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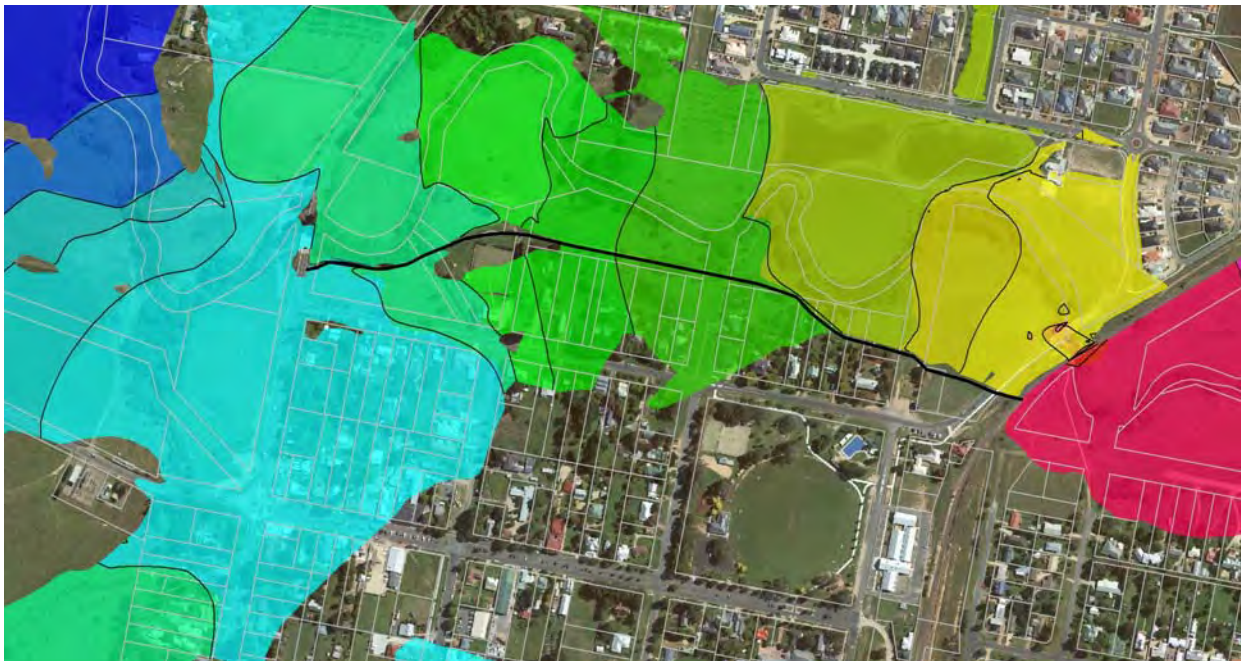
BUNGENDORE FLOODPLAIN RISK MANAGEMENT PLAN



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Project: 3777 - BUNGENDORE FLOODPLAIN RISK MANAGEMENT PLAN

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The following report was prepared by WorleyParsons Services Pty on behalf of Palerang Council's Floodplain Risk Management Committee.

The Bungendore Floodplain Risk Management Plan (FRMP) has been funded jointly by Council and the Office of Environment and Heritage on a 1:2 subsidy basis, under the New South Wales Government's Floodplain Management Program.

It has been prepared by incorporating contributions from individuals from the local community and key stakeholders. Contributions from members of the Floodplain Risk Management Committee have been essential to the formation of management strategies that have been considered as part of the Study and are greatly appreciated.

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Palerang Council has prepared this document with financial assistance from the NSW and Commonwealth Government through the Natural Disaster Resilience Program. The document does not necessarily represent the opinions of the NSW or Commonwealth Governments.

FOREWORD

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

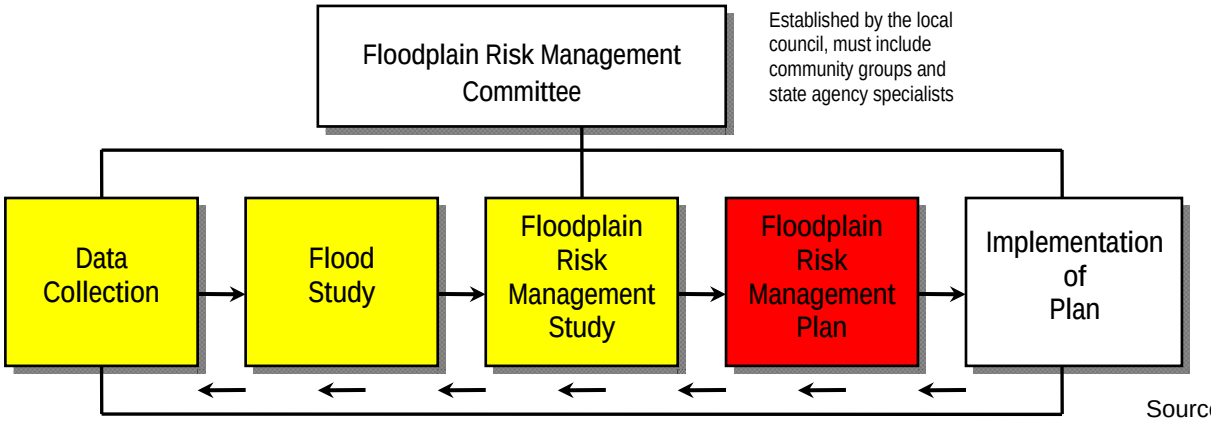
Under the Policy, the management of flood liable land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Local Government in the discharge of their floodplain risk management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

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

Stages of Floodplain Risk Management

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

A detailed description of the inter-relationship between these stages is provided overleaf. The link between the various outcomes of the studies involved in the floodplain risk management process and the implementation of measures (*both planning and structural*) to reduce flood damages is also shown.



'Floodplain Development Manual'(2005)

EXECUTIVE SUMMARY

SETTING

Bungendore is located at the junction of Turallo and Halfway Creeks which are tributaries that drain to the southern shoreline of Lake George. The village has a population of about 2,754 (*Australian Bureau of Statistics, 2011 Census*) and is situated about 40 kilometres north-east of Canberra near the New South Wales / Australian Capital Territory border

Major flooding at Bungendore has occurred on a number of occasions over the last 75 years. The most severe floods occurred in 1934, June 1956, August 1974, and in 1988. The 1934 flood is regarded as being the largest, although it is understood that the resulting damage was similar to that incurred during the 1956 and 1974 floods. The 1974 flood is generally considered to be about 400 mm lower than the 1956 flood.

The most recent flood occurred in 1988 and reached a peak level in the village that was about 1 metre lower than the 1974 event.

These floods have typically resulted in inundation of substantial areas of the village. This is primarily due to the location of the town at the junction of two streams and the flat topography of the area. Although the duration of inundation is relatively short and the depth of inundation is typically relatively shallow, the anecdotal evidence indicates that these floods have led to substantial damage.

Perhaps more significantly, there is typically only 2 hours warning time from the onset of flood producing rainfall in the catchment before the commencement of inundation of low lying areas of the village. This is a function of backwater flooding caused by the constriction at the confluence of Turallo and Halfway Creeks and overtopping of the existing informal low level levee located along the rear of properties that front Turallo Terrace (*between the Goulburn-Bombala Railway and the Tarago Road Bridge crossing*).

DESCRIPTION OF THE FLOODING PROBLEM

The existing flooding problem at Bungendore is documented in the *'Bungendore Flood Study'* (*Issue No 3, November 2002*) and the *'Bungendore Floodplain Risk Management Study'* (*Issue No 6, June 2013*). These studies have established that the network of streams that drain land adjacent to the village of Bungendore is characterised by creek channels that have limited in-channel flow carrying capacity. Consequently, runoff from the upper catchment can easily lead to overtopping of stream banks and the discharge of floodwaters across the floodplain.

Both Turallo and Halfway Creeks overtop their banks in floods as minor as the 1 year recurrence event. In fact, the majority of the flow carried by Turallo Creek in a 1 year recurrence flood travels overland along the floodplain that adjoins the creek banks.

Calculations indicate that the flow carrying capacity of Turallo Creek is only 12% of the total flow of 80 m^3/s that is predicted in a 1 year recurrence event.

The limited capacity of the Turallo Creek channel is particularly evident upstream of the railway which acts as a levee and causes floodwaters to 'back up'. As a result, floodwaters inundate Turallo Terrace between Powell Street and Mecca Lane in events rarer than the 5 year recurrence flood.

An existing earth levee extends along sections of the southern creek banks between the railway and the Tarago Road crossing of Turallo Creek. The levee, for the most part, prevents floodwaters from entering the village in events up to and including the 20 year recurrence flood, although the northern end of Butmaroo Street becomes submerged in most floods where floodwaters overtop the creek banks.

Significantly, the levee is overtopped in rarer events and relatively fast flowing floodwaters from Turallo Creek discharge across the levee in a south-westerly direction during events of the magnitude of the 100 year recurrence flood. Modelling shows that floodwaters inundate the northern end of Ellendon and Butmaroo Streets and extend across to Molonglo Street and Halfway Creek.

Dwellings and buildings within the village that would be threatened by flooding are generally those located nearest to the southern bank of Turallo Creek and the eastern bank of Halfway Creek. It is estimated that 29 buildings are potentially threatened by floodwaters in events of the magnitude of the 100 year recurrence flood. In a 20 year recurrence event, a total of 10 buildings would be threatened by floodwaters. Whereas, in a 5 year recurrence event, only 4 buildings would be threatened.

The number of properties susceptible to flooding is substantially higher with up to 61 properties predicted to be inundated at the peak of the 100 year recurrence flood. Even in the 5 year recurrence flood, approximately 20 properties would be at threat.

The total flood damage estimate for each design flood event was combined with the probability of occurrence to determine an Average Annual Damage (*AAD*) cost for existing conditions. The results of this analysis determined the average annual damage for the Village of Bungendore to be about $438,180. The inundation of potentially flood affected properties in the occurrence of 100 year ARI event is estimated to result in damages on the order of $3.1M.

Therefore, the flooding of Turallo and Halfway Creeks will result in economic and social impacts to residents and business owners at Bungendore. Accordingly, it is appropriate to implement a floodplain management plan aimed at reducing these impacts and ensuring future development is cognisant of the potential flood risk.

FLOODPLAIN MANAGEMENT PLAN

Recommended Options

A range of potential floodplain management strategies were considered by Council's Committee as part of the *'Bungendore Floodplain Risk Management Study'*. These were assessed in terms of the reduction in flood damages that would be afforded as measured by reduced floodwater depths, increased flood warning advice and increased levels of flood protection for vulnerable areas of the town. The strategies recommended for implementation under this Floodplain Risk Management Plan are shown in **Figure S1**. Each of these is summarised in the following.

FIGURE S1

RECOMMENDED 'FLOOD MODIFICATION WORKS'

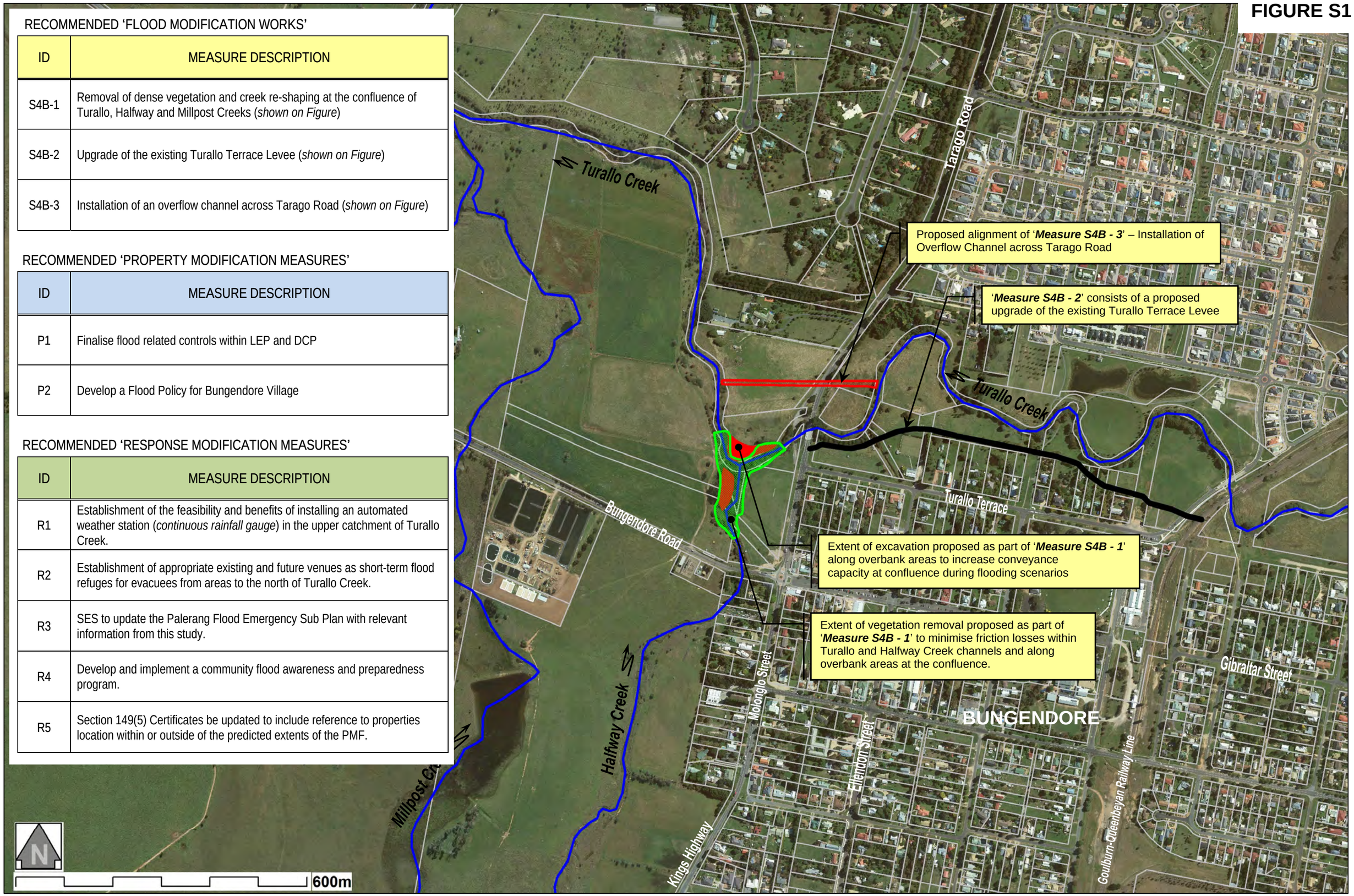
ID	MEASURE DESCRIPTION
S4B-1	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks (*shown on Figure*)
S4B-2	Upgrade of the existing Turallo Terrace Levee (*shown on Figure*)
S4B-3	Installation of an overflow channel across Tarago Road (*shown on Figure*)

RECOMMENDED 'PROPERTY MODIFICATION MEASURES'

ID	MEASURE DESCRIPTION
P1	Finalise flood related controls within LEP and DCP
P2	Develop a Flood Policy for Bungendore Village

RECOMMENDED 'RESPONSE MODIFICATION MEASURES'

ID	MEASURE DESCRIPTION
R1	Establishment of the feasibility and benefits of installing an automated weather station (*continuous rainfall gauge*) in the upper catchment of Turallo Creek.
R2	Establishment of appropriate existing and future venues as short-term flood refuges for evacuees from areas to the north of Turallo Creek.
R3	SES to update the Palerang Flood Emergency Sub Plan with relevant information from this study.
R4	Develop and implement a community flood awareness and preparedness program.
R5	Section 149(5) Certificates be updated to include reference to properties location within or outside of the predicted extents of the PMF.



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OVERVIEW OF RECOMMENDED STRATEGIES

Flood Modification Measures

S4B. Implementation of Option S4B which includes the following works:

- Upgrade of the existing Turallo Terrace levee (*no extension*)
- Construction of an overflow channel across Tarago Road
- Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks

Property Modification Measures

P1. That the flood-related planning controls that are proposed within the draft LEP and the draft DCP be finalised recognising the following points and the associated recommendations listed in **Section 3.3** of this Plan:

- Need for recognition of flood risk on land above the 1% AEP flood level for all development types
- Need for a mechanism to address flood risk associated with exempt and complying development
- Need for clear definition of "Significant Adverse Impacts" in the flood clause referred to in the Standard Instrument LEP
- Need for a mechanism for identifying areas beyond the FPA that could become a flood island in floods rarer than those covered by the extent of the FPA
- Need for a mechanism to be defined within the draft LEP for managing future changes to Council's knowledge of FPAs

P2. That a specific Flood Policy be developed for the Village of Bungendore to guide development and to assist the determination of development applications.

Response Modification Measures

R1. Consider the feasibility and benefits of installing an automated weather station (*continuous rainfall gauge*) in the upper catchment of Turallo Creek.

R2. Assess the potential for existing and/or future facilities at North Bungendore to be utilised as assembly areas for evacuees from north of Turallo Creek (*i.e., Elmslea Estate*).

R3. SES to update the Palerang Flood Emergency Sub Plan with relevant information from this Plan and from the *Bungendore Floodplain Risk Management Study* (*2013*).

R4. Develop and implement a community flood awareness and preparedness program, working with SES to use FloodSafe Program materials.

R5. Update notations on Section 149 (5) certificates to include notification of whether or not the property is within the predicted extents of the PMF.

Estimated Costs and Program for Implementation

The total upfront cost of all recommended works and measures is estimated to be approximately **$1.8M**. The priority and relative timeframes for implementation of the recommended measures are provided in the *Preliminary Implementation Program* provided overleaf.

In that regard, Option S4B which is the major Flood Modification Option proposed under the Plan, has a projected capital works cost of $1.6M (*2012 dollars*) and an estimated benefit-cost ratio of 1.6.

It should also be noted that Council's ability to implement the works proposed in the *Implementation Program* will be subject to Council sourcing appropriate funding, and also further investigation and design of the proposed works. .

PRELIMINARY IMPLEMENTATION PROGRAM

Year	1	2	3	4	5
	2015/16	*2016/17*	*2017/18*	*2018/19*	*2019/20*
Flood Modification Measures					
S4B-1 – Design and Construct Vegetation Clearing Works and Re-Shaping at Confluence	Design	Works			
S4B-2 – Design and Construct Upgrade of the existing Turallo Terrace Levee	Design	Works			
S4B-3 – Design and Construct Overflow Channel across Tarago Road	Design	Works			
Property Modification Measures					
P1 - Finalise flood related controls within LEP and DCP					
P2 – Develop a Flood Policy for Bungendore Village					
Response Modification Measures					
R1 – Assess feasibility and potential to install of automatic weather station in upper catchment	Design	Works			
R2 - Establish additional venues for short-term flood refuge in North Bungendore					
R3 - SES to update the Palerang Flood Emergency Sub Plan					
R4 - Develop and implement community awareness program					
R5 - Update Section 149(5) Certificates with flood information					

1. SETTING

1.1 BACKGROUND

Bungendore is located on the banks of Turallo and Halfway Creeks which are tributaries that drain to the southern shoreline of Lake George to the north (*refer* **Figure 1.1**). The village has a population of about 2,754 (*Australian Bureau of Statistics, 2011 Census*) and is situated about 40 kilometres north-east of Canberra near the New South Wales / Australian Capital Territory border.

Major flooding at Bungendore has occurred on a number of occasions over the last 75 years. The most severe floods occurred in 1934, June 1956, August 1974, and in 1988. The 1934 flood is regarded as being the largest, although it is understood that the resulting damage was similar to that incurred during the 1956 and 1974 floods.

Very little reliable information is available for the 1934 flood. The only available data indicates that the floodwaters peaked at an elevation of 692.78 mAHD at the old railway shed located on the downstream side of the Goulburn to Queanbeyan Railway bridge crossing of Turallo Creek. A level of 691.8 mAHD was recorded at the same shed during the 1956 flood. However, it should be noted that both the railway embankment and the railway bridge are likely to have been substantially altered over the intervening period.

Available records indicate that floodwaters reached an elevation of 690.9 mAHD at the petrol station located at the north-eastern corner of Gibralter and Molonglo Streets during the 1956 flood. In contrast, a flood level of 690.4 mAHD was recorded at the petrol station at the peak of the 1974 flood. Accordingly, the 1974 flood is generally considered to have generated flood levels that were 500 mm lower than those recorded during the 1956 flood.

More recently, the 1988 flood reached a peak level of about 689.4 mAHD at the petrol station. Therefore, the 1988 flood was about 1 metre lower than the 1974 event.

In any case, events of the magnitude of these floods have caused the inundation of substantial areas of the village. Anecdotal evidence indicates that in the 1956 event, floodwaters reached to within 500 mm of the railway tracks at the bridge crossing of Turallo Creek, and that floodwaters extended up along Gibraltar Street to the site of the current supermarket.

The existing flooding problem at Bungendore has been documented in the *'Bungendore Flood Study'* (*Issue No 3*) which was published in 2002. Investigations undertaken as part of the Flood Study determined that flooding of the streams that drain through the village can result in damage to both public and private property. Severe flooding can occur in response to intense rainfall in the upstream catchment. If this rainfall occurs overnight, the rapid rate of rise of floodwaters could present as a major risk for loss of life among those who reside near the creeks.

Therefore, the existing flooding problem at Bungendore is both real and potentially life threatening.

The Floodplain Risk Management Plan is to be based on a range of strategies and mitigation measures that address the existing, future and continuing flood problems in accordance with the NSW Government's *Flood Prone Land Policy*. The primary objective of the Government's *Flood Prone Land Policy* is to reduce the impact of flooding on individual owners and occupiers of flood prone land, and to reduce private and public losses caused by flooding. In this regard, the Policy recognises:

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

The NSW Government's *Floodplain Management Program* provides Council's with funding opportunities for the identification and implementation of options aimed at reducing flood damages and supporting implementation of the *Flood Prone Land Policy*. The *'Bungendore Flood Study'* (*2002*) established that the potential for flood damages at Bungendore is real and that major flooding could result in loss of life, particularly if that flooding led to unexpected overtopping of the Turallo Creek Levee.

Accordingly, it was considered appropriate to proceed to the assessment of options for reducing the potential for these flood damages to arise and to reduce the risk for loss of life. The associated assessment is documented in the *'Bungendore Floodplain Risk Management Study'* (*Issue No 6, March 2013*).

This Plan documents the preferred floodplain risk management options for Bungendore arising from the 2013 investigations and incorporates them into a program of works that identifies the likely cost of each measure and their projected benefit to the local community.

1.2 FLOOD BEHAVIOUR

1.2.1 Design Flood Levels

Design flood levels have been determined for the Turallo Creek, Halfway Creek and Millpost Creek floodplains at Bungendore for a range of hypothetical flood events, including the Probable Maximum Flood (*PMF*).

Flood level profiles along Turallo Creek are shown in **Figure 1.2**.

