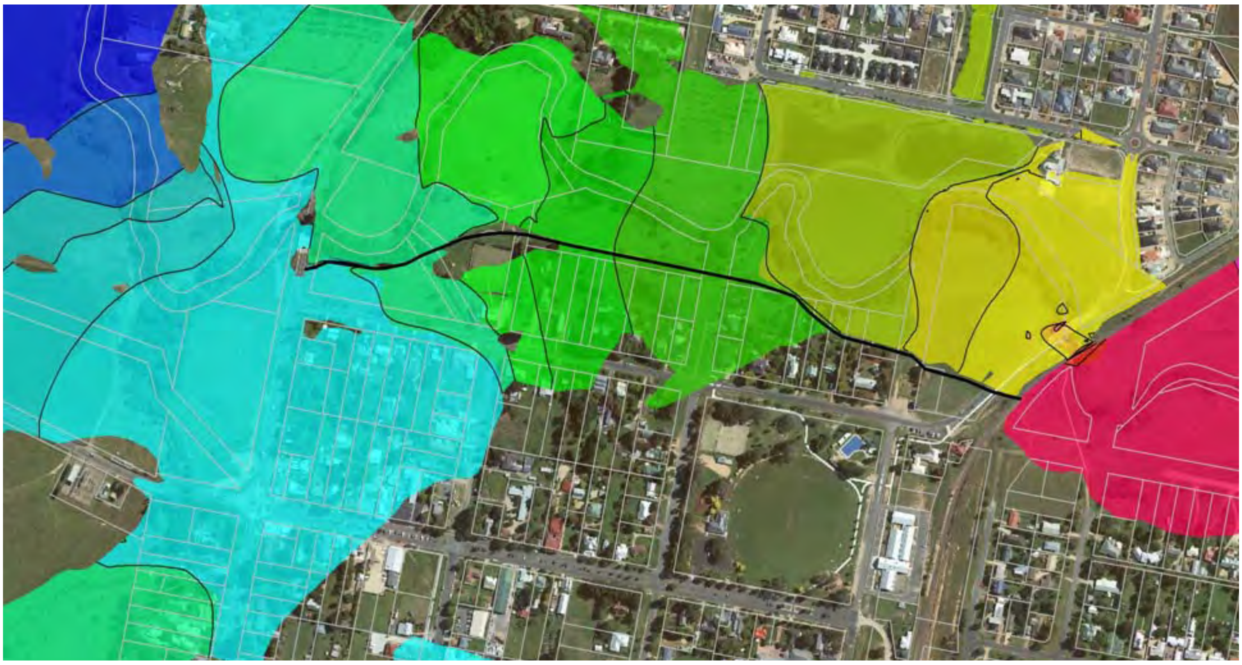
PALERANG COUNCIL

BUNGENDORE FLOODPLAIN RISK MANAGEMENT STUDY



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Project: 3777 – Bungendore Floodplain Risk Management Study

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The following report was prepared by WorleyParsons Services Pty Ltd (*incorporating the former Patterson Britton & Partners*) on behalf of Palerang Council's Floodplain Risk Management Committee.

The Bungendore Floodplain Risk Management Study 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.

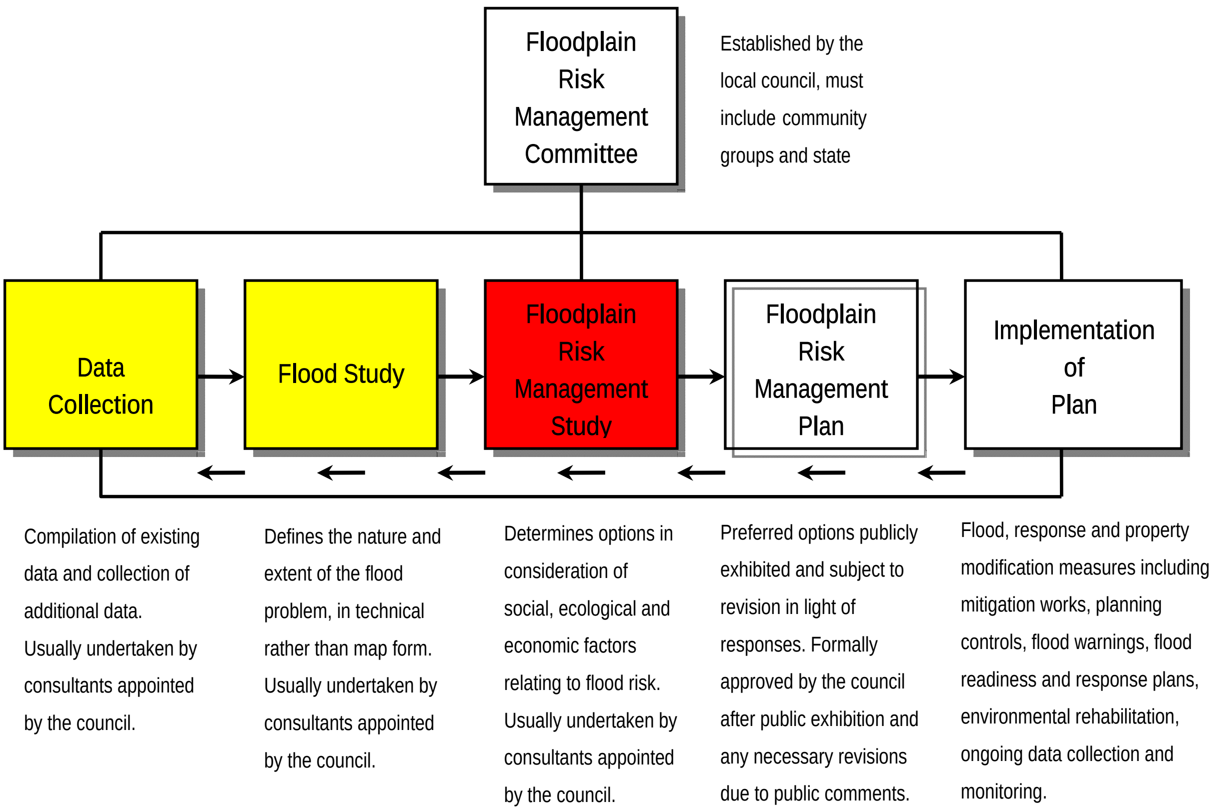
It has been prepared by incorporating contributions from individuals from the local community and a range of key stakeholders. Contributions from the NSW Office of Environment & Heritage (*formerly DECCW*) and the Palerang Floodplain Risk Management Committee have been essential to the formation of management strategies for the Study and are greatly appreciated.

FOREWORD

The State Government's *Flood Prone Land Policy* is directed at 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. The primary objective of the NSW Government's *Flood Prone Land Policy* is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible. Policy and practice are outlined in the NSW Government publication titled, *'Floodplain Development Manual: the management of flood liable land'* (*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 Councils in the discharge of their floodplain management responsibilities.

A detailed description of the inter-relationship between the six iterative stages of floodplain risk management under the NSW Government's *Flood Prone Land Policy* is shown in the flow chart presented below. This flow chart also shows the link between the various outcomes of the studies involved in the floodplain risk management process and the implementation of measures (*both planning and structural*) to reduce flood damages and other negative impacts.



FLOODPLAIN RISK MANAGEMENT PROCESS

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

1. Data Collection
   - Involves the compilation of existing flood related data such as rainfall records, recorded flows and peak flood levels that have been recorded for historical floods. It also involves the collection of additional data such as river and floodplain cross-sections or spot elevations that define the floodplain topography, as well as social, economic, ecological, land use and emergency management data.
2. Flood Study
   - Determines the nature and extent of the flood risk, including the specification of peak flood levels and flow velocities for floods of varying severity up to and including the probable maximum flood (*PMF*). It also provides information on the extent of floodwaters and on the distribution of floodwaters across various sections of the floodplain.
3. Floodplain Risk Management Study
   - Identifies and evaluates management options for the floodplain in terms of their capacity to reduce existing and potential future flooding problems.
   - Provides information on flood behaviour and flood hazard, so that community aspirations for future land-use can be assessed.
   - Provides a framework for revisions to planning instruments such as Local Environmental Plans (*LEPs*), so that land-use controls are consistent with flood risk and flood hazard.
4. Floodplain Risk Management Plan
   - Involves the development of a plan of action for reducing existing flood damages, minimising the potential for further problems in the future and providing mechanisms for flood emergency response management.
   - Involves formal adoption by Council of a plan of management for the floodplain.
5. Implementation of the Plan
   - Construction of flood mitigation works to protect existing development;
   - Modification of local environmental plans to ensure that new development is compatible with the flood hazard;
   - Preparation of Development Control Plans for areas of the floodplain where flood compatible development is considered appropriate.

The first and second stages of the process were completed in November 2002 with the publication of the '*Bungendore Flood Study*' (*refer boxes in flow chart highlighted in yellow*).

The '*Bungendore Floodplain Risk Management Study*' constitutes the third stage of the management process for the floodplains of Turallo, Halfway and Millpost Creeks (*refer to box in flow chart that is highlighted in red*). It has been prepared for Palerang Shire Council and provides the basis for the future management of flood liable lands around Bungendore. This report details the major findings from the investigations that have been undertaken for the Floodplain Risk Management Study.

GLOSSARY

annual exceedance probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (*that is a one-in-twenty chance*) of a peak flood discharge of 500 m^3/s or larger occurring in any one year (*see average recurrence interval*).
Australia Height Datum (AHD)	A common national surface level datum corresponding approximately to mean sea level.
average recurrence interval (ARI)	The long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. The ARI is another way of expressing the likelihood of occurrence of a flood event.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
design flood	A hypothetical flood representing a specific likelihood of occurrence (*for example the 100 year ARI or 1% annual exceedance probability flood*). The design flood may comprise two or more single source dominated floods.
development	Is defined in Part 4 of the Environmental Planning and Assessment Act (*EP&A Act*). infill development: refers to development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development. new development: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve rezoning and typically require major extensions of existing urban services, such as roads, water supply, sewerage and electric power. redevelopment: refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either rezoning or major extensions to urban services.
discharge	The rate of flow of water measured in terms of volume per unit time, for example cubic metres per second (*m^3/s*). Discharge is different from the speed or velocity of flow which is a measure of how fast the water is moving for example, metres per second (*m/s*).
effective warning time	The time available after receiving advice of an impending flood and before floodwaters prevent appropriate flood response actions being undertaken. The

	effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within 6 hours of the causative rainfall.
flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a water course, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood behaviour	The pattern/characteristics/nature of a flood. The flood behaviour is often presented in terms of the peak average velocity of floodwaters and the peak water level at a particular location.
flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
FLOOD FREQUENCY ANALYSIS	A statistical analysis of historical flood records to determine estimates of the magnitude of floods of a selected probability of exceedance (*as adapted from AR&R 1998*)
flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
flood hazard	See hazard
flood level	The height or elevation of flood waters relative to a datum (*typically the Australian Height Datum*). Also referred to as “stage”.
floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
flood planning levels (FPLs)	The combinations of flood levels and freeboards selected for planning purposes, as determined in floodplain risk management studies and incorporated in floodplain risk management plans. The of FPL’s supersedes the “standard flood event” referred to in the 1986 edition of the *‘Floodplain Development Manual’*.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to reduce or eliminate flood damages.
floodplain management	The coordinated management of the risks associated with human activities that occur on the floodplain.
flood prone land	Land susceptible to flooding by the probable maximum flood (PMF) event. Flood prone land is synonymous with flood liable land.

flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk can be divided into three types, existing, future and continuing risk. They are described below. <u>existing flood risk</u>: the risk a community is exposed to as a result of its location on the floodplain. <u>future flood risk</u>: the risk a community may be exposed to as a result of new development on the floodplain. <u>continuing flood risk</u>: the risk a community is exposed to after floodplain risk management measures have been implemented. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storages can increase the severity of flood impacts by reducing natural flood attenuation. Hence it is necessary to investigate a range of flood sizes before defining flood storage areas.
floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are areas often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
freeboard	A factor of safety typically used in relation to the setting of floor levels and levee crest levels etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action, localised hydraulic behaviour and impacts that are specific event related such as levee and embankment settlement, and other effects such as "greenhouse" and climate change. Freeboard is included in the flood planning level.
hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (2005).
historical flood	A flood which has actually occurred.
hydraulics	The term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.

hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
hydrology	The term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
mathematical / computer models	The mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.
minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood. <u>minor flooding</u>: Causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. <u>moderate flooding</u>: Low lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. <u>major flooding</u>: Appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.
peak discharge	The maximum discharge occurring during a flood event.
probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location, usually estimated from the probable maximum precipitation. Generally, it is not physically or economically possible to provide complete protection against this event. The PMF defines the extent of flood prone land; that is, the floodplain. The extent, nature and potential consequences of flooding associated with the PMF event should be addressed in a floodplain risk management study.
probable maximum precipitation (PMP)	The greatest depth of precipitation for a given duration that is meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long term climatic trends (*World Meteorological Organisation 1986*). It is the primary input to the estimation of the probable maximum flood.

probability	A statistical measure of the expected chance of flooding (*see annual exceedance probability*).
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this flood study (*and the subsequent floodplain risk management study*) it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
stage	Equivalent to "water level". Both are measured with reference to a specified datum.
stage hydrograph	A graph that shows how the water level at a particular location changes with time during a flood. It must be referenced to a particular datum.
velocity	The speed or rate of motion (*distance per unit of time*) in a specific direction at which the flood waters are moving. Typically, modelled flood velocities in a river or creek are quoted as the depth and width averaged velocity, i.e., the average velocity across the whole river or creek section (*adapted from Chambers English Dictionary 1988*).

1. INTRODUCTION

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. 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 have probably 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 (*refer* **Figure 2**). 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 be about 400 mm lower than 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 for this report determined that flooding of the streams that drain through the village can result in damage to both public and private property. Severe flooding, particularly overnight and in response to intense rainfall in the catchment, 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.

Accordingly, it is appropriate, under the NSW Government's *Floodplain Management Program*, to consider options for reducing the flood damages that could be experienced by residents and to reduce the risk for loss of life. The associated assessment involves consideration of the flood damages that residents and the broader community may experience as a consequence of the existing flood problem. These damages are a measure of the cost of flooding under existing conditions.

As outlined above, the NSW Government's *Floodplain Management Program* is targeted toward determining measures that can be cost effectively implemented to reduce existing flood damages. Typically, the community is engaged to identify potential flood damage reduction measures (*structural measures*) and to identify potential planning controls (*non-structural measures*) that could reduce the impact of floods. These are tested to establish their relative benefit, which is usually measured in terms of the potential reduction in flood damages, or the potential for additional future development that can occur at no increased risk to the community. The measures are also costed and their respective costs compared to their net benefit, thereby allowing a benefit-cost ratio to be determined for each measure.

Measures with a high benefit-cost ratio are typically recommended for inclusion within a Floodplain Risk Management Plan, which is the fourth phase in the floodplain management process (*refer to flow chart in Foreword*).

This report documents the findings of investigations undertaken to assess a range of potential flood damage reduction measures and floodplain management options that could be implemented at Bungendore to reduce the frequency of flooding. It also documents measures to address emergency response management issues that are likely to exist during major flooding of Turallo, Halfway and Millpost Creeks. The Floodplain Risk Management Study sets out to:

- identify and evaluate management options for the floodplain in terms of their capacity to reduce existing and potential future flooding problems;
- provide information on flood behaviour and flood hazard, so that community aspirations for future land use can be assessed; and,
- provide a framework for revisions to planning instruments such as Local Environmental Plans (*LEPs*), so that land use controls are consistent with flood risk and flood hazard.

Following completion of the flood study in 2002, additional topographic data has become available for parts of the study area. In order to ensure the RMA-2 flood model is up-to-date, this data was incorporated into the model as part of the floodplain risk management study. The updated modelling results for the 5, 20, 50 and 100 year recurrence floods as well as for the Probable Maximum Flood are documented in this report.

2. NATURE OF THE FLOODING PROBLEM

2.1 BACKGROUND

The contemporary flooding problem along Turallo Creek, Halfway Creek and Millpost Creek in the vicinity of Bungendore can be broken up into four major components, namely:

- the ***history*** of flooding at Bungendore,
- the ***existing*** flooding problem;
- the potential ***future*** flooding problem; and,
- the ***residual***, or continuing flooding problem.

Measures to address these components are complicated by the social consequences of removing people from flood affected areas and the political and economic attractiveness of the floodplain lands due to their accessibility to existing infrastructure and their lower cost per hectare. Each component of the flooding problem is discussed in the following sections.

2.2 HISTORY OF FLOODING AT BUNGENDORE

Bungendore is located on the banks of Turallo and Halfway Creeks which are major tributaries that drain to the southern shoreline of Lake George. The village has a population of about 2,754 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 70 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.

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Available records indicate 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 (*refer* **Figure 1**). In contrast, a flood level of 690.4 mAHD was recorded at the petrol station at the peak of the 1974 flood. Accordingly, it is generally regarded that the 1974 flood was about 400 mm lower than 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 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.

2.3 THE EXISTING FLOOD PROBLEM

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.

As outlined in **Section 1**, the existing flooding problem at Bungendore is documented in a report titled, *'Bungendore Flood Study'* (*Issue No 3, November 2002*). The Flood Study 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 (*using a channel cross-section located near the northern end of Majara Street*) 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' (*refer* **Figure 1**). 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.

In events rarer than the 5 year recurrence event, floodwaters also extend in a northerly direction across Bungendore North.

The western end of the village area is particularly susceptible to flooding. Floodwaters 'back-up' from the confluence of Halfway and Turallo Creeks, causing inundation of Molonglo Street, and the western ends of Malbon and Gibraltar Streets and Turallo Terrace. Properties fronting the western side of Molonglo Street between Gibraltar Street and Turallo Terrace are predicted to be inundated in events as frequent as the 5 year recurrence flood.

The existing flood problem is discussed in further detail in **Section 3** of this report. **Section 3** provides details of the updated flood modelling that has been undertaken following completion of the flood study in 2002. The updated modelling results for the 5, 20, 50 and 100 year recurrence floods as well as for the Probable Maximum Flood are discussed and presented as figures showing Water Surface Profiles along Turallo Creek, and the variation in peak flood levels as well as depths and velocities across the study area.

Updated hydraulic and hazard category mapping for the study area based on the updated modelling results is presented and discussed in **Section 7**.

2.4 FUTURE FLOODING 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 rezoning applications.

As land resources for development become increasingly scarce, pressures mount to allow development within floodplain areas where it might otherwise be avoided. The future flooding problem has the greatest potential to cause large scale flood damages along Turallo Creek and presents the greatest potential risk to loss of life.

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 Management Plan is in place and that this Plan or an associated *Flood Policy*, can be used to support decisions to approve or reject development proposals on flood affected sections of the LGA.

2.5 RESIDUAL FLOODING PROBLEM

Unless the Probable Maximum Flood (*PMF*) is adopted as the basis for determining structural and planning measures aimed at reducing flood damages, 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. 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 Services (*SES*) to develop a contingency plan for such events.

3. UPDATED FLOOD STUDY MODELLING

As part of the floodplain risk management study, the two-dimensional RMA-2 hydrodynamic model that was developed as part of the '*Bungendore Flood Study*' (*2002*) by Patterson Britton & Partners (*now WorleyParsons*), was updated to incorporate topographic data acquired since 2002. The model was also updated to ensure it reflected current catchment conditions such as recent development of the floodplain and updates to hydraulic control structures.

This updated RMA-2 model was used as the basis for re-visiting the simulation of design flooding scenarios and for the modelling and assessment of floodplain management options.

No changes were made to the XP-RAFTS hydrologic model that had been developed for the flood study and used as the basis for RMA-2 model inflows.

3.1 RMA-2 MODEL UPDATES

The following provides a summary of the data and the major updates incorporated into the RMA-2 model following completion of the flood study. The extent of the additional data and model updates are also summarised in **Figure 2**.

- Surveyed spot elevations covering floodplain areas upstream of the Goulburn-Bombala railway crossing and extending as far upstream as the Kings Highway bridge crossing of Turallo Creek (*refer* **Figure 2**)
- Work-as-executed survey for the Elmslea Estate development located on the northern floodplain of Turallo Creek. The survey extended downstream from the Goulburn-Bombala railway crossing (*refer* **Figure 2**).
- Survey data covering for the Darmody site located on the western side of Kings Highway on the southern approach to Bungendore. The survey covered approximately 66 hectares of the floodplain between Halfway and Millpost Creeks (*refer* **Figure 2**).
- Work-as-executed drawings and survey of the upgraded Tarago Road bridge crossing (*refer* **Appendix A**).
- Survey Data covering parts of the Millpost Creek and Halfway Creek floodplains upstream of King Street. The survey included road crest elevations and details of culverts along Trucking Yard Lane and Kings Highway. The survey data covered an area of approximately 280 ha (*refer* **Figure 2**).

  Collection of the survey data in February 2012 enabled the RMA-2 model to be extended for an additional 2 kilometre length along Millpost Creek. The data also led to the refinement of the model network in order to more reliably '*pick-up*' channel inverts as well as floodplain features.
- Survey data covering parts of the Halfway Creek floodplain upstream of Trucking Yard Lane and to the west of Kings Highway in the vicinity of the Turalla irrigation pivot (*refer* **Figure 2**). The survey data covered an approximate area of 38.6 ha and was used to improve the

reliability of flooding predications and flood extent mapping along the fringes of the RMA-2 model along Halfway Creek. The survey data was collected in March 2012.

- Spot elevations along the Millpost Creek floodplain to confirm surface elevations in the vicinity of the Davey Property (*refer* **Figure 2**).

The survey data and updates outlined above were incorporated into the RMA-2 model through refinement and adjustment of the model network. This was undertaken in order to ensure the additional topographic detail was reliably represented in the model network.

The updated RMA-2 model network developed as part of the floodplain risk management study is shown in **Figure 3**. As an outcome of the greater refinement of model elements in the updated RMA-2 model, it follows that material roughness values for different land use and floodplain types could be more acutely assigned. Accordingly, the roughness parameters adopted for the 2002 flood study model were reviewed and refined to more reliably reflect the study area. The adopted roughness types and values are shown in **Table 1**.

The re-calibration of the updated RMA-2 model as well as modelling results for the adopted design flooding scenarios are discussed in the following.

Table 1 ADOPTED ELEMENT ROUGHNESS VALUES

Description of RMA-2 Element Type	Manning's 'n'
Defined channel (medium vegetation)	0.045
Defined channel (dense vegetation)	0.075
Rural development with limited obstruction	0.040
Floodplain with short grass	0.030
Floodplain with high grass	0.035
Scattered brush, heavy weeds	0.050
Floodplain with dense trees	0.100

3.2 MODEL VALIDATION

3.2.1 1956 and 1974 Historic Floods

Calibration of the RMA-2 flood model had previously been undertaken to the 1956 and 1974 historic floods as part of the flood study investigations. As part of these investigations, an iterative approach was adopted during which adjustments to the model network and surface roughness values were made in order to achieve a better 'fit' to available flood mark data and anecdotal information. Section 7.3 of the flood study discusses model calibration.

In order to ensure the updated RMA-2 model was reliably predicting flooding conditions, the model results were validated for the 1956 (*100 year recurrence flood*) and 1974 historic floods. This was achieved by comparing the peak Water Surface Profiles (*WSP*) generated along Turallo Creek by the 2002 RMA-2 flood study model and the updated RMA-2 FPRMS model. Peak 1956 and 1974 WSPs have been extracted from the 2002 flood study and 2012 FPRMS modelling and are shown in **Figure 4**.

Figure 4 indicates that the updated flood model is predicting peak flood levels that are generally within 100 to 200 mm of those reported in the 2002 flood study. This indicates that the recently acquired survey data and model modifications to reflect current floodplain conditions has not led to a significant change in the hydraulics along Turallo Creek. The variances in levels are typically localised and are therefore attributed to localised improvements in topographic data or creek geometry as well as recent upgrades to hydraulic structures or recent development.

Taking into consideration the inaccuracies involved in identifying the actual peak flood mark levels (*refer discussion in Section 7.3 of the flood study*) and the tolerances of the survey data on which the 2002 flood study model was based, it is considered that the updated RMA-2 flood model reliably predicts flood behaviour within the study area. The updated model is therefore considered suitable for simulation of the adopted design flooding scenarios and for modelling of the adopted floodplain risk management options.

3.2.2 100 Year Recurrence Flood

The updated RMA-2 model was also used to re-simulate the design 100 year recurrence flood. Because of the substantial model refinement that had been incorporated since the flood study (*to incorporate the survey data shown in* **Figure 2**), it is expected that the updated modelling results will vary to those predicted for the flood study. The differences are expected to be highest in the vicinity of the Tarago Road bridge and the Railway bridge crossings of Turallo Creek. Significant network refinement was undertaken at these bridge crossings as part of the model updates in order to '*pick-up*' bridge upgrade works as well as more reliable survey.

A comparison of the design 100 year recurrence peak WSPs generated by the updated RMA-2 model and the flood study model are presented in **Figure 5**. As shown in **Figure 5**, flood levels are not predicted to have changed by more than 100 mm in the vicinity of the Elmslea Estate development (*between the Railway bridge and Tarago Road bridge crossings*). This is in agreement with the modelling undertaken for the Elmslea Estate development which found that the proposed development will have minimal impacts on flood levels along Turallo Creek.

Overall, the modelling results are generally within 100 mm of each other with the exception of some localised variances in the vicinity of the bridge crossings (*refer* **Figure 5**). Where flood level differences exceed 100 mm the updated modelling results are considered more reliable due to the finer model resolution and more reliable topographic data utilised.

3.3 UPDATED RMA-2 DESIGN SIMULATIONS

The updated RMA-2 hydrodynamic model of the three creeks in the vicinity of Bungendore village was used to re-simulate the design flooding scenarios that had been adopted and documented the '*Bungendore Flood Study*' (*2002*). In that regard, the 5, 20, 50 and 100 year recurrence floods as well as the Probable Maximum Flood (*PMF*) were re-simulated.

The inflow hydrographs and tailwater conditions that were adopted for the flood study simulations were not changed as part of these updated simulations (*refer 'Bungendore Flood Study' for further details*).

3.3.1 Design Water Surface Profiles

Peak Water Surface Profiles (*WSP*) were extracted from the updated modelling results for the full range of design flooding scenarios. The WSP presents peak flood levels along Turallo Creek for the entire extent of the RMA-2 model i.e., extending from upstream of the Kings Highway bridge crossing to approximately 3 kilometres downstream of the confluence with Halfway Creek (*refer* **Figure 3**).

The profile of design floodwater surfaces for the 5, 20, 50 and 100 year recurrence floods as well as the PMF is shown in **Figure 6**.

3.3.2 Flood Level and Flood Extent Mapping

Peak flood levels and peak flood extents across the study area were extracted from the modelling results and are shown in **Figure 7** to **Figure 11**. The figures show the variation in flood levels along Turallo Creek, Millpost Creek and Halfway Creek as well as within the urbanised areas of Bungendore.

3.3.3 Depth and Velocity Mapping

Depth mapping was also extracted from the modelling results and is shown in **Figure 12** to **Figure 16**. Where possible the results have been '*mapped*' to the available survey in order to improve the resolution at which depths are shown.

Velocity vectors for each of the design flooding scenarios are also overlayed on **Figure 11 to Figure 15**. The vectors give an indication of the direction of flow as well as the peak flow velocity.

3.3.4 Discussion

The predicted extent of inundation of the village area in the 100 year recurrence flood is shown in **Figure 10**. Properties along Molonglo Street between Turallo Terrace and Malbon Street are most susceptible to inundation with depths of up to 2.0 metres predicted to occur at the peak of the 100 year recurrence flood (*refer* **Figure 15**). **Figures 12** to **14** indicate that these properties would also be susceptible to flooding during lower events including the 5 year recurrence flood. During these lower flooding scenarios, inundation increasingly occurs due to flooding from Halfway Creek and from the backing-up of floodwaters from the confluence of Turallo and Halfway Creek.

As shown in **Figure 15**, properties along Turallo Terrace between Molonglo Street and Butmaroo Street are predicted to be inundated to depths of up 1.1 metres at the peak of the 100 year recurrence flood. Despite the lower depths of inundation compared to properties along Molonglo Street, velocities are generally higher ranging between 0.5 m/sec and 0.7 m/sec (*refer* **Figure 15**). These higher velocities occur due to floodwaters 'rushing' across properties towards Halfway Creek following overtopping of the existing levee.

Properties fronting Turallo Terrace between Duralla and Modbury Streets are also susceptible to inundation (*refer* **Figure 10** and **Figure 15**), with floodwaters reaching depths of up to 1.3 metres at the peak of the 100 year recurrence flood. Peak flow velocities are typically lower ranging between 0.2 m/sec to 0.3 m/sec due to the backing-up of floodwaters against the railway embankment.

The existing Turallo Terrace Levee, for the most part, prevents floodwaters from entering the village in events up to an including the 20 year recurrence flood. As shown in **Figure 8** and **Figure 13**, only minor flooding is predicted to occur at the rear of a number of properties adjacent to the levee along Turallo Terrace. This flooding is generally limited to shallow ponding with maximum depths of inundation not predicted to exceed 0.7 metres.

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. The updated modelling results predict maximum flow velocities of up to 0.8 m/sec across these properties during the 100 year recurrence flood (*refer* **Figure 15**).

Floodwater velocities generally vary between 0.7 m/s and 1.6 m/s along the channels of Turallo and Halfway Creeks at the peak of the 100 year recurrence flood. As expected, flow velocities increase in the vicinity of the railway and Tarago Road bridge crossings. For example, in-channel flow velocities of 2.3 m/s are predicted just downstream of the confluence of Turallo and Halfway Creeks. In-channel flow velocities downstream of the railway crossing of Turallo Creek and the Tarago Road bridge crossing are estimated to be 4.5 m/s and 2.2 m/sec, respectively.

Flow velocities across the floodplain are generally similar to the velocities predicted within the main channel, typically varying by no more than 0.2 m/sec. This reflects the large proportion of floodwaters that are carried as overbank flow.

To the south of the village, floodwaters are predicted to overtop Kings Highway for a length of approximately 770 metres at the peak of the 100 year recurrence flood. The section of Kings Highway overtopped extends south of Trucking Yard Lane where elevations along Kings Highway are at their lowest. Along this section the updated flood modelling results predict that Kings Highway would be inundated to depths of up 0.3 metres at the peak of the 100 year recurrence flood. However, depths of inundation are typically less than 0.15 metres along most of the 770 metre length of Highway.

PMF conditions see the vast portion of the study area inundated, with the entire town-centre affected. As with lesser floods the land in the vicinity of creek confluences is extremely inundated to great depth, including Elmslea Estate.

Peak flood levels at key locations for each design flood event are listed in **Table 2**.

Table 2 PREDICTED PEAK DESIGN FLOOD LEVELS AT KEY LOCATIONS

LOCATION	PREDICTED PEAK FLOOD LEVEL (*m AHD*)				
	5 year ARI	20 year ARI	50 year ARI	100 year ARI	PMF
Along Turallo Creek					
Turallo Creek upstream of Kings Highway crossing	697.5	698.0	698.3	698.4	699.7
Turallo Creek upstream of railway line bridge crossing	693.2	693.6	693.9	694.2	696.3
Turallo Creek upstream of Tarago Road Bridge	690.4	690.7	690.8	690.9	692.5
Upstream of confluence of Turallo Creek and Halfway Creek	690.2	690.4	690.5	690.6	692.2
Downstream of confluence of Turallo Creek and Halfway Creek	689.9	690.0	690.2	690.3	692.1
Upstream of confluence of Turallo Creek and Millpost Creek	688.5	688.8	688.9	689.0	691.4
Downstream of confluence of Turallo Creek and Millpost Creek	688.5	688.7	688.8	688.9	691.3
Along Halfway Creek					
Halfway Creek adjacent to Malbon Street	690.6	690.8	690.9	691.0	692.6
Halfway Creek adjacent to King Street	691.6	691.9	692.0	692.1	693.3
Halfway Creek upstream of Trucking Yard Lane	695.1	695.2	695.3	695.3	696.0

4. FLOOD DAMAGE ASSESSMENT

4.1 WHAT ARE FLOOD DAMAGES?

Flood damages are adverse impacts that private and public property owners experience as a consequence of flooding. They can be both tangible and intangible and are usually measured in terms of a dollar cost.

Tangible damages include direct damages such as the damage to property as a consequence of inundation (*e.g., the cost of replacing carpets and removing mud from houses in the aftermath of a flood*). Tangible damages can also be indirect damages such as the cost to the community of individuals being unable to get to work because they are isolated due to flooding. These costs can usually be measured and data has been gathered over many years to provide a reliable indication of the likely damage costs that can be incurred by residential, commercial and industrial property owners.

It is more difficult to quantify intangible damages. Intangible damages include less 'concrete' impacts such as the trauma felt by individuals as a result of a major flood and the associated health related impacts. Only limited data is available, but it has been stated that intangible damages could be as much or more than the tangible damage cost.

As part of a Floodplain Risk Management Study, it is necessary to determine the total damages that could be incurred as a consequence of flooding. If the total damage cost is significant, it can be argued that works or planning measures to reduce the cost can be justified. The justification process involves determining an estimate of the flood damage that could be expected to occur over the design life of the works (*say 30 years*). This damage cost is then compared to the damage cost if no works were undertaken. The difference defines the reduction in flood damage cost, or the net benefit. The net benefit of the works is compared against the cost of the works, thereby generating a benefit-cost ratio for the works.

If the benefit-cost ratio is sufficiently high (i.e., ideally greater than 1), it is likely that the works will attract State Government funding and could proceed.

4.1.1 Flood Damage Categories

Flood damage costs for Bungendore were determined based on consideration of the different types of land use across the floodplain. The predominant land uses are:

- residential; and
- industrial or commercial,

Residential, industrial and commercial flood damages include damage to structures (e.g., buildings, houses, factories, offices) and damage to the items within those structures. They also include damages to outdoor facilities and associated infrastructure, and to the land on which the structures are sited.

Damage to infrastructure as a result of flooding includes losses associated with damage caused by inundation of roads, water supply and sewerage services, and damage to utilities such as electricity, gas and telecommunications systems.

Residential, industrial and commercial damages can be separated into direct and indirect damages. Direct damages are the result of the physical contact of floodwaters with the structure and may include the costs associated with repair, replacement or the loss in value of inundated items. Indirect damages represent all other costs not associated with physical damage to property and typically include the loss of income incurred by residents affected by flooding, as well as flood recovery items such as clean-up costs.

The approach developed to calculate flood damages for Bungendore is based upon the development of a representative damage curve for a typical house in study area. A damage curve is a numerical relationship that correlates the depth of flooding to the cost of damages that would result from that flooding. The cost of the damages associated with the flooding increases as the depth of flooding increases.

The approach employed applies procedures outlined in the Department of Environment and Climate Changes' Draft Guideline No 4 titled, *'Residential Flood Damage Calculation'*. It involves the application of the damage curves documented in the literature with the updated flood modelling results documented in this report.

Damage to residences includes the cost of structural damage, the damage to internal items such as furniture and floor coverings, damage to fences, vehicles and landscaping.

As outlined in the Department of Environment and Climate Change's Draft Guideline No 4, the data available on flood damages typically only applies to residential properties. Therefore, an estimate of the direct damages associated with the inundation of industrial and commercial premises was based on recorded damage costs for similar premises reported in the literature. This literature includes a range of previous floodplain management studies and recorded data presented in intergovernmental reports.

It was not possible to calculate indirect damages for each individual lot or property. Therefore, the indirect damage costs were assumed to be 5% of the direct damage costs incurred by residential properties. This is in keeping with procedures adopted in other studies such as the 'Camden Haven Floodplain Management Study' (*2001*), and is considered a reasonable approximation based on the relatively short duration of flooding.

Indirect damages for industrial and commercial premises were assumed to be 50% of the corresponding direct damages. The higher proportion was assumed to account for the greater impact of indirect influences such as the slow down that a business could experience due to employees being unable to get to work due to inundation of roads.

There is no data available to define the extent of the public and corporate infrastructure that could be damaged as a result of flooding. Accordingly, infrastructure damages were assumed to be 30% of the total direct and indirect residential (including dwellings and property damages) and industrial/commercial costs. This is in keeping with approaches employed for other areas of NSW.

4.1.2 Stage – Damage Relationships

Stage-damage curves reflect the potential direct flood damage as a function of the depth of over floor flooding of a building, or the extent of inundation of the land on which the building is sited.

The DECC's (*now OEH*) Draft Guideline No 4 outlines the method for determining stage-damage curves for residential dwellings. This procedure is recommended as the basis for derivation of average annual damages and net present values of damages to enable the comparison of management options.

Standard stage-damage curves have also been developed from records of damages gathered from interviews with residents and landowners in flood affected communities. For example, Smith et al (*1979*) determined stage-damage relationships for different land use types based on data gathered during and following the Lismore floods in the early 1970s.

Accordingly, stage-damage curves were developed for residential properties and commercial/industrial sites based on consideration of the available stage-damage relationships in the literature. The adopted stage-damage curves for the village of Bungendore are included within **Appendix C**.

4.1.3 Average Annual Damage

The relative cost of the potential flood damages is typically expressed in terms of the Average Annual Damage (*AAD*). The AAD is the average damage per year that would occur from flooding over a very long period of time.

In understanding this concept, there may be periods where no floods occur or the floods that do occur are too small to cause significant damage. On the other hand, some floods will be large enough to cause extensive damage.

The average annual damage is equivalent to the total damage caused by all floods over a long period of time divided by the number of years in that period (*DECC, 2007*). It provides a measure for comparing the economic benefits of potential flood damage reduction options.

4.2 FLOOD DAMAGE ESTIMATE FOR EXISTING CONDITIONS

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 in conjunction with peak flood levels generated from the updated flood modelling documented in **Section 3**, to determine the depth of flooding in the vicinity of these buildings. This allowed the depth of "over floor" flooding to be determined (*if any*).

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.

Predicted flood damages associated with the 100, 20 and 5 year recurrence floods for existing conditions are provided in **Table 3** for Bungendore. The number of structures and properties inundated is also listed. Direct and indirect costs have been included in all damage cost estimates (*excluding infrastructure damages which stand alone*). All damage costs are expressed in 2012 dollars.

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.

Based on existing conditions, 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 (*refer* **Table 3**).

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 (*refer* **Table 3**).

Table 3 EXISTING FLOOD DAMAGE COSTS FOR BUNGENDORE

FLOOD EVENT	RESIDENTIAL DAMAGES				INDUSTRIAL / COMMERCIAL DAMAGES		INFRASTRUCTURE DAMAGES	TOTAL DAMAGES
	Number of Dwellings Inundated	Dwelling Damages	Number of Properties Inundated	Property Damages	Number of Sites Inundated	Estimated Cost of Damages	Estimated Cost of Damages	Estimated Cost of Damages
5 Year Recurrence Flood	2	$47,900	18	$159,900	2	$442,500	$195,100	$845,400
20 Year Recurrence Flood	7	$276,600	31	$239,800	3	$664,700	$354,300	$1,535,400
100 Year Recurrence Flood	21	$1,047,900	53	$319,700	8	$1,005,700	$712,000	$3,085,400

Residential dwellings and commercial premises that could be inundated during a 100 year recurrence 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.

As shown in **Table 3**, it is predicted that during the 100 year recurrence flood, the damages associated with the inundation of potentially flood affected properties would amount to about $3,085,400.

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.

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 in the larger floods.

Accordingly, the intangible damages associated with flooding at Bungendore are considered to be significant and an important component of the overall flood scenario.

5. POTENTIAL FLOOD DAMAGE REDUCTION MEASURES

5.1 BACKGROUND

Information presented in the *'Bungendore Flood Study'* (*2002*) indicated that there is a significant potential for flooding to impact and cause damage to infrastructure and residents at Bungendore. These damages would include financial losses to individual property and business owners and losses to the overall community as a result of damage to infrastructure and disruption to everyday life.

As an outcome it was considered appropriate to proceed with preparation of a Floodplain Risk Management Study in order to identify a range of options that could be implemented to reduce the flood damages that the community could be exposed to in the future. Since this process began in 2005, a number of options for floodplain management have already been implemented by Palerang Council. These include:

- Construction of Elmslea Estate on the northern floodplain of Turallo Creek, including floodplain modifications to create a commensurate ornamental lakes system and community playing fields;
- Upgrading of the Tarago Road bridge to increase the conveyance capacity to relieve flooding upstream along Turallo Creek; and
- Upgrading of the Railway Bridge crossing over Turallo Creek to increase the bridge waterway area to increase conveyance capacity.

The updated modelling results in **Section 3**, as well as the damage analysis outlined in **Section 4**, indicates that a substantial threat of flooding still remains for much of the community. Investigation of additional floodplain management options is required as part of the floodplain risk management process in order to further safeguard the community and reduce the existing flood damages that could be incurred by the community.

The proposed floodplain management options are discussed below.

5.2 ADOPTED DAMAGE REDUCTION MEASURES

A floodplain risk management study is a multi-disciplinary process that needs to consider a number of different factors to develop an appropriate mix of management measures that can be implemented to deal with the flood risk (*NSW Government, 2005*). Each floodplain risk management measure will have both advantages and disadvantages. The purpose of the floodplain risk management study is to quantify the relative merits of each measure, giving consideration to any flooding, social, economic and environmental consequences.

As part of this Study, the Bungendore Floodplain Management Committee developed a range of <u>measures</u> aimed at addressing the existing and potential future flood problem. This involved the formulation of a list of potential <u>Flood Damage Reduction Measures</u>.

The Flood Damage Reduction Measures were devised with a view to reducing the existing flood damages that could be incurred by the community. The Flood Damage Reduction Measures that were adopted are listed in **Table 4**.

Table 4 FLOOD DAMAGE REDUCTION MEASURES

MEASURE No.	DESCRIPTION OF MEASURE	OVERVIEW
1	Upgrading and extension of levee along Turallo Terrace	*Refer* Figure 17 & 18
2	Upgrading of the Turallo Terrace levee (*no extension*)	*Refer* Figure 17 & 18
3	Installation of overflow channel across Tarago Road	*Refer* Figure 19
4	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks	*Refer* Figure 19
5	Installation of diversion channel from Halfway to Millpost Creek	*Refer* Figure 19
6	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and excavation to construct a diversion channel	*Refer* Figure 20

Each measure was investigated to establish the hydraulic impact in terms of its potential to reduce peak flood levels and / or flood hazard. A discussion of the hydraulic impact of implementing each of these measures in isolation is presented in **Section 5.3**.

5.3 HYDRAULIC ANALYSIS OF DAMAGE REDUCTION MEASURES

5.3.1 Measure 1 – Upgrade & Extension of Turallo Terrace Levee

Measure 1 involves upgrading and extending the existing levee that is located along the rear of properties that front Turallo Terrace between Molonglo and Majara Streets. This would involve increasing the height of the existing levee so that it is not overtopped in floods up to and including the 100 year recurrence event and extension of the levee east from the railway to Mecca Lane. The extent of the proposed levee upgrade and the location of the proposed extension are shown in **Figure 17** and **Figure 18**.

Although this option will not act to reduce flood levels within Turallo and Halfway Creeks, it will prevent floodwaters from entering the majority of the village. As outlined in the Flood Study and **Section 3** of this report, floodwaters overtop the existing levee in events rarer than the 20 year recurrence flood and inundate properties located between Ellendon and Molonglo Streets.

In order to assess the benefit of the proposed levee upgrade, the RMA-2 hydrodynamic model was modified to incorporate a levee with a crest elevation greater than the predicted 100 year recurrence flood level.

It was assumed that the proposed levee would have a crest elevation 500 mm above the elevation of the 100 year recurrence flood. This will require the crest elevation of the proposed levee to be up to 2 metres above the natural surface of the floodplain in the area between the railway and the Tarago Road bridge, and up to 2.5 metres above the natural surface of the floodplain along the alignment of the proposed extension to the levee.

The modified RMA-2 model was used to simulate flood behaviour with the levee in place for the 5, 20 and 100 year recurrence events.

The results from the simulations were compared to the predicted peak flood levels and velocities for existing conditions (*i.e., as generated in the Flood Study*) and "difference maps" of peak water level were generated. The difference maps give an indication of the relative magnitude of water level changes and the location at which they occur. A difference map showing changes in peak flood levels for the 100 year recurrence event is presented as **Figure 21**. A negative value indicates a drop in level, while a positive value indicates an increase in flood level.

As shown, the proposed levee upgrade is particularly effective in reducing flood levels in areas of the village that are currently susceptible to flooding. In fact, the levee upgrade would prevent flooding of properties east of Ellendon Street in events up to and including the 100 year recurrence flood. West of Ellendon Street, peak 100 year recurrence flood levels would be reduced by up to 0.09 metres (*refer* **Figure 21**).

However, the difference mapping indicates that some flood level increases would be predicted to occur to the north of the levee upgrade and upstream of the levee extension. As shown in **Figure 21**, these flood level increases are not predicted to exceed 0.12 metres.

Investigations indicate that the proposed levee upgrade and extension would reduce the number of properties inundated in events of the magnitude of the 100 year recurrence flood from 61 to 31. The areas that would be most substantially benefited are the areas between Molonglo and Ellenden Streets and between Duralla and Modbury Streets.

Dwellings that would benefit from the levee extension include those situated:

- on the corner of Ellendon Street and Turallo Terrace;
- on the northern and southern side of Turallo Terrace, between Ellendon and Butmaroo Streets; and,
- on the southern side of Turallo Terrace between Duralla and Modbury Streets.

5.3.2 Measure 2 – Upgrade of the Turallo Terrace Levee

Damage Reduction Measure 2 involves upgrading of the Turallo Terrace Levee to increase crest elevations above the peak 100 year recurrence flood level. A freeboard allowance of 0.5 metres is also proposed (*refer* **Figure 17** *and* **18**).

Upgrading of the existing levee was considered as a standalone damage reduction measure (*i.e., without the proposed levee extension component*) following the realisation that it's construction and material costs would comprise a minor component of the total required for Measure 1. As shown in **Figure 18**, the upgrade component of the works requires significantly less material/fill in order to achieve a crest elevation that is 500 mm above the peak 100 year recurrence flood level. This saving in material costs in combination with the associated savings in construction costs supports the investigation of the upgrade scenario in isolation.

Because of the similarities between Measure 1 and Measure 2 (*i.e., Measure 2 represents a reduced version of Measure 1*), flood modelling was not undertaken for Measure 2 in isolation. Notwithstanding, the flood level difference mapping proposed for Measure 1 and shown in **Figure 21** is considered suitable for gaining an understanding of the predicted benefits of Measure 2 in isolation.

In that regard, the predicted variation in peak 100 year recurrence flood levels and extents is shown in **Figure 21** for Measure 2. All flood level increases upstream of the Railway Bridge are generated as an outcome of the levee extension component and as such are not relevant to Measure 2.

Further discussion of the modelling results applicable to the levee upgrade scenario is included in **Section 5.3.1**.

5.3.3 Measure 3 – Overflow Channel across Tarago Road

Investigations for the Flood Study established that flooding between the railway crossing and the Tarago Road bridge crossing of Turallo Creek, can to some extent, be attributed to the afflux caused by the Tarago Road Bridge. However, further investigations undertaken as part of this study determined that the alignment of the channel of Turallo Creek adjacent to the embankment created by the northern approaches of the road bridge, was as much a cause of the afflux as the bridge itself.

Accordingly, the Committee proposed that one of the potential options for flood damage reduction should comprise the construction of a flood relief channel that would allow floodwaters to bypass the Tarago Road bridge crossing of the creek during major events. Measure 3 was therefore developed to comprise the construction of a "relief floodway" that would allow the higher flows to leave the channel about 250 metres upstream of the Tarago Road Bridge crossing (*refer* **Figure 19**). The channel would divert floodwaters across Tarago Road so that they re-entered the creek about 200 metres downstream of the confluence of Turallo and Halfway Creeks.

The updated FPRMS RMA-2 model was modified to incorporate the proposed relief floodway. This was achieved by reducing the ground surface elevations along the alignment of the proposed floodway by approximately 2 metres so that a fairly constant grade was established between the upstream and downstream ends of the floodway. It was assumed that the floodway was a straight, earth lined channel with a trapezoidal cross-section.

The proposed floodway would need to pass under the existing Tarago Road, and thereby a bridge or culvert structure would need to be incorporated into the detail design. The influence of this crossing on hydraulic behaviour was represented by slightly reducing the available cross-sectional flow area and applying a higher roughness coefficient.

The modified model was used to simulate flood behaviour in the 5, 20 and 100 year recurrence events. Results from these simulations were compared to the corresponding set of results derived for existing conditions, and difference maps were created to show the anticipated change in peak flood level and flow velocity.

A difference map showing the change in flood level resulting from implementation of the relief floodway is presented in **Figure 22**. This indicates that peak flood levels along Molonglo Street between Gibraltar Street and Turallo Terrace would reduce by up to 0.10 metres with the proposed relief floodway in place. More detailed inspection indicates that floodwaters would be lowered by 0.08 metres in the vicinity of properties fronting Molonglo Street. This is considered to be a significant reduction in peak flood level.

Results from simulations for the 20 and 5 year recurrence events indicate that floodwaters would typically be lowered by 0.06 and 0.04 metres, respectively. Hence, the relief floodway appears to be particularly effective in lowering flood levels in this area in events rarer than the 20 year recurrence flood.

Despite the reduction in flood levels afforded by the implementation of the relief floodway, it does not reduce levels enough during the 100 year flood to prevent the existing Turallo Terrace levee from overtopping. Hence, the number of properties potentially affected by flooding would remain relatively unchanged.

Notwithstanding, those properties in the vicinity of Molonglo Street would typically experience less damage than is currently the case for a flood of a given frequency.

5.3.4 Measure 4 – Removal of Dense Vegetation and Creek Re-Shaping at the Confluence of Turallo and Halfway Creek

Modelling indicates that the removal of vegetation at the confluence of Turallo and Halfway Creeks in isolation, will only marginally reduce peak flood levels during large floods. However, the reshaping of both Turallo and Halfway Creek could enhance the capacity for floodwaters to “escape” more rapidly from the village reach of Turallo Creek. Accordingly, the additional impact of “streamlining” both creek channels in conjunction with the removal of the dense vegetation was investigated. Excavation of overbank areas at the confluence was also considered in order to provide additional capacity when floodwaters exceed the channel capacity.

The extent of vegetation removal and excavation proposed as part of Measure 4 is shown in **Figure 19**.

The RMA-2 model was modified to reflect the proposal by reducing roughness coefficients near the creek confluence and by adjusting model elevations along those overbank areas indicated in **Figure 19**. In general, elevations along the overbank areas were reduced to approximately 688.0 mAHD, which was reflective of excavation depths of between 1.0 to 1.5 metres.

Simulations were undertaken with the modified model for the 5, 20 and 100 year recurrence events. The results indicate that there is a minor reduction in the extent of flooding through the village. More substantial reductions in flood extent occur across the northern floodplain of Turallo Creek, downstream of Tarago Road. Minor reductions in flood extent are also predicted to occur near the confluence of Turallo and Halfway Creeks. However, there are very few assets in this area and therefore the proposed works are unlikely to result in substantial reductions in flood damages.

A difference map showing the change in water level resulting from the proposed vegetation removal and excavation is presented in **Figure 23**. The difference mapping indicates that a maximum decrease in peak water level of 0.11 metres is predicted to occur east of the creek confluence along Molonglo Street. Flood level reductions of up to 0.08 metres are predicted to occur as far east as Ellendon Street and as far south as Malbon Street.

Despite the reduction in flood levels afforded by Measure 4, it does not significantly reduce the extent of flood liable land. Hence, the number of properties potentially affected by flooding would remain relatively unchanged.

Notwithstanding, those properties in the vicinity of Molonglo Street and the northern end of Turallo Terrace would typically experience less damage than is currently the case for a flood of a given frequency due to a reduction in the likely depths of inundation.

5.3.5 Measure 5 – Diversion Channel from Halfway Creek to Millpost Creek

Damage Reduction Measure 5 involves excavation of high ground separating the Halfway Creek and Millpost Creek floodplains. The proposed excavation shown in **Figure 19** would act as a diversion channel during times of high flow along Halfway Creek.

Figure 24 shows the predicted benefits of Measure 5 in terms of changes to flood levels at the peak of the design 100 year recurrence flood. As shown, the highest flood level decreases of up to 0.11 metres are predicted to occur in the vicinity of the diversion channel. Downstream in the vicinity of Molonglo and Gibraltar Streets, the predicted flood level decreases are lower typically varying between 0.08 and 0.05 metres.

The required extent and depths of excavation are significant at this location and thus acts to limit the potential of this measure; due to the comparatively large costs. Investigation of alternate locations between Trucking Yard Lane and Gibralter Streets did not identify any more suitable locations. As an outcome, the proposed Measure 5 was found to have limited potential and was not investigated further.

5.3.6 Measure 6 – Diversion of Floodwaters upstream of Trucking Yard Lane through Diversion Channels and Contour Banks

Damage Reduction Measure 6 involves construction of a contour bank and diversion channel in order to convey a percentage of flow from Halfway Creek to Millpost Creek. The proposed alignment of contour banks and extent and depth of excavation to construct the diversion channel were determined based on an iterative modelling approach. The proposed layout of Measure 6 is shown in **Figure 20**.

The RMA-2 model was modified to incorporate the proposed contour bank and diversion channel by adjusting the network grid and increasing/reducing node elevations where required. The modified model was used to re-simulate the 5, 20 and 100 year recurrence events.

The results indicated the adopted layout of Measure 6 (*refer* **Figure 20**) would have the capacity to divert up to 80 m^3/s at the peak of the 100 year recurrence flood. As shown in **Table 5**, this represents a diversion of approximately 50%. The diversion potential of the Measure 6 during the 5 year and 20 year ARI floods is also shown in **Table 5**.

Table 5 Diversion Potential of Measure 6 – Halfway Creek to Millpost Creek

ARI (Years)	TOTAL FLOW ALONG HALFWAY CREEK (m^3/s)	DIVERTED FLOW VIA MEASURE 6 (m^3/s)	PERCENTAGE DIVERTED (%)
5	85	35	41
20	120	55	46
100	160	80	50

Figure 25 shows the change in peak 100 year recurrence flood levels predicted to occur as an outcome of Measure 6. A maximum flood level decrease of up to 0.37 metres is predicted to occur along Halfway Creek approximately 800 metres downstream of Trucking Yard Lane. Further downstream in the vicinity of Malbon and Gibraltar Streets the flood level decreases are reduced varying between 0.2 and 0.12 metres (*refer* **Figure 25**).

As expected, the diversion of flows from Halfway Creek to Millpost Creek will also result in some flood level increases along Millpost Creek downstream of the diversion channel. A maximum increase of up to 0.3 metres occurs immediately downstream of the diversion channel at the peak of the 100 year recurrence flood. The predicted flood level increases are lower further downstream, typically varying between 0.1 and 0.2 metres.

The majority of the flood level increases are predicted to occur within the Turalla Property which occupies much of the eastern and western floodplain of Millpost Creek. In that regard, although substantial flood level reductions and benefits would occur within the Bungendore Village as an outcome of Measure 6, some negative impacts would be expected within the Turalla Property.

The potential for Measure 6 to impact the Turalla Property is discussed in further detail in the following.

Potential For Increased Inundation of the Turalla Property

As shown in **Table 5**, the preliminary design of Measure 6 would potentially divert up to 50% of the total 100 year recurrence flow from Halfway Creek to Millpost Creek. The magnitude and percentage of diversion is predicted to reduce for lower design floods.

