 1989 event which was a significant event on the Mirrool Creek system. Somewhat similar to the 1931, the March 1989 event was again driven by a sustained wet period. These types of events typically have a high volumetric runoff, but lower peak flows than those experience in March 2012. The large volume of runoff generated for the March 1989 even resulted in extensive flooding the lower Mirrool Creek system, including Barren Box Swamp as available flood storage was limited.

The March 1939 event is the largest flood to have occurred whilst the flood gates were operational. Water level and flow data was recorded during the event, which provides an understanding of how the siphon and gate structures operate during a large flood. Locally within the Barellan floodplain, the region of highest rainfall intensity across the catchment, the recorded rainfall represents up to a 1 in 50-year probability event. More broadly across the catchment, on average recorded rainfall of around 70mm in three days represents somewhere in the order of a 1 in 10-year probability rainfall. Whilst major flooding of Yenda was avoided in March 1939 with the operation of the EMR flood gates, the structure was close to capacity (with original gates operational).

Community Consultation

The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain risk management activities. It has provided an opportunity to collect information on their flood experience, in particular historical flood data related to catchment flooding.

The key elements of the consultation process have been as follows:

- Meetings with community members to obtain historical flood data and community perspective on flooding issues;
- Feedback through the Floodplain Management Committee meetings; and
- Public exhibition of the draft Flood Study.

Following the initial data compilation and model development phases a number of meetings were held with key community groups. The purpose of these meetings was to provide the community with an appreciation of how the study was being approached and to understand the catchment flood behaviour from those that had experienced it first-hand. Meetings were held with the Yenda Flood Working Group, Yoogali Progress Association and individual landholders from other flood affected locations within the catchment.

The meetings were highly successful as valuable qualitative information regarding flood depths, timings and durations was gathered. Additional flood photograph and video data was also provided by community members. The descriptions of flood behaviour that had been observed during the March 2012 and March 1989 flood events matched reasonably well with what was being produced by the preliminary model simulations. The mutual understanding of flood behaviour within the study area between the community and the project team was a major factor in the successful progression of the study.

Model Development and Calibration

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. For this study, three models were used:

- A hydrologic model of the entire Main Drain J catchment;

- A hydraulic model covering the floodplain of the study catchment, including Main Drain J and the secondary drainage channels; and
- A hydraulic model of the entire Mirrool Creek catchment used to simulate the hydrological response of the catchment and provide inputs to the Main Drain J model.

The hydrologic model simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model. The hydraulic model simulates the flow behaviour of the channel and floodplains, producing flood levels, flow discharges and flow velocities.

Information on the topography and characteristics of the catchments, watercourses and floodplains are built into the models. Recorded historical flood data, including rainfall, flood levels and river flows, are used to simulate and validate (calibrate and verify) the models.

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

The previous studies of Main Drain J had identified that the March 1989 flood was the only suitable event for model calibration. Since the previous studies have been completed the March 2012 event occurred, causing widespread flooding within the catchment. Given the large magnitude of the March 2012 flood and the extent of available data, this event is also suitable to be used for model calibration purposes. The March 1989 and March 2012 events have therefore been used to calibrate the Main Drain J model.

Similarly for the broader Mirrool Creek catchment, the March 2012 and March 1931 events were utilised for model calibration. These events represent the highest and third ranked recorded historical flood events for which sufficient model calibration data is available.

Modelled Flood Conditions

Flooding in the Main Drain J catchment results from excess runoff generated during significant rainfall events. The flood flows are driven principally by catchment runoff from the irrigated agriculture located downstream of the Main Canal. There are three main inputs from upstream of the Main Canal:

- The catchment draining to Myall Park;
- Irrigated agriculture draining through Yenda; and
- Runoff from the city of Griffith.

Flooding in Myall Park is driven primarily from the runoff generated from the irrigated agriculture downstream of the Northern Branch Canal. Although the natural catchment upstream of the canal is some 240km^2, little runoff reaches Myall Park due to infiltration to the sandy soils and detention upstream of the canal. The outflow from the Myall Park flood storage is also well regulated by the siphon structure under the Main Canal. Catchment runoff draining though Yenda is also well regulated by the two siphon structures under the Main Canal.

Runoff emanating from the urban areas of Griffith City has a more rapid response than that of the field drainage and so the flood peaks typically enter Main Drain J before the peak flows from the upstream agricultural areas.

Once catchment runoff is discharged to Main Drain J the water levels rise quite rapidly and are then held at an elevated level for some time, due to the slow release of flood storage from the flat floodplain. Most of the flood flows are retained within the drainage system, which has a relatively large capacity. However, widespread inundation of surrounding fields occurs once the drainage capacity is exceeded.

In Yoogali flooding occurs when the capacity of DC 605 J is exceeded. Water then spills over McCormack Road and inundates the village, backing up behind the railway embankment. Flooding may last for a few days, until the tailwater level in Main Drain J lowers to enable drainage out of Yoogali.

In Hanwood flooding occurs when the fields adjacent to DC A flood to a level which is sufficient to overtop Kidman Way. There is only a small gradient between flood levels at Hanwood and in Main Drain J and so the tailwater level in the drain has a significant influence on flooding here.

Flooding from Mirrool Creek will occur at Yenda when the cross-drainage capacity of the Main Canal structures is exceeded. This is about 40m^3/s (~3,400 ML/day) through the siphon and 80m^3/s (~6,900 ML/day) when both the siphon and flood gates are operational. It is important to note that the existing capacity substantially lower with the flood gates being decommissioned and flows limited to the siphon capacity only. The March 1939 event was in the order of 80m^3/s and with the original flood gates being operational at that stage, flooding of Yenda was prevented. This is similar to the design 2% AEP (1 in 50-year probability) flood condition.

It may therefore be expected that Yenda would remain flood free to around the 2% AEP (1 in 50-year probability) event if the flood gates were operational, but would flood during events of a larger magnitude, once Mirrool Creek flows exceed this level. Given the current state of decommissioning of the flood gates, the existing capacity at the structure and hence flood immunity afforded to Yenda is something of the order of 5% AEP (1 in 20-year probability) event.

The estimated peak flows approaching the EMR for the design 1% AEP (1 in 100-year probability) flood condition is approximately 160m^3/s (~14,000 ML/day). This compares to an estimated, 220m^3/s (~19,000 ML/day) for the March 2012 event. Accordingly, both the estimated 1 in 100-year and March 2012 events significantly exceed the available flow capacity at the EMR, even with flood gates operational.

Once flooding of Yenda from Mirrool Creek occurs the resultant peak flood levels are expected to be similar to those experienced during the March 2012 event, as they are driven principally by the level of the railway.

During the March 2012 event, there were a number of significant breaches along the Main Canal upstream of the EMR. These breaches in many cases served to reduce the peak flows to be conveyed across Canal at the EMR, thereby reducing to some degree the flooding pressures at Yenda. From a future flooding perspective, there is no certainty that similar breaches would occur, such that in defining design flow conditions at the EMR, and significantly for assessing potential flood management options, some redundancy needs to be built in to design flows to accommodate additional flows that may not be lost in future events due to breaching of the Canal.

Conclusions

The objective of the study was to undertake a detailed flood study of the Main Drain J catchment and establish models as necessary for design flood level prediction. This included the assessment of inputs to the catchment from Mirrool Creek.

In completing the flood study, the following activities were undertaken:

- Collation of historical flood information for the study area;
- Consultation with the community to acquire additional historical flood information;
- Development of a RAFTS hydrological model to simulate catchment rainfall-runoff;
- Development of a TUFLOW 2D/1D hydrodynamic model to simulate flood behaviour in the catchment;
- Development of a TUFLOW GPU 2D catchment model for Mirrool Creek to assist in the assessment of the flood hydrology;
- Calibration of the developed models using the available flood data, primarily relating to the March 1989 and March 2012 events;
- Prediction of design flood conditions in the catchment and production of design flood mapping series.

Through the undertaking of the flood study it has been found that the Main Drain J catchment is well regulated by the Main Canal and upstream storage area of Myall Park. The flood flows generated within the urban areas of Yoogali and Hanwood are therefore restricted to runoff from the catchment area downstream of the Main Canal. Coupled with the provision of significant man-made drainage, this results in a limited conveyance of flood flows within the broader floodplain extent. Out-of-bank flooding is predominantly characterised by flood waters ponding behind raised floodplain features such as road and rail embankments.

The performance of the model in representing catchment flood behaviour was supported by observations during the March 1989 and March 2012 flood events.

The conditions observed in the Main Drain J catchment for the March 2012 event are generally representative of the modelled design 1 in 100-year probability event. This represents a significant change from the previously adopted flood study results which typically showed design 100-year flooding much more severe than March 2012 conditions. Accordingly, some changes may be anticipated to currently adopted flood risk and hydraulic category zones through the ongoing floodplain risk management process. Given the scale and nature of flooding, it is considered that suitable mitigation measures can be identified to address the existing flood risk to established urban areas in both Yoogali and Hanwood.

The March 2012 event also saw significant flooding of Mirrool Creek, which overtopped the Northern Branch Canal and spilled into the Main Drain J catchment, causing extensive flooding in Yenda. A catchment model was constructed for Mirrool Creek to represent this behaviour and assist in establishing appropriate design flood conditions for this mechanism.

For Mirrool Creek there is limited data from which to calibrate the models aside from the March 2012 flood event. This event has therefore been an essential platform from which to build an understanding of the catchment flood behaviour and quantifying design flood conditions. The lack of suitable calibration events for Mirrool Creek results in a large amount of uncertainty for design flood flow estimations. The hydrological response of the Mirrool Creek catchment is complex, being heavily influenced by the high infiltration rates of the sandy soils and the significant attenuation through the Barellan floodplain area.

The small number of recorded flood events in the Mirrool Creek catchment also reduces the reliability of flood frequency analysis, where there are large uncertainties in both the estimation of historic flood flows and the plotting position of the flood frequency.

Nevertheless, an attempt has been made to present these levels of uncertainty and determine an appropriate estimation of design flood flows for Mirrool Creek. This analysis will provide a platform for the future assessment of potential flood mitigation measures for Yenda.

The observed flood conditions for Mirrool Creek for the March 2012 event are estimated to be in excess of the 1% AEP (1 in 100-year) design conditions. The flood risk to Yenda from Mirrool Creek floodwaters emanates as the EMR capacity is exceed. With both siphon and flood gates fully operational, this flow capacity may be expected to be exceed for events in excess of the 2% AEP (1 in 50-year probability event). The current decommissioned status of the EMR flood gates structures significantly reduces the capacity to transfer Mirrool Creek flood flows across the Canal to the order of a 5% AEP (1 in 50-year probability) design standard. Accordingly, substantial flood mitigation measures may be required to provide an increased flood immunity to the Yenda township.

This flood study forms the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain risk management process. The Floodplain Risk Management Study will aim to derive an appropriate mix of management measures and strategies to effectively manage flood risk. The findings of the study will be incorporated in a Plan of recommended works and measures and program for implementation.

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Glossary

annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a flood that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the '100 year ARI flood' or '1 in 100 year flood'. The term 100 year ARI flood has been used in this study. See also average recurrence interval (ARI).
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
attenuation	Weakening in force or intensity
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe flood size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The term 100 year ARI flood has been used in this study. See also annual exceedance probability (AEP).
catchment	The catchment at a particular point is the area of land that drains to that point.
design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
development	Existing or proposed works that 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 per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood behaviour	The pattern / characteristics / nature of a flood.
flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
flood hazard	The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.The degree of flood hazard varies with circumstances across the full range of floods.

flood level	The height of the flood described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian Height Datum (eg the flood level was 7.8 mAHD). Terms also used include flood stage and water level.
flood liable land	see flood prone land
floodplain	Land susceptible to flooding up to the probable maximum flood (PMF). Also called flood prone land. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level.
floodplain risk management study	Studies carried out in accordance with the Floodplain Development Manual (NSW Government, 2005) that assesses options for minimising the danger to life and property during floods. These measures, referred to as 'floodplain risk management measures / options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a Floodplain Risk Management Plan.
floodplain risk management plan	The outcome of a Floodplain Risk Management Study.
flood planning levels (FPL)	The combination of flood levels and freeboards selected for planning purposes, as determined in Floodplain Risk Management Studies and incorporated in Floodplain Risk Management Plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies..
flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
flood stage	See flood level.
flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
flood study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodway	Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determing the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.

high flood hazard	For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydrology	The term given to the study of the rainfall-runoff process in catchments.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	metres Australian Height Datum (AHD).
m/s	metres per second. Unit used to describe the velocity of floodwaters.
m^3/s	Cubic metres per second or ‘cumecs’. A unit of measurement for creek or river flows or discharges. It is the rate of flow of water measured in terms of volume per unit time.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as ‘overland flows’, may or may not re-enter the main channel from which they left; they may be diverted to another water course.
peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
probability	A statistical measure of the likely frequency or occurrence of flooding.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
stage	See flood level.
topography	The shape of the surface features of land
velocity	The term used to describe speed of floodwaters, usually in m/s.
water level	See flood level.

Acknowledgements

We would like to acknowledge the stakeholders and community members who have provided valuable input to the Griffith Main Drain J Catchment Flood Study, without their local knowledge and expertise the Study would not have been as comprehensive. This is particularly the case for the model calibration, where community input provided a substantial contribution. The key contributors to the Study include, but are not limited to, the following:

- Griffith City Council;
- NSW Office of Environment and Heritage;
- Floodplain Management Committee;
- Murrumbidgee Irrigation;
- Yenda Flood Working Group;
- Yoogali Progress Association;
- Mick Plos and Peter Budd;
- Tiz Forlico;
- Jillian, Wayne and Gary Andreazza; and
- Cr. Paul Rossetto.

1 Introduction

The Griffith Floodplain Risk Management Study and Plan were completed for Council in 2011. Following the completion of the study the Riverina region suffered from some of the worst flooding in recorded history. During the March 2012 flood event the community of Yenda was severely impacted. The source of flooding in Yenda was from Mirrool Creek flood waters overtopping the irrigation infrastructure and spilling into the catchment of Main Drain J. The existing Floodplain Risk Management Study had only considered flooding from runoff within the Main Drain J catchment and not from external sources. A review of the Study was therefore required to investigate the implications of flood contributions from Mirrool Creek.

BMT WBM was commissioned by Council in early 2013 to undertake a review of the Griffith Floodplain Risk Management Study and Plan, with consideration of flooding from Mirrool Creek. A requirement of the study brief was to convert the existing Main Drain J catchment hydraulic model from RMA-2 to TUFLOW. Having undertaken this process the results from the two models were compared to confirm their consistency. However, significant differences were found between the existing flood modelling and the TUFLOW results. The observations of flooding during the March 2012 event were more consistent with the updated modelling than those of the existing flood study.

In order to fully understand the differences in the model outputs and to have confidence in the model moving forward in the Floodplain Risk Management process, it was necessary to undertake a full model calibration process. The scope of works undertaken was far beyond a simple model conversion and review. It was therefore appropriate that a flood study report be produced to properly document the model development and calibration process.

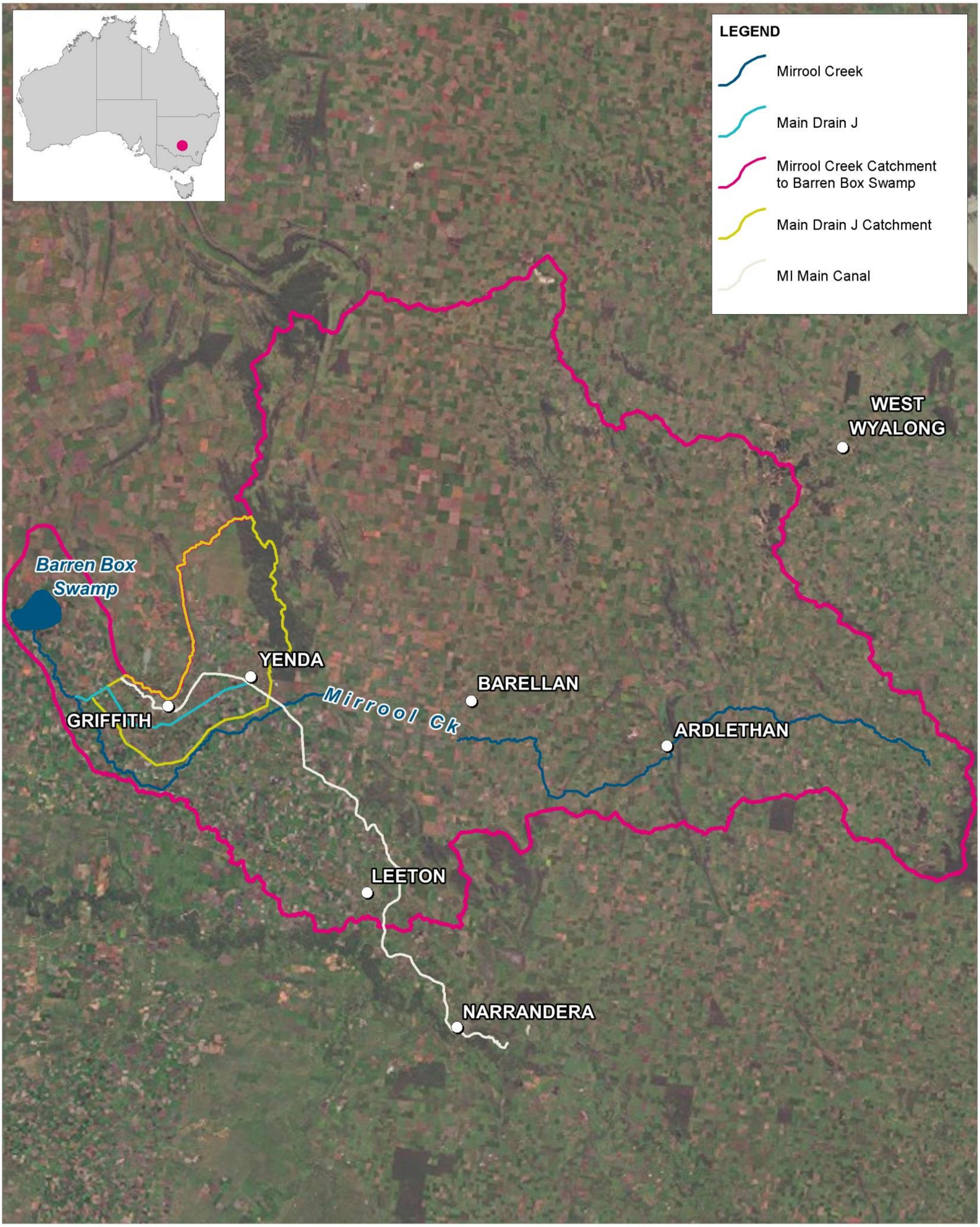
1.1 Study Location

The Main Drain J catchment is around 550km^2 in size and drains the western slopes of the Cocoparra Range. Much of the catchment drainage has been modified by irrigation infrastructure. The principal irrigation drain is Main Drain J, which discharges to Mirrool Creek some 15km upstream of Barren Box Swamp. The city of Griffith is situated within the Main Drain J catchment, as shown in Figure 1-1.

The Mirrool Creek draining to Barren Box Swamp is around 8,500km^2 in size, some 6,500km^2 of which is situated upstream of Yenda. The Murrumbidgee Irrigation Main Canal provides irrigation water supply for the regions agriculture. It crosses Mirrool Creek upstream of Yenda and has a significant influence on flood behaviour in the Mirrool Creek catchment. The Mirrool Creek flows are transferred under the canal by means of a siphon structure located at the East Mirrool Regulator. It is the interaction of the Mirrool Creek floodplain with the irrigation infrastructure at this location that presents a flood risk in Yenda and resulted in the flooding during the March 2012 event.

1.2 Study Background

Significant contributions to floodplain risk management within the Main Drain J catchment have already been undertaken through the completion of the Griffith Flood Study (Patterson Britton & Partners, 2006) and the Griffith Floodplain Risk Management Study and Plan (Worley Parsons, 2011).



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Study Locality

Figure: 1-1

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Approx. Scale

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The Griffith CBD has been investigated in further detail through the Griffith CBD Overland Flow Study (WMA Water, 2012) and the Griffith CBD Floodplain Risk Management Study and Plan (WMA Water, 2013). The current study was undertaken to update the Griffith Floodplain Risk Management Study and Plan for the Main Drain J catchment, considering flood contributions from Mirrool Creek.

There are two main mechanisms governing flood behaviour in the Main Drain J catchment. Runoff from within the catchment produces high flow conditions within the irrigation drainage channels and presents a flood risk to communities such as Yoogali, Hanwood and other areas adjacent to Main Drain J. Significant floods within the Mirrool Creek catchment also present a risk to the community of Yenda, as evidenced by the March 2012 flood. Myall Park can flood from both local catchment runoff and Mirrool Creek flood events. Further discussion of the regional flood behaviour is presented in Section 5.

1.3 The Need for Floodplain Risk Management in the Main Drain J Catchment

As evidenced in the March 2012 flood event, there are a substantial number of properties within the communities of Yoogali (approximately 250 properties) and Yenda (approximately 450 properties) that are at risk of flooding from both local catchment runoff and Mirrool Creek flooding, respectively. Appropriate floodplain risk management activities need to be identified in order to reduce the flood risk that these communities are exposed to. Given that the previous studies within the Main Drain J catchment had not considered flow contributions from Mirrool Creek, a review of these studies was required. The flood risk presented by runoff from the Mirrool Creek catchment was required to be incorporated into Council's Floodplain Risk Management considerations.

Within Council's Growth Strategy 2030 there is planned future development within the Main Drain J catchment, particularly around the localities of Yoogali, Collina and South Griffith. An understanding of the flood behaviour and associated risks is required to effectively plan and manage this future development.

Floodplain risk management considers the consequences of flooding on the community and aims to develop appropriate floodplain risk management measures to minimise and mitigate the impact of flooding. This incorporates the existing flood risk associated with current development, and future flood risk associated with future development and changes in land use.

Accordingly, Council desires to approach local floodplain risk management in a considered and systematic manner. This study comprises the initial stages of that systematic approach, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the Main Drain J catchment.

1.4 The Floodplain Risk Management Process

The State Government's Flood Prone Land 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 being the consenting authority. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils 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:

Table 1-1 Stages of Floodplain Risk Management

	Stage	Description
1	Formation of a Committee	Established by Council and includes community group representatives and State agency specialists.
2	Data Collection	Past data such as flood levels, rainfall records, land use, soil types etc.
3	**Flood Study**	**Determines the nature and extent of the flood problem.**
4	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
5	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of risk management for the floodplain.
6	Implementation of the Floodplain Risk Management Plan	Construction of flood mitigation works to protect existing development. Use of environmental plans to ensure new development is compatible with the flood hazard.

This report represents Stage 3 of the above process and aims to provide an understanding of flood behaviour within the Main Drain J catchment, including the influence of flood contributions from Mirrool Creek.

1.5 Study Objectives

The primary objective of the Flood Study is to define the flood behaviour within the Main Drain J catchment through the establishment of appropriate numerical models. This includes flood flow contributions from Mirrool Creek, as experienced during the March 2012 flood event. The study has produced information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Undertaking a community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain risk management process;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design event including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and extreme flood event;

- Hydraulic categorisation of the floodplain to guide future floodplain management;
- Produce interim flood planning area extents pending completion of the Floodplain Risk Management Plan;
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping; and
- Identification of key locations for consideration during the floodplain risk management process.

The principal outcome of the flood study is the understanding of flood behaviour in the catchments and in particular design flood information that will underpin subsequent floodplain risk management activities.

1.6 About this Report

This report documents the Study's objectives, results and recommendations.

Section 1 introduces the study.

Section 2 provides an overview of the approach adopted to complete the study.

Section 3 outlines the community consultation program undertaken.

Section 4 details the development of the computer model.

Section 5 summarises the complex flood behaviour across the study area.

Section 6 details the model calibration and validation process.

Section 7 presents the design flood conditions and modelling uncertainties.

Section 8 details the flood analysis of Mirrool Creek.

2 Study Approach

2.1 The Study Area

2.1.1 Catchment Description

The study catchment totals an area of around 550km^2 and incorporates the city of Griffith, the communities of Yenda, Bilbul, Beelbangera, Yoogali and Hanwood and numerous agricultural properties.

The topography of the catchment is shown in Figure 2-1. The upper catchment, which forms the western slopes of the Cocoparra Range, is steep and largely elevated above 200m AHD. The lower section of the catchment is a relatively flat expanse, which is heavily influenced by the regional irrigation infrastructure. Elevations are typically between 120m AHD to 150m AHD.

The western slopes of the Cocoparra Range and eastern slopes of the McPhersons Range drain to a naturally occurring topographic depression, situated in the locality of Myall Park. The flat fertile land between Yenda and Hanwood would have formed part of the broader Mirrool Creek floodplain.

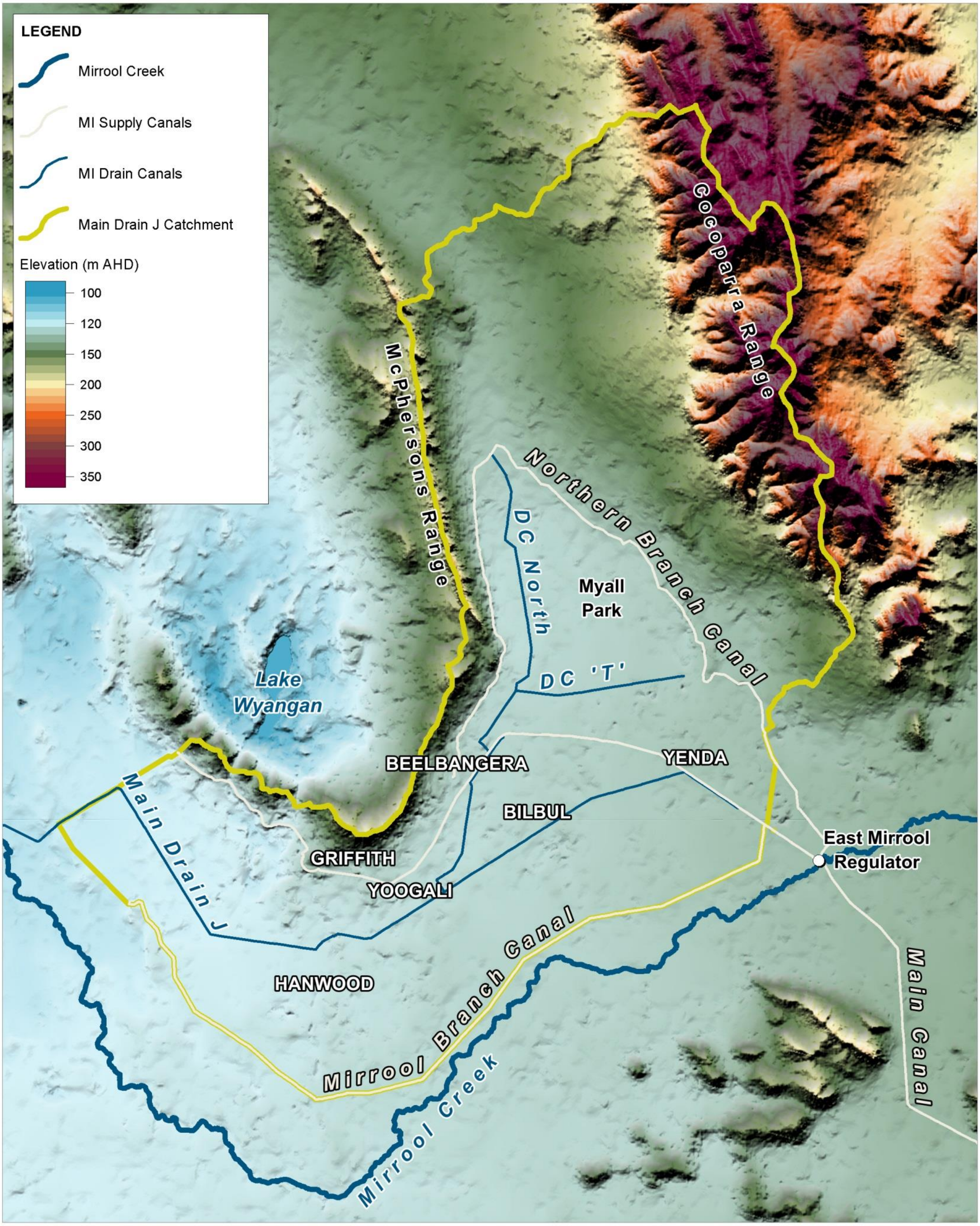
Substantial irrigation supply and drainage infrastructure has modified the natural drainage of the catchment. The principal drainage channel for the catchment is Main Drain J, which extends from Yenda, through Bilbul and Yoogali, before discharging to Mirrool Creek some 14km to the west of Griffith. The DC North and DC 'T' now drain the topographic depression of Myall Park, connecting through to Main Drain J via Beelbangera and Yoogali.

The Mirrool Branch Canal forms the southern limit of the Main Drain J catchment, separating it from the broader Mirrool Creek floodplain. The Main Canal is the principal irrigation supply for the region and crosses Mirrool Creek at the East Mirrool Regulator, some 5km to the east of Yenda. The flows of Mirrool Creek are passed under the canal via means of a siphon structure. However, large flood flows on Mirrool Creek exceed the capacity of this structure and cause flood waters to back up behind the Main Canal and Northern Branch Canal. During the March 2012 event this caused flood waters to breach the canal and flow through to Myall Park via Yenda.

The catchment has been largely cleared for farming purposes (80%, of which around 70% is irrigated agriculture). The other dominant land use is remnant vegetation at around 20%. Approximately 18km^2 is occupied by urban areas, which constitutes around 3% of the total catchment area.

There are a number of major transport routes traversing the catchment, the most significant of which are the Kidman Way and Burley Griffin Way, which between them connect Griffith to all other major urban centres in the region.

As evidenced by the March 2012 flood event, flow contributions from Mirrool Creek also need to be considered in the context of floodplain risk management within the Main Drain J catchment. Background information on the Mirrool Creek catchment and subsequent flood analyses are documented within Section 8 of this report.



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Topography of the Main Drain J Catchment

Figure: 2-1

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2.1.2 History of Flooding

A number of floods have been experienced in the study catchment since European settlement and the construction of the irrigation system in 1912. Major floods are known to have occurred in 1931, 1939, 1956, 1974, 1989 and most recently in 2012.

The June 1931 event was not in itself overly severe, with rainfall records indicating a daily total of 53mm being recorded at Yenda on 24th. This constitutes less than a 20% AEP rainfall event when compared to standard intensity frequency duration (IFD) curves. However, a similar amount of rainfall occurred across the Mirrool Creek catchment. More significant was the rainfall in preceding months, which totalled around 100mm across the Mirrool Creek catchment in the month preceding the event and around 200mm for the two months preceding the event. This represents an extremely wet antecedent condition, when compared to the average annual rainfall of around 450mm. These conditions resulted in the highest flow conditions in Mirrool Creek on record prior to the March 2012 event. The Mirrool Creek flood flows exceeded the available capacity of the siphon under the Main Canal and resulted in the breaching of the Northern Branch Canal and subsequent flooding in Yenda and Myall Park. The flood gates at the East Mirrool Regulator were installed in response to this event, preventing a similar occurrence during the following flood of March 1939.

Less is known about the flood of 1956. It caused substantial flooding within Griffith, with depths of over 1m being reported in Yambil Street. Examination of the rainfall record from Hanwood shows a peak daily rainfall depth of 58mm on 12th March.

The March 1989 flood is one of the largest recorded within the study catchment. The continuous rainfall record at Hanwood indicates that a total of 103mm fell in a 15-hour period on 14th, which is the equivalent of a 1% AEP magnitude design event when compared to the IFD curves. A rainfall depth of 93mm was recorded at Yenda. Flooding is understood to have occurred in Yenda, Bilbul, Yoogali, Griffith in Hanwood. The partial blockage of the siphon structures at Yenda may have made a significant contribution to the severity of flooding at that location.

The March 2012 flood was the largest in recorded history. The continuous rainfall record at Griffith Airport indicates that a total of 147mm fell in a 16-hour period, which is in excess of a 0.1% AEP magnitude design event when compared to the IFD curves. A similar rainfall depth was recorded at Yenda, but total rainfall depths reduced to around half of this amount at the eastern edge of the Mirrool Creek catchment. Flooding in Bilbul, Yoogali, Griffith and Hanwood resulted from the local catchment runoff exceeding the capacity of the available drainage. The flood flow from the Mirrool Creek catchment also exceeded the capacity of the siphon structure at the East Mirrool Regulator. This resulted in breaching of the Northern Branch Canal and subsequent flooding of Yenda.

Further details of the known flood behaviour within the region are presented in Section 5.

2.1.3 Previous Investigation

A number of investigations of the flooding characteristics of the study area have been undertaken over the last 20 years. Many studies focused on assessing design flood levels along the irrigation drain canals and in Griffith CBD. Other studies have looked at the design flood conditions along Mirrool Creek. The studies include:

- Guidelines for Mirrool Creek Floodplain Development Barellan to Yenda (Water Resources Commission, 1978);

- Griffith Flood Study (Water Studies, 1992);
- MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works
- Options on Floodway Lands (Water Resources River Management Branch, 1994);
- Griffith Flood Study (Patterson Britton and Partners, 2006);
- Griffith Floodplain Risk Management Study and Plan (Worley Parsons, 2011);
- Griffith CBD Overland Flow Study (WMA Water, 2012); and
- Griffith CBD Floodplain Risk Management Study and Plan (WMA Water, 2013).

It is noted that an SES Flood Intelligence Report for the 2012 event is in preparation, however, is unavailable at this time in the current study.

Further details of these previous investigations and their relevance in the context of the current flood study are presented in Section 2.2.1.

2.2 Compilation and Review of Available Data

2.2.1 Previous Studies

2.2.1.1 Guidelines for Mirrool Creek Floodplain Development Barellan to Yenda (Water Resources Commission, 1978)

The floodplain development guidelines were prepared for landholders on the Mirrool Creek floodplain between Barellan and the East Mirrool Regulator. Damage from previous flood events had led to landholders constructing embankments to protect certain areas and drains to improve the drainage of other areas. However, these works were undertaken without coordination and resulted in other landholders becoming disadvantaged at the expense of the protection of others.

The guidelines sought to address the problem of uncoordinated flood protection works by defining a system of floodways that were seen as the most efficient way to convey floodwaters through the area. It also suggested areas that could be protected by the construction of embankments if the land holders desired. Guidance was provided in relation to appropriate development of agricultural land within the area and included mapping of the defined floodways.

This study has been used to develop the model representation of the Barellan floodplain area within the hydrological representation of Mirrool Creek.

2.2.1.2 Griffith Flood Study (Water Studies, 1992)

The Griffith Flood Study was initiated in response to the floods of March 1989. It investigated flood behaviour along Main Drain J and its twelve secondary drainage channels, providing estimates of design 1% AEP discharges and water levels. The study focused on the nature and cost of flooding in Griffith, Hanwood, Yoogali, Yenda and Bilbul.

The study included channel and structure details, some of which were surveyed specifically for the study. These details have been used for the construction of the hydraulic model in the current study. Runoff-routing models were used to predict discharges along the drainage channels and backwater models were used to predict flood levels. The models were calibrated to the March 1989 event using data from the three stream gauges and surveyed flood marks.

There have been a number of changes to the infrastructure within the Main Drain J floodplain since this study and these have been incorporated into the current study where required.

2.2.1.3 MIA – Land and Water Management Plan: Hydrology of Mirrool Creek and Works Options on Floodway Lands (Water Resources River Management Branch, 1994)

The options study was initiated in response to the flooding of Murrumbidgee Irrigation Area lands during March and April of 1989. The study had a particular focus on the Mirrool Creek floodplain from Barren Box Swamp downstream to the Lachlan River, as flooding further up the catchment was less severe. However, it also included some assessment for improvements in flood management upstream of Barren Box Swamp.

For the Barellan to Yenda section of the floodplain the study advised that the 1978 guidelines were the most suitable means for managing flood risk. For the Yenda to Barren Box Swamp floodplain, considered during the current study, various potential upgrade options at the East Mirrool Regulator were assessed. A flood frequency analysis was undertaken to estimate likely peak design discharges and flow hydrographs at the regulator. A hydraulic model was constructed to test the potential impacts of upgrade options on downstream flood levels. The largest upgrade option considered was a 68m long siphoning of the Main Canal under the Mirrool Creek floodplain, which was found to produce a typical 0.1m increase in downstream peak flood levels.

This study has been used within the current study as a reference for both the estimation of design flood flows for Mirrool Creek and preliminary flood mitigation options testing at the East Mirrool Regulator.

2.2.1.4 Griffith Flood Study (Patterson Britton and Partners, 2006)

The Griffith Flood Study was initiated to detail flood behaviour within the Main Drain J catchment and form the basis for subsequent floodplain risk management practices. The study included the development of hydrological and hydraulic models. An RMA-2 hydraulic model was constructed, incorporating channel data from the 1992 study and extending the model to cover the out-of-bank floodplain areas. Detailed LiDAR survey of the floodplain was undertaken to meet the study requirements.

The models were calibrated to the March 1989 event, using available data from the stream gauges and surveyed flood marks. A range of design events from the 5% AEP to the extreme event were simulated for both the Griffith CBD catchments and the broader Main Drain J catchment. The CBD catchments were found to have a critical duration in the order of 2-hours and the broader catchment a critical duration of 12-hours.

Following a review of this modelling a new hydraulic model was developed in TUFLOW and has been calibrated to the March 1989 and March 2012 flood events. The flood information for Main Drain J in this study has therefore been superseded by the current study. Flood information for the CBD catchments has been superseded by the CBD Overland Flow Study (WMA Water, 2012).

2.2.1.5 Griffith Floodplain Risk Management Study and Plan (Worley Parsons, 2011)

The Griffith Floodplain Risk Management Study and Plan builds on the findings of the Griffith Flood Study. It identifies the various issues associated with the risk of flooding and options to manage flood risk. Central to this was the calculation of Average Annual Damages caused by flooding and the investigation of a range of structural options to reduce the impact of flooding. The study also included the mapping of floodways (hydraulic categorisation) and flood hazards (hazard categorisation).

Following a review of the modelling undertaken for the Griffith Flood Study (Patterson Britton and Partners, 2006) a new TUFLOW model was developed. The Annual Average Damage calculations and options testing and assessment based on the RMA-2 results have therefore been superseded. These will be revised as part of the Griffith Main Drain J Catchment Floodplain Risk Management Study. Flood flow contributions from Mirrool Creek will also be investigated.

2.2.1.6 Griffith CBD Overland Flow Study (WMA Water, 2012)

The Griffith CBD Overland Flow Study was undertaken by WMA Water to define the overland flow flood behaviour and associated flood liability within the city of Griffith. The study area is essentially defined as the city of Griffith upstream of the Main Canal. The study produced design flood conditions within Griffith and supersedes the flood conditions previously derived within the city in the Griffith Flood Study.

The current study is focussed on the broader catchment of Main Darin J and does not include modelling of Griffith upstream of the Main Canal, or for shorter high intensity storms that are the critical flood condition in this location.

2.2.1.7 Griffith CBD Floodplain Risk Management Study and Plan (WMA Water, 2013)

The Griffith CBD Floodplain Risk Management Study and Plan builds on the findings of the Griffith CBD Overland Flow Study. It identifies the various issues associated with the risk of flooding and options to manage flood risk.

Following the completion of the current study and future update of the Floodplain Risk Management Study and Plan the Griffith Floodplain Risk Management Study and Plan will become superseded. However, the Griffith CBD Floodplain Risk Management Study and Plan is complementary to this and will continue to be used for the management of flood risk within the city of Griffith.

2.2.2 Historical Flood Levels

Available flood level records in the catchment are limited. Water levels have been recorded at gauging stations located on Main Drain J at Yoogali and on DC ‘S’ at Watkins Avenue between 1982 and 1993. Water levels were also recorded on Main Drain J at Warburn Escape from 1989 to 1996. Data from these gauges is useful for calibration of the models to the March 1989 flood event.

A survey of flood marks representing the peak water levels along Main Drain J was acquired by the Department of Water Resources for the March 1989 event and was used as the principal calibration source for both the 1992 and 2006 Griffith Flood Studies. A similar dataset was surveyed for Murrumbidgee Irrigation following the March 2012 flood event. A survey of peak flood levels at affected properties in Yenda, Yoogali and Hanwood was also undertaken following the March 2012 event. These flood mark survey datasets have been used during the model calibration process.

2.2.3 Rainfall Data

There is a network of rainfall gauges across the region, which are operated by the Bureau of Meteorology (BoM). There are two gauges located within the catchment and another 3km away at Rankins Springs that provide a reasonable coverage. The Griffith Airport site has daily records available from 1958, Rankins Springs (Acres) from 1968 and Rankins Springs from 1887. There are a further 21 rainfall gauges located within around 50km of the catchment that were operational until at least the 1980s, the majority of which are daily read gauges. A further 40 gauges that have ceased operation were located in the area, most of which were closed by the 1950s. The Griffith Airport site has been recording continuous rainfall data since 2000. The only other continuous rainfall data available is from the Griffith CSIRO site, which operated from 1989 to 2003. A list of the currently operational and recently closed rainfall stations is shown in Table 2-1, with their respective period of record. The location of the gauges is shown in Figure 2-2.

A detailed discussion of the rainfall data available for the selected calibration events is discussed in Section 5.

2.2.4 Stream Gauge Data

There is limited stream gauge data available for the study area. Within the Main Drain J catchment continuous water level data was recorded at three sites between the years of 1982 and 1996:

- Main Drain J at Warburn Escape (1989 – 1996);
- Main Drain J at Yoogali (1982 – 1993); and
- DC ‘S’ at Watkins Avenue (1982 – 1993).

These gauges provide a reasonable coverage for the March 1989 event and enable valuable information relating to the catchment response to be gained. No such data exists for the March 2012 event.

For the March 2012 event MI provided stream flow records for a number of gauges throughout the system, including Mirrool Creek at McNamara Road. This data provides a reasonable indication of the flood response of the Mirrool Creek catchment.

In addition to the available continuous records, peak flood level data was also recorded on Mirrool Creek at Barellan, at least between the years 1952 and 1978.

2.2.5 Council Data

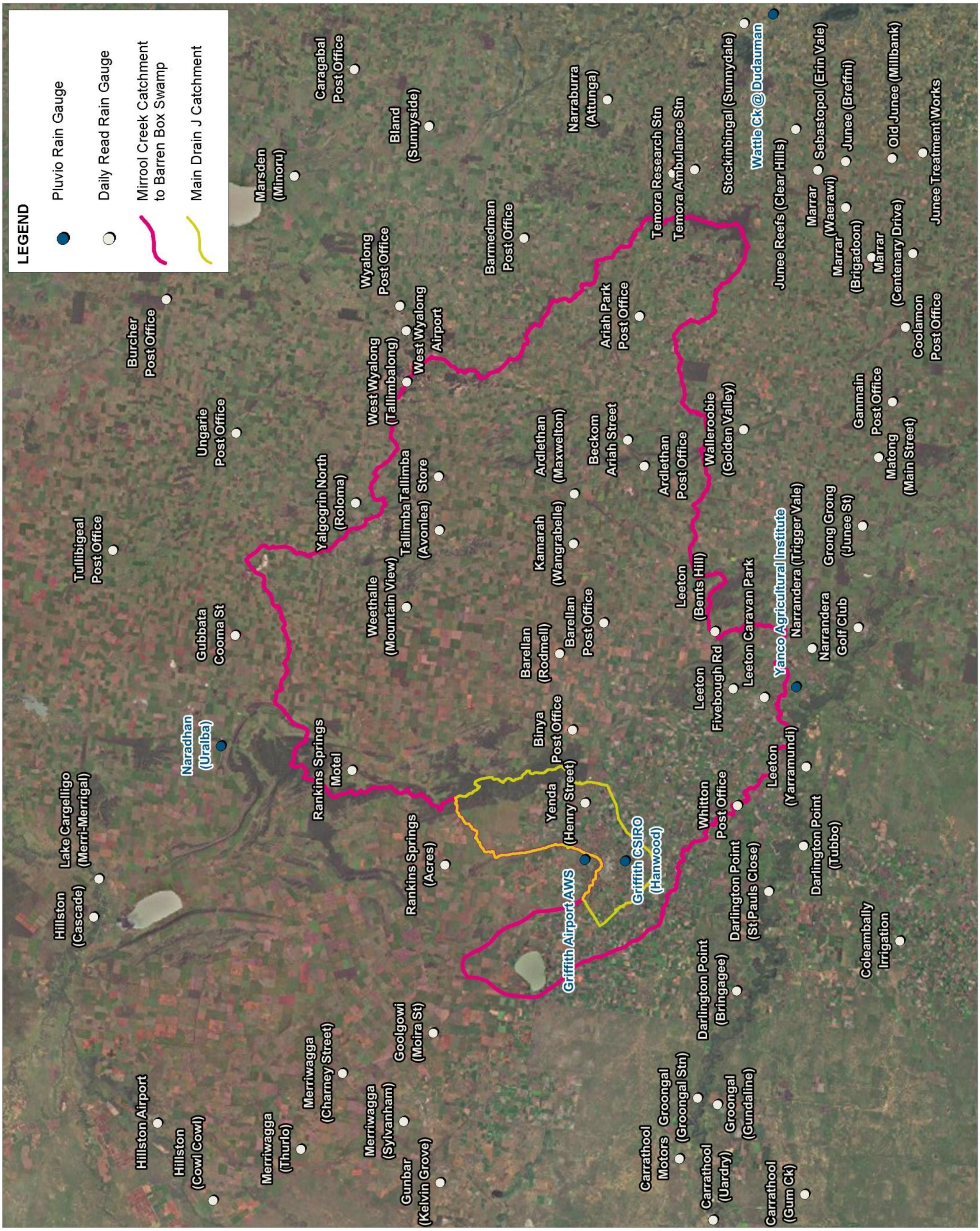
Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, etc. were provided by Council in the form of GIS LiDAR land survey data covering around 360km^2 of the Main Drain J catchment was acquired by AAM Hatch in February 2004. Flood behaviour is inherently dependent on the ground topography and for this study an accurate representation of the floodplain is essential. Advanced GIS analysis also allows the LiDAR imagery to be assessed in concert with spatial 2-D flood model data, facilitating mapping, categorisation, and overall flood management.

Table 2-1 Summary of Rainfall Gauges in the Mirrool Creek Locality

Station	Location	Type	Start Year	End Year
74037	Yanco Agricultural Institute	Pluvio	1957	current
75028	Griffith CSIRO (Hanwood)	Pluvio	1914	1989
75041	Griffith Airport AWS	Pluvio	1960	current
412134	Wattle Ck @ Dudauman	Pluvio	1988	current
49130	Hillston (Cascade)	Daily	1980	2006
50010	Burcher Post Office	Daily	1937	current
50040	Ungarie Post Office	Daily	1895	current
50045	Yalgogrin North (Roloma)	Daily	1887	current
50103	West Wyalong Airport	Daily	1960	current
73000	Barmedman Post Office	Daily	1887	current
73008	Caragabal Post Office	Daily	1916	current
73019	Junee Treatment Works	Daily	1891	current
73025	Old Junee (Millbank)	Daily	1895	current
73037	Temora Ambulance Stn	Daily	1880	current
73038	Temora Research Stn	Daily	1934	current
73054	Wyalong Post Office	Daily	1895	current
73099	Junee Reefs (Clear Hills)	Daily	1898	current
73114	Sebastopol (Erin Vale)	Daily	1887	current
73116	Junee (Breffni)	Daily	1968	current
73143	Narraburra (Attunga)	Daily	2003	current
73145	Bland (Sunnyside)	Daily	2003	current
73149	Marsden (Minoru)	Daily	1997	current
73150	Stockinbingal (Sunnydale)	Daily	1949	current
74000	Ardlethan Post Office	Daily	1909	current
74002	Ariah Park Post Office	Daily	1903	current
74005	Barellan Post Office	Daily	1878	current
74006	Beckom Ariah Street	Daily	1909	current
74007	Leeton (Bents Hill)	Daily	1941	current
74020	West Wyalong (Tallimbalong)	Daily	1880	2007
74033	Coolamon Post Office	Daily	1887	current
74044	Ganmain Post Office	Daily	1899	current
74050	Grong Grong (Junee St)	Daily	1898	current
74062	Leeton Caravan Park	Daily	1913	2006
74068	Marrar (Centenary Drive)	Daily	1887	2008
74071	Matong (Main Street)	Daily	1938	current
74094	Barellan (Rodmell)	Daily	1901	current
74102	Tallimba Store	Daily	1941	2002
74108	Darlington Point (Tubbo)	Daily	1875	current

Station	Location	Type	Start Year	End Year
74118	Whitton Post Office	Daily	1886	current
74132	Leeton (Yarramundi)	Daily	1956	2003
74197	Narrandera (Trigger Vale)	Daily	1999	current
74217	Marrar (Brigadoon)	Daily	1968	current
74221	Narrandera Golf Club	Daily	1969	current
74233	Kamarah (Wangrabelle)	Daily	1968	2007
74249	Coleambally Irrigation	Daily	1978	current
74254	Leeton Fivebough Rd	Daily	1992	current
74259	Marrar (Waerawi)	Daily	1997	current
74261	Walleroobie (Golden Valley)	Daily	2003	current
74266	Ardlethan (Maxwelton)	Daily	2003	current
74267	Tallimba (Avonlea)	Daily	2001	current
75006	Binya Post Office	Daily	1876	current
75010	Darlington Point (Bringagee)	Daily	1894	current
75014	Carrathool Motors	Daily	1890	2006
75016	Gunbar (Kelvin Grove)	Daily	1998	current
75025	Goolgowi (Moira St)	Daily	1930	current
75026	Groongal (Groongal Stn)	Daily	1878	current
75027	Gubbata Cooma St	Daily	1937	current
75029	Carrathool (Gum Ck)	Daily	1882	current
75032	Hillston Airport	Daily	1881	current
75043	Lake Cargelligo (Merri-Merrigal)	Daily	1884	current
75044	Merriwagga (Charney Street)	Daily	1930	current
75050	Naradhan (Uralba)	Daily	1880	current
75057	Rankins Springs Motel	Daily	1880	2011
75064	Groongal (Gundaline)	Daily	1880	current
75066	Tullibigeal Post Office	Daily	1924	2005
75067	Carrathool (Uardry)	Daily	1883	current
75072	Weethalle (Mountain View)	Daily	1930	current
75079	Yenda (Henry Street)	Daily	1925	current
75096	Hillston (Cowl Cowl)	Daily	1871	current
75132	Lake Cargelligo (Wooyeo)	Daily	1906	current
75142	Merriwagga (Sylvanham)	Daily	1968	current
75146	Rankins Springs (Acres)	Daily	1968	current
75166	Darlington Point (St Pauls Close)	Daily	1909	current
75167	Merriwagga (Thurlo)	Daily	1975	current

A wealth of information relating to the March 2012 flood event was provided. This included numerous flood photographs taken from both the ground and the air; details of the flood extent estimated from the aerial observations; surveyed flood levels in the affected communities of Yenda, Yoogali and Hanwood; and details of road bridges that had replaced earlier structures across Main Drain J.



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Rainfall Gauges in the Vicinity of the Mirrool Creek Catchment

Figure: **2-2**

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2.2.6 SRTM Data

The SRTM DEM-H (hydrologically smoothed), which is a 30m resolution Digital Elevation Model (DEM) derived from the Shuttle Radar Topographic Mission (SRTM), was obtained. It has been cleaned, filtered for vegetation and smoothed by CSIRO as part of the One-second DEM for Australia project. This dataset was used to provide topographic information for the Mirrool Creek catchment and the upper catchment of Main Drain J, where LiDAR data was not available.

2.2.7 Murrumbidgee Irrigation Data

Murrumbidgee Irrigation provided a detailed photogrammetric dataset, covering the entire MIA. The dataset included a 2m resolution DEM and breaklines representing features such as drainage channels, channel banks and roads. This data was used to provide model topography beyond the extent of the LiDAR survey, including the area to the east of the Whitton Stock Route and the floodplain of Mirrool Creek.

For the March 2012 event MI provided stream flow records for a number of gauges throughout the system, including Mirrool Creek at McNamara Road. This data provides a reasonable indication of the flood response of the Mirrool Creek catchment.

Flood mark survey was also provided for the March 2012 event, comprising some 50 peak flood levels along Mirrool Creek between the Kidman Way and Barren Box Swamp. This data is useful for determining the flood gradient during the event and assessing Mirrool Creek model calibration performance. Further discussion of the use of MI data is provided in Section 6.

2.2.8 Office of Environment and Heritage Data

The NSW Government Office of Environment and Heritage (OEH) provided some DIEMOS satellite imagery that was captured following the March 2012 flood event. It has been used to assist in the model calibration process and is discussed further in Section 6.

2.3 Site Inspections

A number of site inspections were undertaken during the course of the study to gain an appreciation of local features influencing flooding behaviour. Some of the key observations to be accounted for during the site inspections included:

- Presence of local structural hydraulic controls such as roads and embankments that may have an impact on flooding behaviour;
- Confirmation of the location and configuration of the irrigation supply and drainage network, including associated cross-drainage structures, culverts and bridges;
- Location of existing development and infrastructure on the floodplain.

This visual assessment was useful for defining hydraulic properties within the hydraulic model and ground-truthing of topographic features identified from the available data.

2.4 Community Consultation

The success of a floodplain risk management plan hinges on its acceptance by the community, residents within the study area, and other stake-holders. This can be achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and knowledge on flood behaviour in the study area, together with discussing the issues and outcomes of the study with them.

The key elements of the consultation process in undertaking the flood study have included:

- Meetings with community members to obtain historical flood data and community perspective on flooding issues;
- Feedback through the Floodplain Management Committee meetings; and
- Public exhibition of Draft Report.

These elements are discussed in further detail in Section 3.

2.5 Development of Computer Models

2.5.1 Main Drain J Hydrological Model

For the purpose of the Flood Study, a hydrologic model (discussed in Section 4.1) was developed to simulate the rate of storm runoff from the catchment. The model predicts the amount of runoff from rainfall and the attenuation of the flood wave as it travels down the catchment. This process is dependent on:

- Catchment area, slope and vegetation;
- Variation in distribution, intensity and amount of rainfall; and
- Antecedent conditions of the catchment.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydrodynamic model. These hydrographs are used by a hydraulic model to simulate the passage of a flood through the Main Drain J catchment to the downstream study limits at Warburn Escape.

2.5.2 Main Drain J Hydraulic Model

The hydraulic model (discussed in Section 4.2) developed for this study includes:

two-dimensional (2D) representation of the floodplain of the Main Drain J catchment and the adjoining Mirrool Creek, covering an area of some 600 km^2, which includes all of the floodplain in the developed and irrigated areas of the catchment; and

one-dimensional (1D) representation of primary and secondary drainage channels, including key hydraulic structures.