Flood level contour maps for the range of design events are provided in **Figures 1.3** to **1.7**, which also show the maximum extent of inundation.

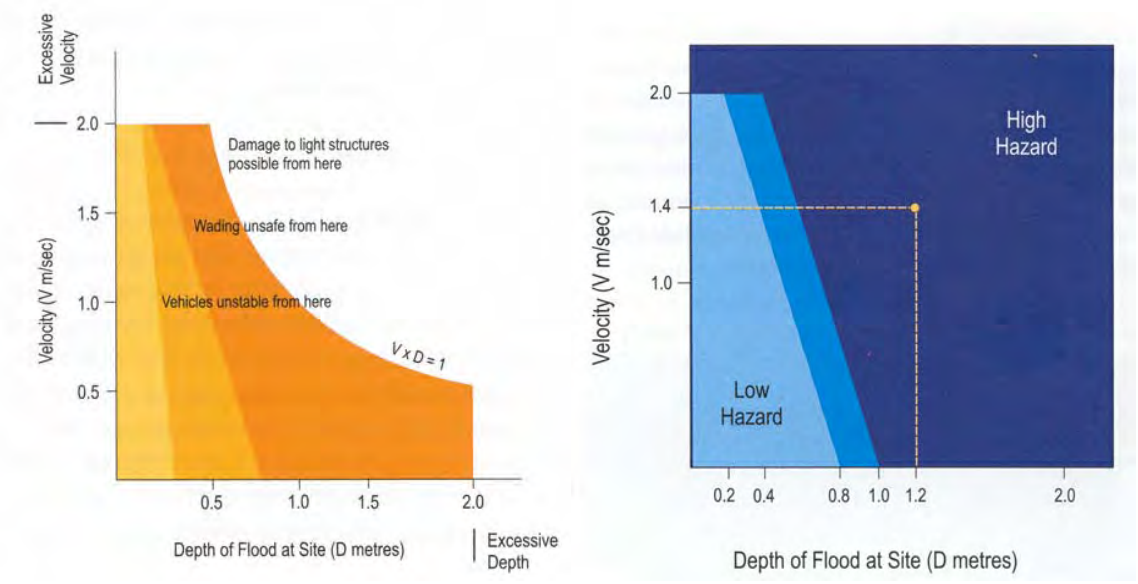
As shown, flooding will lead to inundation of residential areas in Bungendore during the design 1% Annual Exceedance Probability (*AEP*) event, otherwise known as the 1 in 100 year average recurrence interval event. The affected properties are typically situated adjacent to Turallo and Halfway Creeks.

1.2.2 Flood Hazard

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

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

The NSW Government's *'Floodplain Development Manual'* (*2005*), divides hazard associated with flooding into two categories, namely, high and low hazard. An interpretation of the hazard at a particular site can be established from the following graphs, which have been taken directly from the Manual.



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

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

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

The results from computer modelling undertaken as part of the *'Bungendore Floodplain Risk Management Study'* (*2013*) were used to determine the variation in flood hazard across the floodplain at Bungendore.

Spatial and temporal distributions of flow, velocity and water level determined from the computer modelling undertaken as part of the *'Floodplain Risk Management Study'* (*2013*), were used to determine the flood hazard along the Turallo Creek, Halfway Creek and Millpost Creek floodplains.

For the purpose of understanding how the flood hazard affects existing development and areas of potential future development, it is useful to further subdivide areas falling within the high hazard category, into High Hazard, Very High Hazard and Extreme Hazard. Similarly, the low hazard category defined in the Manual has been subdivided to create a Low Hazard and a Medium Hazard category.

The greater refinement of the categories allows floodplain areas to be further differentiated for the purpose of better understanding how the flood hazard affects existing developments and areas of potential future development.

A summary of the hydraulic criteria adopted for each hazard category is provided in **Table 1**. These criteria are also represented graphically in **Plate 1**.

Table 1 ADOPTED HYDRAULIC HAZARD CRITERIA

HAZARD CATEGORY	CRITERIA	PRACTICAL APPLICATION
Low	Depth (d) < 0.4 m & velocity (v) < 0.5 m/s	Car movements possible (*vehicle instability unlikely*)
Medium	exceeding Low criteria, and $d \leq 0.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 0.5$	Heavy vehicle movements and wading by able bodied adults possible
High	exceeding Medium criteria, and $d \leq 1.8$ m, $v \leq 2.0$ m/s, and $v \times d \leq 1.5$	Light timber frame and brick veneer construction are likely to withstand impacts
Very High	exceeding High criteria, and 0.5 m/s < velocity < 4 m/s & $v \times d \leq 2.5$	Heavy steel frame and concrete construction are likely to withstand impacts
Extreme	exceeding Very High criteria and v > 4 m/s	Unsuitable for any development – indicates significant conveyance of flow or floodway

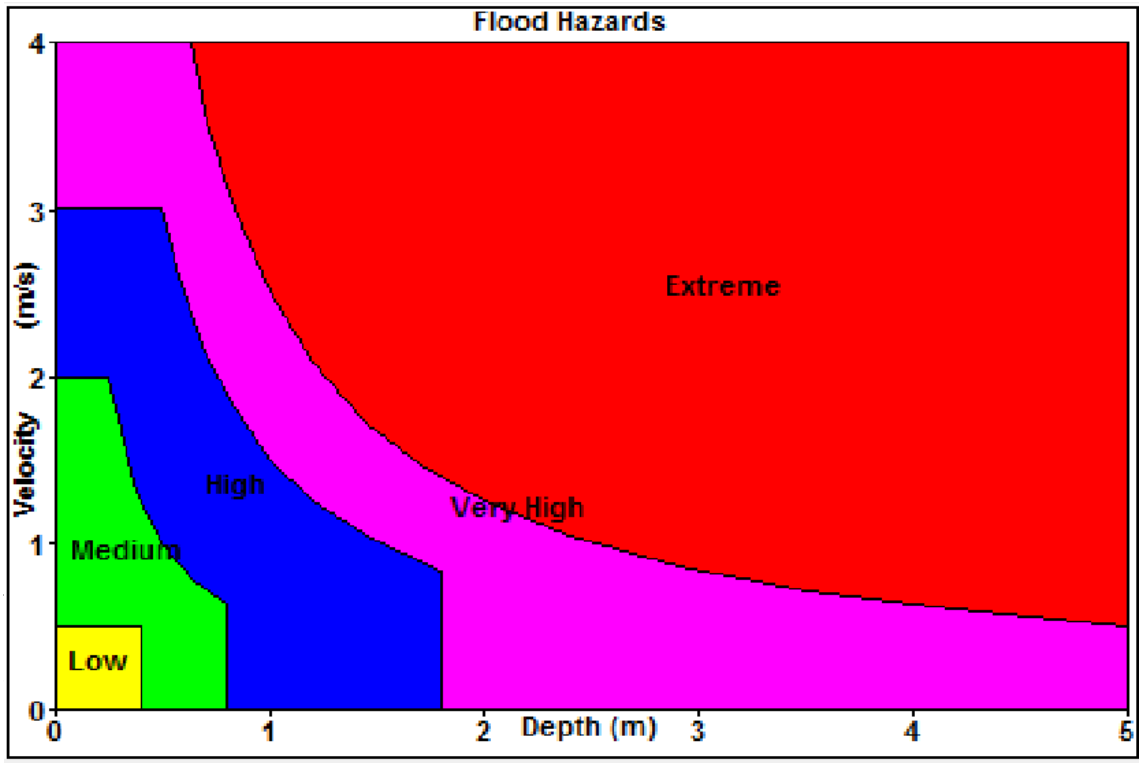


Plate 1 GRAPHICAL REPRESENTATION OF ADOPTED HYDRAULIC HAZARD CATEGORIES

As shown, **Plate 1** and **Table 1** effectively divide the flood hazard into five categories. It should be noted that these criteria define the provisional or hydraulic hazard only. This is because they are based only on an interpretation of the flood hydraulics and do not consider the significance of other factors that can influence flood hazard, such as the potential for evacuation or the rate of rise of floodwaters.

Provisional or hydraulic hazard mapping was generated using the hydraulic characteristics of flooding (*i.e., velocities, depths and velocity-depth product*) derived from flood modelling undertaken as part of the Flood Study and the Floodplain Risk Management Study. This provisional hazard mapping is included within the *'Bungendore Floodplain Risk Management Study'* (*March 2013*).

As part of the development of this Plan, additional factors such as the rate of rise of floodwaters, evacuation potential and effective flood-free access were considered as part of the process involved in developing '*True*' flood hazard mapping. The True Flood Hazard Mapping for Bungendore is presented in **Figures 1.8** to **1.10**.

It should be noted that the mapping is based on the hydraulic characteristics of flooding, but in line with the Manual, also considers the potential for areas of the floodplain to become low flood islands where residents could be surrounded by high hazard flood conditions. The hazard for these areas has been increased to the hazard of the surrounding areas as part of the process in generating the adopted and 'true" hazard mapping.

The mapping indicates that a large proportion of the floodplain would be subject to a high to very high flood hazard. Only localised parcels of the floodplain, most of which are located within the creek channels, are predicted to be classified as extreme hazard.

As shown in **Figure 1.8**, a number of properties along Halfway Creek along Molonglo Street between Malbon Street and Turallo Terrace fall within the high hazard area. However, the majority of inundated properties are located on land that would be classified as low to medium flood hazard areas.

1.2.3 Hydraulic Category Mapping

The results of computer modelling undertaken as part of the Floodplain Risk Management Study were also used to prepare hydraulic category mapping for the Turallo Creek, Halfway Creek and Millpost Creek floodplains.

Hydraulic category mapping separates the floodplain/s into areas of:

- Floodway
- Flood Storage
- Flood Fringe

Floodways are those areas of a floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels and are areas that if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood level. By definition floodways are areas of high flow conveyance and can typically be identified by areas of high flow velocity.

The blocking of floodways typically results in significant impacts on flood characteristics such as increases in predicted peak flood level and changes in flow velocities. Therefore, it is important to define floodways in floodplain risk management studies and plans so that areas where development is undesirable can be identified.

The floodway investigations undertaken for the Bungendore Floodplain Risk Management Study involved an analytical assessment of all available hydraulic, topographic and cadastral data-sets. It also involved flood modelling to test the hydraulic impact of partial blockage of identified floodway corridors. An iterative process similar to that outlined by Thomas et al (*2012*) was followed.

Following determination of those areas of the floodplain categorised as floodway, investigations were focused towards identifying the remaining flood storage and flood fringe.

As outlined in the NSW Floodplain Development Manual (*2005*) flood storage and flood fringe make up the remainder of the floodplain outside of the floodway corridor.

Flood storage areas are typically defined as those flood prone areas that afford significant temporary storage of floodwaters during a major flood. If filled or obstructed (*through the construction of levees or road embankments or building platforms*) the reduction in storage would be expected to result in a commensurate increase in flood levels in nearby areas.

The remaining flood prone areas not classified as floodway or flood storage are termed flood fringe. In order to determine the boundary between flood storage and flood fringe, the variation in peak flood depths in areas outside of the floodway extent were mapped to identify areas inundated to depths of approximately 0.3 metres.

For the study area, a depth of 0.3 metres was selected as the transitionary point between flood storage and flood fringe. Depths below 0.3 metres are generally considered to correspond to areas where negligible flow is conveyed, and represent a relatively small proportion of the available storage for floodwaters. These areas, if filled, are unlikely to have any impact on flood levels or patterns of floodwater distribution.

The hydraulic category mapping that was generated for the floodplains of Turallo Creek, Halfway Creek and Millpost Creek is shown in **Figures 1.11** to **1.13**.

2. EXISTING FLOOD PROBLEM

2.1 GENERAL

The existing flooding problem relates to those areas where flood damages are likely to arise as a consequence of flooding. It concerns existing dwellings, industrial complexes and commercial premises that would be inundated during a flood, as well as all associated infrastructure within the floodplain, including roads, railways and utility services.

In this context, the existing flooding problem is usually addressed by structural measures which aim to modify flood behaviour and thereby reduce flood damages.

2.2 FLOOD DAMAGES

Data defining the floor levels of structures in and around the village that could be inundated by floodwaters was provided by Palerang Council. This data was used with peak flood levels generated from flood modelling to determine the depth of flooding in the vicinity of each building. This allowed the depth of 'over floor' flooding to be determined (*if any*). The depth of flooding at each property was converted to a dollar value of damages using depth-damage curves developed for each property type (*e.g., residential, industrial*).

Damage costs were assigned to individual buildings according to the depth of inundation and the associated 'damage' as reflected in the applicable stage-damage curve. The elevation of residential properties was also extracted from the modelled digital terrain surface in order to determine the costs associated with damage to residential property.

Because flood level information was not available for all properties located within the floodplain, an estimate of floor levels for residential, commercial and industrial properties were estimate by assuming that they were 0.3 metres above the existing ground surface.

Properties affected by flooding in the 1% AEP event are listed in **Appendix A**. Residential dwellings and commercial premises that could be inundated during a 1% AEP flood include:

- houses on the northern side of Gibraltar Street between Molonglo Street and Ellendon Street;
- houses on the western side of Molonglo Street between Gibraltar Street and Malbon Street;
- houses on the eastern side of Molonglo Street between Gibraltar Street and Malbon Street;
- houses on the northern side of the intersection between Turallo Terrace and Butmaroo Street;
- a house on the corner of Turallo Terrace and Mecca Lane;
- a house on the eastern side of Duralla Street between Turallo Terrace and Gibraltar Street;
- a house on the northern floodplain of Turallo Creek south of Elmslea Estate;
- service station on the corner of Molonglo Street and Gibraltar Street.

The relative cost of the potential flood damages is typically expressed in terms of the Average Annual Damage (*AAD*), which represents the average damage per year that would occur from flooding over a very long period of time. Based on the damages analysis presented in **Table 2**, the Average Annual Damage (*AAD*) for Bungendore is estimated to be about **$438,200** (*2012 dollars*). This estimate of the AAD is based on the total tangible damages only. That is, the calculations do not consider the potential intangible costs that are likely to be experienced, particularly during the larger floods.

Intangible flood damages are those that are unable to be quantified in monetary terms. These damages are related to the physical and mental health of individuals, environmental concerns, the ability to undertake necessary evacuation measures and disruption to essential community services and operations. It is possible that the intangible damage cost could be as high or higher than the total tangible damage cost.

Table 2 EXISTING FLOOD DAMAGES

FLOOD EVENT	RESIDENTIAL		COMMERCIAL & INDUSTRIAL		INFRASTRUCTURE DAMAGES	TOTAL
	Number^	Damages	Number	Damages		
20% AEP	18 (2)	$207,800	2	$442,500	$195,100	$845,400
5% AEP	31 (7)	$516,400	3	$664,700	$354,300	$1,535,400
1% AEP	53 (21)	$1,367,600	8	$1,005,700	$712,000	$3,085,400

^ *Number subject to over-floor inundation shown in parentheses*

2.3 OPTIONS TO ADDRESS THE EXISTING FLOOD PROBLEM

According to the *'Floodplain Development Manual'* (*2005*), floodplain risk management options are separated into the following categories:

- **Flood Modification Measures** - these are typically structural works, such as flood protection levees, flood detention basins or bypass floodways.
- **Property Modification Measures** - these measures typically include flood planning measures for future development and can also include voluntary house raising and purchase, or flood-proofing of buildings.
- **Response Modification Measures** - these typically include emergency response management measures, flood predictions and warnings and community flood awareness and preparedness.

Measures to address the existing flood problem typically comprise a mixture of flood modification measures and property modification measures. These measures are typically focussed toward reducing existing flood damages.

The flood modification measures that were investigated for Bungendore as part of the Floodplain Risk Management Study are listed in **Table 3**.

Table 3 INVESTIGATED FLOOD MODIFICATION MEASURES

MEASURE No.	DESCRIPTION OF MEASURE	OVERVIEW
1	Upgrading and extension of levee along Turallo Terrace	*Refer* Figure 2.1
2	Upgrading of the Turallo Terrace levee (*no extension*)	*Refer* Figure 2.1
3	Installation of overflow channel across Tarago Road	*Refer* Figure 2.2
4	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks	*Refer* Figure 2.2
5	Installation of diversion channel from Halfway to Millpost Creek	*Refer* Figure 2.2
6	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and excavation to construct a diversion channel	*Refer* Figure 2.3

An initial hydraulic assessment was undertaken for each of these measures with a view to establishing the likely benefit that they might afford in terms of reduced flood damages. Council's Floodplain Risk Management Committee considered the results from the analysis and determined a series of Flood Modification Options for further investigation. These options comprise combinations of the various Flood Modification Measures listed in **Table 3**.

The Flood Modification Options that were identified for further investigation are listed in **Table 4**.

Table 4 POTENTIAL FLOOD MODIFICATION OPTIONS

OPTION	DESCRIPTION
S1	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks
	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and excavation to construct a diversion channel
S2	Upgrading and extension of levee along Turallo Terrace
	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks
	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and selective excavation
S3A	Upgrading and extension of levee along Turallo Terrace
	Installation of overflow channel across Tarago Road
	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks
	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and selective excavation
S3B	Upgrading of the Turallo Terrace (*no extension*)
	Installation of overflow channel across Tarago Road
	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks
	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and selective excavation
S4A	Upgrading and extension of levee along Turallo Terrace
	Installation of overflow channel across Tarago Road
	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks
S4B	Upgrading of the Turallo Terrace levee (*no extension*)
	Installation of overflow channel across Tarago Road
	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks

2.4 ASSESSMENT OF FLOOD MODIFICATION OPTIONS

2.4.1 Hydraulic Assessment

The RMA-2 flood model was updated and used to simulate flood behaviour with each of the proposed options in place. The impact of each management option was then quantified by developing flood level difference mapping for each option.

Difference maps are created by comparing peak flood level estimates at each node in the RMA-2 model from simulations undertaken for both existing and post-development (*i.e., incorporating the proposed management options*) scenarios. This effectively creates a contour map of predicted changes in peak flood levels and flow velocities and allows easy determination of the impact that each proposed management options is likely to have on existing flood behaviour.

The difference mapping for each option can be viewed in the *'Bungendore Floodplain Risk Management Study'* (*Issue No 6, March 2013*).

2.4.2 Benefit-Cost Assessment

A benefit-cost analysis was undertaken to assess the economic viability of implementing the potential flood management options. The cost of construction works was estimated and compared with the predicted monetary benefit offered by each option in terms of the reduction in flood damages.

The reduction in Average Annual Damage (AAD) for each management option relative to the AAD that would be incurred under existing conditions was used to determine the total net present value of the 'benefit' provided by the option, considering a design life of 30 years for each option and a real discount rate of 7%. The 'cost' is an estimate of the present value of capital costs plus on-going maintenance costs (*refer* **Appendix B**).

The flood damages costs for each option are provided in **Table 5**. The existing damages have been included for comparison. As shown, Option S3A provides the greatest reduction in damages. The damages for Option S3A are reduced by 54% during the 20% AEP flood, 59% during the 5% AEP flood and 69% during the 1% AEP event. Option S1 offers the least reduction in flood damages.

The results of the benefit-cost analysis for each option are presented in **Table 6**.

Option S4B is the most cost-effective floodplain management option with a Benefit-Cost Ratio (*BCR*) of 1.6. This is largely due to the comparatively low present value of the costs to implement compared to most other proposed options. Furthermore, the present value of benefits is also significant and is the highest of the all the options.

Option S1 is also predicted to return a BCR greater than 1 and as such, is considered to provide a reasonable return on investment.

Table 5 FLOOD DAMAGES ASSOCIATED WITH EACH FLOOD MODIFICATION OPTION

OPTION	FLOOD DAMAGES		
	20% AEP EVENT	5% AEP EVENT	1% AEP EVENT
Existing	*845,300*	*1,535,300*	*3,085,400*
S1	454,800	747,200	1,877,800
S2	454,800	668,300	1,204,500
S3A	389,900	629,300	964,000
S3B	454,800	707,000	1,360,000
S4A	288,000	828,800	1,504,600
S4B	286,800	865,400	1,800,000

Table 6 BENEFIT-COST RATIOS FOR FLOOD MODIFICATION OPTIONS

OPTION	CAPITAL COST	PRESENT VALUE OF COSTS	PRESENT VALUE OF DAMAGES REDUCTION	BENEFIT-COST RATIO
S1	$1.7M	$1.6M	$2.1M	1.3
S2	$4.2M	$3.7M	$2.1M	0.57
S3A	$4.8M	$4.1M	$2.4M	0.57
S3B	$3.0M	$2.7M	$2.3M	0.83
S4A	$3.4M	$3.0M	$2.3M	0.76
S4B	$1.6M	$1.5M	$2.4M	1.6

3. FUTURE FLOOD PROBLEM

The potential *future* flooding problem refers to those areas of the floodplain that are likely to be proposed for future development or to be the subject of future rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise have been avoided. These pressures can result in undesirable development in the floodplain which can create a future flooding problem for an area with the potential to lead to increased flood damages.

Council has a duty of care to ensure that its current planning instruments recognise the potential flood risk. Council also has a responsibility to ensure that a Floodplain Risk Management Plan is in place and that this Plan, or an associated *Flood Policy*, can be used to support decisions to approve, modify or reject development that is proposed on flood affected areas.

Accordingly, it is appropriate to consider the potential future flooding problem at Bungendore and to identify Planning Modification Measures that if implemented, would serve to reduce the potential for this future flooding problem to manifest. The following sections provide a summary of the existing planning instruments that reference flood constraints in guiding development and opportunities for improved planning in flood affected areas.

3.1 CURRENT PLANNING INSTRUMENTS

The *Yarrowlumla Local Environmental Plan 2002* and the *Palerang Development Control Plan YLEP 2002 2(v) Village Zone* currently apply to Bungendore. Both documents contain provisions relating to flood. However, it is anticipated that the local environmental plan and the other five local environmental plans applying to various parts of the Palerang local government area (LGA) will be replaced in the second half of 2014 with one local environmental plan for the entire Palerang LGA. The *Palerang Development Control Plan YLEP 2002 2(v) Village Zone* will also be replaced in late 2014.

Both of these documents are discussed in the following sections.

3.2 PROPOSED PLANNING INSTRUMENTS

3.2.1 Draft Palerang Local Environmental Plan 2014

The draft local environmental plan uses the Standard Instrument as required under the NSW Environmental Planning & Assessment Act 1979. The plan includes a model flood clause which the Department of Planning and Environment requires all Councils to use where there is a flood hazard in an urban area. The majority of the residential areas of Bungendore are zoned *R2 Low Density Residential*, with small areas zoned *R1 General Residential* and the central part of the town zoned *B2 Local Centre* and *B4 Mixed Use*.

There is also an area in the north-west part of the town zoned *R5 Large Lot Residential* as well as an area of *E2 Environmental Conservation*. The overbank areas adjacent to Turallo Creek are zoned as *RE1 Public Recreation*. The rural areas surrounding Bungendore are generally zoned *RU1 Primary Production*.

