Ordinary Meeting of Council

26 June 2019

UNDER SEPARATE COVER ATTACHMENTS

ITEM 10.11

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QUEANBEYAN-PALERANG REGIONAL COUNCIL

Council Meeting Attachment

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ITEM 10.11 BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

ATTACHMENT 1 BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN: VOLUME 1: REPORT

QUEANBEYAN-PALERANG REGIONAL COUNCIL

BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

JUNE 2019

VOLUME 1 – REPORT

DRAFT REPORT FOR PUBLIC EXHIBITION

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FOREWORD

NSW Government's Flood Policy

The NSW Government's Flood 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 risk management responsibilities. The Policy provides for technical and financial support by the State through the following four sequential stages:

1.	Data Collection and Flood Study	Collects flood related data and undertakes an investigation to determine the nature and extent of flooding.
2.	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3.	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4.	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 procedures.

Presentation of Study Results

The results of the flood study investigations commissioned by Queanbeyan Palerang Regional Council have been presented in two separate reports:

- *Braidwood Creeks Flood Study* (Cardno Willing, 2005).
- ***Braidwood Floodplain Risk Management Study & Plan (this present report)***

The studies have been prepared under the guidance of the Floodplain Risk Management Committee comprising representatives from Queanbeyan-Palerang Regional Council, the NSW Office of Environment and Heritage and the NSW State Emergency Service.

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ACKNOWLEDGEMENT

Queanbeyan-Palerang Regional 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 Office of Environment and Heritage.

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff (2016 Edition)
AWS	All Weather Station
BoM	Bureau of Meteorology
Council	Queanbeyan-Palerang Regional Council
DCP	Development Control Plan
DECC	Department of Environment and Climate Change
FDM	Floodplain Development Manual, 2005
FPL	Flood Planning Level (1% AEP flood level + freeboard)
FPA	Flood Planning Area (area inundated at the FPL)
FRMS	Floodplain Risk Management Study
FRMP	Floodplain Risk Management Plan
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
LiDAR	Light Detection and Ranging
MFL	Minimum Floor Level
NSW SES	New South Wales State Emergency Service
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
VP	Voluntary Purchase

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SUMMARY

S1 Study Objectives

Queanbeyan-Palerang Regional Council (**Council**) commissioned the *Floodplain Risk Management Study and Plan* for the township of Braidwood. The overall objectives of the *Floodplain Risk Management Study (**FRMS**)* were to assess the impacts of flooding, review existing Council policies as they relate to development of land in flood liable areas, consider options for the management of flood affected land and to develop a *Floodplain Risk Management Plan (**FRMP**)* which:

i) Proposes modifications to existing Council policies to ensure that the development of flood affected land is undertaken so as to be compatible with the flood hazard and risk.

ii) Proposes *Flood Planning Levels* for the various land uses in the floodplain.

iii) Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding.

iv) Provides a program for implementation of the proposed works and measures.

The FRMS focuses on **Main Stream Flooding** along Gillamatong Creek, Monkittee Creek, Mona Creek, Flood Creek and Recreation Ground Creek, **Minor Tributary Flooding** that occurs along an unnamed tributary which joins Monkittee Creek downstream of the Wallace Street bridge, and **Major Overland Flow** in parts of the Recreation Ground Creek catchment. **Figure 2.1** shows the existing drainage system at Braidwood.

S2 Study Activities

The activities undertaken in this *FRMS* included:

1. Undertaking a consultation program over the course of the study to ensure that the Braidwood community was informed of the objectives, progress and outcomes over the course of the study (**Chapter 1** and **Appendix A**).
2. Review and updating of flooding patterns in Braidwood for flood events up to the Probable Maximum Flood (**PMF**). (**Chapter 2**, as well as **Appendices B** and **C**).
3. Assessment of the economic impacts of flooding, including the numbers of affected properties and estimation of flood damages (**Chapter 2** and **Appendix D**).
4. Review of current flood related planning controls for Braidwood and their compatibility with flooding conditions (**Chapter 2**).
5. Strategic review of potential floodplain risk management works and measures aimed at reducing flood damages, including an economic assessment of the most promising measures (**Chapter 3** and **Appendix E**).
6. Ranking of works and measures using a multi-objective scoring system which took into account economic, financial, environmental and planning considerations (**Chapter 4**).
7. Preparation of a *FRMP* for the town (**Chapter 5**).

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S3 Summary of Flood Impacts

Figures 2.2 and **2.3** show the indicative extent and depths of inundation of both the 1% annual exceedance probability (**AEP**) and Probable Maximum Flood (**PMF**) events, respectively, while **Figure 2.4** shows design water surface profiles along Gillamatong Creek, Monkittee Creek, Flood Creek and Recreation Ground Creek. **Figure 2.5** shows the time of rise of floodwaters, while **Figure 2.6** shows the indicative extent of flooding at Braidwood for the 20%, 5%, and 1% AEP events, as well as the PMF event.

While water levels in the major creeks which run through Braidwood are relatively slow rising, typically taking a little over six hours to reach their peak, flooding on Recreation Ground Creek and the aforementioned unnamed tributary is of a flash flooding nature, with water levels typically rising to their peak in less than one hour.

While hazardous in nature, flooding along Gillamatong Creek, Monkittee Creek and Flood Creek is generally confined to the immediate overbank areas of the three watercourses for events up to 1% AEP in magnitude. While floodwater surcharges the inbank area of Recreation Ground Creek and the aforementioned unnamed tributary, it is relatively shallow and slow moving in nature for events up to 1% AEP in magnitude. As a result, overbank flooding in these two catchments is generally of a low hazard nature.

At the 1% AEP level of flooding, fifteen residential properties would be flood affected (i.e. water has entered the allotment), five of which would experience above-floor inundation. Of these five properties three are subject to Main Stream Flooding, while the remaining two are subject to Major Overland Flow. A 1% AEP event would also result in above-floor inundation in one commercial property and one public building. All the buildings that would experience above-floor inundation in a 1% AEP event are located in the Recreation Ground Creek catchment. The total flood damages in Braidwood resulting from a 1% AEP flood event would amount to $0.49 Million, increasing to $9.52 Million for a PMF event.

The "*Present Worth Value*" of damages resulting from all floods up to the magnitude of the 1% AEP at a seven per cent discount rate and a 50 year economic life is $0.6 Million. This number represents the amount of capital spending which would be justified if a particular flood mitigation measure prevented flooding for all properties in Braidwood up to the 1% AEP event.

S4 Flood Risk and Development Controls

Recommendations have been included in the *FRMS* (**Appendix E**) for updating the wording in *Palerang Development Control Plan 2015* (***Palerang DCP 2015***). The recommended updates are based on the concepts of *flood hazard* and *hydraulic categorisation* and are aimed at imposing a graded set of controls over development according to the flood risk. The delineation of flood hazard zones is based on the proximity to flow paths, depths and velocities of flow, the rate of rise of floodwaters and ease of evacuation from the floodplain in the event of a flood emergency.

Figure E1.1 in **Appendix E** is an extract from the *Flood Planning Map* relating to Braidwood and its immediate environs. The extent of the Flood Planning Area (**FPA**) (the area subject to flood related development controls) is shown in a solid red colour on the *Flood Planning Map* and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 500 mm freeboard.
- In areas subject to Minor Tributary Flooding, the FPA is defined as areas where depths of inundation in a 1% AEP event exceed 100 mm.

- In areas subject to Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm.

Minimum floor level requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The minimum floor levels for all land use types in Braidwood is the level of the 1% AEP flood event plus 500 mm freeboard.

S5 The Floodplain Risk Management Plan

The *FRMP* showing recommended flood management measures for Braidwood is presented in **Table S1**. They have been given a provisional priority ranking, confirmed by the Floodplain Risk Management Committee, according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report.

The *FRMP* comprises four "non-structural" management measures which could be implemented by Council with the assistance of New South Wales State Emergency Service (**NSW SES**), using existing data and without requiring Government funding. The measures are as follows:

- **Measure 1** – Updating of the wording in Clause 6.2 of *Palerang Local Environmental Plan 2014* (***Palerang LEP 2014***) titled *Flood planning*. The changes to *Palerang LEP 2014* will provide flexibility in defining the FPL in areas subject to different types of flooding across the whole of the local government area and for ease of implementing **Measure 2**.
- **Measure 2** - The application of a graded set of planning controls for future development that recognise the location of the development within the floodplain; to be applied through an update of the wording in the *Palerang Development Control Plan 2015* (***Palerang DCP 2015***). Recommended wording for inclusion in *Palerang DCP 2015* is set out in **Appendix E**. Adoption of the recommended updates will ensure that future development in flood liable areas at Braidwood is compatible with the flood risk.
- **Measures 3** - Improvements in the NSW SES's emergency planning, including use of the flood related information contained in this study to update the *Palerang Local Flood Plan* which is dated April 2013 (***Palerang Local Flood Plan 2013***). Information in this present report which would be of assistance to NSW SES includes data on the nature and extent of flooding in Braidwood, times of rise of floodwaters, duration and depth of inundation at major road crossings for a range of flood events and properties affected by flooding.
- **Measure 4** - Council should take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplain of the flood risk. This could be achieved through the preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

The FRMP also comprises the following flood modification measure which would require Government funding to facilitate its implementation:

- **Measure 5** – The development and implementation of a *Vegetation Management Plan* for Recreation Ground Creek. This would reduce the risk of the existing road crossings becoming blocked by flood debris and reduce the frequency of nuisance flooding.

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S6 Council Action Plan

1. Floodplain Risk Management Committee to consider and adopt recommendations of this study. In particular, the Committee should review the basis for ranking floodplain risk management measures (as set out in **Table 4.1** of the *FRMS* and the proposed works and measures to be included in the *FRMP* as set out in **Table S1**); exhibit the *FRMS* and *FRMP* and seek community comment.

2. Consider public comment, modify the document if and as required, and submit to Council.

3. Council adopts the *FRMP*.

4. Council and NSW SES commence work on the "non-structural" measures comprising the *FRMP* (**Measures 1**, **2**, **3** and **4**)

5. Council applies for Government Funding for the development and implementation of a *Vegetation Management Plan* for Recreation Ground Creek (**Measure 5**).

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TABLE S1
RECOMMENDED MEASURES FOR INCLUSION IN
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT PLAN

Measure	Required Funding	Features of the Measure	Priority
1. Update of *Palerang LEP 2014*	Council's staff costs	• Update wording in clause 6.2 of *Palerang LEP 2014* titled *Flood planning* to reflect the recommended approach to defining the FPL.	**Priority 1**: this measure is designed to reduce the flood risk to future development and has a high priority for inclusion in the *FRMP*.
2. Incorporate recommended set of controls into an update of *Palerang DCP 2015*.	Council's staff costs	• Control development in floodplain as presented in **Appendix E** of the *Braidwood Floodplain Risk Management Study and Plan 2019*. • Graded set of flood controls based on the type of development and their location within the floodplain, defined as land inundated by the Probable Maximum Flood. • Floodplain divided into four hazard zones: **Inner Floodplain (Hazard Category 1)**, **Inner Floodplain (Hazard Category 2)**, **Intermediate Floodplain** and **Outer Floodplain**. • Graded set of flood controls based on location within the Flood Planning Area (**FPA**) (the area that lies below the Flood Planning Level (**FPL**) and is subject to flood related development controls). For areas affected by Main Stream Flooding, the FPA is defined as land which lies below the peak 1% AEP flood level plus 500 mm, while for areas affected by Minor Tributary Flooding, the FPA is defined as areas where depths of inundation in a 1% AEP event exceed 100 mm. For areas affected by Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm. • The minimum floor level requirement for residential development to be 1% AEP flood level plus 500 mm. Critical services, educational establishments (e.g. schools) flood-vulnerable residential development (e.g. housing for aged persons and persons with disabilities) to be subject to more stringent controls than other land uses. • Council's evaluation of development proposals to use data presented in this *FRMS*.	**Priority 1**: this measure is designed to mitigate the flood risk to future development and has a high priority for inclusion in the *FRMP*.
3. Ensure flood data in this *FRMS* are available to the NSW SES for improvement of flood emergency planning.	NSW SES costs	• NSW SES to update the *Palerang Local Flood Plan 2013* using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in this *FRMS*.	**Priority 2**: this measure would improve emergency response procedures.
4. Implement flood awareness and education program for residents bordering the creeks.	Council staff and NSW SES costs	• Council to inform residents and business owners of the flood risk, based on the information presented in the *FRMS*. (e.g. displays of flood mapping at Council offices, preparation of *Flood Information Brochure* for distribution with rate notices, etc).	**Priority 2**: this measure would improve the flood awareness of the community.
5. Develop and implement a *Vegetation Management Plan* for Recreation Ground Creek.	$50,000	• The *Vegetation Management Plan* will identify areas which require regular maintenance along Recreation ground Creek. It will also describe the scope of any rehabilitation works which would be required following the completion of any inbank works. • The required funding would permit the development of the *Vegetation Management Plan*, the removal of dense vegetation from the inbank area of the watercourse and the implementation of a regular maintenance program over a five year period.	**Priority 2**: this measure reduce the risk of a blockage being experienced at the various road crossings, as well as reduce the frequency of nuisance flooding.

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1 INTRODUCTION

1.1 Study Background

Queanbeyan-Palerang Regional Council (**Council**) commissioned the preparation of the *Floodplain Risk Management Study and Plan* (***FRMS&P***) for the township of Braidwood in accordance with the New South Wales Government's *Flood Prone Land* policy. This report sets out the findings of the *FRMS&P* investigation which utilised new flood models that were developed as part of the present study (***Updated Flood Study***).

The *Floodplain Risk Management Study* (***FRMS***) reviewed and updated baseline flooding conditions, including an assessment of economic impacts and the feasibility of potential measures aimed at reducing the impact of flooding on both existing and future development. This process allowed the formulation of the *Floodplain Risk Management Plan* (***FRMP***) for Braidwood.

1.2 Background Information

The following documents were used in the preparation of this report.

- *Floodplain Development Manual* (New South Wales Government (NSWG), 2005)
- *Palerang Local Environmental Plan 2014*
- *Palerang Development Control Plan 2015* (Queanbeyan-Palerang Regional Council, 2015)
- *Braidwood Creeks Flood Study* (***Flood Study***) (Cardno Willing, 2005)

1.3 Overview of FRMS Report

The results of the *FRMS* and the *FRMP* are set out in this report. Contents of each Chapter of the report are briefly outlined below:

- **Chapter 2**, **Baseline Flooding Conditions**. This Chapter includes a description of the drainage system and a review of existing flood behaviour at Braidwood as derived by the *Updated Flood Study*. The Chapter also summarises the economic impacts of flooding on existing urban development, reviews Council's existing flood related planning controls and management measures and NSW State Emergency Service's (**NSW SES's**) flood emergency planning. The Chapter concludes with an assessment of the impact future urbanisation in Braidwood, as envisaged by the *Palerang Local Environmental Plan 2014*, and potential increases in rainfall intensities linked to future climate change would have on flooding behaviour.
- **Chapter 3**, **Potential Floodplain Risk Management Measures**. This Chapter reviews the feasibility of floodplain risk management options for their possible inclusion in the *FRMP*. The list of measures considered is based on input from the Community Consultation process, which sought the views of residents and business owners at Braidwood in regard to potential flood management measures which could be included in the *FRMP*. The measures are investigated at the strategic level of detail, including indicative cost estimates of the most promising measures and benefit/cost analysis.
- **Chapter 4**, **Selection of Floodplain Risk Management Measures**. This Chapter assesses the feasibility of potential floodplain risk management strategies using a multi-objective scoring procedure which was developed in consultation with the Floodplain Risk Management Committee and outlines the preferred strategy.

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- **Chapter 5** presents the ***Floodplain Risk Management Plan***. The *FRMP* comprises a number of non-structural measures which are aimed at increasing the flood awareness of the community and ensuring that future development is undertaken in accordance with the local flood risk. One structural measure was also included in the *FRMP* to further reduce flood risk and damages to existing development.
- **Chapter 6** contains a glossary of terms used in the study.
- **Chapter 7** contains a list of References.

Five technical appendices provide further information on the study results:

Appendix A – Community Consultation summarises residents' and business owners' views on potential flood management measures which could be incorporated in the *FRMP*.

Appendix B – Hydrologic and Hydraulic Modelling contains a series of figures which are bound in Volume 2 of the report showing the layout of the hydrologic and hydraulic models that were developed as part of the present study, as well as flooding behaviour at Braidwood for a range of design storm events.

Appendix C - Differences in Design Flood Estimation for Braidwood - ARR1987 versus ARR2016 sets out the findings of an investigation which was undertaken to assess the difference between design peak flows derived using the procedures set out in the 1987 and 2016 editions of Australian Rainfall and Runoff. Also presented in the Appendix are the results of modelling the 1% AEP flood event at Braidwood based on the application of the two sets of procedures.

Appendix D – Flood Damages is an assessment of the economic impacts of flooding to existing residential, commercial and industrial development, as well as public buildings in Braidwood. The damages have been assessed using the results of the *Updated Flood Study*, an estimate of floor levels and characteristics of affected development derived from a combination of a "drive-by" property survey and use of Google Street View, as well as data from LiDAR survey.

Appendix E – Recommended Updates to Palerang Development Control Plan 2015 presents guidelines for the control of future urban development in flood prone areas at Braidwood, noting that the guidelines only cater for main stream flooding in and around the urban areas of the township.

Figures referred to in this report are bound in a separate A3 volume (**Volume 2**).

1.4 Community Consultation

Following the Inception Meeting of the Floodplain Risk Management Committee which included Council, the NSW Office of Environment and Heritage (**OEH**) and NSW SES, a *Community Newsletter* was prepared by the Consultants and distributed to residents and business owners by Council. The Newsletter contained a *Community Questionnaire* seeking the community's views on potential floodplain risk management options. Community responses are summarised in **Chapter 3** of the report, with supporting information in **Appendix A**.

The Floodplain Risk Management Committee reviewed the potential flood management measures developed in **Chapter 3** and assessed the measures using the proposed scoring system of **Chapter 4**. The *FRMS* and accompanying *FRMP* were also reviewed by the Floodplain Risk Management Committee and amended prior to public exhibition.

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1.5 Flood Frequency and Terminology

In this report, the frequency of floods is referred to in terms of their Annual Exceedance Probability (**AEP**). The frequency of floods may also be referred to in terms of their Average Recurrence Interval (**ARI**). 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
5	20
20	5

The AEP of a flood represents the percentage chance of it being equalled or exceeded in any one year. Thus a 1% AEP flood, which is equivalent to a 100 year ARI, has a 1% chance of being equalled or exceeded in any one year and would be experienced, on the average, once in 100 years; similarly, a 20 year ARI flood has a 5% chance of exceedance, and so on.

The 1% AEP flood (plus freeboard) is usually used to define the Flood Planning Level (**FPL**) and Flood Planning Area (**FPA**) for the application of flood related planning controls over residential development. While a 1% AEP flood is a major flood event, it does not define the upper limit of possible flooding. Over the course of a human lifetime of, say 70 years, there is a 50 per cent chance that a flood at least as big as a 1% AEP event will be experienced. Accordingly, a knowledge of flooding patterns in the event of larger flood events up to the Probable Maximum Flood (**PMF**), the largest flood that could reasonably be expected to occur, is required for floodplain and emergency management purposes. In the *Flood Study Update*, flooding patterns were assessed for design floods ranging between a 20% AEP event and the PMF.

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2 BASELINE FLOODING CONDITIONS

2.1 Physical Setting

The township of Braidwood is located approximately 50 km to the east of Queanbeyan in the Shoalhaven River basin. Braidwood and its setting are of state significance as they represent an example of a Georgian period town plan dating back to the 1830s. As a result, both the town and its setting were listed on the New South Wales State Heritage Register on 3 April 2006. The population of Braidwood was about 1650 at the time of the 2016 census.

Braidwood is located in the middle reaches of the Gillamatong Creek system at the confluence of Monkittee Creek and Flood Creek (refer **Figure 1.1**). The catchment upstream of Braidwood is characterised by hilly pastoral land, with Monkittee Creek and Flood Creek having a combined catchment area of about 70 km² at their confluence.

Future development in Braidwood is mainly located to the south of the main commercial area of town along Araluen Road and in the vicinity of Badgery Street. Low density residential development is also occurring along Hassall Circuit.

2.2 Drainage System

Figure 2.1 (3 sheets) shows the layout of the existing drainage system at Braidwood.

As mentioned, the township of Braidwood is located at the confluence of Monkittee Creek and Flood Creek. Monkittee Creek has a catchment area of about 43 km² and generally forms the northern limit of the town, while Flood Creek has a catchment area of about 27 km² and generally forms the southern limit of the town. Both streams are characterised by relatively confined floodplains, with their main channels remaining in a largely natural state.

Both MacKellar Creek and Mona Creek join Monkittee Creek upstream of the township, while an unnamed watercourse (denoted herein as the "Unnamed Tributary") joins Monkittee Creek on its northern bank a short distance downstream of the Wallace Street bridge crossing.

Recreation Ground Creek joins Flood Creek a short distance downstream of Archer Bridge on Coghill Street and controls a catchment area of about 2.5 km². The main channel of Recreation Ground Creek has been highly modified where it runs through the urbanised parts of the town and is characterised by an incised channel which is densely vegetated.

While not shown on **Figure 2.1**, the local stormwater drainage system in the township generally comprises either kerb and gutter or roadside table drains, with minor transverse drainage structures and converter pits located at road intersections. As a result, relatively deep and fast flowing major overland flow can occur in the road reserves during intense rainfall events.[1]

[1] Note that with the exception of an area in the vicinity of the Braidwood Recreation Ground, the assessment of major overland flow and its impact on existing development does not form part of the scope of work for the *FRMS*.

2.3 Recent Flood Experience

The *Flood Study* makes reference to two major floods that have occurred in Braidwood dating back to 1925. The earliest identified flood occurred in 1925 when daily rainfall records show that about 356 mm of rain fell over the consecutive rain days of 27-30 May 1925, while the more recent flood occurred in 1978 when about 295 mm of rain fell over the consecutive rain days of 20-23 March 1978. The *Flood Study* identified the availability of one flood mark for the May 1925 flood and two flood marks for the March 1978 flood.

An article in the *Goulburn Herald* dated 18 February 1860 and entitled "Fatal Flood at Braidwood" makes reference to major flooding that occurred in the Braidwood area in February 1860 and the fact that there were several fatalities and widespread damage to property as a result of the event.

Another article contained in *The Braidwood Dispatch and Mining Journal* dated 19 February 1898 and entitled "The Floods in the Braidwood District – Braidwood and Environs" states the following:

> *"The weather took up on Wednesday. After a fine warm day on Tuesday a thunderstorm broke over the district on Tuesday evening, the rain falling in torrents for several hours. The gauge at the Post Office on Wednesday morning registered 180 points* [64 mm[2]], *making a total of 1234 points* [435 mm] *since the previous Saturday. The Bedervale gauge gave the rainfall up to Wednesday at 1652 points* [583 mm]. *The immense volume of water which was brought down by the rains between Saturday and Monday night was altogether unparalleled in the district during the time. Even the big flood of 1860, the highest that was ever known here, when there were so many lives lost and so much damage done at Araluen, Little River and other gold fields upon which there were thousands of men then engaged in mining, was very little if any higher than the flood at the beginning of the week, as the rain at that time lasted a week, while it all fell on this occasion in little more than 48 hours, with the exception of some 10 points* [3.5 mm] *on Thursday and Friday. According to the gauge at Bedervale, which is always very carefully kept by Mr. C. Maddrell, there were 140 points* [49 mm] *on Sunday morning, 900* [318 mm] *on Monday, 430* [152 mm] *on Tuesday, and 171* [60 mm] *on Wednesday which was the quantity which fell in about 2 hours until 11 p.m. on Tuesday during the heavy thunderstorm. From Sunday morning until Tuesday morning nearly 15 inches* [381 mm] *fell, and at Mongarlowe, Monga, and Reidsdale the fall greatly exceeded this, and it is estimated that it was fully up to what fell in Araluen up to Monday morning, 27½ inches* [699 mm], *without reckoning the thunderstorm on Tuesday night.*
>
> *Gillamatong Creek was a roaring torrent instead of a small meandering brook as it usually is. It rose 18ft* [5.5 m] *and on Monday morning the waters came galloping along like a racehorse, rolling over in foam-erected waves like the angry ocean. The Chinese garden just above the town was washed clean out, not only of all the vegetables which were growing so prolifically, notwithstanding the drought by the aid of irrigation, but of most of its soil as well. The fencing on either side from Monkittee to the Shoalhaven River was swept away like thistledown on the face of the waters, and along with cattle and horses which came within reach of the swollen stream, was the nightsoil cart of the Municipal Council, which, after being entangled in the fluming and other timber carried away from the Colombo Co's race, got free again and was afterwards seen riding the waves about a mile above the Warri Bridge in a much more*

[2] Depths quoted in millimetres (mm) have been rounded to the nearest millimetre.

graceful manner than that in which it did its work on shore, its wheels going round like the paddles wheels of a steamer. The last that was seen of it was by a farmer looking after his cattle, he espying one of his heifers in it, with its head just above the top of the sanitorium, which he recognised by the earmark. No doubt it will pull up somewhere before it reaches the falls below Nerriga."

While there has been several intense short duration rainfall events since the completion of the *Flood Study* in 2005 which have resulted in surcharge of the local stormwater drainage system in parts of the town, major flooding has been limited to a storm that occurred on 7 February 2019, when a number of properties that are located along Recreation Ground Creek were inundated by floodwater.[3] Records show that a total of 79.4 mm fell in Braidwood to 9 am on 8 February 2019,[4,5] which had it occurred over a two hour period[6] would have equated to a storm with an equivalent AEP of between 2 and 1 per cent. Flood marks surveyed by Council following the event also indicate that the storm generated peak flood levels that were equivalent to a design flood event of between 2 and 1% AEP.

2.4 Design Flood Behaviour

2.4.1 Background to Flood Study

The *Flood Study* defined the nature of main stream flooding in the study area for storms ranging between 20% and 1% AEP, as well as the PMF event. Flood behaviour was defined using a two-staged approach to flood modelling involving the running in series of:

1. The hydrologic model of the study catchments which was based on the XP-RAFTS rainfall-runoff software.
2. The hydraulic model of the study creeks which was based on the XP-SWMM software.

The RAFTS model was used to compute discharge hydrographs which were then applied to the XP-SWMM hydraulic model. Design storms were derived using procedures set out in *Australian Rainfall and Runoff* (**ARR1987**) (IEAust, 1987) and then applied to the RAFTS model to generate discharge hydrographs. These hydrographs constituted input to the XP-SWMM hydraulic model.

The XP-SWMM model used a quasi-two-dimensional (in plan) cross sectional based representation of natural surface levels along the study creek. The model also included details of existing culvert and bridge structures. Field survey was used to derive cross sections normal to the direction of flow.

It was not possible to calibrate the XP-RAFTS hydrologic model as only daily rainfall totals are available for the May 1925 and March 1978 flood events and there are no stream gauges located in the Gillamatong Creek system at Braidwood. Rather, it was necessary to adopt an iterative approach whereby the hydrologic and hydraulic model were run in series, with changes made to model parameters until a reasonable match was achieved with the three available historic flood marks.

[3] Council advised that there were no reports of above-floor inundation.

[4] Source: BoM operated daily read rain gauge *Braidwood (Wallace Street)* (Station No. 069010) which is located on Wallace Street in Braidwood.

[5] While there is an All Weather Station (**AWS**) located a short distance to the north of Braidwood (*Braidwood Racecourse AWS* (Station No. 069132)) it only recorded a total of 54.4 mm to 9 am on 8 February 2019.

[6] Council advised that heavy rain fell over a period of approximately one to one and a half hours.

A series of figures were prepared as part of the *Flood Study* showing the indicative extent of inundation for the assessed design flood events. The floodplain was also divided into low and high hazard floodway, flood storage and flood fringe areas for the 1% AEP design flood event. One of the limitations of the flood extent mapping contained in the *Flood Study* is that it was based on the survey irregularly spaced cross section data and the available ground contour information which had an interval of 10 m.[7]

2.4.2 Background to Development of Updated Flood Models

During the Inception Meeting when an inspection of the study creeks was carried out by representatives from Council and OEH, it was agreed that the flood extent mapping was not necessarily accurate, especially in the case of flooding on Recreation Ground Creek. With the availability of more detailed LiDAR survey data it was agreed that the *FRMS* would benefit from undertaking more detailed two-dimensional (in plan) hydraulic modelling of Recreation Ground Creek. In subsequent discussions with OEH it was agreed that it would be beneficial to update the flood mapping for the whole of the study area requiring the extension of the two-dimensional (in plan) hydraulic modelling to include all of the study creeks.

A new hydrologic model was developed as part of the *FRMS* to enable design discharge hydrographs to be used as input to the two-dimensional (in plan) hydraulic modelling. The hydrologic response of the rural and urban parts of the study catchment was simulated using the RAFTS and ILSAX sub-models in the DRAINS software, respectively.

Figure B2.1 (2 sheets) in **Appendix B** shows the sub-catchment areas that were modelled using the RAFTS and ILSAX sub-models in DRAINS. The outlets of the sub-catchments in the headwaters of the study area were linked and the lag times between each assumed to be equal to the distance along the main drainage line divided by an assumed flow velocity of 1 m/s.

Percentages of impervious area were assessed using the available aerial photography and cadastre boundary data. Sub-catchment slopes used for input to the RAFTS component of the hydrologic model were derived using the vectored average slope approach. The available LiDAR derived contour data was used as the basis for computing the slope for both methods.

The design discharge hydrographs generated by the new hydrologic model (refer **Figure B2.2** in **Appendix B**) were used as input to a new hydraulic model which was used to define the nature of main stream flooding at Braidwood. The TUFLOW software was used for this purpose.

Figure B3.3 (3 sheets) in **Appendix B** shows the layout of the various components which comprise the TUFLOW model that was developed for Braidwood. A 3 m grid spacing was found to provide the appropriate balance between the need to define features along the study creeks versus model run times. Grid data were derived from the LiDAR survey of the floodplain, with ridge and gully lines added to the model where the grid spacing was considered too coarse to accurately represent important topographic features.

The footprints of a large number of individual buildings located adjacent to the study were digitised and assigned an artificially high hydraulic roughness value which accounted for their blocking effect on flow while maintaining storage in the model. Individual allotments along the overbank flow paths where development is present were also digitised and assigned an artificially high hydraulic roughness value (although not as high as for individual buildings) to account for

[7] The error in contour mapping is typically stated as being equal to ± half a contour interval, which in this case is ± 5 m.

the reduction in conveyance capacity which will result from fences and other obstructions stored on these properties.

Figure B3.4 in **Appendix B** is a typical example of flow patterns derived from the assigning of different roughness values to the floodplain. This example applies for the 1% AEP design storm event and shows flows through the Braidwood Recreation Ground as well as adjacent development.

2.4.3 Design Flood Estimation

The Study Brief required that the design flood data contained in the *Flood Study* be updated in accordance with the procedures set out in the 2016 version of Australian Rainfall and Runoff (**ARR2016**) (Geoscience Australia, 1987). **Appendix C** deals with the investigation which was carried out using the hydrologic and hydraulic models described in **Section 2.4.2** to assess the differences in design flood estimation based on the procedures set out in ARR1987 and ARR2016

The investigation found that the application of the procedures set out in ARR2016, which included the adoption of updated design intensity-frequency-duration data results in a reduction in peak flow estimates at Braidwood of between about 43% and 48% when compared to those derived using the procedures set out in ARR1987. The reduction in peak flows is attributed to a 21-23% reduction in design rainfall intensities associated with ARR2016, in combination with differences in the temporal variability of the design rainfall.[8]

Based on the findings of the investigation and in the knowledge that at the time of writing the authors of ARR2016 are in the processes of reassessing the recommended storm and pre-burst losses for NSW, it was concluded that the findings of the *Flood Study* should be updated using the procedures set out in ARR1987 in combination with the flood models described in **Section 2.4.2**.

2.4.4 Design Flooding Patterns

Figures 2.3 and **2.4** (3 sheets each) show the indicative depths of above-ground inundation at Braidwood for the 1% AEP and PMF events, respectively, as well as the indicative depth of above-floor inundation of individual properties in these two design flood events. Similar information is shown on **Figures B3.3** to **B3.7** in **Appendix B** for floods with AEPs of 20, 5, 2, 0.5 and 0.2 per cent.

While flood flows are generally confined to the main channels of Monkittee Creek and Flood Creek and their immediate overbank areas for floods up to 0.2% AEP in magnitude, floodwater surcharges the inbank area of Recreation Ground Creek during relatively frequent storm events where it impacts existing development. Development located to the south of the Kings Highway is also impacted by major overland flow which discharge to Recreation Ground Creek in the vicinity of the Braidwood Recreation Ground.

Figure 2.5 shows the design water surface profiles along the study creeks, while **Figure 2.6** shows discharge and stage hydrographs at several road crossings for the range of assessed flood events.

[8] Runs of the Braidwood Hydrologic Model showed that the adoption of the 10 off ARR2016 ensemble based temporal patterns lead to greater than a 20% reduction in the peak 1% AEP flow estimate when compared to the ARR1987 single storm based temporal pattern (Note that the rainfall intensity was kept the same and a zero loss model was adopted).

A key finding of the *Updated Flood Study* is that all the road crossings of the study creeks with the exception of the Wallace Street crossings of Monkittee Creek and Recreation Ground Creek have a hydrologic standard of less than 20% AEP. In regards the Wallace Street crossing of Monkittee Creek, the modelling shows that the northern approach to the existing bridge is surcharged during a 2% AEP flood event to a depth of about 0.2 m, with both approaches including the deck of the bridge inundated during a 1% AEP event.

2.5 Existing Flood Mitigation Measures

Existing flood mitigation measures in Braidwood are limited to the recent upgrade of the existing culverts on Wallace Street where it crosses Recreation Ground Creek. As shown on **Figure 2.5**, the new culvert crossing has a hydrologic standard of between 0.5% and 0.2% AEP.

2.6 Economic Impacts of Flooding

The economic consequences of floods are discussed in **Appendix D**, which assesses flood damages to residential, commercial and industrial property and public buildings in areas affected by principally main stream flooding. There were only limited data provided by respondents to the *Community Questionnaire* on historic flood damages to the urban sectors in the study area. Accordingly, it was necessary to use data on damages experienced as a result of historic flooding in other urban centres. The residential flood damages were based on the publication *Floodplain Risk Management Guideline No. 4, 2007* (**Guideline No. 4**) published by the Department of Environment and Climate Change (**DECCW**) (now OEH). Damages to industrial and commercial development, as well as public buildings were evaluated using data from previous floodplain risk management investigations in NSW.

It is to be noted that the principal objectives of the damages assessment were to gauge the severity of urban flooding likely to be experienced at Braidwood and also to provide data to allow the comparative economic benefits of various flood modification measures to be evaluated in **Chapter 3** of the report. As explained in **Appendix D**, it is not the intention to determine the depths of inundation or the damages accruing to *individual properties*, but rather to obtain a reasonable estimate of damages experienced over the extent of the urban area in the town for the various design flood events. The estimation of damages using *Guideline No. 4* (in lieu of site specific data determined by a loss adjustor) also allows a uniform approach to be adopted by Government when assessing the relative merits of measures competing for financial assistance in flood prone centres in NSW.

Damages were estimated for the design flood levels determined from the hydraulic modelling undertaken as part of the present investigation. Elevations of the floors of affected properties were estimated by a "drive-by" survey which assessed the height of the floor above local natural surface elevations. These natural surface elevations were derived from the LiDAR survey data used to construct the aforementioned TUFLOW model. The number of properties predicted to experience "above-floor" inundation as a result of main stream flooding, together with estimated flood damages is listed in **Table 2.1** over.

At the 1% AEP level of flooding, five dwellings, one commercial building and one public building are subjected to above-floor inundation, all of which are located in the Recreation Ground Creek catchment (refer **Figure 2.3** for the location of the affected properties), while in the PMF event, 87 dwellings, six commercial buildings and two public buildings would experience above-floor inundation (refer **Figure 2.4** for the location of the affected properties).

The total flood damages in Braidwood amounts to $0.49 Million in the event of a 1% AEP flood, increasing to about $9.5 Million in a PMF event. For a discount rate of 7% pa and an economic

life of 50 years, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $0.6 Million. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Braidwood 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. Flood management measures are considered on a multi-objective basis in **Chapter 4**.

TABLE 2.1
FLOOD DAMAGES AT BRAIDWOOD

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	5	1	0	0	0	0	0.10
5	8	2	1	1	1	0	0.20
2	13	4	1	1	1	1	0.39
1	15	5	2	1	1	1	0.49
0.5	22	7	2	1	1	1	0.71
0.2	27	12	2	2	1	1	1.09
PMF	113	87	7	6	2	2	9.52

2.7 Impact of Flooding on Vulnerable Development and Critical Infrastructure

Figure 2.6 shows the location of vulnerable development and critical infrastructure relative to the extent of the inundation resulting from the 20%, 5% and 1% AEP flood events, as well as the PMF event. With the exception of the major road crossings and the existing sewage pumping stations, all vulnerable development and critical infrastructure at Braidwood is located off the floodplain.

2.8 Flood Hazard and Hydraulic Categorisation of the Floodplain

2.8.1 General

According to Appendix L of *NSWG, 2005*, in order to achieve effective and responsible floodplain risk management, it is necessary to divide the floodplain into areas that reflect:

1. The impact of flooding on existing and future development and people. To examine this impact it is necessary to divide the floodplain into *"flood hazard"* categories, which are provisionally assessed on the basis of the velocity and depth of flow. This task was undertaken in the *Flood Study* where the floodplain was divided into *Low Hazard* and *High Hazard* zones. In this present report, a *final determination* of hazard was undertaken which involved consideration of a number of additional factors which are site specific to the study area. **Section 2.9.2** below provides details of the procedure adopted.

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2. The impact of future development activity on flood behaviour. Development in active flow paths (i.e. *"floodways"*) has the potential to adversely re-direct flows towards adjacent properties. Examination of this impact requires the division of flood prone land into various *"hydraulic categories"* to assess those parts which are effective for the conveyance of flow, where development may affect local flooding patterns. Hydraulic categorisation of the floodplain was also undertaken in the *Flood Study* and was reviewed and updated in this present study. **Section 2.9.3** below summarises the procedure adopted.

2.8.2 Flood Hazard Categorisation

As mentioned above, flood prone areas may be *provisionally* categorised into *Low Hazard* and *High Hazard* areas depending on the depth of inundation and flow velocity. A flood depth of 1 m in the absence of significant flow velocity represents the boundary between *Low Hazard* and *High Hazard* conditions. Similarly, a flow velocity of 2.0 m/s but with a small flood depth around 200 mm also represents the boundary between these two conditions. Interpolation may be used to assess the hazard for intermediate values of depth and velocity. Flood hazards categorised on the basis of depth and velocity only are *provisional*. They do not reflect the effects of other factors that influence hazard.

These other factors include:

1. Size of flood – major floods though rare can cause extensive damage and disruption.
2. Effective warning time – flood hazard and flood damage can be reduced by sandbagging entrances, raising contents above floor level and also by evacuation if adequate warning time is available.
3. Flood awareness of the population – flood awareness greatly influences the time taken by flood affected residents to respond effectively to flood warnings. The preparation and promotion by Council of the *Flood Study* and *Floodplain Risk Management Study and Plan* increases flood awareness, as does the formulation and implementation of a response plan by NSW SES (*Local Flood Plan*) for the evacuation of people and possessions.
4. Rate of rise of floodwaters – situations where floodwaters rise rapidly are potentially more dangerous and cause more damage than situations in which flood levels increase slowly.
5. Duration of flooding – the duration of flooding (or length of time a community is cut off) can have a significant impact on costs associated with flooding. This duration is shorter in smaller, steeper catchments.
6. Evacuation problems and access routes – the availability of effective access routes from flood prone areas directly influences flood hazard and potential damage reduction measures.

Provisional hazard categories may be reduced or increased after consideration of the above factors in arriving at a final determination. A qualitative assessment of the influence of the above factors on the *provisional flood hazard* (i.e. the hazard based on velocity and depth considerations only) is presented in **Table 2.2** over.

Figure 2.7 shows the division of the floodplain into true high and low hazard areas, noting that the provisional categories which were derived based on the depth of inundation and flow velocity have been converted directly to true hazard following consideration of the factors set out in **Table 2.2**.

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TABLE 2.2
INFLUENCE OF FLOOD RELATED PARAMETERS ON PROVISIONAL FLOOD HAZARD

Parameter	Flood Characteristics	Influence on Provisional Hazard
Size of flood	Main stream flooding is generally confined to the main channels and immediate overbank areas of Gillamatong Creek, Monkittee Creek and Flood Creek for events up to 0.2% AEP. While floodwater surcharges the main channel of Recreation Ground Creek and the unnamed tributary during relatively frequent storm events, the resulting depths of overbank flow are relatively shallow	0
Effective warning time	Times of rise are relatively short, especially on Recreation Ground Creek and the unnamed tributary where water levels rise to their peak in less than an hour after the onset of flood producing rain. BoM maintains a storm warning service which would provide some warning for short duration 'flash flooding'.	+1
Flood awareness	While flood awareness would be relatively low within the community given major flooding has not been experienced in Braidwood for a number of years, the majority of development in the town is not impacted by main stream flooding. The exception is development located along Recreation Ground Creek where flood awareness would be relatively high given the relatively frequent occurrence of overbank flooding.	0
Rate of rise and velocity of floodwaters	Floodwaters rise relatively quickly after the onset of rain on Recreation Ground Creek and the unnamed tributary, which would provide limited warning for residents to raise contents above floor level and evacuate from the floodplain. This is somewhat offset by the limited number of properties that experience above-floor inundation during storms up to 1% AEP in intensity.	+1
Duration of flooding	The duration of flooding in Braidwood is relatively short and is in the order of a few hours.	-1
Evacuation problems	Evacuation routes to higher ground are maintained for all events up to the PMF.	-1
	OVERALL SCORE	**0**

Legend 0 = neutral impact on provisional hazard
+ 1 = tendency to increase provisional hazard
– 1 = tendency to reduce provisional hazard

2.8.3 Hydraulic Categorisation of the Floodplain

According to the *NSWG, 2005*, the floodplain may be subdivided into the following zones:

- ***Floodways*** are those areas where a significant volume of water flows during floods and are often aligned with obvious natural channels. They are areas that, even if partially blocked, would cause a significant increase in flood level and/or a significant re-distribution of flow, which may in turn adversely affect other areas. They are often, but not necessarily, areas with deeper flow or areas where higher velocities occur.
- ***Flood Storage*** 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.

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- ***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.

While the *Flood Study* incorporated a set of figures which showed the floodway, flood storage and flood fringe areas, these were reassessed for the 1% AEP flood event based on the results of the *Updated Flood Study*.

Floodplain Risk Management Guideline No. 2 Floodway Definition, offers guidance in relation to two alternative procedures for identifying floodways. They are:

- **Approach A**. Using a *qualitative approach* which is based on the judgement of an experienced hydraulic engineer. In assessing whether or not the area under consideration was a floodway, the qualitative approach would need to consider; whether obstruction would divert water to other existing flow paths; or would have a significant impact on upstream flood levels during major flood events; or would adversely re-direct flows towards existing development.
- **Approach B**. Using the hydraulic model, in this case TUFLOW, to define the floodway based on *quantitative experiments* where flows are restricted or the conveyance capacity of the flow path reduced, until there was a significant effect on upstream flood levels and/or a diversion of flows to existing or new flow paths.

One quantitative experimental procedure commonly used is to progressively encroach across either floodplain towards the channel until the designated flood level has increased by a significant amount (for example 0.1 m) above the existing (un-encroached) flood levels. This indicates the limits of the hydraulic floodway since any further encroachment will intrude into that part of the floodplain necessary for the free flow of flood waters – that is, into the floodway.

The *quantitative assessment* associated with **Approach B** is technically difficult to implement. Restricting the flow to achieve the 0.1 m increase in flood levels can result in contradictory results, especially in unsteady flow modelling, with the restriction actually causing reductions in computed levels in some areas due to changes in the distribution of flows along the main drainage line.

Accordingly the *qualitative approach* associated with **Approach A** was adopted, together with consideration of the findings of *Howells et al, 2004* who defined the floodway based on velocity of flow and depth. Howells et al suggested the following criteria for defining 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.

Adoption of the above criteria was found to provide a reasonable definition of the floodway areas at Braidwood and was therefore adopted for hydraulic categorisation mapping purposes.

Flood storage areas were 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.

Figure 2.7 shows the division of the floodplain into floodway, flood storage and flood fringe areas at the 1% AEP level of flooding.

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High hazard floodway areas are generally confined to the main channel of the study creeks and their immediate overbank areas, while low hazard floodways are generally confined to the overbank areas of Recreations Ground Creek, as well as the major overland flow paths that drain to it from the north. A low hazard floodway also develops along the lower reaches of Unnamed Tributary where it crosses the Kings Highway to the east of the location where the watercourse joins Monkittee Creek.

2.9 Potential Impacts of a Change in Hydraulic Roughness

An analysis was undertaken to assess the sensitivity of flooding behaviour to potential changes in hydraulic roughness. **Figure 2.8** (3 sheets) shows the impact that a 20% increase in the "best estimate" hydraulic roughness values would have on flooding behaviour for a 1% AEP flood event.

The analysis showed that a 20% increase in the "best estimate" hydraulic roughness values would increase peak 1% AEP flood levels on Monkittee Creek and Flood Creek by a maximum of about 300 mm, while on Recreation Ground Creek peak 1% AEP flood levels would be increased by a maximum of about 50 mm.

Based on this finding, the adoption of a freeboard of 500 mm for setting minimum floor levels in future development would cater for any potential increases in peak 1% AEP flood levels associated with changes in hydraulic roughness.

2.10 Potential Impacts of a Partial Blockage of Stormwater Drainage Structures

An analysis was undertaken to assess the impact a partial blockage of hydraulic structures would have on flooding behaviour. **Figure 2.9** (3 sheets) shows the impact a 50% blockage of those hydraulic structures that are located within the extent of the two-dimensional TUFLOW model domain would have on flooding behaviour for a 1% AEP event.

A partial blockage of the Wallace Street bridge crossing of Monkittee Creek would have a minor impact on flooding behaviour, with peak 1% AEP flood levels increased by a maximum of about 30 mm. While a partial blockage of Archer Bridge on Flood Creek would increase peak 1% AEP flood levels by about 0.2 m, the extent inundation would not increase significantly, with floodwater generally confined to the immediate overbank area of the watercourse.

A partial blockage of the recently upgraded culverts on the Wallace Street crossing of Recreation Ground Creek would result in about a 0.3 m increase in peak 1% AEP flood levels, with the resulting impacts extending into several residential properties that are located on the eastern (upstream) side of the road reserve.

Based on the above finding, the adoption of a 500 mm freeboard when setting the minimum floor level requirements for new development would cater for any potential increases in peak 1% AEP flood levels associated with a partial blockage of bridge and culvert structures at Braidwood.

2.11 Potential Impacts of Future Urbanisation

Future urbanisation has the potential to increase the rate and volume of runoff conveyed by the study creeks, as well as increase the frequency of surcharge of the local stormwater drainage system. It is also likely to result in changes in the existing drainage system. While existing minor watercourses are likely to be retained and formalised in drainage reserves, piped drainage systems associated with urban subdivisions will result in significant amendments to existing overland flow paths leading to the watercourses.

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The *Palerang Development Control Plan 2015* permits up to 50% of an allotment to comprise hard stand areas. An assessment was therefore undertaken to assess the impact an increase in hard stand areas would have on flooding behaviour along the main arms of the study creeks. **Figure 2.10** shows that an increase in hard stand area to a maximum of 50% in individual allotments would not have a measurable impact on peak 1% AEP flood levels at Braidwood.

2.12 Potential Impacts of Climate Change

Consideration was given to the impacts on design flood levels of future climate change when estimating freeboard requirements on minimum floor levels of future development.

OEHs guideline titled *Practical Consideration of Climate Change, 2007* was used as the basis for examining climate change at Braidwood. 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.

For the purpose of the present investigation, the impact a 10% increase in design rainfall intensities would have on flooding behaviour was assessed by comparing the peak flood levels which were derived from the flood modelling for design events with AEPs of 1 and 0.5 per cent.

Figure 2.11 (3 sheets) shows the afflux data (i.e. increase in peak flood levels compared with present day conditions) derived from the hydraulic modelling that was undertaken as part of the present study for the 1 and 0.5% AEP events. The potential impact of a 10% increase in rainfall intensity on flooding patterns in the study area may be summarised as follows:

- Peak 1% AEP flood levels would be increased by a maximum of about 220 mm along Monkittee Creek and 200 mm along Flood Creek.
- Peak 1% AEP flood levels would be generally increased in the range 50-100 mm along Recreation Ground Creek and the Unnamed Tributary of Monkittee Creek.

Figure 2.12 (3 sheets) shows the afflux data derived from the hydraulic modelling that was undertaken as part of the present study for the 1 and 0.2% AEP events under ideal flow conditions. The potential impact of a 30% increase in rainfall intensity on flooding patterns in the study area may be summarised as follows:

- Peak 1% AEP flood levels would be increased by a maximum of about 500 mm along Monkittee Creek and 400 mm along Flood Creek.
- Peak 1% AEP flood levels would be generally increased in the range 100-200 mm along Recreation Ground Creek and the Unnamed Tributary of Monkittee Creek.

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Figure 2.13 (3 sheets) shows that there would only be a minor increase in the extent of inundation resulting from a 10 to 30% increase in 1% AEP rainfall intensities. In general, no new flow paths would develop in the study area, with the exception of Recreation Ground Creek where the north-east corner of the oval would be subject to shallow overland flow, as would several residential allotments that are located along the northern side of Coghill Street between its intersection with Ryrie Street and Wallace Street.

Given the current uncertainties in the estimation of increased rainfalls resulting from climate change and its timeframe, it is considered that its impacts on peak flood levels in areas subject to flooding could reasonably be catered for within the proposed freeboard of 500 mm, with a reasonable margin remaining for other uncertainties such as local hydraulic effects and wave action.

2.13 Environmental Considerations

The main arms of Monkittee Creek and Flood Creek are largely in their natural state where they run through Braidwood, while Recreation Ground Creek has been highly modified where it runs between Monkittee Street and Ryrie Street.

As there is no existing development located along Monkittee Creek and Flood Creek that is subject to above-floor inundation for floods up to 1% AEP in magnitude, channel modifications and stream clearing need not form part of the flood mitigation option assessment process. Given that the flood damages are mainly centred on Recreation Ground Creek and given its highly modified nature, there is scope to implement channel modification and stream clearing measures which are aimed at reducing the impact of flooding on existing development.

2.14 Council's Existing Planning Instruments and Policies

2.14.1 General

The *Palerang Local Environmental Plan 2014* (***Palerang LEP 2014***) is the principal statutory planning document used by Council for controlling development by defining zoning provisions, establishing permissibility of land use and regulating the extent of development in Braidwood.

The *Palerang Development Control Plan 2015* (***Palerang DCP 2015***) supplements *Palerang LEP 2014* by providing general information and detailed guidelines and controls which relate to the decision making process.

2.14.2 Land Use Zoning – Palerang LEP 2014

Figure 2.14 shows the zonings incorporated in *Palerang LEP 2014* at Braidwood. Most of the urban area of Braidwood is zoned *R2 Low Density Residential*, while the main commercial area centred along Wallace Street is zoned *B2 Local Centre*. Land zoned *B4 Mixed Use* is also located at the northern end of Wallace Street, as well as along Lascelles Street.

Land zoned *IN2 Light Industrial* is located on the western side of Araluen Road near the southern limits of the town.

While land zoned *RE1 Public Recreation* is located along the main arms of Monkittee Creek Flood Creek, large lengths of the two watercourses are also zoned *R2 Low Density Residential*.

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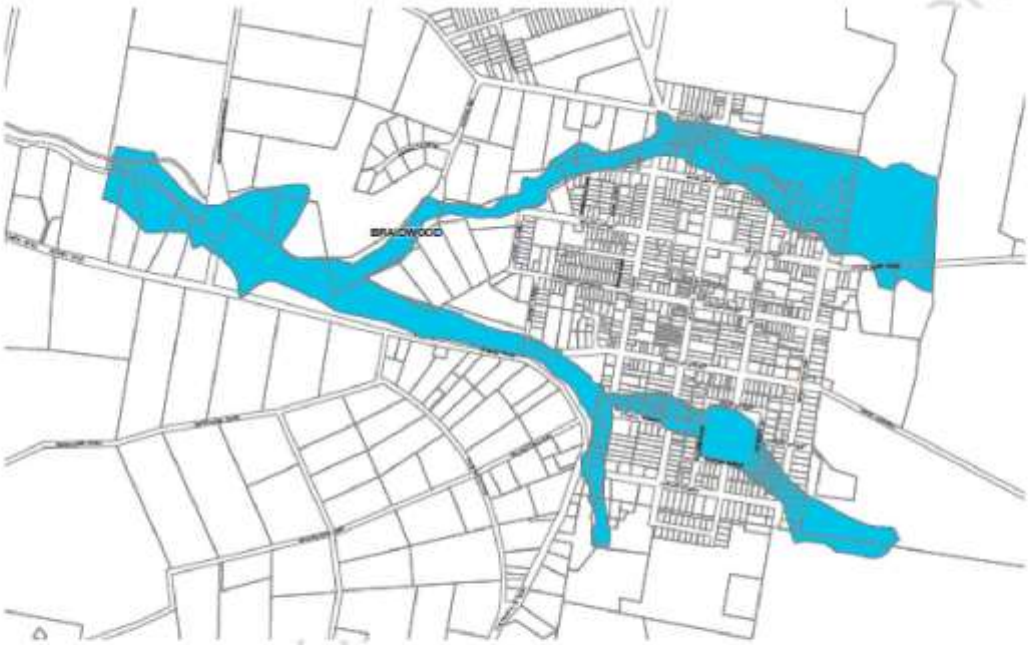
2.14.3 Flood Provisions – Palerang LEP 2014

Clause 6.2 of *Palerang LEP 2014* entitled "Flood Planning" outlines its objectives in regard to development of land that is at or below the FPL. The FPL referred to is the 1:100 ARI (or 1% AEP) flood plus an allowance for freeboard of 500 mm. The area encompassed by the FPL (i.e. the FPA) denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development. The illustration below is an extract from the *Flood Planning Map* which is referred to in clause 6.2 (2)(a) of *Palerang LEP 2014* showing the extent of the FPA in Braidwood (as currently defined).



Whilst appropriate for defining the extent of land to which clause 6.2 applies, it is recommended that the current wording be amended to better align with contemporaneous flood risk management considerations such as the adoption of a variable freeboard approach to defining the FPL. Recommended amendments to the wording of clause 6.2 are set out in **Section 3.5.1.4** of the report.

Palerang LEP 2014 would need to be supported by an updated version of *Palerang DCP 2015*, recommendations for which are contained in **Appendix E**.

It is also recommended that a new floodplain risk management clause be included in *Palerang LEP 2014*. The objectives of the new clause are as follows:

- in relation to development with particular evacuation or emergency response issues (e.g. schools, group homes, residential care facilities, hospitals, seniors living etc.) to enable evacuation of land which lies above the FPL; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The new clause would apply to land which lies between the FPL and the level of the PMF, but would not apply to land at or below the FPL. Suggested wording in relation to this new clause is given in **Section 3.5.1.4**.

2.14.4 Flooding and Stormwater Controls – Palerang DCP 2015

Section B9 – 'Flood Planning' of *Palerang DCP 2015* specifies the following flood related controls for future development in the urbanised parts of Braidwood:

- ***Residential – New Development***
  - Development designed to cater for vulnerable sections of the community (such as seniors housing) are not suitable for land identified as being a FPA
  - Floor levels of habitable rooms are to be at or above the FPL
  - Flood safe access and emergency egress for all flood events up to the 1% AEP event plus 500 mm freeboard is to be provided
  - Residential garages are to be at or above the 1% AEP level. Where this in impractical, garages are to be as high as practical and electrical points are to be at or above the FPL
- ***Residential Development – Extension to Existing Dwelling***
  - Extensions with a floor area up to 35 m² may be approved with floor levels below the 1% AEP flood level if the applicant can demonstrate that:
    - no practical alternative exists, and
    - the level of hazard will not increase
  - Extensions with a floor area up to 50 m² may be approved with floor levels at or above the 1% AEP flood level but less than the FPL if the applicant can demonstrate that:
    - no practical alternative exists, and
    - the level of hazard will not increase
- ***Non-habitable Extensions or Alternations, Outbuildings and Swimming Pools***
  - Any portion of a building that may be subject to inundation is to be built from flood compatible materials
  - All electrical services shall be adequately flood proofed
  - All flood sensitive equipment shall be located above the 1% AEP flood level
- ***Industrial and Commercial Development***
  - Floor levels at or above the FPL or the buildings are to be flood proofed to at least the FPL
  - Flood safe access and emergency egress for all flood events up to the FPL is to be provided
  - All flood sensitive equipment shall be located above the 1% AEP flood level
- ***Alterations to the natural Surface Level of Land***
  - Proposed earthworks are not to increase the flooding hazard or flood damage to other properties or adversely affect other properties during flood events

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- ***Fencing***
  - Fencing construction and materials are to allow floodwaters to equalise on either side
  - Fencing construction and materials are to safely allow floodwaters or debris to pass

2.15 Flood Response Planning in Braidwood

The NSW SES is nominated as the principal combat and response agency for flood emergencies in NSW. NSW SES is responsible for the issuing of relevant warnings (in collaboration with BoM), as well as ensuring that the community is aware of the flood threat and how to mitigate its impact.

The *Palerang Local Flood Plan* which is dated April 2013 (***Palerang Local Flood Plan 2013***) published by NSW SES covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures for all levels of flooding within the now extinguished Palerang local government area. *Palerang Local Flood Plan 2013* is administered by the Palerang Local Controller who controls flood operations within the Palerang area. NSW SES maintains a local headquarters in Cowper Street, Braidwood.

Volume 1 of *Palerang Local Flood Plan 2013* entitled '*Palerang Flood Emergency Sub Plan*' which was completed in 2013 and includes sections on flood preparedness, response and recovery. Volume 1 follows the standard NSW SES template and is divided into the following sections:

- ***Introduction***; this section of *Palerang Local Flood Plan 2013* identifies the responsibilities of the NSW SES Local Controller and NSW SES members and supporting services such as the Police, BoM, Ambulance, Country Energy, Fire Brigades, Council, etc. The *Palerang Local Flood Plan 2013* identifies the importance for NSW SES and Council to coordinate the development and implementation of a public education program to advise the population of the flood risk.
- ***Preparedness***; this section deals with activities required to ensure the *Palerang Local Flood Plan 2013* functions during the occurrence of the flood emergency. The Plan will devote considerable attention to flood alert and emergency response.
- ***Response***. The NSW SES maintains an operation centre at the Local NSW SES Headquarters in Cowper Street. Response operations will commence: on receipt of a severe weather warning for flash flooding from BoM or when other evidence leads to an expectation of flooding within the Palerang area. Sources of Flood Intelligence identified will include the BoM, Southern Highlands Region headquarters and Council.
- ***Recovery***, involving measures to ensure the long term welfare for people who have been evacuated, recovery operations to restore services and clean up and de-briefing of emergency management personnel to review the effectiveness of the *Palerang Local Flood Plan 2013*.

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3 POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES

3.1 Range of Available Measures

A variety of floodplain risk management measures can be implemented to reduce flood damages. They may be divided into three categories, as follows:

Flood modification measures change the behaviour of floods in regard to discharges and water surface levels to reduce flood risk. This can be done by the construction of levees, detention basins, channel improvements and upgrades of piped drainage systems in urban areas. Such measures are also known as "structural" options as they involve the construction of engineering works. Vegetation management is also classified as a flood modification measure.

Property modification measures reduce risk to properties through appropriate land use zoning, specifying minimum floor levels for new developments, voluntary purchase of residential property in high hazard areas, or raising existing residences in the less hazardous areas. Such options are largely planning (i.e. "non-structural") measures, as they are aimed at ensuring that the use of floodplains and the design of buildings are consistent with flood risk. Property modification measures could comprise a mix of structural and non-structural methods of damage minimisation to individual properties.

Response modification measures change the response of flood affected communities to the flood risk by increasing flood awareness, implementation of a flood warning system and the development of an emergency response plan for property evacuation.

3.2 Community Views

Comments on potential flood management measures were sought from the Braidwood community by way of the *Community Questionnaire*, which was distributed at the commencement of the study. The responses are summarised in **Appendix A** of this *FRMS* report. Question 7 in the *Community Questionnaire* outlined a range of potential flood management options. The responses are shown on **Table 3.1** over the page together with initial comments on the feasibility of the measures. The measures are discussed in more detail in later sections of this Chapter.

The Community favoured the following measures:

- Manage vegetation along the creek corridors
- Improvements in the stormwater system
- Flood related controls over future development in flood liable areas
- Improved flood warning, evacuation and flood response procedures
- Community education to promote flood awareness
- Advice of flood affectation via Planning Certificates for properties located within the *Flood Planning Area*

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TABLE 3.1
COMMUNITY VIEWS ON POTENTIAL FLOOD MANAGEMENT MEASURES

Flood Management Measure		Classification[1]	Respondent's Views		Comments
			Yes	No	
a)	Management of vegetation along the creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits	FM	31	1	Given the confined nature of the Monkittee Creek and Flood Creek floodplains, reducing the density of vegetation along their length would not provide any flood mitigation benefits. While there is merit in managing inbank vegetation along Recreation Ground Creek given its relatively low hydraulic capacity, the flood mitigation benefits which this would achieve could not be relied upon for reducing the FPL (i.e. because they rely on ongoing and regular maintenance, which cannot always be guaranteed).
b)	Widening of watercourses	FM	6	21	While this measure would provide limited, if any, benefit along the main arms of Monkittee Creek and Flood Creek given the relatively confined nature of their floodplains, its application to Recreation Ground Creek would reduce its frequency of surcharge. That said, its effectiveness in reducing flooding along Recreation Ground Creek would be limited given the close proximity of existing residential development which would constrain the width of any future channel widening works.
c)	Construction of detention basins	FM	8	13	While this option is not favoured by the community, it does have merit in regards reducing the impact of flooding on existing development that is located adjacent to the main arm of Recreation Ground Creek. This option is reviewed in more detail in **Section 3.4**.
d)	Improve the stormwater system within the town area.	FM	30	0	While this measure is strongly supported by the community, the assessment of measures aimed at improving the stormwater drainage system in Braidwood does not form part of the scope of the *FRMS* for Braidwood.
e)	Construct permanent levees along the creeks to contain floodwaters.	FM	10	22	The community is not in favour of this option and there is limited scope to construct a levee that would protect existing development that is located along Recreation Ground Creek and subject to flooding for events up to 1% AEP in magnitude.
f)	Voluntary purchase of residential property in **high hazard floodway** areas.	PM	6	13	This option is often adopted to remove residential property in high hazard areas of the floodplain. The results of the present investigation show that there is one dwelling located in a High Hazard Floodway area. While the community is not in favour of this option it is reviewed in **Section 3.5.2**.
g)	Provide funding or subsidies to raise houses above the major flood level in **high hazard flood storage** and **low hazard floodway** areas.	PM	9	15	The community is generally not in favour of this option. This option would have application for timber framed houses located in low hazard zones on the floodplain and is reviewed in **Section 3.5.3**.
h)	Specify controls over future development in flood-liable areas (e.g. controls on extent of filling, minimum floor levels, etc.).	PM	22	5	The community strongly supports this option, which is an essential part of the FRMP. The issue is covered in **Section 3.5.1**, with recommendations for the update of *Palerang DCP 2015* contained in **Appendix E**.
i)	Improve flood warning and evacuation procedures both before and during a flood.	RM	30	2	While the development of a formal flood warning system for Braidwood would have limited benefit in terms of reducing the flood risk in the township (i.e. because most of the developed parts of the town are not subject to flooding), there is merit in improving flood emergency response planning using information contained in this study. This measure is strongly supported by the community and is considered further in **Sections 3.6.1** and **3.6.2**.
j)	Community education, participation and flood awareness programs.	RM	25	3	Promotion of awareness of the flood risk is strongly favoured among the community. This option is reviewed in **Section 3.6.3**.
k)	Provide a Planning Certificate to purchasers in flood prone areas stating that the property is flood affected.	PM	24	6	Provision of information on flood affection of properties is strongly favoured by the community. This may be achieved by notation of flood affectation of allotments on Section S10.7 Planning Certificates. This option is reviewed in **Section 3.5.1**.

