PARKES SHIRE COUNCIL

COOKAMIDGERA
FLOOD STUDY

OCTOBER 2024

DRAFT REPORT FOR PUBLIC EXHIBITION

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FOREWORD

The NSW State Government's Flood Prone Land Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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

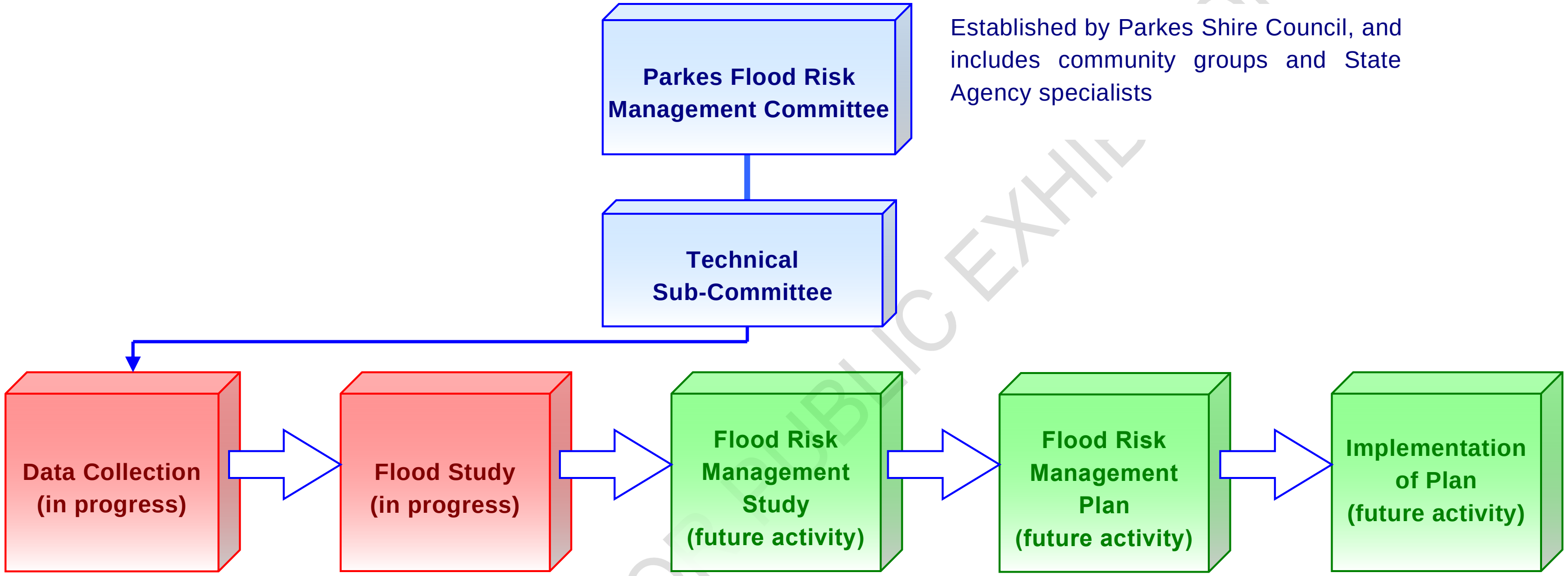
1.	Data Collection	Collects, compiles and reviews both new and existing data.
2.	Flood Study	Determines the nature and extent of flooding.
3.	Flood Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
4.	Flood Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
5.	Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Local Environmental Plans to ensure new development is compatible with the flood hazard. Improvements to flood emergency management measures.

The *Cookamidgera Flood Study* is jointly funded by Parkes Shire Council and the NSW Government, via the Department of Climate Change, Energy, the Environment and Water. The *Flood Study* constitutes the first and second stage of the Flood Risk Management process (refer over) for this area and has been prepared for Parkes Shire Council to define flood behaviour under current conditions.

ACKNOWLEDGEMENT

Parkes Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Climate Change, Energy, the Environment and Water.

FLOOD RISK MANAGEMENT PROCESS



Involves the compilation and review of existing data and the collection of additional data.

Involves detailed hydrologic and hydraulic modelling of the existing stormwater drainage system at Cookamidgera.

The Flood Risk Management Study will determine options which will seek to reduce the impact of flooding on the community in consideration of social, ecological and economic factors.

Preferred flood management options will be publicly exhibited and the responses from the community incorporated in the Plan. The Plan will then be formally approved by Council following the public exhibition period.

Implementation of the Plan will allow Council to reduce the impact of flooding on the community through flood, property, and response modification measures. The measures may include structural works, planning controls, flood warnings, flood readiness and response plans, ongoing data collection and monitoring.

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LIST OF MAIN REPORT FIGURES
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NOTE ON FLOOD FREQUENCY

The frequency of floods is generally referred to in terms of their Annual Exceedance Probability (**AEP**) or Average Recurrence Interval (**ARI**). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of greater magnitude each year. As another example, for a flood having a 5 year ARI, there will be floods of equal or greater magnitude once in 5 years on average. The approximate correspondence between these two systems is:

Annual Exceedance Probability (AEP) (%)	**Average Recurrence Interval (ARI) (years)**
0.2	500
0.5	200
1	100
2	50
5	20
10	10
20	5

The report also refers to the Probable Maximum Flood (**PMF**). This flood occurs as a result of the Probable Maximum Precipitation (**PMP**). The PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism as regards rainfall production. The PMP is used to estimate PMF discharges using computer models which simulates the conversion of rainfall to runoff. The PMF is defined as the limiting value of floods that could reasonably be expected to occur. It is an extremely rare flood, generally considered to have a return period greater than 1 in 10^6 years.

NOTE ON QUOTED LEVEL OF ACCURACY

Peak flood levels have on occasion been quoted to more than one decimal place in the report in order to identify minor differences in values. For example, to demonstrate minor differences between peak heights reached by both historic and design floods and also minor differences in peak flood levels which will result from, for example, a partial blockage of hydraulic structures. It is not intended to infer a greater level of accuracy than is possible in hydrologic and hydraulic modelling.

ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff
AWS	All Weather Station
BoM	Bureau of Meteorology
Council	Parkes Shire Council
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DEM	Digital Elevation Model
FRMM	Flood Risk Management Manual (NSW Government, 2023)
FPL	Flood Planning Level
FPA	Flood Planning Area
FRMS&P	Flood Risk Management Study and Plan
GDSM	Generalised Short Duration Method
GS	Gauging Station
IFD	Intensity-Frequency-Duration
LiDAR	Light Detecting and Ranging (type of aerial based survey)
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PNBIL	Probability Neutral Burst Initial Loss
TUFLOW	A true two-dimensional hydrodynamic computer model which has been used to define flooding patterns as part of the present study.

Chapter 8 of the report contains definitions of flood-related terms used in the study.

SUMMARY

S.1 Study Objective

The objective of the study was to define the nature of the following two types of flooding that are experienced at the village of Cookamidgera for flood frequencies ranging between 20% (1 in 5) and 0.2% (1 in 500) per cent Annual Exceedance Probability (**AEP**), together with the Probable Maximum Flood (**PMF**):

- **Main Stream Flooding** which occurs when floodwater surcharges the inbank area of Quart Pot Creek and Bartleys Creek (also known locally as Flagstone Creek). Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater but can include shallower and slower moving floodwater on the overbank of the aforementioned creeks.
- **Major Overland Flow**, which is experienced during periods of heavy rain and is generally characterised by relatively shallow and slow-moving floodwater that is conveyed overland in an uncontrolled manner toward the abovementioned watercourses and other major drainage lines.

The findings of the study will be used as the basis for preparing the future *Cookamidgera Flood Risk Management Study and Plan* (***Cookamidgera FRMS&P***) which will assess options for flood mitigation and prepare a plan of works and measures for managing the existing, future and continuing flood risk at Cookamidgera.

S.2 Study Area

While the definition of flood behaviour was limited to the village of Cookamidgera and its immediate environs, the present study assessed the runoff potential of the whole of the Bartleys Creek catchment. **Figures 1.1** and **2.1** bound in **Volume 2** of this report show the extent of the 180 km^2 Bartleys Creek catchment at its confluence with Goobang Creek, while **Figure 2.2** (2 sheets) shows the key features of the existing stormwater drainage system in the vicinity of the urbanised parts of Cookamidgera.

S.3 Study Method

The flood study involved the following activities:

- The forwarding of a *Community Newsletter and Questionnaire* to approximately 50 residents and business owners in the study area. The *Community Newsletter and Questionnaire*, a copy of which is contained in **Appendix A** of this report, introduced the study objectives and sought information on historic flood behaviour. In-person consultation was also undertaken by Council on 31 May 2022 and by the Consultant on 6 December 2022. Of those that responded, more than half noted that they had been affected by flooding. Respondents provided information on flooding that occurred on a number of occasions, the most notable of which occurred on 23 March 2017 and 14 November 2022.
- The collection of flood data, details of which are set out in **Appendix B** of this report. Pluviographic rainfall data recorded by Bureau of Meteorology (**BoM**) and privately operated rain gauges that are located in the vicinity of Cookamidgera were obtained. A number of photographs were also provided by respondents to the *Community Questionnaire* showing historic flood behaviour in the study area, copies of which are contained in **Appendix C** of this report.

- The hydrologic modelling of the Bartleys Creek catchment. The RAFTS sub-model in the DRAINS software was principally used to simulate the hydrologic response of the rural and urbanised parts of the Bartleys Creek catchment, with the hydrologic response of the rural land that is located immediately to the north of the village simulated using the rainfall-on-grid approach which is built into the TUFLOW software. The DRAINS-based hydrologic model was used to generate discharge hydrographs resulting from both historic and design storms.
- Application of the discharge hydrographs to a hydraulic model of Bartleys Creek and its major tributaries, as well as the Major Overland Flow paths that are present in the urbanised parts of Cookamidgera and its immediate surrounds. The TUFLOW two-dimensional modelling system was used for this purpose.
- Presentation of study results as diagrams showing indicative extents and depths of inundation, flood hazard vulnerability and the hydraulic categorisation of the floodplain into floodway, flood storage and flood fringe areas.
- An assessment of the economic impacts of flooding, including the number of affected properties and an estimation of flood damages.
- Sensitivity studies to assess the effects on model results resulting from variations in model parameters such as hydraulic roughness of the floodplain and a potential partial blockage of hydraulic structures. The effects that a potential increase in rainfall intensities associated with future climate change could have on flood behaviour were also assessed.

After calibrating the hydrologic and hydraulic models (collectively referred to herein as "the flood models") using data that were available for the 23 March 2017 and 14 November 2022 storm events, design storm rainfalls ranging between 20% and 0.2% AEP were derived using procedures set out in the 2019 edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (**ARR 2019**) and applied to the hydrologic models in order to derive discharge hydrographs. The PMF was also modelled.

S.4 Flood Model Development and Calibration

Figure 2.3 shows a comparison between rainfall that was recorded by BoM's *Parkes Airport All Weather Station* (**AWS**) and *Mandagery (Rawene)* Flood Warning Network rain gauge during a number of intense storms that have been experienced in the vicinity of Cookamidgera dating back to December 2010 and design intensity-frequency-duration curves, noting that the most intense burst of rain occurred on 3 December 2010.

Due to the limited availability of historic flood data at Cookamidgera, the flood models could only be calibrated using data that were recorded during the storms that occurred on 23 March 2017 and 14 November 2022. **Figure 2.4** shows the cumulative rainfall that was recorded by the two aforementioned rain gauges for these two historic storm events.

Figures 3.1 and **4.1** show the layout of the flood models that were developed as part of the present investigation, while **Figures 4.3** and **4.4** (3 sheets each) show the indicative extent and depth of inundation as defined by the hydraulic model for the 23 March 2017 and 14 November 2022 storm events, respectively.

Through the model calibration process, the 23 March 2017 and 14 November 2022 storm events were found to be equivalent to a design storm with an AEP of about 10% (1 in 10).

S.5 Design Flood Estimation

Figures 6.1 to **6.8** show the TUFLOW model results for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP storm events, together with the PMF. These diagrams show the indicative extent and depth of inundation in the study area for each design storm event. **Figure 6.9** shows stage hydrographs at selected road crossings throughout the study area.

Table F1 in **Appendix F** sets out peak flood levels and the depth of inundation and at the aforementioned road crossings, while **Table G1** in **Appendix G** sets out design peak flows and corresponding critical storm durations at various locations in the study area. **Figures H1.1** to **H1.8** shows the maximum flow velocities for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP storm events, together with the PMF.

Flooding patterns derived by TUFLOW for the design storm events are described in **Chapter 6** of the report.

S.6 Economic Impact of Flooding

Two dwellings that are located in the Village Centre would be above-floor inundated level in a 1% AEP flood event, resulting in total flood damages of about $0.27 Million. During a PMF event, there would be a total of 22 dwellings and one public building that would be above-floor inundated, resulting in total flood damages of about $5.92 Million.

The *"Net Present Value"* of damages resulting from all floods up to 1% AEP event for a discount rate of 5% and an economic life of 30 years is about $0.27 Million. This value represents the amount of capital spending that would be justified if one or more flood mitigation schemes prevented flooding for all properties in the Village Centre up to the 1% AEP event. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

Appendix I of this report contains further details on the economic assessment that was undertaken as part of the present study.

S.7 Flood Hazard Classification and Hydraulic Categorisation

Diagrams showing the flood hazard vulnerability classification for the 5%, 1% and 0.2% AEP flood events, as well as the PMF are shown on **Figures 6.10**, **6.11**, **6.12** and **6.13**, respectively, while the hydraulic categorisation of the floodplain for the same four design flood events are shown on **Figures 6.14**, **6.15**, **6.16** and **6.17**.

The flood hazard vulnerability classification is dependent on the depth and velocity of flow on the floodplain. Flood affected areas in the study area have been divided into the following six flood hazard vulnerability categories on the basis of these two variables and the relationships presented in ARR 2019:

- H1 which is considered to be safe for people, vehicles and buildings
- H2 which is considered to be unsafe for small vehicles
- H3 which is considered to be unsafe for vehicles, children and the elderly
- H4 which is considered to be unsafe for people and vehicles
- H5 which is considered to be unsafe for people and vehicles, and where all buildings would be vulnerable to structural damage, with some less robust building types vulnerable to failure

- H6 which is considered to be unsafe for people and vehicles, and where all buildings are considered to be vulnerable to failure

The study found that at the 1% AEP level of flooding, areas classified as H6 are limited to the inbank and immediate overbank areas of Bartleys Creek and Quart Pot Creek, while the majority of the Village Centre is classified as either H1 or H2, with isolated pockets of H3 to H5 present along the Major Overland Flow path that runs in a westerly direction to the north of Railway Street and in the road reserve in the vicinity of the intersection of Haynes Street and Flagstone Street.

The hydraulic categorisation of the floodplain requires the assessment of the main flow paths. Those areas of the floodplain where a significant discharge of water occurs during floods are denoted Floodways and are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant re-distribution of flood flow or a significant increase in flood levels. The remainder of the floodplain is denoted either Flood Storage or Flood Fringe.

As the hydraulic capacity of the watercourses is not large enough to convey the flow in a 5% AEP flood, their overbank areas also function as a floodway. As the ground levels rise relatively steeply at the edge of the floodplain, the majority of the floodplain along Quart Pot Creek and the lower reaches of Bartleys Creek function as floodways at a number of locations.

At the 1% AEP level of flooding, floodways are present along the natural low point that is located on the northern side of Railway Street, as well as along Railway Street and Flagstone Street in the Village Centre.

S.8 Sensitivity Analyses

Analyses were undertaken to test the sensitivity of flood behaviour to:

a. An increase in hydraulic roughness. **Figure 6.18** shows the effects a 20 per cent increase in the adopted 'best estimate' hydraulic roughness values would have on flood behaviour at the 1% AEP level of flooding.

b. A partial blockage of major hydraulic structures by debris. **Figure 6.19** shows the effects a partial blockage of the major culvert structures would have on flood behaviour at the 1% AEP level of flooding.

c. Increases in rainfall intensity associated with future climate change. **Figures 6.20**, **6.21** and **6.22** show the effects a 10 and 30 per cent increase in design 1% AEP rainfall intensities would have on flood behaviour in the study area.

The sensitivity analyses identified that:

- peak 1% AEP flood levels could be increased by up to 200 mm and 60 mm in areas that are subject to Main Stream Flooding and Major Overland Flow, respectively as a result of an increase in hydraulic roughness;
- a partial blockage of the hydraulic structures has a negligible impact on flood behaviour; and
- an increase in the intensity of rainfall associated with future climate change has the potential to increase peak 1% AEP flood levels by a maximum of about 300 mm.

S.9 Interim Flood Planning Area

Figure 6.23 shows the extent of the Interim Flood Planning Area (**FPA**) for the study area as it relates to both Main Stream Flooding and Major Overland Flow. The extent of the FPA has been defined as follows:

- Main Stream Flooding FPA – Land which is located along the three main flow paths and lies at or below the peak 1% AEP flood level plus 0.5 m freeboard.
- Major Overland Flow FPA – Land which lies outside the Main Stream Flooding FPA but would be subject to depths of inundation of greater than 0.1 m in a 1% AEP storm event.

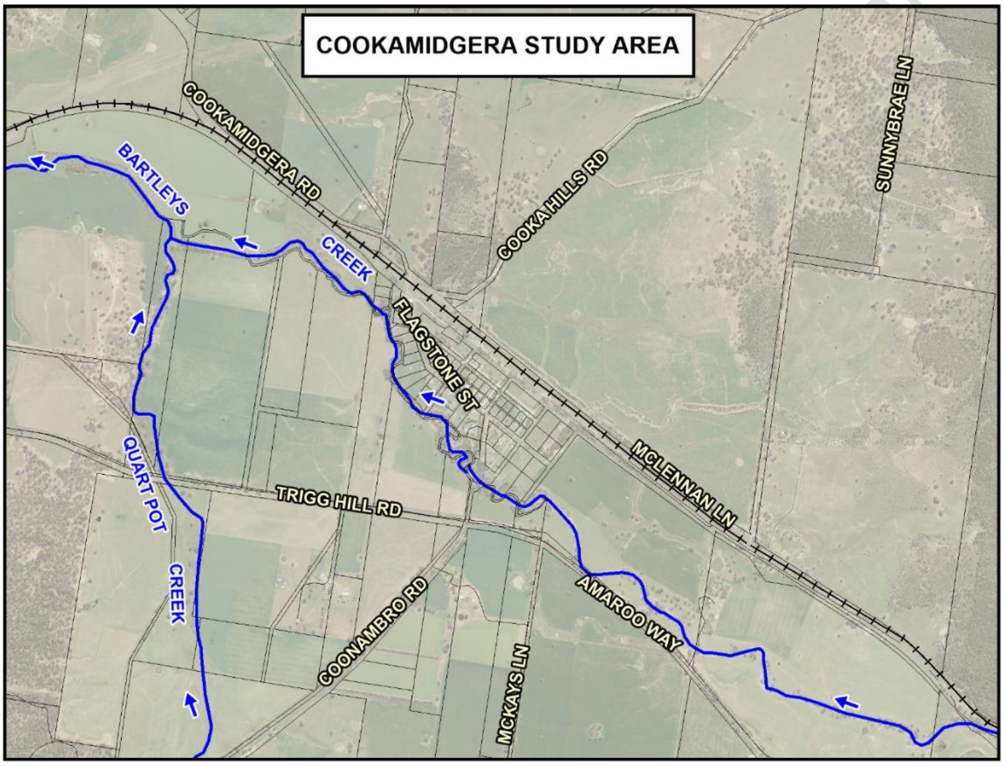
Pending the completion of the future *Cookamidgera FRMS&P* it is recommended that the habitable floor levels of future development be set a minimum 0.5 m above the corresponding peak 1% AEP flood level, noting that the future study may determine that the freeboard provision may be reduced in areas that lie within the extent of the Major Overland Flow FPA. An assessment should also be undertaken by Council as part of any future Development Application to confirm that the proposed development will not form an obstruction to the passage of overland flow through the subject site.

1 INTRODUCTION

1.1 Study Background

This report presents the findings of an investigation of flooding at the village of Cookamidgera in the Parkes Shire Council (**Council**) Local Government Area (**LGA**). The study has been commissioned by Council with financial and technical support from the NSW Government, via the Department of Climate Change, Energy, the Environment and Water (**DCCEEW**). **Figure 1.1** shows the extent of the study catchment at Cookamidgera.

The study objective was to define flood behaviour in terms of flows, water levels and velocities for floods ranging between 20 and 0.2 per cent Annual Exceedance Probability (**AEP**), as well as for the Probable Maximum Flood (**PMF**) within the extent of the study area shown below.



The investigation involved rainfall-runoff hydrologic modelling of the catchments to assess flows in the drainage systems of the study catchment and application of these flows to a hydraulic model to assess peak water levels and flow velocities (collectively referred to herein as 'flood modelling'). The model results were interpreted to present a detailed picture of flooding under present day conditions.

The study focuses on the following two types of flooding which are present in different parts of the study area:

- **Main Stream Flooding** which occurs when floodwater surcharges the inbank area of Quart Pot Creek and Bartleys Creek (also known locally as Flagstone Creek). Main Stream Flooding is typically characterised by relatively deep and fast flowing floodwater but can include shallower and slower moving floodwater on the overbank of the aforementioned creeks.

- **Major Overland Flow**, which is experienced during periods of heavy rain and is generally characterised by relatively shallow and slow-moving floodwater that is conveyed overland in an uncontrolled manner toward the abovementioned watercourses and other major drainage lines.

The study forms the first and second step in the flood risk management process for Cookamidgera (refer process diagram presented in the Foreword) and is a precursor of the future *Cookamidgera Flood Risk Management Study and Plan* (***Cookamidgera FRMS&P***) which will consider measures which are aimed at reducing the existing, future and continuing flood risk in the village.

1.2 Community Consultation and Available Data

To assist with data collection and promotion of the study to the community, a *Community Newsletter* and *Questionnaire* was distributed by Council in May 2022 to residents and business owners in the study area. In-person consultation was also undertaken by Council in May 2022 and by the Consultants in December 2023. A copy of the *Community Newsletter* and *Questionnaire* is contained in **Appendix A** of this report.