The hydraulic model is applied to determine flood levels, velocities and depths across the study area for historical and design events.

2.5.3 Mirrool Creek Catchment Model

In recent years the advancement in computer technology has enabled the use of the direct rainfall approach as a viable alternative to traditional hydrological modelling. With the direct rainfall method the design rainfall is applied directly to the individual cells of a 2D hydraulic model. This is particularly useful for catchments where the sub-catchment boundaries are difficult to define or significant cross-catchment flows occur. This study has adopted the direct rainfall approach for modelling the Mirrool Creek hydrology, details of which are discussed in Section 4.3. This was deemed the most appropriate approach, given the substantial flow divergences and floodplain attenuation within the catchment.

2.6 Calibration and Sensitivity Testing of Models

The following criteria are generally used to determine the suitability of historical events to use for calibration or validation:

- The availability, completeness and quality of rainfall and flood level event data;
- The amount of reliable data collected during the historical flood information survey; and
- The variability of events – preferably events would cover a range of flood sizes.

The Main Drain J models were calibrated to the March 1989 and March 2012 flood events to establish the values of key model parameters and confirm that the models were capable of adequately simulating real flood events. A broader range of flood events was investigated when considering the Mirrool Creek hydrology.

The calibration and validation of the models is presented in Section 6 and Section 8. The flood levels in Main Drain J were found to be particularly sensitive to the in-channel Manning's 'n' and modelled control levels of the channel banks. However, assessments have been made to ensure the most suitable estimates of these parameters are being applied. Modelled flood flows in the Mirrool Creek catchment model are significantly influenced by the adopted Manning's 'n', soil losses and the representation of floodplain attenuation through the Barellan floodplain. Based largely on the March 2012 event, there remains a relatively large amount of uncertainty.

2.7 Establishing Design Flood Conditions

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event, which is sometimes referred to as the 100 year Average Recurrence Interval (ARI) flood, is the best estimate of a flood with a peak discharge that has a 1% (i.e. 100 year ARI) chance of occurring in any one year.

For the Main Drain J catchment, design floods were based on design rainfall estimates according to Australian Rainfall and Runoff (IEAust, 2001).

The assessment of appropriate design flood flows for Mirrool Creek has been based on both rainfall-runoff modelling from the catchment model and the analysis of the recorded historic events. There is a large amount of uncertainty associated with both these methods and so a simplified estimation of an appropriate flood frequency distribution is proposed.

The design flood conditions form the basis for floodplain risk management in the catchment and in particular design planning levels for future development controls. The predicted design flood conditions are presented in Section 7.2.

2.8 Mapping of Flood Behaviour

Design flood mapping is undertaken using output from the hydraulic model. Maps are produced showing water depth and velocity for each of the design events. The maps present the peak value of each parameter. Provisional flood hazard categories and hydraulic categories derived from the hydrodynamic model results are also mapped. Some mapping outputs are presented Section 7.2, with the full flood mapping series presented in the accompanying mapping compendium.

3 Community Consultation

3.1 The Community Consultation Process

The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain risk management activities. It has provided an opportunity to collect information on their flood experience, in particular historical flood data related to catchment flooding.

The key elements of the consultation process have been as follows:

- Meetings with community members to obtain historical flood data and community perspective on flooding issues;
- Feedback through the Floodplain Management Committee meetings; and
- Public exhibition of the draft Flood Study.

These elements are discussed in detail below.

3.2 Community Meetings

Following the initial data compilation and model development phases a number of meetings were held with key community groups. The purpose of these meetings was to provide the community with an appreciation of how the study was being approached and to understand the catchment flood behaviour from those that had experienced it first-hand. Meetings were held with the Yenda Flood Working Group, Yoogali Progress Association and individual landholders from other flood affected locations within the catchment.

The meetings were highly successful as valuable qualitative information regarding flood depths, timings and durations was gathered. Additional flood photograph and video data was also provided by some individuals, including Paul Rossetto, David Rossetto, Craig Bardney, Peter Budd, Tiz Forlico and the Andreazzas. The descriptions of flood behaviour that had been observed during the March 2012 and March 1989 flood events matched reasonably well with what was being produced by the preliminary model simulations. The mutual understanding of flood behaviour within the study area between the community and the project team was a major factor in the successful progression of the study.

On Monday 3rd June 2013 a meeting was held with the Yenda Flood Working Group. This included members of the Yenda Progress Association, Rural Fire Service, former MI workers and local farmers. The discussions resulted in a good understanding of the March 2012 flood event on Mirrool Creek and the broader flood behaviour of the catchment as a whole. Key pieces of information to come out of the meeting included:

- It typically takes 5-7 days travel time from Mirrool to near Merribee Hill. March 2012 event was four days from the rain until the flood peak;
- Flood flows from Colinroobie Creek reached the Main Canal two days earlier;
- During the March 2012 event the Main Canal was breaching at Parizotto's (~30m by 1.5m);
- The 2012 floods impacted Yenda on the Tuesday 6th March, from around 12:30-13:00 onwards;

- Many photos were taken during the 2012 flood, both from the air and on the ground. These were provided to BMT WBM to assist with the model calibration;
- The local drainage in Yenda performed well, with only one property on Dredge Street threatened;
- During the March 2012 flood there was extensive breaching of the Northern Branch Canal, which was breaching for most of the week;
- North Yenda flooded a day later than Yenda, with flood waters coming around through Binya Forest; and
- The flooding in Myall Park took months to drain away properly.

On Tuesday 4th June 2013 a meeting was held with Murrumbidgee Irrigation, represented by Robert Kelly and Jody Rudd. The main outcome of this meeting was ascertaining the extent of additional data available to assist with the model development and calibration. Some observations of the March 2012 flood behaviour were also gained. MI were forthcoming with their provision of data, which proved invaluable in providing a robust assessment of flood behaviour for Mirrool Creek. Key pieces of information to come out of the meeting included:

- Flood survey capturing flood heights during the March 2012 event was undertaken along Mirrool Creek;
- Flow gauging records were available that recorded the flows in Mirrool Creek during the March 2012 flood event;
- MI have an elevation dataset from 2005 photogrammetry covering the entire MIA;
- The Main Drain J is wider and deeper now than the design due to erosion;
- MI have original siphon designs that contain invert information;
- During a flood event the canal operation is to let water out to prevent breaching. This occurs at Daltons Road, Merribee Channel and the EMR;
- The main canal was fully locked up during the March 2012 event with zero flow; and
- Water level data had been logged at Fowlers Road in Myall Park and also at Brobenah (although only for one day at the latter) during the March 2012 event.

On Tuesday 4th June 2013 a meeting was held with Mick Plos & Peter Budd, who have interests in property on Mackay Avenue at Yoogali. Because of the potential flooding issues at their site, they were vigilant in observing the flood behaviour of the March 2012 flood as events unfolded, capturing many photos during the event. Key pieces of information to come out of the meeting included:

- The intersection of MacKay Avenue and Kurrajong Avenue was dry – only the bottom end of Oakes Road flooded;
- Kurrajong Avenue was flooded to Ceccato Road;
- Water seeped over the railway and flooded halfway across MacKay Avenue for a few hours at the peak of the March 2012 event in the afternoon of March 4th; and

- The flood level was 50mm below the top of the concrete slab of the Yoogali Service Station.

On the evening of Tuesday 4th June a meeting was held at the Yoogali Club with the Yoogali Progress Association. The discussions were important to gain an understanding of the nature of flooding within Yoogali, particularly in relation to the March 2012 event. Key pieces of information to come out of the meeting included:

- Drain 605 J broke at the McCormack Road intersection at 04:30 on Sunday 4th, with flood waters progressing into Yoogali along Gorton Street;
- There was no spilling from Main Drain J, just backing up of waters in Yoogali due to the high tailwater conditions;
- The 605 J drain was about 30-40cm off bank full on Saturday (3rd) night;
- Water was kerb height at the school 05:00 on Sunday 4th and a few hours later it was over 0.3m deep;
- A 500mm pipe was discharging water into the village at the Gorton Street and McCormack Road intersection;
- All of the drainage pipes were surcharging back into Yoogali when the drain levels were up;
- Around 50 acres of the village was flooded;
- The flood waters were held up behind the railway line with little cross-drainage;
- Flood depth was only 50mm over the road at McCormack Road, but 800mm at Edon Street; and
- In Moura Street in 1989 the flood water came in from the back yards and was mostly from the local drainage – it did not spill in from drain 605 J.

On Wednesday 5th June 2013 a meeting was held with Tiz Forlico, who owns a property on Kidman Way. His property was flooded during the March 2012 event, with flood waters breaking the right bank of Main Drain J upstream of the property. Water then flowed through his property, backing up behind Kidman Way. He expressed concerns over the maintenance of the drainage channel, both in terms of vegetation growth and the reclamation of channel banks for clay. His situation highlighted the localised nature of some of the potential flooding issues within the Main Drain J catchment. It can be difficult to capture all of these within the modelling without prior knowledge of their existence.

Later on Wednesday 5th June 2013 a meeting was held with Jillian, Wayne and Gary Andreazza, who own a property on Tyson Lane. The discussions were important to understand the nature of flooding in the lower reaches of the Main Drain J catchment. Key pieces of information to come out of the meeting included:

- Both Tyson Lane and Bromleys Road were flooded, including the properties situated there;
- Concerns were expressed over a lack of maintenance of Main Drain J downstream of Walla Avenue and the reductions on channel capacity that this might have;
- Walla Avenue went under but the flood waters were not over Brogden Road – the water backed up behind, flooding the fields along Tyson Lane;

- Flooding from the March 1989 and March 2012 flood events was similar in nature;
- During the March 2012 event on Saturday 3rd it was OK but on the morning of Sunday 4th the fields were flooded and Walla Avenue was overflowing. Sunday night was the worst and it stayed like that for a couple of days;
- The flooding was maybe 0.5m deep at the Bromley Road properties and was around 0.6m in the paddock on the left bank downstream of Walla Avenue;
- The worst flooding was from Walla Avenue down to Brown Road; and
- There was a big upgrade of DC Western after 1989 but not of Main Drain J.

3.3 Floodplain Management Committee

The study has been overseen by the Floodplain Management Committee (Committee). Members of the Committee include representatives from the following:

- Griffith City Council - Councillors;
- Technical staff from Griffith City Council;
- Representatives from the Office of Environment and Heritage;
- Representatives from Murrumbidgee Irrigation (MI); and
- Representatives from the State Emergency Service (SES); and
- Community representatives.

The Committee has assisted and advised Council in the development of the Flood Study and is responsible for recommending the outcomes of the study for formal consideration by Council. Throughout the course of the study a number of Floodplain Management Committee meetings were held. The progress of the study was presented to the committee, who were able to provide valuable feedback on some of the information that was being presented. This included local knowledge of the catchment and historic flood events, which enabled findings of the study to be verified where possible.

3.4 Public Exhibition

The draft report is to be placed on public exhibition to allow feedback from the wider community. Landowners, residents and businesses are invited to participate in the study by providing comment on the exhibition report.

This will then be followed by additional community involvement during the course of the Floodplain Risk Management Study.

4 Model Development

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. For this study, three models were used:

- A hydrologic model of the entire Main Drain J catchment;
- A hydraulic model covering the floodplain of the study catchment, including Main Drain J and the secondary drainage channels; and
- A hydraulic model of the entire Mirrool Creek catchment used to simulate the hydrological response of the catchment and provide inputs to the Main Drain J model.

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the channel and floodplains, producing flood levels, flow discharges and flow velocities.

Both of these models were calibrated interactively.

Information on the topography and characteristics of the catchments, watercourses and floodplains are built into the models. Recorded historical flood data, including rainfall, flood levels and river flows, are used to simulate and validate (calibrate and verify) the models. The models produce as output, flood levels, flows (discharges) and flow velocities.

Development of a hydraulic model follows a relatively standard procedure:

- Discretisation of the catchment, watercourses, floodplain, etc.
- Incorporation of physical characteristics (channel details, floodplain levels, structures etc).
- Establishment of hydrographic databases (rainfall, flood 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).
- Verification to one or more other historic floods (verification is a check on the model's performance without further adjustment of parameters).
- Sensitivity analysis of parameters to measure dependence of the results upon model assumptions.

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

- Establishing design flood conditions;
- Determining flood extents, levels and hydraulic categories for planning control; and
- Modelling development or management options to assess the hydraulic impacts.

4.1 Main Drain J Catchment Hydrological Model

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff and the attenuation of the flood wave as it travels down the catchment is dependent on:

- The catchment slope, area, vegetation and other characteristics;
- Variations in the distribution, intensity and amount of rainfall;
- The amount of surface storage (natural or manmade) within the catchment; and
- The antecedent conditions (dryness/wetness) of the catchment.

These factors are represented in the model by:

- Sub-dividing (discretising) the catchment into a network of sub-catchments inter-connected by channel reaches representing the watercourses. The sub-catchments are delineated, where practical, so that they each have a general uniformity in their slope, landuse, vegetation density, etc;
- The amount and intensity of rainfall is varied across the catchment based on available information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent conditions are modelled by varying the amount of rainfall which is “lost” into the ground and “absorbed” by storages. For very dry antecedent conditions, there is typically a higher initial rainfall loss.

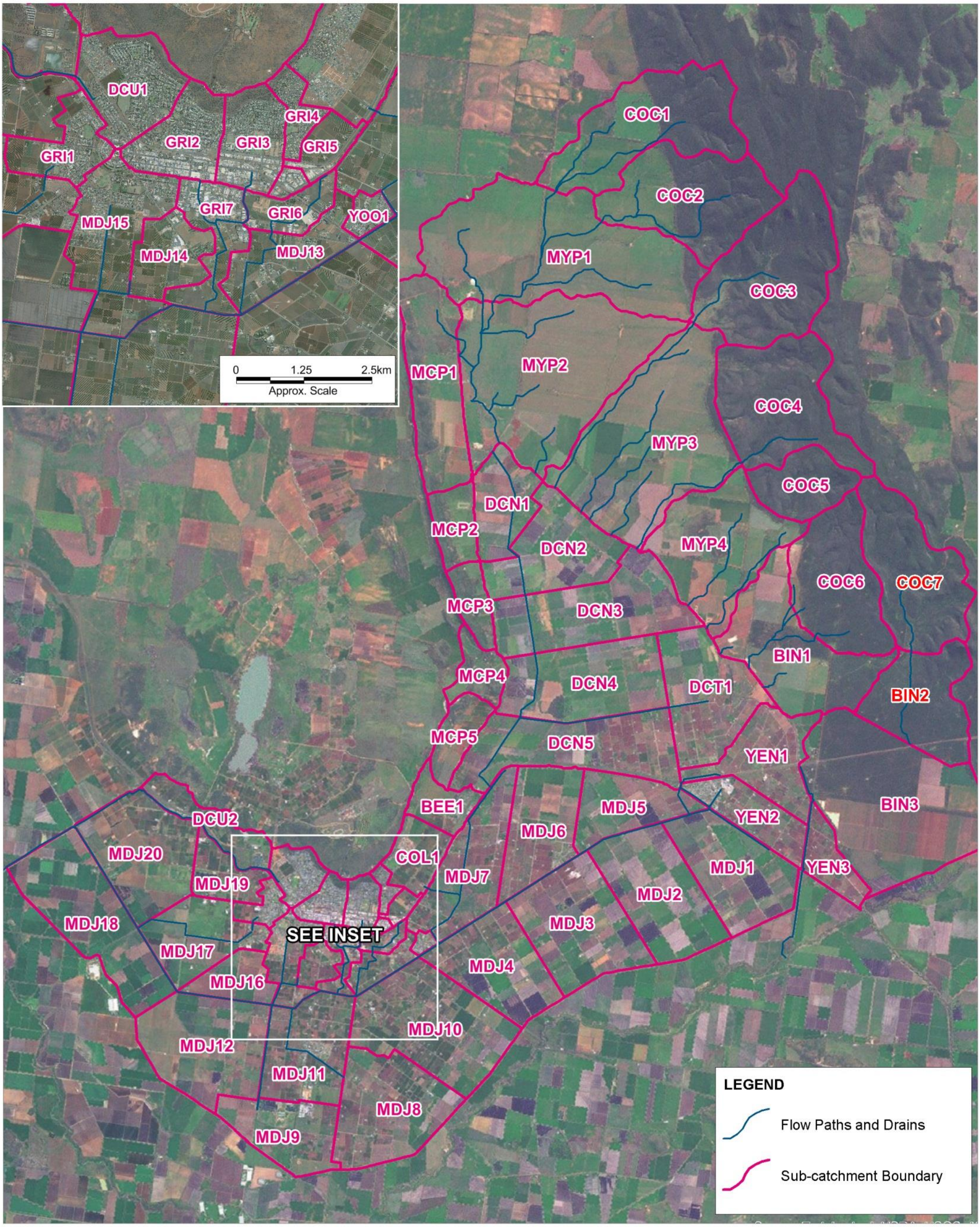
The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood through the Main Drain J catchment.

The RAFTS-XP software was used to develop the hydrologic model using the physical characteristics of the catchment including catchment areas, ground slopes and vegetation cover as detailed in the following sections.

4.1.1 Sub-catchment Delineation

The Main Drain J catchment drains an area of approximately 550km^2 to Mirrool Creek. For the hydrological model this area has been delineated into 60 sub-catchments as shown in Figure 4-1. The discretisation of individual sub-catchments has given consideration to the underlying land-use, topography and drainage infrastructure The sub-catchment delineation provides for generation of flow hydrographs at key confluences or inflow points to the hydraulic model.

Table 4-1 summarises the key catchment parameters adopted in the RAFTS-XP model, including catchment area, vectored slope and PERN (roughness) value estimated from the available topographic information and aerial photography. The adopted PERN values considered the proportion of woodland catchment (PERN of 0.12) to cleared/irrigated area (PERN of 0.06). As indicated in the table and evident from aerial photography, the greater proportion of the Main Drain J catchment is cleared/irrigated.



Title:

RAFTS Model Sub-catchment Layout

Figure: **4-1**

Rev: **A**

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The PERN values provided in Table 4-1 represent the largely undeveloped catchment area of Main Drain J. For sub-catchments that contain regions of urban development, lower PERN values have been adopted to reflect the increased responsiveness of the urban land use types. These urban sub-catchments have also been modelled using a second sub-catchment approach, where the impervious areas are treated separately. The PERN value for these impervious areas has been set to 0.02 accordingly.

Table 4-1 RAFTS Sub-catchment Properties

ID	Area (ha)	Slope (%)	PERN	ID	Area (ha)	Slope (%)	PERN
COC1	1790	1.2	0.09	MDJ1	1170	0.1	0.06
COC2	1650	1.7	0.1	MDJ2	1320	0.1	0.06
COC3	1910	1.8	0.12	MDJ3	1390	0.1	0.06
COC4	1670	3.9	0.12	MDJ4	1090	0.1	0.06
COC5	660	4.7	0.12	MDJ5	740	0.1	0.06
COC6	1370	1.9	0.12	MDJ6	960	0.1	0.06
COC7	1490	1.7	0.12	MDJ7	1070	0.1	0.06
BIN1	1580	0.3	0.08	MDJ8	1310	0.1	0.06
BIN2	1110	1.1	0.12	MDJ9	810	0.1	0.06
BIN3	2730	0.1	0.09	MDJ10	1650	0.1	0.06
MYP1	3200	0.4	0.06	MDJ11	1040	0.1	0.06
MYP2	3180	0.3	0.06	MDJ12	1410	0.1	0.06
MYP3	2870	0.6	0.06	MDJ13	240	0.1	0.06
MYP4	1630	0.6	0.06	MDJ14	180	0.1	0.06
MCP1	1350	1.4	0.08	MDJ15	425	0.1	0.06
MCP2	390	3.4	0.08	MDJ16	400	0.1	0.06
MCP3	300	6	0.09	MDJ17	840	0.1	0.06
MCP4	330	2.1	0.06	MDJ18	1530	0.1	0.06
MCP5	380	2.7	0.06	MDJ19	400	0.3	0.06
BEE1	350	0.5	0.06	MDJ20	1270	0.3	0.06
COL1	420	0.6	0.06	DCU1	300	0.6	0.02
DCN1	670	0.1	0.06	DCU2	490	1.9	0.06
DCN2	1120	0.1	0.06	GRI1	180	0.2	0.03
DCN3	1520	0.1	0.06	GRI2	220	0.9	0.02
DCN4	1400	0.1	0.06	GRI3	210	0.8	0.02
DCN5	1480	0.1	0.06	GRI4	115	0.8	0.02
DCT1	1220	0.2	0.06	GRI5	95	0.3	0.05
YEN1	885	0.1	0.06	GRI6	120	0.1	0.06
YEN2	595	0.1	0.06	GRI7	210	0.2	0.04
YEN3	380	0.1	0.06	YOO1	50	0.2	0.02

4.1.2 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model, which simulates the catchment's response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment.

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern. Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in AR&R (2001). Similarly AR&R (2001) defines standard temporal patterns for use in design flood estimation. For design event rainfall it is also necessary to consider areal reduction factors, which scale down point rainfall intensities to a level appropriate to the scale of the area of interest.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 5 and design events discussed in Section 7.

4.1.3 Northern Branch Canal

The Northern Branch canal impedes runoff from the upper catchment areas from reaching the Myall Park storage area. Flood levels will build up behind the canal and are transferred downstream via local cross-drainage infrastructure. When the upstream flood storage capacity is exceeded then overtopping of the canal will occur. This was evidenced in both the 1931 and 2012 flood events. This will serve to attenuate the flood wave as it moves down the catchment.

The attenuating effect of the Northern Branch Canal has been incorporated into the hydrological modelling through the utilisation of the Retarding Basin option in RAFTS. The following details were input for the sub-catchments on the upstream side of the canal, including MCP2, MCP3, MCP4, MCP5, MYP2, MYP3, MYP4 and BIN1:

- Stage-storage relationship upstream of the canal, extracted from the LiDAR DEM;
- Cross-drainage structure dimensions; and
- Width and level for canal overtopping spills.

The influence of the Northern Branch Canal on catchment flood behaviour is generally minor, but is significant for sub-catchments MYP2 and BIN1.

4.2 Main Drain J Catchment Hydraulic Model

BMT WBM has applied the fully 2D software modelling package TUFLOW. TUFLOW was developed in-house at BMT WBM and has been used extensively for over 20 years on a commercial basis by BMT WBM. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels and overland flows through complex overland flow paths using a linked 2D / 1D flood modelling approach.

4.2.1 Extents and Layout

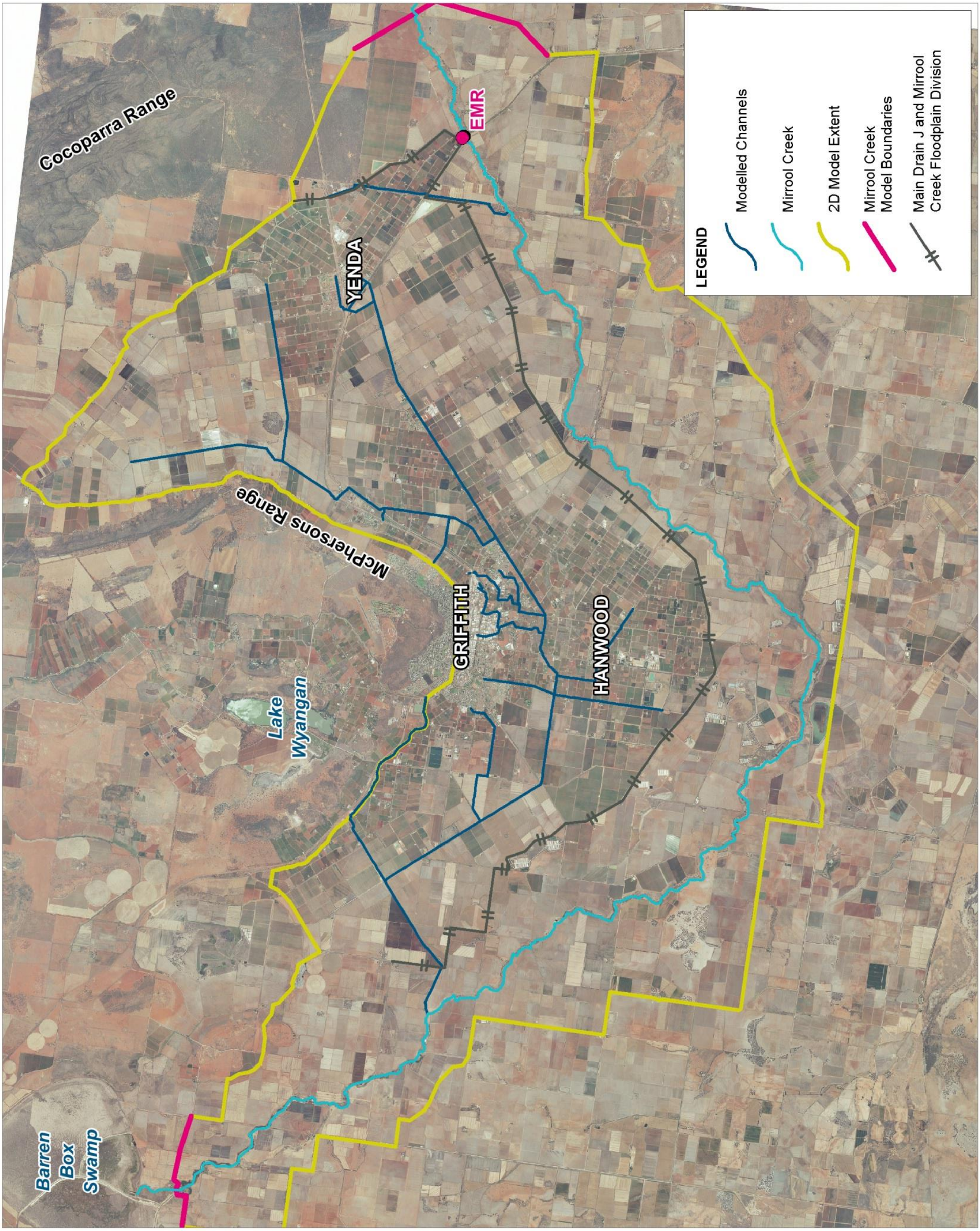
Consideration needs to be given to the following elements in constructing the model:

- Topographical data coverage and resolution;
- Location of recorded data (eg. levels/flows for calibration);
- Location of controlling features (eg. dams, levees, bridges);
- Desired accuracy to meet the study's objectives; and
- Computational limitations.

With consideration to the available survey information and local topographical and hydraulic controls, a linked 1D/2D model was developed representing both the Main Drain J catchment and the adjoining Mirrool Creek floodplain. The model extends from Willow Dam at the downstream limit, to around 5km upstream of the East Mirrool Regulator. The model is generally bounded to the north by the McPhersons Range and Northern Branch Canal and to the south by the Benerembah Channel. The significant elements of the irrigation drainage network have been modelled as 1D branches embedded within the 2D (floodplain) domain. This approach enables the hydraulic capacity of Main Drain J and the secondary drainage channels to be accurately defined by true channel dimensions, whilst enabling the overland flow to be represented in 2D. The model layout is presented in Figure 4-2.

The floodplain area modelled within the 2D domain comprises a total area of some 600km^2, which includes the entire floodplain of the developed and irrigated areas of the Main Drain J catchment. It also includes the adjoining Mirrool Creek floodplain, which runs parallel with and to the south of Main Drain J. The floodplains of the Main Drain J and Mirrool Creek systems are largely separated by the Mirrool Branch Canal. However, as evidenced by the March 2012 flood event, a transfer of flow from Mirrool Creek into the Main Drain J catchment can occur during major flood events. Mirrool Creek flood waters build up behind the Main Canal at the East Mirrool Regulator and can then spill across the Northern Branch Canal and into the catchment of Main Drain J.

A TUFLOW 2D domain model resolution of 20m was adopted for the study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 20m cell size results in DEM elevations being sampled every 10m. This resolution was selected to give necessary detail required for accurate representation of floodplain topography and its influence on overland flows.



Title:

Main Drain J Catchment Model Layout

Figure: 4-2

Rev: A

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0 2.5 5km
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4.2.2 Base Topography

A high resolution DEM was derived for the study area from the LiDAR data provided by Council and the photogrammetry data provided by MI. It is a representation of the ground surface and does not include features such as buildings or vegetation. The LiDAR data was used where available and covers the whole of the modelled Main Drain J catchment. Beyond the Main Drain J catchment, the base elevation data source is the photogrammetry data, which covers the whole of the modelled Mirrool Creek floodplain.

The ability of the model to provide an accurate representation of the overland flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the study area, a high resolution DEM (2m grid) was derived from LiDAR and photogrammetric sources. The model grid samples elevations from this DEM and so a high resolution was used to maximise the quality of information available during the sampling process.

4.2.3 Topographic Controls

The study area is characterised by flat topography with a large number of linear features elevated above the floodplain. These features include road and rail alignments and embankments associated with the irrigation supply and drainage infrastructure and farming practices. The largest of such features present barriers to flood flows and often have associated cross drainage infrastructure to transfer flows through them. The smaller features will act as hydraulic controls, resulting in flood water ponding behind them before spilling over the crest.

To ensure that the extensive network of topographic features is correctly represented within the model breaklines were created representing elevations along the crests of the embankments.

For the Main Drain J catchment the elevations were derived from the LiDAR DEM, applying a 5m search radius to ensure that the crest was extracted.

For the Mirrool Creek floodplain breaklines were already defined within the MI photogrammetry dataset. The breaklines were imported into the TUFLOW model to ensure that a continuous crest elevation is represented within the model topography. Water levels in the upstream model cells must exceed the crest of the embankment before spilling into the downstream cells. This approach ensures that the influence of the topographic controls across the floodplain is correctly represented.

4.2.4 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (eg. cleared land, scrub, roads, urban areas, etc) for modelling the variation in flow resistance.

The adopted hydraulic roughness (Manning's 'n') applied in the model according to land use type (material) is shown in Table 4-2. The derivation of the Manning's 'n' values is discussed further in Section 5.

The roughness values for the channel network were derived from spot gaugings available at the stream gauges and interpretation of aerial imagery. The land use across the floodplain is fairly consistent, comprising primarily agricultural uses for which a representative value of 0.06 has been adopted.

Table 4-2 Adopted Hydraulic Roughness Coefficients Based on Land Use

Material	Manning's 'n' Value
Clear channels	0.025
Vegetated channels	0.04
Floodplain	0.06

4.2.5 Channel Network

The study requires the modelling of the Main Drain J and its secondary drainage channels, as they have a significant impact on flood propagation in the catchment. Council provided information from Murrumbidgee Irrigation (MI) as to the properties of the channel network. This data comprised a GIS layer of supply and drainage channel locations, together with details on dimensions and channel lining. The bed width data contained within this dataset has been used to determine the size of each channel reach. A trapezoidal channel shape has been adopted, with an assumed side slope of 1-in-1. Channel invert details have been determined from the survey details contained within the 1992 Griffith Flood Study.

Channel bank elevations were derived from the LiDAR DEM, applying a 5m search radius to ensure that the bank crest was extracted. A long-section of the Main Drain J details extracted from the various datasets is shown in Figure 4-3. The figure shows the elevations of the left and right bank crests and the channel bed profile. Channel bed width information is also presented. It can be seen that the channel bed is typically 5m to 8m wide and 2m to 3m deep. A sample cross-section derived from the MI channel dimensions and surveyed bed level is presented in Figure 4-4.

The channel network, represented as a 1D layer in the model, is dynamically linked to the 2D domains along the banks. Catchment runoff will flow through the drainage channels until the water level exceeds that of the bank crests. The excess flow will then spill out of the channel, inundating the adjoining floodplain. The modelled channel network, which consists of a length of approximately 99km, is shown in Figure 4-2.

The defined floodplain of Mirrool Creek has also been represented as a 1D channel network, with cross-section details extracted from the photogrammetric DEM of the MIA. The surrounding agricultural land has been represented within the 2D model domain.

4.2.6 Hydraulic Structures

There are over 150 bridge and culvert crossings over the watercourses within the model extents as presented on Figure 4-5. These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the model provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

The structures that most significantly influence flood behaviour are the siphon structures that transfer catchment drainage under the irrigation supply canal infrastructure. There are 15 such structures within the model, including that under the Main Canal at the East Mirrool Regulator.

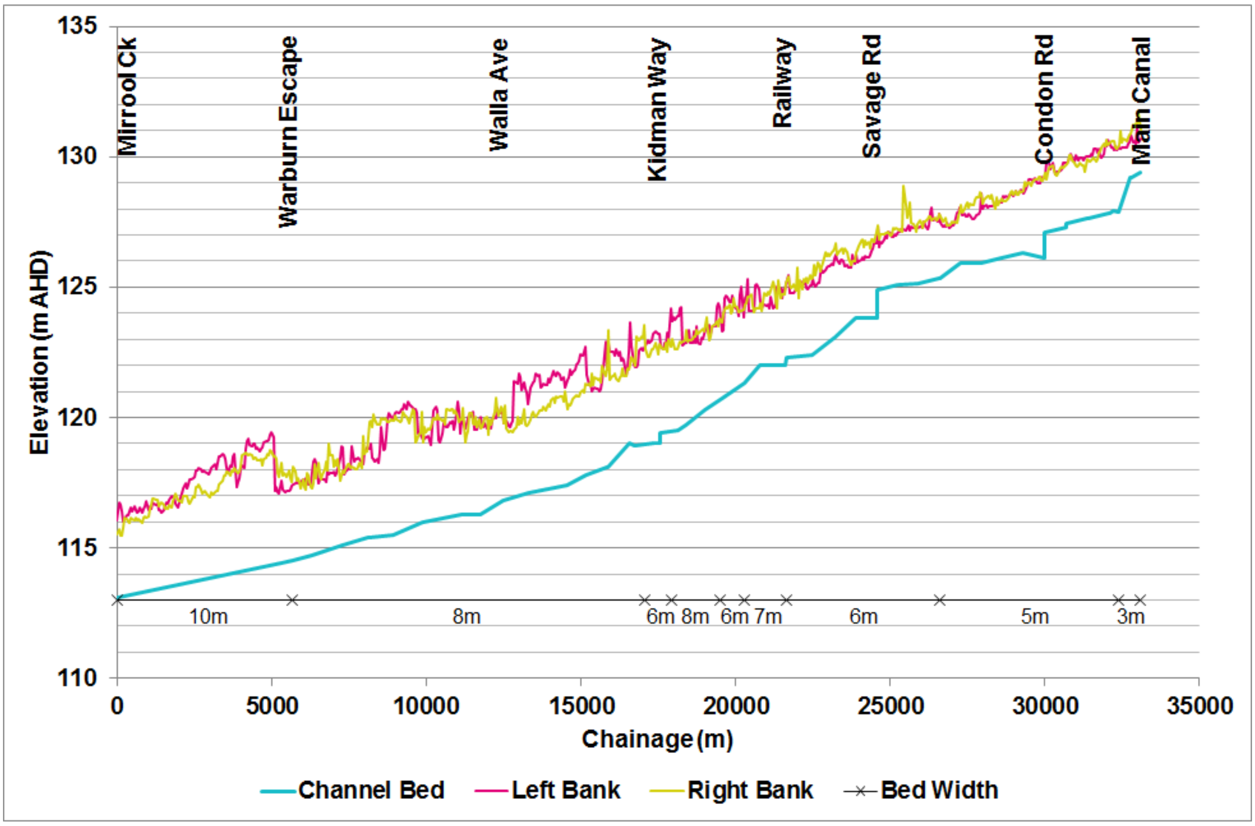


Figure 4-3 Main Drain J Channel Long Section

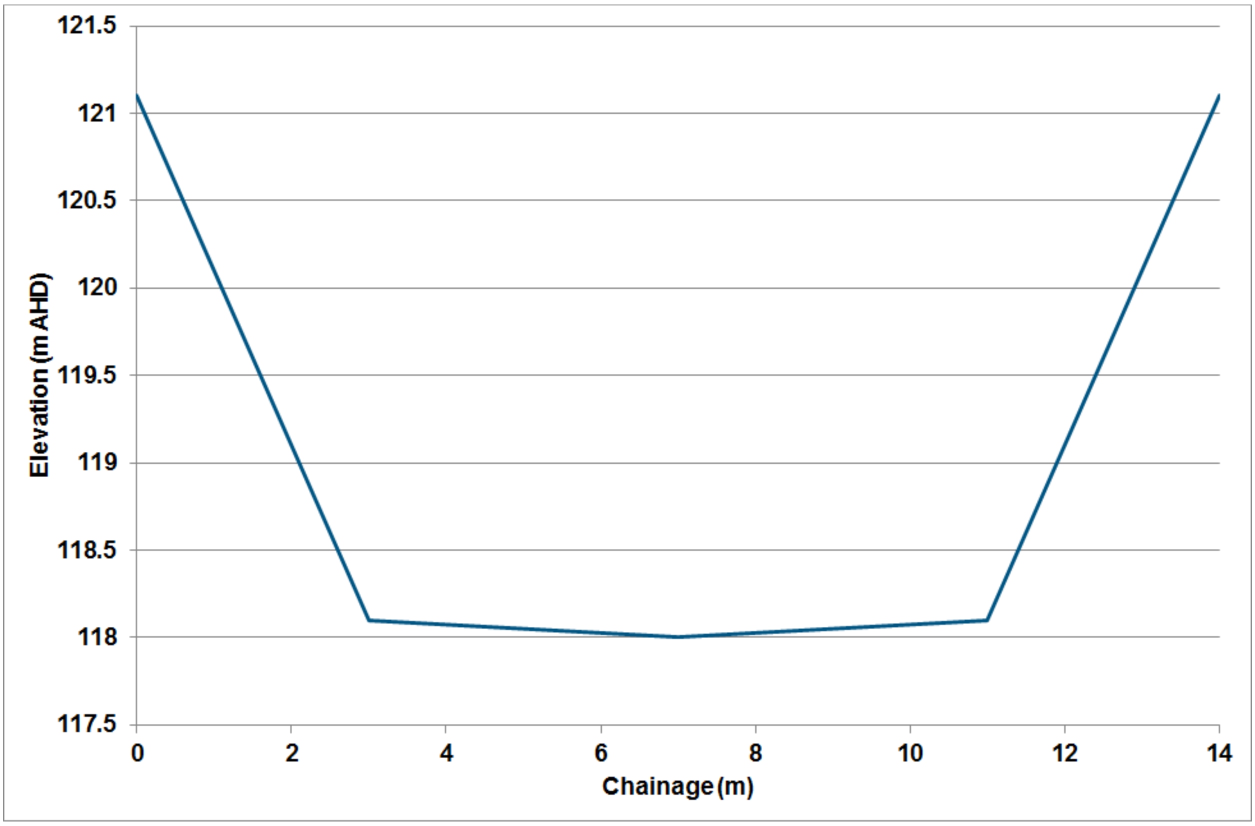
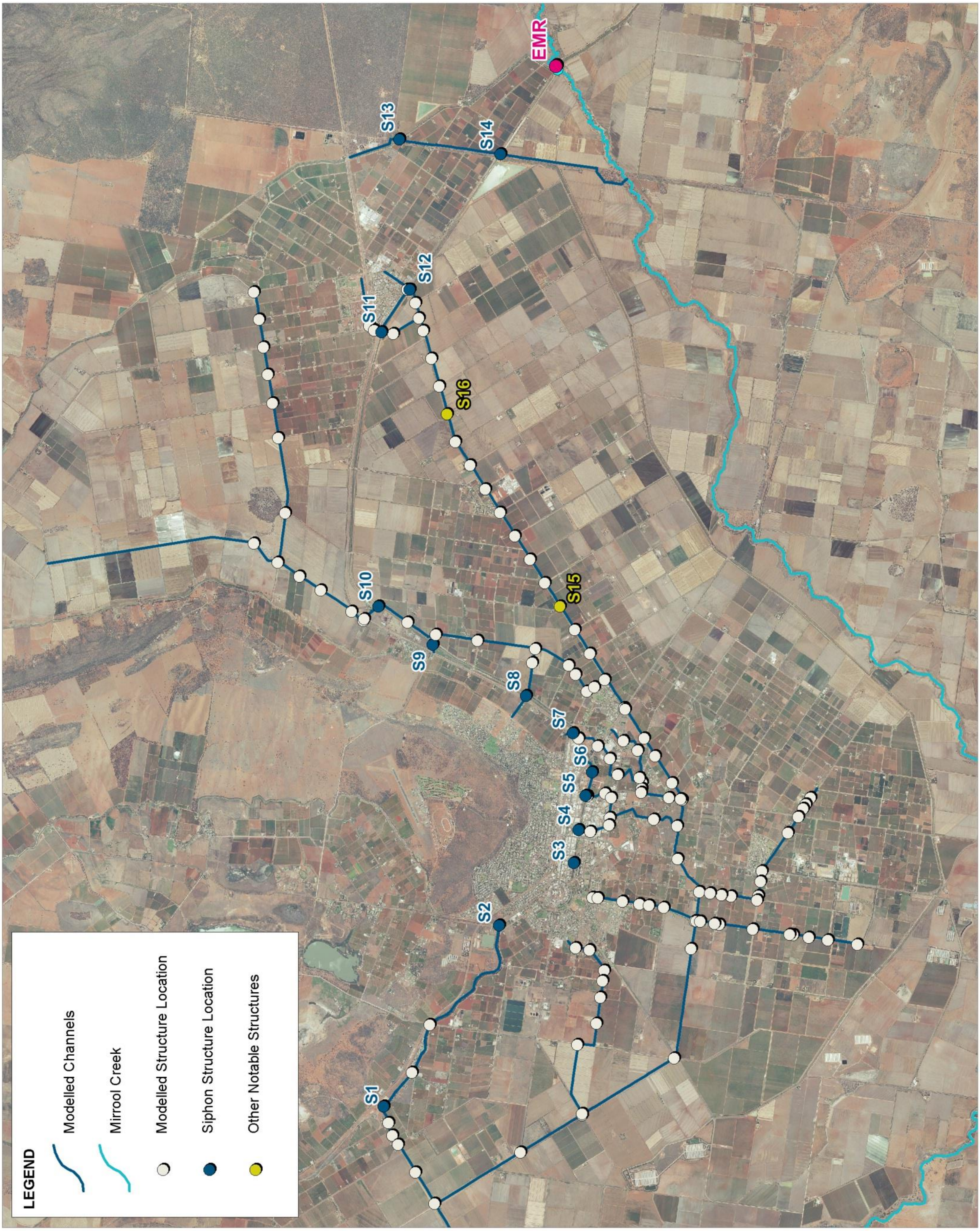


Figure 4-4 Sample Channel Cross Section



Title:

Modelled Structure Locations

Figure: 4-5

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Approx. Scale

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The details of these structures are summarised in Table 4-3. Most of the bridge and culvert structures in the model do not represent a significant flow constriction and so will only have relatively minor affluxes associated with them. Culverts on Main Drain J at Savage Road and Condon Road are an exception and so are also included in Table 4-3.

Table 4-3 Key Hydraulic Structures

ID	Location	Structure
EMR	Mirrool Creek under Main Canal	Five 2.3m x 1.15m box culvert
S1	DC U under Main Canal	Twin 1.2m and twin 0.9m pipe culverts
S2	DC U under Lake View Branch Canal	Twin 1.2m and twin 0.75m pipe culverts
S3	Yambil Street under Main Canal	Twin 1.05m pipe culverts
S4	DC S under Main Canal	Twin 1.8m pipe culverts
S5	DC S Industrial under Main Canal	Twin 1.8m pipe culverts
S6	Piped Industrial under Main Canal	Twin 1.5m pipe culverts
S7	DC 1690 J under Main Canal	Single 1.05m and single 0.45m pipe culverts
S8	DC Collina under Main Canal	Single 1.8m pipe culvert
S9	DC 1677 J under Main Canal	Twin 1.2m pipe culverts
S10	DC North under Main Canal	Triple 1.2m x 1.2m box culvert
S11	Yenda Dredge St West under Main Canal	Twin 1.2m pipe culverts
S12	Yenda Dredge St East under Main Canal	Single 1.2m pipe culvert
S13	DC 1483 MC under Northern Branch Canal	Single 1.2m pipe culvert
S14	DC 1483 MC under Main Canal	Single 1.2m pipe culvert
S15	Main Drain J at Savage Rd	Single 2.75m x 1.85m box culvert
S16	Main Drain J at Condon Rd	Single 2.75m x 2.05m box culvert

The structure dimensions were obtained from the Griffith Flood Study (Water Studies, 1992).

Some of the structures along Main Drain J have been replaced since the Griffith Flood Study and were updated for the representation of the March 2012 flood event and the design flood conditions. These include:

- Four box culverts at Old Willbriggie Road replaced by a clear span bridge structure;
- Four box culverts at Kidman Way replaced by a clear span bridge structure;
- Four box culverts at Murrumbidgee Avenue replaced by a clear span bridge structure;
- Four box culverts at Walla Avenue replaced by a clear span bridge structure;
- Four box culverts at Brogden Road replaced by a clear span bridge structure.

Council has also constructed a new siphon structure under the Main Canal at Ulong Street. This has been incorporated into the hydrological modelling to represent the changed catchment runoff distribution.

4.2.7 Boundary Conditions

The catchment runoff is determined through the hydrological model and is applied to the TUFLOW model as flow vs. time inputs. The flows are applied directly into Main Drain J and the secondary drainage channels. An indicative spatial distribution of these inflows can be observed within the information presented in Figure 4-1. Once the capacity of the drains is exceeded water will spill into the 2D model domain and inundate the surrounding floodplain.

Inflows to the Mirrool Creek system are extracted from the Mirrool Creek catchment model and are applied to the Main Drain J model upstream of the East Mirrool Regulator.

The downstream model limit is on Mirrool Creek immediately upstream of Barren Box Swamp. It has been represented as a fixed water level boundary of 112m AHD, consistent with the peak flood level observed during the March 2012 flood event.

4.3 Mirrool Creek Catchment Model

The Mirrool Creek catchment model is a TUFLOW hydraulic model, which is used principally in a hydrological application, to simulate the catchment response to rainfall inputs. This approach to modelling the Mirrool Creek catchment hydrology was selected due to:

- The significant floodplain storage and attenuation within the catchment; and
- The divergence of floodplain flows in the upstream approach to the East Mirrool Regulator.

These factors would present significant challenges to a traditional hydrological modelling approach and it was considered that using TUFLOW to model the catchment hydrology would provide a better representation of the catchment flood response.

In recent years the advancement in computer technology has enabled the use of the direct rainfall approach as a viable hydrological method. With the direct rainfall method the design rainfall is applied directly to the individual cells of the 2D hydraulic model. The utilisation of the recently developed TUFLOW GPU solver enables catchments as large as that of Mirrool Creek to be simulated relatively quickly.

The Mirrool Creek model covers the entire catchment downstream to Barren Box Swamp, with a model grid resolution of 60m. It was used to generate flood flow hydrographs that were extracted from the results and used as inputs to the Main Drain J catchment hydraulic model.

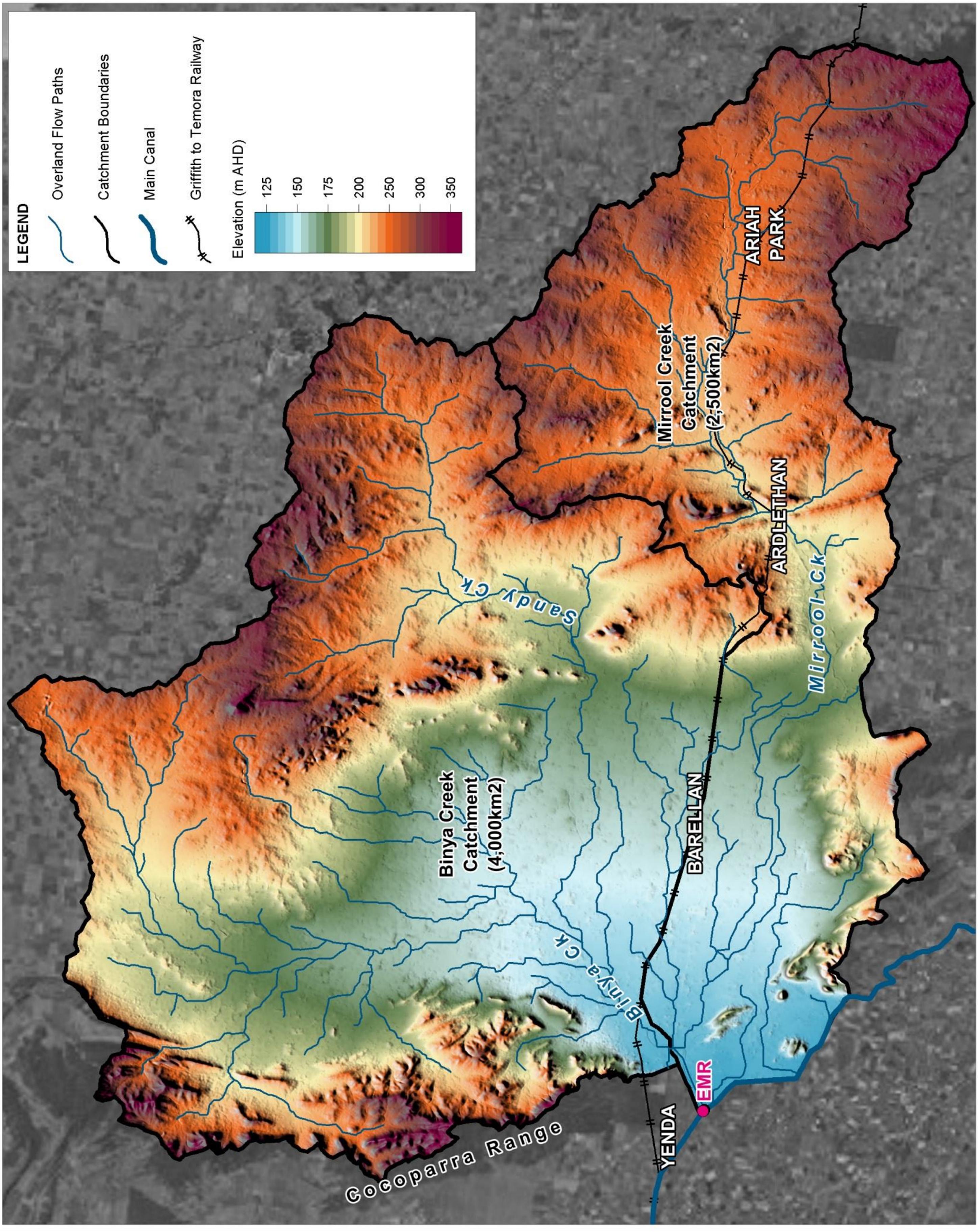
4.3.1 Flow Path Mapping and Catchment Delineation

The Mirrool Creek catchment drains an area of approximately 6,500km^2 to the East Mirrool Regulator, on the Main Canal. The extent of the hydrologic catchment is shown in Figure 4-6.

Flow path mapping and catchment delineation has been undertaken using the CatchmentSIM software. The SRTM DEM was imported into the software and following hydrologic conditioning, flow paths and catchment boundaries were generated.

The delineation of the hydrologic catchment boundary was important for defining the limits of the hydraulic model extent and the associated direct rainfall input. It can be seen from Figure 4-6 that much of the catchment runoff is generated from the upland ranges draining to Mirrool Creek and Sandy Creek.

Additional upland areas contributing to catchment runoff are the eastern slopes of the Cocoparra Range. These steeper upland areas drain into a large and relatively flat expanse, centred around Barellan, in which the main stream alignments are much less well defined.



Title:

Mirrool Creek Catchment Boundary to EMR and Overland Flow Paths

Figure: 4-6

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Approx. Scale

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Within the flat floodplain expanse the Griffith to Temora railway has a significant influence on catchment hydrology. It is elevated above the floodplain and essentially divides the Mirrool Creek floodplain from that of the Binya Creek – Sandy Creek system to the north. The Mirrool Creek catchment is some 2,500km^2 in size and drains to the siphons under the Main Canal at the East Mirrool Regulator. The Binya Creek catchment is some 4,000km^2 in size and drains to Mirrool Creek around 6km upstream of the Main Canal.

4.3.2 Rainfall Data

As for the Main Drain J Catchment hydrological model, the rainfall information is the primary input and driver, which simulates the catchments response in generating surface run-off. Rainfall depth and temporal pattern varies spatially across the catchment and the procedure for defining these is different for historical and design events.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 5. Given the size of the catchment and inherent variability in rainfall across the catchment during any given event, defining appropriate design rainfall conditions is not straightforward. The adopted approach is discussed in Section 0. The catchment rainfall inputs are applied directly to the 2D model grid and are routed through the hydraulic model.

4.3.3 Surface Type Hydrological Properties

The response of the catchment to the input rainfall data is dependent on the spatial distribution and hydrologic properties of the land use surface types. The properties assigned to each surface type (or material) within TUFLOW that influence the hydrologic response of the model are:

- Rainfall losses determine how much rainfall is lost to surface and soil storage etc. and therefore the effective rainfall contributing to surface runoff;
- Roughness parameters govern the speed with which the runoff will travel, influencing the hydrologic response of the model.

The material layers input to the model define these properties for each land use surface type within the catchment. Each material has rainfall losses and a roughness parameter assigned to it. Along with the model topography, it is these parameters which determine the runoff routing and hydrological response of the model.

The continuous infiltration functionality of TUFLOW was incorporated into the Mirrool Creek catchment model. This approach assigns parameters based on soil types, utilising the Green-Ampt methods to determine initial and continuing rainfall losses. This approach was required to adequately represent the continuous losses of the sandy soils, not only for the period during the rainfall event, but also as the flood wave travels through the catchment. Different parameters were assigned for each of the two broad soil types across the catchment, as discussed in Section 8.

4.3.4 Model Topography

For the Mirrool Creek catchment model the base elevation data source is the SRTM DEM-H (hydrologically smoothed), which is a 30m resolution Digital Elevation Model (DEM) derived from the Shuttle Radar Topographic Mission (SRTM). It has been cleaned, filtered for vegetation, smoothed and hydrologically enforced by CSIRO as part of the One-second DEM for Australia project. The ground surface elevation for the TUFLOW model grid points are sampled directly from the DEM. The DEM elevations are presented in Figure 4-6.