The draft local environmental plan uses the term flood planning level which is defined as the level of a 100 average recurrence interval (ARI) flood event plus 0.5 metres freeboard.

The Flood Planning Area for Bungendore is shown on the flood planning map that is contained in the draft Palerang Local Environmental Plan (*and reproduced here in* **Appendix D**). The flood planning map is based on the results of the flood modelling that was undertaken by WorleyParsons for the *'Bungendore Floodplain Risk Management Study'* (*2013*). It is based on peak flood levels generated for the 1% AEP flood, plus 500 mm freeboard.

The flood related clause contained within Council's draft local environmental plan applies to land that falls within the extent of the flood planning level defined by this mapping.

The flood planning clause states that development consent must not be granted unless the consent authority (*in most instances Council*) is satisfied that the development:

- is compatible with the flood hazard of the land; and,
- will not adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties; and,
- incorporates appropriate measures to manage risk to life from flood; and
- will not adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability or river banks or watercourses; and,
- is not likely to result in unsustainable and economic costs to the community as a consequence of flooding.

The draft local environmental plan also states that exempt or complying development cannot be carried out on land that is shown as *flood planning area* on the flood planning map or is within 40 metres of the bank of a waterway.

It should be noted that at the time of writing the Bungendore Floodplain Risk Management Plan the draft Palerang Local Environmental Plan was being considered for gazettal and the above provisions may change prior to gazettal. It is acknowledged that Council will be unable to amend the draft LEP prior to gazettal and that the recommended changes in this Floodplain Risk Management Plan will need to be considered as potential amendments to the PLEP 2014.

3.2.2 Draft Palerang Development Control Plan

At the time of writing, a draft development control plan was being prepared by Council for the Palerang LGA. The comments and recommendations in this Floodplain Risk Management Plan are based on the preliminary draft of the DCP. Significant changes to the DCP are expected prior to exhibition and adoption. It is expected that the draft Palerang Development Control Plan will be exhibited and adopted in 2014.

The Development Control Plan will use the same terminology as the draft Palerang Local Environmental Plan. It will include building controls to address flood constraints and will outline flood impact assessment requirements.

3.3 POTENTIAL ISSUES WITH PLANNING INSTRUMENTS

As outlined in **Section 3.2**, the draft Palerang LEP has been developed from the Standard Instrument as required by the Department of Planning and Environment.

However, there are a number of potential issues associated with blanket implementation of the Standard Instrument that can result in critical flood related constraints being overlooked in land use planning. A commentary on the issues is provided in the following.

(i) **Need for recognition of flood risk on land above the 1% AEP flood level for all development types**

Identification and management of flood risks associated with events rarer than the 1% AEP flood is of critical importance to disaster management. The Standard Instrument infers that flood risk management and disaster planning should be restricted to areas defined by the Flood Planning Area which corresponds to the area captured by the 1% AEP flood level plus 500 mm freeboard.

This means that there is potential for inappropriate development to occur on areas outside the Flood Planning Area but which are below the level of the Probable Maximum Flood.

There is also uncertainty in considering the impact of the PMF within the FPA particularly as it relates to public safety.

An example of this would be the potential siting of a sensitive vulnerable development or emergency facility such as a hospital in the area between the extent of the FPA and the PMF. Typically the siting of a hospital in this area would be unacceptable. However, blanket application of the flood related clause in the Standard Instrument may result in it being missed in the development assessment process or being considered permissible.

It is recommended that the draft DCP that is being developed by Council address this issue.

(ii) **Need for clear definition of "Significant Adverse Impacts" in the flood clause referred to in the Standard Instrument LEP**

Both Clause 7.3 of the Standard Instrument and the Section 117(2) Direction 4.3 refer to "significant adverse impacts" or similar phrases in several locations. Experience has shown that to define "significant adverse impacts", let alone evaluate whether a development proposal will have "significant adverse impacts", is extremely difficult and often leads to varying subjectivity of the impacts.

It is recommended that in developing Council's draft DCP that it specifically refer to the 2005 Floodplain Development Manual for an appropriate methodology for the assessment of flood impacts.

(iii) **Need for a mechanism for identifying areas beyond the FPA that could become a flood island in floods rarer than those covered by the extent of the FPA.**

This issue is related to Item (i) above.

Land at Bungendore that is below the flood planning level is defined in the draft LEP with reference to a Flood Planning Map. As outlined above, the flood planning level is equivalent to the 1% AEP flood level plus 500 mm. Hence, there may be areas outside the extent of the flood planning area that are inundated in floods rarer than the flood that generates a level equivalent to the 1% AEP flood plus 500 mm; for example, floods between the 0.2% AEP and the PMF.

This presents an emergency response management issue because there may be areas beyond the flood planning area which present as low flood islands in these rarer floods and which are not identified by the mapping that accompanies the LEP.

Accordingly, it is recommended that the draft DCP include a clause that highlights the importance of considering flooding up to the extent of the PMF and in accordance with the 2005 Floodplain Management Manual. It is also recommended that the flood extent of the 0.2% AEP event be mapped and incorporated within an updated version of the Palerang Flood Emergency Sub Plan to provide a mechanism for identifying potential low flood islands in areas of the floodplain between the FPA extent and the PMF extent.

(iv) **Need for a mechanism to be defined within the draft LEP for managing future changes to Council's knowledge of FPAs**

As outlined above, the draft Palerang LEP references the Flood Planning Map which specifies the Flood Planning Area for Bungendore, or the area where flood considerations need to be addressed. Therefore, the Flood Planning Map is integral to the draft LEP and any changes to it that may be required due to improved flood knowledge or data, revised flood modelling or even changes in flood characteristics due to implementation of recommendations arising from this Plan, will require amendment to the Map. Any amendment to the Map is likely to be considered as an amendment to the LEP, which in turn will require exhibition and subsequent gazettal.

3.4 MEASURES TO ADDRESS THE FUTURE FLOOD PROBLEM

Property modification measures include planning measures and controls aimed at preventing development that is not compatible with the flood risk or hazard, and which if implemented would result in increased or additional flood damages. They also include voluntary purchase and voluntary house raising options.

Accordingly, it follows that Property Modification Measures can include amendments to planning instruments such as LEPs, DCPs and flood policies, to make them consistent with the topographic and flood data arising from the flood investigations that have been completed for this project and contemporary policy. The following outlines the Property Modification Measures that were recommended through the Floodplain Risk Management Study process for inclusion with the Plan.

3.4.1 Option P1 – Consider Suggested Amendments to the Flood Related Controls in the Draft LEP and the Draft DCP

The following general comments are provided on the flood related controls within the draft LEP and DCP.

- It is noted that the draft LEP and the draft DCP do not use consistent terminology for the 1% AEP flood. At places it is referred to as the 1% AEP flood and in other places the 1:100 ARI event. The latter approach does not imply any set reference to the interval period (*i.e., year*) and it is recommended that it should not be used or referred to as the 1 in 100 year ARI flood.

  A draft Discussion Paper prepared as part of the current Australian Rainfall & Runoff Revision Project attempts to clarify the terminology currently in use across the industry and that proposed for future use. The range of available terminology includes Average Recurrence Interval (*ARI*), Annual Exceedance Probability (*as % or "1 in X"*) and Exceedances per Year (*EY*).

  The National Committee on Water Engineering and the National Flood Risk Advisory Group (*NFRAG*), has indicated a preference for EY to be used for lesser events, including up to the 0.5 EY and 0.2 EY events (*2 and 5 year ARI events, respectively*).

  For larger events up to the 2,000 year ARI flood, the % AEP terminology is to be used, which includes the 1% AEP event, such as referenced in Council's flood planning controls.

- The preliminary draft DCP indicates that development within high hazard areas will not be considered. However, such a control can be over-limiting on particular parcels of land.

  For example, a site may be classified as high hazard due primarily to large depths across the site (*even if velocities are low*). In this case, the filling of such a site may not result in significant flood impacts, despite the loss in flood storage, although this may create cumulative impacts if filling of flood storage areas is uncontrolled.

A merits based approach is recommended, which would require detailed assessment (*likely involving flood modelling*) to confirm that flood level and velocity impacts are acceptable.

Should future development in Bungendore involve substantial filling of flood storage areas, Council should undertake a cumulative impact assessment.

- In finalising the Palerang LEP, Council should consider the recommendations outlined in **Section 3.3** for each of Items (i) to (iv).

3.4.2 Option P2 – Develop a Flood Policy for Bungendore

It is recommended that a formal flood policy be developed in conjunction with the DCP that Council is currently preparing. This flood policy should incorporate details of a development assessment process that ensures a merit based assessment of development proposals but which takes advantage of the flood data that has been generated from work undertaken for the *Bungendore Floodplain Risk Management Study*.

This new data includes flood fringe, flood storage and floodway extent mapping, emergency management data including critical road level information, and provisions for the impact of climate change.

It is suggested that the following steps form the basis for development assessment. These steps are summarised in the flow chart provided as **Figure 3.1**.

Step 1 Establish whether the site of the proposed development falls within the Flood Planning Area (*FPA*) as defined by the Bungendore Flood Map.

If critical infrastructure / services are proposed on the land, assess whether the land falls within the area between the FPA and the PMF extent.

Step 2 If the development site falls within the FPA, establish whether the proposed land use is appropriate relative to the flood conditions. This should consider peak flood level, depth, hazard and the location of the site relative to floodway, flood storage and flood fringe areas that have been mapped in this study and similar studies.

Step 3 If the development site falls within a designated floodway, development should be refused.

Step 4 If the development site falls within a designated flood fringe or flood storage area, then consideration of the development proposal can proceed in accordance with the flood-related requirements of the new DCP.

Step 5 The development site should be assessed relative to the requirements of the DCP to establish whether:

(i) a Flood Impact Assessment is required, involving an assessment of the potential for adverse impacts on adjoining property measured in terms of increases in peak flood level and/or flow velocity;

(ii) whether a Flood Risk Assessment is required, measured in terms of the risk to future occupants of the site, including consideration of evacuation potential; or,

(iii) whether both a Flood Impact Assessment and a Flood Risk Assessment are required.

Step 6 Ensure the proponent undertakes investigations required to address the conclusions drawn from completing Step 5, viz.:

- Undertake flood modelling as required to complete a Flood Impact Assessment for the development proposal
- Undertake emergency response management assessment to minimise any risk that the development could result in loss of life.

Step 7 Assess the development proposal and the outcomes from Steps 2 to 6 inclusive relative to the DCP requirements.

4. RESIDUAL FLOOD PROBLEM

Unless the community is free from the impacts of flooding up to the Probable Maximum Flood (PMF), and the PMF is adopted as the basis for determining structural and planning measures, there will always be a residual or continuing flooding problem. However, the adoption of the PMF as the 'planning flood' is not realistic or practical because it would sterilise a large area of land, thereby forcing development to areas of higher ground which may not historically be serviced or which could introduce unrealistically high infrastructure costs.

Hence, a lesser flood standard is adopted. The new Palerang Local Environmental Plan will use the term *flood planning level* as required by the NSW Department of Planning & Environment. The *flood planning level* is defined as the 1% Annual Exceedence Probability flood level plus a freeboard of 0.5 metres. As a result, measures that are put in place to control flood damage will ultimately be overwhelmed by a flood that is larger than that adopted as the threshold for the planning control of land use, or as the limiting flood for the design of structural measures.

Accordingly, it is incumbent upon Council to consider the implications of floods greater than the adopted planning flood and to work with the State Emergency Service (SES) to develop a contingency plan for all events up to the PMF.

4.1 EXISTING PROTOCOLS FOR EMERGENCY RESPONSE

The NSW SES and Palerang Council have prepared Volume 1 of the *Palerang Flood Emergency Sub Plan* (*2013*), which is a sub-plan of the *Lake George Local Emergency Management Plan*. The area covered by the Plan includes the townships of Bungendore, Braidwood and Captains Flat, as well as a number of outlying villages. The Palerang LGA is within the NSW SES Southern Highlands Region and for emergency management purposes is part of the South Eastern Emergency Management Region.

The primary infrastructure for delivering emergency response in Bungendore is shown in **Figure 4.1**. This infrastructure includes:

- the SES Operations Centre, which is located at 106 Ellendon Street;
- Bungendore Public School, which is located along Gibraltor Street and would serve as an evacuation centre during times of flood; and,
- Bungendore Community Centre, which is located at 2 Majara Street, which would also serve as an evacuation centre during times of flood.

The Palerang Flood Emergency Sub Plan (*FESP*) contains various pieces of information that are specific to flood emergency response at Bungendore. This information includes the following.

- The Bureau of Meteorology (*BoM*) provides *Flood Watches* for the Queanbeyan / Molongolo catchments and severe weather warnings when flash flooding is likely to occur (*in the case when significant rainfall is forecasted*). No *Flood Warnings* are issued by BoM for catchments

within the Palerang LGA, but the likelihood of flooding can be inferred from the Flood Watches that are issued for the Queanbeyan / Molongolo River catchments.

- The BoM and the NSW Office of Water (*NOW*) provide SES with real-time or near real-time access to river height data for the development of official flood warnings. However, no river gauges are located upstream of Bungendore on Turallo, Halfway or Millpost Creeks. There is a gauge on Millpost Creek at Bungendore (*# 411001*), but it is not a continuous flood level gauge and is not automatically monitored in real-time.
- The SES is to issue evacuation warnings and evacuation orders through radio and television stations, doorknocking by emergency services personnel, public address systems and telephony based systems, including Emergency Alert.
- The location of evacuation centres will be subject to decisions made by the SES Local Controller during the onset of major flooding, but are nominally identified in the Flood Emergency Sub-Plan as:
  - Bungendore Community Centre at 2 Majara Street, Bungendore
  - Bungendore Public School at Gilbraltor Street, Bungendore

  As shown in **Figure 4.1**, these facilities are expected to remain flood-free during the PMF event.

4.2 EMERGENCY RESPONSE CONSIDERATIONS

The following flood data and flood characteristics have been considered in the review of emergency response measures for Bungendore (*refer* **Figure 4.2**).

4.2.1 Flood Characteristics

Flood inundation mapping prepared from RMA-2 flood modelling undertaken for the *Bungendore Floodplain Risk Management Study* (*2013*) provides details of predicted floodwater depths, levels, velocities and flood hazard for a range of floods. The Study also provides details of the location of flood affected properties and therefore is a source of useful information for emergency management.

4.2.2 Flood Warning Times

The results of the flood modelling undertaken for the *Bungendore Floodplain Risk Management Study* (*2013*) indicates that peak PMF and 1% AEP flood levels along Turallo Creek will occur at Bungendore about 5 hours after the start of flood producing rainfall in the upstream catchment.

Inundation of properties in the western areas of Bungendore Village occurs due to the flooding of Halfway Creek which begins about 1 hour after the commencement of rainfall in the upstream catchment. Most of the properties located between the Kings Highway and Millpost Creek north from Forster Street are affected within 2 hours of the commencement of flood producing rainfall in the upper catchment.

Accordingly, there is limited opportunity to provide advanced warning of flooding to properties along Halfway and Millpost Creeks.

A stream gauge exists in the adjacent Butmaroo Creek catchment to the east of Bungendore, which may provide an indication of the likely flood conditions in Bungendore (*assuming similar rainfall occurs over the adjacent catchment areas*). However, there are no stream gauges that would provide any significant warning time prior to flooding in Bungendore. Hence, there is currently reliance on BoM rainfall forecasts and *Flood Watches* and severe weather warnings for *Flash Flooding*.

4.2.3 Flood Evacuation Constraints

The Kings Highway bridge crossing of Turallo Creek will not be overtopped by floodwaters during the design 1% AEP flood. However, during the PMF, floodwaters will overtop the bridge about 2 hours after commencement of the flood producing rainfall.

The Tarago Road crossing of Turallo Creek will also be flood free at the peak of the 1% AEP flood. However, the southern and northern approaches to the bridge will be inundated in an event of this magnitude. The southern approach will be inundated due to the flooding of Halfway Creek which will begin to be inundated about 2 hours into the storm and once flood levels reach the 20% AEP flood level. The Tarago Road / Kings Highway intersection will be cut off by floodwaters within the first hour of a flood of the magnitude of the PMF.

Bungendore Road will also be cut off by flooding once floodwaters reach the peak level of the 20% AEP flood, due to the flooding of both Millpost and Halfway Creeks.

Therefore, safe evacuation from areas of the Village south of Turallo Creek cannot feasibly occur to the north via Tarago Road (across Turallo Creek), to the west via Bungendore Road or to the south via the Kings Highway, in most flood events. The only available routes into and out of the township south of Turallo Creek during floods exceeding the 20% AEP event (*1 in 5 year ARI flood*) and up to the 1% AEP event, will be to the east via the Kings Highway and to the south via Hoskinstown Road (*Ellendon Street*).

For areas north of Turallo Creek, there is access to the north via Tarago Road, provided sufficient warning is provided.

The results of the flood modelling indicate that the maximum duration of local catchment flooding across overbank areas would be between 5 and 7 hours. This relatively short duration of flooding indicates that any residents evacuating from creek-side properties, that are otherwise cut-off from the designated evacuation centres to the south of Turallo Creek, would not remain isolated for an extended period of time.

4.2.4 Flood Management Communities

The flood characteristics, flood warning times and the flood evacuation constraint data was used to classify areas of Bungendore using the SES system for classification of communities for flood emergency response planning. The resultant mapping of these Flood Management Communities is provided as **Figure 4.2**.

As shown in **Figure 4.2**, most of the study area within the extent of the PMF can be classified as *Rising Road Access Areas*. These are areas where evacuation can safely occur along roads that rise out of the floodplain.

Figure 4.2 shows that flood-free vehicle access to the nominated evacuation centres is possible from all flood affected areas to the south of Turallo Creek.

Figure 4.2 also shows that most areas to the north of Turallo Creek (*Elmslea Estate*) can be evacuated to the north by vehicle along roads that are gradually rising, albeit that no formal refuge area exists or has been identified in the Palerang Flood Emergency Sub Plan. Only a small pocket of houses on the north side of Turallo Creek and adjacent to the Goulburn – Bombala Railway would not be able to be evacuated by vehicle along gradually increasing roads.

Although road access to all lots is possible, evacuation from those identified in this area will require vehicles to travel down to lower areas of the floodplain before evacuation to higher ground can occur. This area is therefore classified as an *Area with Overland Escape Route*. This is because the road access to the north may be cut-off prior to the properties being inundated (*refer* **Figure 4.2**). Once the road becomes closed (*during only very rare events*) local residents will be able to reach safety unassisted by walking overland to flood-free areas to the north.

4.3 MEASURES TO ADDRESS THE RESIDUAL FLOOD PROBLEM

Investigations completed for the *Bungendore Floodplain Risk Management Study* (*2013*) indicate that a significant number of properties experience inundation in floods up to and including the 1% AEP event. Furthermore, flood modelling indicates that warning times for inundation of low lying areas of the town are typically less than 2 hours from the onset of heavy rainfall in the catchment. Therefore, there will be a residual flood problem irrespective of the flood modification measures (*structural* works) that might be implemented as a consequence of this Plan to reduce flood damages, or the property modification measures (*planning measures*) that are proposed.

Measures to address the residual flood problem are referred to as Response Modification Measures. It is recommended that the following Response Modification Measures be implemented in an attempt to improve flood emergency response management at Bungendore.

R1 Assess the benefits and feasibility of installing an automated weather station (*continuous rainfall gauge*) in the upper catchment of Turallo Creek. This would ideally be operated by and linked to the Bureau of Meteorology's flood warning system.

R2 Assess the potential for existing and/or future facilities at North Bungendore to be utilised as assembly areas for evacuees from north of Turallo Creek (*i.e., Elmslea Estate*).

R3 Update the Palerang Flood Emergency Sub Plan with relevant information from this Plan and the *Bungendore Floodplain Risk Management Study* (*2013*) and finalise the Sub Plan to incorporate Volume 2.

It is also recommended that the following measure be implemented to increase community awareness and preparedness for flooding:

R4 Develop and implement a community flood awareness and preparedness program, working with SES to use FloodSafe Program materials.

R5 Update notations on Section 149 (5) certificates to include whether a property is affected by the PMF.

5. FLOODPLAIN RISK MANAGEMENT PLAN

5.1 RECOMMENDED ACTIONS

The following floodplain risk management strategies are recommended for implementation under this Floodplain Risk Management Plan. Further details of the actions associated with each strategy are provided in the *Schedule of Actions* shown as **Tables 5.1**, **5.2** and **5.3**.

FLOOD MODIFICATION MEASURES

S5B. It is recommended that the Option S4B be implemented (*refer* **Figures 2.1** *and* **2.2**), including the following works:

- Upgrade of the existing Turallo Terrace levee (*no extension*) (*Measure 2*)
- Construction of an overflow channel across Tarago Road (*Measure 3*)
- Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks (*Measure 4*).

PROPERTY MODIFICATION MEASURES

P1. That the flood-related planning controls that are proposed within the draft LEP and the draft DCP be finalised recognising the following points and the associated recommendations listed in **Section 3.3** of this Plan:

- Need for recognition of flood risk on land above the 1% AEP flood level for all development types
- Need for clear definition of “Significant Adverse Impacts” in the flood clause referred to in the Standard Instrument LEP
- Need for a mechanism for identifying areas beyond the FPA that could become a flood island in floods rarer than those covered by the extent of the FPA
- Need for a mechanism to be defined within the draft LEP for managing future changes to Council’s knowledge of FPAs

P2. That a specific Flood Policy be developed for the Village of Bungendore to guide development and to assist the determination of development applications.

R5 Update notations on Section 149 (2) certificates to include notification of whether or not the property is within the predicted extents of the PMF.

RESPONSE MODIFICATION MEASURES

R1. Consider the feasibility and benefits of installing an automated weather station (*continuous rainfall gauge*) in the upper catchment of Turallo Creek.

R2. Assess the potential for existing and/or future facilities at North Bungendore to be utilised as assembly areas for evacuees from north of Turallo Creek (*i.e., Elmslea Estate*).

R3. SES to update the Palerang Flood Emergency Sub Plan with relevant information from this Plan and from the *Bungendore Floodplain Risk Management Study* (*2013*).

R4. Develop and implement a community flood awareness and preparedness program, working with SES to use FloodSafe Program materials.

5.2 COSTS, FUNDING, RESPONSIBILITIES AND TIMEFRAMES

The estimated costs, potential funding sources and responsibilities for implementation associated with each recommended measure are provided in **Tables 5.1**, **5.2** and **5.3** for the proposed flood modification works, property modification works and response modification works, respectively.

The total upfront cost of all recommended works and measures is estimated to be approximately **$1.8M**. The priority and relative timeframes for implementation of the recommended measures are provided in the *Implementation Program* contained within the executive summary.

Note that Council's ability to follow the *Implementation Program* will be subject to Council sourcing appropriate funding, and also further investigation and design of such works.