1. FM = Flood Modification Option
   PM = Property Modification Option
   RM = Response Modification Option

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3.3 Outline of Chapter

A range of potential flood management measures were examined at the strategic level of detail and where appropriate, tested for feasibility on a range of assessment criteria in **Chapter 4**. Following consideration of the results by the FRMC, selected measures were included in the *FRMP* in **Chapter 5**.

The assessment of potential flood modification measures was limited to Recreation Ground Creek given that floodwater originating from Monkittee Creek and Flood Creek does not impact existing development for floods up to 1% AEP in magnitude.

Given the relatively large flood flows in Recreation Ground Creek relative to the conveyance capacity of the existing channel, coupled with the close proximity of existing residential development (which limits the scope of channel widening works), options for mitigating flooding along the watercourse is limited to the construction of a detention basin on vacant land upstream of Monkittee Street.

The property modification measures considered as part of this study include controls over future development, voluntary purchase of residential properties and house raising. Response modification measures such as improvements to emergency planning and responses and public awareness programs have been considered for Braidwood.

3.4 Flood Modification Measures

3.4.1 Detention Basin

As mentioned, the only viable flood modification measure for Recreation Ground Creek is the construction of a detention basin on vacant land upstream of Monkittee Street. The land on which the basin could be built is relatively flat, meaning that the construction of an earth embankment across the floodplain would result in an increase in the depth of inundation over a relatively large area, albeit with reduced velocity in the flow due to its ponding nature.

An assessment was undertaken using the hydraulic model that was developed as part of the present investigation to quantify the flood mitigation benefits which could be achieved by constructing a detention basin upstream of Monkittee Creek. The following three outlet pipe arrangements were modelled so as to assess the change that would occur in extent of ponding which would occur upstream of the basin embankment versus the reduction in flood flows downstream in existing development:

- Flood Mitigation Scheme 1A – 2 off 1050 mm diameter pipes
- Flood Mitigation Scheme 1B – 2 off 900 mm diameter pipes
- Flood Mitigation Scheme 1C – 2 off 750 mm diameter pipes

Figures 3.1, **3.2** and **3.3** show the layout of Flood Mitigation Schemes 1A, 1B and 1C, respectively, as well as the impact that their construction would have on the extent and depth of inundation for storms of 20%, 5% and 1% AEP. The figures also show the location of dwellings/buildings that would be rendered free of above-floor inundation as a result of the scheme. **Table 3.2** over gives the peak flows in Recreation Ground Creek at Monkittee Street under pre- and post-basin conditions, as well as the maximum depth of ponding in the impoundment for storms of 20%, 5% and 1% AEP.

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TABLE 3.2
SUMMARY OF PEAK FLOWS AND PONDING DEPTHS
PRE- AND POST-BASIN CONDITIONS[1]

Design Storm Event (% AEP)	Present Day Conditions		Post-Flood Mitigation Scheme 1A		Post-Flood Mitigation Scheme 1B		Post-Flood Mitigation Scheme 1C	
	Peak Flow (m^3/s)	Maximum Ponding Depth (m)	Peak Flow (m^3/s)	Maximum Ponding Depth (m)	Peak Flow (m^3/s)	Maximum Ponding Depth (m)	Peak Flow (m^3/s)	Maximum Ponding Depth (m)
20	8.0	-	5.2 [35]	1.55	4.3 [46]	1.73	3.4 [58]	2.00
5	11.6	-	6.2 [47]	1.93	5.0 [57]	2.16	3.9 [66]	2.42
1	17.2	-	7.3 [58]	2.38	5.9 [66]	2.56	4.8 [72]	2.75

1. Values in [ ] represent the percentage reduction in peak flow when compared to present day conditions.

The key findings of the basin assessment were as follows:

- All three schemes remove above-floor flooding in one dwelling at the 5% AEP level of flooding and in three dwellings and one public building at the 1% AEP level of flooding.
- All three schemes will result in a significant reduction in peak flows in Recreation Ground Creek, with Flood Mitigation Scheme 1C providing the greatest attenuating effects.
- Flood Mitigation Scheme 1C has the greatest flood mitigation benefit in terms of a reduction in the extent and depth of inundation for events up to 1% AEP in magnitude.
- Flood Mitigation Scheme 1C would result in greater depths of ponding upstream of the basin embankment and hence back flood a larger area.
- Flood Mitigation Scheme 1A and 1B would result in a minor increase in peak flood levels along the downstream reach of Flood Creek. The impact is a result of the prolongation of the flood wave in Recreation Ground Creek which results in a minor increase in the peak flow in Flood Creek downstream of the confluence of the two watercourses. Given the confined nature of the Flood Creek floodplain the minor increase in peak flood levels would not result in adverse flooding conditions being experienced in existing development.

Council advised that it plans to enclose a section of Recreation Ground Creek as part of a planned upgrade of the Braidwood Recreation Ground. In addition to enclosing a section of the creek, the proposed works would involve the lowering of the immediate overbank area to provide a defined overland flow path for the conveyance of flows which surcharge the new culvert arrangement. The top left hand side of **Figure 3.4** shows the key features of the proposed works, details of which were provided by Council. The works have been denoted "Flood Mitigation Scheme 2" for the purpose of the present discussion.

While a flooding assessment was carried out as part of a Review of Environmental Factors, details of Flood Mitigation Scheme 2 were incorporated in the hydraulic model that was developed as part of the present investigation to assess the impact that they would have on flooding behaviour. By inspection of **Figure 3.4**, the impacts of Flood Mitigation Scheme 2 will be confined to the Braidwood Recreation Ground.

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To assist Council in the assessment process, the hydraulic model was run for the case where Flood Mitigation Schemes 1A, 1B and 1C were assumed to be constructed in combination with Flood Mitigation Scheme 2. The results of the modelling are shown on **Figures 3.5**, **3.6** and **3.7**.

It is estimated that it would cost about $550,000[9] to construct the detention basin and upgrade the existing transverse drainage structure at Monkittee Street. It is also estimated that the construction of the basin would reduce the present worth value of flood damages for all events up to 1% AEP in magnitude by about $270,000, resulting in a benefit cost ratio for the scheme of about 0.5.

In addition to the scheme not being justified on economic grounds (i.e. because its benefit cost ratio is less than 1), it can also not be justified on social grounds as the overbank flow is presently relatively shallow and slow moving in nature and therefore does not pose a significant flood risk to the affected community.[10] As a result, the inclusion of a detention basin scheme in the *FRMP* could not be justified.

3.4.2 Vegetation Management

Management programs in creeks typically involve maintenance of batters, the removal of sediment, removal of dense vegetation and the clearance of flood debris after significant flow events. Clearance of debris within the stream corridor reduces the potential for future capture by the flow and blockage of culverts.

While there is merit in removing flood debris on the main arms of the study creeks after significant flow events, it would have limited effect on flood behaviour given the confined nature of the flow combined with the limited number of creek crossings. The exception is Recreation Ground Creek, where there is a large number of culvert crossings which could experience a partial blockage if flood debris is allowed to build up on the floodplain.

The removal of dense vegetation would on the main arms of the study creeks would also have limited effect on flood behaviour, again due to the confined nature of flow. The exception is Recreation Ground Creek, where the removal of dense vegetation from the inbank area of the watercourse would reduce the frequency of nuisance flooding. A run of the hydraulic model found that reducing the effective hydraulic roughness of the inbank area of Recreation Ground Creek would not have a significant impact on peak 1% AEP flood levels, given the low capacity nature of the existing channel and the relatively slow moving nature of the floodwater upstream of Wallace Street.

While the implementation of a vegetation management strategy would not reduce the flood risk in Braidwood, there is merit in its application to Recreation Ground Creek given it would reduce the frequency of surcharge of the inbank area of the watercourse. For this reason it has been included in the *FRMP* for Braidwood.

[9] Note that this amount assumes that the land upon which the basin would be built would not need to be acquired, but rather an *Easement for Drainage* would simply be created to allow access by Council for maintenance.

[10] This is supported by the storm that occurred in February 2019 which while estimated to have had an AEP of between 2 and 1 per cent, resulted in limited damage and disruption in affected properties.

3.5 Property Modification Measures

3.5.1 Controls over Future Development

3.5.1.1 Considerations for Setting Flood Planning Level

Selection of the FPL for an area is an important and fundamental decision as the standard is the reference point for the preparation of floodplain risk management plans. It is based on adoption of the peak level reached by a particular flood plus an appropriate allowance for freeboard. It involves balancing social, economic and ecological considerations against the consequences of flooding, with a view to minimising the potential for property damage and the risk to life and limb. If the adopted FPL is too low, new development in areas outside the FPA (particularly where the difference in level is not great) may be inundated relatively frequently and damage to associated public services will be greater. Alternatively, adoption of an excessively high FPL will subject land that is rarely flooded to unwarranted controls.

Councils are responsible for determining the appropriate FPLs within their local government area. *Palerang LEP 2014* nominates the "*1:100 ARI (average recurrence interval) flood event plus 0.5 m freeboard*" as the FPL.

3.5.1.2 Current Government Policy

The circular issued by the Department of Planning on 31 January 2007 contained a package of changes clarifying flood related development controls to be applied on land in low flood risk areas (land above the 1% AEP flood plus freeboard). The package included an amendment to the Environmental Planning and Assessment Regulation 2000 in relation to the questions about flooding to be answered in Section S10.7 planning certificates, a revised ministerial direction (Direction 15 – now Direction 4.3 issued of 1 July 2009) regarding flood prone land (issued under Section 9.1 of the EP&A Act, 1979) and a new Guideline concerning flood-related development controls in low flood risk areas. The Circular advised that Councils will need to follow both NSWG, 2005, as well as the Guideline to gain the legal protection given by Section 733 of the Local Government Act.

The Department of Planning Guideline confirmed that unless exceptional circumstances applied, councils should adopt the 1% AEP flood with appropriate freeboard as the FPL for residential development. In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood. Unless there were exceptional circumstances, Council should not impose flood-related development controls on residential development on land with a low probability of flooding, that is land above the residential FPL.

However, the guideline does advise consideration be given to evacuation routes and vulnerable developments (e.g. nursing homes) in areas above the residential FPL. The safety of people and associated emergency response management needs to be considered in low flood risk areas, which may result in:

- Restrictions on types of development which are particularly vulnerable to emergency response, for example, developments for aged care and schools.

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- Restrictions on critical emergency response and recovery facilities and infrastructure. These aim to ensure that these facilities and the infrastructure can fulfil their emergency response and recovery functions during and after a flood event. Examples include evacuation centres and routes, hospitals and major utility facilities. There are currently no critical developments of this nature in the floodplain.

3.5.1.3 Proposed Planning Controls for Braidwood

While *Palerang LEP 2014* contains a set of flood related development controls, these are linked to flood mapping and peak flood levels which have been superseded by the more detailed flood modelling that has been undertaken as part of the present investigation. Proposed planning controls for flood prone areas in Braidwood, along with recommended updates to *Palerang DCP 2015* are presented in **Appendix E**. They are based on the proposed subdivision of the floodplain and amendments to *Palerang LEP 2014* introduced in **Section 2.14** of the report.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard (dependent on depth of inundation and flow velocity). NSWG, 2005 suggests wording on S10.7 (2) Planning Certificates along the following lines:

> *"Council considers the land in question to be within the Flood Planning Area and therefore subject to flood related development controls. Information relating to this flood risk may be obtained from Council. Restrictions on development in relation to flooding apply to this land as set out in Council's Flood Policy which is available for inspection at Council offices or website."*

Annexure 2 in **Appendix E** sets out the graded set of flood related planning controls which have been developed for Braidwood. Minimum floor level (**MFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on **Figure E1.1**. The MFLs for all land use types is the level of the 1% AEP flood event plus 500 mm freeboard.
For areas outside the FPA shown on **Figure E1.1**, the MFL for all land use types is the level of the 1% AEP flood event plus 500 mm freeboard, with the exception of Essential Community Facilities, Critical Utilities and Flood Vulnerable development which is not permitted on land which is subject to main stream flooding.

Figure E1.2 in **Appendix E** is the *Flood Hazard Map* for Braidwood which shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls.

The floodplain has been divided into the following four categories in areas that are affected by main stream flooding:

- **Inner Floodplain (Hazard Category 1)**, which is shown in solid red colour. This zone comprises areas where factors such as the depth and velocity of flow, time of rise and evacuation problems mean that the land is unsuitable for some types of development. It principally comprises areas of High Hazard Floodway, but does include some areas of Low Hazard Floodway in some areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are considered to be unsuitable land uses in this zone.

- **Inner Floodplain (Hazard Category 2)**, which is shown in solid yellow colour. This zone comprises Low Hazard Floodway and Flood Storage areas where development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
- **Intermediate Floodplain**, which is shown in solid blue colour. This area is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA. Within this zone, there would only be the requirement for MFLs to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
- **Outer Floodplain**, which is shown in solid cyan colour. This area represents the remainder of the floodplain between the Intermediate Floodplain and the extent of the Probable Maximum Flood (PMF) (that is, the extent of the floodplain). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development are considered to be unsuitable land uses in this zone.

3.5.1.4 Revision of Palerang LEP 2014 by Council

To implement the recommended approach set out in the *FRMS&P*, clause 6.2 of *Palerang LEP 2014* would require minor amendments, namely in regards the wording of sub clause (2) and (5). It is recommended that the following clause replaces the existing clause 6.2 of *Palerang LEP 2014*:

"6.2 Flood planning

(1) The objectives of this clause are as follows:

(a) to minimise the flood risk to life and property associated with the use of land,

(b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change,

(c) to avoid significant adverse impacts on flood behaviour and the environment.

(2) This clause applies to land at or below the flood planning level.

(3) Development consent must not be granted for development on land to which this clause applies unless the consent authority is satisfied that the development:

(a) is compatible with the flood hazard of the land, and

(b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and

(c) incorporates appropriate measures to manage risk to life from flood, and

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(d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses, and

(e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

(4) A word or expression used in this clause has the same meaning as it has in the Floodplain Development Manual, unless it is otherwise defined in this Plan."

(5) In this clause:

***flood planning level** means the level of a 1% AEP (annual exceedance probability) flood event plus 0.5 metre freeboard, or other freeboard as determined by an adopted floodplain risk management plan.*

The steps involved in Council's amending *Palerang LEP 2014* following the finalisation and adoption of the *FRMS&P* are:

1. Council Planning Staff consider the conclusions of the *FRMS&P* and suggested amendments to *Palerang LEP 2014*.
2. Council resolves to amend *Palerang LEP 2014* in accordance with the *FRMS&P*.
3. Council prepares a Planning Proposal in accordance with NSW Planning and Environment Guidelines. Planning Proposal submitted to NSW Planning and Environment in accordance with section 3.33 of the EP&A Act, 1979.
4. Planning Proposal considered by NSW Planning and Environment and determination made in accordance with section 3.34(2) of the EP&A Act, 1979 as follows:
   (a) whether the matter should proceed (with or without variation),
   (b) whether the matter should be resubmitted for any reason (including for further studies or other information, or for the revision of the planning proposal),
   (c) community consultation required before consideration is given to the making of the proposed instrument (the community consultation requirements),
   (d) any consultation required with State or Commonwealth public authorities that will or may be adversely affected by the proposed instrument,
   (e) whether a public hearing is to be held into the matter by the Planning Assessment Commission or other specified person or body,
   (f) the times within which the various stages of the procedure for the making of the proposed instrument are to be completed.
5. Planning Proposal exhibited for public comment.
6. Planning Proposal reviewed following public submissions and submissions from relevant State and Commonwealth authorities.
7. Final Local Environmental Plan with proposed amendments drafted.
8. Amending Local Environmental Plan made by the Minister and gazetted.

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3.5.2 Voluntary Purchase of Residential Properties

Removal of housing from high hazard floodway areas in the floodplain is generally accepted as a cost effective means of correcting previous decisions to build in such areas. The Voluntary Purchase (**VP**) of residential property in hazardous areas has been part of subsidised floodplain risk management programs in NSW for over 20 years.[11] After purchase, land is subsequently cleared and the site re-developed and re-zoned for public open space or some other flood compatible use. A further criterion applied by State Government agencies in assessing eligibility for funding is that the property must be in a high hazard floodway area, that is, in the path of flowing floodwaters where the depth and velocity at the peak of the flood are such that life could be threatened, damage of property is likely and evacuation difficult.

Under a VP scheme the owner is notified that the body controlling the scheme, Council in the present case, is prepared to purchase the property when the owner is ready to sell. There is no compulsion whatsoever to sell at any time. The price is determined by independent valuers and the Valuer General, and by negotiation between Council and the owners. Valuations are not reduced due to the flood affected nature of the site.

The hydraulic calculations described in **Chapter 2** identified that there is an existing dwelling located at the northern end of Monkittee Street that is located on the southern limit of the High Hazard Floodway area on Monkittee Creek (refer **Figure 2.7**, sheet 2 for location). The floor level of the existing dwelling, which by inspection is elevated above ground by about 1.5 m along its southern side, lies about 0.7 m above the peak 1% AEP flood level. Based on the findings of the flooding modelling the floor of the dwelling is also not inundated by a 0.2% AEP flood event.

Given the dwelling is not above-floor inundated for events up to 0.2% AEP in magnitude and rising ground is located immediately to its south which would facilitate self-evacuation to flood free land, its inclusion in the State Government's VP scheme cannot be justified.

3.5.3 Raising Floor Levels of Residential Properties

The term "house raising" refers to procedures undertaken, usually on a property by property basis, to protect structures from damage by floodwaters. The most common process is to raise the affected house by a convenient amount so that the floor level is at or above the MFL. For weatherboard and similar buildings this can be achieved by jacking up the house, constructing new supports, stairways and balconies and reconnecting services. Alternatively, where the house contains high ceilings, floor levels can be raised within rooms without actually raising the house. It is usually not practical to raise brick or masonry houses. Most of the costs associated with this measure relate to the disconnection and reconnection of services. Accordingly, houses may be raised a considerable elevation without incurring large incremental costs.

State and Federal Governments have agreed that flood mitigation funds will be available for house raising, subject to the same economic evaluation and subsidy arrangements that apply to other structural and non-structural flood mitigation measures. In accepting schemes for eligibility, the Government has set out the following conditions:

- House raising should be part of the adopted *FRMP*.
- The scheme should be administered by the local authority.

[11] State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual.

State government funding is only available for properties where the buildings were approved and constructed prior to 1986 when the original Floodplain Development Manual was gazetted. Properties built after this date should have been constructed in accordance with the principles in the manual. The Government also requires that councils carry out ongoing monitoring in areas where subsidised voluntary house raising has occurred to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level. In addition, it is expected that councils will provide documentation during the conveyancing process so that subsequent owners are made aware of restrictions on development below the design floor level.

Council's principal role in subsidised voluntary house raising would be to:

- Define a habitable floor level, which it will have already done in exercising controls over new house building in the area.
- Guarantee a payment to the builder after satisfactory completion of the agreed work.
- Monitor the area of voluntary house raising to ensure that redevelopment does not occur to re-establish habitable areas below the design floor level.

The current cost to raise a medium sized (150 m^2) house is about $100,000 based on recent experience in other centres.

While there are five existing dwellings in Braidwood which would experience above-floor flooding in a 1% AEP flood event, the resulting depth of above-floor flooding would not exceed 0.1 m. Given the relatively shallow and short duration nature of the flooding in the affected properties, all of which are located in the Recreation Ground Creek catchment, their inclusion in a voluntary house raisings scheme could not be justified.

3.6 Response Modification Measures

3.6.1 Improvements to Flood Warning System

Improvements to the flood warning and response procedures were strongly favoured by the community during the community consultation process. An effective flood warning system has three key components, i.e. a flood forecasting system, a flood warning broadcast system and a response/evacuation plan. All systems need to be underpinned by an appropriate public flood awareness program.

Presently warnings regarding the potential for flooding to occur at Braidwood are limited to BoMs *Severe Thunderstorm Warning* and *Severe Weather Warnings for Flash Flooding* alert services which are publically available via the internet or on smart phones via free Apps.

Funding to establish local flash flood warning systems has traditionally been made available on the basis of no Council contribution to the initial capital cost in recognition of the high maintenance costs which Council would have to meet. The costs of maintaining the system would include such items as rain and river gauges, warning communication systems and ongoing public awareness/education programs. The maintenance obligations need to be identified and included in any initial funding grant. An operation and maintenance manual would need to be prepared for the system. Reference to the system would also need to be incorporated into the NSW SES Local Flood Plan (the development of which is recommended in the *FRMP*).

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Given the confined nature of the floodplains of Gillamatong, Monkittee Creek and Flood Creek, as well as the relatively shallow and slow moving nature of the flooding that is experienced on Recreation Ground Creek and the unnamed tributary, the establishment of a local flash flood warning system is not considered to be warranted. That said, Council and NSW SES should develop a flood awareness program that is specifically tailored to Braidwood, further details of which are set out in **Section 3.6.3**.

3.6.2 Improved Emergency Planning and Response

As mentioned in **Section 2.15**, the *Palerang Local Flood Plan 2013* provides detailed information regarding preparedness measures, conduct of response operations and coordination of immediate recovery measures for all levels of flooding.

NSW SES should ensure information contained in this report on the impacts of flooding on urban development, as well as recommendations regarding flood warning and community education are used to update Volume 2 of the *Palerang Local Flood Plan 2013*. Volume 2 should include the following sections:

1 – The Flood Threat includes the following sub-sections:

1.1 Land Forms and River Systems – ref. **Sections 2.1** and **2.2** of the report for information on these topics.

1.4 Characteristics of Flooding – Indicative extents of inundation for the 1% AEP and PMF events and the typical times of rise of floodwaters at key locations on the major watercourses are shown on **Figures 2.2**, **2.3** and **2.5**. The location of vulnerable development and critical infrastructure relative to the flood extents is shown on **Figure 2.6**.

1.5 Flood History – Recent flood experience at Braidwood is discussed in **Section 2.3** of the report.

1.6 Flood Mitigation Systems – There are no significant flood mitigation systems in Braidwood.

1.7 Extreme Flood Events – The Probable Maximum Flood was modelled and the indicative extent and depth of inundation presented on **Figure 2.4**.

2 – Effects on the Community

Information on the properties affected by the 1% AEP design flood are included in this report (**Figure 2.2**). As floor level data used in this assessment were estimated from the LiDAR survey and "drive by" survey they are indicative only. While fit for use in estimating the economic impacts of design floods, the data should not be used to provide specific details of the degree of flood affectation of individual properties.

Figure 2.5 shows stage hydrographs at road crossings at Braidwood, the locations of which are shown on **Figure 2.1**.

Figure 2.6 shows the location of vulnerable development and critical infrastructure in Braidwood relative to the flood extents of the 20, 5 and 1% AEP flood events, as well as the PMF. Refer **Section 2.7** for details of affected infrastructure.

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Figures 3.8 and **3.9** show the flood emergency response planning classifications for the 1% AEP and PMF events, respectively, based on the definitions set out in the *Floodplain Risk Management Guideline – Flood Emergency Response Classification of Communities* (DECC, 2007).

3.6.3 Public Awareness Programs

Community awareness and appreciation of the existing flood hazards in the floodplain would promote proper land use and development in flood affected areas. A well informed community would be more receptive to requirements for flood proofing of buildings and general building and development controls imposed by Council. Council should also take advantage of the information on flooding presented in this report, including the flood mapping, to inform occupiers of the floodplains of the flood risk.

One aspect of a community's preparedness for flooding is the "flood awareness" of individuals. This includes awareness of the flood threat in their area and how to protect themselves against it. The overall level of flood awareness within the community tends to reduce with time, as memories fade and as residents move into and out of the floodplain. The improvements to flood warning arrangements described above, as well as the process of disseminating this information to the community, would represent a major opportunity for increasing flood awareness in Braidwood.

Means by which community awareness of flood risks can be maintained or may be increased include:

- displays at Council offices using the information contained in the present study and photographs of historic flooding in the area; and
- talks by NSW SES officers with participation by Council and longstanding residents with first-hand experience of flooding in the area.
- preparation of a *Flood Information Brochure* which could be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with rate notices.

The community should also be made aware that a flood greater than historic levels or the flood planning level can, and will, occur at some time in the future.

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4 SELECTION OF FLOODPLAIN RISK MANAGEMENT MEASURES

4.1 Background

NSWG, 2005 requires a Council to develop a *FRMP* based on balancing the merits of social, economic and environmental considerations which are relevant to the community. This chapter sets out a range of factors which need to be taken into consideration when selecting the mix of works and measures that should be included in the *FRMP*.

The community will have different priorities and, therefore, needs to establish its own set of considerations used to assess the merits of different options. The considerations adopted by a community must, however, recognise the State Government's requirements for floodplain risk management as set out in NSWG, 2005 and other relevant policies. A further consideration is that some elements of the *FRMP* may be eligible for subsidy from State and Federal Government sources and the requirements for such funding must, therefore, be taken into account.

Typically, State and Federal Government funding is given on the basis of merit, as judged by a range of criteria:

- The magnitude of damage to property caused by flooding and the effectiveness of the option in mitigating damage and reducing the flood risk to the community.
- Community involvement in the preparation of the *FRMP* and acceptance of the option.
- The technical feasibility of the option (relevant to structural works).
- Conformance of the option with Council's planning objectives.
- Impacts of the option on the environment.
- The economic justification, as measured by the benefit/cost ratio of the option.
- The financial feasibility as gauged by Council's ability to meet its commitment to fund its part of the cost.
- The performance of the option in the event of a flood greater than the design event.
- Conformance of the option with Government Policies (e.g. NSWG, 2005 and Catchment Management objectives).

4.2 Ranking of Options

A suggested approach to assessing the merits of various options is to use a subjective scoring system. The chief merits of such a system are that it allows comparisons to be made between alternatives using a common "currency". In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). The system does not, however, provide an absolute "right" answer as to what should be included in the *FRMP* and what should be left out. Rather, it provides a method by which the Council can re-examine its options and if necessary, debate the relative scoring given to aspects of the *FRMP*.

Each option is given a score according to how well the option meets the considerations discussed above. In order to keep the scoring simple the following system is proposed:

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+2 Option rates very highly

+1 Option rates well

0 Option is neutral

- 1 Option rates poorly

- 2 Option rates very poorly

The scores are added to get a total for each option.

Based on considerations outlined in this chapter, **Table 4.1** presents a suggested scoring matrix for the options reviewed in **Chapter 3** at Braidwood. This scoring has been used as the basis for prioritising the components of the *FRMP*.

4.3 Summary

Table 4.1 indicates that there are good reasons to consider including the following elements into the *FRMP*:

- Development and implementation of a *Vegetation Management Plan* for Recreation Ground Creek
- An update of the *Palerang LEP 2014* to allow better management of the floodplain.
- An updated set of planning controls for future development in Braidwood.
- Incorporation of the catchment specific information on flooding impacts contained in this Study in NSW SES Response Planning and Flood Awareness documentation for the study area.
- Improved public awareness of flood risk in the community

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TABLE 4.1
ASSESSMENT OF POTENTIAL FLOODPLAIN RISK MANAGEMENT MEASURES FOR INCLUSION IN THE FLOODPLAIN RISK MANAGEMENT PLAN

Option	Impact on Flooding/ Reduction in Flood Risk	Community Acceptance	Technical Feasibility	Planning Objectives	Environ. Impacts	Economic Justification	Financial Feasibility	Government Policies and TCM Objectives	Score
Flood Modification									
Flood Modification Scheme 1A	+1	-1	+2	+1	0	-2	0	+1	+2
Flood Modification Scheme 1B	+1	-1	+2	+1	0	-2	0	+1	+2
Flood Modification Scheme 1C	+2	-1	+2	+2	0	-2	0	+1	+4
Vegetation Management Plan for Recreation Ground Creek	+1	+2	+2	0	+1	0	0	+2	+8
Property Modification									
Controls over Future Development (via update of *Palerang LEP 2014* and *Palerang DCP 2015*)	+2	+2	+2	+2	0	0	0	+2	+10
Voluntary Purchase of Residential Property	+1	-2	+2	+1	0	-2	-2	+1	-1
House Raising in High Hazard Flood Storage Areas	+1	-2	+2	+1	0	-2	-2	0	-2
Response Modification									
Improvements to Flood Warning System	+1	+2	+2	0	0	-2	-1	+1	+2
Improved Emergency Planning and Response	+1	+2	+2	+1	0	0	+1	+2	+9
Public Awareness Programs	+1	+2	+1	+1	0	0	+1	+2	+9

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5 FLOODPLAIN RISK MANAGEMENT PLAN

5.1 The Floodplain Risk Management Process

The *Floodplain Risk Management Study* (***FRMS***) and *Floodplain Risk Management Plan* (***FRMP***) have been prepared for Braidwood as part of a Government program to mitigate the impacts of major floods and reduce the hazards in the floodplain. The *FRMP* which is set out in this Chapter has been prepared as part of the Floodplain Risk Management Process in accordance with NSW Government's Flood Prone Land Policy.

The first steps in the process of preparing the *FRMP* were the collection of flood data and the review of the *Flood Study*. The *Flood Study* was the formal starting process of defining management measures for flood liable land and represented a detailed technical investigation of flood behaviour for Braidwood.

5.2 Purpose of the Plan

The overall objectives of the *FRMS* were to assess the impacts of flooding, review policies and options for management of flood affected land and to develop a *FRMP* which:

- Sets out the recommended program of works and measures aimed at reducing over time, the social, environmental and economic impacts of flooding and establishes a program and funding mechanism for the *FRMP*.
- Proposes amendments to Queanbeyan-Palerang Regional Council's (**Council's**) existing policies to ensure that the future development of flood affected land at Braidwood is undertaken so as to be compatible with the flood hazard and risk.
- Ensures the *FRMP* is consistent with NSW SES's local emergency response planning procedures.
- Ensures that the *FRMP* has the support of the community.

5.3 The Study Area

The study area for this *FRMP* comprises the town of Braidwood and its immediate environs. The *FRMP* applies in areas affected by **Main Stream Flooding** along Gillamatong Creek, Monkittee Creek, Mona Creek, Flood Creek and Recreation Ground Creek, **Minor Tributary Flooding** that occurs along an unnamed tributary which joins Gillamatong Creek downstream of the Wallace Street bridge, and **Major Overland Flow** in parts of the Recreation Ground Creek catchment. **Figure 2.1** shows the existing drainage system at Braidwood.

5.4 Community Consultation

The Community Consultation process provided valuable direction over the course of the investigations, bringing together views from key Council staff, other departments and agencies, and importantly, the views of the community gained through:

- the delivery of a *Community Newsletter and Questionnaire* to property occupiers located in the floodplain allowed the wider community to gain an understanding of the issues being addressed as part of the study;
- meetings of the Floodplain Risk Management Committee to discuss results as they became available; and
- public exhibition of the draft *FRMS* and *FRMP*.

A summary of the responses to the questions contained in the *Community Questionnaire* is contained in **Appendix A** of the *FRMS*.

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5.5 Existing Flood Behaviour

Figures 2.2 and **2.3** show the indicate extent and depths of inundation of both the 1% annual exceedance probability (**AEP**) and Probable Maximum Flood (**PMF**) events, respectively, while **Figure 2.4** shows design water surface profiles along Gillamatong Creek, Monkittee Creek, Flood Creek and Recreation Ground Creek. **Figure 2.5** shows the time of rise of floodwaters, while **Figure 2.6** shows the indicate extent of flooding at Braidwood for the 20%, 5%, and 1% AEP events, as well as the PMF event.

Flooding in the Recreation Ground Creek catchment and along the aforementioned unnamed tributary is of a flash flooding nature, with water levels typically rising to their peak in less than one hour, whereas flooding along the other major creeks where they run through Braidwood is of a longer duration nature, with water levels typically rising to their peak in a little over six hours.

With the exception of Recreation Ground Creek and the aforementioned unnamed tributary, floodwater is generally confined to the major creeks and their immediate overbank area for events up to 1% AEP in magnitude. Floodwater that surcharges the inbank area of Recreation Ground Creek is relatively shallow and slow moving in nature for events up to 1% AEP in magnitude. As a result, overbank flooding in the catchment is typically classified as low hazard in nature.

The 1% AEP design flood has been adopted as the "planning flood" for the purposes of specifying flood related controls over future development. The extent of flooding is indicative only, being based on hydrologic and hydraulic models that were developed as part of the *FRMS*. Consequently, the results should not be used to identify the degree of flood affectation or otherwise of individual properties, for which a site specific survey would be required. This level of accuracy in the flood mapping is supported by Office of Environment and Heritage (**OEH**), as the costs associated with undertaking of detailed ground survey in each flood affected property lies outside the scope of the NSW Government's floodplain program. Under the program, it is Council's responsibility to identify the flood risk within the floodplain and prepare maps showing indicative flood extents (i.e. the mapping presented in this *FRMS* report), with the onus being on the property owner to carry out sufficient survey to allow a more accurate picture of flood affection to be described in his/her allotment.

To allow Council to assess individual development proposals (ref. **Section 5.8** below), a detailed site survey would be required to allow the extent of flooding and the flood hazard to be evaluated using the results of the *FRMS*. For this reason, proponents will be required to submit a detailed survey plan of the site for which development is proposed.

5.6 Economic Impacts of Flooding

Table 5.1 over shows the number of properties that would be flooded to above-floor level and the total damages experienced in Braidwood. Details of the flood damages assessment that was undertaken for Braidwood are contained in **Appendix B** of the *FRMS*.

Figure 2.2 (Sheets 2 and 3) and **Figure 2.3** (Sheets 2 and 3) show the location and indicative depth of above-floor inundation in properties that are affected by the 1% AEP and PMF events, respectively. By inspection of **Figure 2.2** (Sheets 2 and 3) the five dwellings that are above-floor inundated during a 1% AEP flood event are all located in the Recreation Ground Creek catchment, as is the single commercial property and single public building. Depths of above-floor inundation in all seven buildings are relatively shallow and do not exceed 150 mm in a 1% AEP flood event.

For a discount rate of 7% pa, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood and an economic life of 50 years is about $0.6 Million. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Braidwood 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.

TABLE 5.1
FLOOD DAMAGES AT BRAIDWOOD(1)

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total Damage ($ Million)
20	1	0	0	0.10
5	2	1	0	0.20
2	4	1	1	0.39
1	5	1	1	0.49
0.5	7	1	1	0.71
0.2	12	2	1	1.09
PMF	87	6	2	9.52

1. Note that the number of properties that would be above-floor inundated was determined from a comparison between the computed flood levels and floor levels that were estimated from a "drive-by" survey.

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5.7 Structure of Floodplain Risk Management Study and Plan

The *FRMS* and *FRMP* are supported by Appendices which provide additional details of the investigations. A summary of the *FRMP* proposed for the study area along with broad funding requirements for the recommended measures are shown in **Table S1** at the commencement of the *FRMS* report. These measures comprise preparation of planning documentation by Council, improvements to flood emergency response planning and community education on flooding by Council and NSW SES to improve flood awareness and response. The measures will over time achieve the objectives of reducing the flood risk to existing and future development for the full range of floods.

The *FRMP* is based on the following mix of measures which have been given a provisional priority ranking according to a range of economic, social, environmental and other criteria set out in **Table 4.1** of the report:

- **Measure 1** – Update wording in *Palerang Local Environmental Plan 2014* (***Palerang LEP 2014***).
- **Measure 2** – Update wording in *Palerang Development Control Plan 2015* (***Palerang DCP 2015***) to incorporate improved controls for future development in flood prone areas.
- **Measure 3** – Improvements in flood emergency response planning.
- **Measure 4** – Increase public awareness of the risks of flooding in the community.
- **Measure 5** – Develop and implement a *Vegetation Management Plan* for Recreation Ground Creek

5.8 Planning and Development Controls

The results of the *FRMS* indicate that an important measure for Council to adopt in the floodplain would be strong floodplain risk management planning applied consistently by all of its branches.

5.8.1 Revision to Palerang LEP 2014

Clause 6.2 of *Palerang LEP 2014* entitled "Flood planning" outlines its objectives in regard to development of flood prone land. The Flood Planning Level (**FPL**) referred to is the 1% AEP flood plus an allowance for freeboard of 500 mm. The area encompassed by the FPL is known as the Flood Planning Area (**FPA**) and denotes the area subject to flood related development controls, such as locating development outside high hazard areas and setting minimum floor levels for future residential development.

To provide flexibility in defining the FPL in areas subject to different types of flooding and for ease of implementing the recommended updates to *Palerang DCP 2015* set out in **Appendix E** of the *FRMS*, clause 6.2 of *Palerang LEP 2014* would require minor amendment (**Measure 1**). Suggested amendments are given in **Section 3.5.1.4**.

5.8.2 Update of Palerang DCP 2015

The recommended updates to *Palerang DCP 2015* (**Measure 2**) used the concepts of *flood hazard* and *hydraulic categorisation* outlined in **Section 2.8** of the *FRMS* to develop controls for future development in flood prone land. **Figure E1.1** in **Appendix E** is an extract from the *Flood Planning Map* relating to the urbanised parts of Braidwood. The extent of the FPA is shown in a solid red colour and has been defined as follows:

- In areas subject to Main Stream Flooding, the FPA is based on the traditional definition of the area inundated by the 1% AEP plus 500 mm freeboard.
- In areas subject to Minor Tributary Flooding, the FPA is defined as areas where depths of inundation in a 1% AEP event exceed 100 mm.
- In areas subject to Major Overland Flow, the FPA is defined as the extent of the High and Low Hazard Floodway zones, as well as areas where depths of inundation in a 1% AEP event exceed 100 mm.

It is proposed that properties intersected by the extent of the FPA would be subject to S10.7 flood affectation notification and planning controls graded according to flood hazard (dependent on depth of inundation and flow velocity). **Annexure 2** in **Appendix E** sets out the graded set of flood related planning controls which have been developed for Braidwood.

Minimum floor level (**MFL**) requirements would be imposed on future development in properties that are identified as lying either partially or wholly within the extent of the FPA shown on the *Flood Planning Map*. The MFLs for all land use types affected by flooding in Braidwood is the level of the 1% AEP flood event plus 500 mm freeboard.

Figure E1.2 in **Appendix E** is the *Flood Hazard Map*. The figure shows the subdivision of the floodplain into a number of categories which have been used as the basis for developing the graded set of planning controls. The floodplain has been divided into the following four categories:

- **Inner Floodplain (Hazard Category 1)**, which is shown in solid red colour. This zone comprises areas where factors such as the depth and velocity of flow, time of rise and evacuation problems mean that the land is unsuitable for some types of development. It principally comprises areas of High Hazard Floodway, but does include some areas of Low Hazard Floodway in some areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are considered to be unsuitable land uses in this zone.
- **Inner Floodplain (Hazard Category 2)**, which is shown in solid yellow colour. This zone comprises Low Hazard Floodway and Flood Storage areas where development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
- **Intermediate Floodplain**, which is shown in solid blue colour. This area is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA. Within this zone, there would only be the requirement for MFLs to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
- **Outer Floodplain**, which is shown in solid cyan colour. This area represents the remainder of the floodplain between the Intermediate Floodplain and the extent of the Probable Maximum Flood (PMF) (that is, the extent of the floodplain). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development are considered to be unsuitable land uses in this zone.

A full list of prescriptive controls that apply to flood prone areas in Braidwood are set out in **Annexure 2** of **Appendix E**.

5.9 Improvements in Emergency Planning and Flood Awareness

Two measures are proposed in the *FRMP* to improve flood emergency planning and maintain awareness in the community of the threat posed by floods:

Measure 3 involves the update by NSW SES of the *Palerang Local Flood Plan* which is dated April 2013 (***Palerang Local Flood Plan 2013***) using information on flooding patterns, times of rise of floodwaters and flood prone areas identified in this report. Figures have been prepared showing indicative extents of flooding, high hazard areas, expected rates of rise of floodwaters in key areas and locations where flooding problems would be expected. **Section 3.6.2** of the *FRMS* references the locations of key data within this report.

Council should also take advantage of the information on flooding presented in the *FRMS*, including the flood mapping, to inform occupiers of the floodplains of the flood risk (included as **Measure 4** of the *FRMP*). This information could be included in a *Flood Information Brochure* to be prepared by Council with the assistance of NSW SES containing both general and site specific data and distributed with the rate notices. The community should also be made aware that a flood greater than historic levels or the planning level can, and will, occur at some time in the future. The *FRMP* should be publicised and exhibited in Council offices and at community gathering places to make residents aware of the measures being proposed.

While the removal of flood debris on the main arms of the study creeks after significant flow events would generally have limited benefit in reducing the flood risk at Braidwood, the approach does have merit in the case of Recreation Ground Creek where the build up of debris on the floodplain over time could increase the risk of a partial blockage of the various road crossings, thereby exacerbating flooding in existing development.

The removal of dense vegetation from the inbank area of the study creeks would also provide limited benefit in terms of reducing the flood risk at Braidwood. The exception is Recreation Ground Creek, where the removal of dense vegetation from the inbank area of the watercourse would reduce the frequency of nuisance flooding.

For the above reasons, the development and implementation of a *Vegetation Management Plan* for Recreation Ground Creek has been included as **Measure 5** in the *FRMP* for Braidwood.

5.10 Implementation Program

The steps in progressing the floodplain risk management process from this point onwards are:

1. Floodplain Risk Management Committee to consider and adopt recommendations of this study. In particular, the Committee should review the basis for ranking floodplain risk management measures (as set out in **Table 4.1** of the *FRMS* and the proposed works and measures to be included in the *FRMP* as set out in **Table S1**); exhibit the *FRMS* and *FRMP* and seek community comment.
2. Consider public comment, modify the document if and as required, and submit to Council.
3. Council adopts the *FRMP* and submits an application for funding assistance in the next funding round for qualifying projects. Assistance for funding **Measure 5** may be available upon application under the Commonwealth and State funded floodplain management programs, currently administered by NSW Office of Environment and Heritage.
4. As funds become available from Government agencies and/or Council's own resources, implement the measures in accordance with the established priorities.

The *FRMP* should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding, reviews of Council's planning strategies and importantly, the outcome of some of the study proposed in this report as part of the *FRMP*. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the *FRMP*.

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6 GLOSSARY OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
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, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Flood Affected Properties	Properties that are either encompassed or intersected by the **Flood Planning Area (FPA)**.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply, an extract of which is shown on **Figure D1.1**.
Flood Planning Level (FPL)	The combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The Flood Planning Level (FPL) for Braidwood is the level of the 1% Annual Exceedance Probability (AEP) flood event plus 500 mm freeboard.
Flood Prone/Flood Liable Land	Land susceptible to flooding by the PMF. Flood Prone land is synonymous with Flood Liable land.
Floodway	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.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the FPL and MFL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the FPL and MFL.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

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TERM	DEFINITION
Inner Floodplain (Hazard Category 1)	Comprises areas where factors such as the depth and velocity of flow, time of rise, isolation and evacuation difficulties mean that the land is unsuitable for future development. It includes areas of High and Low Hazard Floodway, Flood Storage, Flood Fringe, Intermediate Floodplain and Outer Floodplain areas subject to main stream flooding. It also includes land which may become isolated during a flood event. Future development is not permitted in this zone.
Inner Floodplain (Hazard Category 2)	Comprises areas of Low Hazard Floodway and Flood Storage areas where development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. It also includes land which may become isolated during a flood event. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
Intermediate Floodplain	It is land within the indicative extent of flooding resulting from the occurrence of the 1% AEP flood plus 500 mm (i.e. the FPA), but not classified as Inner Floodplain.
Local Drainage	Land on an overland flow path where the depth of inundation during the 1% AEP storm event is less than 100 mm.
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.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 100 mm.
Minimum Floor Level (MFL)	The combinations of flood levels and freeboards selected for setting the Minimum Floor Levels (MFLs) of future development located in properties subject to flood related planning controls. For properties in Braidwood, the MFL is the level of the 1% AEP flood event plus 500 mm freeboard.
Outer Floodplain	This is defined as the land between the FPA and the extent of the PMF.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. For the study area, the extent of the PMF has been trimmed to include depths greater than 100 mm.

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7 REFERENCES

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APPENDIX A

COMMUNITY CONSULTATION

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A1. INTRODUCTION

At the commencement of the *FRMS*, the Consultants prepared a *Community Newsletter* and a *Community Questionnaire*, both of which were distributed by Council to residents and business owners bordering Monkittee Creek, Flood Creek and Recreation Ground Creek (refer to **Attachment 1**).[1]

The purpose of the *Community Newsletter* was to introduce the objectives of the study and set the scene on flooding conditions so that the community would be better able to respond to the *Community Questionnaire* and contribute to the study process.

The *Newsletter* contained the following information:

- A plan showing the extent of the study area.
- A statement of the objectives of the *FRMS&P*, namely the development of a strategy for reducing the flood risk and minimising the long-term impact of flooding on the community.

The *Community Questionnaire* was structured with the objectives of:

- Determining residents' and business owners' attitudes to controls over future development in flood liable areas.
- Inviting community views on possible flood management options which could be considered for further investigation in the *FRMS* and possible inclusion in the resulting *FRMP*.
- Obtaining feedback on any other flood related issues and concerns which the residents and business owners cared to raise.

This **Appendix** to the *FRMS&P* report discusses the responses to the eight questions included in the *Questionnaire* and comments made by respondents.

Chapter A2 deals with the residents' and business owners' experience with historic flooding, as well as determining their views on the relative importance of classes of development over which flood-related controls should be imposed by Council.

Chapter A3 identifies residents' and business owners' views on the suitability of the various options which could be considered in more detail in the *FRMS&P*.

Chapter A4 discusses the best methods by which the community could provide feedback to the Consultants over the course of the study.

Chapter A5 summarises the findings of the *Community Questionnaire*.

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[1] The reach of Gillamatong Creek upstream of its confluence with Flood Creek was subsequently relabelled on the report figures as Monkittee Creek.

A2 RESIDENT PROFILE AND FLOOD AWARENESS

A2.1 General

Residents were requested to complete the *Community Questionnaire* and return it to the Consultants by 1 December 2017. The deadline was extended to include any submissions that were received after this date. The Consultants received 38 responses in total out of the 254 that had been distributed. Six of these responses were received via Council's "YourVoice" online survey.

The Consultants have collated the responses, which are shown in graphical format in **Attachment 2**.

A2.2 Information about Respondents and Properties

The first three questions of the *Community Questionnaire* canvassed information including whether the respondent is a resident or business owner, length of time at the property and the type of property (e.g. house, unit/flat).

Of the 38 responses, 32 were residents, two were business owners, two were land owners and one response was received from a church (**Question 1**). The remaining response did not specify a property classification type. The length of time at which respondents had been at the address was most commonly between 5 to 20 years as specified by twenty respondents. Nine respondents indicated that they had been at the address for 1-5 years, while another nine respondents indicated that they had been at the address for more than 20 years (**Question 2**). The majority of respondents occupied a single dwelling (31), while there were four respondents who owned vacant land, three warehouse or factory responses, an apartment occupier, a shop owner, a farm owner and one response for the aforementioned church building (**Question 3**). Note that some responses were included in more than one property classification type.

A2.3 Controls over Development in Flood Prone Areas

The respondents were asked to rank from 1 to 4 the classes of development which they consider should receive protection from flooding (**Question 4**). Rank 1 was the most important and rank 4 the least.

The classes in decreasing order of importance to respondents ranged from vulnerable residential (e.g. aged persons accommodation), residential property, essential community facilities (e.g. schools, evacuation centres) and lastly, commercial business.

These results gave a guide to the Consultants as to the appropriate location of future development of the various classes within the floodplain. For example, on the basis of community views, vulnerable residential development would receive the highest level of protection by locating future development of this nature outside the floodplain.

In **Question 5**, respondents were asked what notifications Council should give about the flood affectation of individual properties. The community was strongly in favour of advising existing residents (22) and prospective purchasers (26) of the known potential flood threat, with only six respondents who favoured only advising those who enquire to Council about the known potential flood risk and one respondent who favoured not providing any notification. Two respondents provided other suggestions on the level of advice Council should provide to the community.

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Respondents were also asked in **Question 6** about the level of control Council should place on new development to minimise flood-related risks. The most popular response was to advise of the flood risks, but allow the individual the choice as to whether they develop or not, provided they take steps to minimise the potential flood risks. The next most favoured response was to prohibit all new development on land with any potential to flood. A number of respondents also favoured placing restrictions on development which reduces the potential for flood damage, and others favoured prohibiting all new development but only in hazardous locations.

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A3 POTENTIAL FLOOD MANAGEMENT MEASURES

The respondents were also asked for their opinion on potential flood management measures which could be evaluated in the *FRMS&P* (and if found to be feasible included in the Plan), by ticking a "yes" or "no" to the eleven potential options identified in **Question 7**.

The options comprised a range of *structural flood management measures* (management of vegetation along creek corridors, widening of watercourses, removal of floodplain obstructions, improving the stormwater system; levees to contain floodwaters); as well as various *non-structural management measures* (voluntary purchase of residential properties in high hazard areas; raising floor levels of houses in low hazard areas; flood related controls over new developments; improvements to flood warning and evacuation procedures; community education on flooding; and flood advice certificates). The options were not mutually exclusive, as the *FRMP* adopted could, in theory, include all of the options set out in the *Questionnaire*, or indeed, other measures to be nominated by the respondents or the FMC.

The most popular *structural flood management measure* was the management of vegetation along the creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits, closely followed by improvements to the local stormwater drainage system to capture and convey overland flows travelling to the creek system more efficiently. The respondents were not in favour of widening watercourses in Braidwood, removing floodplain obstacles on the floodplain or the construction of levee banks to contain floodwaters.

Improvements to flood warning and evacuation procedures were strongly favoured by the respondents. The implementation of flood-related controls over future development (e.g. by Council nominating minimum permissible floor levels), provision of Planning Certificates to property purchasers and community education also received very positive responses.

The respondents were generally not in favour of providing subsidies for raising the floor levels of existing residential properties located in less hazardous zones of the floodplain. The implementation of a residential Voluntary Purchase scheme (to be administered by Council and designed to allow residents on a wholly voluntary basis to vacate high hazard areas in the floodplain) was also a less popular scheme, with a majority of respondents again not in favour of the scheme.

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A4 INPUT TO THE STUDY AND FEEDBACK FROM THE COMMUNITY

At **Question 8** residents were asked for their view on the best methods of their providing input to the Study and feedback to the Consultants over the course of the investigation. Articles in the local newspaper and communication via Council's website were the two most popular methods, whilst communication through Council's Floodplain Management Committee was also popular. Two respondents suggested mail drops would be effective while one proposed social media and local radio as a means to engage with the local community.

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A5 SUMMARY

Thirty-eight responses were received to the *Community Questionnaire* which was distributed by Council to residents and business owners in Braidwood. The responses amounted to 15 per cent of the total distributed.

A5.1 Issues

The issues identified by the community in their responses to the *Community Questionnaire* support the objectives of the study, as nominated in the attached *Community Newsletter*, and the activities nominated in the Study Brief. Respondents were found to be in favour of providing information on the potential flood threat to residents and prospective purchasers of property in Braidwood. All respondents were also in favour of Council taking some role to reduce flood risks in the community. However, respondents were split between prohibiting development in some or all of the floodplain, or whether Council should allow development in the floodplain areas provided appropriate measures to minimise flood risk are taken. The respondents generally prioritised flood protection towards residential and vulnerable residential type development rather than essential community facilities or commercial development.

A5.2 Flood Management Measures

Of the *structural management measures* which could be incorporated in the *FRMP*, the two favoured measures were maintenance of vegetation along creek corridors and improving the capacity of the local stormwater drainage system, while widening watercourses, removal of floodplain obstacles and construction of levees were unpopular measures among respondents.

Planning controls over new development in flood liable areas, improvements to flood warning, issuing of planning certificates and community education appear to be the most popular of the potential *non-structural measures* set out in the *Questionnaire*. There do not appear to be any new measures raised by the respondents in their responses to **Question 7**.

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ATTACHMENT 1

COMMUNITY NEWSLETTER AND QUESTIONNAIRE

Braidwood Floodplain Risk Management Study & Plan

QPRC

To Residents and Business Owners of Braidwood:

Queanbeyan-Palerang Regional Council has engaged consultants to undertake a Floodplain Risk Management Study and Plan for the township of Braidwood. The Floodplain Risk Management Study will assess options which are aimed at reducing the impacts of flooding on existing development and the establishment of a framework to manage flood liable land in accordance with current best floodplain management principles, while the Plan will set out a recommended program of works and measures which will over time reduce the social, environmental and economic impacts of flooding at Braidwood.

The preparation of the Study and Plan is jointly funded by Council and the NSW Office of Environment & Heritage. Council has established a Floodplain Risk Management Committee which is comprised of relevant council members, state government agencies and community representatives.

The Study and Plan will build on the results of the *Braidwood Creeks Flood Study* (completed in 2005) which defined flooding patterns and flood levels in Braidwood under present day conditions.

The attached figure shows the indicative extent of the 1 in 100 annual exceedance probability (AEP) flood along Gillamatong, Monkittee, Flood and Recreation Ground Creeks, as well as the extent of flood prone land at Braidwood (as defined by the extent of the Probable Maximum Flood). The 1 in 100 AEP flood is a flood which has a 1% chance of occurrence in any one year, while the Probable Maximum Flood is the largest flood that could conceivably occur at Braidwood.

Have Your Say on Floodplain Management

An important first step in the preparation of a Floodplain Risk Management Study and Plan is to determine the flood issues which are important to the community. The attached **questionnaire** has been provided to residents and businesses to assist the consultants in gathering this important information. The questionnaire may also be completed online via Council's website at http://yourvoice.qprc.nsw.gov.au/braidwood-floodplain-risk-management-plan. 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 **Friday 1 December 2017**.

Contact: Queanbeyan-Palerang Regional Council

Thomas Hogg | Engineer
Phone: (02) 6285 6992
Email: Thomas.Hogg@qprc.nsw.gov.au

Braidwood Floodplain Risk Management Study & Plan

QPRC

Community Questionnaire

This Questionnaire is part of the *Braidwood Floodplain Risk Management Study and Plan*, which is currently being prepared by Queanbeyan-Palerang Regional Council with the financial and technical support of the NSW Office of Environment & Heritage. Your responses to the questionnaire will help us determine the flood issues that are important to you.

Please return your completed Questionnaire in the reply paid envelope provided by **Friday 1 December 2017**. No postage stamp is required. If you have misplaced the supplied envelope or wish to send an additional submission the address is:

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

Alternatively, the questionnaire can be completed online via the following link:

http://yourvoice.qprc.nsw.gov.au/braidwood-floodplain-risk-management-plan

Your name (optional):_____

Address:_____

About your property

1. Please tick as appropriate:

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

2. How long have you been at this address?

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

3. What is your property?

- ☐ House
- ☐ Villa/Townhouse
- ☐ Unit/Flat/Apartment
- ☐ Vacant land
- ☐ Industrial unit in larger complex
- ☐ Stand alone warehouse or factory
- ☐ Shop
- ☐ Community building
- ☐ Other (_____)

Your attitudes to Council's development controls

4. Please rank the following development types according to which you think are the most important to protect from floods

(1=highest priority to 4=least priority)

Development Type	Rank
Commercial/Business	
Residential	
Vulnerable residential development (e.g. aged persons accommodation)	
Essential community facilities (e.g. schools, evacuation centres)	

5. What notifications do you consider Council should give about the potential flood affectation of individual properties?

(Tick one or more boxes)

- ☐ Advise every resident and property owner on a regular basis of the known potential flood threat
- ☐ Advise only those who enquire to Council about the known potential flood threat
- ☐ Advise prospective purchasers of property of the known potential flood threat.
- ☐ Provide no notifications
- ☐ Other (_____)

6. What level of control do you consider Council should place on new development to minimise flood-related risks?

(Tick only one box)

(In addition to being favoured by the Community, these options would also need to comply with legislation)

- ☐ Prohibit all new development on land with any potential to flood
- ☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
- ☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or the use of flood compatible building materials)
- ☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
- ☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks

Your opinions on floodplain risk management measures

7. Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the study area (see plan attached).

This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes" or "no" to indicate if you favour the option. Please leave blank if undecided.

Option	Yes	No
Management of vegetation along creek corridors to provide flood mitigation, stability, aesthetic and habitat benefits.		
Widening of watercourses.		
Construction of detention basins		
Improve the stormwater system within the town area.		
Construct permanent levees along the creeks to contain floodwaters.		
Voluntary scheme to purchase residential property in high hazard areas.		
Provide funding or subsidies to raise houses above major flood level in low hazard areas.		
Specify controls on future development in flood-liable areas (eg. controls on extent of filling, minimum floor levels.)		
Improve flood warning and evacuation procedures both before and during a flood.		
Community education, participation and flood awareness programs.		
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.		

Other Information

8. What do you think is the best way for us to get input and feedback from the local community about the results and proposals from this study?

(Tick one or more boxes)

- ☐ Council's website
- ☐ Articles in local newspaper
- ☐ Through Council's Floodplain Management Committee
- ☐ Other (please specify) _____

9. If you wish us to contact you so you can provide further information, please provide your details below:

Name: _____

Address: _____

_____

Phone: _____

Best time to call is _____

Fax No: _____

Email: _____

Who can I contact for further information?