Council advised that approximately 50 *Community Newsletters* and *Questionnaires* were distributed to residents and business owners in the study area, with a total of 13 responses received by the closing date of submissions (a response rate of less than 20 per cent). Of the 13 respondents, 12 noted that they had been affected by flooding.

The following events were identified during the community consultation process:

- 1952 (specific date not mentioned);
- 1986 (specific date not mentioned);
- 7 November 2005;
- 6 January 2006;
- 3 November 2007;
- December 2010;
- February 2016;
- 23 March 2017;
- January 2020;
- January 2021; and
- 14 November 2022.

Information on historic flooding patterns obtained from the responses assisted with "ground-truthing" the results of the flood modelling.

Appendix B contains details of the data that were available for the present study, while **Appendix C** contains several photos that were provided by Council and respondents to the *Community Questionnaire* which show historic flood behaviour at Cookamidgera during storms that occurred on 23 March 2017 and 14 November 2022.

1.3 Layout of Report

Chapter 2 contains background information including a brief description of the study catchment and its drainage systems, a brief history of flooding and an analysis of the available rain gauge record.

Chapter 3 deals with the hydrology of the study catchment and describes the development and calibration of the DRAINS-based hydrologic model that was used to generate discharge hydrographs for input to the hydraulic model.

Chapter 4 deals with the development and calibration of the TUFLOW hydraulic model that was used to analyse flood behaviour in the study area.

Chapter 5 deals with the derivation of design discharge hydrographs, which involved the determination of design storm rainfall depths over the catchment for a range of storm durations and conversion of the rainfalls to discharge hydrographs.

Chapter 6 details the results of the hydraulic modelling of the design floods in the study area. Results are presented as plans showing indicative extents and depths of inundation for a range of design flood events up to the PMF. This chapter also includes an assessment of flood hazard and hydraulic categorisation. It also presents the results of various sensitivity studies undertaken using the TUFLOW model, including the effects changes in hydraulic roughness, a partial blockage of the hydraulic structures and potential increases in rainfall intensities due to future climate change will have on flood behaviour. This chapter also deals with the derivation of *Flood Planning Levels* for the study area.

Chapter 7 contains a list of references, whilst **Chapter 8** contains a list of flood-related terminology that is relevant to the scope of the study.

The following appendices are included in the report:

- **Appendix A**, which contains a copy of the *Community Newsletter* and *Questionnaire* that were distributed at the commencement of the study to residents and business owners in the study area.
- **Appendix B**, which contains a list of data that were available for the present study and a summary of the responses to the *Community Questionnaire*.
- **Appendix C**, which contains photographs showing flood behaviour in the study area during storms that occurred on 23 March 2017 and 14 November 2022.
- **Appendix D**, which contains a copy of the design input data that were extracted from the *Australian Rainfall and Runoff* (**ARR**) *Data Hub* for the study area.
- **Appendix E**, which summarises design blockage values that were assigned to the transverse drainage structures in the TUFLOW.
- **Appendix F**, which contains a table containing flood data on individual road crossings at Cookamidgera
- **Appendix G**, which contains a table listing the peak flow at key locations in the study area for the full range of design storm events.
- **Appendix H**, which contains figures showing the maximum flow velocities in the study area for the full range of assessed design storm events.
- **Appendix I**, which contains an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings in Cookamidgera.

Figures referred to in the main body of the report are bound separately in **Volume 2**.

2 BACKGROUND INFORMATION

2.1 Catchment Description

2.1.1. General

The village of Cookamidgera has a population of about 150 and is located on the right bank of Bartleys Creek (which is also known locally as Flagstone Creek) in the Parkes Shire Council LGA. **Figure 2.1** shows that Bartleys Creek flows in a westerly direction through Cookamidgera where it discharges to Goobang Creek approximately 12 km to the west of the village. **Figure 2.1** also shows the alignment of Quart Pot Creek which is a tributary of Bartleys Creek. Bartleys Creek and Quart Pot Creek have catchment areas of 37 km^2 and 55 km^2, respectively at their confluence, while Bartleys Creek has a total catchment area of about 180 km^2 where it joins Goobang Creek.

Figure 2.2 (2 sheets) shows the layout of the existing drainage system in the vicinity of Cookamidgera. The existing stormwater drainage system in the village generally comprises piped and culvert crossings beneath the roads and railway, and grass lined table drains that convey overland flow towards Bartleys Creek and its tributaries.

A network of earth bunds and dams, the layout of which is shown in **Figure 2.2**, were constructed immediately to the north of the village between 1986 and 1990 as part of what was called "the Cookamidgera Project". The aim of the Cookamidgera Project was to reduce the uncontrolled transportation of sediment from eroded drainage lines so as to reduce the impact that it has on Council and community owned assets and land. **Section B1.6.1** of **Appendix B** of this report provides further background to the Cookamidgera Project.

As shown on **Figure 2.2**, the extent of land zoned for urban type development in the village (herein referred as the "Village Centre") is bounded by Bartleys Creek to the south and west, the Orange–Broken Hill Railway (herein referred to as "the railway") to the north and rural land to the east. **Figure 2.2** also shows that the southern and eastern boundary of the Village Centre form the boundary between the Parkes and Forbes Shire Council LGA boundaries.

The following sections of this report provide a description of the various watercourses which contribute to flooding in the study area.

2.1.2. Bartleys Creek (Locally Known as Flagstone Creek)

Figure 2.1 shows that the headwaters of Bartleys Creek are located approximately 9 km to the east of Cookamidgera. The inbank area of Bartleys Creek generally comprises an incised 5 m wide by 1.5-3 m deep channel which has a grade of about 0.7% where it runs between the upstream (eastern) side of the Village Centre and its confluence with Quart Pot Creek. While the inbank area of the creek is generally about 10 m wide and up to 4 m deep downstream of the confluence, there is a 1.3 km section in the vicinity of the eastern end of Wybara Lane where the width increases to a maximum of about 30 m.

There are three road crossings of Bartleys Creek in the study area; two low level culvert and causeway crossings along Trig Hill Road and one higher level bridge crossing at the Parkes Eugowra Road.

2.1.3. Quart Pot Creek

Figure 2.1 shows that the headwaters of Quart Pot Creek catchment are located approximately 12 km to the south of Cookamidgera in the Forbes Shire Council LGA. Quart Pot Creek generally runs in a northerly direction through the study area and discharges to Bartleys Creek approximately 1.2 km downstream (west) of the village. Quart Pot Creek generally comprises a 5 m wide by 1 m deep channel which has a grade of about 0.3% where it runs through the study area.

There are two road crossings of Quart Pot Creek in the study area; one low level culvert and causeway crossing of at Trig Hill Road and one higher level road crossing at Coonambro Way.

2.2 Flood History and Analysis of Historic Rainfall

2.2.1. General

Respondents to the *Community Questionnaire* identified a number of notably intense storm events that have been experienced in the study area, the dates of which are given in **Section 1.2** of the report. A number of respondents also provided photographic evidence (refer **Appendix C**), as well as descriptions of the patterns of overland flow in the vicinity of their properties. It is understood that a flood that occurred in 1952 is considered the flood of record at Cookamidgera, although there is no information on flood behaviour during this event.

Figure 1.1 shows the location of the nearby Bureau of Meteorology (**BoM**) and WaterNSW operated pluviographic rain gauges that are located in the vicinity of the study area. **Table 2.1** over the page shows a comparison of the 24-hour rainfall totals at the rain gauges that are located within 15 km of the study catchment for the historic storm events that were identified during the community consultation process, noting that none of the rain gauges were in operation during the flooding that is said to have occurred in 1952 and 1986.

Figure 2.3 shows design versus historic intensity-frequency-duration (**IFD**) curves for the two BoM operated pluviographic rain gauges that are located in the vicinity of Cookamidgera for the storm events identified by the respondents to the *Community Questionnaire*, while **Table 2.2** gives the approximate AEP of the recorded rainfall for durations ranging between 0.25 and 24 hours.

Table 2.2 and **Figure 2.3** show that the storms identified by the respondents to the *Community Questionnaire* varied in intensity. The storm that occurred in December 2010 was equivalent to between about 0.5% (1 in 200) and 0.2% (1 in 500) AEP design storm event at Parkes, while the storms that occurred in March 2017, January 2021 and November 2022 were equivalent to about a 10% (1 in 10) AEP design storm event for durations ranging between 1 and 24 hours. The January 2020 storm was equivalent to about a 20% (1 in 5) AEP design storm event.

Based on the availability of historic flood data, the storm events that occurred on 23 March 2017 and 14 November 2022 were selected for use in the calibration of the hydrologic and hydraulic models that were developed as part of the present study. **Figure 2.4** shows the cumulative rainfall that was recorded at the nearby rain gauges for these two storm events.

2.2.2. 23 March 2017 Storm Event

While only one respondent identified that they had experienced flooding as a result of the March 2017 storm event, the respondent provided a large number of photos that show flood behaviour in the village between the 08:17 hours and 09:30 hours on 23 March 2017 (refer **Plates C1.1** to **C1.24** in **Appendix C** for details). It is unclear if these photos were taken at the peak of the flood event.

TABLE 2.1
RECORDED DAILY RAINFALL TOTALS FOR HISTORIC STORM EVENTS[(1)]

Historic Storm	Rainday	Daily Rainfall Total (mm)			
		BoM Daily Read Gauge	**Bom AWS**	**BoM FWN**	**Privately Owned Gauge**
		Parkes Airport AWS (GS 65068)		**Mandagery (Rawene) (GS 65096)**	**Hillside**
November 2005	8 November 2005	130	Pluviographic rainfall data not available	Data not available for the purpose of the present study	
January 2006	6 January 2006	0			
November 2007	3 November 2007	14			
	4 November 2007	19			
December 2010	3 December 2010	105.6			
	4 December 2010	21			
February 2016	Date not defined	No rainfall recorded in February 2016			
March 2017	23 March 2017	19.4			
	24 March 2017	48.4			
January 2020	17 January 2020	35.8			
January 2021	2 January 2021	20.8			
	3 January 2021	52			
November 2022	13 November 2022	25.8		25.2	24
	14 November 2022	80		73.2	84

1. Refer **Figure 1.1** for gauge location.

The left hand side of **Figure 2.4** shows that 52.8 mm of rain fell between 08:00 hours and 10:30 hours on 23 March 2017 at the Parkes Airport AWS rain gauge which is located about 12 km north-west of the village. A review of historic weather records show that the wind was blowing in a westerly direction at about 12 km/hr on the morning of 23 March 2017 which explains why the rainfall was recorded during or after the time the photos were taken. It is not possible to verify the exact timing of the rainfall at Cookamidgera as there were no pluviographic rain gauges in operation within the study catchment. **Figure 2.3** and **Table 2.2** show that the recorded rainfall at Parkes was equivalent to design storm with an AEP of about 10%.

Plates C1.1 and **C1.2** of **Appendix C** show floodwater ponding on the northern side of the railway in the vicinity of the intersection of Flagstone Street and Cooka Hills Road, while **Plates C1.3** to **C1.6** show floodwater surcharging the railway in a southerly direction adjacent to the Flagstone Street level crossing of the railway.

TABLE 2.2
APPROXIMATE AEPs OF RECORDED RAINFALL FOR HISTORIC STORM EVENTS
(% AEP)

Storm Event	Rain Gauge Station Name[1]	Storm Duration (hours)						
		1	2	3	6	9	12	24
December 2010	Parkes Airport AWS (GS 65068)	5-2%	0.5%	0.2%	0.5%	1-0.5%	1%	2-1%
March 2017	Parkes Airport AWS (GS 65068)	10%	10-5%	10%	20%	20%	50-20%	20%
January 2020	Parkes Airport AWS (GS 65068)	50-20%	50-20%	50-20%	50%	>50%	>50%	>50%
January 2021	Parkes Airport AWS (GS 65068)	20-10%	50-20%	50%	20%	20%	50-20%	20%
November 2022	Parkes Airport AWS (GS 65068)	50-20%	20-10%	10%	5%	5%	10-5%	5%
November 2022	Mandagery (Rawene) (GS 65096)	50%	50%	50-20%	20-10%	10%	10%	10-5%

1. Refer **Figure 1.1** for gauge location.

Plate C1.7 shows floodwater overtopping Flagstone Street at the low point that is located approximately 50 m to the south of the railway, while **Plates C1.8** to **C1.10** show floodwater flowing in a northerly direction along a grass-lined drain that runs parallel to Flagstone Street on its eastern side.

Plates C1.11 and **C1.12** show that the Trig Hill Road crossing of Bartleys Creek was at the point of overtopping at 08:46 hours. **Plates C1.14** to **C1.17**, as well as **Plates C1.22** and **C1.24** show that Railway Street and Haynes Street within the Village Centre were inundated at around 09:00 hours.

2.2.3. 14 November 2022 Storm Event

Table 2.1 shows that the recorded rainfall depths at the Parkes Airport AWS and the Mandagery (Rawene) gauge, the latter which is located about 14 km to the south east of the village, were comparable to that recorded at the privately owned Hillside rain gauge which is located 2 km to the north-east of the village. Based on this finding, the rainfall that was recorded by both the Parkes Airport AWS and Mandagery (Rawene) rain gauges is considered to be representative of the rain that fell at Cookamidgera.

The right hand side of **Figure 2.4** shows that 79.8 mm of rain fell between 16:30 hours on 13 November 2022 and 03:30 hours on 14 November 2022 at the location of the Parkes Airport AWS gauge, while 75.8 mm of rain fell at the location of the Mandagery (Rawene) rain gauge during the same time period. **Figure 2.3** and **Table 2.2** show that the rainfall that was recorded by the two rain gauges was equivalent to a design storm with an AEP of about 10%.

Plates C2.1 to **C2.6** show that floodwater completely inundated the lower sections of Flagstone Street immediately to the south of the level crossing of the railway at sunrise on 14 November 2022, which records show was at about 06:00 hours.

3 HYDROLOGIC MODEL DEVELOPMENT AND CALIBRATION

3.1 Hydrologic Modelling Approach

The present study required the use of a hydrologic model which is capable of representing the rainfall-runoff processes that occur within both the rural and urbanised parts of the study catchments. For hydrologic modelling, the practical choice is between the models known as DRAINS, RAFTS, RORB and WBNM. Whilst there is little to choose technically between these models, Hortonian and IL-CL loss models within the DRAINS software have been developed primarily for use in modelling the passage of a flood wave through highly urbanised catchments, whilst RAFTS, RORB and WBNM have been widely used in the preparation of rural flood studies.

The RAFTS modelling approach which is built into the DRAINS software was used as part of the present study to generate discharge hydrographs from the various sub-catchments which comprise the Bartleys Creek catchment, noting that the hydrologic response of the catchment within the extent of the Cookamidgera Project was simulated using the rainfall-on-grid approach which is built into the TUFLOW software in order to assess the impact that the complex network of earthworks that comprise the project have on the way that overland flow approaches the village. The discharge hydrographs generated by applying the RAFTS modelling approach were applied to the TUFLOW hydraulic model as either point or distributed inflow sources (refer **Section 4.4** of this report for further details).

3.2 Hydrologic Model Layout

Figure 3.1 shows the layout of the hydrologic model that was developed as part of the present study (**Cookamidgera DRAINS Model**). Careful consideration was given to the definition of the sub-catchments which comprise the Cookamidgera DRAINS Model to ensure peak flows throughout the drainage system would be properly routed through the hydraulic model. In addition to using the Light Detecting and Ranging (**LiDAR**) based contour data, the location of headwalls were also taken into consideration when deriving the boundaries of the various sub-catchments. The study area was split into a total of 178 sub-catchments.

As the primary function of the hydrologic model was to generate discharge hydrographs for input to the TUFLOW hydraulic model, individual reaches linking the various sub-catchments were not incorporated in the model. Percentages of impervious area were based on a visual inspection of the aerial photography and experience in determining appropriate values for different land-use types.

Figure 3.1 shows that the RAFTS modelling approach has been used for sub-catchments predominately comprising the rural portion of the study catchment, while the hydrologic response of the catchment within the extent of the Cookamidgera Project was simulated using the rainfall-on-grid approach which is built into the TUFLOW software.

Sub-catchment slopes used for input to the hydrologic model were derived using the vectored average slope approach for sub-catchments characterised as rural (which are modelled using the RAFTS approach) and the average sub-catchment slope approach for sub-catchments characterised as urbanised (which are modelled using the IL-CL approach). Digital Elevation Models (**DEMs**) derived from the available LiDAR survey data were used as the basis for computing the slope.

3.3 Hydrologic Model Testing

3.3.1. General

Historic flood data suitable for use in the model calibration process comprises photographic and anecdotal evidence of flooding patterns that were observed during the storms that occurred on 23 March 2017 and 14 November 2022. As discussed in **Section 2.2**, the storms for which data were available are equivalent to about a 10% (1 in 10) AEP event.

As there are no historic data on flood flows anywhere in the study area, the procedure adopted for the calibration of the hydrologic model involved an iterative process sometimes referred to as "tuning". This process involved the generation of discharge hydrographs for the historic storm events using a starting set of hydrologic model parameters. The discharge hydrographs were then input to the hydraulic model, which was then run with an initial set of hydraulic roughness parameters and the resulting flooding patterns compared with the photographic and anecdotal evidence.

Minimal iterations of this process were required, whereby changes were made to the hydrologic model parameters, after which the resulting adjusted discharge hydrographs were input to the hydraulic model until a good fit with observed data was achieved (refer **Chapter 4** for further details).

3.3.2. Application of Historic Rainfall to the Hydrologic Model

The rainfall burst that was recorded at the Parkes Airport AWS rain gauge shown on the left-hand side of **Figure 2.4** was input to the hydrologic model for the 23 March 2017 storm event, while the rainfall burst that was recorded at the Mandagery (Rawene) rain gauge was relied upon for the 14 November 2022 storm event. **Table 2.2** shows that it was not necessary to apply a rainfall multiplier to the recorded rainfall at the Mandagery (Rawene) rain gauge in order to match the rainfall that was recorded by the privately owned Hillside rain gauge for the 14 November 2022 storm event.

3.3.3. Hydrologic Model Parameters

For the sub-catchments modelled using the RAFTS hydrologic modelling approach, a Manning's n value of 0.04 was applied to sub-catchments primarily characterised as rural pastoral land, while a value of 0.06 was applied to sub-catchments comprising a mixture of cleared pastoral land and dense vegetation. A Manning's n value of 0.08 was applied to sub-catchments comprising mostly dense vegetation. A Bx routing parameter of 1.0 was adopted for sub-catchments that were modelled in RAFTS.

An initial storm loss value of 23 mm was adopted based on the data extracted from the *ARR Data Hub* (a copy of which is contained in **Appendix D)**.

It was not possible to achieve a good match with the observed flood behaviour using the NSW jurisdictional losses procedure for deriving continuing loss values by factoring the raw continuing loss value obtained from the *ARR Data Hub* of 2.3 mm/hr by a factor of 0.4. A better fit was achieved by adopting the raw value of 2.3 mm/hr.

3.3.4. Results of Model Testing

When applied to the hydraulic model, the discharge hydrographs that were generated by the hydrologic model gave reasonable correspondence with observed flood behaviour. The hydrologic model parameters set out in this chapter were therefore adopted for design flood estimation purposes, noting that due to the limited availability of historic flood related data for use in the model calibration process, the initial and continuing loss values contained in the *ARR Data Hub* were ultimately adopted for design flood estimation purposes (refer **Chapter 5** of this report for further details).

4 HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION

4.1 General

The present study required the use of a hydraulic model that is capable of analysing the time varying effects of flow in the local stormwater drainage system and the two-dimensional nature of flow on the floodplain and in the steeper parts of the study area that are subject to overland flow. The TUFLOW modelling software was adopted as it is one of only a few commercially available hydraulic models which contain all the required features.

This chapter deals with the development and calibration of the TUFLOW model that was then used to define the nature of flooding in the study area for a range of design storm events (refer **Chapter 6** for further details).

4.2 The TUFLOW Modelling Approach

TUFLOW is a true two-dimensional hydraulic model which does not rely on a prior knowledge of the pattern of flood flows in order to set up the various fluvial and weir type linkages which describe the passage of a flood wave through the system.

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

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

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

The TUFLOW model developed as part of the present study will allow for the future assessment of potential flood management measures, such as detention storage, increased channel and floodway dimensions, augmentation of culverts and bridge crossing dimensions, diversion banks and levee systems.

4.3 TUFLOW Model Setup

4.3.1. Model Structure

Figure 4.1 (2 sheets) shows the layout of the TUFLOW model that was developed as part of the present study (**Cookamidgera TUFLOW Model**). The Cookamidgera TUFLOW Model comprises the piped drainage system, while the inbank, overbank and shallow “overland” flow are modelled by the rectangular grid.

The following sections provide further details of the model development process.

4.3.2. Two-dimensional Model Domain

An important consideration of two-dimensional modelling is how best to represent the roads, fences, buildings and other features which influence the passage of flow over the natural surface. Two-dimensional modelling is very computationally intensive, and it is not practicable to use a mesh of very fine elements without excessive times to complete the simulation, particularly for long duration flood events. The requirement for a reasonable simulation time influences the way in which these features are represented in the model.

A grid spacing of 6 m with a smaller 3 m grid spacing embedded internal to the model in the vicinity of the Village Centre (refer **Figure 4.1** for extent) was found to provide an appropriate balance between the need to define features on the floodplain versus model run times and was adopted for the investigation. Ground surface elevations for model grid points were initially assigned using the LiDAR derived DEMs for the study area.

Ridge and gully lines were added to the Cookamidgera TUFLOW Model where the grid spacing was considered to be too coarse to accurately represent important topographic features which influence the passage of overland flow, such as the railway line and earth embankments on rural land. The elevations for these ridge and gully lines were determined from inspection of the LiDAR survey data or site-based measurements.

Gully lines were also used to represent the major creeks and watercourses in the study area. The use of gully lines ensured that positive drainage was achieved along the full length of these watercourses, and thus avoided creation of artificial ponding areas as artefacts of the 'bumpy' nature of the underlying LiDAR survey data.

The local farm dams, including those located within the Cookamidgera Project were assumed full at the start of the model simulation (i.e. at the onset of flood producing rain).