Table 5.1 Bungendore Floodplain Risk Management Plan – Schedule of Actions for Flood Modification Measures

RECOMMENDED STRATEGY		RECOMMENDED ACTIONS	ESTIMATED COST	SUGGESTED RESPONSIBILITY	POTENTIAL FUNDING SOURCES	PRIORITY
Flood Modification Measures						
S4B-1	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks (Measure 4)	1. Undertake environmental assessment to confirm nature, extent and condition of vegetation communities at the proposed works. Undertake flora and fauna survey if required. 2. Design of vegetation clearing works and re-shaping works, including development of appropriate access methods, clearing techniques, environmental controls. 3. Consultation with land owners along sections of proposed clearing. 4. Undertake clearing works.	$280,000	Palerang Council	Palerang Council and Office of Environment & Heritage	HIGH
S4B-2	Upgrade of the existing Turallo Terrace levee (Measure 2)	1. Undertake further design investigations, including modelling if required. 2. Undertake geotechnical investigations to determine condition of existing levee, and prepare appropriate design for upgrading. 3. Prepare Review of Environmental Factors for works adjacent to the creek. 4. Consultation with land owners along sections of proposed upgrade works. 5. Undertake levee upgrade works.	$690,000	Palerang Council	Palerang Council and Office of Environment & Heritage	HIGH
S4B-3	Installation of an overflow channel across Tarago Road (Measure 3)	1. Undertake further design investigations, including modelling if required. 2. Consultation with land owners along channel alignment. 3. Prepare Review of Environmental Factors for works. 4. Undertake overflow channel works.	$595,000	Palerang Council	Palerang Council and Office of Environment & Heritage	HIGH

Notes: (i) Cost estimates are based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry.
(ii) Cost estimates can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers.
(iii) Cost estimates may exclude items which should be considered in a cost plan such as design fees, project management fees, authority approval fees, contractors risk and project contingencies.
(iv) Cost estimates by WorleyParsons are not to be relied upon. If a reliable cost estimate is required, then an appropriately qualified Quantity Surveyor should be engaged

Table 5.2 Bungendore Floodplain Risk Management Plan – Schedule of Actions for Property Modification Measures

RECOMMENDED STRATEGY		RECOMMENDED ACTIONS	ESTIMATED COST	SUGGESTED RESPONSIBILITY	POTENTIAL FUNDING SOURCES	PRIORITY
Property Modification Measures						
P1	Finalise flood related controls within LEP and DCP	1. Compile all available flood mapping for modelled catchments, including flood hazard and hydraulic category mapping, and mapping of the Flood Planning Area (1% AEP level plus 0.5m freeboard). 2. Detailed review of flood related controls and clauses in the draft Local Environmental Plan and Development Control Plan. 3. Workshop draft revisions with Council planners and engineers. 4. Exhibit and adopt revised flood related controls.	$20,000	Palerang Council	Palerang Council and Office of Environment & Heritage	HIGH
P2	Develop a Flood Policy for Bungendore Village	1. Workshop incorporation of revised flood related controls for LEP/DCPs into the existing development assessment process with Council planners and engineers, and (external) floodplain management specialists. 2. Document draft preferred development assessment process. 3. Council review of draft development assessment process. 4. Adopt revised development assessment process.	$10,000	Palerang Council	Palerang Council and Office of Environment & Heritage	HIGH
R5	Update Section 149(2) Certificates to include relevant flood information	Certificates to include notification of whether or not the property is within the predicted extents of the PMF.	-	Palerang Council	-	HIGH

Notes: (i) Cost estimates are based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry.
(ii) Cost estimates can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers.
(iii) Cost estimates may exclude items which should be considered in a cost plan such as design fees, project management fees, authority approval fees, contractors risk and project contingencies.
(v) Cost estimates by WorleyParsons are not to be relied upon. If a reliable cost estimate is required, then an appropriately qualified Quantity Surveyor should be engaged

Table 5.3 Bungendore Floodplain Risk Management Plan – Schedule of Actions for Response Modification Measures

RECOMMENDED STRATEGY		RECOMMENDED ACTIONS	ESTIMATED COST	SUGGESTED RESPONSIBILITY	POTENTIAL FUNDING SOURCES	PRIORITY
Response Modification Measures						
R1	Consider feasibility and benefits of installing an automated weather station (continuous rainfall gauge) in the upper catchment of Turallo Creek	1. Convene meeting with Council, SES, BoM and OEH to consider feasibility for establishing a flood warning system in Bungendore. 2. If outcome from Task 1 identifies benefit, then Council to seek funding to: ▪ Confirm appropriate location for AWS in the upper catchment, according to analysis of typical weather systems. Consider locations with ready access for setup and maintenance. ▪ Engage suitable consultant and/or contractor to design appropriate automated system to provide warnings to SES/Council. This may involve consultation with Bureau of Meteorology to use BOM ALERT network, if deemed appropriate. ▪ Consult with landowners to obtain permission to install AWS. ▪ Install AWS and connect to wider telemetry network. ▪ Establish data sharing agreement with NSW Office of Water.	$30,000	Palerang Council (*with SES, OEH, NOW & BoM*)	Palerang Council / Office of Environment & Heritage / NSW SES	MEDIUM
R2	Consider potential for any future facilities that may be sited north of Turallo Creek to also serve as Flood Evacuation Assembly Area	1. Confirm extent of flood-free land. 2. Identify suitable flood-free facilites (ideally community buildings) and consider potential future facilities that may be constructed with sufficient capacity for the at-risk population. 3. Liaise with owners or managers of identified facilities. 4. Prepare a formal or informal agreement regarding to the use of the facility during a flood event, specifically acknowledging the role of the NSW SES as the 'combat agency' for flooding. 5. Add refuge to SES or Community Services Disaster Refuge database and Local Flood Plan, with associated information on the magnitude of flood that would trigger evacuation to each refuge.	-	NSW SES / Palerang Council / Community Services	-	MEDIUM

Table 5.3 Continued

RECOMMENDED STRATEGY		RECOMMENDED ACTIONS	ESTIMATED COST	SUGGESTED RESPONSIBILITY	POTENTIAL FUNDING SOURCES	PRIORITY
R3	Update the Palerang Flood Emergency Sub Plan	1. Consult with Local and Regional SES officers to update the Sub Plan. 2. Update the Sub Plan to incorporate new flood information from this Floodplain Risk Management Plan, including flood modelling results, the magnitude of flooding that causes road blockage, classification of flood management communities. This data should be tied to SES consequences and evacuation triggers. 3. Incorporate protocols for the dissemination of flood warnings to potentially flood affected residents based on warnings from the proposed upstream rainfall gauge. 4. Warnings should be broadcasted by the local media to assist in reducing the burden of SES in relation to door knocking and ensuring all residents are evacuated. 5. Incorporate the relocation of flood affected residents to the north of Turallo Creek to an appropriate temporary refuge during flooding.	-	NSW SES	NSW SES	HIGH
R4	Develop and implement a Community Flood Awareness and Preparedness Program	1. Develop awareness and education program to target 'at-risk' population (refer Figure 4.2). 2. Determine appropriate methodology to engage 'at risk' population; e.g., brochure drop, with rates notices, public events. 3. Implement Community Flood Awareness and Preparedness Program.	Ongoing	Palerang Council / NSW SES	Palerang Council / NSW SES	HIGH

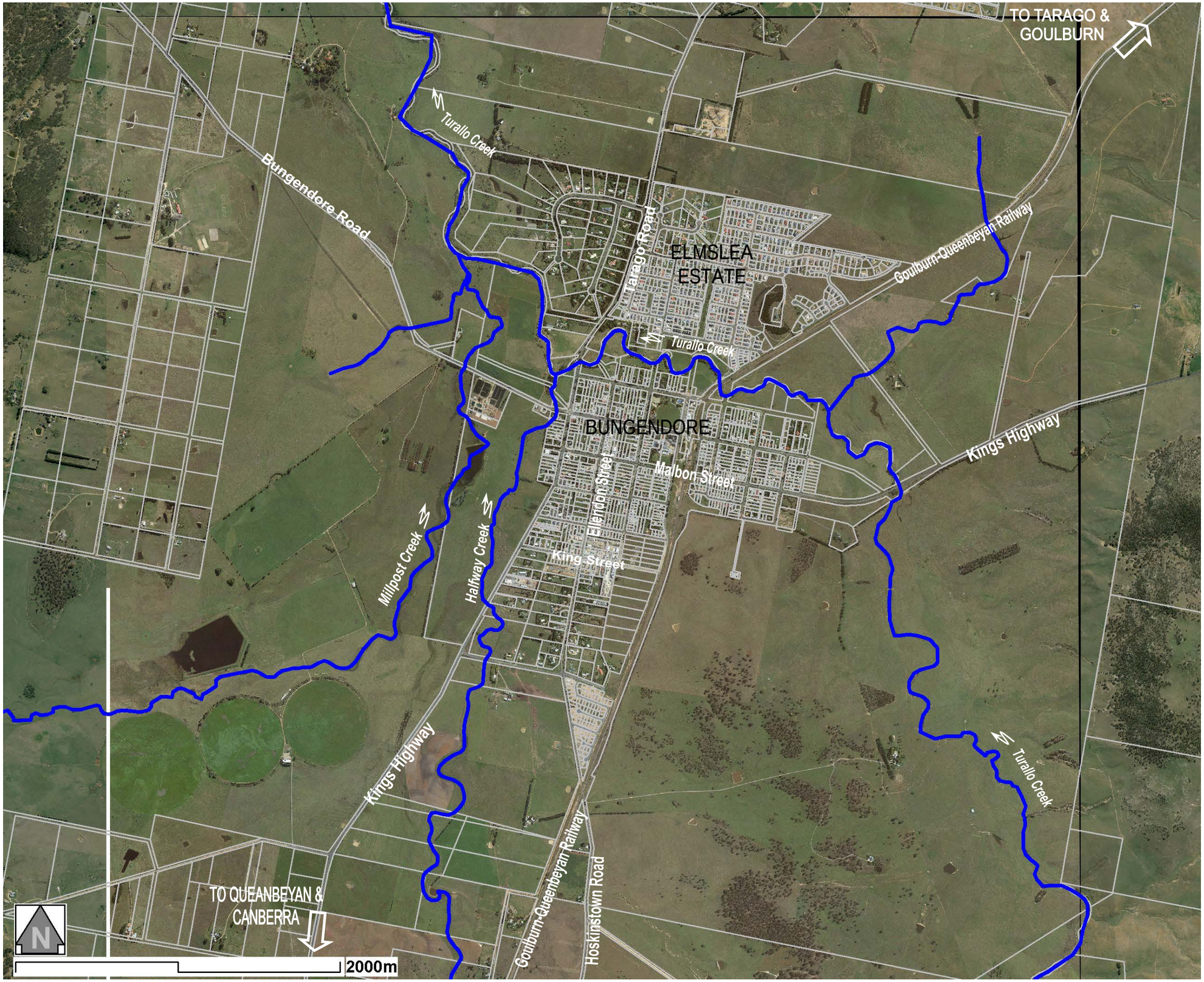
Notes: (i) Cost estimates are based on WorleyParsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry.
(ii) Cost estimates can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers.
(iii) Cost estimates may exclude items which should be considered in a cost plan such as design fees, project management fees, authority approval fees, contractors risk and project contingencies.
(vi) Cost estimates by WorleyParsons are not to be relied upon. If a reliable cost estimate is required, then an appropriately qualified Quantity Surveyor should be engaged.

6. REFERENCES

- New South Wales Government (2005), *'Floodplain Development Manual: the management of flood liable land'*, ISBN 07313 0370 9
- Palerang Council (*2002*), *'Yarrowlumla Local Environmental Plan'*.
- Palerang Council (*2009*), *'Development Control Plan Yarrowlumla LEP 2002 2(v) Village Zone'*.
- Palerang Council (*2013*), *'Draft Palerang Local Environmental Plan'*.
- Palerang Council and NSW SES (*2013*), *'Palerang Flood Emergency Sub Plan'*.
- Patterson Britton & Partners (*2002*), *'Bungendore Flood Study'*; prepared for Yarrowlumla Shire Council (*now Palerang Council*)
- Rawlinsons (*2012*), *'Australian Construction Handbook'*, Edition 30.
- State Emergency Services, Department of Environment and Climate Change (*2007*), *'SES Requirements from the Floodplain Risk Management Process',* Floodplain Risk Management Guideline.
- Thomas C, Golaszewski R, Honour W (*2010*), *'Procedures for Floodway Definition: Is there a Uniform Approach?'* Proceedings of 50th NSW Annual Floodplain Management Authorities Conference.
- Thomas C, Golaszewski R (*2012*), *'Refinement of Procedures for Floodway Delineation'*. Proceedings 52nd Annual NSW Floodplain Management Authorities Conference, Batemans Bay, February 2012.
- WorleyParsons (*2013*), *'Bungendore Floodplain Risk Management Study'*; prepared for Palerang Council.
- Yarrowlumla Shire Council (*2002*), *'Bungendore Flood Study'*; prepared by Patterson Britton & Partners.
- Yarrowlumla Shire Council (*2007, Issue 3 - final draft*), *'Bungendore Floodplain Risk Management Study'*; prepared by Patterson Britton & Partners.

REPORT FIGURES

FIGURE 1.1



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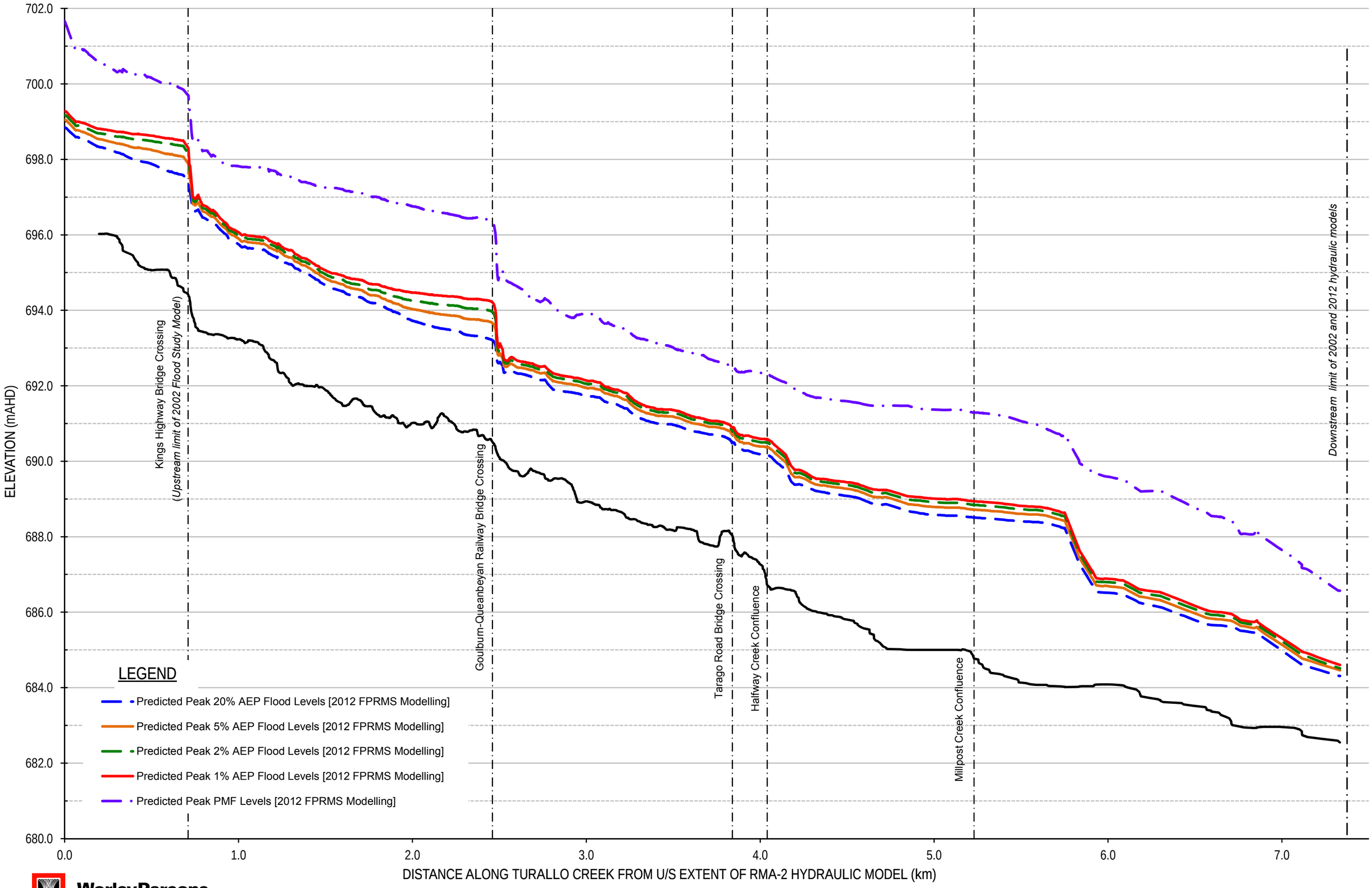
fg3777rg140404-fig1_Study Area.doc

LOCATION OF THE FLOODPLAIN RISK MANAGEMENT PLAN STUDY AREA

FIGURE 1.2



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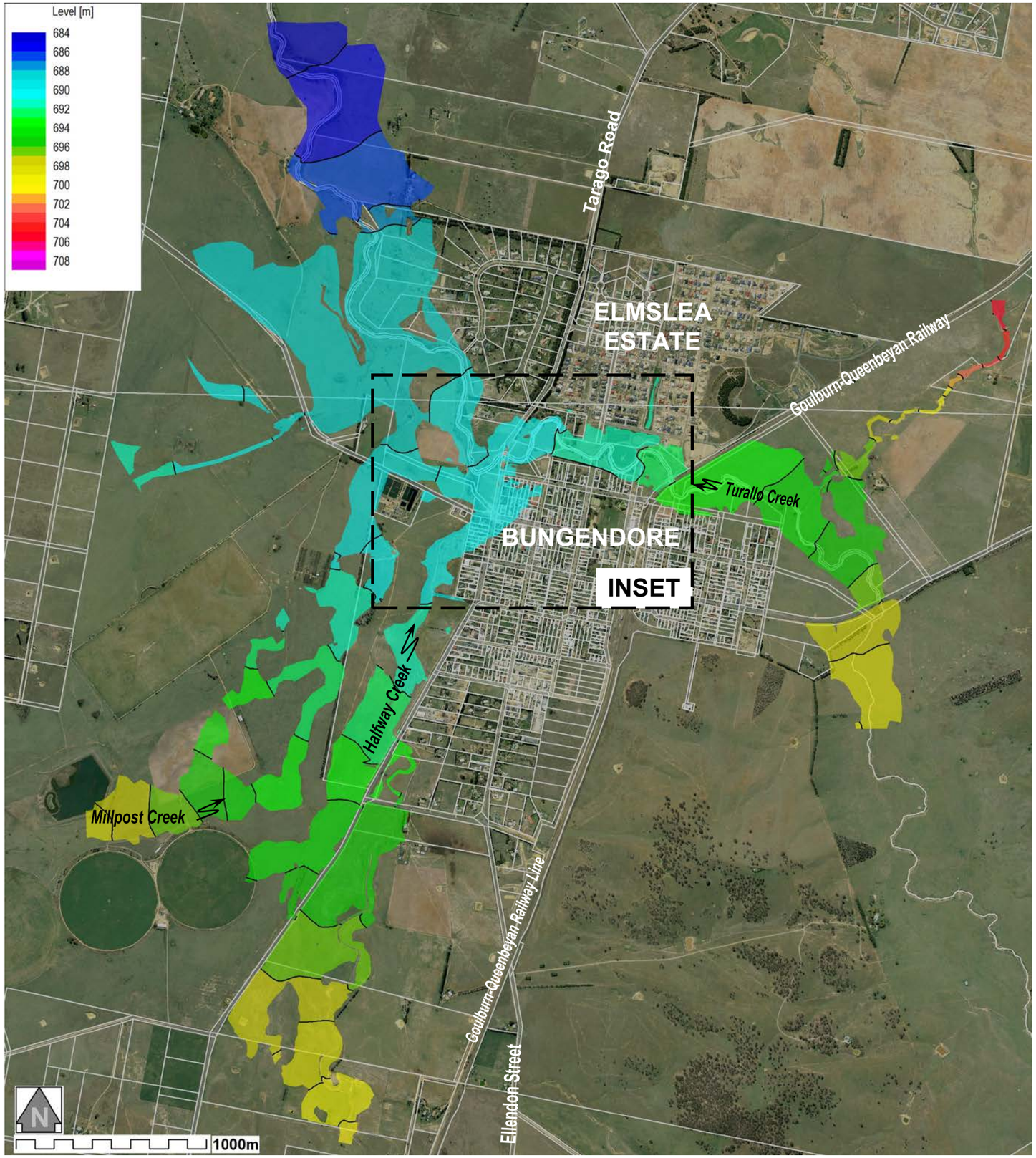
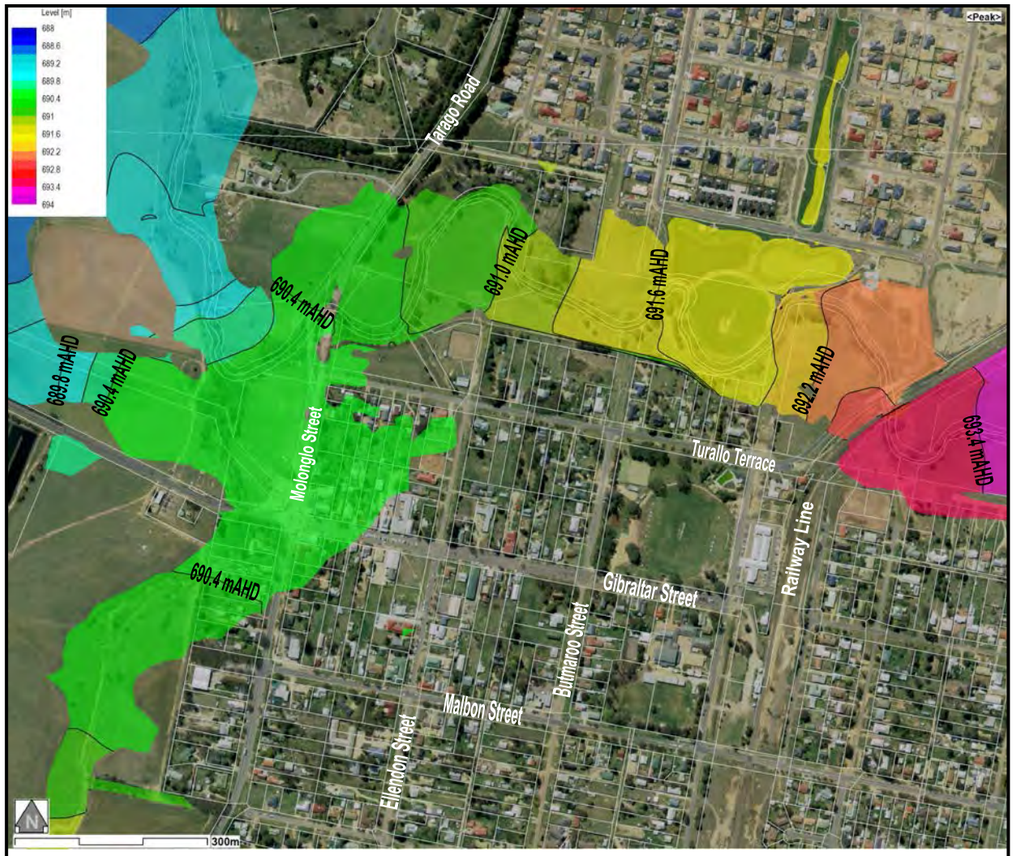
Bungendore Floodplain Risk Management Plan
3777wjh140404_FPRMPlan WSPs.xls

PREDICTED FLOODWATER SURFACE PROFILES ALONG TURALLO CREEK AT THE PEAK OF THE ADOPTED DESIGN FLOODING SCENARIOS

FIGURE 1.3





INSET Close-up of flooding in the vicinity of the Village

NOTE The variation in peak 5 year ARI flood levels are shown at a reduced contour interval of 0.3 metres (*the larger view is shown at 1 metre intervals*).