Table 5 has been expanded in order to quantify the increase in flows along Millpost Creek that could impact the Turalla Property. The expanded table, **Table 6**, shows that diversion of 50% of flow from Halfway Creek would result in an increase in peak flows along Millpost Creek of up to 55%. A lower increase in peak flow of up to 44% is predicted at the peak of the 5 year recurrence flood.

Table 6 Increased Peak Discharge along Millpost Creek Due to Measure 6

ARI (Years)	TOTAL FLOW ALONG HALFWAY CREEK (*Downstream of Proposed Diversion*) (*m³/s*)		TOTAL FLOW ALONG MILLPOST CREEK (*Downstream of Proposed Diversion*) (*m³/s*)	
	EXISTING	WITH 'FDRM 6'	EXISTING	WITH 'FDRM 6'
5	85	50 (-41%)	80	115 (+44%)
20	120	65 (-46%)	110	165 (+50%)
100	160	80 (-50%)	145	225 (+55%)

NOTES:
1. Design events lower than the 5 year ARI flood have not been modelled as part of the Floodplain Risk Management Study.
2. Increase in peak flow along Millpost Creek assumes peak flow rate along Halfway Creek occurs simultaneously.

Based on the bed elevations of the proposed Measure 6 - Diversion Channel, there would be the potential for minor flows to be diverted from Halfway Creek to Millpost Creek during lower floods such as the 1 and 2 year ARI. The magnitude of diversion would however be minimal, following the trend of decreasing diversion shown in **Table 6**.

Impact of Measure 6 on Accessibility within the Turalla Property

Three (*3*) existing crossings are located within the Turalla Property which have been used to provide internal access throughout the site during occasions of 'low flows' within Millpost Creek. The locations of these crossings are shown in **Figure B1** of **Appendix B**.

Figure B2 to **B7** have been prepared to show the predicted impacts of Measure 6 on flood levels and flood extents in the vicinity of the Turalla Property for the 5, 20 and 100 year recurrence floods.

Based on the modelling results shown in **Figure B2** to **B7**, the proposed '*FDRM 6*' would have some impact on the three existing '*low flow*' crossings located on the Turalla property. As shown on **Figure B3**, each of the crossings are predicted to be inundated at the peak of the 5 year recurrence flood; with and without Measure 6. Modelling results for the 5 year recurrence flood show that under existing conditions depths of between 0.1 to 2.5 metres would be predicted across the crossings.

The highest depth of overtopping of up to 2.5 metres is predicted along the northernmost crossing which is located just upstream of the Turrallo Creek confluence. The southernmost crossing, located immediately downstream of Measure 6, would also experience substantial inundation at the peak of the 5 year recurrence flood with depths of up to 0.7 metres predicted (*refer* **Figure B3**). Due to the significant depths of overtopping predicted at the peak of the 5 year recurrence flood, there is potential for the northern and southernmost crossings to also experience overtopping during events as low as the 1 and 2 year recurrence floods.

The crossing located to the east of the existing cottage and dwelling is predicted to experience only minor overtopping of up to 0.1 metres at the peak of the 5 year recurrence flood (*refer* **Figure B3**). We understand however that this crossing has been washed away with only the embankments remaining.

Based on the above depths of overtopping, Measure 6 is considered to have minimal impact on the accessibility provided by the northern and southernmost crossings. These crossings are already predicted to experience substantial overtopping during floods as frequent as the 1 and 2 year recurrence floods under existing catchment conditions.

The crossing located to the east of the existing cottage and dwelling could potentially experience more frequent inundation and higher depths of overtopping. As shown in **Figures B3**, **B5** and **B7**, increased flood levels of between 0.1 and 0.15 metres would be predicted in the vicinity of the crossing if Measure 6 were implemented.

Impact of Measure 6 on Existing Dwelling and Cottage Located on the Turalla Property

The flood modelling results shown in **Figures B2** to **B7** show that the existing cottage and dwelling are not predicted to experience over-floor flooding under existing conditions and with the proposed Measure 6. A comparison of the surveyed floor levels of the dwelling and cottage and peak 5 year, 20 year and 100 year recurrence flood levels are shown in **Table 7**.

Table 7 Freeboard Available to Existing Cottage and Dwelling Floor Levels

Average Recurrence Interval (*Years*)	Peak Flood Level (*mAHD*) With Measure 6	Existing Dwelling		Existing Cottage	
		Floor Level (*mAHD*)	Freeboard (*m*)	Floor Level (*mAHD*)	Freeboard (*m*)
5	691.30	692.40	1.10	692.80	1.50
20	691.44		0.96		1.36
100	691.56		0.84		1.24

NOTE: Finished Floor Levels for the existing cottage and dwelling were surveyed by Council and provided to WorleyParsons in November 2012.

Table 7 therefore shows the proposed Measure 6 would not cause over-floor flooding of the existing dwelling and cottage during floods up to and including the 100 year recurrence flood.

6. ASSESSMENT OF FLOODPLAIN MANAGEMENT OPTIONS

6.1 ADOPTED FLOODPLAIN MANAGEMENT OPTIONS

The Committee considered the results from the analysis of the Flood Damage Reduction Measures and determined a range of Flood Management Options that were to be considered as part of further investigation. These options comprised combinations of the various Flood Damage Reduction Measures listed in **Table 4**.

Although each of the floodplain risk management options will result in a positive impact on flooding conditions, they may also generate negative impacts such as flood level and/or flow velocity increases. The purpose of the floodplain risk management study is to quantify the relative merits of each option, giving consideration to any flooding, social, economic and environmental consequences.

To assess the merits of each of the options identified in **Table 5** on the following page, hydraulic modelling and a cost benefit analysis was completed.

6.2 HYDRAULIC ANALYSIS OF FLOODPLAIN MANAGEMENT OPTIONS

The hydraulic benefit and cost-benefit that would be afforded by each floodplain management option was determined using the RMA-2 flood model that was developed as part of the *'Bungendore Flood Study'* (*2002*) and updated as part of the floodplain risk management study (*refer* **Section 3**). Different versions of the RMA-2 model were developed for each option and each was used to simulate flood behaviour with each of the proposed options in place.

The impact of each option was then quantified by developing flood extent and flood level difference mapping for each option.

Difference maps are created by comparing peak flood level and flow velocity 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 option is likely to have on existing flood behaviour and characteristics.

The hydraulic benefits of each of the floodplain management options are discussed in the following.

Table 8 FLOOD MANAGEMENT OPTIONS

OPTION	CONSISTS OF MEASURES	FLOOD MANAGEMENT OPTIONS
S1	4 & 6	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	1, 4 & 6	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	1, 3, 4 & 6	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	2, 3, 4 & 6	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	1, 3 and 4	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	2, 3 and 4	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

6.2.1 Option S1 – Combination of Measures 4 and 6

Floodplain Management Option '*S1*' consists of creek re-shaping and removal of vegetation at the confluence of Turallo Creek and Halfway Creek, as well as structural works to divert flows from Halfway Creek to Millpost Creek upstream of Trucking Yard Lane. The location and extent of works proposed as part of each of these measures is shown in **Figure 19** and **Figure 20**, respectively.

Flood modelling of the 5, 20 and 100 year recurrence floods was completed for Option '*S1*' using a modified version of the RMA-2 model *i.e., with the options in place*. To assess the benefits of Option '*S1*', flood extent mapping was produced from the results for the 100 year recurrence flood. The predicted extent of inundation with and without Option '*S1*' is shown in **Figure 26**.

As shown in **Figure 26**, Option '*S1*' results in a reduced extent of flooding at the peak of the 100 year recurrence flood along Halfway Creek downstream of Trucking Yard Lane. Flood extents are most significantly reduced upstream of Malbon Street where backwater influences from Turallo Creek are minimal. Flood extents are also reduced within the village along Gibralter and Molonglo Streets, albeit to a lesser extent.

Figure 26 also shows that flood extents would be increased along parts of the Millpost Creek floodplain downstream of the proposed diversion channel and Trucking Yard Lane.

Difference mapping showing the impact of Option '*S1*' on peak 100 year recurrence flood levels is shown in **Figure 27**. As shown, Option '*S1*' will have the potential to reduce flood levels in the vicinity of Gibralter and Molonglo Streets by up to 0.25 metres. The highest flood level decrease is predicted to occur at the rear of properties along Molonglo Street (*refer* **Figure 27**).

Flood level increases along Millpost Creek are not predicted to exceed 0.3 metres (*refer* **Figure 27**). In the vicinity of the Davey Property, flood level increases are predicted to be less than 0.15 metres. Despite increases of this magnitude at the peak of the 100 year recurrence flood, floodwaters are not predicted to cause inundation of the existing dwelling or cottage which are sited on the property.

The reduction in flood levels along Halfway Creek, and increased levels along Millpost Creek, are a result of the proposed channel diverting approximately 80 m^3/s of flow during the 100 year recurrence flood (*of a total flow of 160* m^3/s). This represents a diversion of approximately 50% of the peak flow from Halfway Creek to Millpost Creek.

The approximate diversion capacity of the channel and contour bank (*Measure 6*) was summarised in **Table 5** for the 5, 20 and 100 year recurrence floods.

6.2.2 Option S2 – Combination of Measure 1, Measure 4 and Measure 6

Floodplain Management Option '*S2*' consists of creek re-shaping and removal of vegetation at the confluence of Turallo Creek and Halfway Creek, structural works to divert flows from Halfway Creek to Millpost Creek upstream of Trucking Yard Lane, as well as the upgrading and extension of Turallo Terrace Levee. The location and extent of works proposed as part of each of these measures is shown in **Figure 17** to **20**.

Flood extent mapping was also produced for Option '*S2*' and is shown in **Figure 28**. Because of the overlap in adopted measures that form Option '*S1*' and '*S2*', the changes in flood extents upstream of Gibraltar Street are very similar (*compare* **Figure 26** *and* **Figure 28**). The reduction in flood extent is however more significant downstream of Gibraltar street within the village due to the complete blockage of floodwaters overtopping Turallo Terrace Levee. The upgrade of the Turallo Terrace Levee therefore prevents inundation of the village from flooding along Turallo Creek during events up to and including the 100 year recurrence flood. Accordingly, the inundation of properties along Molonglo Street and Gibraltar Street occurs due to flooding along Halfway Creek in isolation (*refer* **Figure 28**).

As shown in **Figure 29**, flood level difference mapping indicates that Option '*S2*' would have the potential to reduce flood levels within the village by up to 0.36 metres. This indicates that the upgrading of the Turallo Terrace Levee would be predicted to result in a further 0.14 metre decrease in levels within the village above that predicted for Option '*S1*' (*compare flood level difference mapping for Option 'S1' and 'S2',* **Figure 27** *and* **Figure 29** *respectively*).

Upgrading and extension of the Turallo Terrace Levee is also predicted to cause minor flood level increases of up to 0.07 metres along Turallo Creek (*refer* **Figure 29**). The magnitude of these increases are offset by the hydraulic benefits of the creek re-shaping and removal of vegetation at the creek confluence.

6.2.3 Option S3A – Combination of Measure 1, Measure 3, Measure 4 and Measure 6

Floodplain Management Option '*S3A*' is a further progression of Options '*S1*' and '*S2*', incorporating a further damage reduction measure; Measure 3. The incorporation of the overflow channel across Tarago Road will have the potential to further offset the flood level increases that are predicted to be generated as an adverse impact of the Turallo Terrace levee upgrade.

Flood extent and flood level difference mapping for Option '*S3A*' are shown in **Figure 30** and **Figure 31**. **Figure 30** indicates that incorporation of the overflow channel will have minimal impact on flood extents upstream along Turallo Creek. The predicted differences in flood extents and flood levels are similar elsewhere when compared to Option '*S2*'; and Option '*S1*' along Millpost Creek and Halfway Creek (*refer discussion in* **Section 5.4.1** *and* **5.4.2**).

6.2.4 Option S3B – Combination of Measure 2, Measure 3, Measure 4 and Measure 6

Floodplain Management Option '*S3B*' and Option '*S3A*' are identical with the exception of Option '*S3B*' adopting the reduced scope of Measure 2 instead of Measure 1. This Option had been proposed in recognition of the significant construction and material costs required to extend the Turallo Terrace Levee east of the Railway Line.

Flood extent and flood level difference mapping for Option '*S3B*' are shown in **Figure 32** and **Figure 33**. The modelling results are identical to those for Option '*S3A*' with the exception of those floodplain areas upstream of the Railway Line that would no longer be 'shielded' by the proposed levee extension; i.e., Measure 1.

6.2.5 Option S4A – Combination of Measure 1, Measure 3 and Measure 4

Floodplain Management Option '*S4A*' is the first floodplain management option that does not include the construction of a channel to divert flows from Halfway Creek to Millpost Creek (*Measure 6*). This option is therefore focused on improving hydraulics along Turallo Creek upstream of the confluence with Halfway Creek.

Flood extent and flood level difference mapping for floodplain management Option 'S4A' is shown in **Figure 34** and **Figure 35**, respectively. As expected, Option '*S4A*' is not predicted to decrease flood extents or flood levels upstream of Malbon Street along Halfway Creek. Furthermore, flood level decreases within the village are up to 0.12 metres lower than had been predicted when Measure 6 was included. This provides an indication of the benefit the flow diversion upstream of Trucking Yard Lane (*Measure 6*) has on flooding within the village (*compare flood levels decreases predicted on* **Figure 31** *and* **Figure 35** *for Option 'S3A' and Option 'S4A', respectively*).

6.2.6 Option S4B – Combination of Measure 2, Measure 3 and Measure 4

Floodplain Management Option '*S4B*' is similar to Option '*S4A*' with the exception of the proposed extension of the Turallo Terrace Levee to the east of the railway line (*refer* **Figure 17** *and* **Figure 18**). It was considered appropriate to test the impact of the removal of the levee extension on flooding conditions given the significant costs associated with the levee extension component in isolation.

Figure 36 and **Figure 37** show the impact of Option '*S4B*' on 100 year recurrence flood extents and peak flood levels, respectively. The impacts are generally similar to those generated for Option 'S4A' (*refer* **Section 5.4.4**) with the exception of floodplain areas upstream of the railway crossing in the vicinity of the proposed levee extension. In that regard, a maximum flood level decrease of 0.31 metres is still predicted to occur.

6.3 BENEFIT-COST ANALYSIS OF FLOODPLAIN MANAGEMENT OPTIONS

A benefit-cost analysis was undertaken to assess the economic viability of implementing the proposed 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 potential reduction in flood damages

In order to determine the relative benefits of a range of structural flood risk mitigation measures, it is necessary to firstly understand the extent of the damages that could be incurred in major floods if no mitigation measures were implemented. That is, the potential flood damages need to be determined for existing conditions.

This information is also required in determining the benefit-cost ratio for any proposed mitigation works. The benefit is effectively measured as the reduction in damages that would arise as a result of constructing particular mitigation works (*e.g., constructing levees*). If the benefit is determined as an average annual reduction in flood damage cost, it is then possible to compare this against the cost of the works, measured also as an average annual cost over the design life of the works.

The 'Average Annual Damage' (*AAD*) was calculated for each scenario according to the damages corresponding to the different design events, factored by their probability of occurrence. The 'benefit' was calculated over a design life of 30 years using a Net Present Value (*NPV*) analysis of the reduction in AAD for each management option relative to the AAD that would be incurred under existing conditions.

A benefit -cost ratio was determined for each floodplain management option. The overall 'cost' is an estimate of the capital required to implement the management option in 2012 dollars, and also incorporating an allowance for maintenance during the 30 year life of the works.

6.3.1 Construction Cost Estimates

Construction cost estimates for each measure were determined based on the application of indicative costs rates outlined in '*Rawlinsons Construction Handbook Edition 30, 2012*' to preliminary quantities of construction materials and services. Cost estimates for each of the flood damage reductions measures are included as **Appendix D**.

A summary of the estimated costs for each measure is outlined in **Table 9**. Cost estimates for each of the floodplain management options are outlined in **Table 10**.

Table 9 Summary of construction cost estimates for each flood damage reduction Measure

MEASURE No.	DESCRIPTION	CONSTRUCTION COST ESTIMATE ($ *AUD*)
1	Upgrading and extension of levee along Turallo Terrace	2,494,000
2	Upgrading of the Turallo Terrace levee (*no extension*)	687,000
3	Installation of overflow channel across Tarago Road	595,000
4	Removal of dense vegetation and creek re-shaping at the confluence of Turallo, Halfway and Millpost Creeks	278,000
5	Installation of diversion channel from Halfway to Millpost Creek	1,551,000
6	Diversion of floodwaters upstream of Trucking Yard Lane through construction of contour banks and excavation to construct a diversion channel	1,409,000

Table 10 Summary of construction cost estimates for each of the adopted floodplain management option

OPTION No.	DESCRIPTION	CONSTRUCTION COST ESTIMATE ($ *AUD*)
S1	Combination of Measures 4 and 6	1,687,000
S2	Combination of Measures 1, 4 and 6	4,181,000
S3A	Combination of Measures 1, 3, 4 and 6	4,776,000
S3B	Combination of Measures 2, 3, 4 and 6	2,969,000
S4A	Combination of Measures 1, 3 and 4	3,367,000
S4B	Combination of Measures 2, 3, and 4	1,560,000

6.3.2 Flood Damages

Flood damages for floodplain management options were determined according to the process outlined in **Section 4.1.1**.

The reduction in flood damages were determined on the basis of the reduced extent and level of flooding that would occur if the respective options were implemented. The reduced level of flooding has been established by simulating the 5, 20 and 100 year recurrence floods with each of the floodplain management options assumed to be "in place" or constructed.

The damages resulting from inundation during the 100 year recurrence flood are listed in **Table 11** for each floodplain management options. The number of structures and properties inundated is also indicated in this analysis.

Direct and indirect costs have been included in all damage cost estimates (*excluding infrastructure damages which stand alone*). All damage costs are expressed in 2012 dollars.

The results of the flood damage analysis (*refer* **Table 11**) shows that the floodplain management Option 'S3A' will result in the greatest associated reduction in flood damages in the 100 year recurrence event. Option 'S1' offers the least reduction in flood damages.

Table 12 provides a summary of the flood damages calculated for each of the design flooding scenarios.

Table 11 PREDICTED FLOOD DAMAGES FOR THE ADOPTED FLOODPLAIN MANAGEMENT OPTIONS FOR THE 100 YEAR RECURRENCE FLOOD

FLOODPLAIN MANAGEMENT OPTION	RESIDENTIAL DAMAGES				INDUSTRIAL / COMMERCIAL DAMAGES		INFRA-STRUCTURE DAMAGES	TOTAL DAMAGES
	Damage to Dwellings		Damage to Properties					
	Number of Dwellings Inundated	Estimated Cost of Damages	Number of Properties Inundated	Estimated Cost of Damages	Number of Sites Inundated	Estimated Cost of Damages	Estimated Cost of Damages	Estimated Cost of Damages
Existing Conditions	21	$1,047,900	53	$319,700	8	$1,005,700	$712,000	$3,085,400
S1	12	$504,700	40	$269,800	4	$669,900	$433,300	$1,877,800
S2	6	$183,200	23	$169,900	2	$573,500	$278,000	$1,204,500
S3A	3	$89,400	19	$159,900	2	$492,300	$222,500	$964,000
S3B	8	$323,300	27	$189,800	2	$532,900	$313,800	$1,356,000
S4A	8	$308,600	28	$199,800	3	$648,900	$347,200	$1,504,600
S4B	12	$507,300	35	$229,800	3	$646,700	$415,100	$1,799,000

Table 12 Summary of flood damage analysis

OPTION No.	TOTAL DAMAGES (*Including direct and indirect costs*) ($)		
	5yr ARI	20yr ARI	100yr ARI
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	1,799,000

6.3.3 Benefit-Cost Analysis

A benefit-cost analysis was undertaken to assess the economic viability of implementing the proposed 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 potential reduction in flood damages.

The results of the benefit-cost assessment for each of the adopted floodplain management options are included as **Appendix E**.

A summary of the analysis is presented in **Table 13**.

Table 13 Summary of Predicted Benefit-Cost Ratio for Flood Management Options

OPTION No.	APPROXIMATE PRESENT VALUE OF COST TO IMPLEMENT	AVERAGE ANNUAL DAMAGE*	PRESENT VALUE OF BENEFITS	BENEFIT / COST RATIO
Existing	-	$438,200	-	-
S1	$1,600,000	$245,300	$2,079,000	1.30
S2	$3,683,000	$220,900	$2,109,000	0.57
S3A	$4,124,000	$196,600	$2,352,000	0.57
S3B	$2,734,000	$228,500	$2,262,000	0.83
S4A	$3,033,000	$206,200	$2,292,000	0.76
S4B	$1,490,000	$216,700	$2,386,000	1.60

6.3.4 Discussion

The results of the benefit-cost analysis indicates that Option ‘*S4B*’ is the most cost effective floodplain management option with a benefit-cost ratio of 1.60. 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.

The primary reason for the comparatively low cost to implement Option ‘*S4B*’ is the adoption of Damage Reduction ‘*Measure 2*’ as opposed to ‘*Measure 1*’. As shown in **Table 9**, the difference in costs between ‘*Measure 1*’ and ‘*Measure 2*’ is approximately $1,800,000. This difference in costs is directly associated with the additional material and construction costs required to extend the existing Turallo Terrace Levee upstream of the railway crossing. **Table 13** indicates that the significant additional cost to extend the Turallo Terrace Levee does not return a comparable benefit or a positive return on investment (*compare benefit-cost ratio for Option ‘S4A’ and ‘S4B’ in* **Table 13**). This is similarly the case for Option ‘*S3A’* and ‘*S3B’*

Options ‘*S1*’ is also predicted to return a benefit-cost ratio greater than 1 and as such, is considered to provide a reasonable return on investment. The third highest benefit-cost ratio was calculated to Option *‘S3B’* with a value of 0.83 (*refer* **Table 13**).

7. HAZARD AND HYDRAULIC CATEGORISATION

7.1 GENERAL

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

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

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

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

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

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

7.2 UPDATED FLOOD HAZARD

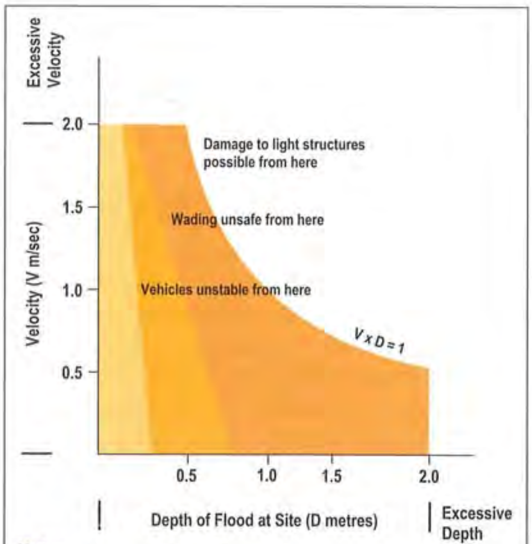
Hazard mapping had previously been prepared for the Turallo Creek, Halfway Creek and Millpost Creek floodplains as part of investigations for the *'Bungendore Flood Study'* (*2002*). As part of this provisional assessment, the hazard mapping was based on hazard criteria documented in the '*Floodplain Development Manual*' (*2001*) and was based on modeling results developed for the flood study.

As an outcome of the updated modeling results (*refer* **Section 3**) and the updated '*Floodplain Development Manual*' (*2005*), revised flood hazard mapping has been produced for the floodplain as part of the investigations for the Floodplain Risk Management Study. The adopted hazard criteria and hazard mapping is discussed in the following.

7.2.1 Adopted Provisional Hazard Categorisation

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

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

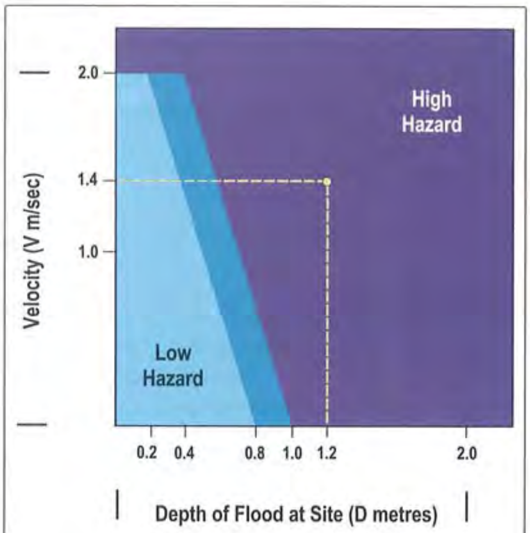


Notes

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

Derived from laboratory testing and flood conditions which caused damage.

FIGURE L1 - Velocity & Depth Relationships



Notes

The degree of hazard may be either -

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

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

Example:

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

FIGURE L2 - Provisional Hydraulic Hazard Categories

Spatial and temporal distributions of flow, velocity and water level determined from the computer modelling undertaken as part of this study, were used to determine the flood hazard along the Turallo Creek, Halfway Creek and Millpost Creek floodplains.

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

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

A summary of the criteria adopted for each hazard category is listed in **Table 14**.

Table 14 ADOPTED HAZARD CRITERIA

HAZARD CATEGORY	CRITERIA	PRACTICAL APPLICATION
Low	Depth (*d*) < 0.4 m & velocity (*v*) < 0.5 m/s	Suitable for cars (*vehicle instability unlikely*)
Medium	exceeding Low criteria, and $d \le 0.8$ m, $v \le 2.0$ m/s, and $v \times d \le 0.5$	Suitable for heavy vehicles and wading by able bodied adults
High	exceeding Medium criteria, and $d \le 1.8$ m, $v \le 2.0$ m/s, and $v \times d \le 1.5$	Suitable for light construction, timber frame, brick veneer etc
Very High	exceeding High criteria, and 0.5 m/s < velocity < 4 m/s & $v \times d \le 2.5$	Suitable for heavy construction, steel frame, concrete etc
Extreme	exceeding Very High criteria and v > 4 m/s	Unsuitable for development – indicates significant conveyance of flow or floodway

7.2.2 Provisional Flood Hazard

The criteria presented in **Table 14** were used to develop provisional hazard mapping for the floodplain of Turallo Creek, Halfway Creek and Millpost Creek in the vicinity of Bungendore. Results from the flood modelling that was undertaken for this study (*refer* **Section 3**) were combined with the hazard category criteria listed in **Table 14** to generate the flood hazard mapping.

Provisional flood hazard mapping generated for the 100 year ARI flood is presented in **Figures 38** to **Figure 40**.

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 38**, a number of properties along Halfway Creek along Molonglo Street between Malbon Street and Turallo Terrace are predicted to experience high hazard flooding. The majority of inundated properties are classified as low to medium flood hazard.

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

7.3 HYDRAULIC CATEGORIES

7.3.1 Adopted Hydraulic Categorisation

The NSW Government's *'Floodplain Development Manual'* (*2005*) also characterises flood prone areas according to the hydraulic categories presented in **Table 15**. The hydraulic categories provide an indication of the potential for development across different sections of the floodplain to impact on existing flood behaviour.

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

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

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

The hydraulic category mapping that was prepared for the Turallo Cree, Halfway Creek and Millpost Creek floodplains as part of the Bungendore Floodplain Risk Management Study investigations is shown in **Figure 41** to **Figure 43**.

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

Table 15 HYDRAULIC CATEGORY CRITERIA

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

7.3.2 Adopted Methodology for Determination of Floodway Corridors

The adopted methodology for determination of hydraulic categories for the study area involved several stages of assessment that relied on rigorous analytical analysis of all available hydraulic, topographic, cadastral and geomorphic data-sets.

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

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

Determination of Floodway Extent

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

- the location of flood storages that are readily identifiable from aerial photography;
- the location and potential impact of hydraulic controls and geomorphic features that could influence floodwater movement and flood characteristics (*e.g., velocity*);

- mapping of contours of 'velocity-depth' product (*V x D*); and,
- mapping of the variation in peak flow velocity.

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

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

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

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

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

In this regard, an analysis of the floodway extents was undertaken to identify areas where the velocity-depth product is greater than 0.8 m^2/s and where flow velocities are greater than 0.5 m/s. The alignment of significant flow paths across the floodplain (*i.e., potential flood runners*), as inferred by the velocity and V x D contour mapping, was also considered in determining the preliminary floodway extents.

Due consideration was also given to the full range of design flood events; that is, the assessment was not solely reliant on hydraulic data for the 100 year ARI event. Particular attention was paid to identifying floodways that could emerge during varying stages of the Probable Maximum Flooding scenario i.e., *the PMF was 'stepped through' to establish any flow paths that emerged above and beyond those determined for the 100 year ARI event.*

This methodology was applied to generate a "Preliminary" Floodway Extent.

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

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

Prior to finalising the floodway corridor a further review was undertaken to apply a practical "*common sense*" check of the floodway extent against cadastral and property constraints. The review relied on flood engineer judgment and experience to "*fine tune*" the floodway extent mapping. Consideration was also given to property boundaries and land use zoning boundaries. For example, in some cases it was found that the floodway extent could be adjusted by a short distance, of up to 10 metres, to line-up with the property boundaries without having any significant impact on the conveyance capacity of the floodway corridor. This ensured a practical common sense approach which avoided unnecessary constraints being placed on particular properties near the edge of the floodway corridor.

Application of this process led to the determination of those areas of the floodplain that would be classified as floodway.

7.3.3 Adopted Methodology for Determining Flood Storage and Flood Fringe

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

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

In order to determine the boundary between flood storage and flood fringe, the variation in peak flood depths in areas outside of the floodway extent was mapped to identify areas inundated to depths of approximately 0.3 metres. A depth of 0.3 metres was selected as it is considered to be the transitionary point between flood storage and flood fringe.

In terms of the study area, peak depths below 0.3 metres are generally considered to correspond to areas where negligible flow is conveyed and represent a relatively small proportion of storage for floodwaters.

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

Accordingly, the boundary between flood storage and flood fringe was defined by a peak 100 year ARI flood depth of 0.3 metres.

Flood storage and flood fringe mapping for the floodplains of Turallo Creek, Halfway Creek and Millpost Creek is presented as **Figure 41** to **Figure 43**.

8. CLIMATE CHANGE ASSESSMENT

8.1 BACKGROUND

To date, the NSW Government has published a number of documents which provide guidance to account for climate change impacts on flooding. The guidelines address the impacts of climate change on peak rainfall intensities as well as sea level rise projection. These documents include:

- Department of Environment and Climate Change (*DECC*) Floodplain Risk Management Guideline titled: *'Practical Consideration of Climate Change'* (*2007*).

  This guideline provides an estimate of the range for increases in sea level associated with climate change. It also provides an estimate for the change in "Extreme Rainfall" in different parts of NSW.
- Department of Environment, Climate Change & Water (*DECCW*) Draft Flood Risk Management Guide titled *'Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments'* (*2009*).

  This document provides direction on appropriate risk mitigation techniques for flood planning areas, as well as an updated direction for the assessment of ocean boundary conditions in flood modelling.
- DECCW Technical Note titled *'Derivation of the NSW Government's Sea Level Risk Planning Benchmarks'* (*2009*).

  This document provides the technical background for the sea level rise projections adopted in the above documents.

These documents do not represent an exhaustive list of the information prepared by the NSW Government. However, they are considered the most pertinent providing an overall guide to the current projections of the impacts of climate change.

As addressed in the above documents, there are two main drivers for CC flood impacts:

1. Sea Level Rise (SLR) - Assessment of the impacts using the NSW Government's SLR benchmarks of 0.4 m by 2050 and 0.9 m by 2100.
2. Changes to rainfall intensity – The guideline recommends consideration of increased rainfall intensities and storm volumes of 10%, 20% and 30%.

The potential impacts of climate change on sea levels does not apply to this study due to the significant distance of the study area inland from the coast line of NSW. Accordingly, sea level rise is not considered as part of this assessment.

The *Practical Consideration of Climate Change* guideline recommends that sensitivity analyses be undertaken to assess the impact of changes in peak rainfall intensity of 10%, 20% and 30% on flooding. In the context of Bungendore, it is considered appropriate to focus on a 10% increase in rainfall intensity, given the current projection for the increase in rainfall intensity for the Murrumbidgee area is 5% and that further investigations are currently being carried out to refine estimates associated with increases in rainfall intensity.

In the context of the above considerations, the assessment of climate change will be based on the adoption of a 10% increase in rainfall intensity on peak flows in the 100 year recurrence event.

8.2 CLIMATE CHANGE MODELLING

Hydrologic (*XP-RAFTS*) and hydraulic (*RMA-2*) modelling was required in order to determine the potential impacts of the adopted climate change scenario on peak flood levels within the study area. The methodology and modelling results for the hydrologic and hydraulic components of this assessment are discussed in the following.

8.2.1 Hydrologic Modelling – XP-RAFTS

The existing XP-RAFTS hydrologic model that was developed as part of the '*Bungendore Flood Study*' (*2002*) was used to simulate a design storm based on a 10% increase in the design 100 year recurrence rainfall intensity. To accomplish this, the 100 year recurrence design hyetograph was increased by 10% and the RAFTS model was used to route the resultant runoff through the catchment draining to the study area.

Table 16 provides a summary of the estimated increase in peak 100 year recurrence flood discharge at upstream boundaries adopted for the RMA-2 model simulations (*refer* **Figure 3**). The average increase in peak discharge resulting from the 10% increase in rainfall intensity was established to be about 12.9%. The resulting design flood hydrographs were used as boundary conditions for the climate change simulation.

Table 16 Increase in Peak Flows Resulting from 10% Increase in Rainfall Intensity

RMA-2 INFLOW LOCATION	PEAK DISCHARGE (m^3/s)		INCREASE IN PEAK FLOW (%)
	100yr ARI	100yr ARI + 10%	
Turallo Creek	261.4	295.1	12.9
Halfway Creek	161.1	181.9	12.9
Millpost Creek	147.4	166.5	13.0

8.2.2 Hydraulic Modelling – RMA-2

The updated RMA-2 model was used to simulate the adopted climate change scenario *i.e., design 100 year recurrence flood + 10% increase in rainfall intensity*. The peak discharges determined in **Table 16** were adopted as the upstream boundary inflows for the climate change simulation.

Peak flood levels for the adopted climate change scenario (*design 100 year recurrence event + 10% increase in rainfall intensity*) are shown in **Figure 44**. Difference mapping showing the location and extent of flood level increases due to the 10% increase in rainfall intensity is shown in **Figure 45**.

As shown in **Figure 45**, flood level increases are predicted to range between 0.03 metres to 0.17 metres throughout the study area. The highest flood level increase is predicted to occur upstream of the Railway Bridge Crossing where flood levels and the increased flows are predicted to back-up against the railway embankment. Within the village, flood level increases are predicted to range between 0.10 metres and 0.11 metres (*refer* **Figure 45**).

The change in peak flood levels as a result of the adopted climate change is summarised in **Table 17** for a number of key locations throughout the study area.

Table 17 Impact of Climate Change on Design Flood Levels

LOCATION	PREDICTED PEAK FLOOD LEVEL (*m AHD*)		DIFFERENCE IN LEVELS
	100 year ARI	100 year ARI + 10%	
Along Turallo Creek			
Turallo Creek upstream of Kings Highway crossing	698.4	698.46	+ 0.06
Turallo Creek upstream of railway line bridge crossing	694.2	694.37	+ 0.17
Turallo Creek upstream of Tarago Road Bridge	690.9	690.98	+ 0.08
Upstream of confluence of Turallo Creek and Halfway Creek	690.6	690.69	+ 0.09
Downstream of confluence of Turallo Creek and Halfway Creek	690.3	690.39	+ 0.09
Upstream of confluence of Turallo Creek and Millpost Creek	689.0	689.10	+ 0.10
Downstream of confluence of Turallo Creek and Millpost Creek	688.9	688.99	+ 0.09
Along Halfway Creek			
Halfway Creek adjacent to Malbon Street	691.0	691.10	+ 0.10
Halfway Creek adjacent to King Street	692.1	692.18	+ 0.08
Halfway Creek upstream of Trucking Yard Lane	695.3	695.33	+ 0.03

9. PLANNING RECOMMENDATIONS

9.1 EXISTING PLANNING DOCUMENTATION

As part of the study, a review of the range of existing planning instruments that relate to flooding was undertaken. This involved a review of the following documents:

- Yarrowlumla Local Environmental Plan 2012 (*draft, on public exhibition*);
- Yarrowlumla Council Interim Local Flood Policy for the village of Bungendore; and,

9.2 SECTION 149 CERTIFICATE

In the interests of flood awareness, and in order to address Council's duty of care, it is recommended that notations on Section 149 certificates be updated. The modifications should include:

- Notification of the approximate level of the PMF in the vicinity of the land to which the certificate applies.
- Notification of the level that floodwaters reached in the 1956 or 1974 flood in the vicinity of the land to which the certificate applies.

9.3 EMERGENCY RESPONSE

Investigations completed for the Flood Study indicate that a significant number of properties experience inundation in floods up to and including the 100 year recurrence event. Furthermore, modelling and a review of historical floods indicates that warning times for inundation of low lying areas of the town are typically within 12 hours of the onset of heavy rainfall in the catchment. Accordingly, it is recommended that:

- A flood warning system be developed for Bungendore in conjunction with the SES, and;
- Protocols be determined for flood emergency response for Bungendore, including flood damage minimisation strategies, and options for community awareness of the potential risk.

10. CONCLUSIONS

As part of the Floodplain Risk Management Study, additional topographic data has been incorporated into the RMA-2 hydraulic model that had been developed as part of the 2002 flood study. Incorporation of this survey data has led to significant refinement of the model network thereby improving the reliability of the topography on which the model is based.

Verification of the updated RMA-2 model was undertaken successfully to the historic 1956 and 1974 floods, as well as to the design 100 year recurrence flood. This verification process determined that the updated modelling results were typically within 100 to 200 mm of those documented in the '*Bungendore Flood Study*' (*Issue 3, 2002*).

Accordingly, the updated RMA-2 model was used as the basis of the flood modelling investigations for the floodplain risk management study.

The updated modelling results for the adopted design flooding scenarios (*5, 20, 50 and 100 year recurrence floods as well as the Probable Maximum Flood*) were documented in **Section 3** of this report. Updated flood level mapping, and depth and velocity mapping was produced for each of the design flood events. These figures are included as **Figures 7** to **16**.

The following conclusions can be drawn from the hydraulic and benefit-cost analyses undertaken for the Floodplain Management Study.

(1) The most cost effective flood management option that will result in a reduction in existing flood damages in Bungendore is Option '*S4B*'. This option involves the upgrade of the existing Turallo Terrace levee (*without extending the levee east of the railway line*), channel clearing and excavation at the confluence of Turallo and Halfway Creek, and the construction of a flood relief channel across Tarago Road. As shown in **Table 13**, a benefit-cost ration of 1.60 was determined for Option '*S4B*'.

However, it should be noted that the costs associated with implementing this option do not include an allowance for any compensation that may be required to construct the flood relief channel nor does it include allowance for any geotechnical investigations that may be required as part of the levee upgrade. This may substantially lower the benefit-cost ratio of 1.60.

(2) The analysis showed that Option '*S1*' has a benefit-cost ratio of 1.30. Although some flood level increases were predicted to occur along the Millpost Creek floodplain, of up to 0.30 metres (*refer* **Figure 27**), these increases are typically along undeveloped sections of the floodplain. In the vicinity of the Davey Property, flood level increases are less than 0.15 metres. Despite increased peak 100 year recurrence flood levels, floodwaters would not be predicted to inundate the existing dwelling and cottage cited on the property.

Therefore, it is recommended that Option '*S1*' and '*S4B*' be considered for inclusion within the floodplain management plan.

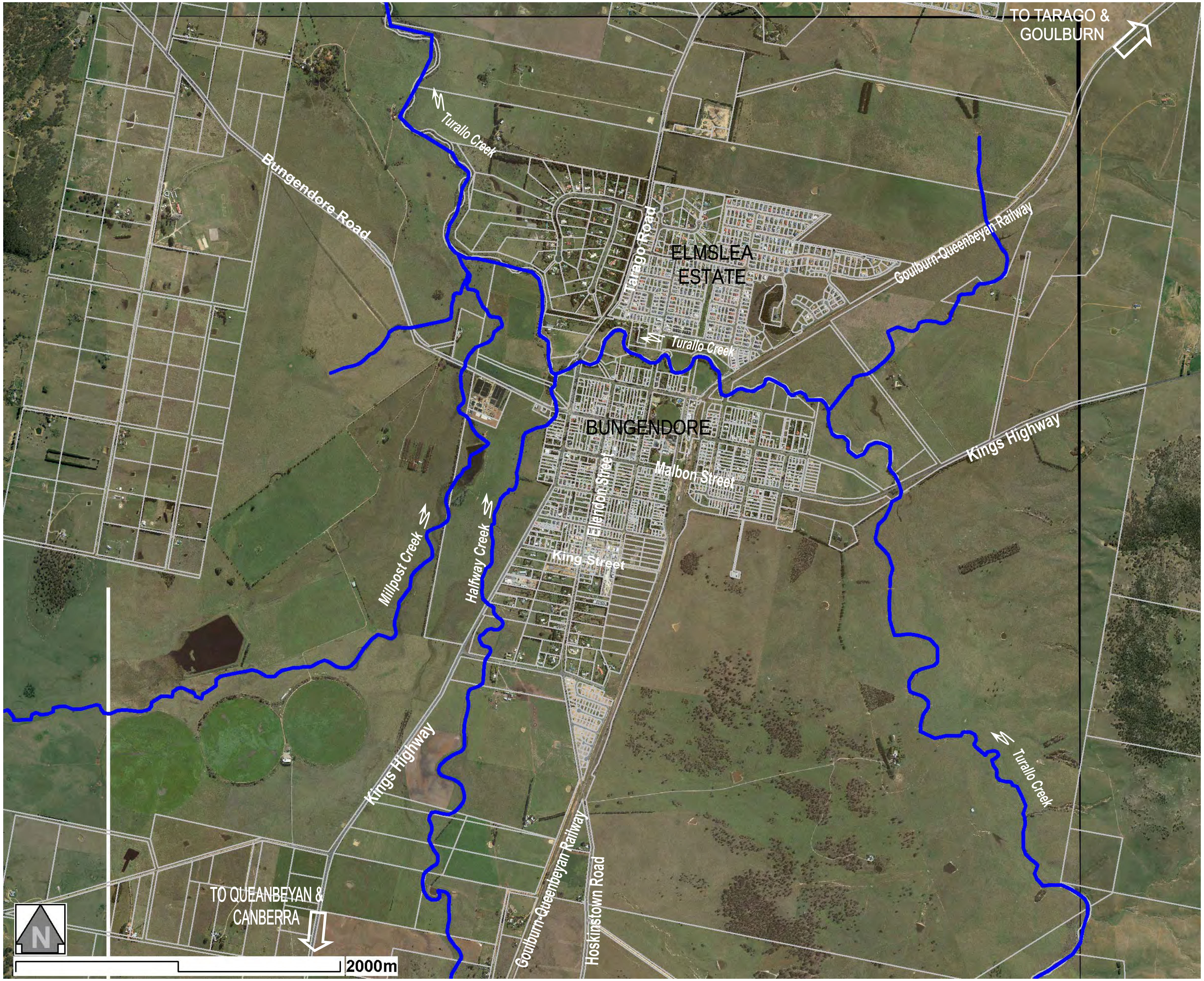
(3) Option 'S3B' formed a combination of Options 'S1' and 'S4B' and returned a reasonable benefit-cost ratio of 0.83. This was the third highest of the six options considered.

11. REFERENCES

- Institution of Engineers (*1987*), '*Australian Rainfall and Runoff – A Guide to Flood Estimation*'; edited by DH Pilgrim.
- New South Wales Government (2005), '*Floodplain Development Manual: the management of flood liable land*', ISBN 07313 0370 9
- King, I (*2001*), *'RMA2 – A Two Dimensional Finite Element Model for Flow in Estuaries and Streams*', developed by Resource Modelling Associates, Sydney, Australia.
- 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
- Yarrowlumla Shire Council (*2002*), *'Bungendore Flood Study'*; prepared by Patterson Britton & Partners.
- Yarrowlumla Shire Council (*2004, in draft*), *'Bungendore Floodplain Risk Management Study'*; prepared by Patterson Britton & Partners.
- Yarrowlumla Shire Council (*2007, Issue 3 - final draft*), *'Bungendore Floodplain Risk Management Study'*; prepared by Patterson Britton & Partners.

FIGURES

FIGURE 1



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3777 – Bungendore Floodplain Risk Management Study
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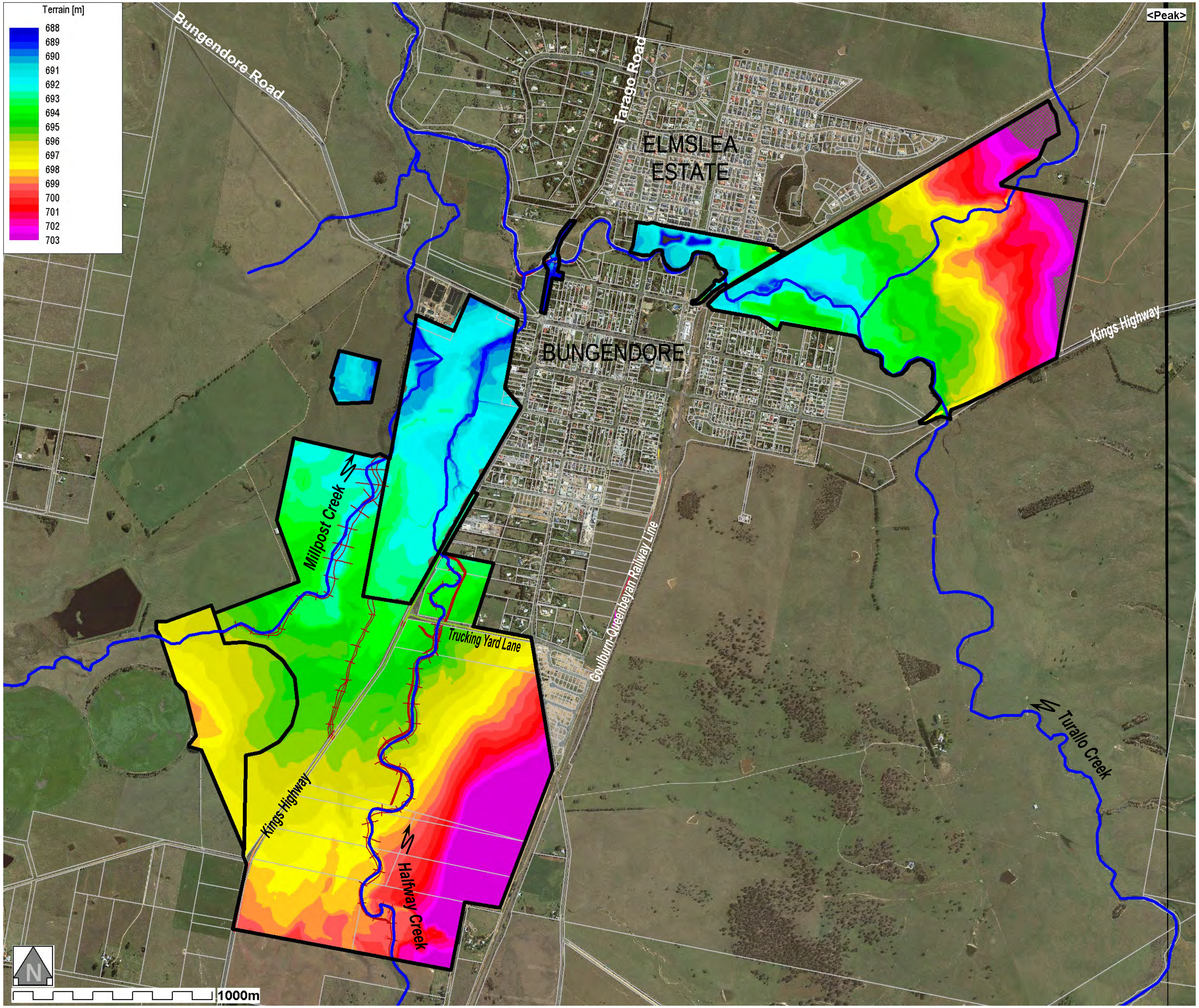
LOCATION OF THE
FPRMS STUDY AREA

FIGURE 2



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3777 - Bungendore Floodplain Risk Management Study
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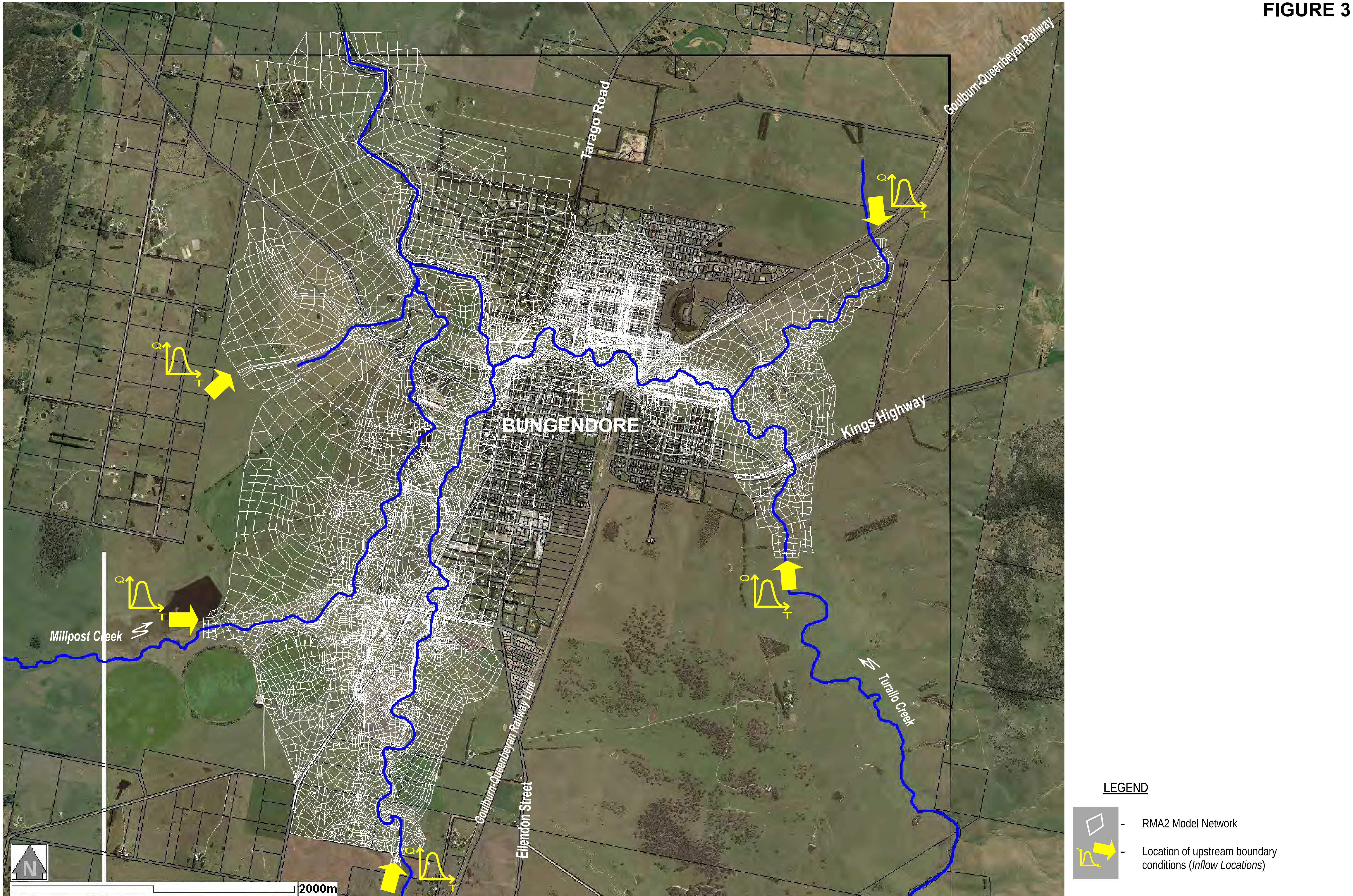
ADDITIONAL TOPOGRAPHIC DATA COLLECTED SINCE THE 2002 FLOOD STUDY



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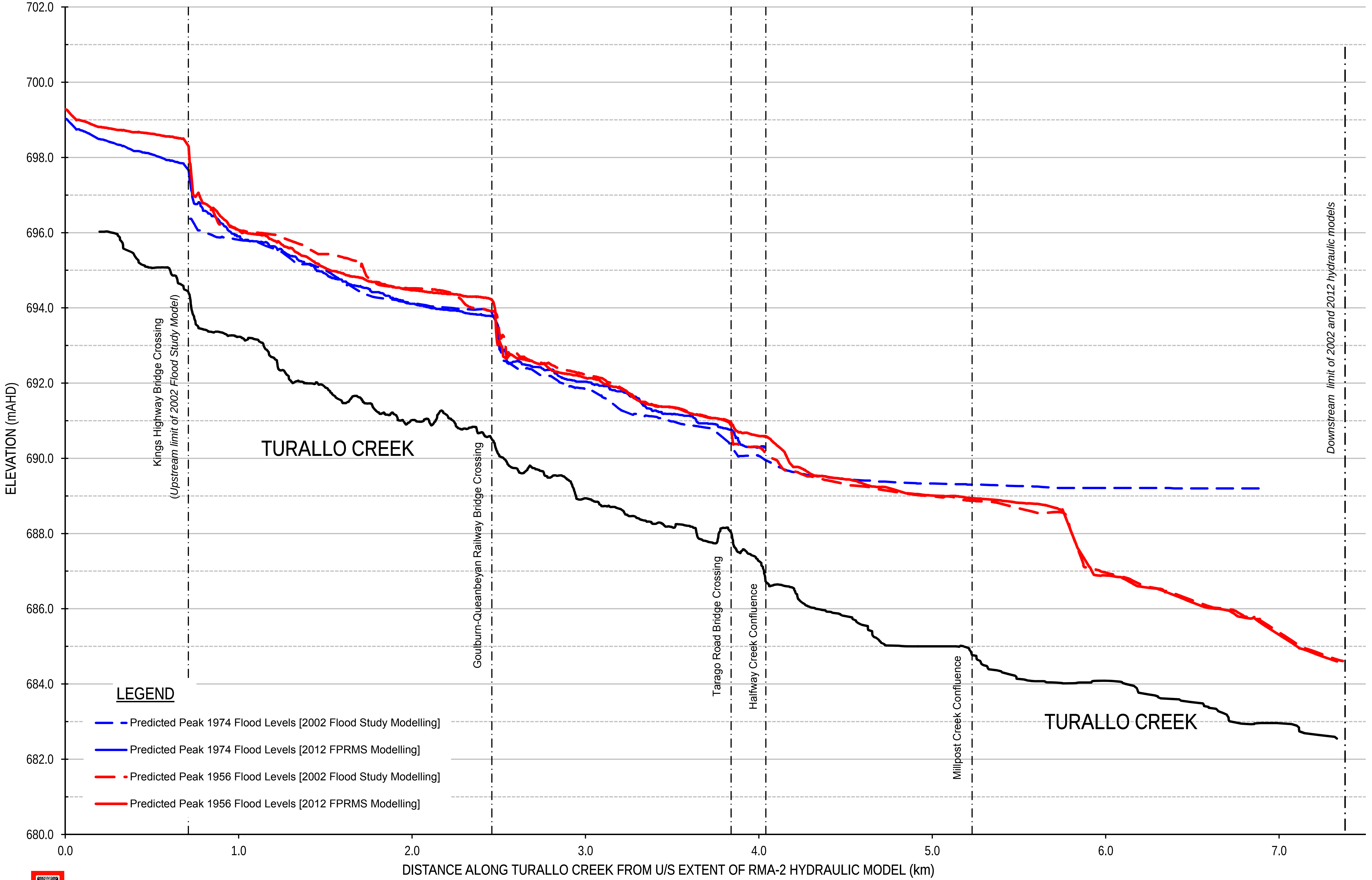
3777 - Bungendore Floodplain Risk Management Study
fg3777rg120802-fig2_Updated Model Network [July 2012].doc