Queanbeyan-Palerang Regional Council
Thomas Hogg | Engineer
Phone: (02) 6285 6992
Email: Thomas.Hogg@qprc.nsw.gov.au

Copies of this Questionnaire can be obtained from:
http://yourvoice.qprc.nsw.gov.au/braidwood-floodplain-risk-management-plan

COMMENTS

Please write any additional comments here:

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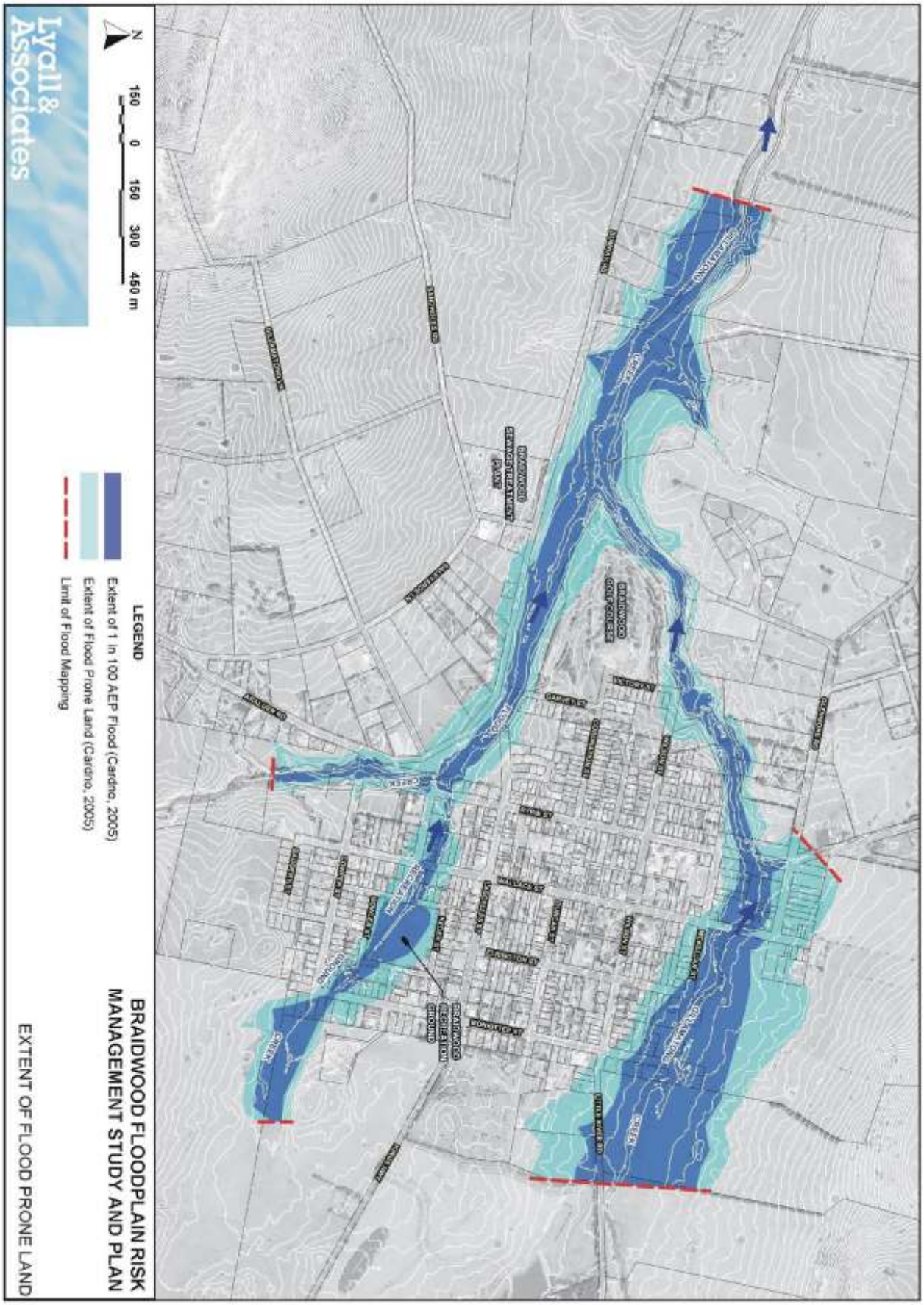
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LEGEND
Extent of 1 in 100 AEP Flood (Cardno, 2005)
Extent of Flood Prone Land (Cardno, 2005)
Limit of Flood Mapping
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
EXTENT OF FLOOD PRONE LAND

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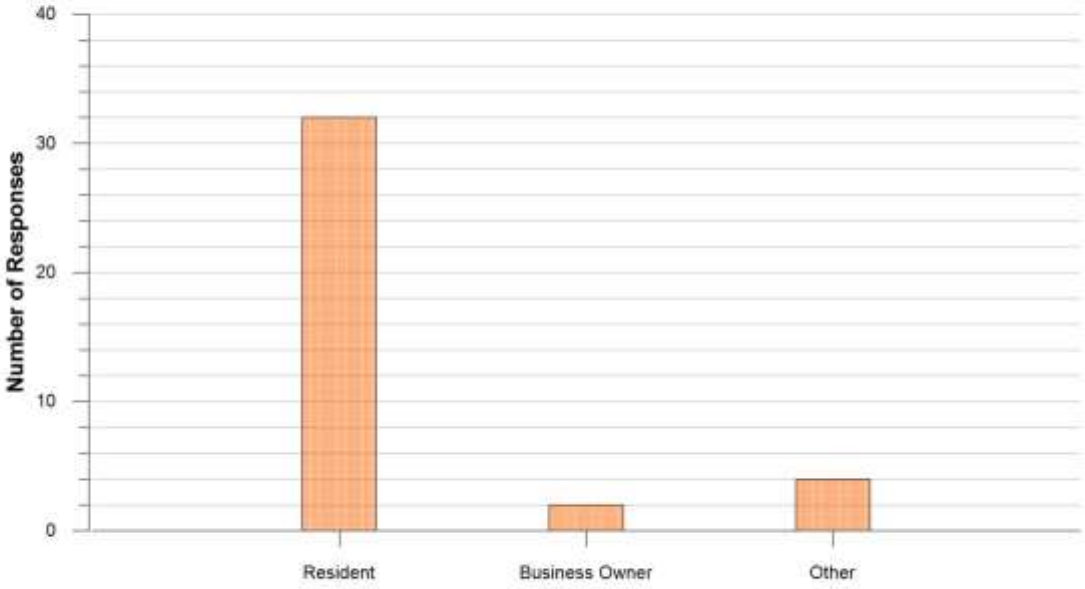
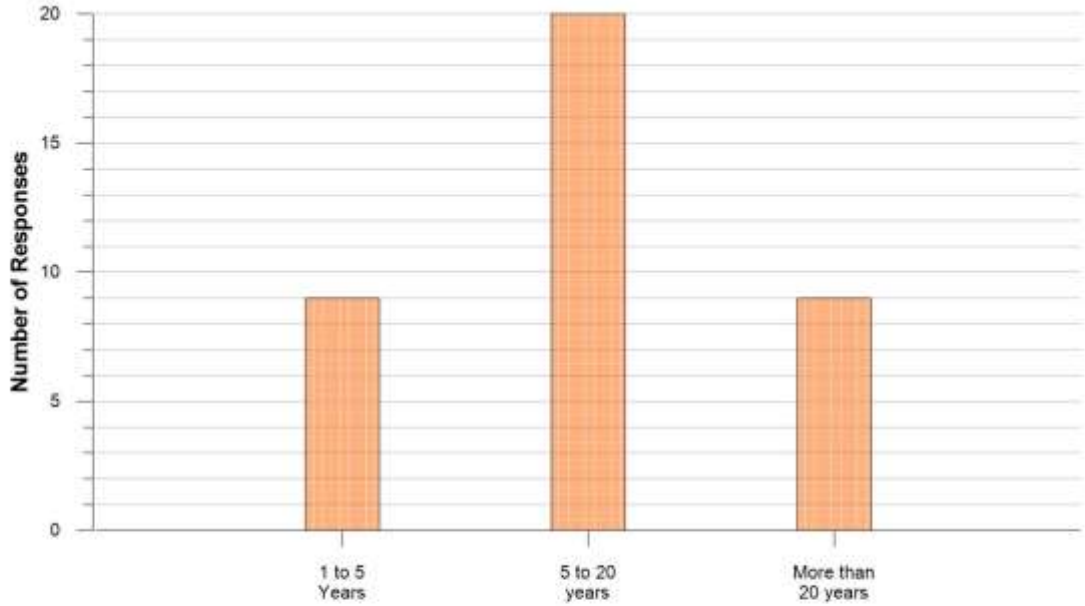
ATTACHMENT 2

RESPONSES TO COMMUNITY QUESTIONNAIRE

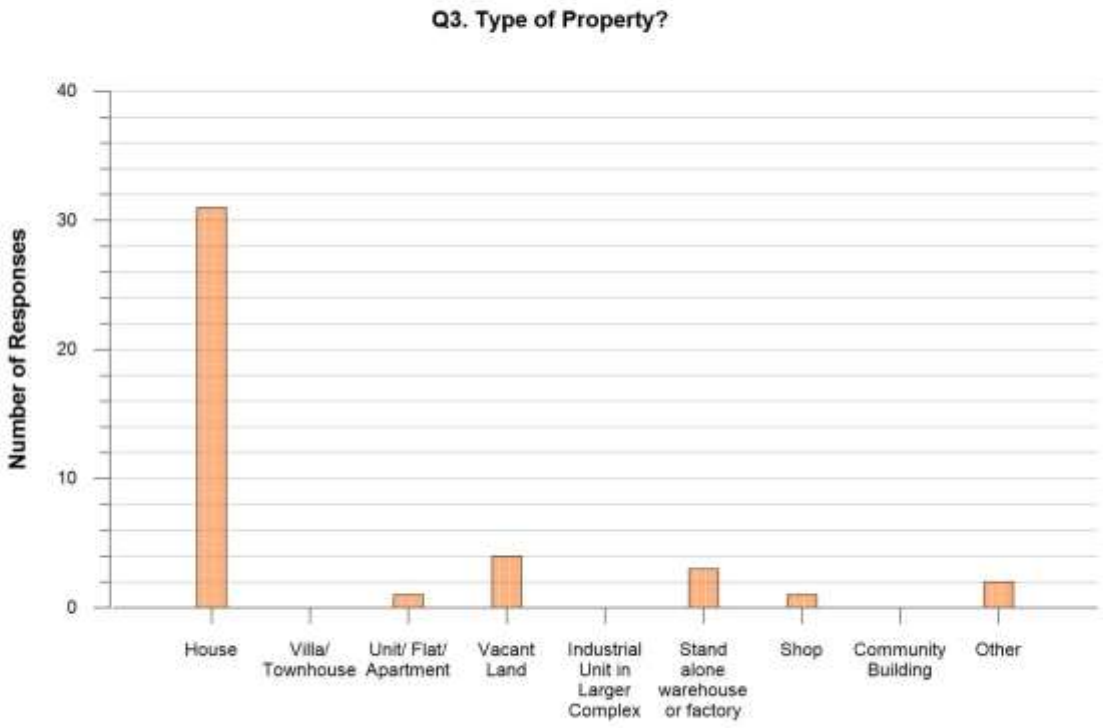
Q1. Residential Status



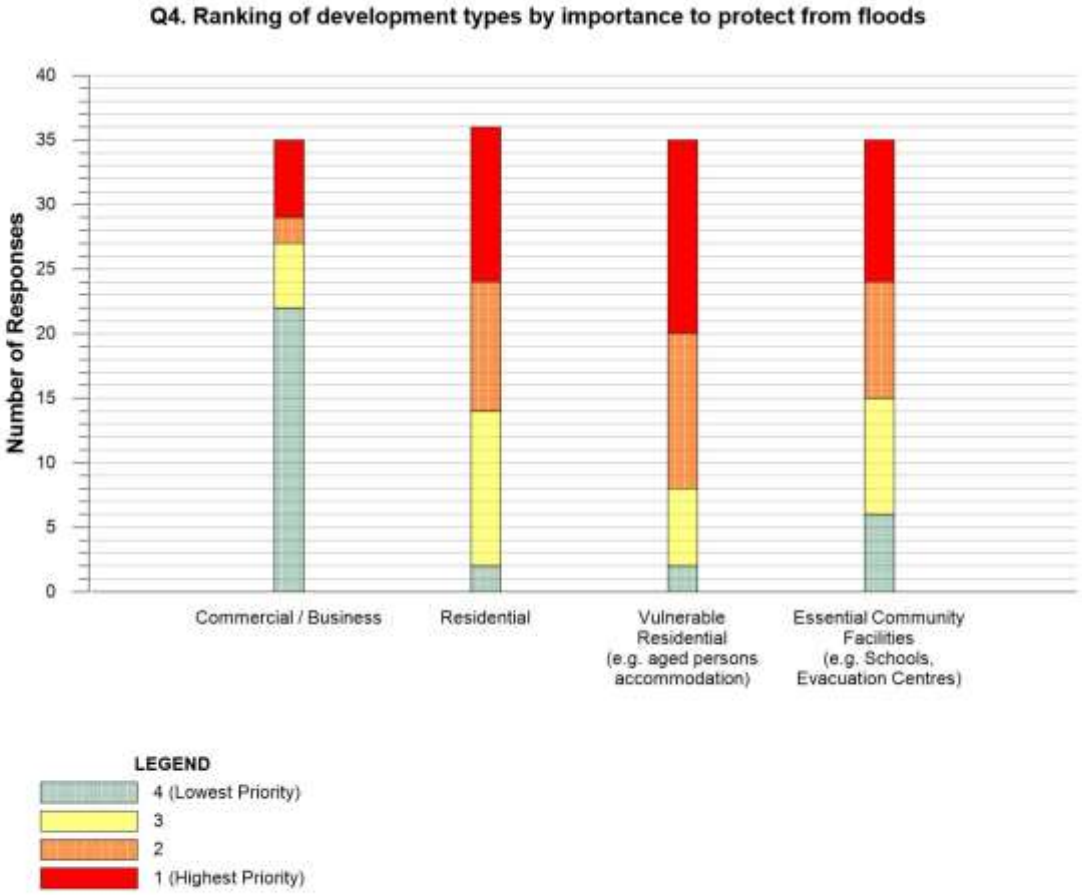
Q2. How long have you owned or lived at this address?



RESPONSE TO COMMUNITY QUESTIONNAIRE

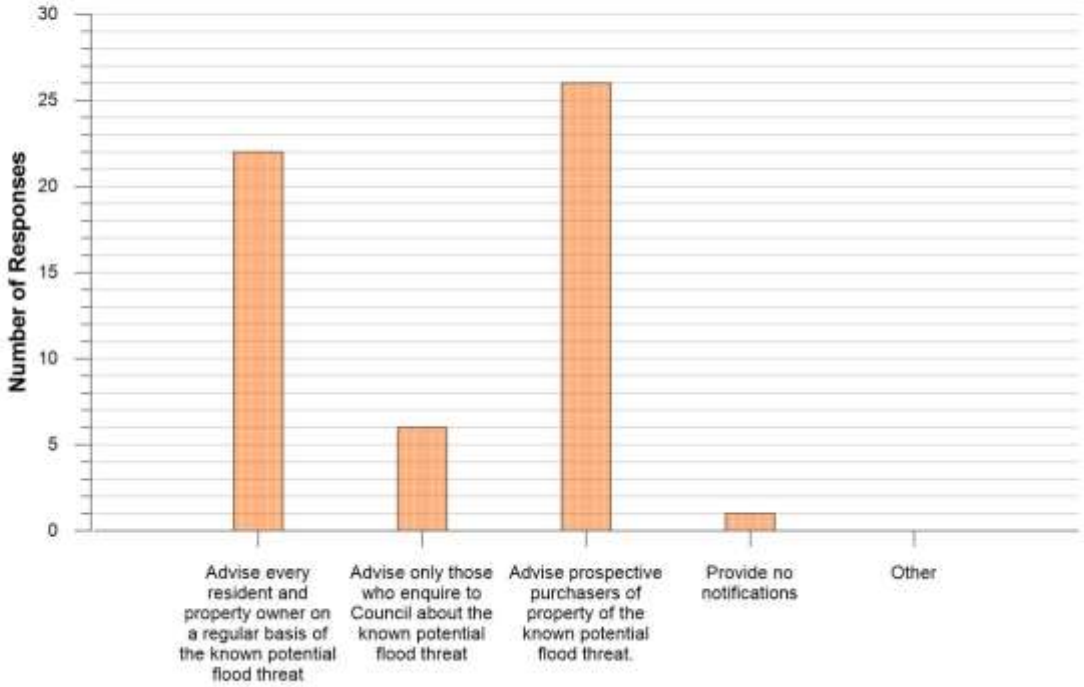


RESPONSE TO COMMUNITY QUESTIONNAIRE

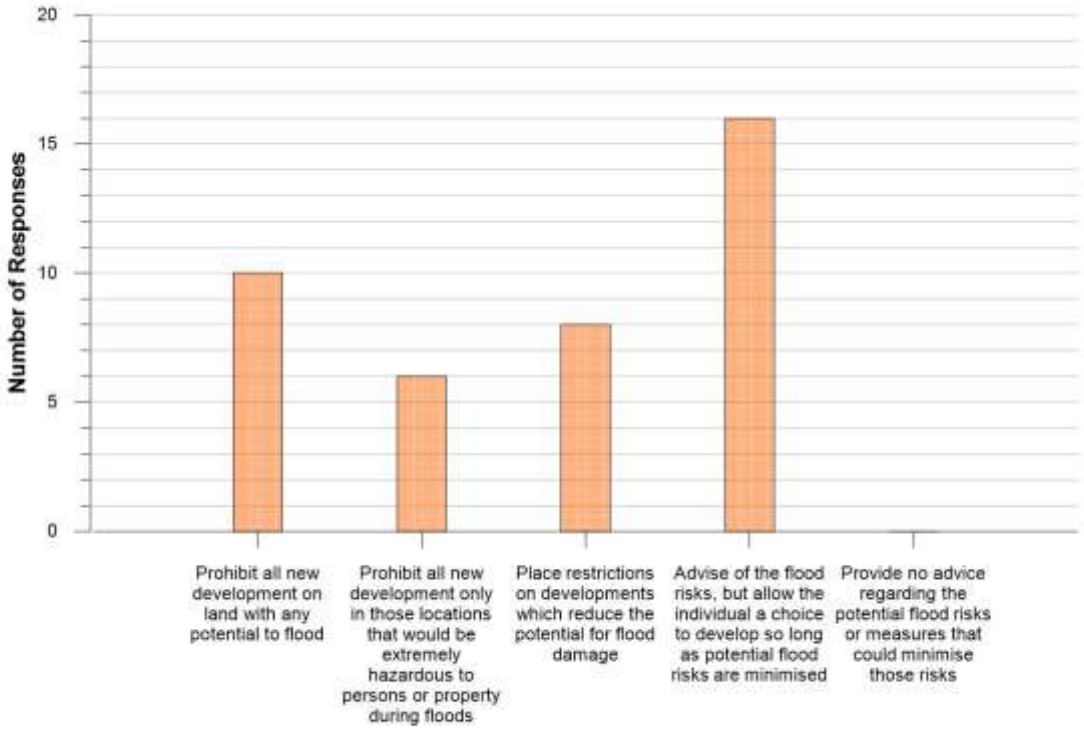


RESPONSE TO COMMUNITY QUESTIONNAIRE

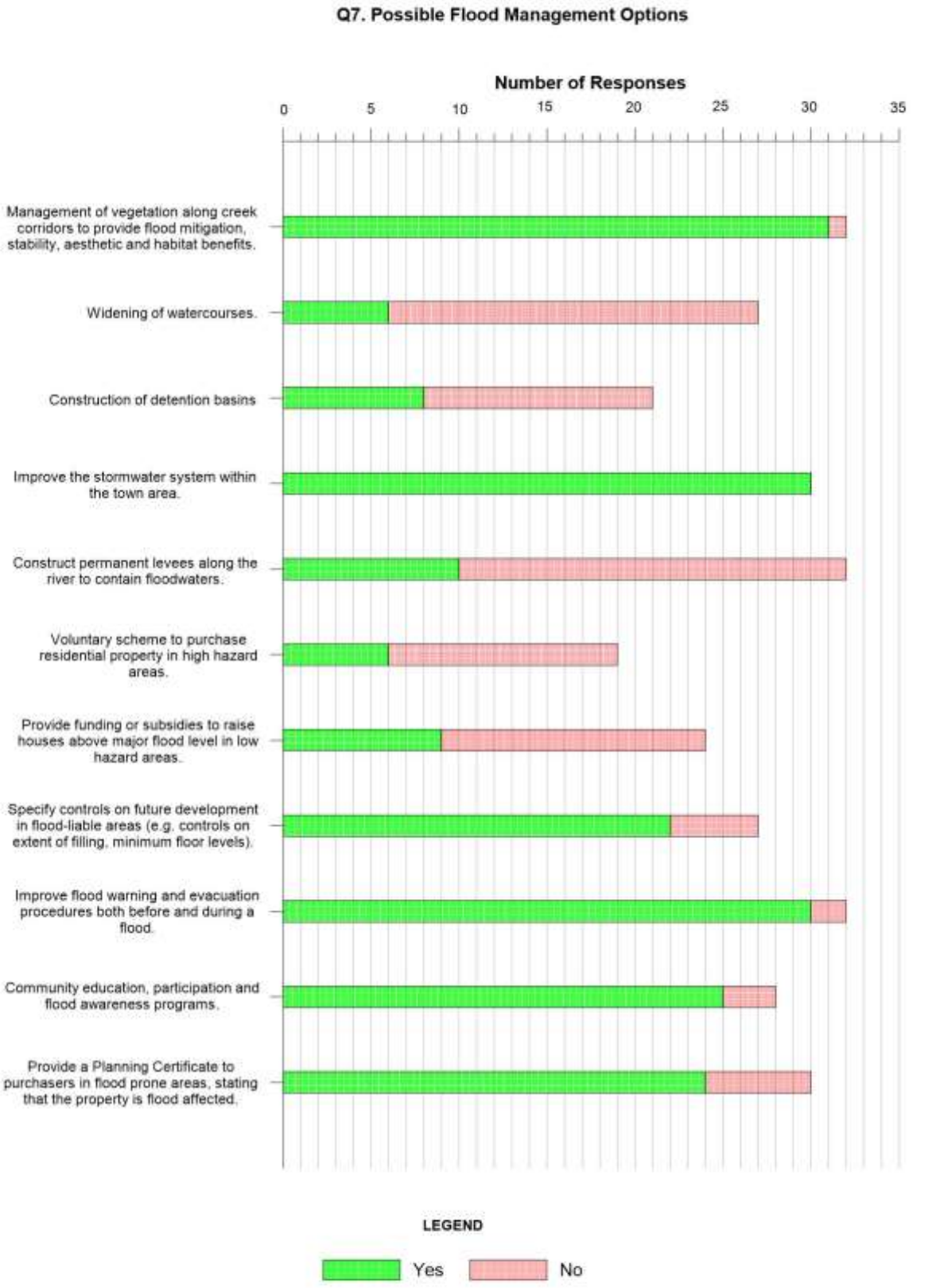
Q5. What notifications should Council give about the potential flood affectation of properties?



Q6. What level of control should Council place on new development to minimise flood-related risks?

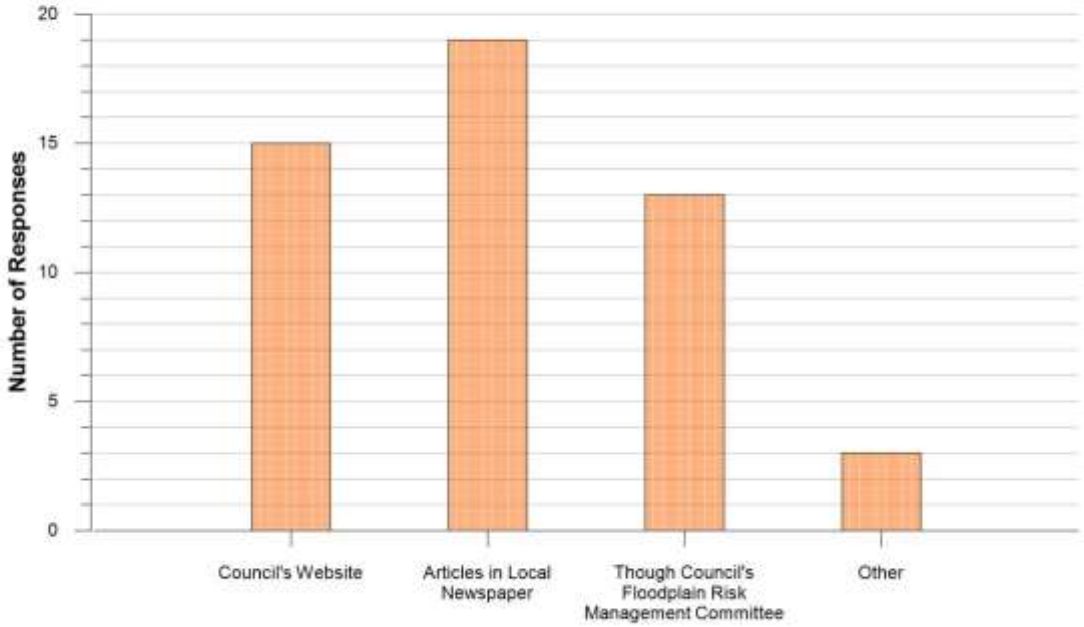


RESPONSE TO COMMUNITY QUESTIONNAIRE



RESPONSE TO COMMUNITY QUESTIONNAIRE

Q8. Best methods to get input and feedback from the local community



RESPONSE TO COMMUNITY QUESTIONNAIRE

APPENDIX B

HYDROLOGIC AND HYDRAULIC MODELLING (BOUND IN VOLUME 2)

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APPENDIX C

DIFFERENCES IN DESIGN FLOOD ESTIMATION FOR BRAIDWOOD ARR1987 VERSUS ARR2016

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C2.1 Difference in Peak Flood Levels Derived using Procedures set out in ARR1987 and ARR2016 – 1% AEP

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C1. INTRODUCTION

This Appendix sets out the findings of an investigation which was undertaken to assess the difference between design peak flows derived using the procedures set out in ARR1987 and ARR2016. Also presented in this Appendix are the results of modelling the 1% AEP flood event at Braidwood based on the application of the two sets of procedures.

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C2. ASSESSMENT METHODOLOGY AND KEY FINDINGS

C2.1 General

Table C2.1 at the end of this Appendix shows a comparison of the peak flow estimates on Monkittee Creek at its confluence with Mona Creek, and Flood Creek at its confluence with Recreation Ground Creek based on the procedures set out in ARR1987 and ARR2016 for events with AEP's of 20, 5, 2 and 1 per cent.

The procedures that were adopted to derive the design peak flow estimates in **Table C2.1** and a discussion on the findings are discussed below. Note that the columns referred to in the following discussion relate to **Table C2.1**.

C2.2 Hydrologic Modelling (ARR1987)

The RAFTS hydrologic model that was developed as part of the *Flood Study* adopted a BX value of 1.0, a Manning's n value of 0.04 and an assumed constant flow velocity of 2 m/s for deriving lag times between nodes. The RAFTS model also incorporated the Australian Representative Basin Model (**ARBM**) for computing rainfall losses.

While the peak flows presented in the *Flood Study* (refer Column D) are similar to the values derived using the PRM (refer Column E), they are not considered to be a close match.

When the same set of hydrologic model parameters were applied to the Braidwood Hydrologic Model, with the exception of the adoption of an initial loss-continuing loss model, a close match was achieved with peak flows derived using the PRM (refer Column F).[1]

C2.3 Regional Flood Frequency Estimation

Column G shows the raw output data from the Regional Flood Frequency Estimation (**RFFE**) Model, the procedures for which are set out in ARR2016 (**Raw RFFE Flows**).[2] The Raw RFFE Flows are comparable to those derived using ARR1987 for the 1% AEP flood event, but are significantly lower for the more frequent events.

The left hand side of **Plate 1** over the page is a screen shot taken from the RFFE model website showing the location of the 15 gauged catchments that are relied upon to derive the Raw RFFE Flows at Braidwood, while the right hand side shows the relationship between peak 1% AEP flow and catchment area for the 15 sites.

Table C2.2 at the end of this Appendix sets out the details of the 15 gauged catchments shown in **Plate 1**, as well as a comment about the suitability of each for determining design peak flows at Braidwood.

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[1] The ARBM loss model adopted as part of the *Flood Study* was replaced with an initial loss-continuing loss model, with an initial loss value of 15 mm and a continuing loss model of 2.5 mm/hr found to achieve a good match with peak flows derived using the PRM (**ARR1987 Tuning Losses**).

[2] Data input to the RFFE Model:

- Monkittee Creek (GI5.0): Outlet (Longitude – 149.811791, Latitude - -35.44205), Centroid (Longitude – 149.851018, Latitude - -35.447375), catchment Area – 38.5 km^2.
- Flood Creek (FL5.0): Outlet (Longitude – 149.795659, Latitude - -35.447784), Centroid (Longitude – 149.808327, Latitude - -35.47767), catchment Area – 23.3 km^2.

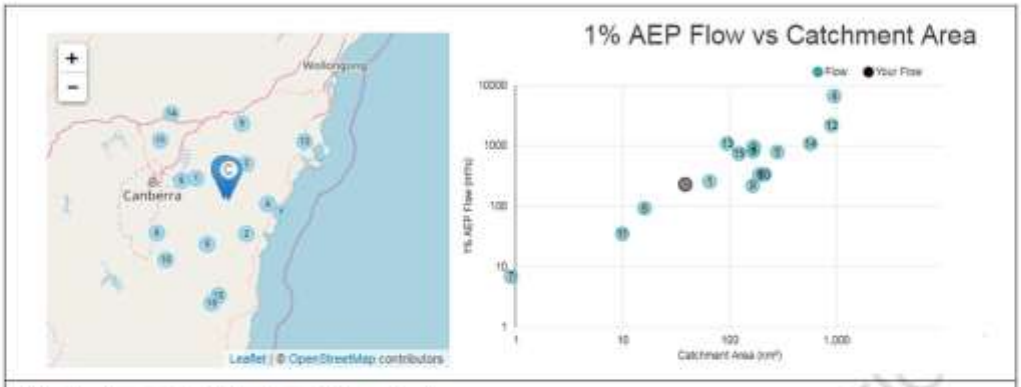

Plate 1 – Screenshot taken from RFEE website.

Gauged Catchment No.'s 1 (**GC1**) and 6 (**GC6**) were found to be the most suitable catchments for use in deriving design peak flow estimates at Braidwood. GC1 is the WaterNSW operated Butmaroo Creek at Butmaroo (Site No. 411003) stream gauge, while GC6 is the Bureau of Meteorology (**BoM**) operated Mill Post Creek at Bungendore (Site No. 411001) stream gauge.

Column H shows the flood frequency derived peak flow estimates at GC1 (**GC1 RFFE Flows**). Comparison of Columns G and H show that the GC1 RFFE Flows are similar to the Raw RFFE Flows for the Monkittee Creek catchment, even though its catchment area (38.5 km²) is about half that of GC1 (65 km²).[3]

Column I shows the flood frequency derived peak flow estimates at GC6 (**GC6 RFFE Flows**). The GC6 RFFE Flows (where the catchment area is 16 km²) are significantly lower than the Raw RFFE Flows derived for the Flood Creek catchment, which has a catchment area of 23.3 km².[4]

As the Raw RFFE Flows are larger than those at nearby and comparable gauge sites, design peak flows for Monkittee Creek and Flood Creek were derived by interpolating between the GC1 RFFE Flows and the GC6 RFFE Flows (**Interpolated RFFE Flows**) (refer Column J). By comparison of the peak flows set out in Columns D and J, the Interpolated RFFE Flows are between 32% and 67% lower than those set out in the *Flood Study* and between 34% and 56% lower than the corresponding PRM estimates.

C2.4 Comparison of ARR1987 and ARR2016 Intensity-Frequency-Duration Data

Table C2.3 at the end of this Appendix shows a comparison of the design rainfall intensities for a range of AEP's and storm durations as derived using the procedures set out in both ARR1987 and ARR2016. The rainfall intensities derived using the procedures set out in ARR2016 are between 21% and 23% lower than those derived using procedures set out in ARR1987 for the 9 hour storm event which was found to be critical for maximising peak flows in both Monkittee Creek and Flood Creek.

[3] A review of the raw stream flow data on BoM's Water Data Online website shows that the highest gauged flow at the site is 81 m³/s, which based on the values set out in Column H, has an AEP of between 5 and 20 per cent. The online data also shows that there are a large number of missing stream flow data, with continuous annual maximum flows only available for the period 1979-1996 (i.e. 18 years of continuous annual maximums).

[4] Gauge data similar to that for GC1 are not available for GC6.

C2.5 Hydrologic Modelling (ARR2016)

Table C2.4 at the end of this Appendix sets out the rainfall losses that were generated by the ARR2016 Data Hub (**ARR2016 Data Hub Losses**).

Column K shows the peak flows that were generated by the Braidwood Hydrologic Model after application of the ARR2016 Data Hub Losses. By comparison of the peak flows set out in Columns J and K, the resulting peak flows are between 40% and 60% lower than the Interpolated RFFE Flows.

Table 5.3.14 in Chapter 3 of Book 5 of ARR2016 contains a list of the median loss values at 35 gauged catchments across Australia that were used to derive prediction equations used to estimate the Storm Loss and Continuing Loss values for rural catchments in ARR2016. One of the gauged catchments is the Butmaroo Creek catchment which is located about 30 km north-west of Braidwood where the median Storm Loss and Continuing Loss were found to be 40 mm and 2.6 mm/hr, respectively (**Butmaroo Creek Losses**).

Column L shows that the design peak flow estimates derived by applying the Butmaroo Creek Losses to the Braidwood Hydrologic Model are between 20% and 30% lower than the Interpolated RFFE Flows.[5]

Column M shows that the design peak flows derived using the losses that provided a good match with the PRM (i.e. the ARR1987 Tuning Losses) also provide a reasonable match with the Interpolated RFFE Flows.

Column N shows that the design peak flows derived using the ARR2016 Storm Loss and median pre-burst losses, but with a reduced Continuing Loss of 2.5 mm/hr (**Adjusted ARR2016 Data Hub Losses Set 1**) also provides a reasonable match with the Interpolated RFFE Flows, albeit slightly lower than those presented in Column M.

Column O shows that while reducing the Continuing Loss from 2.5 mm/hr to 1 mm/hr (**Adjusted ARR2016 Data Hub Losses Set 2**) will provide a close match with peak 1% AEP Interpolated RFFE Flows, the computed 20% AEP flows are about 50% higher.

C2.6 Impact of Difference in Design Flow Estimation Approaches on Flooding Behaviour

Figures C2.1 shows the difference in the extent and depth of inundation resulting from the application of the flood hydrology to the TUFLOW hydraulic model that was developed as part of the present investigation, noting that a positive afflux indicates that the modelled peak flood levels derived using the procedures set out in ARR1987 are higher than those derived using ARR2016.

The modelling shows that the adoption of flood hydrology derived using the procedures set out in ARR2016 would result in a reduction in peak 1% AEP flood levels of more than 1 m on Monkittee Creek and by up to about 0.8 m on Flood Creek. The reduction in peak flood levels would also have a significant impact on the extent of land which would be subject to flood related planning controls, especially on Monkittee Creek on land that is presently zoned *R2 Low Density Residential*.

[5] The ARR2016 Data Hub median pre-burst losses were subtracted from the Storm Loss of 40 mm.

C3. CONCLUDING REMARKS

Application of the procedures set out in ARR2016, which included the adoption of updated design intensity-frequency-duration data results in a reduction in peak flow estimates at Braidwood of between about 43% and 48% when compared to those derived using the procedures set out in ARR1987 (based on a comparison of peak flows set out in Columns F and M). The reduction in peak flows is attributed to the 21-23% reduction in design rainfall intensities and the difference in the temporal patterns.[6]

In the absence of any recorded flow data in the streams which run through Braidwood and in the knowledge that at the time of writing the authors of ARR2016 are in the processes of reassessing the recommended storm and pre-burst losses for NSW, it was concluded that the findings of the *Flood Study* should be updated using the procedures set out in ARR1987 in combination with the flood models described in **Section 2.4.2** of the Main Report.

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[6] Runs of the Braidwood Hydrologic Model showed that the adoption of the 10 off ARR2016 ensemble based temporal patterns lead to greater than a 20% reduction in the peak 1% AEP flow estimate when compared to the ARR1987 single storm based temporal pattern (Note that the rainfall intensity was kept the same and a zero loss model was adopted).

TABLE C2.1
COMPARISON OF DESIGN PEAK FLOW ESTIMATES AT BRAIDWOOD
(m^3/s)

ID[1]	Location	AEP (%)	ARR1987			ARR2016								
					Braidwood Hydrologic Model	RFFE				Braidwood Hydrologic Model				
			Flood Study	PRM	ARR1987 Tuning Losses[3]	Raw RFFE Flows	GC1 RFFE Flows (Area = 65km²)	GC6 RFFE Flows (Area = 10km²)	Interpolated RFFE Flows	ARR2016 Data Hub Losses[3]	Butmaroo Creek Losses[4]	ARR1987 Tuning Losses[2]	Adjusted ARR2016 Data Hub Losses Set 1[5]	Adjusted ARR2016 Data Hub Losses Set 2[6]
[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]	[O]
GI5.0	Monkittee Creek at Confluence with Mona Creek (Area = 38.5 km²)	20	137	103	100	58	59		46	19	37	57	50	64
		5	200	153	159	121	131		86	50	74	83	81	94
		2	229	200	198	178	196		116	73	104	110	112	128
		1	259	238	233	230	256		147	93	122	129	130	147
FL5.0	Flood Creek at Confluence with Recreation Ground Creek (Area = 23.3 km²)	20	81	71	79	35		36	38	17	29	41	38	47
		5	117	104	118	74		61	67	39	52	62	57	64
		2	133	136	142	108		78	90	55	71	76	77	87
		1	158	163	165	140		92	108	68	85	88	91	101

1. Refer **Figure B2.1**, sheet 2 for location.
2. An initial loss (**IL**) of 15 mm, continuing loss (**CL**) of 2.5 mm/hr and a BX routing parameter of 1.0 were found to provide a close match with the peak flows derived using the PRM, and to a lesser extent the peak flows presented in the *Flood Study*.
3. Derived using the raw ARR2016 Data Hub losses (i.e. Storm Loss = 31 mm and CL = 6.0 mm/hr) and a BX routing parameter of 1.0, as well as the median pre-burst losses in the ARR2016 Data Hub.
4. Derived using the Butmaroo Creek losses (i.e. Storm Loss = 40 mm and CL = 2.6 mm/hr [refer Table 5.3.14 in Book 5, Chapter 3 of ARR2016]) and a BX routing parameter of 1.0, as well as the median pre-burst losses in the ARR2016 Data Hub.
5. Derived using the ARR2016 Data Hub Storm Loss (i.e. 31 mm), a CL value that provided a good match with the PRM (i.e. 2.5 mm/hr) and a BX routing parameter of 1.0, as well as the median pre-burst losses in the ARR2016 Data Hub.
6. Derived using the ARR2016 Data Hub Storm Loss (i.e. 31 mm), a CL value of 1.0 mm/hr and a BX routing parameter of 1.0, as well as the median pre-burst losses in the ARR2016 Data Hub.

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TABLE C2.2
GAUGED CATCHMENTS USED TO DERIVE DESIGN PEAK FLOWS AS PART OF THE RFFE METHOD

Gauge Catchment No.[1]	Site Number	River Basin	Distance from Braidwood (km)	Catchment Area[2] (km^2)	Suitable for use at Braidwood
1	411003	Lake George	32	65	Yes, comparable catchment size and located in close proximity to Braidwood
2	216009	Clyde River	36	168	No, catchment area too large
3	215004	Shoalhaven River	38	166	
4	216002	Clyde River	39	952	
5	215008	Shoalhaven River	42	280	
6	411001	Lake George	42	16	Yes, comparable catchment size and located in close proximity to Braidwood
7	216008	Clyde River	51	0.9	No, catchment area too small
8	410141	Murrumbidgee River	67	190	No, catchment area too large
9	215014	Shoalhaven River	71	164	
10	410076	Murrumbidgee River	74	212	
11	410160	Murrumbidgee River	78	9.9	More suitable catchments located in closer proximity to Braidwood
12	218005	Tuross River	84	900	No, located too far away from Braidwood
13	216004	Clyde River	89	95	
14	412063	Lachlan River	91	570	
15	218007	Tuross River	92	122	

1. Refer **Plate 1** for location of gauged catchments.
2. By comparison, the catchment area of Monkittee Creek and Flood Creek are 38.5 and 23.3 km^2, respectively.

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TABLE C2.3
COMPARISON OF ARR1987 AND ARR2016
INTENSITY-FREQUENCY-DURATION DATA
(mm/hr)

AEP (%)	6 Hour Storm			9 Hour Storm			12 Hour Storm			24 Hour Storm		
	ARR 1987	ARR 2016	Reduction (%)	ARR 1987	ARR 2016	Reduction (%)	ARR 1987	ARR 2016	Reduction (%)	ARR 1987	ARR 2016	Reduction (%)
20	12.0	9.0	25%	9.3	7.3	22%	7.8	6.4	18%	5.1	4.5	11%
5	16.0	11.9	26%	12.4	9.8	21%	10.4	8.6	17%	6.8	6.3	8%
2	19.1	13.9	27%	14.8	11.6	22%	12.4	10.3	17%	8.2	7.6	7%
1	21.4	15.4	28%	16.7	12.9	23%	13.9	11.5	17%	9.3	8.7	6%

TABLE C2.4
ARR2016 DATA HUB LOSSES[1]
9 HOUR STORM DURATION

AEP (%)	Pre-burst Depths (mm)					Burst Loss (mm)[2]				
	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%
20	0	0.2	6.25	29.9	56.75	31	30.8	24.75	1.1	0
5	0	0.45	12.6	46.55	85.35	31	30.55	18.4	0	0
2	0	0.2	15.2	53.9	94.95	31	30.8	15.8	0	0
1	0	0	17.1	59.4	102.15	31	31	13.9	0	0

1. Storm Loss = 31.0 mm, Continuing Loss = 6.0 mm/hr.
2. Burst Loss = Storm Loss minus Pre-burst Loss.

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APPENDIX D

FLOOD DAMAGES

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FIGURES
(BOUND IN VOLUME 2)

D8.1 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram – 1% AEP

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D1. INTRODUCTION AND SCOPE

D1.1 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. Indirect damages result from the interruption of community activities, including traffic flows, trade, industrial production, costs to relief agencies, evacuation of people and contents and clean up after the flood.

Generally, tangible damages are estimated in dollar values using survey procedures, interpretation of data from actual floods and research of government files.

The various factors included in the **intangible damage** category may be significant. However, these effects are difficult to quantify due to lack of data and the absence of an accepted method. Such factors may include:

- inconvenience
- isolation
- disruption of family and social activities
- anxiety, pain and suffering, trauma
- physical ill-health
- psychological ill-health.

D1.2 Scope of Investigation

In the following sections, tangible damages to residential, commercial and industrial properties and public buildings have been estimated resulting from flooding at Braidwood. Intangible damages have not been quantified. 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.

D1.3 Terminology

Definitions of the terms used in this Appendix are presented in **Section D8** which also summarises the value of Tangible Flood Damages.

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D2. 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. A spreadsheet model which has been developed by OEH for estimating residential damages and an in-house spreadsheet model which has been developed for previous investigations of this nature for estimating commercial, industrial and public building damages were 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 spreadsheet model 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 elevations of building floors 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.

The depth-damage curves for residential damages were determined using procedures described in *"Floodplain Management Guideline No 4. Residential Flood Damage Calculation"*, *2007* published by DECC. Damage curves for other categories of development (commercial and industrial, public buildings) were derived from previous floodplain management investigations.

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 catchments should not be used to provide information on the depths of above-floor inundation of individual properties.

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D3. SOURCES OF DATA

D3.1 General

To estimate *Average 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 at Braidwood as specific damage surveys were not conducted following the recent floods in October 2010 and March 2012.
- 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 (LMJ, 1985). It was not used for the present investigation.
- The third way is to use generalised data such as that published by CRES (Centre for Resource & Economic Studies, Canberra) and used in the Floodplain Management Study for Forbes (SKM, 1994). These kinds of data are considered to be suitable for generalised studies, such as 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. This was the approach used for the present study. As mentioned, the *DECC Guideline No 4, 2007* procedure was adopted for the assessment of residential damages. The approach was based on data collected following major flooding in Katherine in 1998, with adjustments to account for changes in values due to inflation, and after taking into account the nature of development and flooding patterns in the study area. The data collected during site inspection in the flood liable areas assisted in providing the necessary adjustments. Commercial and industrial damages were assessed via reference to recent floodplain management investigations of a similar nature to the present study (L&A, 2018).

D3.2 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

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For commercial/industrial properties, the Property Survey obtained information regarding:

- 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 and public 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 is shown in **Table D3.1**.

TABLE D3.1
NUMBER OF PROPERTIES INCLUDED IN DAMAGES DATABASE

Development Type	Number of Properties
Residential	177
Commercial / Industrial	13
Public	2
Total	**192**

D3.3 Flood Levels Used in the Analysis

Damages were computed for the design flood levels determined from the hydraulic model that was 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, debris build-ups in the channels which may cause a partial blockage of bridges and 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.

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D4. RESIDENTIAL DAMAGES

D4.1 Damage Functions

The procedures identified in *DECCW Guideline No 4, 2007* allow for the preparation of a depth versus damage relationship which incorporates structural damage to the building, damage to internals and contents, external damages and clean-up costs. In addition, there is the facility for including allowance for accommodation costs and loss of rent. Separate curves are computed for three residential categories:

- Single storey slab on ground construction
- Single storey elevated floor
- Two storey residence

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 Braidwood is "flash flooding" in nature, with surcharge of for example Recreation Ground Creek occurring in less than one hour after 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 creek, and for them to take action to mitigate flood losses.

Provided adequate warning were available, house contents may be raised above floor level to about 0.9 m, which corresponds with the height of a typical table/bench height. The spreadsheet provides two factors for assessing damages to contents, one for above and one for below the typical bench height. The reduction in damages is also dependent on the likely duration of inundation of contents, which would be limited to no more than an hour for most flooded properties.

Table D4.1 over shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m. A typical ground floor area of 240 m^2 was adopted for the assessment. The values in **Table D4.1** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

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TABLE D4.1
DAMAGE ADJUSTMENT FACTORS/PARAMETERS FOR RESIDENTIAL DEVELOPMENT SUBJECT TO MAIN STREAM FLOODING AND MAJOR OVERLAND FLOW

Property Damage	Parameter/Factor	Main Stream Flooding and Major Overland Flow
Building	Typical Duration of Immersion (hours)	2
	Building Damage Repair Limitation Factor	0.75
	Total Building Adjustment Factor	1.33
Contents	Contents Damage Repair Limitation Factor	0.75
	Level of Flood Awareness	Low
	Effective Warning Time	0
	Typical Table/Bench Height (TTBH) (m)	0.9
	Total Contents Adjustment Factor (Above-Floor Depth <= TTBH)	1.34
	Total Contents Adjustment Factor (Above-Floor Depth > TTBH)	1.34

1. Maximum value permitted in damages spreadsheet.

Table D4.2 shows total flood damages estimated for the three classes of residential property using the procedures identified in *Guideline No. 4*, for typical depths of above-floor inundation of 0.3 m and 1.0 m. A typical ground floor area of 200 m² was adopted for the assessment. The values in **Table D4.2** allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

TABLE D4.2
DAMAGES TO RESIDENTIAL PROPERTIES

Type of Residential Construction	0.3 m Depth of Inundation Above Floor Level	1.0 m Depth of Inundation Above Floor Level
Single Storey Slab on Ground	$62,881	$72,570
Single Storey High Set	$57,293	$65,951
Double Storey	$40,105	$46,166

Note: These values allow for damages to buildings and contents, as well as external damages and provision for alternative accommodation.

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D4.2 Total Residential Damages

Table D4.3 summarises residential damages for the range of floods in Braidwood. The damage estimates were carried out for floods between the 20% AEP and the PMF, which were modelled hydraulically as part of the present study.

While the threshold of flooding for residential type development in Braidwood is relatively low, at the 1% AEP level of flooding only five dwellings would experience above-floor inundation. All five dwellings are located in the Recreation Ground Creek catchment, with three flooded due to surcharge of the main arm of the watercourse and the other two by major overland flow which discharges through a number of properties east of the Braidwood Recreation Ground. **Figure 2.2**, sheet 3 shows the location of the five above-floor inundated dwellings.

During a PMF event, 87 individual dwellings would experience above-floor inundation in Braidwood, the locations of which are shown on **Figure 2.4**, sheets 2 and 3.

TABLE D4.3
RESIDENTIAL FLOOD DAMAGES IN BRAIDWOOD

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20	5	1	0.10
5	8	2	0.16
2	13	4	0.34
1	15	5	0.42
0.5	22	7	0.64
0.2	27	12	0.98
PMF	113	87	8.06

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D5. COMMERCIAL AND INDUSTRIAL DAMAGES

D5.1 Direct Commercial and Industrial Damages

The method used to calculate damages requires each property to be categorised in terms of the following:

- damage category;
- floor area; and
- floor elevation.

The damage category assigned to each enterprise may vary between "low", "medium" or "high", depending on the nature of the enterprise and the likely effects of flooding. Damages also depend on the floor area.

It has recently been recognised following the 1998 flood in Katherine that previous investigations using stage damage curves contained in proprietary software tend to seriously underestimate true damage costs (*DECC Guideline No 4, 2007*). OEH are currently researching appropriate damage functions which could be adopted in the estimation of commercial and industrial categories as they have already done with residential damages. However, these data were not available for the Braidwood study.

On the basis of previous investigations the following typical damage rates are considered appropriate for potential external and internal damages and clean-up costs for both commercial and industrial properties. They are indexed to a depth of inundation of 2 metres. At floor level and 1.2 m inundation, zero and 70% of these values respectively were assumed to occur:

Low value enterprise	$280/m^2	(e.g. Commercial: small shops, cafes, joinery, public halls. Industrial: auto workshop with concrete floor and minimal goods at floor level, Council or Government Depots, storage areas.)
Medium value enterprise	$420/m^2	(e.g. Commercial: food shops, hardware, banks, professional offices, retail enterprises, with furniture/fixtures at floor level which would suffer damage if inundated. Industrial: warehouses, equipment hire.)
High value enterprise	$650/m^2	(e.g. Commercial : electrical shops, clothing stores, bookshops, newsagents, restaurants, schools, showrooms and retailers with goods and furniture, or other high value items at ground or lower floor level. Industrial: service stations, vehicle showrooms, smash repairs.)

The factor for converting potential to actual damages depends on a range of variables such as the available warning time, flood awareness and the depth of inundation. Given sufficient warning time a well prepared business will be able to temporarily lift property above floor level. However, unless property is actually moved to flood free areas, floods which result in a large depth of inundation, will cause considerable damage to stock and contents.

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For the Braidwood study, the above potential damages were converted to actual damages using a multiplier which ranged between 0.5 and 0.8 depending on the depth of inundation above the floor. As shown on **Figures D8.1**, the maximum depth of above-floor inundation experienced at the 1% AEP level of flooding for commercial and industrial property is only about 100 mm. At these relatively shallow depths it would be expected that owners may be able to take significant action to mitigate damages, even when allowing for the flash flooding nature of inundation. Consequently, a multiplier of 0.5 was adopted to convert potential to actual damages for depths of inundation up to 1.2 m, and a multiplier of 0.8 for greater depths.

D5.2 Indirect Commercial and Industrial Damages

Indirect commercial and industrial damages comprise costs of removal of goods and storage, loss of trading profit and loss of business confidence.

Disruption to trade takes the following forms:

- The loss through isolation at the time of the flood when water is in the business premises or separating clients and customers. The total loss of trade is influenced by the opportunity for trade to divert to an alternative source. There may be significant local loss but due to the trade transfer this may be considerably reduced at the regional or state level.
- In the case of major flooding, a downturn in business can occur within the flood affected region due to the cancellation of contracts and loss of business confidence. This is in addition to the actual loss of trading caused by closure of the business by flooding.

Loss of trading profit is a difficult value to assess and the magnitude of damages can vary depending on whether the assessment is made at the local, regional or national level. Differences between regional and national economic effects arise because of transfers between the sectors, such as taxes, and subsidies such as flood relief returned to the region.

Some investigations have lumped this loss with indirect damages and have adopted total damage as a percentage of the direct damage. In other cases, loss of profit has been related to the gross margin of the business, i.e. turnover less average wages. The former approach has been adopted in this present study. Indirect damages have been taken as 50% of direct actual damages. A clean-up cost of $15/m^2 of floor area of each flooded property was also included.

D5.3 Total Commercial and Industrial Damages

Table D5.1 over summarises estimated commercial and industrial damages in Braidwood.

Of the seven commercial properties that comprise the flood damages database for Braidwood, only one would experience above-floor inundation in a 1% AEP event, and only then to a depth of about 100 mm. As shown on **Figure 2.2**, sheet 3, the affected property is located on the western side of Monkittee Street north of its intersection with Goghill Street and is subject to inundation by major overland flow.

During a PMF event, six of the seven properties would be above-floor inundated. **Figure 2.3**, sheets 2 and 3 shows the location of the affected properties.

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TABLE D5.1
COMMERCIAL AND INDUSTRIAL FLOOD DAMAGES IN BRAIDWOOD

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20	0	0	0.00
5	1	1	0.02
2	1	1	0.03
1	2	1	0.05
0.5	2	1	0.05
0.2	2	2	0.08
PMF	7	6	1.38

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D6. DAMAGES TO PUBLIC BUILDINGS

D6.1 Direct Damages – Public Buildings

Included under this heading are government buildings, churches, swimming pools and parks. Damages were estimated individually on an areal basis according to the perceived value of the property. Potential internal damages were indexed to a depth of above floor inundation of 2 m as shown below. At floor level and 1.2 m depth of inundation, zero and 70% of these values respectively were assumed to occur.

Low value	$280/m²	
Medium value	$420/m²	(eg. council buildings, SES HQ, fire station)
High value	$650/m²	(eg. schools)

These values were obtained from the Nyngan Study (DWR, 1990) as well as commercial data presented in the Forbes Water Studies report (WS, 1992). External and structural damages were taken as 4 and 10% of internal damages respectively.

D6.2 Indirect Damages – Public Buildings

A value of $15/m² was adopted for the clean-up of each property. This value is based on results presented in the Nyngan Study and adjusted for inflation. Total "welfare and disaster" relief costs were assessed as 50% of the actual direct costs.

D6.3 Total Damages – Public Buildings

Table D6.1 over summarises estimated damages to public buildings in Braidwood.

The two public buildings comprising the flood damages database for Braidwood are the playing field and tennis court clubhouses that are respectively located on the northern and southern side of Recreation Ground Creek in the Braidwood Recreation Ground. The northern clubhouse would experience above-floor inundation during floods larger than about 5% AEP, while the southern clubhouse would only be above-floor inundated during a PMF event.

TABLE D6.1
PUBLIC FLOOD DAMAGES IN BRAIDWOOD

Design Flood Event (% AEP)	Number of Properties		Damages ($ Million)
	Flood Affected	Flood Above Floor Level	
20	0	0	0.00
5	1	0	0.02
2	1	1	0.02
1	1	1	0.02
0.5	1	1	0.02
0.2	1	1	0.03
PMF	2	2	0.08

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D7. 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 around Braidwood is presented in **Table D7.1**.

TABLE D7.1
QUALITATIVE EFFECTS OF FLOODING ON INFRASTRUCTURE AND COMMUNITY ASSETS IN BRAIDWOOD

Damage Sector	Design Flood Event (% AEP)						
	20%	5%	2%	1%	0.5%	0.2%	PMF
Telephone	O	O	O	O	O	O	O
Roads	X	X	X	X	X	X	X
Bridges/Weirs	O	O	X	X	X	X	X
Sewage Treatment Plant	O	O	O	O	O	O	O
Sewage Pumping Station	O	O	O	X	X	X	X
Water Supply	O	O	O	O	O	O	O
Parks and Gardens	X	X	X	X	X	X	X

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

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D8. SUMMARY OF TANGIBLE DAMAGES

D8.1 Tangible Damages

Floods 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 in the drainage system. From **Table D8.1**, significant flood damages at Braidwood are limited to the PMF event, with less than $0.5 Million of damages being incurred at the 1% AEP level of flooding.

TABLE D8.1
TOTAL FLOOD DAMAGES IN BRAIDWOOD
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20	0.10	0	0	0.10
5	0.16	0.02	0.02	0.20
2	0.34	0.03	0.02	0.39
1	0.42	0.05	0.02	0.49
0.5	0.64	0.05	0.02	0.71
0.2	0.98	0.08	0.03	1.09
PMF	8.06	1.38	0.08	9.52

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D8.2 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 "*Present Worth Value*" 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 *Present Worth Value* via the discount rate.

Using the procedures outlined in *Guideline No. 4*, as well as current NSW Treasury guidelines, economic analyses were carried out assuming a 50 year economic life for projects and discount rates of 7% pa. (best estimate) and 11% and 4% pa. (sensitivity analyses).

D8.3 Average Annual Damages

The average annual damages for all flood events up to the PMF are shown below in **Table D8.2**. Note that values have been quoted to three decimal places to highlight the relatively small recurring damages.

TABLE D8.2
AVERAGE ANNUAL DAMAGES IN BRAIDWOOD
$ MILLION

Design Flood Event (% AEP)	Residential	Commercial/ Industrial	Public	Total
20	0.01	0	0	0.01
5	0.03	0	0	0.03
2	0.04	0	0	0.04
1	0.04	0	0	0.04
0.5	0.05	0	0	0.05
0.2	0.05	0	0	0.05
PMF	0.06	0	0	0.06

D8.4 Present Worth of Damages at Braidwood

The *Present Worth Value* of damages likely to be experienced for all flood events up to the 1% AEP and PMF, for a 50 year economic life and discount rates of 4, 7 and 11 per cent are shown in **Table D8.3**.

For a discount rate of 7% pa, the *Present Worth Value* of damages for all flood events up to the 1% AEP flood is about $0.6 Million, for a 50 year economic life. Therefore one or more schemes costing up to this amount could be economically justified if they eliminated damages in Braidwood 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. Flood management measures are considered on a multi-objective basis in **Chapter 4** of the Main Report.

TABLE D8.3
PRESENT WORTH VALUE OF DAMAGES IN BRAIDWOOD
$ MILLION

Discount Rate (%)	Nominal Flood Level Case	
	All Floods up to 1% AEP	All Floods up to PMF
4	0.9	1.3
7	0.6	0.8
11	0.4	0.5

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D9. REFERENCES AND BIBLIOGRAPHY

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APPENDIX E

RECOMMENDED WORDING FOR INCLUSION IN UPDATED DEVELOPMENT CONTROL PLAN

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FIGURES
(BOUND IN VOLUME 2)

E1.1 Extract of Flood Planning Map at Braidwood

E1.2 Braidwood Flood Hazard Map

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ABBREVIATIONS

AHD	Australian Height Datum
AEP	Annual Exceedance Probability (%)
Council	Queanbeyan-Palerang Regional Council
EP&A	Environmental Planning and Assessment
FPL	Flood Planning Level (1% AEP flood level + freeboard)
FPA	Flood Planning Area (area inundated at the FPL)
FRMS&P	Floodplain Risk Management Study and Plan
LEP	Local Environmental Plan
MFL	Minimum Floor Level (1% AEP flood level + freeboard)
NSW SES	New South Wales State Emergency Service
PMF	Probable Maximum Flood

Refer **Section E5** of this Appendix for glossary of terms.

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E1. INTRODUCTION

E1.1 Overview

The Appendix sets out the wording which should be incorporated in the update of *Palerang DCP 2015*. The approach to managing future development that is subject to flooding at Braidwood as set out in this Appendix supports the findings and recommendations of the *Braidwood Floodplain Risk Management Study and Plan, 2019*, which has been prepared as part of the NSW Government's program to mitigate the impact of major floods and reduce the associated hazards in the floodplain.

Note that the wording in this Appendix deals specifically with the management of future development that is subject to flooding in Braidwood. A more general form of wording could be incorporated in the update of *Palerang DCP 2015*, with location and flood behaviour specific related controls set out in a separate set of development control matrices.

E1.2 Objectives

The purpose of this draft Development Control Policy is to responsibly exercise Council's duty of care, in order that the development of properties located in flood prone areas in Braidwood is undertaken in a responsible manner to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods.

The policy applies to all flood prone land in Braidwood as identified in the *Braidwood Floodplain Risk Management Study and Plan, 2019* and shown on **Figure E1.1** as the **Outer Floodplain**.

The objectives of this policy are to implement development controls that over time raise the floor levels of all development on flood affected properties to the **Flood Planning Level** appropriate for the particular land use, as a minimum floor elevation, and ensure that all new development is located in areas compatible with the flood risk, with minimum impact on adjacent development and flooding patterns. The policy aims to ensure that development in flood prone areas is undertaken so that:

- The proposed development does not result in any significant increase in risk of loss of life.
- Increases in economic and social costs resulting from new development are minimised.
- There is no significant increase in flood affectation on adjacent development or properties, either individually or in combination with cumulative development likely to occur on the floodplain.
- Reliable access is available for the evacuation from the area and evacuation is consistent with any flood evacuation strategies set out in the *Palerang Local Flood Plan, 2013* published by the NSW State Emergency Service.

Definitions of flood related terms used herein are provided in the **Glossary** in **Section E5** of this document.

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E2. APPLICATION OF THE POLICY

E2.1 Overview

Development controls on flood prone land are set out in **Chapter E3** of this Flood Policy. The controls recognise that different controls are applicable to different land use, location within the floodplain, depths of potential flood inundation and **Flood Hazard**.

The controls applicable to proposed development depend upon:

- the type of development proposed; and
- the location of the development within the floodplain and the **Flood Hazard Zone** in which it is located.

E2.2 Nature of Flooding in Braidwood

Braidwood is subject to flooding from Gillamatong Creek and its two major tributaries, Monkittee Creek and Flood Creek, as well as Recreation Ground Creek, which is a major tributary of Flood Creek. While floodwater is generally confined to Gillamatong Creek, Monkittee Creek and Flood Creek and their immediate overbank areas, flooding is more extensive along Recreation Ground Creek, albeit to relatively shallow depths.

While residential development in flood affected areas is generally confined to the overbank area of Recreation Ground Creek for events up to 1% AEP in magnitude, the rear of several properties that are located on either side of Monkittee Creek between Wallace Street and Ryrie Street are also affected. Flow which surcharges an unnamed tributary of Monkittee Street where it crosses the Kings Highway near its intersection with Glenmore Road also affects several residential properties.

While hazardous flooding conditions are generally confined to the immediate overbank area of the major watercourses which run through Braidwood for floods up to 1% AEP in magnitude, they do extend into the rear of several residential properties which are located along Monkittee Creek between Wallace Street and Ryrie Street. High hazard flooding conditions are also experienced in a single allotment which is located on the southern bank of Monkittee Creek at the northern end of Monkittee Street.

E2.3 Procedure for Applying the Flood Policy

The procedure Council will apply for determining the specific controls applying to proposed development in flood prone areas in Braidwood is set out below. Upon enquiry by a prospective applicant, Council will make an initial assessment of the flood affectation and flood levels at the site using the following procedure and the results of the *Braidwood Floodplain Risk Management Study and Plan, 2019*.

- Assess whether the development is located in Flood Prone Land, that is, land within the extent of the **Outer Floodplain** from **Figure E1.1**.
- Determine which part of the floodplain the development is located in from the **Flood Hazard Map** (**Figure E1.2**).
- Identify the category of the development from **Schedule1: Land Use Categories.**
- Determine the appropriate **Flood Planning Level** for the category of development from **Schedule 2: Prescriptive Controls** and the flood level at the site from the results of the *Braidwood Floodplain Risk Management Study and Plan, 2019*.
- Confirm that the development conforms with the controls set out in **Schedule 2**.

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With the benefit of this initial information from Council, the applicant will:

- Prepare the Documentation to support the Development Application according to the requirements of **Section E4** of this policy.

A survey plan showing natural surface levels over the site will be required as part of the Development Application Documentation. Provision of this plan by the applicant at the initial enquiry stage will assist Council in providing flood related information.

E2.4 Land Use Category and Prescriptive Controls

The policy recognises eight different types of land use for which the provisions of this policy applies. They are included in **Schedule 1: Land Use Categories.**

The policy imposes controls over these land uses according to their location within the floodplain. The floodplain of the Gillamatong Creek system at Braidwood has been divided into the following Flood Hazard Zones, the extents of which are shown on **Figure E1.2**:

- **Inner Floodplain (Hazard Category 1)**, which is shown in solid red colour. This zone comprises areas where factors such as the depth and velocity of flow, time of rise and evacuation problems mean that the land is unsuitable for some types of development. It principally comprises areas of High Hazard Floodway, but does include some areas of Low Hazard Floodway in some areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are considered to be unsuitable land uses in this zone.
- **Inner Floodplain (Hazard Category 2)**, which is shown in solid yellow colour. This zone comprises Low Hazard Floodway and Flood Storage areas where development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a *Flood Risk Report* if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
- **Intermediate Floodplain**, which is shown in solid blue colour. This area is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA. Within this zone, there would only be the requirement for MFLs to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
- **Outer Floodplain**, which is shown in solid cyan colour. This area represents the remainder of the floodplain between the Intermediate Floodplain and the extent of the Probable Maximum Flood (PMF) (that is, the extent of the floodplain). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development are considered to be unsuitable land uses in this zone.

E2.5 The Need to Consider Cumulative Development in Assessing Developments

The **Flood Policy** is based on the recognition that individual developments should not be evaluated in isolation, but rather, should be considered in a strategic sense as if it were one of several developments in the area. Whilst individual developments in isolation may not have a measurable impact on flooding, the cumulative impacts of ongoing development could be significant.

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E3. DEVELOPMENT CONTROLS

E3.1 Residential Development

E3.1.1 New Residential Development

No new dwellings or residential developments, including residential flat buildings, dual occupancy buildings or other similar developments will be permitted in the **Inner Floodplain (Hazard Category 1)** zone.

Proposals for new dwellings in flood prone areas which are outside the **Inner Floodplain (Hazard Category 1)** zone shall be considered following receipt of a suitable development application and the information set out in **Section E4**.

The **Flood Planning Level** defining the minimum floor level for all habitable rooms is the 1% AEP flood plus 500 mm freeboard.

Council will require any approvals granted for a new dwelling to have all electrical circuit connections to be automatically isolated in the event of floodwaters having the potential to gain access to exposed electrical circuits, either internal or external of the building.

E3.1.2 Replacement of Existing Dwellings

In the event of the destruction of or proposals to replace an existing dwelling or structure, the requirements specified in this plan for the erection of a new dwelling shall be applied to the replacement dwelling or structure.

E3.1.3 Additions to Existing Single Dwellings

Additions in Inner Floodplain (Hazard Category 1) Zone

This Policy **does not favour** additions to existing dwellings in this zone because of the potential increase in risk to life and limb resulting from developments in floodway areas where velocities are significant and because of potential increases in the economic impacts of flooding. Council may at its discretion and based on the merits of the case allow a "once only" minor addition, (30 m² maximum floor area) provided that:

a) There is a safe evacuation route via continuously rising ground from the subject property to flood free ground.

b) The underside of the floor structure (lowest elevation of floor beams) is to be above the Flood Planning Level for residential development (1% AEP flood level plus 500 mm).

c) No filling is permissible and obstruction to flow by piers and other supporting structures are to be minimised.

d) A *Flood Risk Report* is required confirming the adequacy of structure to resist hydrodynamic loadings and that the proposal would have no adverse impacts on local flooding patterns, either individually or cumulatively in conjunction with similar extensions in adjacent properties.

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Additions in Other Flood Prone Areas

For additions in flood prone areas other than the **Inner Floodplain (Hazard Category 1)** zone, the Policy's controls for new residential development in the applicable Precinct will apply.

Minor Additions with Floor Level below the Flood Planning Level

Where existing floor levels are below the **Flood Planning Level** and it is not practicable to raise the floor level of the addition to the **Flood Planning Level**, Council may, based on the merits of the proposal, allow a Minor Addition to a single residential dwelling, provided that the following controls are complied with:

a) The area is **not** located in the **Inner Floodplain (Hazard Category 1)** zone.

b) The maximum floor area of the ground floor is restricted to 30 m² if any part of the existing dwelling is below the **Flood Planning Level.**

c) Other than for the floor level, the controls for new residential development will apply to the Minor Addition.

E3.2 Commercial and Industrial Development

The *Flood Policy* nominates the same Minimum Floor Level (**MFL**) as for residential development. However, where it is not practicable to achieve this level, Council may approve a lesser level commensurate with the local streetscape. In this eventuality, the applicant is to provide an area within the development for the storage of goods at a minimum level equal to the MFL. This area should be at least 20% of the gross floor area, or as determined by Council.

E3.3 Land Uses Requiring Special Flood Protection

The Flood Policy has regard to several special types of development and the need for a higher level of flood protection than would normally be warranted in order to achieve its objective of minimising risk to human life and maintaining the operation of essential services during a flood emergency. These uses are categorised in **Schedule 1** under the headings *"Essential Community Facilities"* and *"Critical Infrastructure and Uses"* and *"Flood Vulnerable Residential Uses"*.

E3.4 Subdivision on Flood Affected Land

Subdivision on flood affected land will not be permitted on land located within the **Inner Floodplain (Hazard Category 1)** zone, or where additional flood affected residential allotments will be created below the **Flood Planning Level**.

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E4. INFORMATION TO BE SUBMITTED WITH THE DEVELOPMENT APPLICATION

E4.1 Outline of Council's Requirements

The procedure for determining the specific controls applying to proposed development in flood prone areas in Braidwood requires the applicant to undertake the following procedure:

- Make initial enquiries of Council regarding flood levels applicable to the site; its location within the **Flood Hazard Zones**; Land Use category and Prescriptive Controls (see **Section E2.3**).
- Prepare the documentation to support the development application according to **Sections E4.2** and **E4.3** below.

Further information is available by discussion with and upon written application to Council.