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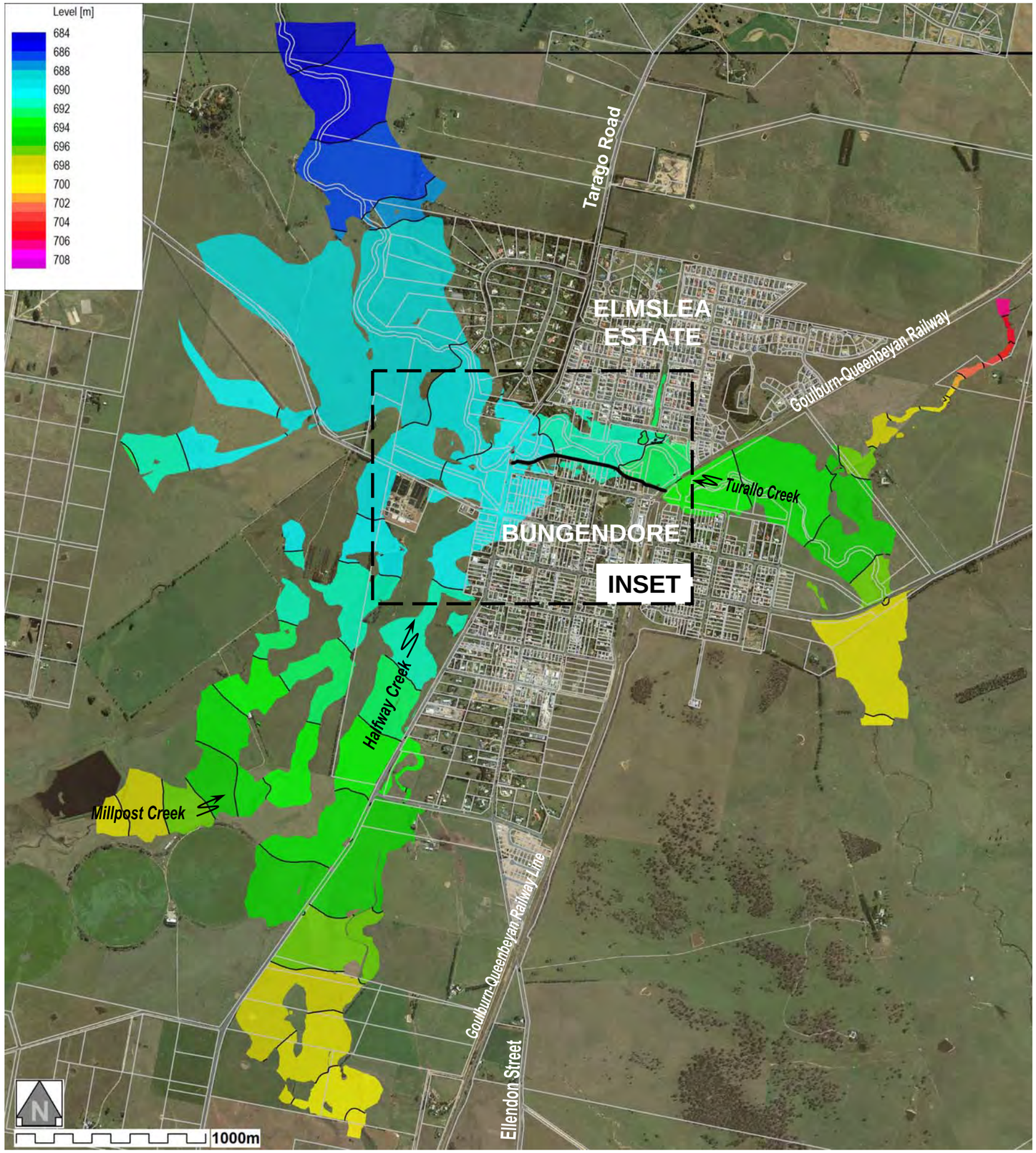
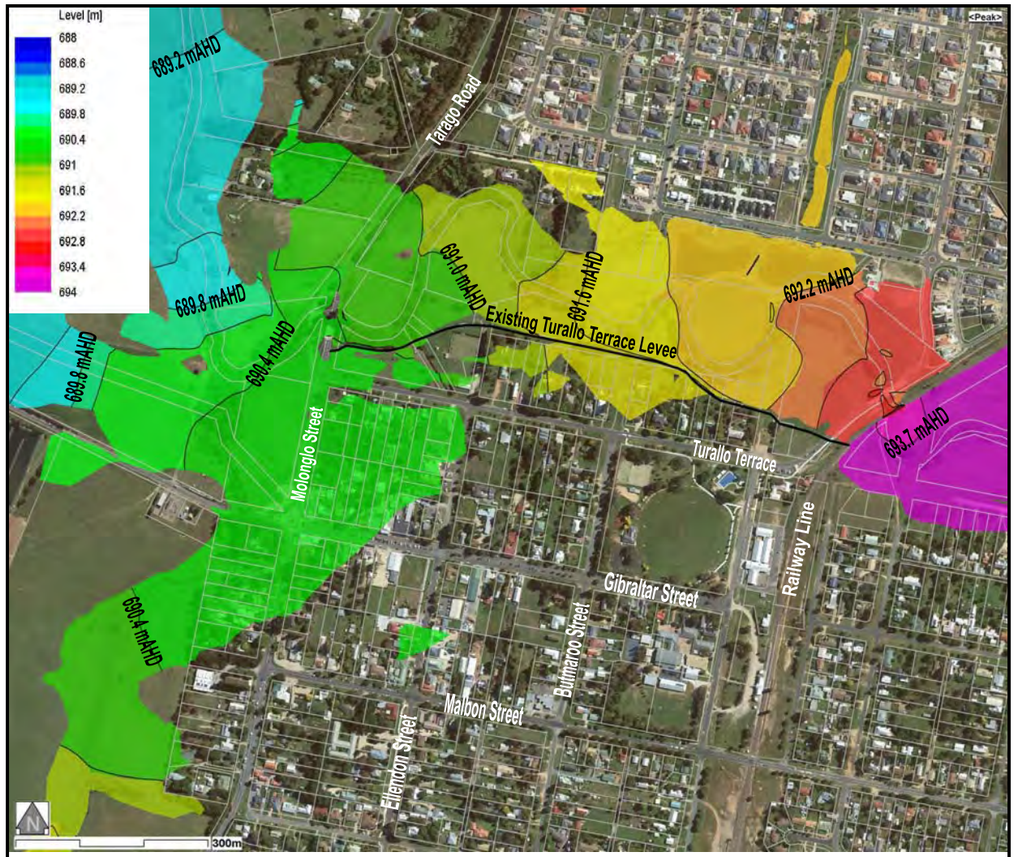
fg3777rg121114-fig1.3_5yr ARI Levels.doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE 5 YEAR RECURRENCE FLOOD
[BASED ON UPDATED FPRMS MODELLING]

FIGURE 1.4





INSET Close-up of flooding in the vicinity of the Village

NOTE The variation in peak 20 year ARI flood levels are shown at a reduced contour interval of 0.3 metres (*the larger view is shown at 1 metre intervals*).

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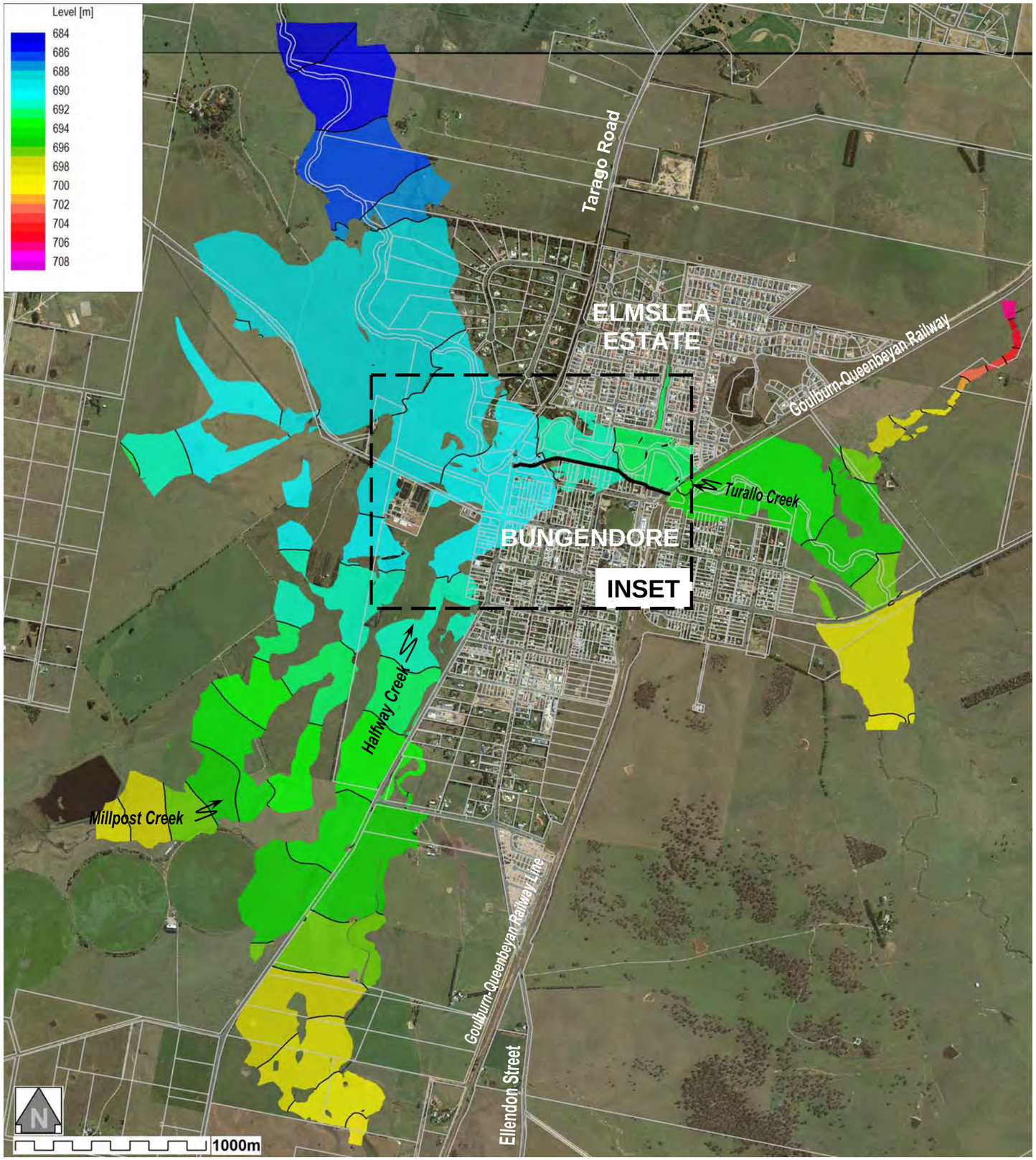
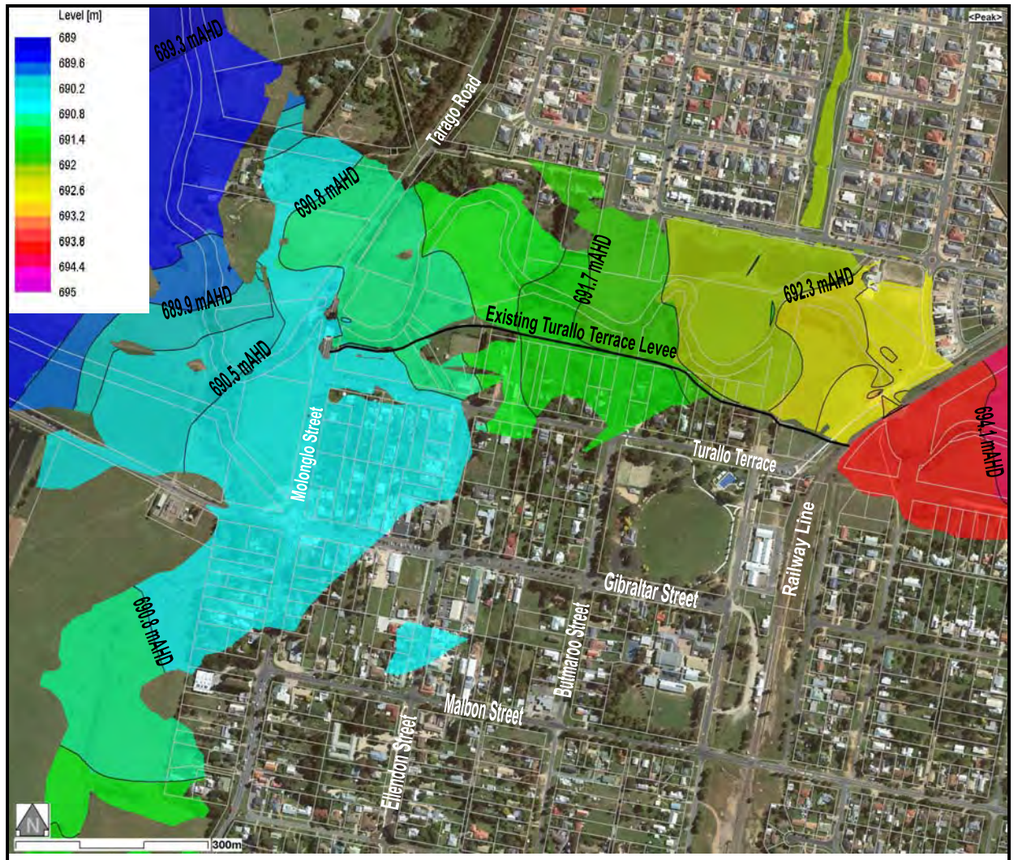
fg3777rg121114-fig7_20yr ARI Levels.doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE 20 YEAR RECURRENCE FLOOD
[BASED ON UPDATED FPRMS MODELLING]





INSET Close-up of flooding in the vicinity of the Village

NOTE The variation in peak 50 year ARI flood levels are shown at a reduced contour interval of 0.3 metres (*the larger view is shown at 1 metre intervals*).

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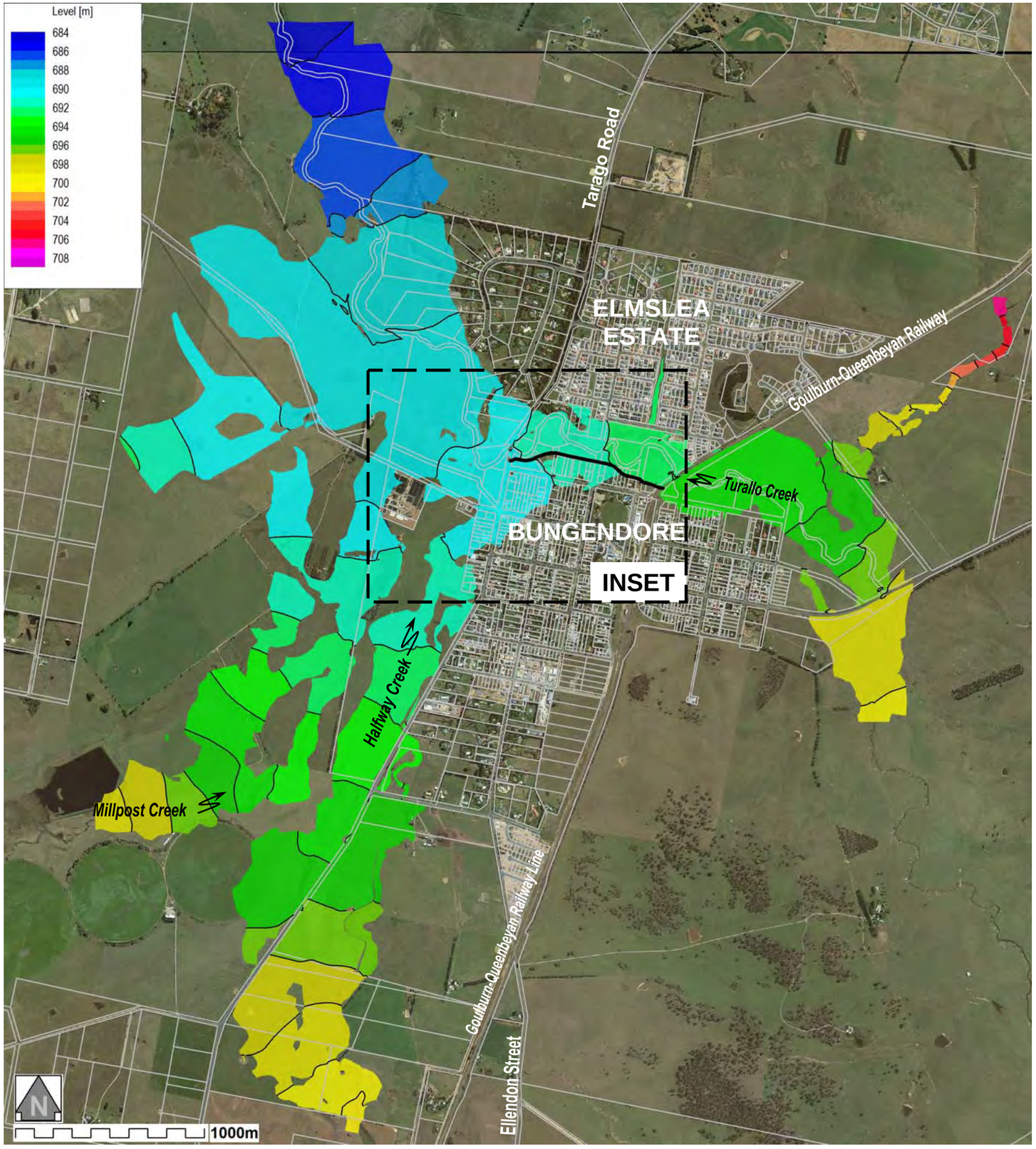
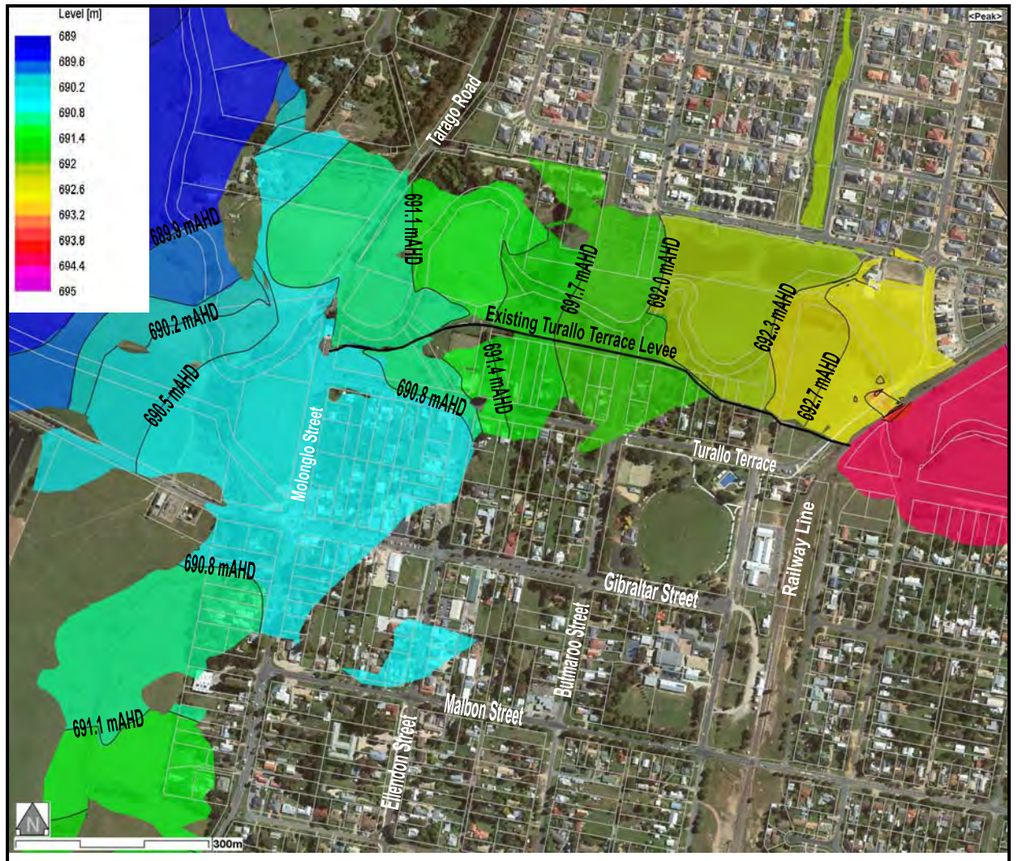
fg3777rg121114-fig8_50yr ARI Levels.doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE 50 YEAR RECURRENCE FLOOD [BASED ON UPDATED FPRMS MODELLING]

FIGURE 1.6





INSET Close-up of flooding in the vicinity of the Village

NOTE The variation in peak 100 year ARI flood levels are shown at a reduced contour interval of 0.3 metres (*the larger view is shown a 1 metre intervals*).