UPDATED RMA-2 MODEL NETWORK INCORPORATING ALL AVAILABLE SURVEY DATA



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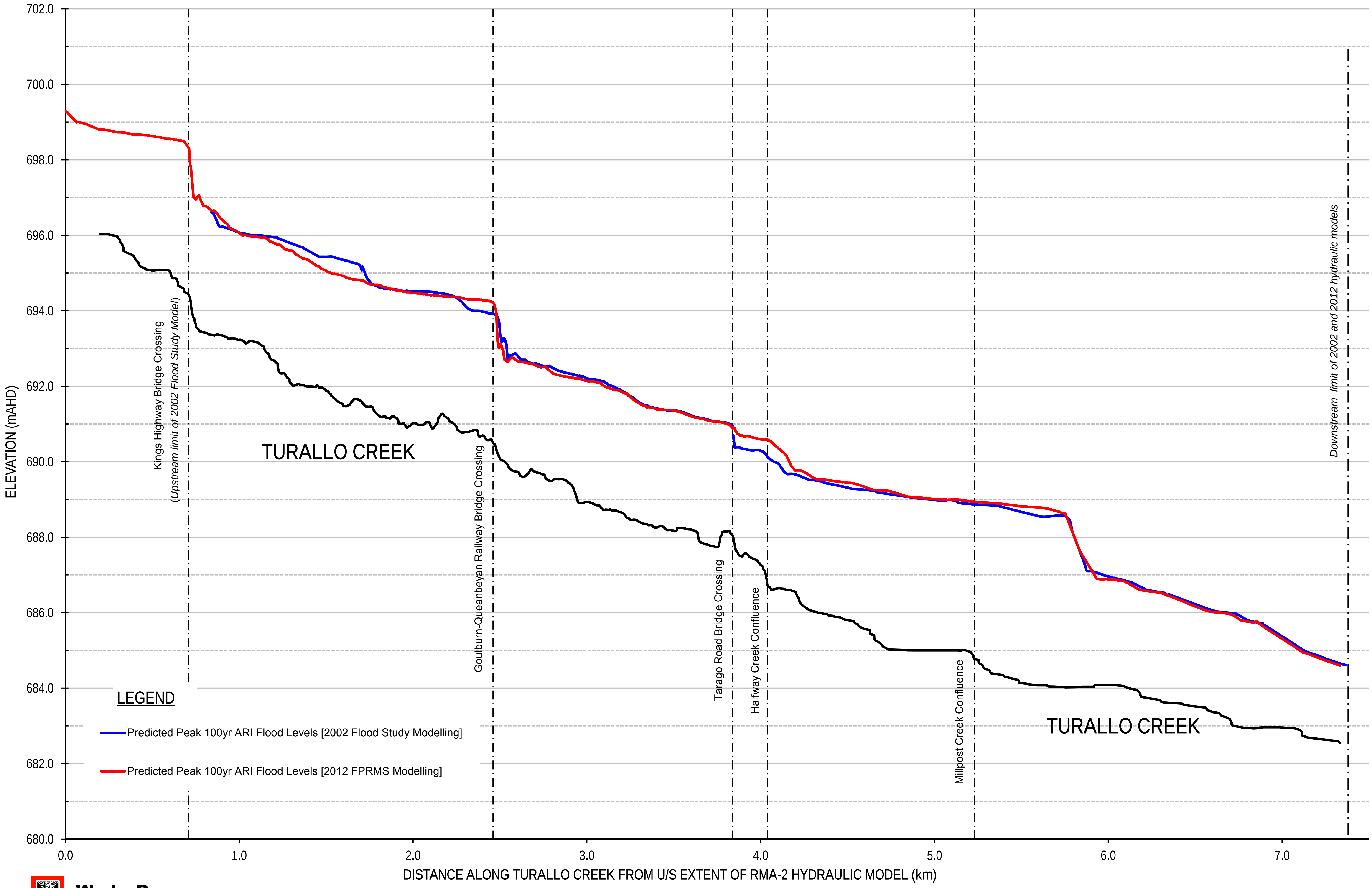
Bungendore Floodplain Risk Management Study
3777rg110617_FPRMS WSPs.xls

PREDICTED 1956 &1974 HISTORIC FLOODWATER SURFACE PROFILES ALONG TURALLO CREEK
[*2002* AND *2012* RESULTS]

FIGURE 5



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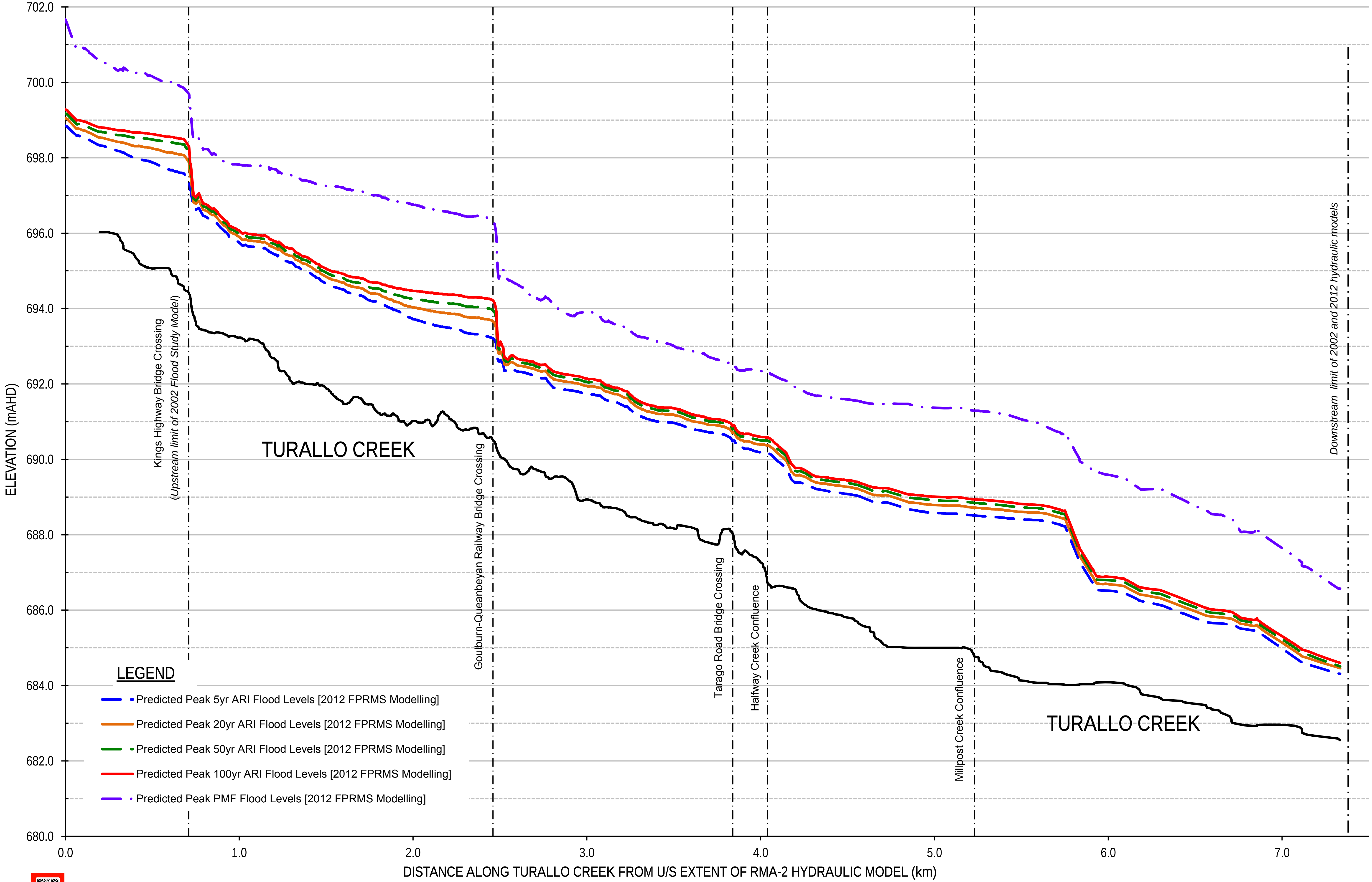
PREDICTED FLOODWATER SURFACE PROFILES ALONG TURALLO CREEK AT THE PEAK OF THE 100 YEAR RECURRENCE FLOOD [*2002 AND 2012 RESULTS*]

FIGURE 6



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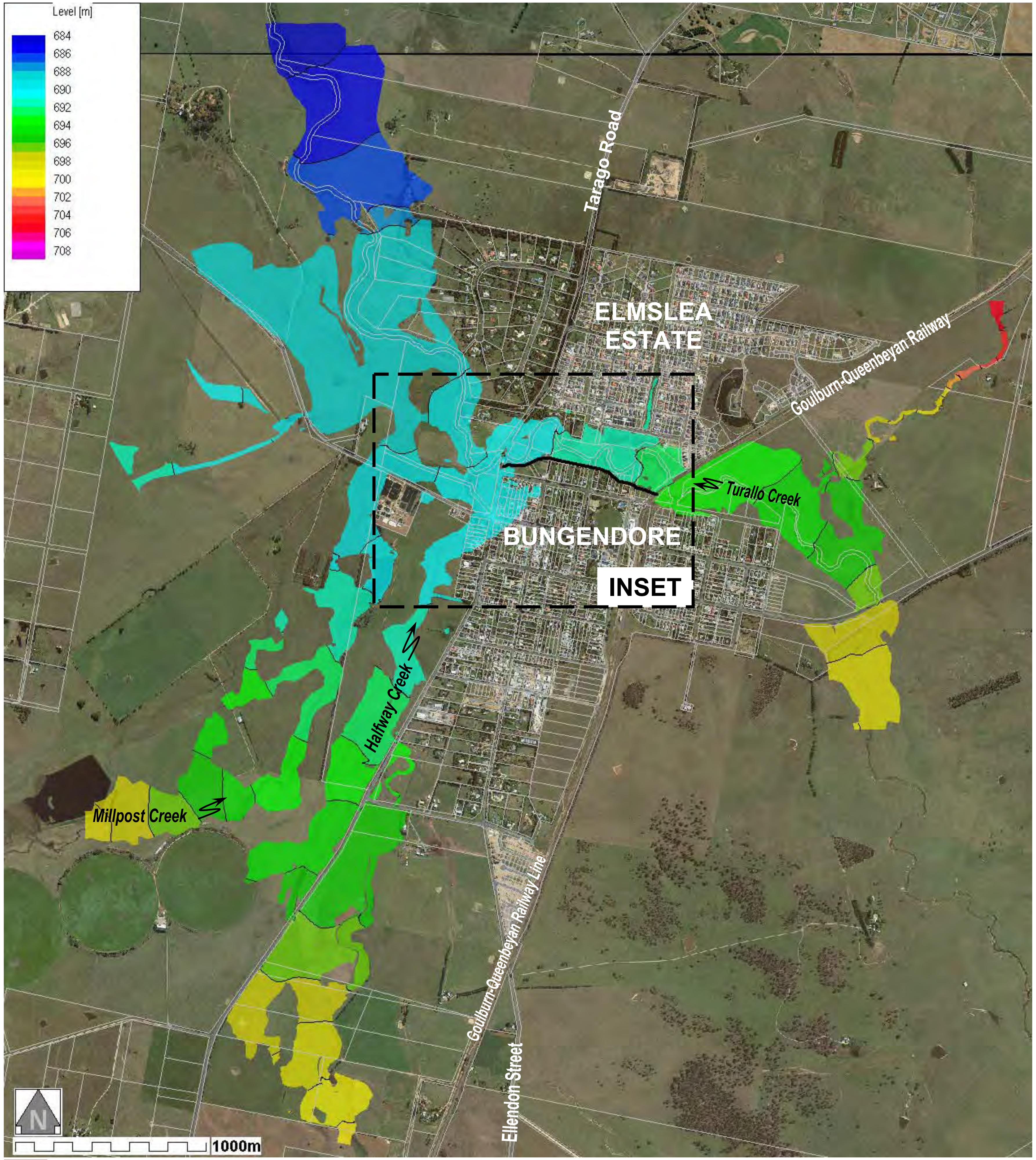
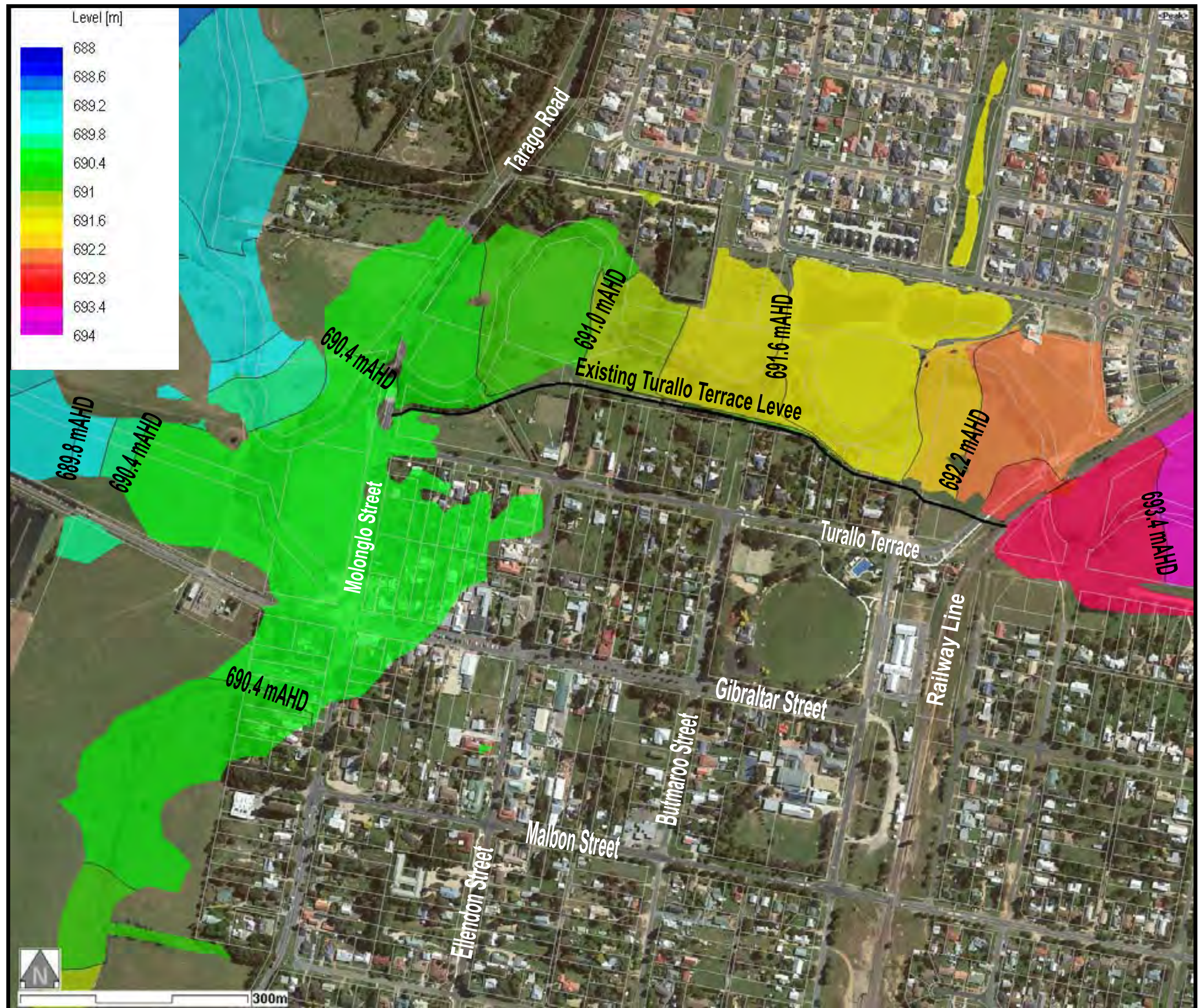
3777rg110617_FPRMS WSPs.xls

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

FIGURE 7





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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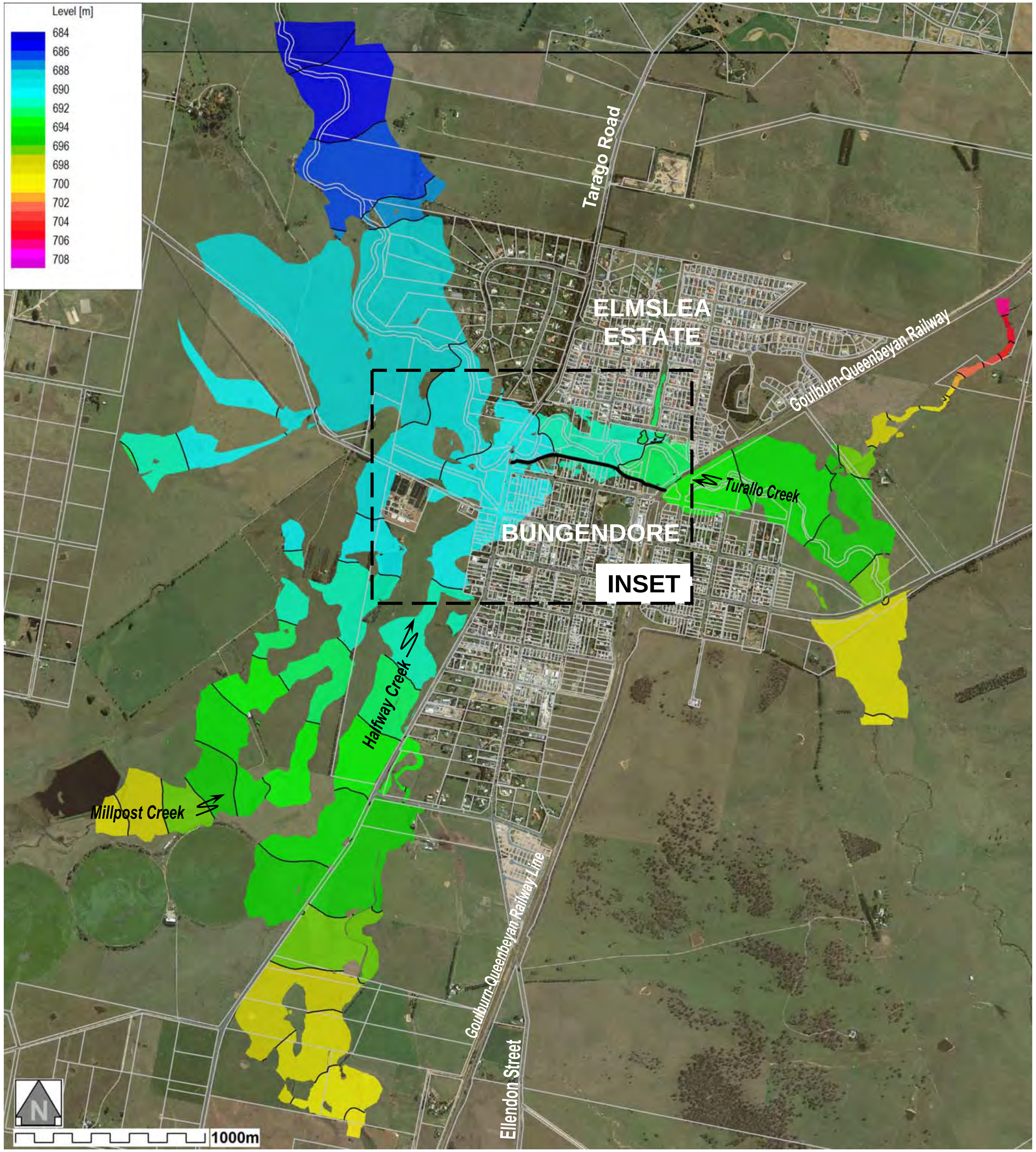
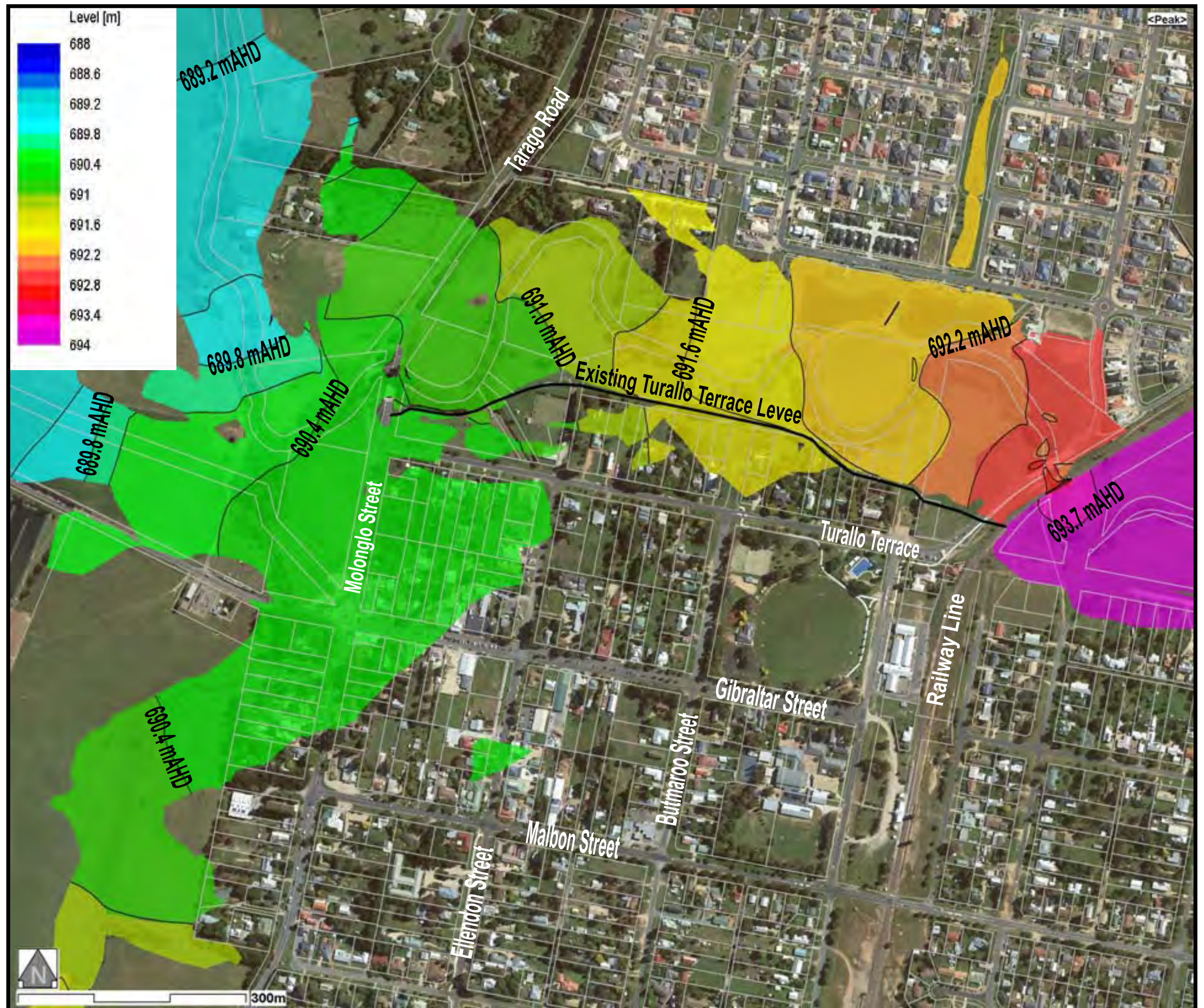
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig6_5yr ARI Levels.doc

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

FIGURE 8





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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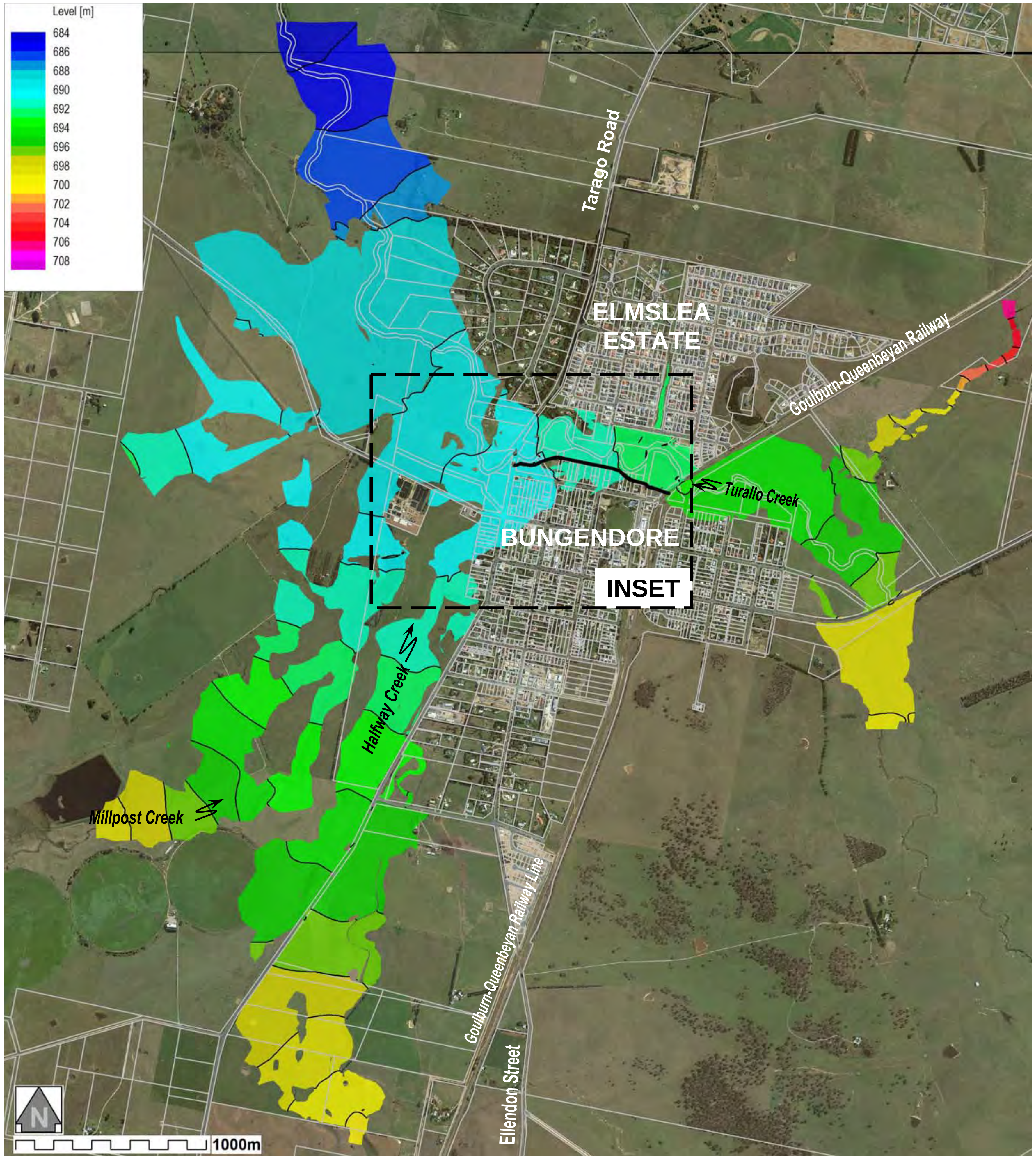
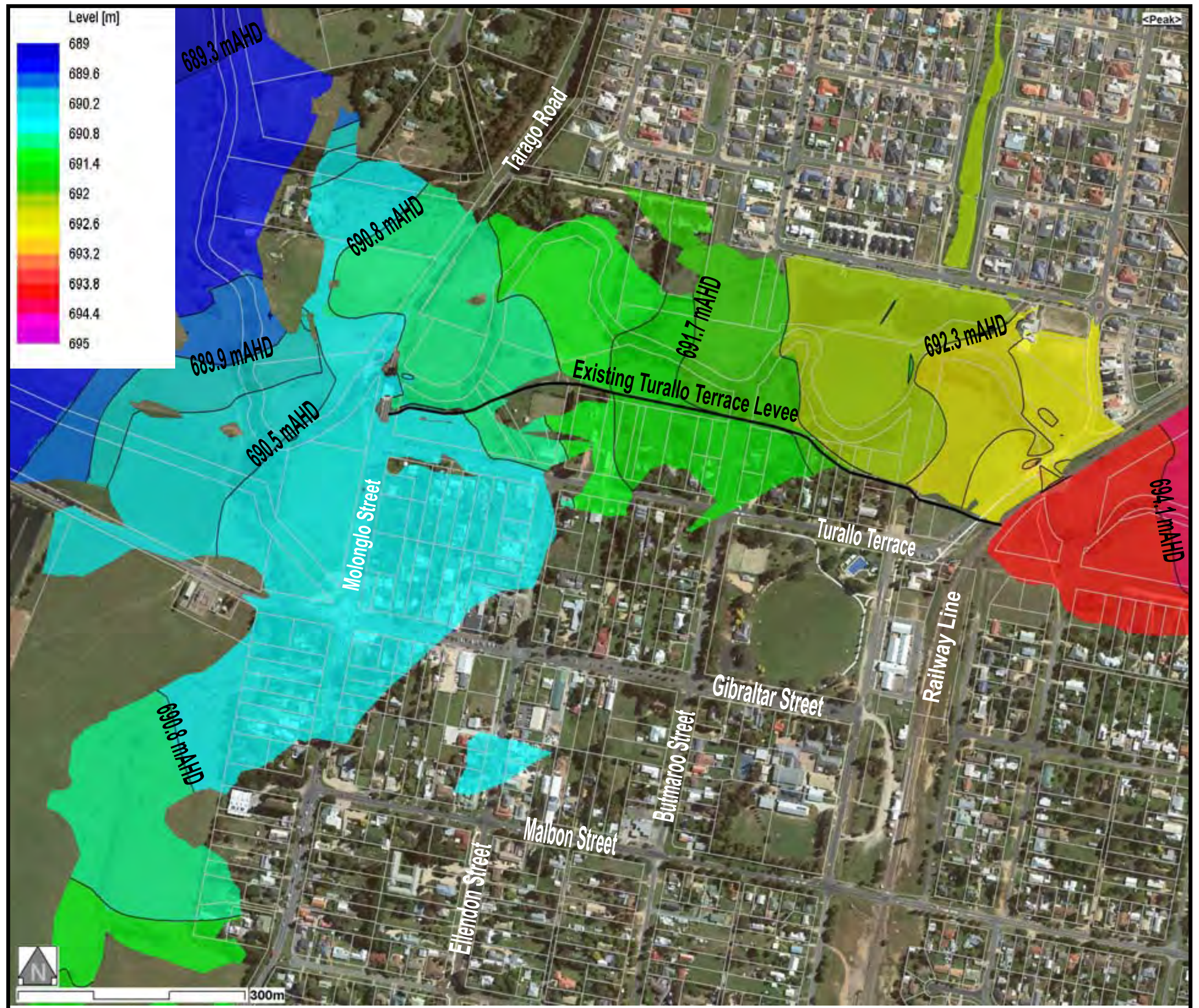
fg3777rg121114-fig7_20yr ARI Levels.doc

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

FIGURE 9





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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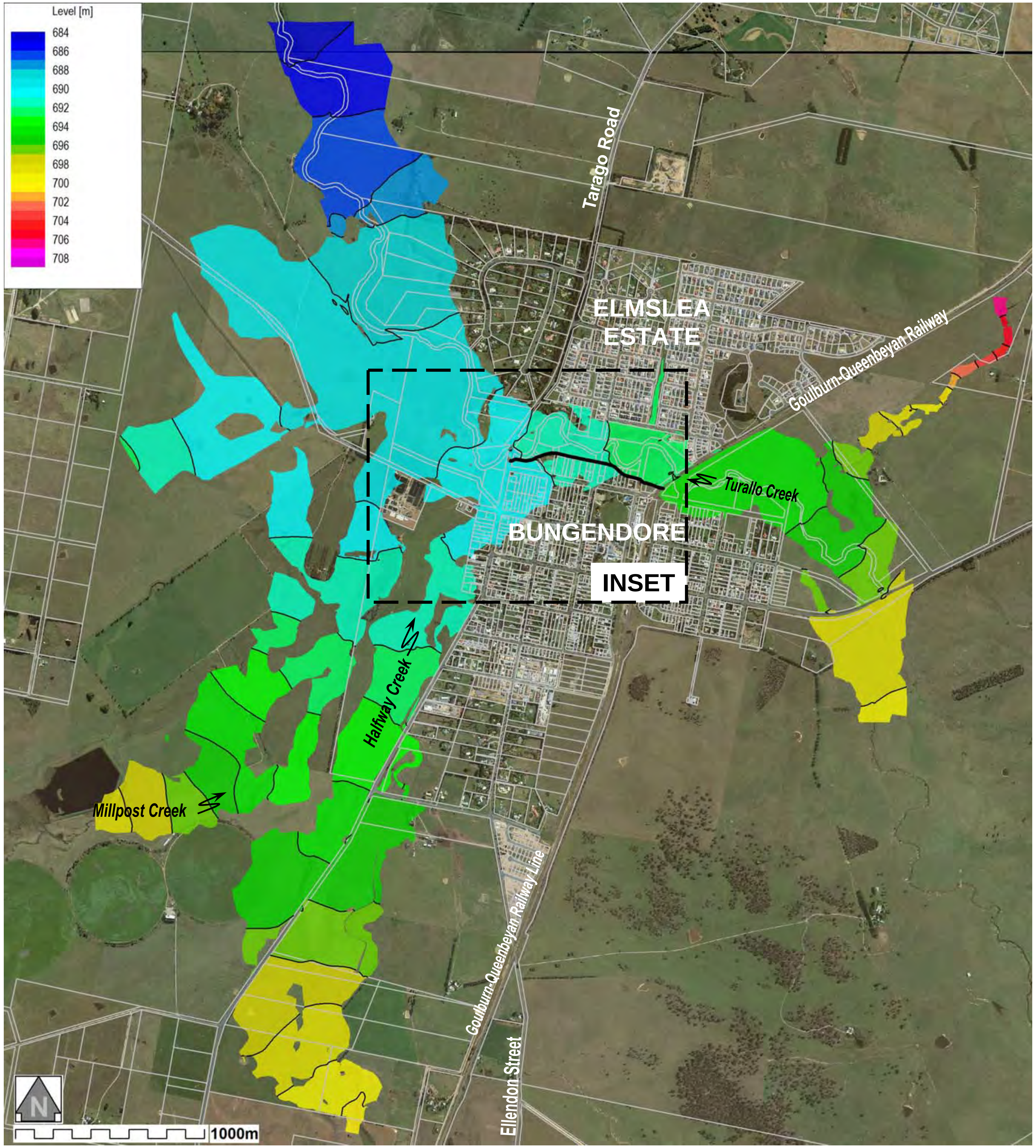
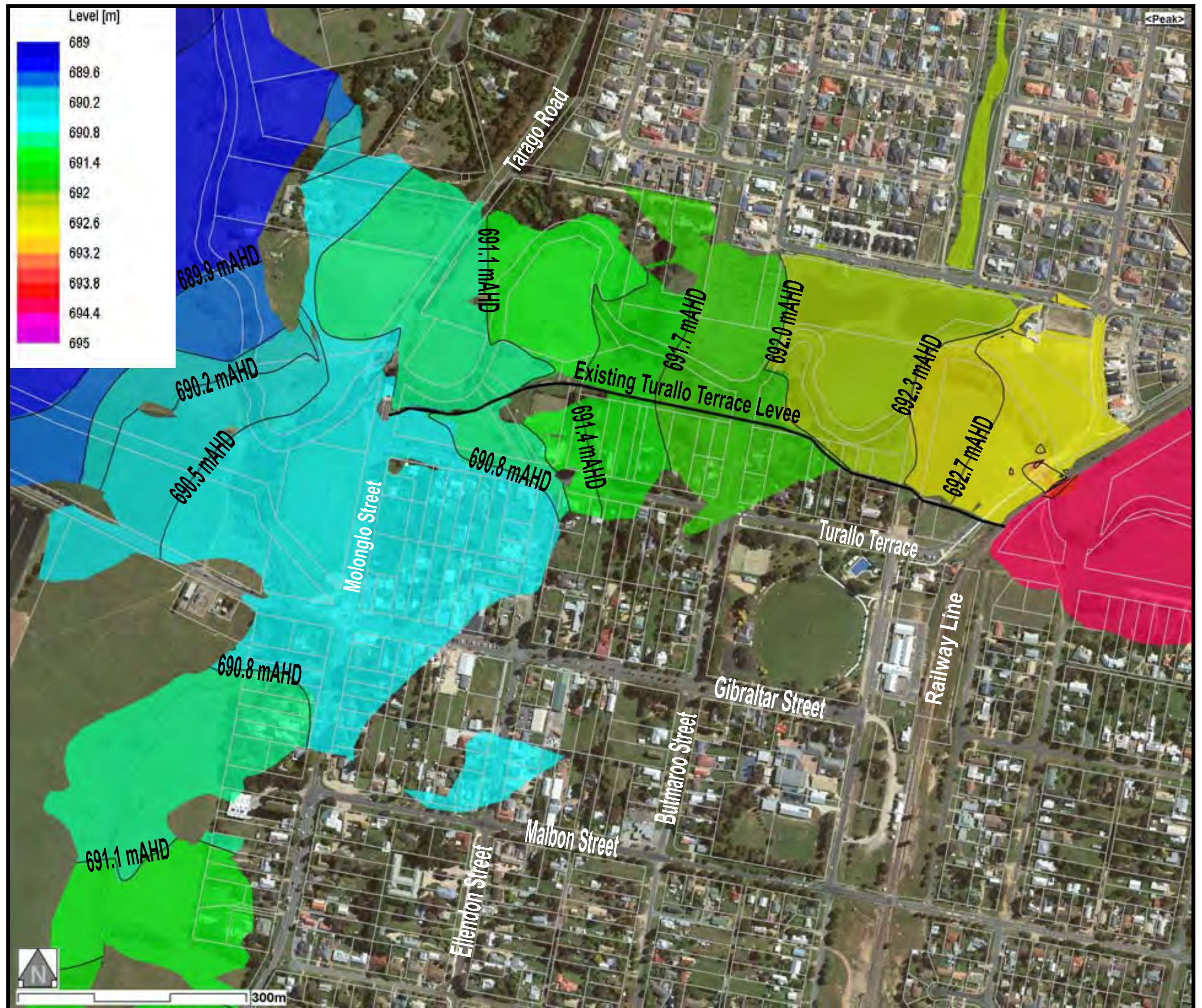
fg3777rg121114-fig8_50yr ARI Levels.doc

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

FIGURE 10





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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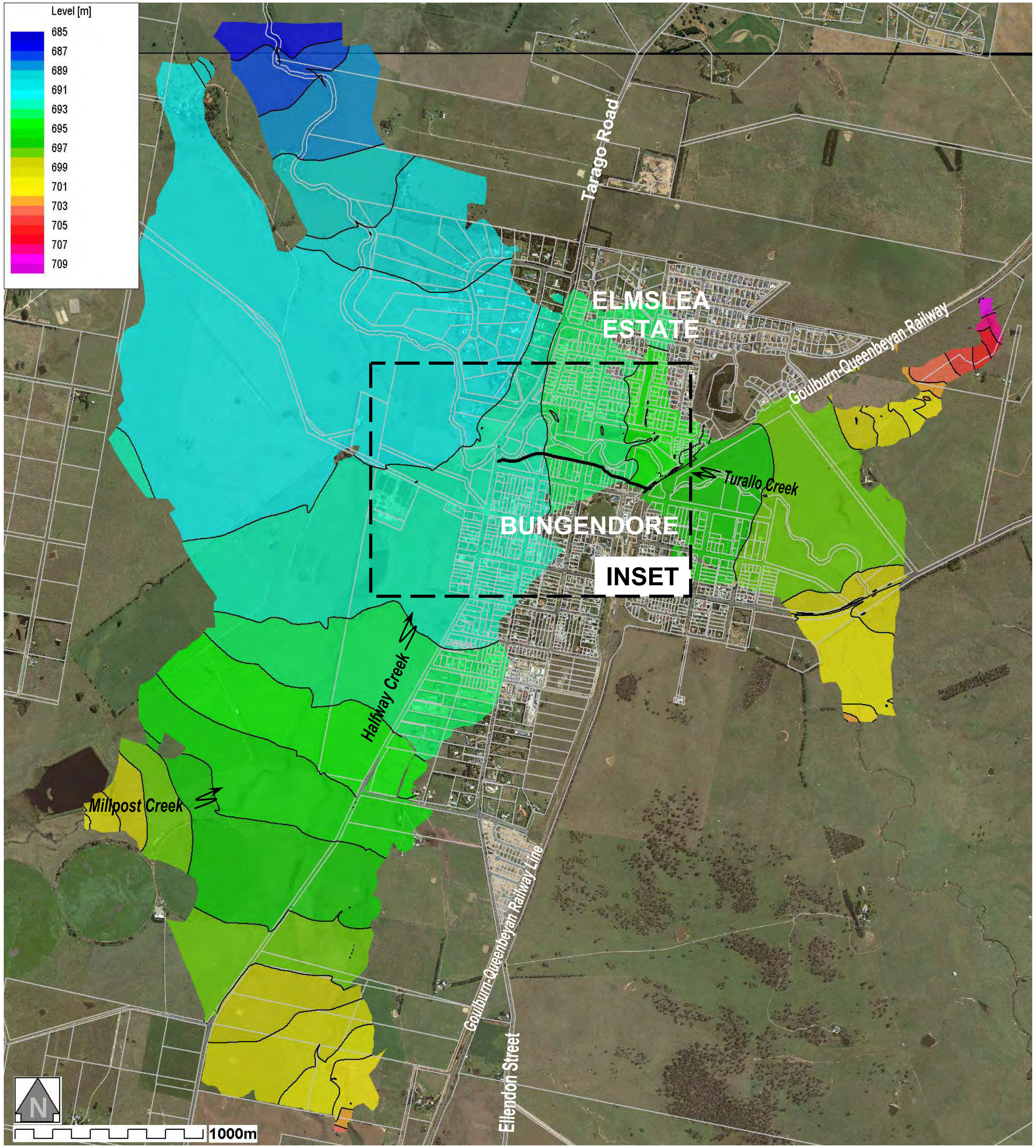
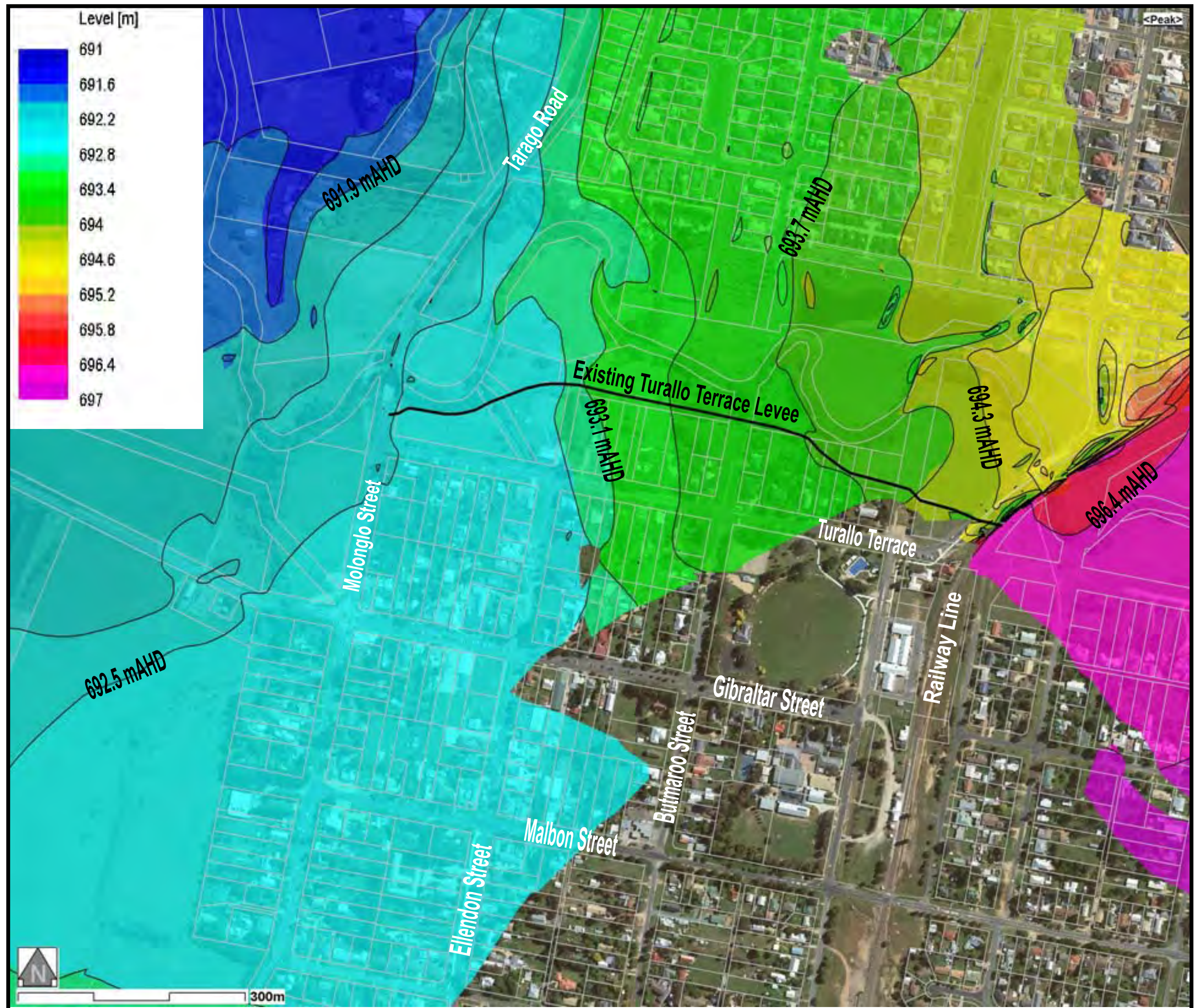
fg3777rg121114-fig9_100yr ARI Levels.doc

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



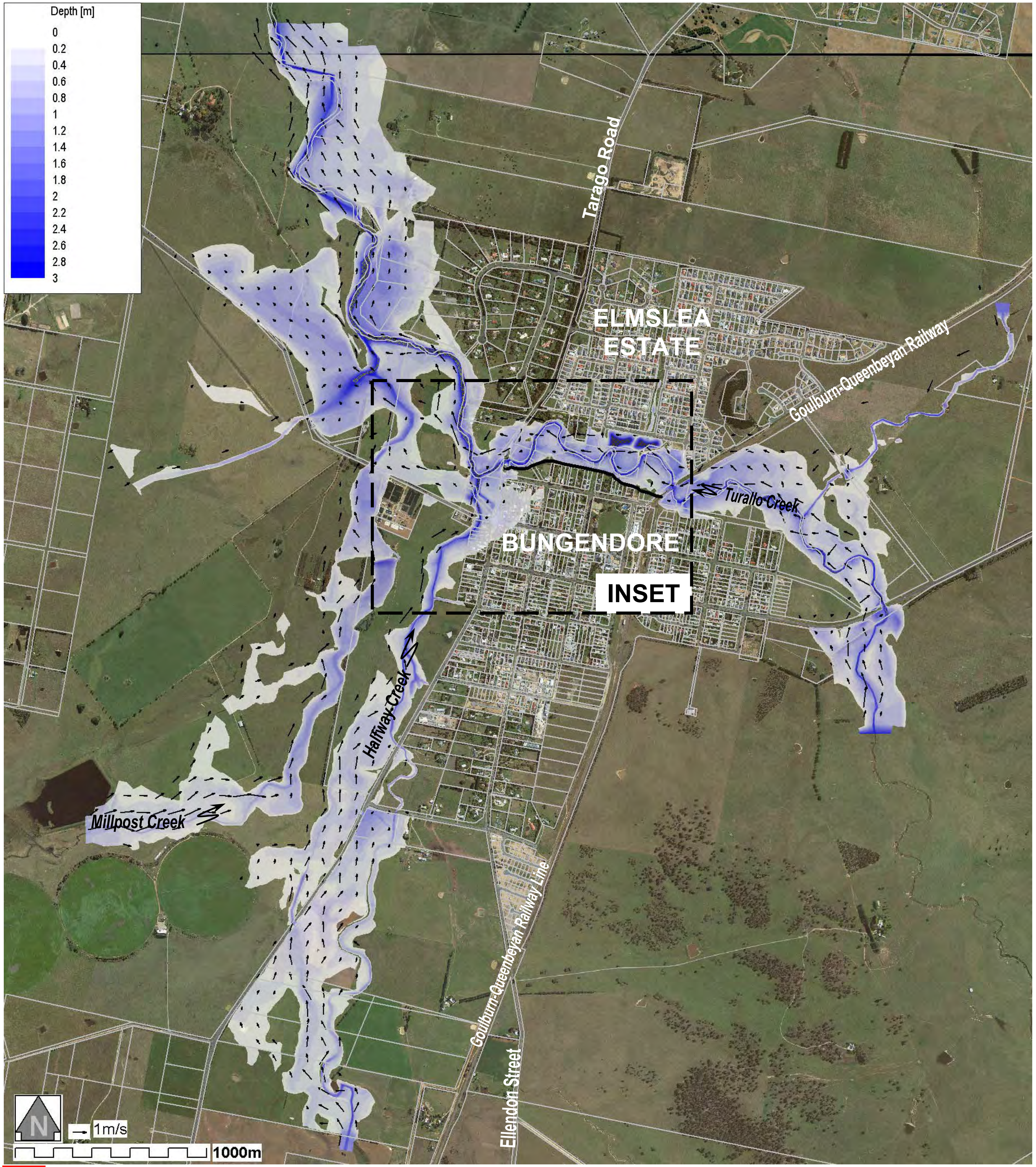


INSET Close-up of flooding in the vicinity of the Village

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*).