E4.2 Survey Details

A Survey Plan prepared by a Registered Surveyor is required to be lodged with the Development Application. For property lying within the floodplain i.e. within the extent of the **Outer Floodplain**, additional details relating to flood affectation are required. The Survey Plan must indicate the following:

- The location of existing building or structures;
- The floor levels and ceiling heights of all existing buildings or structures to be retained;
- Existing and/or proposed drainage easements and watercourses or other means of conveying flood flows that are relevant to the flood characteristics of the site;
- **1% AEP and Probable Maximum Flood Levels** over the site; and flood extents;
- 0.2 metre natural surface contour intervals across the entire property (existing and proposed). Note: All levels must be relative to Australian Height Datum (AHD)

E4.3 Flood Risk Report

E4.3.1 Flood Risk Report - Scope of Work

A **Flood Risk Report** is to be submitted for all development on land which lies within the Inner Floodplain zones, noting that only *Non-Urban and Outbuildings* is considered to be a suitable land use in the Inner Floodplain (Hazard Category 1) zone. This report is to be prepared by a suitably qualified Consulting Engineer and must address the following:

a) Confirm the **Flood Hazard Zone** and the relevant **Flood Planning Level** through enquiries of Council.

b) Specify proposed floor levels (and existing floor levels where they are to be retained) of habitable and non-habitable structures, and where basement or enclosed car parking is proposed, include levels of access, ventilation and any other potential water entry points.

c) Identify the constraints due to flood impacts on the land, including an assessment of the degree of inundation, hazard level, impacts of waterborne debris, buoyancy, evacuation and emergency issues during the 1% AEP and where applicable, the Probable Maximum Flood event.

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d) Include a site specific flood assessment that may require flood modelling to demonstrate that there will be no adverse impact on surrounding properties as a result of the development, up to the 1% AEP flood (both as a result of local catchment and riverine type flooding).

e) Provide flood related factors which are to be considered in the structural design and construction of the total development and appropriate modifications to any existing structures to be retained.

f) Propose measures to minimise risk to personal safety of occupants and the risk of property damage, addressing the flood impacts on the site for the 1% AEP event. These measures shall include but are not limited to the following:

- Types of materials to be used, up to the **Flood Planning Level** to ensure the structural integrity for immersion and impact of velocity and debris.
- Waterproofing methods, including but not limited to electrical equipment, wiring, fuel lines or any other service pipes and connections.

g) For subdivisions, demonstrate that adequate building platforms or developable area, including car parking facilities, can be provided on each of the proposed new lots with levels at or above the residential **Flood Planning Level**.

E4.3.2 Floor Level below Flood Planning Level (Minor Addition to a Single Dwelling only)

Where it is proposed to construct the addition to an existing dwelling below the **Flood Planning Level**, the following issues must be addressed in the **Flood Risk Report**, in addition to the issues listed above:

a) Confirm with council that the property is not located within the **Inner Floodplain (Hazard Category 1)** zone.

b) Confirm the gross floor area of the addition does not exceed 30 m^2.

c) Provide sound reasoning as to why it is not practicable to raise the floor level of the proposed addition to the level of the **Flood Planning Level.**

d) Demonstrate that there are no potential adverse impacts created by this development on the future development of surrounding properties

E4.3.3 Floor Level Variations (Commercial and Industrial Development only)

Where it is proposed to retain the floor levels of any existing part of the development below the **Flood Planning Level**, the following issues must be addressed in the architectural drawings and the **Flood Risk Report**, in addition to the issues listed above in **Section E4.3.1** for consideration in the report.

a) Provide sound reasoning as to why the exemption is being sought including identification of the constraints that make it impracticable to raise the floor levels to the **Flood Planning Level**.

b) Demonstrate that there are no potential adverse impacts created by this development on the future development of surrounding properties.

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E5. GLOSSARY OF TERMS

Note: For expanded list of definitions, refer to Glossary contained within the NSW Government Floodplain Development Manual, 2005.

TERM	DEFINITION
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, for a flood magnitude having five per cent AEP, there is a five per cent probability that there would be floods of greater magnitude each year.
Australian Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
Floodplain	Area of land which is subject to inundation by floods up to and including the Probable Maximum Flood (**PMF**) event, that is, flood prone land.
Flood Planning Area	The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map*.
Flood Planning Map	The *Flood Planning Map* shows the extent of land on which flood related development controls apply, an extract of which is shown on **Figure E1.1**.
Flood Planning Level (FPL)	Flood levels selected for planning purposes, as determined in the *Braidwood Floodplain Risk Management Study, 2019* and incorporated in the associated *Braidwood Floodplain Risk Management Plan, 2019*. For residential, commercial and industrial development at Braidwood, the FPL denotes the minimum permissible floor level and is equal to the flood level derived from the 1% AEP flood event, plus the addition of a 500 mm freeboard.
Flood Prone/Flood Liable Land	Land susceptible to flooding by the Probable Maximum Flood. Flood Prone land is synonymous with Flood Liable land.
Floodway	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.
Flood Storage Area	Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.
Freeboard	Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the FPL and MFL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the FPL and MFL.
Habitable Room	In a residential situation: a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

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TERM	DEFINITION
Inner Floodplain (Hazard Category 1)	This zone comprises areas where factors such as the depth and velocity of flow, time of rise and evacuation problems mean that the land is unsuitable for some types of development. It principally comprises areas of High Hazard Floodway, but does include some areas of Low Hazard Floodway in some areas. Erection of buildings and carrying out of work; use of land, subdivision of land and demolition subject to State Environmental Planning Policies and Local Environmental Plan provisions are considered to be unsuitable land uses in this zone.
Inner Floodplain (Hazard Category 2)	This zone comprises Low Hazard Floodway and Flood Storage areas where development other than Essential Community Facilities, Critical Utilities, Schools and Flood Vulnerable development is permitted provided it is capable of withstanding hydraulic forces and sited on the allotment to minimise adverse redirections of flow towards adjacent properties. Council may require a Flood Risk Report if it considers that the proposal has the potential to significantly affect flooding behaviour in adjacent properties.
Intermediate Floodplain	This area is the remaining land lying outside the extent of the Inner Floodplain zones, but within the FPA. Within this zone, there would only be the requirement for MFLs to be set at the 1% AEP flood levels plus 500 mm. Land use permissibility would be as specified by State Environmental Planning Policies or the Local Environmental Plan.
Outer Floodplain	This area represents the remainder of the floodplain between the Intermediate Floodplain and the extent of the Probable Maximum Flood (PMF) (that is, the extent of the floodplain). This area is outside the extent of the FPA and hence controls on residential, commercial and industrial development do not apply. However, Essential Community Facilities, Critical Utilities and Flood Vulnerable development are considered to be unsuitable land uses in this zone.
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. In Braidwood, Main Stream Flooding results from floodwater which surcharges the inbank areas of Gillamatong Creek, Monkittee Creek, Flood Creek, Recreation Ground Creek and Unnamed Tributary.
Major Overland Flow	Where the depth of overland flow during the 1% AEP storm event is greater than 100 mm. At Braidwood, the nature of Major Overland Flow has only been defined in the Recreation Ground Creek catchment.
Minimum Floor Level (MFL)	The combinations of flood levels and freeboards selected for setting the Minimum Floor Levels (MFLs) of future development located in properties subject to flood related planning controls.
Probable Maximum Flood (PMF)	The largest flood that could conceivably occur at a particular location. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. For the study area, the extent of the PMF has been trimmed to include depths greater than 100 mm.

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E6. REFERENCES

Lyall and Associates (2019) "***Braidwood Floodplain Risk Management Study and Plan***".

New South Wales Government (2005) ***"Floodplain Development Manual – The Management of Flood Liable Land"***.

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ANNEXURE 1
LAND USE CATEGORIES

Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business, Commercial/Industrial & Rural Industry	Non-Urban and Outbuildings	Residential Subdivision	Minor Additions (Residential)
Development that may provide an important contribution to the notification and evacuation of the community during flood events; Hospitals; Institutions; Child care centres; Educational establishments.	Telecommunication facilities; Public Utility Installation that may cause pollution of waterways during flooding, or if affected during flood events would significantly affect the ability of the community to return to normal activities after the flood events. Hazardous industry; Hazardous storage establishments.	Group home; Housing for aged or disabled persons; and Units for aged persons.	Dwelling; Residential flat building; Home industry; Boarding house; Professional consulting rooms;	Bulk Store; Bus depot; Bus station; Car repair stations; Club; Commercial premises (other than where referred to elsewhere); General store; Health care professional; Hotel; Intensive livestock keeping; Junkyard; Liquid fuel depot; Motel; Motor showroom; Place of Assembly (other than essential community facilities; Place of public worship; Public building (other than essential community facilities); Recreation facility; Refreshment room; Road transport terminal; Rural industry; Service station; Shop; Tourist facilities; Warehouse.	Retail nursery; Recreation area; Roadside stall; Outbuildings (Sheds, Garages) up to 40 m^2 area.	Subdivision of land involving the creation of new allotments for residential purposes; Earthworks or filling operations covering 100 m^2 or more than 0.3 m deep.	An addition to an existing dwelling of not more than 30 m^2 (habitable floor area)

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ANNEXURE 2
DEVELOPMENT CONTROLS MATRIX

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	Outer Floodplain								Intermediate Floodplain								Inner Floodplain (Hazard Category 2)								Inner Floodplain (Hazard Category 1)							
	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)	Essential Community Facilities	Critical Utilities and Uses	Flood Vulnerable Residential	Residential	Business & Commercial/Industrial	Non-Urban and Outbuildings	Residential Sub-Division	Minor Additions (Residential)
Floor Level												A1	A1		A1	A1				A1	A1		A1	A1								
Building Components												B1	B1		B1	B1				B1	B1		B1	B1								
Structural Soundness												C1	C1		C1	C1				C1	C1		C1	C1								
Flood Affectation																				D1	D1	D1	D1	D1						D1		
Evacuation / Access																				E1	E1	E1	E1	E1								
Management and Design													F3		F1	F4				F5	F3, F5	F2, F5	F1, F5	F4						F2, F5		

Not Relevant Unsuitable Land Use

The Intermediate Floodplain is defined by the area between the two Inner Floodplain zones and the Flood Planning Area (FPA). The Outer Floodplain is the area between the FPA and the Probable Maximum Flood (PMF).

See Notes over page:

ANNEXURE 2 (CONT'D)
DEVELOPMENT CONTROLS MATRIX

Floor Level

A1. Floor levels to be equal to or greater than the 1% AEP flood level plus 500 mm freeboard.

Building Components

B1. All structures to have flood compatible building components below the 1% AEP flood level plus 500 mm freeboard.

Structural Soundness

C1. Structure to be designed to withstand the forces of floodwater, debris and buoyancy up to the 1% AEP flood level plus 500 mm freeboard.

Flood Affection

D.1 A Flood Risk Report may be required to demonstrate that the development will not increase flood hazard (see Item 5 Management and Design below).

Note: When assessing Flood Affectation the following must be considered:

i. Loss of conveyance capacity in the floodway or areas where there is significant flow velocity.
ii. Changes in flood levels and flow velocities caused by the alteration of conveyance of floodwaters.

Evacuation/ Access

E. Reliable access for pedestrians or vehicles required in the event of 1% AEP flood.

Management and Design

F1. Applicant to demonstrate that potential developments as a consequence of a subdivision proposal can be undertaken in accordance with this Policy and the Plan.

F2. No external storage of materials which may cause pollution or be potentially hazardous during PMF.

F3. Where it is not practicable to provide floor levels to the 1% AEP flood level plus 500 mm freeboard, applicant is to provide an area equivalent to 20% of the whole floor area of the building to store goods at that level.

F4. Where it is not practicable to provide floor levels to the 1% AEP flood level plus 500 mm freeboard, Council may allow a reduction for minor additions to habitable areas.

F5. Flood Risk Report may be required prior to development of this area.

NOTE: THESE NOTES ARE TO BE READ IN CONJUNCTION WITH REMAINDER OF THE FLOOD POLICY, IN PARTICULAR CHAPTERS E2 and E3.

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ANNEXURE 3A

GENERAL BUILDING MATTERS

Electrical and Mechanical Equipment

For dwellings constructed on land to which this policy applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.

Main Power Supply

Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the MFL. Means shall be available to easily isolate the dwelling from the main power supply.

Wiring

All wiring, power outlets, switches, etc, should be, to the maximum extent possible, located above the MFL. All electrical wiring installed below this level should be suitable for continuous underwater immersion and should contain no fibrous components. Earth leakage circuit breakers (core balance relays) must be installed. Only submersible type splices should be used below the MFL. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.

Equipment

All equipment installed below or partially below the MFL should be capable of disconnection by a single plug and socket assembly.

Reconnection

Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.

Heating and Air Conditioning Systems

Where viable, heating and air conditioning systems should be installed in areas and spaces of the house above the MFL. When this is not feasible, every precaution should be taken to minimise the damage caused by submersion according to the following guidelines:

i) Fuel

Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.

ii) Installation

The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to the MFL.

iii) Ducting

All ductwork located below the MFL should be provided with openings for drainage and cleaning. Self-draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a watertight wall or floor below the relevant flood level, a closure assembly operated from above the MFL should protect the ductwork.

Sewer

All sewer connections to properties in flood prone areas are to be fitted with reflux valves.

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ANNEXURE 3B

FLOOD COMPATIBLE MATERIALS

Building Component	Flood Compatible Material	Building Component	Flood Compatible Material
Flooring and Sub Floor Structure	• Concrete slab-on-ground monolith construction. Note: clay filling is not permitted beneath slab-on-ground construction which could be inundated. • Pier and beam construction or • Suspended reinforced concrete slab	**Doors**	• Solid panel with waterproof adhesives • Flush door with marine ply filled with closed cell foam • Painted material construction • Aluminium or galvanised steel frame
Floor Covering	• Clay tiles • Concrete, precast or in situ • Concrete tiles • Epoxy formed-in-place • Mastic flooring, formed-in-place • Rubber sheets or tiles with chemical set adhesive • Silicone floors formed-in-place • Vinyl sheets or tiles with chemical-set adhesive • Ceramic tiles, fixed with mortar or chemical set adhesive • Asphalt tiles, fixed with water resistant adhesive • Removable rubber-backed carpet	**Wall and Ceiling Linings**	• Brick, face or glazed • Clay tile glazed in waterproof mortar • Concrete • Concrete block • Steel with waterproof applications • Stone natural solid or veneer, waterproof grout • Glass blocks • Glass • Plastic sheeting or wall with waterproof adhesive
Wall Structure	Solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation**	• Foam or closed cell types
Windows	Aluminium frame with stainless steel or brass rollers	**Nails, Bolts, Hinges and Fittings**	• Galvanised • Removable pin hinges

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ANNEXURE 4
DEVELOPMENT APPLICATION REQUIREMENTS

Step 1

Check with Council staff to see whether or not the proposal:

- Is located on *Flood Prone Land* (Based on initial assessment of the extent of flood affectation and flood levels (refer from **Section E2.3** for details)).
- Is permissible in the Flood Hazard zone and determine the MFL for the particular category of land use.
- Note: an existing site survey (see **Section E4.2** of the Policy) is to accompany development proposals to confirm the flood affectation of the allotment and its location within the flood hazard zoning system.

Step 2

Plans – A Development Application should include the following plans showing the nature of the proposed development and its extent within the allotment:

- A locality plan identifying the location of the property.
- Plan of the existing site layout including the site dimensions (in metric), site area, contours (0.20 m intervals), existing trees, other natural features, existing structures, north point, location of building on adjoining properties (if development involves a building), floor plans located on a site plan, roof plan, elevations and sections of the proposed building, finished levels of floors, paving and landscaped areas, vehicular access and parking.
- Plans should indicate:
  a) The existing ground levels to Australian Height Datum around the perimeter of the proposed building; and
  b) The existing or proposed floor levels to Australian Height Datum.
- Minor additions to an existing dwelling must be accompanied by documentation from a registered surveyor confirming existing floor levels.
- In the case of subdivision, four (4) copies of the proposed site layout showing the number of lots to be created (numbered as proposed lot 1, 2, 3 etc), the proposed areas of each lot in square metres, a north point, nearest roads and the like.

Council require plans presented on A3 sheets as a minimum

A scale of 1:200 is recommended for site plans

Extent of Cut and Fill – All areas subject to cut and fill require the depths of both to be shown as well as the measures proposed to retain both. Applications shall be accompanied by a survey plan (with existing and finished contours at 0.20 m intervals) showing relative levels to Australian height datum.

Vegetation Clearing – Landscaping details including a description of trees to be removed existing and proposed planting, retaining walls, detention basins, fences and paving.

Stormwater Drainage – Any existing and all proposed stormwater drainage to be indicated on the site plan.

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QUEANBEYAN-PALERANG REGIONAL COUNCIL

Council Meeting Attachment

26 JUNE 2019

ITEM 10.11 BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

ATTACHMENT 2 BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN: VOLUME 2 - FIGURES

Lyall & Associates

QPRC

NEXUS Environmental Planning Pty Ltd

QUEANBEYAN-PALERANG REGIONAL COUNCIL

BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

JUNE 2019

VOLUME 2 – FIGURES

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Job No: CO414 File: BFRMS_V2_Figures_[Rev 1.2].docx	Date: June 2019 Rev No: 1.2	Principal: SAB Author: SAB

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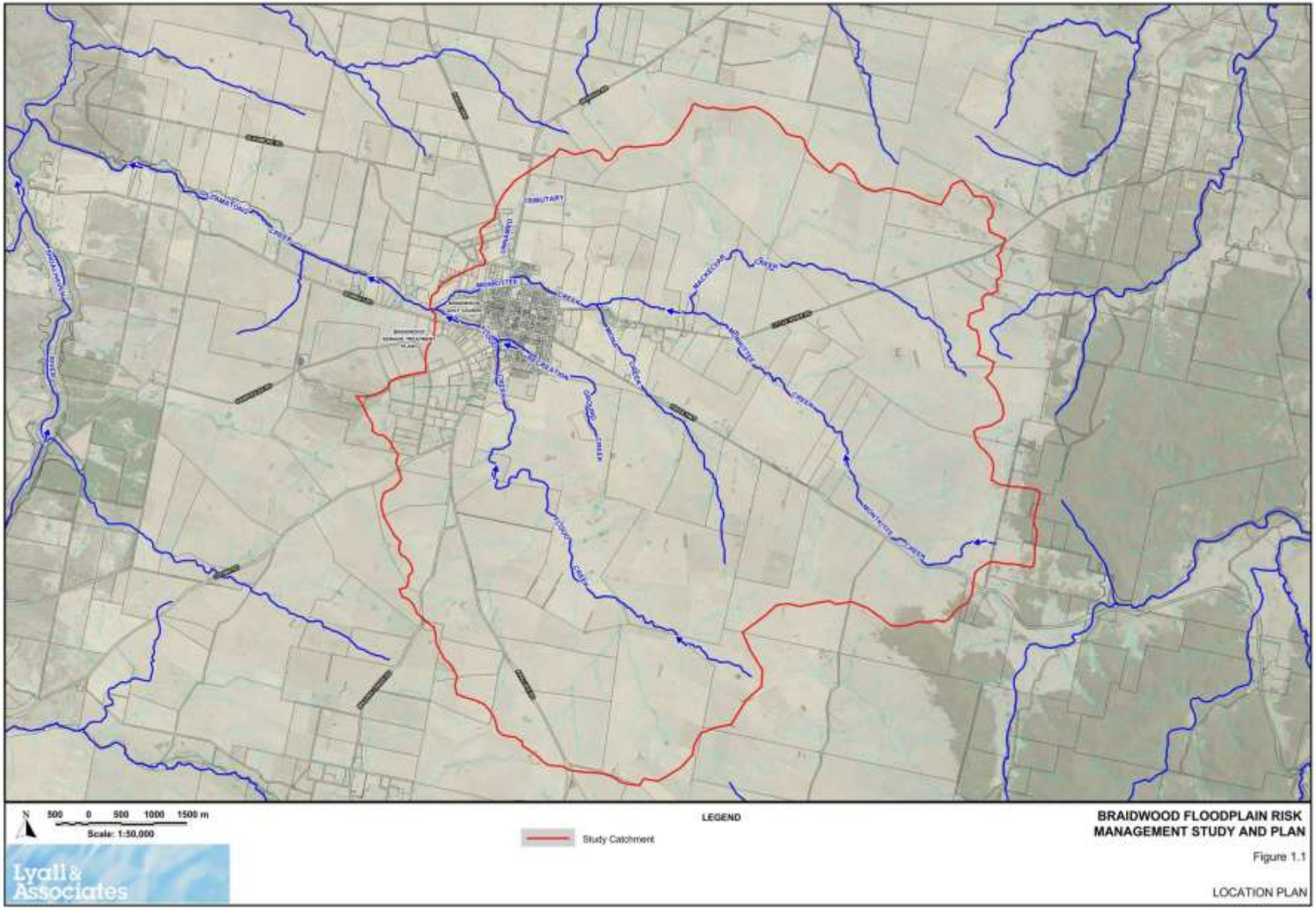
LIST OF FIGURES

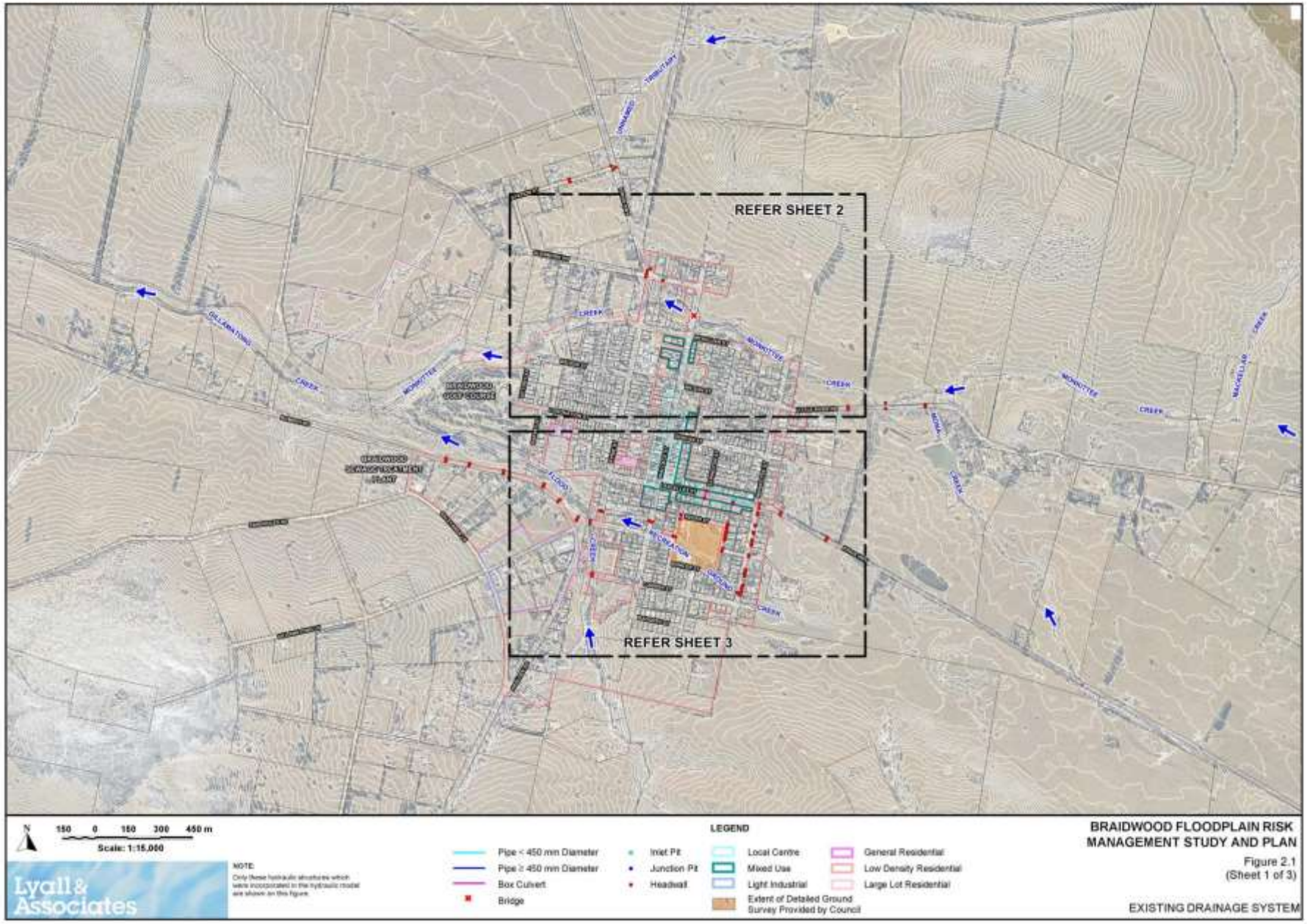
1.1 Location Plan

2.1 Existing Drainage System (3 Sheets)
2.2 Indicative Extent and Depths of Inundation – 1% AEP (3 Sheets)
2.3 Indicative Extent and Depths of Inundation – PMF (3 Sheets)
2.4 Design Water Surface Profiles (2 Sheets)
2.5 Time of Rise of Floodwaters
2.6 Indicative Extent of Inundation and Location of Vulnerable Development and Critical Infrastructure
2.7 Flood Hazard and Hydraulic Categorisation of Floodplain – 1% AEP (3 Sheets)
2.8 Sensitivity of Flood Behaviour to 20% Increase in Hydraulic Roughness Values – 1% AEP (3 Sheets)
2.9 Sensitivity of Flood Behaviour to Partial Blockage of Hydraulic Structures – 1% AEP (3 Sheets)
2.10 Potential Impact of Future Urbanisation on Flooding and Drainage Patterns – 1% AEP
2.11 Potential Impact of 10% Increase in Rainfall on Flooding and Drainage Patterns – 1% AEP (3 Sheets)
2.12 Potential Impact of 30% Increase in Rainfall on Flooding and Drainage Patterns – 1% AEP (3 Sheets)
2.13 Impact of Increased Rainfall Intensities on Extent of Flooding – 1% AEP (3 Sheets)
2.14 Palerang LEP 2014 Zoning

3.1 Impact of Recreation Ground Creek Flood Mitigation Scheme 1A on Flooding Behaviour
3.2 Impact of Recreation Ground Creek Flood Mitigation Scheme 1B on Flooding Behaviour
3.3 Impact of Recreation Ground Creek Flood Mitigation Scheme 1C on Flooding Behaviour
3.4 Impact of Recreation Ground Creek Flood Mitigation Scheme 2 on Flooding Behaviour
3.5 Impact of Recreation Ground Creek Flood Mitigation Schemes 1A and 2 on Flooding Behaviour
3.6 Impact of Recreation Ground Creek Flood Mitigation Schemes 1B and 2 on Flooding Behaviour
3.7 Impact of Recreation Ground Creek Flood Mitigation Schemes 1C and 2 on Flooding Behaviour
3.8 Flood Emergency Response Planning Classifications – 1% AEP (3 Sheets)
3.9 Flood Emergency Response Planning Classifications – PMF (3 Sheets)

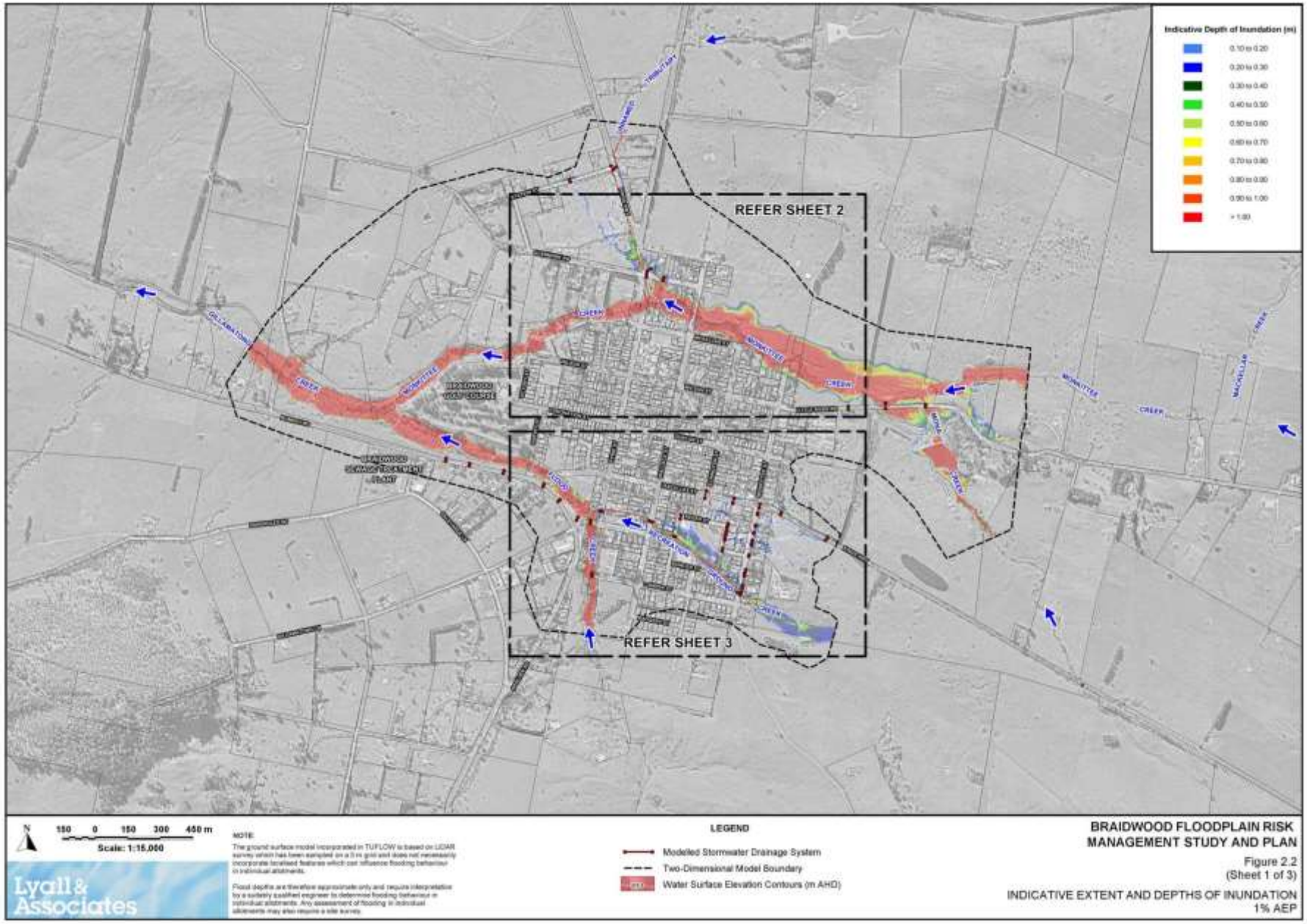
DRAFT REPORT FOR PUBLIC EXHIBITION

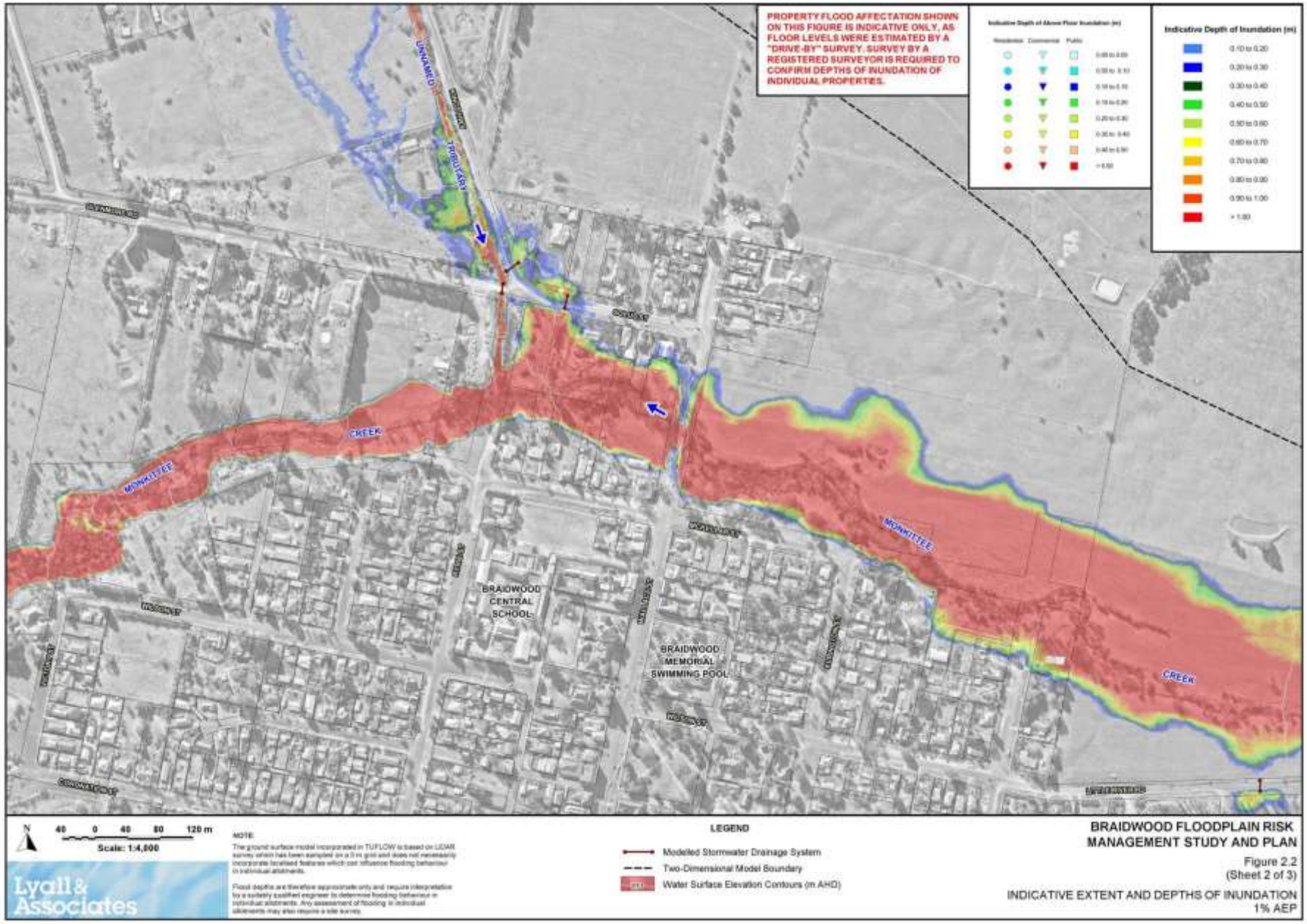

N
500 0 500 1000 1500 m
Scale: 1:50,000
LEGEND
Study Catchment
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 1.1
LOCATION PLAN
Lyall & Associates

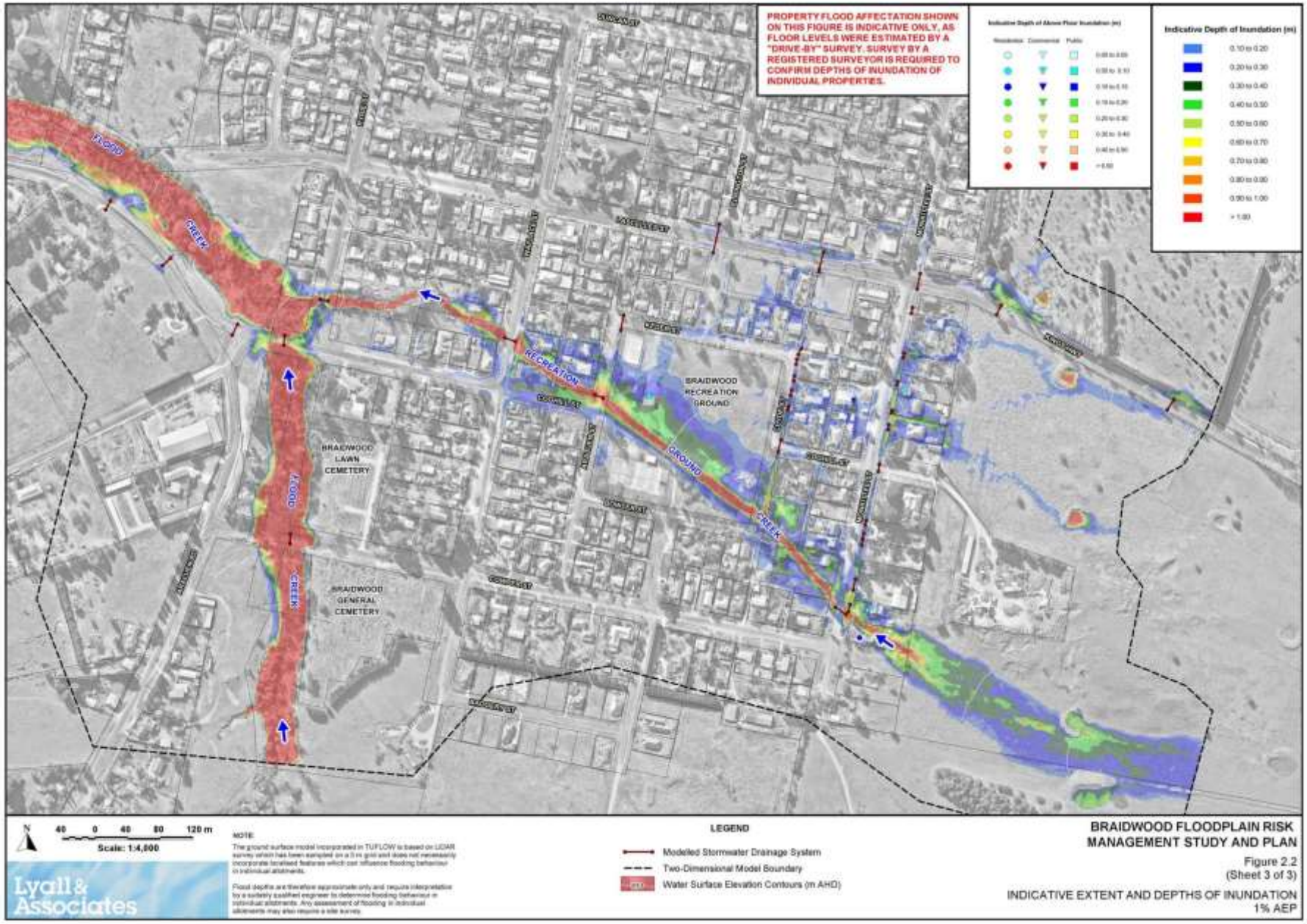

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
LEGEND
Pipe < 450 mm Diameter
Pipe ≥ 450 mm Diameter
Box Culvert
Bridge
Inlet Pit
Junction Pit
Headwall
Local Centre
Mixed Use
Light Industrial
Extent of Detailed Ground Survey Provided by Council
General Residential
Low Density Residential
Large Lot Residential
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.1
(Sheet 1 of 3)
EXISTING DRAINAGE SYSTEM

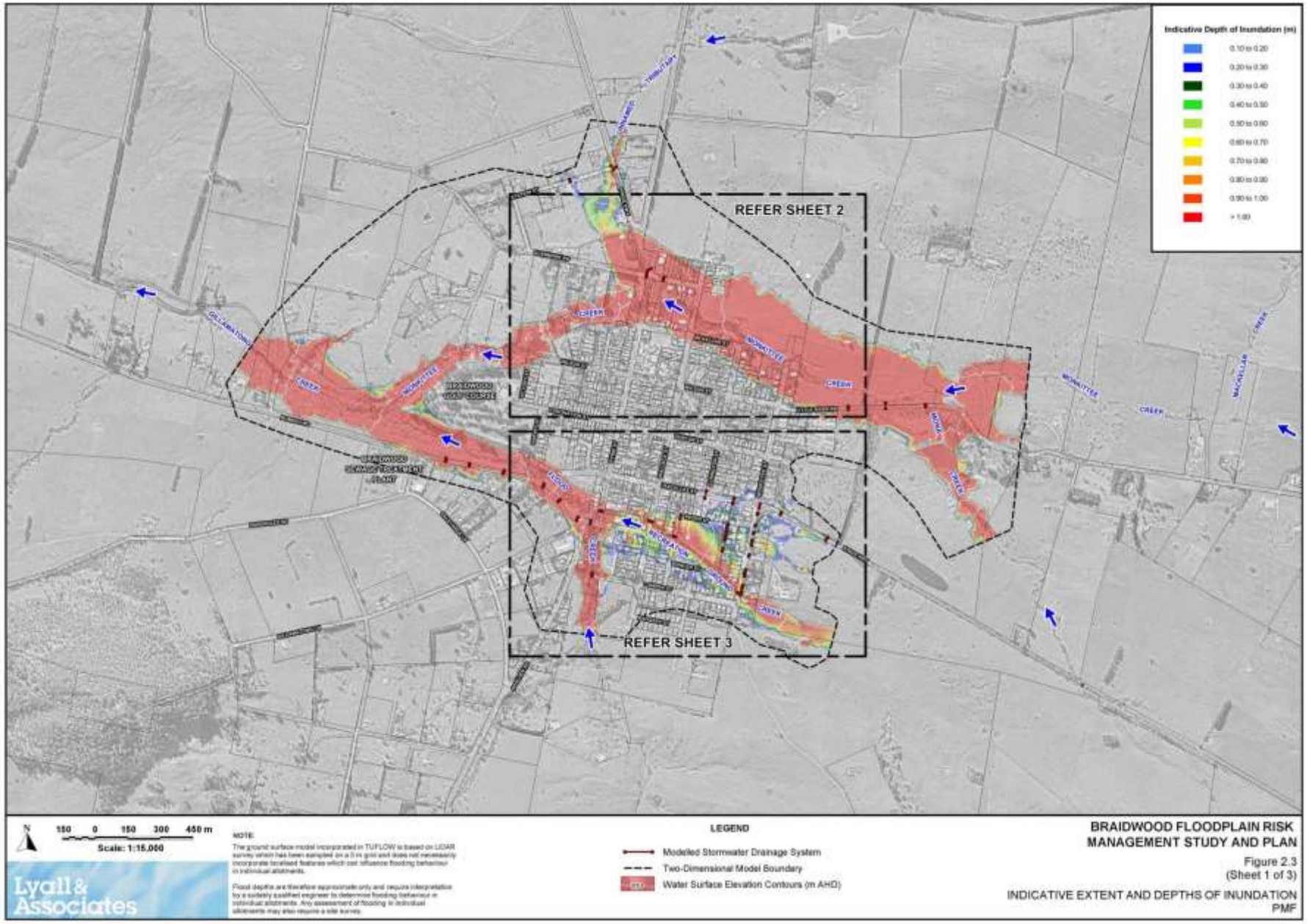
UNNAMED
TRIBUTARY
CREEK
MONKITTEE
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE:
LEGEND
Pipe < 450 mm Diameter
Pipe ≥ 450 mm Diameter
Box Culvert
Bridge
Inlet Pit
Junction Pit
Headwall
Local Centre
Mixed Use
Light Industrial
General Residential
Low Density Residential
Large Lot Residential
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.1
(Sheet 2 of 3)
EXISTING DRAINAGE SYSTEM

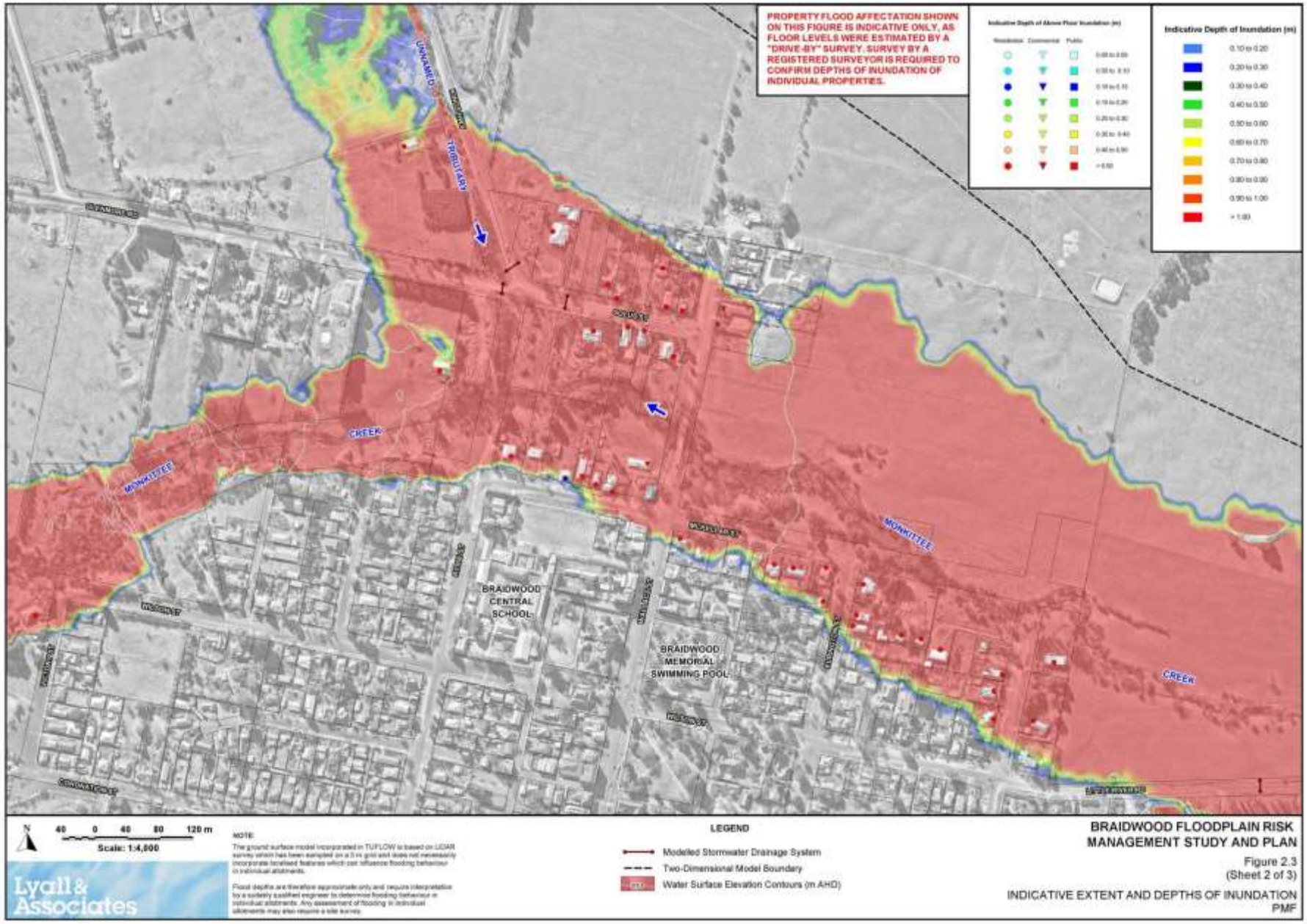
FLOOD
CREEK
ARCHER BRIDGE
RECREATION
BRAIDWOOD RECREATION GROUND
GROUND
CREEK
BRAIDWOOD LAWN CEMETERY
FLOOD
CREEK
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE:
Only those hydraulic structures which were incorporated in the hydraulic model are shown on this figure.
Lyall & Associates
LEGEND
Pipe < 450 mm Diameter
Pipe ≥ 450 mm Diameter
Box Culvert
Extent of Detailed Ground Survey Provided by Council
Inlet Pit
Junction Pit
Headwall
Local Centre
Mixed Use
Light Industrial
General Residential
Low Density Residential
Large Lot Residential
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.1
(Sheet 3 of 3)
EXISTING DRAINAGE SYSTEM

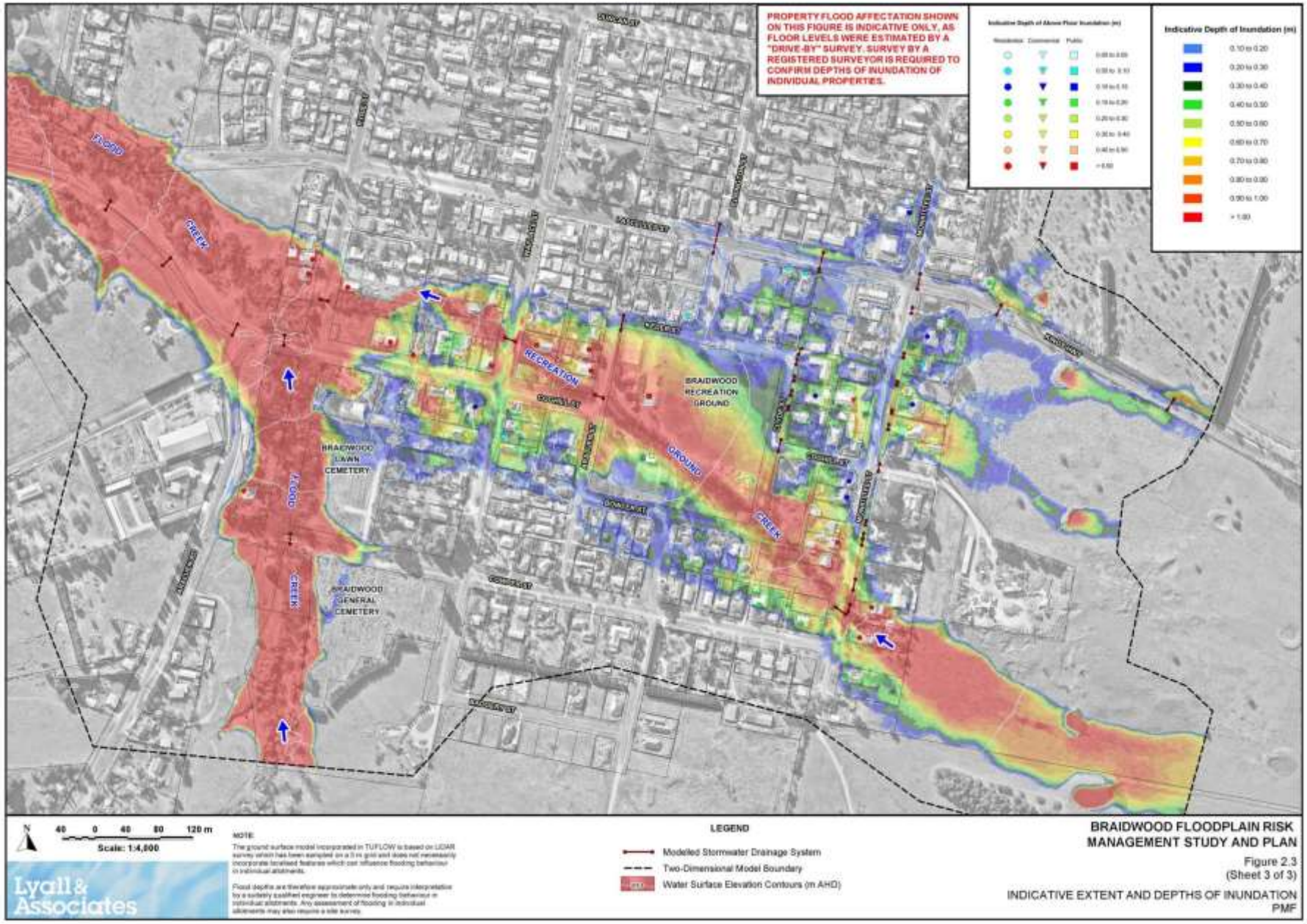

Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretative by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.2
(Sheet 1 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
1% AEP

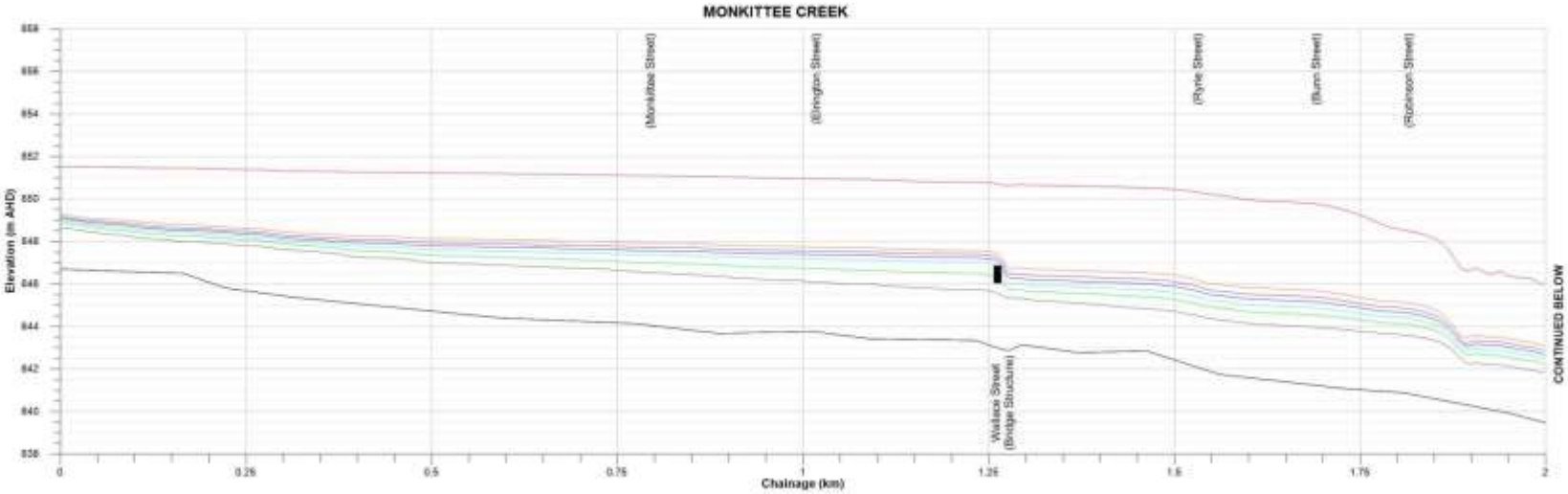

PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.2
(Sheet 2 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
1% AEP

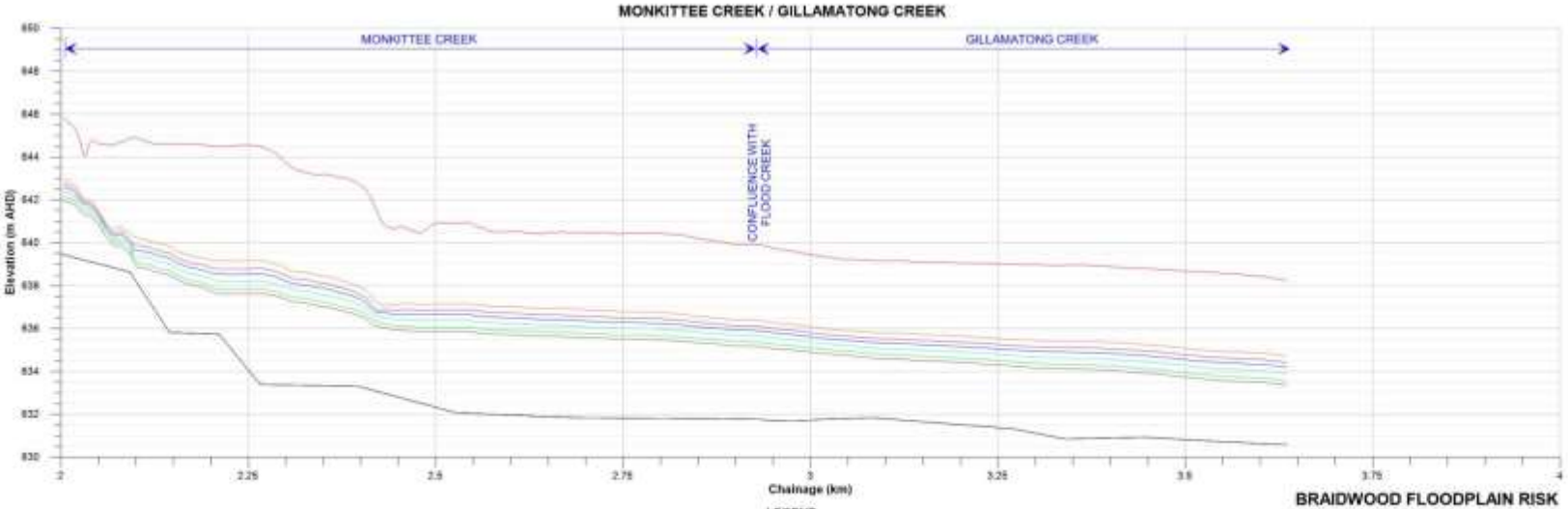

PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.2
(Sheet 3 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
1% AEP


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.3
(Sheet 1 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
PMF


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
CREEK
MONKITTEE
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.3
(Sheet 2 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
PMF


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.3
(Sheet 3 of 3)
INDICATIVE EXTENT AND DEPTHS OF INUNDATION
PMF





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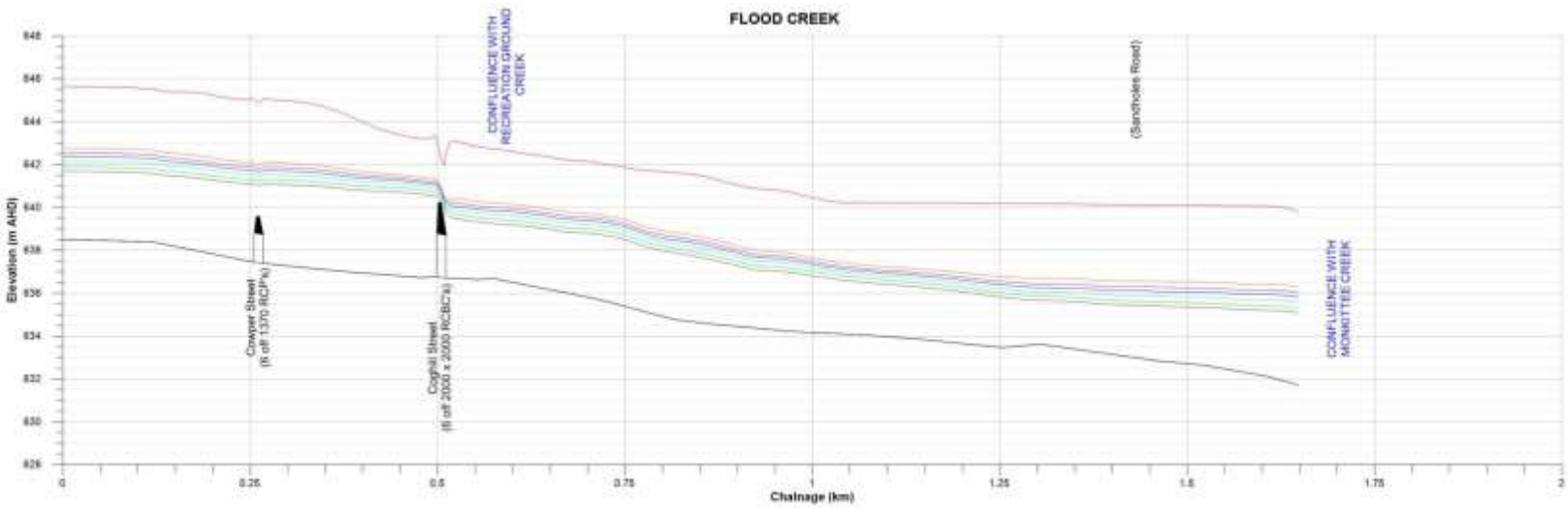
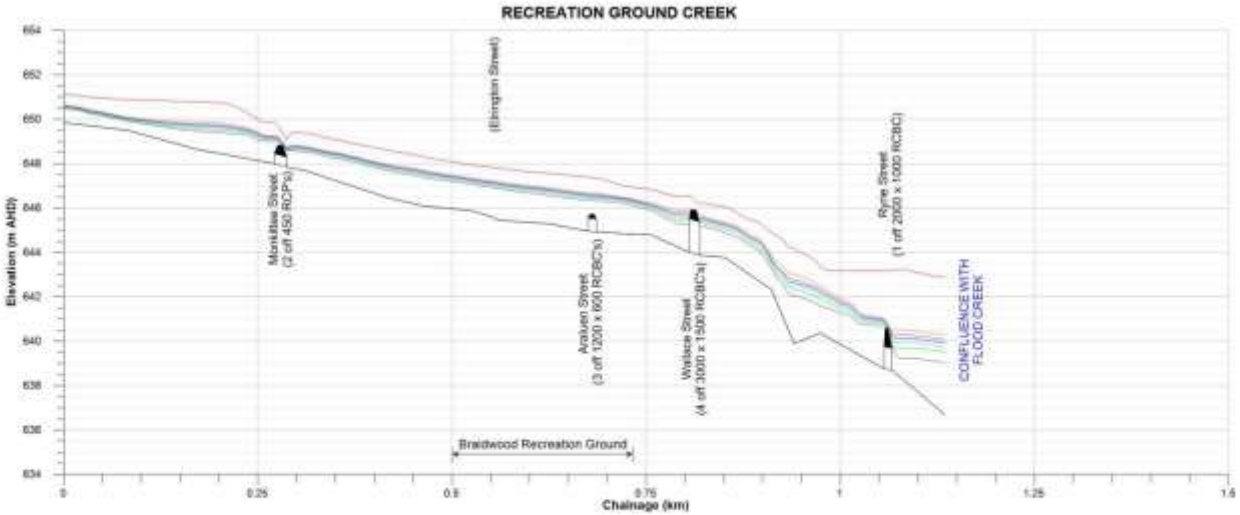
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.4
(Sheet 1 of 2)

DESIGN WATER SURFACE PROFILES





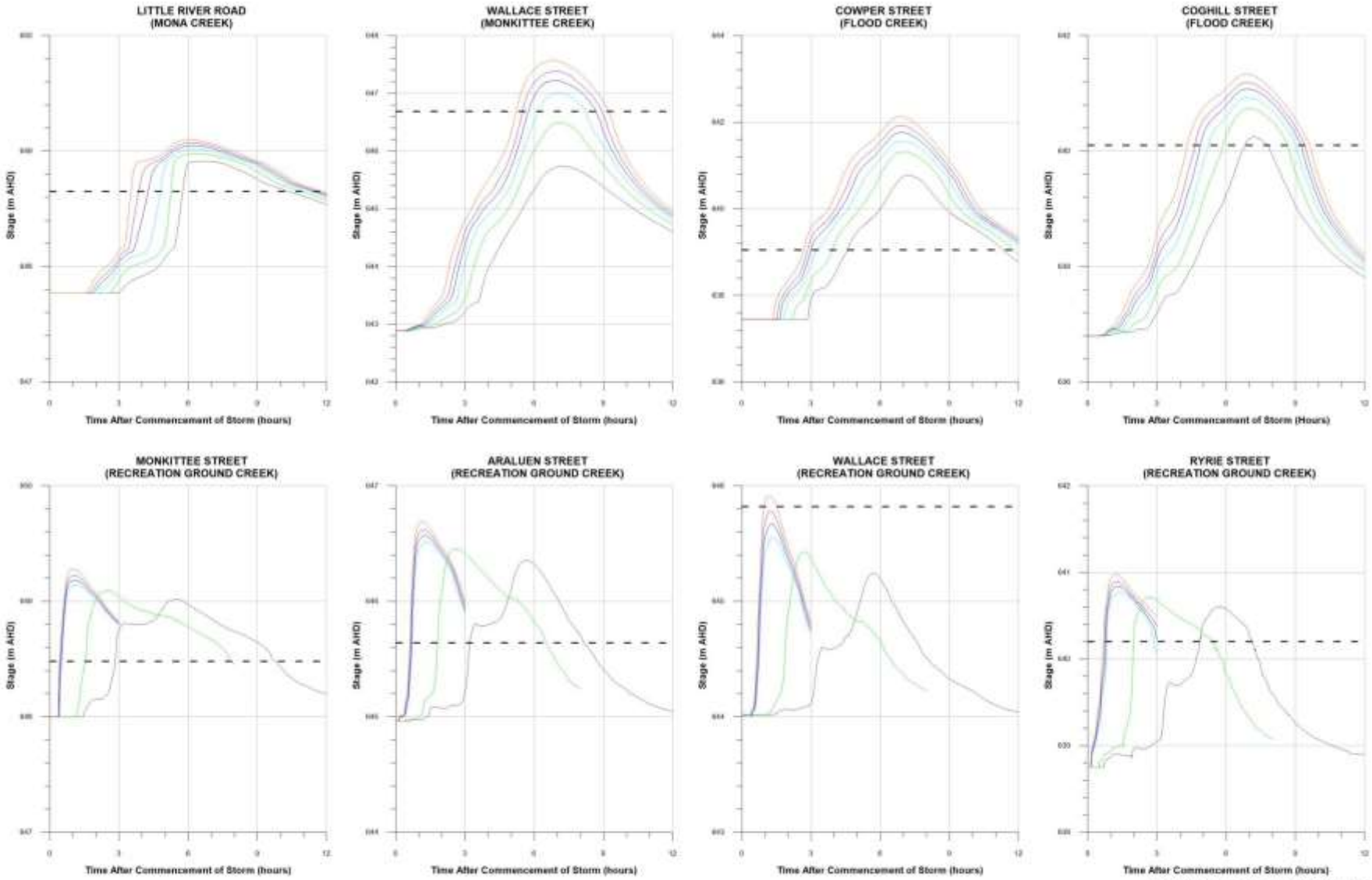
LEGEND

- Probable Maximum Flood
- 0.2% AEP
- 0.5% AEP
- 1% AEP
- 2% AEP
- 5% AEP
- 20% AEP

BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure 2.4
(Sheet 2 of 2)

DESIGN WATER SURFACE PROFILES

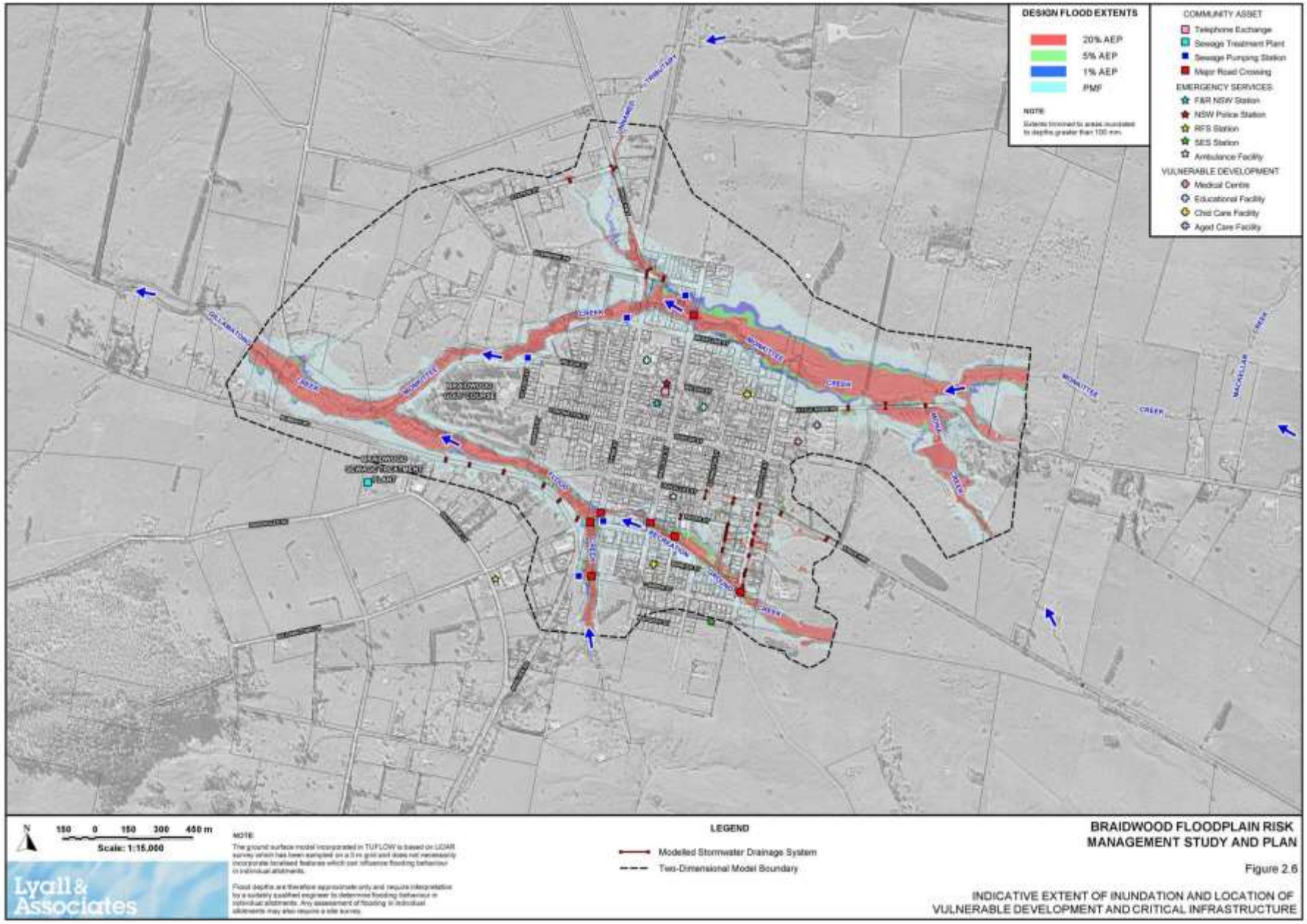


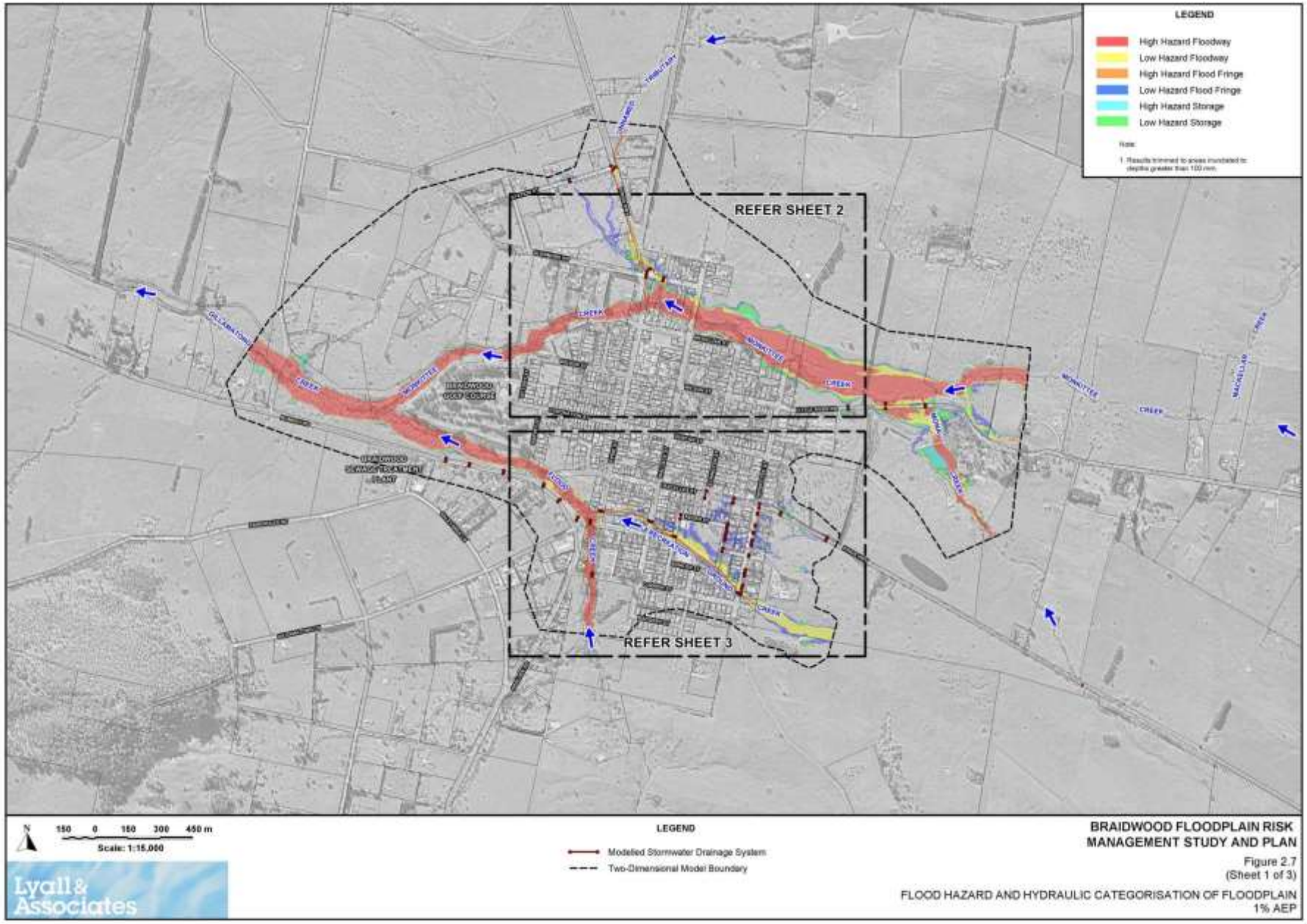
Lyall & Associates

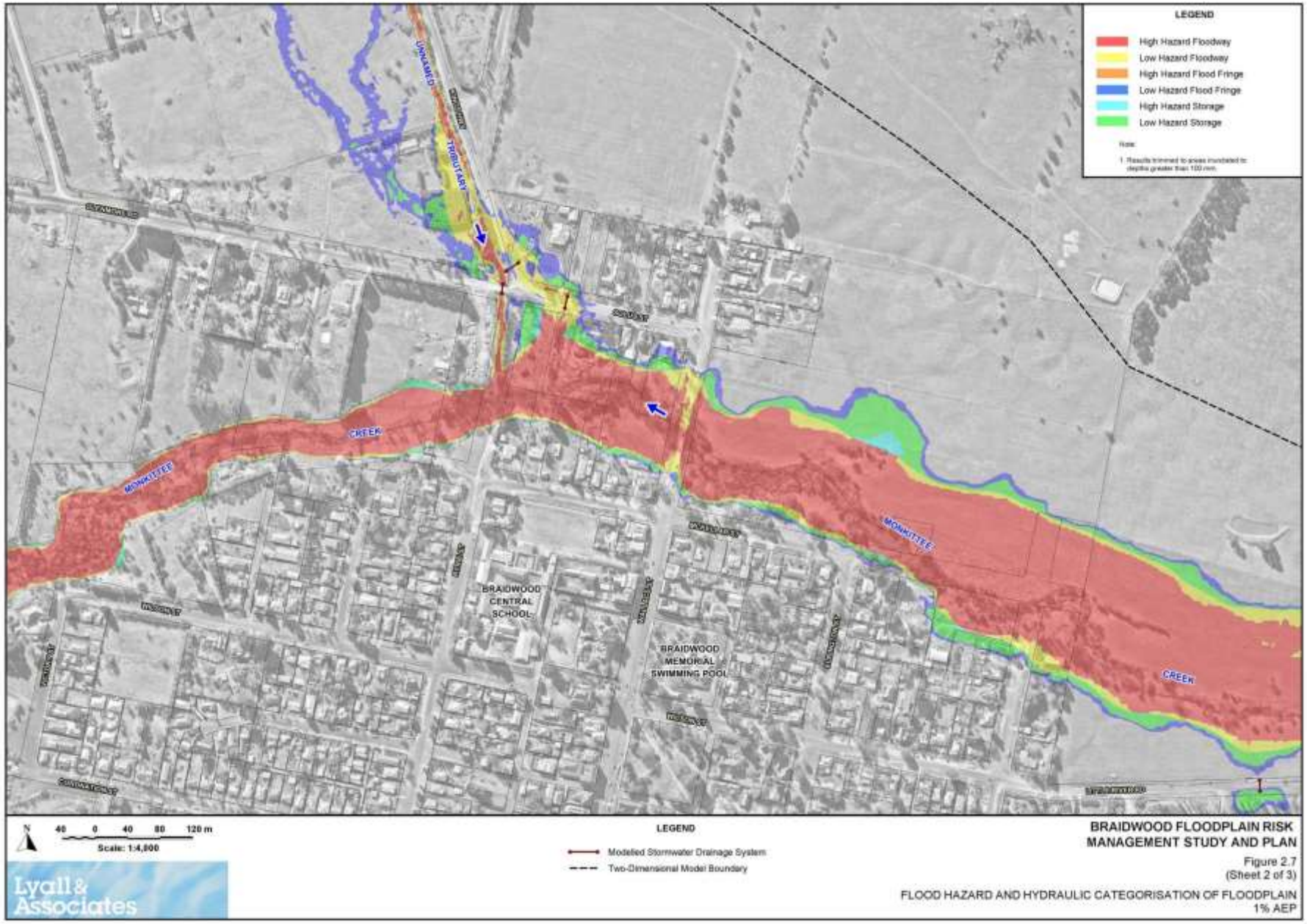
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

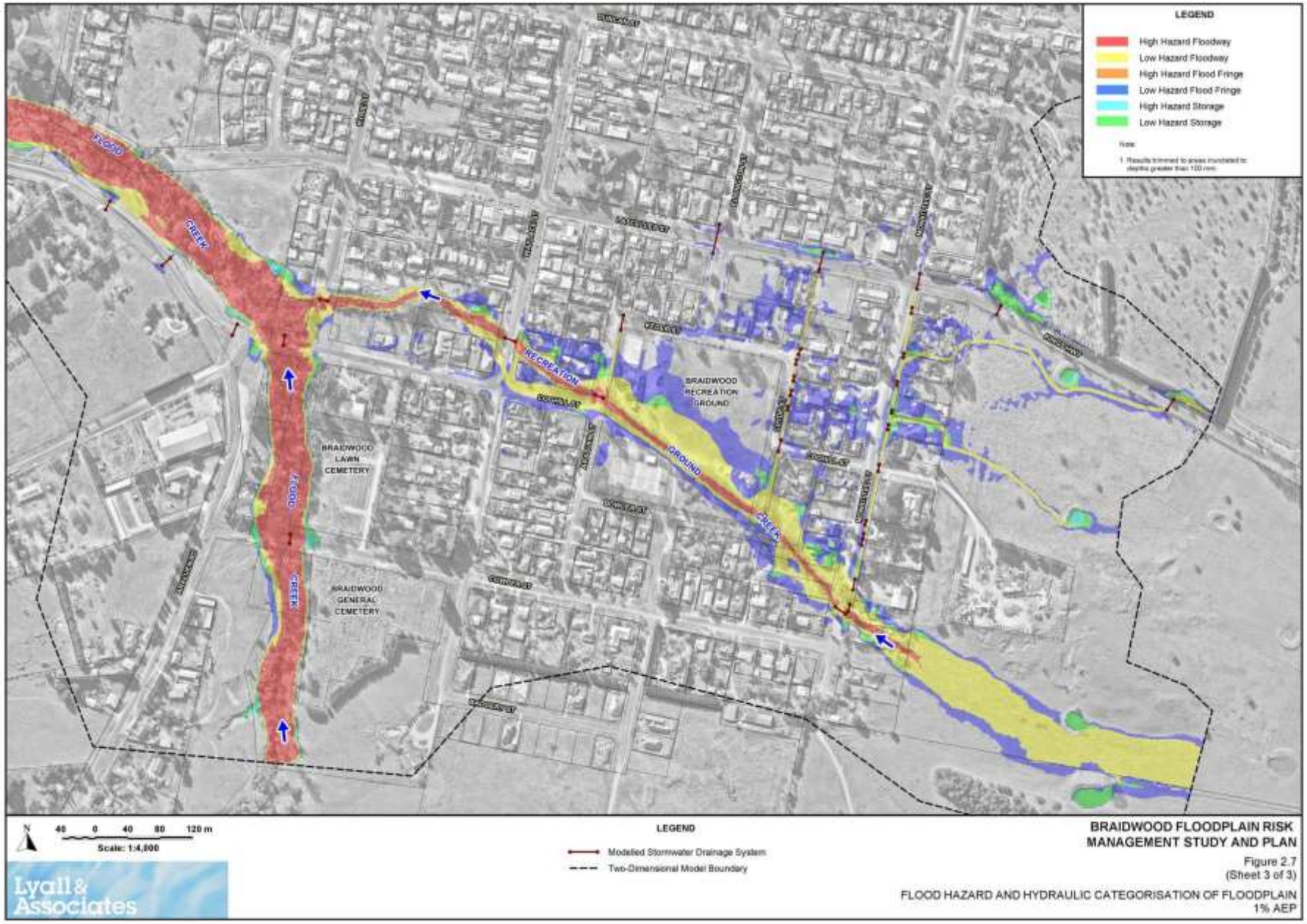
Figure 2.5

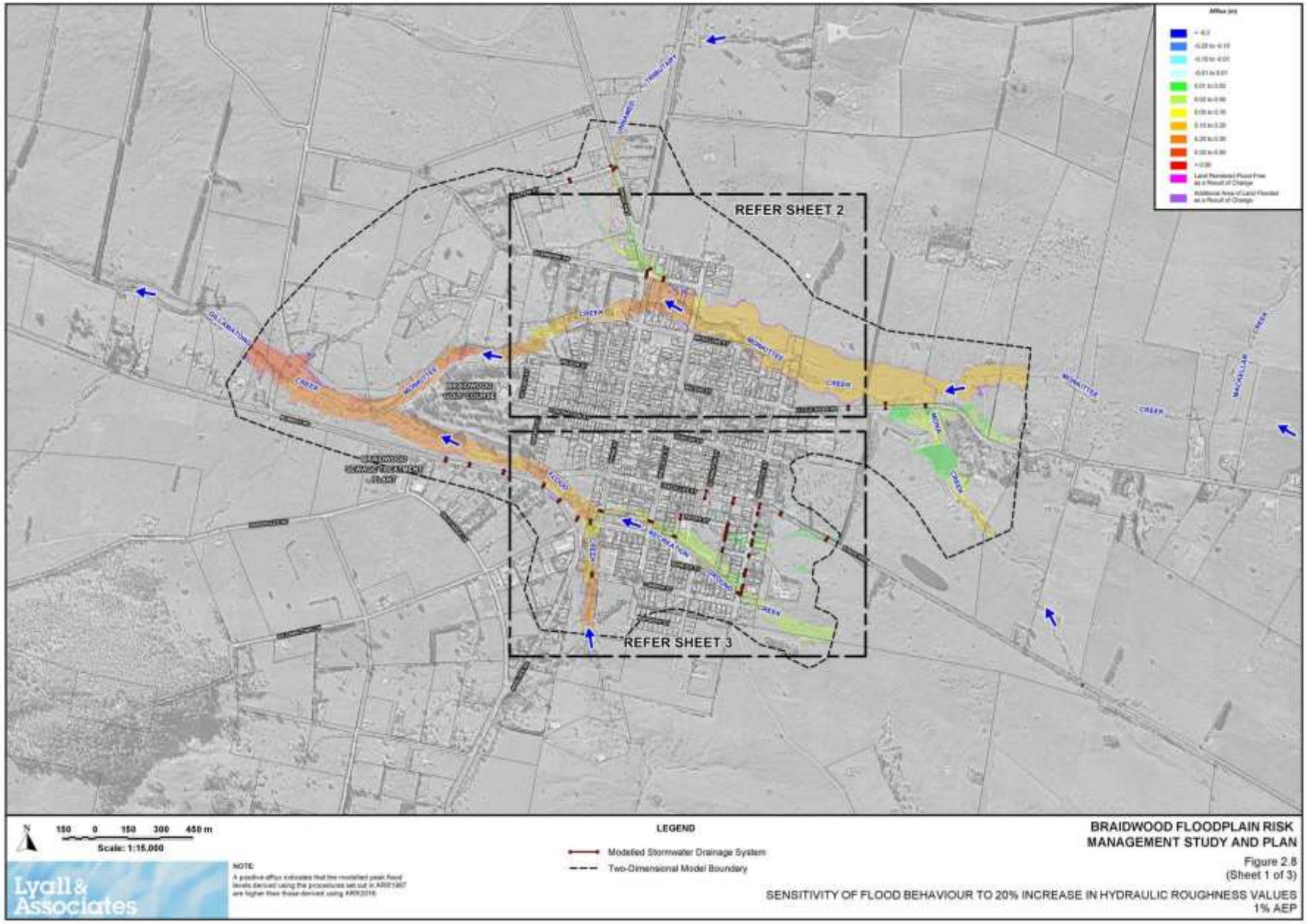
TIME OF RISE OF FLOODWATERS

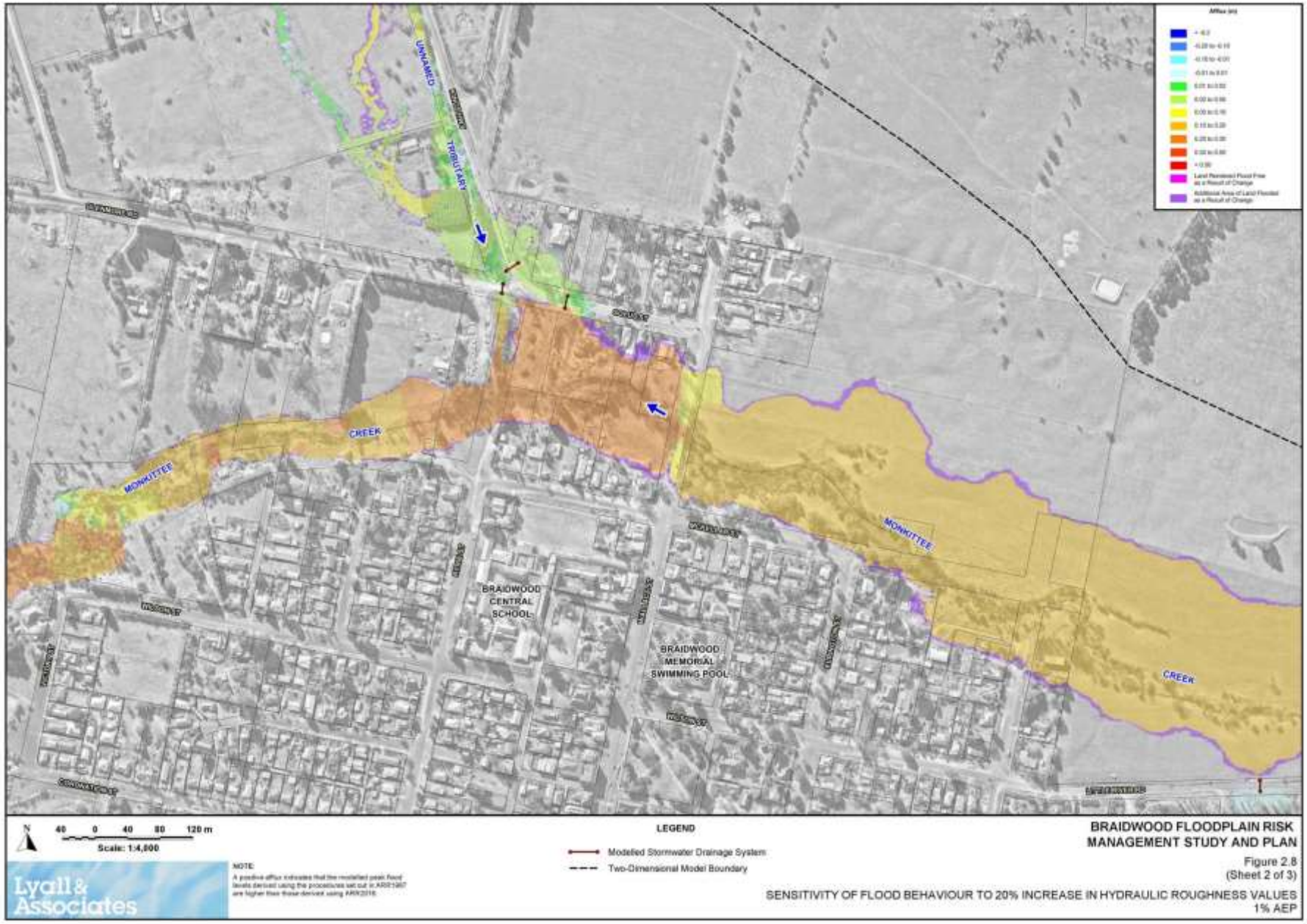

DESIGN FLOOD EXTENTS
20% AEP
5% AEP
1% AEP
PMF
NOTE
Extents trimmed to areas inundated to depths greater than 100 mm
COMMUNITY ASSET
Telephone Exchange
Sewage Treatment Plant
Sewage Pumping Station
Major Road Crossing
EMERGENCY SERVICES
F&R NSW Station
NSW Police Station
RFS Station
SES Station
Ambulance Facility
VULNERABLE DEVELOPMENT
Medical Centre
Educational Facility
Child Care Facility
Aged Care Facility
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.6
INDICATIVE EXTENT OF INUNDATION AND LOCATION OF VULNERABLE DEVELOPMENT AND CRITICAL INFRASTRUCTURE


LEGEND
High Hazard Floodway
Low Hazard Floodway
High Hazard Flood Fringe
Low Hazard Flood Fringe
High Hazard Storage
Low Hazard Storage
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.7
(Sheet 1 of 3)
FLOOD HAZARD AND HYDRAULIC CATEGORISATION OF FLOODPLAIN
1% AEP

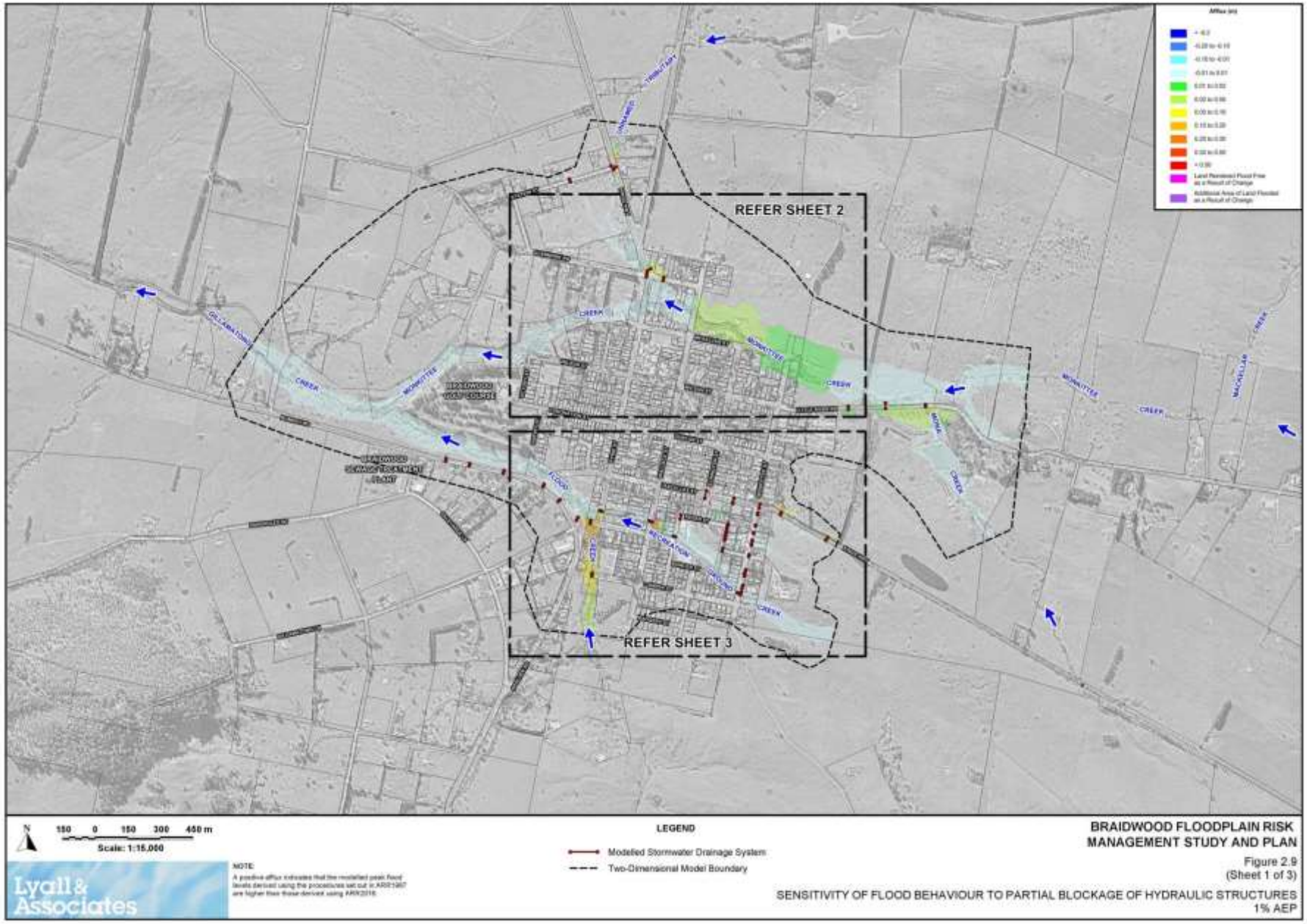

LEGEND
High Hazard Floodway
Low Hazard Floodway
High Hazard Flood Fringe
Low Hazard Flood Fringe
High Hazard Storage
Low Hazard Storage
UNNAMED
TRIBUTARY
MONKITEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.7
(Sheet 2 of 3)
FLOOD HAZARD AND HYDRAULIC CATEGORISATION OF FLOODPLAIN
1% AEP

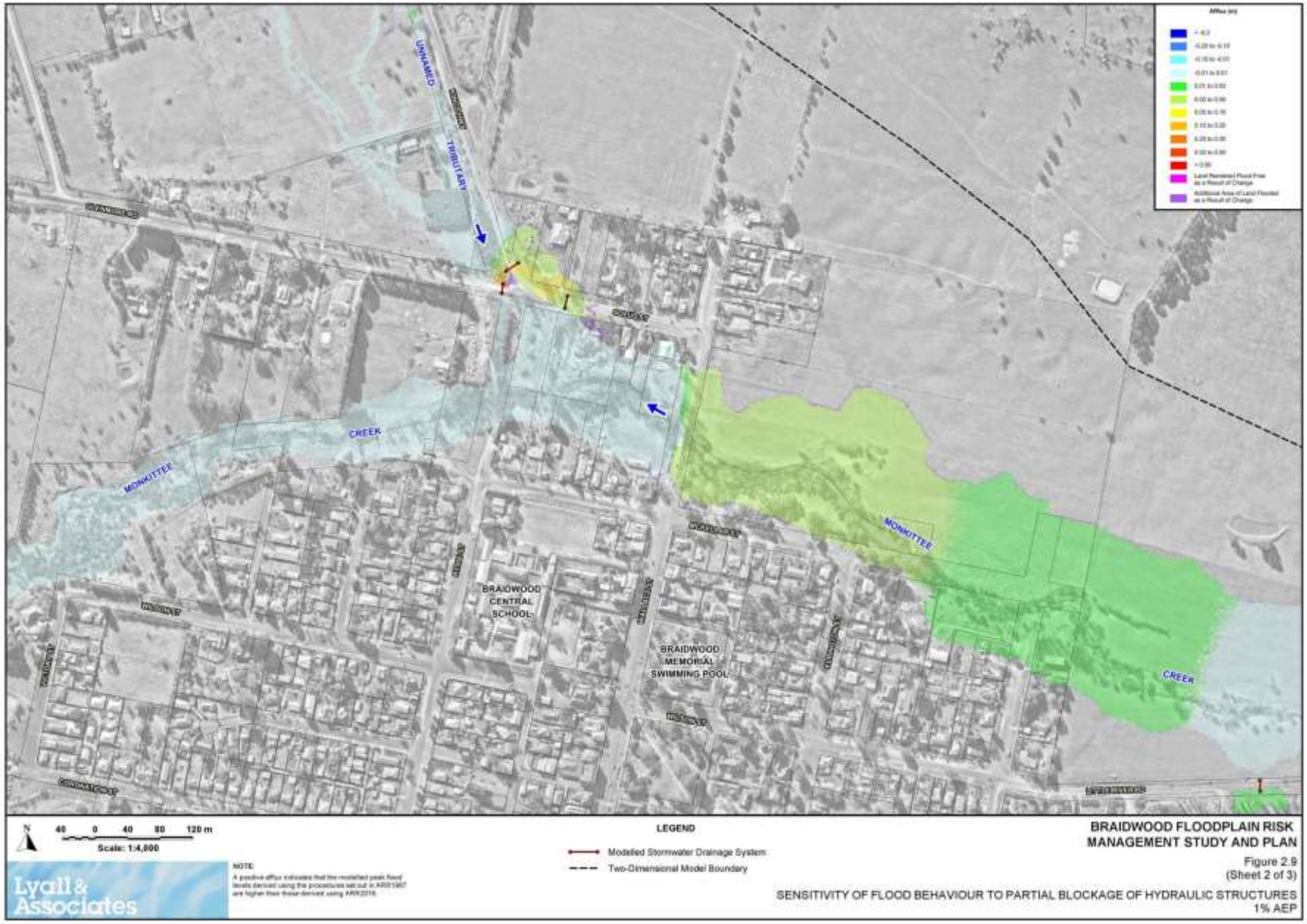

LEGEND
High Hazard Floodway
Low Hazard Floodway
High Hazard Flood Fringe
Low Hazard Flood Fringe
High Hazard Storage
Low Hazard Storage
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,800
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.7
(Sheet 3 of 3)
FLOOD HAZARD AND HYDRAULIC CATEGORISATION OF FLOODPLAIN
1% AEP

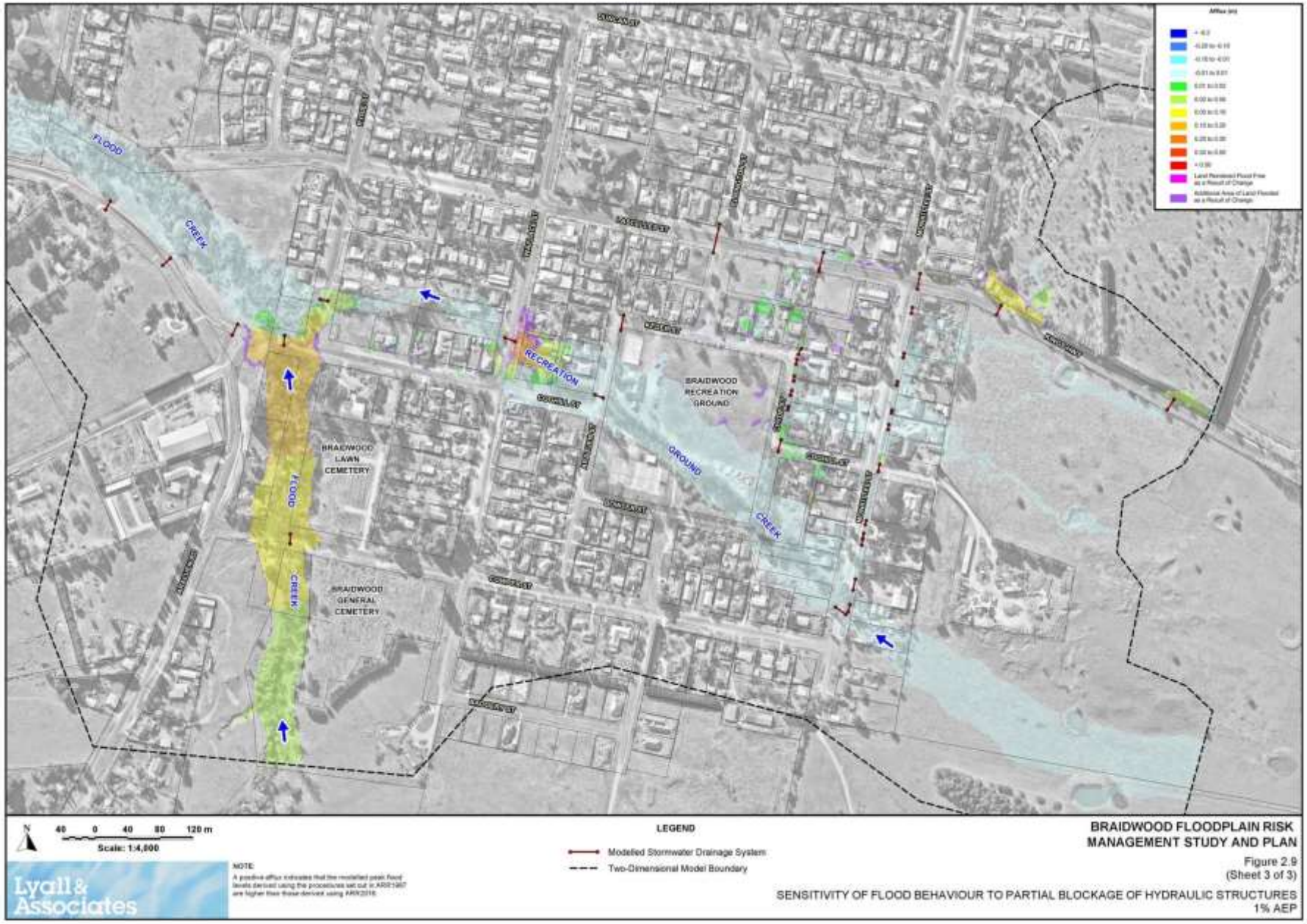

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
A positive afflux indicates that the modelled peak flood levels derived using the procedures set out in ARR1987 are higher than those derived using ARR2016
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.8
(Sheet 1 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
1% AEP

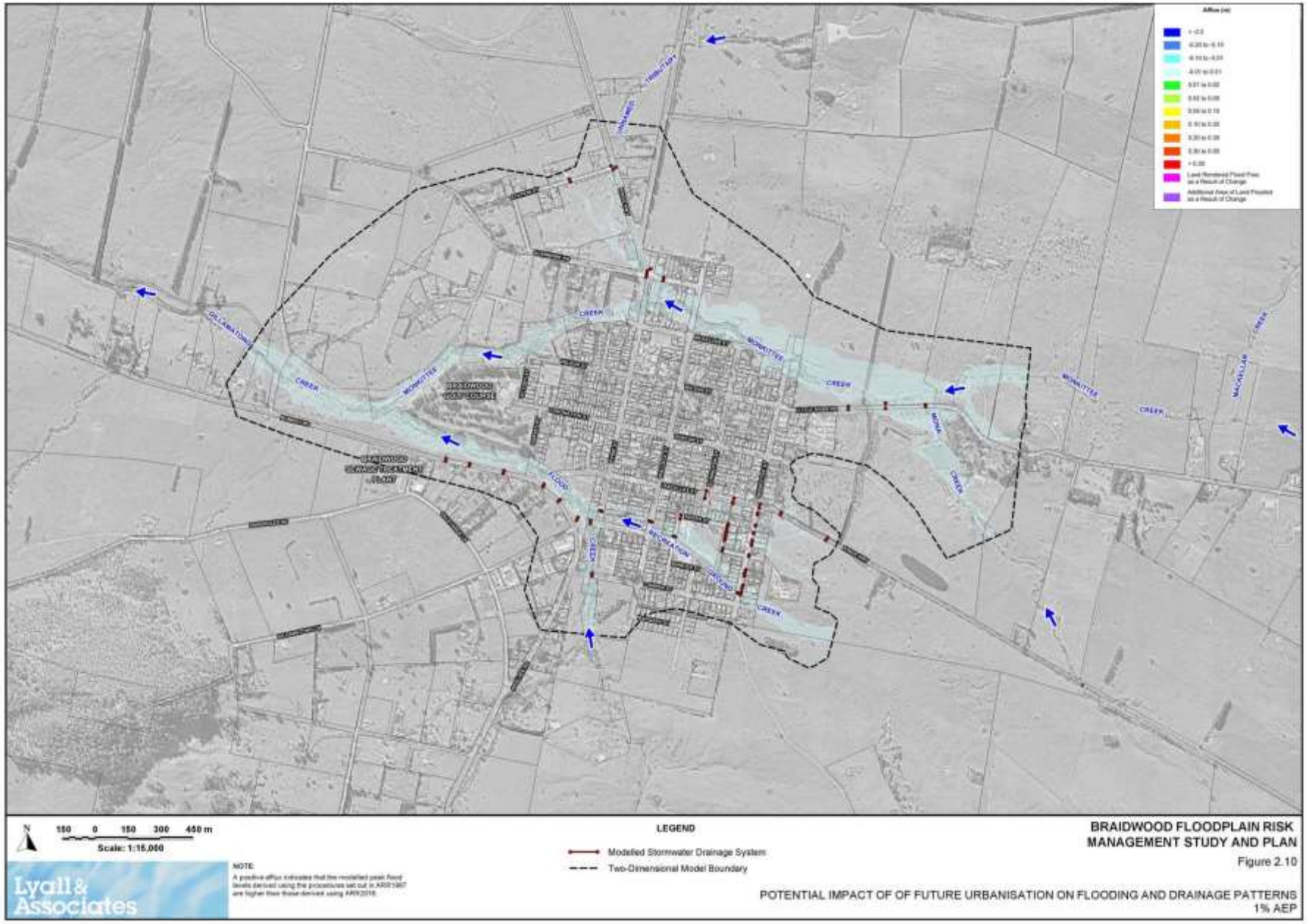

UNNAMED
TRIBUTARY
CREEK
MONKITTEE
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.8
(Sheet 2 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
1% AEP

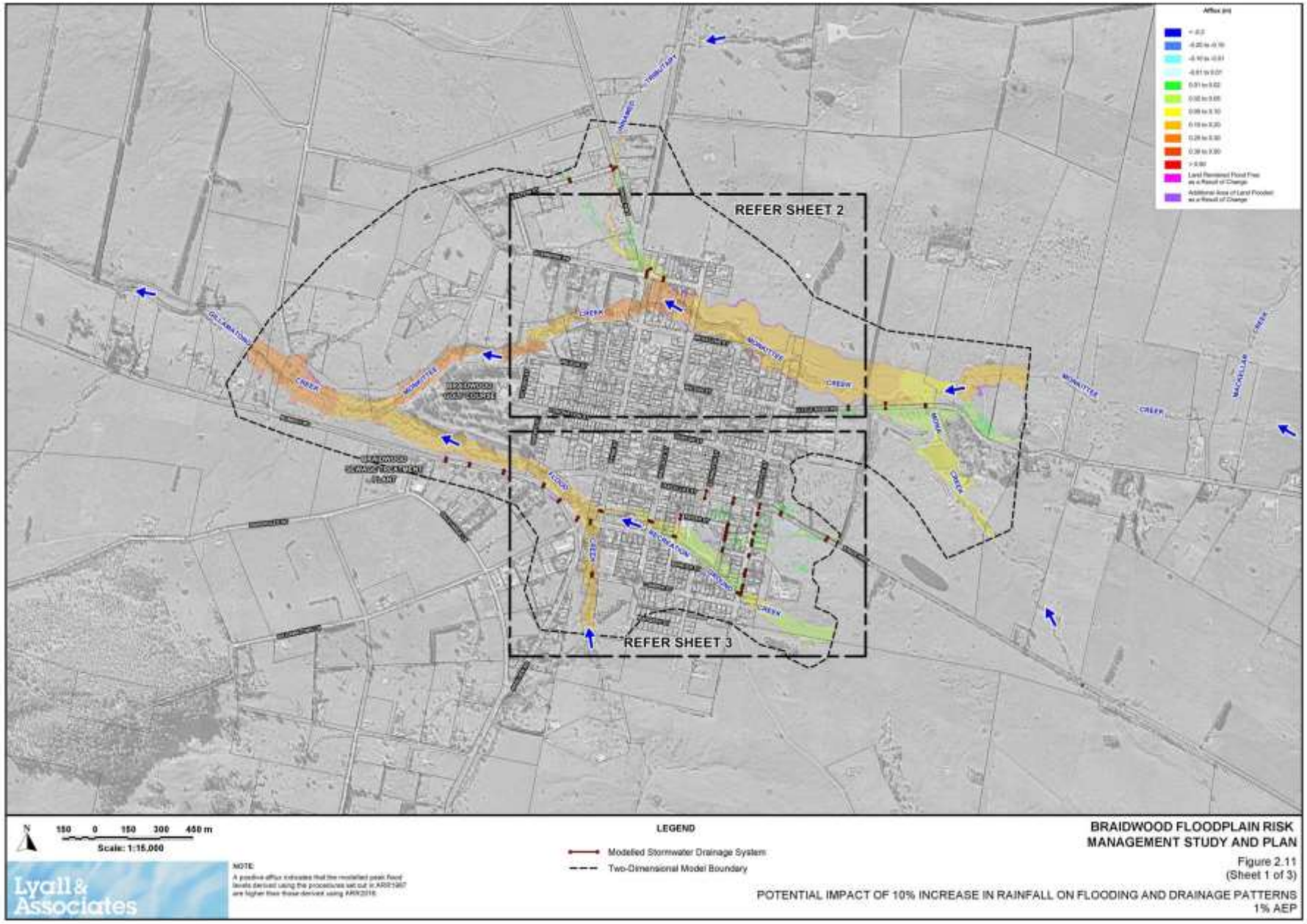
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD
RECREATION
GROUND
BRAIDWOOD
LAWN
CEMETERY
BRAIDWOOD
GENERAL
CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
NOTE
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK
MANAGEMENT STUDY AND PLAN
Figure 2.8
(Sheet 3 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO 20% INCREASE IN HYDRAULIC ROUGHNESS VALUES
1% AEP

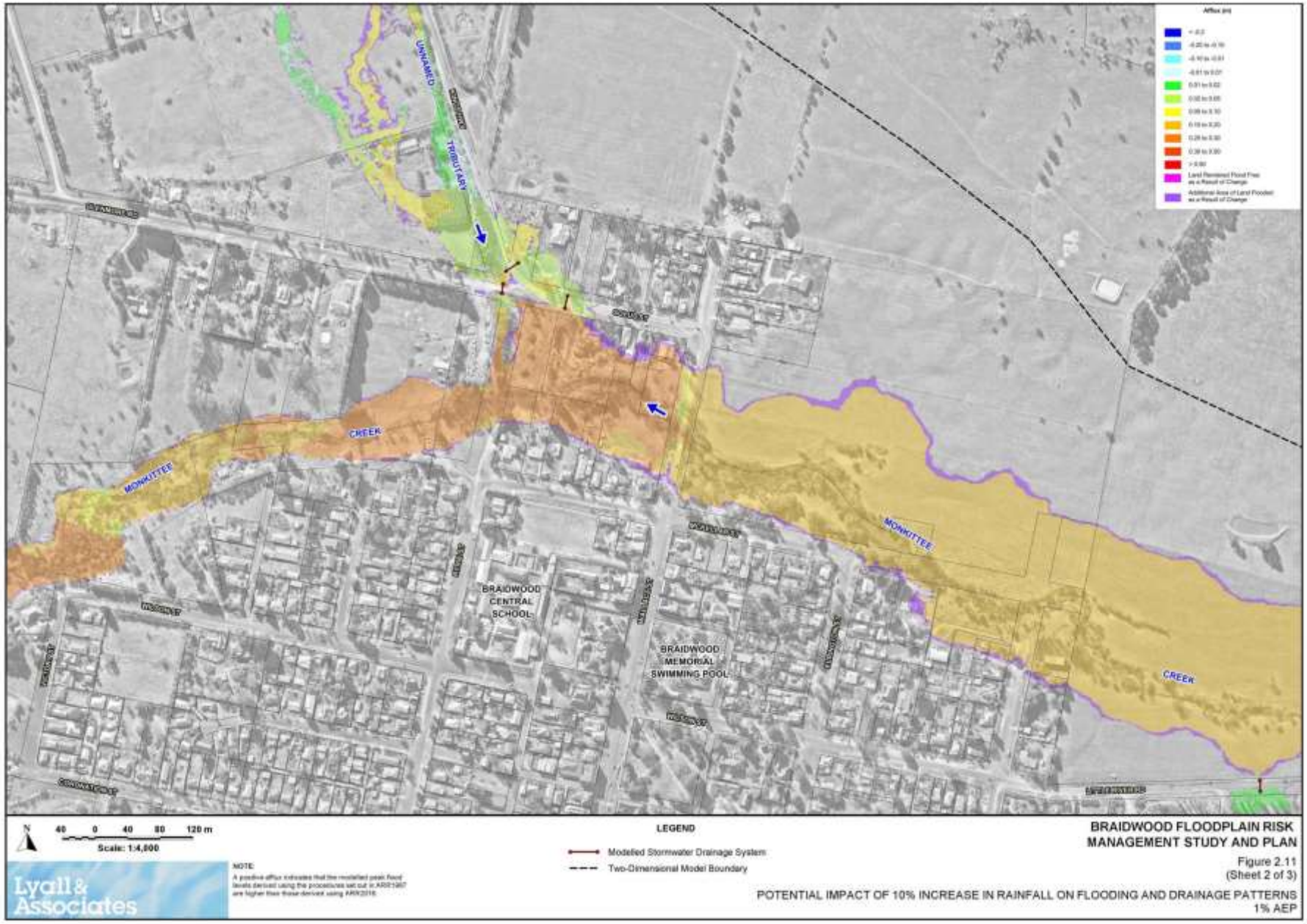

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
NOTE
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.9
(Sheet 1 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO PARTIAL BLOCKAGE OF HYDRAULIC STRUCTURES
1% AEP


UNNAMED
TRIBUTARY
CREEK
MONKITTEE
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
NOTE
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.9
(Sheet 2 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO PARTIAL BLOCKAGE OF HYDRAULIC STRUCTURES
1% AEP

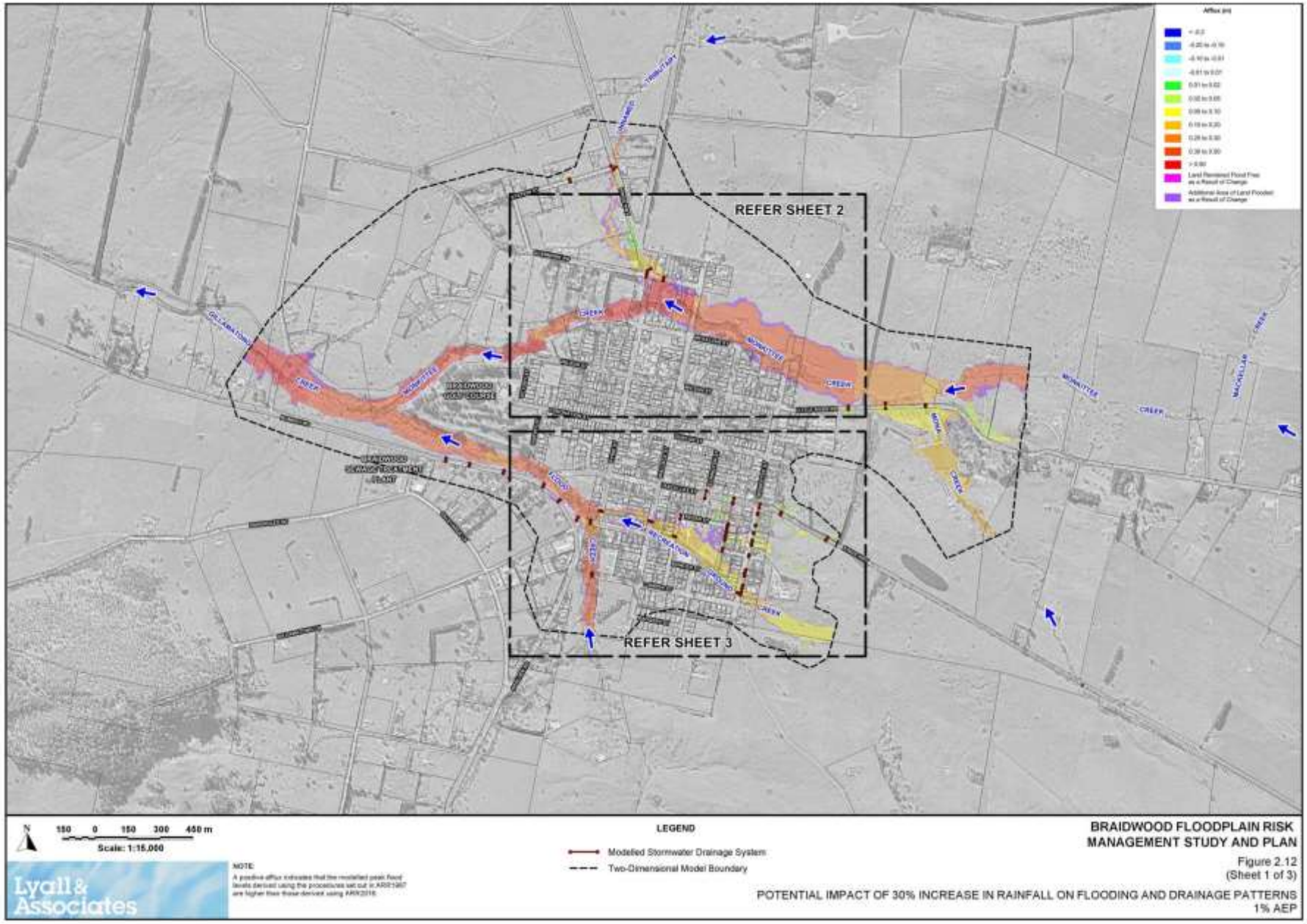

FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD
RECREATION
GROUND
BRAIDWOOD
LAWN
CEMETERY
BRAIDWOOD
GENERAL
CEMETERY
FLOOD
CREEK
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK
MANAGEMENT STUDY AND PLAN
Figure 2.9
(Sheet 3 of 3)
SENSITIVITY OF FLOOD BEHAVIOUR TO PARTIAL BLOCKAGE OF HYDRAULIC STRUCTURES
1% AEP

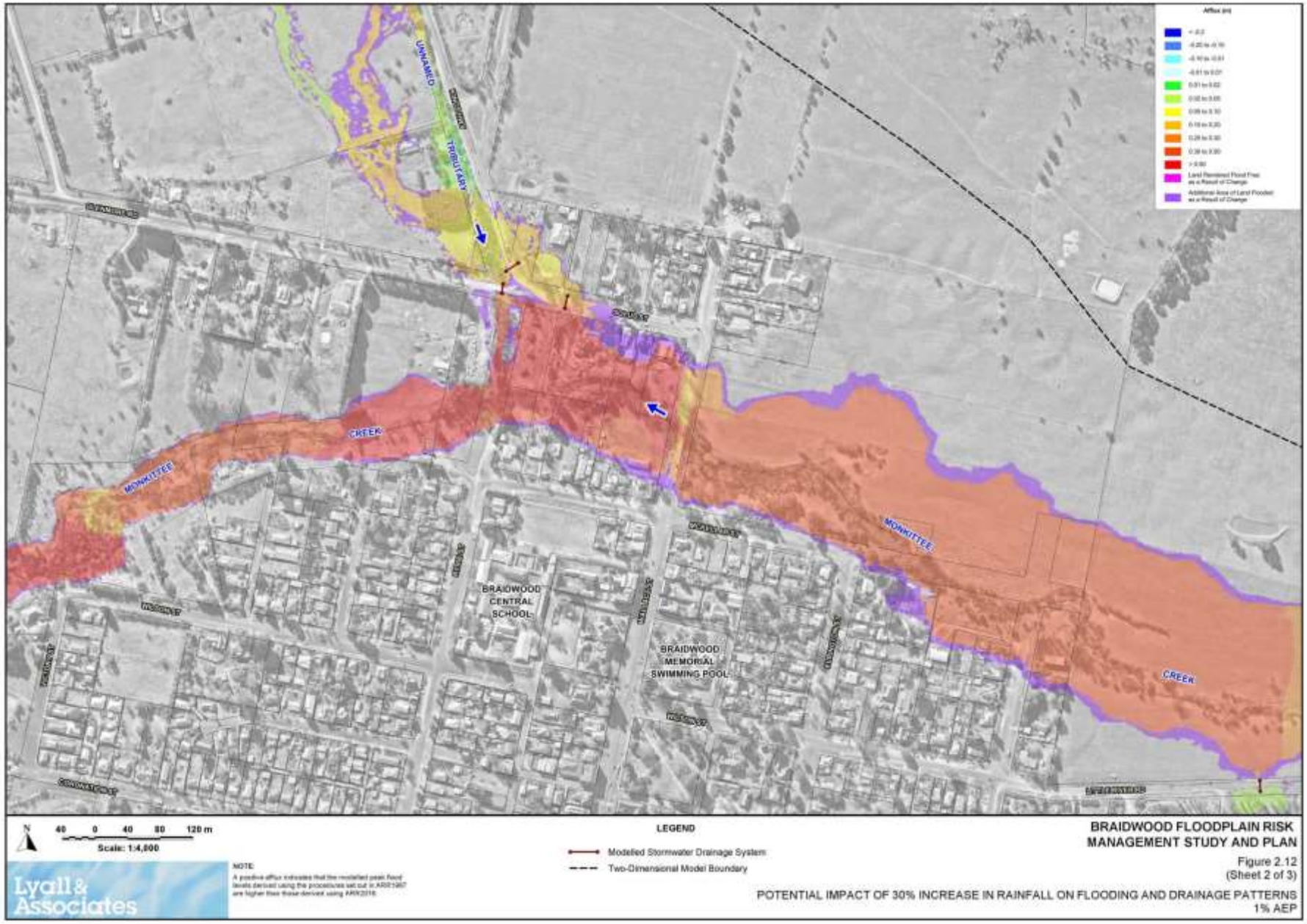

N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.10
POTENTIAL IMPACT OF OF FUTURE URBANISATION ON FLOODING AND DRAINAGE PATTERNS
1% AEP

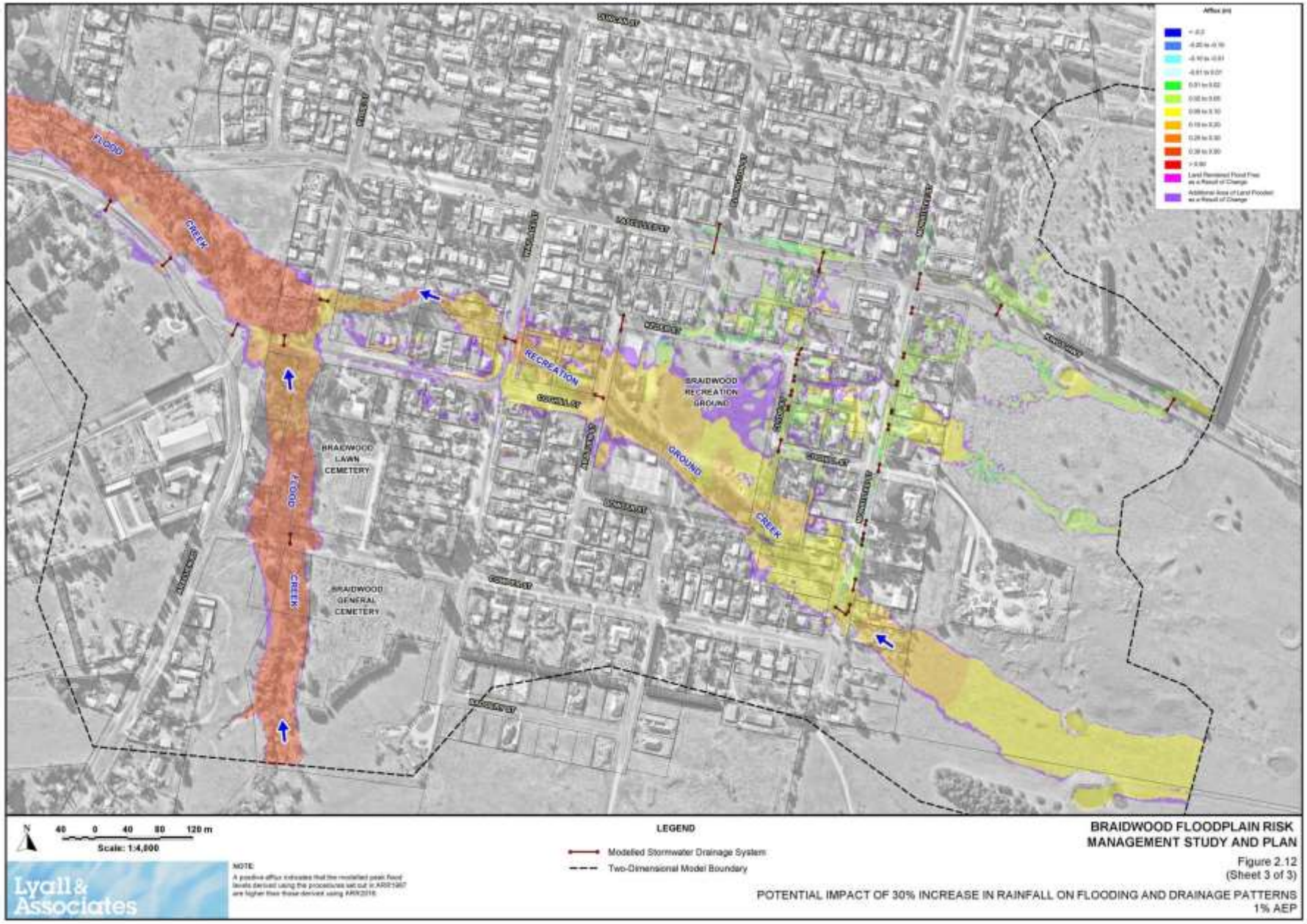

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.11
(Sheet 1 of 3)
POTENTIAL IMPACT OF 10% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

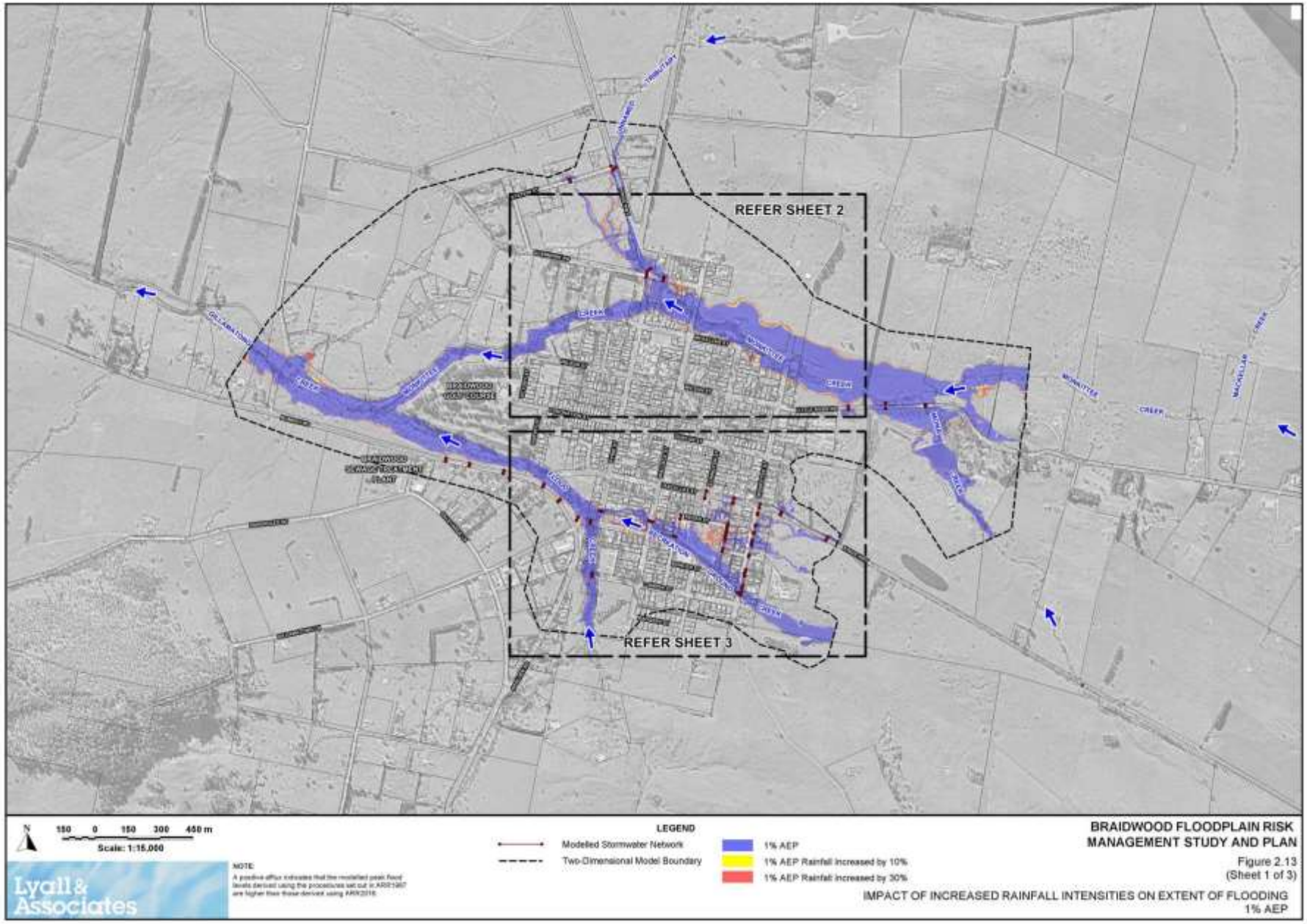

UNNAMED
TRIBUTARY
CREEK
MONKITTEE
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.11
(Sheet 2 of 3)
POTENTIAL IMPACT OF 10% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