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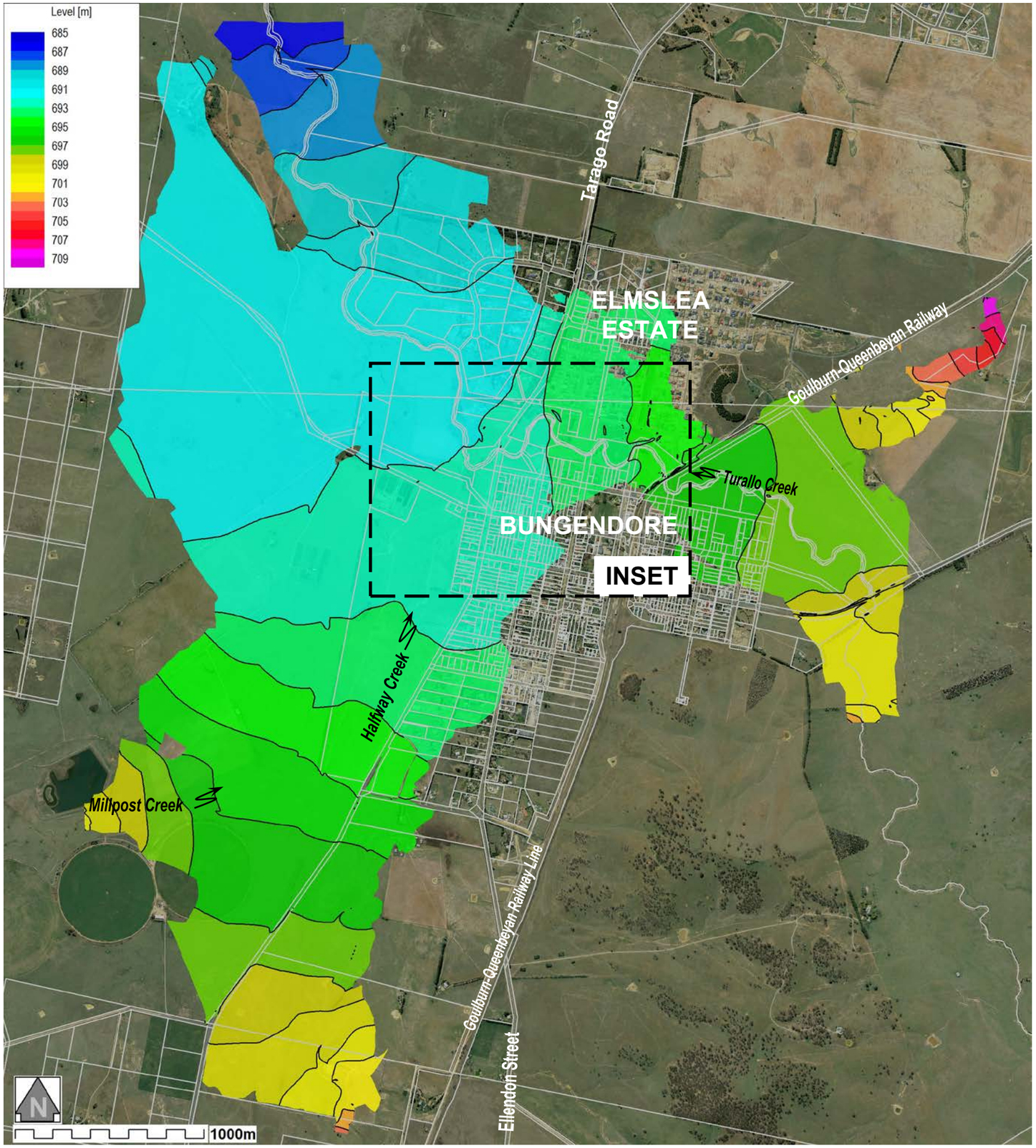
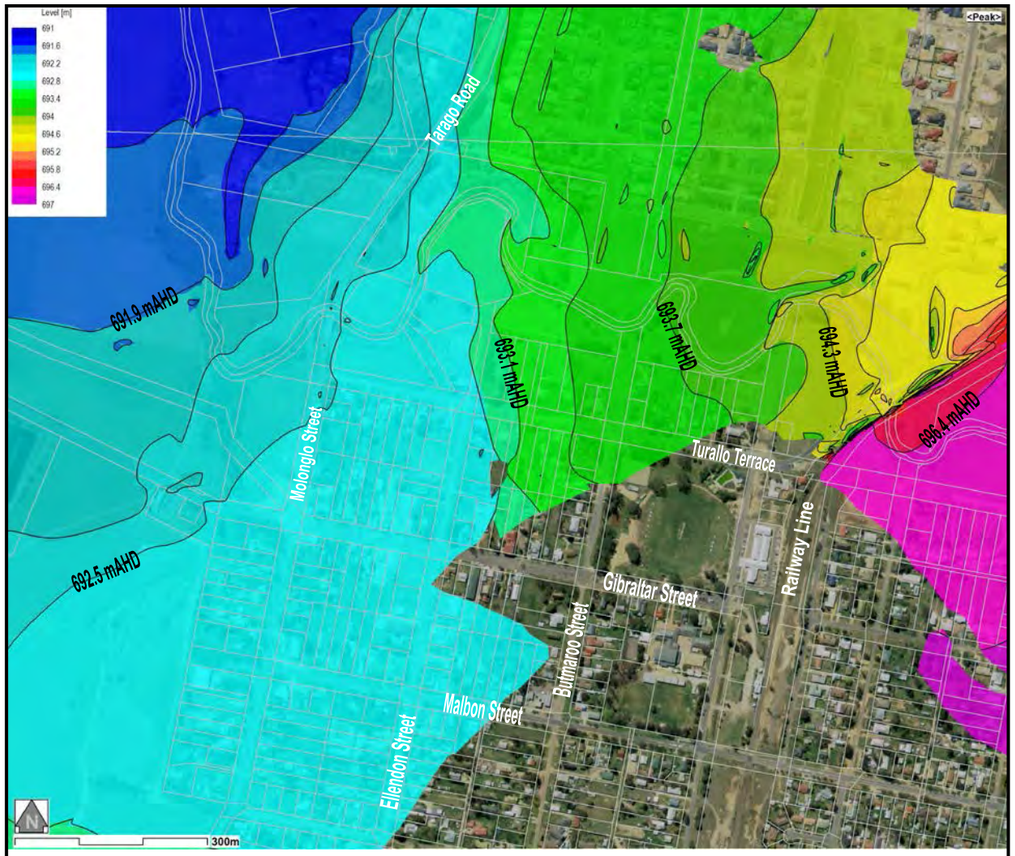
fg3777rg121114-fig9_100yr ARI Levels.doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE 100 YEAR RECURRENCE FLOOD
[BASED ON UPDATED FPRMS MODELLING]

FIGURE 1.7





INSET Close-up of flooding in the vicinity of the Village

NOTE The variation in flood levels at the peak of the Probable Maximum Flood are shown at a reduced contour interval of 0.3 metres (*the larger view is shown at 1 metre intervals*).

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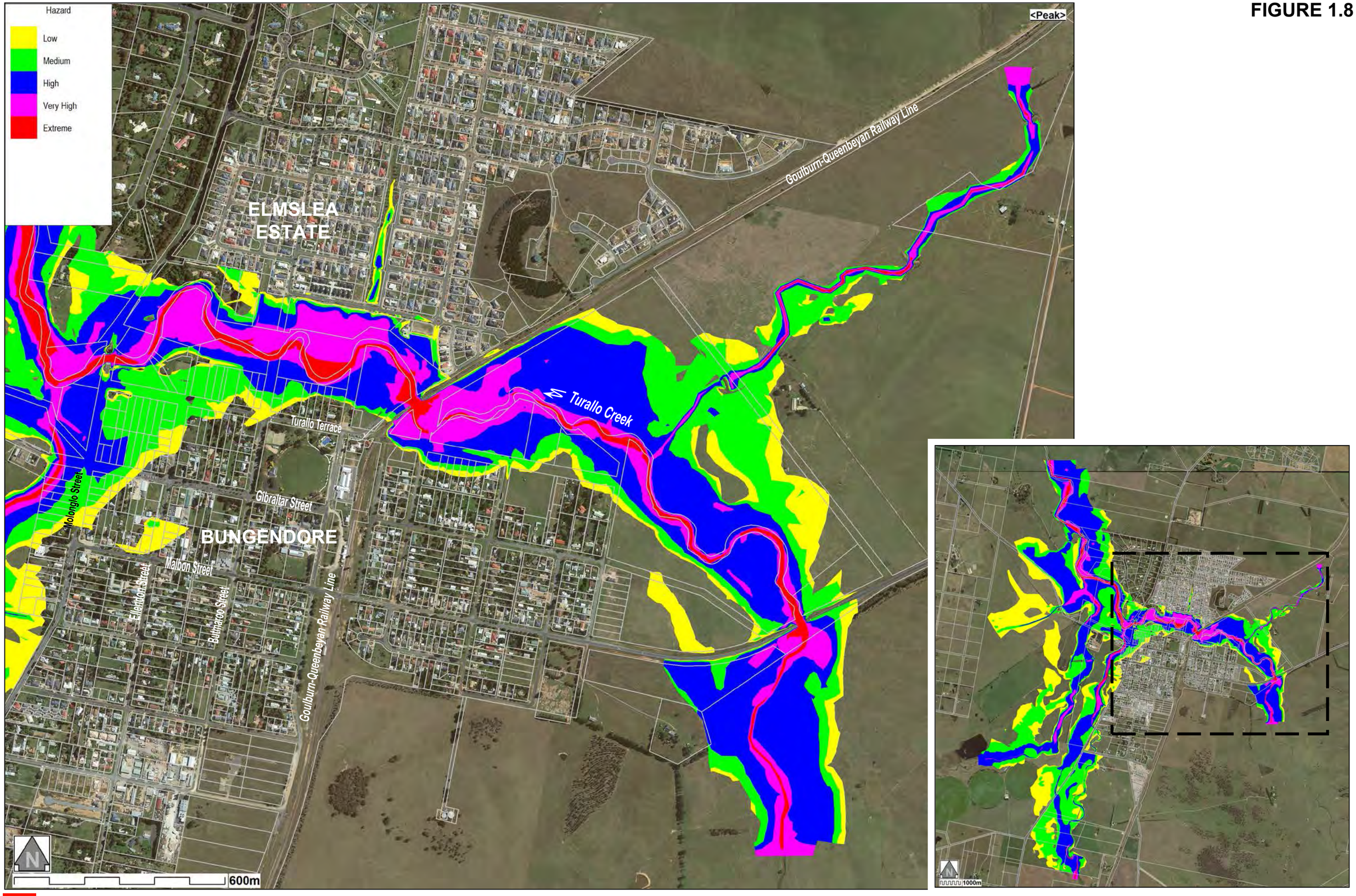
3777 - Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig1.7_PMF Levels.doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE PROBABALE MAXIMUM FLOOD [BASED ON UPDATED FPRMS MODELLING]

FIGURE 1.8



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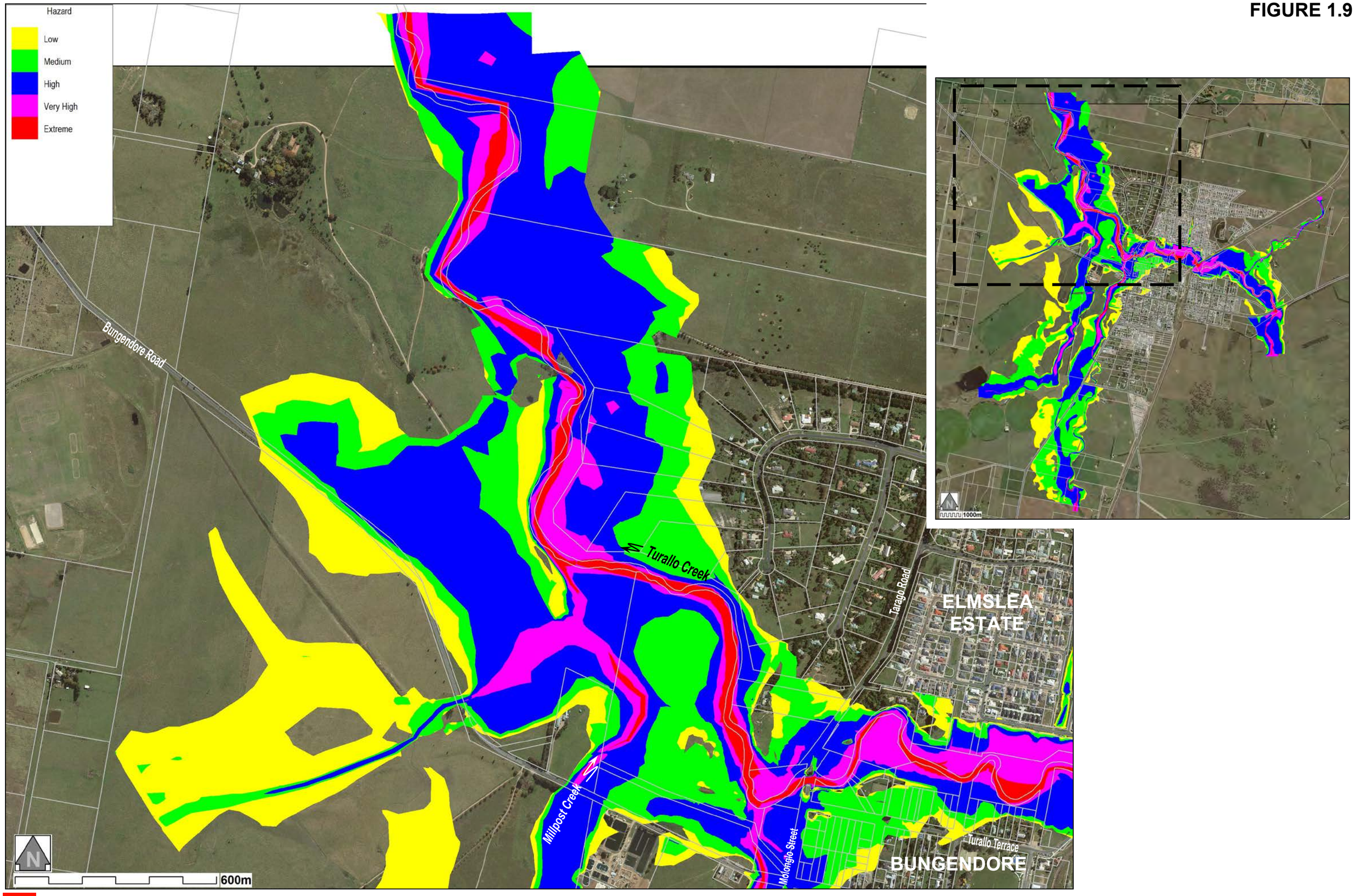
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig31_Hazard Mapping (1 of 3).doc

TRUE FLOOD HAZARD MAPPING FOR THE 1% AEP EVENT [MAP 1 of 3]

FIGURE 1.9



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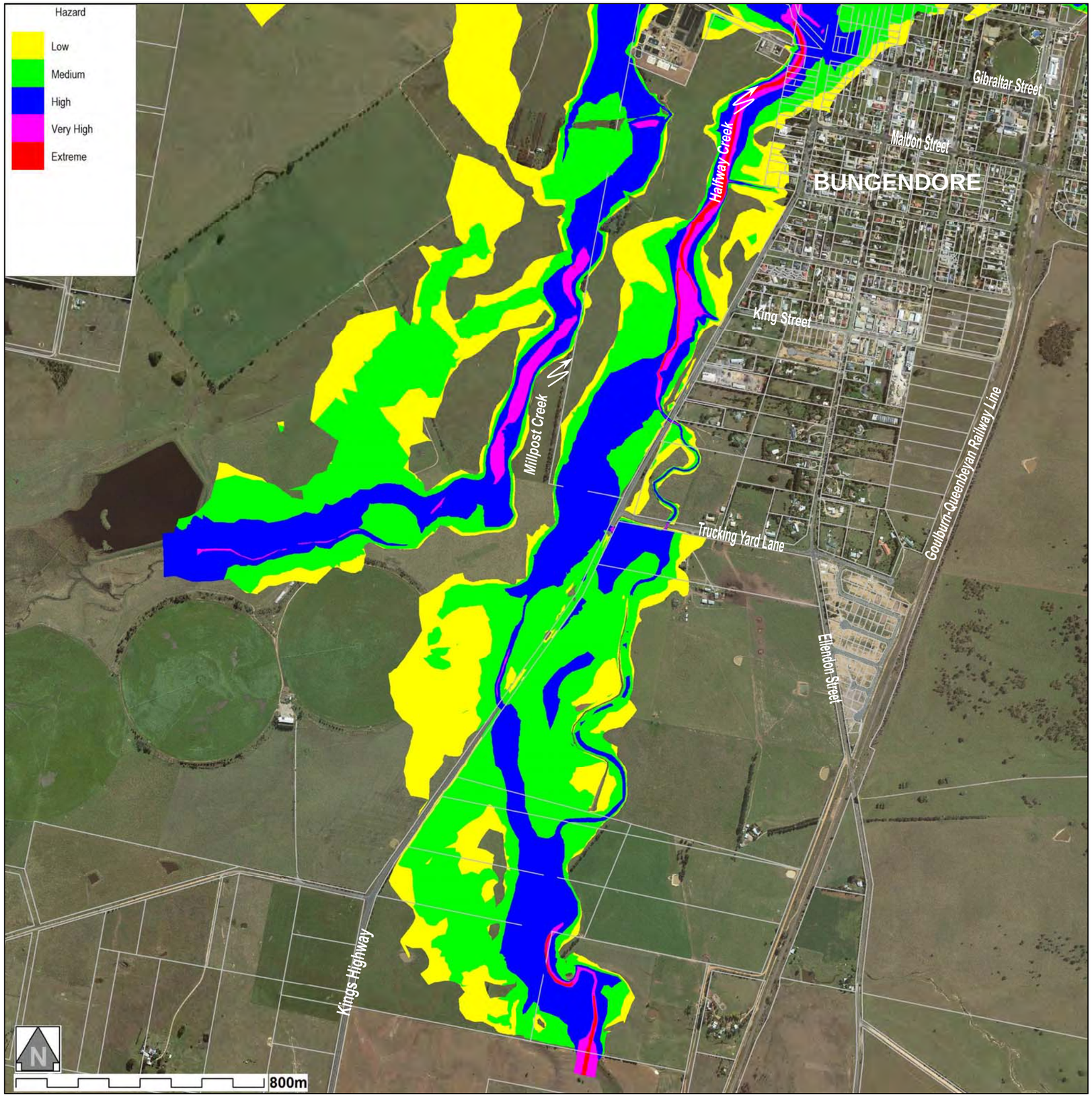
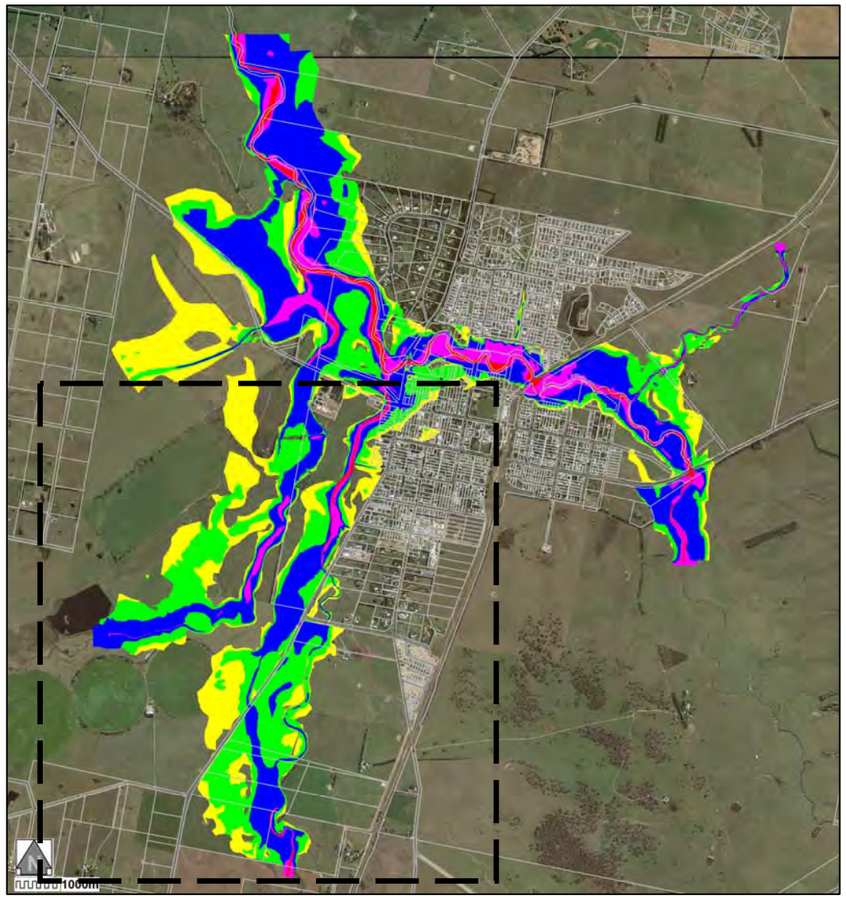
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig32_Hazard Mapping (2 of 3).doc

TRUE FLOOD HAZARD MAPPING FOR THE 1% AEP EVENT [MAP 2 of 3]