A review of the surveyed cross sections of Bartleys Creek found that the LiDAR survey data accurately captured the invert of the watercourse. Therefore the elevations assigned to the gully line representing the creek in the vicinity of the village were derived from the LiDAR survey data.

The existing Parkes Eugowra Road bridge crossing of Bartleys Creek was incorporated in the two-dimensional domain as a layered flow constriction elements based on cross sectional survey data. The bridge deck and handrails were assumed to be 100% blocked (i.e. impervious to flow).

The footprints of individual buildings located in the two-dimensional model domain were digitised and assigned a high hydraulic roughness value relative to the more hydraulically efficient roads and flow paths through allotments. This accounted for their blocking effect on flow while maintaining a correct estimate of floodplain storage in the model.

It was not practicable to model the individual fences surrounding the many allotments in the study area. For the purpose of the present study, it was assumed that there would be sufficient openings in the fences to allow water to enter the properties, whether as flow under or through fences and via openings at driveways. Individual allotments where development is present were digitised and assigned a high hydraulic roughness value (although not as high as for individual buildings) to account for the reduction in conveyance capacity which will result from obstructive fences, such as Colorbond or brick, and other obstructions stored on these properties.

4.3.3. One-dimensional Model Elements

Survey data provided by Ardnell Surveying were used as the primary source of details of the piped drainage system which were incorporated into the Cookamidgera TUFLOW Model. These data were supplemented with field measurements. **Table 4.1** over the page summarises the pit and pipe data that were incorporated into the Cookamidgera TUFLOW Model.

TABLE 4.1
SUMMARY OF MODELLED DRAINAGE STRUCTURES

Pipes		Box Culverts		Headwalls
No.	**Length (m)**	**No.**	**Length (m)**	**No.**
28	750	38	570	120

4.3.4. Model Parameters

The main physical parameter for TUFLOW is the hydraulic roughness. Hydraulic roughness is required for each of the various types of surfaces comprising the overland flow paths, as well as inbank areas of the creeks. In addition to the energy lost by bed friction, obstructions to flow also dissipate energy by forcing water to change direction and velocity and by forming eddies. Hydraulic modelling traditionally represents all of these effects via the surface roughness parameter known as "Manning's n". Flow in the piped system also requires an estimate of hydraulic roughness.

Manning's n values along the channel and immediate overbank areas along the modelled length of creeks were varied, with the values in **Table 4.2** over the page providing reasonable correspondence between recorded and modelled flood levels.

The adoption of a value of 0.02 for the surfaces of roads, along with an adequate description of their widths and centreline/kerb elevations, allowed an accurate assessment of their conveyance capacity to be made. A relatively high roughness value of 0.1 has been applied to the grassed and paved inter-allotment area to account for the blocking effect that various features in private properties such as fences, landscaping, vegetation etc. will have on flood behaviour.

TABLE 4.2
BEST ESTIMATE HYDRAULIC ROUGHNESS VALUES

Surface Treatment	**Manning's n Value**
Concrete piped elements	0.015[(1)]
Asphalt or concrete road surface	0.02
Overbank area, including grass and lawns	0.045
Vegetated areas	0.08
Allotments (between buildings)	0.10
Buildings	10

1. It has been assumed that the piped elements are old and have a slightly higher Manning's n value than a new concrete pipe.

Figure 4.2 is a typical example of flow patterns derived from the above roughness values. This example applies to the 23 March 2017 flood event and shows flooding patterns in the vicinity of the Flagstone Street level crossing of the railway. The left hand side of the figure shows the roads and inter-allotment areas, as well as the outlines of buildings, which have all been assigned different hydraulic roughness values in the model. The right hand side shows the resulting flow paths in the form of scaled velocity vectors and the depths of inundation. The buildings with their high values of hydraulic roughness block the passage of flow, although the model recognises that they store floodwater when inundated and therefore correctly accounts for flood storage.[1] Similar information to that shown on **Figure 4.2** may be presented at any location within the model domain and will be of assistance to Council in assessing individual flooding problems in the study area.

4.4 Model Boundary Conditions

The locations where sub-catchment inflow hydrographs were applied to the Cookamidgera TUFLOW Model are shown on **Figure 4.1**. These comprise both point-source inflows at selected locations around the perimeter of the two-dimensional model domain and as distributed inflows via "Rain Boundaries".

The Rain Boundaries act to "inject" flow into the Cookamidgera TUFLOW Model, firstly at a point which has the lowest elevation, and then progressively over the extent of the Rain Boundary as the grid in the two-dimensional model domain becomes wet as a result of overland flow. The Rain Boundaries have been digitised at the outlet of the catchment in order to reduce the "double-routing" of runoff from the sub-catchment.

The direct-rainfall-on-grid approach involves the application of rainfall excess to the two-dimensional model domain, with the routing of the rainfall excess (runoff) simulated across each grid cell within the area shown on **Figure 4.1**.

The downstream boundary of the model comprises a TUFLOW-derived normal depth relationship which is located approximately 1 km downstream (west) of the Parkes Eugowra Road. The downstream boundary has been located a sufficient distance downstream of the study area so as to not impact flood behaviour in the area of interest.

4.5 Results of Model Calibration Process

As previously mentioned, the hydrologic and hydraulic models were calibrated using data that were available for the storm that occurred on 23 March 2017 and 14 November 2022.

Figures 4.3 and **4.4** (2 sheets each) show the Cookamidgera TUFLOW Model results for the 23 March 2017 and 14 November 2022 storm events, respectively, while **Tables 4.3** and **4.4** at the end of this chapter briefly describes the flood behaviour that was observed during each storm event and how it compares to the results of the Cookamidgera TUFLOW Model. In general, the Cookamidgera TUFLOW Model was able to reproduce the flood behaviour which was approximated from the available photographs and anecdotal descriptions of flooding for the 23 March 2017 and 14 November 2022 storm events.

[1] Note that the depth grid has been trimmed to the building polygons as based on previous experience, residents tend to interpret the figure as showing the depth of above-floor inundation, when in fact it is showing the depth of above-ground inundation over the footprint of the building. The same approach has been adopted for presenting the results for the various design flood events, details of which are contained in **Chapter 6**.

Based on the findings of the model calibration process, the hydrologic and hydraulic models were considered to give satisfactory correspondence with the available historic flood data. As such, the hydraulic model parameters set out in **Sections 4.3** and **4.4**, and in particular the hydraulic roughness values set out in **Table 4.2,** were considered appropriate for use in defining flood behaviour in the study area over the full range of design flood events. Further discussion and presentation of hydrologic model parameters that were adopted for design flood estimation purposes is provided in **Section 5.3**.

TABLE 4.3
COMPARISON OF OBSERVED AND MODELLED FLOOD BEHAVIOUR
23 MARCH 2017 FLOOD

Response Identifier[(1)]	Observed Flood Behaviour/ Other Comment	Model Verification Comments
FM_2017.1	**Plates C1.1** and **C1.2** show floodwater inundating the low point in Flagstone Street on the northern side of the railway.	The Cookamidgera TUFLOW Model results show the low point inundated to a maximum depth of about 1.2 m.
FM_2017.2	**Plates C1.4** and **C1.5** show floodwater flowing in a southerly direction across the railway on the eastern and western sides of the Flagstone Street level crossing.	The Cookamidgera TUFLOW Model results show the railway overtopped by a maximum depth of about 0.3 m adjacent to the level crossing.
FM_2017.3	**Plate C1.7** shows floodwater flowing in a westerly direction across Flagstone Street approximately 50 m to the south of the railway.	The Cookamidgera TUFLOW Model results show Flagstone Street inundated to a maximum depth of about 0.3 m.
FM_2017.4	**Plates C1.8** and **C1.9** show floodwater flowing in a northerly direction along the eastern side of Flagstone Street.	The observed patterns of overland flow are reproduced by the Cookamidgera TUFLOW Model.
FM_2017.5	**Plates C1.11** and **C1.12** shows floodwater at the point of overtopping the Trig Hill Road crossing of Bartleys Creek. The timing of the flood peak relative to the time of the photographs is not known.	The Cookamidgera TUFLOW Model results show the road inundated to a maximum depth of about 0.6 m.
FM_2017.6	**Plates C1.14** and **C1.15** show Railway Street inundated on the western and eastern sides of its intersection with Mullins Street.	The Cookamidgera TUFLOW Model results show Railway Street inundated to a maximum depth of about 0.2 m adjacent to its intersection with Mullins Street.
FM_2017.7	**Plates C1.16** and **C1.17** show floodwater inundated the intersection of Railway Street and Hynes Street.	The Cookamidgera TUFLOW Model results show the intersection inundated to a maximum depth of about 0.2 m.
FM_2017.8	**Plate C1.24** shows floodwater ponding in Haynes Street to the north of its intersection with Railway Street.	The Cookamidgera TUFLOW Model results show Haynes Street inundated to a depth of about 0.6 m.
FM_2017.9	**Plate C1.22** shows floodwater flowing in a southerly direction from Railway land and discharging to the northern end of Haynes Street.	The Cookamidgera TUFLOW Model results reproduce the observed flood behaviour.

1. Refer **Figure 4.3** (3 sheets) for location of observed flood behaviour.

TABLE 4.4
COMPARISON OF OBSERVED AND MODELLED FLOOD BEHAVIOUR
14 NOVEMBER 2022 FLOOD

Response Identifier[(1)]	Observed Flood Behaviour/ Other Comment	Model Verification Comments
FM_2022.1	**Plate C2.2** shows floodwater flowing in a westerly direction across Flagstone Street approximately 50 m to the south of the railway.	The Cookamidgera TUFLOW Model results show Flagstone Street inundated to a maximum depth of about 0.3 m.
FM_2022.3	**Plate C2.3** shows floodwater inundating Flagstone Street.	The Cookamidgera TUFLOW Model results show along a 200 m section of Flagstone Street inundated to maximum depth of up to 0.2 m
FM_2022.4	Anecdotal advice that the Trig Hill Road crossing of Quart Pot Creek was overtopped by between 1.5-2 m.	The Cookamidgera TUFLOW Model results show Quart Pot Creek inundated by a depth of about 1 m.
FM_2022.5	The depth of flow over the eastern (right) bank of Quart Pot Creek was about 1.5 m based the debris line in the trees.	The Cookamidgera TUFLOW Model results show the depth of inundation adjacent to the trees was about 1.4 m.
FM_2022.2	The maximum depth of overland flow was about 0.3-0.5 m based on anecdotal advice provide by community member.	The Cookamidgera TUFLOW Model results show the maximum depth of overland flow was about 0.4 m at the location shown.

1. Refer **Figure 4.4** (3 sheets) for location of observed flood behaviour.

5 DERIVATION OF DESIGN FLOOD HYDROGRAPHS

5.1 Design Storms

5.1.1. Rainfall Intensity

The procedures used to obtain temporally and spatially accurate and consistent Intensity-Frequency-Duration (**IFD**) design rainfall curves for the assessment of flood behaviour in the study area are presented in the 2019 edition of *Australian Rainfall and Runoff* (Geoscience Australia, 2019) (**ARR 2019**). Design storms for frequencies of 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP were derived for storm durations ranging between 15 minutes and seven days. The IFD dataset was downloaded from the BoM's *2016 Rainfall IFD Data System*.

5.1.2. Areal Reduction Factors

The rainfalls derived using the processes outlined in ARR 2019 are applicable strictly to a point. In the case of a catchment of over tens of square kilometres area, it is not realistic to assume that the same rainfall intensity can be maintained. An Areal Reduction Factor (**ARF**) is typically applied to obtain an intensity that is applicable over the entire catchment.

While ARFs of between 0.8 and 0.95 are applicable on the catchments contributing to flow in Bartleys Creek (37 km^2) and Quart Pot Creek (55 km^2) at their confluence, a good match was achieved between the flows derived by the hydrologic model that was developed as part of the present study using a single ARF value of 1.0 and those derived by the Regional Flood Frequency Estimation (**RFFE**) Model, the procedures for which are set out in ARR 2019. Furthermore, as the purpose of the study was to also define the nature of Major Overland Flow which is typically associated with smaller catchments, where point rainfall is more applicable, a global ARF value of 1.0 was adopted for design flood estimation purposes.

5.1.3. Temporal Patterns

ARR 2019 prescribes the analysis of an ensemble of 10 temporal patterns per storm duration for various zones in Australia. These patterns are used in the conversion of a design rainfall depth with a specific AEP into a design flood of the same frequency. The patterns may be used for AEPs down to 0.2 per cent where the design rainfall data is extrapolated for storm events with an AEP less than 1 per cent.

The temporal pattern ensembles that are applicable to Frequent (more frequent than 14.4% AEP), Intermediate (between 14.4% and 3.2% AEP) and Rare (rarer than 3.2% AEP) storm events were obtained from the ARR Data Hub[2], while those for the very rare events were taken from BoM's publication entitled *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (BoM, 2003) and Jordan et. al., 2005.

A copy of the data extracted from the ARR Data Hub is contained in **Appendix D**.

5.1.4. Probable Maximum Precipitation

Estimates of Probable Maximum Precipitation (**PMP**) were made using the Generalised Short Duration Method (**GSDM**) as described in the BoM, 2003. This method is appropriate for estimating extreme rainfall depths for catchments up to 1000 km^2 in area and storm durations up to 3 hours.

[2] It is noted that the temporal pattern data set for the *Murray-Darling Basin* region is suitable for use in the study area.

The steps involved in assessing PMP for the study catchments are briefly as follows:

- Calculate PMP for a given duration and catchment area using depth-duration-area envelope curves derived from the highest recorded US and Australian rainfalls.
- Adjust the PMP estimate according to the percentages of the catchment which are meteorologically rough and smooth, and also according to elevation adjustment and moisture adjustment factors.
- Assess the design spatial distribution of rainfall using the distribution for convective storms based on US and world data but modified in the light of Australian experience.
- Derive storm hyetographs using the eleven temporal distributions contained in BoM, 2003, and Jordan et. al., 2005 which are based on pluviographic traces recorded in major Australian storms.

Figure 3.1 shows the location and orientation of the PMP ellipses which were used to derive the rainfall estimates for the present study.

5.2 Design Rainfall Losses

The initial and continuing loss values to be applied in flood hydrograph estimation were derived using the NSW jurisdictional specific procedures set out in the *ARR Data Hub*. The raw Probability Neutral Burst Initial Loss values obtained from the *ARR Data Hub* were reviewed and adjusted to remove inconsistencies in values with varying storm probability and duration. **Figure 5.1** shows the original Probability Neutral Burst Initial Loss curves derived from the tables obtained from the *ARR Data Hub*, together with the adopted PNBIL curves following the adjustments that were made as part of the present study.

While the NSW jurisdictional advice recommends multiplying the raw (or unadjusted) continuing loss value that is contained on the *ARR Data Hub* of 2.3 mm/hr by a factor of 0.4 for design flood estimation (i.e. 2.3 mm/hr x 0.4 = 0.92 mm/hr), a continuing loss value of 2.3 mm/hr which was found to achieve a reasonable match between observed and modelled flood behaviour for the 23 March 2017 and 14 November 2022 storm events was adopted for design flood estimation purposes.

5.3 Derivation of Design Discharges

The hydrologic model was run with the design rainfall data set out in **Sections 5.1** and **5.2**, as well as the hydrologic model parameters set out in **Section 3.3.3** in order to obtain design discharge hydrographs for input to the Cookamidgera TUFLOW Model.

Table 5.1 shows a comparison of design peak flow estimates derived from the Bogan Gate DRAINS Model for the two continuing loss values compared to those derived by the Probabilistic Rational Method (**PRM**), the procedures for which are set out in the 1987 edition of *Australian Rainfall & Runoff* (The Institution of Engineers Australia, 1987) (**ARR 1987**) and the RFFE Model, the procedures for which are set out in ARR 2019, noting **Figure 3.1** shows the locations at which the comparisons were made.

TABLE 5.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES
(m^3/s)

Identifier(1) [A]	**AEP (%)** [B]	**PRM** [C]	**RFFE** [D]	**Cookamidgera DRAINS Model**	
				Adjusted PNBIL CL = 2.3 mm/hr(2) [E]	**Adjusted PNBIL CL = 0.92 mm/hr(3)** [F]
Cooka_RFFE_1 Quart Pot Creek [Area = 24.4 km^2]	1	70	127	125	132
	2	49	94	99	107
	5	30	61	73	79
	10	21	41	57	63
	20	15	26	41	47
Cooka_RFFE_2 Bartleys Creek [Area = 24.2 km^2]	1	69	120	94	103
	2	51	89	77	82
	5	30	58	55	63
	10	21	40	42	49
	20	15	25	29	35

1. Refer **Figure 3.1** for location of peak flow comparison.
2. Based on the raw continuing loss value that is set out in the *ARR Data Hub* and which was also found to achieve a good match with the observed flood behaviour.
3. Based on the NSW jurisdictional advice for deriving continuing loss values.

Table 5.1 shows that the Cookamidgera DRAINS Model derived design peak flow estimates for the continuing loss values of 2.3 mm/hr and 0.92 mm/hr more closely match the peak flow estimates derived using the RFFE, than those derived using the PRM.

It is noted that a recent flooding investigation that was undertaken for the adjacent gauged Mandagery Creek on behalf of NSW Reconstruction Authority (Lyall & Associates, 2024) found that the adoption of a continuing loss value of 2.5 mm/hr best fitted the peak flow that was recorded by WaterNSWs *Mandagery Creek at Upstream Eugowra (Smithfield)* stream gauge for the November 2022 flood, as well as the design peak flow estimates that were derived from a flood frequency analysis for the same gauge.

Based on the above findings and as per the recommended hierarchical approach that is set out in Section 3.7.1 of *Floodplain Risk Management Guide - Incorporating 2016 Australian Rainfall and Runoff in studies* (OEH, 2019), it was decided to adopt the raw continuing loss value of 2.3 mm/hr for design flood estimation purposes as part of the present study given:

a) it is the raw continuing loss value given in the *ARR Data Hub*; and
b) it closely correlates with the 2.5 mm/hr that was found to best fit both historic and design peak flow data in the adjacent gauged catchment of Mandagery Creek.

6 HYDRAULIC MODELLING OF DESIGN FLOOD EVENTS

6.1 Modifications to Hydraulic Model Structure

As per the requirements of ARR 2019, the potential for the existing drainage system to experience a partial blockage during a flood event was taken into account when deriving the design flood envelopes. **Table E1** in **Appendix E** provides a summary of the probability neutral blockage factors that were derived to each individual headwall and bridge structure in the study area based on the procedures set out in ARR 2019. As per the recommendations in ARR 2019, an L_{10}[3] of 1.5 m was adopted for the blockage assessment, which is the recommended minimum value that should be adopted for urban areas in the absence of a record of past debris accumulated at a structure.

6.2 Presentation and Discussion of Results

6.2.1. Accuracy of Hydraulic Modelling

The accuracy of results depends on the precision of the numerical finite difference procedure used to solve the partial differential equations of flow, which is also influenced by the time step used for routing the floodwave through the system and the grid spacing adopted for describing the natural surface levels in the floodplain. Channels are described by cross-sections normal to the direction of flow, so their spacing also has a bearing on the accuracy of the results. The results are also heavily dependent on the size of the two-dimensional grid, as well as the accuracy of the LiDAR survey data which has a design accuracy based on 95% of points within +/- 150 mm. Given the uncertainties in the LiDAR survey data and the definition of features affecting the passage of flow, maintenance of a depth of flow of at least 200 mm is required for the definition of a “continuous” flow path in the areas subject to shallow overland flow. Lesser modelled depths of inundation may be influenced by the above factors and therefore may be spurious, especially where that inundation occurs at isolated locations and is not part of a continuous flow path. In areas where the depth of inundation is greater than the 200 mm threshold and the flow path is continuous, the likely accuracy of the hydraulic modelling in deriving peak flood levels is considered to be between 100 and 150 mm.

Use of the flood study results when applying flood related controls to development proposals should be undertaken with the above limitations in mind. Proposals should be assessed with the benefit of a site survey to be supplied by applicants in order to allow any inconsistencies in results to be identified and given consideration. This comment is especially appropriate in the areas subject to shallow overland flow, where the inaccuracies in the LiDAR survey data or obstructions to flow would have a proportionally greater influence on the computed water surface levels than in the deeper flooded areas.

6.2.2. Critical Duration and Temporal Pattern Assessment

The critical storm durations and associated median temporal patterns for the design storm events were derived based on the results of running both the DRAINS and TUFLOW models in tandem. For example, design discharge hydrographs for the ensemble of temporal patterns for storm durations ranging between 30 minutes and 18 hours were exported from the DRAINS model and input to the TUFLOW model. The assessment was undertaken for the 20%, 5% and 1% AEP storm events which represent the three temporal pattern bins (i.e. frequent, infrequent and rare, respectively) that were downloaded from the *ARR Data Hub.*

[3] L_{10} is defined as the average length of the longest 10% of the debris reaching the site.

A similar process was adopted for determining the critical durations for the PMF using the procedures set out in BoM, 2003 and Jordan et al., 2005, whereby design discharge hydrographs for storm durations ranging between 15 minutes and 3 hours were exported from the DRAINS model and input to the TUFLOW model.

Table 6.1 sets out the storm durations and temporal patterns that were adopted as being critical for AEPs ranging from 50% and 0.2%, as well as the PMF.

TABLE 6.1
CRITICAL DURATIONS AND TEMPORAL PATTERNS

Design Storm Event	Temporal Pattern Bin	Critical Storm Duration and Temporal Pattern(1)
20%	Frequent	3 hour, temporal pattern 3 [3982] 4.5 hour, temporal pattern 6 [4016]
10%	Infrequent	2 hour, temporal pattern 6 [3944] 3 hour, temporal pattern 3 [3974] 6 hour, temporal pattern 3 [4033]
5%		
2%	Rare	1.5 hour, temporal pattern 3 [3890] 2 hour, temporal pattern 4 [3934] 3 hour, temporal pattern 6 [3963] 4.5 hour, temporal pattern 7 [3993]
1%		
0.5%		
0.2%		
PMF	Very Rare	45 minute, Melbourne 1972 temporal pattern 1.5 hour, Melbourne 1972 temporal pattern 2 hour, Melbourne 1972 temporal pattern 3 hour, Alice Springs 1966 temporal pattern

1. Value in [ ] represent the Event ID for the critical storm duration and temporal pattern.

6.2.3. Design Flood Extents, Depths and Elevations

Figures 6.1 to **6.8** (2 sheets each) show the TUFLOW model results for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP floods, together with the PMF. These diagrams show the indicative extent and depth of inundation for the full range of design storm events throughout the study area.