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

FIGURE 12



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

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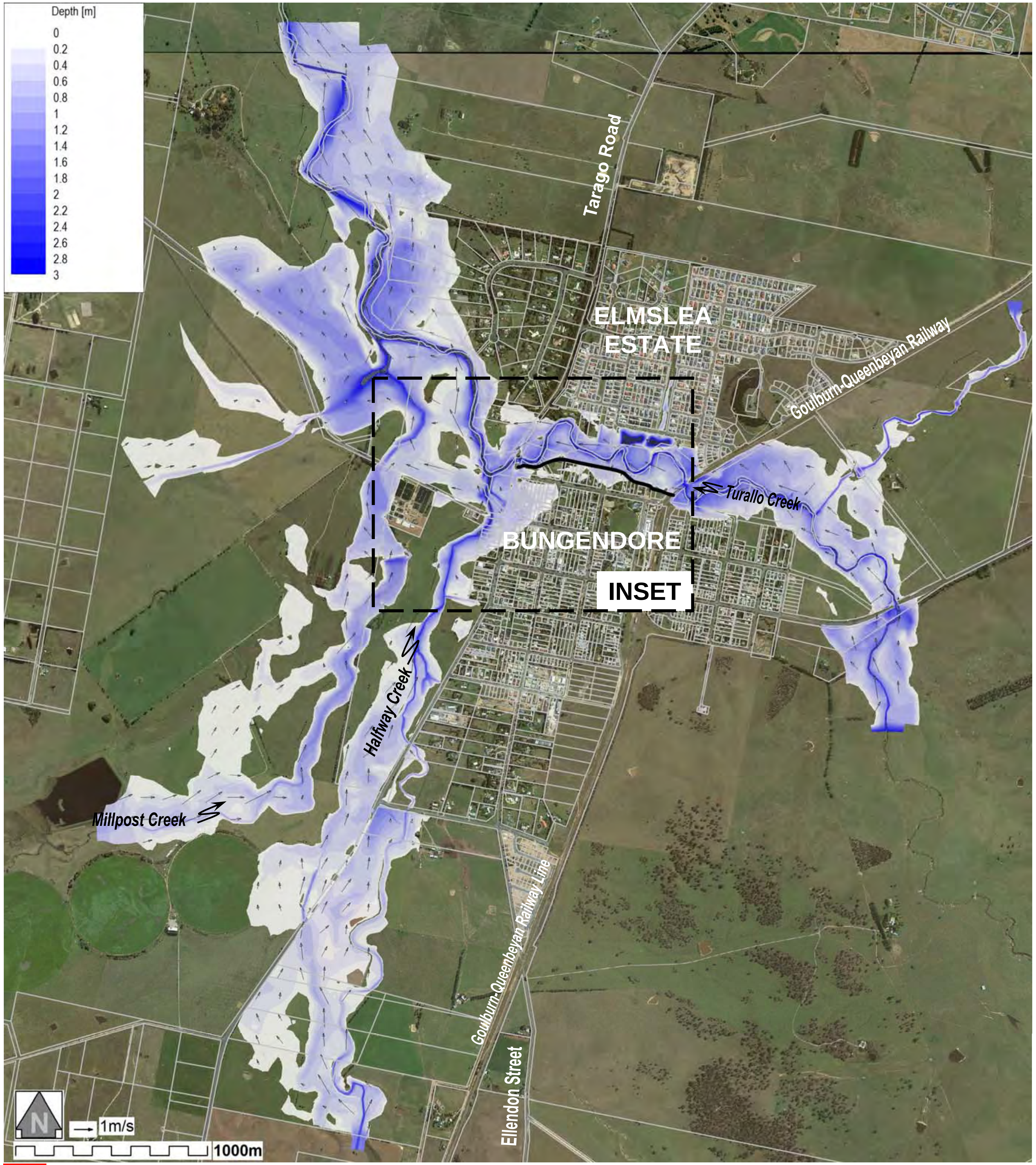
fg3777rg121114-fig12_5yr ARI Depths & Velocities.doc

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

FIGURE 13



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

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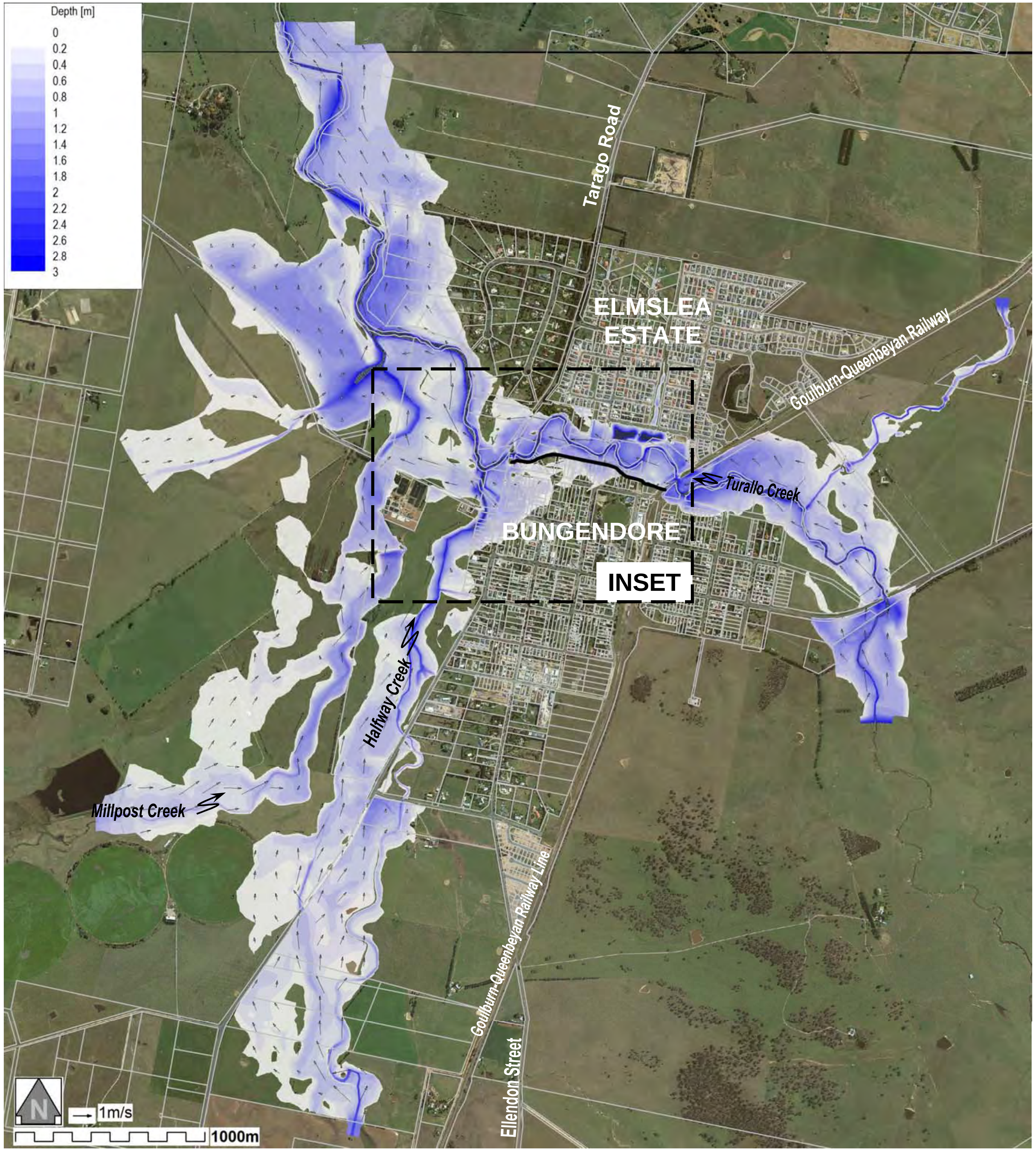
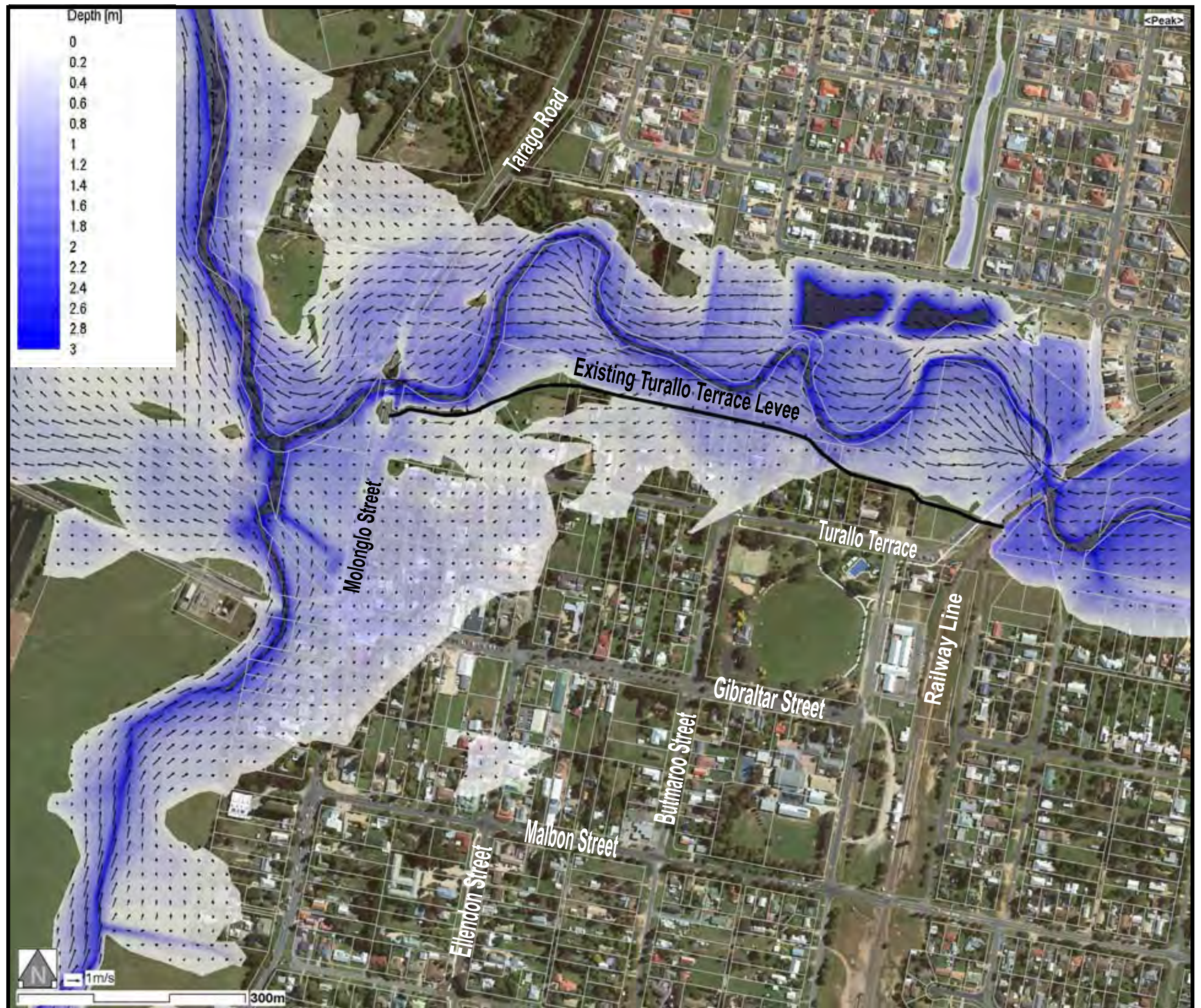
fg3777rg121114-fig13_20yr ARI Depths & Velocities.doc

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

FIGURE 14





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

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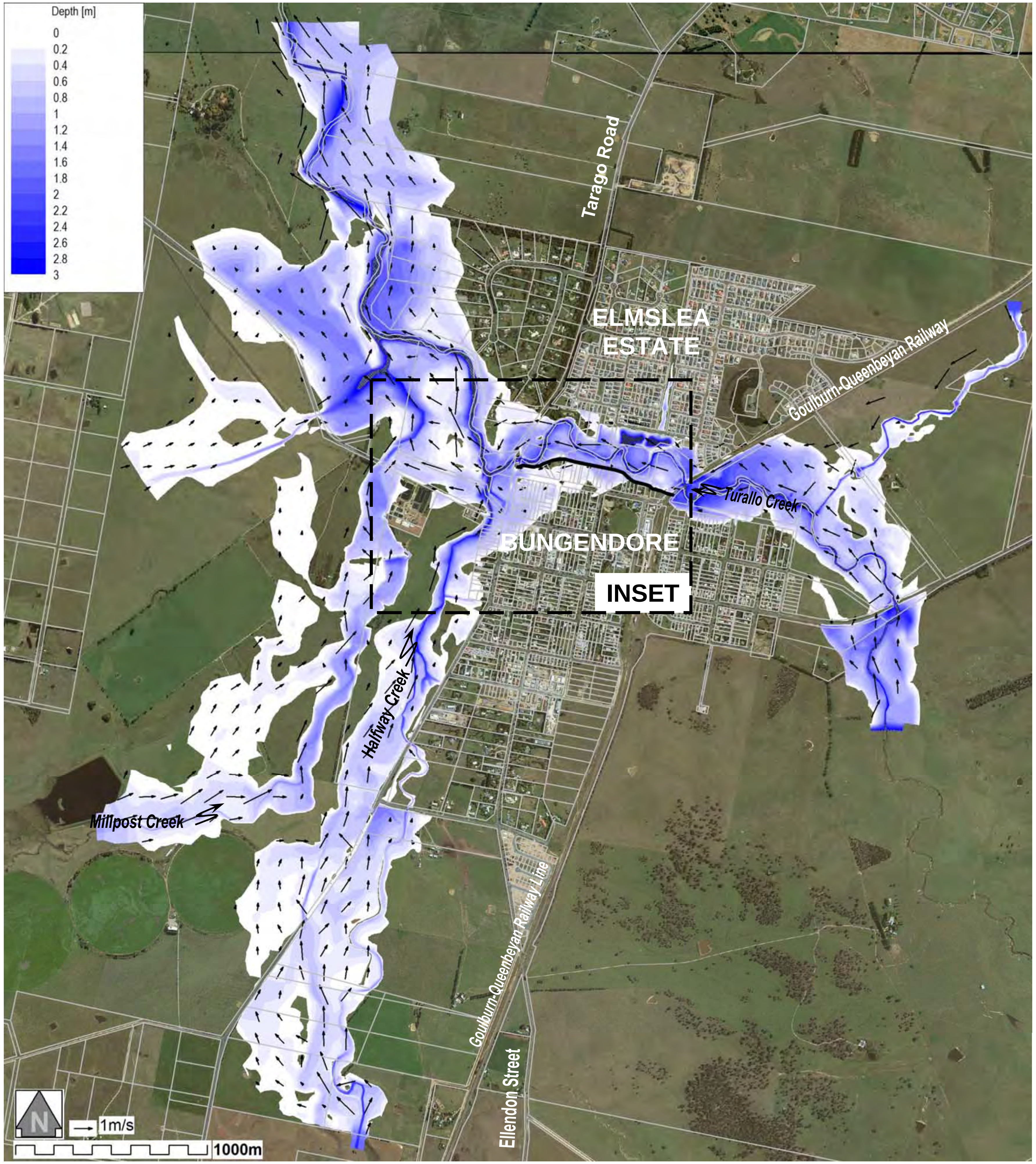
fg3777rg121114-fig14_50yr ARI Depths & Velocities.doc

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

FIGURE 15



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

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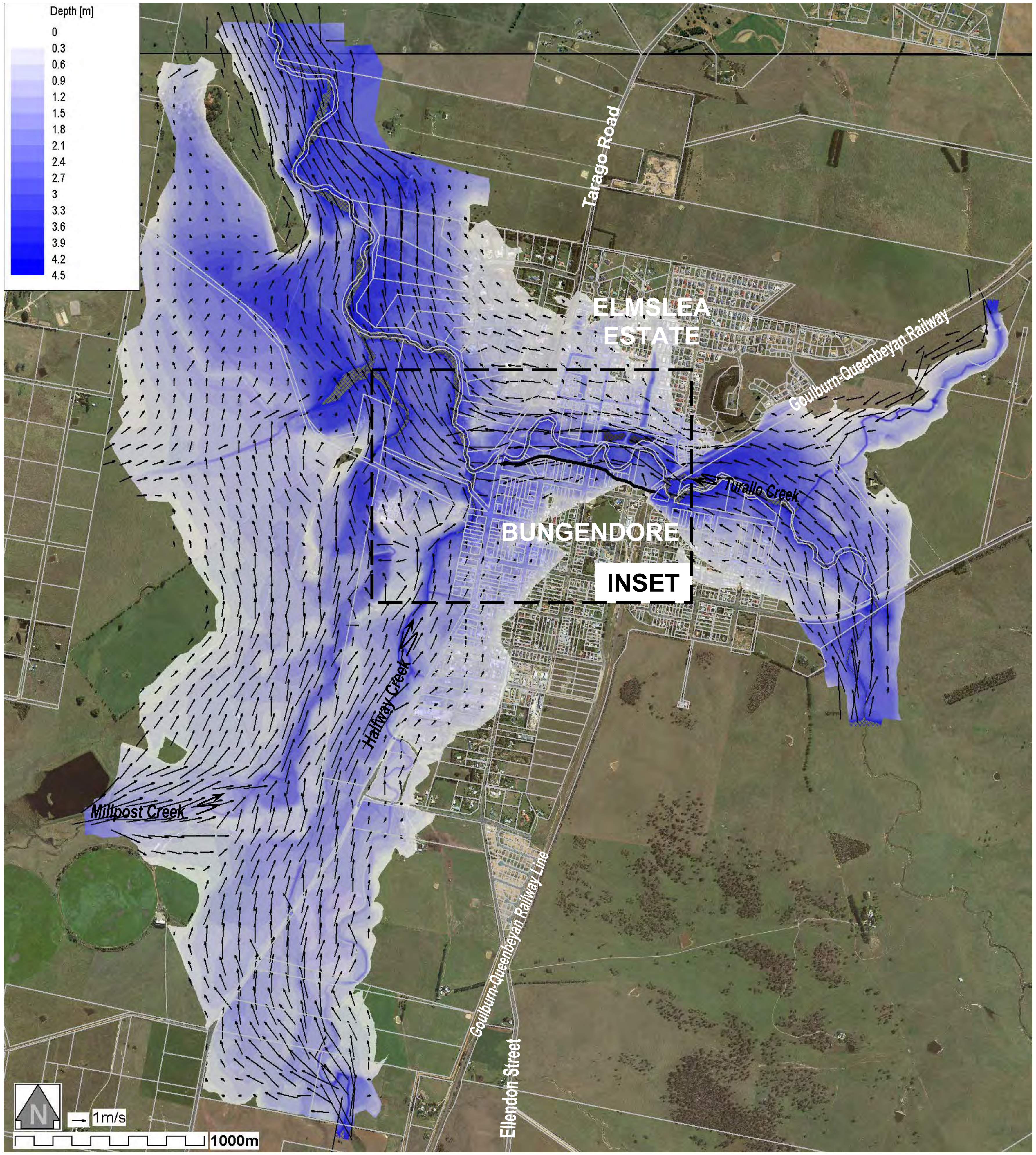
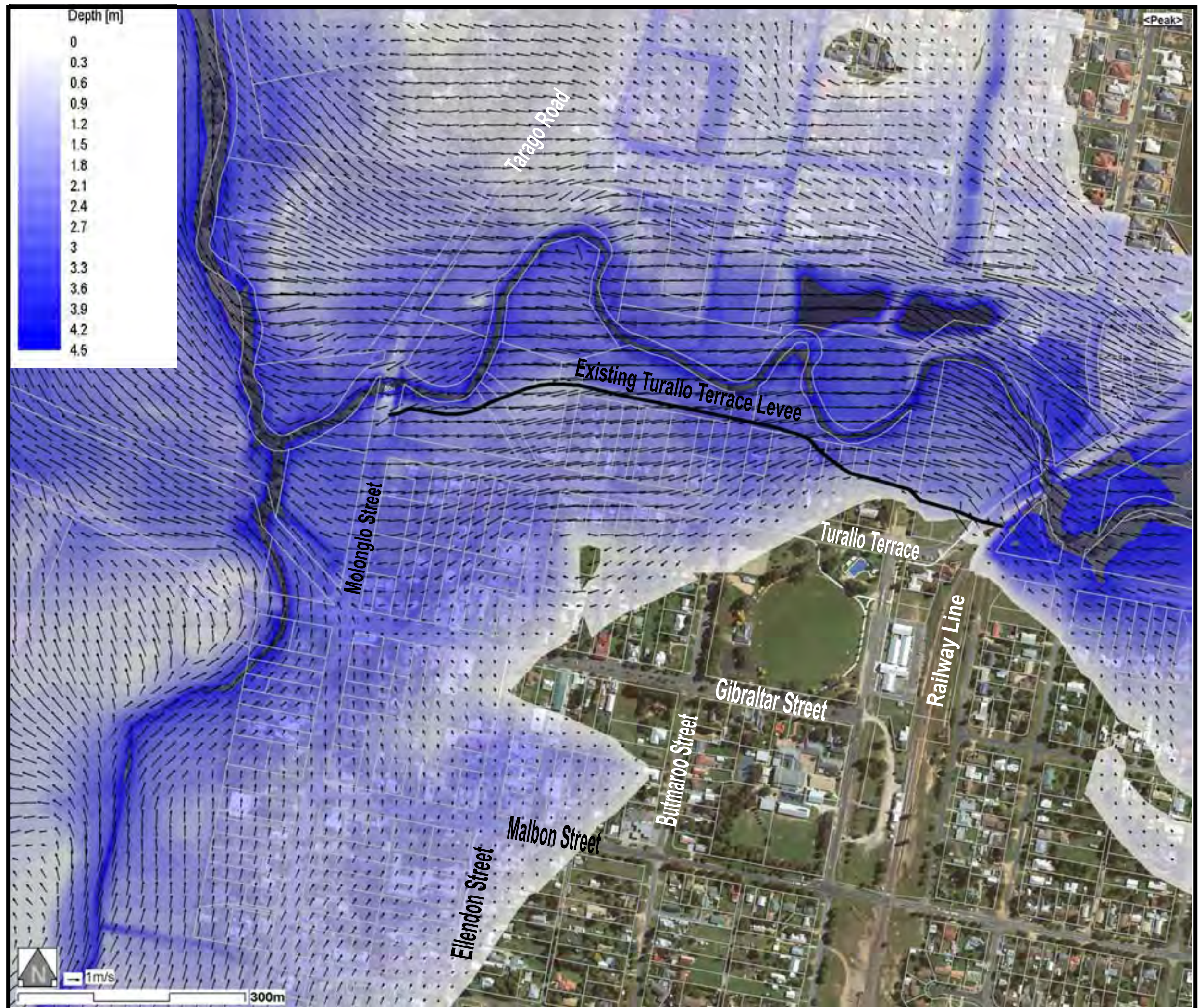
fg3777rg121114-fig15_100yr ARI Depths & Velocities.doc

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

FIGURE 16





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

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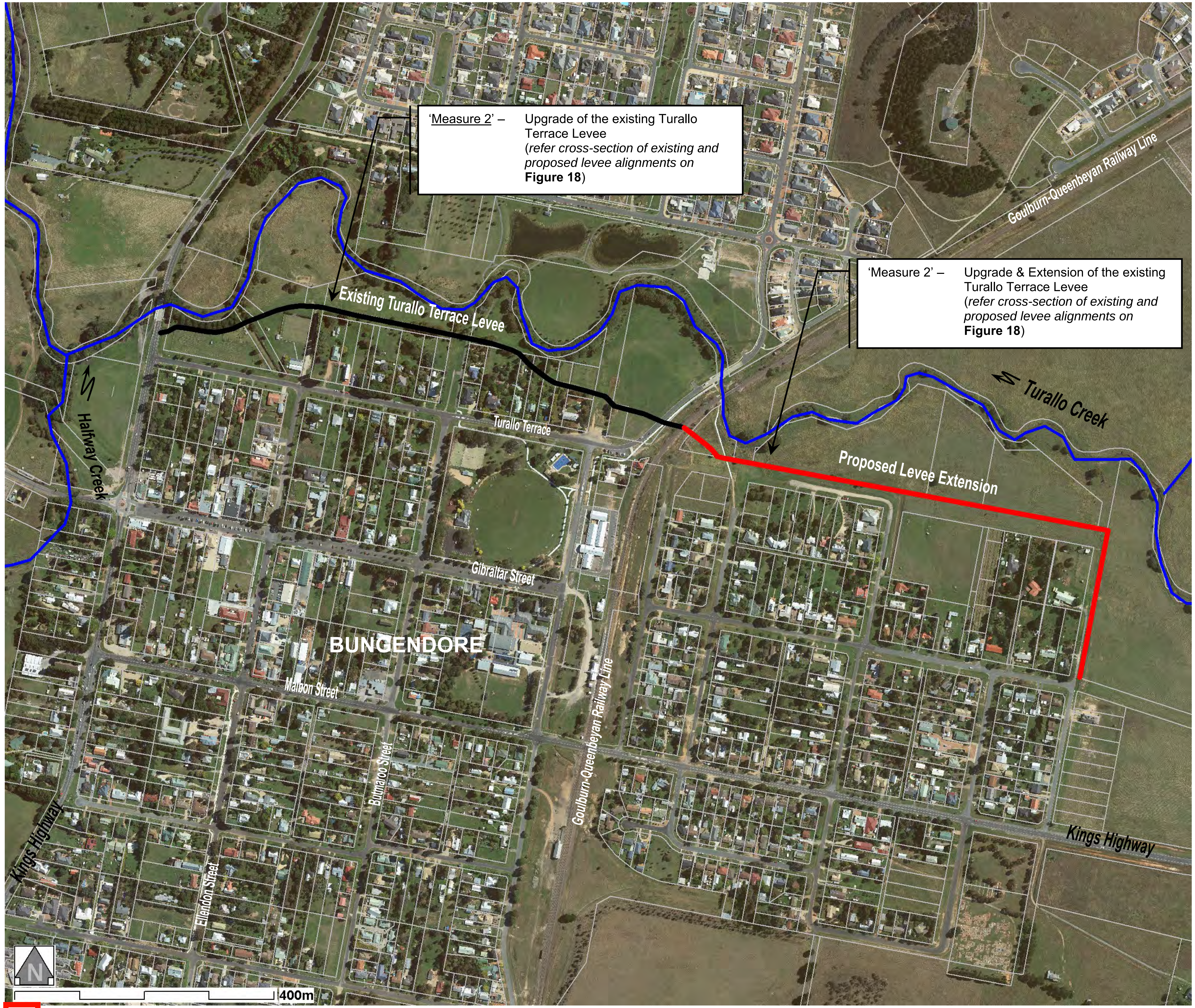
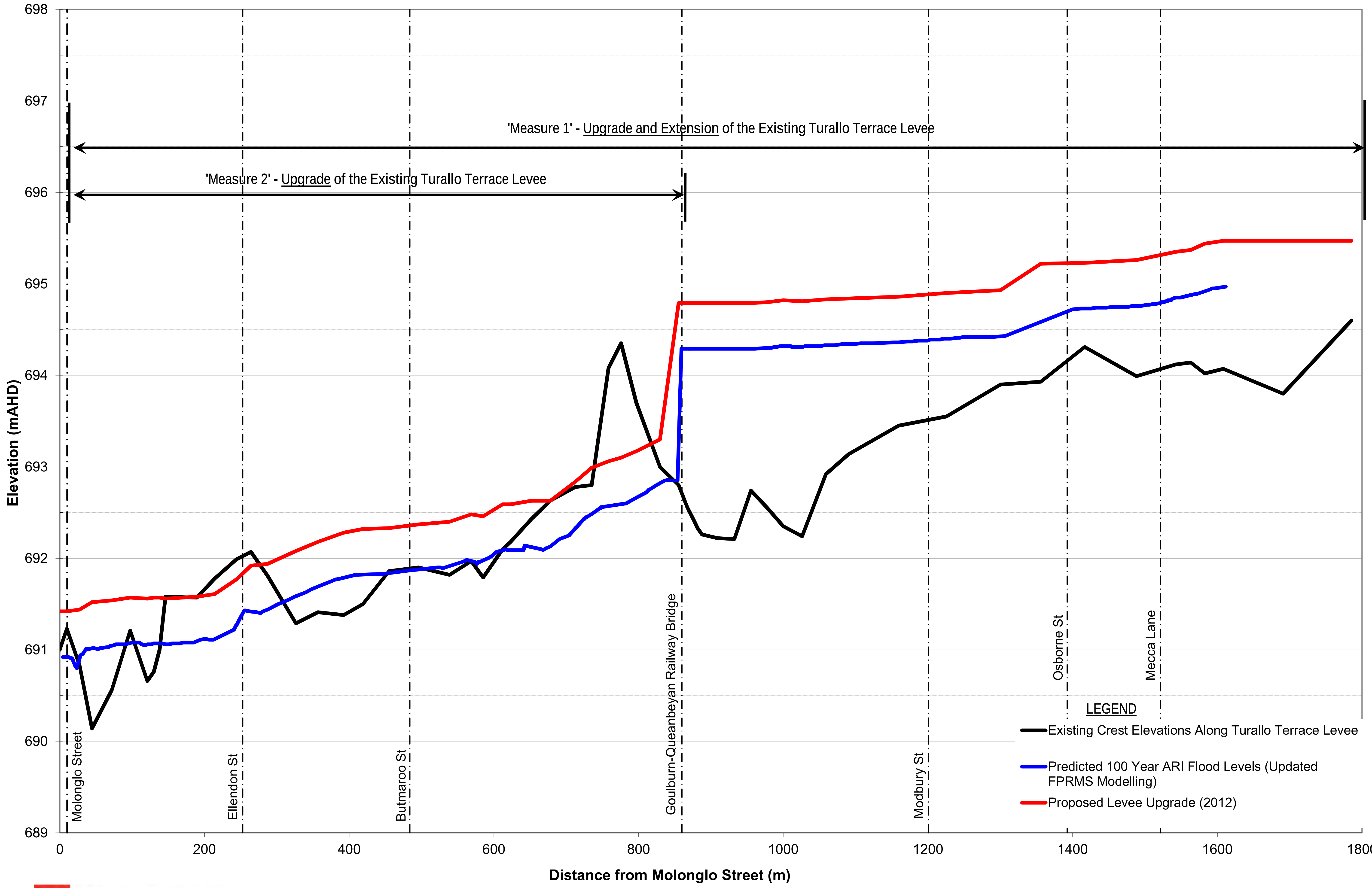
fg3777rg121114-fig16_PMF Depths & Velocities.doc

PREDICTED DEPTHS AND VELOCITIES AT THE PEAK OF THE PROBABLE MAXIMUM FLOOD [BASED ON UPDATED FPRMS MODELLING]



ADOPTED CONFIGURATION FOR FLOOD DAMAGE REDUCTION MEASURE 1 AND MEASURE 2

FIGURE 18



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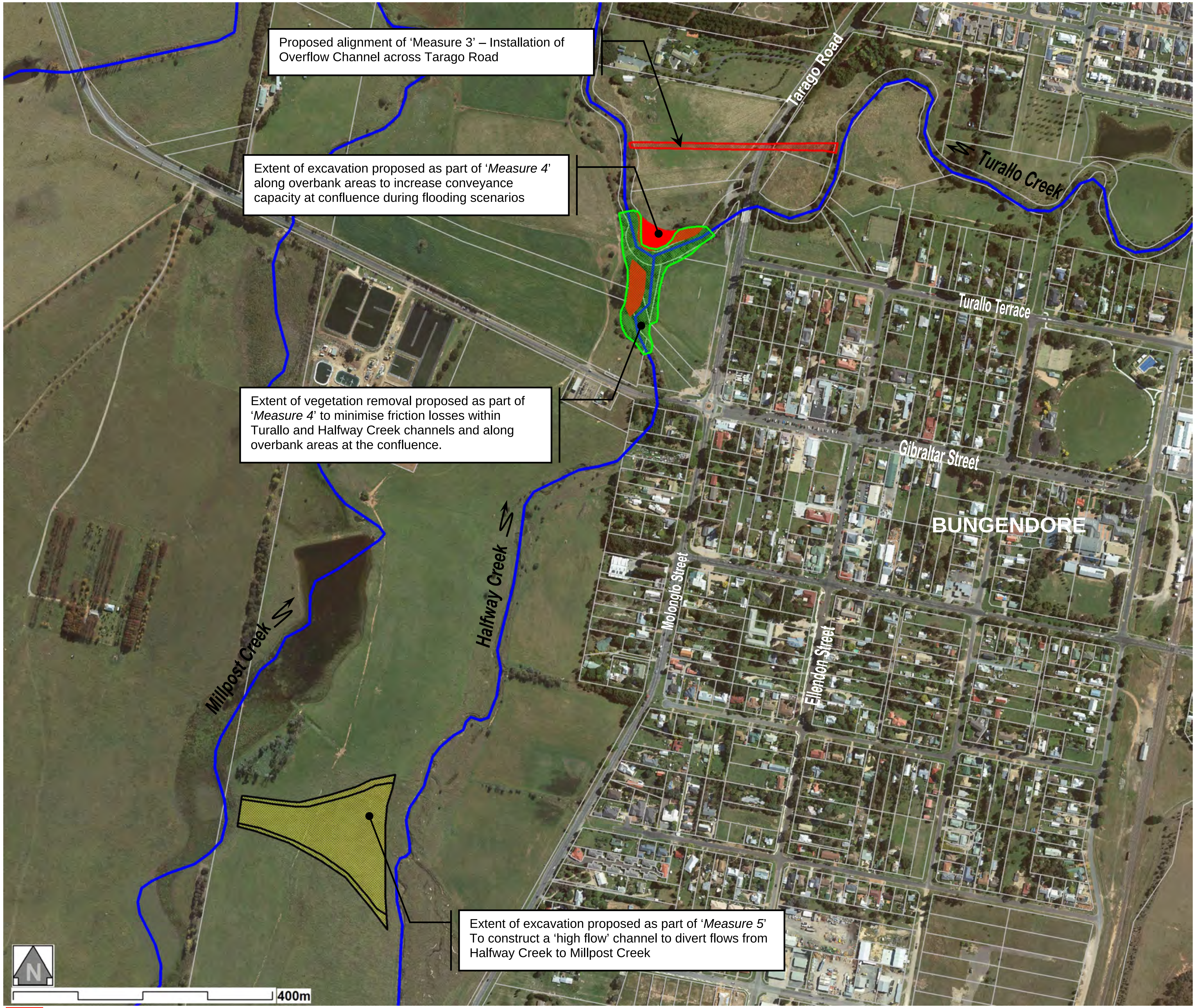
rp3777 - Bungendore FPMS
Levee (proposed vs old).xls

LONGITUDINAL PROFILE FOR FLOOD DAMAGE REDUCTION 'MEASURE 1' AND 'MEASURE 2'



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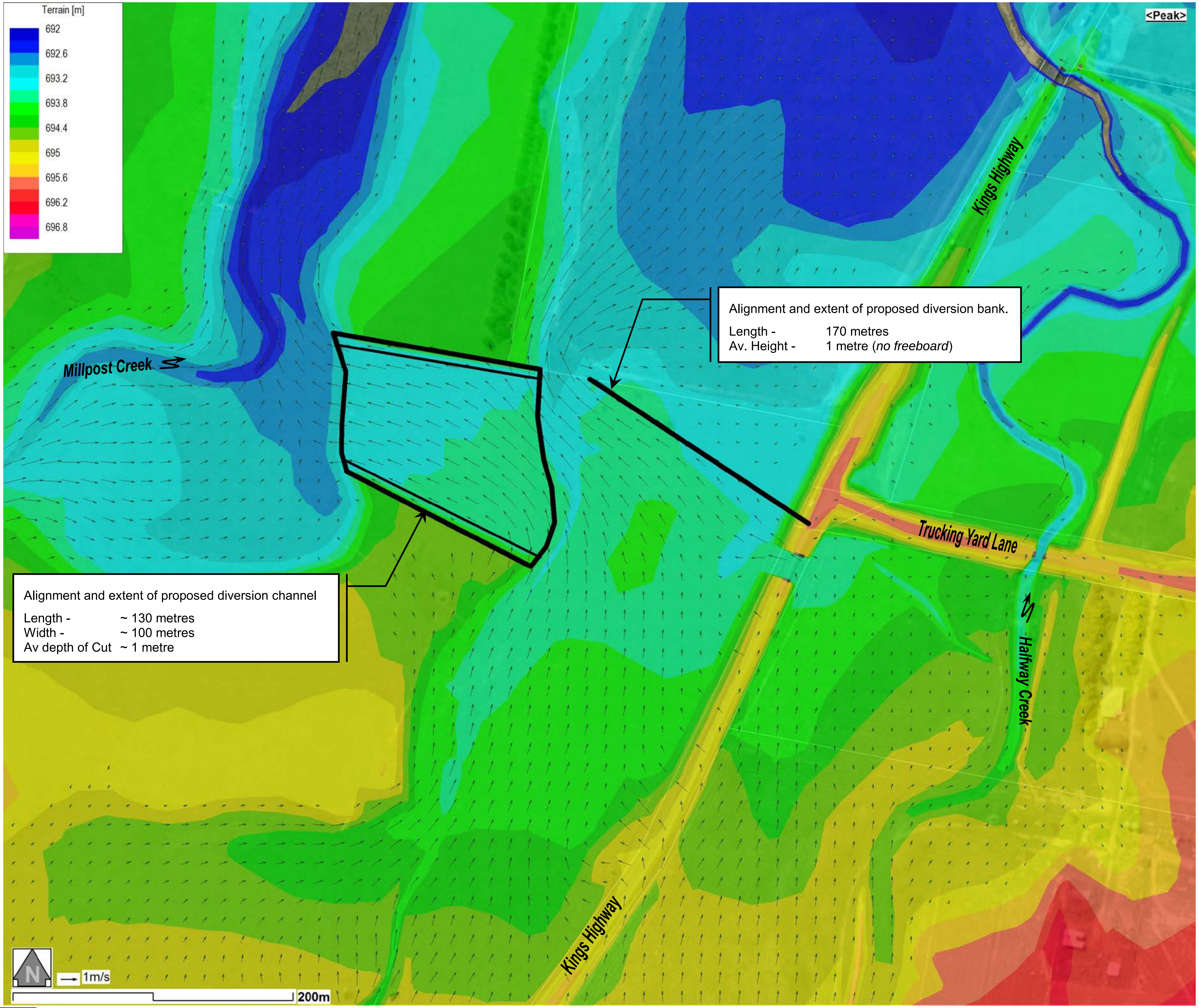
ADOPTED CONFIGURATION FOR FLOOD DAMAGE REDUCTION MEASURE 3, MEASURE 4 AND MEASURE 5

FIGURE 20



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 Study
fg3777rg121114-fig20_Damage Reduction 'Measure 5' Configuration.doc

ADOPTED CONFIGURATION FOR FLOOD DAMAGE REDUCTION MEASURE No 5

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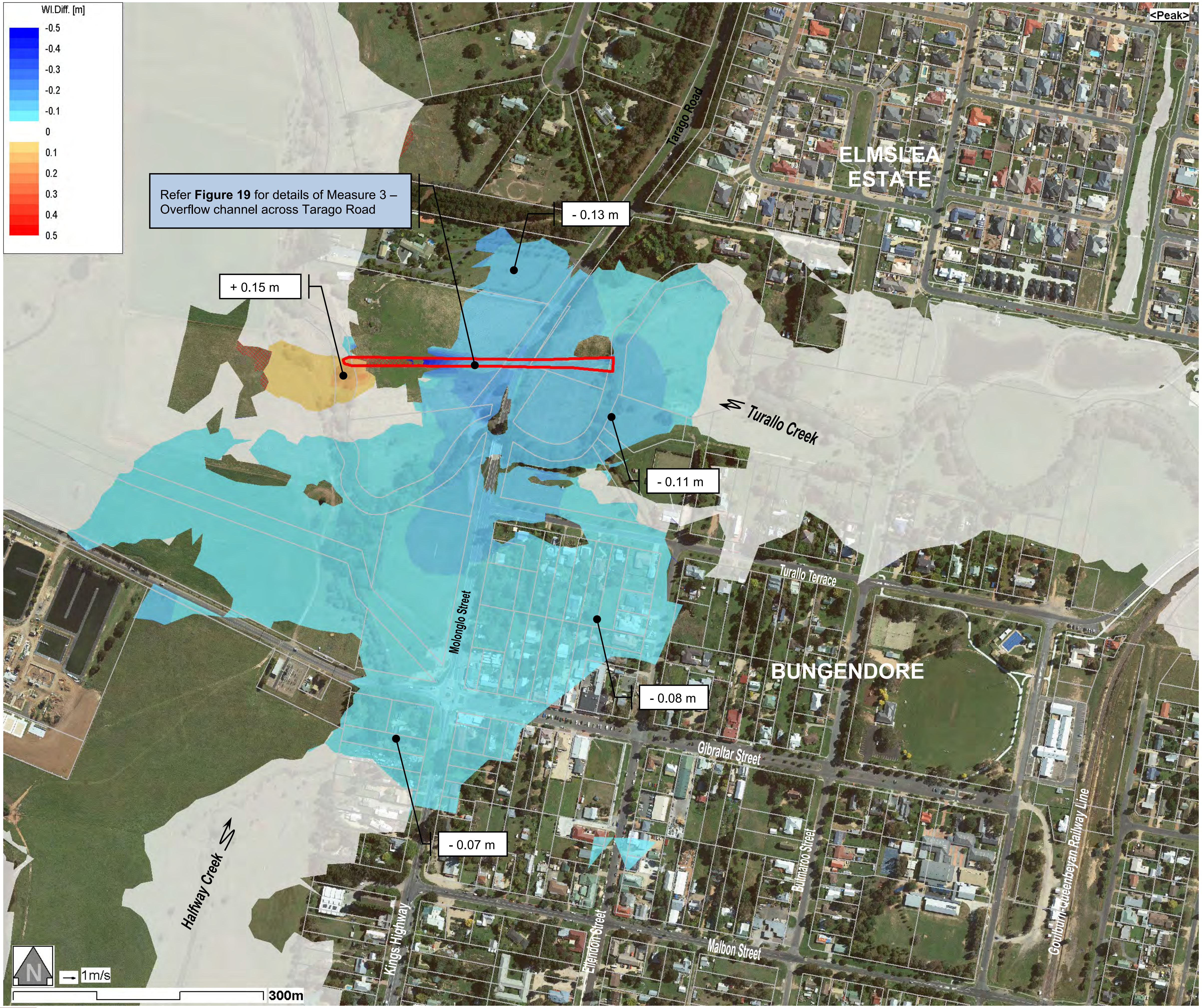
VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCORPORATION OF MEASURE 1



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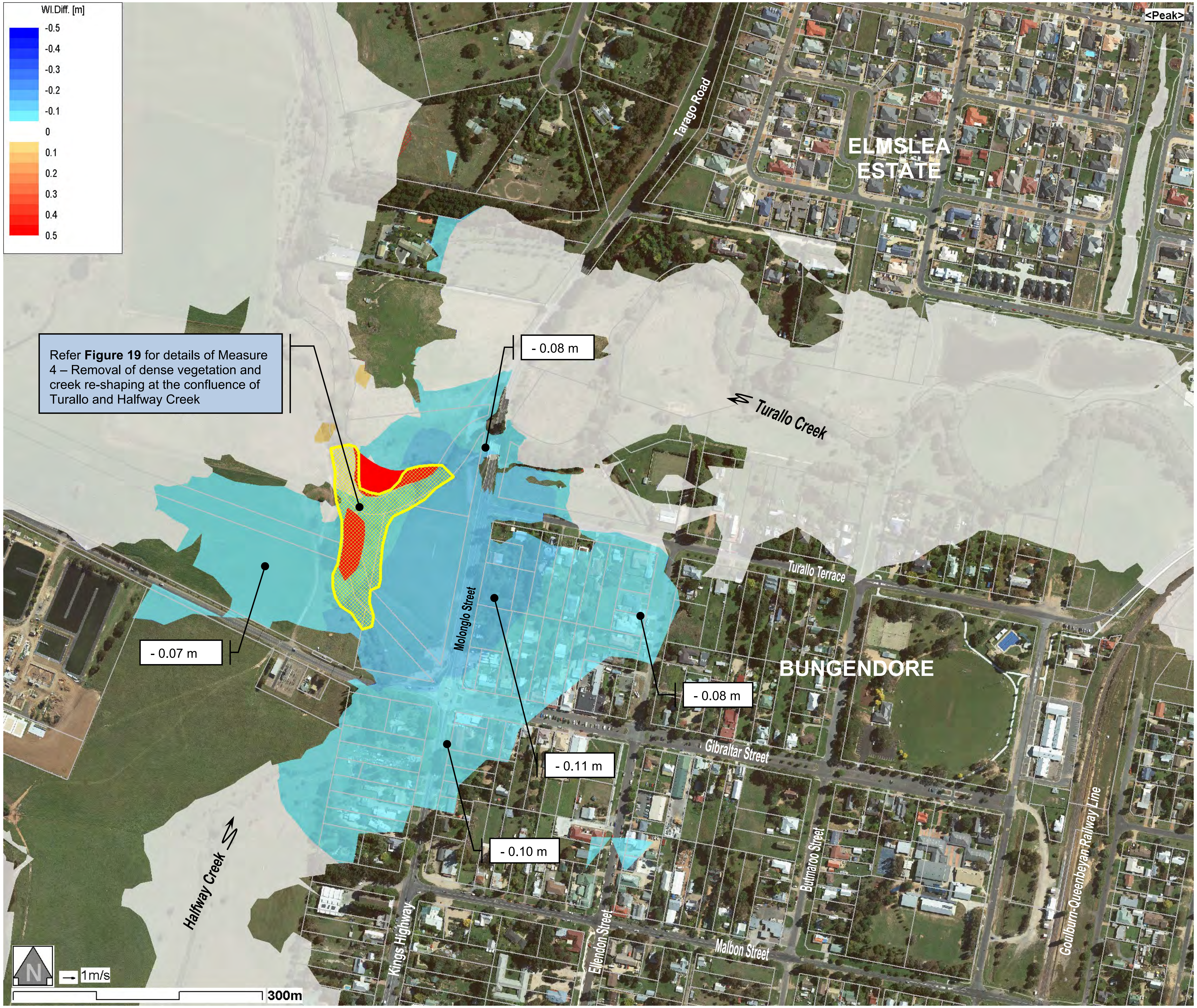
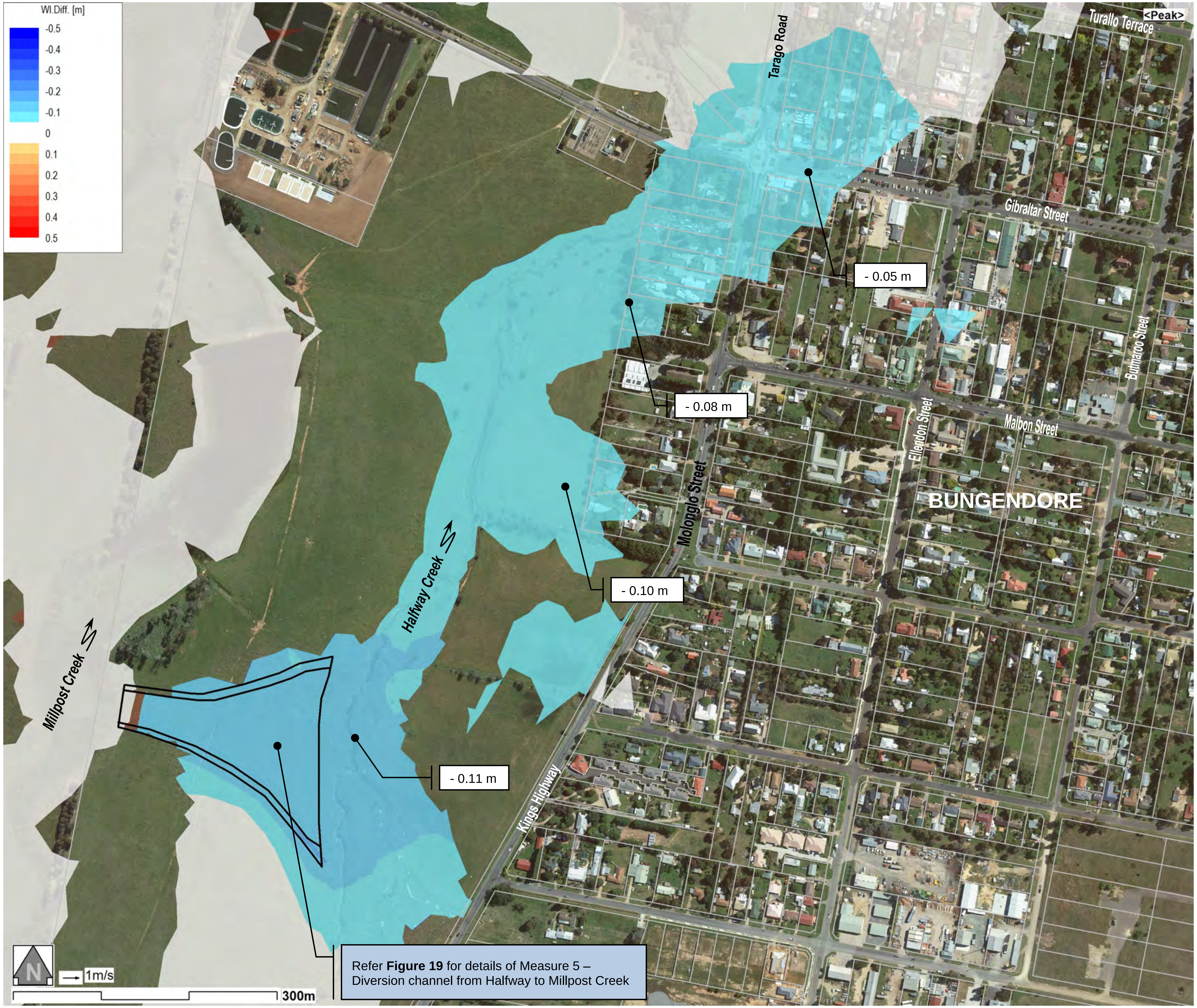
fg3777rg121114-fig22_Measure 2 Level DIFF (NEW).doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCORPORATION OF MEASURE 3

FIGURE 23



VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCORPORATION OF MEASURE 4



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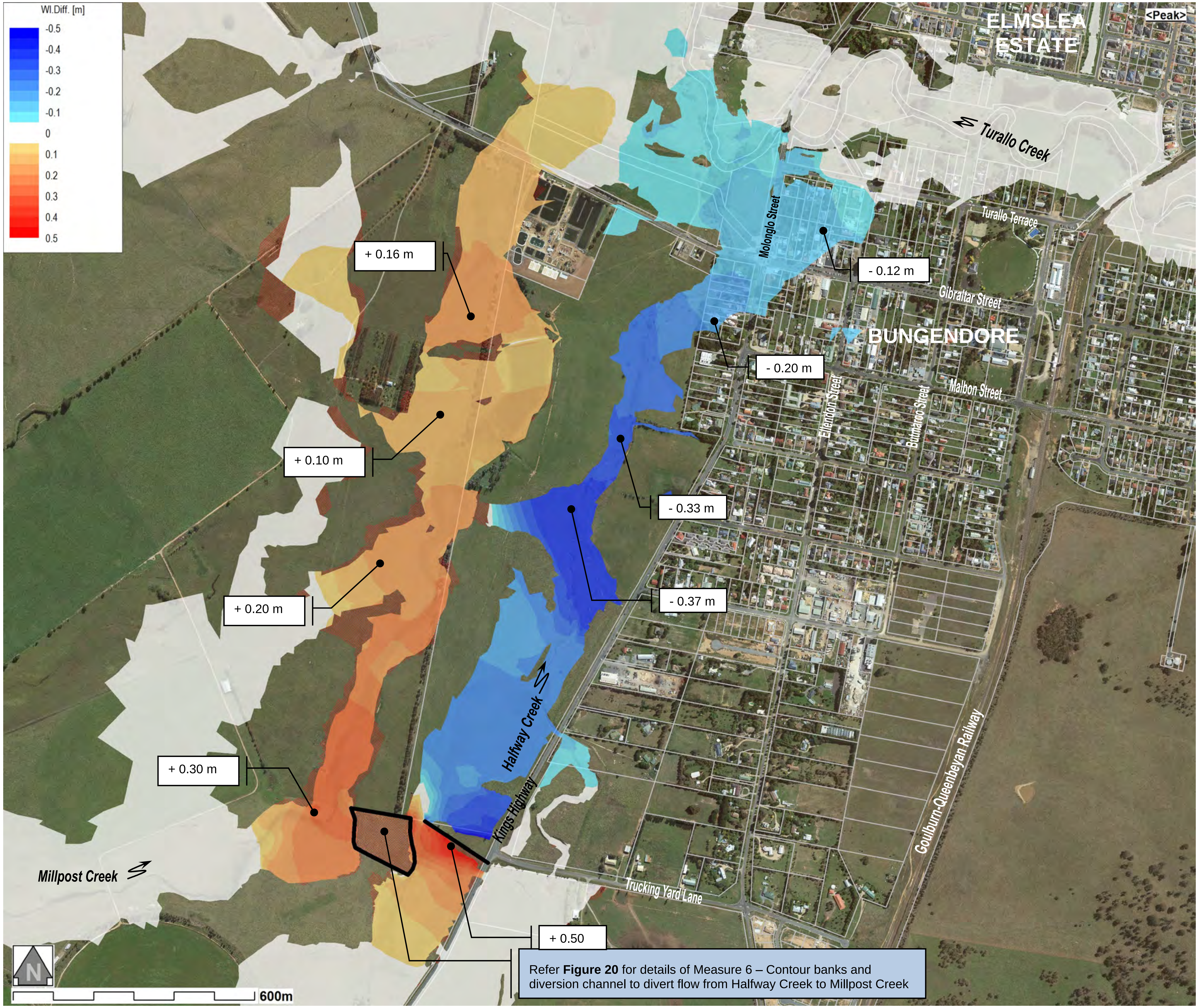
fg3777rg121114-fig22_Measure 2 Level DIFF (NEW).doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCORPORATION OF MEASURE 5

FIGURE 25



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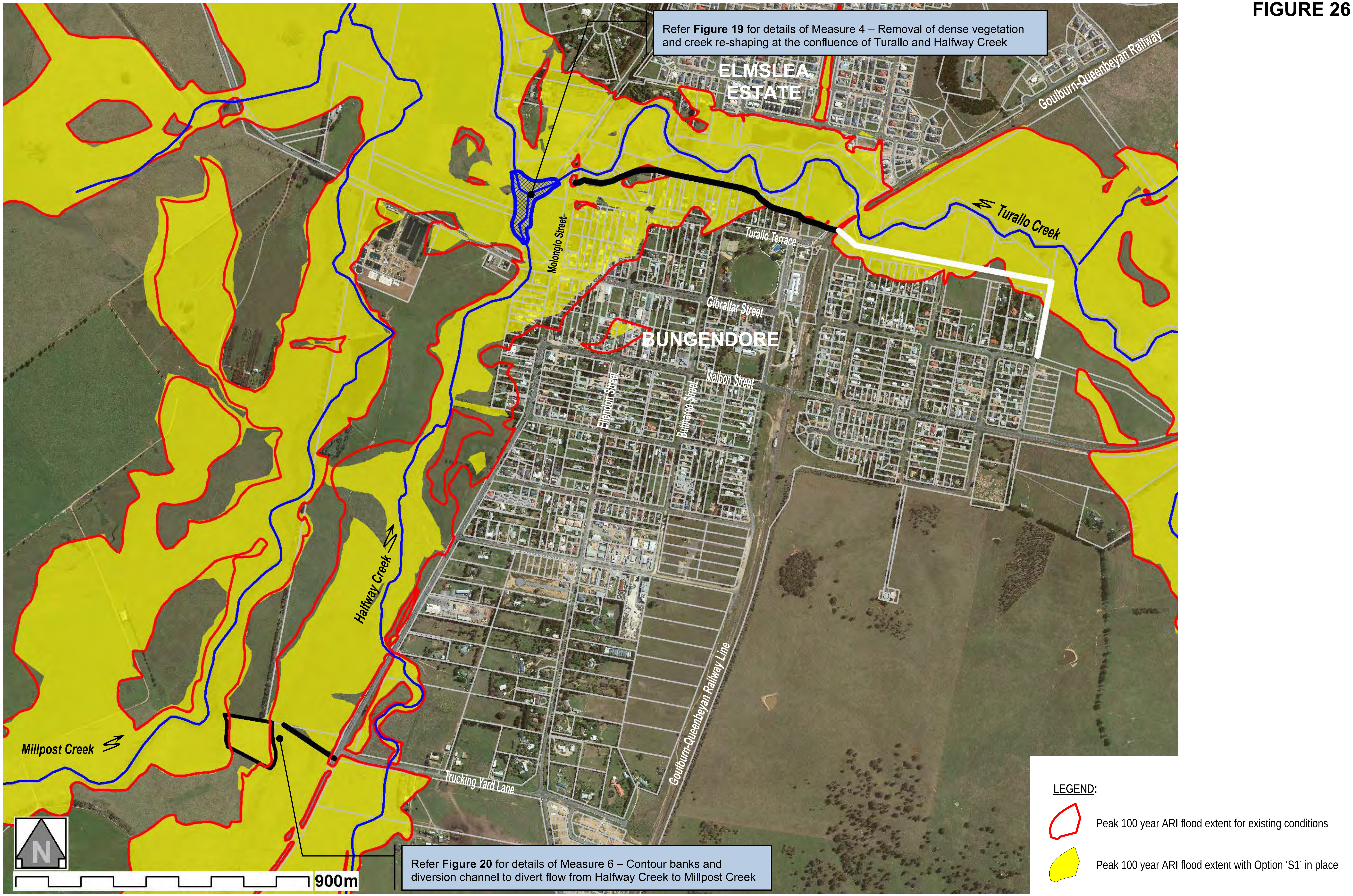
fg3777rg121114-fig22_Option S1 Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF MEASURE 6

FIGURE 26



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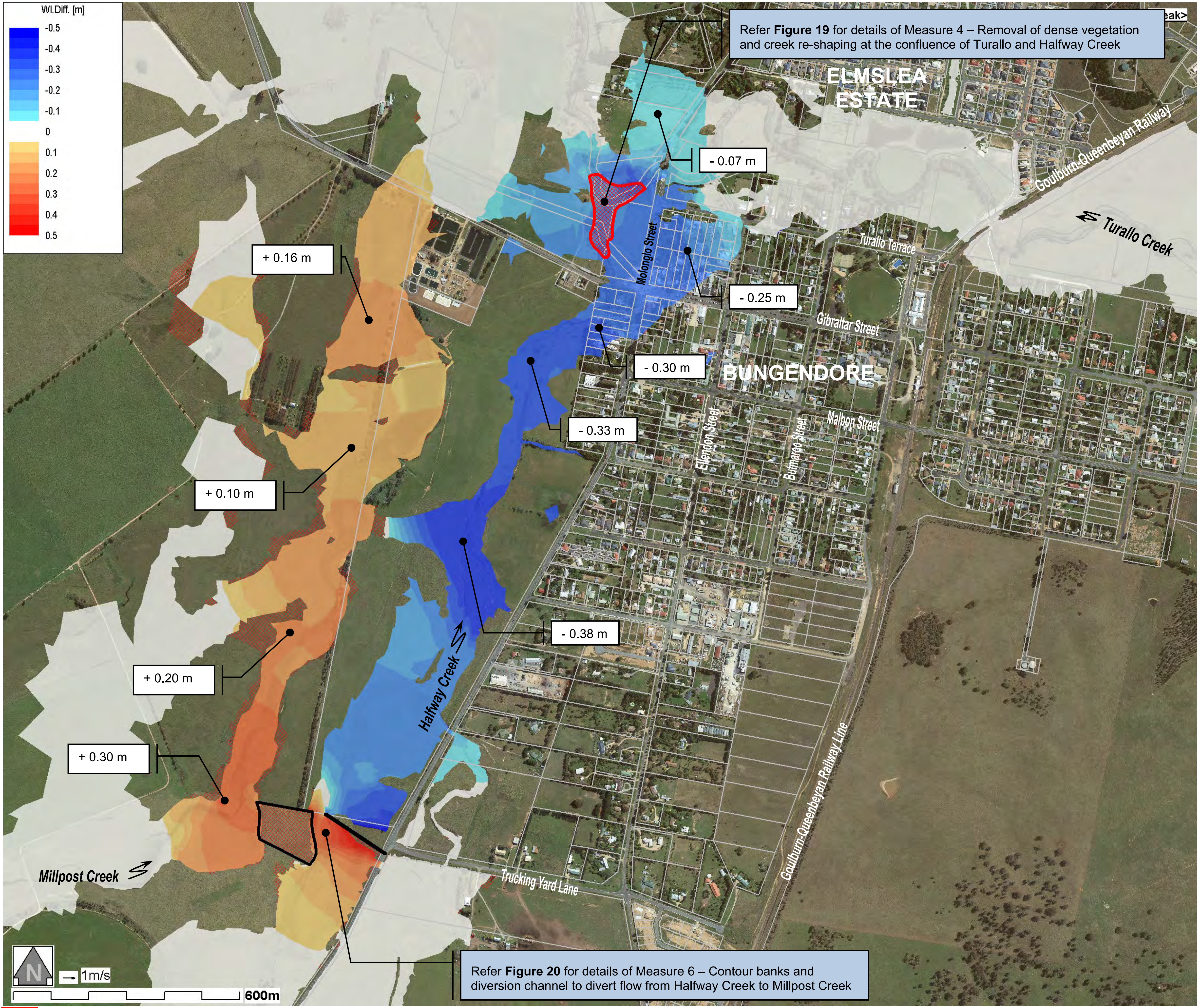
fg3777rg121114-fig21_Option S1 Extent DIFF.doc

COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT OPTION '*S1*'

FIGURE 27



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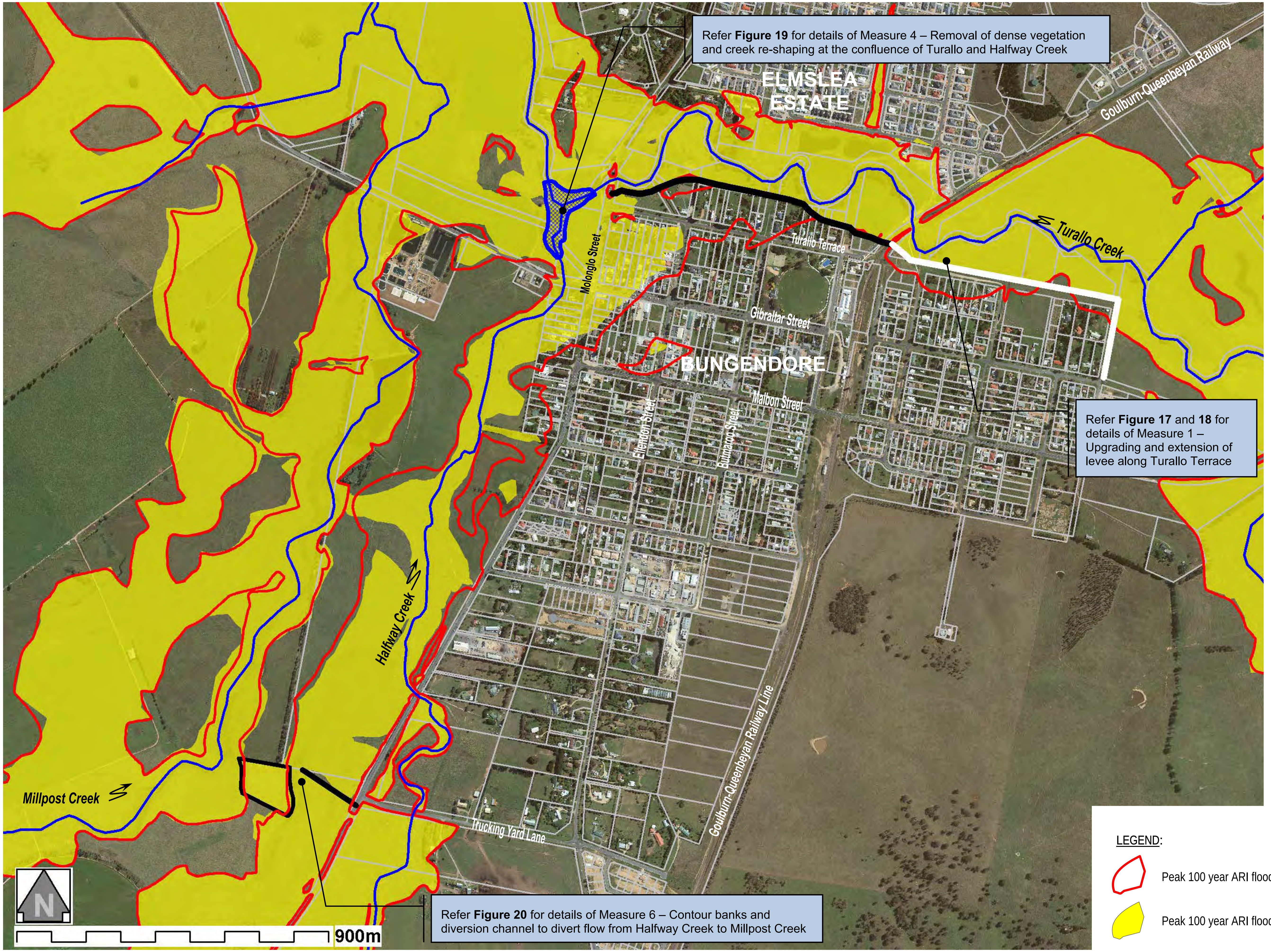
fg3777rg121114-fig22_Option S1 Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF OPTION '*S1*'



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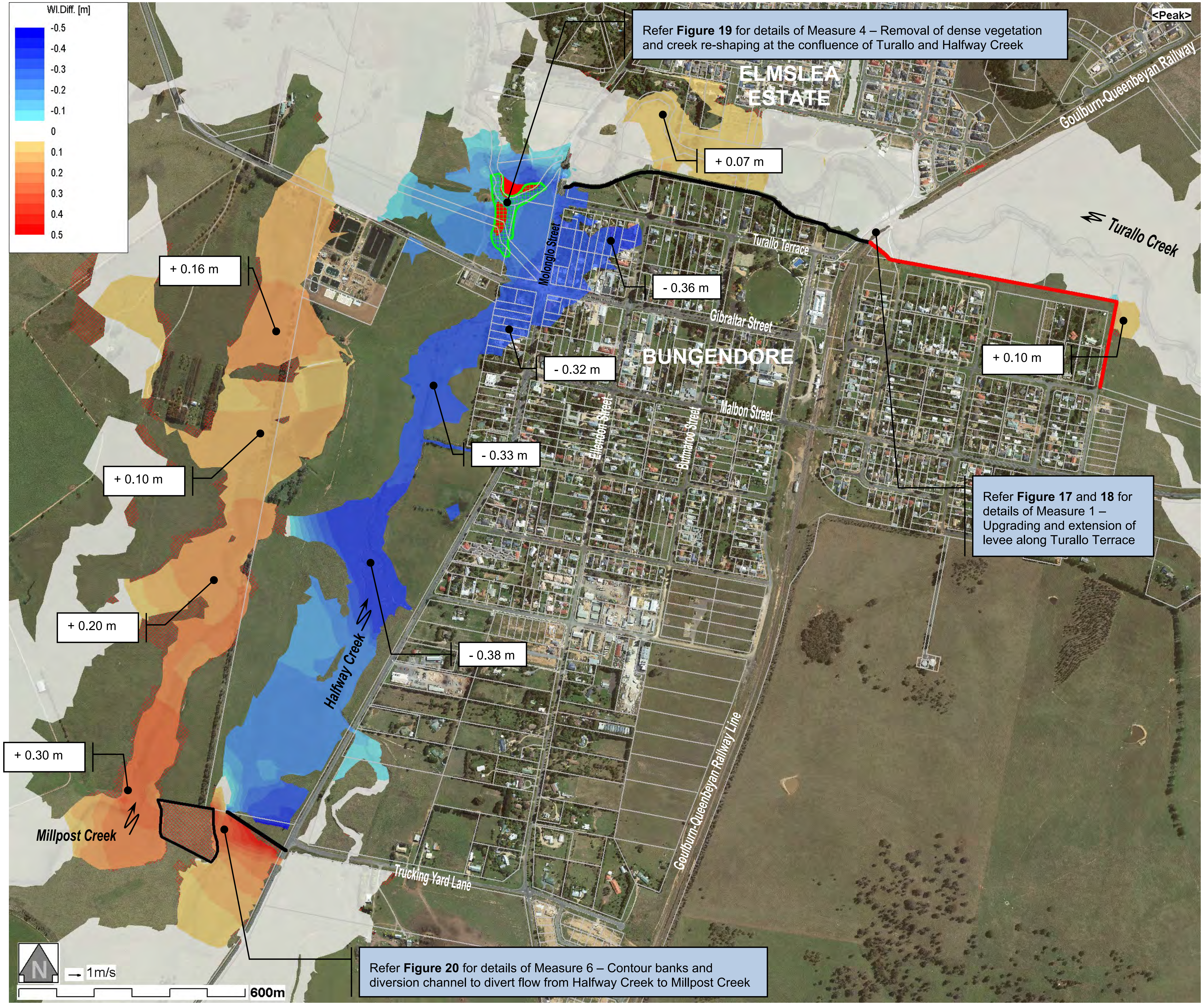
COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT OPTION '*S2*'

FIGURE 29



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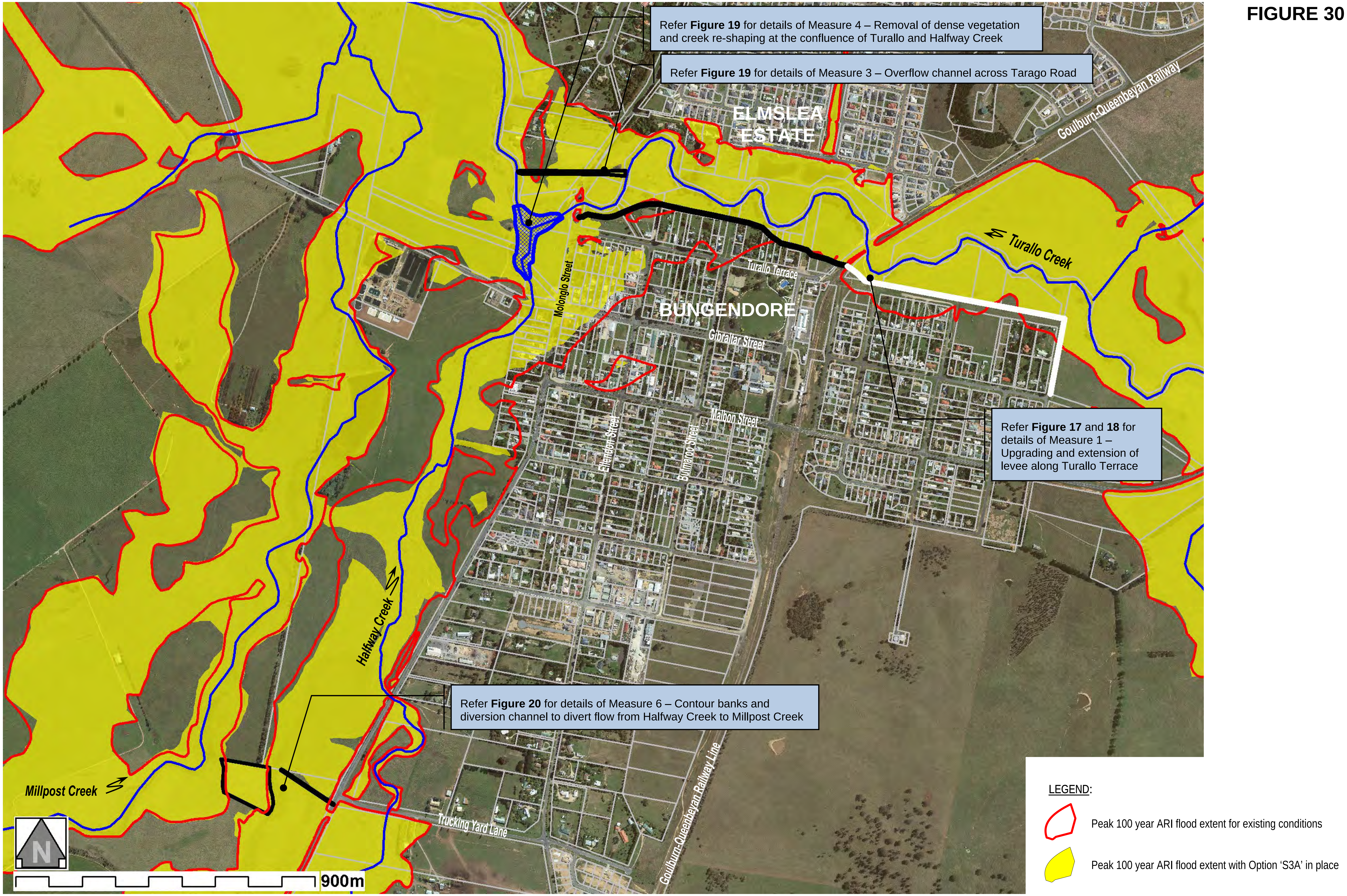
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig24_Option S2 Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF OPTION '*S2*'

FIGURE 30



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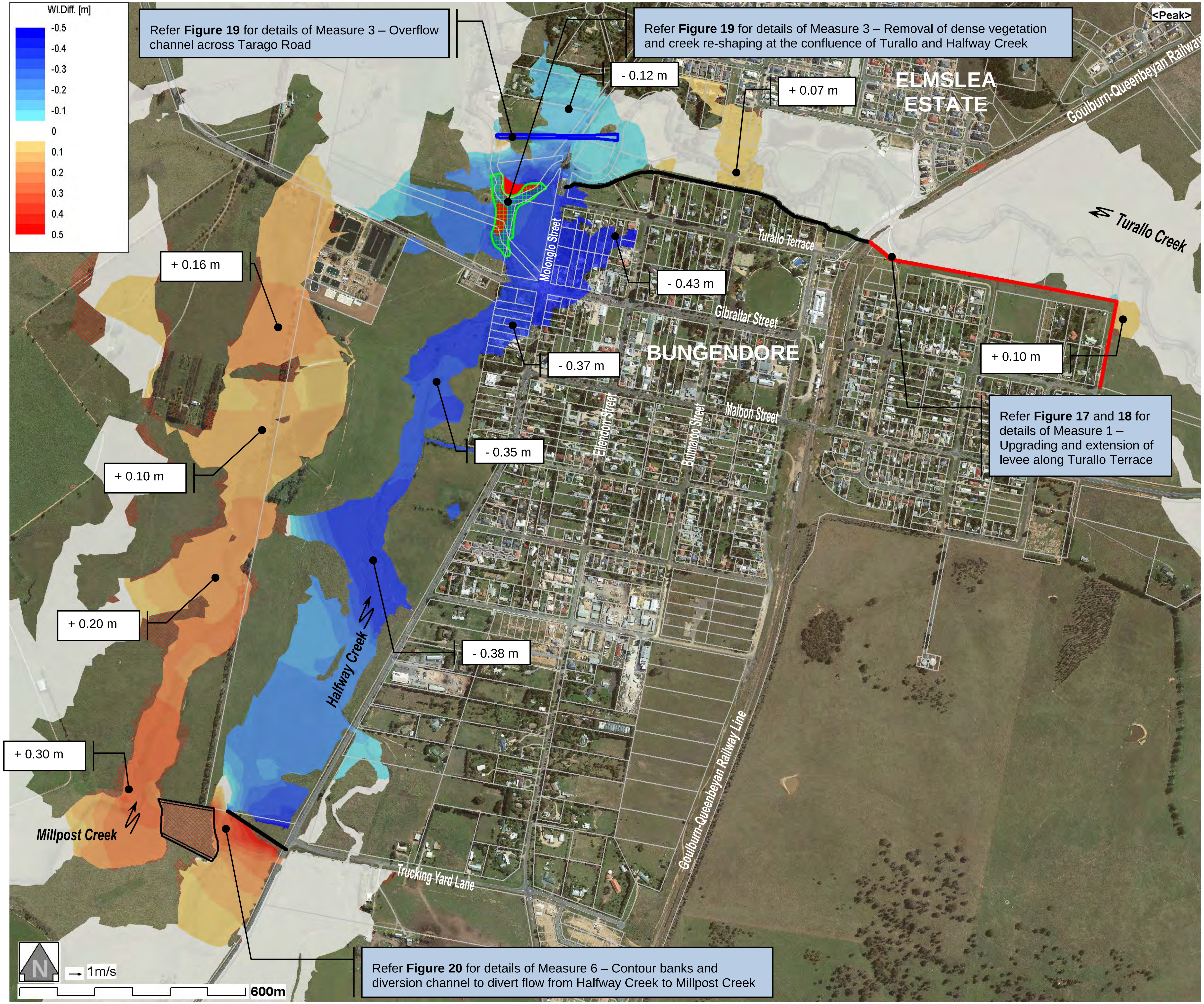
fg3777rg121114-fig25_Option S3 Extent DIFF.doc

COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT OPTION '*S3A*'



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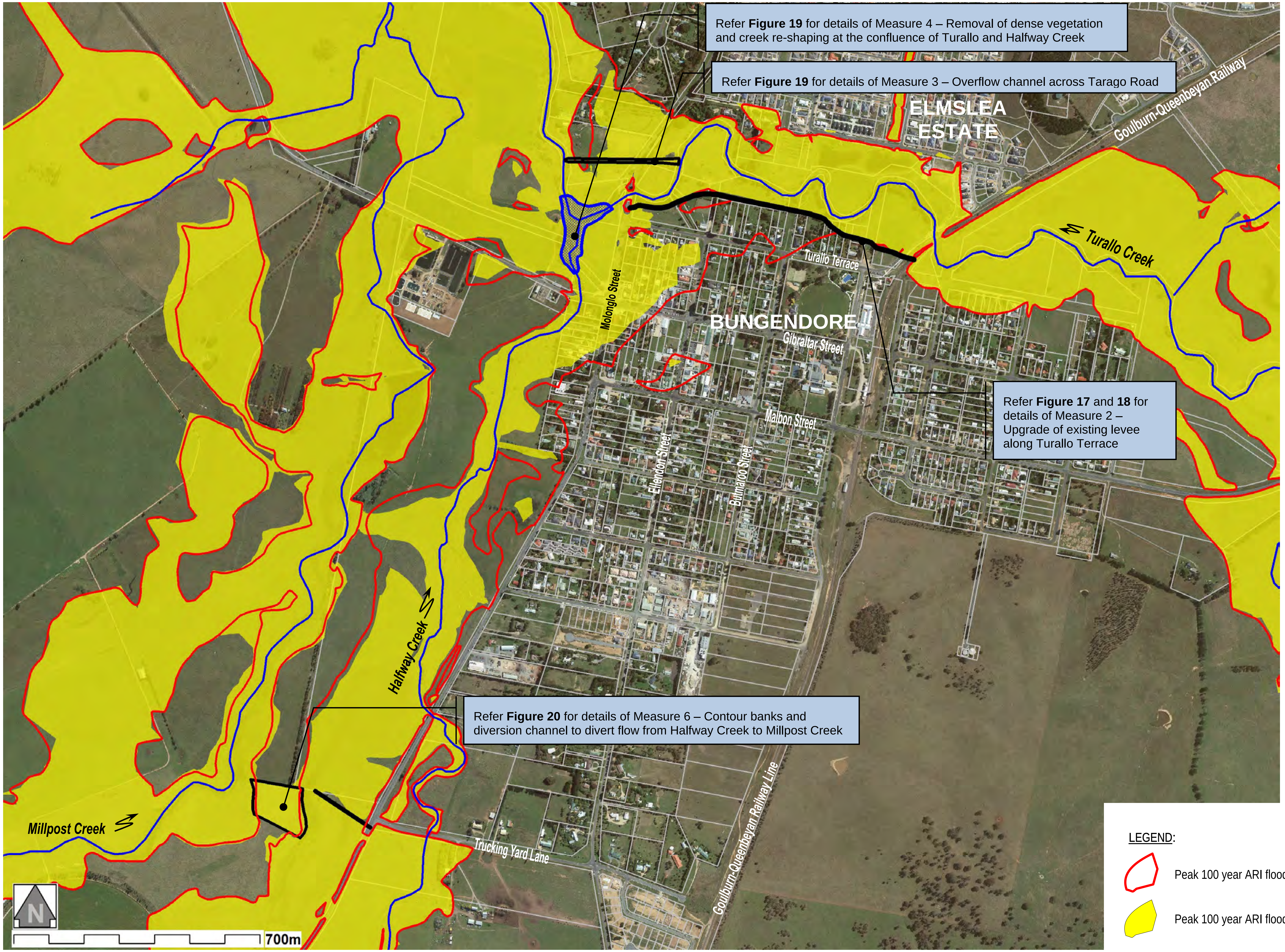
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig26_Option S3 Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF <u>OPTION '*S3A*'</u>

FIGURE 32



LEGEND:

Peak 100 year ARI flood extent for existing conditions

Peak 100 year ARI flood extent with Option 'S3B' in place

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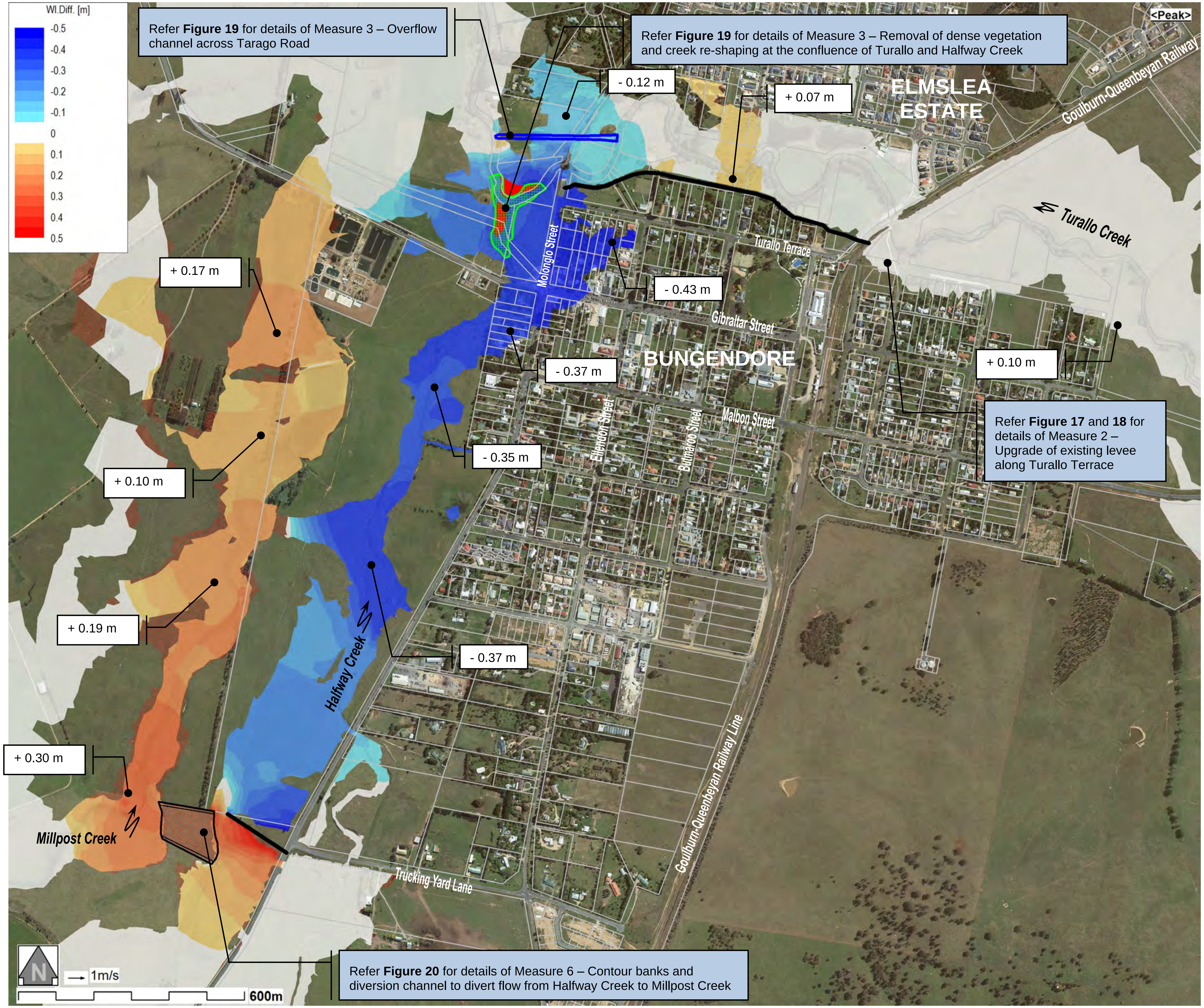
fg3777rg121114-fig25_Option S3 Extent DIFF.doc

COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT <u>OPTION '*S3B*'</u>

FIGURE 33



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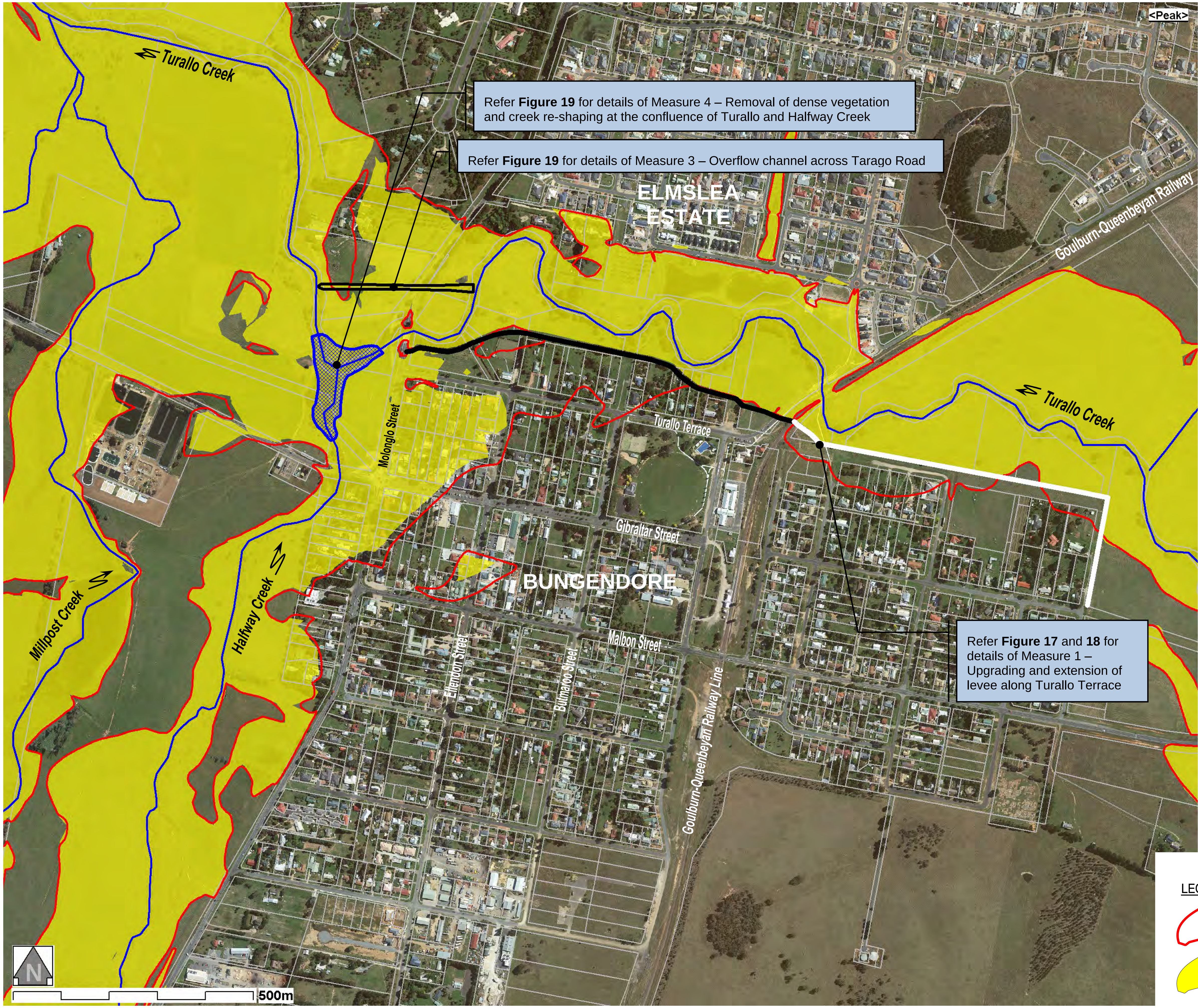
fg3777rg121114-fig26_Option S3 Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF <u>OPTION '*S3B*'</u>

FIGURE 34



LEGEND:

Peak 100 year ARI flood extent for existing conditions

Peak 100 year ARI flood extent with Option 'S4A' in place

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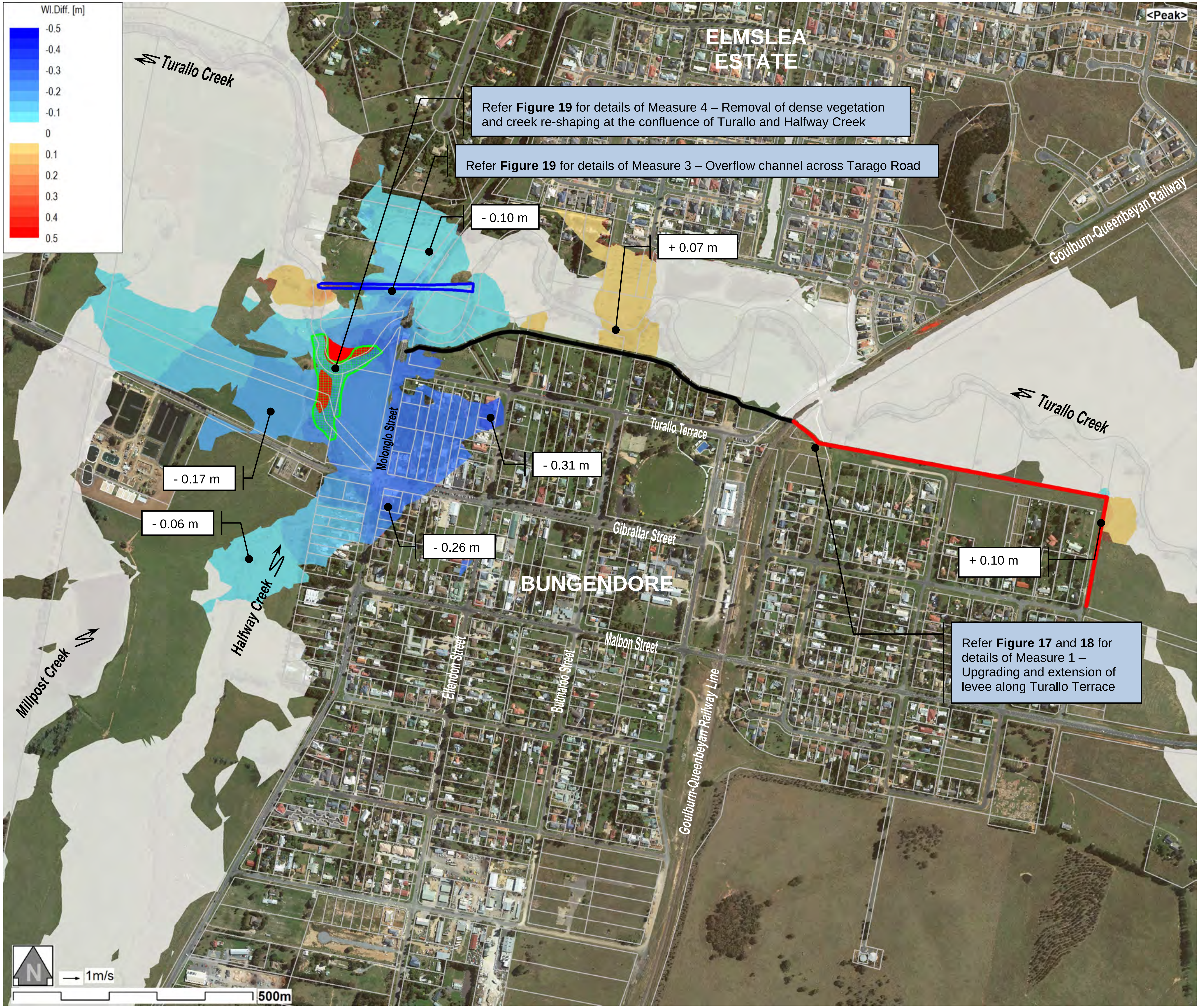
COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT OPTION '*S4A*'

FIGURE 35



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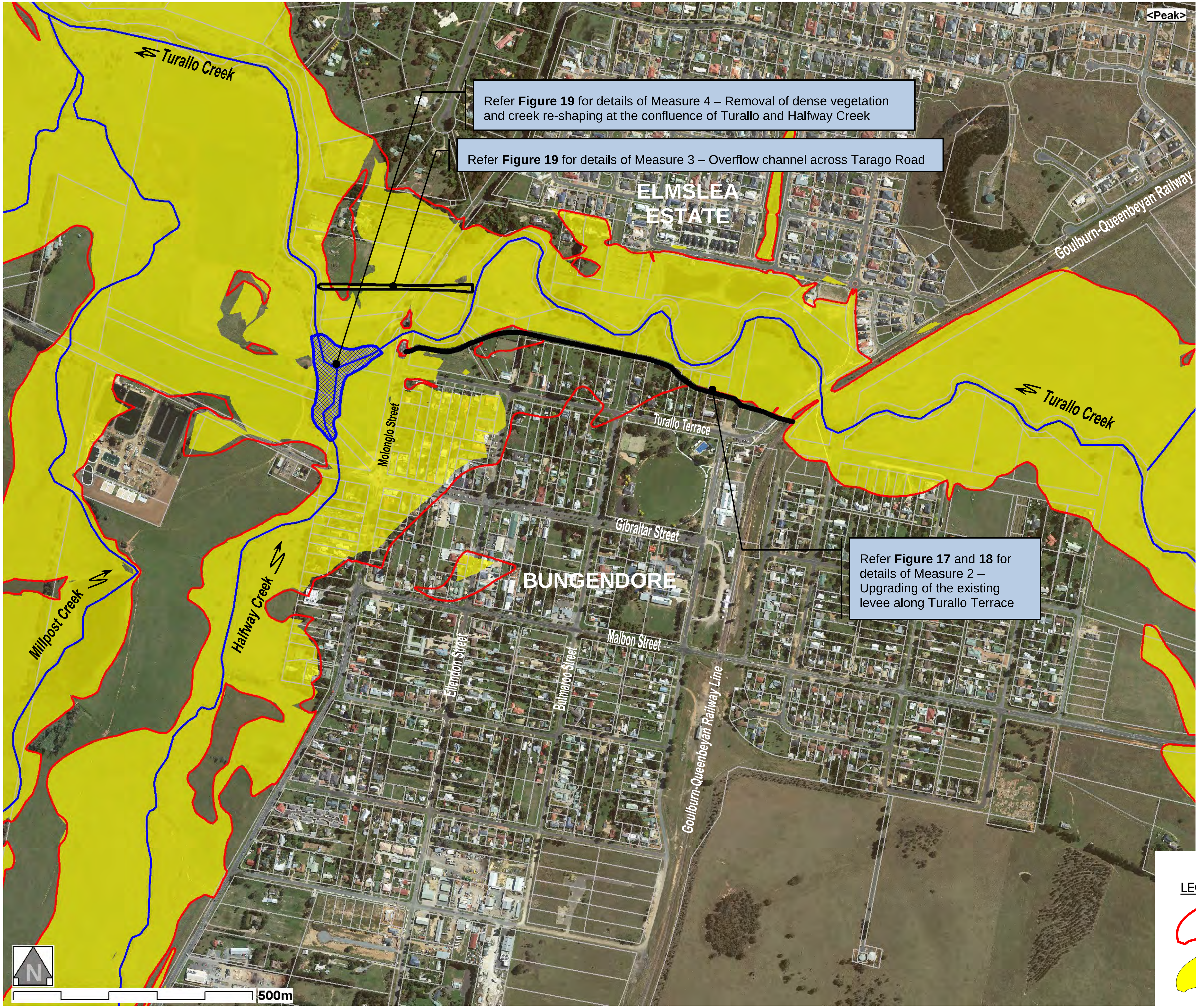
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig28_Option S4A Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF OPTION '*S4A*'

FIGURE 36



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fg3777rg121114-fig29_Option S4B Extent DIFF.doc

COMPARISON OF PEAK 100 YEAR RECURRENCE FLOOD EXTENTS WITH AND WITHOUT OPTION '*S4B*'

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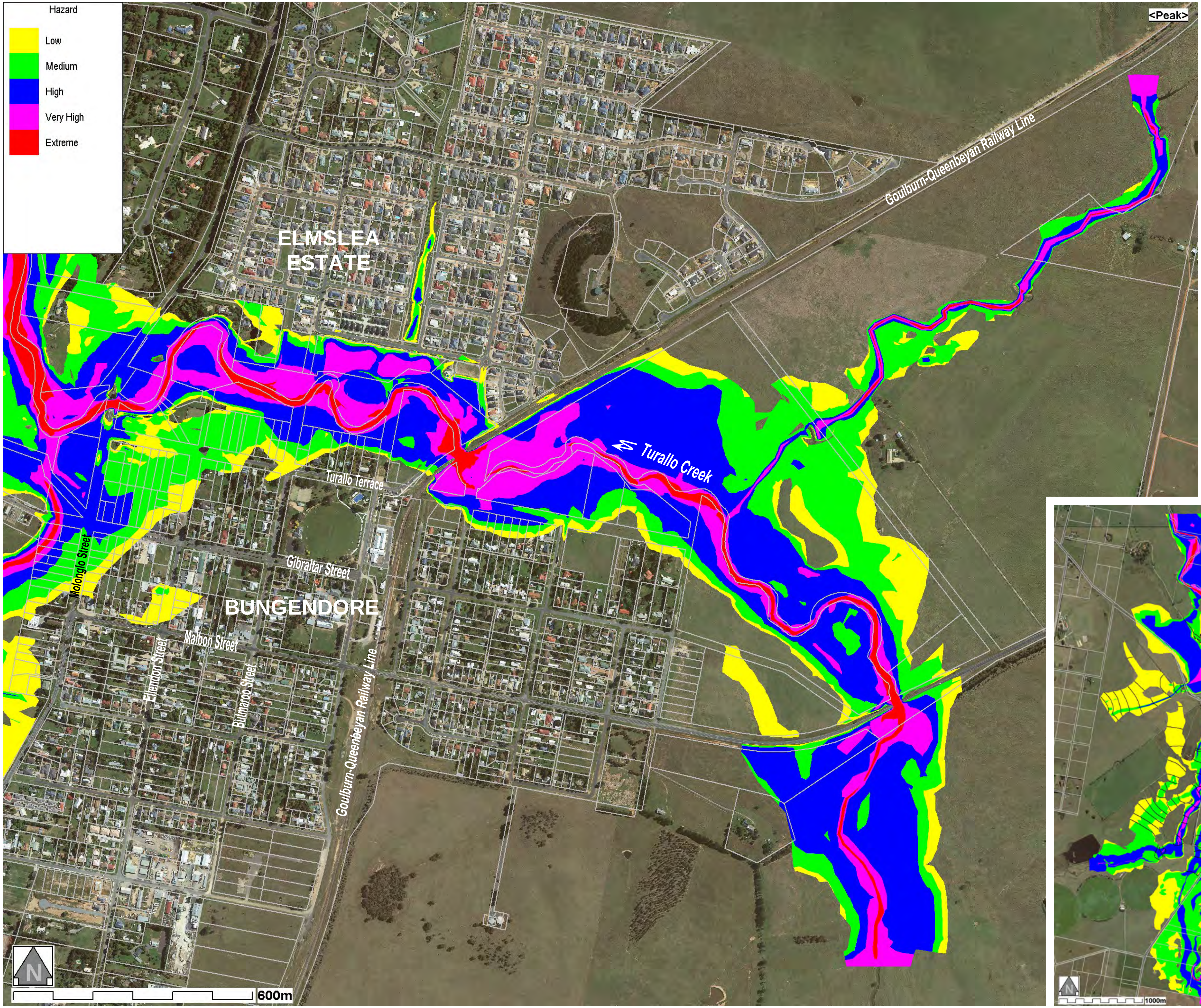
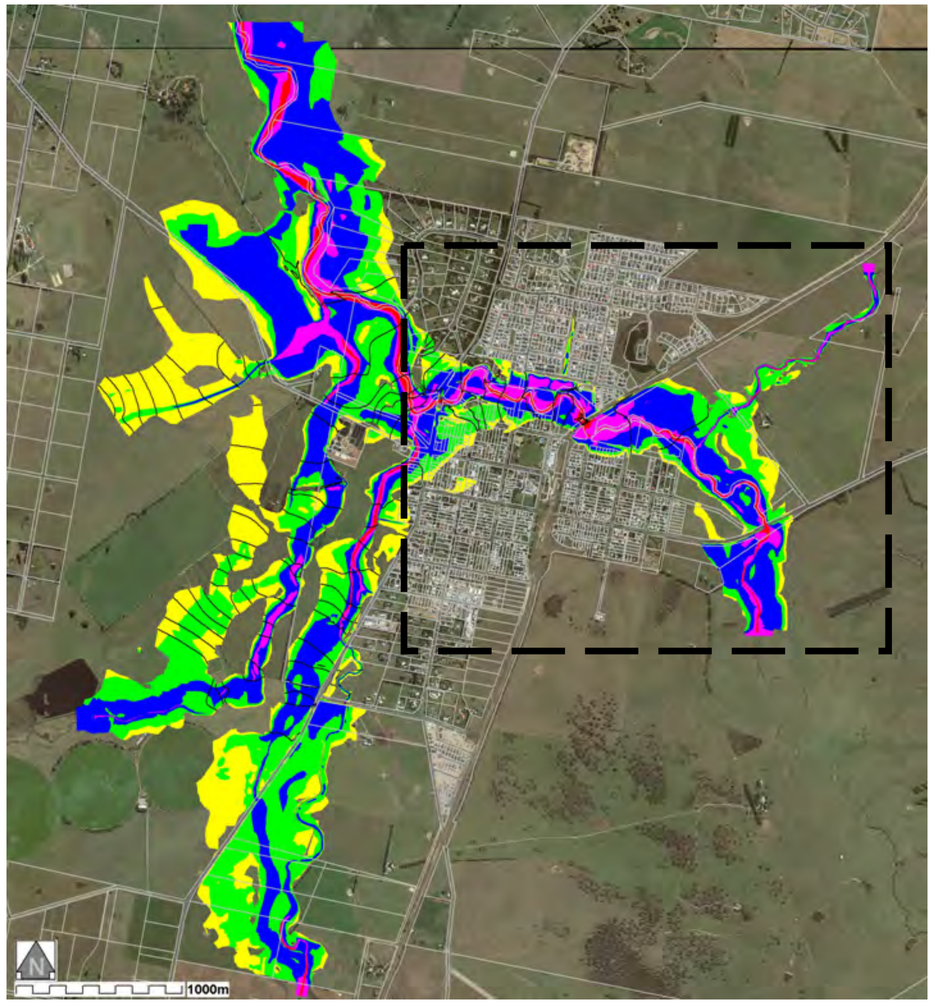
fg3777rg121114-fig28_Option S4B Level DIFF.doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF <u>OPTION '*S4B*'</u>

FIGURE 38





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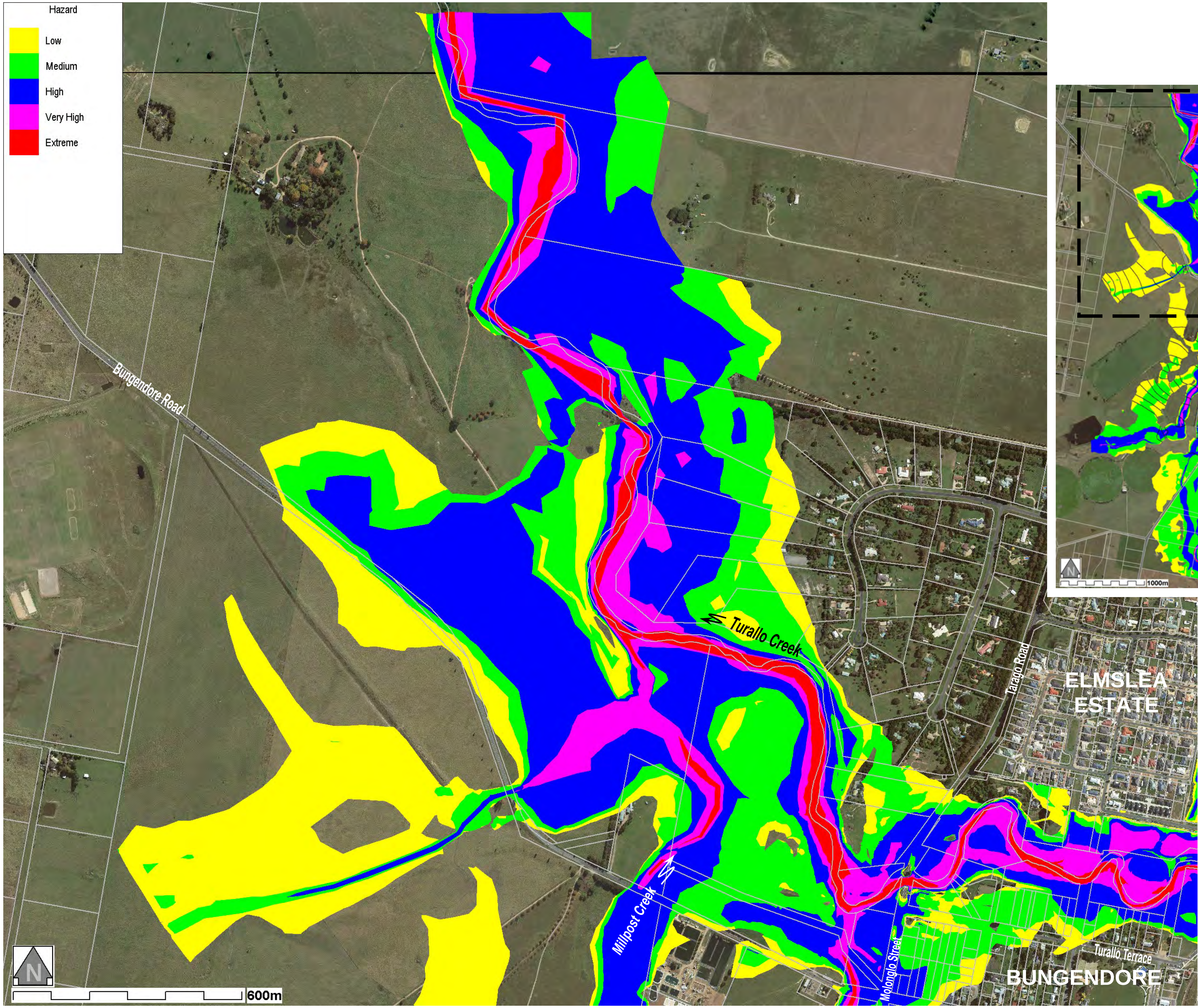
fg3777rg121114-fig31_Hazard Mapping (1 of 3).doc

PROVISIONAL FLOOD HAZARD MAPPING
[MAP 1 of 3]

FIGURE 39



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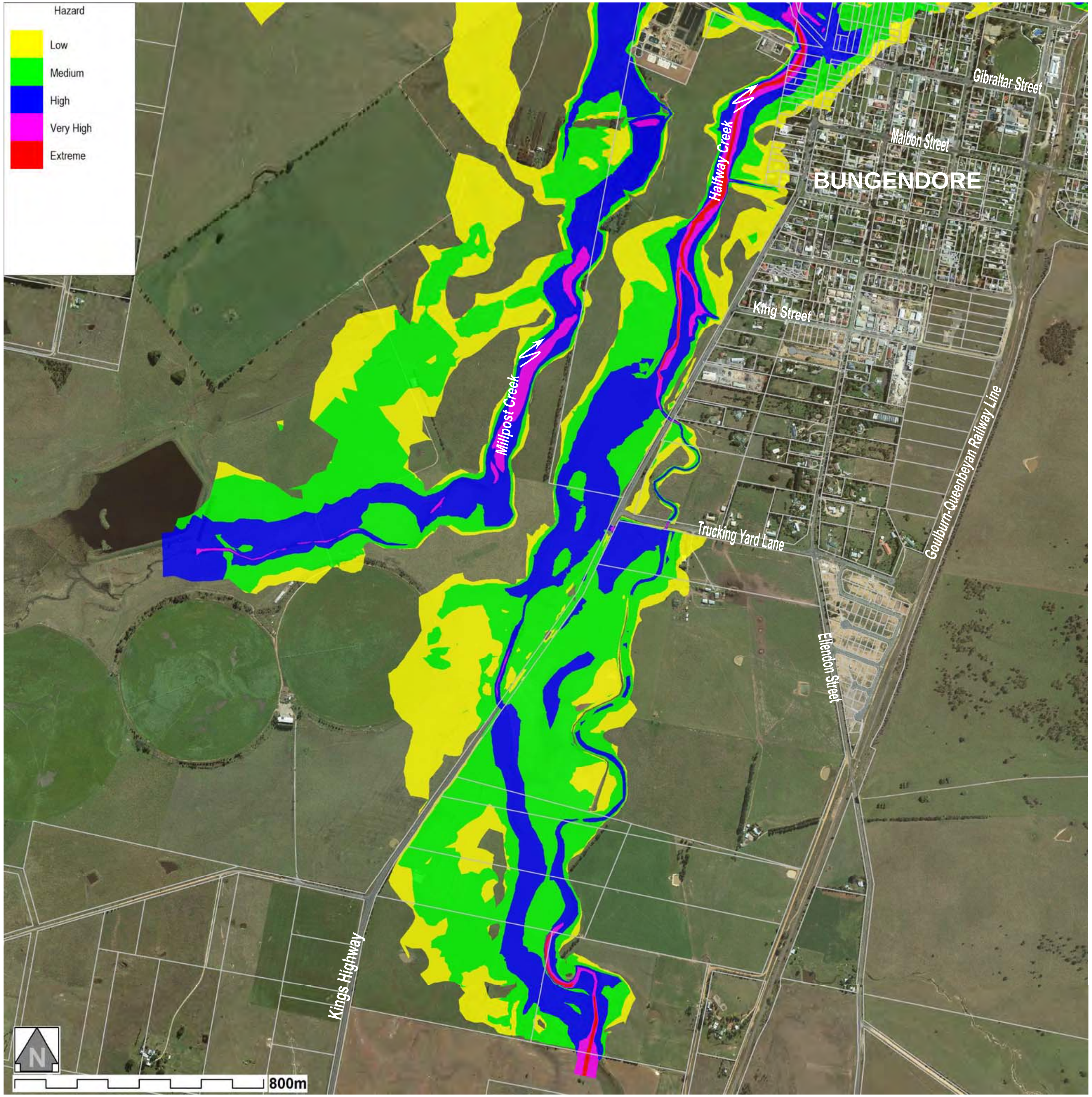
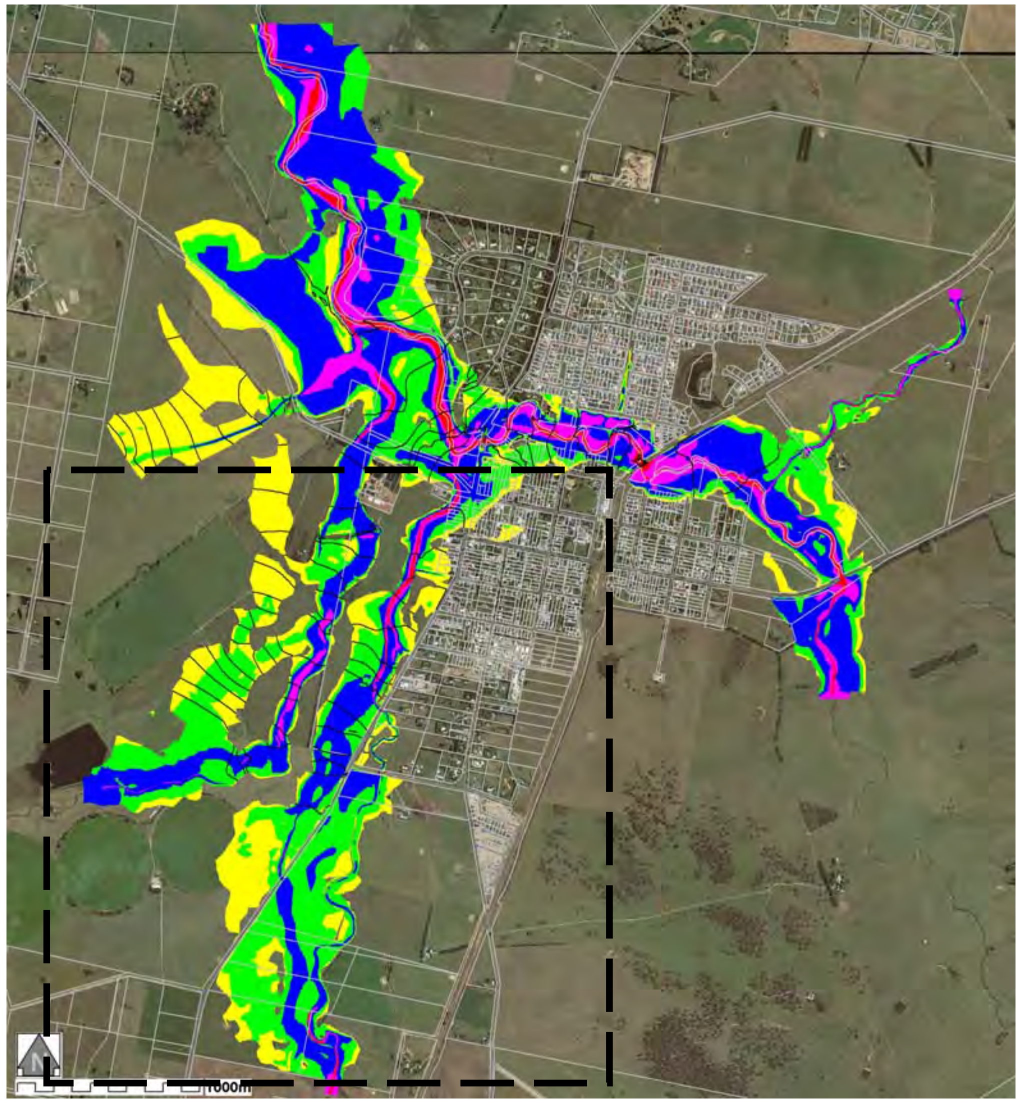
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig32_Hazard Mapping (2 of 3).doc

PROVISIONAL FLOOD HAZARD MAPPING
[MAP 2 of 3]