FIGURE 1.10





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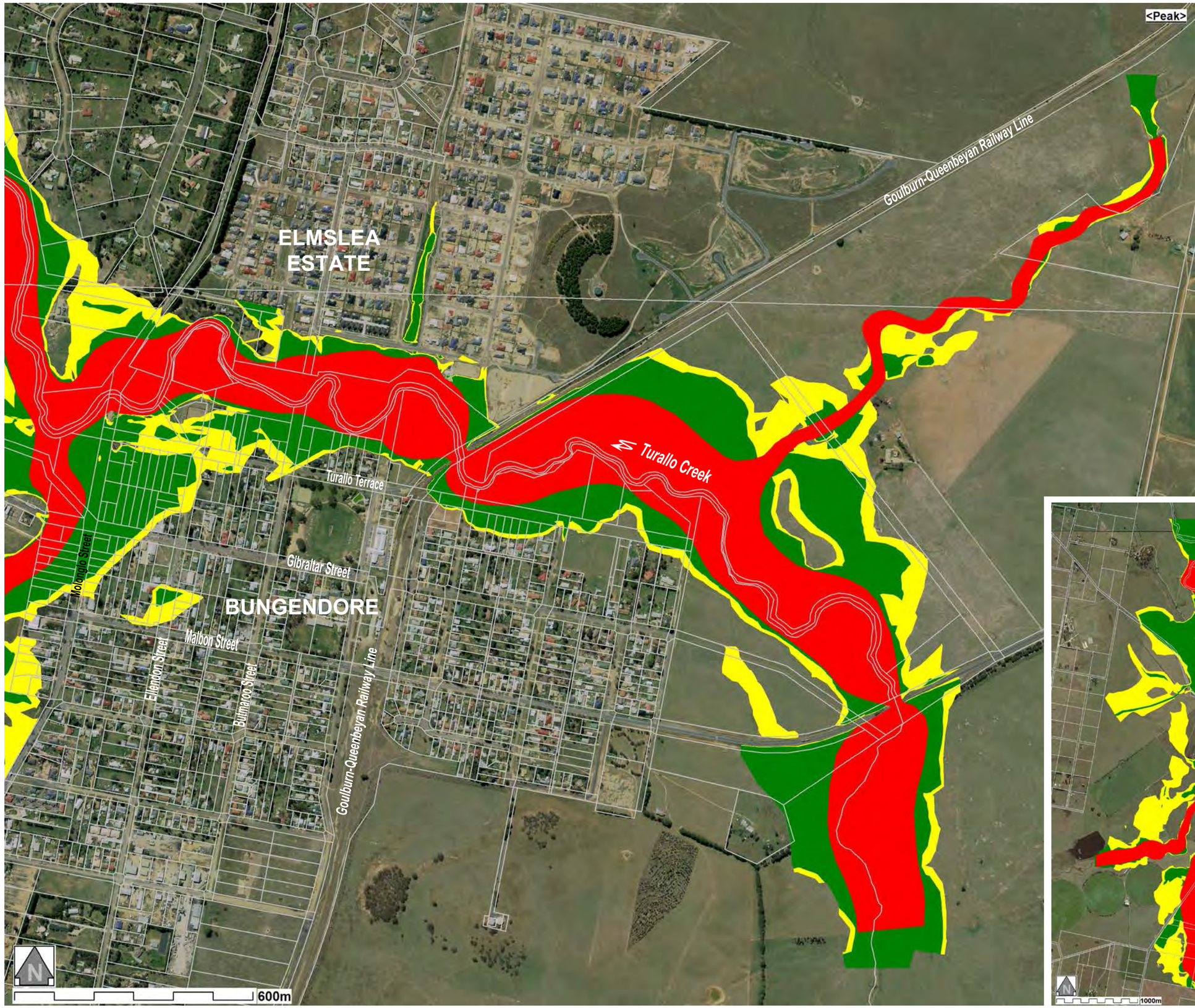
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig33_Hazard Mapping (3 of 3).doc

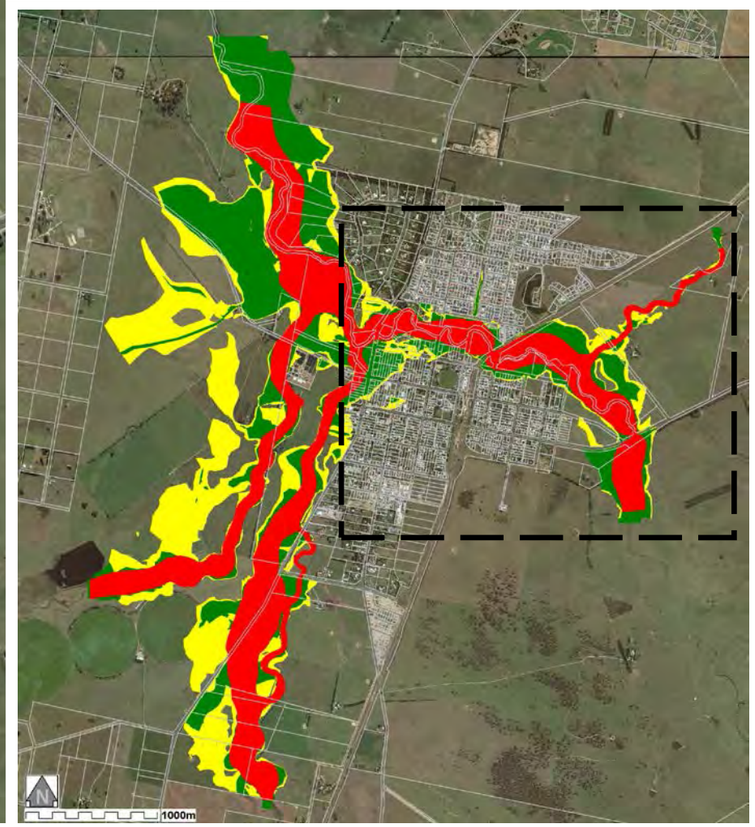
TRUE FLOOD HAZARD MAPPING FOR THE 1% AEP EVENT [MAP 3 of 3]

FIGURE 1.11



LEGEND

- Floodway
- Flood Storage
- Flood Fringe



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3777 - Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig1.11_Hydraulic Category Mapping (1 of 3).doc

HYDRAULIC CATEGORY MAPPING FOR THE 1% AEP EVENT [MAP 1 of 3]

FIGURE 1.12

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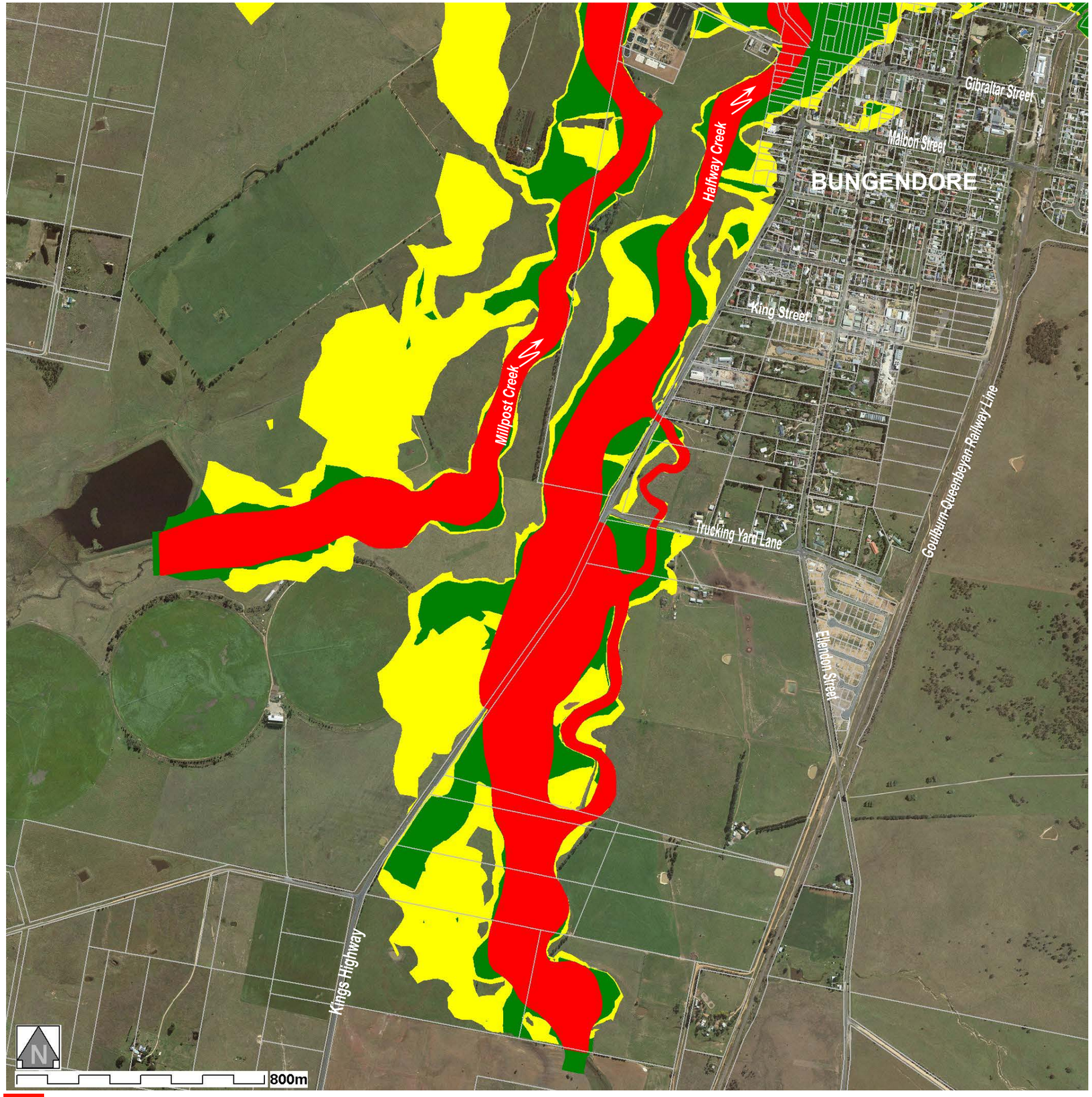
3777 - Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig1.12_Hydraulic Category Mapping (2 of 3).doc

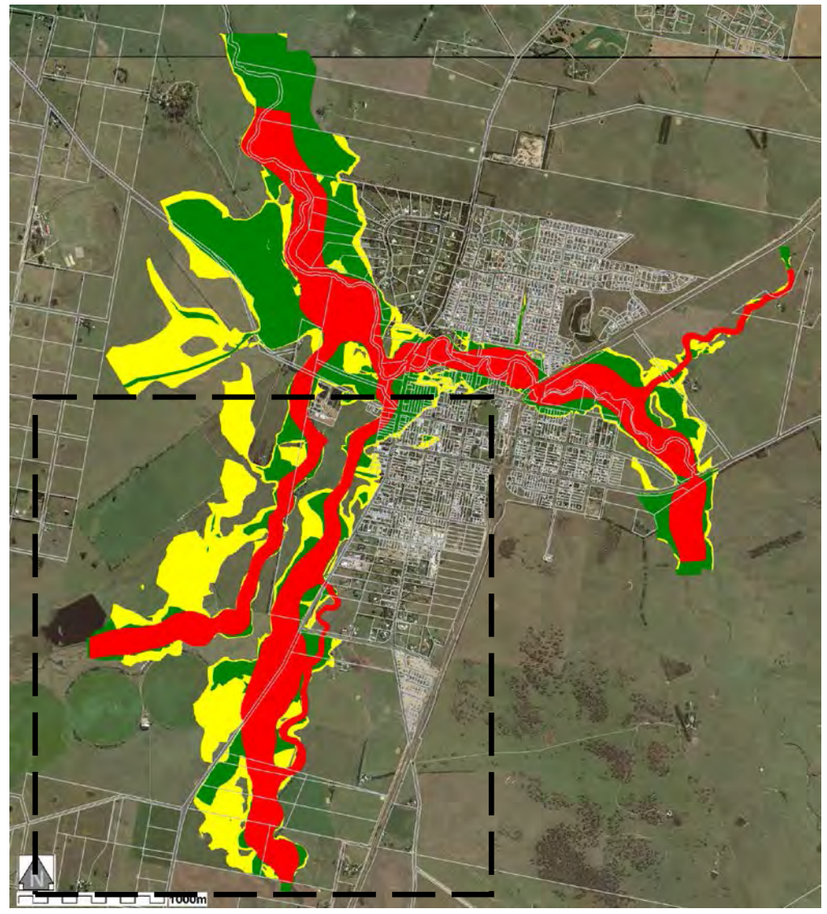
HYDRAULIC CATEGORY MAPPING FOR THE 1% AEP EVENT [MAP 2 of 3]

FIGURE 1.13



LEGEND

- Floodway
- Flood Storage
- Flood Fringe



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3777 - Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig1.13_Hydraulic Category Mapping (3 of 3).doc

HYDRAULIC CATEGORY MAPPING FOR THE 1% AEP EVENT [MAP 3 of 3]

FIGURE 2.1

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Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig2.1_Damage Reduction 'Measure 1 & 2' Configuration.doc

MEASURES CONSIDERED FOR FLOOD DAMAGE REDUCTION MEASURE 1 AND MEASURE 2

FIGURE 2.2

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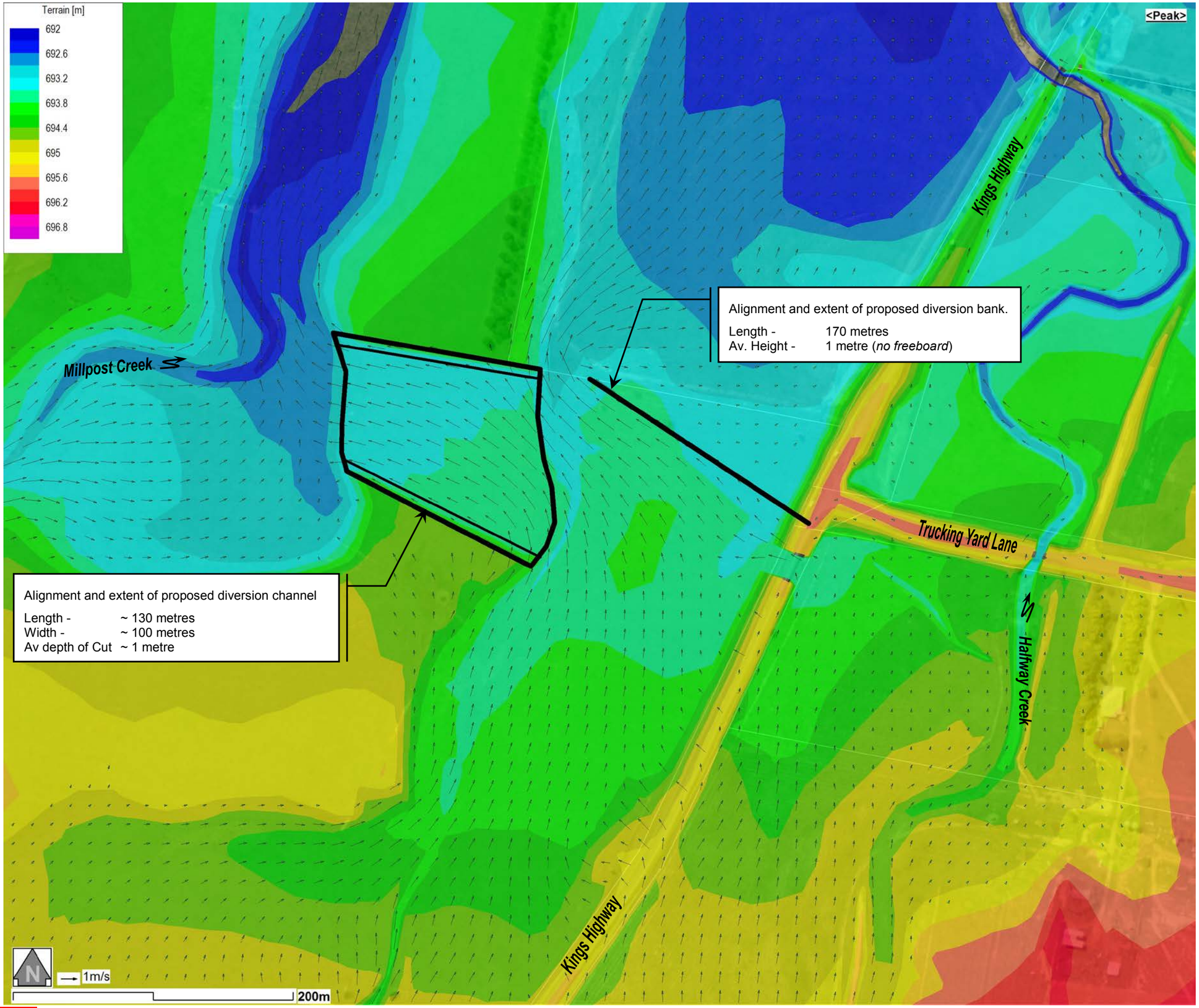
Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig2.2_Damage Reduction 'Measure 3 & 4' Configuration.doc

MEASURES CONSIDERED FOR FLOOD DAMAGE REDUCTION MEASURE 3, MEASURE 4 AND MEASURE 5

FIGURE 2.3



NOTE:

Velocity vectors shown represent post-development velocities at the peak of the design 100 year ARI flood.

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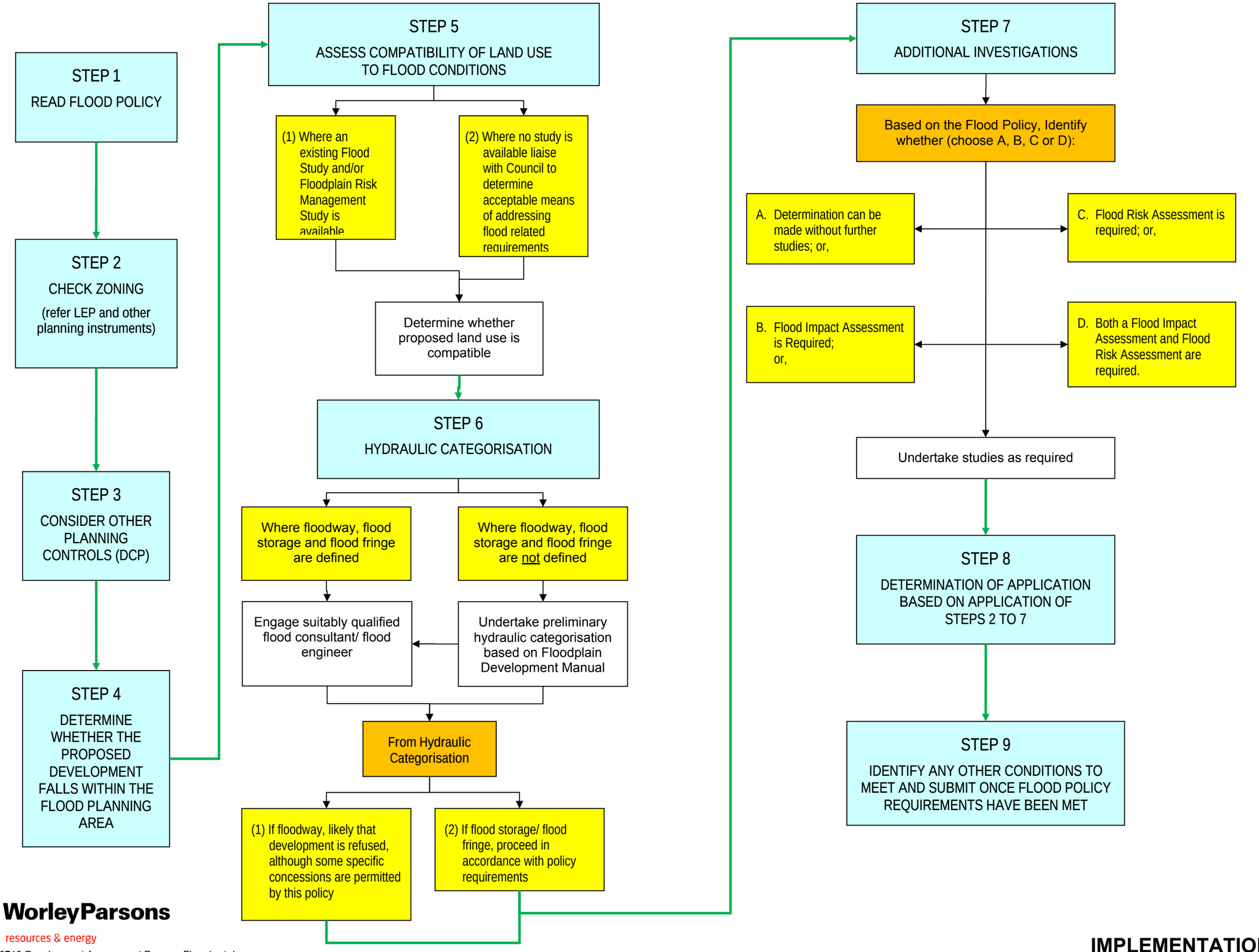
Bungendore Floodplain Risk Management Plan
fg3777rg121114-fig2.3_Damage Reduction 'Measure 5' Configuration.doc

MEASURES CONSIDERED FOR FLOOD DAMAGE REDUCTION MEASURE No 5



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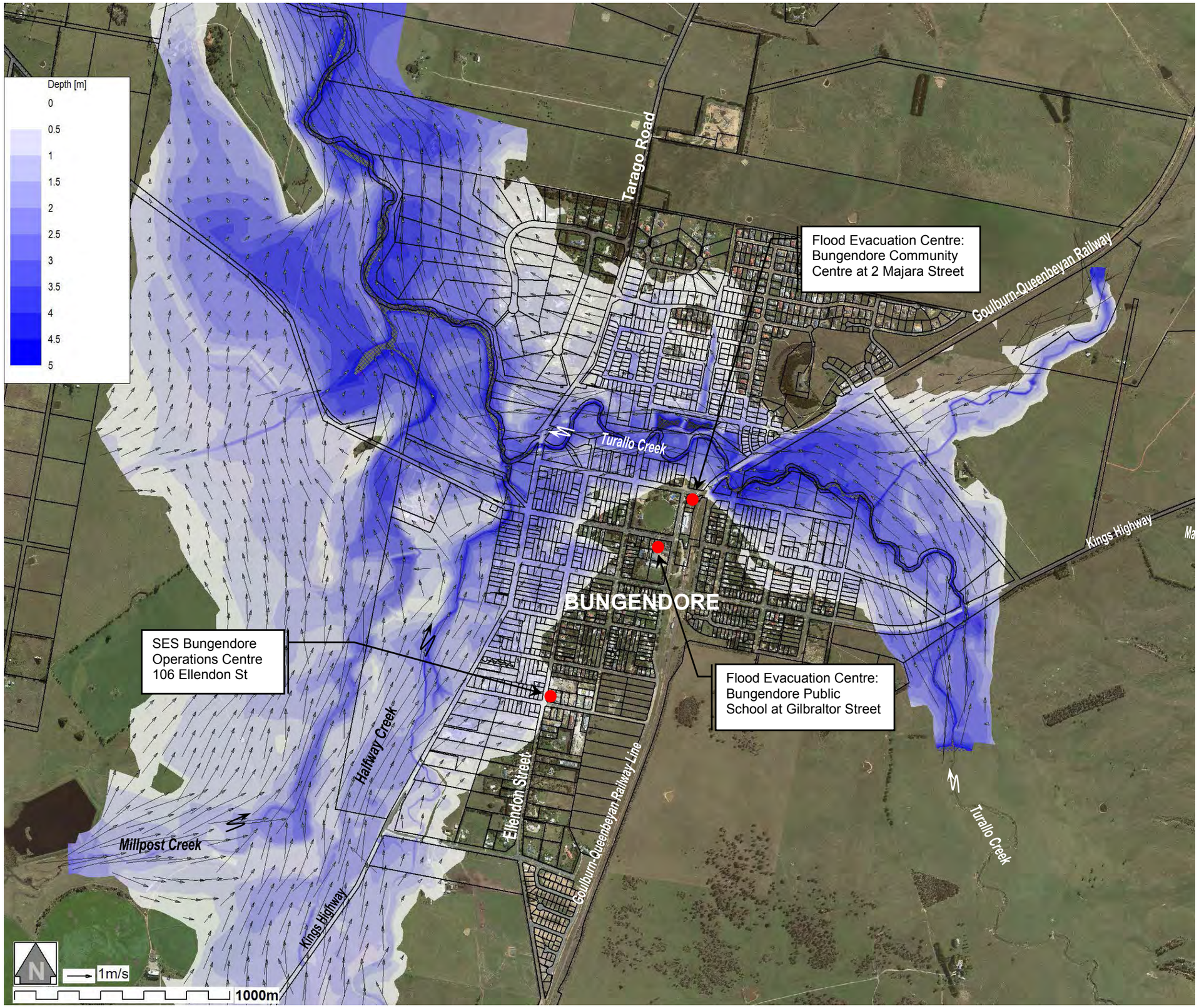
3777CRT140710-Development Assessment Process Flowchart.doc
Figure # - Flood Policy Planning Pathway