In order to create realistic results which remove most of the anomalies caused by inaccuracies in the LiDAR survey data, a filter was applied to remove depths of inundation over the natural surface less than 100 mm. This has the effect of removing the very shallow depths which are more prone to be artefacts of the model, but at the same time giving a reasonable representation of the various overland flow paths. The depth grids shown on the figures have also been trimmed to the building polygons, as experience has shown that property owners incorrectly associate depths of above-ground inundation at the location of buildings with depths of above-floor inundation.

Figure 6.9 shows stage hydrographs at selected road crossings throughout the study area, while **Table F1** in **Appendix F** sets out the peak flood level and maximum depth of inundation at each crossing. **Table G1** in **Appendix G** sets out design peak flows and corresponding critical storm durations at key locations throughout the study area. **Figures H1.1** to **H1.8** shows the maximum flow velocities for the 20%, 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP storm events, together with the PMF.

The sensitivity studies and discussion presented in **Section 6.5** provide guidance on suitable freeboard provisions under present day catchment and climatic conditions.

In accordance with DCCEEW recommendations, sensitivity studies have also been carried out to assess the potential impacts of future climate change on flood behaviour (refer **Section 6.6**). While increases in flood levels due to future increases in rainfall intensities may influence the selection of Flood Planning Levels (**FPLs**), final selection of FPLs is a matter for more detailed consideration during the preparation of the future *Cookamidgera FRMS&P*.

6.2.4. Description of Flood Behaviour

The key features of Main Stream Flooding along Bartleys Creek are as follows:

i. Floodwater surcharges Bartleys Creek in flood events as frequent as 20% AEP at the following locations:

    a. along its left bank immediately upstream of Trigg Hill Road where it then flows in a westerly direction across rural land before discharging to Quart Pot Creek downstream of Trigg Hill Road;

    b. along its left and right bank in the vicinity of its confluence with Quart Pot Creek;

    c. along its left and right bank upstream of the western Trigg Hill Road crossing of Bartleys Creek (refer Peak Flow Location (**PFL**) Q10); and

    d. along its left bank on the upstream side of the Parkes Eugowra Road bridge crossing.

ii. Floodwater commences to surcharge the banks of Bartleys Creek in a 10% AEP at the following locations:

    a. along its right bank upstream of Trigg Hill Road (refer PFL Q3A), where the resulting surcharge flow discharges in a north-westerly direction towards the intersection of Flagstone Street and Haynes Street, before continuing along Flagstone Stone where it rejoins flow in the main arm of the watercourse to the west of the Village Centre. It is noted that floodwater does not surcharge the right bank of Bartleys Creek upstream of this location in flood events up to 0.2% AEP in magnitude.

    b. along its left bank approximately 600 m to the north-west of Trigg Hill Road (between PFLs Q5B and Q6B), where the resulting surcharge flow discharges in a north-westerly direction across rural land before rejoining flow in the main arm of the watercourse upstream of its confluence with Quart Pot Creek.

iii. **Table G1** of **Appendix G** shows that the inbank area of Bartleys Creek downstream of Trigg Hill Road generally has a capacity of about 40 m^3/s (refer PFL Q6B) and that the portion of the flow that surcharges its left bank and discharges in a westerly direction across rural land (refer PFL Q6A) increases with increasing flood magnitude.

iv. **Figure H1.5** in **Appendix H** shows that the maximum flow velocities within the inbank areas of Bartleys Creek are generally in the range of 1.0 m/s to 1.8 m/s in a 1% AEP storm event.

v. **Figure 6.9** and **Table F1** in **Appendix F** show that the road crossings of Bartleys Creek commence to become inundated as follows:

    a. The Trigg Hill Road crossings (refer Peak Flood Level Location (**PFLL**) H01 and H02) in flood events more frequent that 20% AEP flood.

    b. While the Parkes Eugowra Road bridge crossing of Bartleys Creek will remain flood free for events up to 0.2% AEP, the low point in the road that is located approximately 600 m to the north of the bridge (refer PFFL H03) will be inundated in flood events as frequent as 20% AEP.

vi. **Table G1** in **Appendix G** shows that the peak PMF flow in Bartleys Creek is about nine times the corresponding peak 1% AEP flow.

vii. **Figure 6.8** shows that existing development within the extent of the Village Centre is inundated to depths of up to 1.4 m in a PMF event.

viii. **Figure H1.8** in **Appendix H** shows that the maximum flow velocities along Bartleys Creek in a PMF are generally greater than 1.6 m/s.

The key features of Main Stream Flooding along Quart Pot Creek are as follows:

i. While Quart Pot Creek surcharges its banks in flood events more frequent that 20% AEP, floodwater generally flows in a northerly direction parallel to the watercourse on its immediate overbank area.

ii. **Figure 6.9** and **Table F1** in **Appendix F** show that the Coonambro Way (refer PFLL H04) and Trigg Hill Road (refer PFLL H05) crossings of Quart Pot Creek are inundated in flood events more frequent than 20% AEP.

iii. **Table G1** in **Appendix G** shows that the peak PMF flow in Quart Pot Creek is about nine times the corresponding peak 1% AEP flow.

iv. **Figure H1.5** in **Appendix H** shows that the maximum flow velocities along Quart Pot Creek in a 1% AEP storm event are generally in the range of 1.0 m/s to 1.8 m/s.

Major Overland Flow generally approaches the Village Centre from the following directions:

i. Runoff from a catchment that is located in the south-eastern corner of the Cookamidgera Project discharges through two drainage structures that are located beneath the Orange-Broken Hill Railway at the eastern end of McLennan Lane, where it continues in a westerly direction and discharges to the Village Centre to the east of Haynes Street.

   The key features of Major Overland Flow along this flow path are as follows:

   a. **Figure 6.1** shows that Major Overland Flow that discharges to the Village Centre from the east in a 20% AEP flood event generally flows in a north-westerly direction along Railway Street and the natural low point that is located to its north.

   b. Major Overland Flow that discharges to the Village Centre from the east combines with floodwater that surcharges the right bank of Bartleys Creek upstream of Trigg Hill Road in flood events as frequent as 10% AEP.

ii. Runoff from the remainder of the Cookamidgera Project is directed towards the intersection of Cooka Hills Road and McLennan Lane via the network of earth bunds and dams that were constructed in the 1980s, before discharging to the Village Centre along its northern boundary in the vicinity of the low level rail crossing.

   The key features of Major Overland Flow along this flow path are as follows:

   a. **Table G1** shows that in flood events as frequent as 20% AEP, the majority of the runoff from the catchment approach Cooka Hills Road from the north-east and east (refer PFL Q16B and Q16C), while there is significantly less flow in the remnant channel that runs in an easterly direction along the northern side of MacLennan Lane (refer PFL Q16A).

b. **Table G1** shows that the abovementioned remnant channel (refer PFL Q16A) commences to convey a higher proportion of the total catchment runoff once the network of earth bunds and dams are overtopped in flood events as frequent as 10% AEP.

c. **Table G1** shows that the majority of the runoff from the catchment surcharges the Orange-Broken Hill Railway, where it discharges to the Village Centre along its northern boundary (refer PFL Q17B), while the remainder of the flow continues in a westerly direction on the northern side of the railway.

iii. Major Overland Flow that discharges to the Village Centre from the north and east combine in the vicinity of the low point in Flagstone Street that is located approximately 50 m to the south of the low level railway crossing. It then flows in a westerly direction where it discharges to Bartleys Creek to the west of the Village Centre.

iv. **Figure H1.5** in **Appendix H** shows that the maximum flow velocities within the Village Centre are generally in the range of 0.4 m/s to 1.4 m/s in a 1% AEP storm event.

v. **Table G1** in **Appendix G** shows that the peak PMF flow in areas subject to Major Overland Flow are up to 12 times the corresponding peak 1% AEP flow.

6.3 Economic Impacts of Flooding

Table 6.2 sets out the number of properties that are flood affected in the Village Centre and the estimated damages which would occur for flood of varying magnitude.

TABLE 6.2
SUMMARY OF FLOOD DAMAGES

Design Flood Event (% AEP)	Number of Properties						Total Damage ($ Million)
	Residential		Commercial/ Industrial		Public		
	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	Flood Affected	Flood Above Floor Level	
20	1	0	No commercial / industrial buildings in the Village Centre		0	0	0
10	3	0			0	0	0
5	6	0			0	0	0.02
2	8	1			0	0	0.08
1	11	2			11	0	0.27
0.5	13	3			0	0	0.38
0.2	16	3			0	0	0.5
PMF	26	22			1	1	5.92

Two dwellings would be above-floor inundated in a 1% AEP flood event, resulting in flood damages totalling about $0.27 Million. During a PMF event, 22 dwellings and one public building would be above-floor inundated, resulting in flood damages totalling about $5.92 Million.

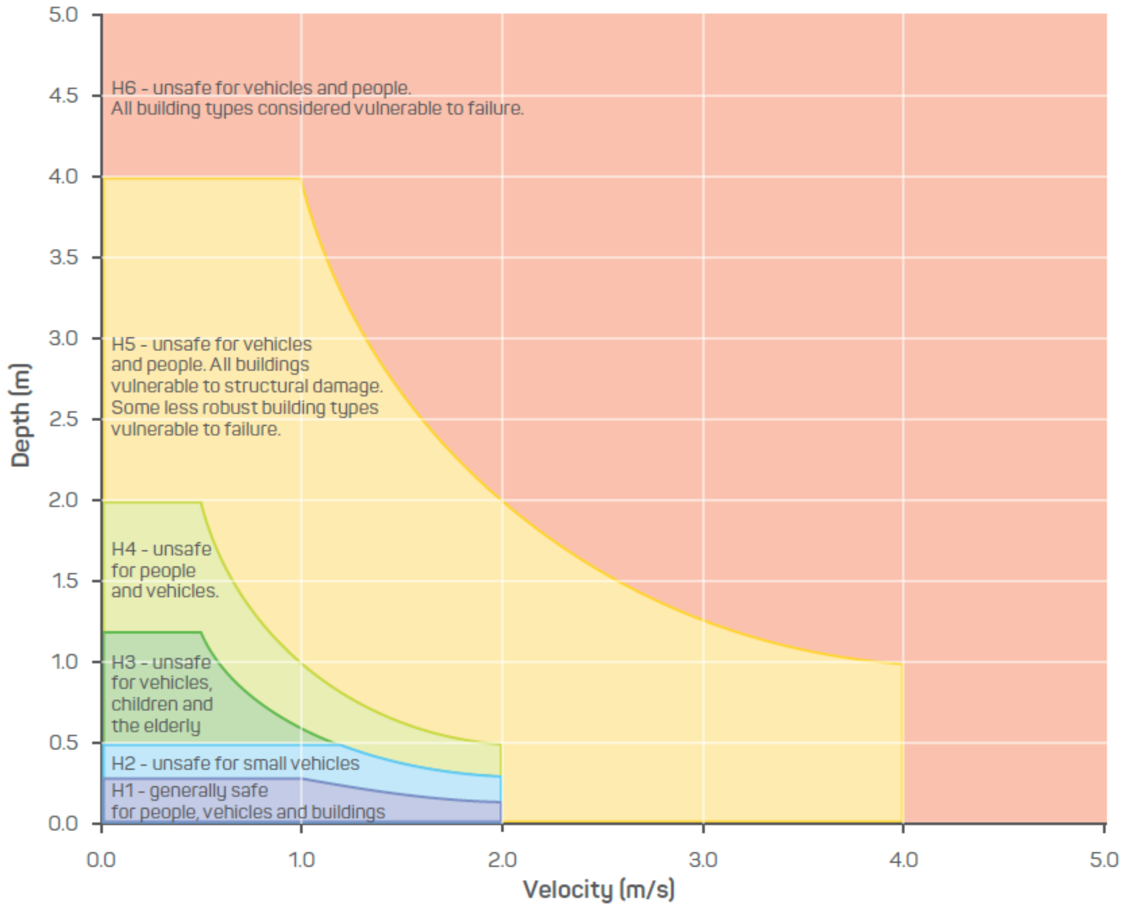
For a discount rate of 5% pa, the *Net Present Worth* of damages for all flood events up to the 1% AEP flood at Cookamidgera is about $0.07 Million. Therefore, one or more schemes costing up to this amount could be economically justified if they eliminated damages in the study area for all flood events up to this level. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

Appendix I of this report contains further details on the economic assessment that was undertaken as part of the present study.

6.4 Flood Hazard Zones and Floodways

6.4.1. Flood Hazard Vulnerability Classification

Flood hazard categories may be assigned to flood affected areas in accordance with the definitions set out in ARR 2019. Flood prone areas may be classified into six hazard categories based on the depth of inundation and flow velocity that relate to the vulnerability of the community when interacting with floodwater as shown in the illustration over which has been taken from ARR 2019.



Flood Hazard Vulnerability Classification diagrams for the 5%, 1% and 0.2% AEP flood events, as well as the PMF based on the procedures set out in ARR 2019 are presented on **Figures 6.10** to **6.13**. It was found that areas classified as H6 are generally limited to the inbank area of Bartleys and Quart Pot Creek for floods up 0.2% AEP in magnitude, with large areas of H5 located on its overbank area and along its tributary arms.

Figure 6.10 shows that the majority of the Village Centre is classified as H1 and H2 in a 5% AEP flood event, with isolated pockets of H3 to H5 along the Major Overland Flow path that runs in a westerly direction to the north of Railway Street and in the road reserve in the vicinity of the intersection of Haynes Street and Flagstone Street. **Figures 6.11** and **6.12** show that the extent of land classified as H1 and H2 in the Village Centre increases in the 1% and 0.2% AEP flood events, respectively.

For the PMF event, the width of the H5 and H6 hazard zones increases significantly, mainly along the alignment of Bartleys Creek and Quart Pot Creek. The hazard category in the majority of the Village Centre increases to H5 during a flood of this magnitude.

6.4.2. Hydraulic Categorisation of the Floodplain

According to the *FRMM*, the floodplain may be subdivided into the following three hydraulic categories:

- Floodways;
- Flood storage; and
- Flood fringe.

Floodways are those areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with obvious naturally defined channels. Floodways are the areas that, even if only partially blocked, would cause a significant re-distribution of flow, or a significant increase in flood level which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.

Flood storage areas are those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. If the capacity of a flood storage area is substantially reduced by, for example, the construction of levees or by landfill, flood levels in nearby areas may rise and the peak discharge downstream may be increased. Substantial reduction of the capacity of a flood storage area can also cause a significant redistribution of flood flows.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

Flood Risk Management Guideline FB02 Floodway Function, offers guidance in relation to two alternative procedures for identifying the portion of the floodplain that functions as floodways, flood storage and flood fringe areas.

The indicator technique set out in *Howells et al, 2003* was used to identify the preliminary extent of the floodway based on velocity of flow and depth. Based on the findings of a trial and error process, the following criteria were adopted for identifying those areas which operate as a "floodway" in a 1% AEP event:

- Velocity x Depth greater than 0.25 m^2/s **and** Velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Manual assessment and cleaning of the raw model output data was then undertaken as recommended in *Flood Risk Management Guideline FB02 Floodway Function*.

Flood storage areas are identified as those areas which do not operate as floodways in a 1% AEP event but where the depth of inundation exceeds 300 mm. The remainder of the flood affected area was classified as flood fringe.

Figures 6.14 to **6.17** show the division of the floodplain into floodway, flood storage and flood fringe areas for the 5%, 1% and 0.2% AEP storm events, as well as the PMF.

As the hydraulic capacity of the watercourses is not large enough to convey the flow in a 5% AEP flood, their overbank areas also function as a floodway. As the ground levels rise relatively steeply at the edge of the floodplain, the majority of the floodplain along Quart Pot Creek and the lower reaches of Bartleys Creek are considered floodway at a number of locations.

Figure 6.14 shows that the floodway is located along the natural low point on the northern side of Railway Street in the Village Centre in a 5% AEP flood, while **Figure 6.15** shows that floodways commence to operate along Railway Street and Flagstone Street in a 1% AEP flood.

Flood storage areas are confined to the major ponding areas which are located on the upstream side of the road and railway embankments, as well as in the local farm dams that have been constructed to capture surface runoff in different parts of the study area.

6.5 Sensitivity Studies

6.5.1. General

The sensitivity of the hydraulic model to variations in model parameters such as hydraulic roughness and the partial blockage of the major hydraulic structures by woody debris was tested as part of the present study. The main purpose of these studies was to give some guidance on:

a) the freeboard to be adopted when setting minimum floor levels of development in flood prone areas, pending the completion of the future *Cookamidgera FRMS&P*; and

b) areas where additional flood related planning controls should be implemented due to the development of new hazardous flow paths.

6.5.2. Sensitivity of Flood Behaviour to an Increase in Hydraulic Roughness

Figure 6.18 shows the difference in peak flood levels (i.e. the “afflux”) for the 1% AEP event resulting from an assumed 20% increase in hydraulic roughness (compared to the values given in **Table 4.2**).

The typical increases in peak flood level in the areas subject to Main Stream Flooding are generally in the range 50 to 200 mm, while increases in peak flood levels in those parts of the Village Centre that are subject to Major Overland Flow are generally in the range 10 to 50 mm.

6.5.3. Sensitivity of Flood Behaviour to a Partial Blockage of Hydraulic Structures

As mentioned in **Section 6.1**, the design flood envelopes presented in this report incorporate the probability neutral blockage factors that are set out in **Table E1** in **Appendix E** of this report. As the degree to which each individual hydraulic structure experiences a blockage will varying during a real flood, the sensitivity of flood behaviour assuming no blockage of each structure was assessed as part of the present study.

Figure 6.19 shows that the removal of the probability neutral blockage factors has a negligible effect on flood behaviour at the 1% AEP level of flooding.

6.6 Climate Change Sensitivity Analysis

6.6.1. General

At the present flood study stage, the principal issue regarding climate change is the potential increase in flood levels and extents of inundation throughout the study area. In addition it is necessary to assess whether the patterns of flow will be altered by new floodways being developed for key design events, or whether the provisional flood hazard will be increased.

DCCEEW recommends that the advice set out in Section 3.7.4 of its floodplain risk management guide *Incorporating 2016 Australian Rainfall and Runoff in studies* (OEH, 2019) be used as the basis for examining climate change in projects undertaken under the State Floodplain Management Program and the FRMM. The guideline recommends that until more work is completed in relation to the climate change impacts on rainfall intensities, sensitivity analyses should be undertaken based on increases in rainfall intensities ranging between 10 and 30 per cent.

On current projections the increase in rainfalls within the service life of developments or flood management measures is likely to be around 10 per cent, with the higher value of 30 per cent representing an upper limit which may apply near the end of the century. Under present day climatic conditions, increasing the 1% AEP design rainfall intensities by 10 per cent would produce about a 0.5% AEP flood; and increasing those rainfalls by 30 per cent would produce about a 0.2% AEP event.

The impacts of climate change and associated effects on the viability of flood risk management options and development decisions may be significant and will need to be taken into account in the future *Cookamidgera FRMS&P* for the village using site specific data.

In the *Cookamidgera FRMS&P* it will be necessary to consider the impact of climate change on flood damages to existing development. Consideration will also be given both to setting floor levels for future development and in the formulation of works and measures aimed at mitigating adverse effects expected within the service life of development.

Mitigating measures which could be considered in the *Cookamidgera FRMS&P* include the implementation of structural works such as levees and channel improvements, improved flood warning and emergency management procedures and education of the population as to the nature of the flood risk.

6.6.2. Sensitivity to Increased Rainfall Intensities

As mentioned, the investigations undertaken at the flood study stage are mainly seen as sensitivity studies pending more detailed consideration in the *Cookamidgera FRMS&P*. For the purposes of the present study, the design rainfalls for 0.5 and 0.2 per cent AEP events were adopted as being analogous to flooding which could be expected should present day 1% AEP rainfall intensities increase by 10 and 30 per cent, respectively.

Figure 6.20 shows the increase in peak flood levels resulting from a 10 per cent increase in 1% AEP rainfall intensities. The increase in peak flood levels along Bartleys Creek and Quart Pot Creek varies between 50 to 200 mm, while increases in peak flood levels of generally between 10 to 50 mm are shown to occur in areas subject to Major Overland Flow.

Figure 6.21 shows the afflux for a 30 per cent increase in 1% AEP rainfall intensities. The increase in peak flood levels along Bartleys Creek and Quart Pot Creek varies between 100 to 300 mm, while increases in peak flood levels of generally up to 200 mm are shown to occur in areas subject to Major Overland Flow.

Figure 6.22 shows the increase in the extent of land that would be affected by floodwater should 1% AEP rainfall intensities increase by 10 or 30 per cent. The extent of land that would be inundated by floodwater should 1% AEP rainfall intensities increase by up to 30% is negligible due to the relatively steep sided nature of the floodplain adjacent to the relatively flat overbank areas. No new flow paths area formed should 1% AEP rainfall intensities increase by up to 30%.

Consideration will need to be given to the identified changes that occur in flood behaviour during the preparation of the future *Cookamidgera FRMS&P*.

6.7 Selection of Interim Flood Planning Levels

After consideration of the TUFLOW model results and the findings of the sensitivity analyses outlined in **Sections 6.5** and **6.6**, the following criteria were adopted for defining the Interim FPA:

- in areas subject to Main Stream Flooding, the extent of the FPA was defined as land lying at or below the peak 1% AEP flood level plus a freeboard allowance of 0.5 m; and
- in areas subject to Major Overland Flow and that also lie outside the extent of the Main Stream Flooding FPA, the extent of the FPA was defined as land inundated to a depth greater than 100 mm or within the extent of the floodway.[4]

Figure 6.23 shows the extent of the Interim FPA in the immediate vicinity of the Village Centre. In areas that lie within the extent of the Interim FPA it is recommended that a freeboard of 0.5 m be applied to peak 1% AEP flood levels when setting the minimum habitable floor levels of future development. An assessment should also be undertaken by Council as part of any future Development Application to confirm that the proposed development will not form an obstruction to the passage of flow through the subject site.