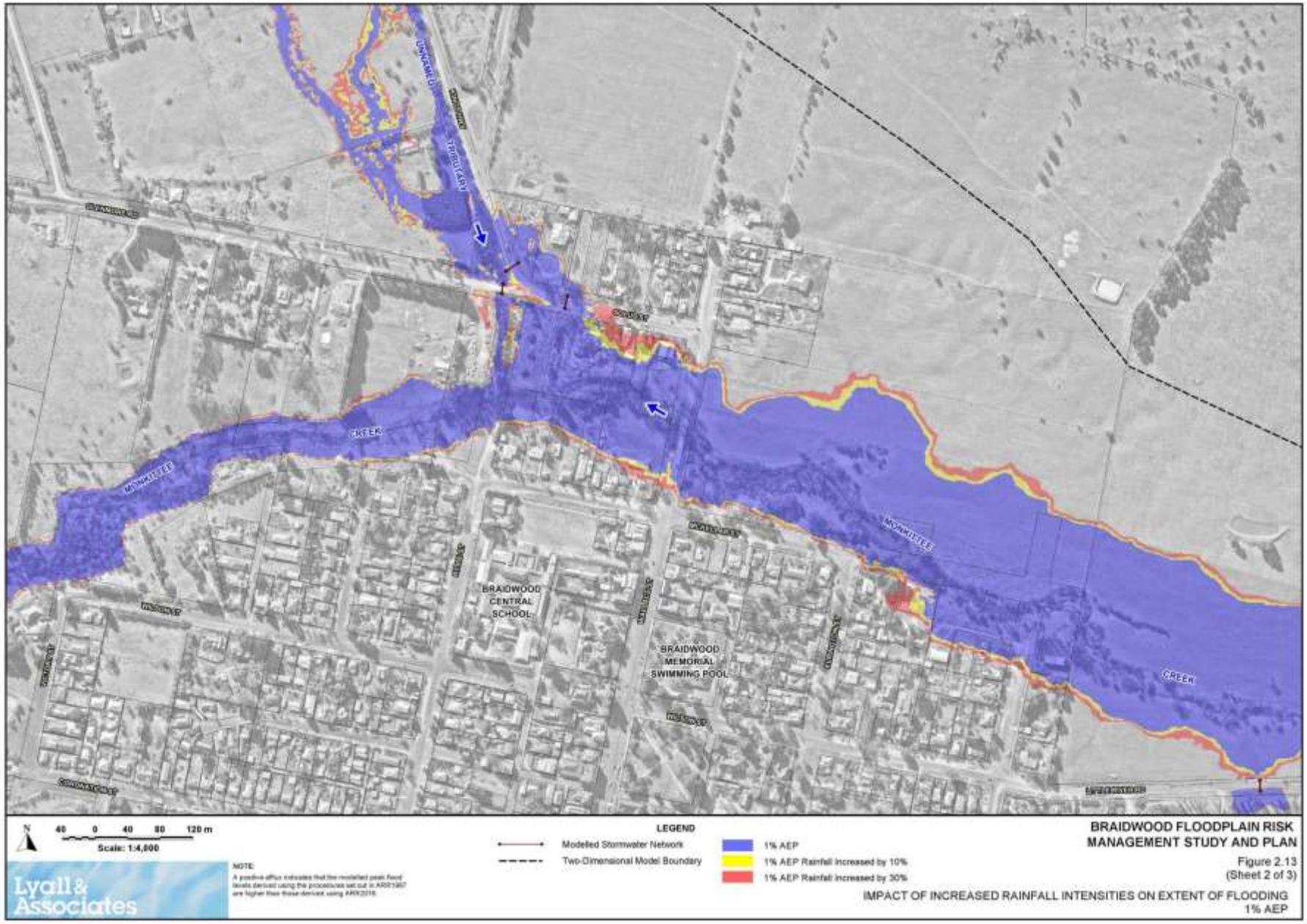
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.11
(Sheet 3 of 3)
POTENTIAL IMPACT OF 10% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

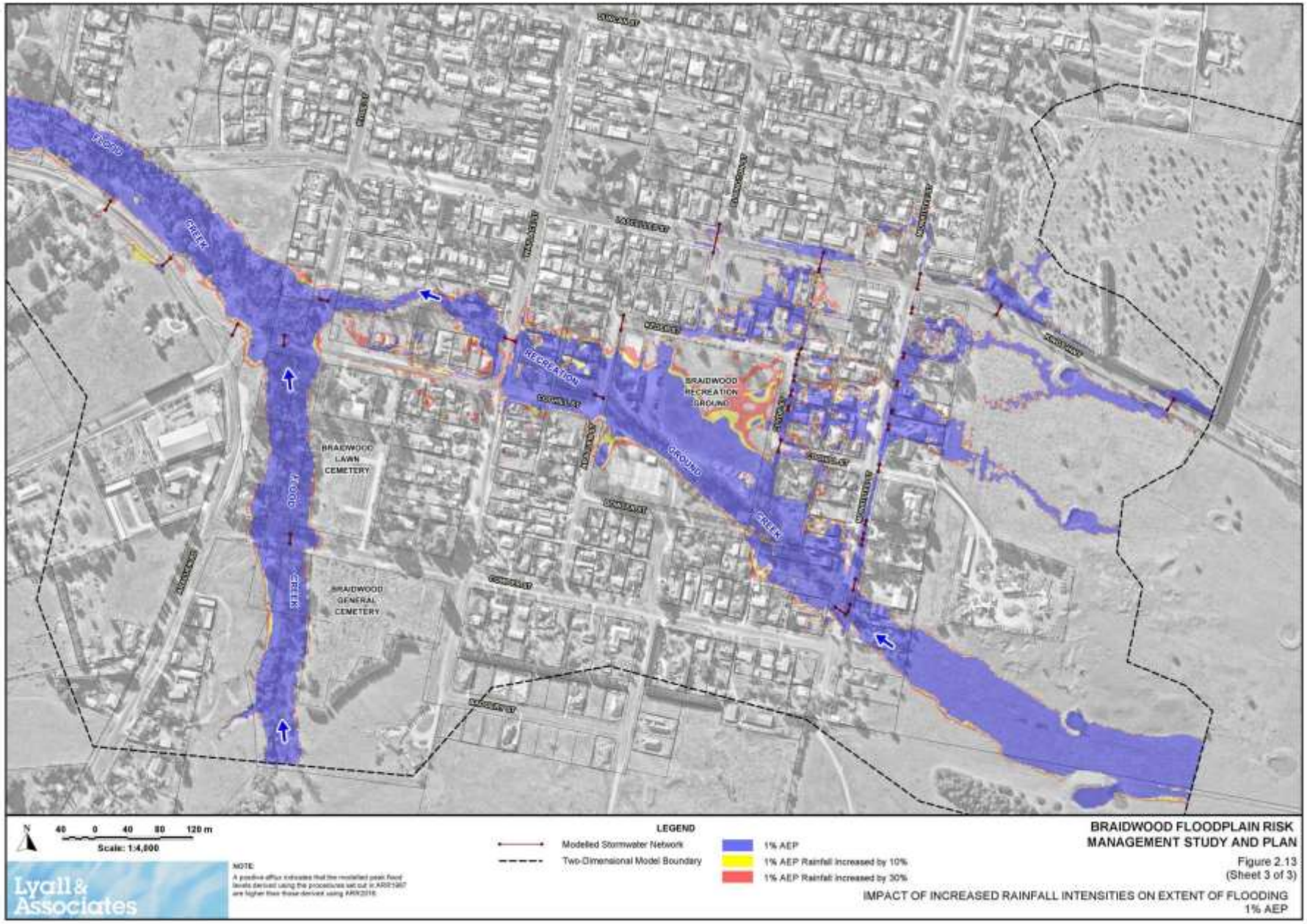

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.12
(Sheet 1 of 3)
POTENTIAL IMPACT OF 30% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

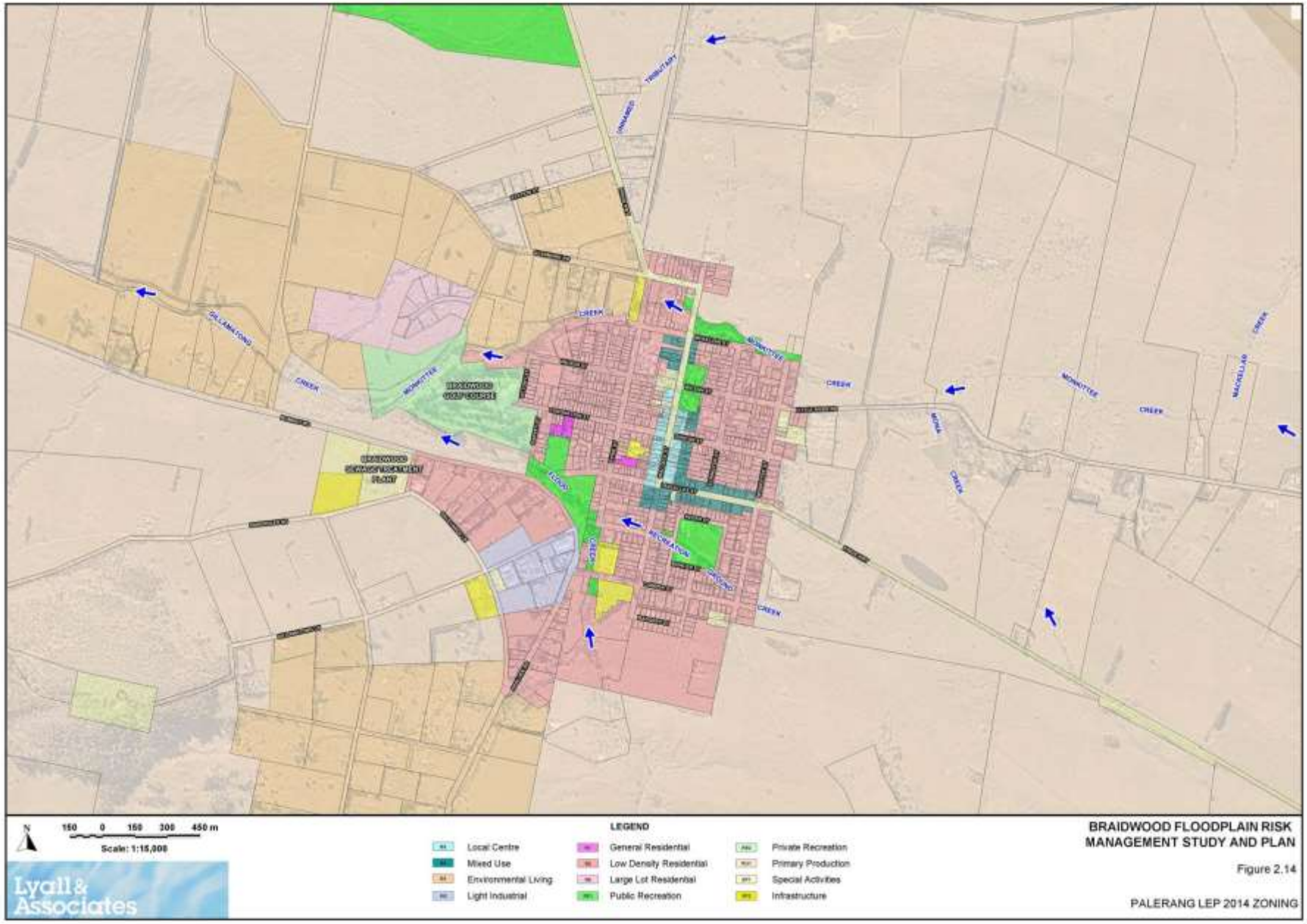

UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.12
(Sheet 2 of 3)
POTENTIAL IMPACT OF 30% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

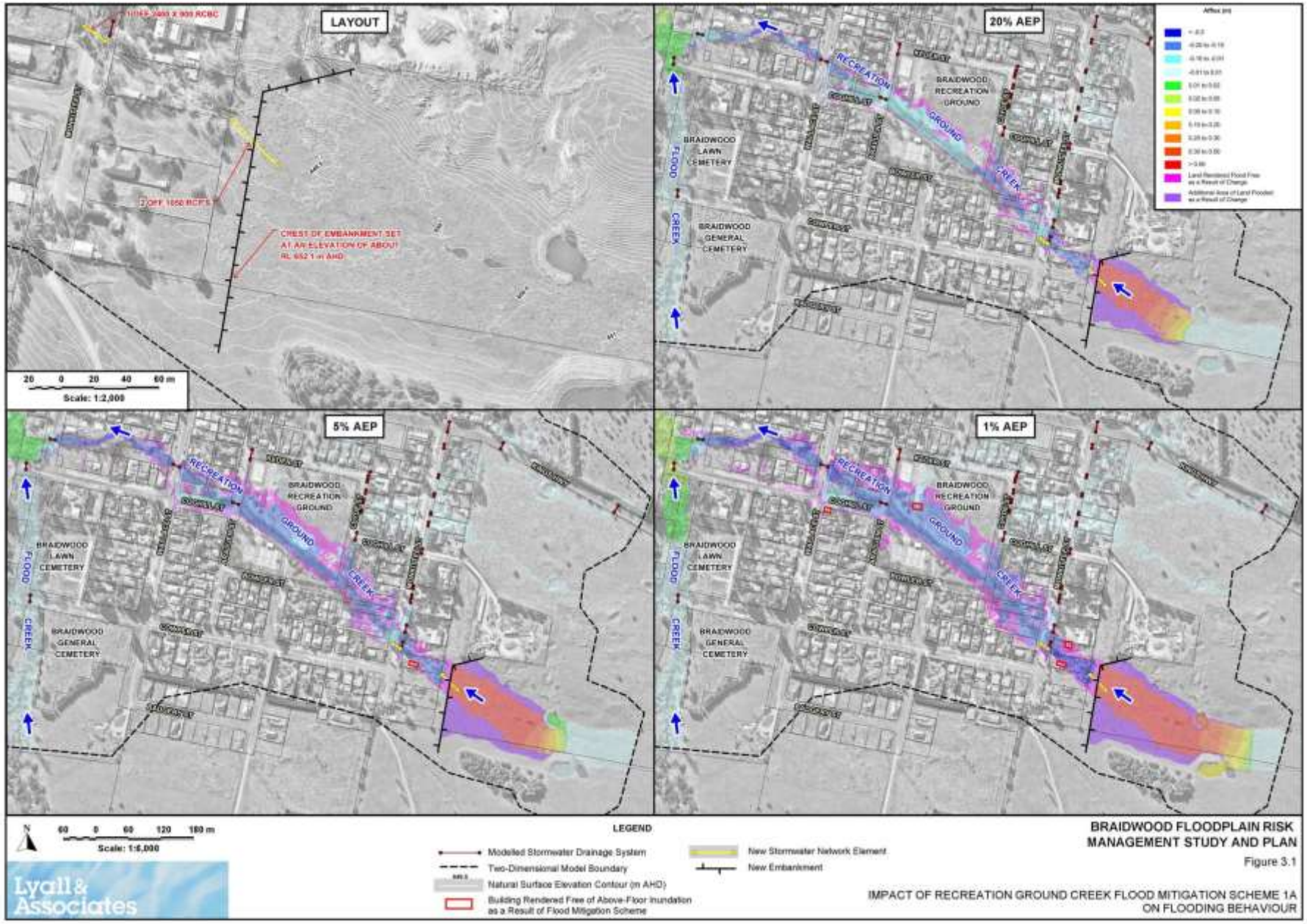

FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD
RECREATION
GROUND
BRAIDWOOD
LAWN
CEMETERY
BRAIDWOOD
GENERAL
CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK
MANAGEMENT STUDY AND PLAN
Figure 2.12
(Sheet 3 of 3)
POTENTIAL IMPACT OF 30% INCREASE IN RAINFALL ON FLOODING AND DRAINAGE PATTERNS
1% AEP

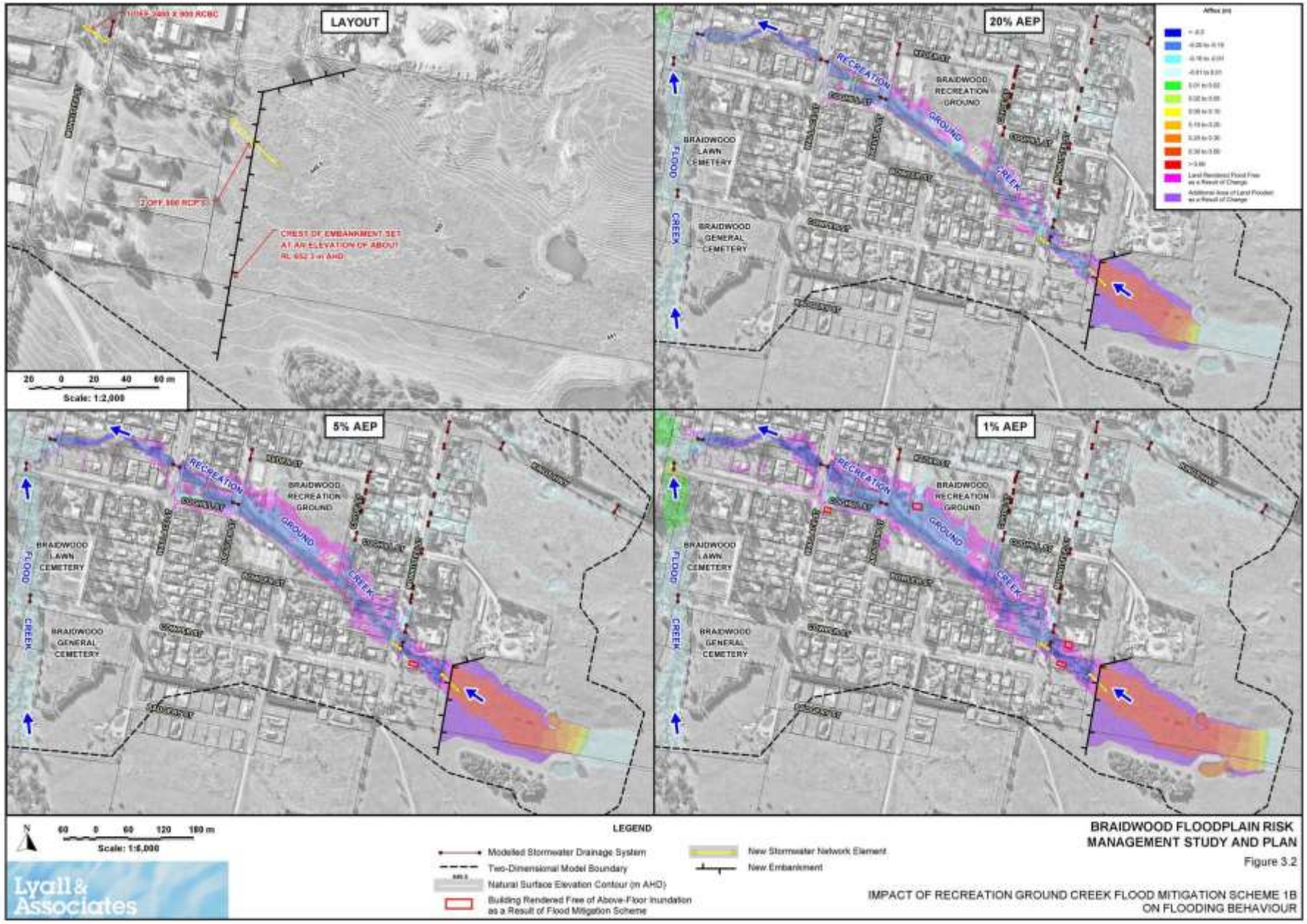

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
A positive efflux indicates that the modelled peak flood levels derived using the procedures set out in ARR1987 are higher than those derived using ARR2016
LEGEND
Modelled Stormwater Network
Two-Dimensional Model Boundary
1% AEP
1% AEP Rainfall Increased by 10%
1% AEP Rainfall Increased by 30%
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.13
(Sheet 1 of 3)
IMPACT OF INCREASED RAINFALL INTENSITIES ON EXTENT OF FLOODING
1% AEP

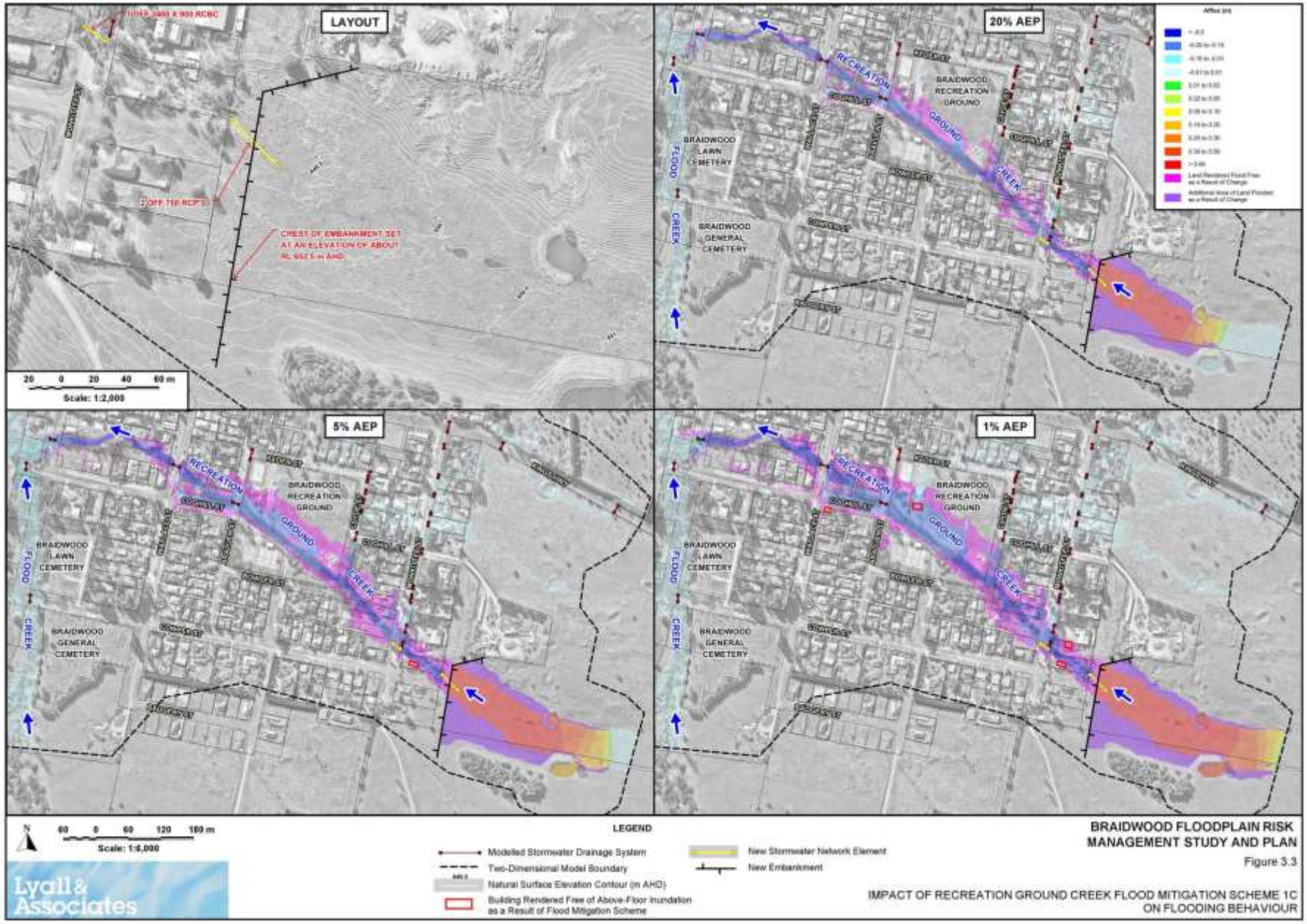

UNNAMED
TRIBUTARY
CREEK
MONKHILLER
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE
A positive efflux indicates that the modelled peak flood levels derived using the procedures set out in ARR1987 are higher than those derived using ARR2016
LEGEND
Modelled Stormwater Network
Two-Dimensional Model Boundary
1% AEP
1% AEP Rainfall Increased by 10%
1% AEP Rainfall Increased by 30%
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.13
(Sheet 2 of 3)
IMPACT OF INCREASED RAINFALL INTENSITIES ON EXTENT OF FLOODING
1% AEP

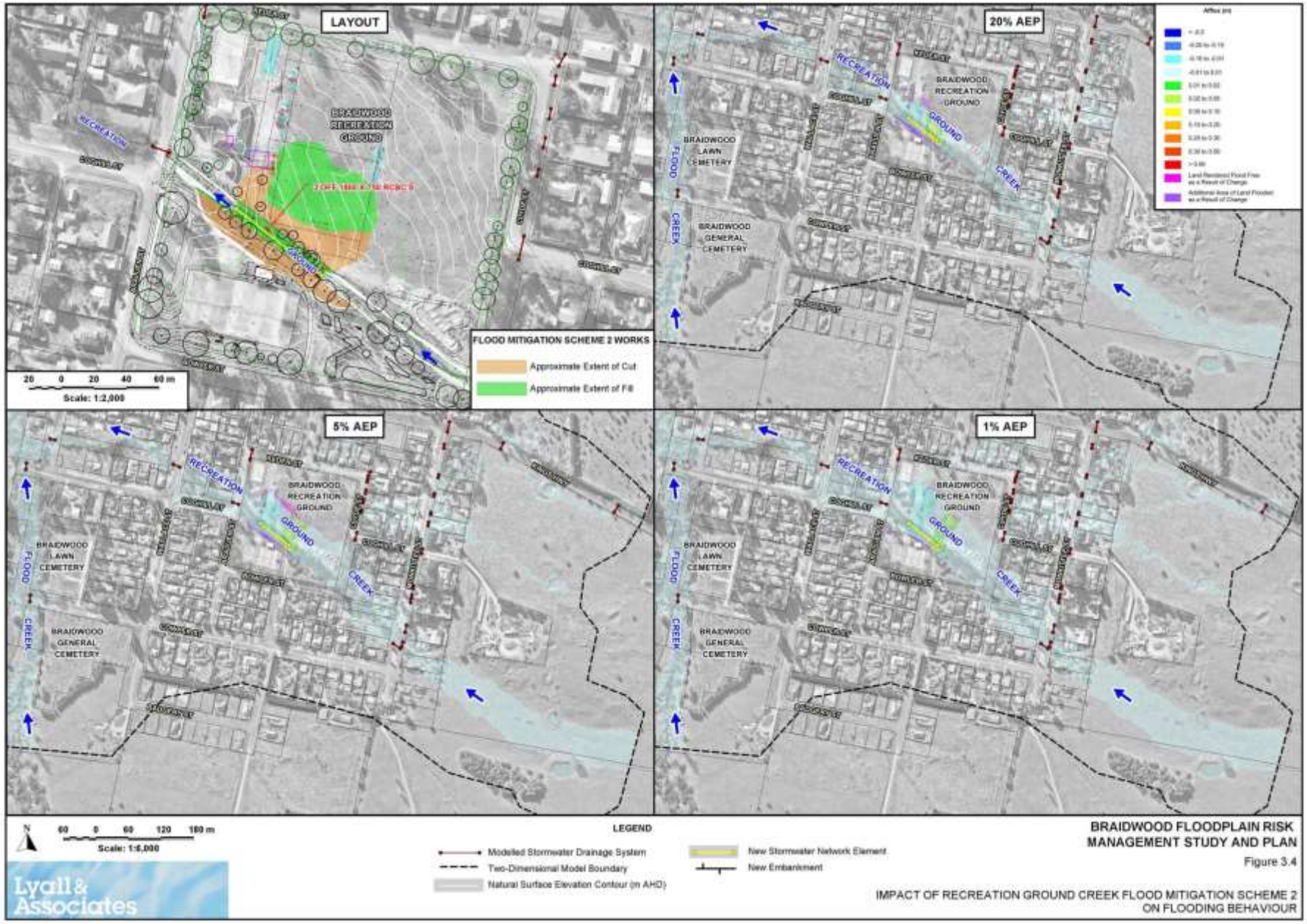

BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
BRAIDWOOD RECREATION GROUND
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Network
Two-Dimensional Model Boundary
1% AEP
1% AEP Rainfall Increased by 10%
1% AEP Rainfall Increased by 30%
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.13
(Sheet 3 of 3)
IMPACT OF INCREASED RAINFALL INTENSITIES ON EXTENT OF FLOODING
1% AEP
Lyall & Associates

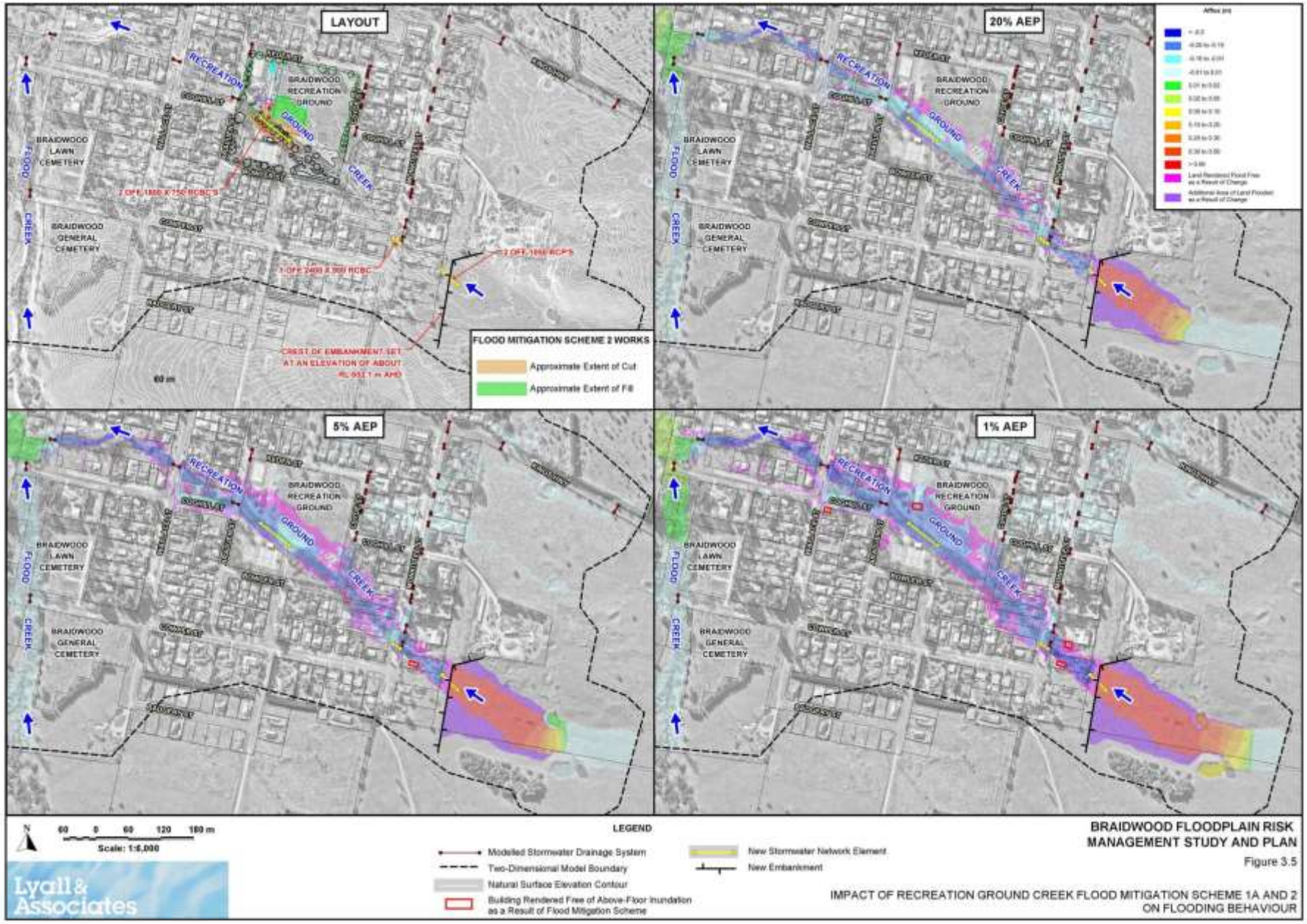

N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
LEGEND
Local Centre
Mixed Use
Environmental Living
Light Industrial
General Residential
Low Density Residential
Large Lot Residential
Public Recreation
Private Recreation
Primary Production
Special Activities
Infrastructure
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 2.14
PALERANG LEP 2014 ZONING

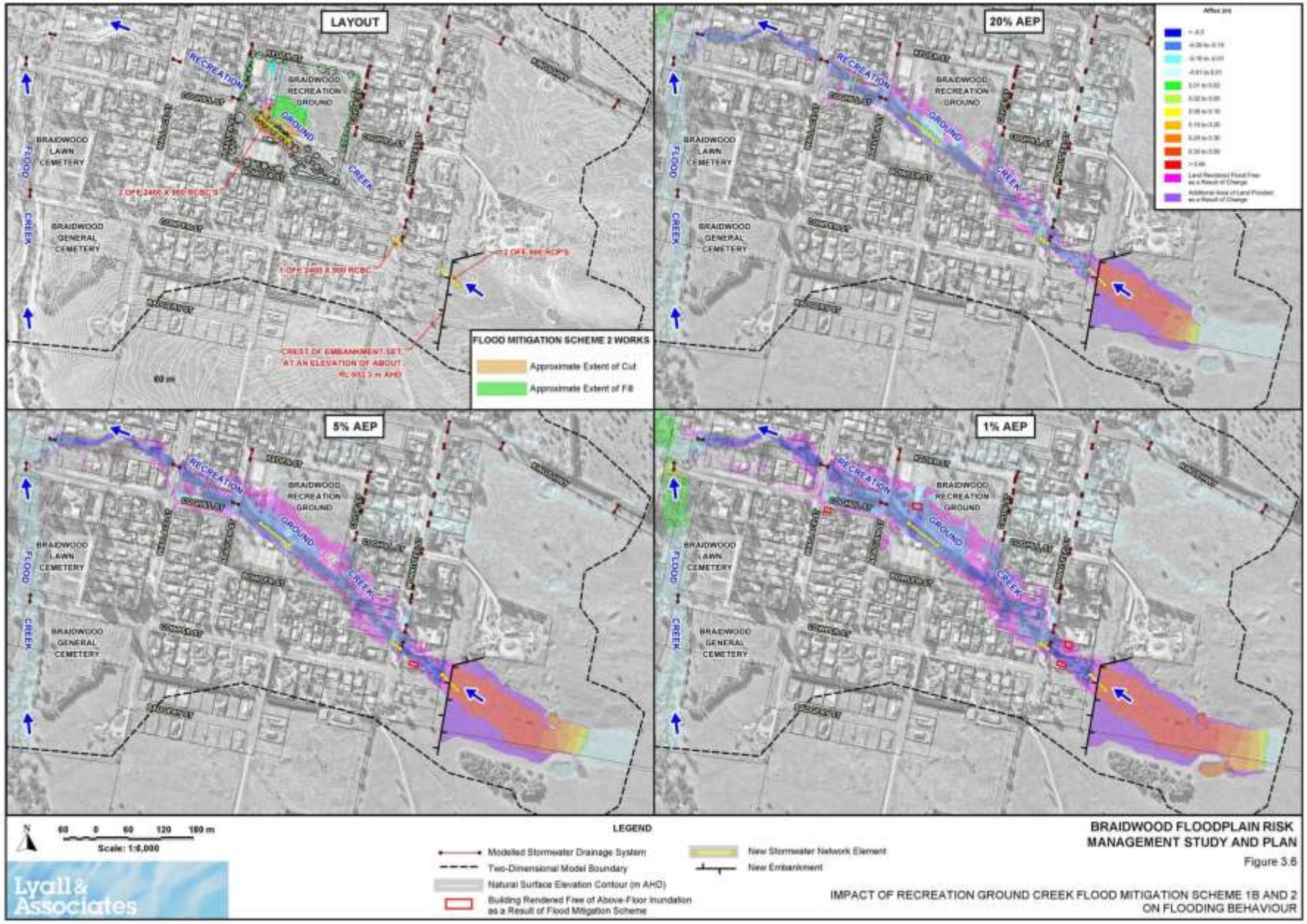

LAYOUT
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT RL 652.1 m AHD
20 0 20 40 60 m
Scale: 1:2,000
20% AEP
5% AEP
1% AEP
RECREATION GROUND CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD CREEK
60 0 60 120 180 m
Scale: 1:6,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.1
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1A ON FLOODING BEHAVIOUR

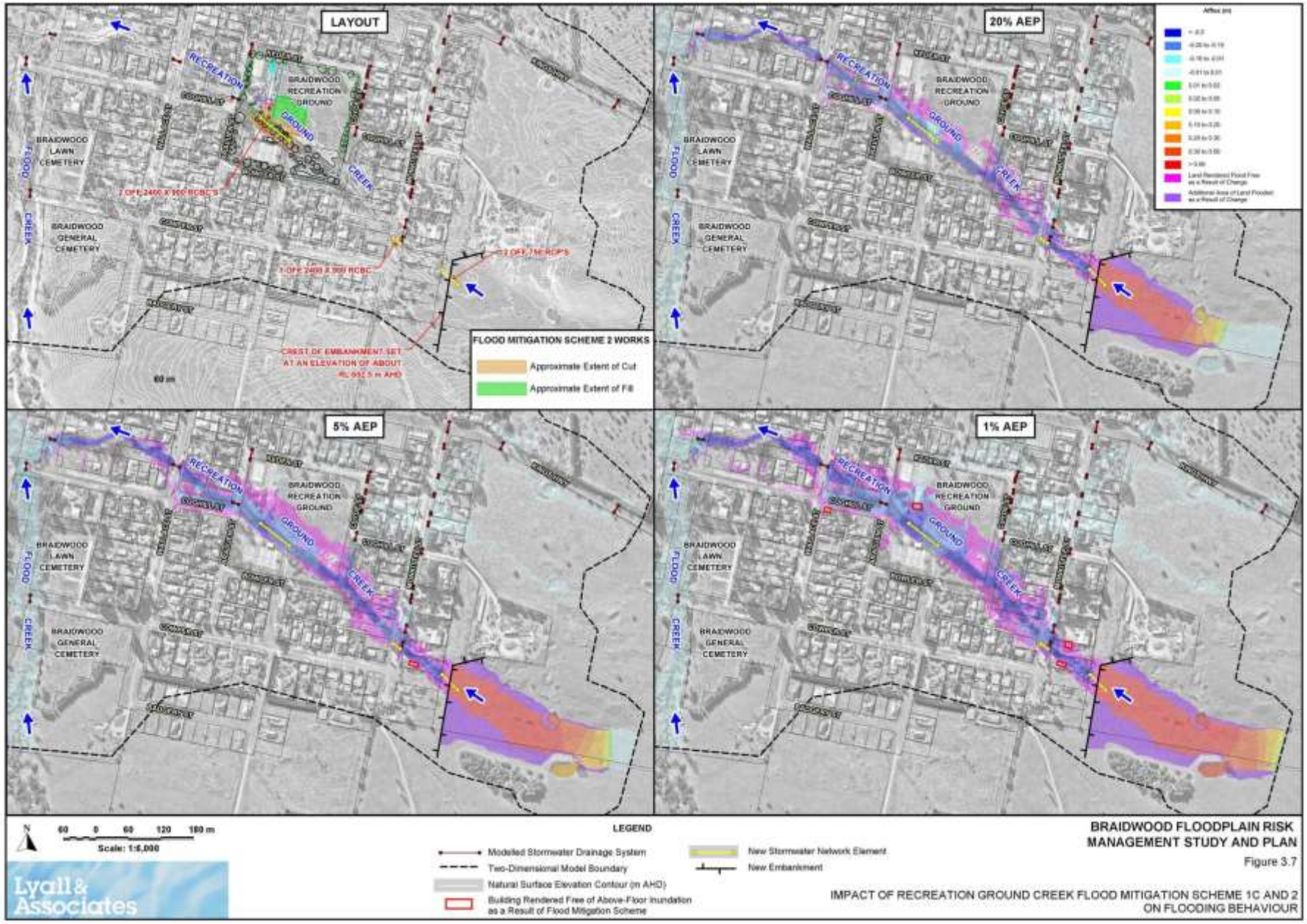

LAYOUT
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT RL 652.3 m AHD
20 0 20 40 60 m
Scale: 1:2,000
20% AEP
5% AEP
1% AEP
RECREATION GROUND CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD CREEK
60 0 60 120 180 m
Scale: 1:6,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.2
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1B ON FLOODING BEHAVIOUR

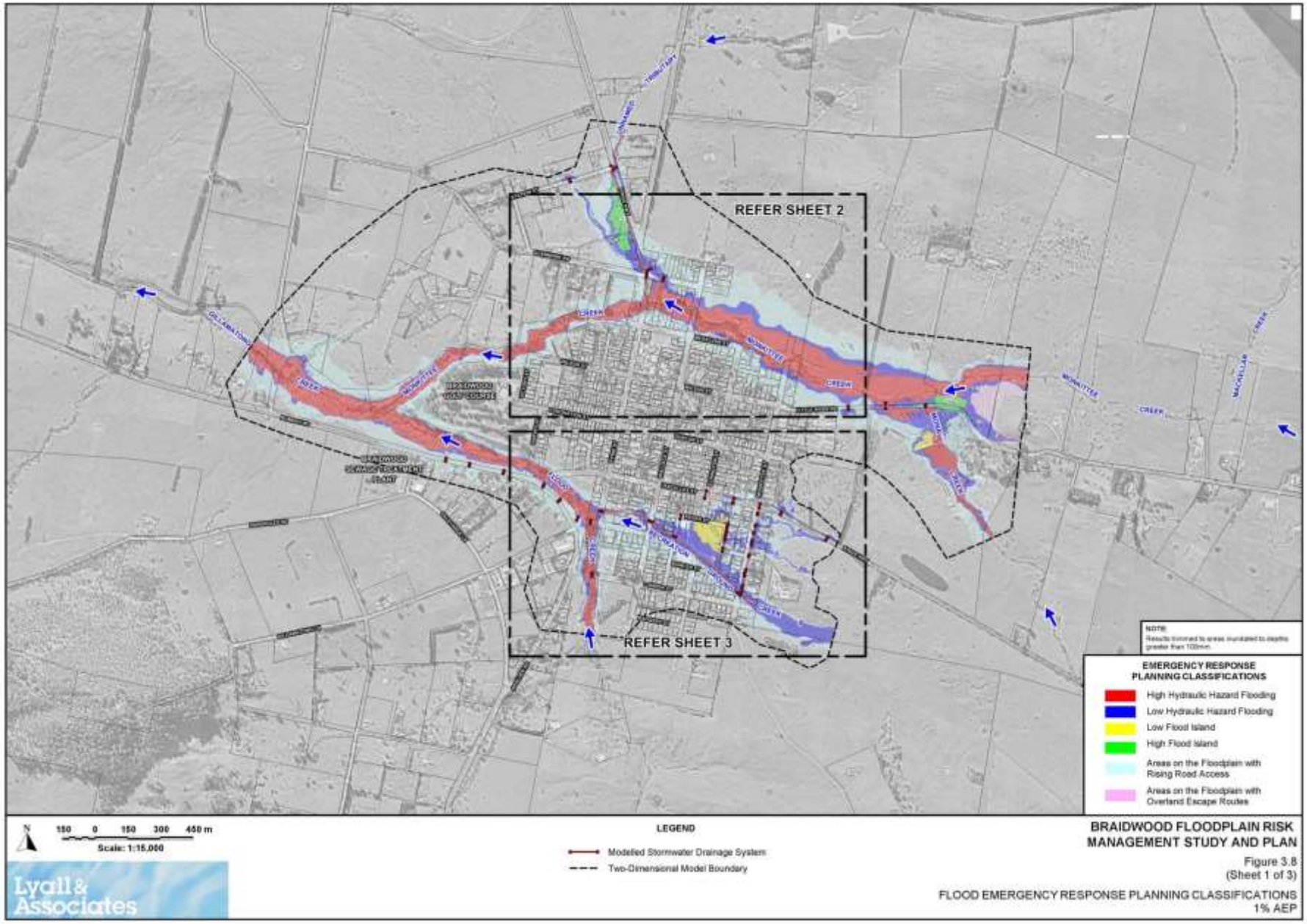

LAYOUT
20% AEP
5% AEP
1% AEP
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT RL 652.5 m AHD
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
RECREATION GROUND CREEK
FLOOD CREEK
Scale: 1:2,000
Scale: 1:6,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.3
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1C ON FLOODING BEHAVIOUR

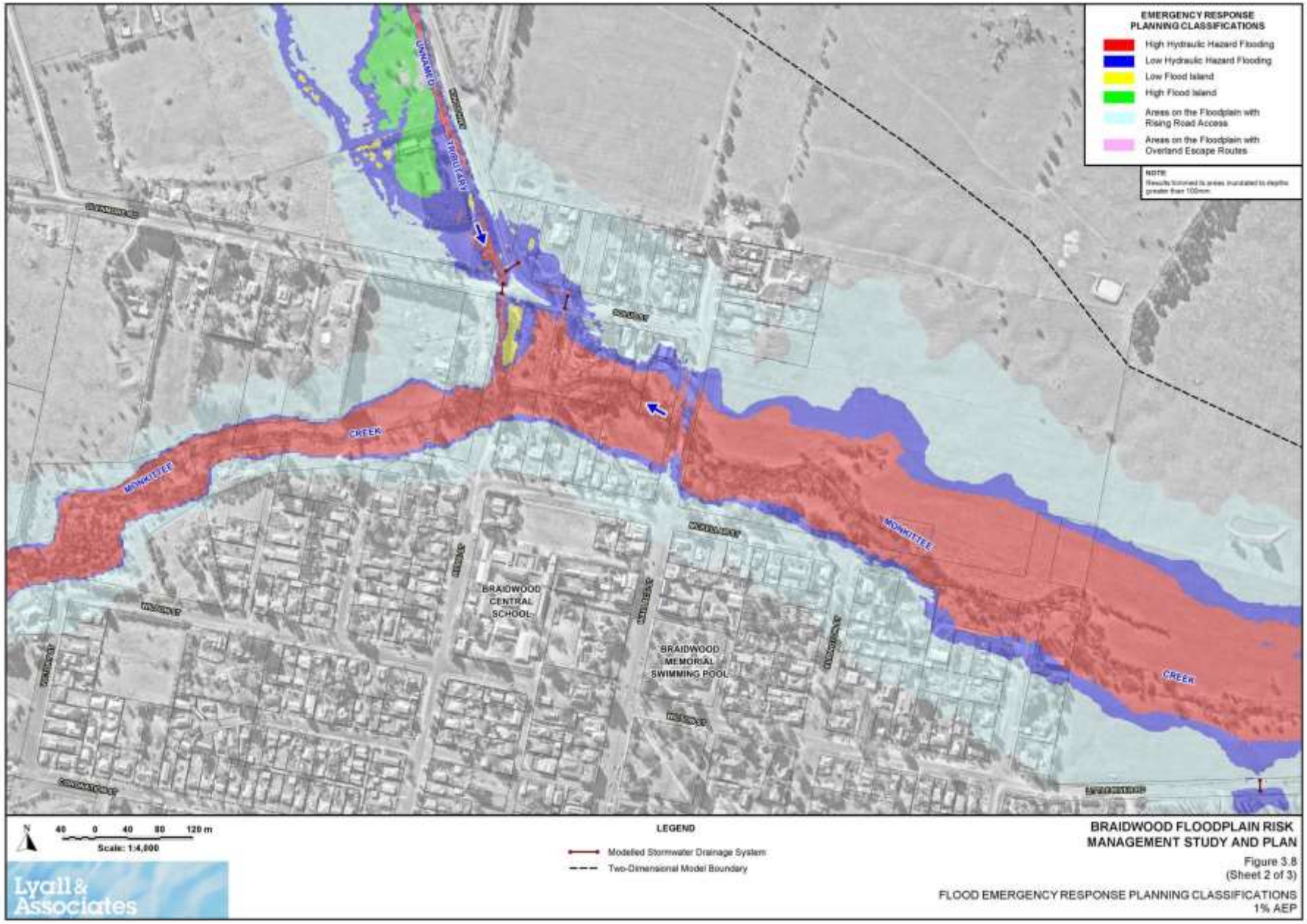

LAYOUT
20% AEP
5% AEP
1% AEP
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
RECREATION
GROUND
FLOOD
CREEK
FLOOD MITIGATION SCHEME 2 WORKS
Approximate Extent of Cut
Approximate Extent of Fill
Scale: 1:2,000
Scale: 1:6,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
New Stormwater Network Element
New Embankment
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.4
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 2 ON FLOODING BEHAVIOUR
Lyall & Associates

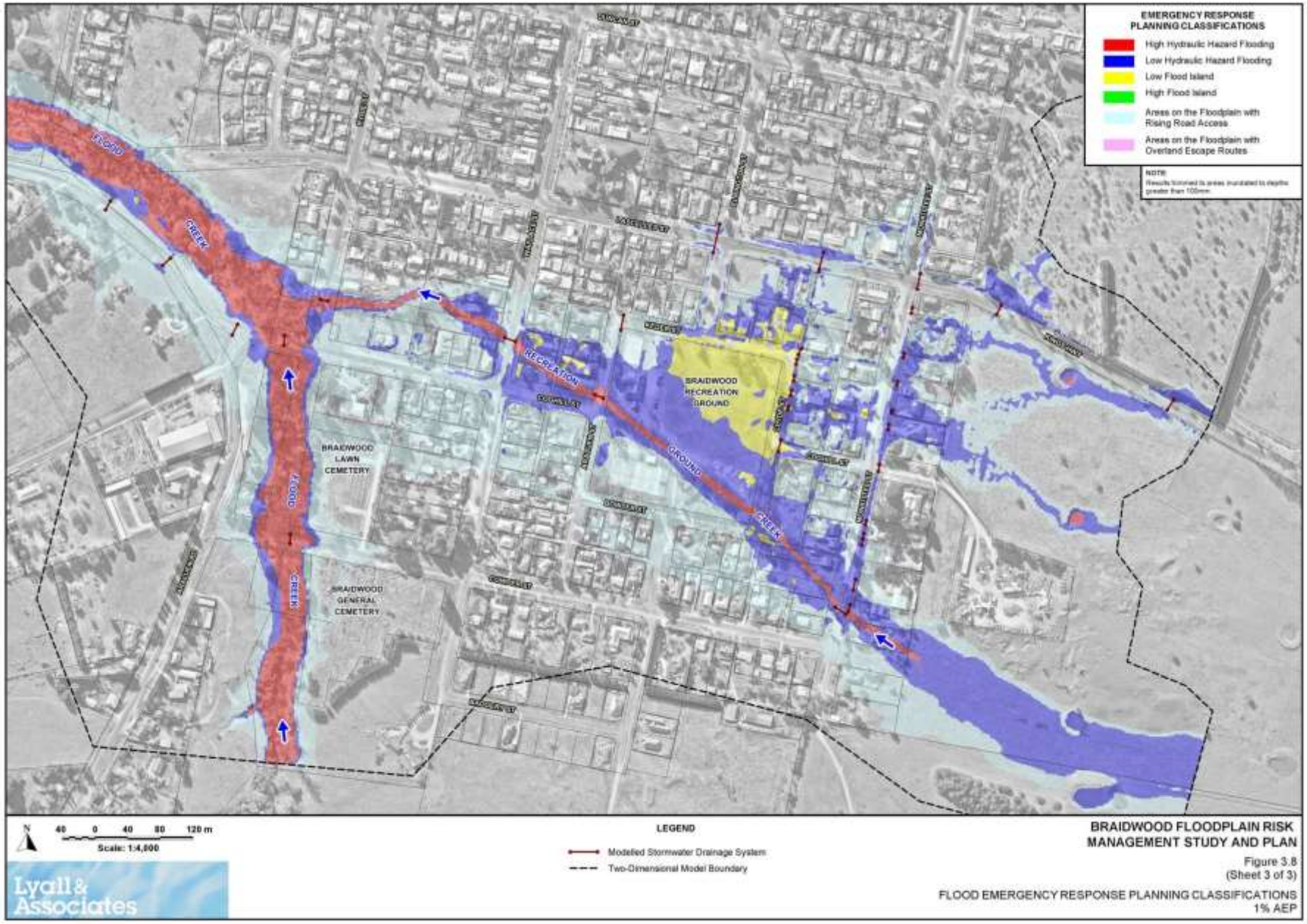

LAYOUT
20% AEP
5% AEP
1% AEP
RECREATION
GROUND
CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD
CREEK
FLOOD MITIGATION SCHEME 2 WORKS
Approximate Extent of Cut
Approximate Extent of Fill
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT
60 m
N
60 0 60 120 180 m
Scale: 1:6,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.5
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1A AND 2 ON FLOODING BEHAVIOUR

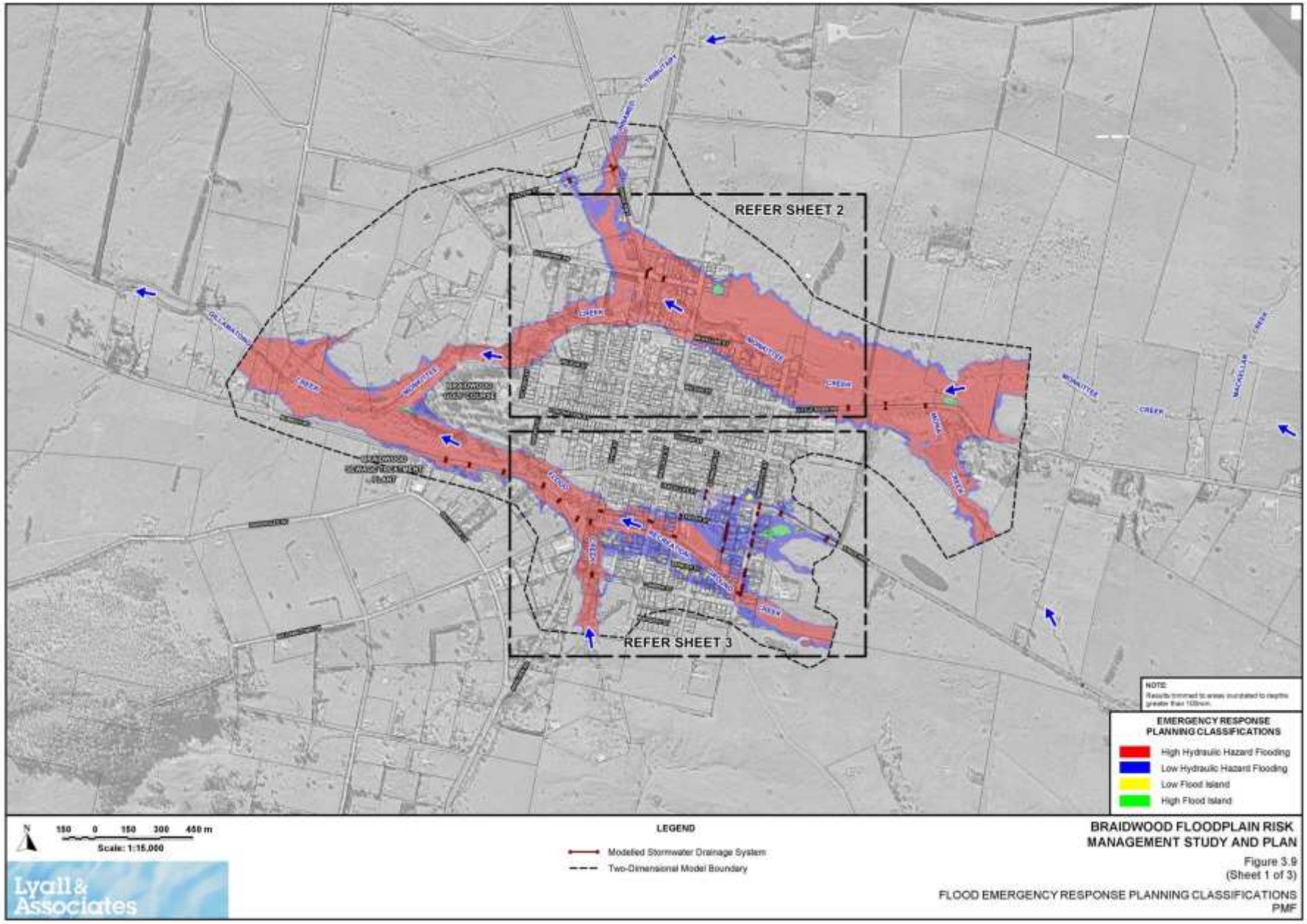

LAYOUT
20% AEP
5% AEP
1% AEP
RECREATION
GROUND
CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD
CREEK
FLOOD MITIGATION SCHEME 2 WORKS
Approximate Extent of Cut
Approximate Extent of Fill
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT
60 m
N
60 0 60 120 180 m
Scale: 1:6,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.6
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1B AND 2 ON FLOODING BEHAVIOUR

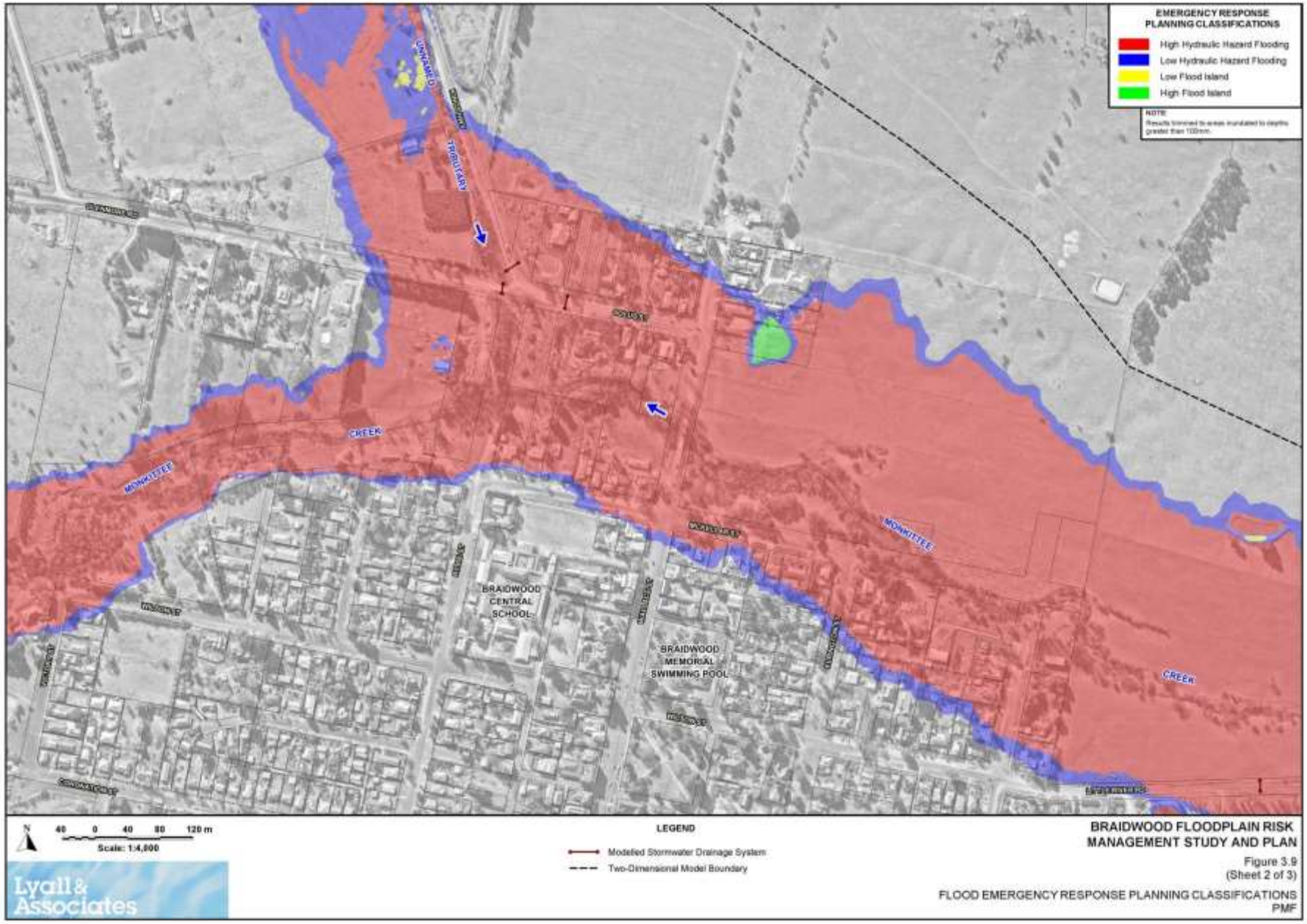

LAYOUT
20% AEP
5% AEP
1% AEP
RECREATION
GROUND
CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD
CREEK
FLOOD MITIGATION SCHEME 2 WORKS
Approximate Extent of Cut
Approximate Extent of Fill
CREST OF EMBANKMENT SET AT AN ELEVATION OF ABOUT
60 m
N
60 0 60 120 180 m
Scale: 1:6,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Natural Surface Elevation Contour (m AHD)
Building Rendered Free of Above-Floor Inundation as a Result of Flood Mitigation Scheme
New Stormwater Network Element
New Embankment
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.7
IMPACT OF RECREATION GROUND CREEK FLOOD MITIGATION SCHEME 1C AND 2 ON FLOODING BEHAVIOUR

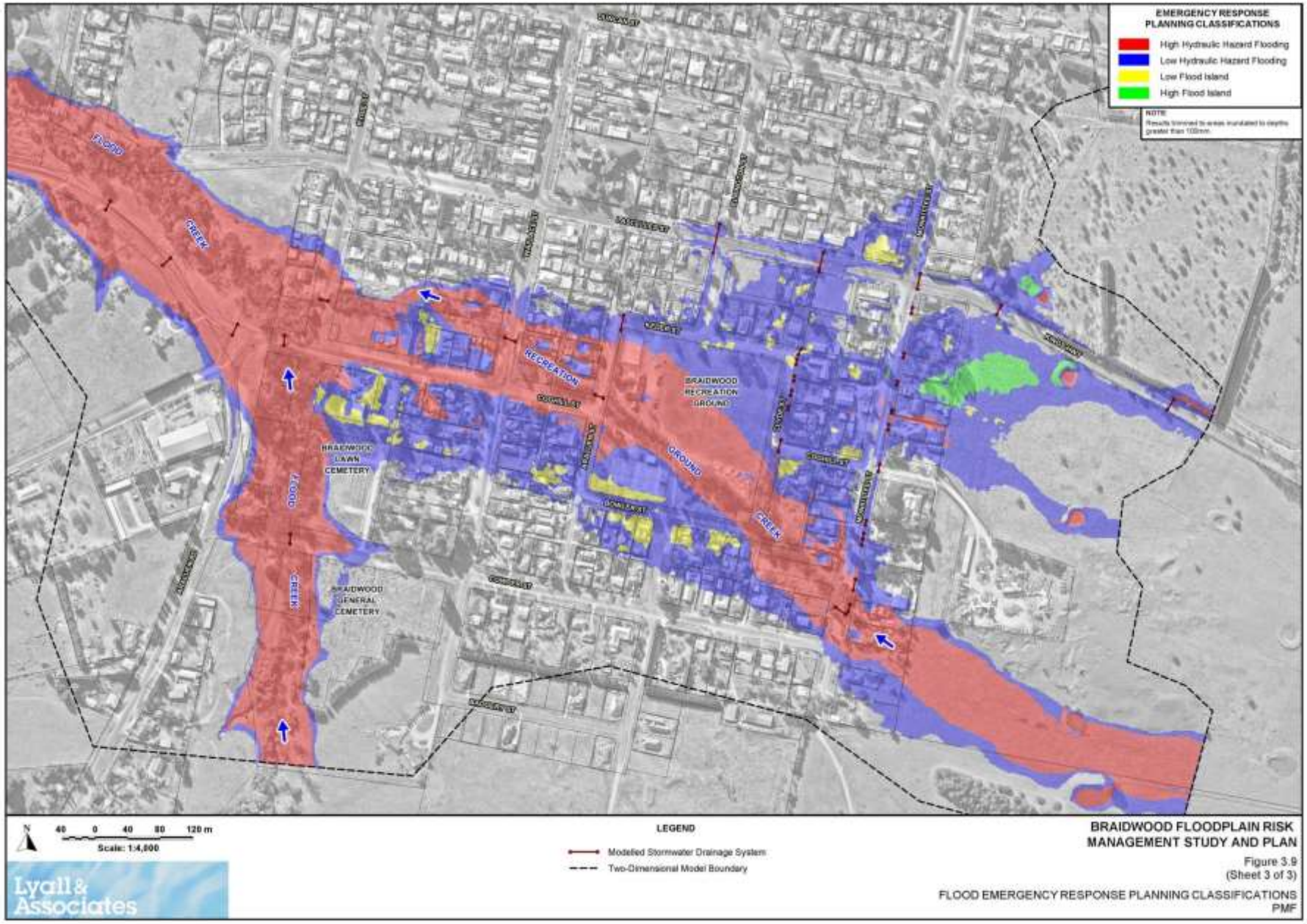

REFER SHEET 2
REFER SHEET 3
EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
Areas on the Floodplain with Rising Road Access
Areas on the Floodplain with Overland Escape Routes
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.8
(Sheet 1 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
1% AEP


EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
Areas on the Floodplain with Rising Road Access
Areas on the Floodplain with Overland Escape Routes
NOTE:
UNNAMED TRIBUTARY
MONKITEE CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.8
(Sheet 2 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
1% AEP


EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
Areas on the Floodplain with Rising Road Access
Areas on the Floodplain with Overland Escape Routes
NOTE:
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
FLOOD
CREEK
RECREATION
GROUND
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.8
(Sheet 3 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
1% AEP


REFER SHEET 2
REFER SHEET 3
NOTE:
EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
N
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.9
(Sheet 1 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
PMF


EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
NOTE:
Results trimmed to areas inundated to depths greater than 100mm.
UNNAMED TRIBUTARY
MONKITTEE CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.9
(Sheet 2 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
PMF


EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
High Hydraulic Hazard Flooding
Low Hydraulic Hazard Flooding
Low Flood Island
High Flood Island
NOTE:
Results trimmed to areas inundated to depths greater than 100mm
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure 3.9
(Sheet 3 of 3)
FLOOD EMERGENCY RESPONSE PLANNING CLASSIFICATIONS
PMF

DRAFT REPORT FOR PUBLIC EXHIBITION

APPENDIX B

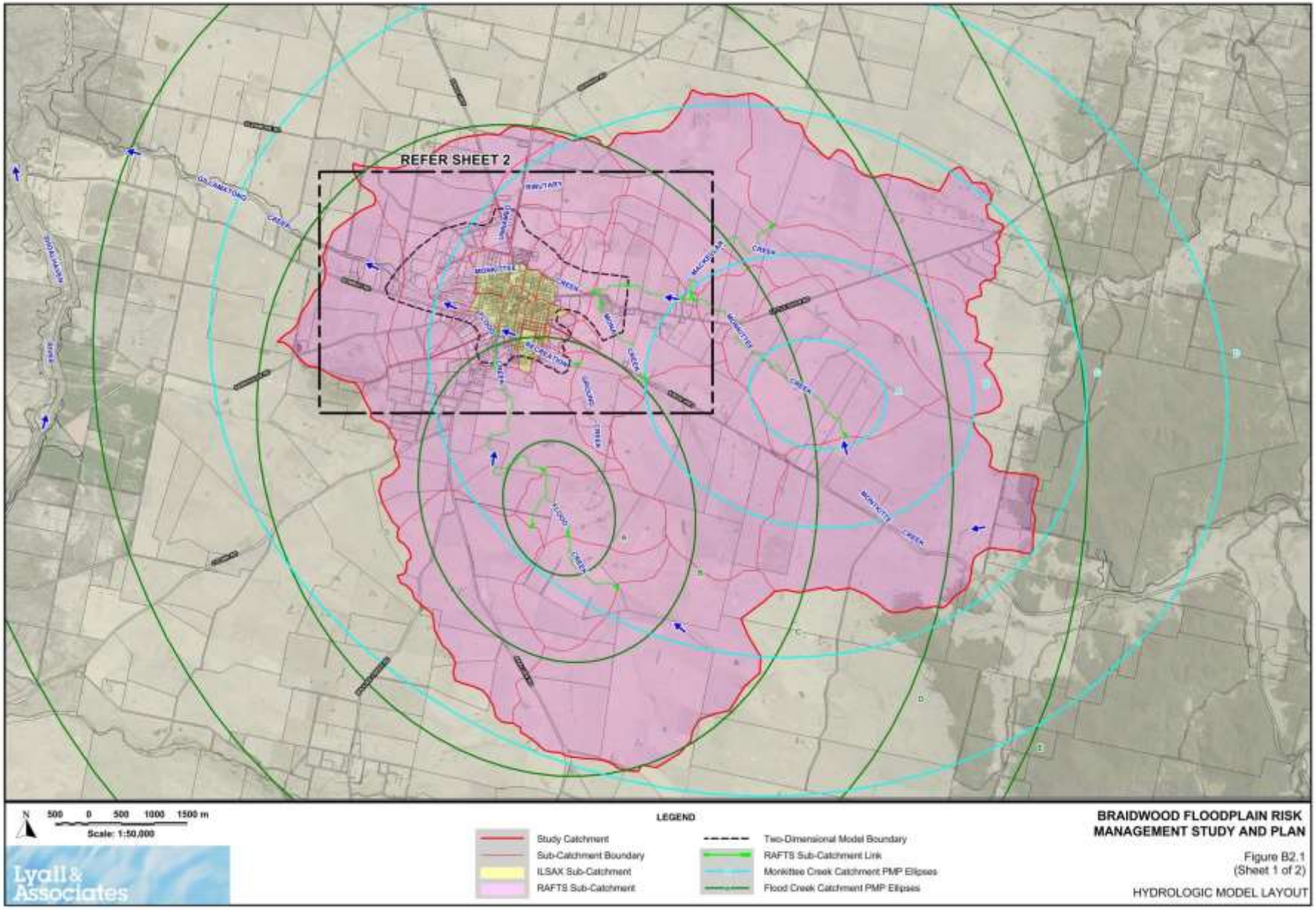
HYDROLOGIC AND HYDRAULIC MODELLING

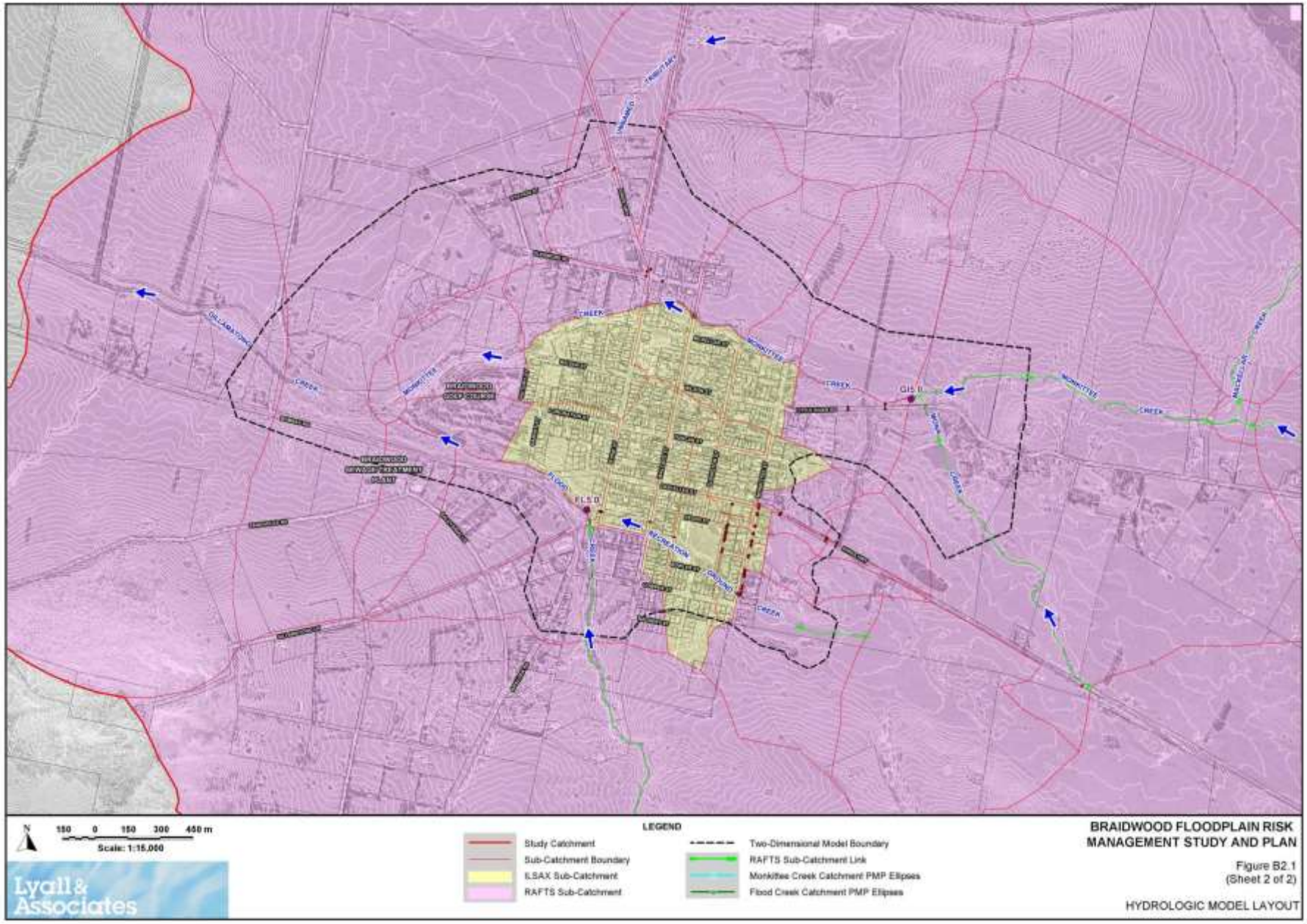
LIST OF FIGURES (APPENDIX B)

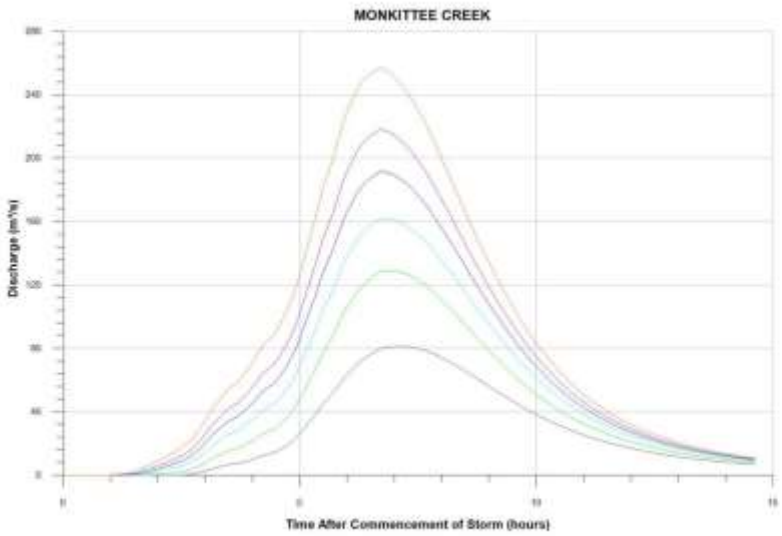
B2.1 Hydrologic Model Layout (2 Sheets)
B2.2 Design Inflow Hydrographs

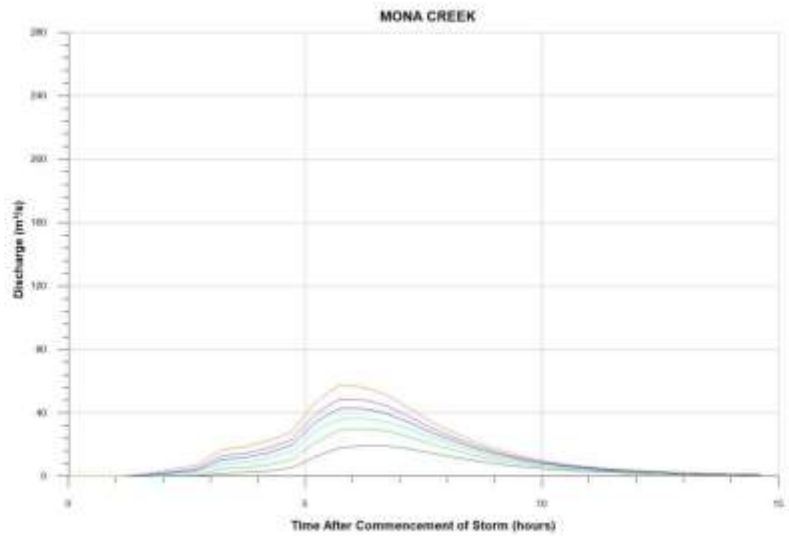
B3.1 TUFLOW Model Layout (3 Sheets)
B3.2 TUFLOW Schematisation of Floodplain
B3.3 TUFLOW Model Results – 20% AEP (3 Sheets)
B3.4 TUFLOW Model Results – 5% AEP (3 Sheets)
B3.5 TUFLOW Model Results – 2% AEP (3 Sheets)
B3.6 TUFLOW Model Results – 0.5% AEP (3 Sheets)
B3.7 TUFLOW Model Results – 0.2% AEP (3 Sheets)

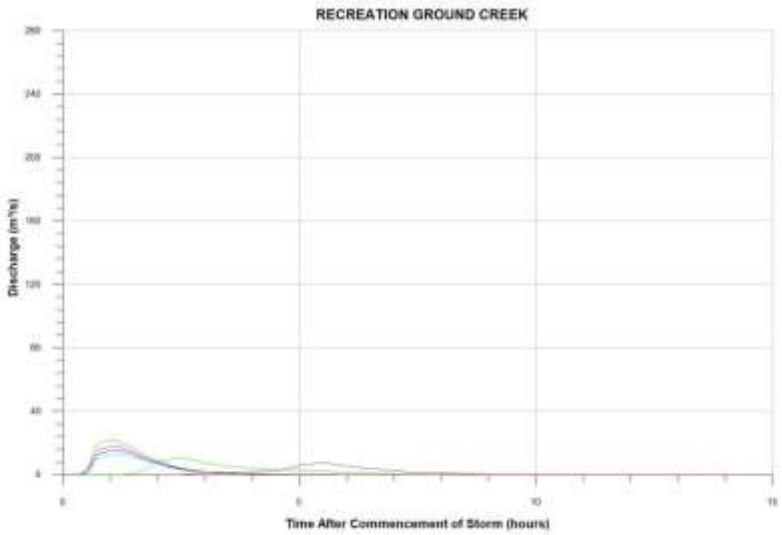
DRAFT REPORT FOR PUBLIC EXHIBITION

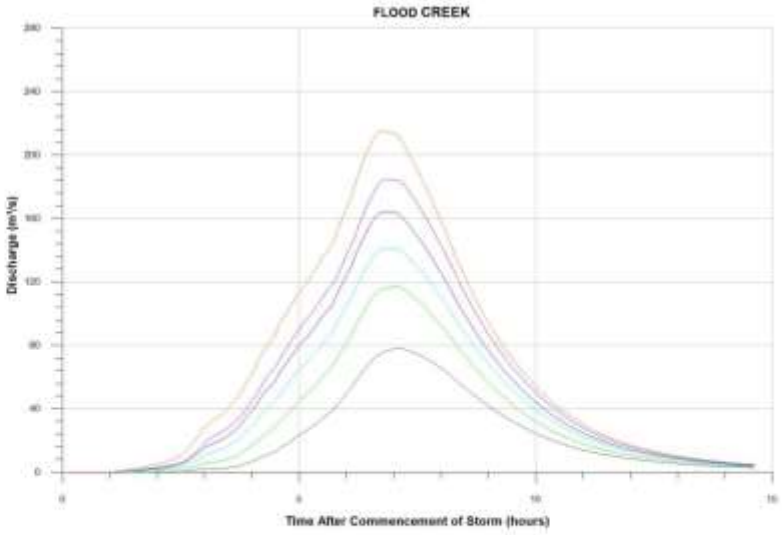

REFER SHEET 2
N
500 0 500 1000 1500 m
Scale: 1:50,000
Lyall & Associates
LEGEND
Study Catchment
Sub-Catchment Boundary
ILSAX Sub-Catchment
RAFTS Sub-Catchment
Two-Dimensional Model Boundary
RAFTS Sub-Catchment Link
Monkittee Creek Catchment PMP Ellipses
Flood Creek Catchment PMP Ellipses
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B2.1
(Sheet 1 of 2)
HYDROLOGIC MODEL LAYOUT


N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
LEGEND
Study Catchment
Sub-Catchment Boundary
ILSAX Sub-Catchment
RAFTS Sub-Catchment
Two-Dimensional Model Boundary
RAFTS Sub-Catchment Link
Monkittee Creek Catchment PMP Ellipses
Flood Creek Catchment PMP Ellipses
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B2.1
(Sheet 2 of 2)
HYDROLOGIC MODEL LAYOUT









LEGEND

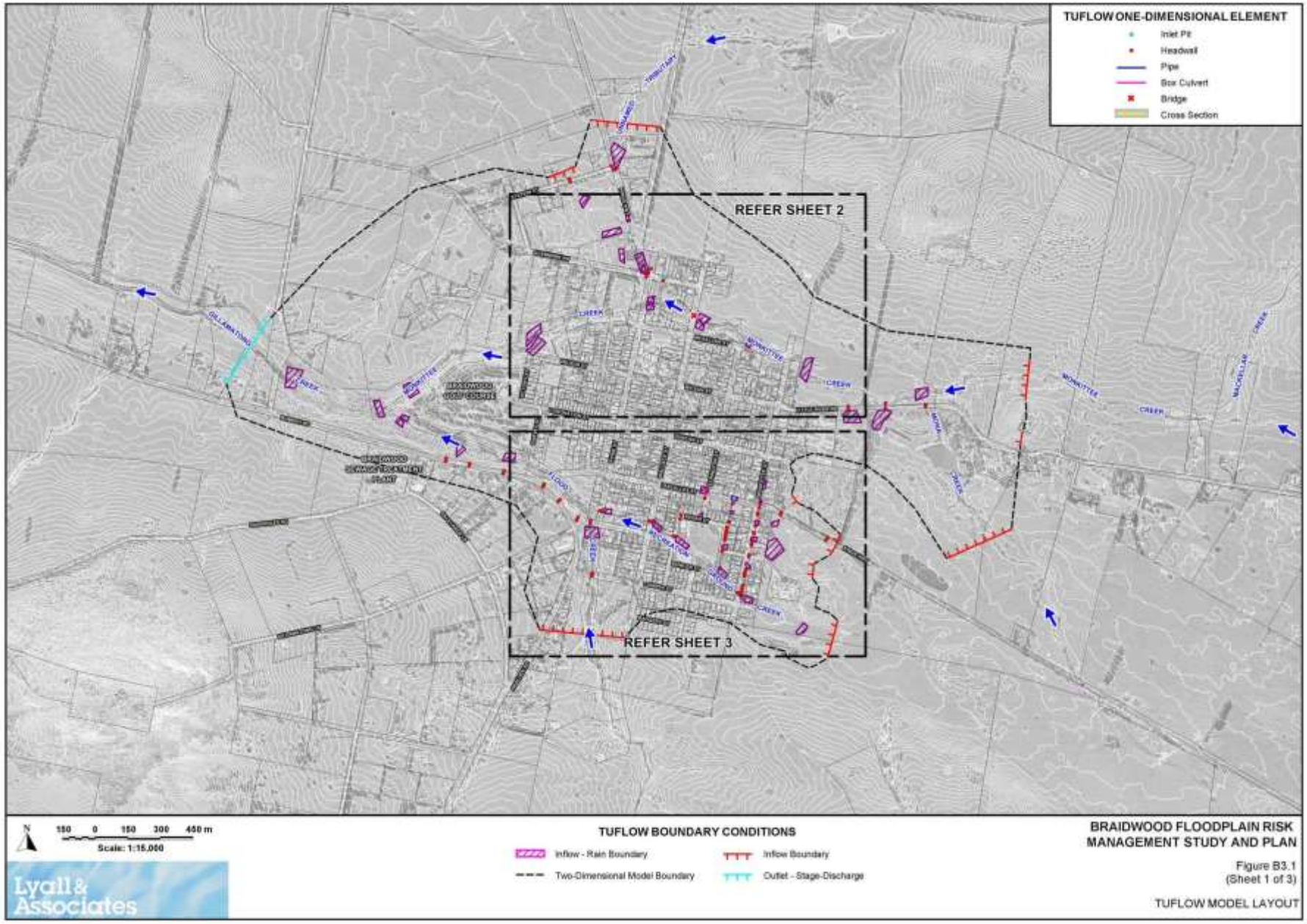
0.2% AEP
0.5% AEP
1% AEP
2% AEP
5% AEP
20% AEP

Lyall & Associates

BRAINDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

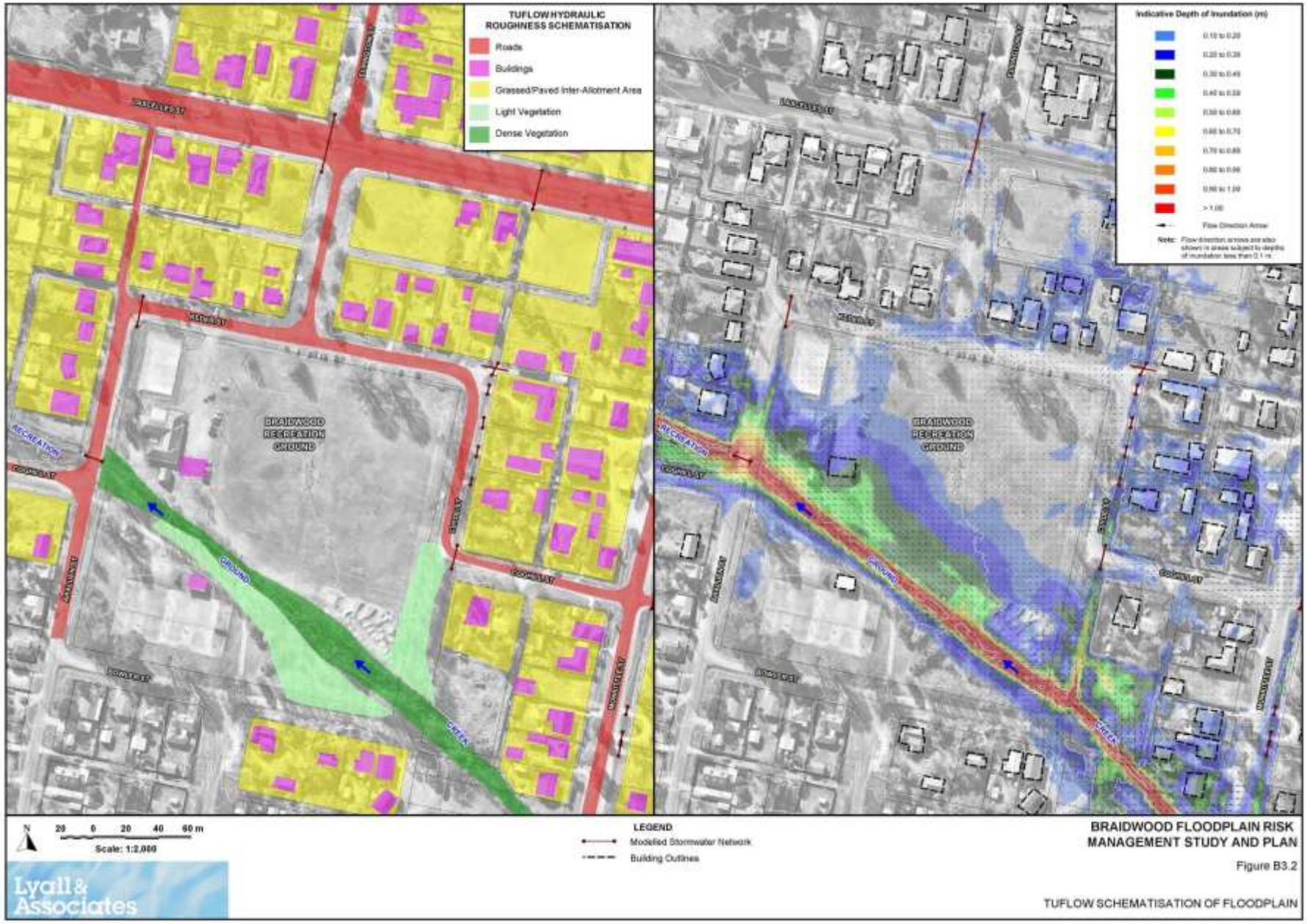
Figure B2.2

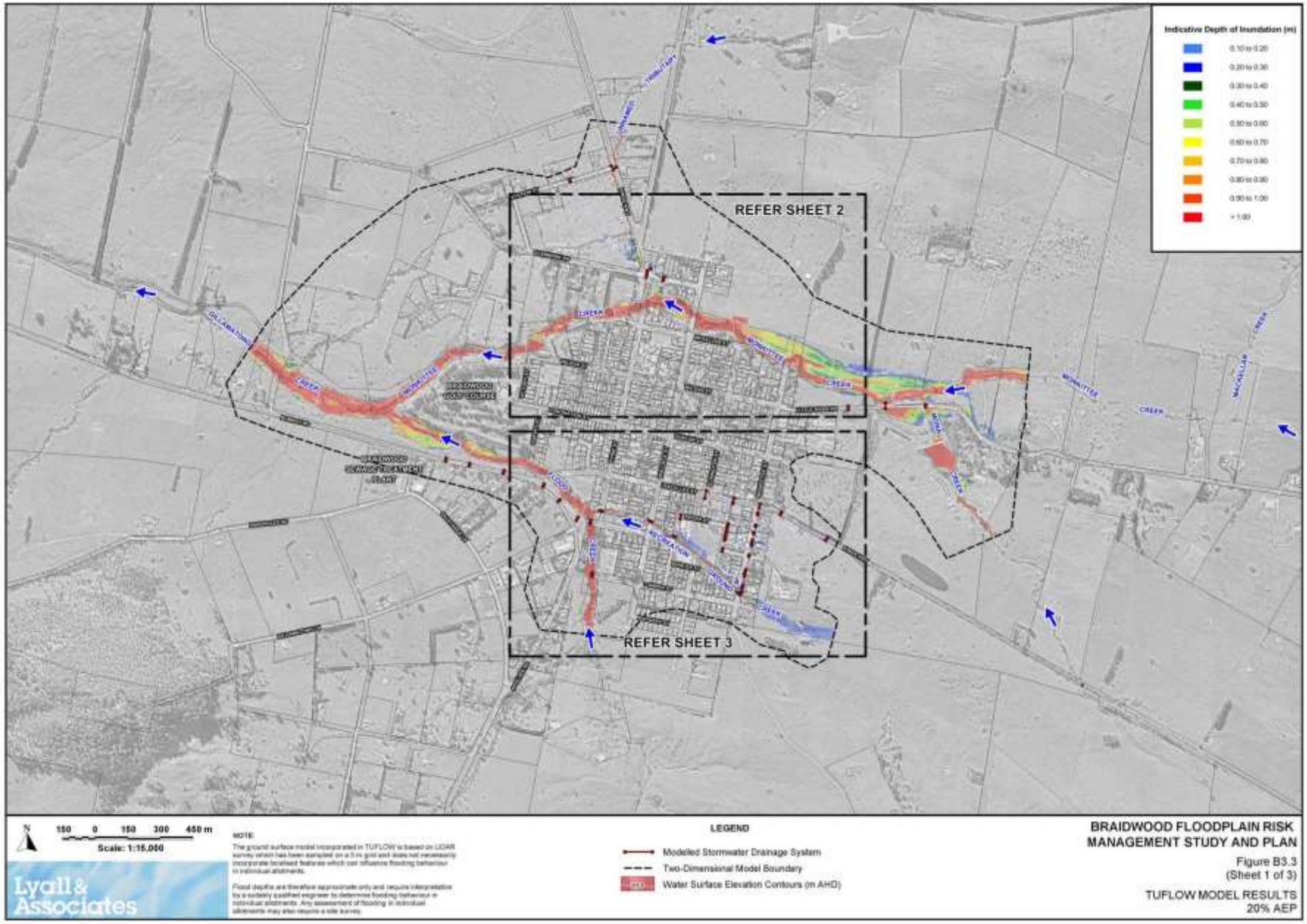
DESIGN INFLOW HYDROGRAPHS

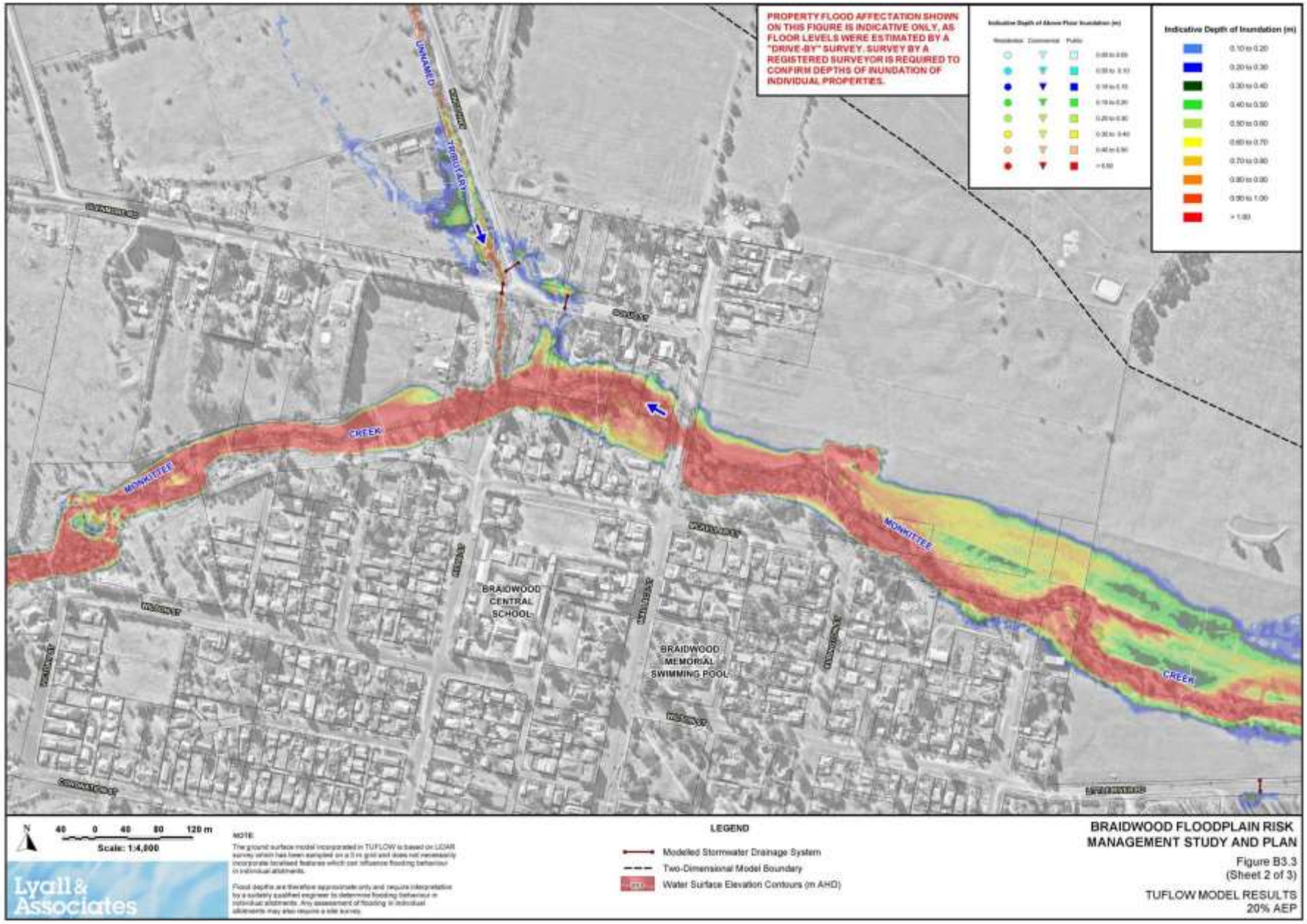

TUFLOW ONE-DIMENSIONAL ELEMENT
Inlet Pit
Headwall
Pipe
Box Culvert
Bridge
Cross Section
REFER SHEET 2
REFER SHEET 3
150 0 150 300 450 m
Scale: 1:15,000
TUFLOW BOUNDARY CONDITIONS
Inflow - Rain Boundary
Inflow Boundary
Two-Dimensional Model Boundary
Outlet - Stage-Discharge
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.1
(Sheet 1 of 3)
TUFLOW MODEL LAYOUT
Lyall & Associates

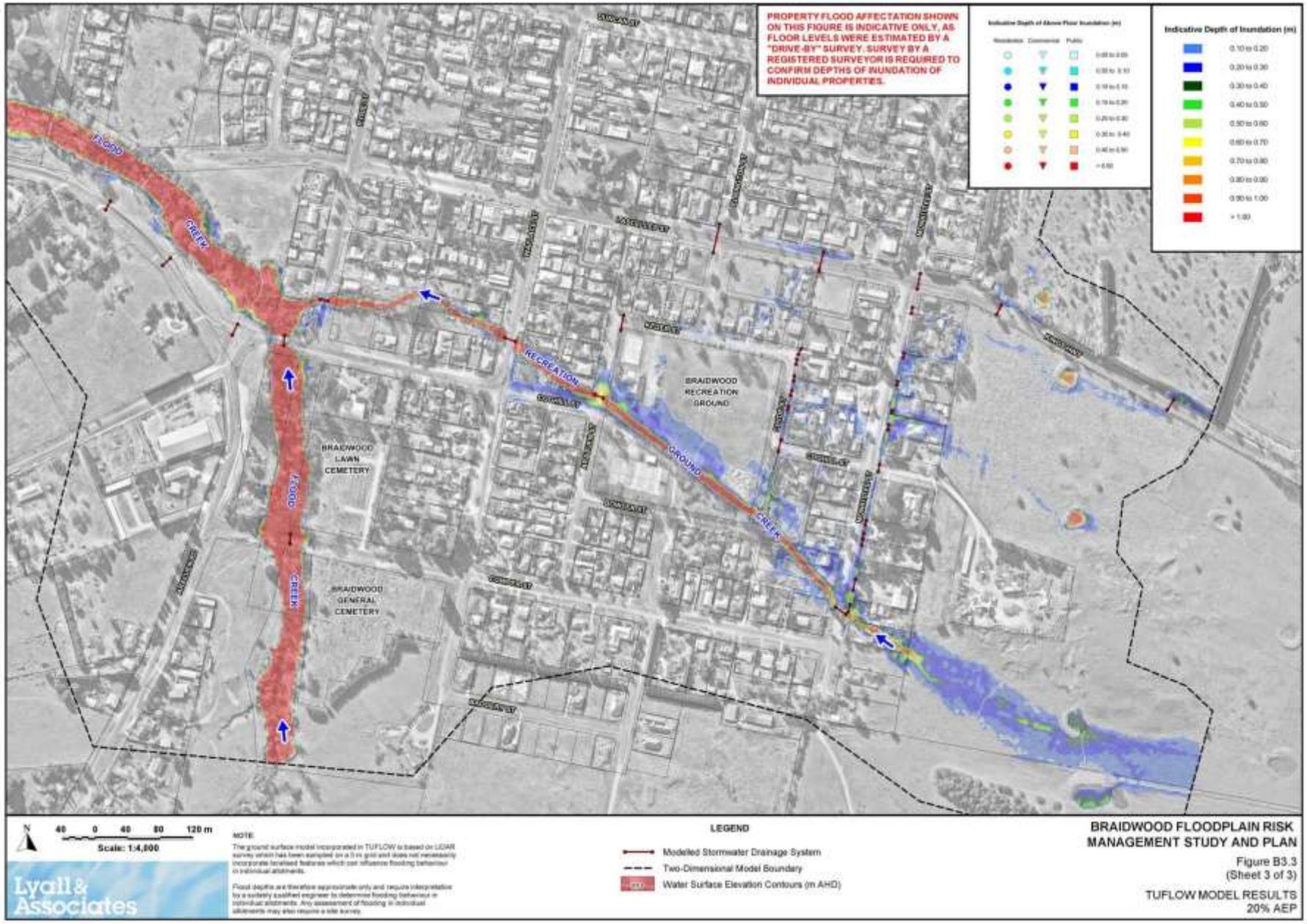
TUFLOW ONE-DIMENSIONAL ELEMENT
Inlet Pit
Headwall
Pipe
Box Culvert
Bridge
Cross Section
UNNAMED
TRIBUTARY
CREEK
MONKITTEE
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
TUFLOW BOUNDARY CONDITIONS
Inflow - Rain Boundary
Inflow Boundary
Inflow - Point Source
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.1
(Sheet 2 of 3)
TUFLOW MODEL LAYOUT

TUFLOW ONE-DIMENSIONAL ELEMENT
Inlet Pit
Headwall
Pipe
Box Culvert
Cross Section
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
TUFLOW BOUNDARY CONDITIONS
Inflow - Rain Boundary
Inflow Boundary
Inflow - Point Source
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.1
(Sheet 3 of 3)
TUFLOW MODEL LAYOUT


TUFLOW HYDRAULIC ROUGHNESS SCHEMATISATION
Roads
Buildings
Grassed/Paved Inter-Allotment Area
Light Vegetation
Dense Vegetation
Indicative Depth of Inundation (m)
Flow Direction Arrow
BRAIDWOOD RECREATION GROUND
N
20 0 20 40 60 m
Scale: 1:2,000
LEGEND
Modelled Stormwater Network
Building Outlines
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.2
TUFLOW SCHEMATISATION OF FLOODPLAIN


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretative by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.3
(Sheet 1 of 3)
TUFLOW MODEL RESULTS
20% AEP


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.3
(Sheet 2 of 3)
TUFLOW MODEL RESULTS
20% AEP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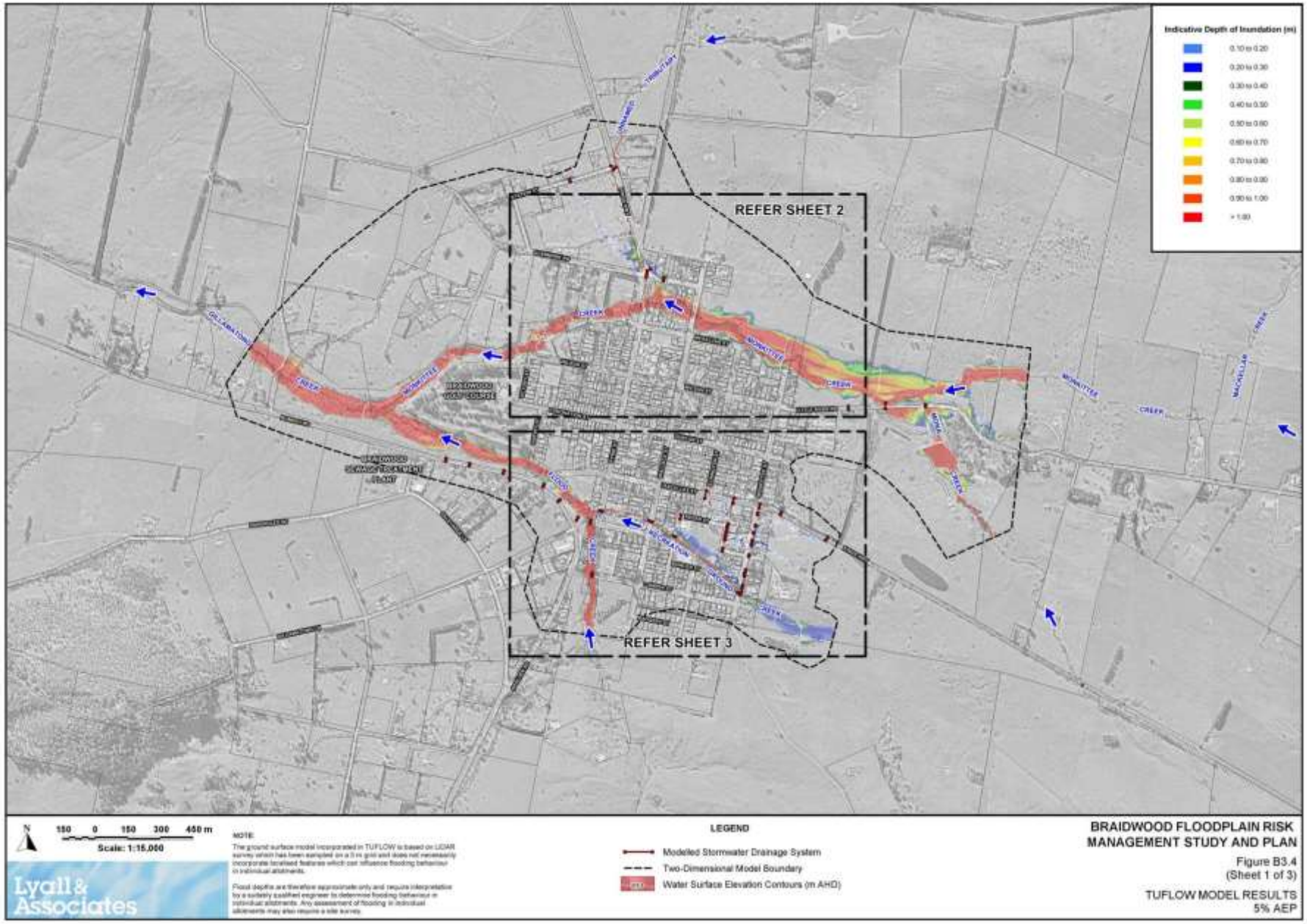
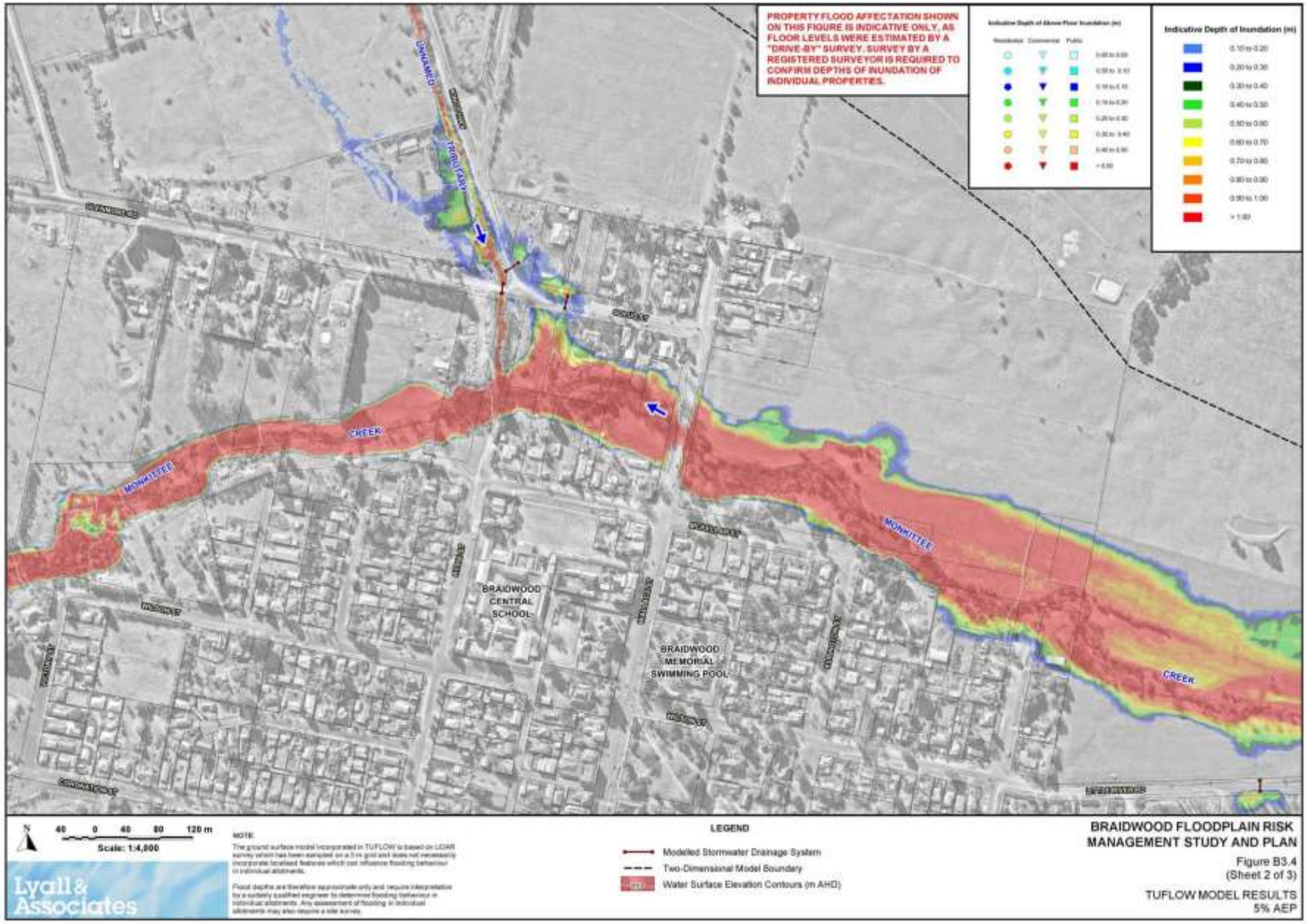
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.3
(Sheet 3 of 3)
TUFLOW MODEL RESULTS
20% AEP


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour on individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.4
(Sheet 1 of 3)
TUFLOW MODEL RESULTS
5% AEP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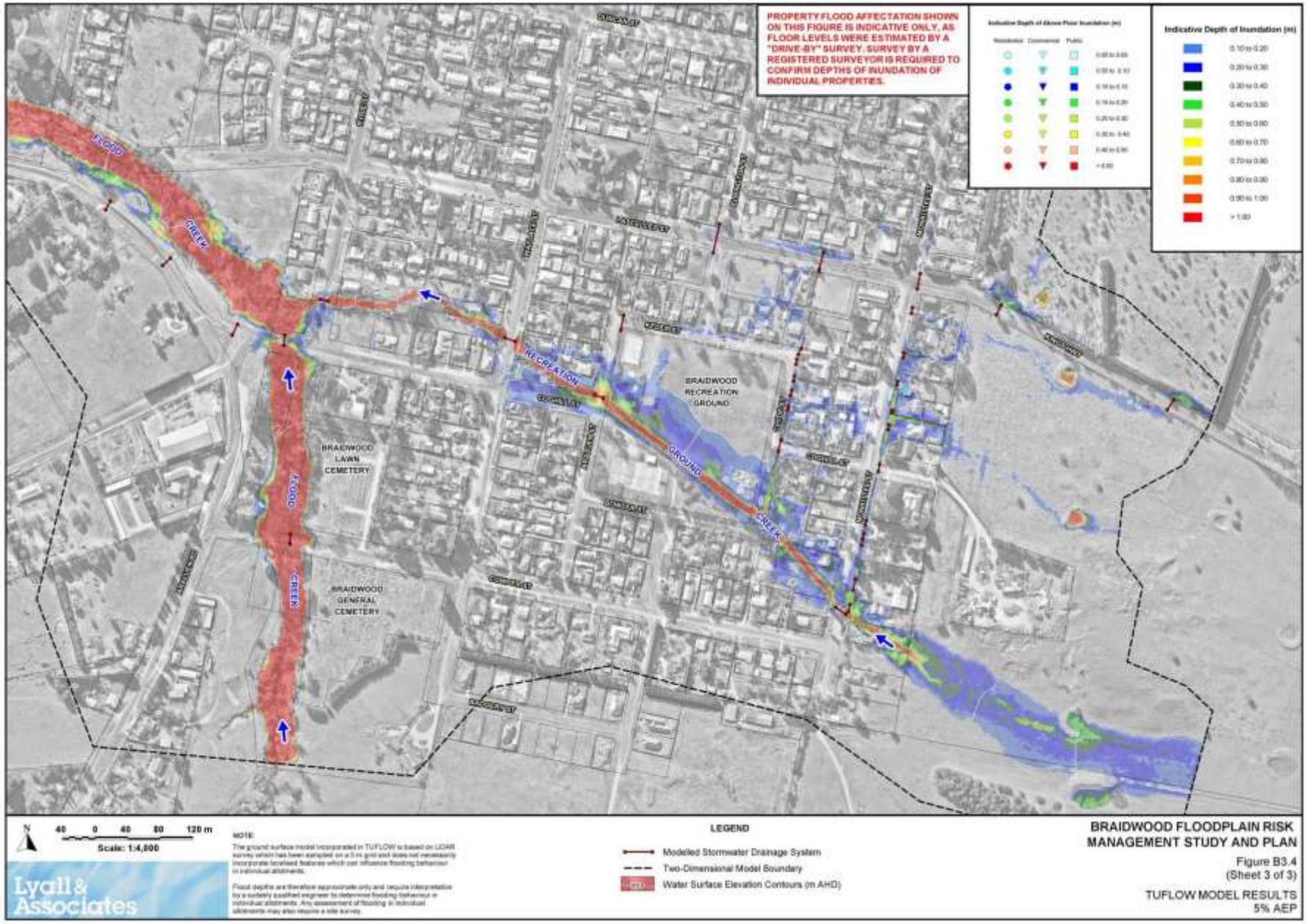
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour on individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.4
(Sheet 2 of 3)
TUFLOW MODEL RESULTS
5% AEP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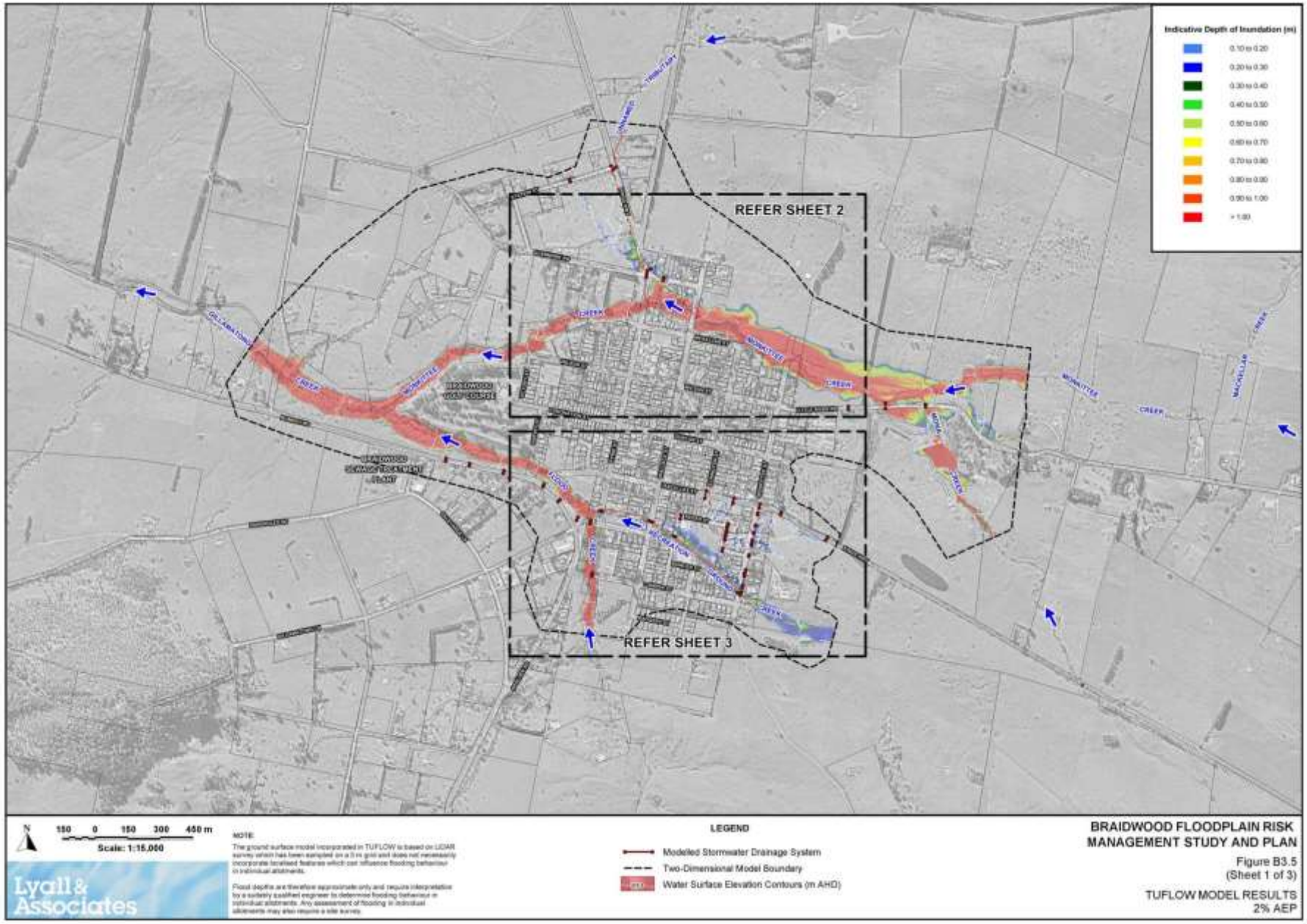
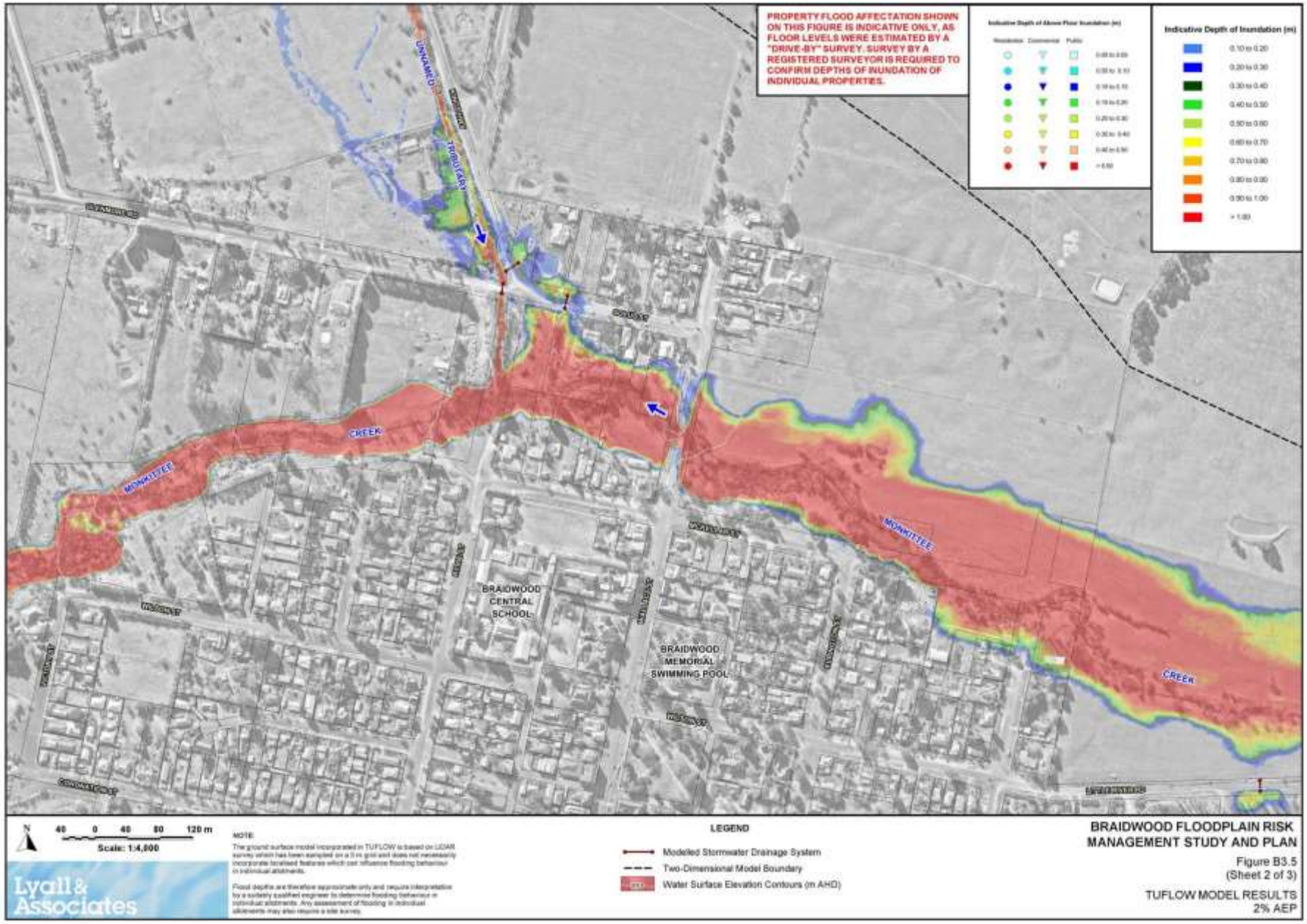
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.4
(Sheet 3 of 3)
TUFLOW MODEL RESULTS
5% AEP