FIGURE 40





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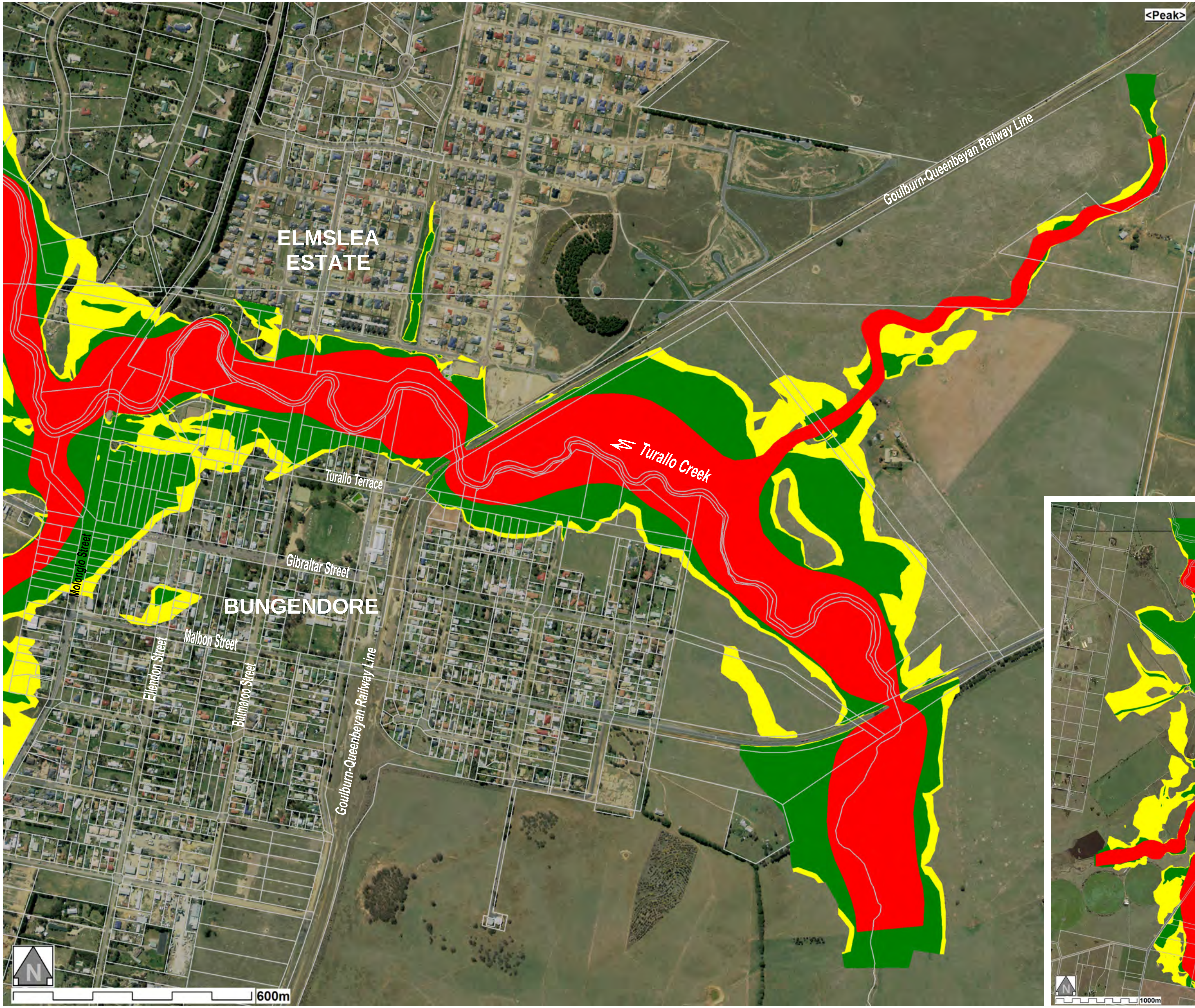
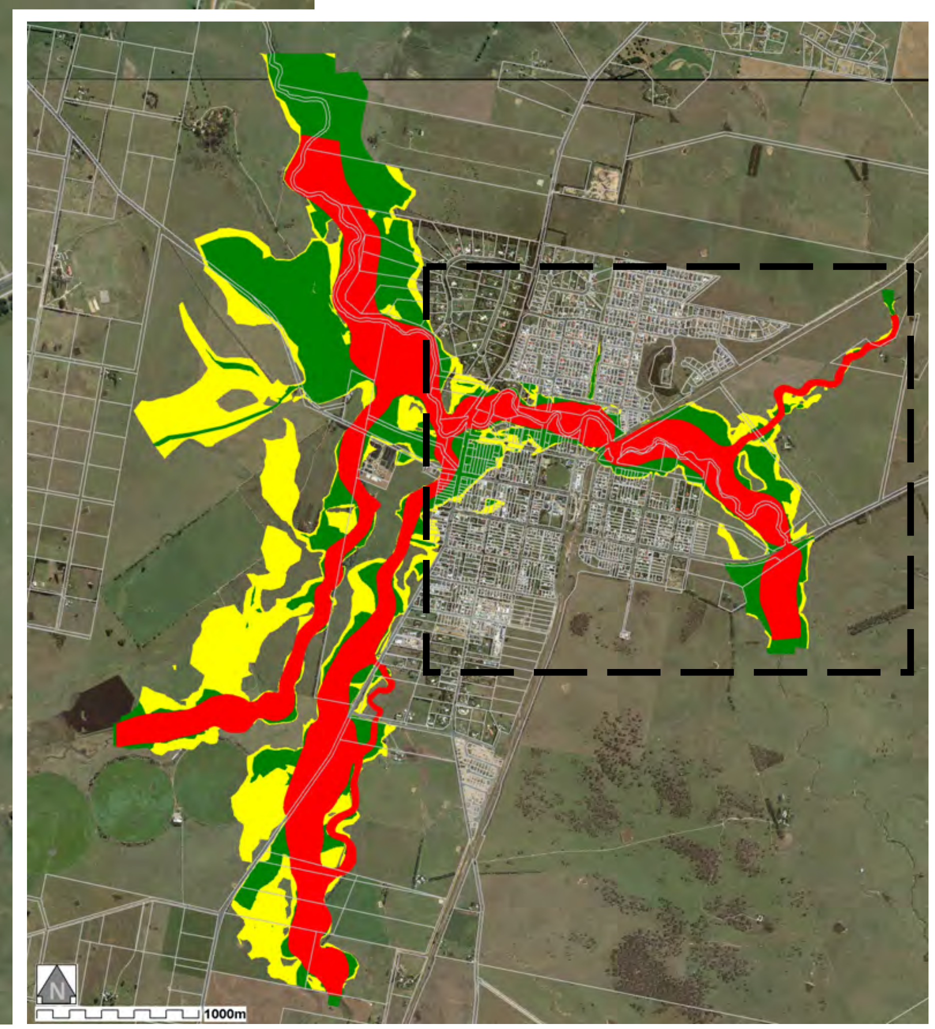
PROVISIONAL FLOOD HAZARD MAPPING [MAP 3 of 3]

FIGURE 41





LEGEND

- Floodway
- Flood Storage
- Flood Fringe

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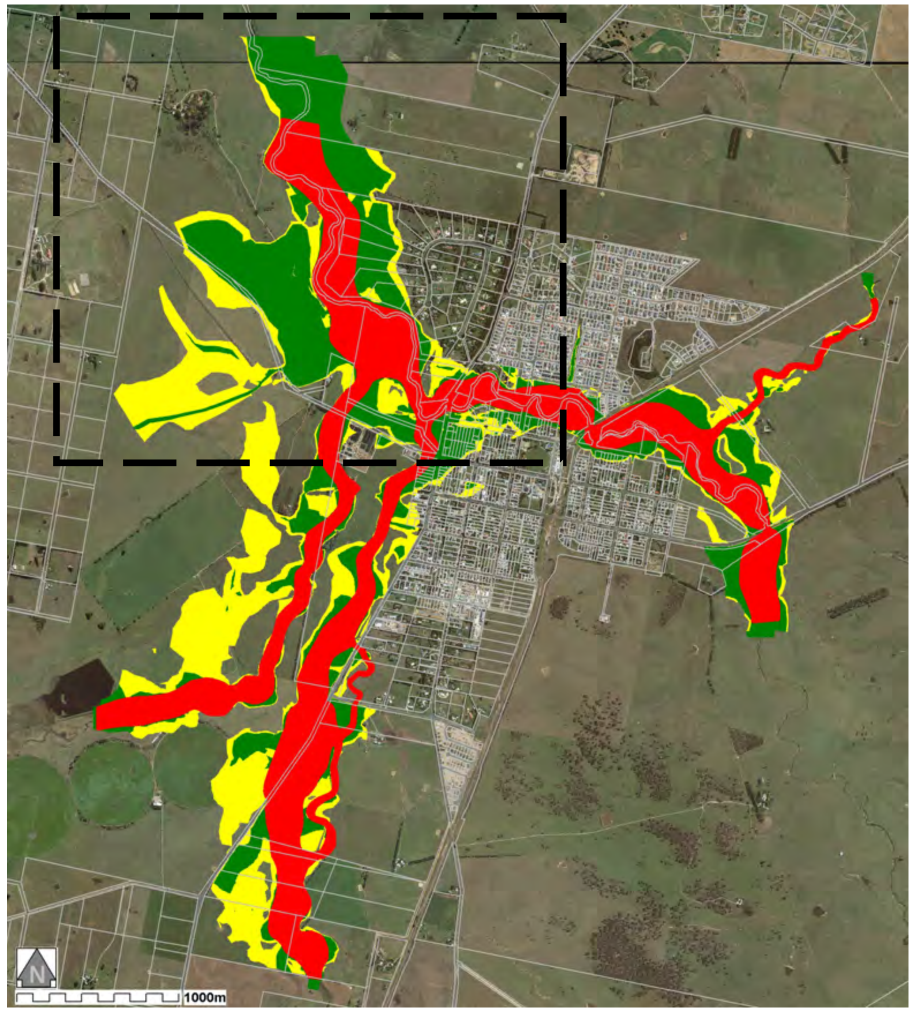
fg3777rg121114-fig34_Hydraulic Category Mapping (1 of 3).doc

HYDRAULIC CATEGORY MAPPING [MAP 1 of 3]

FIGURE 42



LEGEND

- Floodway
- Flood Storage
- Flood Fringe

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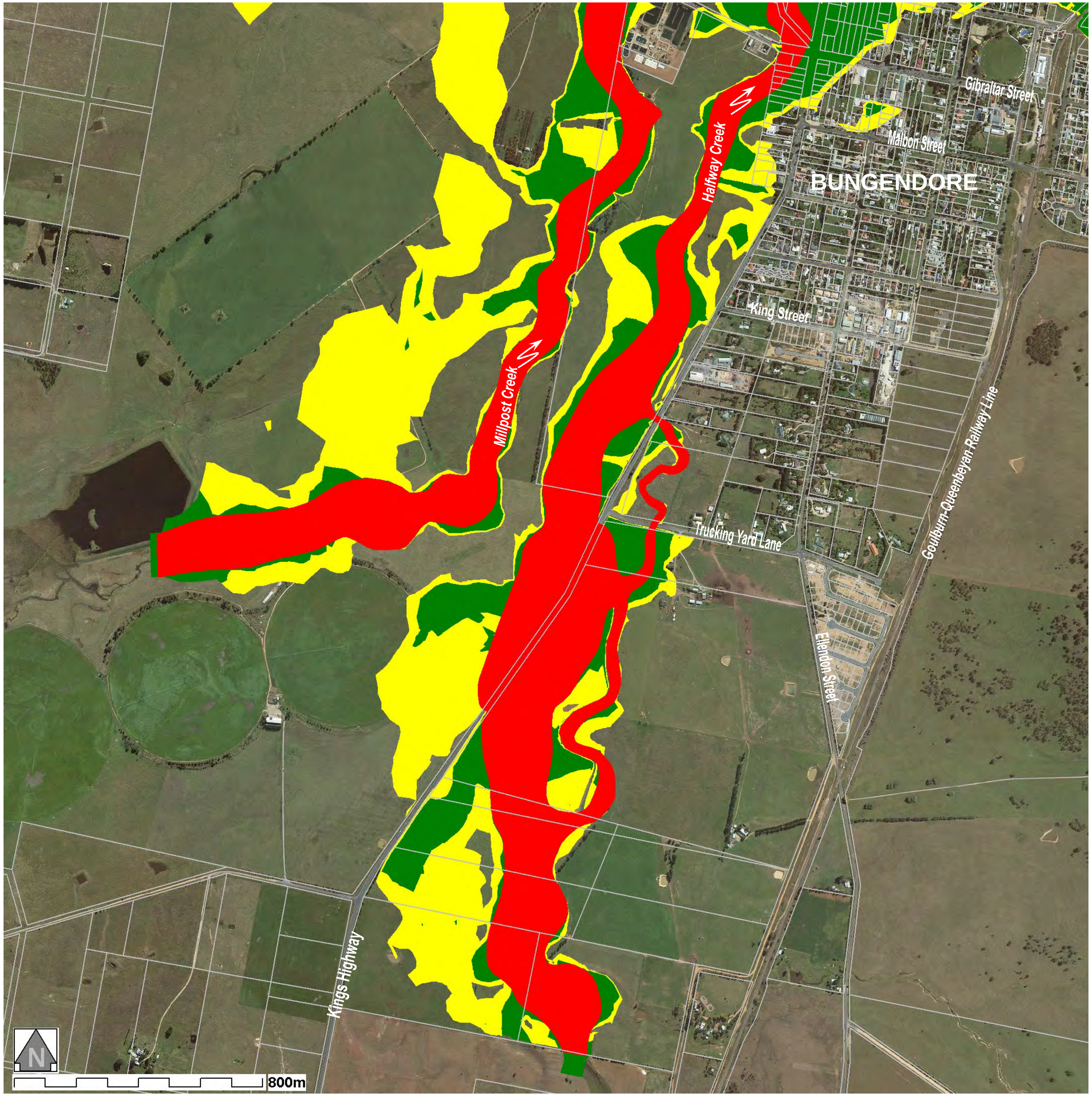
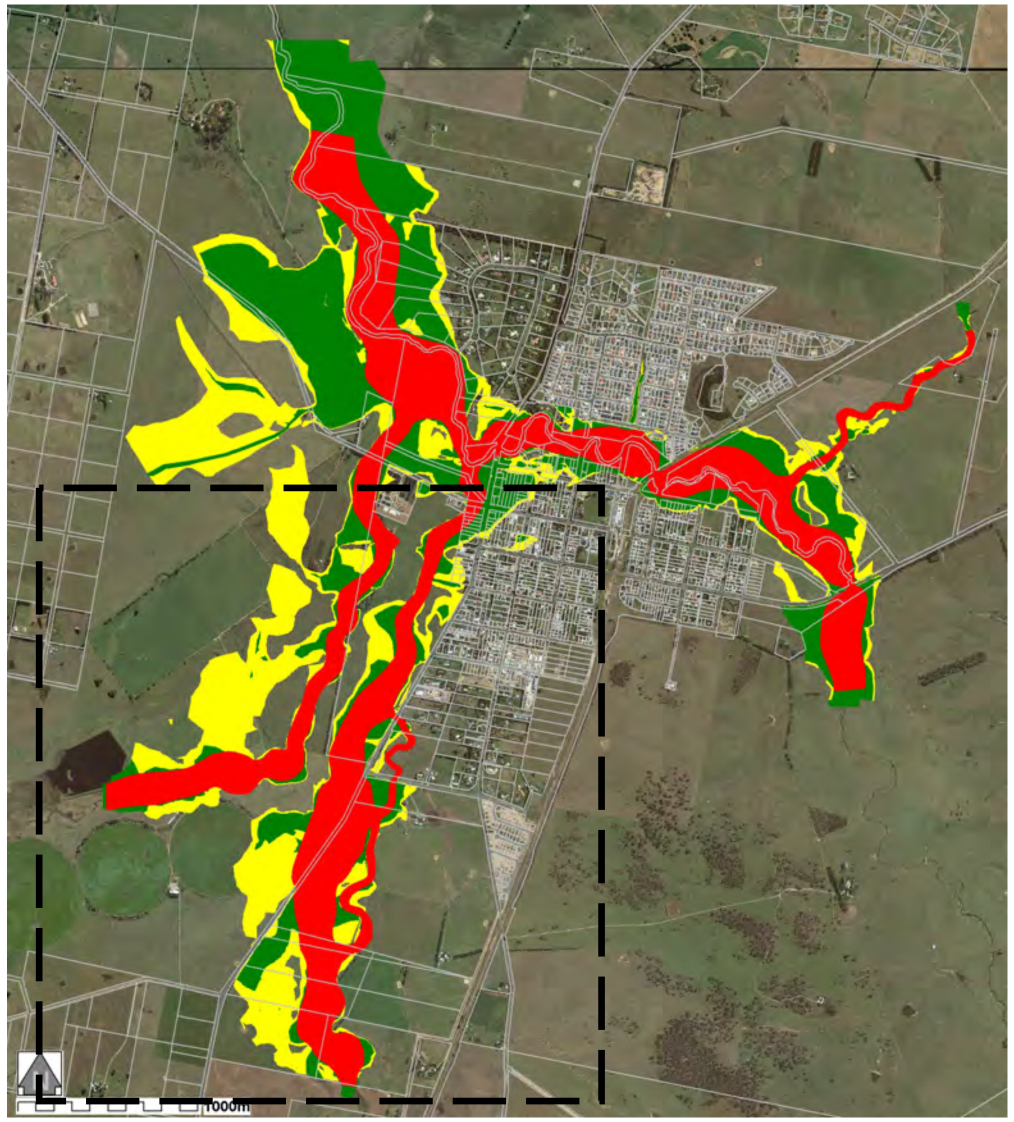
HYDRAULIC CATEGORY MAPPING
[MAP 2 of 3]

FIGURE 43



LEGEND

- Floodway
- Flood Storage
- Flood Fringe



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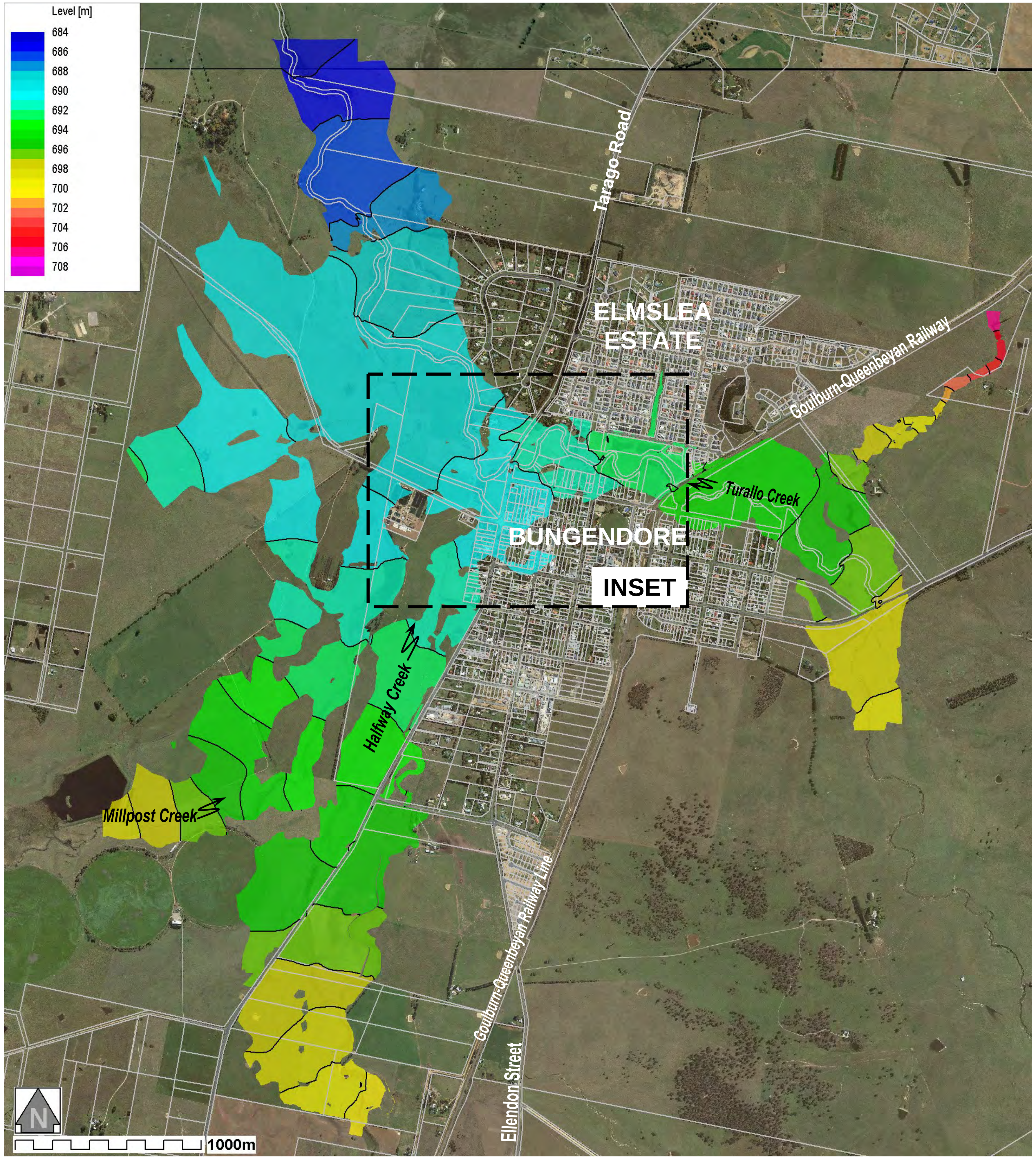
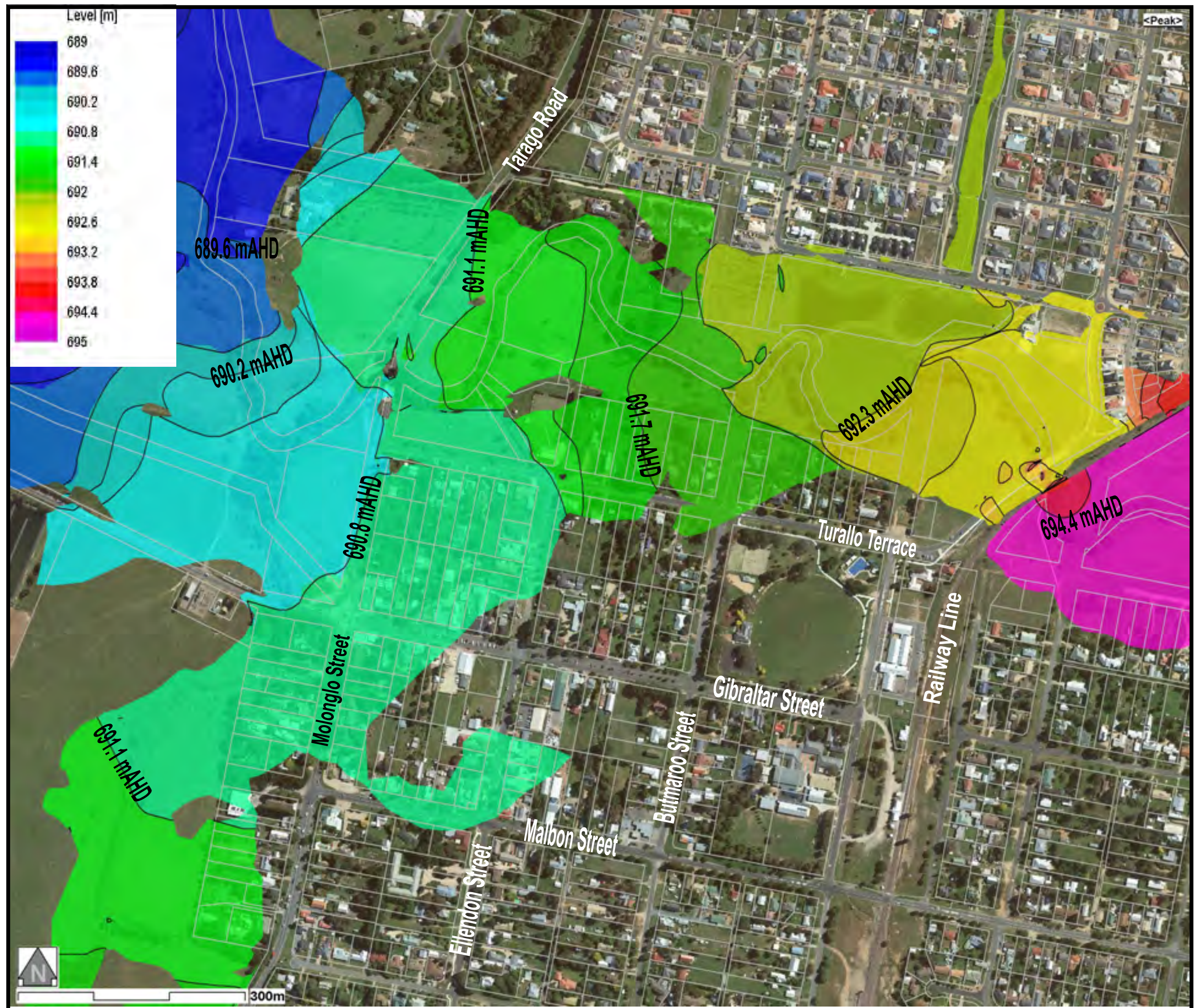
3777 - Bungendore Floodplain Risk Management Study
fg3777rg121114-fig36_Hydraulic Category Mapping (3 of 3).doc

HYDRAULIC CATEGORY MAPPING
[MAP 3 of 3]

FIGURE 44





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

NOTE The variation in flood levels at the peak of the adopted 100 year ARI climate change scenario 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 Study
fg3777rg121114-fig42_100yr ARI + 10% Levels (Climate Change).doc

PREDICTED FLOOD LEVELS AT THE PEAK OF THE ADOPTED 100 YEAR ARI CLIMATE CHANGE SCENARIO [100 YEAR RECURRENCE EVENT + 10% INCREASE IN RAINFALL INTENSITY]

FIGURE 45

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO CLIMATE CHANGE - 10% INCREASE IN RAINFALL INTENSITIES

WorleyParsons
resources & energy

Appendix A

-

Additional Topographic Data

ORIGINAL A2 SHEET

TOPOGRAPHIC & HYDROGRAPHIC SURVEY
ALONG HALFWAY & MILLPOST CREEKS
BUNGENDORE
CLIENT: PALERANG COUNCIL

SCHEDULE OF DRAWINGS

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

COMMENTS:
COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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13 Gibraltar Street, Bungendore NSW 2621 Ph (02) 6238 0144
www.phlsurveyors.com.au

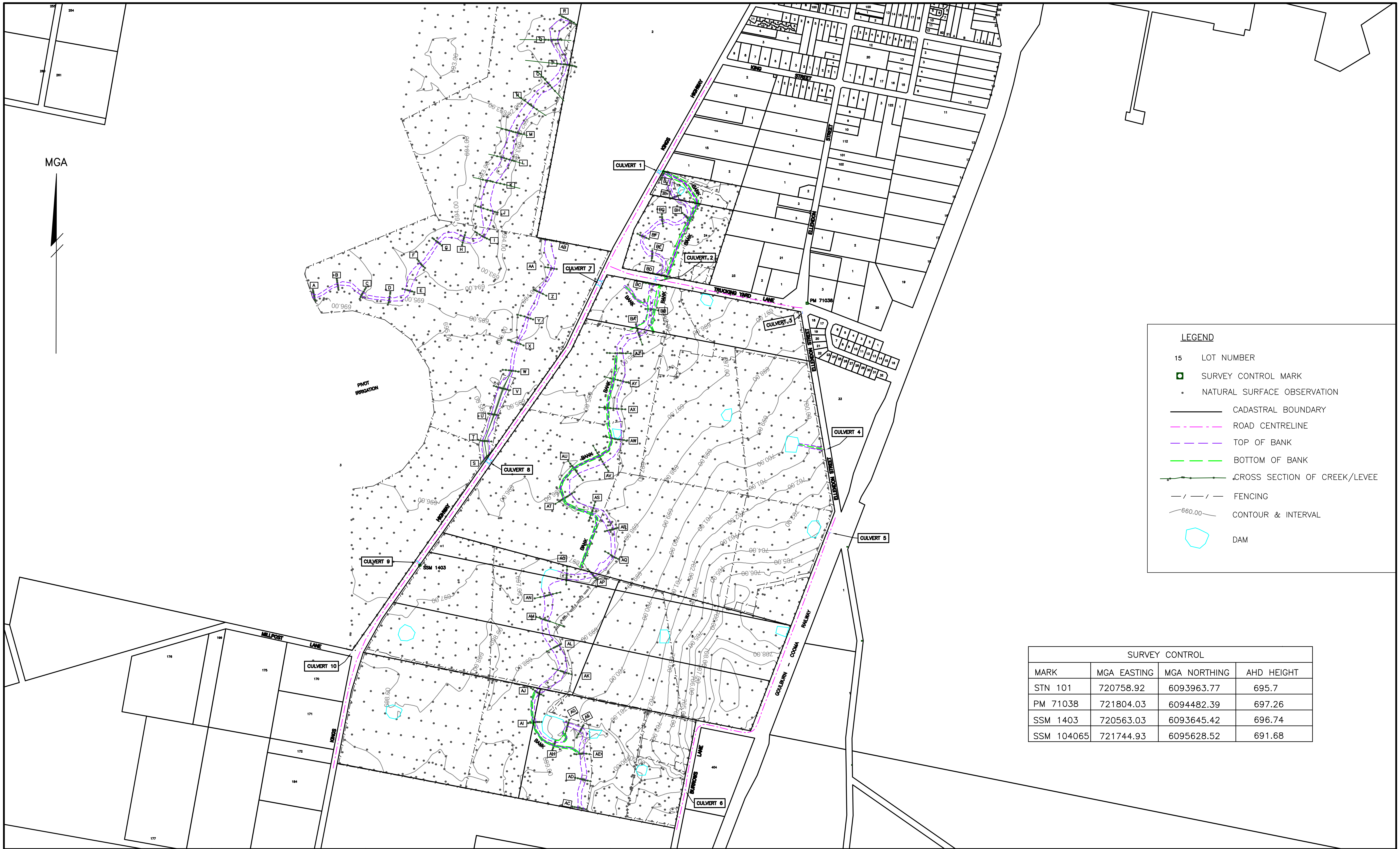
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
COVERSHEET & SCHEDULE OF DRAWINGS
SHEET 1 OF 18

DATE: 24/01/2012
FILE: PN 12011
SCALE: --
A2- 531197

LIABILITY LIMITED BY A SCHEME UNDER PROFESSIONAL STANDARDS LEGISLATION

ORIGINAL A2 SHEET



LEGEND

15	LOT NUMBER
	SURVEY CONTROL MARK
	NATURAL SURFACE OBSERVATION
	CADASTRAL BOUNDARY
	ROAD CENTRELINE
	TOP OF BANK
	BOTTOM OF BANK
	CROSS SECTION OF CREEK/LEVEE
	FENCING
660.00	CONTOUR & INTERVAL
	DAM

SURVEY CONTROL

MARK	MGA EASTING	MGA NORTHING	AHD HEIGHT
STN 101	720758.92	6093963.77	695.7
PM 71038	721804.03	6094482.39	697.26
SSM 1403	720563.03	6093645.42	696.74
SSM 104065	721744.93	6095628.52	691.68

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255
CONTOUR INTERVAL IS 1m

COMPUTER FILES: CCAD: 12011A12.ccx
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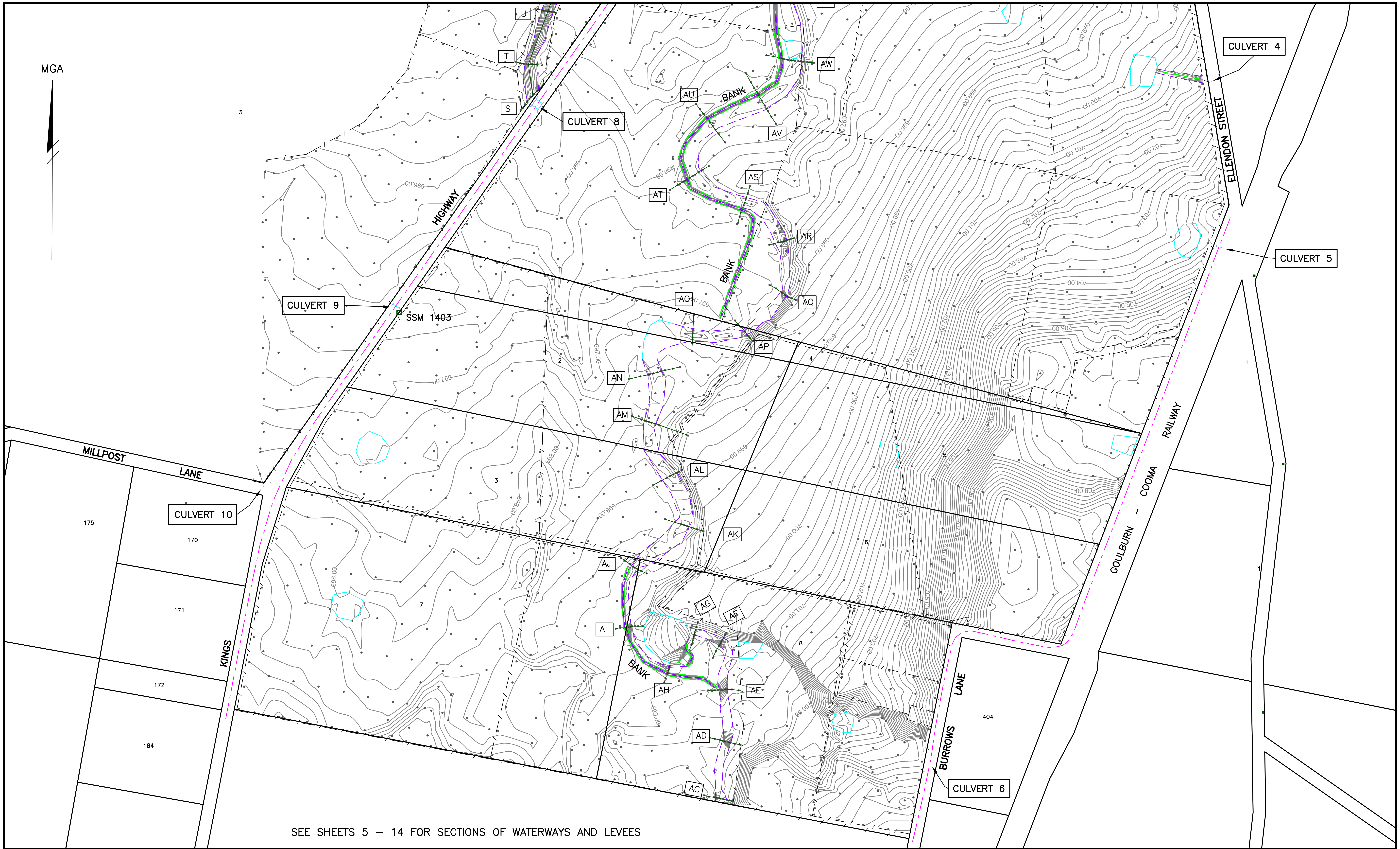
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
OVERALL PLAN
SHEET 2 OF 18

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:8000
A2- 531198



DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255
CONTOUR INTERVAL IS 0.2m

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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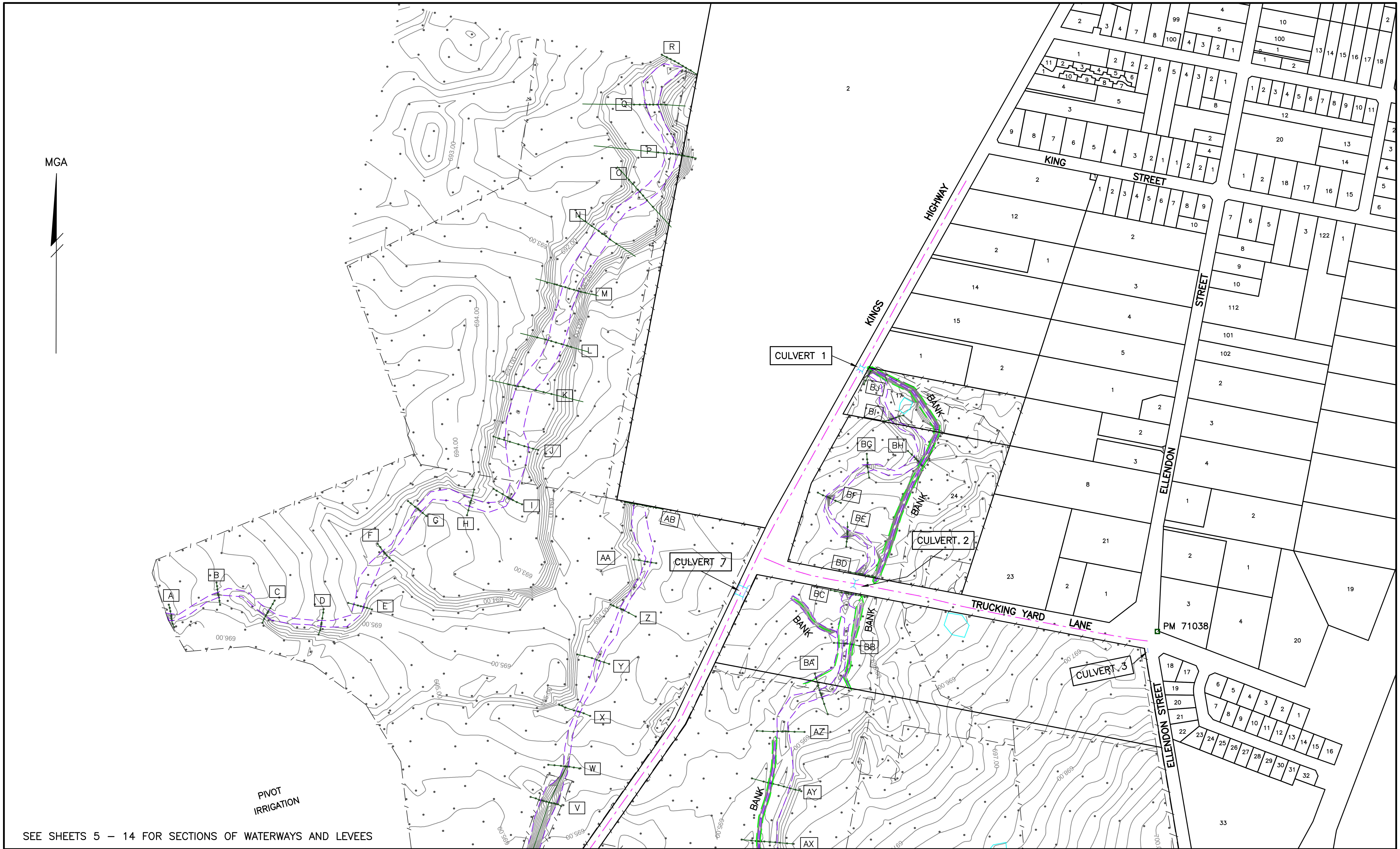
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL SURVEY
SHEET 3 OF 18

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:4000
A2– 531199

ORIGINAL A2 SHEET



SEE SHEETS 5 – 14 FOR SECTIONS OF WATERWAYS AND LEVEES

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

COMMENTS:

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ORIGIN OF LEVELS IS PM 71038. R.L. 697.255
CONTOUR INTERVAL 0.2m

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

JOINS SHEET 3

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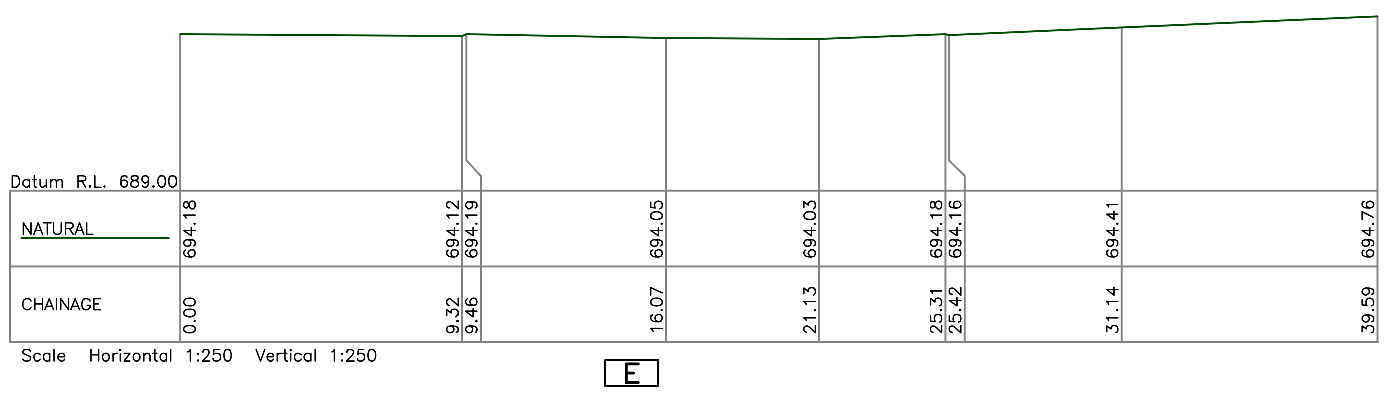
TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL SURVEY
SHEET 4 OF 18

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:4000
A2– 531200

ORIGINAL A2 SHEET

200mm
100mm
0



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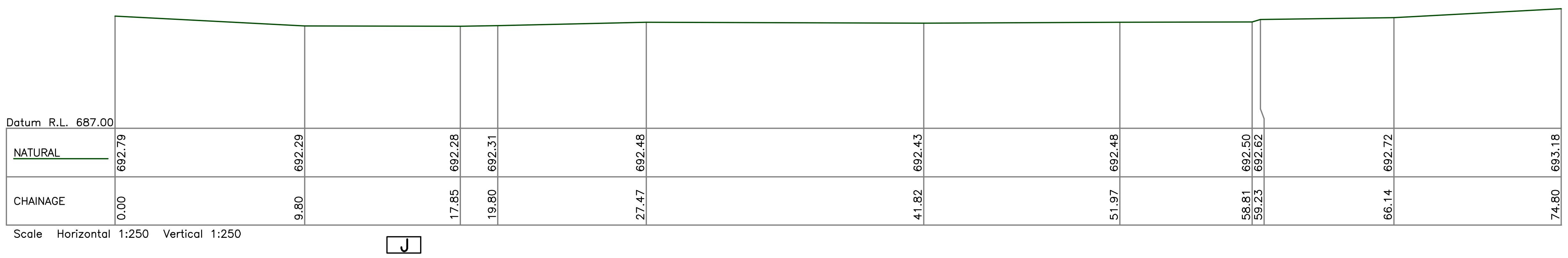

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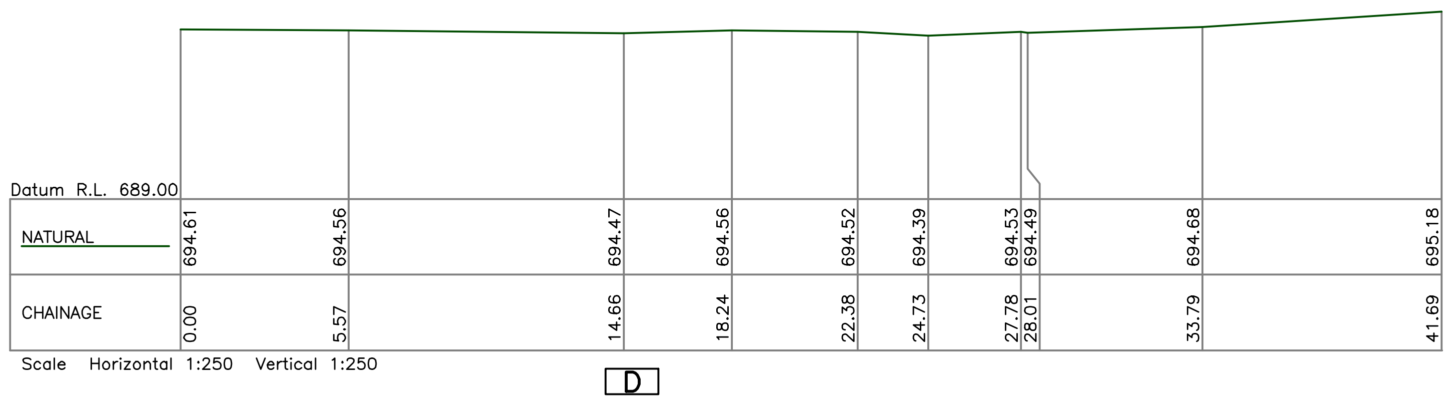

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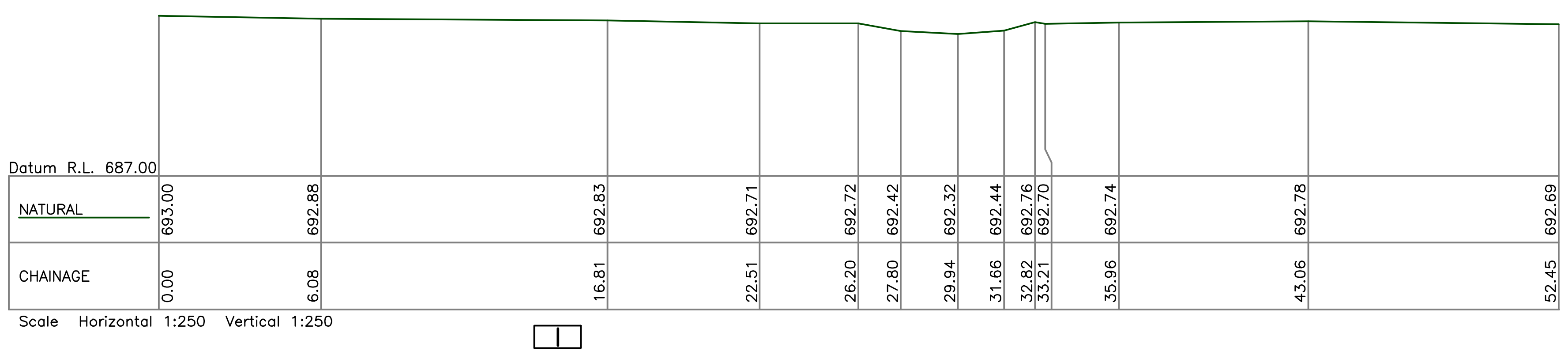

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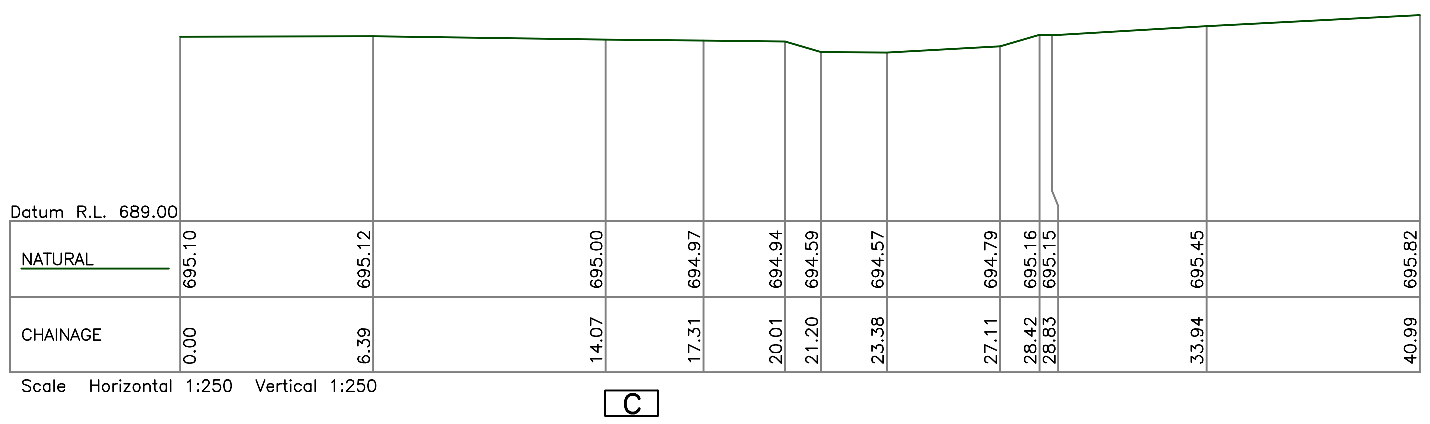

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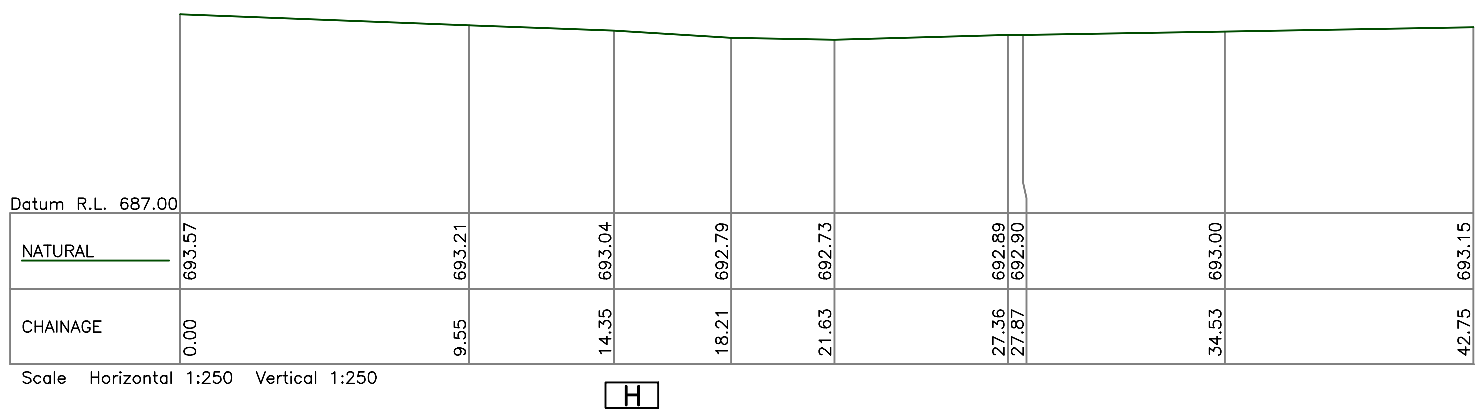

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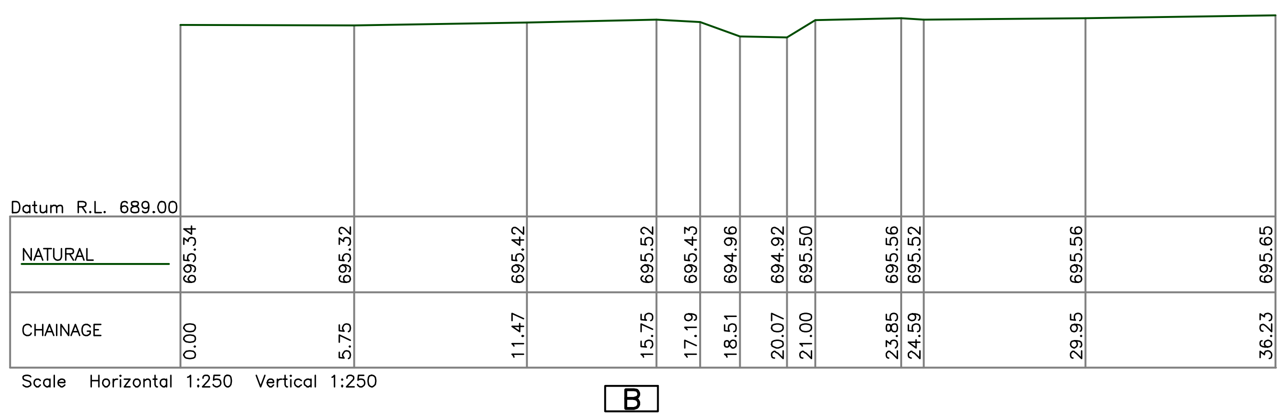

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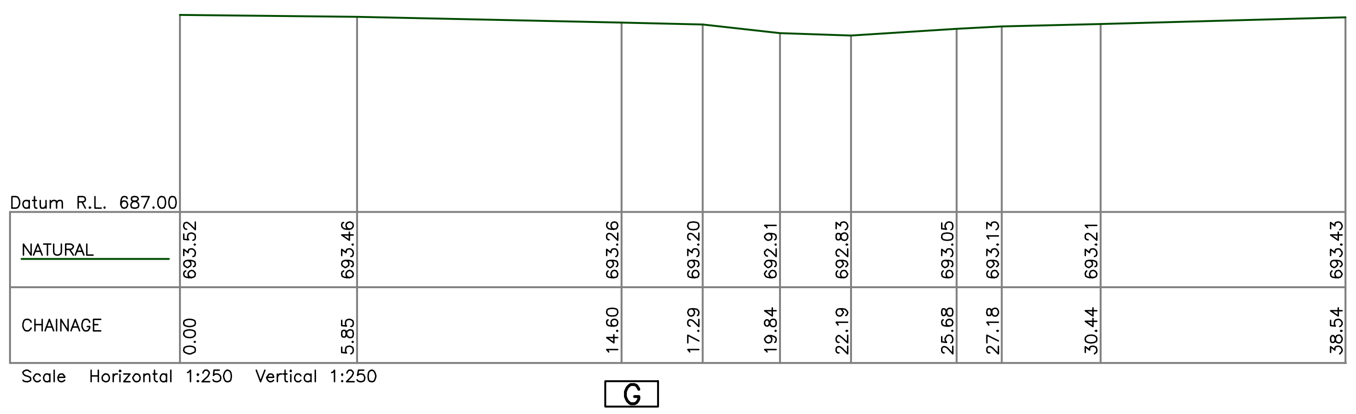

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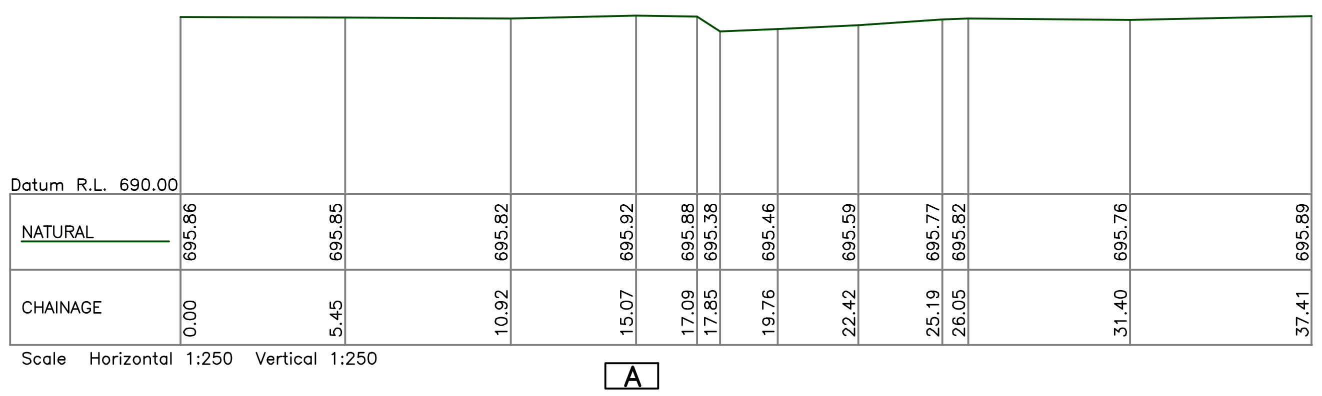