Consideration will need to be given during the preparation of the future *Cookamidgera FRMS&P* to the appropriateness of the adopted freeboard allowance of 0.5 m given the impact changes in hydraulic roughness and future increases in rainfall intensity could have on peak flood levels. Consideration will also need to be given to the setting of an appropriate freeboard for areas subject to Major Overland Flow given that the adopted value of 0.5 m may be found to be too conservative.

Figure 6.23 also shows the extent of the *Outer Floodplain*, which is the area that lies between the FPA and the extent of the PMF. It is recommended that Council consider precluding critical, sensitive and vulnerable type development such as hospitals with emergency facilities, emergency services facilities, utilities, community evacuation centres, aged care homes, seniors housing, group homes, boarding houses, hostels, caravan parks, schools and childcare facilities in this area.

[4] The extent of Major Overland Flow FPA was filtered to remove pockets of flooding where the area was less than 100 m^2.

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8 FLOOD-RELATED TERMINOLOGY

Note: For an expanded list of flood-related terminology, refer to glossary contained within the Floodplain Development Manual, NSW Government, 2005).

TERM	DEFINITION
Afflux	Increase in water level resulting from a change in conditions. The change may relate to the watercourse, floodplain, flow rate, tailwater level etc.
Annual Exceedance Probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 50 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 50 m^3/s or larger events occurring in any one year (see average recurrence interval).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average period in years between the occurrence of a flood of a particular magnitude or greater. In a long period of say 1,000 years, a flood equivalent to or greater than a 100 year ARI event would occur 10 times. The 100 year ARI flood has a 1% chance (i.e. a one-in-100 chance) of occurrence in any one year (see annual exceedance probability).
Catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Critical Duration	The storm duration which produces the highest peak flood level for a given design flood event.
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 (e.g. metres per second [m/s]).
Flood fringe area	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood Planning Area (FPA)	The area of land inundated at the Flood Planning Level.
Flood Planning Level (FPL)	A combination of flood level and freeboard selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans.
Flood prone land	Land susceptible to flooding by the Probable Maximum Flood. Note that the flood prone land is synonymous with flood liable land.
Flood storage area	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event (i.e. flood prone land).

TERM	DEFINITION
Flood Risk Management Plan	A management plan developed in accordance with the principles and guidelines in the *Flood Risk Management Manual, 2023*. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Floodway area	Those areas of the floodplain where a significant discharge of water occurs during floods. They 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 typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted Flood Planning Level and the peak height of the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such and wave action, localised hydraulic behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the flood planning level.
High hazard	Where land in the event of a 1% AEP flood is subject to a combination of flood water velocities and depths greater than the following combinations: 2 metres per second with shallow depth of flood water depths greater than 0.8 metres in depth with low velocity. Damage to structures is possible and wading would be unsafe for able bodied adults.
Low hazard	Where land may be affected by floodway or flood storage subject to a combination of floodwater velocities less than 2 metres per second with shallow depth or flood water depths less than 0.8 metres with low velocity. Nuisance damage to structures is possible and able bodied adults would have little difficulty wading.
Main Stream Flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
Merit approach	The merit approach weighs social, economic, ecological and cultural impacts of land use options for different flood prone areas together with flood damage, hazard and behaviour implications, and environmental protection and well-being of the State's rivers and floodplains.
Major Overland Flow	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.

TERM	DEFINITION
Peak flood level	The maximum water level occurring during a flood event.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land (i.e. the floodplain). The extent, nature and potential consequences of flooding associated with events up to and including the PMF should be addressed in a floodplain risk management study.
Probability	A statistical measure of the expected chance of flooding (see annual exceedance probability).
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as stream flow, also known as rainfall excess.
Stage	Equivalent to water level (both measured with reference to a specified datum).

APPENDIX A

COMMUNITY NEWSLETTER AND QUESTIONNAIRE

Cookamidgera Flood Study

Community Newsletter

Parkes Shire Council has engaged consultants to undertake a *Flood Study* for the township of Cookamidgera which will define mainstream flooding patterns along Bartleys Creek. The study will also define areas that are subject to major overland flow that occurs as a result of surcharge of the local stormwater drainage system. Please see the back of this page for the approximate extent of the study area at each village.

The study is being undertaken by Council with funding assistance from the Department of Planning and Environment and aims to build community resilience towards flooding through informing better planning of development, emergency management and community awareness. The study will also assess a range of structural type measures such as culvert and channel improvements which are aimed at reducing the impact of flooding on existing development. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The *Flood Study* is an important first step in the Floodplain Risk Management process for Cookamidgera and will be managed by Council according to the NSW Government's Flood Prone Land Policy and Floodplain Development Manual. Following the completion of the *Flood Study*, a *Floodplain Risk Management Study* and *Plan* will also be completed which will include further consultation on management options.

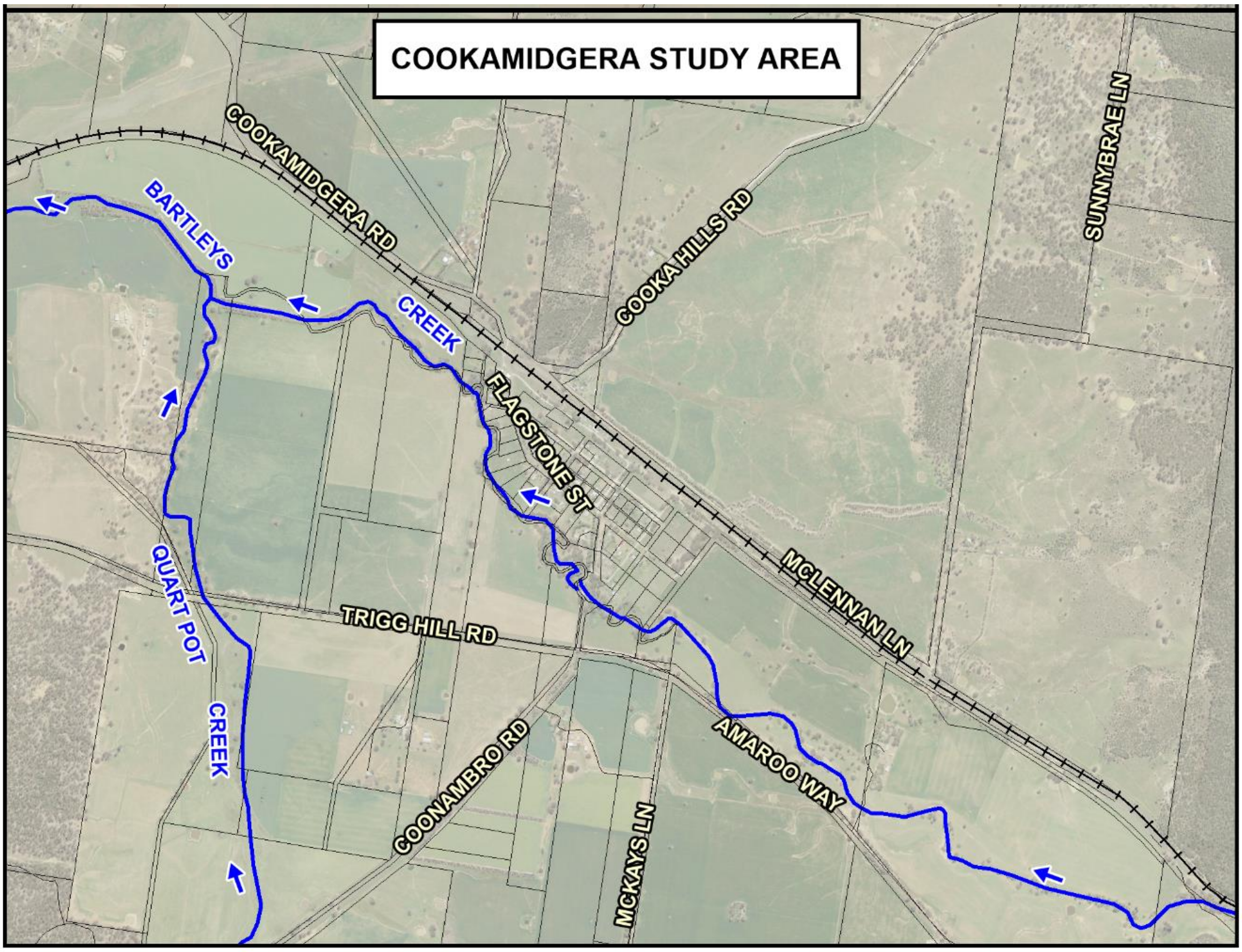
The various stages of the Flood Study will be as follows:

- Survey along the creeks and collection of data on historic flooding;
- Preparation of computer models of the creeks and floodplain to determine flooding and drainage patterns, flood levels, flow velocities and depths of inundation;
- Preparation of a *Flood Study* report which will document the findings of the investigation. The draft *Flood Study* report will be placed on public exhibition following completion of the investigation seeking community feedback on its findings

An important first step in the preparation of a *Flood Study* is to identify the availability of information on historic flooding in the township and up and downstream catchment. The attached **questionnaire** has been provided to residents and business owners to assist the consultants in gathering this important information. The questionnaire may also be completed online via Council's website at www.parkes.nsw.gov.au, accessible by scanning the QR code over the page. All information provided will remain confidential and for use in this study only. Please return the completed questionnaire in the reply-paid envelope provided by **3 June 2022.** Council staff will be available at the Cookamidgera Hall on the **31 May** from **10.30 to 4.30** to assist with the completion of the survey, answer questions and scan copies of photos, documents, maps or any other information that may assist.

Cookamidgera Flood Study

Contact: Parkes Shire Council's Director of Infrastructure Andrew Francis, (02) 6861 2344
council@parkes.nsw.gov.au.



Scan the QR code below to access the attached survey via an online form

Cookamidgera Flood Study

Community Questionnaire

This questionnaire is for the ***Cookamidgera Flood Study***, which is currently being prepared by Parkes Shire Council with the financial support of the Department of Planning and Environment. Your responses to the questionnaire will help us determine the flood issues that are important to you. Please note that all information provided will remain confidential and for use in this study only.

Lyall & Associates Consulting Water Engineers
Reply Paid 85163
NORTH SYDNEY NSW 2060

An electronic copy of the questionnaire can be completed online at www.parkes.nsw.gov.au.

1. What township do you live in?

____

2. Your details:

a. Name (Optional):____

b. Address:____

c. Phone Number (Optional):____

d. Email (Optional): ____

3. Please tick as appropriate:

- ☐ I am a resident
- ☐ I am a business owner
- ☐ Other (please specify ______________________________)

4. How long have you been at this address?

- ☐ 1 year to 5 years
- ☐ 5 years to 20 years
- ☐ More than 20 years (____________ years)

5. What is your property?

- ☐ House
- ☐ Unit/Flat/Apartment
- ☐ Warehouse / Factory / Industrial Unit
- ☐ Shop / Building
- ☐ Community building
- ☐ Other

(______________________________________)

Flooding at Your Property

6. Have you ever been affected by flooding?

[ ] Yes [ ] No

7. If you answered "Yes" to Question 6, on what dates were you affected by flooding?

- ☐ November 2005
- ☐ December 2010
- ☐ December 2012
- ☐ February 2016
- ☐ January 2020
- ☐ January 2021
- ☐ Other: ________________

8. Can you please describe the flooding (flood water depth/height and location etc.) that you experienced? (Please use area provided in Question 14 if you have information for more than two floods)

	Flood #1	Flood #2
Date of flood(s)	☐ November 2005 ☐ December 2010 ☐ December 2012 ☐ February 2016 ☐ January 2020 ☐ January 2021 ☐ Other: ______________	☐ November 2005 ☐ December 2010 ☐ December 2012 ☐ February 2016 ☐ January 2020 ☐ January 2021 ☐ Other: ______________
Description of flooding (flood water depth/height and location etc.) (The attached map may be useful to mark the location of any problem areas).		

9. Do you have any information on pipe blockage or the inundation of local roads due to surcharge of the existing drainage system?

[ ] Yes [ ] No

10. If you answered yes to Question 9, could you please identify the location? Could you also comment on the nature of the blockage and/or the duration and depth of the flooding in the local road network?

____

____

____

____

11. Do you have any photos, videos, rainfall records or other evidence of the flood marks that you have identified?

[ ] Yes [ ] No

12. If you answered yes to Question 11, could you please provide as much detail as possible, including whether you would be willing to provide Council with electronic copies of any photos/videos?

You may wish to email any flood data that you have directly to Council (refer email address provided at the bottom of the page).

____

____

____

____

13. If you are happy for us to contact you to provide further information, please provide your details below:

Name: ____

Address: ____

____

Phone: ____

Email: ____

Who can I contact for further information?

Parkes Shire Council
Andrew Francis | Director of Infrastructure
Phone: (02) 6861 2344
Email: council@parkes.nsw.gov.au

14. Please write any additional comments here:

APPENDIX B

DETAILS OF AVAILABLE DATA AND COMMUNITY CONSULTATION

TABLE OF CONTENTS

Page No.

ANNEXURES

LIST OF FIGURES (BOUND IN VOLUME 2)

B1 COLLECTION OF MISCELLANEOUS DATA

B1.1 Airborne Laser Scanning Survey

Figure B1.1 (2 sheets) shows the extent of LiDAR survey data that are available in the vicinity of Cookamidgera, while **Table B1.1** sets out the details of the data. The LiDAR data set were captured in accordance with the International Committee on Surveying and Mapping guidelines for digital elevation data with a 95% confidence interval on horizontal accuracy of ±800 mm and a vertical accuracy of ±100 mm.

TABLE B1.1
LiDAR SURVEY DATA SPECIFICATIONS

Data Set	Date of Capture	Data Provider
Cookamidgera202203	15 March 2022	Aerometrex

B1.2 Existing Stormwater Network

Figure B1.1 shows the alignment of the existing stormwater drainage network in the study area. Details of the existing stormwater drainage network were taken from survey data captured by Ardnell Surveying in 2023, else assumed based on a desktop analysis and verified during subsequent field measurements where possible.

A member of the community provided marked up plans showing the layout of the drainage network on the northern side of the railway which comprise the Cookamidgera Project (refer **Section B1.6.1** for further discussion).

B1.3 Cross Sectional Survey

Ardnell Surveying was also engaged to undertake inbank cross sectional survey at regular intervals along Bartleys Creek in the vicinity of the Village Centre (refer **Figure B1.1** for location). Cross section data were provided as tabulations of offset versus elevation in an Excel spreadsheet. A photographic record of each cross section was also compiled by the surveyor.

B1.4 Historic Rainfall Data

Figure 1.1 shows the plan location of the five pluviographic and eight daily-read Bureau of Meteorology (**BoM**) operated rain gauges that are located in the vicinity of Cookamidgera, while **Table B1.2** over the page sets out the details of each. **Figure 1.1** and **Table 1.2** also show the details of a privately owned Hillside rain gauge that is located approximately 2 km to the north of the Village Centre.

B1.5 Photographic Record

Appendix C contains a number of photographs that were provided by respondents to the *Community Questionnaire* showing flood behaviour in the study area during storms that occurred on 17 March 2017 and 14 November 2022.

TABLE B1.2
SUMMARY OF AVAILABLE RAIN GAUGE DATA(1)

Gauge Number	Gauge Name	Gauge Type	Site Commence	Site Cease	Distance from Cookamidgera
65068	Parkes Airport AWS	BoM All Weather Station	October 2010	Ongoing	12 km
65103	Forbes Airport AWS		January 2012	Ongoing	48 km
65100	Alectown (**Cawdor**)	BoM Pluviographic Rain Gauge	June 1992	November 2022	29 km
50016	Goonumbla (Coradgery)	Bom Flood Warning Network	Gauge data only recorded when BoM's flood warning system is activated		40 km
65096	Mandagery (Rawene)				14 km
-	Hillside	Private Rain Gauge	July 2021	Ongoing	2 km
65068	Parkes Airport AWS	BoM Daily Rain Gauge	September 1941	Ongoing	12 km
50119	Alectown (Vanvilla)		September 1949	Ongoing	36 km
65114	Forbes (Bedgerabong Rd)		January 2012	Ongoing	46 km
65103	Forbes Airport AWS		December 1995	Ongoing	48 km
65039	Forbes (Muddy Water)		January 1969	Ongoing	53 km
65096	Mandagery (Rawene)		January 1992	Ongoing	14 km
50016	Goonumbla (Coradgery)		March 1882	Ongoing	40 km
50036	Trundle (Long St)		March 1895	Ongoing	76 km
50004	Bogan Gate Post Office		January 1894	August 2017	57 km

1. Refer **Figure 1.1** for location.

B1.6 Previous Reports

B1.6.1. The Cookamidgera Project – A National Soil Conservation Program (Soil Conservation Service New South Wales, 2020)

The Cookamidgera Project – A National Soil Conservation Program report provides a summary of the network of earthworks that were constructed on the "Fernhills East" and "Hillside" properties as part of the Cookamidgera Project (refer **Figure B1.1** for extent) between 1986 and 1990. The aim of the Cookamidgera Project was to halt the uncontrolled transportation of sediment from eroded drainage lines that are located to the north of the village and reduce its impact on Council and community owned assets and land. The report states that a secondary benefit of the project was that it reduced the impact of flooding on farmland, roads and the railway.

The scheme was funded by the National Soil Conservation Program and comprised he following:

- Broadacre earthworks consisting of waterways and broad based graded banks designed to protect sloping farmlands from further erosion; and
- Gully works, including concrete flumes, in-gully weirs, sediment traps and diversion dams, all of which are designed to prevent gully migration and to control the moment of sediment within the gully systems.

In addition to Soil Conservation Service New South Wales, 2020, a community member provided marked up plans that show the intended function of the project. **Figure B1.1** (sheet 2) shows the plan location of the 21 dams that comprise the project, as well as the approximate direction of flow between each dam. Runoff discharges from the two properties at six locations; two locations along Cooka Hills Road (refer Locations A and B on **Figure B1.1**) and five along the Orange-Broken Hill Railway (refer Locations C, D, E, F and G on **Figure B1.1**).

It is understood that the project was designed to divert runoff that falls to Dam 5 in a northerly direction to Dam 6 before it continues in a westerly direction to Cooka Hills Road at Location A. As a result, there is a remnant section of natural channel that runs between Dam 5 and Location G that is no longer connected to the upstream catchment (refer **Figure B1.1** for location).

B2 COMMUNITY CONSULTATION

B2.1 Background

At the commencement of the study, the Consultants prepared a *Community Newsletter and Questionnaire* which were distributed by Council to residents and business owners in the study area (refer **Appendix A**).

The purpose of the *Community Newsletter* was to introduce the objectives of the study so that the community would be better able to respond to the *Community Questionnair*e and contribute to the study process. The *Community Newsletter* contained a plan showing the extent of the study area and a summary of the proposed methodology and outcomes.

The *Community Questionnaire* was structured with the objectives of collecting information on historical flood behaviour in the study area.

The *Community Newsletter and Questionnaire* were advertised in the local newspaper and posted to approximately 50 residents and business owners in the study area in May 2022. The *Community Newsletter and Questionnaire* were also advertised on Council's website and social media platforms. Council undertook in-person consultation with the community on 31 May 2022 where they captured hard copy information which they forwarded on to the Consultants.

As the *Community Questionnaire* mail out period occurred prior to the significant storm event that occurred in November 2022, the Consultants also undertook further in-person consultation with community members on 6 December 2023.

B2.2 Summary of Findings

B2.2.1. General

Residents and business owners were requested to complete the *Community Questionnaire* by 3 June 2022. The deadline was extended to include any submissions that were received after this date. The Consultants received 13 responses in total, which amounted to less than 20 per cent of the total number of questionnaires that were distributed to the community.

The collated responses to the *Community Questionnaire* are shown in graphical format in **Annexure B1** of this Appendix.

B2.2.2. Resident Profile

The first four questions of the *Community Questionnaire* canvassed resident information such as whether the respondent was a resident or business owner, length of time at the property and the type of property (e.g. residential, commercial, farm land etc.).

Of the 13 responses, 11 respondents were residents (**Question 3**), one of which also indicated that they were a business owner, while two respondents were owners of vacant land in the vicinity of Cookamidgera.

The length of time that respondents had been at their current address was found to be varied, with one respondent having lived at the residence for between '0-5 years', three for '5-20 years', and nine for 'more than 20 years' (**Question 4**).

In response to **Question 5**, nine of the respondents indicated that their property was a house. Of the five that responded "Other" to Question 5, three owned farms and two indicated that they owned vacant land.

B2.2.3. Experiences of Flooding

In **Question 6**, of the 13 respondents, 12 advised that they had previously been affected by flooding. In response to **Question 7**, the majority of respondents to the *Community Questionnaire* indicated that they been affected by multiple flooding events, including those that occurred in November 2005 (six respondents), December 2010 (eight), December 2012 (nine), February 2016 (nine), March 2017 (one), January 2020 (nine) and January 2021 (nine).

Questions 8 to **12** of the *Community Questionnaire* asked the respondents the describe how they were effected by flooding. A summary of the responses are as follows:

- The majority of respondents stated that the roads in the village (Flagstone Street, Railway Street and Haynes Street) become flow paths during flood events and remain inundated for up to three days.
- Trig Hill Lane and Flagstone Street become inundated during relatively frequent storm events resulting in the village becoming isolated.
- McLennan Lane, Mybara Lane and Mungicoble Lane are regularly inundated and damaged during storm events which restricts access to rural properties that rely on these roads for access.
- Two respondents reported that their fences are damaged when floodwater breaks the creek banks.
- The railway land is heavily overgrown which restricts the flow of water around the village.
- The Trig Hill Road culvert crossing of Bartley's Creek is undersized and is regularly inundated by floodwaters.

Additional documents were provided by community members at the in-person consultation that was undertaken by Council in May 2022. A number of these documents relate to floodwater that surcharges the northern (right) banks of Bartleys Creek approximately 400 m upstream of Trig Hill Road where it flows in a north-westerly direction toward the intersection of Haynes Street and Flagstone Street where it regularly inundates a dwelling that is located on the southern side of the intersection. It is understood that funding was granted to clear the creek of debris and construct a small earth embankment to prevent the floodwater from surcharging the banks of the creek at this location.