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.5
(Sheet 1 of 3)
TUFLOW MODEL RESULTS
2% AEP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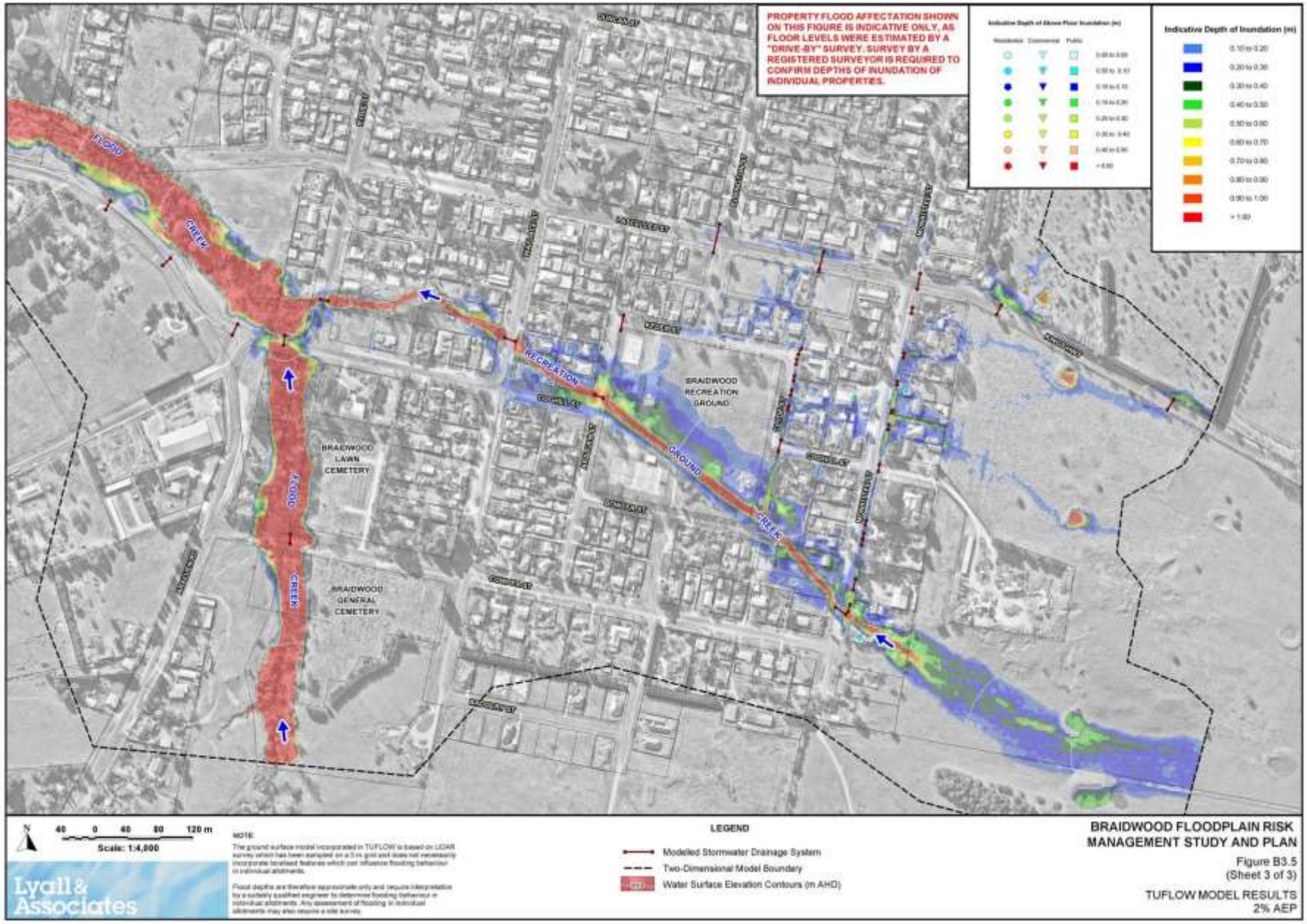
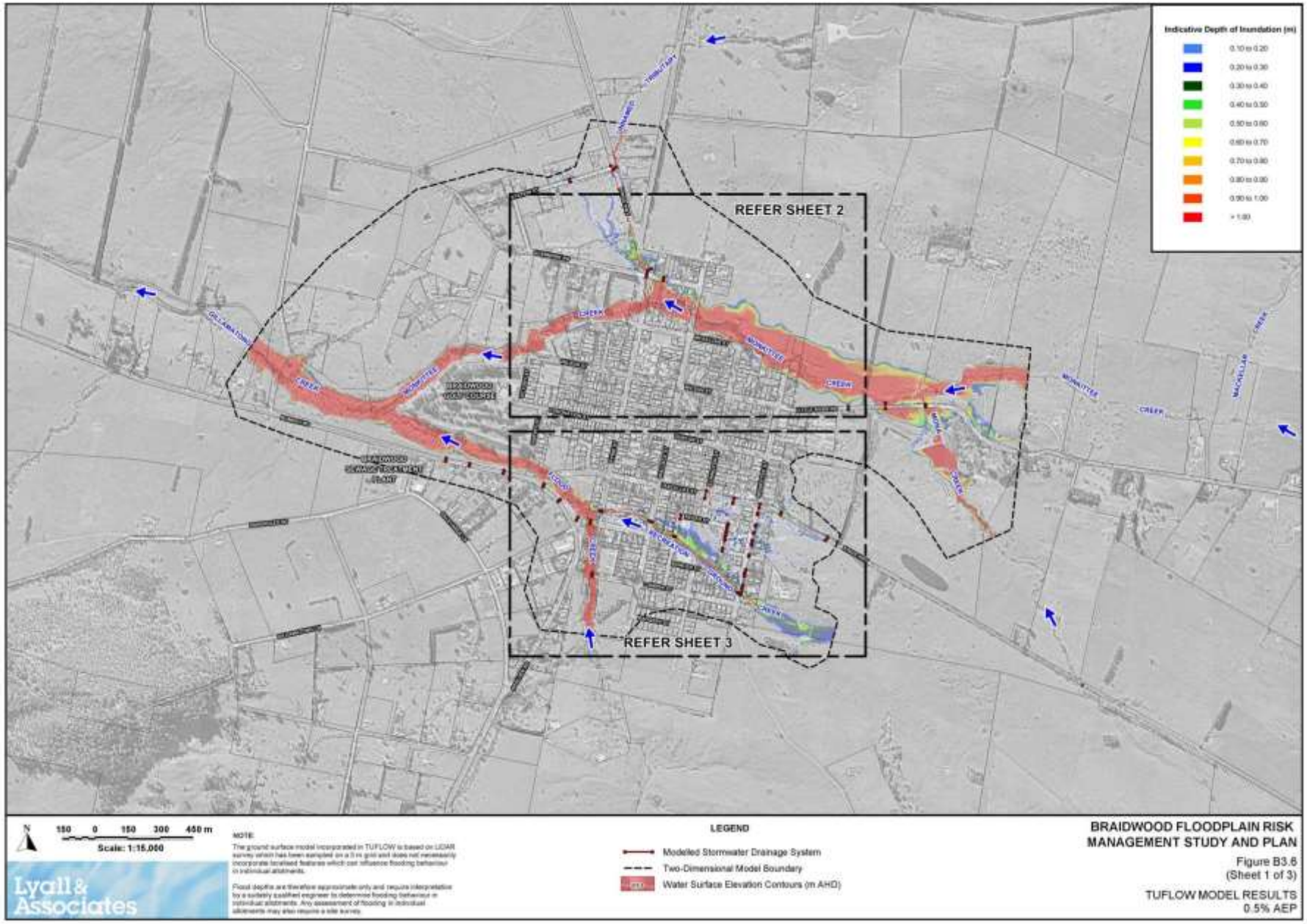
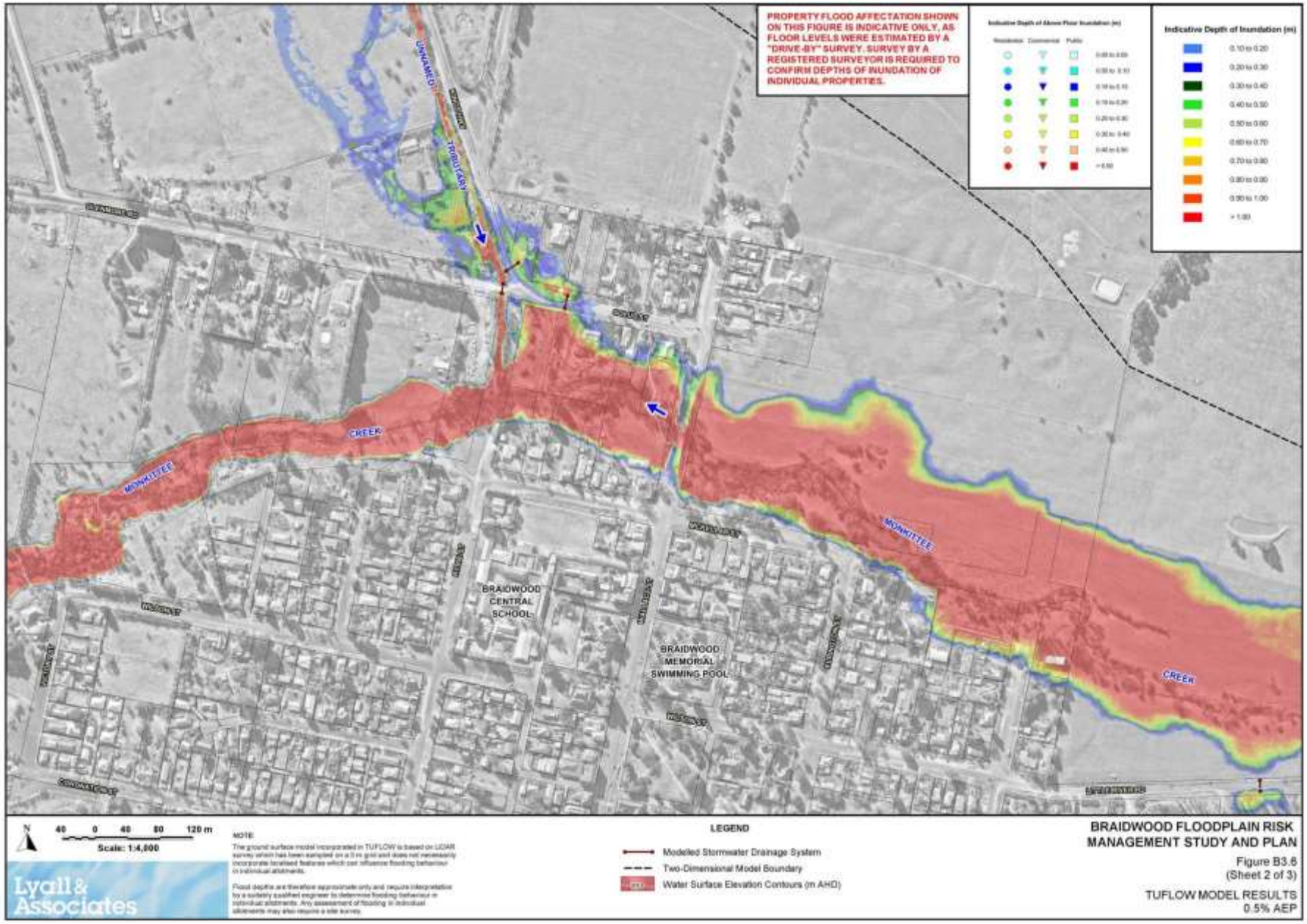
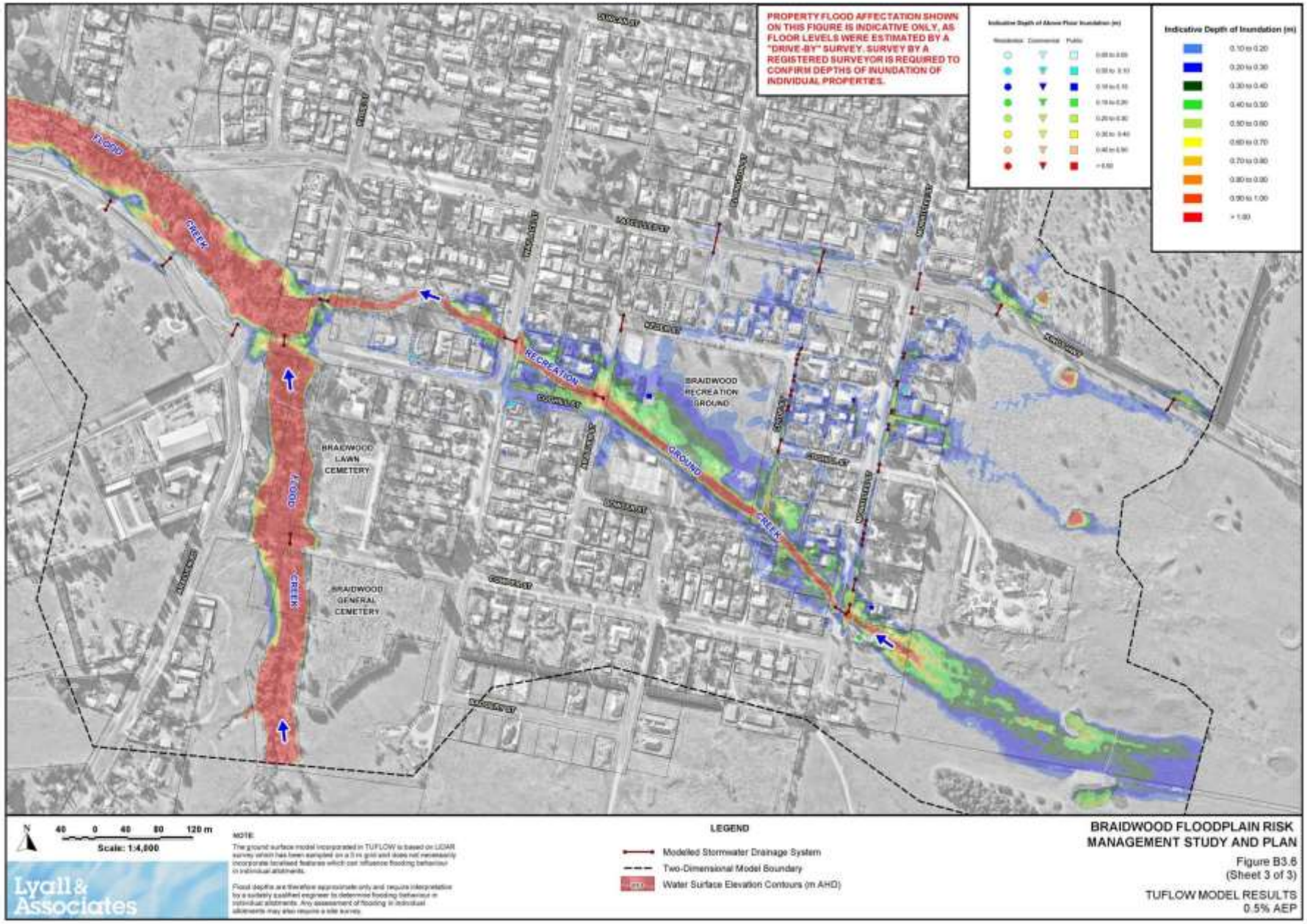
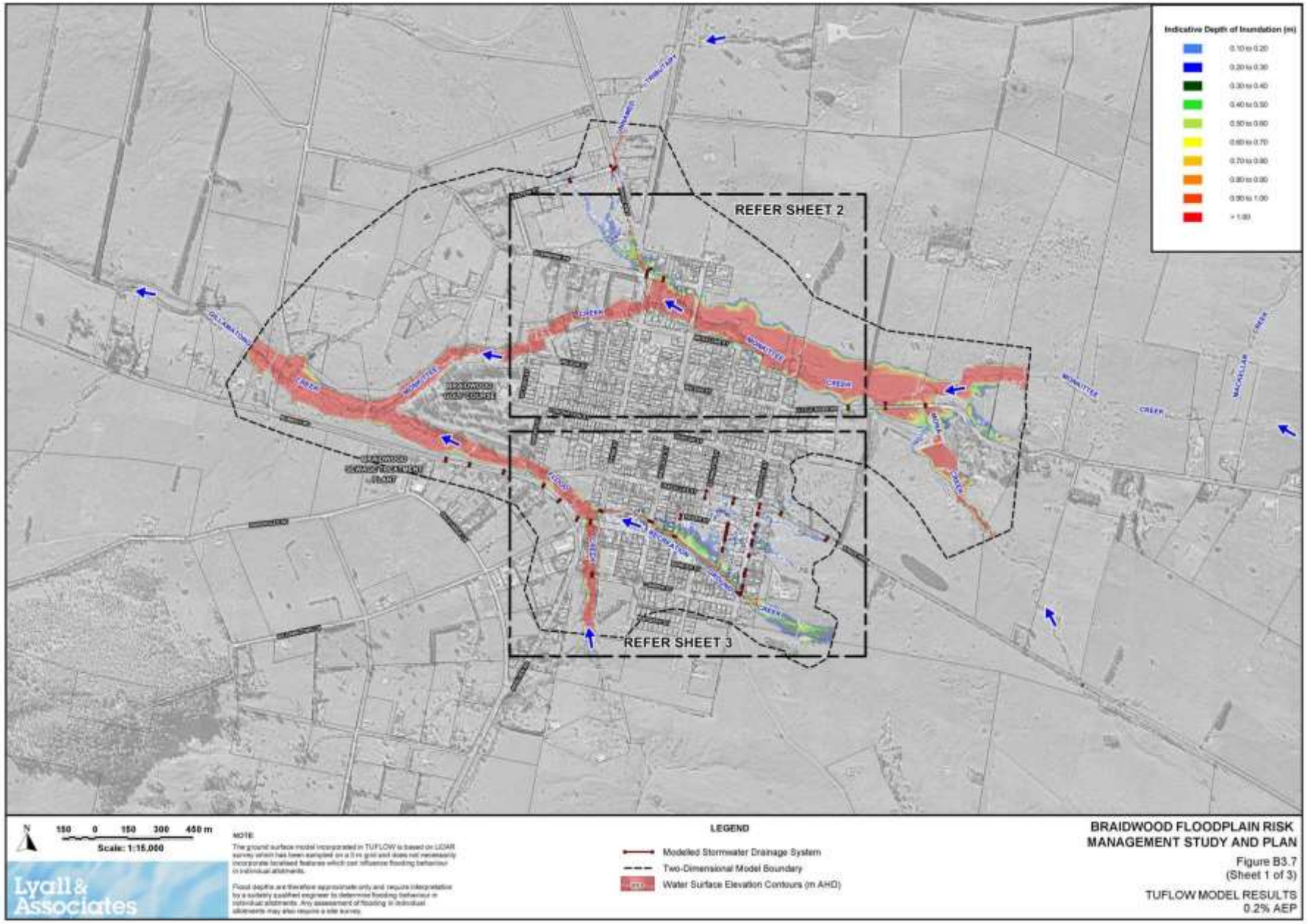
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour on individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.5
(Sheet 2 of 3)
TUFLOW MODEL RESULTS
2% AEP

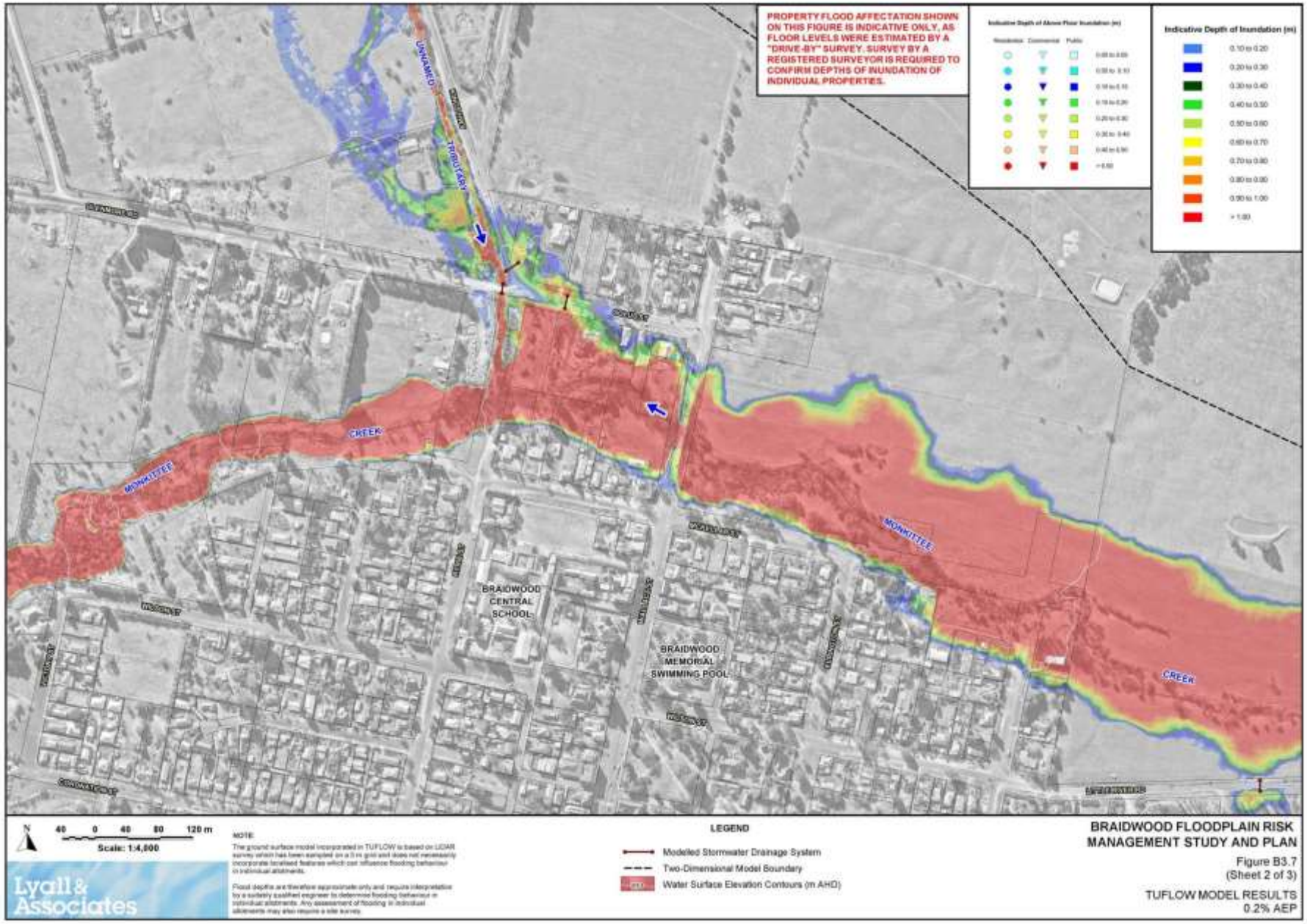

PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.5
(Sheet 3 of 3)
TUFLOW MODEL RESULTS
2% AEP


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretative by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.6
(Sheet 1 of 3)
TUFLOW MODEL RESULTS
0.5% AEP


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.6
(Sheet 2 of 3)
TUFLOW MODEL RESULTS
0.5% AEP


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.6
(Sheet 3 of 3)
TUFLOW MODEL RESULTS
0.5% AEP


Indicative Depth of Inundation (m)
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.7
(Sheet 1 of 3)
TUFLOW MODEL RESULTS
0.2% AEP


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
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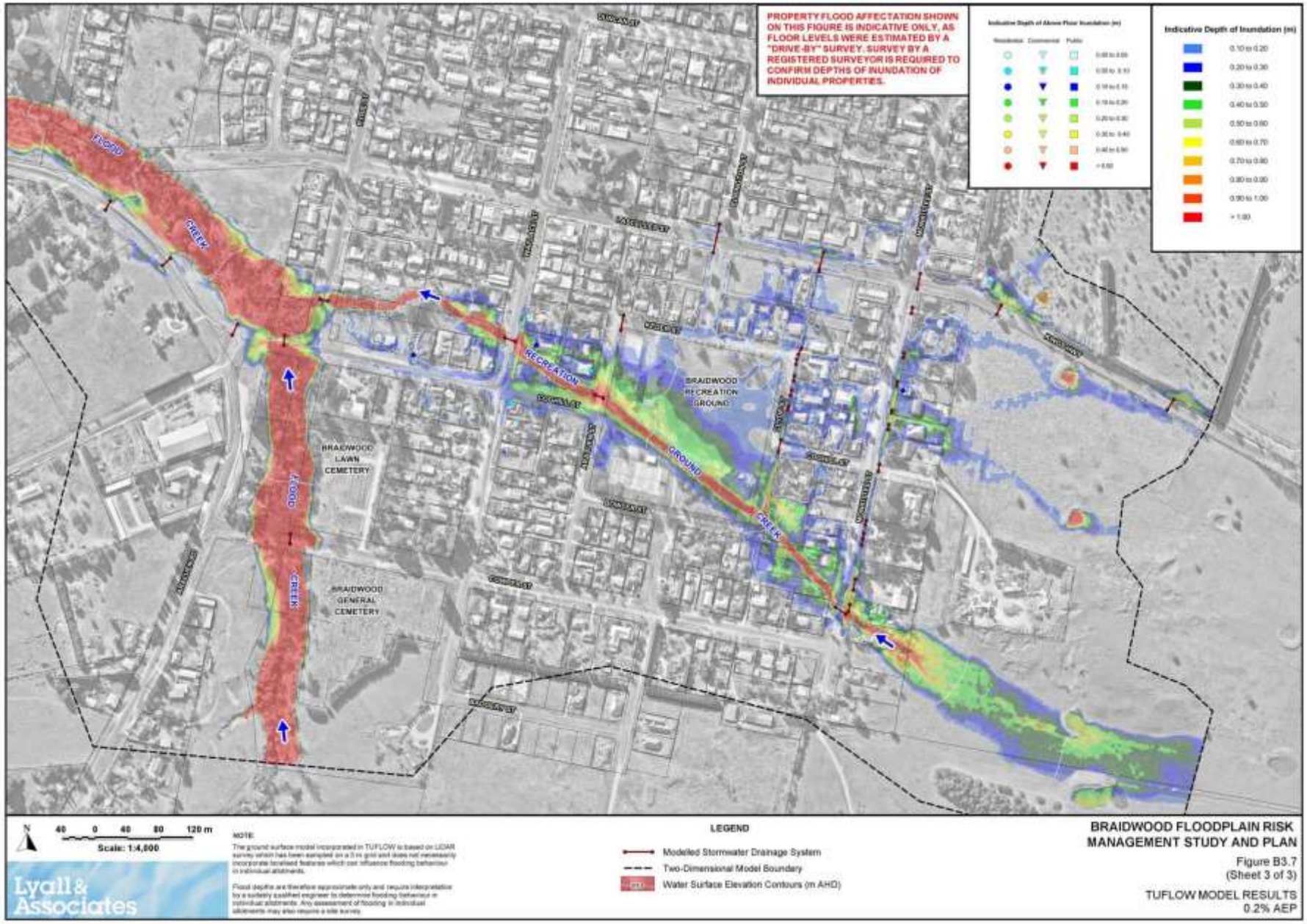
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretation by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.7
(Sheet 2 of 3)
TUFLOW MODEL RESULTS
0.2% AEP


PROPERTY FLOOD AFFECTATION SHOWN ON THIS FIGURE IS INDICATIVE ONLY, AS FLOOR LEVELS WERE ESTIMATED BY A "DRIVE-BY" SURVEY. SURVEY BY A REGISTERED SURVEYOR IS REQUIRED TO CONFIRM DEPTHS OF INUNDATION OF INDIVIDUAL PROPERTIES.
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0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.60
0.60 to 0.70
0.70 to 0.80
0.80 to 0.90
0.90 to 1.00
> 1.00
FLOOD
CREEK
RECREATION
GROUND
CREEK
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
Lyall & Associates
NOTE:
The ground surface model incorporated in TUFLOW is based on LIDAR survey which has been sampled on a 5 m grid and does not necessarily incorporate localised features which can influence flooding behaviour in individual allotments.
Flood depths are therefore approximate only and require interpretative by a suitably qualified engineer to determine flooding behaviour in individual allotments. Any assessment of flooding in individual allotments may also require a site survey.
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Water Surface Elevation Contours (m AHD)
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure B3.7
(Sheet 3 of 3)
TUFLOW MODEL RESULTS
0.2% AEP

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APPENDIX C

DIFFERENCES IN DESIGN FLOOD ESTIMATION FOR BRAIDWOOD ARR1987 VERSUS ARR2016

LIST OF FIGURES (APPENDIX C)

C2.1 Difference in Peak Flood Levels Derived using Procedures set out in ARR1987 and ARR2016 – 1% AEP

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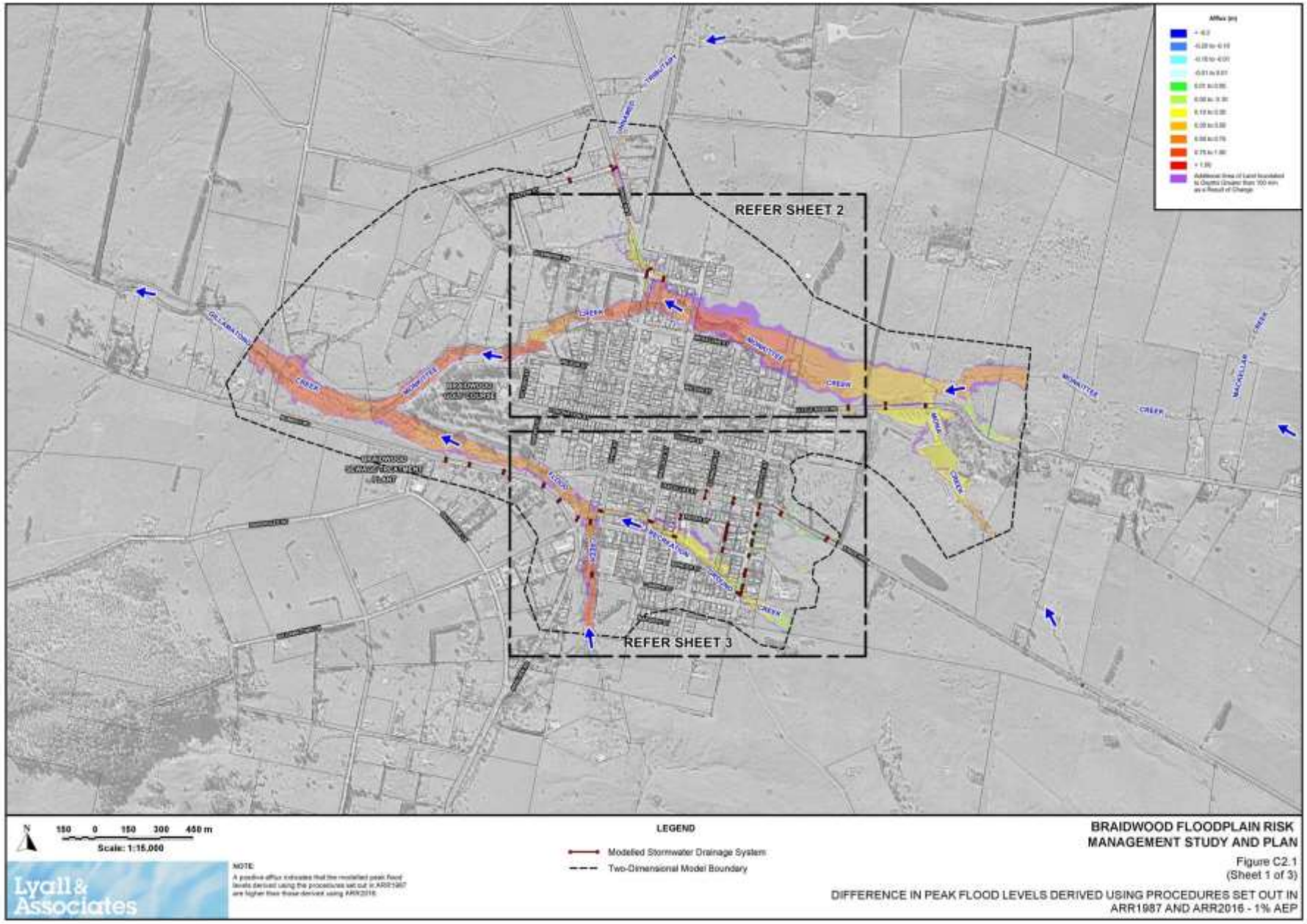
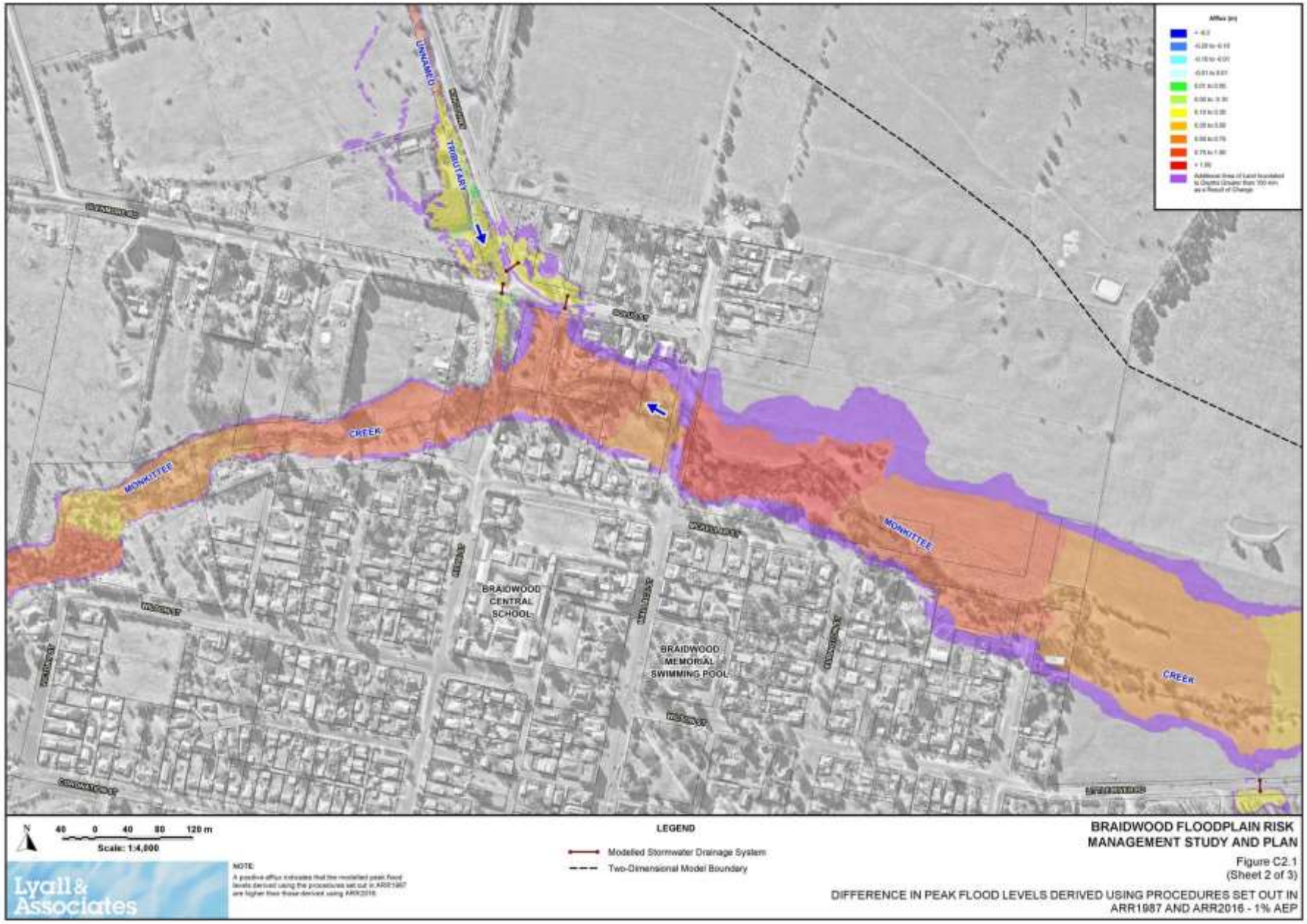
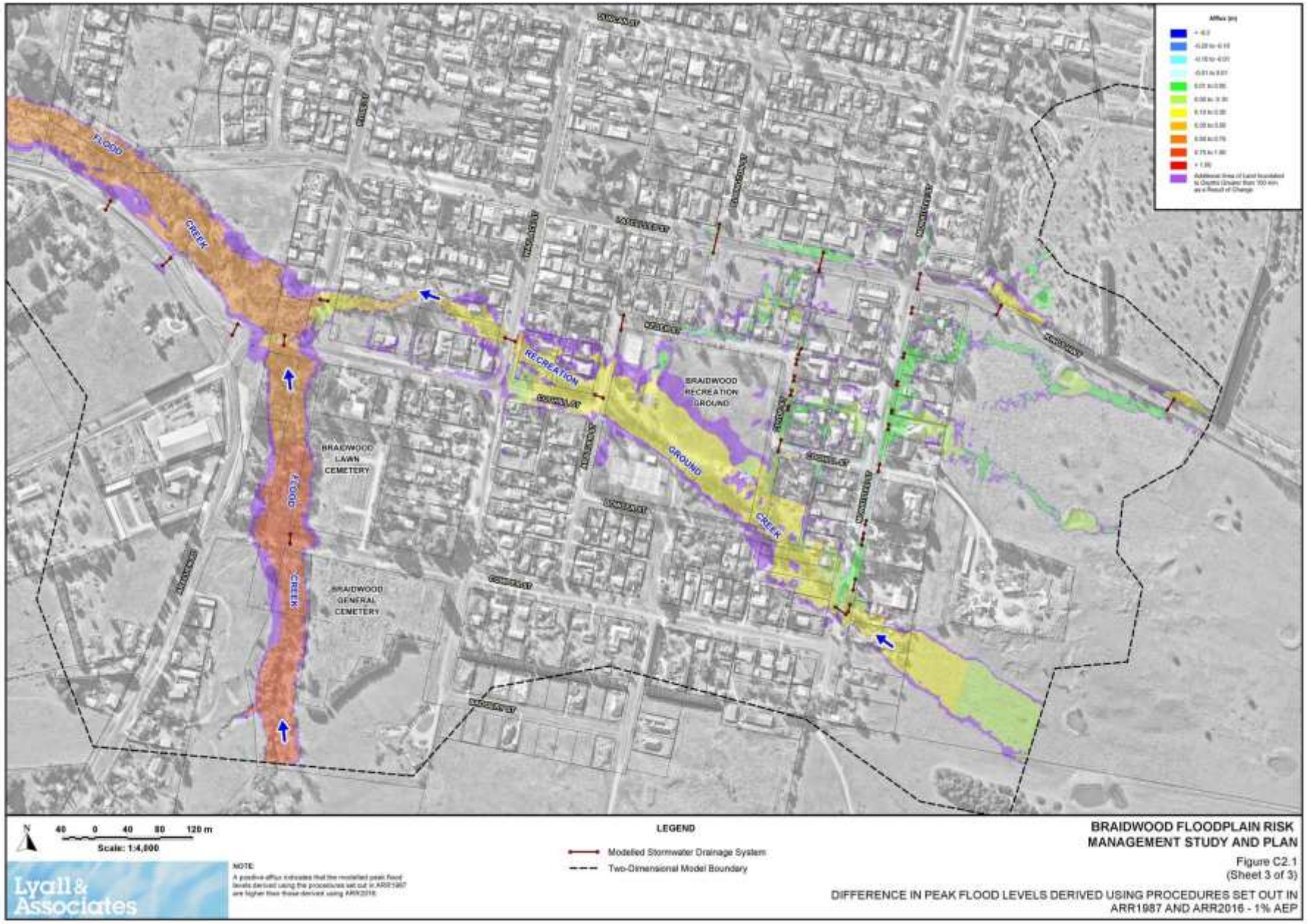

REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
Lyall & Associates
NOTE
A positive afflux indicates that the modelled peak flood levels derived using the procedures set out in ARR1987 are higher than those derived using ARR2016
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure C2.1
(Sheet 1 of 3)
DIFFERENCE IN PEAK FLOOD LEVELS DERIVED USING PROCEDURES SET OUT IN ARR1987 AND ARR2016 - 1% AEP


UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
NOTE
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure C2.1
(Sheet 2 of 3)
DIFFERENCE IN PEAK FLOOD LEVELS DERIVED USING PROCEDURES SET OUT IN ARR1987 AND ARR2016 - 1% AEP


FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD
RECREATION
GROUND
BRAIDWOOD
LAWN
CEMETERY
BRAIDWOOD
GENERAL
CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
NOTE
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK
MANAGEMENT STUDY AND PLAN
Figure C2.1
(Sheet 3 of 3)
DIFFERENCE IN PEAK FLOOD LEVELS DERIVED USING PROCEDURES SET OUT IN
ARR1987 AND ARR2016 - 1% AEP

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APPENDIX D

FLOOD DAMAGES

LIST OF FIGURES (APPENDIX D)

D8.1 Damage - Frequency Curves and Cumulative Flooded Properties versus Depth of Inundation Diagram (Nominal 1% AEP Design Flood Level Case)

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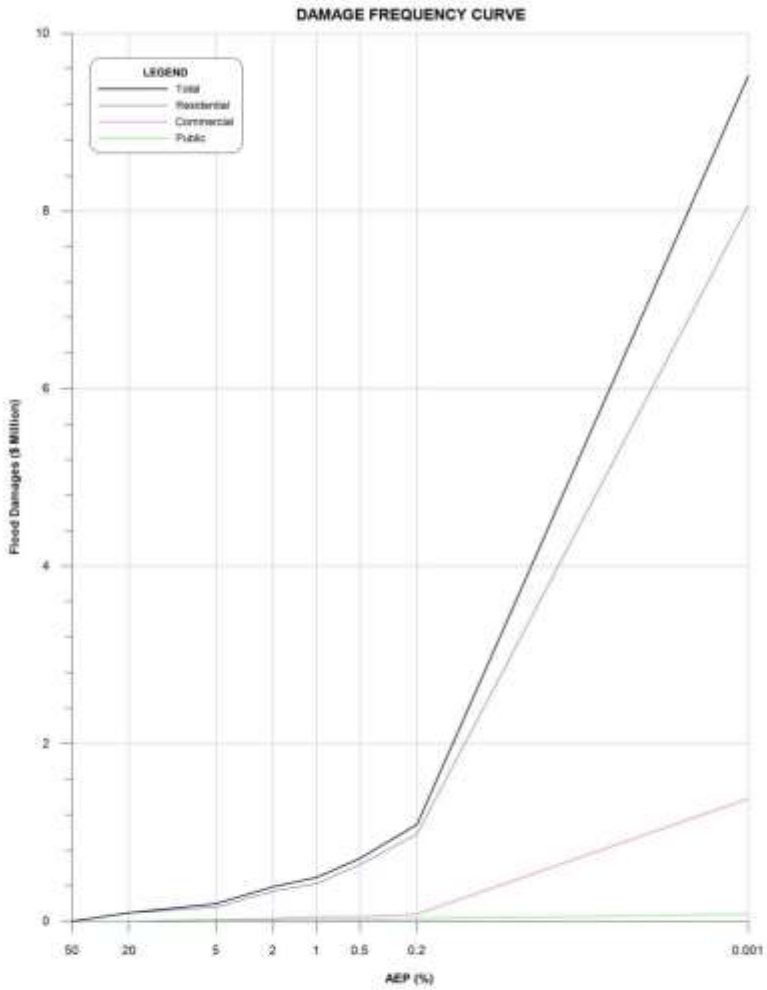

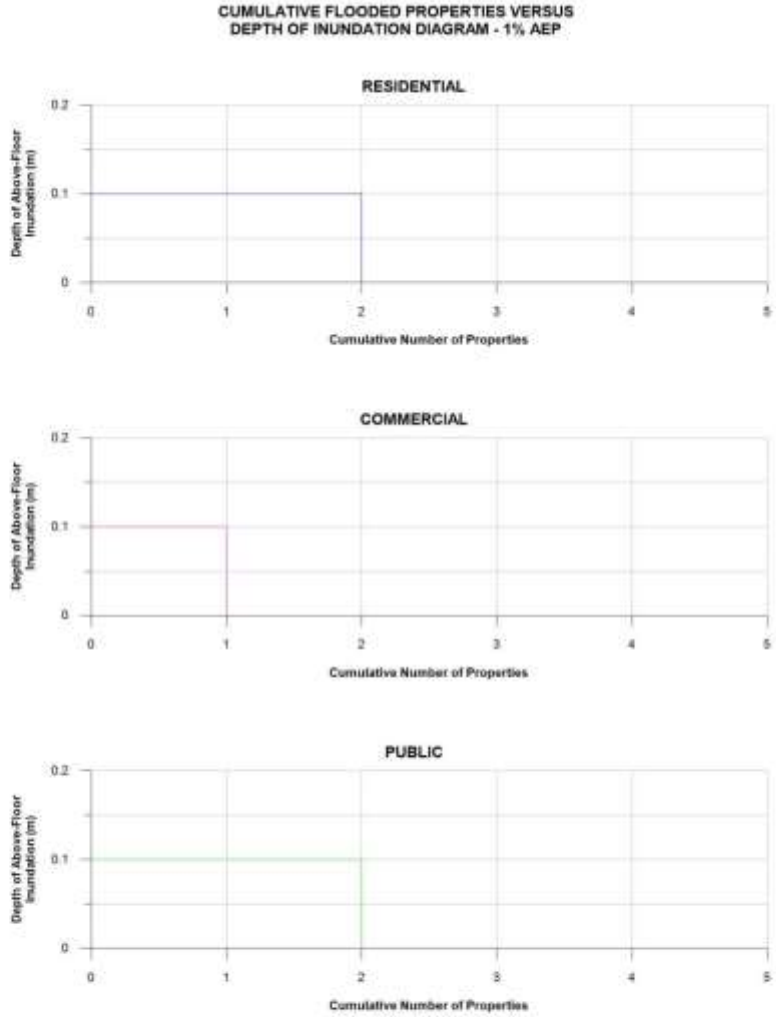

BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

Figure D8.1

DAMAGE - FREQUENCY CURVES AND
CUMULATIVE FLOODED PROPERTIES VERSUS DEPTH OF INUNDATION DIAGRAM
NOMINAL 1% AEP DESIGN FLOOD LEVEL CASE

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APPENDIX E

DRAFT FLOOD POLICY

LIST OF FIGURES (APPENDIX E)

E1.1 Extract of Flood Planning Map at Braidwood
E1.2 Braidwood Flood Hazard Map

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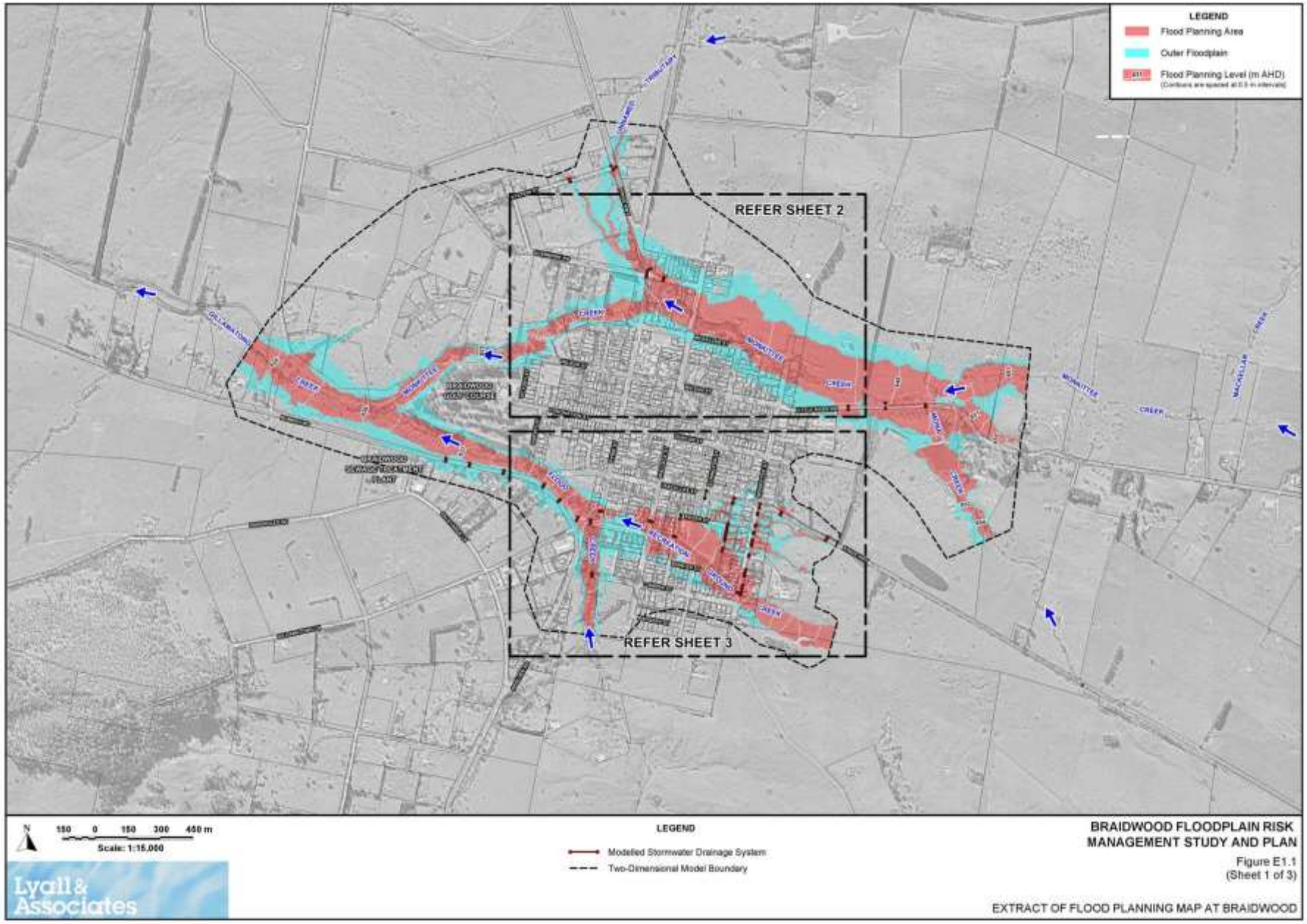
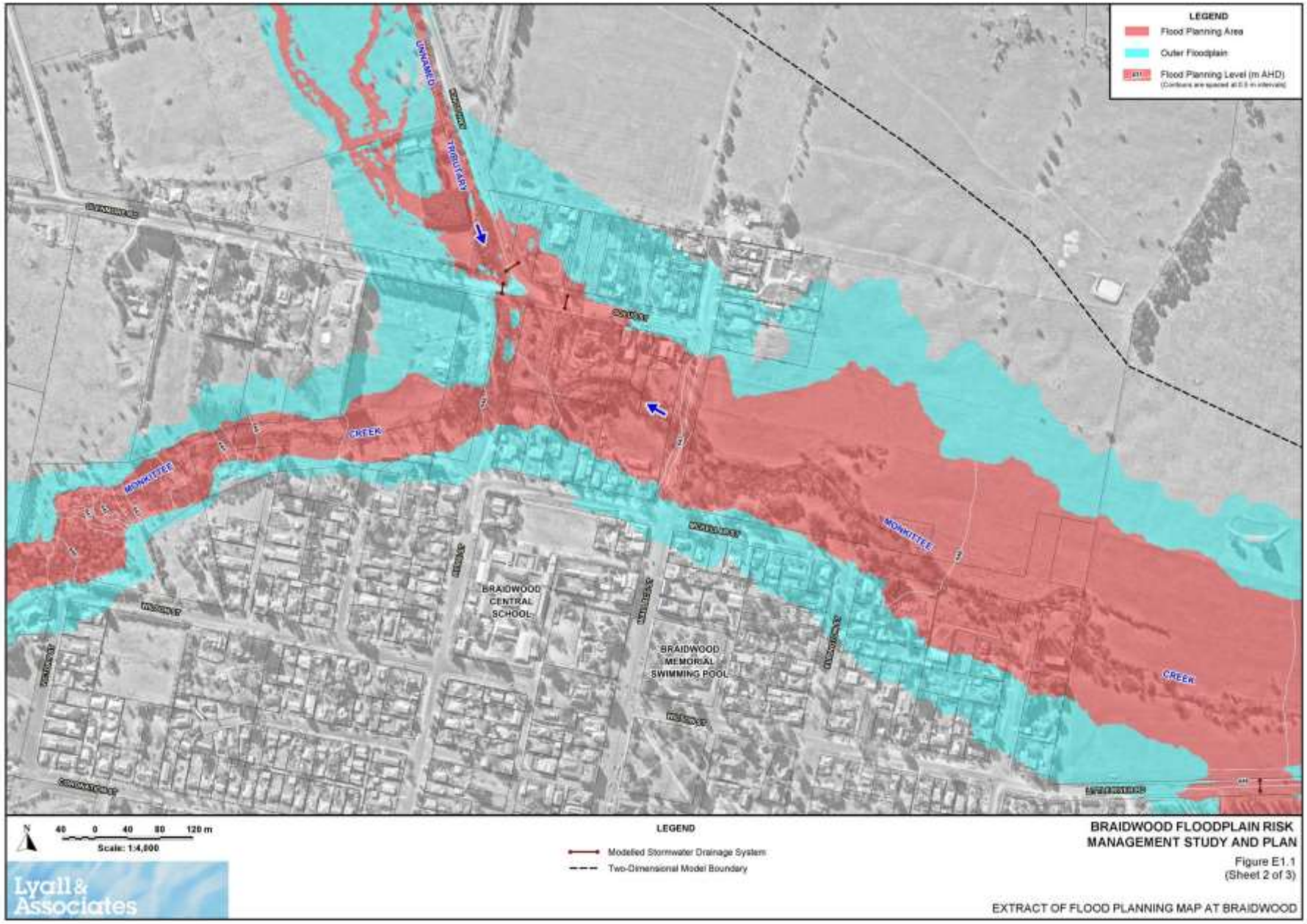
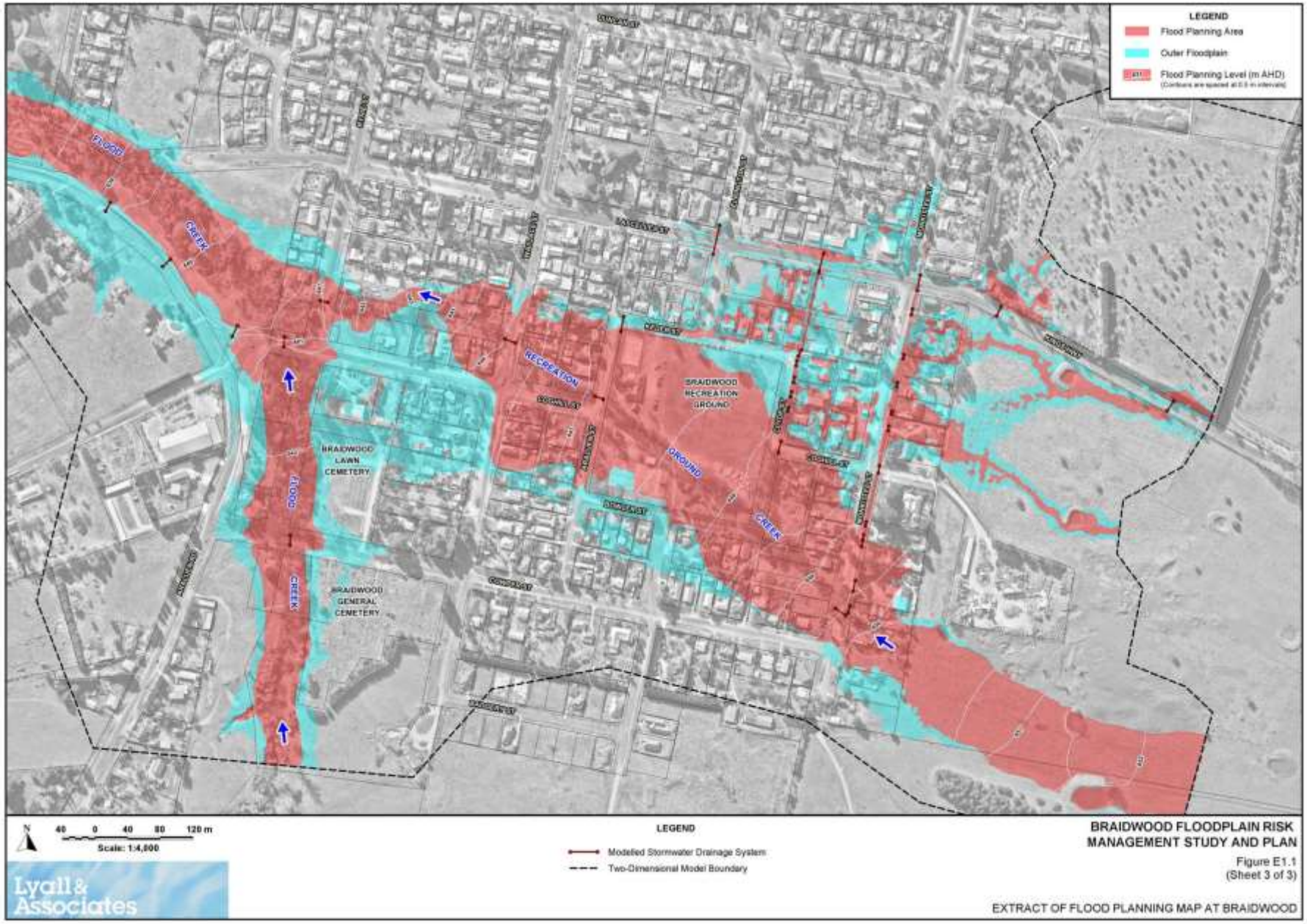
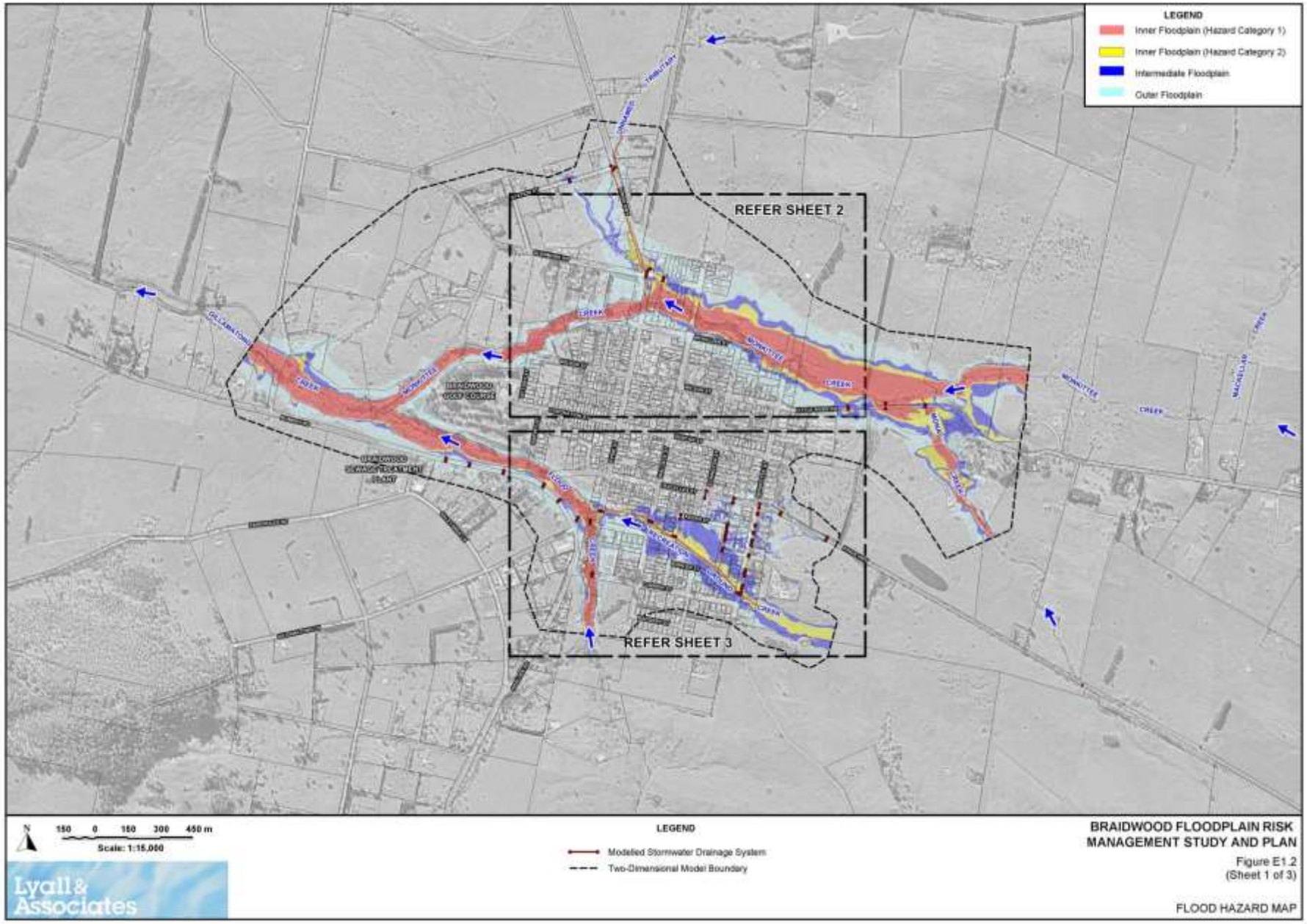
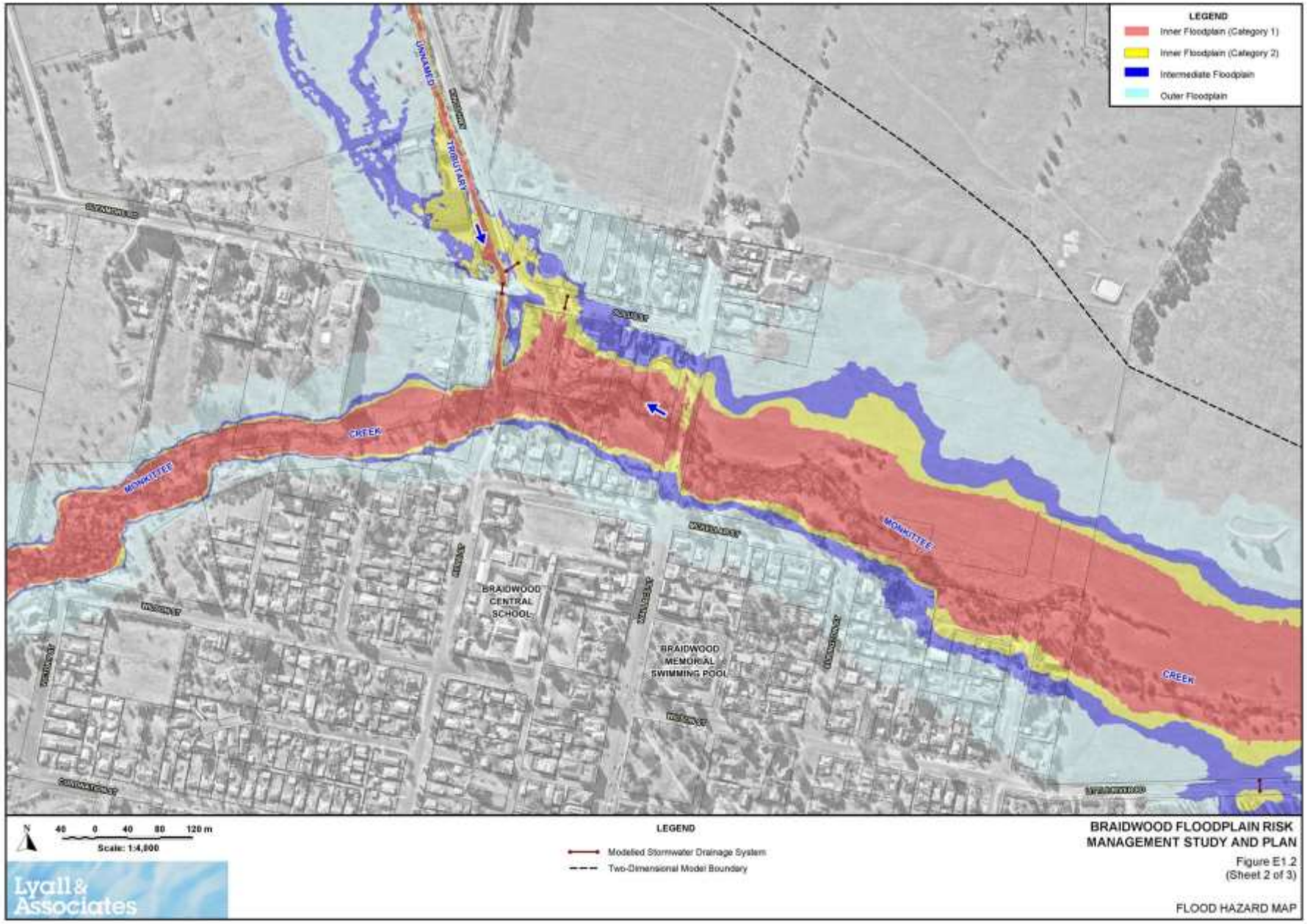
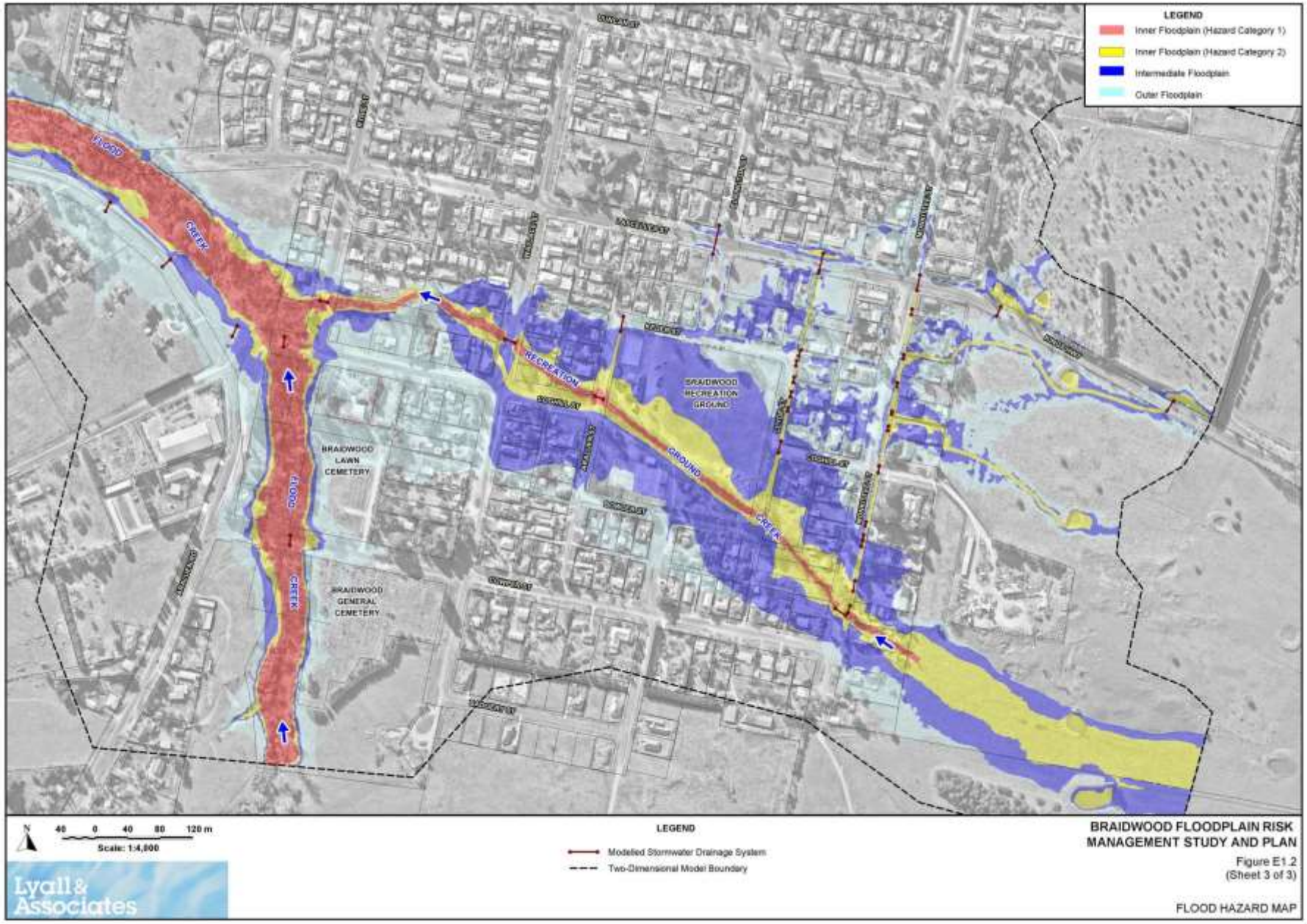

LEGEND
Flood Planning Area
Outer Floodplain
Flood Planning Level (m AHD)
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.1
(Sheet 1 of 3)
EXTRACT OF FLOOD PLANNING MAP AT BRAIDWOOD


LEGEND
Flood Planning Area
Outer Floodplain
Flood Planning Level (m AHD)
UNNAMED
TRIBUTARY
CREEK
MONKITTEE
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.1
(Sheet 2 of 3)
EXTRACT OF FLOOD PLANNING MAP AT BRAIDWOOD


LEGEND
Flood Planning Area
Outer Floodplain
Flood Planning Level (m AHD)
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.1
(Sheet 3 of 3)
EXTRACT OF FLOOD PLANNING MAP AT BRAIDWOOD


LEGEND
Inner Floodplain (Hazard Category 1)
Inner Floodplain (Hazard Category 2)
Intermediate Floodplain
Outer Floodplain
REFER SHEET 2
REFER SHEET 3
N
150 0 150 300 450 m
Scale: 1:15,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.2
(Sheet 1 of 3)
FLOOD HAZARD MAP


LEGEND
Inner Floodplain (Category 1)
Inner Floodplain (Category 2)
Intermediate Floodplain
Outer Floodplain
UNNAMED
TRIBUTARY
MONKITTEE
CREEK
BRAIDWOOD CENTRAL SCHOOL
BRAIDWOOD MEMORIAL SWIMMING POOL
N
40 0 40 80 120 m
Scale: 1:4,000
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.2
(Sheet 2 of 3)
FLOOD HAZARD MAP


LEGEND
Inner Floodplain (Hazard Category 1)
Inner Floodplain (Hazard Category 2)
Intermediate Floodplain
Outer Floodplain
FLOOD
CREEK
RECREATION
GROUND
BRAIDWOOD RECREATION GROUND
BRAIDWOOD LAWN CEMETERY
BRAIDWOOD GENERAL CEMETERY
N
40 0 40 80 120 m
Scale: 1:4,800
LEGEND
Modelled Stormwater Drainage System
Two-Dimensional Model Boundary
Lyall & Associates
BRAIDWOOD FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN
Figure E1.2
(Sheet 3 of 3)
FLOOD HAZARD MAP