4.3.5 Topographic Controls

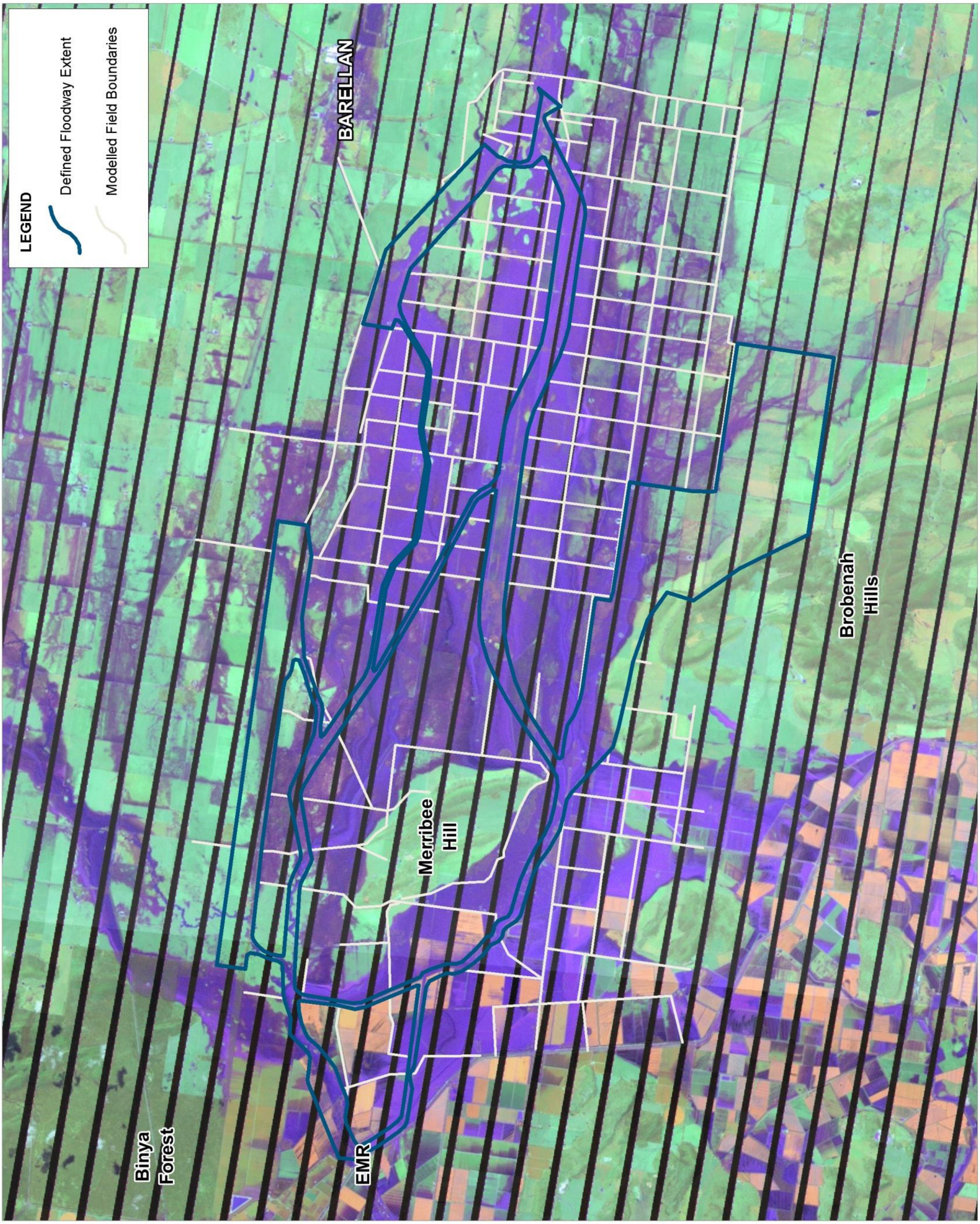
The major topographic controls influencing catchment flood behaviour have been incorporated into the model, including:

- The Main Canal;
- The Northern Branch Canal;
- The Mirrool Branch Canal;
- The Griffith Temora Railway; and
- Barellan field boundaries.

The canals and railway have been input as physical obstructions to the floodplain, preventing cross-drainage. Cross-drainage is provided at the East Mirrool Regulator on Mirrool Creek and through the railway on Binya Creek. This representation enables the model to account for the significant attenuation of the flood flows upstream of the canal infrastructure.

In the Barellan floodplain area there has been a history of uncoordinated construction of embankments and channels to protect the farms. In 1978 a guideline was developed to designate a floodway through the area in which works to influence flood behaviour could not be undertaken. Works outside of the defined floodway were permitted however. On-site observations indicated that field boundaries are typically defined by low earthworks. The influence of these on the flood behaviour is clearly visible within the satellite imagery of the March 2012 event and serves to attenuate the flood wave as it traverses the Barellan floodplain area.

To represent this within the model field boundaries at Barellan have been incorporated as 0.5m high embankments to provide representation of the attenuation throughout the expansive floodplain. The embankments have been excluded from the defined floodway areas. The modelled field boundaries and defined floodway extent are presented on Figure 4-7 alongside the satellite imagery for 4th March 2012.



Title:
Barellan Floodplain Field Boundaries and Defined Floodway Areas

Figure: 4-7

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Approx. Scale

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5 Regional Flood Behaviour

The nature of flooding in the Mirrool Creek catchment is relatively complex in nature. An understanding of the catchment flood behaviour has been built over time through the following sources:

- Analysis of information relating to past flood events;
- Review of previous catchment studies;
- Discussions with the community and other key stakeholders; and
- Flood simulations using the Mirrool Creek and Main Drain J catchment flood models.

The Main Drain J catchment forms part of the broader Mirrool Creek catchment, but the two systems essentially operate independently of one another during flood events. Therefore the analysis of the two catchments is documented separately within this report, in Sections 0 to 8.

This section of the report provides an overview of the flooding mechanisms and behaviour within the Main Drain J and Mirrool Creek catchments. These are then discussed in more detail for the model calibration and design flood considerations in the subsequent sections.

5.1 Mirrool Creek Catchment Flood Behaviour

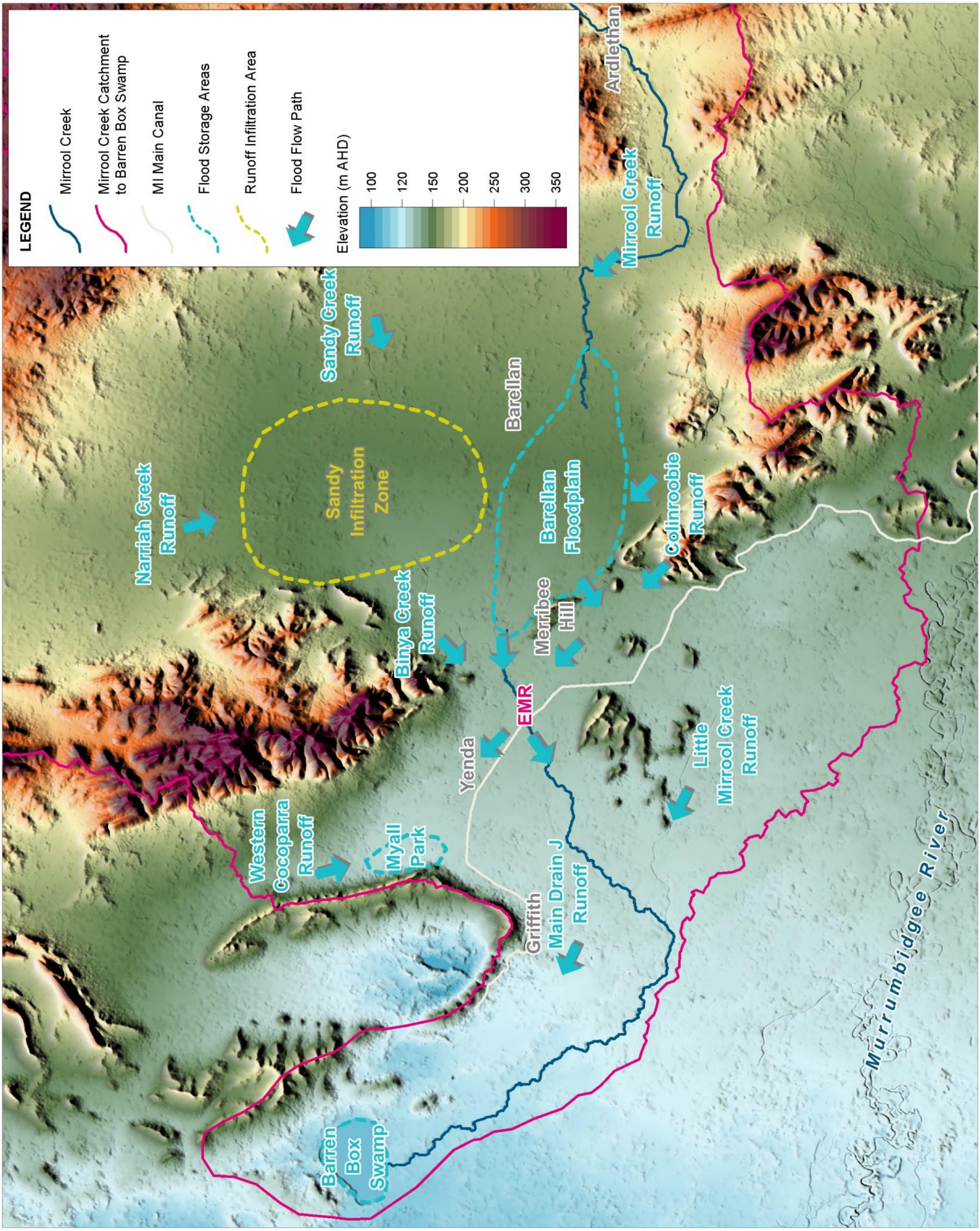
A schematisation of the Mirrool Creek catchment flood behaviour is presented in Figure 5-1. Flooding of Mirrool Creek at the Main Canal is driven by the volume of water entering the Barellan floodplain area. The Barellan floodplain is characterised by flat topography which is criss-crossed by a network of field boundaries and access roads. There is no natural creek alignment through the area, but a defined floodway extent is maintained. The flat topography, coupled with elevated field boundaries, provides significant attenuation of flood flows entering the floodplain area.

The Barellan floodplain is fed by the following sources sources:

- Flows from the upper Mirool Creek catchment, which is well-defined downstream to Ardlethan;
- Local catchment runoff from the Colinroobie area to the south; and
- Rain falling directly on to the floodplain.

Flood flows through the floodplain area are often characterised by a dual response. Rainfall over the Barellan floodplain and Colinroobie produces an early response, which is then followed by a second flood wave from the upper Mirrool Creek (dependant on the rainfall distribution). This was evidenced by the March 2012 flood event. Runoff from the Colinroobie area will typically reach the Barellan floodplain within a day of the rainfall. Flow from the upper Mirrool Creek catchment may take a few days to arrive. Rainfall occurring over specific locations within the catchment at different times will produce a different response, representative of the spatial and temporal rainfall distribution.

When exiting the Barellan floodplain, flood flows can progress both around the north and south of Merribee Hill, along the alignments of Mirrool Creek or the Merribee Station Canal respectively. Runoff from the Colinroobie area will mostly flow around the south of Merribee Hill, whereas Mirrool Creek flows will predominantly proceed around the north of Merribee Hill.



Title:

Schematisation of Mirrool Creek Flood Behaviour

Figure: 5-1

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As flood flows are attenuated through the Barellan floodplain the flood peak is typically reduced and occurs a day later than the flows entering the floodplain.

Flood flows around the north of Merribee Hill proceed to the East Mirrool Regulator along the alignment of Mirrool Creek. Flows around the south of Merribee Hill are impeded by the Main Canal and are pushed north to the EMR. As flood waters build up behind the canal there is the risk of local breaching, as occurred during the March 2012 flood event.

Flood waters arriving at the EMR from the Barellan floodplain are further supplemented by runoff from the Binya Creek catchment. The size of the broader Binya Creek catchment is actually almost twice that of Mirrool Creek. It therefore has the potential to generate much more substantial flood flows than those of Mirrool Creek. However, there is an extensive flat, sandy area to the north of Barellan in which catchment runoff is infiltrated into the soil.

The relatively large catchments of Narriah Creek to the north and Sandy Creek to the east generate significant flood overland flow paths. These then soak away when traversing the sandy infiltration zone. This was observed during the March 2012 flood event and is evident within the associated satellite imagery. Therefore, runoff from the Binya Creek catchment is predominantly driven by local runoff from the southern Cocoparra Range. Binya Creek runoff would typically reach the EMR within a day of the rainfall.

Flood flows from Mirrool Creek will reach the Main Canal at the East Mirrool Regulator. Flood flows around the south of Merribee Hill will spread out behind the Main Canal in the vicinity of Burnt Hill, where they are further attenuated. The flood waters will then progress in a northerly direction towards the East Mirrool Regulator. This interface between the flood wave and the Main Canal presents the possibility of flow transfer across the canal prior to reaching the EMR. There is a siphon structure that feeds the top end of Little Mirrool Creek but this is relatively small. Localised breaching of the canal may also occur such as at Briens Road and Parizotto's during the March 2012 event. Flood flows from Binya Creek will generally be conveyed towards the EMR but there is also the potential for flood waters to be diverted towards the Whitton Stock Route in Binya Forest (bypassing the EMR), particularly when Mirrool Creek is in flood.

Flood waters arrive at the EMR firstly from Binya Creek, followed by runoff from the Colinroobie area and finally from Mirrool Creek, as the flood level begins to rise behind the Main Canal. Flood waters are conveyed to the downstream Mirrool Creek floodplain through the siphon structures and the operation of flood gates to allow flood flows into the canal and then out again through the downstream side. When the capacity of these structures is exceeded then flood waters can spill over the Northern Branch Canal and proceed to the township of Yenda.

Flood waters spilling into Yenda from Mirrool Creek will build up behind the railway before overtopping and progressing into the Myall Park floodplain storage area. The Myall Park storage area is a natural topographic depression that collects runoff from the western slopes of the Cocoparra Range, in what would have historically been a terminal ephemeral wetland. However, the area is now drained by the irrigation infrastructure and is conveyed along Main Drain J and into Mirrool Creek upstream of Barren Box Swamp.

Flooding within the Main Drain J catchment is essentially driven by local runoff from the land situated to west of Yenda, between the Main Canal and Mirrool Creek. The runoff from the western

Cocoparra and flood flows from Mirrool Creek via Yenda are contained within Myall Park and well regulated by the Main Canal and associated siphon structures.

Discharge across the Main Canal at the EMR is supplemented by runoff from the Little Mirrool Creek and Main Drain J catchments and discharges to Barren Box Swamp. It takes some three days or so for the flood wave to travel from the EMR to Barren Box Swamp.

A more detailed analysis of flooding within the Mirrool Creek catchment is presented in Section 8.

The flood behaviour of the broader Main Drain J catchment is discussed in further detail in Section 5.2.

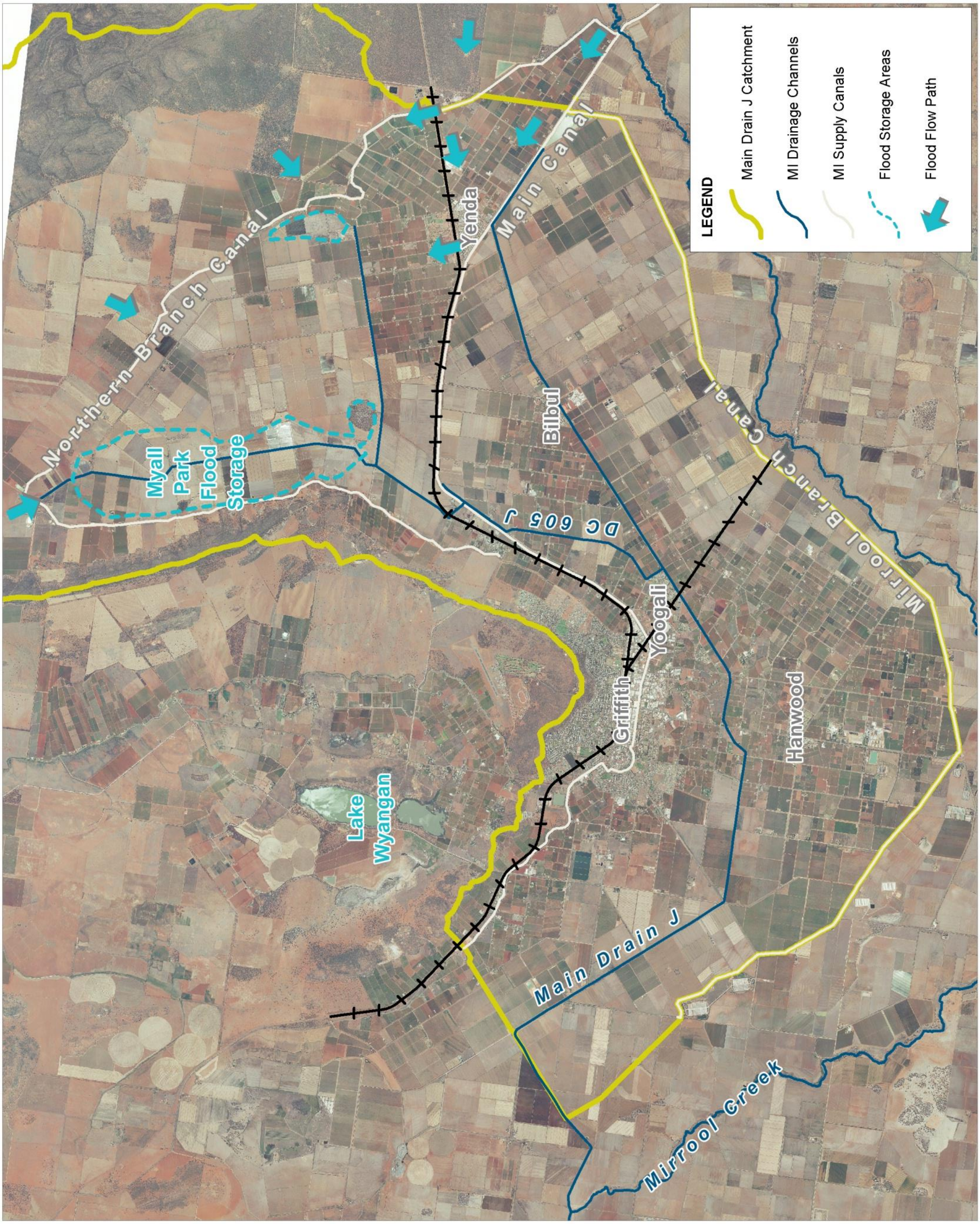
A more detailed analysis of flooding within the Main Drain J catchment is presented in Section 6 and Section 7.

5.2 Main Drain J Catchment Flood Behaviour

A schematisation of the Main Drain J catchment flood behaviour is presented in Figure 5-2. The Main Drain J catchment referred to in this and previous studies, is more accurately described as two separate catchments – one upstream of the Main Canal, draining to Myall Park and one downstream of the canal, draining to Mirrool Creek via Main Drain J. Historically the flood storage area of Myall Park would have been a terminal ephemeral wetland, receiving catchment runoff from the western slopes of the Cocoparra Range. However, the development of the regional irrigation has included a drainage connection from the Myall Park storage through to Main Drain J catchment. Despite this connectivity, the two systems still operate essentially independently in terms of flood behaviour.

The Myall Park flood storage is a natural topographic depression of some 15km^2, that is elevated around 1.5m below the surrounding area. It would have traditionally been an extensive ephemeral wetland prior to the construction of the irrigation drainage. It is the natural receiver of over 300km^2 of catchment, situated between the McPherson and Cocoparra Ranges. The upper catchment areas are now separated from the storage area by the Northern Branch Canal. They are characterised by sandy soils and have significant associated infiltration losses. However, during substantial storm events catchment runoff will be generated and will begin to build up behind the canal, being transferred to the downstream storage through local cross-drainage structures. The canal will be overtopped by flood waters once the available upstream storage capacity is exceeded, as is known to have occurred in the 1931 and 2012 floods.

The peak flood conditions within Myall Park are contributed to by local catchment runoff, Mirrool Creek contributions (if overtopping of the Northern Branch Canal occurs at Yenda) and through continued deep drainage from the sandy soils. Catchment runoff may be expected to peak in the storage some three or four days after the rainfall event. The timing of flood flow contributions from Mirrool Creek (if they occur) is dependent on the rainfall distribution over the upper Mirrool Creek catchment, but would typically peak some 10 days or so following the onset of rainfall. The infiltration of catchment rainfall into the sandy soils is then likely to contribute to the Myall Park storage over a long period of time. During the March 2012 flood event the peak level in Myall Park occurred some two weeks after the rainfall and flood levels in the storage were elevated for over a month.



Title:

Schematisation of Main Drain J Flood Behaviour

Figure: **5-2**

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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Flooding within Main Drain J is driven principally by runoff from the farm drainage in the area bounded by the Main Canal and Mirrool Branch Canal. It is a relatively small catchment (80km^2 to Yoogali and 120km^2 to Hanwood) compared to that of Myall Park and the critical flood conditions are driven by shorter duration storm events. There are additional runoff contributions from the southern slopes of the McPherson Range, which are attenuated to some degree by the Main Canal and associated cross-drainage infrastructure. Flows also enter the system from the Myall Park storage area, but would be restricted to a baseflow contribution during the flood recession, rather than driving the peak flood conditions.

There is no well-defined natural drainage line evident in the catchment topography. The provision of drainage infrastructure has therefore provided capacity above that which naturally existed. Even in large flood events, such as March 2012, the drainage network conveys around 90% of the flood flows.

The most extensive area of out-of-bank flooding occurs between Hanwood and Mirrool Creek. It is typically no more than 0.5m deep and has minimal flow velocities. Additional localised out-of-bank flooding is known to occur, most notably at Yoogali, which is located near the confluence of Main Drain J and DC 605 J. Here flows spilling from DC 605 J are impeded by the railway and are contained by the raised banks of Main Drain J. Flooding can also occur from the local drainage network becoming 'locked' by elevated water levels within Main Drain J, as occurred in March 1989. Out-of-bank flooding is also known to occur around Bilbul.

Flood conditions along Main Drain J would be expected to occur within 12 hours of the onset of the rainfall event. Elevated water level conditions may be maintained for a day or two following the event.

6 Main Drain J Model Calibration

6.1 Selection of Calibration Events

The selection of suitable historical events for calibration of computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

The previous studies of Main Drain J had identified that the March 1989 flood was the only suitable event for model calibration. Since the previous studies have been completed the March 2012 event occurred, causing widespread flooding within the catchment. Given the large magnitude of the March 2012 flood and the extent of available data, this event is also suitable to be used for model calibration purposes. The March 1989 and March 2012 events have therefore been used to calibrate the Main Drain J models. As only two historic events are available for model calibration extensive sensitivity analyses were also undertaken for each event.

6.2 March 1989 Model Calibration

The March 1989 event caused localised flooding throughout the catchment, resulting from local catchment runoff. There was no flood flow contribution from Mirrool Creek. A number of water level gauges were operational during the event and additional peak flood level survey was also captured. This provides a good reference to assess the local catchment response and drainage characteristics.

6.2.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the Mirrool Creek catchment was shown in Figure 2-2 with their respective periods of record shown in Table 2-1. The gauges that best represent rainfall within the Main Drain J catchment are Griffith Airport, Griffith CSIRO, Yenda (Henry Street) and Rankins Springs (Acres). These stations have recorded rainfall depth totals of 103mm, 103mm, 93mm and 71mm respectively for the two day period 14th – 15th March 1989.

The hyetograph for the hourly rainfall record recorded at the CSIRO Hanwood gauge for the March 1989 event is provided in Figure 6-1. The record shows that the storm lasted around 15 hours, during which time around 103mm rainfall depth was recorded. It started in the early hours of 14th March, lasting until the late afternoon. This record has been adopted as the temporal pattern for the catchment rainfall used in the model calibration process.

The spatial variation of rainfall depth for the March 1989 event has been analysed using the recorded daily rainfall totals at rainfall gauges in the vicinity of the Main Drain J catchment. The locations of the rain gauges together with their recorded rainfall depths for the March 1989 event are presented in Figure 6-2. The event rainfall depths were obtained from BoM and are a summation of the recorded rainfall depths for 14th and 15th March. A continuous surface of rainfall depths was interpolated from the point recordings. Rainfall depth contours extracted from this interpolation at 10mm intervals are included on Figure 6-2 to show the spatial variation of total rainfall depths for the March 1989 event across the Main Drain J catchment and the wider region.

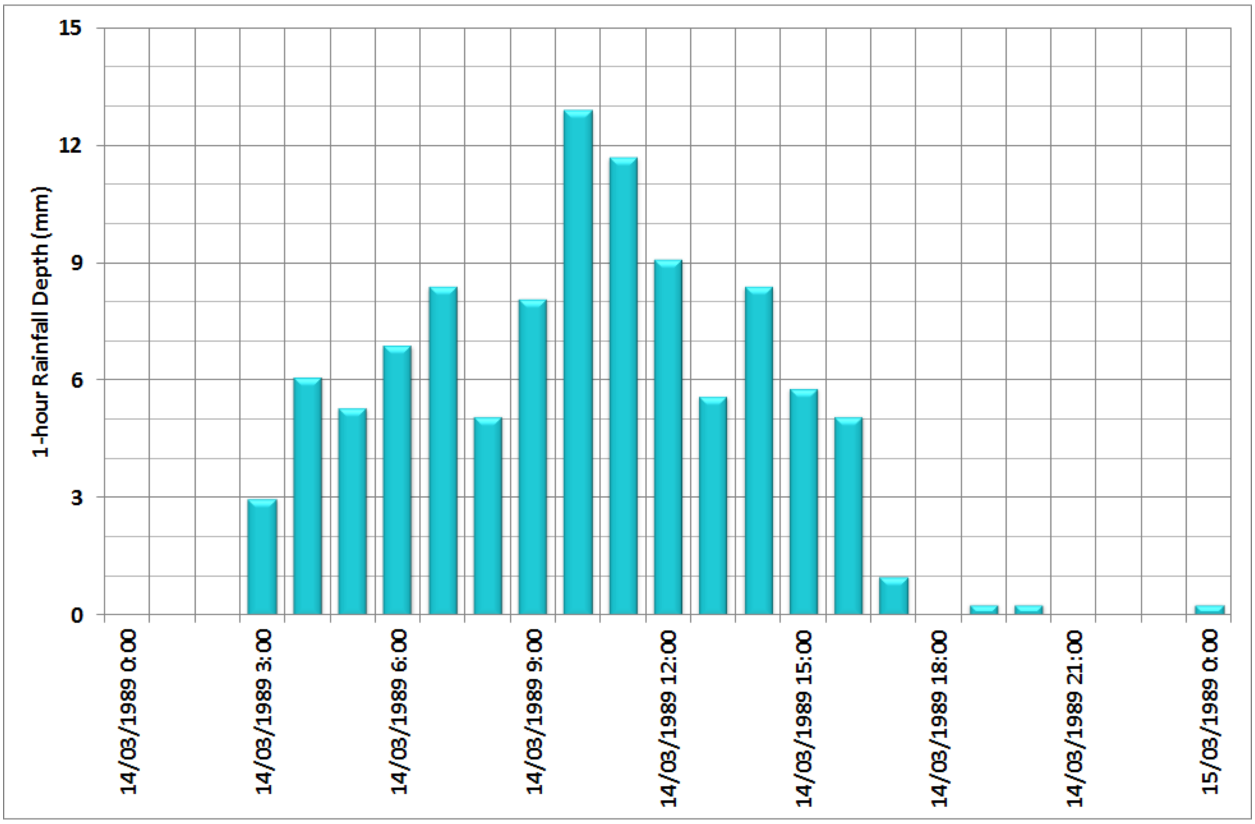
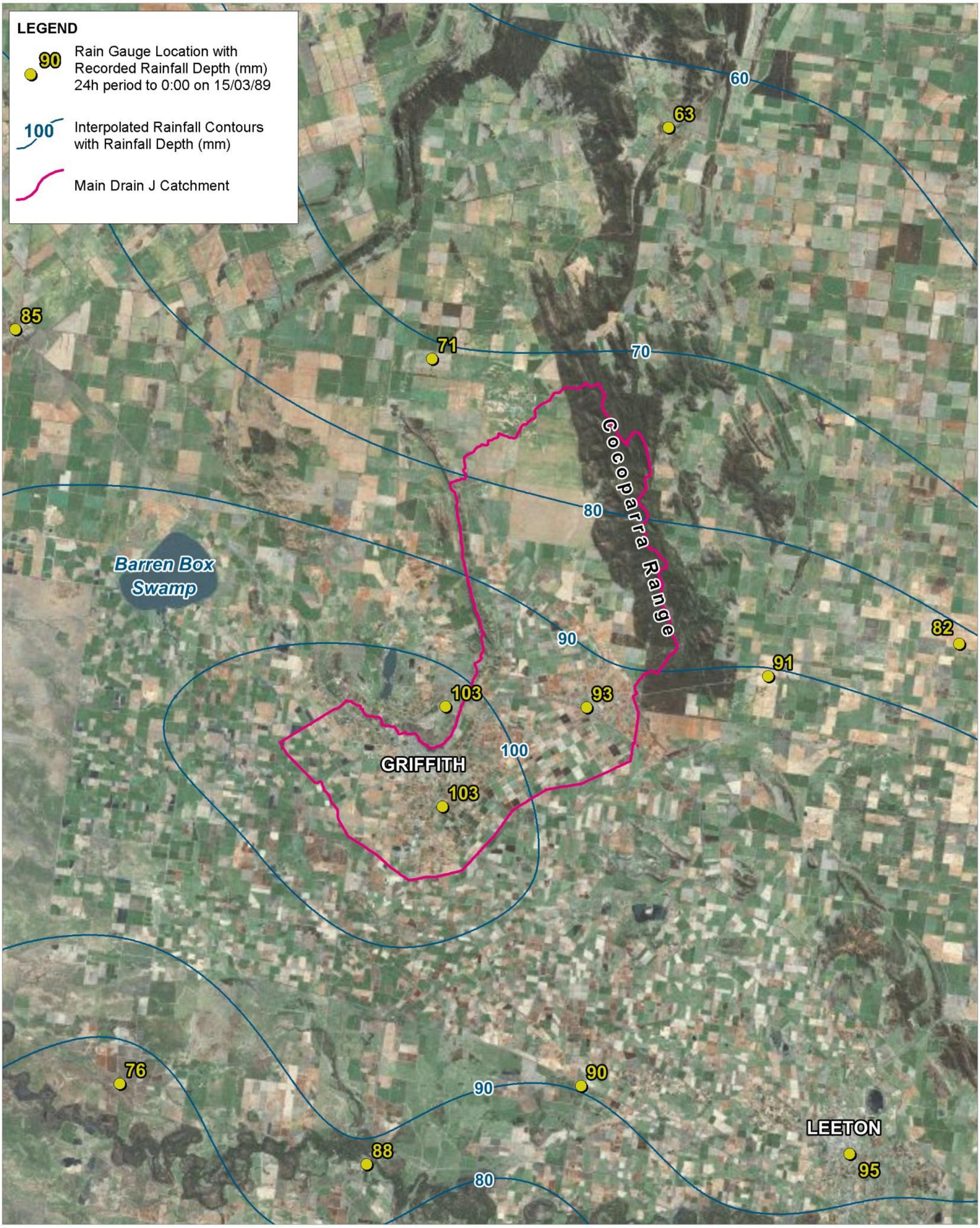


Figure 6-1 1-hour Rainfall Hyetograph for the March 1989 Calibration Event at the CSIRO Gauge

It can be seen from Figure 6-2 that the band of heaviest rainfall is aligned approximately east to west and is situated over the southern end of the catchment. Rainfall depths decrease gradually to the south and more markedly to the north. A rainfall depth of 103mm was recorded at the Griffith CSIRO gauge in the south of the catchment. The rainfall depth reduces in the upper catchment, with a total of 71mm recorded at the Rankins Springs (Acres) gauge to the north. There is a consistent pattern in the recorded rainfall depths and this provides for a good interpolation.

To gain an appreciation of the relative intensity of the March 1989 event, the derived rainfall depths for various storm durations at these two rain gauge locations is compared with the design IFD data for Yoogali as shown in Figure 6-3.

The derived depth vs. duration profile for the March 1989 event from the adopted temporal pattern shows a storm containing no prominent intense rainfall burst. It shows fairly consistent rainfall intensity, with the event steadily increasing in magnitude until a duration of around 14 hours, which is close to the total duration of the event. As a 14-hour duration storm the March 1989 event is equivalent to the design 1% AEP (100-year ARI) rainfall at Yoogali. At the top of the upper catchment at the Rankins Springs (Acres) gauge the magnitude of 14-hour duration rainfall total is closer to a design 5% AEP (20-year ARI) event.



Title:

Spatial Variation of Rainfall Depths for the March 1989 Event

Figure: 6-2

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Approx. Scale

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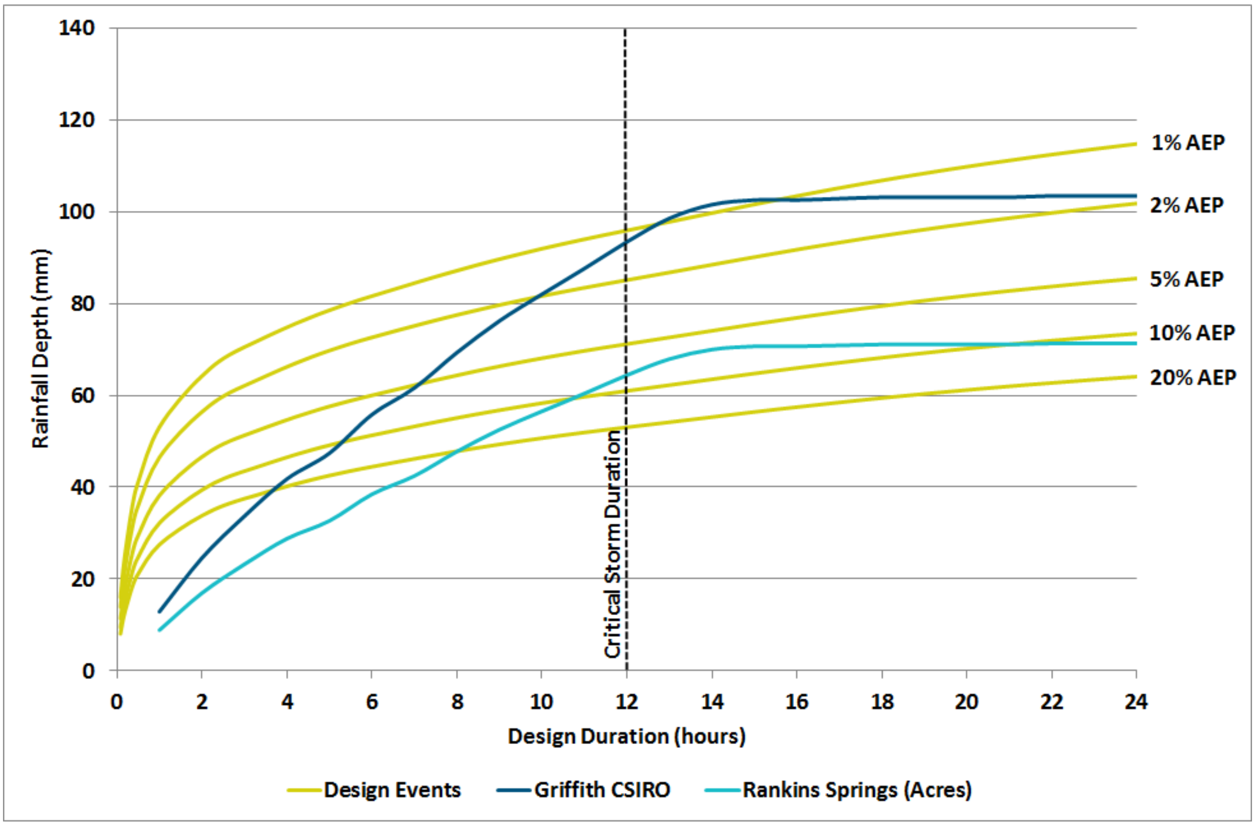


Figure 6-3 Comparison of Derived March 1989 Rainfall with IFD Relationships

6.2.2 Model Roughness Values

One of the key model parameters that influences the flow routing and flood levels in the hydraulic model is the adopted in-channel roughness, or manning's 'n' values. Calibrating manning's 'n' independently of the model inflows can be difficult. However, for the Main Drain J catchment there are three stream gauge locations that provide spot gauging data. These spot gaugings describe the relationship between flows in the drainage channel and the resultant water levels.

A range of in-channel roughness conditions were modelled and rating curves were extracted from the results for comparison with the spot gauging data. This enables appropriate manning's 'n' values to be determined for the drainage channels. The Yoogali gauge recorded continuous water levels between 1982 and 1993, with spot gauging records collected during a similar period. The spot gauging record on Main Drain J at Yoogali is presented in Figure 6-4. Modelled rating curves for a range of manning's 'n' values are also shown for comparison. It can be seen that the spot gauging records indicate that 'n' values between 0.02 and 0.025 are typically representative of the channel condition. A value of 0.025 was adopted for the Main Drain J model, given that the highest gauged flows sit close to the modelled rating curve for an 'n' value of 0.025.

Figure 6-5 shows the modelled rating curve for the adopted manning's 'n' value of 0.025 in Main Drain J at Warburn Escape. Spot gaugings at the site were recorded between 1940 and 1995 and also presented. The distribution of the spot gaugings was originally very noisy. On closer inspection there was a clear distinction between the gauging records collected prior to 1977 and those collected since.

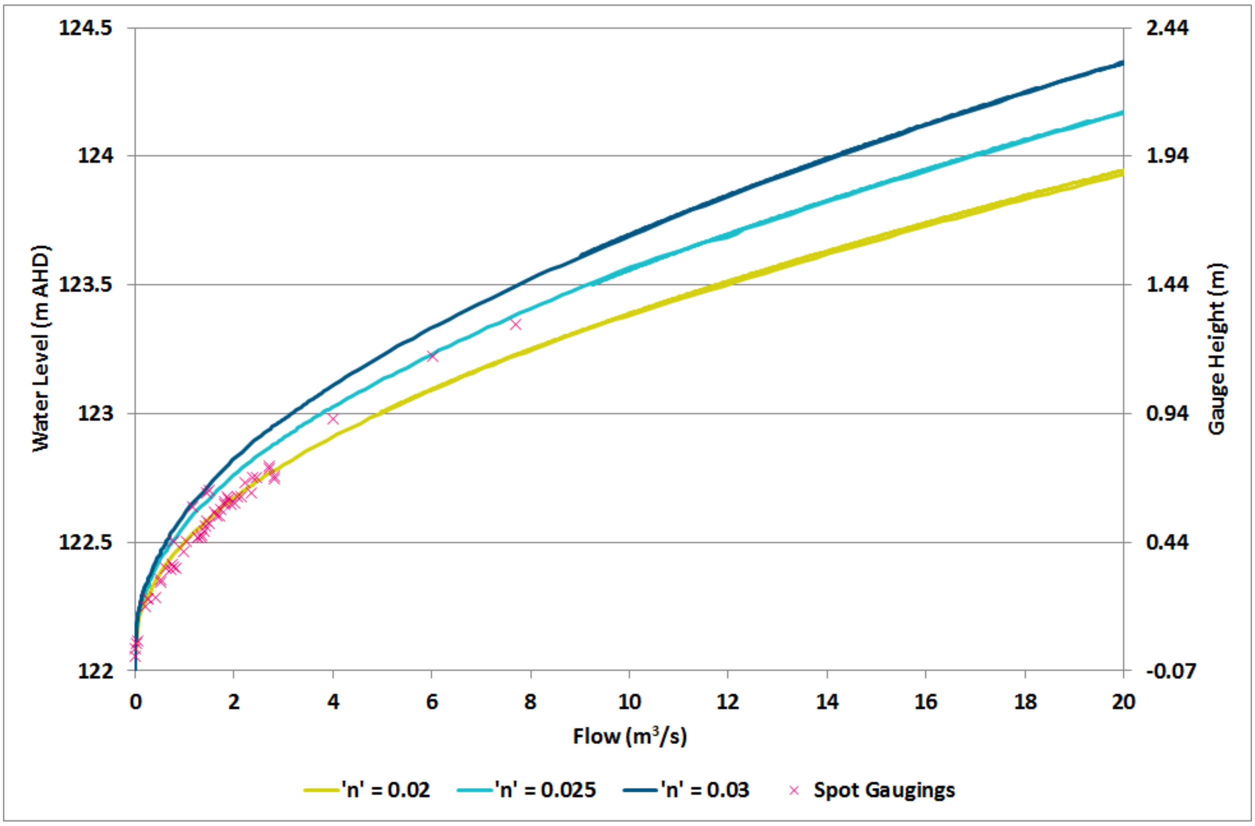


Figure 6-4 Calibration of In-channel Roughness at Yoogali

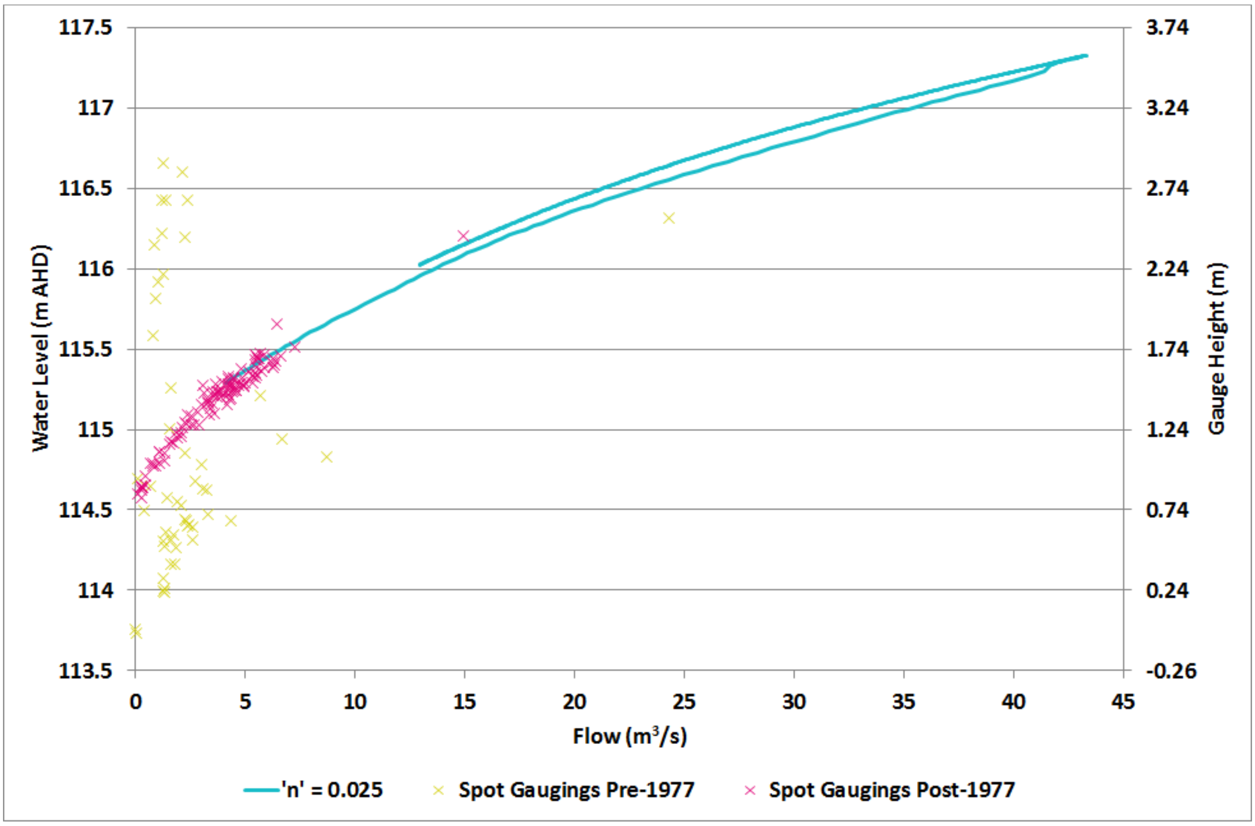


Figure 6-5 Calibration of In-channel Roughness at Warburn Escape

Classification of the spot gaugings into pre-1977 and post-1977 values provides a clearer distribution and is consistent with the adopted modelled rating curve for a manning's 'n' of 0.025.

The other gauge location is on DC S at Watkins Avenue. The water levels at this location are heavily influenced by the downstream tailwater condition in Main Drain J. The modelled rating curve is presented in Figure 6-6. It shows a strong hysteresis effect, with water levels of the rising limb of the flood hydrograph being much lower than those of falling limb. Spot gaugings were recorded between 1982 and 1994. Although there are only a few spot gaugings available at higher flows, they seem to indicate that a manning's 'n' value of 0.025 may be too low at this location. A value of 0.04 was found to provide a better match. However, some level of caution should be applied to this given the possibility of elevated tailwater conditions impacting the spot gauging records.

Inspection of the DC S channel indicates heavier in-channel vegetation than for Main Drain J, which justifies the use of a higher model roughness. Calibration of the water level hydrograph at Watkins Avenue for the March 1989 event (presented in Figure 6-9) provided further justification for using a higher manning's 'n' and therefore a value of 0.04 has been adopted in the model for DC S and the other urban drainage channels, which all exhibit in-channel vegetation.

For the floodplain areas, which are predominantly irrigated agriculture, a representative manning's 'n' value of 0.06 was adopted. This would actually vary seasonally with the cropping, but has a limited impact on the modelled flood behaviour. It is the in-channel roughness values which are more critical.

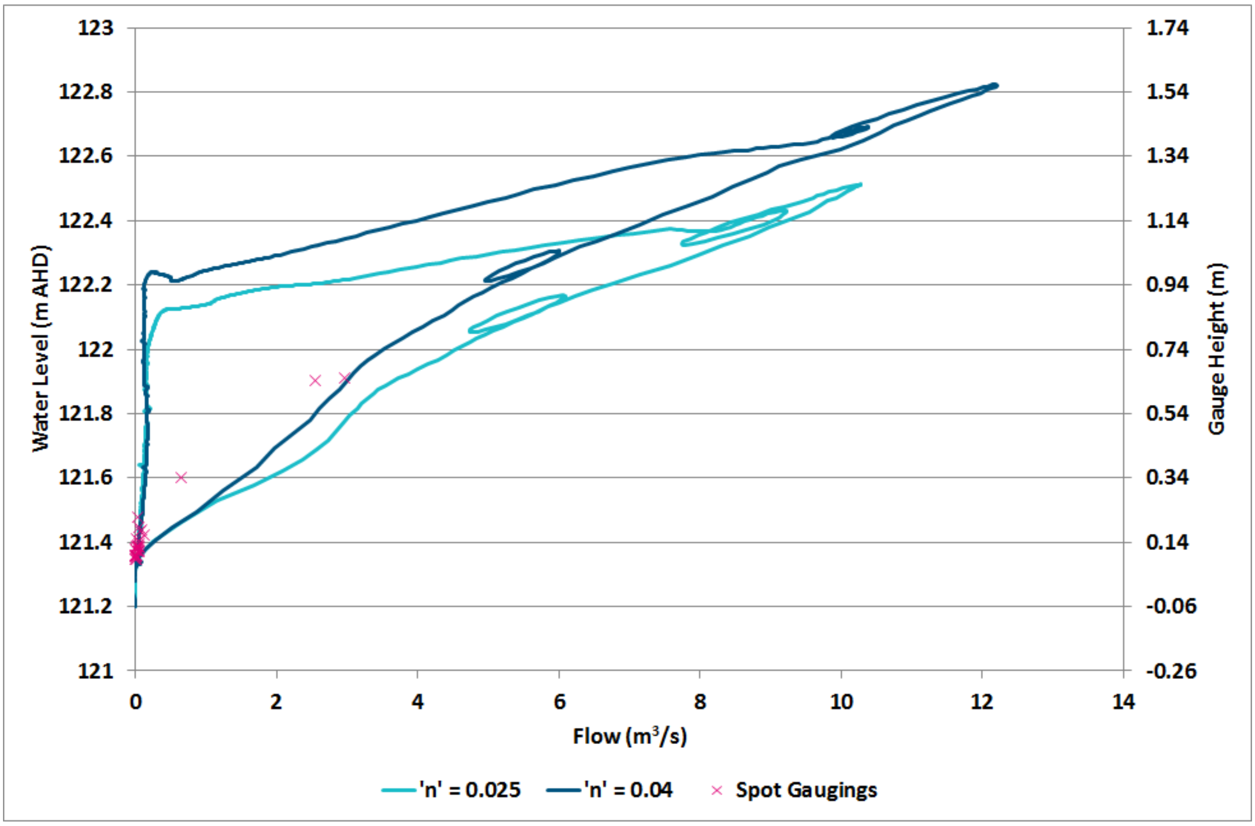


Figure 6-6 Calibration of In-channel Roughness at Watkins Avenue

6.2.3 Rainfall Losses

The assumed rainfall losses are the parameter that has the most significant impact on modelled flood behaviour. The adopted rainfall inputs and rainfall loss model together determine the amount of effective rainfall and subsequent volume of flood waters entering the system. This also has a direct influence on the peak flow rates and flood levels in the modelled drainage channels. With the in-channel roughness calibrated with some level of certainty, the rainfall losses can be altered to derive the correct flow rates required to calibrate modelled flood levels to those which were observed for the event.

The extent of rainfall losses are a function of:

- The catchment soil type and structure;
- The land use within the catchment; and
- The antecedent catchment conditions at the onset of the event.

It is difficult to determine the influence of each of these factors without a large number of calibration events to assess them. For the Main Drain J catchment only two suitable calibration events are available.

The rainfall loss model adopted for this study was the initial loss – continuing loss model. In this model the cumulative rainfall depth must exceed the initial loss value before any runoff occurs. Once the initial loss has been exceeded further losses are calculated at a continuous rate to determine the effective rainfall. The initial and continuing loss values adopted in the RAFTS hydrological model are given in Table 6-1. The continuing loss rate adopted for the natural catchment areas is relatively high and representative of the sandy nature of the soils. Observed flood storage levels in Myall Park for the March 2012 flood event assisted in establishing appropriate continuing loss rates and is discussed in more detail in Section 6.3.2 and Section 8.3.3.

Table 6-1 Adopted Initial and Continuing Losses for RAFTS

Sub-catchment Type	Initial Loss (mm)	Continuing Loss (mm/h)
Impervious Surfaces	5	0
Irrigated Land	15	4
Natural Vegetation	15	8

6.2.4 Irrigation Return Flows

Return flows are the irrigation water that is returned to the drainage channels following application to the irrigated lands. These represent an additional volumetric input to the catchment system as water is transferred from the Murrumbidgee River via the supply canal network and then discharged to the local drainage canal network and into Main Drain J. These return flows represent a significant contribution to base flows during the irrigation season and need to be considered within the flood modelling. During flood events additional flood water will also enter the catchment via the supply canal network.

The stream flow gauge records at Yoogali and Warburn escape were inspected to determine representative return flow contributions during the irrigation season. These were found to be around 2m^3/s (170 ML/day) and 5m^3/s (430 ML/day) at Yoogali and Warburn Escape respectively.

The return flow rates were distributed accordingly to the drainage channels and represent flows additional to those from the hydrological model inputs.

6.2.5 Observed and Simulated Flood Behaviour

For the March 1989 event three stream gauges were operational. This enables the models' representation of the hydrological catchment response to be assessed. The principal location for assessing the model performance is at Yoogali, where flooding is of greatest concern. The modelled water level hydrograph at the Yoogali gauge on Main Drain J is presented in Figure 6-7, along with the water level points recorded at the gauge during the event. The comparison indicates that a good calibration has been achieved. Both the modelled peak flood level and hydrograph shape match well to the observed data. The peak water level of 124.5m AHD corresponds to a peak flow rate of around 26m^3/s (2,200 ML/day)

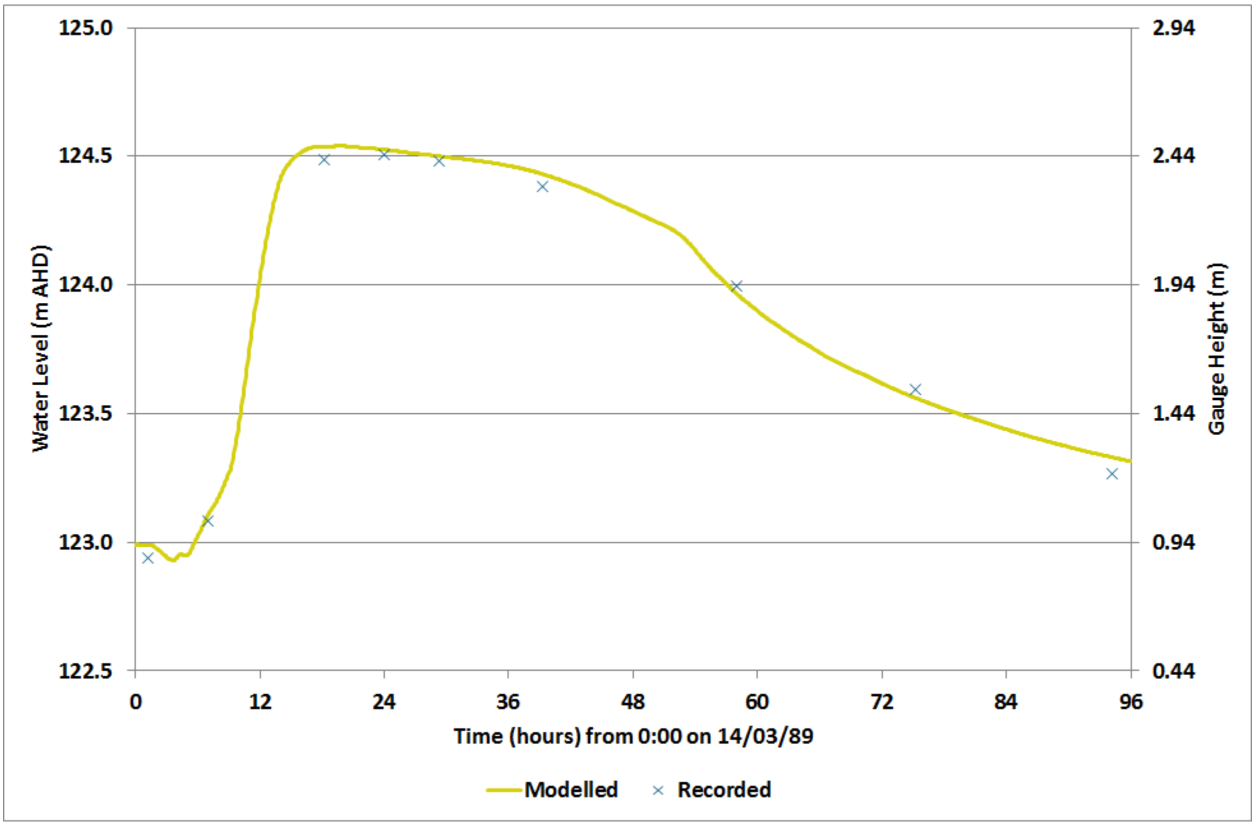


Figure 6-7 March 1989 Modelled Water Level at the Yoogali Gauge

In order to achieve this calibration at Yoogali, Main Drain J flows have had to be retained in-bank between Evans Road and Walla Avenue. Sensitivity testing of hydrological inputs showed that flood levels as high as 124.5m AHD could not be achieved without retaining flows in-bank. Downstream of Yoogali flows were spilling from the channel and into the floodplain storages, limiting peak flood levels to just above the top-of-bank. Discussions with local residents found that MI has been undertaking bank-scraping operations to retrieve the clays from the drainage channel banks. It is therefore likely that sections of channel banks within the DEM are not representative of the conditions during the March 1989 event.