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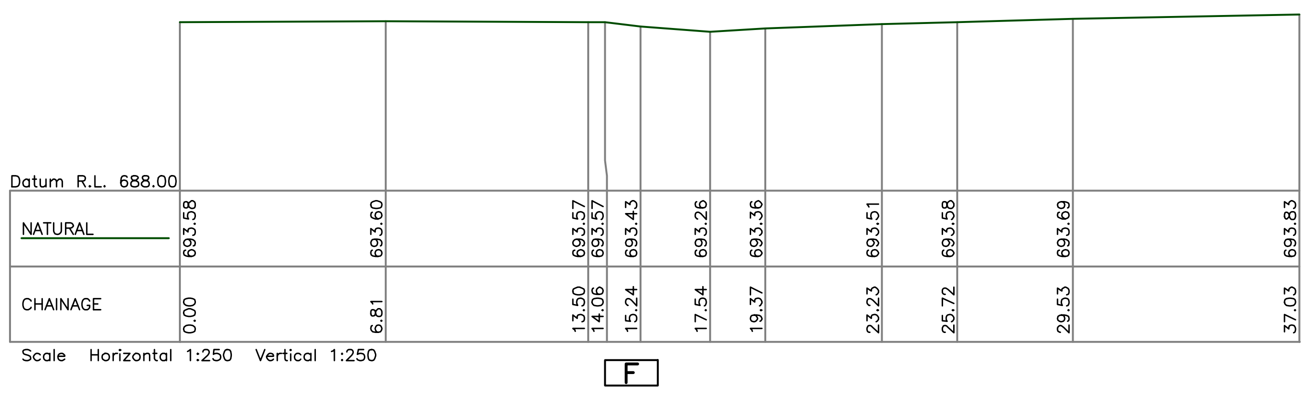

F

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

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COMMENTS:

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ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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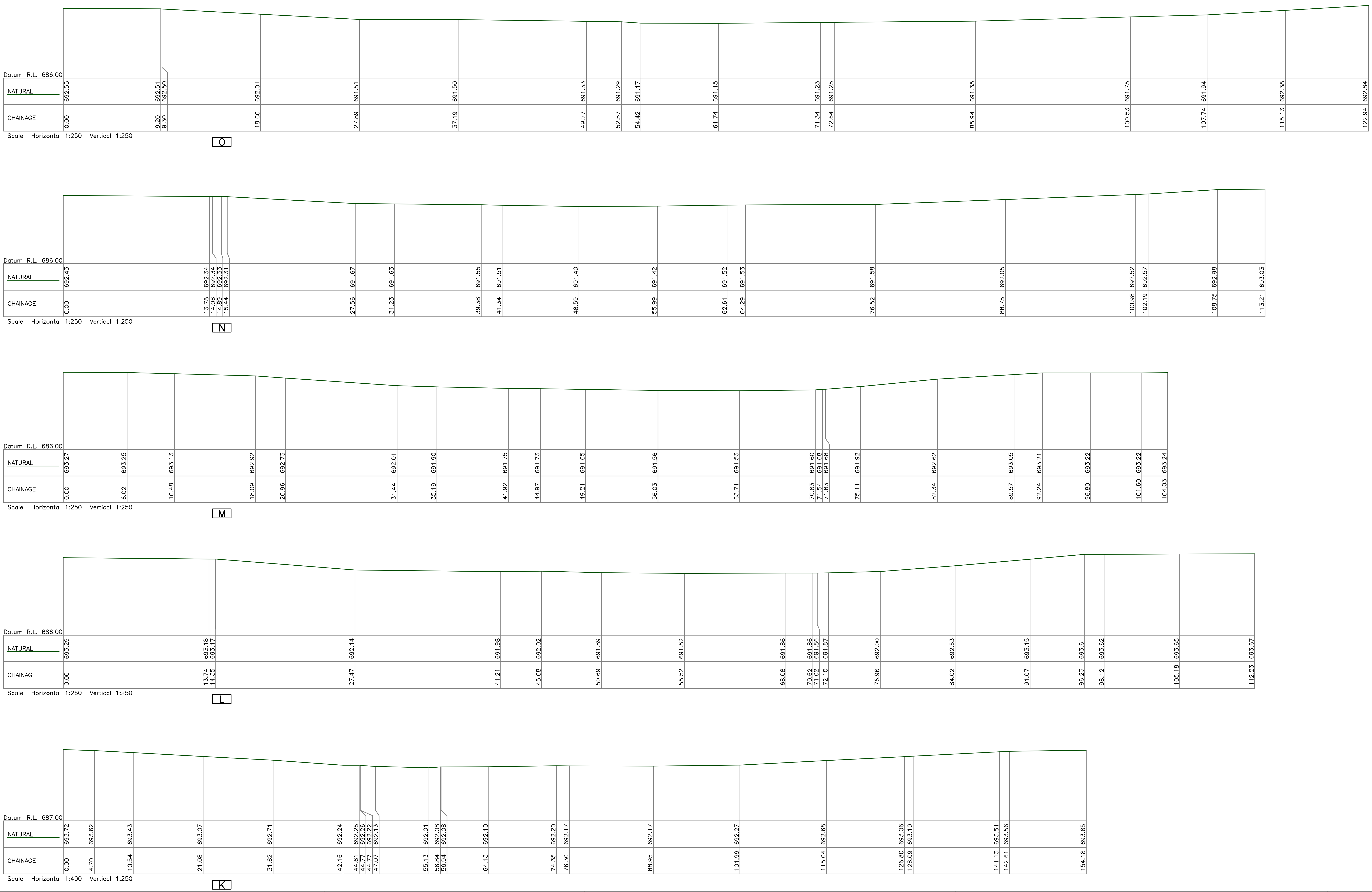
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS A – J
SHEET 5 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531201



ORIGINAL A2 SHEET

200mm 100mm 0

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

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ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS K – O
SHEET 6 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531202

ORIGINAL A2 SHEET

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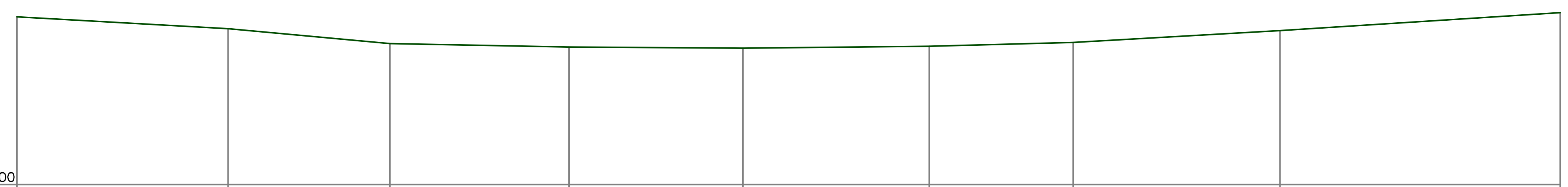
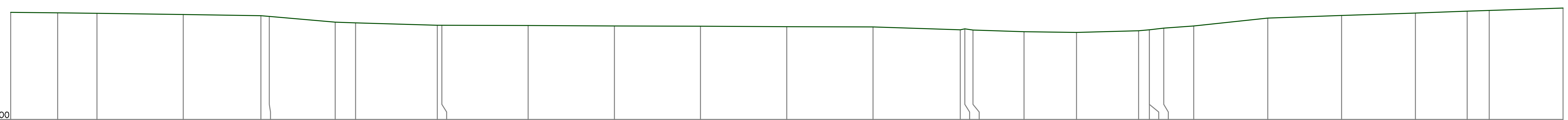


Datum R.L. 685.00

CHAINAGE	NATURAL
0.00	691.97
8.78	691.48
15.51	690.86
22.95	690.71
30.20	690.67
37.95	690.74
43.93	690.91
52.54	691.39
64.18	692.14

Scale Horizontal 1:250 Vertical 1:250

R

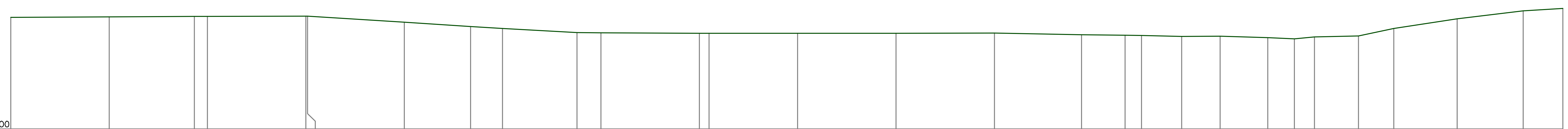


Datum R.L. 685.00

CHAINAGE	NATURAL
0.00	692.12
4.99	692.09
9.14	692.05
18.28	691.97
26.52	691.89
27.42	691.85
34.39	691.46
36.56	691.42
45.21	691.27
45.70	691.27
54.84	691.24
63.98	691.22
73.12	691.20
82.26	691.17
91.40	691.15
100.64	690.96
101.13	691.03
101.99	690.95
107.40	690.84
112.97	690.79
119.53	690.89
120.68	690.97
120.69	690.97
122.20	691.06
125.39	691.21
133.22	691.74
141.05	691.90
148.87	692.07
154.37	692.19
156.70	692.24
164.53	692.41

Scale Horizontal 1:400 Vertical 1:250

Q



Datum R.L. 685.00

CHAINAGE	NATURAL
0.00	692.34
10.33	692.37
19.28	692.39
20.66	692.40
30.99	692.42
31.16	692.42
41.32	692.01
48.30	691.73
51.65	691.61
59.47	691.33
61.98	691.32
72.31	691.29
73.33	691.28
82.64	691.29
92.97	691.29
103.30	691.30
112.44	691.20
117.02	691.16
118.76	691.15
122.96	691.08
127.02	691.09
132.01	691.01
134.81	690.92
136.90	691.04
141.52	691.11
145.24	691.60
151.89	692.23
158.84	692.75
163.00	692.93

Scale Horizontal 1:400 Vertical 1:250

P

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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CLIENT: **PALERANG COUNCIL**

TITLE: **TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE**

CROSS SECTIONS P – R

SHEET 7 OF 18 SHEETS

DATE: 24/01/2012

FILE: PN 12011

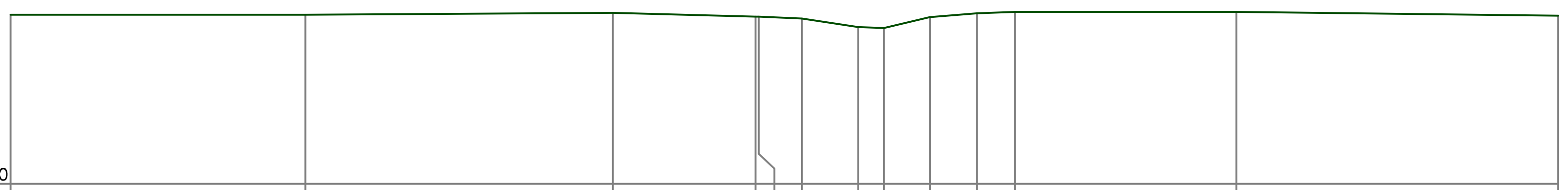
SCALE: AS SHOWN

A2– 531203

LIABILITY LIMITED BY A SCHEME UNDER PROFESSIONAL STANDARDS LEGISLATION

ORIGINAL A2 SHEET

200mm 100mm 0

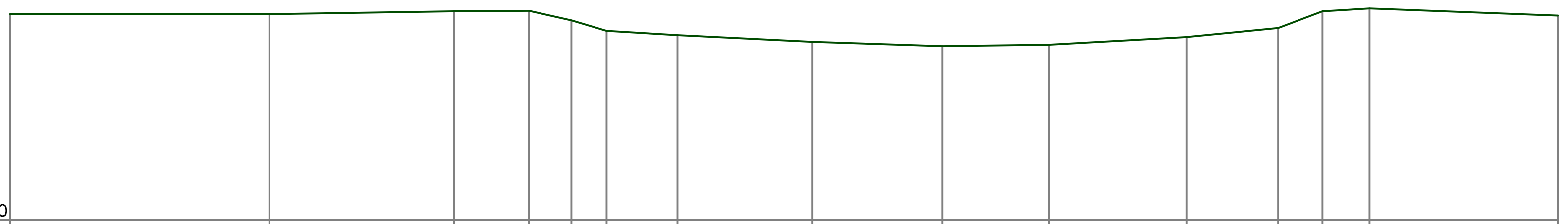


Datum R.L. 689.00

NATURAL	694.64	694.64	694.71	694.57	694.57	694.52	694.23	694.20	694.56	694.69	694.75	694.73	694.62
CHAINAGE	0.00	9.87	20.17	24.96	25.06	26.51	28.39	29.26	30.79	32.37	33.65	41.07	51.85

Scale Horizontal 1:250 Vertical 1:250

W



Datum R.L. 688.00

NATURAL	694.84	694.85	694.94	694.95	694.64	694.28	694.14	693.92	693.78	693.83	694.08	694.38	694.94	695.03	694.80
CHAINAGE	0.00	8.64	14.81	17.31	18.74	19.91	22.27	26.78	31.12	34.67	39.25	42.31	43.80	45.36	51.65

Scale Horizontal 1:250 Vertical 1:250

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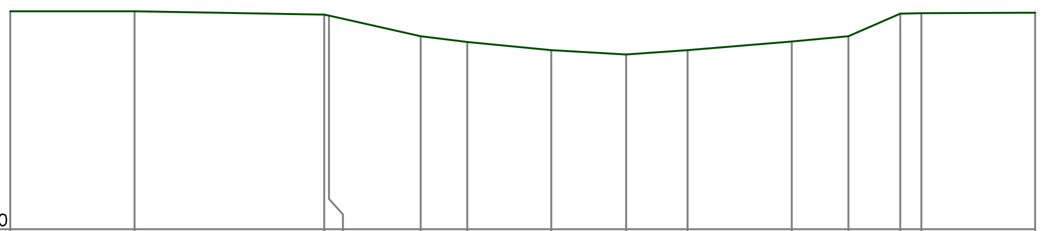

Datum R.L. 688.00

NATURAL	695.21	695.22	695.10	695.07	694.39	694.20	693.93	693.79	693.93	694.21	694.39	695.13	695.15	695.17
CHAINAGE	0.00	4.12	10.38	10.54	13.58	15.11	17.89	20.36	22.39	25.84	27.72	29.43	30.13	33.89

Scale Horizontal 1:250 Vertical 1:250

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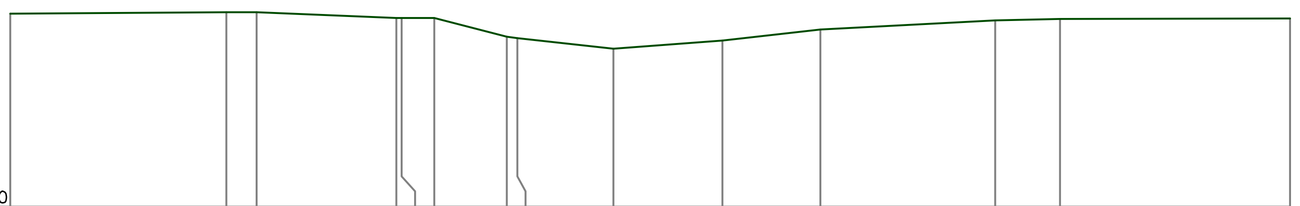

Datum R.L. 689.00

NATURAL	695.38	695.43	695.43	695.24	695.23	695.24	694.61	694.57	694.22	694.48	694.86	695.16	695.20	695.23
CHAINAGE	0.00	7.14	8.14	12.76	12.93	14.01	16.41	16.76	19.94	23.53	26.78	32.55	34.70	42.29

Scale Horizontal 1:250 Vertical 1:250

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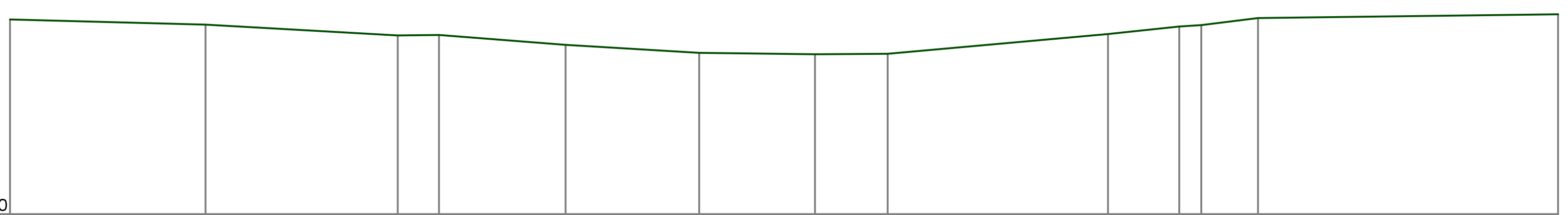

Datum R.L. 689.00

NATURAL	695.58	695.41	695.03	695.06	694.72	694.44	694.40	694.43	695.09	695.34	695.39	695.62	695.75
CHAINAGE	0.00	6.61	13.13	14.52	18.81	23.33	27.25	29.72	37.18	39.60	40.34	42.25	52.42

Scale Horizontal 1:250 Vertical 1:250

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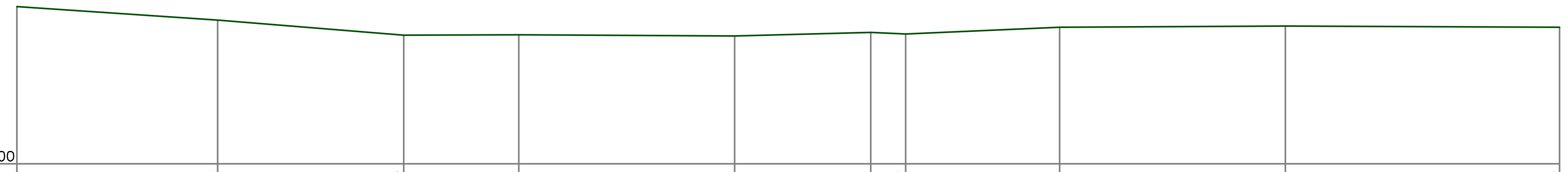
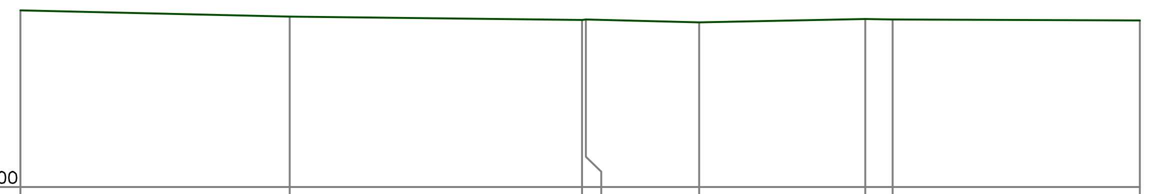


Datum R.L. 688.00

NATURAL	694.29	693.75	693.14	693.16	693.13	693.26	693.20	693.47	693.51	693.48
CHAINAGE	0.00	8.04	15.49	20.09	28.72	34.17	35.56	41.72	50.75	61.73

Scale Horizontal 1:250 Vertical 1:250

AB

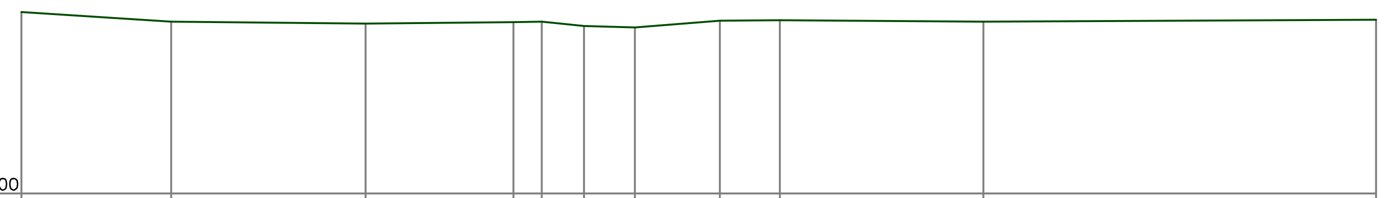


Datum R.L. 688.00

NATURAL	693.83	693.63	693.53	693.55	693.45	693.55	693.54	693.51
CHAINAGE	0.00	8.91	18.58	18.71	22.45	27.95	28.85	37.03

Scale Horizontal 1:250 Vertical 1:250

AA



Datum R.L. 688.00

NATURAL	693.99	693.67	693.61	693.66	693.67	693.53	693.48	693.70	693.72	693.67	693.74
CHAINAGE	0.00	4.96	11.38	16.28	17.21	18.62	20.29	23.11	25.09	31.82	44.80

Scale Horizontal 1:250 Vertical 1:250

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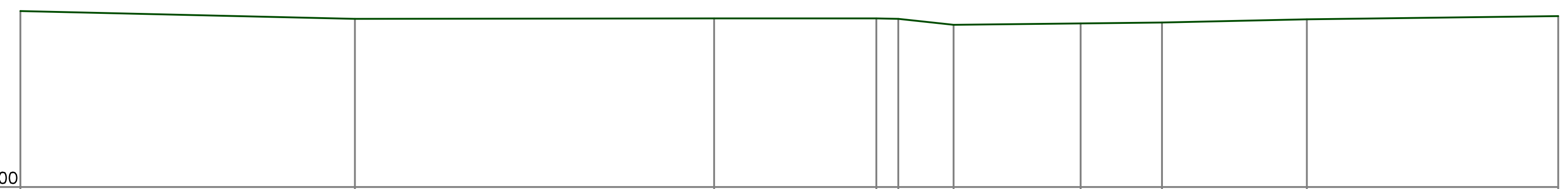
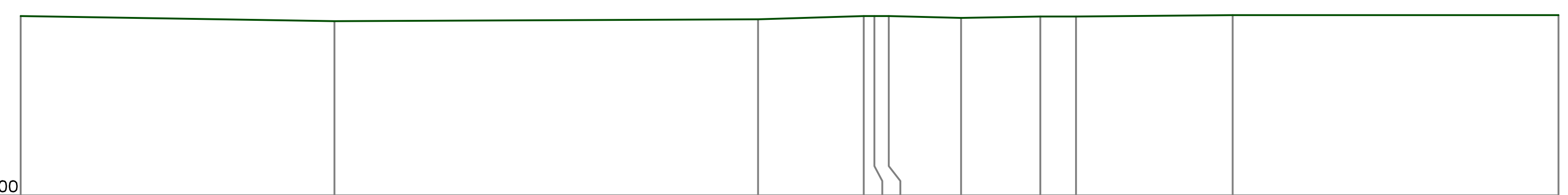


Datum R.L. 688.00

NATURAL	694.09	693.83	693.84	693.84	693.83	693.62	693.67	693.69	693.80	693.92
CHAINAGE	0.00	11.63	24.11	29.74	30.50	32.42	36.84	39.66	44.69	53.43

Scale Horizontal 1:250 Vertical 1:250

Y



Datum R.L. 688.00

NATURAL	694.13	693.95	694.02	694.13	694.13	694.13	694.06	694.11	694.12	694.17	694.17
CHAINAGE	0.00	10.75	25.26	28.89	29.24	29.75	32.21	34.93	36.15	41.51	52.67

Scale Horizontal 1:250 Vertical 1:250

X

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC
DRAWN: TC		CHECKED: TC	

COMMENTS:

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ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS S – AB
SHEET 8 OF 18 SHEETS

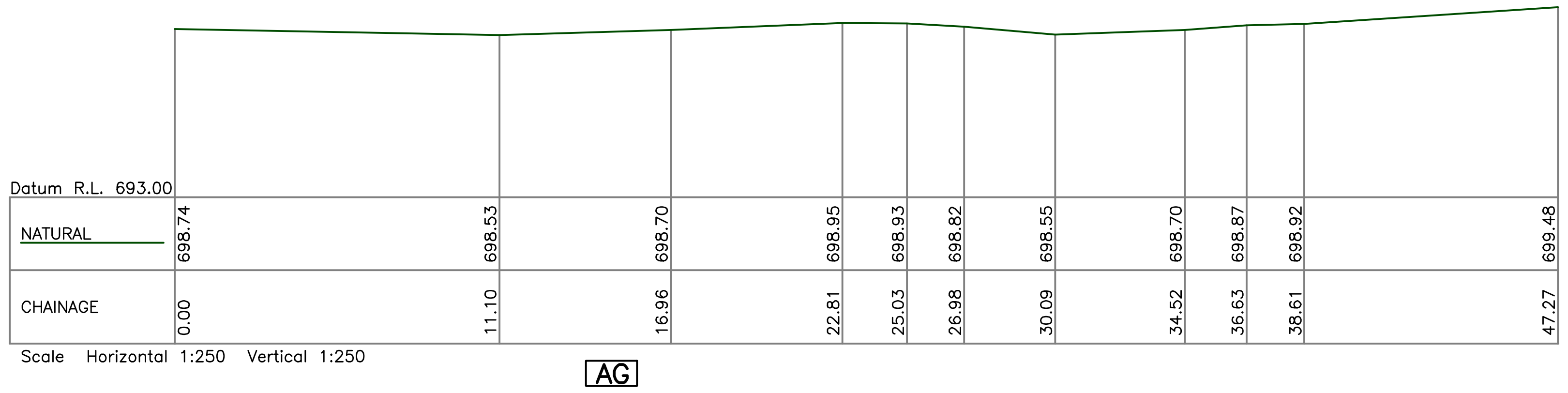
DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531204

ORIGINAL A2 SHEET

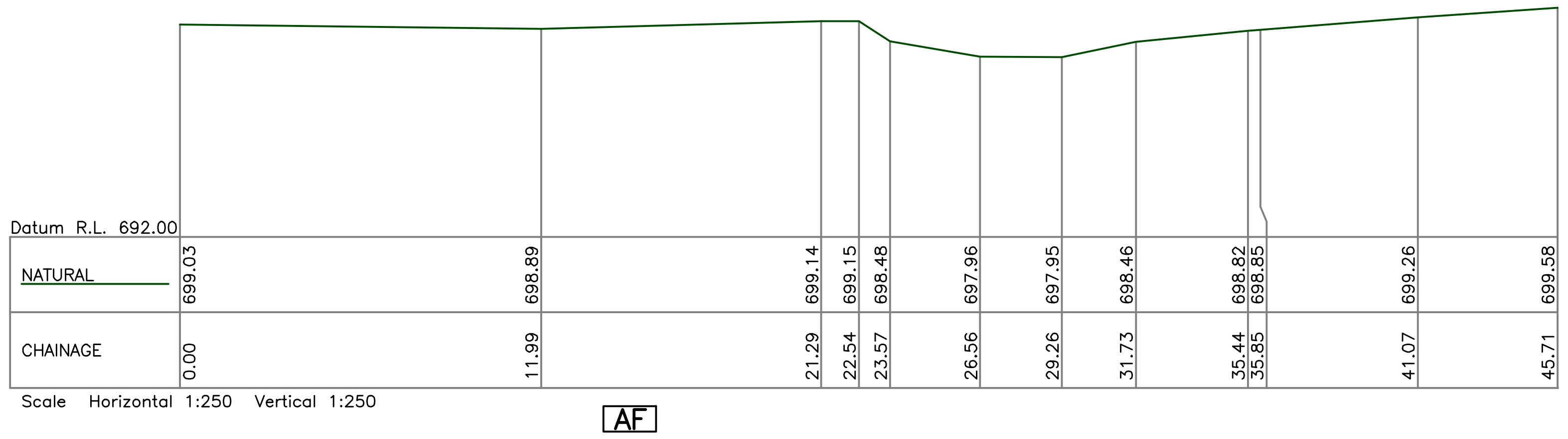
200mm

100mm

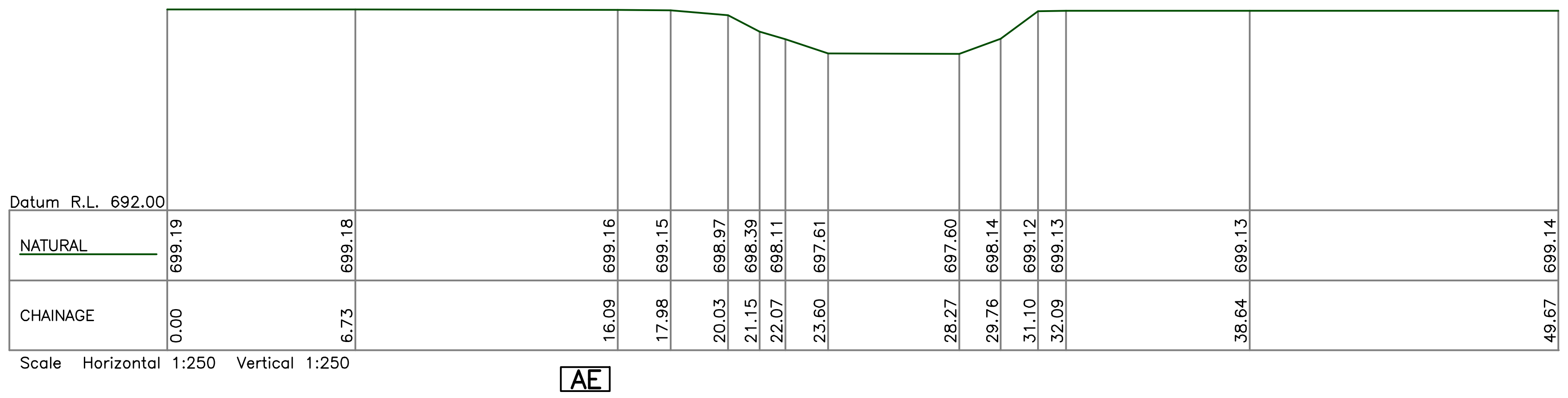
0



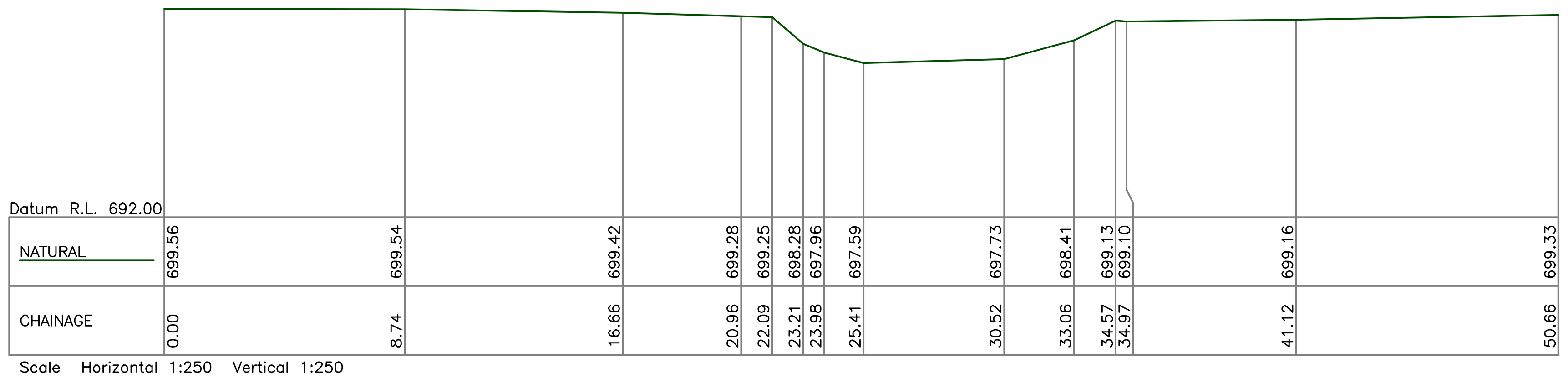
AG



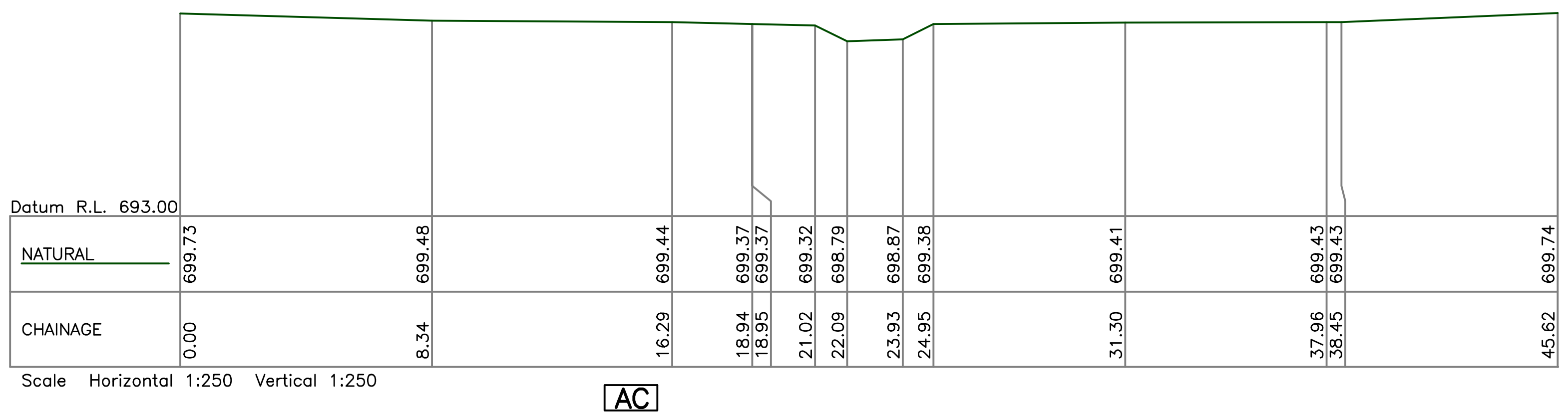
AF



AE



AD



AC

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

phl surveyors

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13 Gibraltar Street, Bungendore NSW 2621 Ph (02) 6238 0144
www.phlsurveyors.com.au

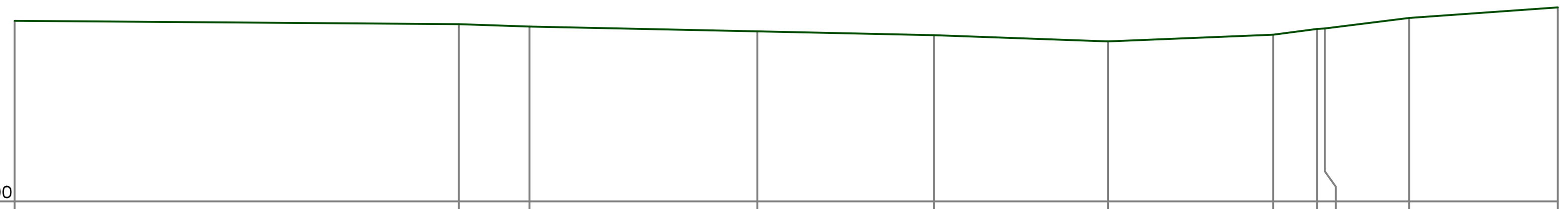
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS AC – AG
SHEET 9 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531205

ORIGINAL A2 SHEET

200mm 100mm 0

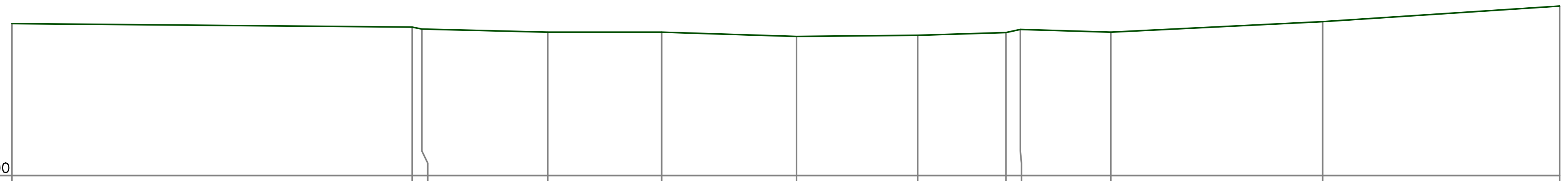


Datum R.L. 692.00

NATURAL	697.99	697.88	697.80	697.64	697.51	697.31	697.52	697.71	697.73	698.08	698.43
CHAINAGE	0.00	14.77	17.12	24.69	30.56	36.35	41.85	43.30	43.55	46.36	51.30

Scale Horizontal 1:250 Vertical 1:250

AL

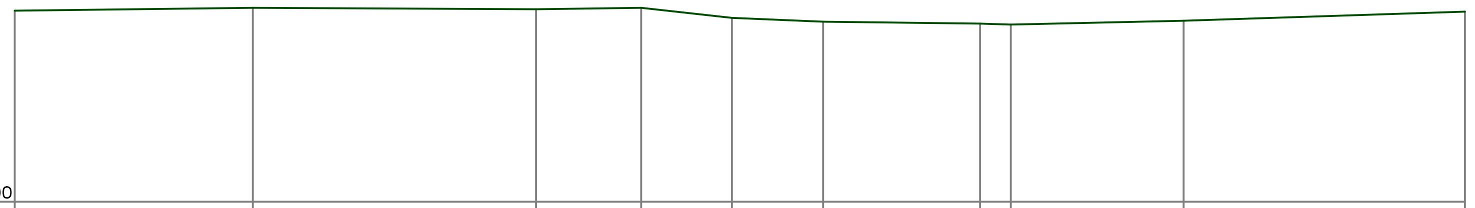


Datum R.L. 692.00

NATURAL	698.18	698.04	697.96	697.84	697.84	697.66	697.70	697.82	697.94	697.84	698.26	698.90
CHAINAGE	0.00	16.36	16.76	21.90	26.55	32.06	37.01	40.62	41.21	44.90	53.56	63.24

Scale Horizontal 1:250 Vertical 1:250

AK

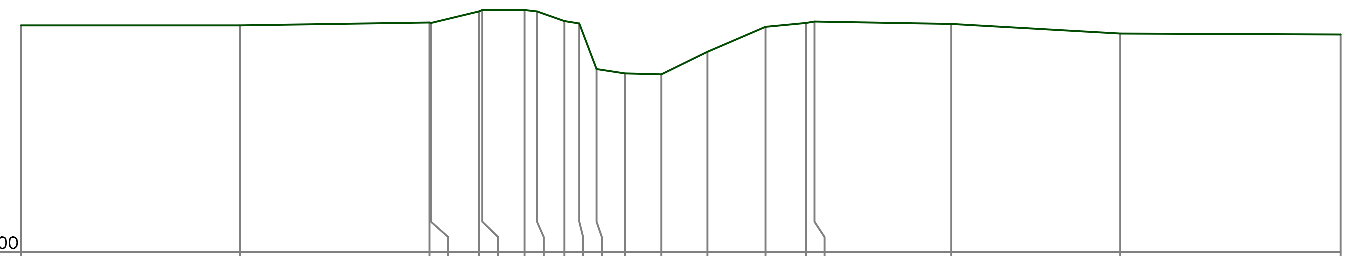


Datum R.L. 692.00

NATURAL	698.34	698.42	698.38	698.43	698.09	697.97	697.91	697.87	698.01	698.31
CHAINAGE	0.00	7.87	17.24	20.72	23.73	26.74	31.93	32.95	38.67	47.96

Scale Horizontal 1:250 Vertical 1:250

AJ

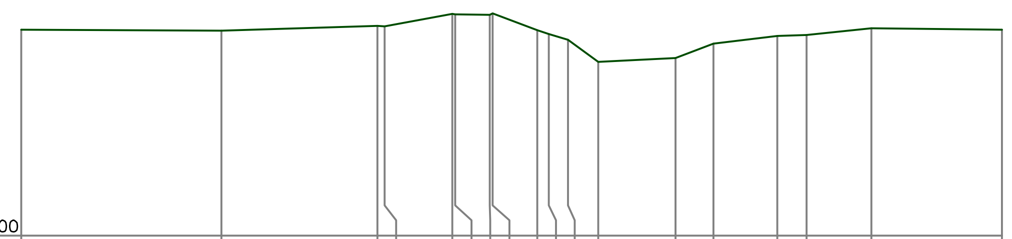


Datum R.L. 691.00

NATURAL	698.50	698.50	698.60	698.58	698.96	699.01	699.01	698.97	698.64	698.56	697.05	696.92	696.88	697.63	698.46	698.58	698.63	698.54	698.24	698.20
CHAINAGE	0.00	7.25	13.51	13.56	15.16	15.26	16.66	17.07	17.97	18.46	19.04	19.98	21.19	22.70	24.63	25.96	26.25	30.78	36.36	43.65

Scale Horizontal 1:250 Vertical 1:250

AI



Datum R.L. 692.00

NATURAL	698.80	698.78	698.94	698.93	699.34	699.31	699.30	699.35	698.78	698.67	698.48	697.74	697.87	698.35	698.60	698.63	698.85	698.81
CHAINAGE	0.00	6.63	11.78	12.03	14.27	14.35	15.50	15.60	17.07	17.45	18.08	19.09	21.64	22.91	25.01	25.98	28.13	32.43

Scale Horizontal 1:250 Vertical 1:250

AH

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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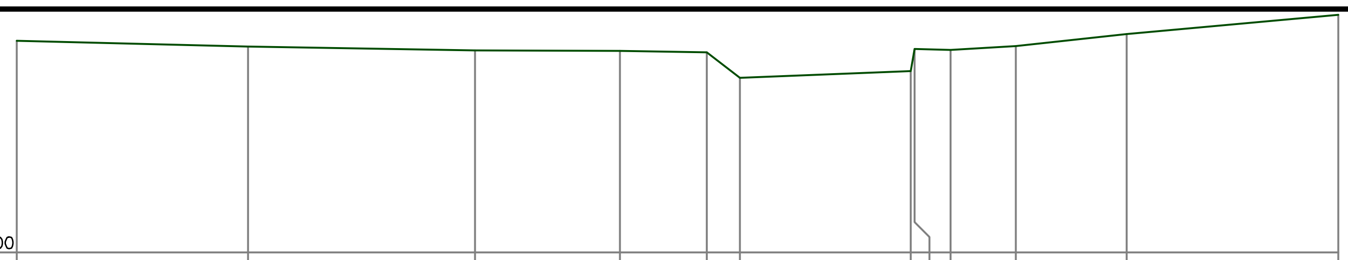
www.phlsurveyors.com.au

CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS AH– AL
SHEET 10 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531206

ORIGINAL A2 SHEET

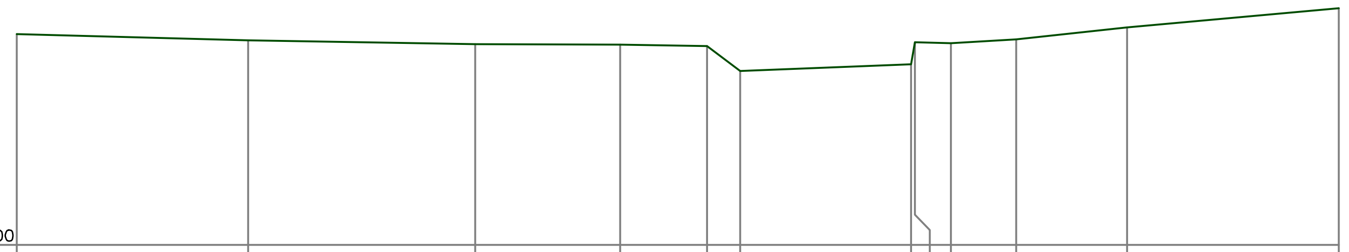


Datum R.L. 690.00

NATURAL	696.98	696.79	696.66	696.65	696.59	695.76	695.98	696.71	696.69	696.81	697.21	697.84
CHAINAGE	0.00	7.65	15.17	19.95	22.83	23.93	29.57	29.70	30.89	33.06	36.72	43.72

Scale Horizontal 1:250 Vertical 1:250

AQ

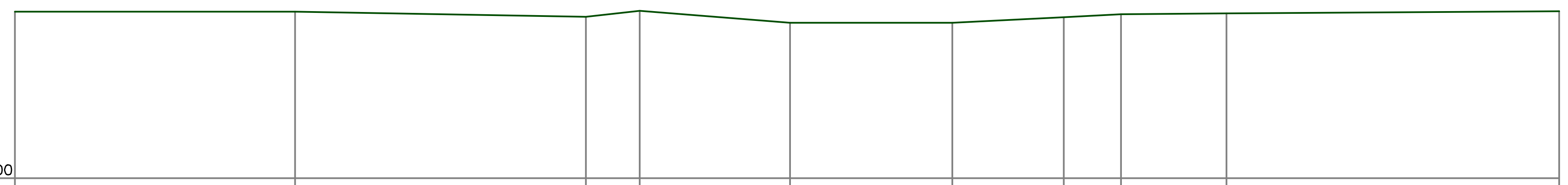


Datum R.L. 690.00

NATURAL	696.98	696.79	696.66	696.65	696.59	695.76	695.98	696.71	696.69	696.81	697.21	697.84
CHAINAGE	0.00	7.65	15.17	19.95	22.83	23.93	29.57	29.70	30.89	33.06	36.72	43.72

Scale Horizontal 1:250 Vertical 1:250

AP

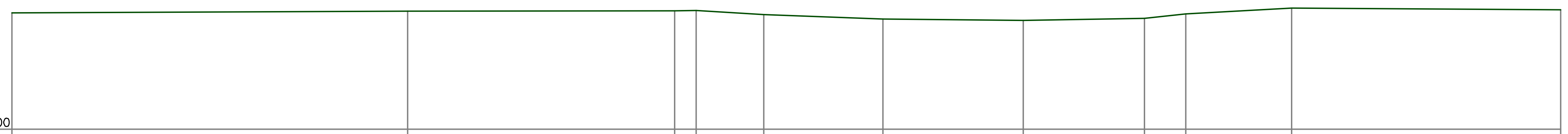


Datum R.L. 691.00

NATURAL	697.20	697.20	697.01	697.23	696.79	696.78	696.98	697.10	697.14	697.21
CHAINAGE	0.00	10.41	21.22	23.22	28.81	34.85	38.99	41.12	45.03	57.40

Scale Horizontal 1:250 Vertical 1:250

AO

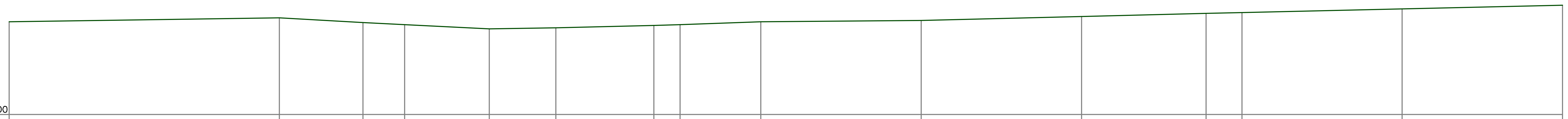


Datum R.L. 692.00

NATURAL	697.39	697.48	697.49	697.50	697.31	697.11	697.04	697.13	697.34	697.62	697.53
CHAINAGE	0.00	18.41	30.82	31.82	34.96	40.50	47.03	52.66	54.57	59.50	72.02

Scale Horizontal 1:250 Vertical 1:250

AN



Datum R.L. 692.00

NATURAL	697.60	697.85	697.56	697.42	697.18	697.25	697.38	697.43	697.60	697.69	697.93	698.12	698.17	698.39	698.60
CHAINAGE	0.00	16.37	21.43	23.96	29.08	33.11	39.05	40.64	45.53	55.25	64.96	72.50	74.67	84.38	94.10

Scale Horizontal 1:250 Vertical 1:250

AM

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS AM – AQ
SHEET 11 OF 18 SHEETS

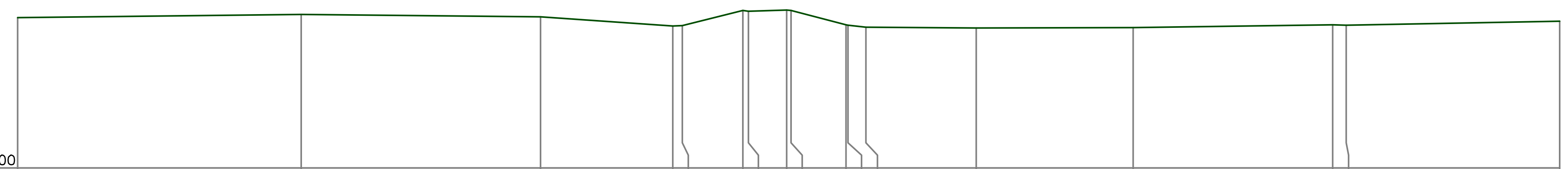
DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531207

Datum R.L. 690.00

CHAINAGE	NATURAL
0.00	695.68
10.98	695.75
18.67	695.48
18.70	695.47
18.84	695.50
21.93	696.02
22.41	696.10
23.74	696.06
23.96	696.10
26.44	695.46
26.90	695.43
33.94	695.35
42.97	695.44
50.24	695.66
54.11	695.75
64.48	695.77

Scale Horizontal 1:250 Vertical 1:250

AV

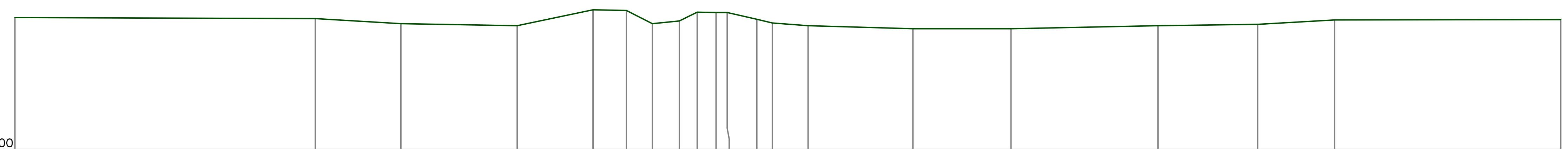


Datum R.L. 690.00

CHAINAGE	NATURAL
0.00	695.99
11.30	696.12
20.84	696.01
26.12	695.65
26.50	695.67
28.91	696.26
29.14	696.24
30.66	696.29
30.83	696.26
33.02	695.70
33.10	695.68
33.83	695.60
38.22	695.57
44.48	695.58
52.43	695.69
52.97	695.68
61.47	695.84

Scale Horizontal 1:250 Vertical 1:250

AU

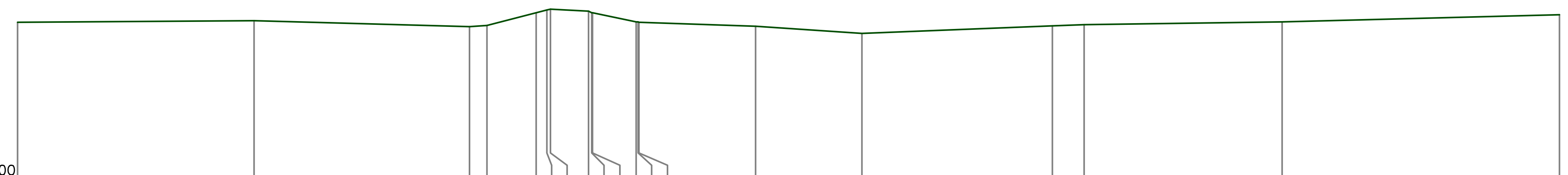


Datum R.L. 690.00

CHAINAGE	NATURAL
0.00	696.19
14.15	696.14
18.18	695.91
23.65	695.82
27.24	696.57
28.81	696.52
30.03	695.90
31.30	696.04
32.13	696.45
33.02	696.44
33.55	696.44
34.95	696.12
35.68	695.94
37.36	695.82
42.29	695.67
46.92	695.67
53.84	695.82
58.54	695.88
62.16	696.08
72.81	696.10

Scale Horizontal 1:250 Vertical 1:250

AT

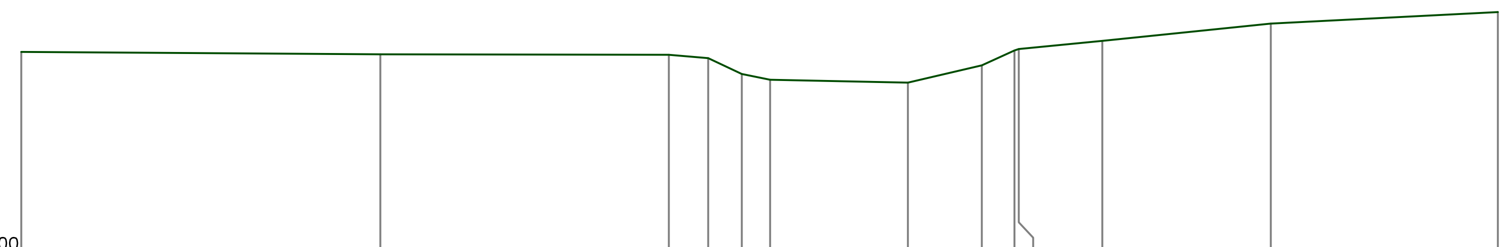


Datum R.L. 690.00

CHAINAGE	NATURAL
0.00	696.23
9.46	696.28
18.08	696.04
18.79	696.10
20.75	696.60
21.18	696.71
21.32	696.75
22.85	696.66
22.97	696.61
23.00	696.60
24.75	696.23
24.84	696.24
24.87	696.22
29.53	696.06
33.78	695.77
41.41	696.08
42.67	696.13
50.60	696.24
61.70	696.51

Scale Horizontal 1:250 Vertical 1:250

AS



Datum R.L. 690.00

CHAINAGE	NATURAL
0.00	696.64
11.87	696.56
21.42	696.54
22.72	696.43
23.83	695.91
24.77	695.71
29.33	695.63
31.78	696.20
32.85	696.69
33.00	696.73
35.75	697.00
41.33	697.58
48.84	697.95

Scale Horizontal 1:250 Vertical 1:250

AR

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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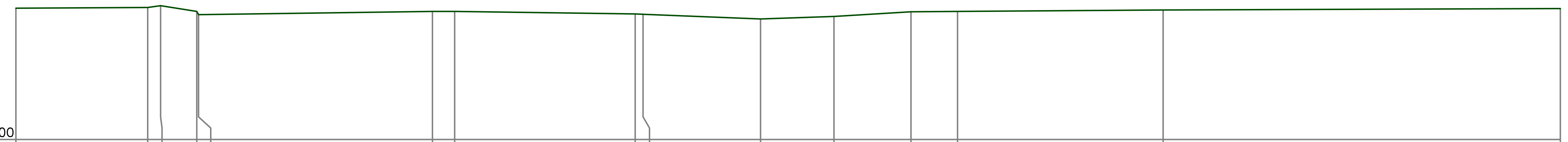
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS AR – AV
SHEET 12 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531208

200mm
100mm
0

ORIGINAL A2 SHEET

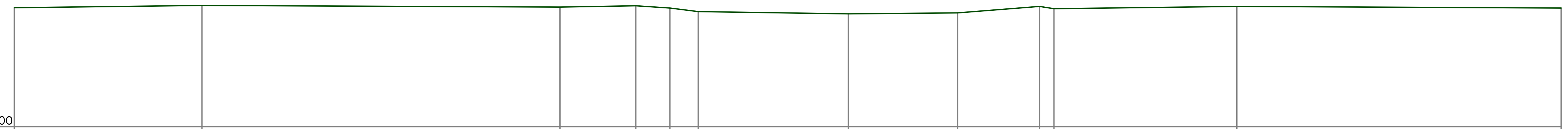


Datum R.L. 689.00

NATURAL	694.81	694.83	694.91	694.65	694.52	694.66	694.66	694.56	694.54	694.33	694.44	694.65	694.66	694.73	694.80
CHAINAGE	0.00	5.85	6.42	8.02	8.10	18.47	19.46	27.45	27.79	33.00	36.26	39.68	41.75	50.84	68.45