IMPLEMENTATION STEPS FOR APPLICATION OF FLOOD POLICY

FIGURE 4.1



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3777 - Bungendore Floodplain Risk Management Plan
fg3777wjh140709fig4.1-Existing Flood Emergency Response.doc

EXISTING EMERGENCY RESPONSE PROTOCOLS
[PROBABALE MAXIMUM FLOOD DEPTHS]

FIGURE 4.2

Depth [m]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Tarago Road

Tarago Road cut at Turallo Creek during 20% AEP event

Bungendore Road

Goulburn-Queenbeyan Railway

Turallo Creek

Kings Highway

Bungendore Road cut at Millpost and Halfway Creeks during 20% AEP event

BUNGENDORE

Kings Highway cut during PMF (remains open during 1% AEP event)

Halfway Creek

Elliendon Street

Goulburn-Queenbeyan Railway Line

Turallo Creek

Millpost Creek

Kings Highway

Kings Highway cut during 20% AEP event

N

1m/s

1000m

LEGEND

Flood Management Communities:

- Indirectly affected area
- Rising road access area
- Area with overland escape route

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3777 - Bungendore Floodplain Risk Management Plan
fg3777wjh140709fig4.2-Flood Emergency Response.doc

FLOOD EMERGENCY RESPONSE CONSIDERATIONS [PROBABALE MAXIMUM FLOOD DEPTHS]

Appendix A – Properties Affected by Flooding

Table A1 - Properties Affected by Flooding

EASTING	NORTHING	STREET_NAME	LOCALITY	LANDUSE	BUILDING_TYPE	FLOOR_LEVEL	BUILDING_TYPE	PMF_LEVEL	100YR_LEVEL	100YR_DEPTH	20YR_LEVEL	5YR_LEVEL
721752.02	6095929.61	Gibraltar Street	Bungendore Village	service station	concrete/iron	690.04	IH	692.61	690.73	0.69	690.48	690.26
721751.46	6095866.57	Gibraltar Street	Bungendore Village	service station	concrete	690.11	IH	692.63	690.73	0.62	690.48	690.26
721818.66	6095943.29	Gibraltar Street	Bungendore Village	residential	brick	690.2	R	692.63	690.73	0.53	690.48	690.26
721640.41	6095822.79	Molonglo Street	Bungendore Village	residential	weatherboard/fibro	690.28	R	692.62	690.8	0.52	690.58	690.38
721774.52	6095977.61	Molonglo Street	Bungendore Village	residential	stone	690.32	R	692.59	690.72	0.4	690.48	690.26
721892.58	6095908.22	Gibraltar Street	Bungendore Village	hotel	brick	690.37	R	692.63	690.73	0.36	690.48	690.26
721892.58	6095908.22					690.37	R	692.63	690.73	0.36	690.48	690.26
721876.41	6095932.00	Gibraltar Street	Bungendore Village	bakery	brick	690.42	CM	692.63	690.73	0.31	690.48	690.26
721674.99	6095867.48	Gibraltar Street	Bungendore Village	residential	stone	690.45	R	692.61	690.75	0.3	690.52	690.31
721652.15	6095799.63	Molonglo Street	Bungendore Village	residential	weatherboard/piers	690.5	R	692.59	690.73	0.23	690.48	690.26
721652.15	6095799.63	Turallo Terrace	Bungendore Village	residential	weatherboard/piers	690.5	R	692.59	690.73	0.23	690.48	690.26
721942.18	6095996.45					690.52	R	692.64	690.76	0.24	690.49	690.26
721942.18	6095996.45					690.52	R	692.64	690.76	0.24	690.49	690.26
721853.06	6095803.35	Gibraltar Street	Bungendore Village	café	brick	690.53	CH	692.63	690.74	0.21	690.49	690.26
721790.89	6096067.30	Molonglo Street	Bungendore Village	residential	weatherboard	690.56	R	692.53	690.71	0.15	690.47	690.26
721813.15	6095810.42	Gibraltar Street	Bungendore Village	residential	brick/stone foundation	690.58	R	692.63	690.73	0.15	690.49	690.26
721918.32	6096027.28	Turallo Terrace	Bungendore Village	residential	weatherboard	690.59	R	692.64	690.75	0.16	690.49	690.26
721858.30	6095935.14	Gibraltar Street	Bungendore Village	shops	brick	690.68	CM	692.63	690.73	0.05	690.48	690.26
721778.16	6095844.90	Gibraltar Street	Bungendore Village	residential	stone	690.69	R	692.63	690.73	0.04	690.48	690.26
721746.94	6095844.10	Molonglo Street	Bungendore Village	residential	brick/stone	690.71	R	692.63	690.73	0.02	690.49	690.26
721972.13	6096162.33	Turallo Terrace	Bungendore Village	bowling club	weatherboard	691.08	CH	692.67	691.21	0.13	690.86	690.29
721632.49	6095782.70	Turallo Terrace	Bungendore Village	residential	weatherboard	691.15	R	692.69	691.16	0.01	690.75	690.26
722693.76	6095857.96	Duralla Street	Bungendore Village	residential		693.95	R	696.52	694.32	0.37	693.78	693.34
722737.57	6095873.94					694	R	696.52	694.33	0.33	693.78	693.34
722767.21	6095868.27	Turallo Terrace	Bungendore Village	residential	brick	694.01	R	696.53	694.33	0.32	693.78	693.35
722786.98	6095864.55	Turallo Terrace	Bungendore Village	residential	weatherboard	694.32	R	696.54	694.34	0.02	693.79	693.36

Appendix B – Cost Estimates for Flood Mitigation Measures

Bungendore FPRMS Measure 1 - Turallo Terrace Levee Extension & Upgrade

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

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Disclaimer

This cost estimate is based on Worley Parsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation				
	- equipment mobilisation and site establishment	1	5	%	62,842
	- remove vegetation	15480	0.48	sqm	7,430
	- remove trees	20	200	no.	4,000
	- remove top soil (150mm)	2322	8.05	cum	18,692
2	Key Foundation Construction				
	- excavate foundation channel	1339	54.90	cum	73,511
	- shaping of batter slopes	1996	2.75	sqm	5,489
	- compact foundation	3781	3.25	sqm	12,288
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	1339	23.70	cum	31,734
	- lime stabilisation of clay core	1339	35.00	cum	46,865
3	Levee Core Construction				
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	10738	23.70	cum	254,491
	- compact clay core at 150 mm layers	11688	3.15	sqm	36,817
	- lime stabilisation of clay core	10738	40.00	cum	429,520
	- shaping of batter slopes	15480	2.75	sqm	42,570
4	Levee Landscaping				
	- vapour barrier sand fill (100mm thick)	1548	35.00	cum	54,180
	- shaping of batter slopes	15480	2.75	sqm	42,570
	- topsoil placement from stockpiles	2322	7.70	cum	17,879
	- leveling top soil	15480	3.25	sqm	50,310
	- turf layed, rolled and watered for 2 weeks	15480	8.30	sqm	128,484
5	Site Clean-Up and Reinstatement				
	- reinstate property fences	20	1,500	no.	30,000
	- reinstate local drainage culverts	10	5,000	no.	50,000
	- clean-up	1	5	%	66,842
6	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	293,303
	- consultation with residents	1	3	%	43,995
	- land acquisition (easements)	1	234,000	item	234,000
				TOTAL (SYDNEY)	$2,037,813
				SUB TOTAL (BUNGENDORE, +2.0%)	$2,078,569
				SUB TOTAL (+20% CONTINGENCY)	$2,494,283

Bungendore FPRMS Measure 2 - Turallo Terrace Levee Upgrade

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

WorleyParsons
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Disclaimer

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Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation				
	- equipment mobilisation and site establishment	1	5	%	14,103
	- remove vegetation	4010	0.48	sqm	1,925
	- remove trees	20	200	no.	4,000
	- remove top soil (150mm)	602	8.05	cum	4,842
2	Key Foundation Construction				
	- excavate foundation channel	660	54.90	cum	36,234
	- shaping of batter slopes	980	2.75	sqm	2,695
	- compact foundation	1860	3.25	sqm	6,045
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	660	23.70	cum	15,642
	- lime stabilisation of clay core	660	35.00	cum	23,100
3	Levee Core Construction				
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	1740	23.70	cum	41,238
	- compact clay core at 150 mm layers	2050	3.15	sqm	6,458
	- lime stabilisation of clay core	1740	40.00	cum	69,600
	- shaping of batter slopes	400	2.75	sqm	1,100
4	Levee Landscaping				
	- vapour barrier sand fill (100mm thick)	40	35.00	cum	1,400
	- shaping of batter slopes	4010	2.75	sqm	11,028
	- topsoil placement from stockpiles	602	7.70	cum	4,632
	- leveling top soil	400	3.25	sqm	1,300
	- turf layed, rolled and watered for 2 weeks	400	8.30	sqm	3,320
5	Site Clean-Up and Reinstatement				
	- reinstate property fences	15	1,500	no.	22,500
	- reinstate local drainage culverts	5	5,000	no.	25,000
	- clean-up	1	5	%	14,103
6	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	62,053
	- consultation with residents	1	3	%	9,308
	- land acquisition (easements)	1	180,000	item	180,000
				TOTAL (SYDNEY)	$561,624
				SUB TOTAL (BUNGENDORE, +2.0%)	$572,856
				SUB TOTAL (+20% CONTINGENCY)	$687,427

Bungendore FPRMS Measure 3 - Overflow Channel across Tarago Road

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

WorleyParsons
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Disclaimer

This cost estimate is based on Worley Parsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation				
	- equipment mobilisation and site establishment	1	5	%	16,629
	- remove vegetation	4100	0.48	sqm	1,968
	- remove top soil (150mm)	615	8.05	cum	4,951
2	Channel Construction				
	- excavation to form channel	5440	27.70	cum	150,688
	- trim excavation to batter	1600	2.75	sqm	4,400
	- compaction of banks and channel base	3840	3.25	sqm	12,480
	- topsoil placement from stockpiles	615	7.70	cum	4,736
	- leveling top soil	4100	3.25	sqm	13,325
	- turf layed, rolled and watered for 2 weeks	4100	8.30	sqm	34,030
	- culvert beneath Tarago Road	1	100,000	item	100,000
3	Site Clean-Up				
	- reinstate property fences	4	1,500	no.	6,000
	- clean-up	1	5	%	16,629
4	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	73,167
	- consultation with residents	1	3	%	10,975
	- land acquisition	1	36,000	item	36,000
				TOTAL (SYDNEY)	$485,977
				SUB TOTAL (BUNGENDORE, +2.0%)	$495,697
				SUB TOTAL (+20% CONTINGENCY)	$594,836

Bungendore FPRMS Measure 5 - Diversion Channel

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

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resources & energy

Disclaimer

This cost estimate is based on Worley Parsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation				
	- equipment mobilisation and site establishment	1	5	%	40,935
	- remove vegetation	28300	0.48	sqm	13,584
	- remove top soil (150mm)	4245	8.05	cum	34,172
2	Channel Construction				
	- excavation to form channel	11010	27.70	cum	304,977
	- trim excavation to batter	1897	2.75	sqm	5,217
	- compaction of banks and channel base	29597	3.25	sqm	96,190
	- topsoil placement from stockpiles	4245	7.70	cum	32,687
	- leveling top soil	28300	3.25	sqm	91,975
	- turf layed, rolled and watered for 2 weeks	28300	8.30	sqm	234,890
3	Site Clean-Up				
	- reinstate property fences	100	50	m	5,000
	- clean-up	1	5	%	40,935
6	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	171,925
	- consultation with residents	1	3	%	27,017
	- land acquisition (easements)	1	168,000	item	168,000
				TOTAL (SYDNEY)	$1,267,503
				SUB TOTAL (BUNGENDORE, +2.0%)	$1,292,853
				SUB TOTAL (+20% CONTINGENCY)	$1,551,424

Bungendore FPRMS Measure 4 - Vegetation Removal & Overbank Excavation / Shaping

WorleyParsons resources & energy

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

Disclaimer

This cost estimate is based on Worley Parsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
1	Site Preparation & Vegetation Removal				
	- equpiment mobilisation and site establishment	1	5	%	7,385
	- remove medium vegetation	14600	0.48	sqm	7,008
	- remove trees along banks	20	200	no.	4,000
2	Channel Construction				
	- remove top soil (150mm)	690	8.05	cum	5,555
	- reduce levels along overbank areas	1160	27.70	cum	32,132
	- trim excavation to batter	220	2.75	sqm	605
	- compaction of banks and channel base	4600	3.25	sqm	14,950
	- topsoil placement from stockpiles	690	7.70	cum	5,313
	- leveling top soil	4600	3.25	sqm	14,950
	- turf layed, rolled and watered for 2 weeks	4600	8.30	sqm	38,180
3	Site Clean-Up				
	- reinstate property fences	500	50	m	25,000
	- clean-up	1	5	%	7,385
6	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	32,492
	- consultation with residents	1	3	%	4,874
	- land acquisition (easements)	1	27,600	item	27,600
				TOTAL (SYDNEY)	$227,428
				SUB TOTAL (BUNGENDORE, +2.0%)	$231,977
				SUB TOTAL (+20% CONTINGENCY)	$278,372

Bungendore FPRMS Measure 6 - Darmody Diversion Banks

Project No.: 3777
Project Name: Bungendore FPRMS
Date: 20-Feb-13

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Disclaimer

This cost estimate is based on Worley Parsons' experience and judgement as a firm of practising professional engineers familiar with the construction industry. This cost estimate can NOT be guaranteed as we have no control over Contractor's prices, market forces and competitive bids from tenderers. This cost estimate excludes design fees, project management fees and authority approval fees.

Note: Wherever possible, cost estimates are based on Rawlinsons Australian Construction Handbook Edition 30, 2012

Item	Description	Quantity	Rate	Unit	Total
	A. DIVERSION BANK COSTING				
1	Site Preparation				
	- equpiment mobilisation and site establishment	1	5	%	38,299
	- remove vegetation	1700	0.48	sqm	816
	- remove top soil (150mm)	255	8.05	cum	2,053
2	Cutoff Foundation Construction				
	- excavate foundation channel	255	54.90	cum	14,000
	- shaping of batter slopes	537	2.75	sqm	1,477
	- compact foundation	877	3.25	sqm	2,851
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	255	23.70	cum	6,044
	- lime stabilisation of clay core	255	35.00	cum	8,925
3	Levee Core Construction				
	- excavate clay, deposit as fill & compact to 90% (*within 20km*)	425	23.70	cum	10,073
	- compact clay core at 150 mm layers	2805	3.15	sqm	8,836
	- lime stabilisation of clay core	425	35.00	cum	14,875
	- shaping of batter slopes	1741	2.75	sqm	4,787
4	Levee Landscaping				
	- vapour barrier sand fill (100mm thick)	174	40.00	cum	6,963
	- balanced cut/fill from diversion channel	595	12.10	cum	7,200
	- shaping of batter slopes	1741	2.75	sqm	4,788
	- topsoil placement from stockpiles	255	7.70	cum	1,964
	- leveling top soil	1741	3.25	sqm	5,658
	- turf layed, rolled and watered for 2 weeks	1741	8.30	sqm	14,449
	B. DIVERSION CHANNEL COSTING				
5	Channel Construction				
	- remove vegetation	17370	0.48	sqm	8,338
	- remove top soil (150mm)	2606	8.05	cum	20,974
	- excavate channel	11470	27.70	cum	317,705
	Note: 595 m3 of material assumed compatible for use as fill in the construction of the diversion bank (*refer above*)				
	- trim excavation to batter	1500	2.75	sqm	4,125
	- compaction of banks and channel base	17970	3.25	sqm	58,403
	- topsoil placement from stockpiles	2606	7.70	cum	20,062
	- leveling top soil	17370	3.25	sqm	56,453
	- turf layed, rolled and watered for 2 weeks	17370	8.30	sqm	144,171
6	Site Clean-Up				
	- reinstate property fences	400	50	m	20,000
	- clean-up	1	5	%	38,299
7	Design & Miscellaneous Items				
	- survey, environmental assessment, design, geotech testing, construction management	1	20	%	168,517
	- consultation with residents	1	3	%	25,278
	- land acquisition (easements)	1	114,665	item	114,665
				TOTAL (SYDNEY)	$1,151,044
				SUB TOTAL (BUNGENDORE, +2.0%)	$1,174,065
				SUB TOTAL (+20% CONTINGENCY)	$1,408,878

Appendix C – Land Use Zoning (Draft Palerang LEP)

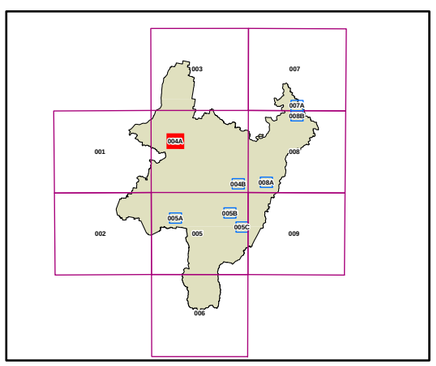
PALERANG COUNCIL

Palerang Local Environmental Plan 2013

Land Zoning Map - Sheet LZN_004A

Zone

- B2 Local Centre
- B4 Mixed Use
- E1 National Parks and Nature Reserves
- E2 Environmental Conservation
- E3 Environmental Management
- E4 Environmental Living
- IN2 Light Industrial
- R1 General Residential
- R2 Low Density Residential
- R5 Large Lot Residential
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU3 Foresty
- RU5 Village
- SP1 Special Activities
- SP2 Infrastructure
- Cadastre 3/10/13 © Land and Property Information



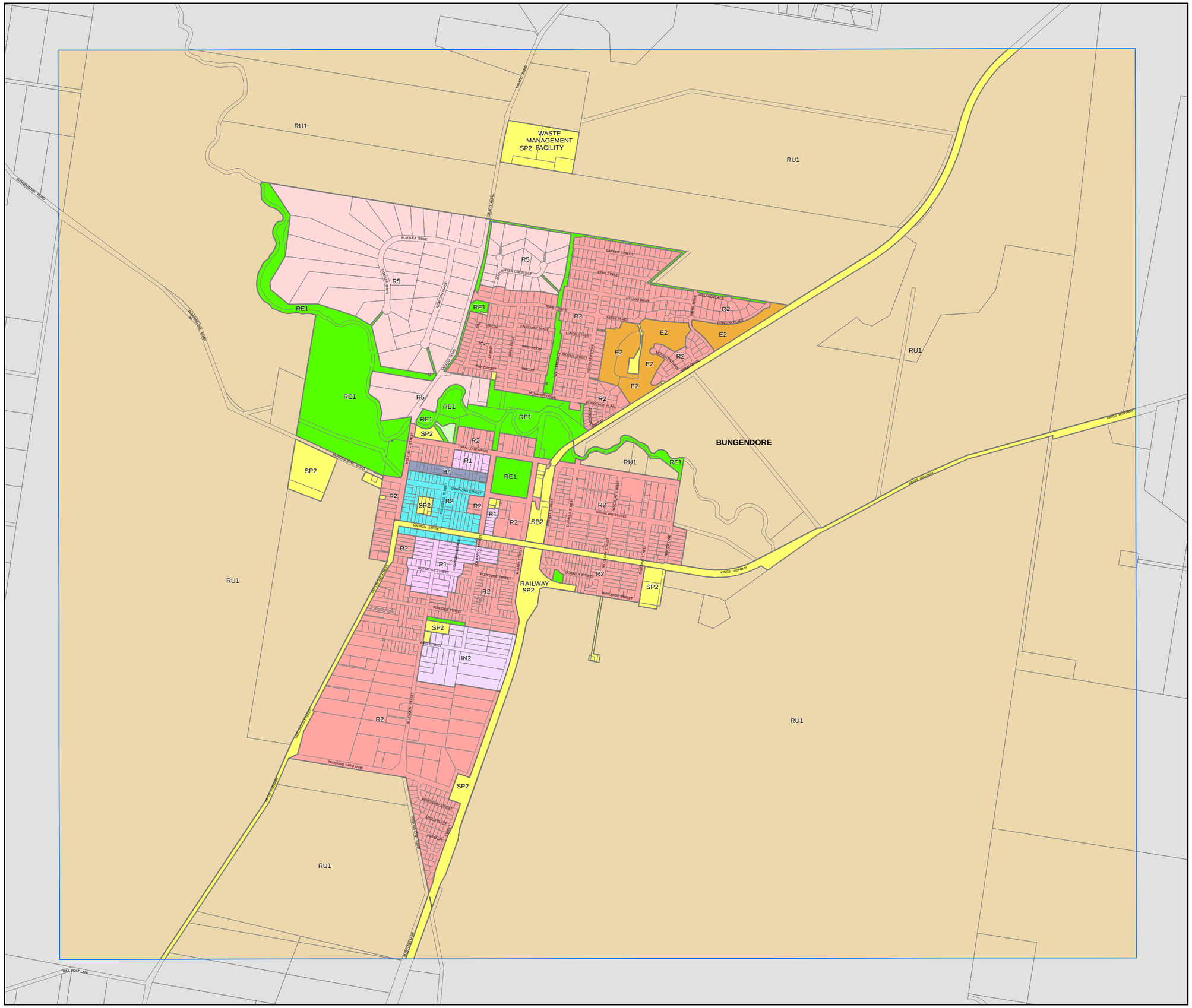
0 1 km

N

Scale: 1:20,000 @ A3

Projection: GDA 1994
MGA Zone 55

Map identification number: 6180_COM_LZN_004A_020-20131003



Appendix D – Flood Planning Map

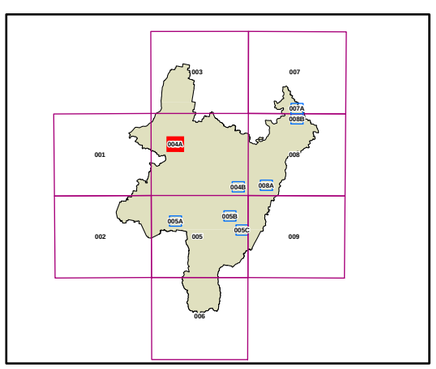
PALERANG COUNCIL

Palerang Local Environmental Plan 2013

Flood Planning Map - Sheet FLD_004A

Flood Planning Level

Cadastre 3/10/13 © Land and Property Information



0 1 km

N

Scale: 1:20,000 @ A3

Projection: GDA 1994
MGA Zone 55

Map identification number: 6180_COM_FLD_004A_020-20131003