Calibration further downstream at Warburn Escape is still reasonable, as indicated in Figure 6-8. The peak modelled water level of 117.4m AHD corresponds to a peak flow rate of around 43m^3/s (3,700 ML/day) The hydrograph shapes of the modelled and recorded data are comparable, but the flood peak is higher in the modelled hydrograph and more attenuated in the recorded hydrograph. However, the modelled peak flood levels match closely with the flood mark survey upstream of the DC U confluence. This might indicate that during the flood event water was spilling from Main Drain J in the vicinity of the Warburn escape, at a control level of just below 117m AHD. The available elevation data in the LiDAR DEM may not be representative of bank conditions during the March 1989 event at this location. Previous studies had indicated a problem with the recorded data at Warburn Escape during the March 1989 event, in that the flow records were not complete and the peak of the flood was not recorded. The water level records appear to be complete, but are potentially unreliable if they haven't been converted to a flow record.

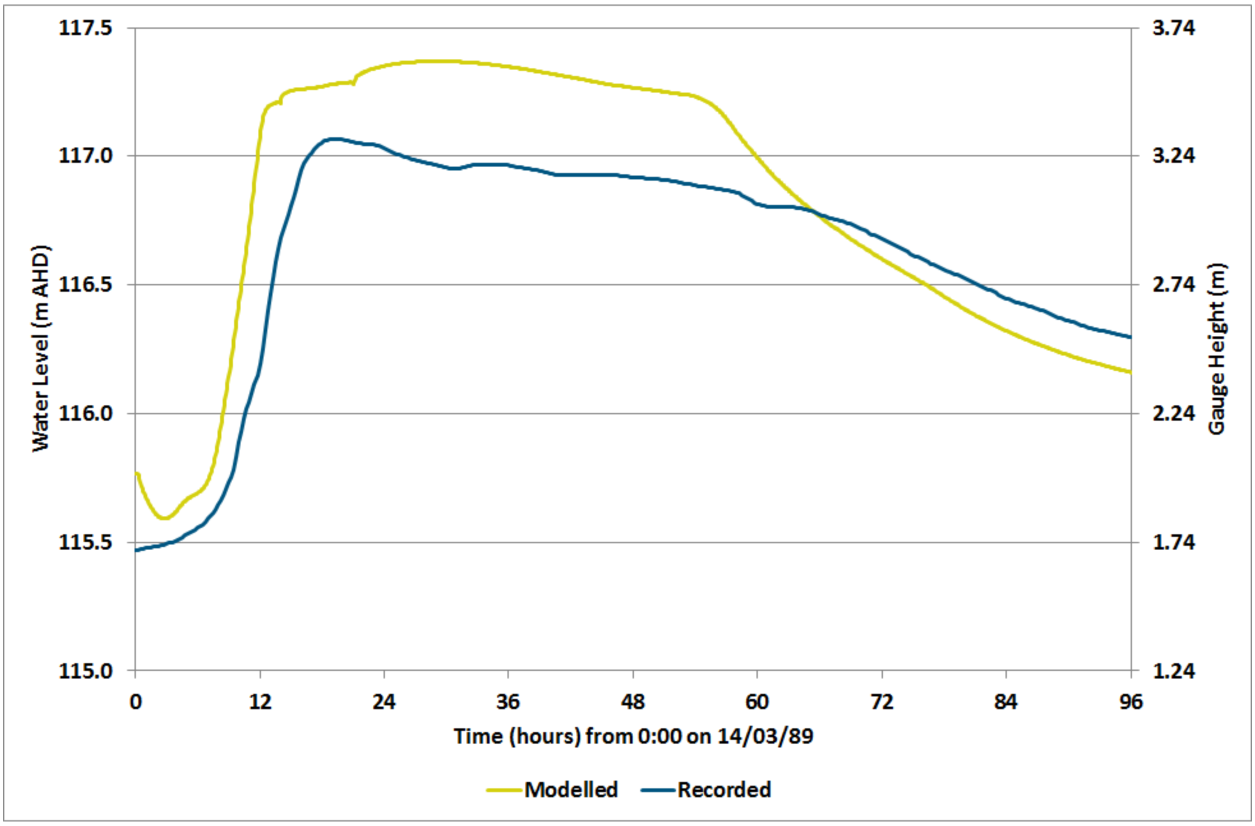


Figure 6-8 March 1989 Modelled Water Level at the Warburn Gauge

The modelled water level hydrograph at the Watkins Avenue gauge on DC 'S' is presented in Figure 6-9, along with the water level points recorded at the gauge during the event. The modelled peak water level of 123m AHD corresponds to a peak flow rate of around 14m3/s (1,200 ML/day). The comparison indicates that a reasonable calibration has been achieved. Both the modelled peak flood level and hydrograph shape of the initial response match well to the observed data. However, the flood recession is under-predicted by the model. This recession is driven by the tailwater condition in Main Drain J and would indicate that the flood levels in Main Drain J are being under-predicted in the DC 'S' reach.

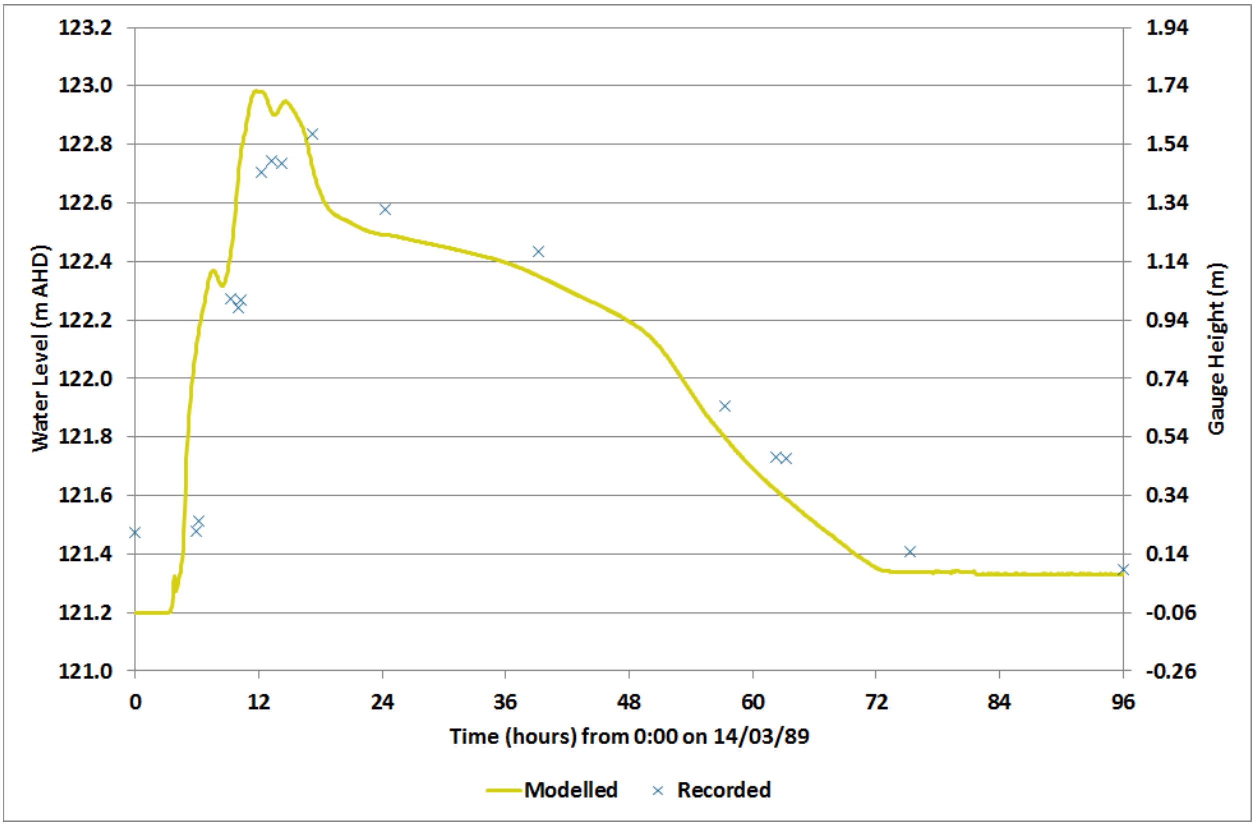


Figure 6-9 March 1989 Modelled Water Level at the Watkins Avenue Gauge

In addition to the stream gauge data extensive flood mark survey was undertaken for the March 1989 event, capturing peak flood levels at bridge structures along the entire length of Main Drain J. These flood marks are presented in Figure 6-10, alongside the modelled peak flood profile along the channel. It shows that the model provides a good representation of the peak flood condition.

A few of the flood marks appear to be questionable, given their inconsistency with the neighbouring survey points. When excluding these the difference between the modelled peak flood levels and the surveyed levels is close to zero, with the majority being within 0.1m. The main area of deviation is at Warburn Escape, where the model is over predicting levels by around 0.3m. This may relate to changes in bank level between the March 1989 event and the acquisition of the LiDAR data in 2004. There is a significant head drop at Savage Road (observed and simulated) due to the restrictive structure (single 2.75m x 2.05m box culvert) and also a local change in bed elevation.

A number of flood photographs for the March 1989 event were made available by Murrumbidgee Irrigation. They were taken on 15th March and represent a flooding condition which is close to the peak, providing a useful comparison with the modelled flood extents shown in Figure 6-11

Figure 6-12 shows flooding at Hanwood, looking north along Kidman Way. It can be seen that the fields south of Beaumonts Road and Hanwood Avenue (across the centre of the picture) are inundated, but the village itself to the north is largely dry, with flooding restricted to Kidman Way. This is similar to the flood extents presented in Figure 6-11.

Figure 6-13 shows flooding to the west of Hanwood, looking north along Crook Road. It can be seen that the fields to the east and west of Crook Road in the foreground of the picture are flooded. Fields west of Crook Road in the middle of the picture are drier, with further inundation to fields close to Main Drain J, towards the back of the picture. This pattern of inundation is matched well by the modelled flood extents in Figure 6-13.

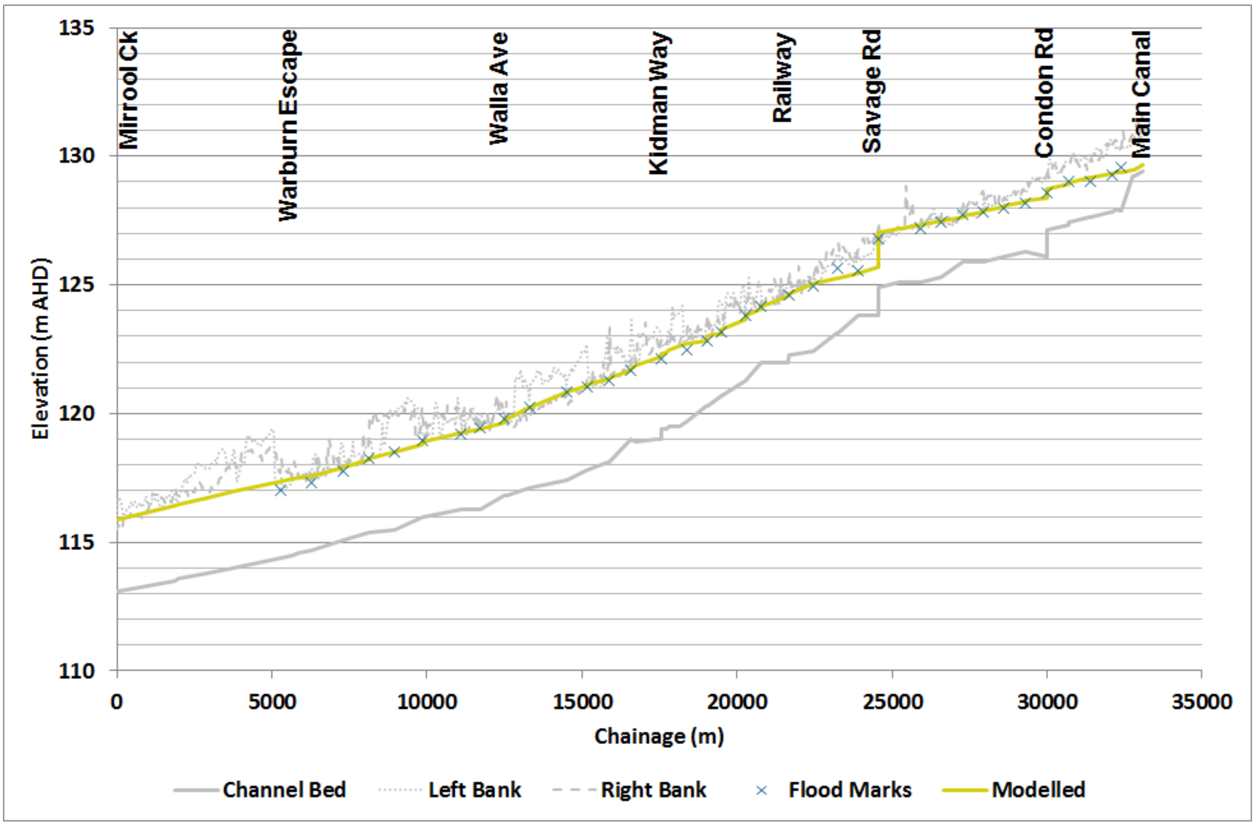


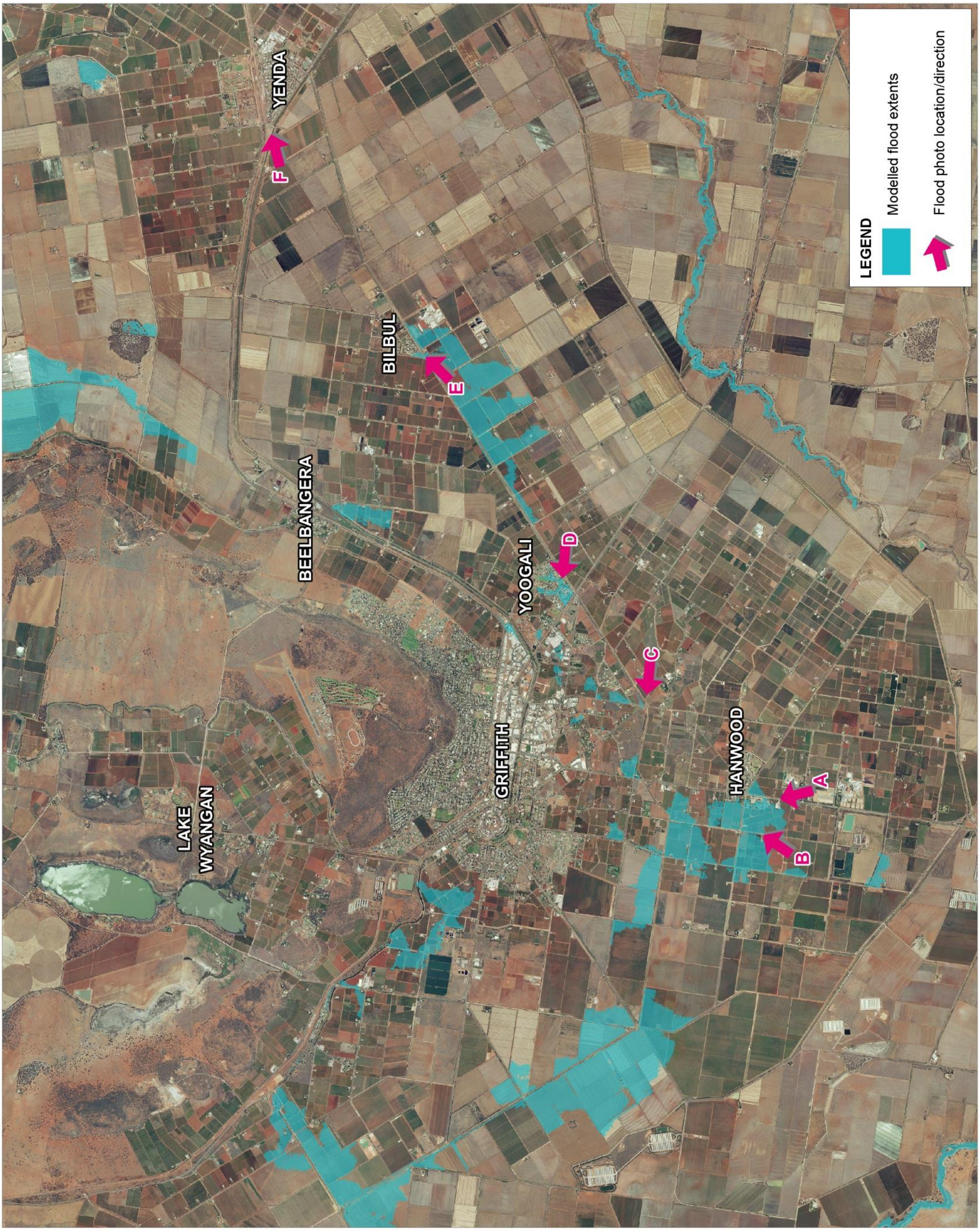
Figure 6-10 March 1989 Modelled Water Level Profile along Main Drain J

Figure 6-14 shows Main Drain J at Old Willbriggie Road, looking west. It can be seen that at this location the flood waters are contained within the channel, with no inundation of the adjacent fields. This is consistent with the flood extents presented in Figure 6-11.

Figure 6-15 shows flooding at Yoogali, looking west towards Mackay Avenue. It can be seen that the western end of the village is flooded. Inspection of the LiDAR DEM against the pictured inundation extent indicates a flood level between 124.6m AHD and 124.7m AHD, which is consistent with the flood mark survey on Main Drain J upstream of Mackay Avenue. This suggests that there was connectivity between Yoogali and the drainage channels through the local stormwater drainage infrastructure. The modelled peak flood level in Yoogali is 124.67m AHD and so the modelled flood extent in Figure 6-11 is similar to that shown in Figure 6-13.

Figure 6-16 shows flooding at Bilbul, looking east along Main Drain J. It can be seen that flood waters appear to be confined largely to the road network, which may have resulted from localised runoff or water backing up the stormwater drainage network. The modelled peak flood level at Bilbul is 127.6m AHD, which is similar to the inundation patterns in Figure 6-16.

Figure 6-17 shows flooding at Yenda, looking east along Burley Griffin Way. It shows extensive flooding, which inspection of the LiDAR DEM indicates is between a level of 130.4m AHD and 130.5m AHD. It is understood through previous investigations the main contributor to March 1989 flooding at Yenda was the blockage of a siphon. The model results shown in Figure 6-11 assume no siphon blockage, a scenario that provides for no flooding in Yenda for this event.



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Modelled Flood Extents for the March 1989 Event

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Figure 6-12 Flooding at Hanwood on 15th March 1989 (Photo A)

Figure 6-13 Flooding at Crook Road on 15th March 1989 (Photo B)

Figure 6-14 Main Drain J at Old Willbriggie Road on 15th March 1989 (Photo C)

Figure 6-15 Flooding at Yoogali on 15th March 1989 (Photo D)

Figure 6-16 Flooding at Bilbul on 15th March 1989 (Photo E)

Figure 6-17 Flooding at Yenda on 15th March 1989 (Photo F)

Given the sensitivity of the local flooding regimes to the performance of the siphon, potential siphon blockages (as contributing to the March 1989 flood inundation) will need to be considered in the Floodplain Risk Management Study.

6.2.6 Sensitivity Analysis

A number of sensitivity tests were undertaken for the March 1989 calibration event model simulations. This was done to identify the level of uncertainty associated with the model results and also to justify the selection of the adopted model parameters. The sensitivity of model results to the flowing parameters was assessed:

- PERN (roughness) value within the hydrological model;
- Continuing rainfall losses within the hydrological model;
- Channel roughness (Manning's 'n') within the hydraulic model; and
- The adoption of channel bank elevations from the LiDAR data.

The PERN value adopted within the RAFTS hydrological model was 0.06 for the irrigated agricultural areas. For the purposes of model sensitivity testing this was varied between 0.05 and 0.07. The results of this sensitivity test at Yoogali are presented in Figure 6-18 and for the length of Main Drain J in Figure 6-19. The results of the sensitivity tests show that the adopted PERN values have only a minor impact on modelled peak flood levels along Main Drain J. The modelled hydrograph shape at Yoogali provides a better match to the recorded data for PERN values of 0.06 or 0.07 and matches less well when adopting a lower PERN value of 0.05.

The continuing loss value adopted within the RAFTS hydrological model was 4mm/h for the irrigated agricultural areas. For the purposes of model sensitivity testing this was varied between 3.5mm/h and 4.5mm/h. The results of this sensitivity test at Yoogali are presented in Figure 6-20 and for the length of Main Drain J in Figure 6-21. The results of the sensitivity tests show that the adopted continuing loss values exert a greater influence on modelled peak flood levels than the adopted PERN. However, the impact is still relatively minor in terms of modelled peak water levels along Main Drain J. The modelled hydrograph shape at Yoogali provides a better match to the recorded data for the adopted continuing loss value of 4mm/h than for continuing loss values of 3.5mm/h or 4.5mm/h.

The Manning's 'n' value adopted for the majority of drainage channels within the TUFLOW hydraulic model was 0.025. For the purposes of model sensitivity testing this was varied between 0.02 and 0.03. The results of this sensitivity test at Yoogali are presented in Figure 6-24 and for the length of Main Drain J in Figure 6-23. The results of the sensitivity tests show that the adopted Manning's 'n' values have a much greater impact on modelled peak flood levels than the adopted PERN or continuing loss. However, the impact is still relatively minor in terms of modelled peak water levels along Main Drain J. The modelled hydrograph shape a Yoogali provides a better match to the recorded data for the adopted Manning's 'n' value of 0.025 than for Manning's 'n' values of 0.02 or 0.03.

The impact of modelling the March 1989 event with the channel bank elevations in the 2004 LiDAR data is presented in Figure 6-24 and for the length of Main Drain J in Figure 6-25. Although the impact on modelled peak flood levels along Main Drain J is relatively minor, the modelled hydrograph shape at Yoogali is significantly improved when raising the bank levels between Evans Road and Walla Avenue, to account for the impact of subsequent bank-scraping activities.

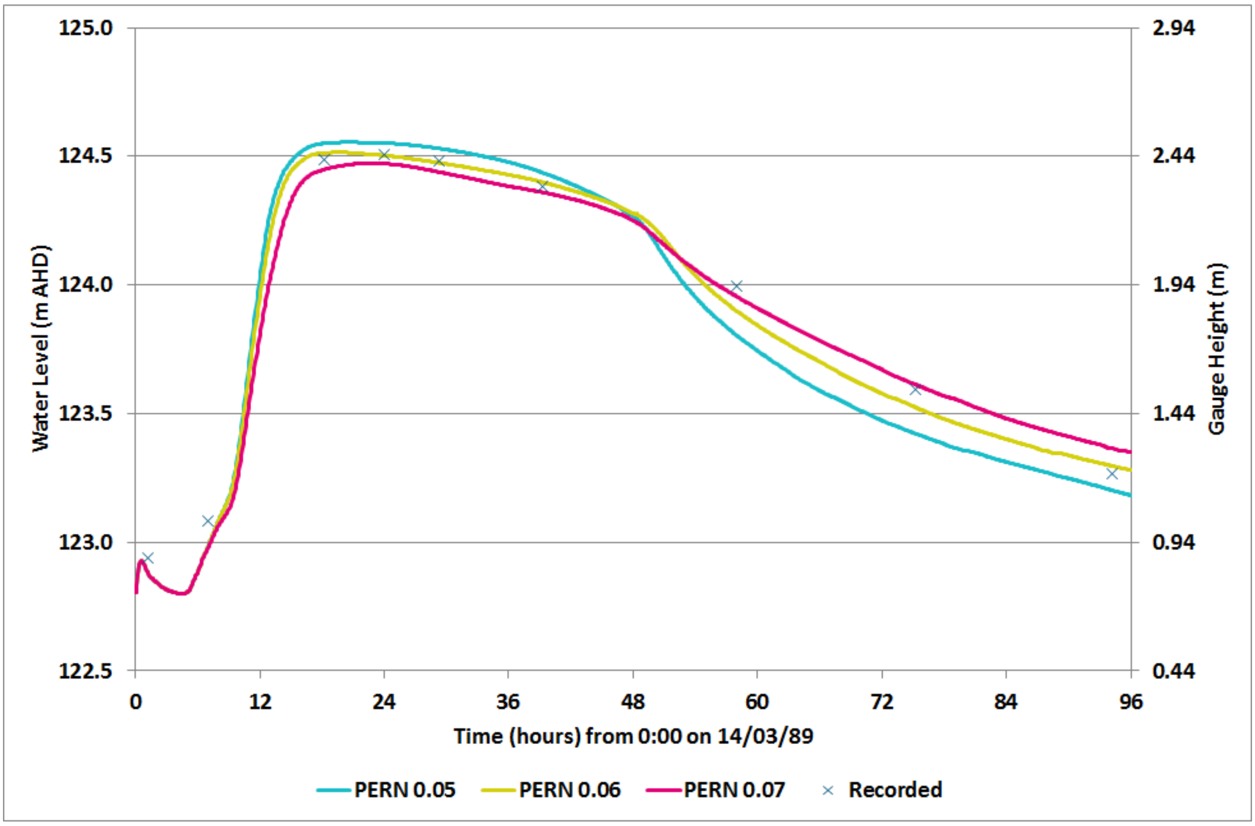


Figure 6-18 Sensitivity of the Modelled Water Level Hydrograph at Yoogali to the Adopted PERN

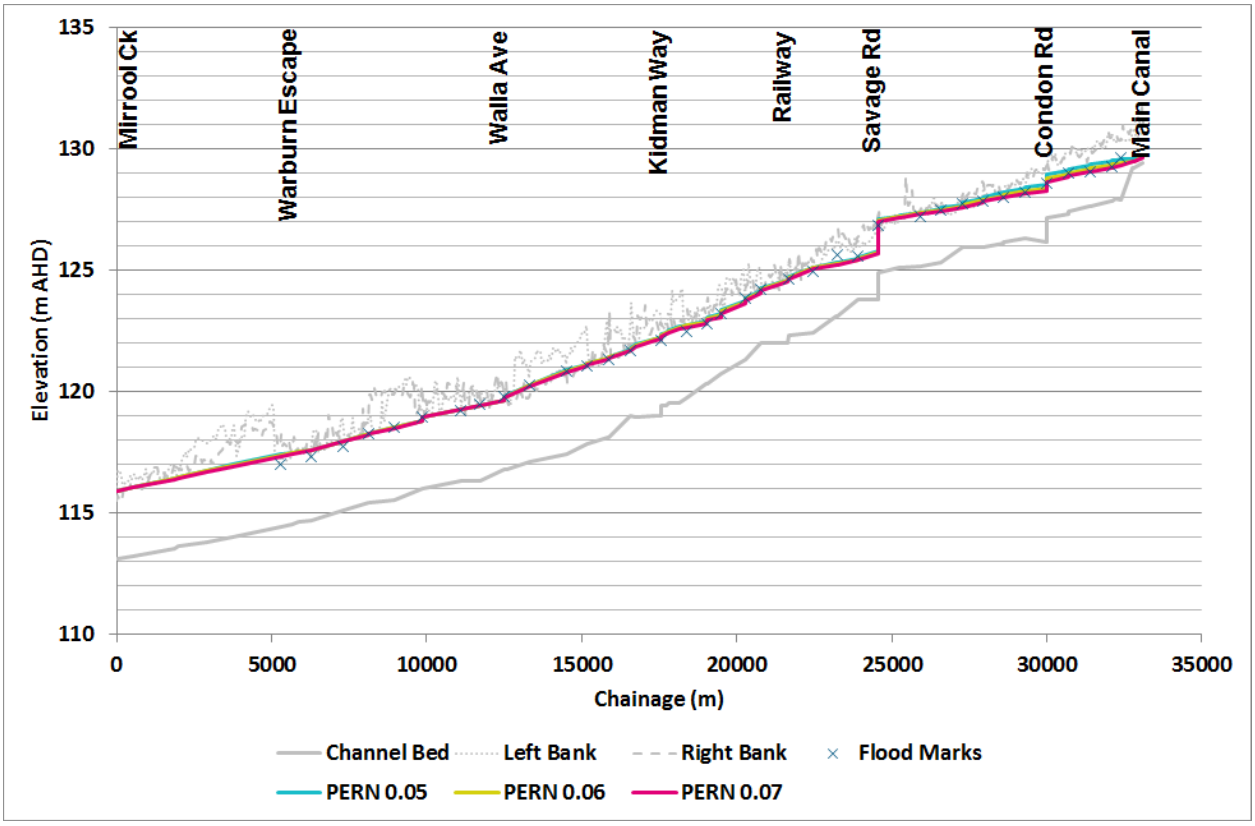


Figure 6-19 Sensitivity of the Modelled Peak Water Level along Main Drain J to the Adopted PERN

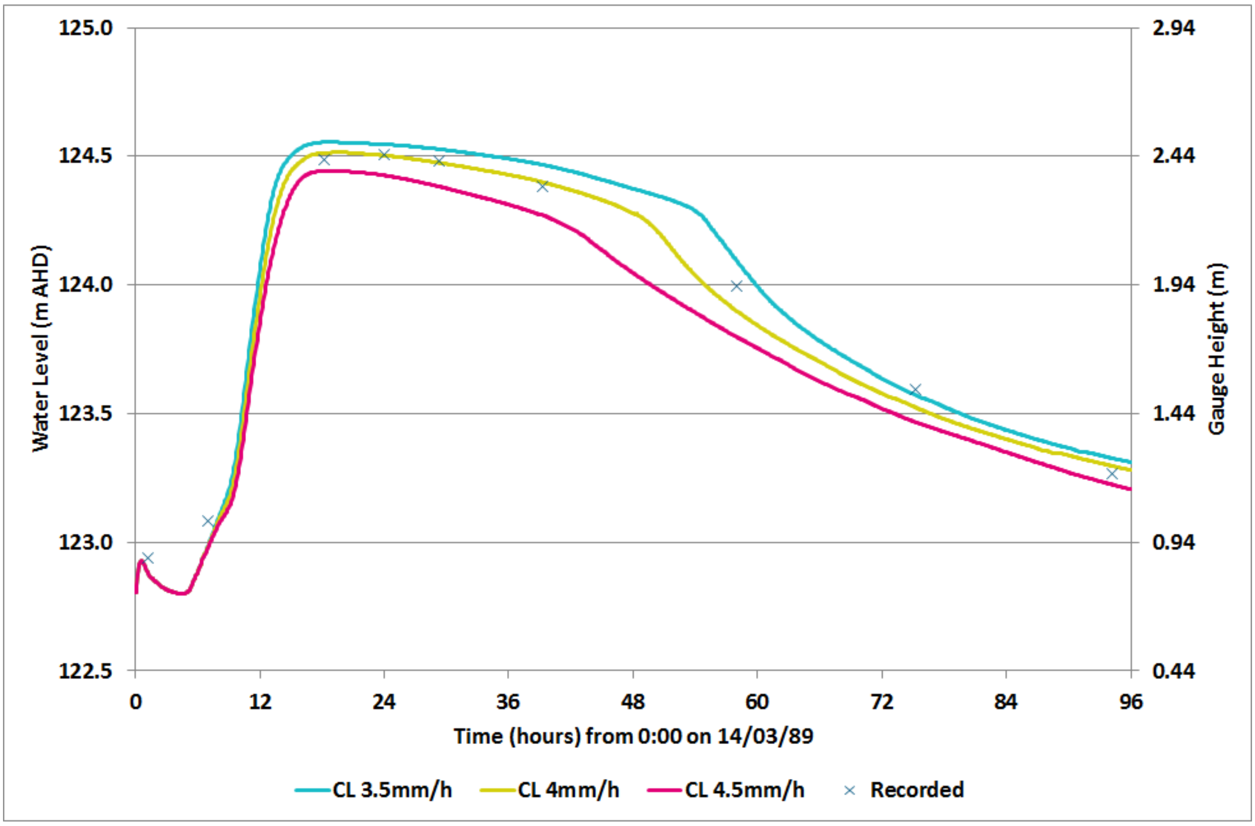


Figure 6-20 Sensitivity of the Modelled Water Level Hydrograph at Yoogali to the Adopted Losses

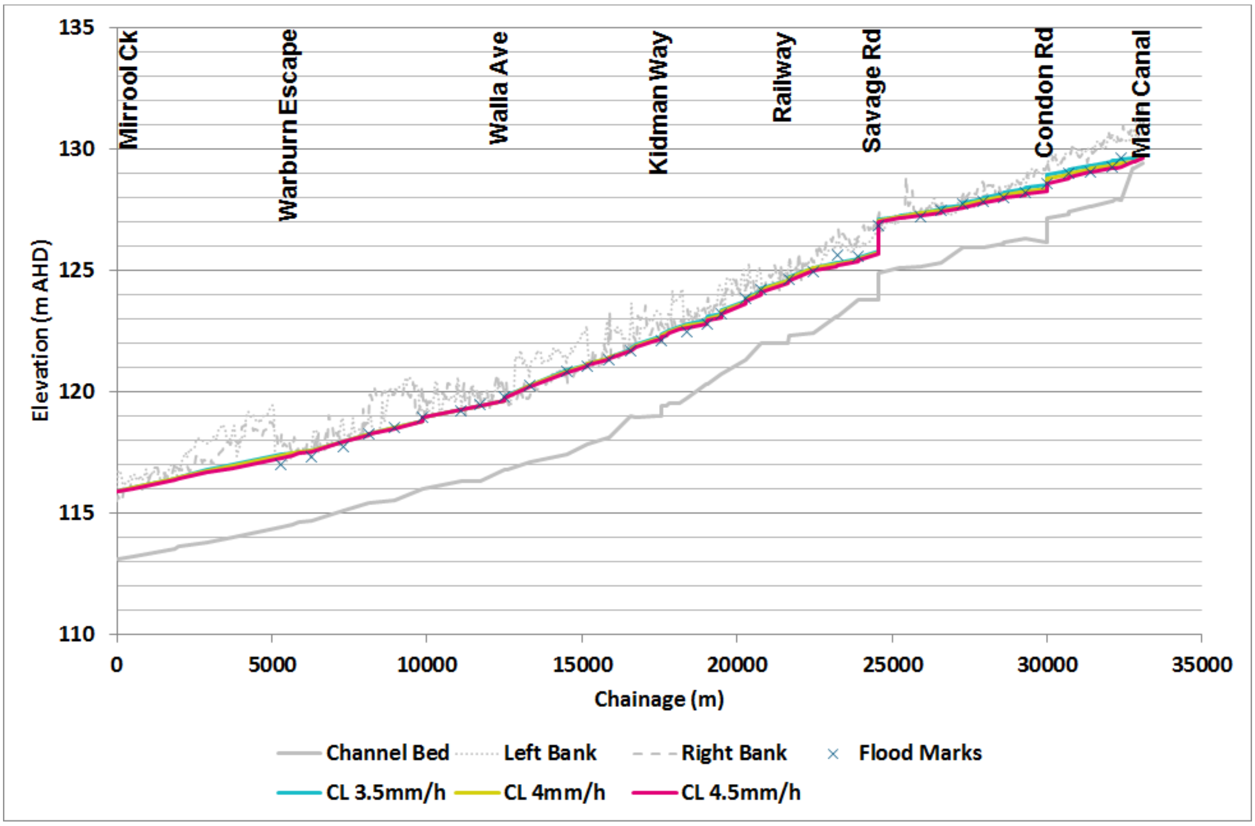


Figure 6-21 Sensitivity of the Modelled Peak Water Level along Main Drain J to the Adopted Losses

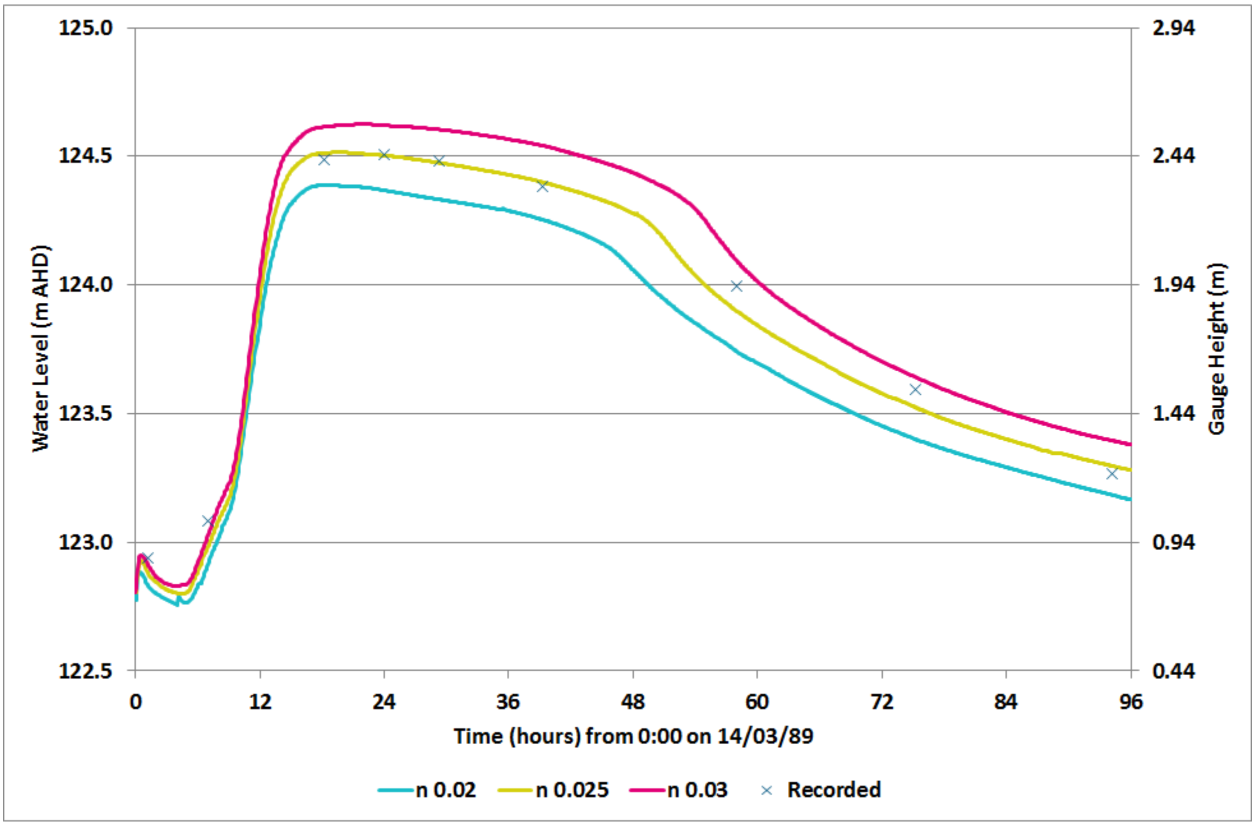


Figure 6-22 Sensitivity of the Modelled Water Level Hydrograph at Yoogali to Channel Roughness

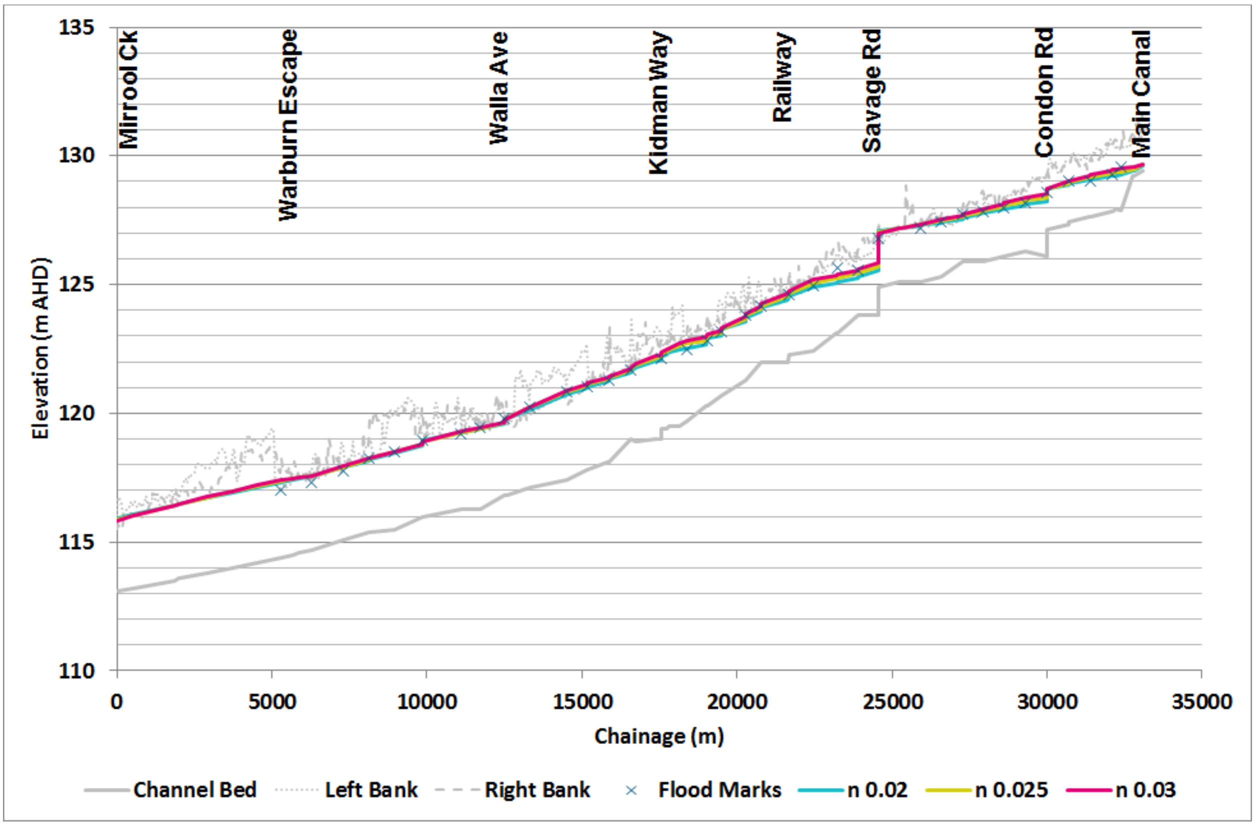


Figure 6-23 Sensitivity of the Modelled Peak Water Level along Main Drain J to Channel Roughness

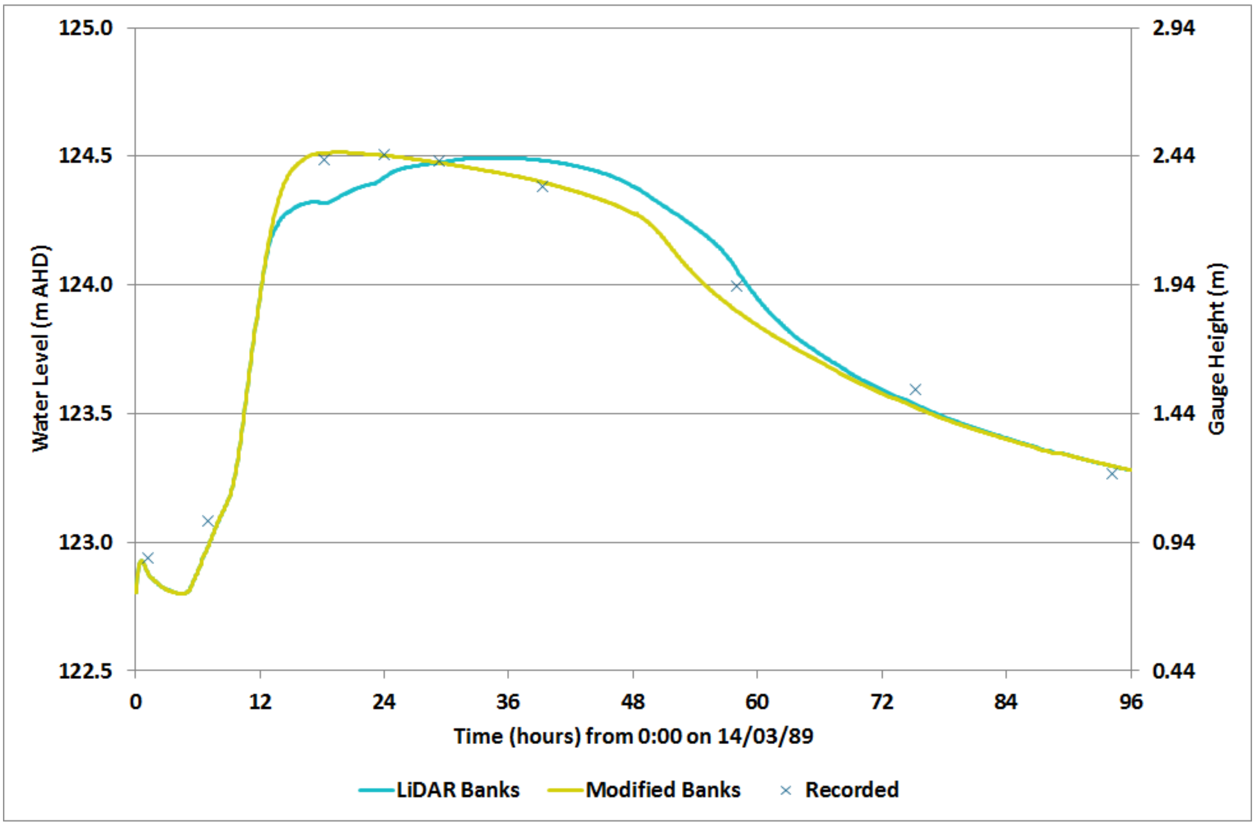


Figure 6-24 Sensitivity of the Modelled Water Level Hydrograph at Yoogali to the Bank Levels

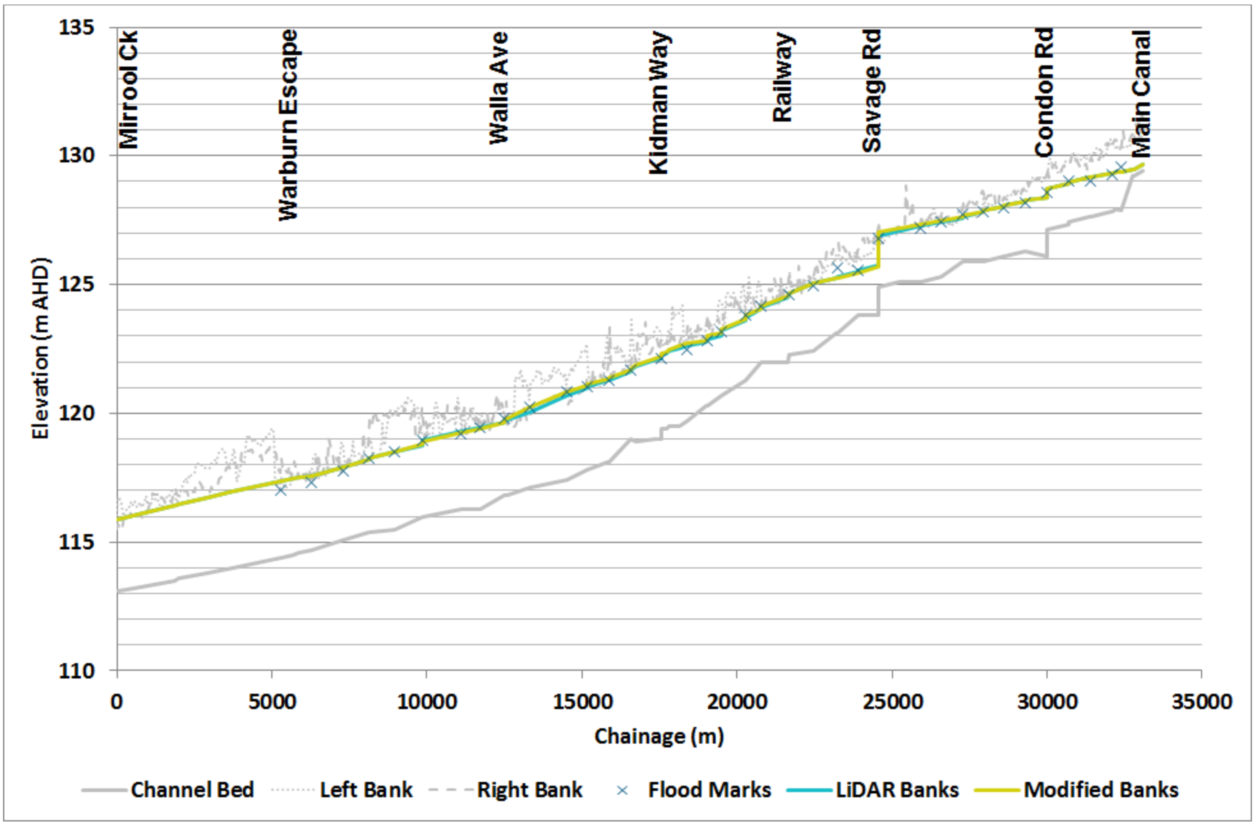


Figure 6-25 Sensitivity of the Modelled Peak Water Level along Main Drain J to the Bank Levels

6.3 March 2012 Model Calibration

The March 2012 event resulted in the worst flooding within the catchment in recorded history. There is less numerical calibration data available than for the March 1989 event, as the stream gauges were no longer in operation. However, a great deal of photographic evidence is available and so the event is well documented. In addition to the local catchment runoff there was considerable flood flow contribution from Mirrool Creek.

The flooding from local catchment runoff and Mirrool Creek essentially functioned as two independent mechanisms. The local catchment runoff initially drove peak flood conditions along Main Drain J. A few days later the flooding from Mirrool Creek then produced the peak flood conditions in Yenda and Myall Park. The only impact of the Mirrool Creek flooding further down the Main Drain J system is through an extended period of elevated base flows.

This section deals only with the flooding from local catchment runoff. Flooding from Mirrool Creek is assessed separately and is discussed in Section 8.

6.3.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the Mirrool Creek catchment was shown in Figure 2-2 with their respective periods of record shown in Table 2-1. The gauges that best represent rainfall within the Main Drain J catchment are Griffith Airport, Griffith CSIRO, Yenda (Henry Street) and Rankins Springs (Acres). These stations have recorded rainfall depth totals of 147mm, 135mm, 149mm and 121mm respectively for the two day period 3rd – 4th March 2012.

The hyetograph for the hourly rainfall record recorded at the Griffith Airport gauge for the March 2012 event is provided in Figure 6-26. The record shows that the storm lasted around 21 hours, during which time around 142mm rainfall depth was recorded. It started in the morning of 3rd March, lasting until the early hours of 4th. This record has been adopted as the temporal pattern for the catchment rainfall used in the model calibration process.

The spatial variation of rainfall depth for the March 2012 event has been analysed using the recorded daily rainfall totals at rainfall gauges in the vicinity of the Main Drain J catchment. The locations of the rain gauges together with their recorded rainfall depths for the March 2012 event are presented in Figure 6-27. The event rainfall depths were obtained from BoM and are a summation of the recorded rainfall depths for 3rd and 4th March. A continuous surface of rainfall depths was interpolated from the point recordings. Rainfall depth contours extracted from this interpolation at 20mm intervals are included on Figure 6-27 to show the spatial variation of total rainfall depths for the March 2012 event across the Main Drain J catchment and the wider region.