The abovementioned documents also refer to historic flood events that occurred on the following dates:

- 1952 (specific date not mentioned).
- 1986 (specific date not mentioned).
- 7 November 2005.
- 6 January 2006.
- 3 November 2007.
- December 2010

There are also a number of documents concerned with obtaining funding to repair and maintain the network of basins, embankments and channels that were constructed to the north of the village as part of the Cookamidgera Project.

It is understood that a flood that occurred in 1952 is considered the flood of record at Cookamidgera, although there is no information on flood behaviour during this event.

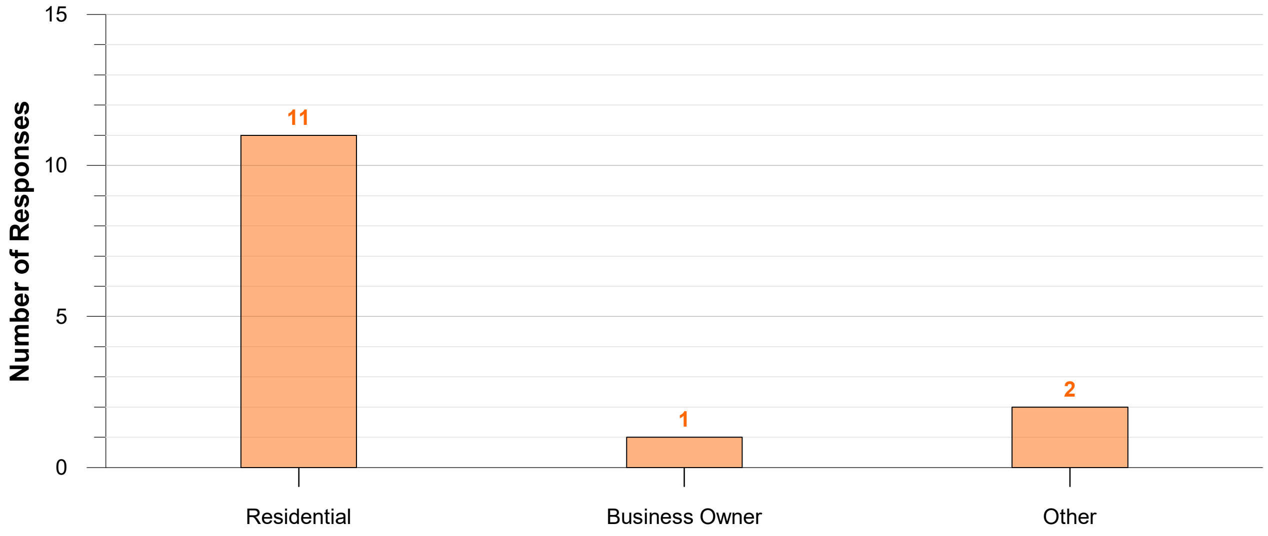
Community members provided anecdotal information on flood behaviour from a storm event that occurred on 14 November 2022 during the in-person consultation that was undertaken by the Consultants on 6 December 2023.

Appendix C of this report contains several photographs that were provided by respondents to the *Community Questionnaire* showing flood behaviour in the study area during the storms that occurred on 23 March 2017 and 14 November 2022.

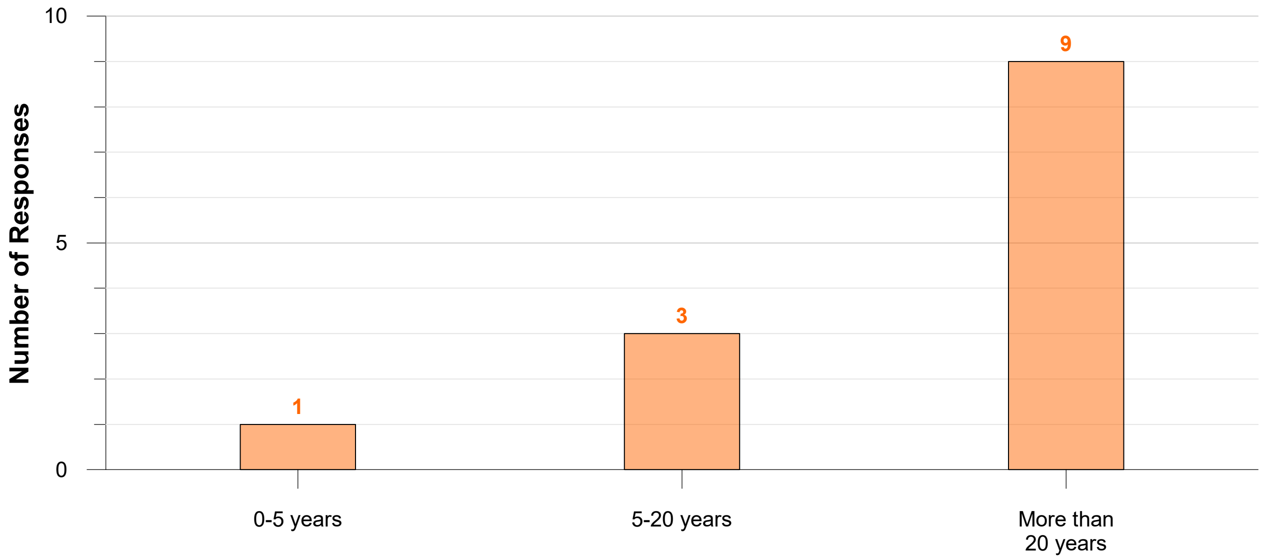
ANNEXURE B1

RESPONSES TO COMMUNITY QUESTIONNAIRE

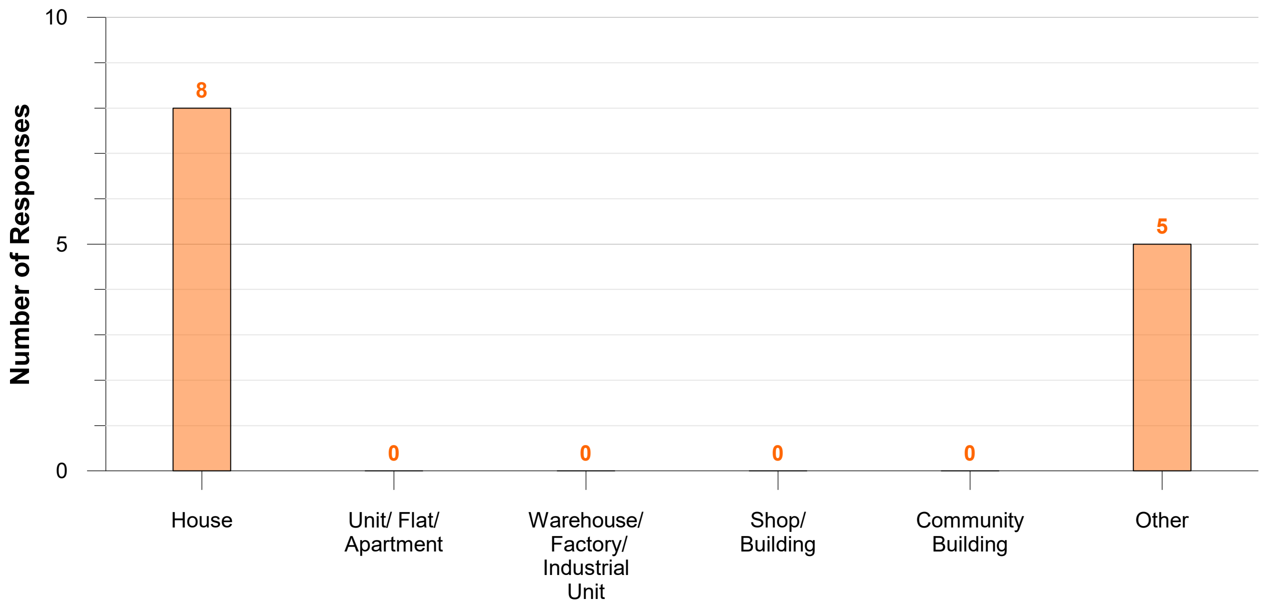
Q3. Respondent status

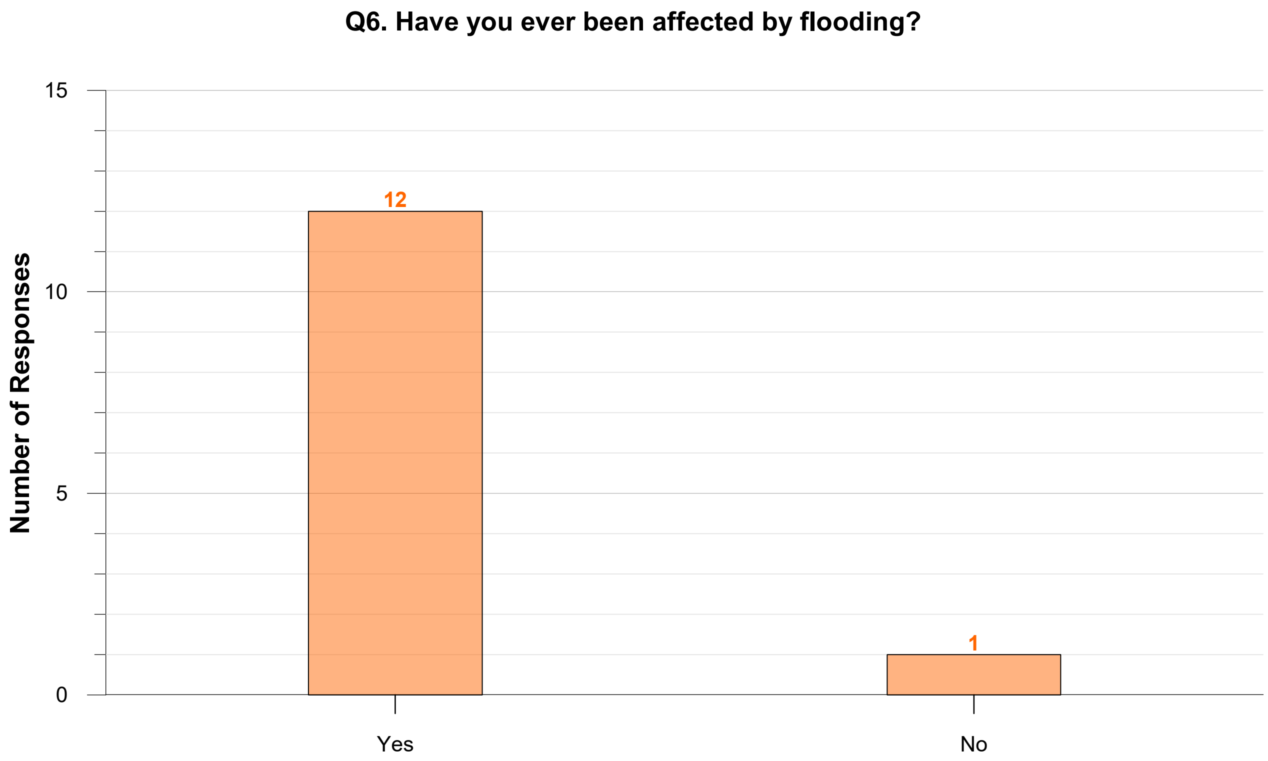


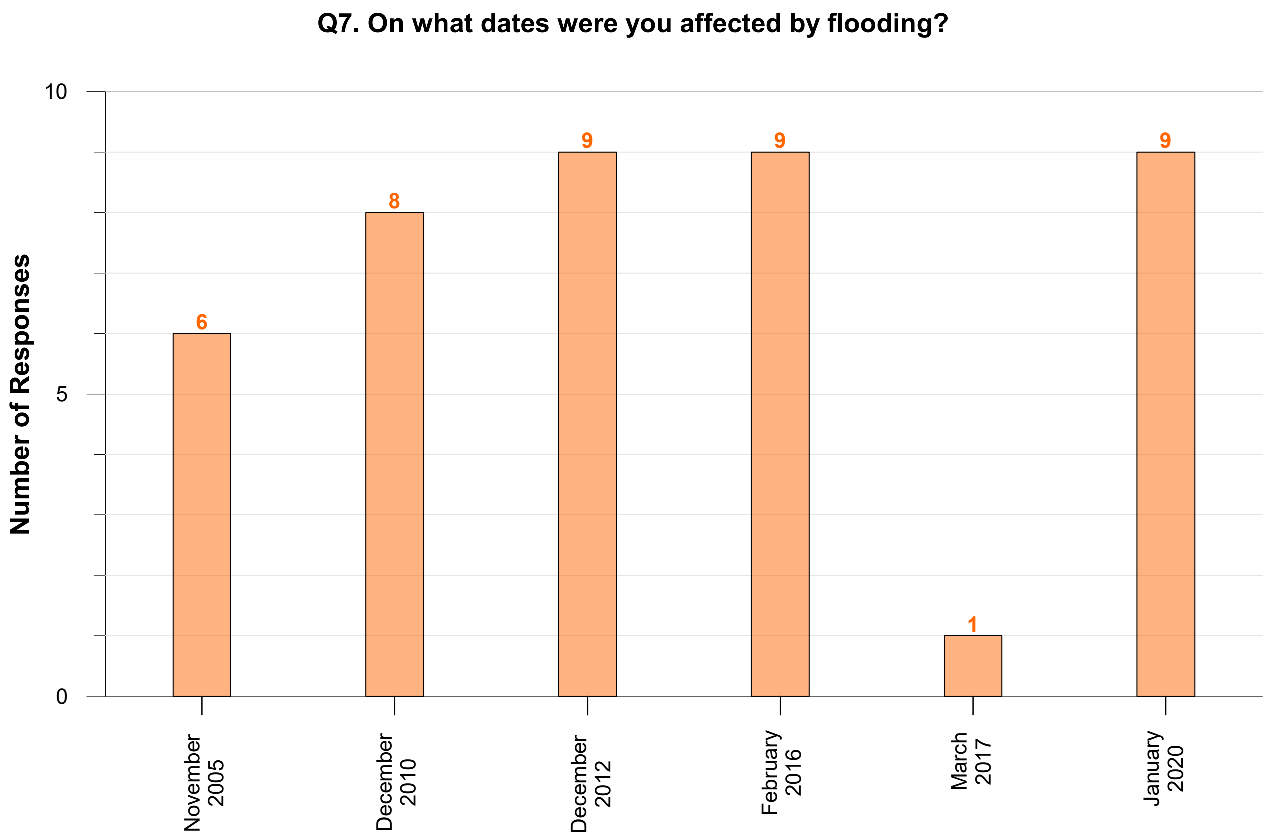
Q4. How long have you lived at this address?



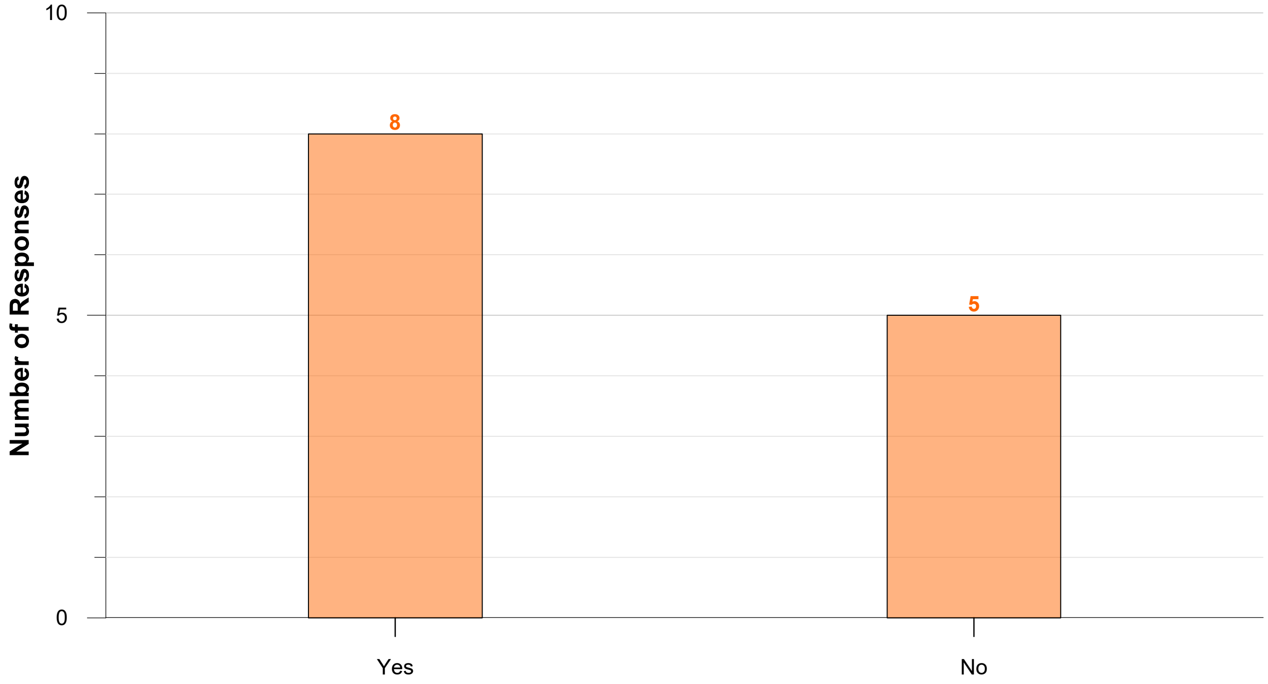
Q5. Property type



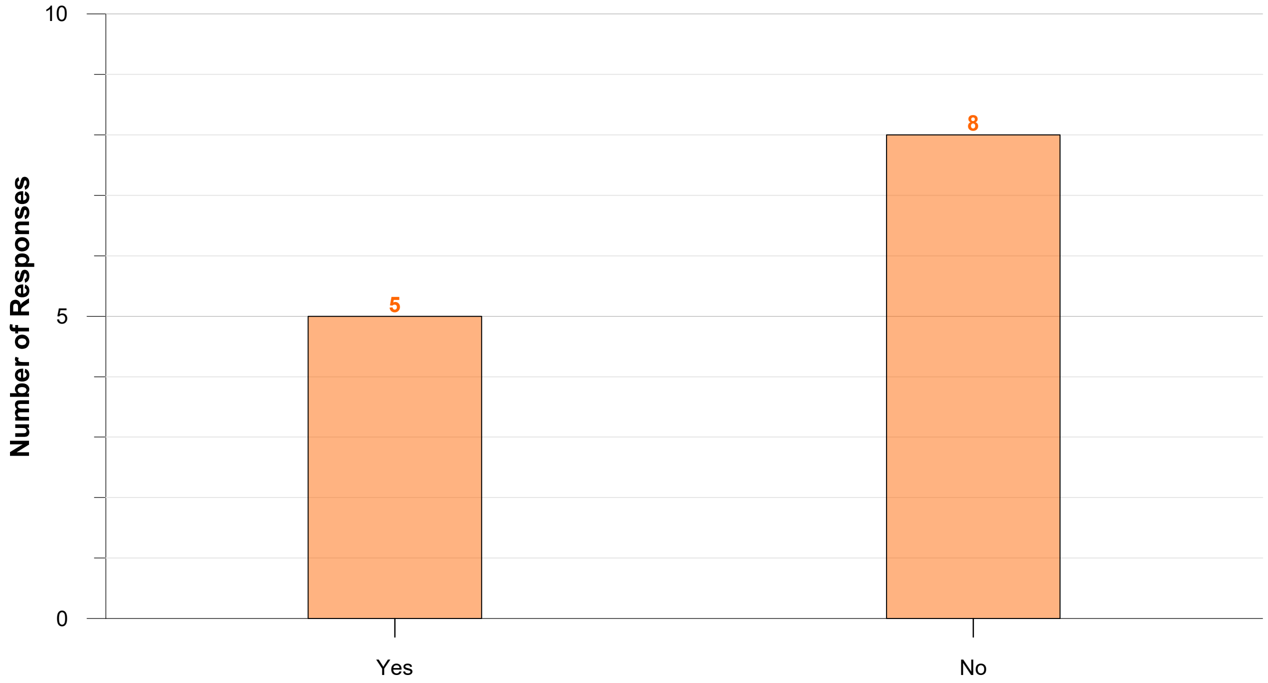

Q6. Have you ever been affected by flooding?
Number of Responses
15
10
5
0
12
1
Yes
No


Q7. On what dates were you affected by flooding?
Number of Responses
10
5
0
6
8
9
9
1
9
November 2005
December 2010
December 2012
February 2016
March 2017
January 2020

Q9. Do you have any information on pipe blockage or the inundation of local roads due to surcharge of the existing drainage system?



Q11. Do you have any photos, videos, rainfall records or other evidence of the flood marks that you have indentified?