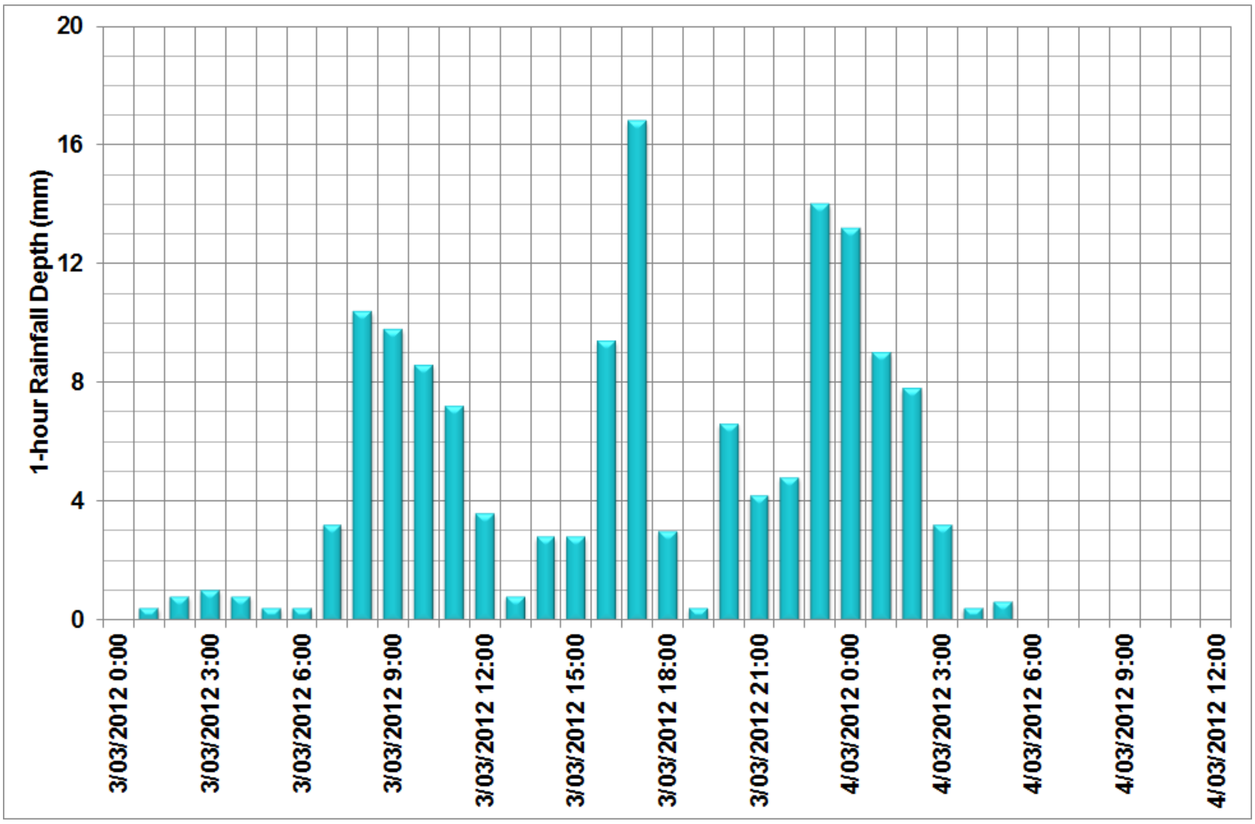
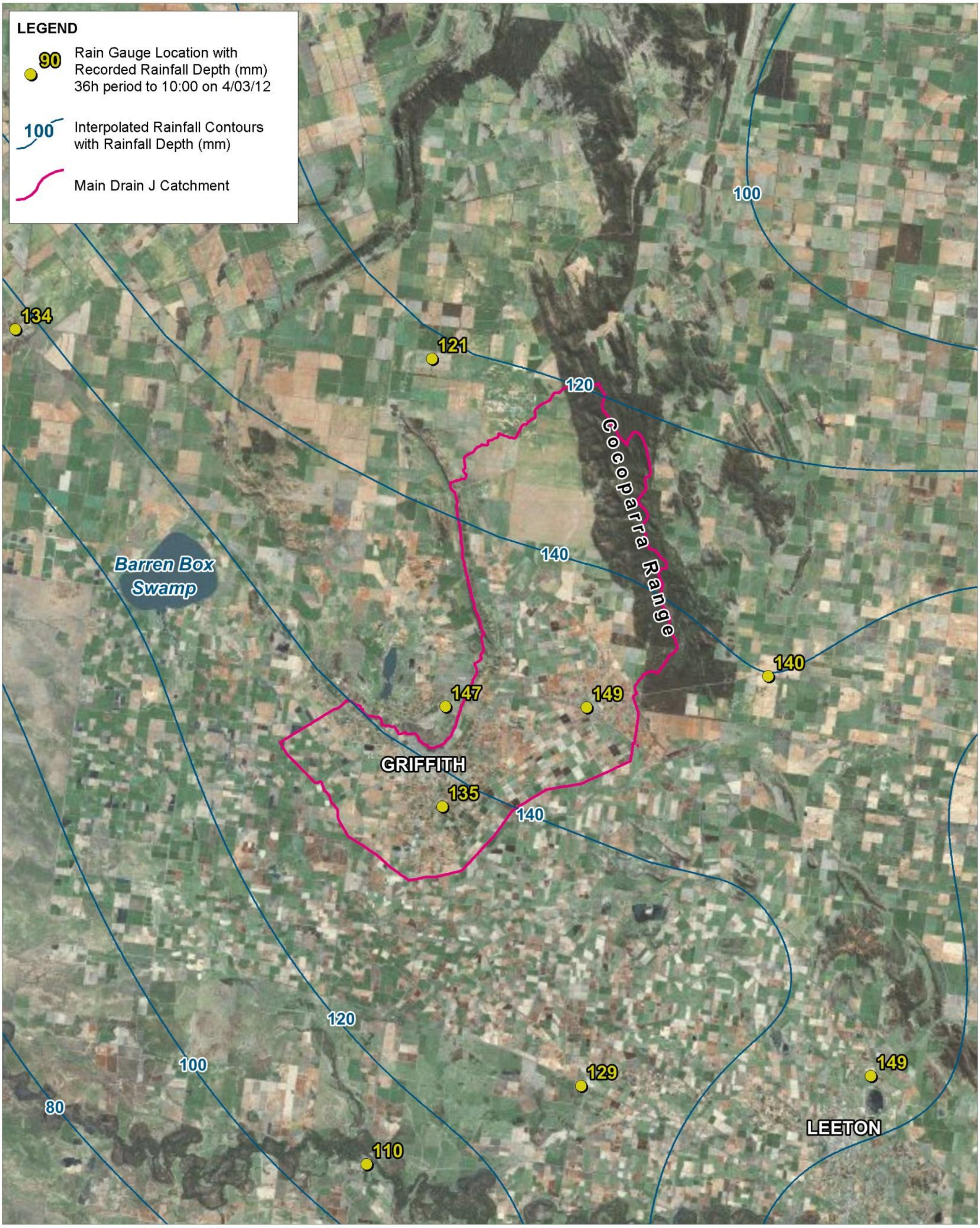


Figure 6-26 1-hour Rainfall Hyetograph for the March 2012 Calibration Event at the Airport Gauge

It can be seen from Figure 6-27 that the band of heaviest rainfall is aligned approximately north-west to south-east and is situated over the middle of the catchment. Rainfall depths decrease gradually to the north-east and more markedly to the south-west. A rainfall depth of 149mm was recorded at the Yenda (Henry Street) gauge in the middle of the catchment. The rainfall depth reduces in the upper catchment, with a total of 121mm recorded at the Rankins Springs (Acres) gauge to the north. There is a consistent pattern in the recorded rainfall depths and this provides for a good interpolation.

To gain an appreciation of the relative intensity of the March 2012 event, the derived rainfall depths for various storm durations at these two rain gauge locations is compared with the design IFD data for Yoogali as shown in Figure 6-28.

The derived depth vs. duration profile for the March 2012 event from the adopted temporal pattern shows a storm containing distinct rainfall bursts. Over a 12-hour to 15-hour duration the March 2012 event is equivalent to the design 1% AEP (100-year ARI) rainfall at Yoogali. At the top of the upper catchment at the Rankins Springs (Acres) gauge the magnitude is still greater than a design 5% AEP (20-year ARI) event. Over an 18-hour to 24-hour duration the March 2012 event is equivalent to the design 0.2% AEP (500-year ARI) rainfall at Yoogali. At the top of the upper catchment at the Rankins Springs (Acres) gauge the magnitude is still greater than a design 1% AEP (100-year ARI) event.



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Spatial Variation of Rainfall Depths for the March 2012 Event

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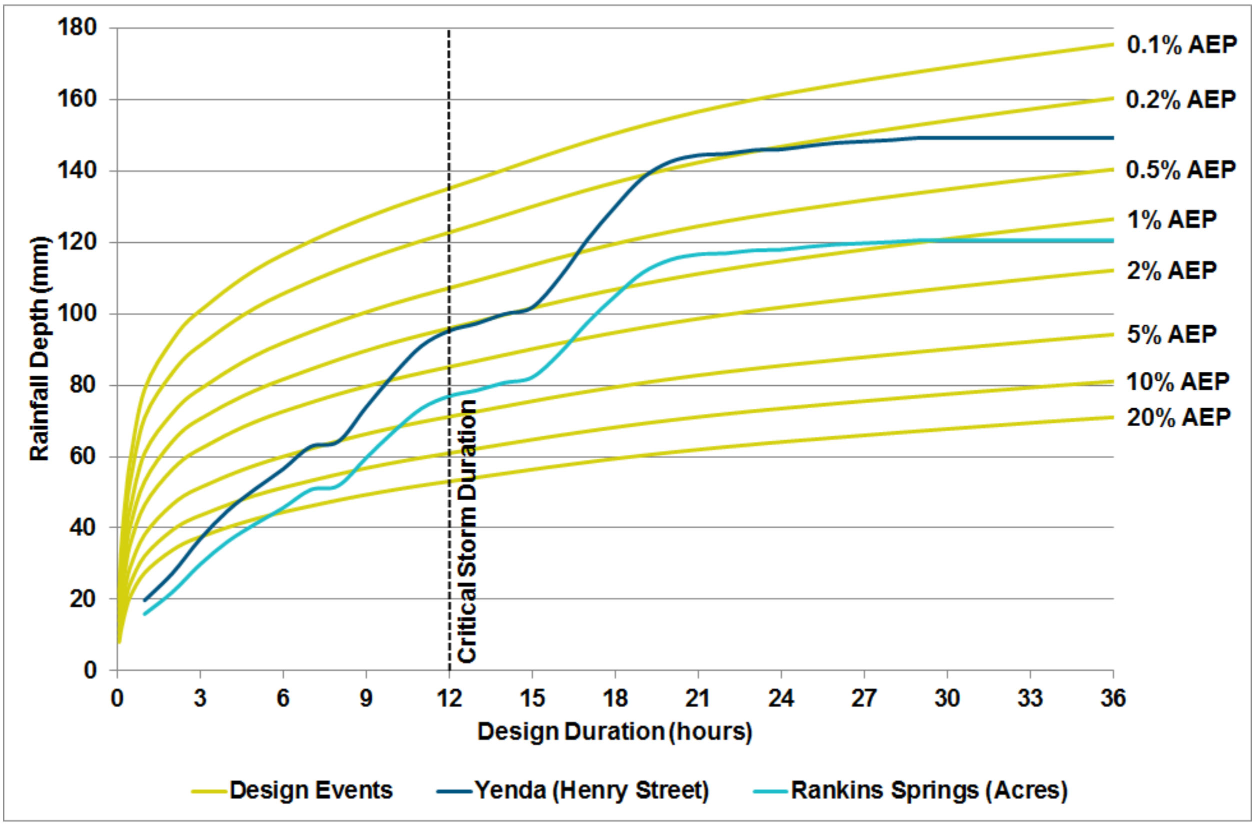

Figure 6-28 Comparison of Derived March 2012 Rainfall with IFD Relationships

6.3.2 Rainfall Losses

The initial and continuing losses adopted for the March 1989 event were also used for the March 2012 event. Flood photographs of the Myall Park flood storage area enabled calibration of an appropriate continuing loss to represent the more natural sub-catchments, beyond the extent of irrigated agriculture. Here adjusting the continuing loss to 10mm/h was found to provide the best representation of effective rainfall for the grassland plains and forested ranges. The calibration of appropriate continuing losses is discussed further in Section 8.3.3.

Both the modelled channel roughness values and irrigation return flow contributions are consistent with those adopted for the March 1989 event.

6.3.3 Observed and Simulated Flood Behaviour

There is no stream gauge data available within the Main Drain J catchment for the March 2012 event. The primary source of quantitative flood data is a survey dataset of flood levels recorded at properties within Yenda, Yoogali and Hanwood. Additional qualitative flood data was obtained from the extensive collection of flood photographs (both from on-ground and aerial sources) and through observations of flood behaviour made by members of the community who experienced the flooding first hand.

Peak flood levels in Yenda were driven by the overtopping of the Northern Branch Canal by flood waters of Mirrool Creek. These are discussed separately in Section 8, as this section focusses on flooding from runoff within the Main Drain J catchment.

The surveyed flood mark levels at Yoogali and Hanwood are presented in Figure 6-29. Surveyed flood levels within Yoogali show a fairly consistent level of around 125.0m AHD, which is just below the crest elevation of the railway. Surveyed flood levels within Hanwood show a fairly consistent level of just over 122.0m AHD.

At Yoogali flooding was initiated by DC 605J flowing out-of-bank and overtopping McCormack Road. Flood waters in Yoogali backed up behind the railway before returning to Main Drain J via the stormwater drainage network and overtopping of the Burley Griffin Way. The modelled peak flood level at Yoogali is slightly over estimated at around 125.1m AHD. The flood levels in Yoogali are highly sensitive to the elevations of the modelled topographic controls, such as McCormack Road, that determine the volume of flood water spilling out of the drainage channel and drive the peak flood level. The model may therefore have more water flowing through Yoogali than was the case during the event. This results in a modelled flow path through properties to the west of Mackay Avenue that during the event was contained within the local drainage and diverted south to the corner of Oakes Road and Kurrajong Avenue.

The modelled peak flood level at Hanwood is slightly under estimated at just over 121.9m AHD. This level is a function of the tailwater condition in Main Drain J, with a slight gradient. Changes to parameters such as channel roughness in DC A have little impact on the modelled flood levels. It is therefore possible that the modelled conveyance of Main Drain J in the reach containing the confluence of DC A is too high. A potential structure blockage during the March 2012 event or some other similar flow constriction downstream of the DC A confluence may have contributed to the higher upstream flood level.

A number of flood photographs for the March 2012 event were made available by Council. They help understand the various flooding mechanisms within the catchment and provide a useful comparison with the modelled flood extents shown in Figure 6-30. It should be noted that the mapped extents represent local Main Drain J catchment runoff only and do not include flow contributions from Mirrool Creek, which are discussed separately in Section 8.

Figure 6-31 shows spilling from DC 605 J over McCormack Road and into Yoogali. This is the principal mechanism for the flooding in Yoogali for the March 2012 event. The flood waters backed up behind the railway, inundating the village, as shown in Figure 6-32. There was some connectivity between the flooding in Yoogali and Main Drain J, with water spilling over Burley Griffin Way, pictured in Figure 6-33.

At the height of the flood water spilled out of DC A, which was constricted by a high tailwater condition in Main Drain J, inundating the village of Hanwood and flooding Kidman Way, as shown in Figure 6-34. Figure 6-35 shows the extent of inundation from the air.

There was extensive flooding of the Myall Park area in March 2012, from both local runoff within the bounds of the Northern Branch Canal and from broader catchment runoff upstream of the canal. The rainfall losses of the natural Main Drain J catchment are significantly higher than those of the irrigated agricultural areas. The modelled continuing loss was modified to calibrate the volumetric runoff from the catchment, using a combination of flood photographs (such as that presented in Figure 6-36) and the LiDAR DEM to determine flood storage levels.

Title:

March 2012 Calibration at Yoogali and Hanwood

Figure: 6-29

Rev: A

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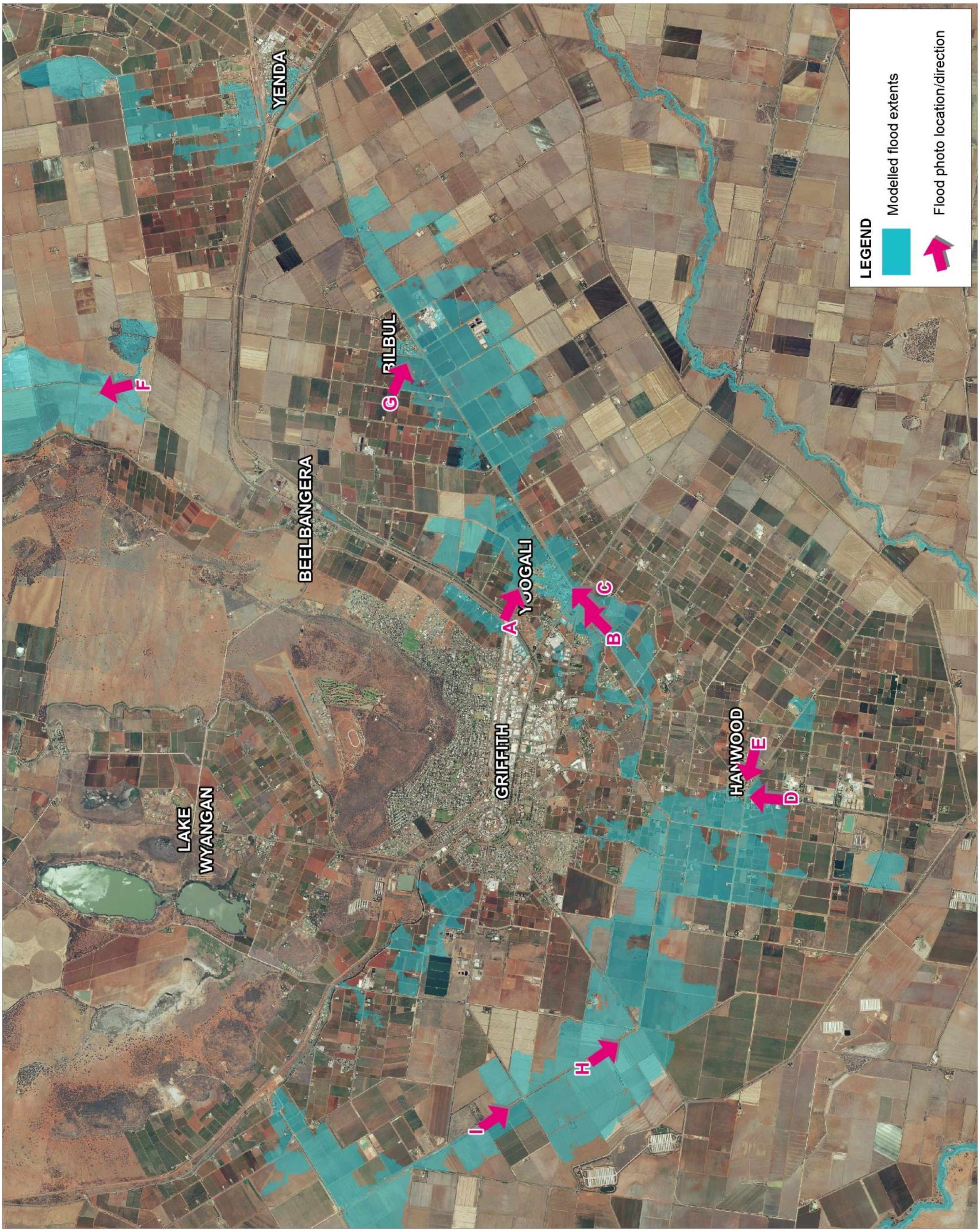

Title:

Modelled Flood Extents for the March 2012 Event

Figure: 6-30

Rev: A

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Figure 6-31 Flooding over McCormack Road at Yoogali on 4th March 2012 15:08 (Photo A)

Figure 6-32 Yoogali in Flood on 5th March 2012 11:27 (Photo B)

Figure 6-33 Flooding over Burley Griffin Way at Yoogali on 4th March 2012 13:35 (Photo C)

Figure 6-34 Flooding over Kidman Way at Hanwood on 5th March 2012 08:20 (Photo D)

Figure 6-35 Hanwood in Flood on 6th March 2012 08:12 (Photo E)

Figure 6-36 Myall Park in Flood on 5th March 2012 11:42 (Photo F)

A peak level of around 127.1m AHD was judged to have been reached in the Myall park storage from local catchment contributions. The flow out of the storage at the downstream end is regulated by the siphon structure under the Main Canal. The continuing loss required to match this flood level in the model was 11mm/h. The continuing loss for the irrigated land was maintained at 4mm/h.

The very high continuing loss value is representative of the sandy soils that occur in the upper Main Drain J catchment and the neighbouring catchment of Lake Wyangan. Rainfall is lost to the soil both prior to runoff generation and by further infiltration during transit through the catchment. A similar response was observed in Tharbogang Swamp, to which the Lake Wyangan catchment drains. Despite the large rainfall depths recorded in the catchment, limited runoff occurred and the resultant flood volume reaching the swamp was relatively small. A component of the adopted continuing loss may also be attributed to the detention of flood waters upstream of the Northern Branch Canal.

Figure 6-37 shows flooding at Bilbul, looking south towards De Bortoli Wines. It can be seen that there is flooding both within the village and more extensively in the fields beyond. The sports fields in Bilbul and the properties to the west are inundated, but the properties to the east are flood free. This is similar to the modelled flood extents in Figure 6-30.

Figure 6-38 and Figure 6-39 show extensive inundation at Walla Avenue and Brogden Road respectively. This is consistent with the modelled flood extents presented in Figure 6-30.

Figure 6-37 Flooding at Bilbul on 5th March 2012 13:04 (Photo G)

Figure 6-38 Flooding at Walla Avenue on 5th March 2012 12:42 (Photo H)

Figure 6-39 Flooding at Brogden Road on 5th March 2012 12:39 (Photo I)

6.3.4 Sensitivity Analysis

As for March 1989, a number of sensitivity tests were undertaken for the March 2012 calibration event model simulations. This was done to identify the level of uncertainty associated with the model results and also to justify the selection of the adopted model parameters. The sensitivity of model results to the flowing parameters was assessed:

- PERN (roughness) value within the hydrological model;
- Continuing rainfall losses within the hydrological model;
- Channel roughness (Manning's 'n') within the hydraulic model; and
- The adopted topographic control crest elevations.

The sensitivity results for the March 2012 calibration event are presented at the location of surveyed peak flood levels (Yoogali and Hanwood) in Table 6-2. The range of sensitivity test results show a limited impact on modelled peak flood levels at these locations, being around 0.2m at Yoogali and 0.1m at Hanwood. Yoogali is particularly sensitive to the adopted control levels of the embankments. This is because the levels along McCormack Road and the railway have a significant impact on the resultant flood levels. When the embankments are lowered by 0.3m the flood level reduces as the railway presents less of a barrier to floodplain flows, reducing the upstream flood levels. When the embankments are raised by 0.3m the flood level in Yoogali reduces as there is less water spilling out of DC 605 J, due to the higher bank representation.

Table 6-2 Model Sensitivity Test Results for the March 2012 Event

Model Simulation	Modelled Peak Water Level (m AHD)	
	Yoogali	Hanwood
Surveyed Level	125.0	122.0
Adopted Model Parameters	125.0	122.0
PERN 0.05	125.1	122.0
PERN 0.07	125.0	121.9
CL 3mm/h	125.1	122.0
CL 5mm/h	125.0	121.9
n 0.02	125.0	121.9
n 0.03	125.1	122.0
Control levels -0.3m	124.9	121.9
Control levels +0.3m	124.8	122.0

7 Main Drain J Model Design Flood Conditions

Design floods are hypothetical floods used for planning and floodplain risk management investigations. They are based on having a probability of occurrence specified either as:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years.

This report uses the AEP terminology. Refer to Table 7-1 for a definition of AEP and the ARI equivalent.

Table 7-1 Design Flood Terminology

ARI[1]	AEP[2]	Comments
0.5%	200 years	A hypothetical flood or combination of floods which represent the worst case scenario likely to occur on average once every 200 years.
1%	100 years	As for the 0.5% AEP flood but with a 1% probability or 100 year return period.
2%	50 years	As for the 0.5% AEP flood but with a 2% probability or 50 year return period.
5%	20 years	As for the 0.5% AEP flood but with a 5% probability or 20 year return period.
10%	10 years	As for the 0.5% AEP flood but with a 10% probability or 10 year return period.
20%	Approx. 5 years	As for the 0.5% AEP flood but with a 20% probability or 5 year return period.
Extreme Flood / PMF[3]		A hypothetical flood or combination of floods which represent an extreme scenario.

1 Average Recurrence Interval (years)
2 Annual Exceedance Probability (%)
3 A PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood.

In determining the design floods it is necessary to take into account the critical storm duration of the catchment (small catchments are more prone to flooding during short duration storms while for large catchments longer durations will be more critical).

The modelled channel and floodplain roughness values adopted for the design events are consistent with those used for the March 1989 and March 2012 calibration events, as presented in Table 4-2. Irrigation return flows used for the calibration events have also been carried through to the design events and represent typical return flow rates during the irrigation season.

Design flood conditions are representative of the local Main Drain J catchment. For consideration of Mirrool Creek flooding refer to Section 8.

7.1 Design Rainfall

Design rainfall parameters are derived from standard procedures defined in AR&R (2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for Main Drain J is presented below.

7.1.1 Rainfall Depths

7.1.1.1 Existing AR&R Guidelines

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is "the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year" (AR&R, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the "credible limit of extrapolation". That is, it is not possible to use rainfall depths determined for the more frequent events (100 year ARI and less) to extrapolate the PMP.

The PMP has been estimated using an approach consistent with that of the 2006 Flood Study. This involved extrapolating the design rainfall depths to the 0.001% AEP and applying the appropriate aerial reduction factor. This provides a total rainfall depth of 182.4mm, which is approximately double the rainfall depth of the 1% AEP event.

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered included the 2-hour, 3-hour, 6-hour, 9-hour, 12-hour, 18-hour, 24-hour, 36-hour and 48-hour durations. The 12-hour storm duration was found to be the critical duration for the catchment. Although the total catchment area is some 550km^2 most of this is regulated by the cross drainage under the Main Canal and upstream flood storages, particularly that of Myall Park. The catchment area upstream of Yoogali to the Main Canal is around 78km^2 in size and it is runoff from this area that drives the critical flood condition in Main Drain J. Table 7-2 shows the average design rainfall intensities based on AR&R adopted for the modelled events.

7.1.1.2 Revised AR&R Guidelines

The Bureau of Meteorology (BoM) is currently undertaking a revision of Engineers Australia's design handbook *Australian Rainfall and Runoff: A Guide to Flood Estimation*. The outputs of the revision will include new IFD design rainfall estimates, revised temporal patters and revised rainfall loss values.

The outputs of the revision project will be released progressively over the next two years, with the first release to be the new IFD design rainfall estimates (released in July 2013). The additional outputs including the revised temporal patterns have not yet been released.

Table 7-2 Design Rainfall Estimates Based on 1987 IFD Data (mm)

Duration (hours)	Design Event Frequency				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
2	30.3	36.9	43.5	52.7	60.1
3	34.4	41.8	49.2	59.5	67.7
6	44.5	51.3	60.0	72.6	81.6
9	49.6	56.7	66.4	79.5	89.8
12	53.0	61.0	71.2	85.1	95.9
18	59.8	68.2	79.6	94.9	107
24	64.1	73.4	85.4	102	115
36	71.6	81.3	94.7	113	127
48	76.3	86.9	101	120	135

The new IFD design rainfall estimates are based on a more extensive rainfall database then the 1987 IFD design rainfall estimates with statistical analysis of an additional 30 years of rainfall data as well as data from an additional 2300 rainfall stations included in the new rainfall database.

Whilst the new IFD design rainfall estimates are derived from a more extensive rainfall database, the BoM recommends careful consideration be used when using the new values with the existing temporal patterns and other design parameters based on AR&R 1987. The BoM states that *you cannot assume that using the 2013 IFD design rainfalls with AR&R87 techniques and design parameters will deliver a more reliable estimate of the design flood* (BoM, 2013).

Until such time as the revised temporal patterns are rainfall loss parameter values are released, the BoM recommends using the AR&R 1987 IFD data system and design parameters and using the new IFD design rainfall estimates to conduct sensitivity testing. This will allow an assessment of the impact of the updates rainfall information to be incorporated into the decision making process.

Based on these recommendations a sensitivity test has been undertaken to assess the impact of the new IFD design rainfall estimates on the design flood levels in Yoogali. The IFD data presented in Table 7-3 provides for the average intensity (or total depth) that occurs over a given storm duration based on the new 2013 IFD design rainfall estimates.

A comparison of the 1987 and 2013 IFD design rainfall estimates, in the form of change in design rainfall estimate for the 2013 IFD data (i.e. 2013 value minus 1987 value), is shown in Table 7-4. The new IFD data provides for an overall reduction in design rainfall depths. This is more pronounced for both the more frequent events and the longer duration events. For the 1% AEP 12-hour design event (previously identified to be the critical 1% AEP flood event) there is a 0.2mm increase in design rainfall which equates to an approximate percentage increase of 0.2%. Given that the changes in design rainfall depths for the 12-hour duration event are negligible, the changes in IFD have no implications for design flood considerations in Main Drain J.

Table 7-3 Design Rainfall Estimates Based on 2013 IFD Data (mm)

Duration (hours)	Design Event Frequency				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
2	30.3	36.9	43.6	52.8	60.2
3	34.4	41.7	49.2	59.4	67.6
6	42.2	50.8	59.6	71.6	81.2
9	47.1	56.6	66.1	79.3	89.7
12	50.8	60.8	71.0	85.0	96.1
18	55.9	66.9	78.0	93.3	106
24	59.6	71.2	83.0	99.4	113
36	64.5	77.1	90.0	108	123
48	67.8	81.1	94.9	114	130

Table 7-4 Comparison of 1987 and 2013 IFD Design Rainfall Estimates

Duration (hours)	Design Event Frequency				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
2	0.0	0.0	+0.1	+0.1	+0.1
3	0.0	-0.1	0.0	-0.1	-0.1
6	-2.3	-0.5	-0.4	-1.0	-0.4
9	-2.5	-0.1	-0.3	-0.2	-0.1
12	-2.2	-0.2	-0.2	-0.1	+0.2
18	-3.9	-1.3	-1.6	-1.6	-1.4
24	-4.5	-2.2	-2.4	-2.4	-2.2
36	-7.1	-4.2	-4.7	-4.6	-4.1
48	-8.5	-5.8	-5.9	-5.9	-5.6

7.1.2 Areal Reduction Factor

The design rainfall intensities derived according to AR&R are applicable strictly to a point location. For larger catchments, it is not realistic to assume that the same rainfall intensity can be maintained over the entire area and an areal reduction factor (ARF) is typically applied.

As discussed in Section 7.1.1, although the study area is some 550km^2, the catchment area driving the critical flood conditions is only around 78km^2. Therefore a catchment are of 78km^2 has been used to determine appropriate ARFs. The adopted methodology for determining ARFs is that proposed in the Review of ARFs Final Report (AR&R Revision Project 2, 2013).

Under the revised AR&R guidelines appropriate ARFs are calculated separately for both long duration events (18 hours or greater) and short duration events (18 hours or less). These calculations incorporate the catchment area, storm duration, event AEP and a set of published parameters which vary according to the geographical location of the study area. The Main Drain J catchment is situated within the NSW GSAM zone. The calculated ARFs for the design events are presented in Table 7-5.

Table 7-5 Areal Reduction Factors for the Main Drain J Catchment

Duration (hours)	Design Event Frequency					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
2	0.836	0.836	0.836	0.836	0.836	0.836
3	0.853	0.853	0.853	0.853	0.853	0.853
6	0.883	0.883	0.883	0.883	0.883	0.883
9	0.900	0.900	0.900	0.900	0.900	0.900
12	0.912	0.912	0.912	0.912	0.912	0.912
18	0.928	0.927	0.927	0.926	0.925	0.924
24	0.942	0.940	0.939	0.937	0.935	0.934
36	0.958	0.957	0.955	0.953	0.951	0.950
48	0.968	0.966	0.964	0.962	0.960	0.959

7.1.3 Temporal Patterns

There are currently no published revisions for the design rainfall temporal patterns in the revised AR&R. Therefore the adopted temporal patterns are based on the standard patterns presented in AR&R (2001). The study area is situated within Zone 2 as it is west of the Great Dividing Range. However, the Zone 1 temporal patterns were adopted within the previous flood study and have been maintained within this study for consistency. The Zone 2 temporal patterns are more representative of the arid areas of NSW, whereas the study catchment is located on the fringes between the arid interior and the western slopes. It is therefore not unreasonable to use the Zone 1 temporal patterns. Using the Zone 1 temporal patterns also produces slightly higher flood peaks, which was also preferable given how much less severe the design flood results of this study are than was previously modelled.

Comparison of the design temporal rainfall patterns for Zone 1(coastal south-east Australia) and Zone 2 with those recorded for the March 1989 and March 2012 events shows that the design temporal patterns for Zone 1 are more similar to the calibration events than are those of Zone 2. The design temporal patterns of Zone 1 are similar to a normal distribution, with the highest intensity rainfall towards the middle of the event. The design temporal patterns of Zone 2 are strongly positively skewed, with the highest intensity rainfall at the onset of the event. The design temporal rainfall patterns for Zone 1 have therefore been adopted for use in this study.

7.1.4 Rainfall Losses

For the irrigated agricultural land the standard design values for western NSW (Zone 2 in AR&R) were adopted for the design rainfall losses, as presented in Table 6-1. This is an initial loss of 15mm and a continuing loss of 4mm/h, which is consistent with the values adopted for model calibration. The March 2012 event demonstrated that the losses from the more natural sub-catchments, beyond the extent of irrigated agriculture, were significantly higher. Here an initial loss of 15mm and continuing loss of 8mm/h has been adopted. There is limited calibration data available to calibrate suitable losses for the natural catchment and so the continuing loss for design has conservatively been reduced from the 11mm/h of the March 2012 calibration. A 5mm initial loss and 0mm/h continuing loss was adopted for impervious sub-catchments.

7.1.5 Probable Maximum Precipitation

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is "the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year" (AR&R, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the "credible limit of extrapolation". That is, it is not possible to use rainfall depths determined for the more frequent events (1% AEP and less) to extrapolate the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology.

For the PMF event the 3-hour storm was found to be the critical duration, which is the duration limit of the GSDM in western NSW. The critical duration for the catchment falls between the recommended limits of the GSDM and the GSAM (the appropriate method for long storm durations). However, given that the critical duration for the PMF event is often much shorter than that of the other design events, adopting the 3-hour GSDM was considered a reasonable representation of the PMF event.

7.2 Design Flood Results

A range of design flood conditions were modelled, the results of which are presented and discussed below. The simulated design events included the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP and 0.5% AEP. The PMF event has also been modelled.

7.2.1 Flood Behaviour

Flooding in the Main Drain J catchment results from excess runoff generated during significant rainfall events. The flood flows are driven principally by catchment runoff from the irrigated agriculture located downstream of the Main Canal. There are three main inputs from upstream of the Main Canal:

- The catchment draining to Myall Park;
- Irrigated agriculture draining through Yenda; and
- Runoff from the city of Griffith.

Flooding in Myall Park is driven primarily from the runoff generated from the irrigated agriculture downstream of the Northern Branch Canal. Although the natural catchment upstream of the canal is some 240km^2, little runoff reaches Myall Park due to infiltration to the sandy soils and detention upstream of the canal. The outflow from the Myall Park flood storage is also well regulated by the siphon structure under the Main Canal. Catchment runoff draining though Yenda is also well regulated by the two siphon structures under the Main Canal.

Runoff emanating from the urban areas of Griffith City has a more rapid response than that of the field drainage and so the flood peaks typically enter Main Drain J before the peak flows from the upstream agricultural areas.

Once catchment runoff is discharged to Main Drain J the water levels rise quite rapidly and are then held at an elevated level for some time, due to the slow release of flood storage from the flat floodplain. Most of the flood flows are retained within the drainage system, which has a relatively large capacity. However, widespread inundation of surrounding fields occurs once the drainage capacity is exceeded.

In Yoogali flooding occurs when the capacity of DC 605 J is exceeded. Water then spills over Mc Cormack Road and inundates the village, backing up behind the railway embankment. Flooding may last for a few days, until the tailwater level in Main Drain J lowers to enable drainage out of Yoogali.

In Hanwood flooding occurs when the fields adjacent to DC A flood to a level which is sufficient to overtop Kidman Way. There is only a small gradient between flood levels at Hanwood and in Main Drain J and so the tailwater level in the drain has a significant influence on flooding here.

7.2.2 Peak Flood Conditions

The design flood results are presented in the mapping compendium. For the simulated design events including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and PMF events, a map of peak flood level, depth and velocity is presented covering the modelled area.

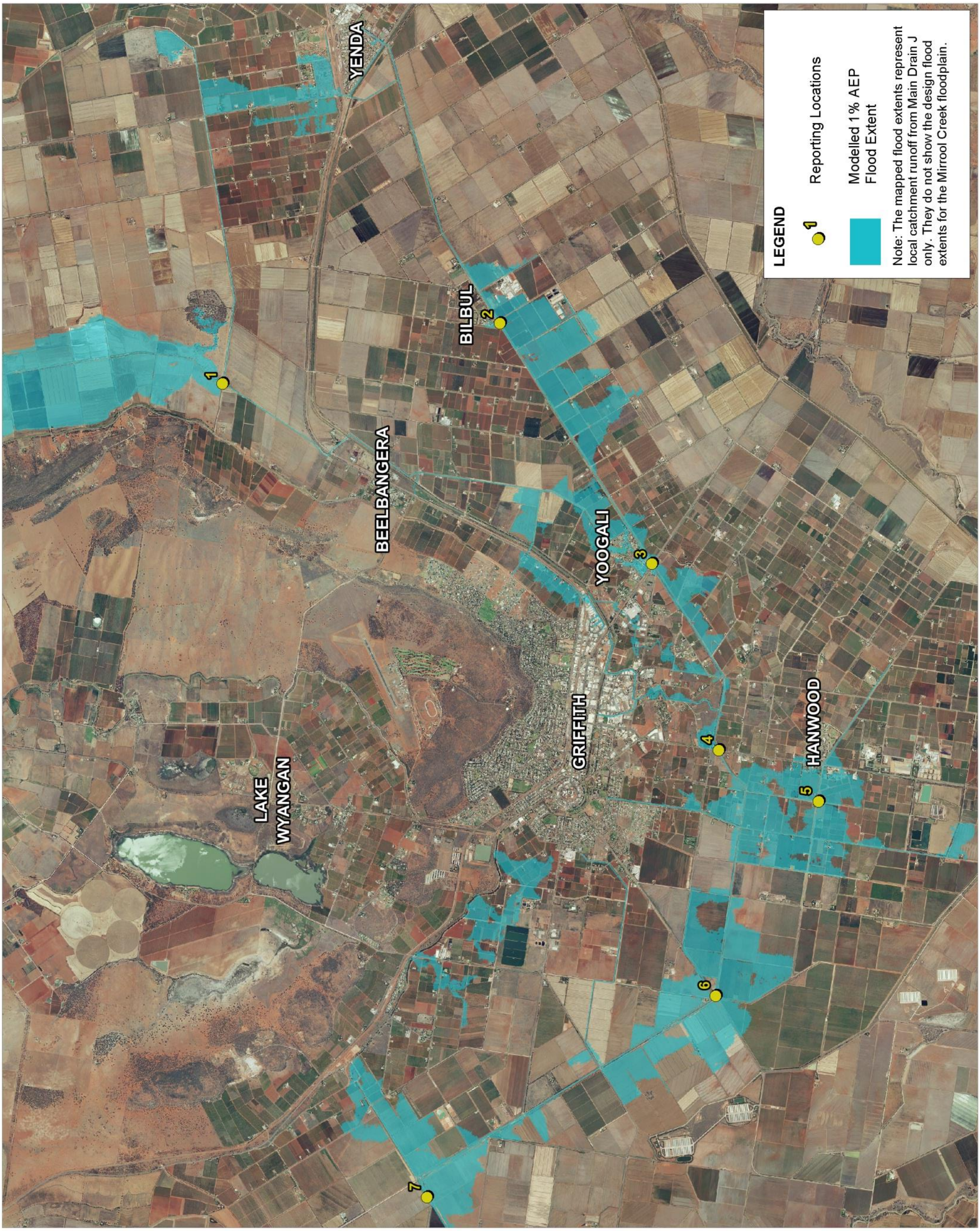
Modelled peak flood levels at selected locations (as presented in Figure 7-1) are shown in Table 7-6, for the full range of design flood events considered. Longitudinal profiles showing modelled peak flood levels along Main Drain J are shown in Figure 7-2, with the channel bed and bank profiles also shown for reference.

Table 7-6 Modelled Peak Flood Levels (m AHD) for Design Flood Events

ID	Location	Flood Event Frequency						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1	DC North at Fowler Road (Myall Park)	127.0	127.1	127.1	127.2	127.2	127.3	128.1
2	Main Drain J at Bilbul	127.0	127.2	127.5	127.6	127.7	127.8	127.8
3	Main Drain J at Yoogali	123.9	124.1	124.3	124.6	124.7	124.8	125.1
4	Main Drain J at Kidman Way	121.5	121.8	122.1	122.3	122.4	122.4	122.8
5	DC A at Beaumonts Road (Hanwood)	121.2	121.5	121.7	121.8	121.9	122.0	122.2
6	Main Drain J at Walla Avenue	119.0	119.3	119.5	119.6	119.6	119.7	119.9
7	Main Drain J at Warburn Escape	116.9	117.1	117.2	117.3	117.3	117.4	117.7

Peak flood velocities within the channels at the reporting locations are presented in Table 7-7. It can be seen that there is not a great deal of variation in modelled peak velocities with design event magnitude.

Peak velocities within Main Drain J are typically around 1m/s and are higher at around 1.5m/s in the steeper reach between Yoogali and Hanwood. Velocities within channels with a limited flood gradient, such as DC North and DC A, are 0.5m/s or less.



Title:

Modelled Design Flood Extents and Reporting Locations

Figure: 7-1

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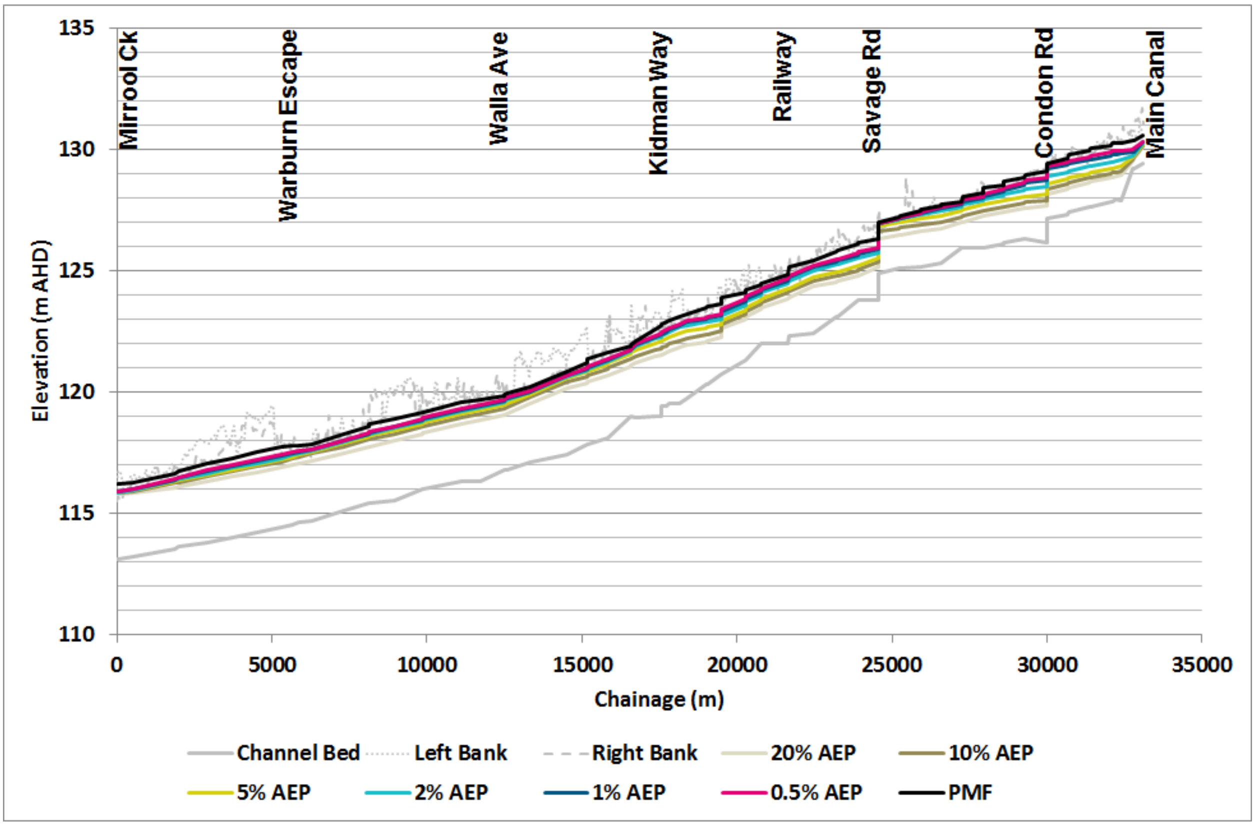


Figure 7-2 Main Drain J Design Peak Flood Level Profiles

Table 7-7 Modelled Peak Flood Velocities (m/s) for Design Flood Events

ID	Location	Flood Event Frequency						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1	DC North at Fowler Road (Myall Park)	0.3	0.3	0.3	0.3	0.3	0.3	0.6
2	Main Drain J at Bilbul	0.7	0.8	0.8	0.9	0.9	0.9	1.0
3	Main Drain J at Yoogali	1.1	1.2	1.2	1.3	1.3	1.3	1.3
4	Main Drain J at Kidman Way	1.1	1.2	1.2	1.4	1.4	1.4	1.5
5	DC A at Beaumonts Road (Hanwood)	0.4	0.5	0.5	0.5	0.5	0.5	0.7
6	Main Drain J at Walla Avenue	1.0	1.1	1.1	1.1	1.2	1.2	1.3
7	Main Drain J at Warburn Escape	1.0	1.1	1.1	1.1	1.1	1.1	1.3

Velocities through some of the structures will be higher than those of the open channels, with modelled peak velocities being in the order of 0.5m/s higher. Flood velocities on the floodplain are generally small as it is mostly flood storage, with few convective flood flow paths. Velocities are expected to be below 0.5m/s, but may be locally higher

7.2.3 Flood Flows

Modelled peak flood flows at the reporting locations are shown in Table 7-8 for the full range of design flood events considered. The peak flood flows increase steadily with event magnitude and increase in a downstream direction as the contributing catchment area increases. These flows represent the channel conveyance only and additional flow would occur on the floodplain during larger events.

Table 7-8 Modelled Peak Flood Flows (m^3/s and *ML/day*) for Design Flood Events

ID	Location	Flood Event Frequency						
		20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
1	DC North at Fowler Road (Myall Park)	2.8 *240*	2.9 *250*	3.0 *260*	3.0 *260*	3.0 *260*	3.0 *260*	11.0 *950*
2	Main Drain J at Bilbul	5.3 *460*	7.1 *610*	9.4 *810*	10.9 *940*	11.6 *1000*	11.8 *1020*	11.9 *1030*
3	Main Drain J at Yoogali	13.3 *1150*	17.1 *1480*	19.6 *1690*	24.5 *2120*	27.6 *2380*	29.7 *2570*	37.6 *3250*
4	Main Drain J at Kidman Way	18.2 *1570*	22.9 *1980*	28.5 *2460*	34.6 *2990*	37.1 *3210*	39.7 *3430*	59.8 *5170*
5	DC A at Beaumonts Road (Hanwood)	1.6 *140*	2.1 *180*	2.9 *250*	3.6 *310*	4.7 *410*	5.4 *470*	6.6 *570*
6	Main Drain J at Walla Avenue	23.3 *2010*	28.8 *2490*	31.8 *2750*	34.7 *3000*	36.6 *3160*	37.6 *3250*	41.8 *3610*
7	Main Drain J at Warburn Escape	31.5 *2720*	38.9 *3360*	41.2 *3560*	43.8 *3780*	46.3 *4000*	48.3 *4170*	60.6 *5240*

The modelled flow hydrographs at various locations are presented in Figure 7-3 for the 1% AEP event. They show that the inflows to Main Drain J through the siphons from Myall Park and Yenda are well regulated, with the Myall Park siphon in particular holding at a relatively constant flow rate. The hydrographs along the length of Main Drain J show a similar shape, increasing in both peak flow and runoff volume when progressing downstream. The flow rates rise rapidly after about six hours and then remain elevated for a period of around two days before beginning to recede again. The peak present at around 12 hours in the Kidman Way hydrograph represents the runoff from Griffith.

The modelled flow hydrographs at Yoogali for the full range of design events are presented in Figure 7-4. The hydrograph shapes for the more frequent flood events, up to the 5% AEP magnitude, are distinctly different from those of the less frequent flood events. The flood flows upstream of Yoogali are largely retained in bank for the more frequent flood events.

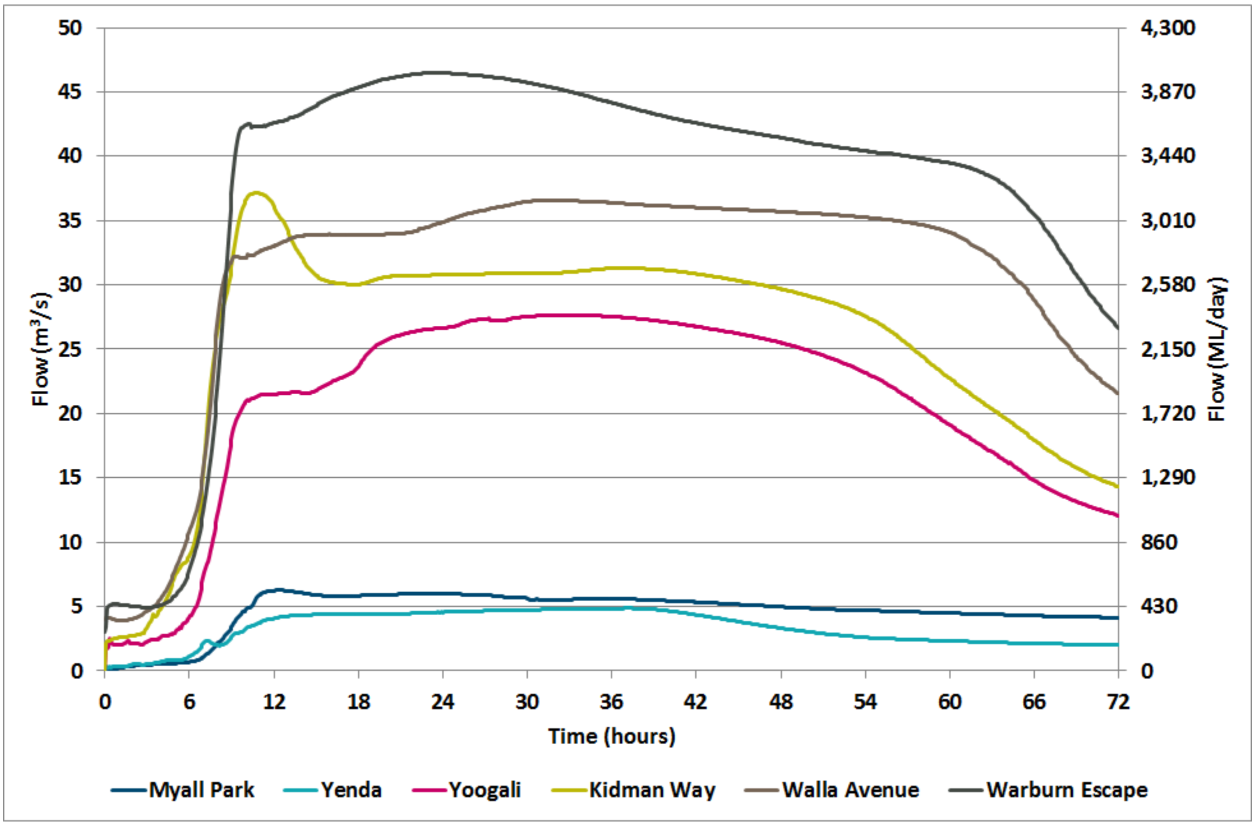


Figure 7-3 Modelled 1% AEP Event Flow Hydrographs at Selected Locations

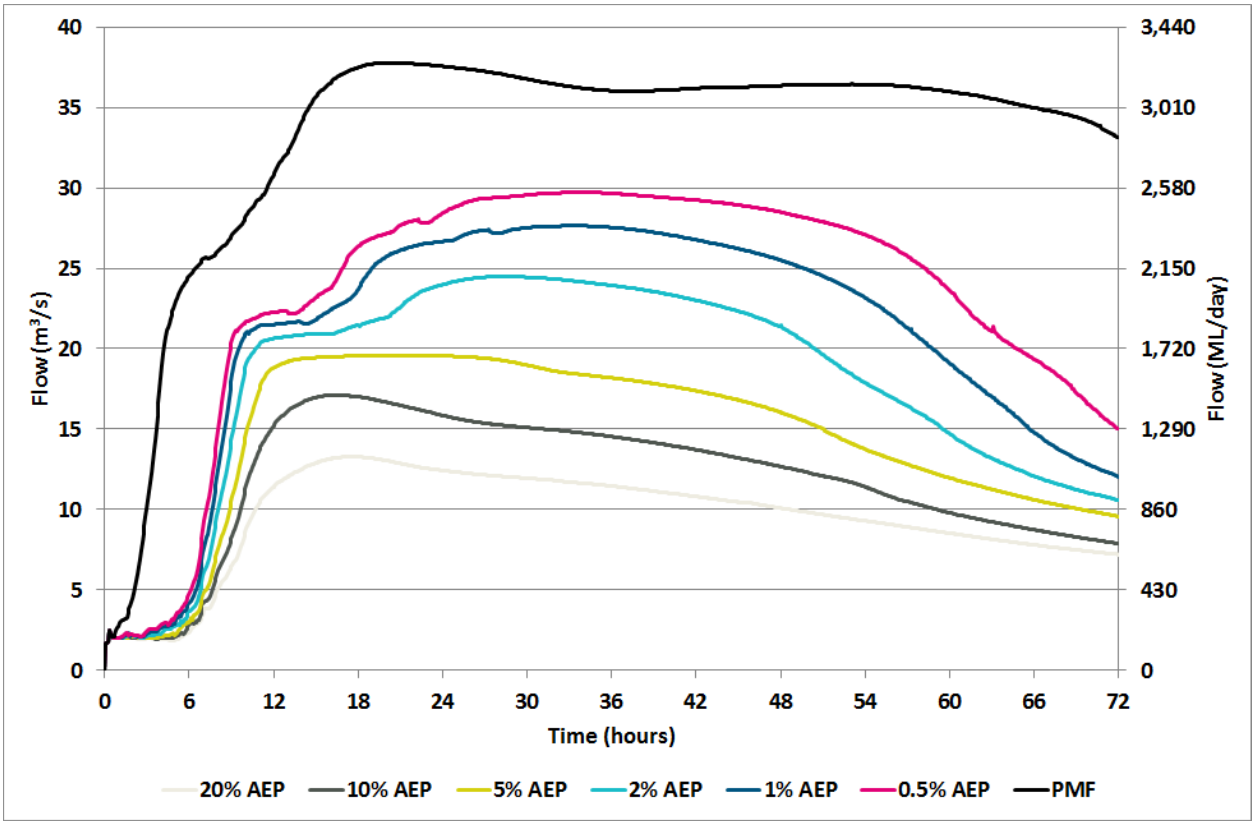


Figure 7-4 Modelled Design Event Flow Hydrographs at Yoogali

This produces a hydrograph that peaks early and then steadily recedes. For the larger flood events there is significant inundation of the floodplain and flows upstream of Yoogali are attenuated, producing a hydrograph shape that peaks later and is sustained at a high level for a longer period of time.

7.2.4 Hydraulic Categorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the study catchment. Given the nature of flooding in the Main Drain J catchment, the different methods for defining floodways produce the same result – floodways are essentially restricted to the drainage channels because little flow is conveyed within the floodplain. Flood storage areas were defined using the modelled peak flood depth. The adopted hydraulic categorisation is defined in Table 7-9.

Table 7-9 Hydraulic Categories

Hydraulic Category	Categorisation Criteria	Description
Floodway	Velocity * Depth > 0.1 at the 1% AEP event	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.1 and Depth > 0.3 at the 1% AEP event	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Flood extent of the 1% AEP event	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

Preliminary hydraulic category mapping is included as mapping series I of the Mapping Compendium. The floodway is contained within the banks of the irrigation drainage channels. Most of the inundated floodplain is classified as flood fringe but there are areas of flood storage, most notably Myall Park but also in the vicinity of Bilbul Yoogali and Hanwood and the area downstream of Walla Avenue.

7.2.5 Provisional Hazard

The Floodplain Development Manual defines flood hazard categories as follows:

- High hazard – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and
- Low hazard – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities generally have no major threat.

Figures L1 and L2 in the Floodplain Development Manual are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 7-5. The provisional hydraulic hazard is included as mapping series H of the Mapping Compendium and is based on the 1% AEP design event.

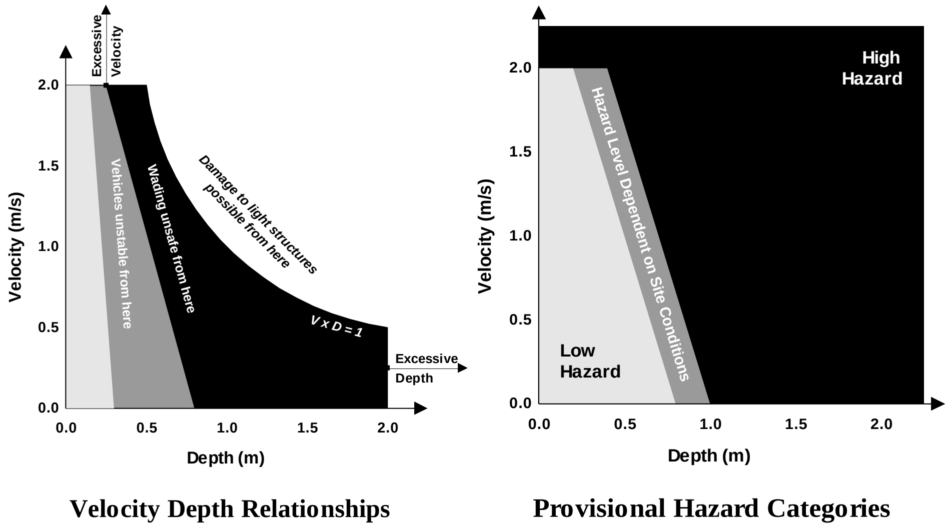


Figure 7-5 Provisional Flood Hazard Categorisation

7.3 Model Sensitivity Tests

A number of sensitivity tests were undertaken for the modelled 1% AEP design event simulation. This was done to identify the level of uncertainty associated with the model results. The sensitivity of model results to the flowing parameters was assessed:

- PERN (roughness) value within the hydrological model;
- Continuing rainfall losses within the hydrological model;
- Channel roughness (Manning's 'n') within the hydraulic model;
- The adopted topographic control crest elevations;
- Assumed return flows from the irrigation network; and
- Modelled structure blockages.

The PERN value adopted within the RAFTS hydrological model was 0.06 for the irrigated agricultural areas. For the purposes of model sensitivity testing this was varied between 0.05 and 0.07.

The continuing loss value adopted within the RAFTS hydrological model was 4mm/h for the irrigated agricultural areas. For the purposes of model sensitivity testing this was varied between 3mm/h and 5mm/h.

The Manning's 'n' value adopted for the majority of drainage channels within the TUFLOW hydraulic model was 0.025. For the purposes of model sensitivity testing this was varied between 0.02 and 0.03.

The modelled elevation of the channel bank crests and other topographic controls such as road and rail embankments has a significant impact on the flood behaviour. The elevations adopted within the model have been extracted from the LiDAR DEM. The vertical accuracy of the LiDAR data is around +/- 0.15m. There are also additional uncertainties such as narrow bank crests or localised low spots that may not be captured by the LiDAR survey. For the purposes of model sensitivity testing the elevations of channel banks and other topographic controls have been raised and lowered by 0.3m.

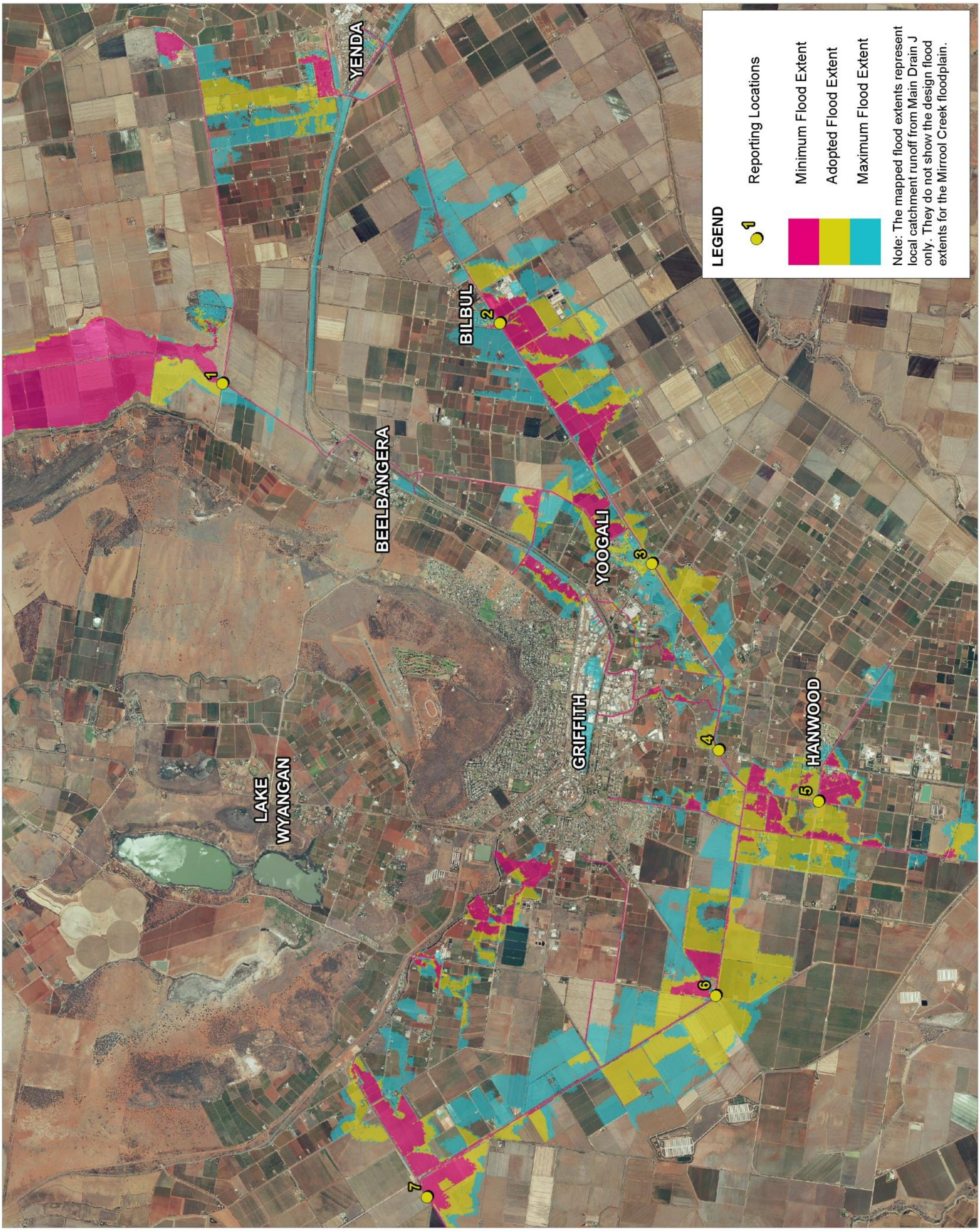
Given the relatively large size of irrigation return flows in comparison to the flows generated from catchment runoff, the adopted return flows for design event simulation have a significant impact on the model results. The return flows adopted for the design events represent typical conditions during the irrigation season. However, the flow rates can be higher than this or could be close to zero outside of the irrigation season. For the purposes of model sensitivity testing the adopted return flows have been doubled and set to zero.

The blockage of hydraulic structures during a flood event can have a significant impact on upstream water levels. To assess the relative impact of structure blockage on the design flood conditions nominal blockages of 25% and 50% have been applied to the modelled structures.

The results of the sensitivity tests on the modelled flood extents of the 1% AEP event are summarised in Figure 7-6. The minimum food extent represents the areas that are inundated in all of the scenarios that were considered. The maximum flood extent represents the areas that are inundated in any of the scenarios considered.

The corresponding impacts on peak 1% AEP flood levels for the sensitivity tests are presented in Table 7-10. Accordingly, the relative change in peak flood levels at the reported locations can be identified for the base case to the upper and lower bounds of the sensitivity tests.

The design 1% AEP flood condition for the Main Drain J catchment lies between the two calibration events of March 1989 and March 2012. Accordingly, similar sensitivities between design flood levels and inundation extents can be anticipated for the modelled condition in comparison with the on-ground observed conditions.



Title:

Sensitivity Testing of Modelled 1% AEP Flood Extents

Figure: 7-6

Rev: A

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Approx. Scale

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Table 7-10 Modelled Peak Flood Levels (m AHD) for Sensitivity Tests

ID	Location	Base Case	PERN 0.05	PERN 0.07	CL 3	CL 5	n 0.02	n 0.03	Banks -0.3	Banks +0.3	RF 0	RF x2	Block 25%	Block 50%
1	DC North at Fowler Road (Myall Park)	127.2	127.3	127.2	127.3	127.2	127.2	127.2	127.2	127.5	127.2	127.2	127.2	127.3
2	Main Drain J at Bilbul	127.7	127.7	127.7	127.8	127.7	127.7	127.7	127.7	127.9	127.7	127.7	127.7	127.7
3	Main Drain J at Yoogali	124.7	124.8	124.6	124.8	124.6	124.6	124.7	124.6	124.7	124.7	124.7	124.8	124.9
4	Main Drain J at Kidman Way	122.4	122.4	122.4	122.4	122.3	122.3	124.4	122.3	122.6	122.4	122.4	122.3	122.0
5	DC A at Beaumonts Road (Hanwood)	121.9	122.0	121.9	122.0	121.9	121.9	122.0	121.8	122.1	122.9	122.0	122.0	122.0
6	Main Drain J at Walla Avenue	119.6	119.7	119.7	119.7	119.7	119.6	119.8	119.6	119.8	119.7	119.7	119.6	119.5
7	Main Drain J at Warburn Escape	117.3	117.4	117.3	117.4	117.3	117.3	117.4	117.3	117.5	117.3	117.4	117.3	117.2

8 Mirrool Creek Flood Analysis

8.1 Background Data of Mirrool Creek Flood Hydrology

8.1.1 Catchment Characteristics

The Mirrool Creek catchment is some 6,500km^2 in size upstream of the East Mirrool Regulator. This catchment area can be divided into two main sub-catchments. Mirrool Creek drains the upland areas around Ariah Park and the Barellan flats to the south of the Griffith Temora Railway, with a total contributing catchment area of around 2,500km^2. Binya Creek joins Mirrool Creek a few kms upstream of the East Mirrool Regulator. It drains the upland areas to the north of Ardlethan, the eastern slopes of the Cocoparra Range and the Barellan flats to the north of the Griffith Temora Railway, with a total contributing catchment area of around 4,000km^2.

The flow path lengths to the East Mirrool Regulator were determined using the catchment DEM and have been presented on Figure 8-1, along with approximate runoff travel times. This highlights the Binya Creek catchment as being potentially much more significant than the Mirrool Creek catchment in generating flood flows, given the larger contributing catchment and shorter travel times. This information has been presented in a graphical form in Figure 8-2, which shows that for a travel time of 3-4 days the contributing catchment of Binya Creek is approximately double that of Mirrool Creek.

Given this information alone, one would expect Binya Creek to be the principal driver of flood conditions within the Mirrool Creek catchment. However, this is contradictory to the anecdotal evidence provided for historic flood events, which seem to have been a consequence of flood flows from Mirrool Creek.

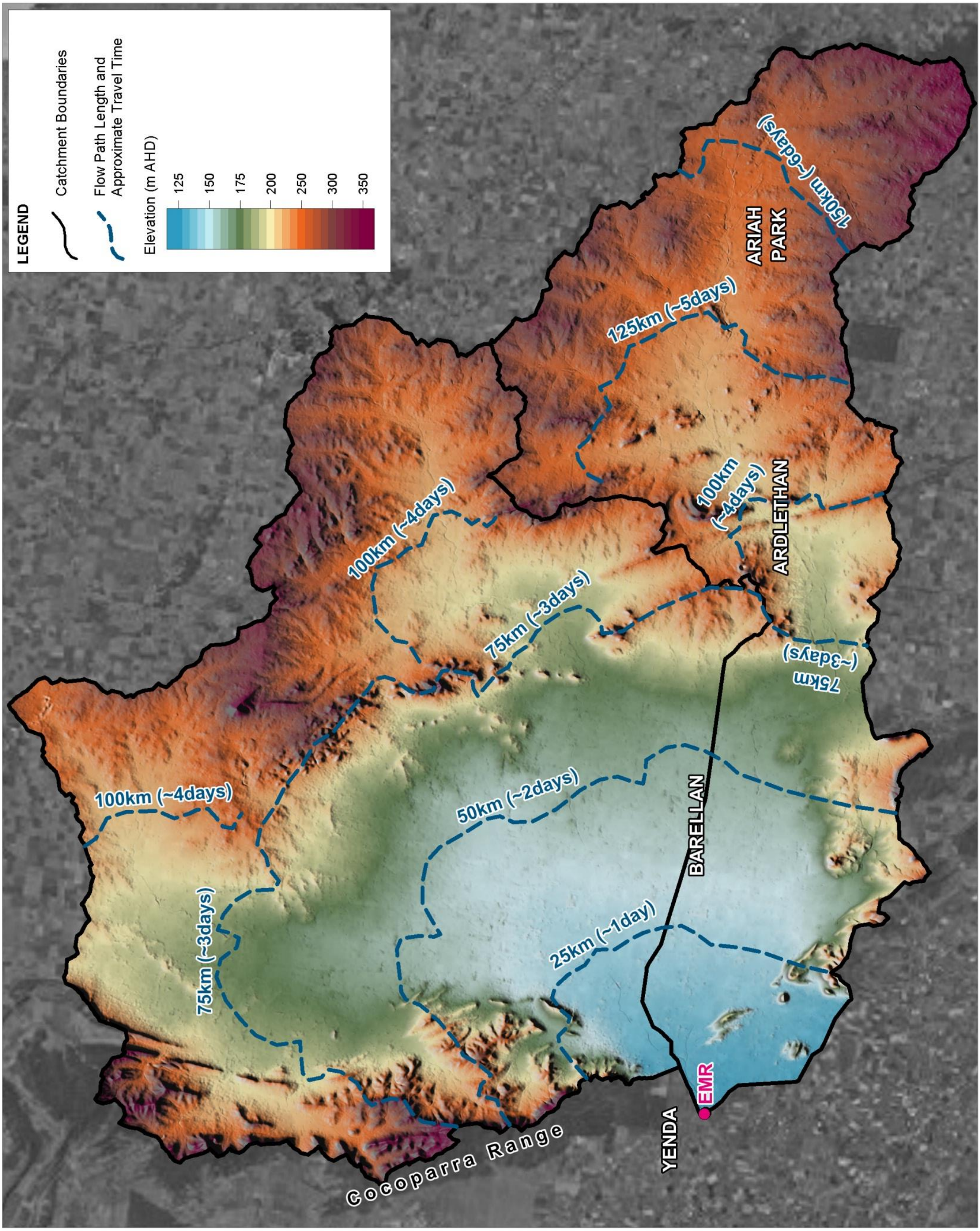
8.1.2 Soil Characteristics

Soil data for the region was obtained from the Australian Soil Resource Information System and showed that two distinctly different soil types exist across the catchment. The area is characterised by a distribution of both well-drained sandy soils and less well-draining clay soils. The distribution of these soils across the catchment has been presented in Figure 8-3. It shows that the upland areas of the catchment are generally sandy soils, whereas the flat areas and those along the major watercourse alignments are typically clay.

There are a larger proportion of sandy soils within the Binya Creek catchment than there is within that of Mirrool Creek. For Binya Creek around 60% of the catchment is sand, compared with around 40% for Mirrool Creek. Higher rainfall losses would be associated with the sandier soils than those of the clays. Also of note is that the downstream reach of Binya Creek is underlain by sand, which is unique amongst the other major watercourse alignments within the catchment.

8.1.3 Climatic Conditions

In addition to the hydrological and soil characteristics of the catchment, another important aspect to consider in understanding the nature of flooding in Mirrool Creek is the climatic conditions. Figure 8-4 presents rainfall climate indicators for the Mirrool Creek catchment. It shows that average monthly rainfall is distributed evenly across the year, with a consistent depth of just under 40mm.



Title:

Mirrool Creek Catchment Flow Path Lengths to the EMR

Figure: 8-1

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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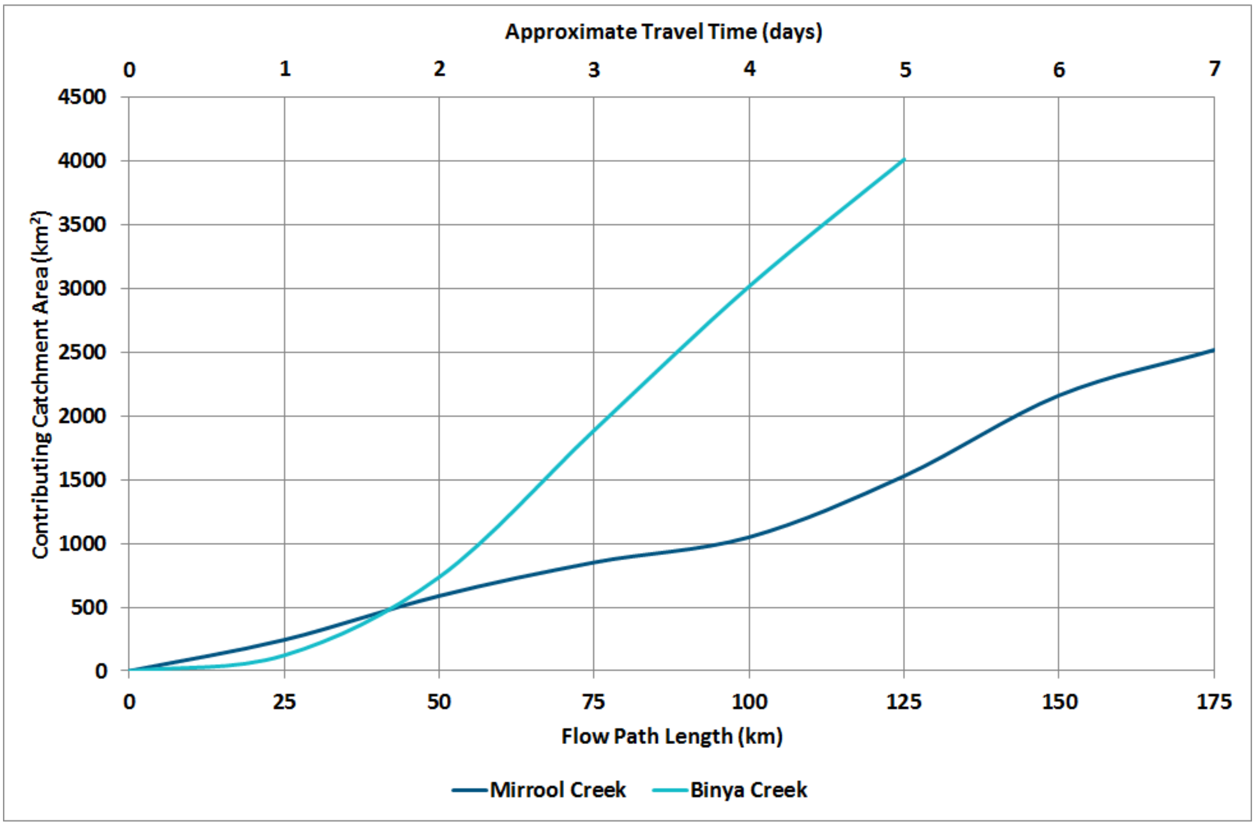


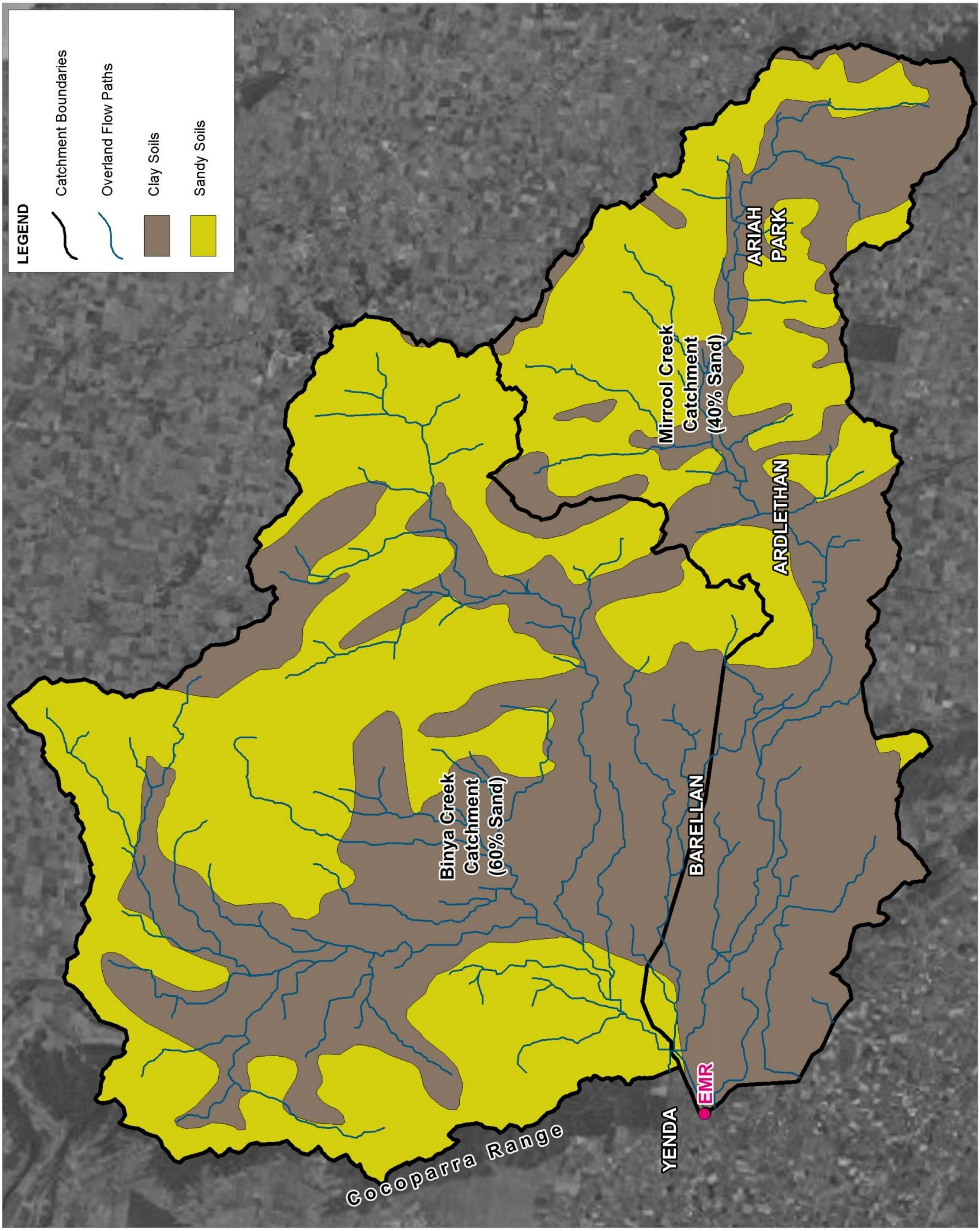
Figure 8-2 Mirrool Creek Flow Path Length and Catchment Area Relationship

The variation in average monthly potential evapotranspiration is much more marked however, ranging from under 40mm in winter to around 190mm in the height of summer.

Although the average monthly rainfall is very consistent, the distribution of extreme rainfall events throughout the year is not. Statistics of maximum 2-day total rainfall depths were derived for each month from ten daily rainfall gauges distributed across the Mirrool Creek catchment, which were averaged to determine mean catchment values. This was also undertaken for a 90th percentile 2-day rainfall depth, to reduce the influence of the most extreme events. Both distributions are consistent, showing that the most extreme rainfall events in the catchment typically occur in the months of January, February and March, when catchment averages of over 100mm have been recorded. For the months of June, July, August and September this drops to below 60mm.

8.1.4 Flood Event Analysis

Presented with the climatic data alone, one might expect the occurrence of flood events to be more prevalent in summer and early autumn. However, analysis of peak flood levels recorded on Mirrool Creek at Barellan between the years of 1952 and 1978 shows that flooding is actually much more frequent in the period from late autumn to early spring. Figure 8-5 shows that of the 18 largest events recorded at Barellan in a 27 year period, 11 of them occur between late autumn and early spring, compared to just two between late spring and early autumn, when the extreme rainfall events are more prevalent. This suggests that the moisture content of the soil is a major driver of flood events in the catchment, as flood events better correlate with periods when the difference between monthly rainfall and PET is smallest, rather than the periods of extreme rainfall.



Title:

Broad Soil Types of the Mirrool Creek Catchment to the EMR

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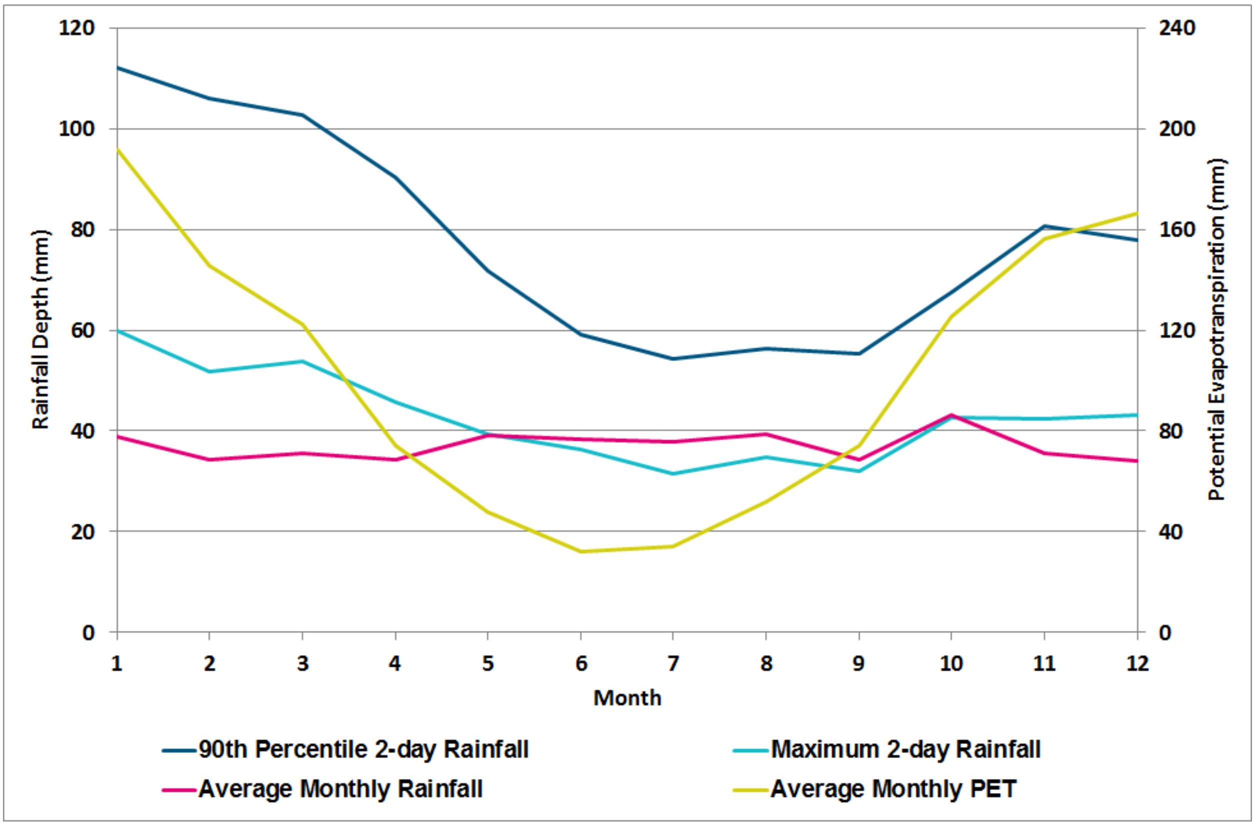


Figure 8-4 Mirrool Creek Catchment Rainfall Climate

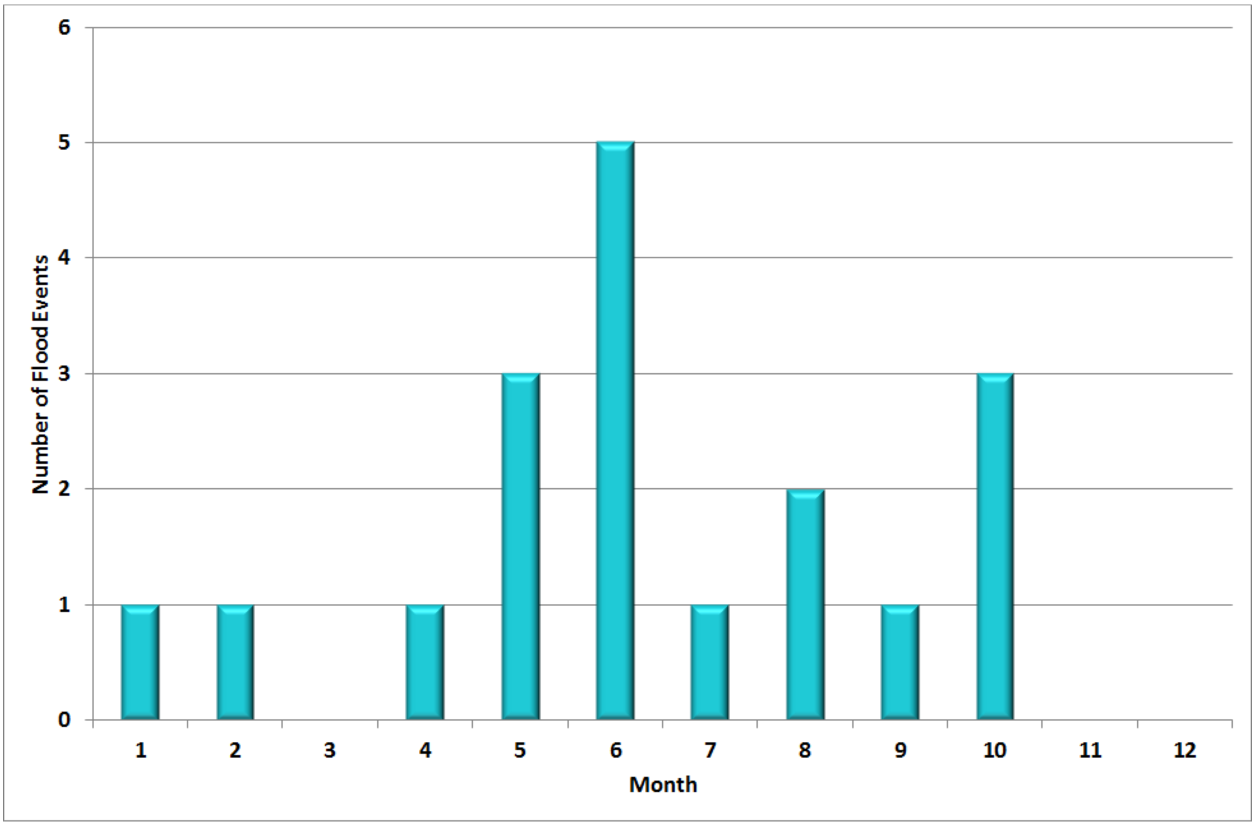


Figure 8-5 Monthly Occurrence of Flood Events at Barellan

However, although flooding is more frequent in winter, three of the largest six floods to have occurred since 1930 have been in March. January, February and March all experience extreme rainfall events, but March appears to be the month in which these rainfall events result in catchment flooding. This could be due to typically higher soil moisture content in March, or the nature of prevailing weather patterns to produce wetter antecedent conditions, or a combination of both.

Figure 8-6 shows the rainfall depths preceding the six largest recorded flood events on Mirrool Creek. The rainfall depth values within the legend are the 2-day totals for the event itself. The data presented is an average of values recorded at Binya Post Office and Ardlethan Post Office, to provide an indicative catchment average for the Mirrool Creek catchment. It indicates a distinct difference between the March floods to those in winter and spring. Flood events in March appear to occur following heavy rainfall over the preceding week or two, with each of the three events having around 100mm rainfall in that period. The event itself is then generated from a burst of intense rainfall, being over 120mm for the 2012 event and 50mm to 60mm for the other two March events. The winter-spring flood events are characterised by a sustained period of above average rainfall, followed by a burst of intense rainfall of up to 60mm. This analysis also highlights just how much larger the March 2012 flood was than previous events.

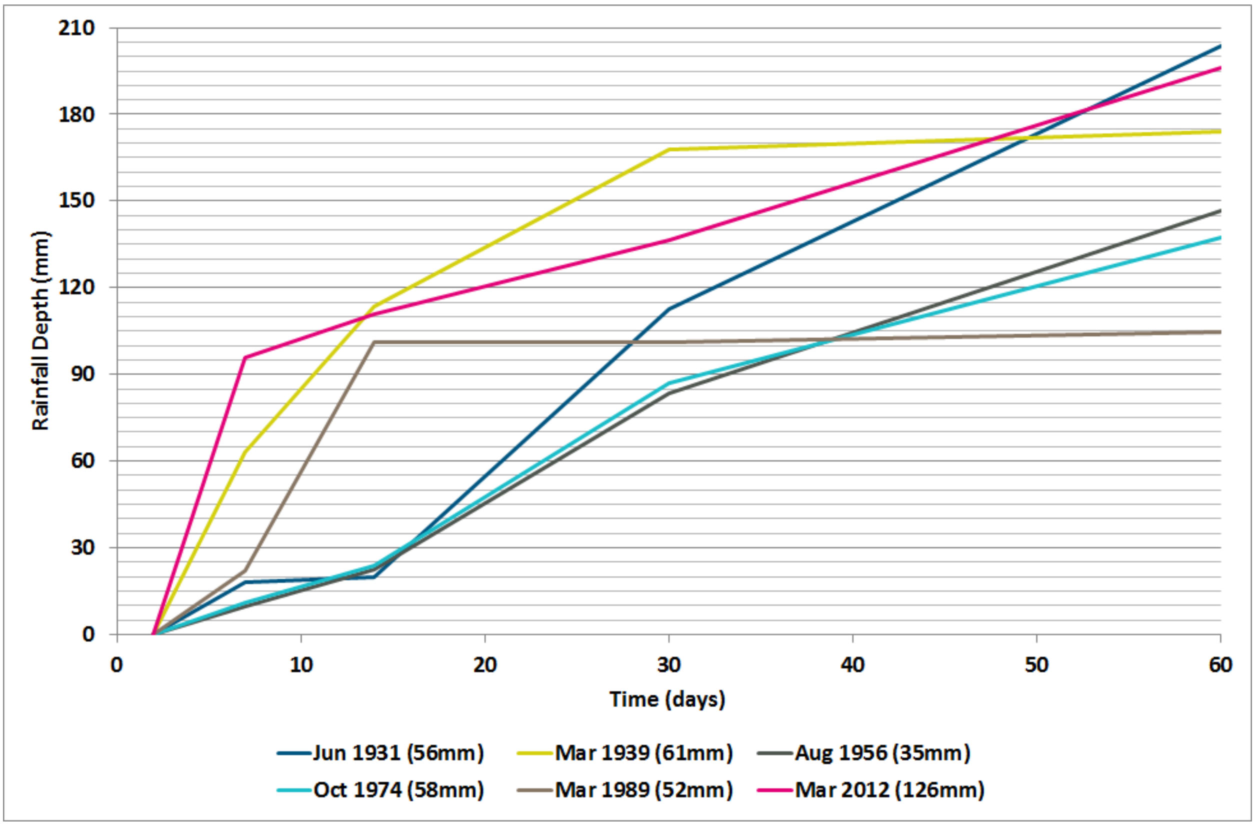


Figure 8-6 Mirrool Creek Flood Event Analysis

8.2 Transfer of Flows across the Main Canal

One of the most significant influences on flooding in the Mirrool Creek catchment is the MI Main Canal. Some 80km length of the Main Canal traverses the Mirrool Creek catchment between Yanco and Griffith, crossing Mirrool Creek itself around 7km east of Yenda. At the Mirrool Creek crossing is a siphon structure that transfers flows under the Main Canal. It has five rectangular barrels, each being around 2.3m wide by 1.15m high, with an invert level of 128m AHD.

There are also a set of escape doors in the Main Canal, which allow the water level in the canal to be drawn down by releasing water to Mirrool Creek on the upstream side of the canal. These have a total width of around 9m, with a sill level of around 132.6m AHD. Following flooding of Yenda in June 1931 a set of flood gates were installed that allow flow to be released from the canal to Mirrool Creek on the downstream side of the canal. The gates have a total width of around 14.8m and a sill level of around 132m AHD. The location of these structures is presented in Figure 8-7.

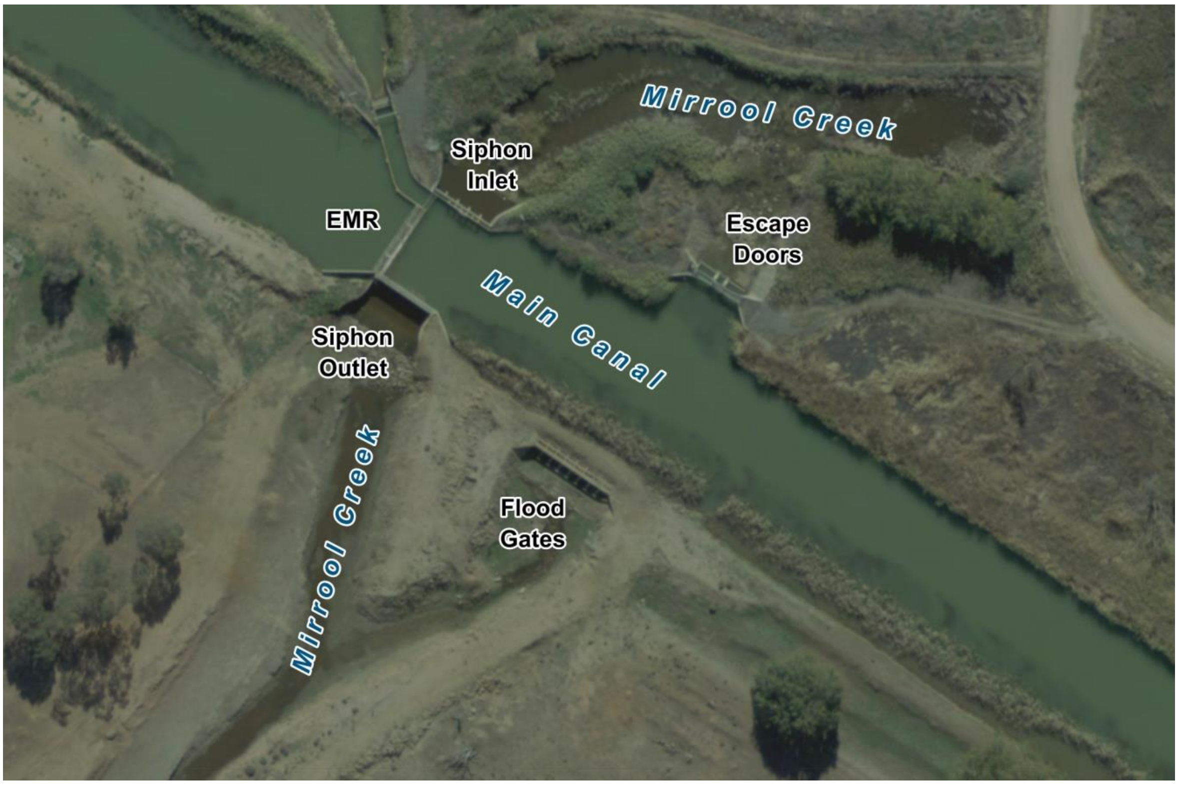


Figure 8-7 Hydraulic Structures at the East Mirrool Regulator

During flood events since 1931 the escape doors and flood gates have been opened to allow flood waters from Mirrool Creek to flow through the Main Canal to the downstream floodplain. However, the flood gates were decommissioned in the early 1990s and were unable to be operated during the March 2012 event. With water levels in the canal unable to be drawn down, the canal banks were placed under enormous strain and this resulted in a number of breaches.

The March 1939 event is the largest flood to have occurred whilst the flood gates were operational. Water level and flow data was recorded during the event, which provides an understanding of how the siphon and gate structures operate during a large flood. The recorded water level hydrographs are presented in Figure 8-8. The water levels upstream of the Main Canal are similar to each other, as would be expected. The location of the gauge is understood to be on Mirrool Creek a little further upstream from the Main Canal and is around 0.1m higher than at the upstream side of the canal. The two water level records on the downstream side of the canal are also similar to each other. The water level downstream of the escape doors is different to those upstream and downstream of the canal and represents the water level within the canal, between the two gate structures.

There is a significant head drop of up to 0.6m through the escape doors, which appear to be a significant control on the flow that can pass through the canal. The escape doors are narrower than the flood gates and have a higher sill level. This structure controls flow through the canal during a flood event and has a smaller capacity than the flood gates on the downstream side.

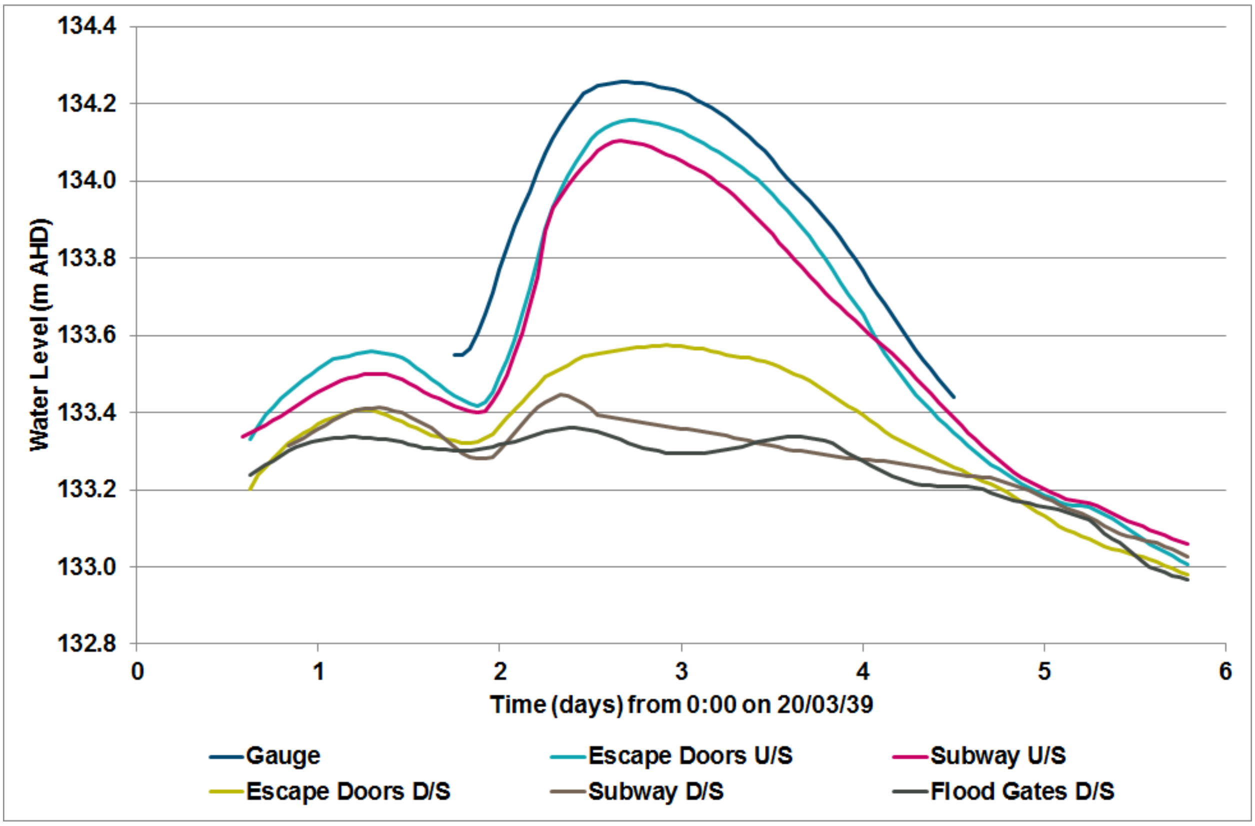


Figure 8-8 Recorded Water Levels at the EMR during the March 1939 Flood

Flows through the siphon and gate structures were also gauged at two different stages during the event and are presented in Figure 8-9. These flow gaugings were used to estimate the peak flow rate through the Main Canal during the peak of the March 1939 flood event. This was established at around 77m^3/s (~6,600 ML/day) by the hydrographers that gauged the flood.

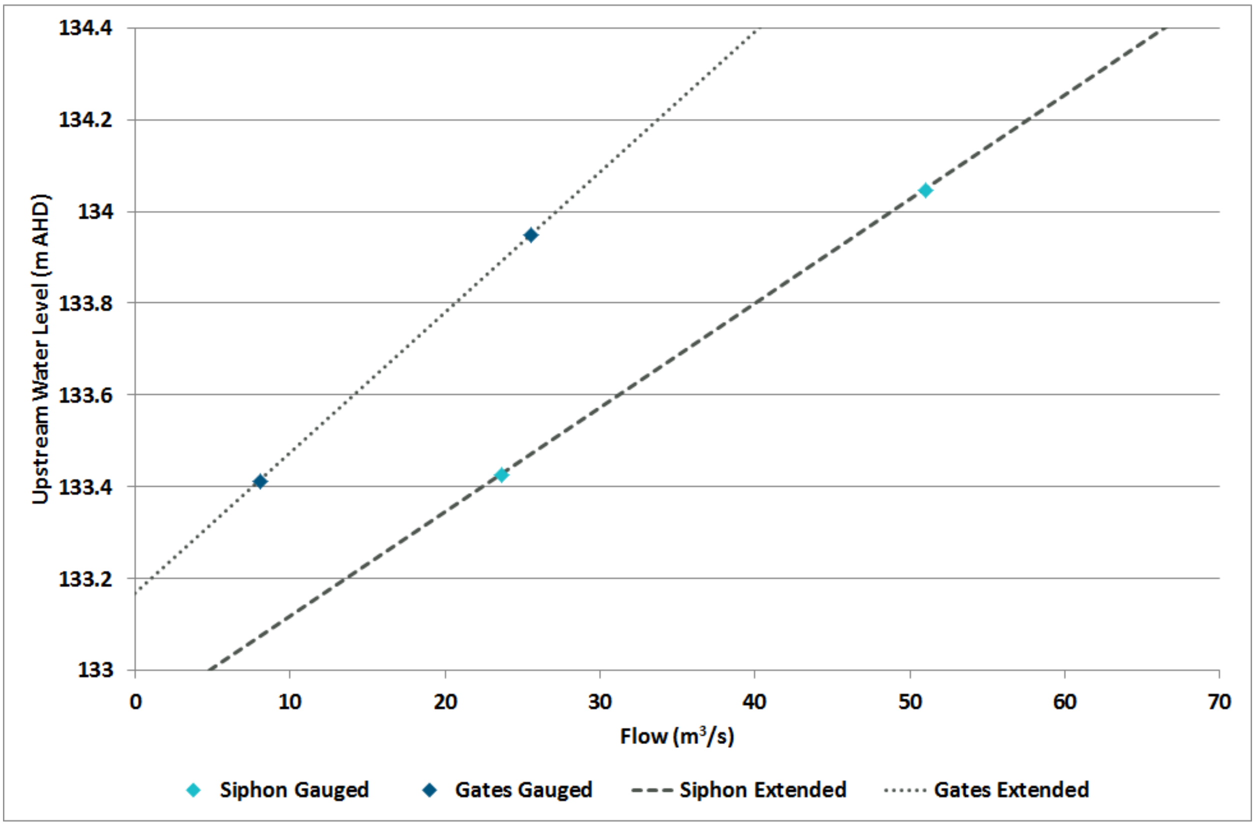


Figure 8-9 Recorded Flows at the EMR during the March 1939 Flood

8.3 Mirrool Creek Catchment Modelling

The Mirrool Creek catchment model is a direct rainfall TUFLOW model of the entire catchment, utilising the rapid GPU solver, as detailed in Section 4.3. The model was used to simulate the March 2012 flood event in order to help understand the way the catchment responds to extreme rainfall events and the relative flow distributions upstream of the East Mirrool Regulator. Flood flow hydrographs were extracted from the catchment model and input to the Main Drain J model to determine the relative flow distributions in the vicinity of the East Mirrool Regulator and provide a basis from which to test various scenarios and mitigation options.

8.3.1 March 2012 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the Mirrool Creek catchment was shown in Figure 2-2 with their respective periods of record shown in Table 2-1. Given the large size of the catchment no particular gauges best represent the rainfall, as there is a large amount of spatial variability. There are five continuous rainfall gauges in the vicinity of the catchment and these have been used to represent the temporal patterns of the March 2012 rainfall.

The hyetographs for the hourly rainfall record recorded at the Griffith Airport, Yanco and Wattle Creek gauges for the March 2012 event are provided in Figure 8-10. The record shows that the storm lasted around 21 hours, with three distinct rainfall bursts. The event started in the morning of 3rd March, lasting until the early hours of 4th. Around 146mm was recorded at Griffith, 177mm at Yanco and 63mm at Wattle Creek.

The temporal pattern at Yanco is similar to that of Griffith, albeit lagging around one hour behind. At Wattle Creek there is a further two hour lag and a distinctly different temporal pattern. The first rainfall burst shows a similar intensity to that of Griffith and Yanco, but the second and third bursts are replaced by steady light rain. The temporal pattern at Griffith CSIRO was similar to that of the airport and Naradhan to that of Yanco. These two additional temporal patterns have been omitted from Figure 8-10 for clarity. The application of these temporal patterns across the Mirrool Creek catchment model is presented in Figure 8-11.

The spatial variation of rainfall depth for the March 2012 event has been analysed using the recorded daily rainfall totals at rainfall gauges in the vicinity of the Mirrool Creek catchment. The locations of the rain gauges together with their recorded rainfall depths for the March 2012 event are presented in Figure 8-11. The event rainfall depths were obtained from BoM and are a summation of the recorded rainfall depths for 3rd and 4th March. A continuous surface of rainfall depths was interpolated from the point recordings. Rainfall depth contours extracted from this interpolation at 20mm intervals are included on Figure 8-11 to show the spatial variation of total rainfall depths for the March 2012 event across the Mirrool Creek catchment and the wider region.

It can be seen from Figure 8-11 that the zone of heaviest rainfall is situated over the south of the catchment. Rainfall depths decrease gradually to the north and to the west, with a more marked decrease to the east. A rainfall depth of 165mm was recorded at the Barellan Post Office gauge in the middle of the catchment. The rainfall depth reduces in the upper catchment, with a total of 56mm recorded at the Ariah Park Post Office gauge. There is a consistent pattern in the recorded rainfall depths and this provides for a good interpolation.

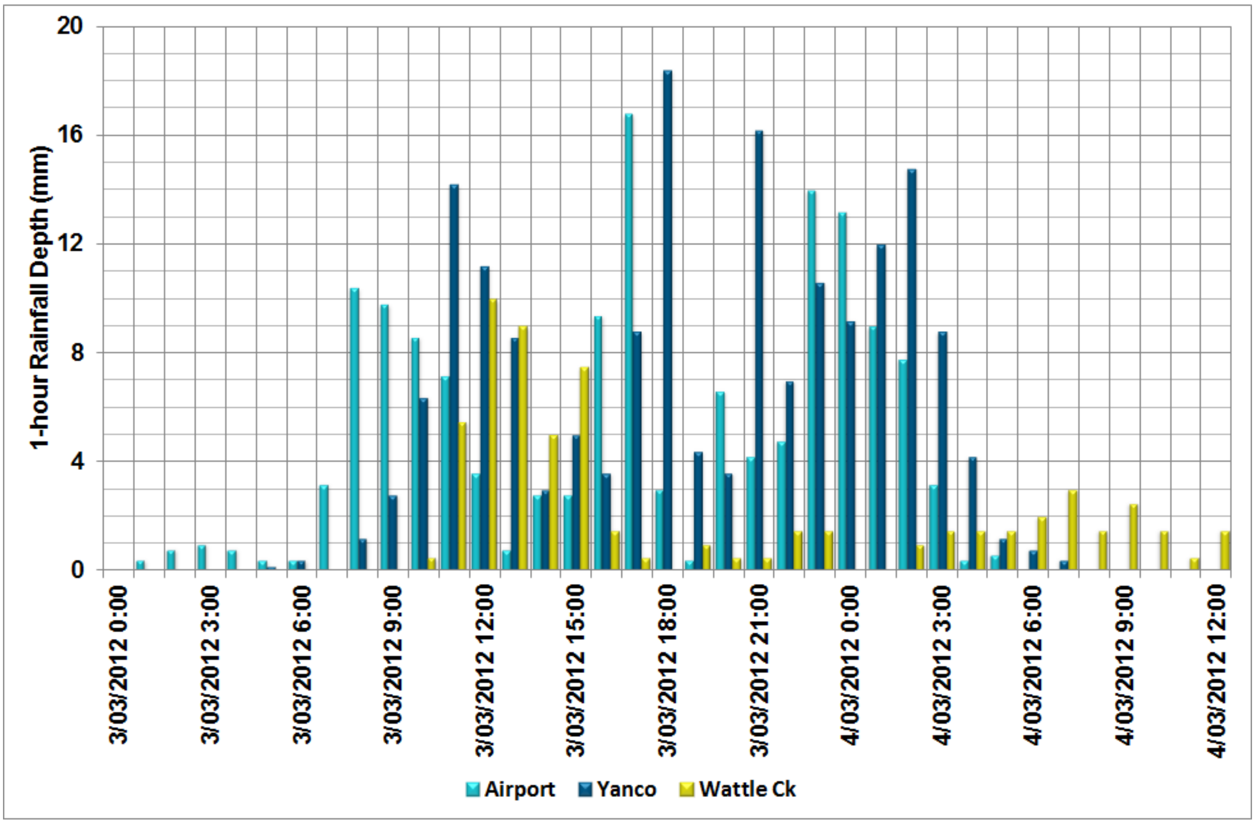
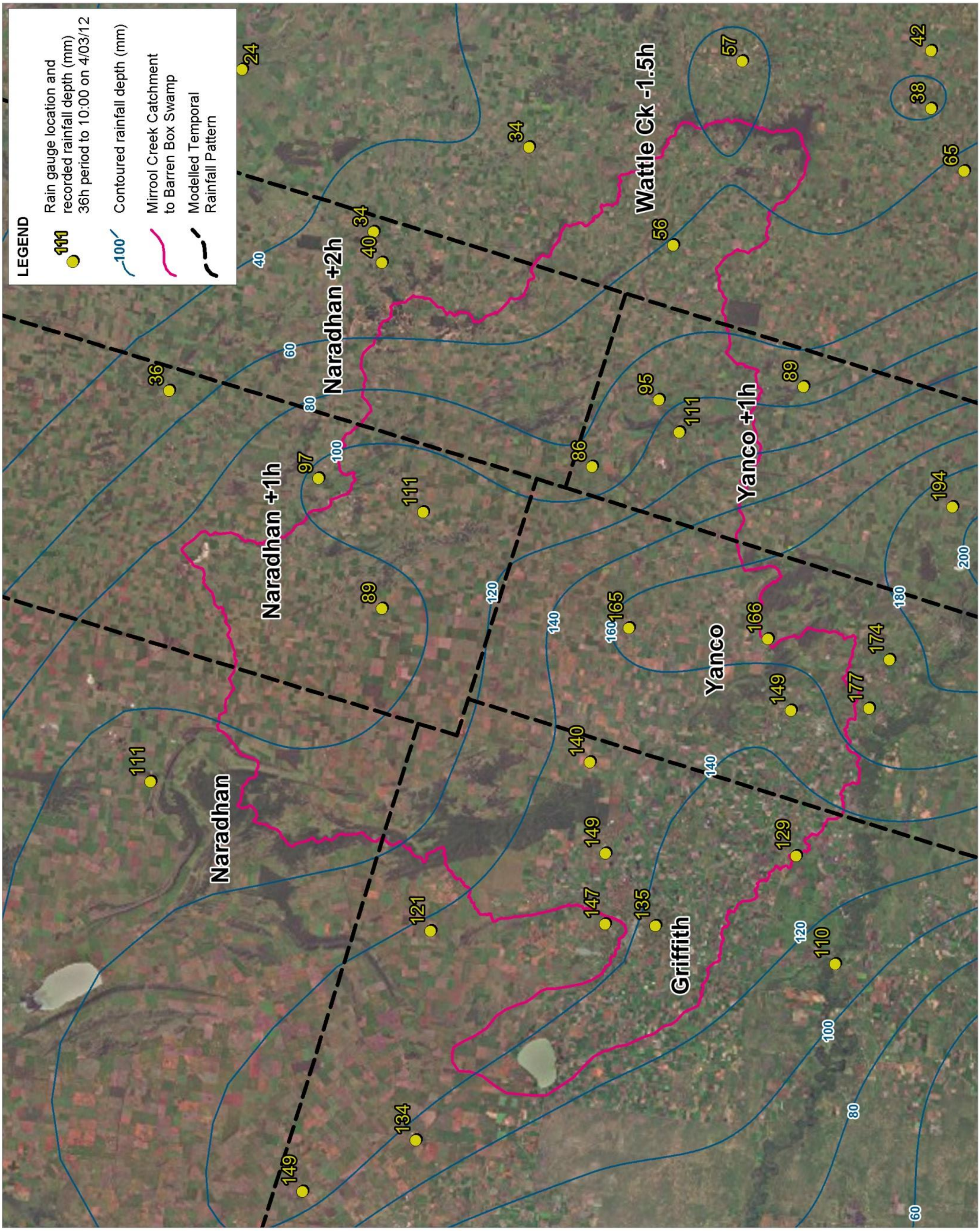


Figure 8-10 Mirrool Creek 1-hour Rainfall Hyetographs for the March 2012 Calibration Event



Title:

Mirrool Creek Spatial Variation of Rainfall Depths for the March 2012 Event

Figure: **8-11**

Rev: **A**

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0 15 30km

Approx. Scale

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To gain an appreciation of the relative intensity of the March 2012 event, the derived rainfall depths for various storm durations at the Yenda (Henry Street), Barellan Post Office, Ardlethan Post Office and Ariah Park Post Office rain gauge locations is compared with the design point IFD data for Yoogali as shown in Figure 8-12.