APPENDIX C

PHOTOGRAPHS SHOWING OBSERVED FLOOD BEHAVIOUR AT COOKAMIDGERA

23 MARCH 2017

Plate C1.1 - Looking south at Flagstone Street level crossing of the railway (*Photo taken at 08:17 hours*)

Plate C1.2 - Looking south at Flagstone Street level crossing of the railway (*Photo taken at 08:17 hours*)

Plate C1.3 - Looking south at railway to the west of the Flagstone Street level (*Photo taken at 08:20 hours*)

Plate C1.4 - Looking south at Flagstone Street level crossing of the railway (*Photo taken at 08:21 hours*)

Plate C1.5 – Looking west along northern (upstream) side of railway from Flagstone Street (*Photo taken at 08:34 hours*)

Plate C1.6 – Looking west along southern (downstream) side of railway from Flagstone Street (*Photo taken at 08:21 hours*)

23 MARCH 2017

Plate C1.7 - Looking east along Flagstone Street at low point that is located approximately 50 m to the south of the railway (*Photo taken at 08:24 hours*)

Plate C1.8 – Looking south along channel on eastern side of Flagstone Street (*Photo taken at 08:38 hours*)

Plate C1.9 – Floodwater ponding on eastern side of Flagstone Street (*Photo taken at 08:40 hours*)

Plate C1.10 - Looking north along channel on eastern side of Flagstone Street (*Photo taken at 08:40 hours*)

Plate C1.11 – Upstream side of Trig Hill Road crossing of Bartleys Creek (*Photo taken at 08:46 hours*)

Plate C1.12 – Looking south along Trig Hill Road from its crossing of Bartleys Creek (*Photo taken at 08:51 hours*)

23 MARCH 2017

Plate C1.13 - Looking south along Trig Hill Road from its crossing of Bartleys Creek (*Photo taken at 08:51 hours*)

Plate C1.14 – Looking east along Railway Street from its intersection with Mullins Street (*Photo taken at 09:03 hours*)

Plate C1.15 – Looking west along Railway Street from its intersection with Mullins Street (*Photo taken at 09:03 hours*)

Plate C1.16 – Looking west along Railway Street from Haynes Street (*Photo taken at 09:06 hours*)

Plate C1.17 – Looking east at the intersection of Railway Street and Haynes Street (*Photo taken at 09:06 hours*)

Plate C1.18 – Downstream side of the three 1050 mm diameter corrugated pipes beneath the railway to the east of Haynes Street (*Photo taken at 09:12 hours*)

23 MARCH 2017

Plate C1.19 – Flooding on the unnamed lane that runs parallel to the railway to its south (*Photo taken at 09:14 hours*)

Plate C1.20 - Flooding on the unnamed lane that runs parallel to the railway to its south (*Photo taken at 09:14 hours*)

Plate C1.21 - Flooding on the unnamed lane that runs parallel to the railway to its south (*Photo taken at 09:17 hours*)

Plate C1.22 – Looking south along Haynes Street from its northern end (*Photo taken at 09:29 hours*)

Plate C1.23 – Floodwater discharging to the northern end of Haynes Street from the railway (*Photo taken at 09:30 hours*)

Plate C1.24 – Looking north along Haynes Street from its intersection with Railway Street (*Photo taken at 09:32 hours*)

14 NOVEMBER 2022

Plate C2.1 – Flooding in Flagstone Street adjacent to the low point that is located 50 m to the south of the railway (*Time unknown*)

Plate C2.2 – Flooding in Flagstone Street adjacent to the low point that is located 50 m to the south of the railway (*Time unknown*)

Plate C2.3 – Looking east along Flagstone Street adjacent to the low point that is located 50 m to the south of the railway (*Time unknown*)

Plate C2.4 – Flooding in the low point in Flagstone Street that is located 50 m to the south of the railway (*Time unknown*)

<table>
<tr><th colspan="2">14 NOVEMBER 2022</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Plate C2.5 – Looking west along Flagstone Street adjacent to the low point that is located 50 m to the south of the railway (Time unknown)</td><td>Plate C2.6 – Flooding in the low point in Flagstone Street that is located 50 m to the south of the railway (Time unknown)</td></tr>
</table>

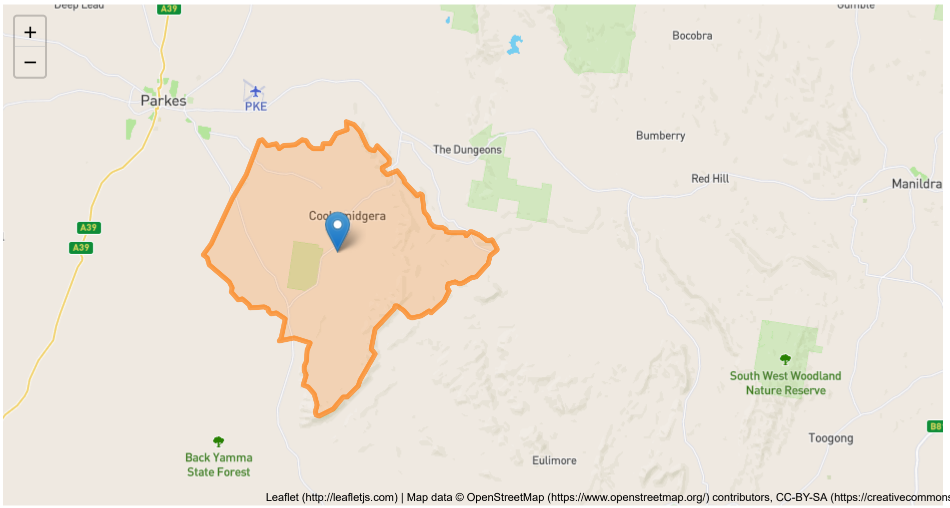
APPENDIX D

DESIGN INPUT DATA FROM ARR DATA HUB

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	148.295
Latitude	-33.224
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Probability Neutral Burst Initial Loss (./nsw_specific)	show



Leaflet (http://leafletjs.com) | Map data © OpenStreetMap (https://www.openstreetmap.org/) contributors, CC-BY-SA (https://creativecommons.org/licenses/by-sa/2.0/), Imagery © Mapbox (https://www.mapbox.com/)

Data

River Region

Division	Murray-Darling Basin
River Number	13
River Name	Lachlan River
Shape Intersection (%)	100.0

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i	Shape Intersection (%)
Central NSW	0.265	0.241	0.505	0.321	0.00056	0.414	-0.021	0.015	-0.00033	100.0

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26 \text{ x } 10^{-3} \text{ x } Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141 \text{ x } Area^{0.213} \text{ x } 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

Note: As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. The continuing storm loss information from the ARR Datahub provided below should only be used where relevant under the loss hierarchy (level 5) and where used is to be multiplied by the factor of 0.4.

Storm Initial Losses (mm)	23.0
Storm Continuing Losses (mm/h)	2.3

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/MB.zip)

code	MB
Label	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_MB.zip)

code	MB
arealabel	Murray Basin
Shape Intersection (%)	100.0

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-33.2242314167&longitude=148.294524858&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	04 August 2022 12:40PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.7 (0.034)	0.6 (0.021)	0.6 (0.016)	0.5 (0.013)	0.7 (0.014)	0.8 (0.015)
90 (1.5)	1.4 (0.058)	1.0 (0.030)	0.7 (0.018)	0.5 (0.010)	0.3 (0.006)	0.2 (0.003)
120 (2.0)	1.6 (0.062)	1.3 (0.034)	1.0 (0.023)	0.8 (0.015)	0.6 (0.011)	0.6 (0.008)
180 (3.0)	1.6 (0.053)	1.9 (0.047)	2.1 (0.044)	2.4 (0.041)	1.3 (0.019)	0.5 (0.007)
360 (6.0)	1.4 (0.037)	1.4 (0.028)	1.5 (0.024)	1.5 (0.022)	5.7 (0.068)	8.8 (0.095)
720 (12.0)	0.0 (0.001)	2.3 (0.035)	3.7 (0.049)	5.1 (0.059)	9.1 (0.088)	12.1 (0.105)
1080 (18.0)	0.0 (0.000)	1.0 (0.014)	1.6 (0.019)	2.3 (0.023)	4.8 (0.041)	6.6 (0.051)
1440 (24.0)	0.0 (0.000)	0.3 (0.003)	0.4 (0.005)	0.6 (0.005)	2.5 (0.020)	4.0 (0.028)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.6 (0.004)	1.0 (0.006)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

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Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

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Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	11.6 (0.547)	8.7 (0.296)	6.8 (0.193)	5.0 (0.121)	9.0 (0.182)	12.0 (0.215)
90 (1.5)	16.6 (0.691)	13.4 (0.403)	11.4 (0.285)	9.4 (0.201)	9.0 (0.162)	8.7 (0.139)
120 (2.0)	13.4 (0.512)	13.5 (0.371)	13.5 (0.311)	13.6 (0.268)	14.9 (0.247)	15.9 (0.234)
180 (3.0)	11.8 (0.394)	16.2 (0.392)	19.1 (0.388)	21.9 (0.383)	22.6 (0.333)	23.1 (0.303)
360 (6.0)	10.8 (0.290)	15.3 (0.298)	18.3 (0.300)	21.1 (0.300)	40.8 (0.491)	55.6 (0.597)
720 (12.0)	6.2 (0.132)	13.4 (0.210)	18.2 (0.240)	22.8 (0.260)	36.3 (0.352)	46.4 (0.403)
1080 (18.0)	3.5 (0.066)	9.8 (0.135)	14.0 (0.162)	18.0 (0.181)	26.7 (0.229)	33.2 (0.255)
1440 (24.0)	0.6 (0.011)	4.5 (0.057)	7.1 (0.075)	9.6 (0.088)	15.5 (0.122)	20.0 (0.141)
2160 (36.0)	0.0 (0.000)	1.8 (0.020)	3.0 (0.028)	4.1 (0.034)	7.8 (0.054)	10.5 (0.066)
2880 (48.0)	0.0 (0.000)	1.5 (0.016)	2.5 (0.022)	3.5 (0.027)	5.4 (0.035)	6.7 (0.039)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

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Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	30.9 (1.463)	24.6 (0.838)	20.5 (0.581)	16.5 (0.401)	30.2 (0.614)	40.5 (0.729)
90 (1.5)	35.9 (1.493)	31.7 (0.952)	29.0 (0.727)	26.4 (0.568)	32.5 (0.585)	37.0 (0.590)
120 (2.0)	34.8 (1.324)	36.3 (0.997)	37.3 (0.857)	38.3 (0.756)	55.9 (0.926)	69.1 (1.016)
180 (3.0)	29.8 (0.998)	40.7 (0.987)	47.9 (0.974)	54.8 (0.960)	69.8 (1.030)	81.1 (1.064)
360 (6.0)	20.3 (0.543)	36.9 (0.719)	47.8 (0.786)	58.4 (0.829)	91.6 (1.101)	116.5 (1.250)
720 (12.0)	21.4 (0.456)	39.7 (0.620)	51.8 (0.683)	63.5 (0.725)	79.9 (0.776)	92.3 (0.802)
1080 (18.0)	19.5 (0.365)	27.5 (0.378)	32.9 (0.381)	38.0 (0.382)	54.4 (0.466)	66.7 (0.512)
1440 (24.0)	9.4 (0.162)	19.5 (0.246)	26.2 (0.279)	32.6 (0.301)	42.1 (0.330)	49.2 (0.346)
2160 (36.0)	4.5 (0.069)	11.0 (0.125)	15.4 (0.146)	19.5 (0.160)	30.9 (0.216)	39.4 (0.247)
2880 (48.0)	3.1 (0.044)	9.6 (0.101)	13.9 (0.123)	18.1 (0.138)	22.7 (0.148)	26.2 (0.153)
4320 (72.0)	0.9 (0.011)	3.8 (0.037)	5.8 (0.047)	7.7 (0.054)	10.4 (0.061)	12.4 (0.066)

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	RCP 8.5
2030	**0.816 (4.1%)**	0.726 (3.6%)	**0.934 (4.7%)**
2040	**1.046 (5.2%)**	1.015 (5.1%)	**1.305 (6.6%)**
2050	**1.260 (6.3%)**	1.277 (6.4%)	**1.737 (8.8%)**
2060	**1.450 (7.3%)**	1.520 (7.7%)	**2.214 (11.4%)**
2070	**1.609 (8.2%)**	1.753 (8.9%)	**2.722 (14.2%)**
2080	**1.728 (8.8%)**	1.985 (10.2%)	**3.246 (17.2%)**
2090	**1.798 (9.2%)**	2.226 (11.5%)	**3.772 (20.2%)**

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Probability Neutral Burst Initial Loss

min (h)\AEP(%)	50.0	20.0	10.0	5.0	2.0	1.0
60 (1.0)	16.5	10.8	10.9	12.2	10.7	8.2
90 (1.5)	15.2	10.5	10.3	11.5	11.3	9.1
120 (2.0)	15.3	10.8	10.1	10.9	9.4	6.4
180 (3.0)	15.7	10.9	10.0	9.9	8.7	6.0
360 (6.0)	16.8	12.3	11.3	10.1	8.0	3.4
720 (12.0)	18.0	13.1	11.7	10.6	8.7	3.6
1080 (18.0)	19.3	15.2	14.6	13.2	11.2	5.0
1440 (24.0)	21.7	17.3	16.6	16.0	13.5	8.3
2160 (36.0)	23.1	19.2	18.7	20.7	16.7	10.4
2880 (48.0)	23.5	19.8	19.4	21.6	17.9	12.3
4320 (72.0)	24.3	21.4	22.3	24.9	22.0	16.9

Layer Info

Time Accessed	04 August 2022 12:40PM
Version	2018_v1
Note	As this point is in NSW the advice provided on losses and pre-burst on the NSW Specific Tab of the ARR Data Hub (./nsw_specific) is to be considered. In NSW losses are derived considering a hierarchy of approaches depending on the available loss information. Probability neutral burst initial loss values for NSW are to be used in place of the standard initial loss and pre-burst as per the losses hierarchy.

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APPENDIX E

ARR 2019 DESIGN BLOCKAGE ASSESSMENT AT DRAINAGE STRUCTURES

TABLE E1

ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES

ID[1]	Structure Details				Floating Debris												Non-Floating Debris									Adopted Design Blockage B_{DES}%		
	Structure Type[2]	Width	Height (m)	No. of Barrels	L_{10}[3]	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Approx. Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP				> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
pCM1	C Culvert	1.05	0	3	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.8	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM2	C Culvert	0.75	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM3	C Culvert	0.75	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	2.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM4	C Culvert	0.52	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM5	R Culvert	0.9	0.25	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM6	C Culvert	0.375	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM7	C Culvert	0.525	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM8	C Culvert	0.525	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM9	C Culvert	0.525	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM10	C Culvert	0.375	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM11	C Culvert	0.45	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM12	C Culvert	0.475	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM13	C Culvert	0.6	0	3	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM14	R Culvert	1.6	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.9	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM15	R Culvert	2.15	1.2	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	2.3	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM16	R Culvert	1.5	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pCM17	R Culvert	3	0.45	5	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pCM18	R Culvert	2.4	1.2	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM19	R Culvert	1.8	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.7	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM20	R Culvert	1.2	0.6	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	2.3	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM21	R Culvert	1.2	0.4	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM22	R Culvert	0.9	0.6	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM23	R Culvert	3	0.9	2	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.5	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM24	R Culvert	0.6	0.25	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM25	C Culvert	0.25	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM26	R Culvert	1.8	0.475	2	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM27	R Culvert	3	1.2	5	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.6	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM28	R Culvert	0.9	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM29	R Culvert	0.9	0.45	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM30	C Culvert	0.6	0	8	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	2.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM31	R Culvert	1.2	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM32	R Culvert	1.8	0.6	8	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM33	C Culvert	0.75	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM34	C Culvert	0.6	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	2.4	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM35	C Culvert	1.2	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM36	C Culvert	1.2	0	8	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM37	C Culvert	1.2	0	4	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.4	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM38	R Culvert	3.05	1.5	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	2.9	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM39	R Culvert	0.9	0.9	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.7	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM40	R Culvert	0.9	0.9	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM41	R Culvert	0.9	0.9	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM42	R Culvert	0.4	1	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.9	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM44	R Culvert	1.2	0.9	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM45	R Culvert	1.2	0.6	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM46	C Culvert	0.9	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM47	C Culvert	0.9	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM48	C Culvert	1.6	0	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	2.4	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM49	R Culvert	0.9	0.9	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM50	R Culvert	2.15	1.8	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.8	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM51	C Culvert	1.5	0	3	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.3	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pCM52	R Culvert	0.6	0.5	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0	Medium	Low	Low	Low	Medium	15%	15%	40%	25%	25%	50%
pCM53	R Culvert	1.5	0.6	2	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	1.3	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM54	R Culvert	1.5	0.5	2	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	0.1	Medium	Low	Low	Low	Medium	15%	15%	40%	15%	15%	40%
pCM55	R Culvert	1.5	0.9	1	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	5.6	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM56	R Culvert	0.9	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	4.5	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM57	R Culvert	1.8	0.3	1	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	3.7	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM58	C Culvert	0.9	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	3.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM59	C Culvert	0.9	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	2.1	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
pCM60	R Culvert	1.8	0.9	2	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	2	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%
pCM61	C Culvert	0.6	0	1	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	0.6	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%
RDC37	C Culvert	1.5	0	4	1.5	M	M	L	MML	Low	Low	Low	Medium	0%	0%	10%	2.3	Low	Low	Low	Low	Medium	0%	0%	15%	0%	0%	15%

TABLE E1

ARR, 2019 DESIGN BLOCKAGE ASSESSMENT AT HYDRAULIC DRAINAGE STRUCTURES

ID[1]	Structure Details				Floating Debris												Non-Floating Debris									Adopted Design Blockage B_{DES}%		
	Structure Type[2]	Width	Height (m)	No. of Barrels	L_{10}[3]	Debris Availability	Debris Mobility	Debris Transportability	Debris Potential	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Inlet Blockage (B_{DES}%)			Approx. Flow Velocity (m/s)	Likelihood of Deposition	Debris Potential at Structure	Adjusted Debris Potential			Most Likely Design Barrel Blockage (B_{DES}%)					
											> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP				> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP	> 5% AEP	5% - 0.5% AEP	< 0.5% AEP
pCM43	C Culvert	0.6	0	2	1.5	M	M	L	MML	Low	Low	Low	Medium	25%	25%	50%	1.2	Low	Low	Low	Low	Medium	0%	0%	15%	25%	25%	50%

1. Note that the plan location of each structure can be identified in the GIS layers contained in the data handover for the present study.
2. C Culvert = Circular Pipe Culvert, R Culvert = Rectangular Box Culvert, I Culvert = Irregularly Shaped Culvert
3. L_{10} is the average length of the longest 10% of the debris that could arrive at the culvert.

APPENDIX F

FLOOD DATA FOR INDIVIDUAL ROAD CROSSINGS AT COOKAMIDGERA

TABLE F1
PEAK FLOOD LEVEL AND MAXIMUM DEPTH OF INUNDATION AT INDIVIDUAL ROAD AND RAIL CROSSINGS AT COOKAMIDGERA[1,2]

ID[3]	Tributary	Road Name	Road/ Rail Level (m AHD)	March 2017		November 2022		20% AEP		10% AEP		5% AEP		2% AEP		1% AEP		0.5% AEP		0.2% AEP		PMF	
				Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)	Peak Flood Level (m AHD)	Depth of Overtopping (m)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]
H01	Bartleys Creek	Trigg Hill Road	354.9	355.6	0.7	355.5	0.6	355.5	0.6	355.6	0.7	355.7	0.8	355.8	0.9	355.8	0.9	355.8	0.9	355.9	1.0	356.0	1.1
H02		Trigg Hill Road	311.8	313.9	2.1	313.9	2.1	313.4	1.6	313.6	1.8	313.8	2.0	314.0	2.2	314.1	2.3	314.2	2.4	314.3	2.5	317.0	5.2
H03		Parkes Eugowra Road	309.8	310.3	0.5	310.3	0.5	310.0	0.2	310.2	0.4	310.3	0.5	310.3	0.5	310.3	0.5	310.3	0.5	310.4	0.6	310.7	0.9
H04	Quart Pot Creek	Coonambro Way	344.7	345.2	0.5	345.2	0.5	345.1	0.4	345.2	0.5	345.3	0.6	345.3	0.6	345.4	0.7	345.5	0.8	345.5	0.8	347.0	2.3
H05		Trigg Hill Road	339.5	340.5	1.0	340.5	1.0	340.2	0.7	340.3	0.8	340.4	0.9	340.6	1.1	340.7	1.2	340.8	1.3	340.9	1.4	342.8	3.3
H06		Railway Street	346.0	346.1	0.2	346.1	0.2	346.1	0.2	346.2	0.3	346.2	0.3	346.2	0.3	346.2	0.3	346.2	0.3	346.3	0.4	347.6	1.7
H07		Cooka Hill Road	350.0	350.6	0.6	350.6	0.6	350.4	0.4	350.4	0.4	350.5	0.5	350.6	0.6	350.7	0.7	350.7	0.7	350.8	0.8	351.5	1.5
H08		Cooka Hill Road	347.5	348.2	0.7	348.2	0.7	347.9	0.4	348.1	0.6	348.2	0.7	348.3	0.8	348.4	0.9	348.4	0.9	348.5	1.0	349.1	1.6

1. Elevations and Depths rounded to nearest 0.1 m.
2. NF = Not Flooded.
3. Refer **Figures 6.1** to **6.8** for location of Peak Flood Level Location.