The derived depth vs. duration profiles for the March 2012 event from the adopted temporal patterns shows a storm containing distinct rainfall bursts. The first burst is prominent across the catchment, whereas the second and third bursts are not prominent in the far east of the catchment. Over a 24-hour duration the March 2012 rainfall is indicative of an event of lower magnitude than the 20% AEP at Ariah Park, around a 1% AEP event at Ardlethan, a 0.2% AEP event at Yenda and a 0.1% AEP event at Barellan.

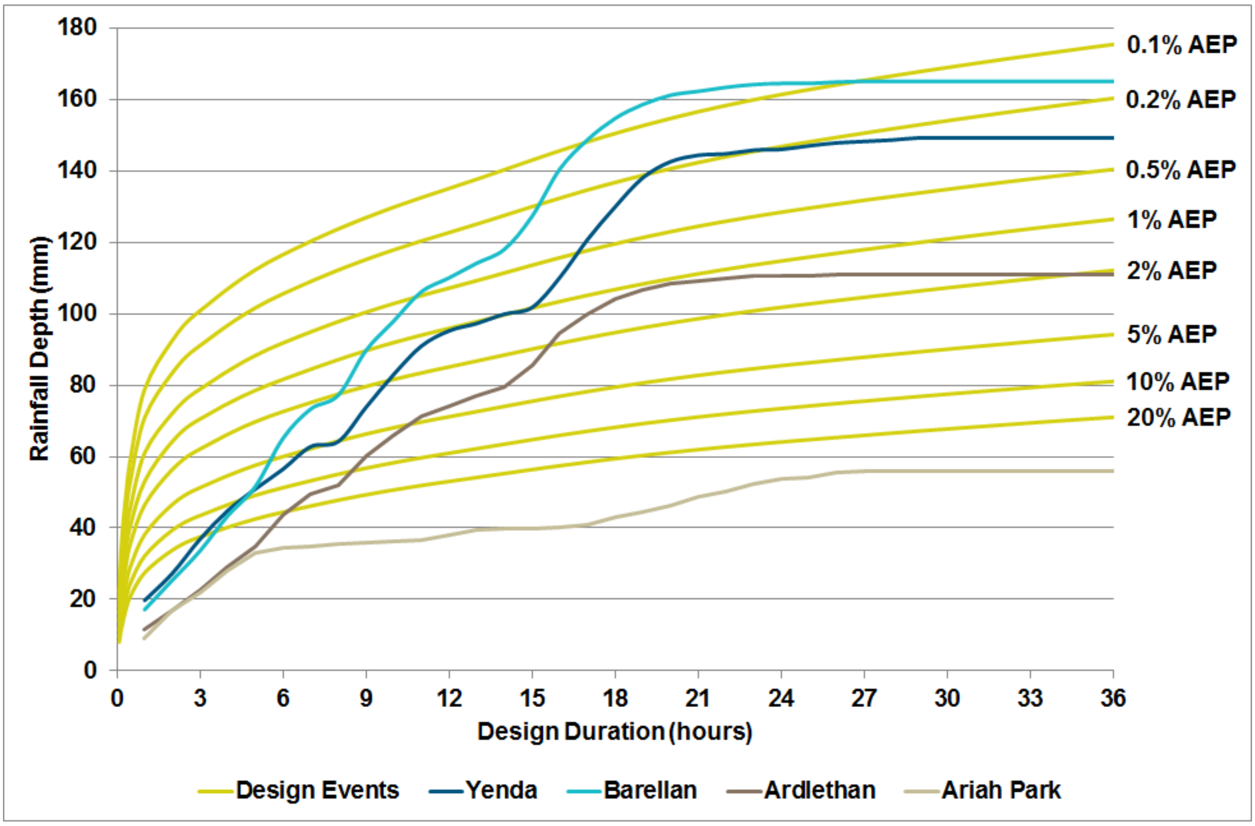

Figure 8-12 Comparison of Mirrool Creek March 2012 Rainfall with IFD Relationships

The March 2012 rainfall represents a large magnitude event throughout most of the catchment. To gain an appreciation of a representative design event magnitude for the Mirrool Creek catchment an average depth vs. duration profile was derived from the four gauge locations. This profile is presented alongside the design IFDs in Figure 8-13. The design IFD curves have had areal reduction factors applied to them, as it is less likely for higher rainfall intensities to be sustained over a large area than it is for any given point location. Accordingly, the comparison is between observed average catchment rainfall for the event and average catchment design rainfall.

As discussed, the Binya Creek contribution to flooding in the Mirrool system for the March 2012 event was relatively small in relation to the Mirrool Creek proper. The majority of the runoff in the Binya Creek catchment is infiltrated into the sandy soils further down the catchment. This is evident in the satellite imagery for the event and backed up by observations from the air during the event. The catchment analysis shown in Figure 8-13 therefore considers only the Mirrool Creek catchment of 2,500km^2.

There is a level of uncertainty regarding an appropriate catchment area, areal reduction factor and also to the critical duration of the Mirrool Creek catchment to use in comparing catchment average conditions to IFD rainfall relationships. Figure 8-13 should not be interpreted as definitively classifying the March 2012 event as an event of particular design magnitude. Rather, it provides an indication of the relative intensity of the March 2012 rainfall (which was a major rainfall event for the Mirrool Creek catchment being in excess of 1% AEP design rainfall) and is likely to provide for similar catchment runoff in excess of a 0.5 AEP standard design conditions. It is also important to note that design rainfall intensity of certain magnitude doesn't directly equate to a design flood level of similar magnitude (i.e. 1% AEP rainfall doesn't necessarily produce 1% AEP water levels).

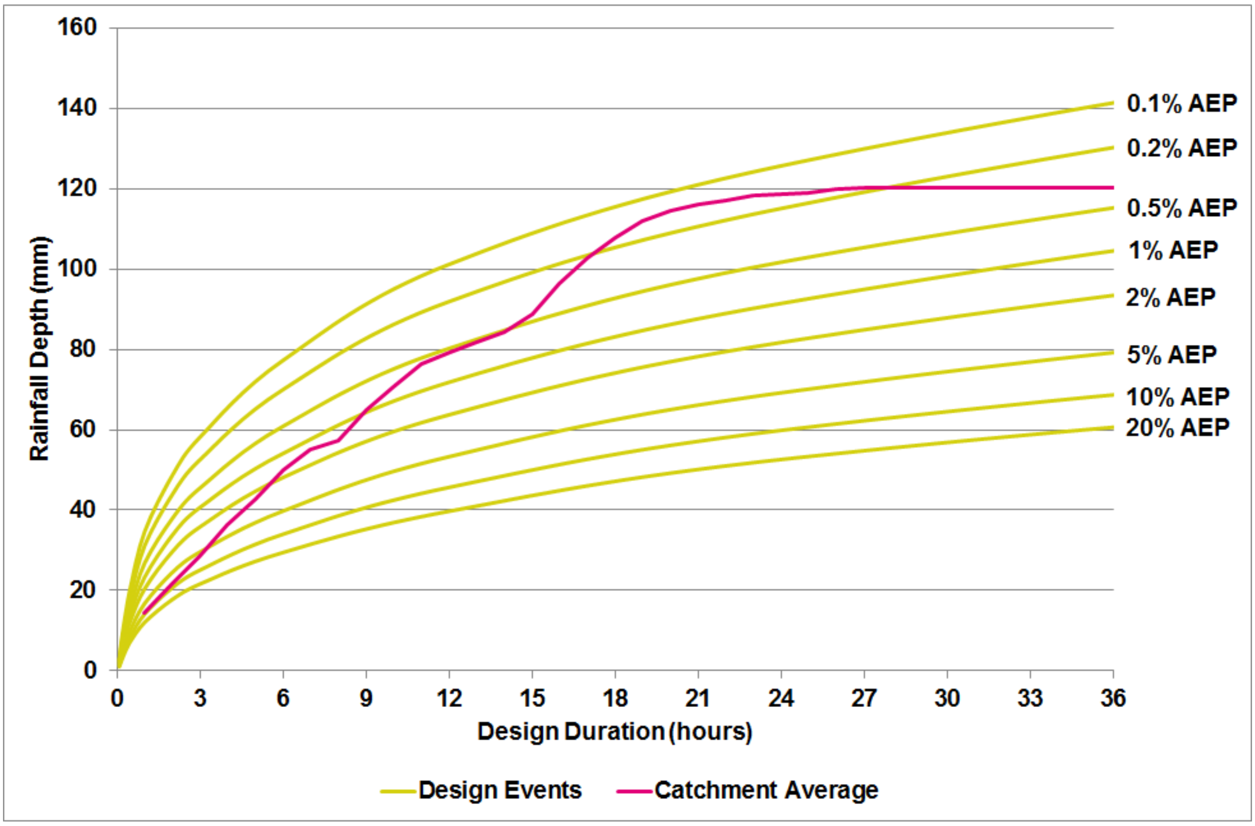

Figure 8-13 Mirrool Creek Catchment Averaged Rainfall Depth vs. Duration Profile for March 2012

8.3.2 Modelled Roughness Values

The vegetation across the Mirrool Creek catchment is grassland for agricultural use. There are also areas of irrigated agriculture for crops and orchards and relatively small extents of remnant native vegetation. Given the levels of uncertainty inherent with other aspects of the catchment modelling, a uniform Manning's 'n' value of 0.06 was adopted, being representative of the principal catchment land use. The model calibration process indicated that a higher roughness of 0.075 better represented the hydrological response of the Mirrool Creek catchment, as discussed further in Section 8.3.4.

8.3.3 Rainfall Losses

The continuous infiltration functionality of TUFLOW was incorporated into the Mirrool Creek catchment model. This approach assigns parameters based on soil types, utilising the Green-Ampt methods to determine initial and continuing rainfall losses. This approach was required to represent the continuous infiltration of the catchment runoff as it travels through the system, which is a prominent feature of the Binya Creek catchment. It also enables the significant attenuation of the flood wave through the Barellan floodplain area to be represented. These features cannot be correctly represented in a more traditional hydrological model such as RAFTS.

The Green-Ampt method defines soil infiltration properties using the following parameters:

- Suction (mm);
- Hydraulic Conductivity (mm/h); and
- Porosity (fraction).

An initial moisture fraction is also defined, to represent the antecedent conditions at the onset of the modelled event. The suction, porosity and initial moisture fraction determine the initial loss of the soil, with the hydraulic conductivity representing the continuing loss.

Published parameters exist for standard soil types and were used as the basis for defining initial values for the two soil types within the Mirrool Creek catchment. For the clay soils a suction of 240mm, hydraulic conductivity of 0.6mm/h and a porosity of 0.3 was selected, which is similar to the standard parameters of sandy clay. For the sandy soils a suction of 110mm, hydraulic conductivity of 11mm/h and a porosity of 0.4 was selected, which is similar to the standard parameters of sandy loam. For the initial moisture fraction, values of 0.3 and 0.4 were adopted for the clays and sands respectively. This represents a saturated soil condition and was based on analysis of the rainfall preceding the storm event. A total rainfall depth of around 100mm fell across the Mirrool Creek catchment in the week prior to the event of 3rd and 4th March. This represents a weekly rainfall in the order of a 10% AEP.

It was anticipated that the selected parameters would have to be adjusted to fit available calibration data, given the variability in hydraulic conductivity between soil types. The Green-Ampt method also has the ability to model groundwater interaction, but given a lack of sufficient data and other inherent uncertainties it was not utilised. Therefore the hydraulic conductivity would likely have to be reduced to compensate for this. The model calibration process indicated that a hydraulic conductivity of 0.5mm/h for the clays and 10mm/h for the sandy soils better represented the hydrological response of the Mirrool Creek catchment, as discussed further in Section 8.3.4. The model was found to be unaffected by the adopted suction and porosity parameters (which affect initial loss), given the high initial moisture fractions adopted.

8.3.4 March 2012 Observed and Simulated Flood Behaviour

The only gauge data within the Mirrool Creek catchment against which to calibrate the modelled catchment response is that recorded on Mirrool Creek at McNamara Road. The gauge site is situated some 12km upstream of Barren Box Swamp and 4km downstream of the Main Drain J confluence. Data was provided by Murrumbidgee Irrigation as daily flow measurements, which given the size of the catchment are adequate for comparison with modelled flow hydrographs. The conversion of the gauge datum to m AHD is unknown.

The McNamara gauge record was used as the principle measure of model calibration and was used to determine suitable parameters of roughness and hydraulic conductivity, in representing the Mirrool Creek catchment hydrological response. Figure 8-14 shows the modelled flow hydrograph at McNamara Road against the recorded flows. The modelled hydrograph matches well to the recorded data. The corresponding flow hydrographs upstream and downstream of the East Mirrool Regulator are also presented.

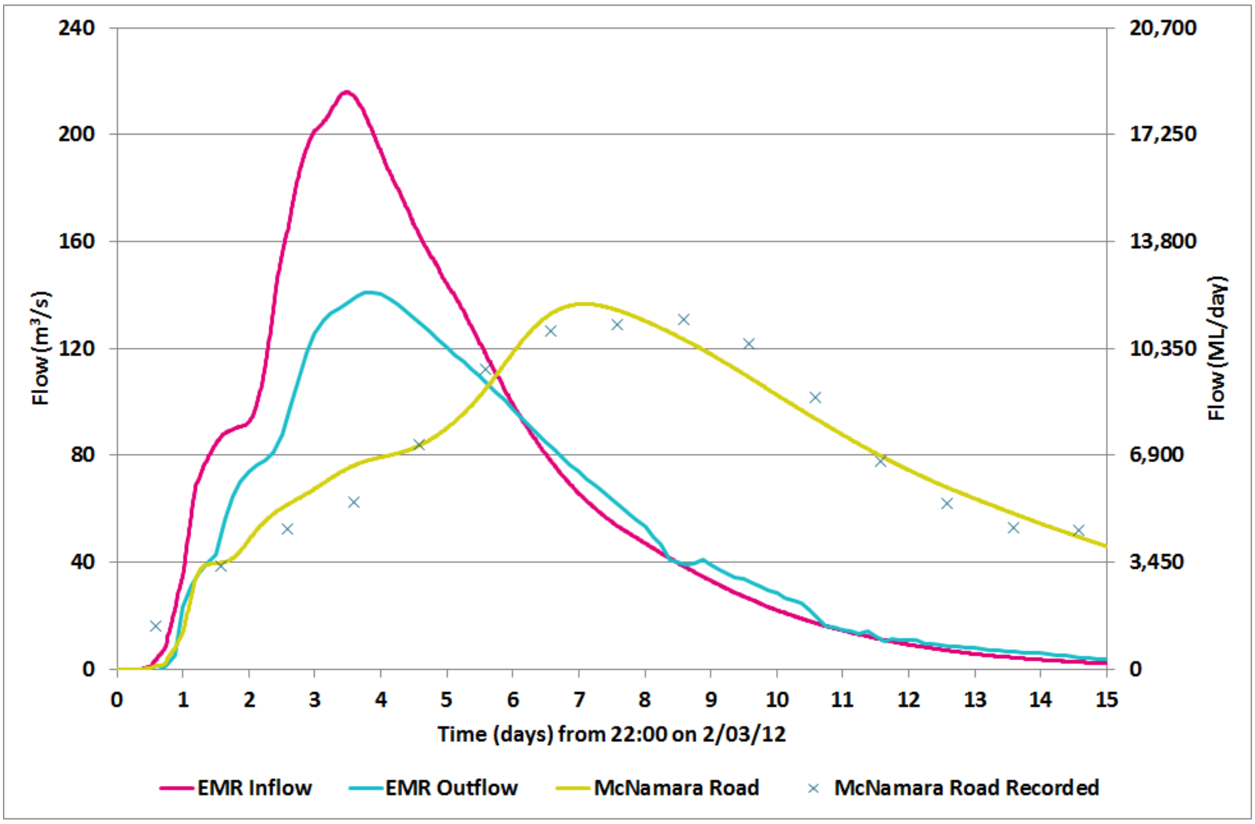

Figure 8-14 March 2012 Modelled Flow Hydrographs for Mirrool Creek

The characteristics of the soils within the Mirrool Creek catchment are the principle driver of the flood hydrology. Despite the Binya Creek catchment being much larger than that of Mirrool Creek, it is the runoff from Mirrool Creek that appears to generate flooding at the East Mirrool Regulator. This is evident in the March 2012 event where despite over 100mm of rainfall across the catchment and a wet antecedent condition, Binya Creek did not contribute significantly to the catchment flooding.

Figure 8-15 shows Landsat 7 satellite imagery captured on 4th March 2012. The turbid flood waters of Mirrool Creek can clearly be seen as buff-coloured extents. Also evident are extents of wet soils where flood waters have previously flowed. These areas show as darker brown than the adjacent dry areas. The nature of flooding in the Binya Creek catchment is noticeably different to that of Mirrool Creek. The flood waters emanating from the upper catchment are disconnected from those in the lower reaches of Binya Creek. There is around a 10km length of floodplain in which there is no surface water visible, but extensive areas of wet soil. It appears that the soils in this area have high rates of infiltration and are retaining the runoff from the upstream catchment.

As the behaviour of the soils in this location are key to the flood hydrology of Binya Creek, the modelled soil distribution was modified to better represent their observed distribution in the satellite imagery. The original and modified interfaces between the modelled clay and sandy soils are included in Figure 8-15. The modification to the distribution of the two soil types has a minimal impact on model calibration at McNamara Road, but a significant impact on the timing of the flood flow hydrograph from the Binya Creek catchment.

Figure 8-16 shows a Landsat 7 satellite image captured on 4th March 2012. It shows extensive inundation of the Barellan floodplain area, which is mostly being drained around the southern end of Merribee Hill (location C). The Mirrool Creek (location B) and Binya Creek (location A) alignments appear to be conveying a smaller proportion of catchment runoff.

Figure 8-17 shows a RapidEye satellite image captured on 6th March 2012. Again, it shows extensive inundation of the Barellan floodplain area. However, Mirrool Creek now appears to be the principal outlet, with an increased flood inundation extent. The flood inundation around the southern end of Merribee Hill is reduced from that on 4th March. The runoff from the Binya Creek catchment has also reduced, as evidenced by the termination of the flood flow path through Binya Forest.

Figure 8-18 shows a DEIMOS satellite image captured on 8th March 2012. By now the inundation of the Barellan floodplain area is beginning to recede. The flood flows along the Mirrool Creek alignment now appear similar to that of 4th March and the flow path around the southern end of Merribee Hill is further reduced.

Figure 8-19 shows the modelled flow hydrographs for the March 2012 event at the three locations marked in Figure 8-16 to Figure 8-18. The flow hydrograph for Binya Creek (location A) shows a moderate response on 4th March which has reduced to a rate of interflow by 6th March. Mirrool Creek (location B) shows a similar response to Binya Creek on 4th March, a significantly increased flow rate on 6th March, followed by a similar decrease by 8th March. The Merribee Hill hydrograph shows a rapid response on 4th March which then reduces significantly by 6th March and further still by 8th March. The modelled hydrograph responses correspond to the flood behaviour captured by the available satellite images.

The flow hydrographs on Binya Creek and Mirrool Creek are representative of the approach flows at the East Mirrool Regulator. However, the approach flow around the southern end of Merribee Hill attenuates significantly in the irrigated floodplain between location C and the East Mirrool Regulator, as evidenced by the Merribee hydrograph presented in Figure 8-19. The Binya Creek, Mirrool Creek and Merribee hydrographs were extracted from the Mirrool Creek catchment model and were applied as inflow boundaries to the Main Drain J catchment model.

Title:

Influence of the Sandy Soils of Binya Creek on Mirrool Creek Flood Hydrology

Figure: 8-12

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BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

BMT WBM

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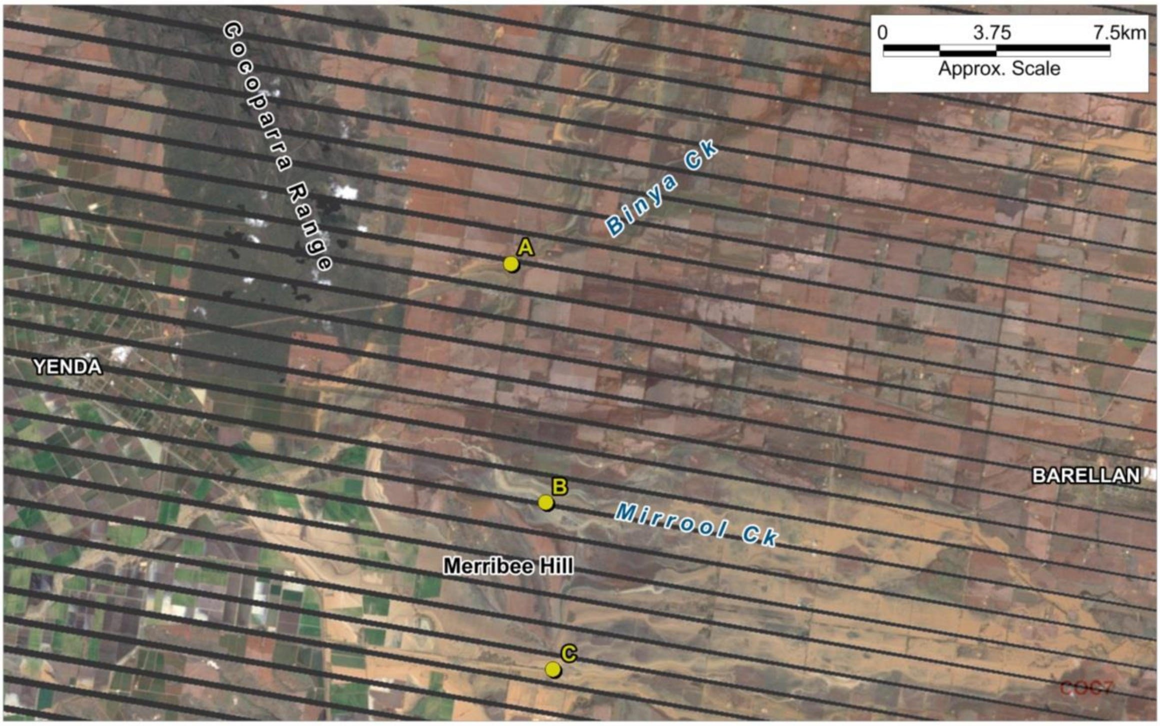


Figure 8-16 Landsat 7 Imagery for 4th March 2012

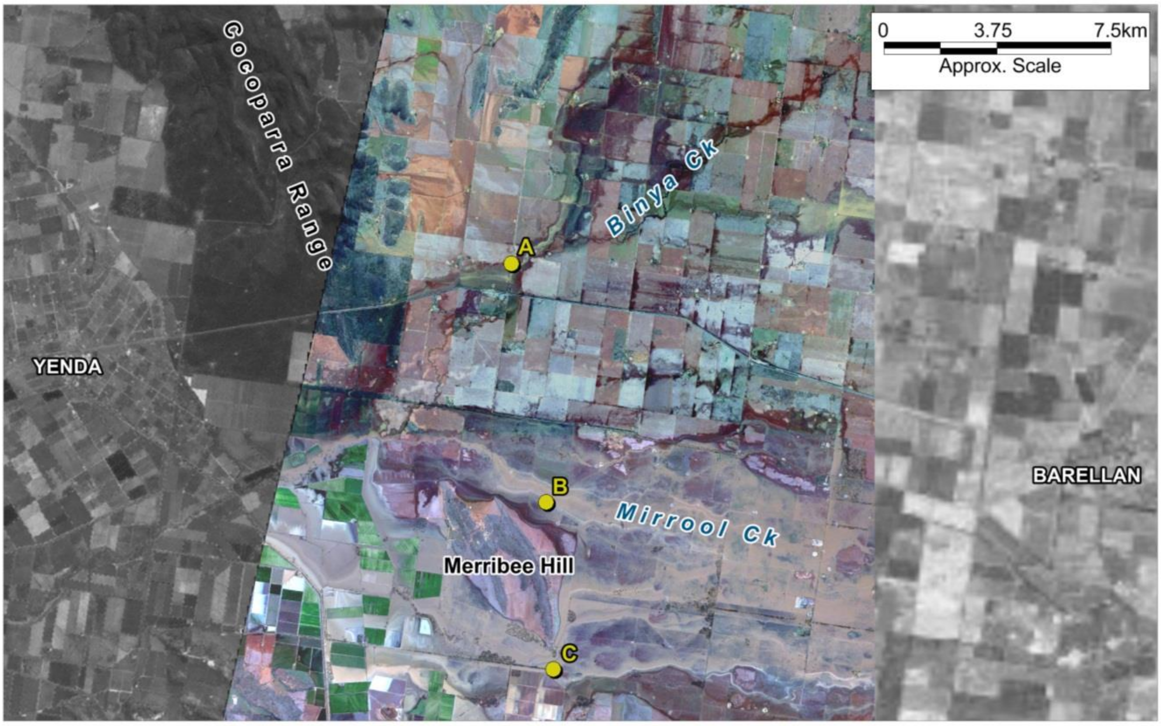


Figure 8-17 RapidEye Imagery for 6th March 2012

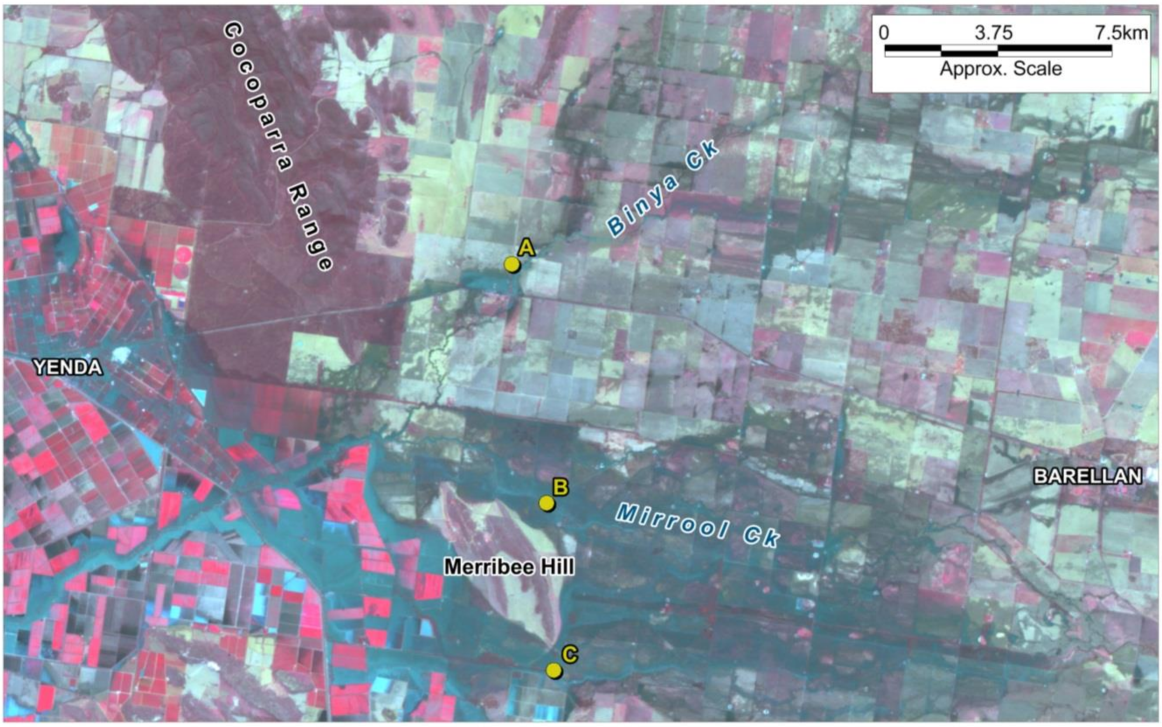


Figure 8-18 DEIMOS Imagery for 8th March 2012

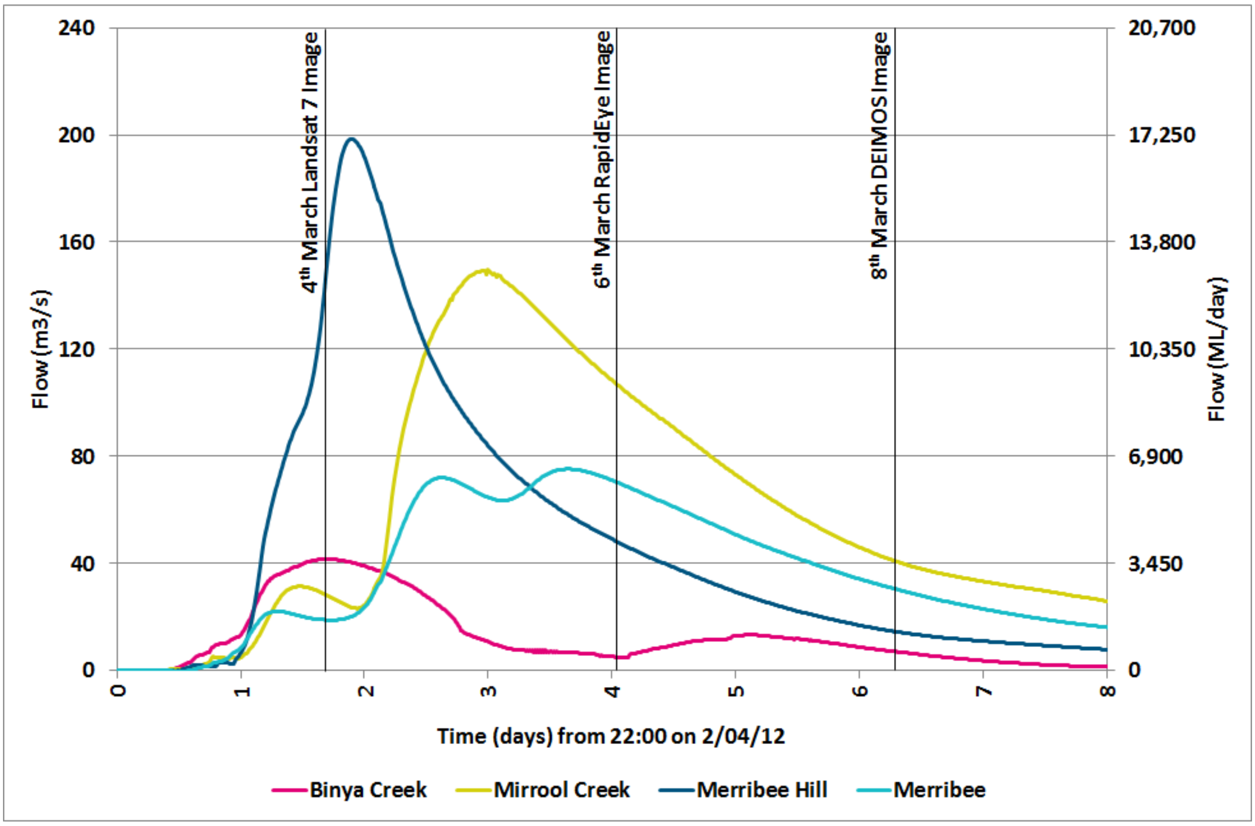


Figure 8-19 March 2012 Modelled Flow Hydrographs of the Mirrool Creek Catchment

8.3.5 Sensitivity Analysis

There are three model parameters that significantly influence the modelled hydrological response of Mirrool Creek at the East Mirrool Regulator:

- Manning's 'n' floodplain roughness;
- Hydraulic conductivity of the soils; and
- Adopted height of the Barellan field boundaries.

The model has been calibrated to the March 2012 event using a single combination of these parameters. However, it is likely that other combinations may also provide a reasonable representation. With no other recent flood events of a suitable magnitude to further calibrate the model, there remains a reasonably large amount of uncertainty regarding the selection of these parameters. It is therefore important to assess the sensitivity of the model to changes in these parameters, in order to better understand this uncertainty.

The adopted Manning's 'n' roughness of 0.075 was modified to 0.06 and 0.09 to test the influence on flow routing through the catchment. The adopted hydraulic conductivity of the soils was increased and decreased by 40% to test the impact of the infiltration rate on catchment runoff volume. The assumed representative height of 0.5m for the field boundaries throughout the Barellan floodplain was modified to 0.3m and 0.7m to test the influence on the flood wave attenuation through the floodplain.

The results of the sensitivity analyses are presented for Manning's 'n', hydraulic conductivity of the soils and the adopted heights of the Barellan field boundaries in Figure 8-20, Figure 8-21 and Figure 8-22 respectively. They highlight the sensitivity of the model results to changes in these three parameters and the inherent level of uncertainty within the catchment modelling. However, this also implies that the adopted model parameters provide a reasonable representation of the system as a whole, as adopting a different set of parameters would likely have a negative impact on the model calibration.

8.3.6 March 1939 Model Validation

For model validation purposes the March 1939 event offered the most comprehensive available dataset of flood records, including gauged flows at the East Mirrool Regulator and peak flood levels along Mirrool Creek. This event was therefore used to validate the Mirrool Creek catchment model, which was principally calibrated to the March 2012 flood event.

The distribution of rainfall gauge locations in the vicinity of the Mirrool Creek catchment was shown in Figure 2-2 with their respective periods of record shown in Table 2-1. Given the large size of the catchment no particular gauges best represent the rainfall, as there is a large amount of spatial variability. There were no continuous rainfall gauges operating during the March 1939 event and so only daily rainfall depths can be applied to the catchment model.

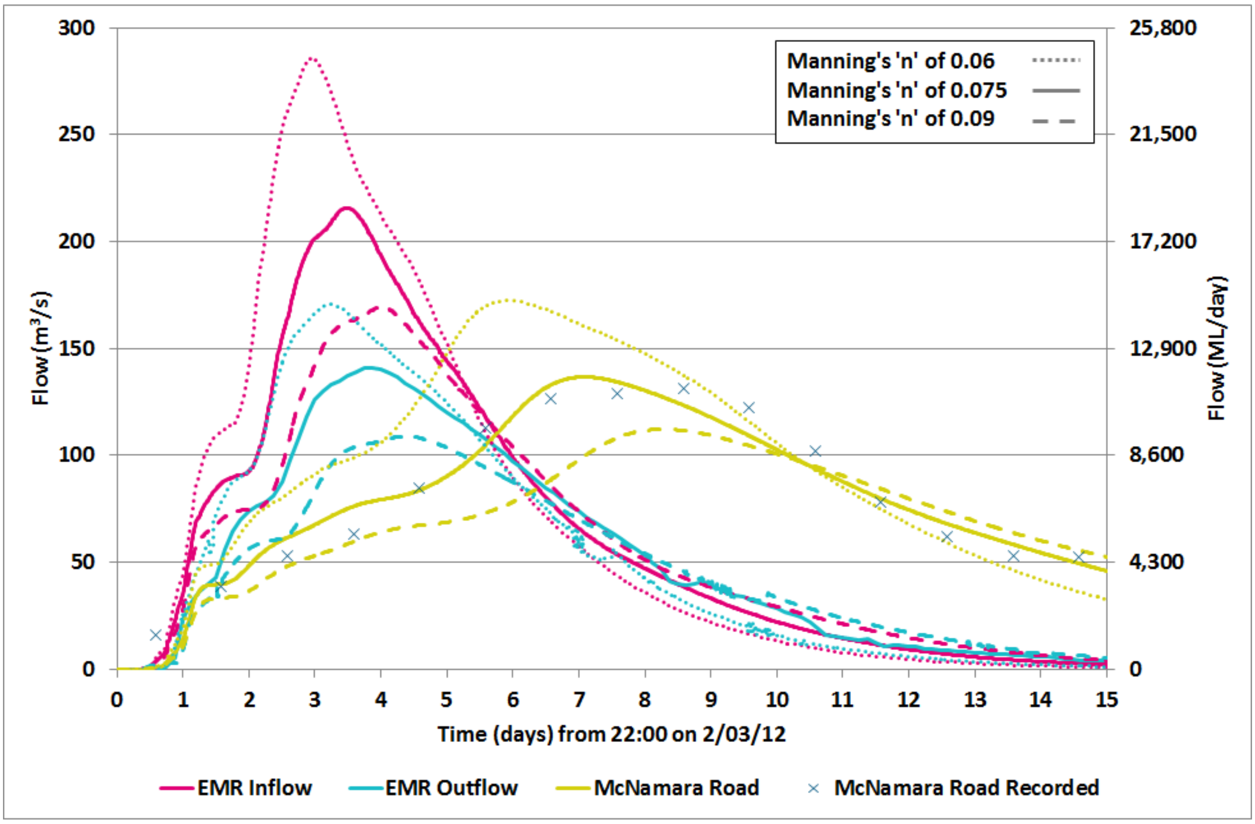


Figure 8-20 Sensitivity Analysis of Manning's 'n' on Mirrool Creek Catchment Model

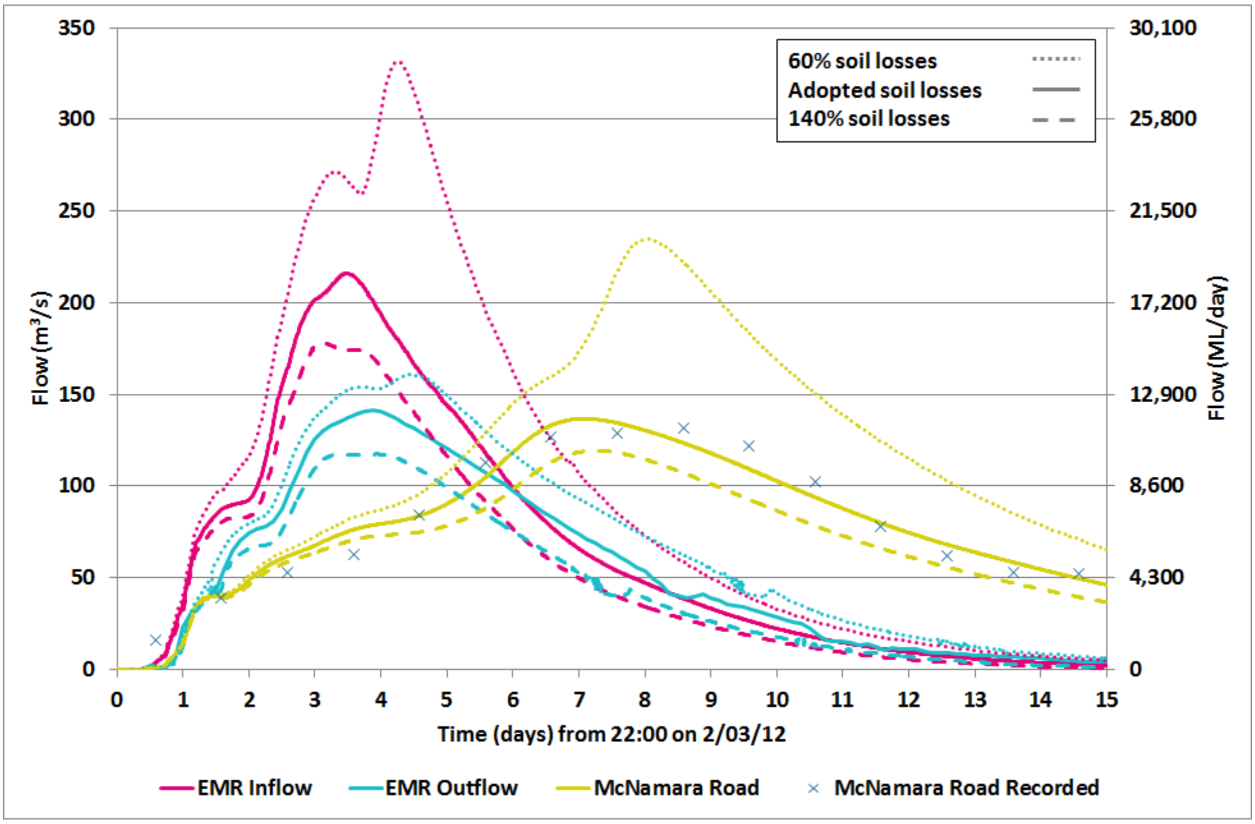


Figure 8-21 Sensitivity Analysis of Soil Losses on Mirrool Creek Catchment Model

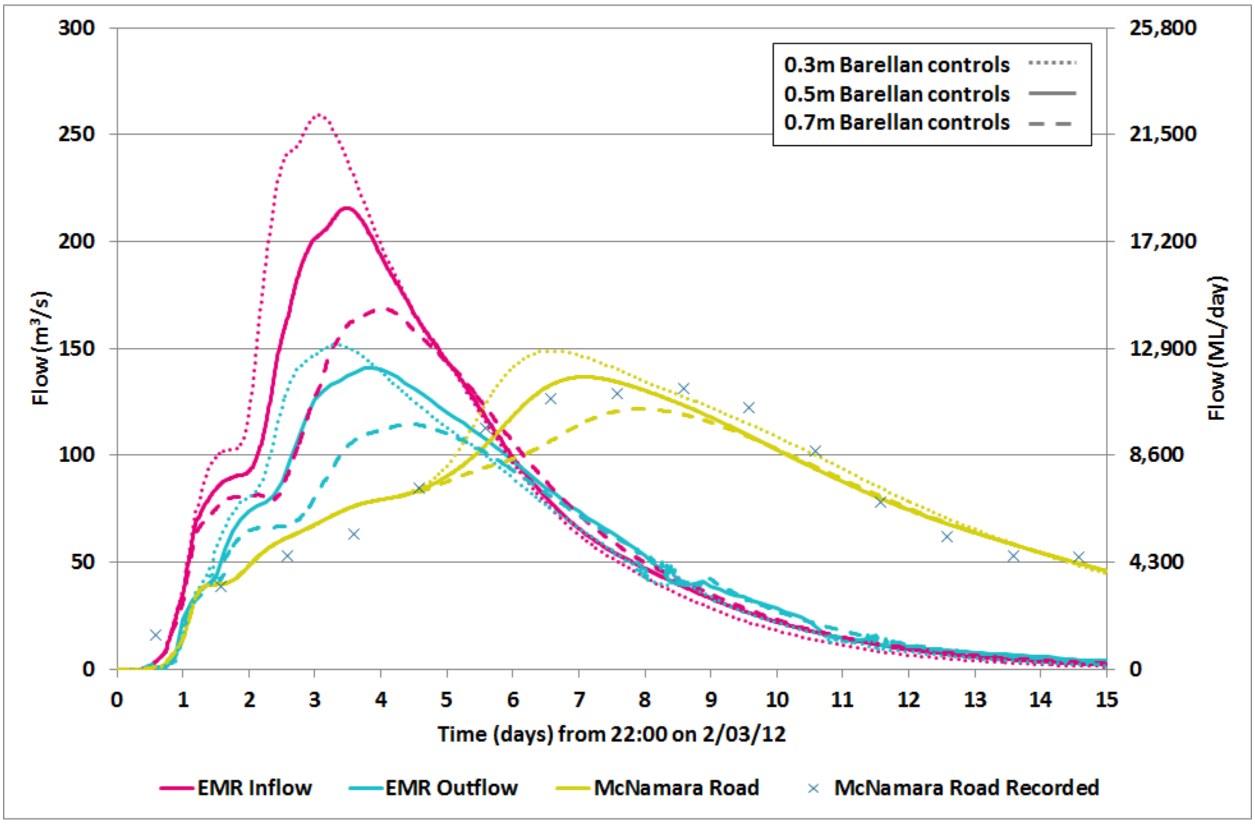
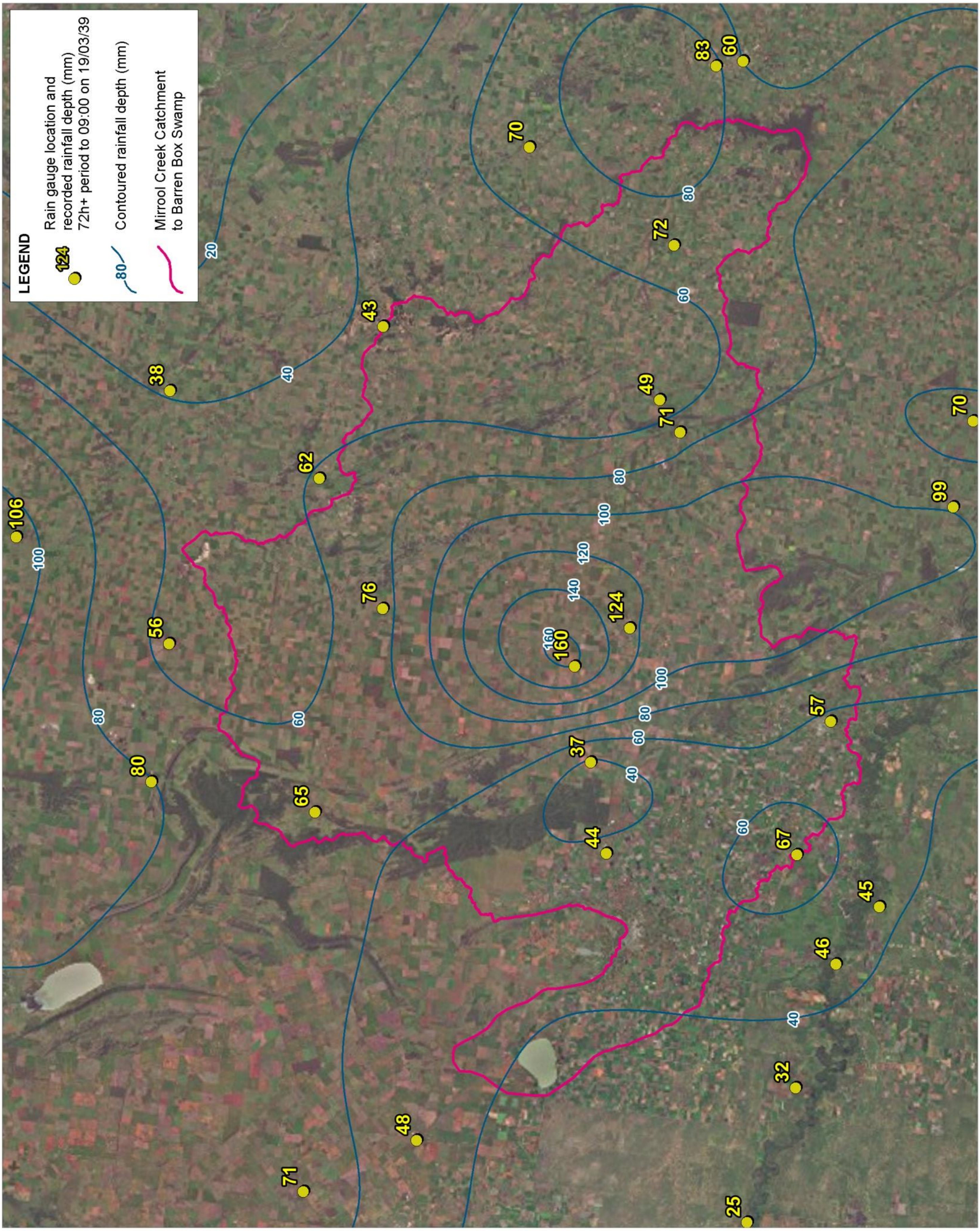


Figure 8-22 Sensitivity Analysis of Barellan Controls on Mirrool Creek Catchment Model

The spatial variation of rainfall depth for the March 1939 event has been analysed using the recorded daily rainfall totals at rainfall gauges in the vicinity of the Mirrool Creek catchment. The locations of the rain gauges together with their recorded rainfall depths for the March 1939 event are presented in Figure 8-23. The event rainfall depths were obtained from BoM and are a summation of the recorded rainfall depths for 16th to 19th March. A continuous surface of rainfall depths was interpolated from the point recordings. Rainfall depth contours extracted from this interpolation at 20mm intervals are included on Figure 8-23 to show the spatial variation of total rainfall depths for the March 1939 event across the Mirrool Creek catchment and the wider region.

The rainfall distribution for the March 1939 is complex. There appears to have been an initial storm aligned just to the east of the Cocoparra Range and Brobenah Hills, recorded predominantly on 17th, but extending slightly into the 16th. The extent of this storm is comparable to the 100mm contour presented on Figure 8-23. This was then followed by scattered storms over the next few days. The rainfall record for 18th March shows a patchy distribution of rainfall across the catchment with the gauges recording between 17mm and 63mm over a 24-hour period, as presented in Table 8-1. On 19th March most of the catchment receives little to no rainfall. However, almost 50mm is recorded at Barellan, which suggests another intense storm occurred around that area.

The March 1939 rainfall has been applied to the Mirrool Creek catchment model as a series of three 24-hour periods of uniform rainfall intensity, matching the recorded depths for each day. In reality there would have been more intense, shorter duration storms occurring at different times in different locations across the catchment. However, there is no temporal data available to determine the appropriate distribution of rainfall through time.



Title:

Mirrool Creek Spatial Variation of Rainfall Depths for the March 1939 Event

Figure: 8-23

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Table 8-1 Recorded Daily Rainfall Depths (mm) for the March 1939 Event

Gauge	Location	16th – 17th	18th	19th	Total
74000	Ardlethan	8	63	0	71
74002	Ariah Park	32	40	0	72
74005	Barellan	87	20	17	124
74006	Beckom	4	38	7	49
74020	West Wyalong	5	28	10	43
74062	Leeton	16	22	19	57
74094	Barellan	72	39	49	160
74118	Whitton	4	63	0	67
75006	Binya	20	17	0	37
75057	Rankins Springs	14	22	29	65
75072	Weethalle	17	38	21	76
75079	Yenda	5	18	21	44

Given the nature of the March 1939 rainfall event it is difficult to determine an accurate representative design magnitude. However, a catchment average of over 70mm in three days probably represents somewhere in the order of a 10% AEP rainfall. Rainfall was locally more intense over the Barellan floodplain and potentially represents up to a 2% AEP magnitude.

Figure 8-24 shows the recorded flow hydrograph through the Main Canal structures during the March 1939 event. It exhibits a dual response, which most likely represents local runoff from Barellan followed by later contributions from the upper Mirrool Creek and Binya Creek catchments.

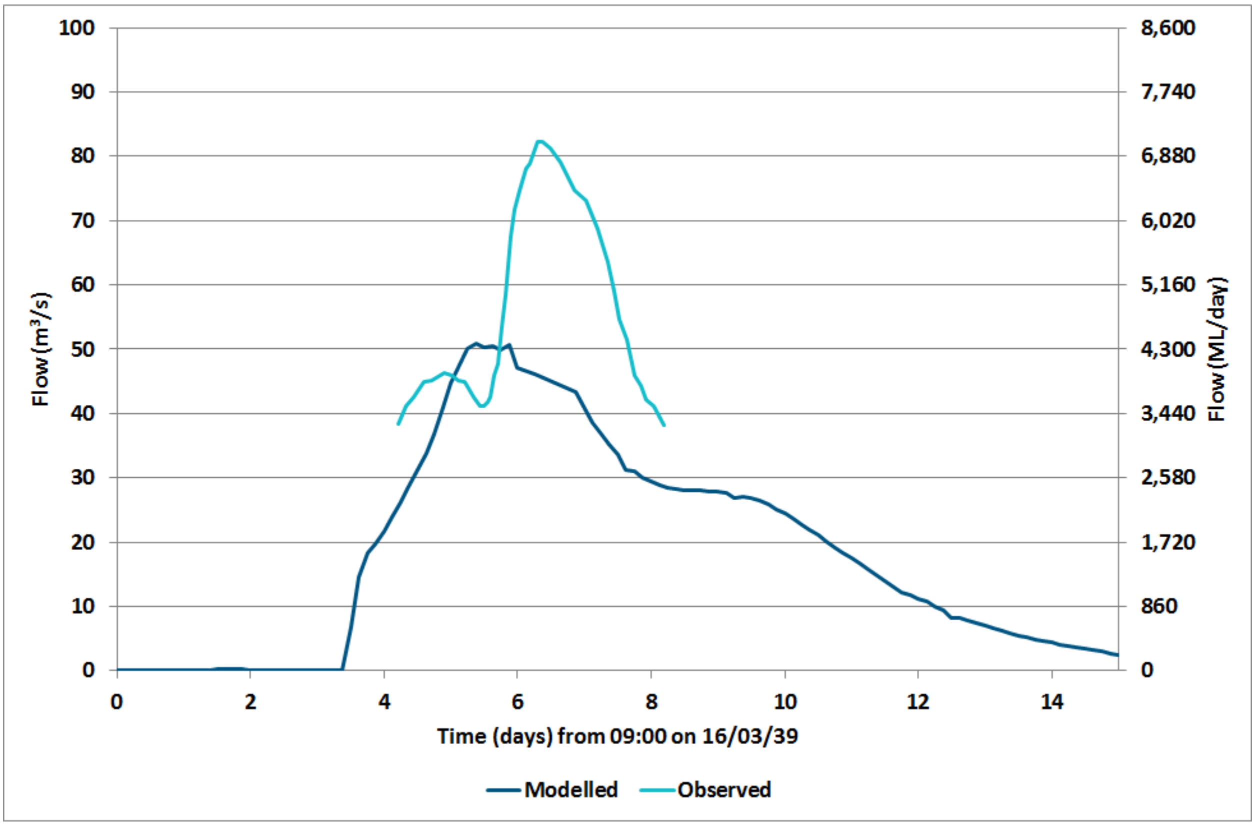


Figure 8-24 Mirrool Creek Flow Hydrograph for the March 1939 Event

As expected, the flow hydrograph from the catchment model does not match well to the observed data. The substantial uncertainties associated with the input rainfall data are key to this. The peakier response observed at the EMR during the event suggests more intense, shorter duration rainfall inputs than the more uniform temporal distribution adopted in the model. Also, the high spatial variability in the rainfall gauge records for 18th and 19th makes it difficult to derive a reliable spatial distribution of rainfall across the catchment for those days.

There is no clear storm pattern on 18th March and a number of different assumptions could be made as to the rainfall depths occurring in between the gauge locations that would significantly alter the modelled hydrological response. The single intense rainfall record at Barellan on 19th suggests the occurrence of a localised storm cell. Assumptions as to the peak intensity and spatial extent of this storm would also significantly alter the modelled flows.

Given the large amount of uncertainty associated with the model rainfall inputs it is not considered beneficial to adjust the adopted model parameters to improve the representation of the March 1939 flood event. This further highlights both the value and reliance upon the March 2012 event in understanding the flood behaviour of the Mirrool Creek catchment. The March 1939 event is the second best recorded event from which to assess the performance of the catchment modelling and yet the uncertainty of the model inputs makes it of limited use.

8.4 Main Drain J Catchment Modelling

8.4.1 Model Boundary Conditions

The calibrated Mirrool Creek catchment model was used to extract flow hydrographs upstream of the East Mirrool Regulator. Two inflow boundaries were applied, representing approach flows around the north and south of Merribee Hill. The Main Drain J model (which includes the Mirrool Creek floodplain) was then used to simulate the March 2012 flood event. Irrigation return flows were also applied to the irrigated land of the Mirrool Creek and Little Mirrool Creek floodplain, using a similar method to that describe in Section 6.2.4.

8.4.2 Canal Breach Representation

During the March 2012 event the flood flows at the East Mirrool Regulator exceeded the capacity of the available canal cross-drainage, which had also been reduced through the decommissioning of the flood gates on the downstream bank. Most of the flow transfer from upstream of the Main Canal into the downstream Mirrool Creek floodplain occurred through a number of localised breaches. These were identified through discussions with stakeholders and evidence contained in the available flood photographs. Known overtopping and breach locations include:

- Around 100m overtopping of the Main Canal at Briens Road;
- Localised spilling of the Main Canal at Daltons Road;
- A 30m wide breach over 1m deep of the Main Canal at Parizotto’s;
- Around 60m overtopping of the Main Canal bank at the EMR;
- Spilling of the Main Canal over the top of the decommissioned EMR flood gates;
- Localised overtopping and breaching of the NBC at the EMR;

- A 35m wide but shallow breach of the NBC near Pomroy Road; and
- Localised overtopping of the NBC between Whitton Stock Route and the railway.

The dimensions of the breaches and canal overtopping locations were estimated from the available photographs and the model representation was amended accordingly, to ensure that these features were being represented within the March 2012 modelling.

Figure 8-25 shows a 100m length of the Main Canal bank at Briens Road, where the bank vegetation has been washed out by extensive overtopping. The extent of overtopping has since decreased, with small patches of white water visible on the downstream face of the embankment.

Figure 8-26 shows a significant breach of the Main Canal at Parizotto’s, around 2km upstream of the East Mirrool Regulator. The breach is estimated at around 30m wide and over 1m deep.

Figure 8-27 shows the banks of the Main Canal at the East Mirrool Regulator. The extensive but shallow overtopping can be seen underneath the trees, as can the white water where the canal is spilling over the closed gate structure at the left of the picture.

Figure 8-28 shows a breach of the Northern Branch Canal near its offtake location from the Main Canal. The breach is visible, close to the house, whereas just a little further along the canal bank overtopping is occurring near the water tanks.

Figure 8-25 Main Canal Overtopping at Briens Road during the March 2012 Flood Event

Figure 8-26 Main Canal Breach at Parizotto's during the March 2012 Flood Event

Figure 8-27 Main Canal Overtopping at the EMR during the March 2012 Flood Event

Figure 8-28 NBC Overtopping at the EMR during the March 2012 Flood Event

Figure 8-29 NBC Breach near Pomroy Road during the March 2012 Flood Event

Figure 8-29 shows the Northern Branch Canal, just upstream of the bridge at Pomroy Road. Aswell as localised bank overtopping at the bridge, a breach of over 30m occurred and is visible in the photograph, under the large trees.

The peak flow rate and total volume of water modelled discharging from the canal at each of these locations during the March 2012 flood event is presented in Table 8-2. The significance of the canal breaches is evident, as the siphon structure under the Main Canal at the East Mirrool Regulator is only conveying around 40% of the total flood volume and 25% of the peak flow rate. The additional Main Canal discharges referred to in the table represents overtopping at Daltons Road and Briens Road and also flows being pushed through the canal off-takes. The additional Northern Branch Canal discharges represents overtopping between Whitton Stock Route and the railway and also flows being pushed through the canal off-takes.

Table 8-2 Modelled Discharge Volumes for the March 2012 Event

Location	Peak Discharge Rate	Total Discharge Volume
Main Canal at Parizotto's	~30-40m^3/s (3,000 ML/day)	17,000 ML
Main Canal through EMR siphon structure	~40-50m^3/s (3,700 ML/day)	31,000 ML
Main Canal overtopping at the EMR	~20-30m^3/s (2,000 ML/day)	6,000 ML
Additional Main Canal discharges	~30-40m^3/s (3,000 ML/day)	11,000 ML
NBC breaching at the EMR	~5-10m^3/s (500 ML/day)	1,700 ML
NBC breaching near Pomroy Road	~5-10m^3/s (700 ML/day)	2,300 ML
Additional NBC discharges	~10-20m^3/s (1,500 ML/day)	3,300 ML

8.4.3 March 2012 Observed and Simulated Flood Behaviour

Figure 8-30 presents the recorded flow data from the McNamara Road gauge against the modelled flow at the same location. The modelled flow hydrograph from the Mirrool Creek catchment model is also presented for comparison. Both the regional and detailed modelling provides a reasonable representation of the flood flows in Mirrool Creek. The detailed modelling of the Main Drain J catchment model better represents the floodplain controls and provides an improved representation of the peak flow conditions.

In addition to the McNamara Road gauge on Mirrool Creek MI also acquired water level data at Fowlers Road, within the Myall Park flood storage. This data covers the period from 6th March to 30th April 2012. No gauge datum is available and so this has been estimated from the available flood photos. Flood extents captured within photographs on the morning of 7th March were compared to the elevation data within the LiDAR to determine a representative flood level. This found the level at the gauge would have been around 127.2m AHD at that time, making the gauge zero datum around 127.0m AHD.

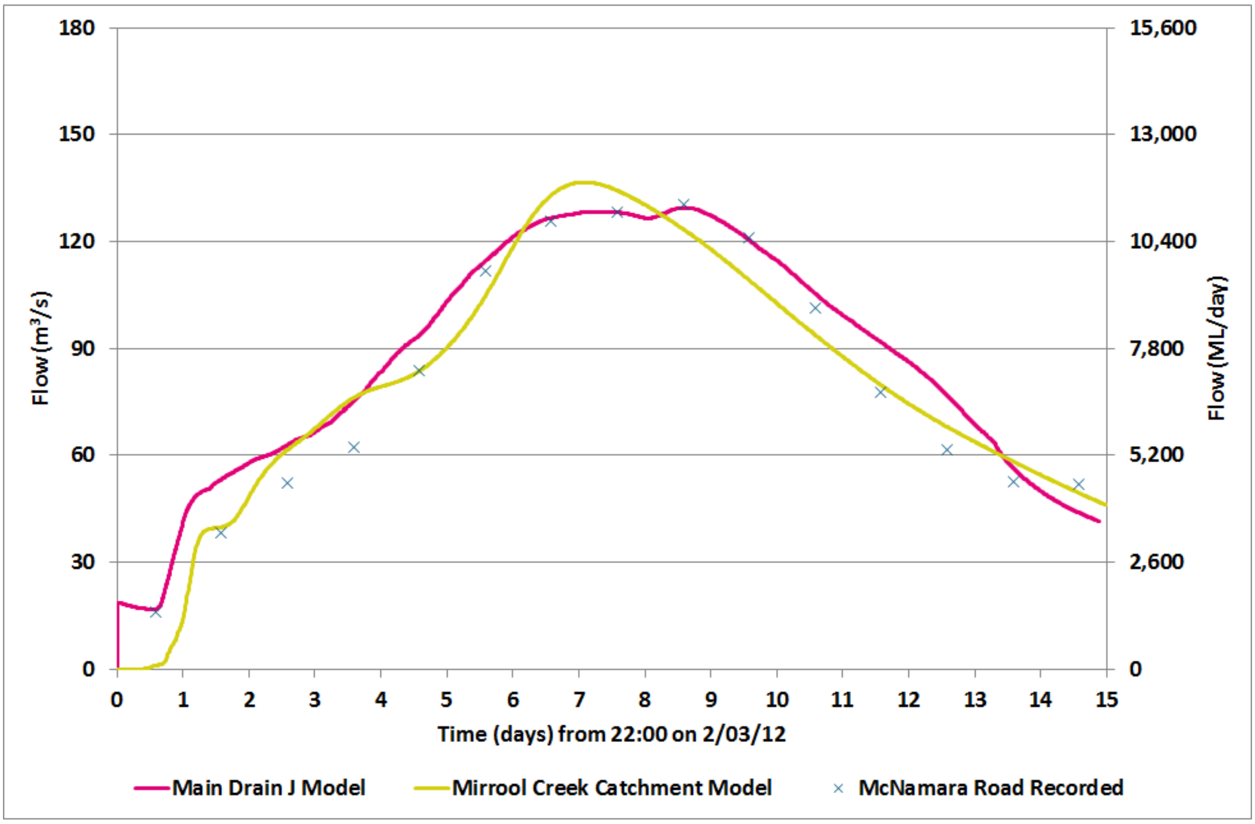


Figure 8-30 March 2012 Modelled Flow at the McNamara Road Gauge

The modelled water level at Fowlers Road is presented against the recorded data in Figure 8-31. The modelled data shows the early response from the local catchment runoff, which begins to drain away until about four days into the simulation. Flow inputs then occur from the Mirrool Creek floodplain and the modelled water levels begin to rise. Comparison with the observed data suggests that too large a volume of water is entering the Myall Park storage too quickly. This response is driven by the water spilling from Mirrool Creek and into Myall Park via Yenda. However, it is difficult to ascertain whether the total volume of water spilling into the storage from Mirrool Creek is overestimated due to the influence of inputs other than surface runoff, as discussed below.

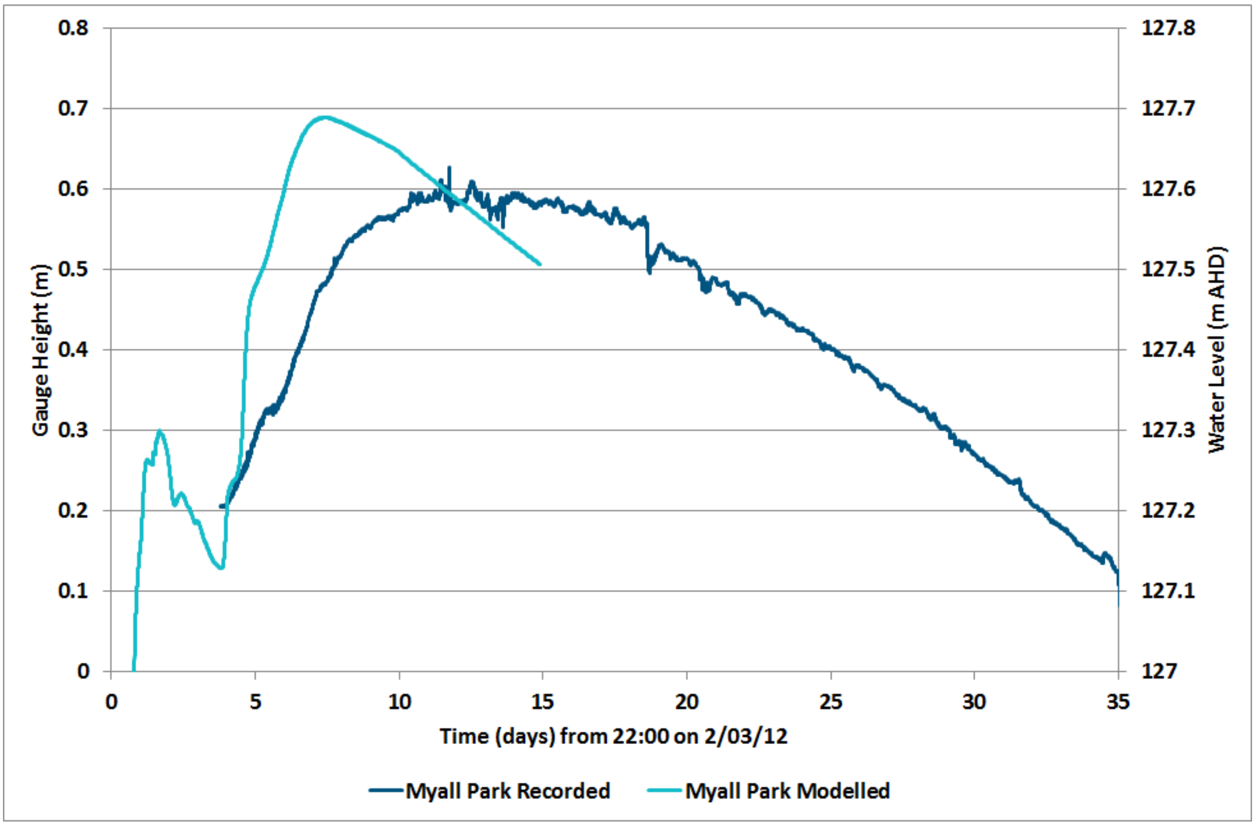


Figure 8-31 March 2012 Water Level Calibration at Myall Park

Observations of the arrival time of the flood wave at Yenda within the model and during the event indicate a good consistency. It is therefore likely that it is the peak flow rate through Yenda which is being overestimated. The model can be readily adjusted to reduce the flow rate through Yenda but there are a large number of parameters that could be altered to achieve this, including both hydrological and hydraulic. The catchment hydrology can be adjusted to change the approach flows to the East Mirrool Regulator, as demonstrated in Section 8.3.5. However, there are a number of other potential factors to consider, including:

- Minor changes in the representation of the canal breaches would alter the flow distribution between Mirrool Creek and Myall Park, as would the broader representation of embankment levels;
- The possibility that the volume of water spilling into Myall Park is correct, but is more highly attenuated than within the model representation;
- Differences in the applied and actual rainfall distribution could also contribute to the observed differences in Myall Park; and
- The AHD datum for the recorded data is an estimate only and could be +/-0.1m to the levels presented in Figure 8-31.

It is therefore considered that the observed difference here for the March 2012 event be accepted as being within the bounds of the model uncertainty, without the requirement for further model adjustments.

It should be noted that within the time scales considered within Figure 8-31, evaporation from the storage would begin to have a reasonable influence, being in the order of 0.15m for the month of March. This would further lower the recession of the modelled hydrograph, which already sits under that of the observed data. It is likely that the elevated recession within the observed data may be contributed to by deep drainage within the sandy soils. Rainfall lost to infiltration further up the catchment has the potential to seep out into the Myall Park storage area, which is situated in a natural topographic depression.

There is also additional quantitative data for the March 2012 flood event to supplement the gauged data. A flood mark survey of peak water levels between Kidman Way and Barren Box Swamp and surveyed flood marks at properties in Yenda also exist.

Figure 8-32 presents the surveyed flood marks along with the modelled peak water level profile on Mirrool Creek, between Kidman Way and Barren Box Swamp. It shows a relatively consistent flood gradient that matches well with the observed data.

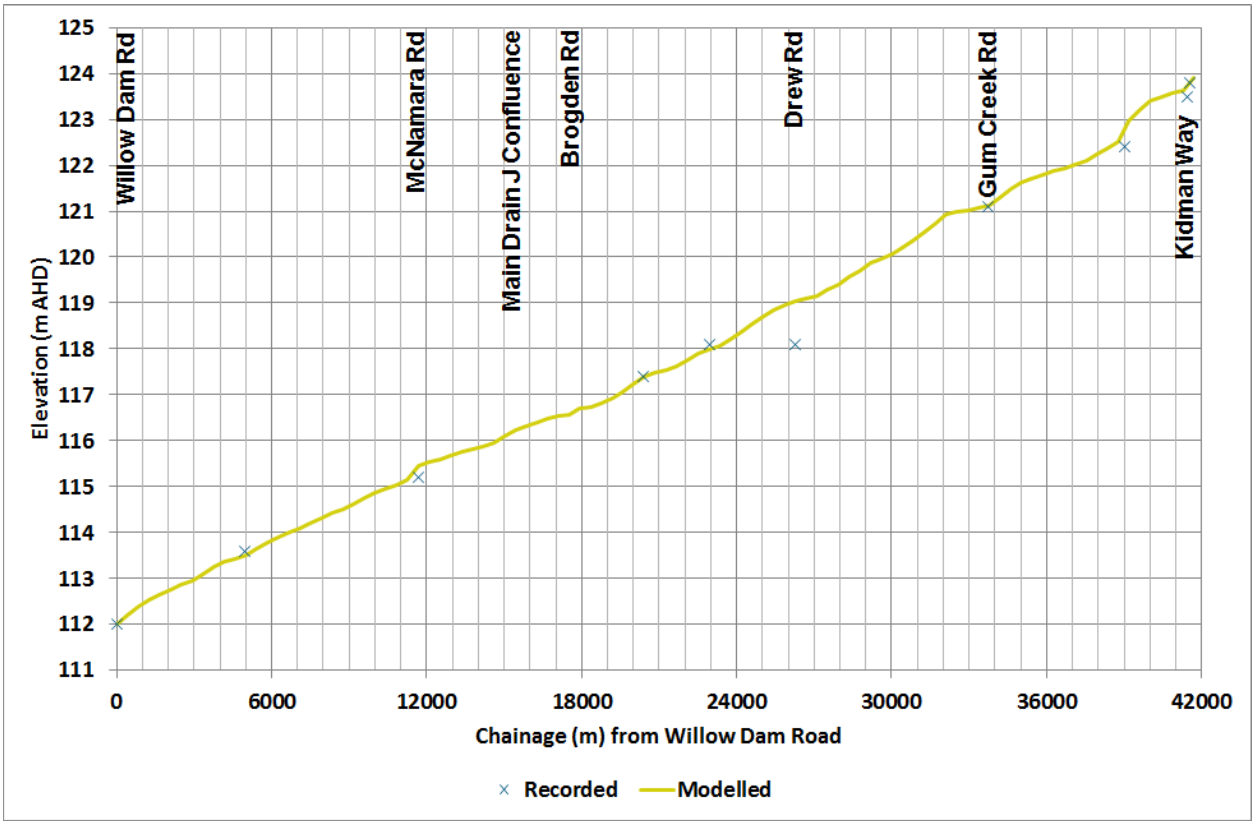
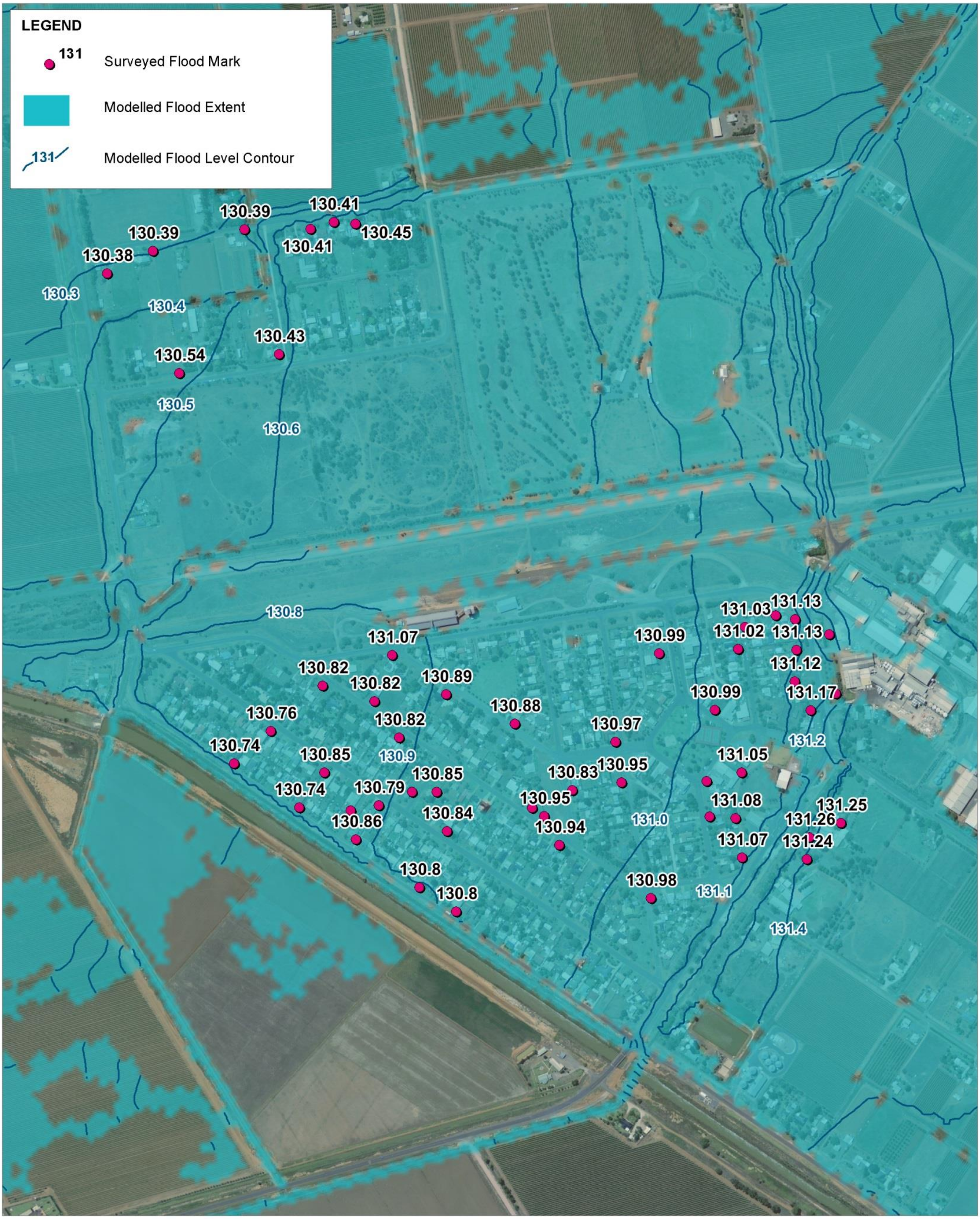


Figure 8-32 March 2012 Modelled Water Level Profile along Mirrool Creek

Figure 8-33 presents the modelled flood extent and water level contours at Yenda. The surveyed flood marks are presented for comparison. It shows that the modelled flood levels match reasonably well to the recorded data. However, there is a slight overestimation of peak flood levels by the model, which suggests that the modelled flow rate is potentially too high. This is consistent with the calibration in Myall Park as discussed previously.



Title:

March 2012 Calibration at Yenda

Figure: 8-33

Rev: A

N

0 200 400m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N20024_Main_Drain_J_Mirrool_Ck_FRMS\MapInfo\Workspaces\DRG_037_140512_Yenda.WOR

8.5 Mirrool Creek Catchment Design Considerations

Determining appropriate design flood conditions for Mirrool Creek at the Main Canal is challenging given the inherent uncertainties, including:

- The infrequency of occurrence of significant flood events;
- The lack of a reliable flood record for levels or flows;
- The influence of sandy soils in the broader Binya Creek catchment;
- The two distinct flood mechanisms of intense storms in summer-autumn and elevated baseflow conditions during extended wet periods in winter-spring; and
- The substantial flood wave attenuation through the Barellan floodplain area.

There is insufficient data available to derive a reliable flood frequency analysis and too much uncertainty within the catchment modelling and design rainfall estimates to rely solely on a rainfall-runoff approach. A combination of the two approaches has therefore been used to establish a representative set of design flood conditions.

8.5.1 Design Rainfall

One of the key design considerations is the adopted design rainfall conditions. The assumed distribution of rainfall across the catchment affects the appropriate areal reduction factor for the point design rainfall intensities. For example, when adopting a design storm across the entire catchment draining to the Main Canal at the East Mirrool Regulator (some 6,500km^2), an areal reduction factor of 0.74 is applied to the design rainfall. This increases to 0.8 when considering a design storm across the Mirrool Creek catchment only (some 2,500km^2). If assuming the design storm occurs only locally around the broader Barellan area (some 800km^2) then the areal reduction factor increases further to 0.85.

Given the knowledge that the broader Binya Creek catchment contributes little to the flooding at the Main Canal (due to the high infiltration rates), the 6,500km^2 scenario is discounted. The critical condition for flooding at Yenda is likely to be somewhere in between the 800km^2 and 2,500km^2 scenarios, where intense rainfall over the Barellan area is the principal driver of the flood event, supplemented by runoff contributions from the upper Mirrool Creek. This is consistent with the conditions during the March 2012 and March 1939 flood events.

Comparison of the March 2012 flood event rainfall across the catchment with the design IFDs was presented in Figure 8-12. It showed the event to be over a 0.1% AEP magnitude at Barellan, where 165mm was recorded over a 24-hour period. This would suggest that the resultant flood condition at the Main Canal may also be in that order of magnitude. Given the implied rarity of such an occurrence it was deemed worthwhile analysing the rainfall record at Barellan to validate the magnitude of the March 2012 event.

Daily rainfall depths have been recorded at Barellan Post Office since 1878, providing over 120 years of data. This data was converted into a series of annual maxima daily rainfall depths, ensuring that multiple day totals were excluded from the analysis. The FLIKE software package was then used to derive a frequency analysis of the daily rainfall totals using the Generalised Extreme Value probability model. The results of this analysis are presented in Table 8-3.

Table 8-3 Daily Rainfall Frequency Analysis at Barellan

Design Rainfall Event Magnitude	Daily Rainfall Depth (mm)
20% AEP	59.1
10% AEP	72.8
5% AEP	87.0
2% AEP	107
1% AEP	124
0.5% AEP	141
0.2% AEP	166

The rainfall depths generated from the frequency analysis appeared to be higher than those of the standard IFD curves from AR&R. A similar analysis was therefore undertaken for other nearby rainfall gauges. This found that across the region the rainfall depths generated by the frequency analyses were typically closer to those of the standard IFD curves. However, the gauges at Barellan and Bents Hill (some 20km to the south) produced significantly higher design rainfall estimates. These are the two gauges that are situated within the critical area for driving flood events on Mirrool Creek at the Main Canal.

The Barellan floodplain area is situated just to the east of an extensive range of hills incorporating the Cocoparra Range, Brobenah Hills and Narrandera Range. This alignment is the first significant relief that storms approaching from the west will encounter. It is possible that this generates a local orographic rainfall effect, resulting in more frequent intense rainfall at Barellan.

Taking into account both the complexities and uncertainties associated with deriving design rainfall distributions to drive design flood conditions for Mirrool Creek, the following approach was considered the most appropriate for a rainfall-runoff analysis:

- The spatial and temporal distribution of rainfall during the March 2012 event was adopted;
- The March 2012 rainfall was then scaled to match rainfall depths at Barellan to the frequency analysis at the same site; and
- The derived design rainfall distributions were input to the Mirrool Creek catchment model to determine resultant flood flows at the Main Canal.

The March 2012 event was approximately a 24-hour storm duration. The best estimate of 24-hour design rainfall depths at Barellan therefore needed to be established and applied to the existing spatial and temporal distribution. It was assumed that the frequency analysis undertaken on recorded daily rainfall depths at Barellan would be representative of a storm duration for a period of less than 24-hours. Within the recorded daily rainfall depths there would be a number of storms that were actually much shorter than a 24-hour duration.

To establish what is the most representative design storm duration of the daily rainfall frequency analysis the continuous rainfall record at the nearby Naradhan gauge was utilised. The Naradhan gauge has over a 40-year period of continuous rainfall data dating back to 1970. This data was used to derive a frequency analysis for a range of storm durations, using the same method adopted for the daily rainfall analysis at Barellan. This was also undertaken for the daily rainfall record at

Naradhan for the period since 1970. Comparison of the frequency analyses at Naradhan found that the frequency distribution of the daily rainfall records was most similar to that of the 18-hour storm duration from the continuous rainfall. The results of this analysis are summarised in Figure 8-34.

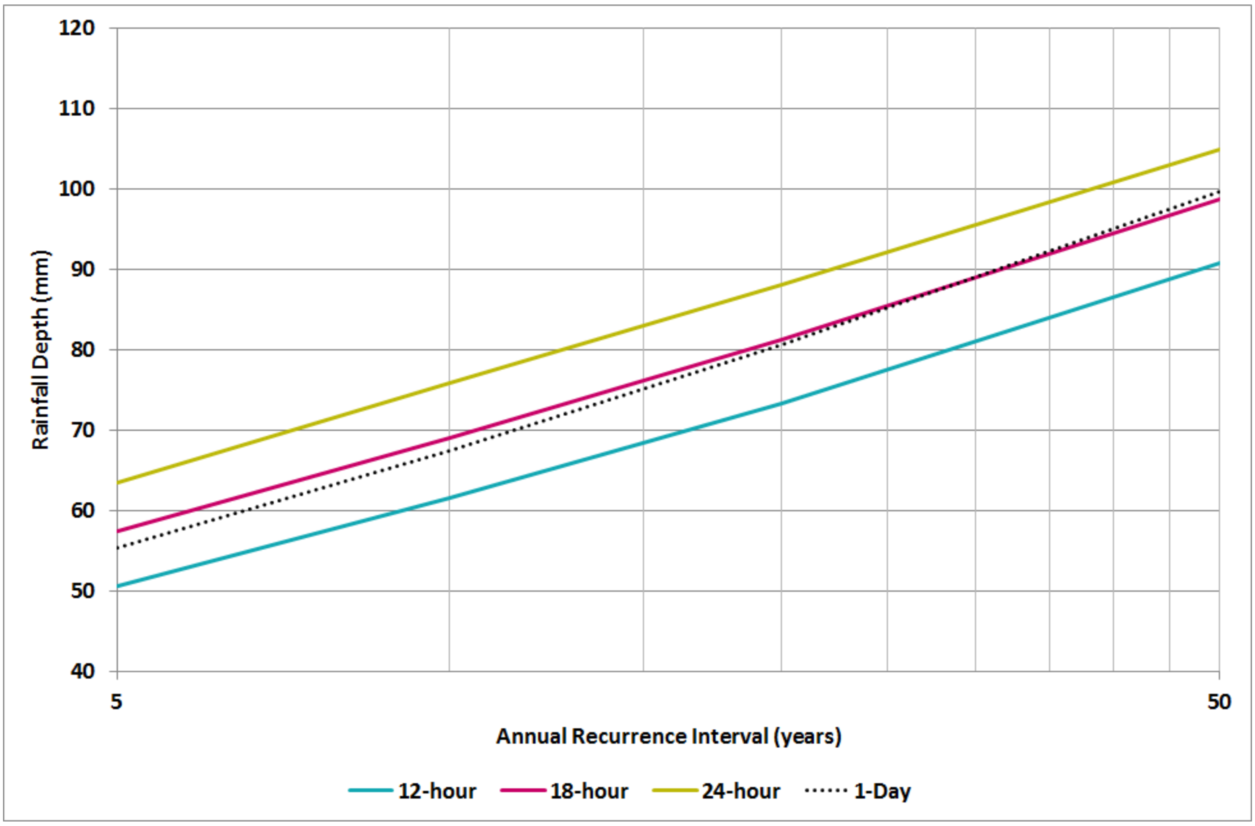


Figure 8-34 Frequency Analysis of Daily and Sub-Daily Rainfall Depths at Naradhan

The rainfall depths derived from the frequency analysis of daily rainfall records at Barellan were assumed to be representative of an 18-hour design storm duration. To determine representative values for a 24-hour storm duration the rainfall depths from the frequency analysis were increased by 7%, which is consistent with the difference between the 18-hour and 24-hour duration IFDs. The resultant design rainfall depths at Barellan and the equivalent scaling factor relative to the March 2012 event are presented in Table 8-4.

Table 8-4 Adopted Design Rainfall Depths at Barellan

Design Event Magnitude	Rainfall Depth (mm)	March 2012 Scaling Factor
20% AEP	63.5	0.38
10% AEP	78.2	0.47
5% AEP	93.4	0.57
2% AEP	115	0.70
1% AEP	133	0.80
0.5% AEP	151	0.92
March 2012	*165*	*1.00*
0.2% AEP	179	1.08

This approach estimates the March 2012 event as being in the order of a 0.5% AEP rainfall, rather than a 0.1% AEP when compared to the standard design rainfall depths.

8.5.2 Rainfall-Runoff Modelling

The Mirrool Creek catchment model was used to derive design flood flows upstream of the Main Canal. The design rainfall distribution derived from the March 2012 event and frequency analysis at the Barellan daily rainfall gauge was input to the model and the resultant flows were extracted 4km upstream of the Main Canal, as presented in Table 8-5.

Table 8-5 Modelled Design Flows for Mirrool Creek using Barellan Frequency Analysis

Design Event Magnitude	Peak Flow U/S of Main Canal
5% AEP	60m^3/s (~5,200 ML/day)
2% AEP	95m^3/s (~8,200 ML/day)
1% AEP	130m^3/s (~11,000 ML/day)
0.5% AEP	170m^3/s (~15,000 ML/day)
March 2012	*220m^3/s (~19,000 ML/day)*
0.2% AEP	270m^3/s (~23,000 ML/day)

The model was also used to derive design flood flows when adopting the standard design rainfall patterns, depths and areal reduction factors in AR&R. This analysis found a 72-hour duration storm across the 2,500km^2 catchment of Mirrool Creek to provide the critical flood conditions. The resultant design flows were extracted 4km upstream of the Main Canal, as presented in Table 8-6. It shows that the standard approach produces lower flow estimates for the range of design events.

Table 8-6 Modelled Design Flows for Mirrool Creek using Standard Design Procedures

Design Event Magnitude	Peak Flow U/S of Main Canal
5% AEP	65m^3/s (~5,600 ML/day)
2% AEP	90m^3/s (~7,800 ML/day)
1% AEP	110m^3/s (~9,500 ML/day)
0.5% AEP	140m^3/s (~12,000 ML/day)
0.2% AEP	180m^3/s (~16,000 ML/day)
March 2012	*220m^3/s (~19,000 ML/day)*

8.5.3 Flood Frequency Analysis

Given the lack of available flood records at the East Mirrool Regulator (which is largely a function of the infrequency of flood events) it is difficult to undertake a meaningful flood frequency analysis. There are only six historic flood records available since the Main Canal was constructed around 100 years ago. There are too few records from which to fit a probability model, but the plotting positions of the historic events have been calculated. Estimates of peak flood outflows across the Main Canal have been determined for the historic events from observed upstream and downstream flood levels and are presented in Table 8-7.

Flow data for 1931, 1939, 1956 and 1974 has been estimated by previous studies in the catchment. The peak outflow for the March 1939 event was derived from gauged water level and flow rates during the event. The water level vs. flow relationship derived from this event was also used to extrapolate an estimate for the June 1931 event. Therefore, there is a large amount of uncertainty associated with this estimate. References to recorded flood flows at the EMR were available for the August 1956 and October 1974 events.

Table 8-7 Historic Mirrool Creek Flood Flows at the Main Canal

Flood Event	Estimated Peak Outflow	Derived Peak Inflow
1931	120m^3/s (~10,000 ML/day)	180m^3/s (~16,000 ML/day)
1939	80m^3/s (~6,900 ML/day)	100m^3/s (~8,600 ML/day)
1956	40m^3/s (~3,500 ML/day)	45m^3/s (~3,900 ML/day)
1974	65m^3/s (~5,600 ML/day)	80m^3/s (~6,900 ML/day)
1989	60m^3/s (~5,200 ML/day)	70m^3/s (~6,000 ML/day)
2012	130m^3/s (~11,000 ML/day)	220m^3/s (~19,000 ML/day)

Peak inflows were derived using the relationship of flood attenuation derived from the catchment modelling. The March 1989 and March 2012 flows have been extracted directly from the Mirrool Creek catchment model. It should be noted that there are uncertainties associated with these flow estimates, given historic floodplain modifications, potential breaching of the Main Canal and other factors.

The calculated plotting positions for the six events against the estimated peak inflow conditions were calculated using the Cunnane formula, as recommended in AR&R and are presented in Figure 8-35. The modelled peak flood flows from the Mirrool Creek catchment model rainfall-runoff analysis have also been presented for comparison. Given the small number of recorded flood events the plotting position of the events is highly sensitive. The inclusion of the March 2012 event also has a significant impact on the plotted frequency of the events due to its large magnitude. The calculated plotting positions of the five recorded events pre-2012 show a significantly different distribution and match more closely with the flows determined through the rainfall-runoff modelling.

The previous flood frequency analysis undertaken for Mirrool Creek at the Main Canal was presented in the Hydrology of Mirrool Creek (Water Resources, 1994). It calculated the plotting positions of the four pre-2012 events using the Weibull formula, recommended in AR&R, 1977 and was based on a period of record of 57 years (1931 to 1987). This provides for lower return period estimates of the observed events, as shown in Figure 8-35.

The period of record assumed for the plotting positions in the current analysis was extended back from 1931 (the year of the first recorded flood event) to 1915 (the year of construction of the Main Canal), giving around a 100 year period of record. It is assumed that the 1931 event was the first significant flood since the construction of the canal.

The Weibull formula estimates lower return periods for the observed events than does the Cunnane formula. It is more appropriate to adopt the Cunnane formula in this instance as the focus of the flood frequency analysis is to estimate the magnitude associated with given exceedance probabilities.

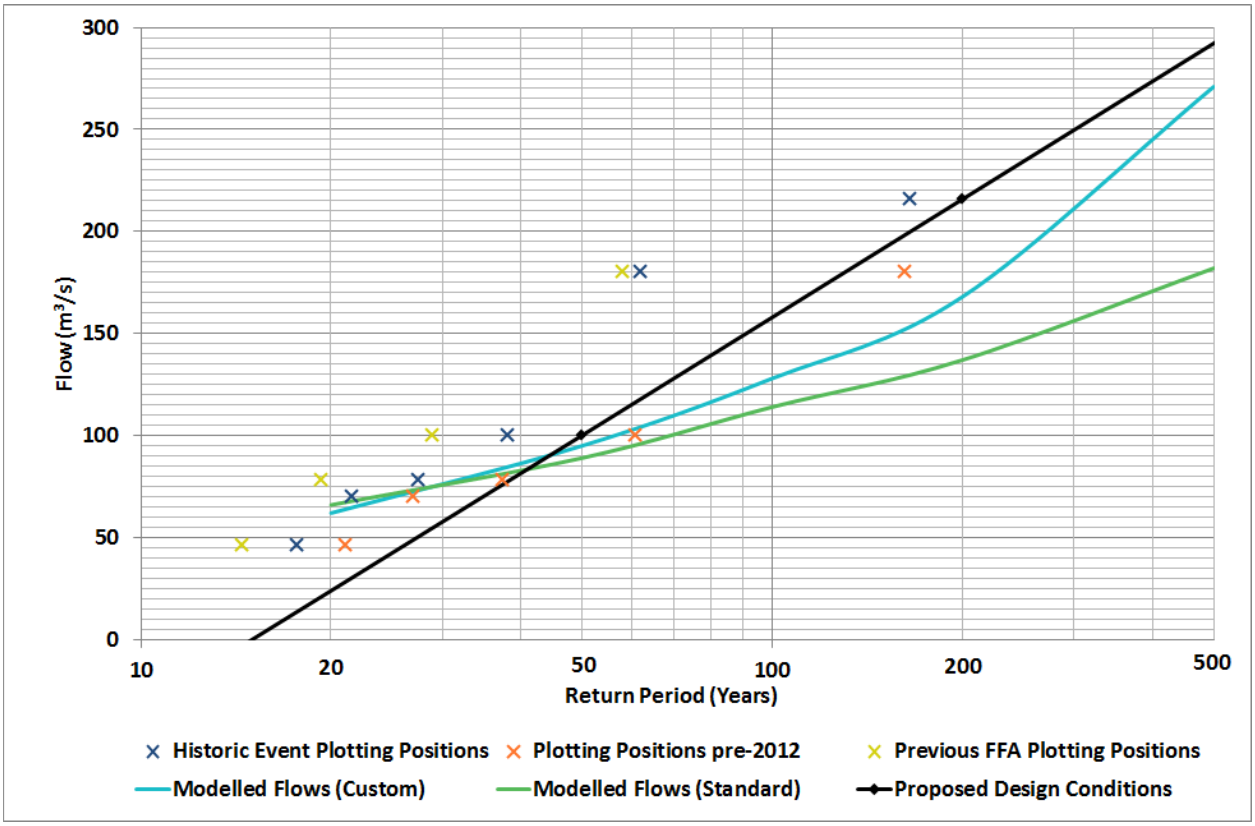


Figure 8-35 Flood Frequency Analysis for Mirrool Creek at the Main Canal

The distribution of information presented in Figure 8-35 highlights the range of uncertainty associated with deriving representative design flood conditions for Mirrool Creek, given the scarcity of recorded flood events and complex nature of the catchment hydrology. The analysis of historic events has uncertainties with both the estimation of peak flows and the appropriate plotting position. The catchment rainfall-runoff modelling has uncertainties associated with the representation of catchment hydrological processes within the model. The modelling is also based on a March flooding condition and does not consider the winter-spring flooding mechanism.

The proposed method for estimating design flows is a simple approach, taking into account the limitations of both the rainfall-runoff modelling and the historic event analysis. It is based upon making the best estimate of the recurrence interval for the March 1939 and March 2012 flood events and extrapolating a flood frequency distribution to cover the full range of design events.

There is a reasonable confidence level with assuming the March 1939 event is representative of a 2% AEP condition, with the historic event analysis and catchment modelling providing estimates within the 40-year to 60-year ARI range. The rarity of the March 2012 event is more difficult to assess, with the various analyses placing it in the range of a 1% AEP to 0.1% AEP. It is considered that assuming a 0.5% AEP for the March 2012 event is most appropriate. The proposed flood frequency distribution is presented in Figure 8-35, with peak design flows presented in Table 8-8.

Table 8-8 Proposed Design Peak Flood Flows for Mirrool Creek at the Main Canal

Design Event Magnitude	Peak Flow U/S of Main Canal
5% AEP	20m^3/s (~1,700 ML/day)
2% AEP	100m^3/s (~8,600 ML/day)
1% AEP	160m^3/s (~14,000 ML/day)
0.5% AEP	220m^3/s (~19,000 ML/day)
0.2% AEP	290m^3/s (~25,000 ML/day)

8.5.4 Status of the EMR Flood Gates and Design Flow Capacity

The flood escape structures at the EMR were constructed following the event of June 1931 that resulted in extensive flooding of the local communities including Yenda. The first test of the flood gates was the event of March 1939 in which successful; operation of the structures provided sufficient flow capacity to prevent extensive inundation to Yenda. Subsequent to this event, the flood structures have played a role in the mitigation of at least four significant events in 1956, 1974, 1984 and 1989.

Subsequent to the 1989 event, and prior to the major flooding of March 2012, the flood gates were decommissioned through the placement of spoil in front of the structures rendering them inoperable. Modification of the escape doors on the northern bank has also seen a change in operation of the original structure, both providing for a reduced gate width, but also providing mechanical doors that only open outwards and that may close under water pressure from the Mirrool Creek. Accordingly, at the time of the March 2012 event, the flood escape structures were largely redundant and not in operation to provide any flow capacity.

It is understood that since the March 2012 event, there has been some partial reinstatement of operating capacity of the flood gates.

As discussed in the previous sections, the March 1939 event was the largest event prior to March 2012 in which the flood gates (in their original configuration) were operable. The estimated peak flow for the 1939 event (based on recorded gauging data) was of the order 80m^3/s. This peak flow represents close to the capacity of the EMR structures (combined siphon/gates) assuming they are fully operational in transferring Mirrool Creek flow across the Main Canal. Flows in excess magnitude, corresponding to approximately a 2% AEP event, would exceed this structure capacity.

The March 2012 event was the first event since the flood gate installation in which the design capacity has been exceeded. The estimated peak flows approaching the regulator for the March 2012 (~220m^3/s or 19,000 ML/day) well exceed both the design capacity (combined siphon/flood gate arrangement) and the existing on-ground works (siphon only with decommissioned gates). Given the magnitude of the flows approaching the EMR for the March 2012, the capacity of the EMR would have been well exceeded even with full design operational capacity of both the siphon and flood gates.

Significantly, the design capacity of the fully operational structures is still well below the design 1% AEP peak flow of approximately 160m^3/s (~14,000 ML/day) approaching the regulator. Accordingly, Yenda and North Yenda would be considered to have well below 1% AEP flood immunity.

The flood gates with full operational capacity provide of the order of 2% AEP flow capacity and accordingly this represents the relative design flood immunity standard for Yenda under these conditions. In its current decommissioned state, however, the flood immunity is reduced to something of the order of a 5% AEP event with only the capacity of the siphon to transfer Mirrool Creek flows.

8.5.5 Design Flood Conditions at Yenda and Myall Park

Design flood mapping for a range of design return period events showing the Mirrool Creek system flooding from upstream of the Main Canal, including the northern areas of Yenda and Myall Park are included in Appendix A.

Flooding from Mirrool Creek will occur at Yenda when the cross-drainage capacity of the Main Canal structures is exceeded. This is about 40m^3/s (~3,400 ML/day) through the siphon and 80m^3/s (~6,900 ML/day) when both the siphon and flood gates are operational. The March 1939 event was in the order of the latter and flooding of Yenda was prevented – noting the flood gates were operational for this event. This is similar to the proposed 2% AEP design flood condition. It may therefore be expected that Yenda would remain flood free to around the 2% AEP event (with the existing flood gates operational), but would flood during events of a larger magnitude. In the existing decommissioned state, the flood immunity to Yenda may only be of the order of 5% AEP. As Mirrool Creek flows exceed the EMR capacity, then Yenda has potential flood.

The estimated peak flows approaching the EMR for the design 1% AEP flood condition is approximately 160m^3/s (~14,000 ML/day). This compares to an estimated, 220m^3/s (~19,000 ML/day) for the March 2012 event. Accordingly, both the estimated 1 in 100-year and March 2012 events significantly exceed the available flow capacity at the EMR, even with flood gates operational.

Once flooding of Yenda from Mirrool Creek occurs, the resultant peak flood levels are expected to be similar to those experienced during the March 2012 event, as they are driven principally by the level of the railway. At events of this magnitude therefore, the resulting peak flood level condition in Yenda would be relatively similar (albeit with a different flow volume moving through the township), irrespective of the flow capacity provided by the existing EMR configuration in either operational or decommissioned state.

The proposed design flood flows were input to the Main Drain J catchment model using the March 2012 hydrograph shape to determine appropriate design flood conditions in Yenda. For the lower order events, i.e. less than 2% AEP magnitude, flood flows may be expected to be conveyed through the EMR siphon and flood gates (if operational) without extensive spilling of flow into Yenda. Beyond these magnitudes, there is potential for redistribution of flow towards Binya and across the NBC into the Main Drain J catchment through Yenda, North Yenda and into Myall Park.

During the March 2012 event, there were a number of significant breaches along the Main Canal upstream of the EMR. These breaches in many cases served to reduce the peak flows to be conveyed across Canal at the EMR, thereby reducing to some degree the flooding pressures at Yenda. From a future flooding perspective, there is no certainty that similar breaches would occur, such that in defining design flow conditions at the EMR, and significantly for assessing potential flood management options, some redundancy needs to be built in to design flows to accommodate additional flows that may not be lost in future events due to breaching of the Canal.

Similarly, the operation of the Main Canal and broader MI system can have an influence on design flood behaviour and represents another variable for consideration in establishing design flood conditions. It could also be considered that operation levels in the Main Canal would also influence the propensity for breaching.

Establishing a baseline design flood condition for the system therefore is complex considering the interaction and interdependencies of a range of system variables. It is suggested that these sensitivities largely preclude a definitive baseline flood condition. The flood conditions discussed therefore provided for a representative design flood condition (based on a set of variable assumptions) to be used as a baseline for assessing management options, in particular options for works to the EMR.

In moving forward with the Floodplain Risk Management Study, the developed models enable testing of a range of floodplain risk management options to facilitate a selection of appropriate measures that ultimately would be expected to redefine the design flood conditions for the study area.

9 Conclusions

The objective of the study was to undertake a detailed flood study of the Main Drain J catchment and establish models as necessary for design flood level prediction. This included the assessment of inputs to the catchment from Mirrool Creek.

In completing the flood study, the following activities were undertaken:

- Collation of historical flood information for the study area;
- Consultation with the community to acquire additional historical flood information;
- Development of a RAFTS hydrological model to simulate catchment rainfall-runoff;
- Development of a TUFLOW 2D/1D hydrodynamic model to simulate flood behaviour in the catchment;
- Development of a TUFLOW GPU 2D catchment model for Mirrool Creek to assist in the assessment of the flood hydrology;
- Calibration of the developed models using the available flood data, primarily relating to the March 1989 and March 2012 events;
- Prediction of design flood conditions in the catchment and production of design flood mapping series.

Through the undertaking of the flood study it has been found that the Main Drain J catchment is well regulated by the Main Canal and upstream storage area of Myall Park. The flood flows generated within the urban areas of Yoogali and Hanwood are therefore restricted to runoff from the catchment area downstream of the Main Canal. Coupled with the provision of significant manmade drainage, this results in a limited conveyance of flood flows within the broader floodplain extent. Out-of-bank flooding is predominantly characterised by flood waters ponding behind raised floodplain features such as road and rail embankments.

The performance of the model in representing catchment flood behaviour was supported by observations during the March 1989 and March 2012 flood events.

The conditions observed in the Main Drain J catchment for the March 2012 event are generally representative of the modelled design 1 in 100-year probability event. This represents a significant change from the previously adopted flood study results which typically showed design 100-year flooding much more severe than March 2012 conditions. Accordingly, some changes may be anticipated to currently adopted flood risk and hydraulic category zones through the ongoing floodplain risk management process. Given the scale and nature of flooding, it is considered that suitable mitigation measures can be identified to address the existing flood risk to established urban areas in both Yoogali and Hanwood.

There is a reasonable level of uncertainty regarding the representation of embankment crest elevations in the Main Drain J model. This can influence localised flooding and the overall extent of the out-of-bank floodplain inundation. However, given the nature of the catchment flooding this does not have significant implications for the determination of flood planning constraints such as the defined floodways.

The March 2012 event also saw significant flooding of Mirrool Creek, which overtopped the Northern Branch Canal and spilled into the Main Drain J catchment, causing extensive flooding in Yenda. A catchment model was constructed for Mirrool Creek to represent this behaviour and assist in establishing appropriate design flood conditions for this mechanism.

For Mirrool Creek there is limited data from which to calibrate the models aside from the March 2012 flood event. This event has therefore been an essential platform from which to build an understanding of the catchment flood behaviour and quantifying design flood conditions. The lack of suitable calibration events for Mirrool Creek results in a large amount of uncertainty for design flood flow estimations. The hydrological response of the Mirrool Creek catchment is complex, being heavily influenced by the high infiltration rates of the sandy soils and the significant attenuation through the Barellan floodplain area.

The small number of recorded flood events in the Mirrool Creek catchment also reduces the reliability of flood frequency analysis, where there are large uncertainties in both the estimation of historic flood flows and the plotting position of the flood frequency.

Nevertheless, an attempt has been made to present these levels of uncertainty and determine an appropriate estimation of design flood flows for Mirrool Creek. This analysis will provide a platform for the future assessment of potential flood mitigation measures for Yenda.

The observed flood conditions for Mirrool Creek for the March 2012 event are estimated to be in excess of the 1% AEP (1 in 100-year) design conditions. The flood risk to Yenda from Mirrool Creek floodwaters emanates as the EMR capacity is exceed. With both siphon and flood gates fully operational, this flow capacity may be expected to be exceed for events in excess of the 2% AEP (1 in 50-year probability event). The current decommissioned status of the EMR flood gates structures significantly reduces the capacity to transfer Mirrool Creek flood flows across the Canal to the order of a 5% AEP (1 in 50-year probability) design standard. Accordingly, substantial flood mitigation measures may be required to provide an increased flood immunity to the Yenda township.

This flood study forms the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain risk management process. The Floodplain Risk Management Study will aim to derive an appropriate mix of management measures and strategies to effectively manage flood risk. The findings of the study will be incorporated in a Plan of recommended works and measures and program for implementation.

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Appendix A Flood Mapping

Note: The local runoff maps for Yenda and North Yenda (such as Figure A-8: Griffith Main Drain J Catchment Flood Study 5% AEP Yenda Peak Flood Conditions - Local Runoff Only) exclude contributions from Mirrool Creek flooding and only consider runoff generated within the local catchment (Main Drain J catchment). All other mapping shown incorporate flooding contributions from the broader Mirrool Creek.

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