APPENDIX G

DESIGN PEAK FLOWS

TABLE G1
DESIGN PEAK FLOWS DERIVED BY TUFLOW MODEL[1]

Peak Flow Location Identifier[2]	Watercourse	Location	20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)	Critical Temporal Pattern[4]	Peak Flow (m^3/s)	Critical Storm Duration[3] (minutes)
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]	[P]	[Q]	[R]	[S]	[T]	[U]	[V]	[W]	[X]	[Y]	[Z]
Q01	Bartleys Creek		27.3	360	6	40.6	360	3	53.3	360	3	75.1	270	7	94.7	270	7	109	270	7	129	270	7	870	180
Q2A	Bartleys Creek	Upstream McKays Lane 0	28.4	360	6	42.0	360	3	55.0	360	3	78.3	270	7	98.4	270	7	113	270	7	134	270	7	738	180
Q2B	Right Overbank		2.8	360	6	5.4	120	6	7.2	120	6	9.9	90	3	12.8	90	3	14.8	90	3	17.2	90	3	202	180
Q3A	Bartleys Creek	Upstream Trigg Hill Road	28.6	360	6	41.3	360	3	53.5	360	3	74.6	270	7	90.7	270	7	102	270	7	119	270	7	-	-
Q3B	Right Overbank		1.0	360	6	2.4	360	3	4.2	120	6	6.0	90	3	8.4	90	3	11.2	90	3	15.4	90	3	-	-
Q4A	Bartleys Creek	Trigg Hill Road	28.9	360	6	41.4	360	3	52.9	360	3	72.2	270	7	86.2	270	7	96.1	270	7	110	270	7	-	-
Q4B	Right Overbank		4.1	360	6	8.2	120	6	9.9	180	3	15.6	270	7	23.3	270	7	29.2	270	7	37.7	270	7	-	-
Q5A	Left Overbank	Downstream Mullins Street	2.6	360	6	7.0	360	3	11.6	360	3	21.0	270	7	28.5	270	7	34.0	270	7	42.5	270	7	298	180
Q5B	Bartleys Creek		26.2	360	6	34.4	360	3	41.3	360	3	52.4	270	7	61.3	270	7	67.4	270	7	75.5	270	7	387	180
Q5C	Right Overbank		4.2	360	6	7.7	120	6	11.3	120	6	16.5	120	4	21.3	90	3	24.7	90	3	30.0	120	4	361	180
Q6A	Left Overbank	Western end of Railway Street	3.0	360	6	10.6	360	3	19.7	360	3	36.4	270	7	49.7	270	7	59.4	270	7	73.2	270	7	-	-
Q6B	Bartleys Creek		24.8	360	6	28.8	360	3	31.4	360	3	34.4	270	7	36.5	270	7	37.9	270	7	39.7	270	7	-	-
Q6C	Right Overbank		4.3	360	6	7.7	120	6	11.2	120	6	16.5	120	4	21.4	120	4	24.7	90	3	29.7	90	3	-	-
Q7A	Left Overbank	Upstream confluence with Quart Pot Creek	1.6	360	6	8.0	360	3	16.6	360	3	33.5	270	7	47.8	270	7	58.4	270	7	73.9	270	7	-	-
Q7B	Bartleys Creek		29.2	360	6	37.7	180	3	44.8	180	3	59.4	180	6	74.6	120	4	83.7	120	4	96.2	120	4	-	-
Q8	Bartleys Creek	Downstream confluence with Quart Pot Creek	110	360	6	164.0	360	3	217	360	3	301.0	270	7	375	180	6	431	180	6	509	180	6	-	-
Q9	Bartleys Creek		138	360	6	207	360	3	274	360	3	383	270	7	474	180	6	544	180	6	643	180	6	4,570	180
Q10	Bartleys Creek		140	360	6	212	360	3	284	360	3	393	270	7	485	270	7	554	270	7	663	270	7	4,950	180
Q11	Bartleys Creek	Parkes Eugowra Road	151	360	6	232	360	3	314	360	3	432	270	7	535	270	7	611	270	7	729	270	7	5,870	180
Q12	Quart Pot Creek		49.8	360	6	75.3	180	3	99.7	360	3	135	180	6	172	180	6	198	180	6	233	180	6	1,450	180
Q13A		Coonambro Way	67.1	360	6	97.4	180	3	128	360	3	173	270	7	218	180	6	249	180	6	292	180	6		
Q13B			10.9	360	6	17.9	120	6	36.9	120	6	33.6	120	4	43.4	120	4	49.8	120	4	58.4	120	4		

Refer over for footnote to table

TABLE G1 (Cont'd)
DESIGN PEAK FLOWS DERIVED BY TUFLOW MODEL[1]

Peak Flow Location Identifier[2] [A]	Watercourse [B]	Location [C]	20% AEP			10% AEP			5% AEP			2% AEP			1% AEP			0.5% AEP			0.2% AEP			PMF	
			Peak Flow (m^3/s) [D]	Critical Storm Duration[3] (minutes) [E]	Critical Temporal Pattern[4] [F]	Peak Flow (m^3/s) [G]	Critical Storm Duration[3] (minutes) [H]	Critical Temporal Pattern[4] [I]	Peak Flow (m^3/s) [J]	Critical Storm Duration[3] (minutes) [K]	Critical Temporal Pattern[4] [L]	Peak Flow (m^3/s) [M]	Critical Storm Duration[3] (minutes) [N]	Critical Temporal Pattern[4] [O]	Peak Flow (m^3/s) [P]	Critical Storm Duration[3] (minutes) [Q]	Critical Temporal Pattern[4] [R]	Peak Flow (m^3/s) [S]	Critical Storm Duration[3] (minutes) [T]	Critical Temporal Pattern[4] [U]	Peak Flow (m^3/s) [V]	Critical Storm Duration[3] (minutes) [W]	Critical Temporal Pattern[4] [X]	Peak Flow (m^3/s) [Y]	Critical Storm Duration[3] (minutes) [Z]
Q14	Quart Pot Creek	Trigg Hill Road	77.4	360	6	116	360	3	153	360	3	210	270	7	264	180	6	303	180	6	357	180	6	2,400	180
Q15		Upstream confluence with Bartleys Creek	75.4	360	6	117	360	3	161	360	3	228	270	7	291	180	6	336	180	6	400	180	6	-	-
Q16A	Major Overland Flowpath	Upstream Cooka Hills Road	0.9	270	3	6.2	120	6	9.1	120	6	12.4	90	3	15.5	90	3	17.8	90	3	21.9	90	3	115	45
Q16B			5.7	360	6	10.7	120	6	12.5	120	6	17.1	90	3	20.1	90	3	22.0	90	3	24.6	90	3	84	45
Q16C			1.1	360	6	2.2	120	6	2.9	180	3	5.6	90	3	8.8	90	3	10.7	90	3	13.3	90	3	103	45
Q17A		Orange Broken Hill Railway	0.0	270	3	0.5	120	6	2.2	120	6	8.1	90	3	14.8	90	3	18.8	90	3	24.8	90	3	-	-
Q17B		Flagstone Street	9.9	360	6	16.7	360	3	20.6	360	3	26.7	120	4	28.2	120	4	31.0	90	3	34.8	90	3	-	-
Q18		Upstream Orange Broken Hill Railway	6.9	360	6	11.3	120	6	12.2	120	6	13.6	90	3	15.3	90	3	16.3	90	3	16.7	120	4	-	-

1. Peak flows less than 100 m^3/s have been quoted to one decimal place in order to show minor differences.
2. Refer **Figures 6.1** to **6.8** for location of Flow Location Identifiers.
3. Relates to storm duration that is critical for maximising the peak flood level at each location, not necessarily the peak flow.
4. Relates to temporal pattern that is critical for maximising the peak flood level at each location, not necessarily the peak flow.

APPENDIX I

FLOOD DAMAGES

TABLE OF CONTENTS

Page No.

I1. INTRODUCTION AND SCOPE

I1.1 Introduction

Damages from flooding belong to two categories:

- **Tangible Damages**
- **Intangible Damages**

Tangible damages are defined as those to which monetary values may be assigned and may be subdivided into direct and indirect damages. Direct damages are those caused by physical contact of floodwater with damageable property. They include damages to commercial and residential building structures and contents as well as damages to infrastructure services such as electricity and water supply.

Intangible damages resulting from flooding includes a number of various factors that can have a significant effect on the community. Such factors may include:

a) risk of injury or loss of life;

b) mental health impacts such as depression, anxiety and post-traumatic stress disorder; and

c) social and wellbeing impacts such as isolation, inconvenience, or disruption of family and social activities.

I1.2 Scope of Investigation

In the following sections, both tangible and intangible damages to residential, commercial and industrial properties, and public buildings have been estimated resulting from flooding in the study area. While the present study defined flood behaviour in land outside of the urban centre of Cookamidgera, the flood damages assessment was only undertaken for properties that are located within the Village Centre (i.e. land that is presently zoned for urban type development).

For the present investigation, the procedures set out in *Flood Risk Management Guideline MM01 – Flood Risk Management Measures* (DPE, 2023) and the associated *NSW Flood Risk Management Tool DT01* (***FRM Tool DT01***) were used to undertake an assessment of both the tangible and intangible damages resulting from flooding at Cookamidgera.

The threshold floods at which damages may commence to infrastructure and community assets have also been estimated, mainly from site inspection and interpretation of flood level data. However, there are no data available to allow a quantitative assessment of damages to be made to this category.

I1.3 Terminology

Definitions of the terms used in this Appendix are presented in **Section I8** which also summarises the value of Tangible Flood Damages.

I2. DESCRIPTION OF APPROACH

The damage caused by a flood to a particular property is a function of the depth of flooding above floor level and the value of the property and its contents. The warning time available for residents to take action to lift property above floor level also influences damages actually experienced. The *FRM Tool DT01* was used to estimate damages on a property by property basis according to the type of development, the location of the property and the depth of inundation.

Using the results of the hydraulic modelling, a peak flood elevation was derived for each event at each property. The property flood levels were input to the *FRM Tool DT01* which also contained property characteristics and depth-damage relationships. The depth of flooding was computed as the difference between the interpolated flood level and the floor elevation at each property.

The floor levels of individual dwellings/buildings were assessed by adding the height of floor above a representative natural surface within the allotment (as estimated by visual inspection) to the natural surface elevation determined from LiDAR survey. The type of structure and potential for property damage were also assessed during the visual inspection. If a property was not accessible to undertake a visual inspection, the height of the floor was assumed to be 300 mm above the adjacent natural surface level.

A series of depth-damages curves in the *FRM Tool DT01* were used to estimate the cost of tangible damages to residential, commercial, industrial and public properties. The spreadsheet model also includes procedures that were used to estimate intangible damages associated with:

a) risk of injury or loss of life correlated to the hazard vulnerability classification of flooding;

b) mental health costs correlated to the depth of above-floor inundation; and

c) social and wellbeing costs correlated to the frequency of above-floor inundation.

It should be understood that this approach is not intended to identify individual properties liable to flood damages and the values of damages in individual properties, even though it appears to be capable of doing so. The reason for this caveat lies in the various assumptions used in the procedure, the main ones being:

- the assumption that computed water levels and topographic data used to define flood extents are exact and without any error;
- the assumption that the water levels as computed by the hydraulic model are not subject to localised influences;
- the estimation of property floor levels by visual inspection rather than by formal field survey;
- the use of "average" stage-damage relationships, rather than a unique relationship for each property;
- the uncertainties associated with assessing appropriate factors to convert *potential damages* to *actual flood damages* experienced for each property after residents have taken action to mitigate damages to contents.

The consequence of these assumptions is that some individual properties may be inappropriately classified as flood liable, while others may be excluded. Nevertheless, when applied over a broad area these effects would tend to cancel, and the resulting estimates of overall damages, would be expected to be reasonably accurate.

For the above reasons, the information contained in the spreadsheets used to prepare the estimates of flood damages for the study area should not be used to provide information on the depths of above-floor inundation of individual properties.

I3. SOURCES OF DATA

I3.1 General

To estimate A*verage Annual Flood Damages* for a specific area it is necessary to estimate the damages for several floods of different magnitudes, i.e., of different frequencies, and then to integrate the area beneath the damage – frequency curve over the whole range of frequencies. To do this it is necessary to have data on the damages sustained by all types of property over the likely range of inundation. There are several ways of doing this:

- The ideal way would be to conduct specific damage surveys in the aftermath of a range of floods, preferably immediately after each. An example approaching this ideal is the case of Nyngan where surveys were conducted in May 1990 following the disastrous flood of a month earlier (DWR, 1990). This approach is not possible in the study area as specific damage surveys have not been conducted following the historic flood events.
- The second best way is for experienced loss adjusters to conduct a survey to estimate likely losses that would arise due to various depths of inundation. This approach is used from time to time, but it can add significantly to the cost of a floodplain management study. It was not used for the present investigation.
- The third way is to use generalised data that are considered to be suitable for broad regional studies. They are not considered to be suitable for use in specific areas unless none of the other approaches can be satisfactorily applied.
- The fourth way is to adapt or transpose data from other flood liable areas. The approach set out in DPE, 2023 and the *FRM Tool DT01* is based on data collected following major flooding in various urban centres across NSW and has been adopted for the present study.

I3.2 Property Data

The properties were divided into three categories: residential, commercial/industrial and public buildings.

For residential properties, the data used in the damages estimation included:

- the location/address of each property
- an assessment of the type of structure
- representative natural surface level of the allotment
- floor level of the residence

For commercial/industrial properties, the data used in the damages estimation included:

- the location of each property
- the nature of each enterprise
- an estimation of the floor area
- natural surface level
- floor level

The property descriptions were used to classify the commercial/industrial developments into categories (i.e., high, medium or low value properties) which relate to the magnitude of likely flood damages.

The total number of residential properties, commercial / industrial and public buildings in the study area is shown in **Table I3.1**.

TABLE I3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties
Residential	26
Commercial / Industrial	0
Public	1
Total	**27**

I3.3 Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic models that were developed as part of the present investigation. The design levels assume that the drainage system is operating at optimum capacity. They do not allow for any increase in levels resulting from wave action and debris build-ups in the channels which may result in conversions of flow from the supercritical to the subcritical flow regime, as well as other local hydraulic effects. These factors are usually taken into account by adding a factor of safety (freeboard) to the "nominal" flood level when assessing the "level of protection" against flooding of a particular property. Freeboard could also include an allowance for the future effects of climate change.

I4. RESIDENTIAL DAMAGES

I4.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship which incorporates structural damage, damage to contents, external damage, relocation costs and clean-up costs. In limited cases, the additional damage costs related to structural integrity due to building failure may also warrant consideration. Depth versus damage curves are computed for single and double storey residences.

The level of flood awareness and available warning time are taken into account by factors which are used to reduce "potential" damages to contents to "actual" damages. "Potential" damages represent losses likely to be experienced if no action were taken by residents to mitigate impacts. A reduction in the potential damages to "actual" damages is usually made to allow for property evacuation and raising valuables above floor level, which would reduce the damages actually experienced. The ability of residents to take action to reduce flood losses is mainly limited to reductions in damages to contents, as damages to the structure and clean-up costs are not usually capable of significant mitigation.

The reduction in damages to contents is site specific, being dependent on a number of factors related to the time of rise of floodwaters, the recent flood history and flood awareness of residents and emergency planning by the various Government Agencies (BoM and NSW SES).

Flooding in the study area is "flash flooding" in nature, with surcharge of the watercourses and various drainage lines occurring within three hours of the onset of flood producing rain. Consequently, there would be very limited time in advance of a flood event in which to warn residents located along the various flow paths and for them to take action to mitigate flood losses.

The actual damage to contents in an event can be reduced by actions taken during the warning time available in response to a flood threat. The actual to potential damage ratio is dependent on the effective warning time, likely duration of inundation of contents, flood awareness of the community, the likelihood of at least one resident being present at the time of the flood, the ability of the individual to lifts goods and the height to which goods would need to be raised. As there is minimal warning time available at Cookamidgera, the default actual to potential damage ratio of 0.9 was adopted for the present study.

I4.2 Total Residential Damages

Table I4.1 over summarises the residential damages in the study area for floods between the 20% AEP and the PMF which were modelled hydraulically as part of the present study.

At the 1% AEP level of flooding, two dwellings would experience above-floor inundation resulting in total flood damages of about $0.27 Million. During a PMF event, 22 dwellings would experience above-floor inundation in the Village Centre, resulting in a total flood damages of about $5.9 Million. The maximum depth of above-floor inundation in the worst affected dwelling would increase from about 0.1 m at the 1% AEP level of flooding to about 1.5 m in a PMF event.

TABLE I4.1
TOTAL RESIDENTIAL FLOOD DAMAGES

Design Flood Event	No. of Properties		Total Damages ($ Million)
	Flood Affected	Flooded Above Floor Level	
20% AEP	1	0	0
10% AEP	3	0	0
5% AEP	6	0	0.02
2% AEP	8	1	0.07
1% AEP	11	2	0.27
0.5% AEP	13	3	0.39
0.2% AEP	16	3	0.50
PMF	26	22	5.90

I5. COMMERCIAL AND INDUSTRIAL DAMAGES

I5.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship for commercial and industrial buildings. The damage costs include the indirect costs associated with loss of trading and post-flood clean-up for commercial and industrial buildings.

Commercial and industrial property damages are highly variable, with the particular use and associated contents (rather than the structure) generally dominating the overall damage. The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise set out in **Table I5.1** below. Damages also depend on the floor area.

TABLE I5.1
ASSESSED COMMERCIAL AND INDUSTRIAL DAMAGE CATEGORIES

Proposed classification	Adjustment to average value curve	Representative uses
Low to medium	60% of average	Restaurants, cafes, offices, doctor's surgeries, retail/food outlets, butchers, bakeries, newsagencies, service stations, hardware
Medium/default	100%	Proposed as a representative average, where the particular use is not known
Medium to high	150% of average	Chemists, electrical goods, clothing stores, bottle shops, electronics

I5.2 Total Commercial and Industrial Damages

There are no commercial or industrial buildings present in the Village Centre at Cookamidgera.

I6. DAMAGES TO PUBLIC BUILDINGS

I6.1 Damage Functions

The procedures identified in DPE, 2023 allow for the preparation of a depth versus damage relationship for public buildings. The damage costs include the indirect costs associated with post-flood clean-up for public buildings.

As part of the *FRM Tool DT01*, depth versus damage relationship for public buildings have been classified for three categories which are schools, hospitals and other buildings, the latter of which comprises the following uses:

a) Health (e.g. aged care, nursing home);

b) Emergency Services (e.g. police station, fire station, ambulance station, NSE SES facilities etc.); and

c) Government Buildings (e.g. courthouse, government administration buildings, diplomatic facilities, consulate facilities, major defence facilities, correctional facilities etc).

I6.2 Total Damages – Public Buildings

Table I6.1 summarises the estimated public damages in the study area

While no public buildings would be impacted during floods up to 0.2% AEP in magnitude, the Community Hall would be above-floor inundated in a PMF event, resulting in total flood damages of about $0.02 Million.

TABLE I6.1
PUBLIC FLOOD DAMAGES

Design Flood Event	No. of Properties		Total Damages ($ Million)
	Flood Affected	Flooded Above Floor Level	
20% AEP	0	0	0
10% AEP	0	0	0
5% AEP	0	0	0
2% AEP	0	0	0
1% AEP	0	0	0
0.5% AEP	0	0	0
0.2% AEP	0	0	0
PMF	1	1	0.02

I7. DAMAGES TO INFRASTRUCTURE AND COMMUNITY ASSETS

No data are available on damages experienced to infrastructure and community assets during historic flood events. However, a qualitative matrix of the effects of flooding on important assets in the study area is presented in **Table I7.1**.

TABLE I7.1
QUALITATIVE EFFECTS OF FLOODING ON
INFRASTRUCTURE AND COMMUNITY ASSETS AT COOKAMIDGERA

Damage Sector	Design Flood Event (AEP)							
	20%	10%	5%	2%	1%	0.5%	0.2%	PMF
Roads	X	X	X	X	X	X	X	X
Electricity	O	O	O	O	O	O	O	O
Telephone	O	O	O	O	O	O	O	O

Notes: O = No significant damages likely to be incurred.
X = Some damages likely to be incurred.

I8. SUMMARY OF TANGIBLE DAMAGES

I8.1 Tangible Damages

Flood damages have been computed for a range of flood frequencies from 20% AEP up to the PMF. For the purposes of assessing damages, the 50% AEP was adopted as the "threshold" flood at which damages commence at Cookamidgera. As set out in **Table I8.1** over, about $0.27 Million of damages would be incurred at the 1% AEP level of flooding at Cookamidgera, increasing to a total of about $5.92 Million for the PMF.

I8.2 Definition of Terms

Average Annual Damages (also termed "expected damages") are determined by integrating the area under the damage-frequency curve. They represent the time stream of annual damages, which would be expected to occur on a year by year basis over a long duration.

Using an appropriate discount rate, average annual damages may be expressed as an equivalent "*Net Present Value"* (**NPV**) of damages and used in the economic analysis of potential flood management measures.

A flood management scheme which has a design 1% AEP level of protection, by definition, will eliminate damages up to this level of flooding. If the scheme has no mitigating effect on larger floods then these damages represent the benefits of the scheme expressed on an average annual basis and converted to the NPV via the discount rate.

Using the procedures outlined in DPE, 2023 and NSW Treasury Guidelines, economic analyses were carried out assuming a 30 year economic life for projects and discount rates of 5% pa. (best estimate) and 7% and 3% pa (sensitivity analyses).

I8.3 Average Annual Damages

The average annual damages for all flood events up to the PMF are shown below in **Table I8.2**. Note that values have been quoted to two decimal places to highlight the relatively small recurring damages.

I8.4 Net Present Value of Damages

The NPV of damages likely to be experienced for all flood events up to the 5% and 1% AEP flood events, as well as the PMF, for a 30 year economic life and discount rates of 3, 5 and 7 per cent are shown in **Table I8.3**.

For a discount rate of 5% pa, the NPV of total damages for flood events up to the 1% AEP flood at Cookamidgera is about $0.07 Million. Based on this finding, one or more schemes costing up to this amount could be economically justified if they eliminated damages at Cookamidgera for all flood events up to the 1% AEP event. While schemes costing more than this value would have a benefit/cost ratio less than 1, they may still be justified according to a multi-objective approach which considers other criteria in addition to economic feasibility.

TABLE I8.1
TOTAL FLOOD DAMAGES
$ MILLION

Design Flood Event	Residential	Commercial/Industrial	Public	Total
20% AEP	0	0	0	0
10% AEP	0	0	0	0
5% AEP	0.02	0	0	0.02
2% AEP	0.08	0	0	0.08
1% AEP	0.27	0	0	0.27
0.5% AEP	0.38	0	0	0.38
0.2% AEP	0.5	0	0	0.5
PMF	5.9	0	0.02	5.92

TABLE I8.2
AVERAGE ANNUAL DAMAGES
$ MILLION

Design Flood Event	Residential	Commercial/ Industrial	Public	Total	
				Contribution to AAD(1)	Cumulative AAD(2)
20% AEP	0	0	0	0	0
10% AEP	<0.001	0	0	<0.001	<0.001
5% AEP	<0.001	0	0	<0.001	<0.001
2% AEP	0.001	0	0	0.001	0.002
1% AEP	0.002	0	0	0.002	0.004
0.5% AEP	0.002	0	0	0.002	0.005
0.2% AEP	0.001	0	0	0.001	0.007
PMF	0.006	0	<0.001	0.006	0.013

1. Represents the contribution to the total average annual damages for the specified design flood event
2. Represents the cumulative annual average damages for all floods up to the specified design flood event in magnitude.

TABLE I8.3
PRESENT WORTH VALUE OF DAMAGES
$ MILLION

Discount Rate (%)	All Floods up to 5% AEP	All Floods up to 1% AEP	All Floods up to PMF
3	0.02	0.09	0.27
5	0.01	0.07	0.21
7	0.01	0.06	0.17

I9. REFERENCES AND BIBLIOGRAPHY

DPE (Department of Planning), 2023. *"**Flood Risk Management Guideline MM01 – Flood Risk Management Measures**"*