Scale Horizontal 1:250 Vertical 1:250

BA

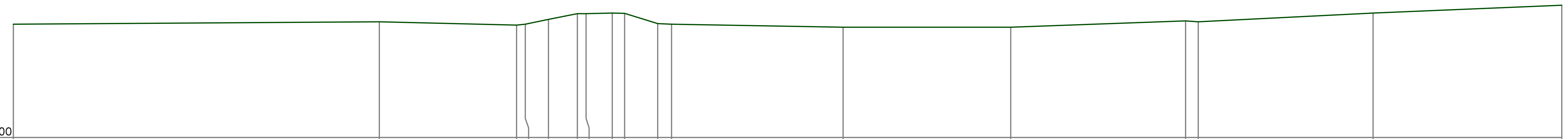


Datum R.L. 689.00

NATURAL	694.87	694.98	694.90	694.96	694.85	694.67	694.56	694.60	694.92	694.81	694.92	694.85
CHAINAGE	0.00	9.28	26.95	30.70	32.38	33.79	41.20	46.61	50.65	51.35	60.40	76.42

Scale Horizontal 1:250 Vertical 1:250

AZ



Datum R.L. 689.00

NATURAL	694.96	695.09	694.92	694.96	695.21	695.52	695.52	695.55	695.53	694.99	694.97	694.80	694.80	695.13	695.08	695.54	695.96
CHAINAGE	0.00	19.31	26.55	27.00	28.22	29.75	30.21	31.60	32.24	33.99	34.73	43.77	52.62	61.83	62.50	71.73	81.68

Scale Horizontal 1:250 Vertical 1:250

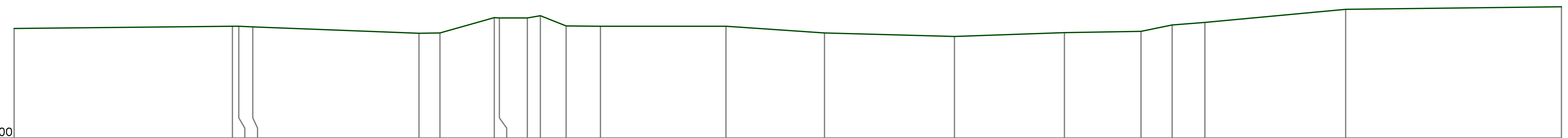
AY

Datum R.L. 689.00

NATURAL	695.19	695.26	695.02	695.12	695.64	695.71	695.72	695.78	695.72	695.28	695.22	695.10	694.98	695.12	695.32	695.54	696.13	696.22
CHAINAGE	0.00	15.66	23.06	24.05	26.49	26.77	26.90	28.46	28.82	30.61	31.27	36.37	45.28	54.30	57.18	61.40	72.82	83.60

Scale Horizontal 1:250 Vertical 1:250

AX



Datum R.L. 690.00

NATURAL	695.45	695.56	695.57	695.54	695.21	695.23	696.00	695.98	695.98	696.09	695.58	695.56	695.57	695.23	695.06	695.24	695.31	695.63	695.76	696.41	696.53
CHAINAGE	0.00	10.91	11.23	11.92	20.23	21.28	23.98	24.24	25.63	26.29	27.58	29.29	35.56	40.49	46.98	52.48	56.29	57.85	59.49	66.52	77.31

Scale Horizontal 1:250 Vertical 1:250

AW

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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www.phlsurveyors.com.au

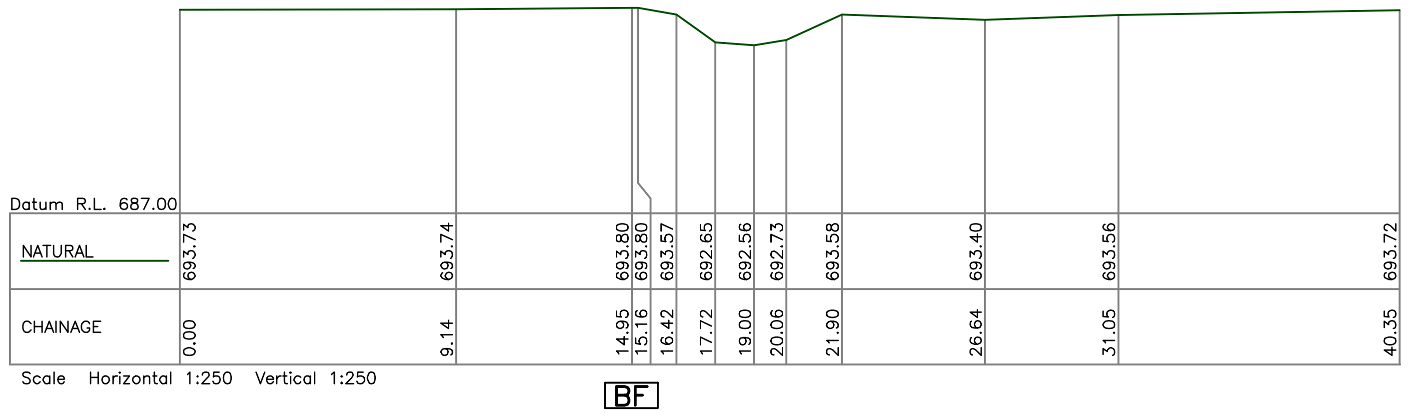
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS AW – BA
SHEET 13 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531209

ORIGINAL A2 SHEET

200mm
100mm
0



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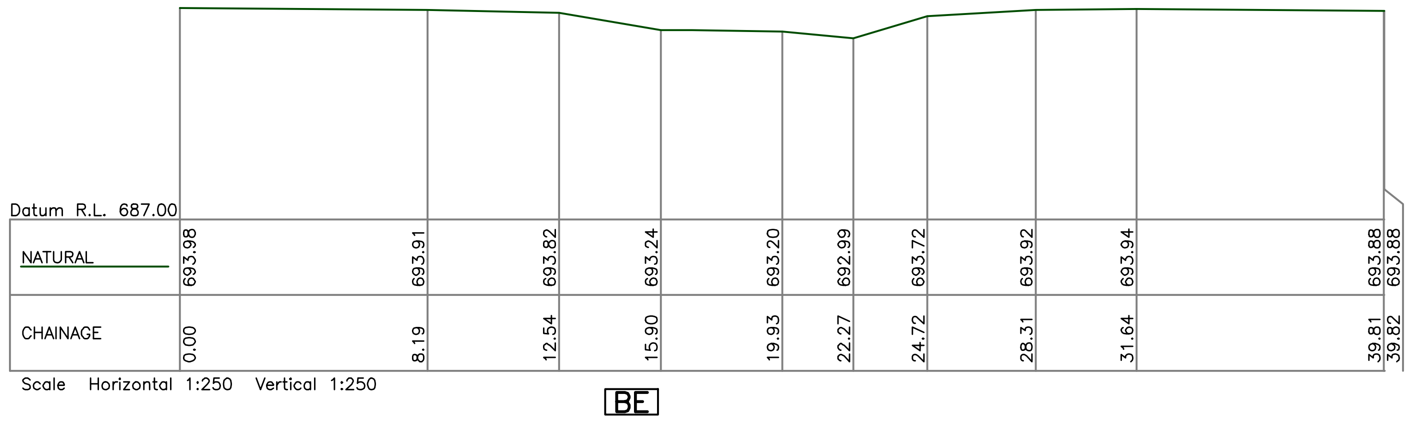

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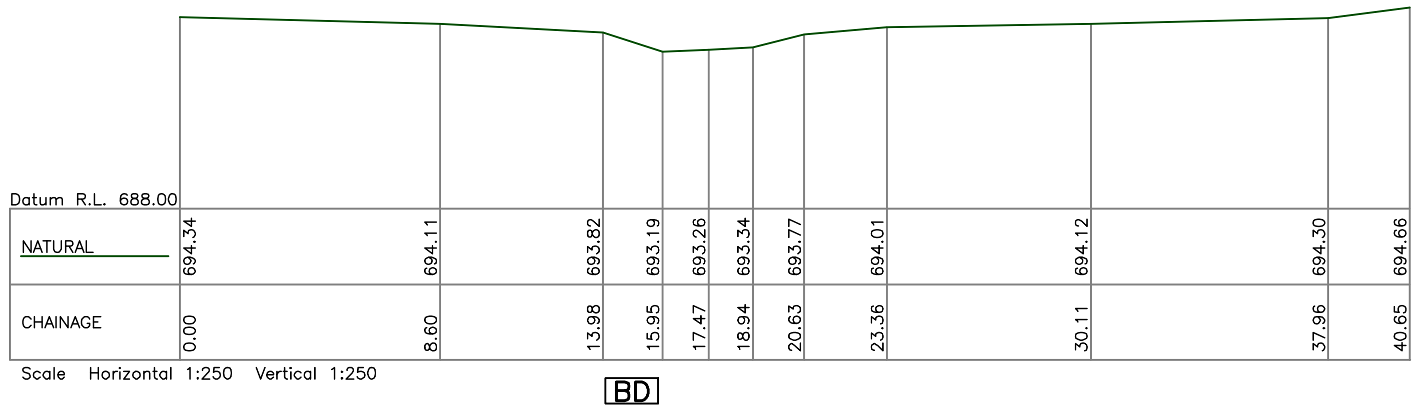

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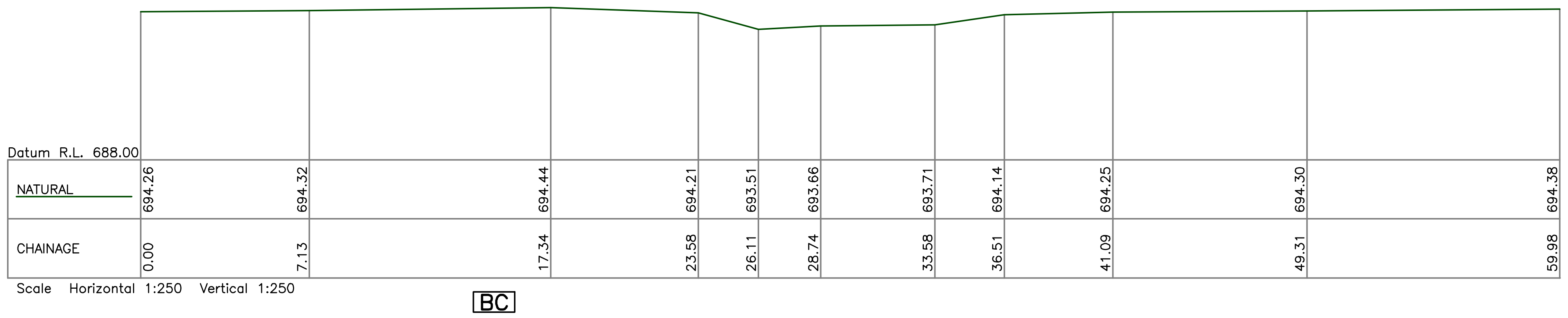
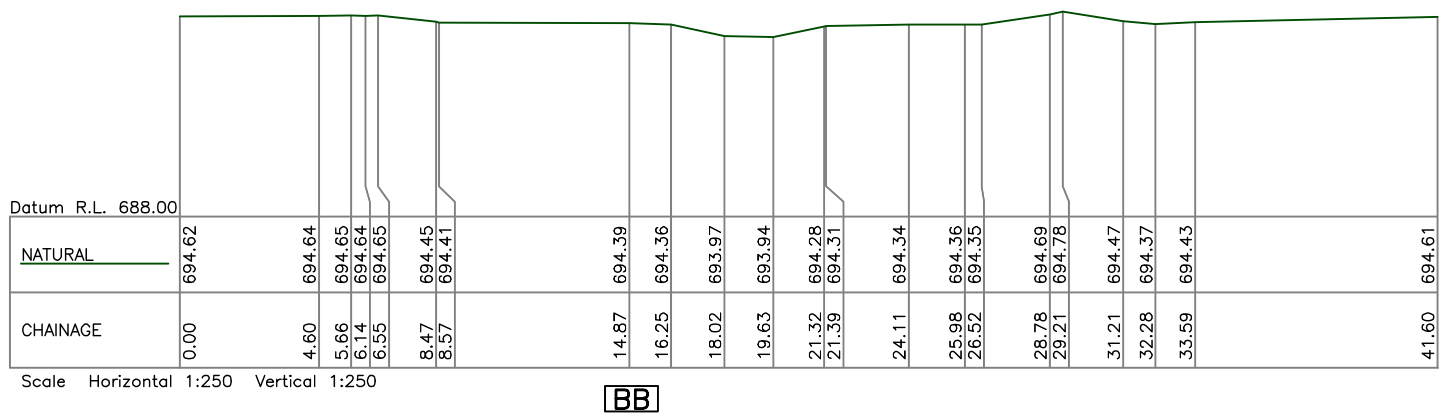
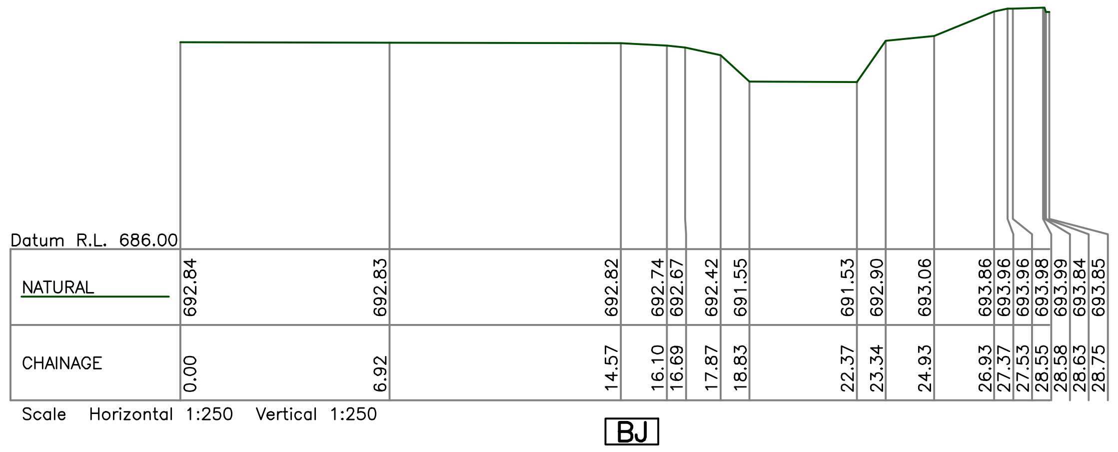


BC



BB



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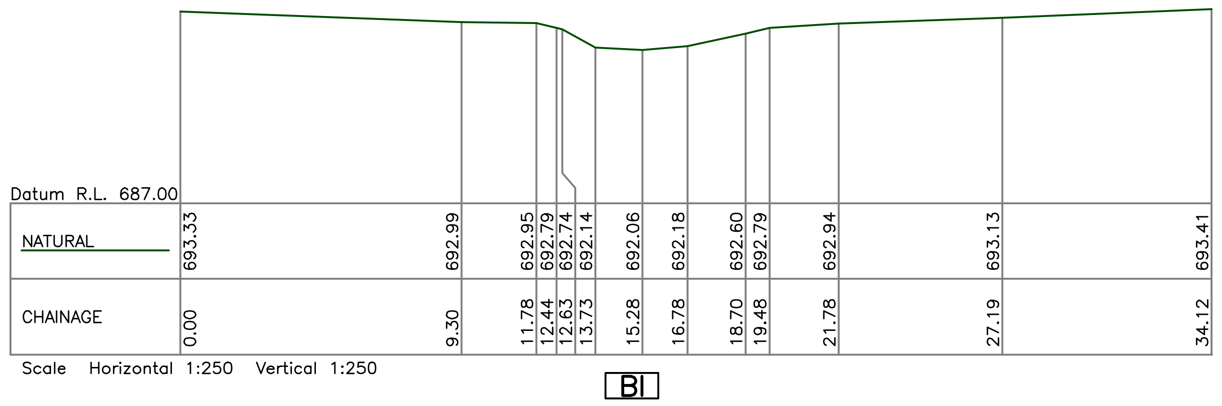
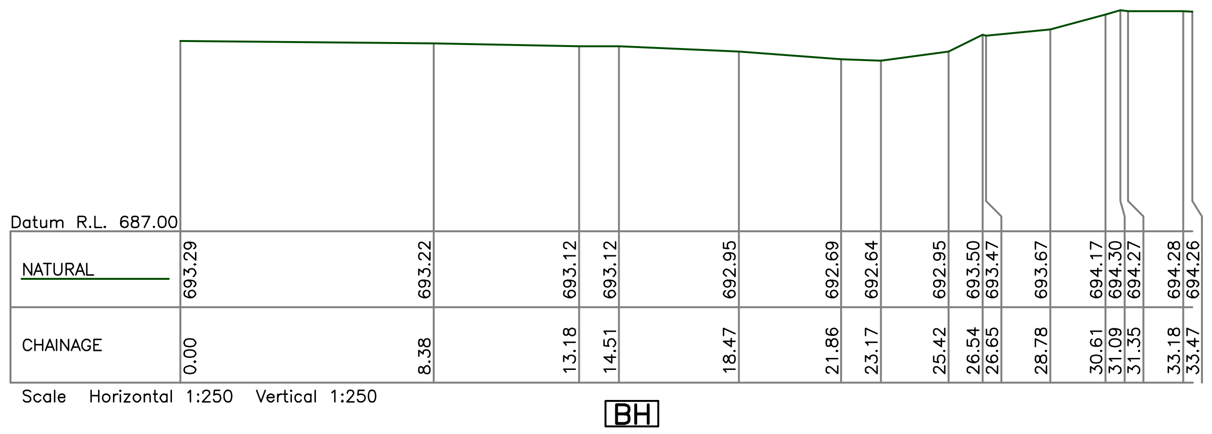
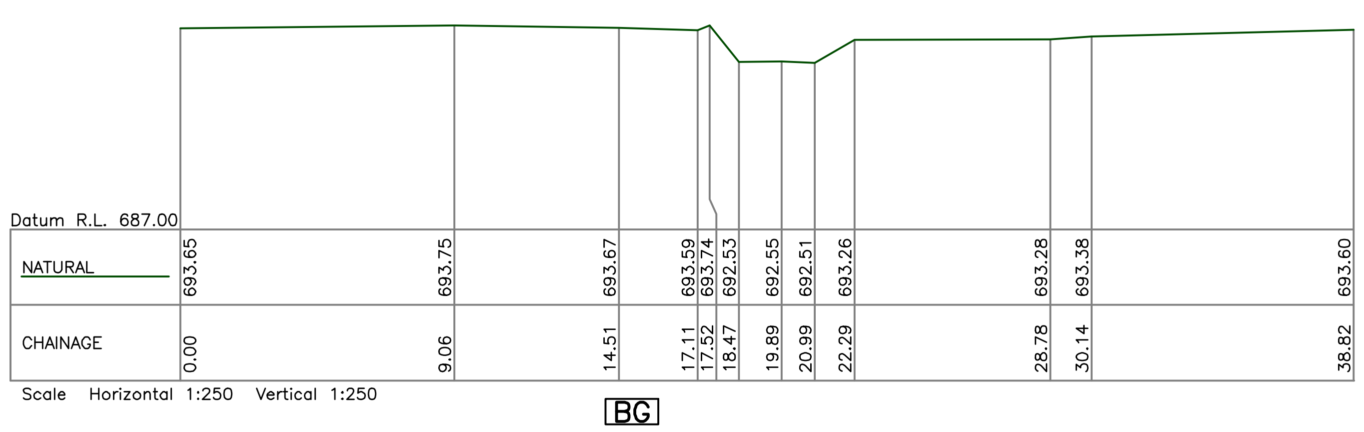


BI



BH



BG

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC
DRAWN: TC		CHECKED: TC	

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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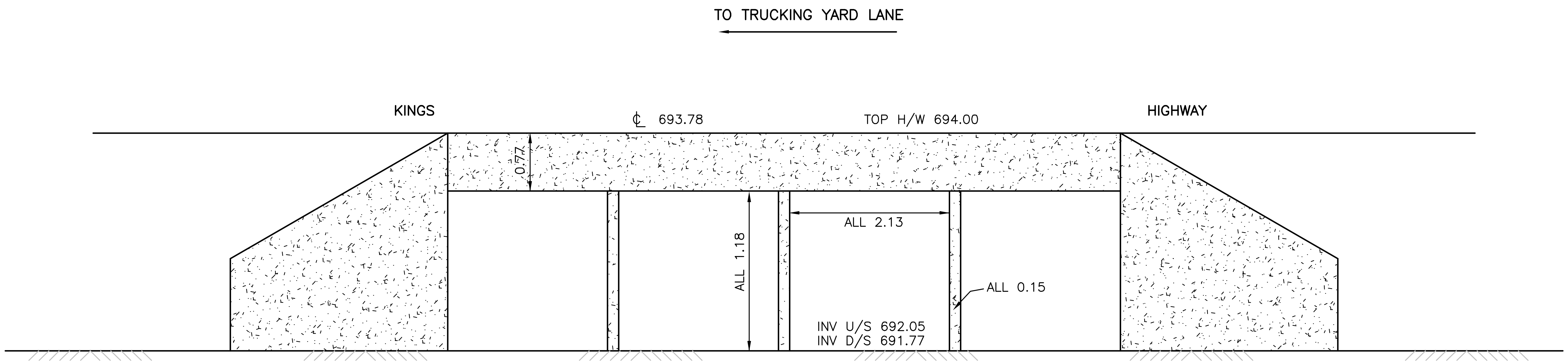
13 Gibraltar Street, Bungendore NSW 2621 Ph (02) 6238 0144
www.phlsurveyors.com.au

CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
CROSS SECTIONS BB – BJ
SHEET 14 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: AS SHOWN
A2– 531210

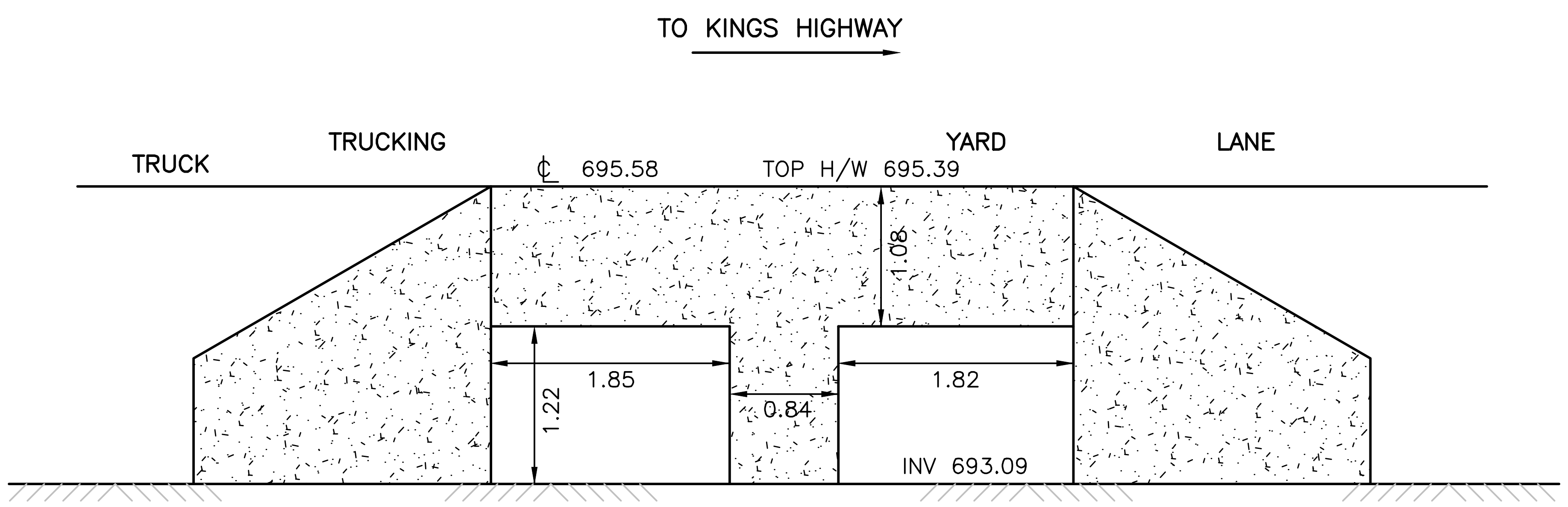
ORIGINAL A2 SHEET



CULVERT 1 – LOOKING WEST

7.94 WIDE

FIG. 1 – LOOKING WEST



CULVERT 2 – LOOKING SOUTH

11.00 WIDE

FIG. 2 – LOOKING SOUTH

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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115 Yambil Street, Griffith NSW 2680 Ph (02) 6964 3192
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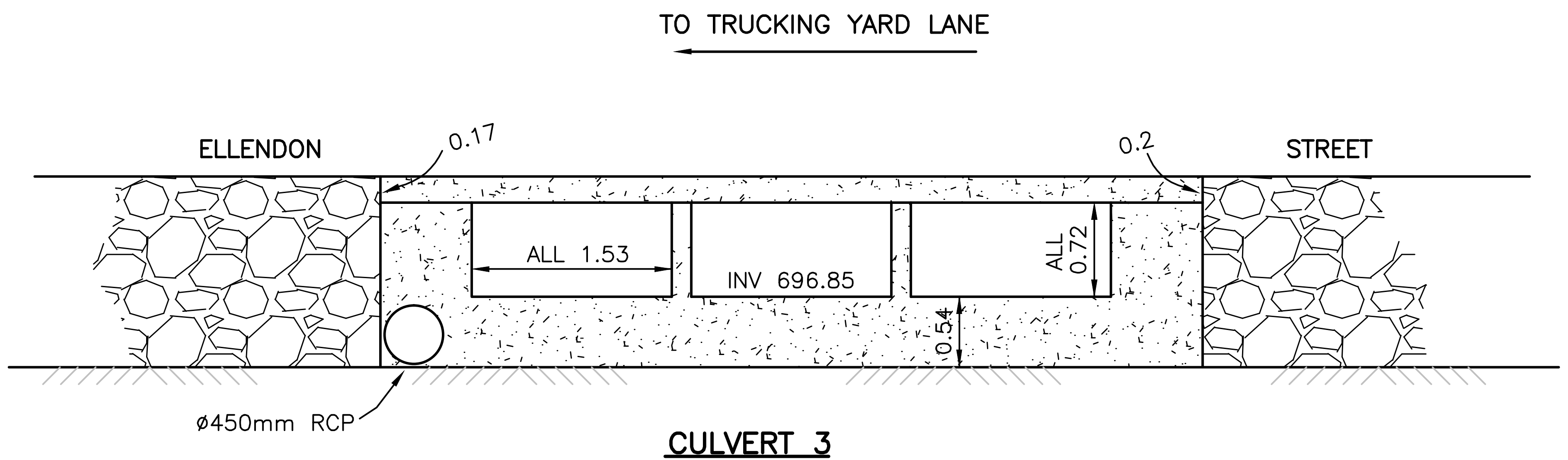
CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL OF STORMWATER STURCTURES
SHEET 15 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:50
A2– 531211

ORIGINAL A2 SHEET



CULVERT 3

FIG. 3 – LOOKING EAST

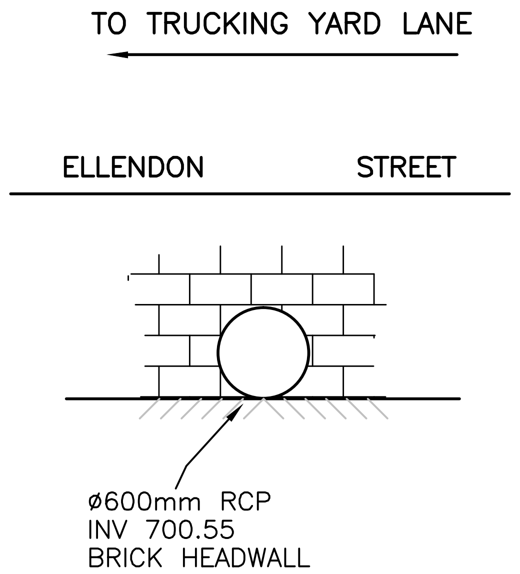


FIG. 4 – LOOKING EAST

CULVERT 4
8.00 WIDE

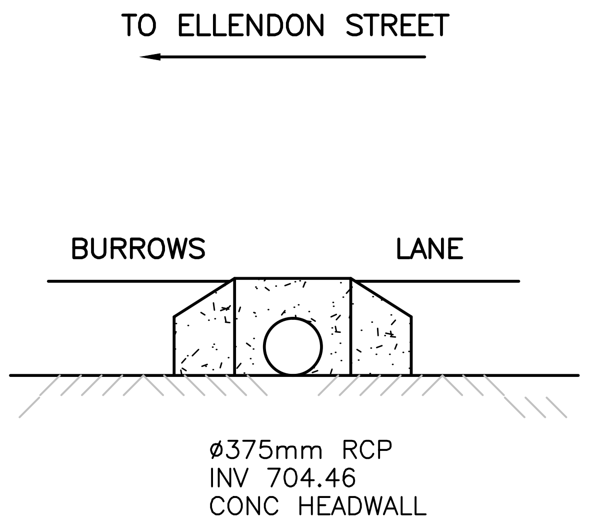


FIG. 5 – LOOKING EAST

CULVERT 5
7.45 WIDE

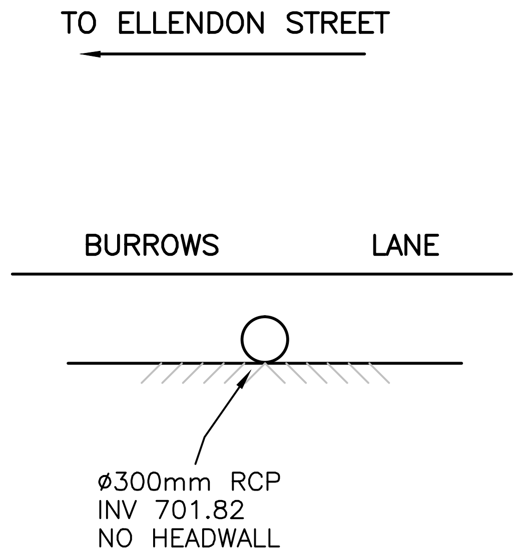


FIG. 6 – LOOKING EAST

CULVERT 6

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: TC CHECKED: TC

COMMENTS:
COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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www.phlsurveyors.com.au

CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL OF STORMWATER STURCTURES
SHEET 16 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:50
A2– 531212

ORIGINAL A2 SHEET

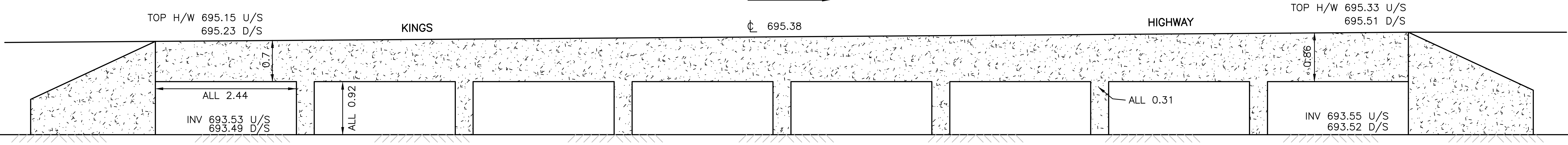
200mm
100mm
0

FIG. 7 — LOOKING EAST

FIG. 8 — LOOKING EAST

FIG. 9 — LOOKING SOUTH

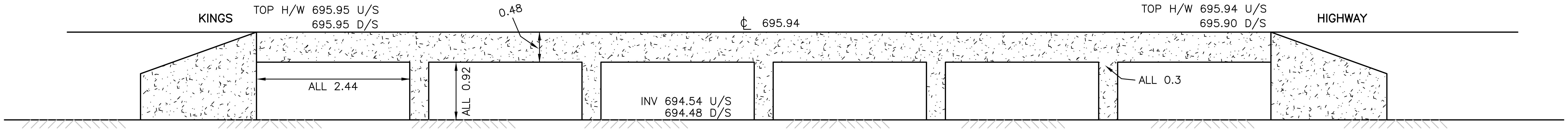
TO BUNGENDORE →



CULVERT 7
13.6 WIDE

FIG. 10 — LOOKING SOUTH

TO BUNGENDORE →



CULVERT 8
12.2 WIDE

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC
DRAWN: TC		CHECKED: TC	

COMMENTS:
COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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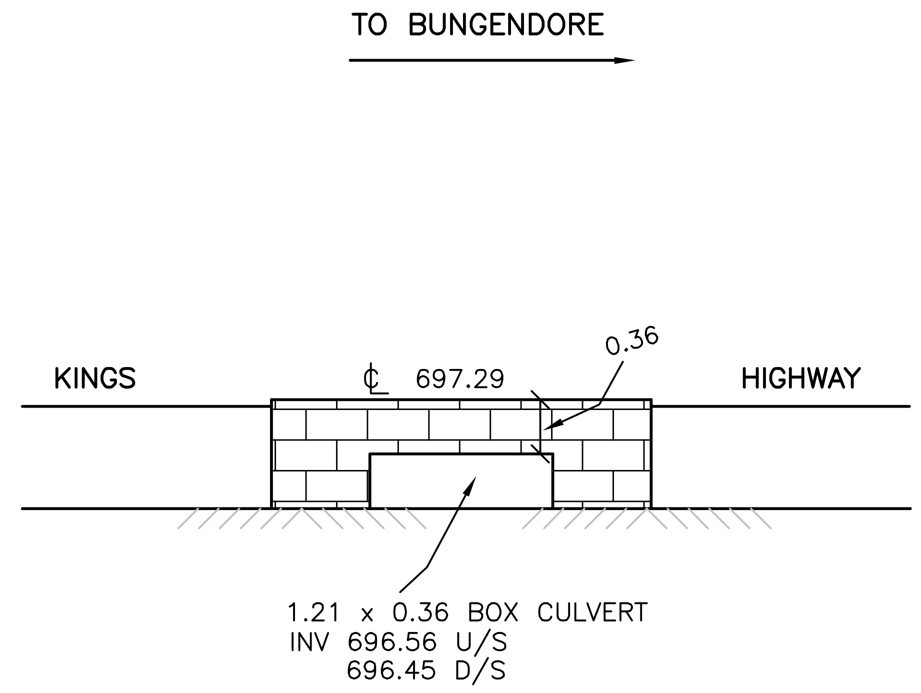
CLIENT: PALERANG COUNCIL

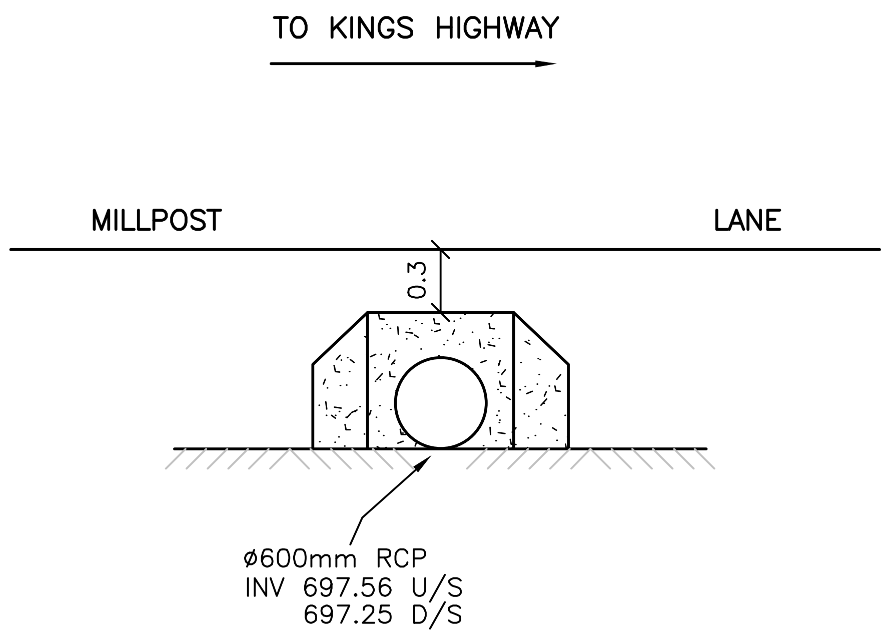
TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL OF STORMWATER STURCTURES
SHEET 17 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:50
A2– 531213



CULVERT 9

FIG. 11 — LOOKING EAST



CULVERT 10

FIG. 12 — LOOKING SOUTH

DATE	No.	ISSUE	AUTHORISED
30/01/2012	A	ISSUED TO CLIENT	TC
DRAWN: TC		CHECKED: TC	

COMMENTS:
COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011A12.dwg

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www.phlsurveyors.com.au

CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL OF STORMWATER STURCTURES
SHEET 18 OF 18 SHEETS

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:50
A2– 531214

PALERANG COUNCIL

10 April 2012

Manager, Environment & Water Resources - Southern Operations
Worley Parsons
Level 11
141 Walker Street
North Sydney
NSW 2060

Attention: Mr Chris Thomas

Bungendore Flood Risk Management Study – Additional Survey Data

Dear Chris,

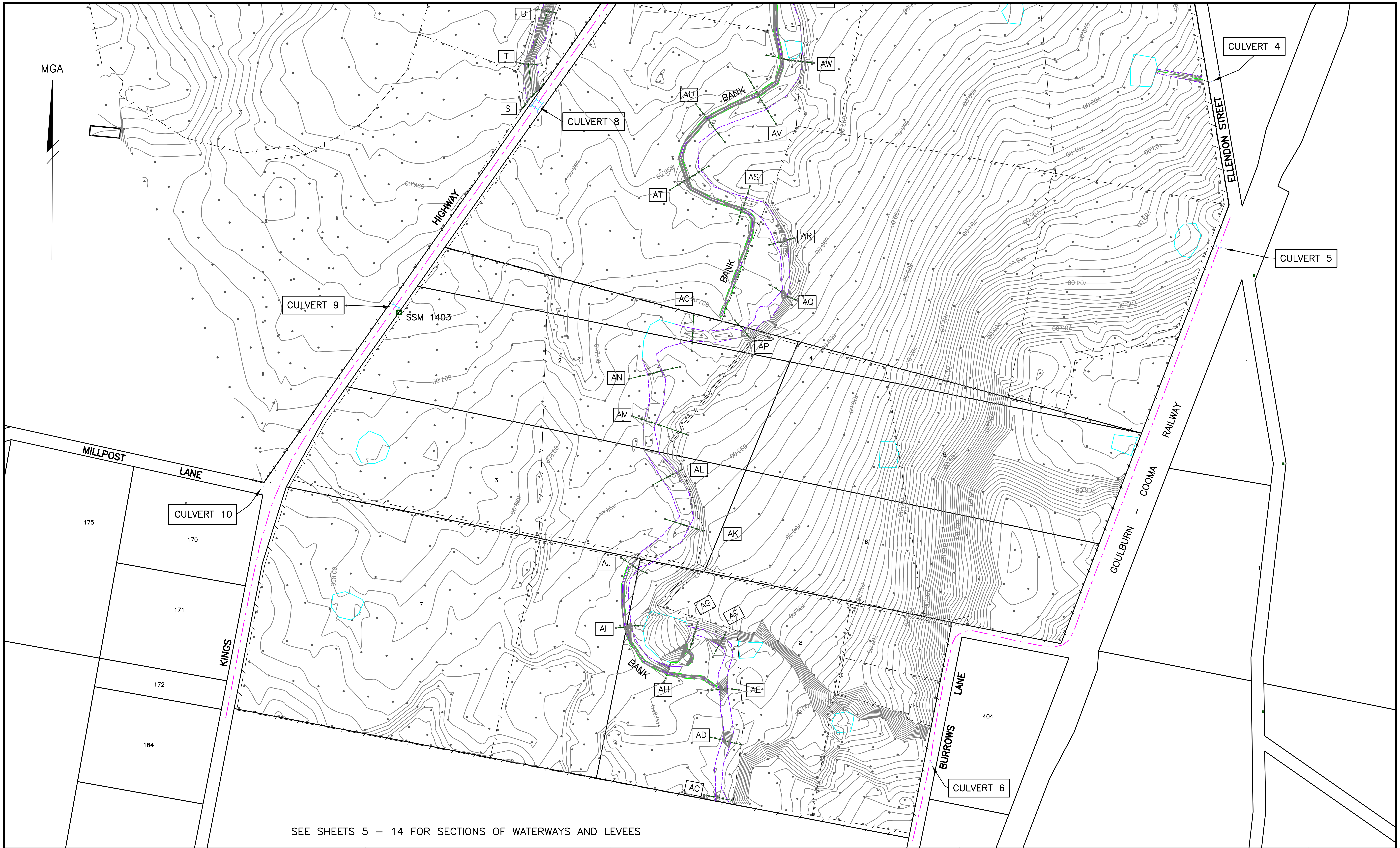
A CD is enclosed containing the additional survey data of Halfway and Millpost Creeks provided to us by PHL Surveyors. It contains:

- A digital 3 dimensional Autocad dxf file showing all the detail and spot heights collected
- An excel spreadsheet with each ground spot elevation; and
- A pdf copy of the revised plans.

Yours faithfully,

P J Mathew
Project Engineer
Palerang Council

ORIGINAL A2 SHEET



DATE	No.	ISSUE	AUTHORISED
29/03/2012	B	ADDITIONAL DATA OVER PIVOT	AL
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

COMMENTS:

COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255
CONTOUR INTERVAL IS 0.2m

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011B12.dwg

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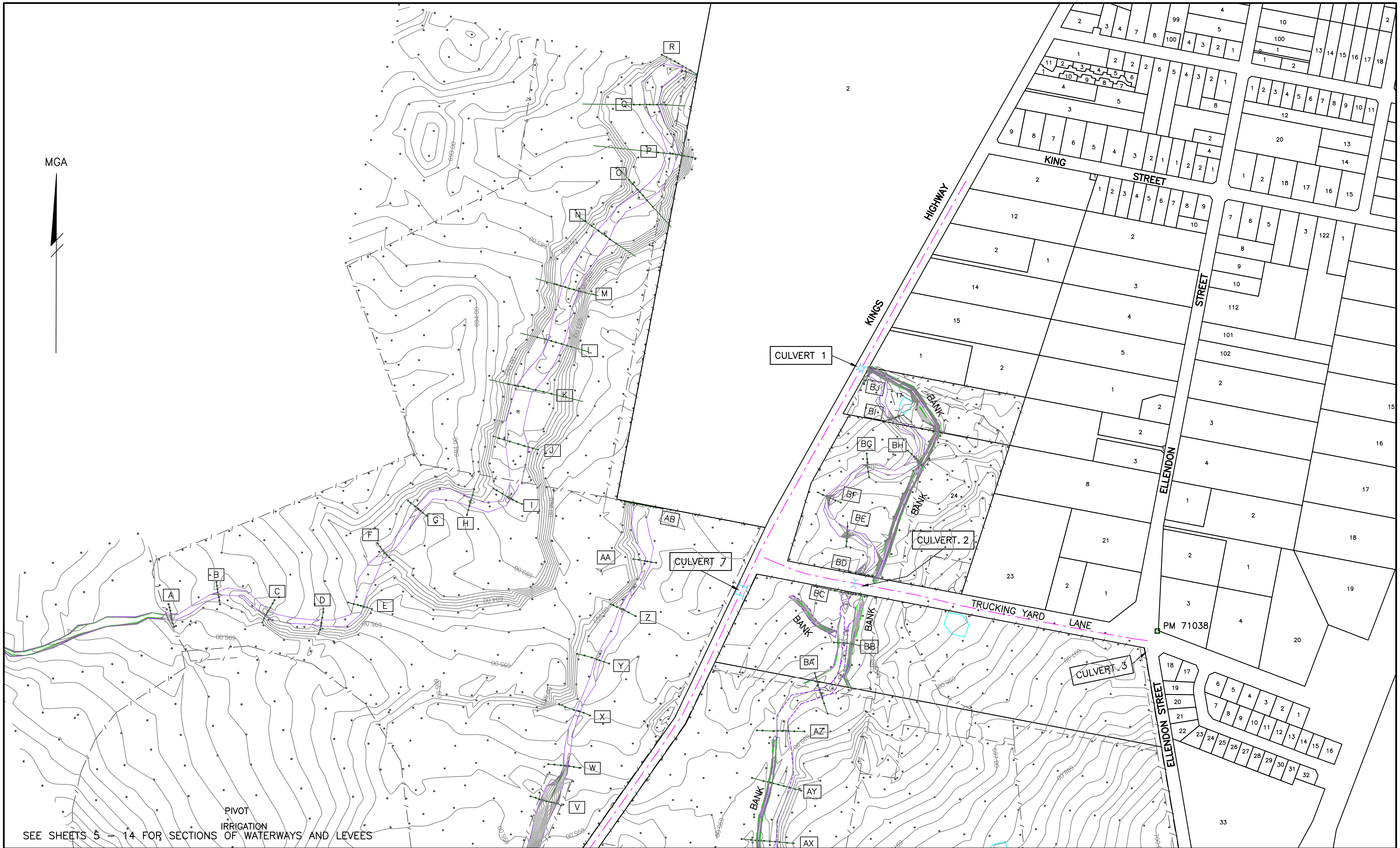
www.phlsurveyors.com.au

CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL SURVEY
SHEET 3 OF 18

DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:4000
A2– 531199(1)

ORIGINAL A2 SHEET



DATE	No.	ISSUE	AUTHORISED
29/03/2012	B	ADDITIONAL DATA OVER PIVOT	AL
30/01/2012	A	ISSUED TO CLIENT	TC

DRAWN: JM CHECKED: TC

JOINS SHEET 3

COMMENTS:
COORDINATE SYSTEM IS MGA BASED ON PM 71038. DATUM IS A.H.D.
ORIGIN OF LEVELS IS PM 71038. R.L. 697.255
CONTOUR INTERVAL 0.2m

COMPUTER FILES: CCAD: 12011A12.ccx
ACAD: 12011B12.dwg

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CLIENT: PALERANG COUNCIL

TITLE: TOPOGRAPHIC & HYDROGRAPHIC SURVEY ALONG HALFWAY & MILLPOST CREEKS, BUNGENDORE
DETAIL SURVEY
SHEET 4 OF 18

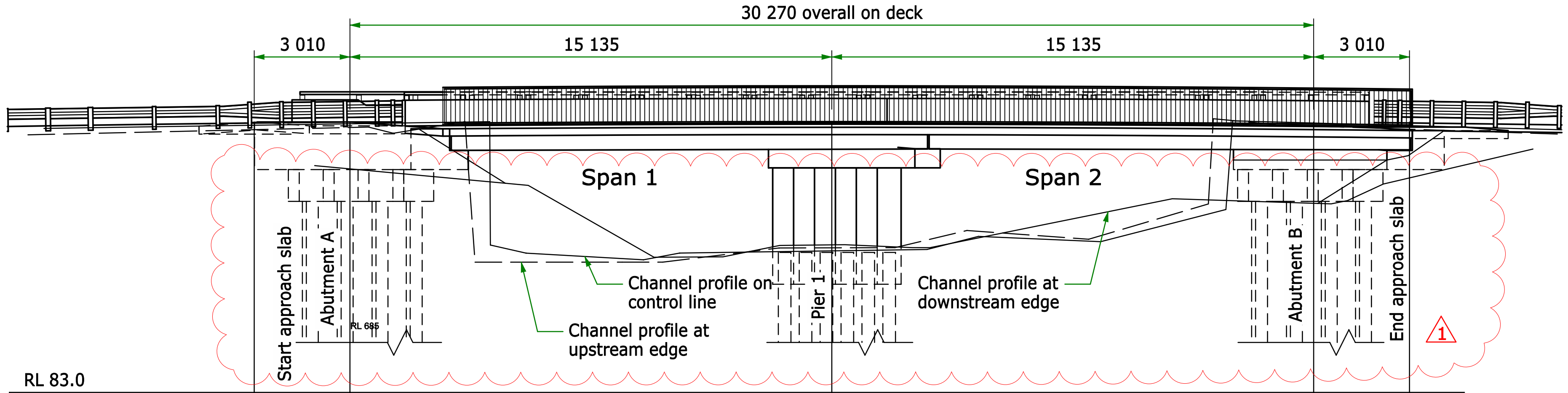
DATE: 24/01/2012
FILE: PN 12011
SCALE: 1:4000
A2– 531200(1)


Carriageway facing north


South abutment scour protection

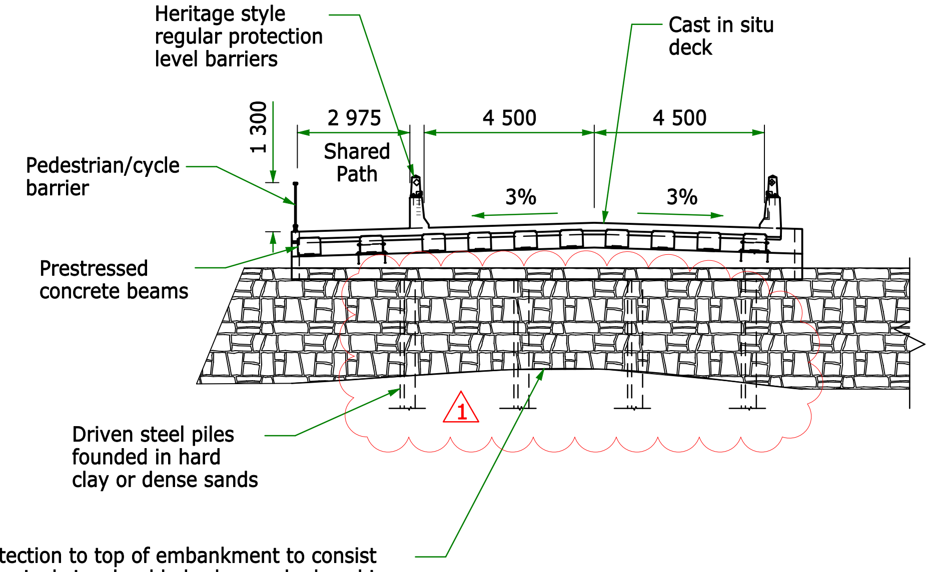

Disused road & existing culvert


North abutment scour protection



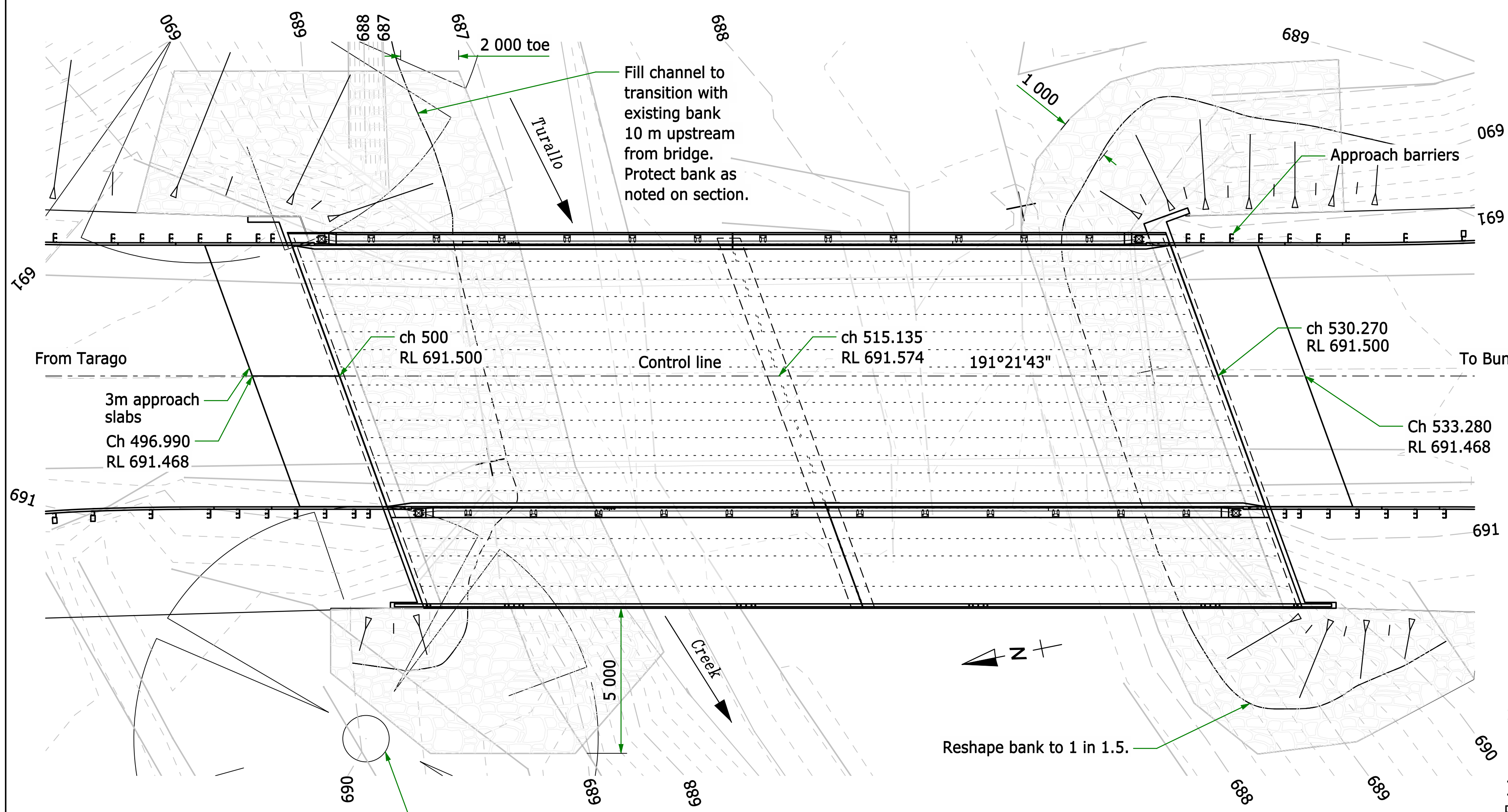
	Ch 491.990	Ch 500.000	Ch 515.135	Ch 530.270	Ch 533.280
Design Level on Control Line	691.468	691.500	691.574	691.500	691.468
Natural Surface on Control Line		691.50	687.20	691.50	
Chainage on Control Line	491.990	500.000	515.135	530.270	533.280

ELEVATION
1:200



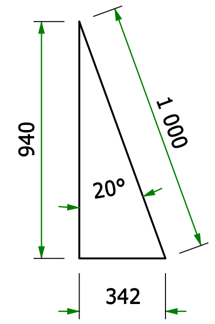
Rock protection to top of embankment to consist of 500 nominal size durable broken rock placed in a single layer over "Bidum A34" or equal geotextile and extended beyond toe of bank as shown on plan.
Approximate area of protection ;
Abut A - 180 m²
Abut B - 150 m²

SECTION AT ABUTMENT A
1:200



PLAN
1:200

General Notes
Scales as shown.
Dimensions in millimetres.
Chainages and reduced levels in metres.
Reduced levels are to AHD datum.
SOL denotes set out line.
The bridge contract excludes approach slabs and earth works above the soffit of the abutment.



SKEW DIAGRAM
1:200 0 1m 2m 3m 4m 5m
1m 0.5m

ISSUED FOR CONSTRUCTION
DRAWING SCALES TRUE AT A3

REV	DATE	COMMENTS	DFT	CHK
1	02/05/08	Piling changed to steel piles	JRA	JRA

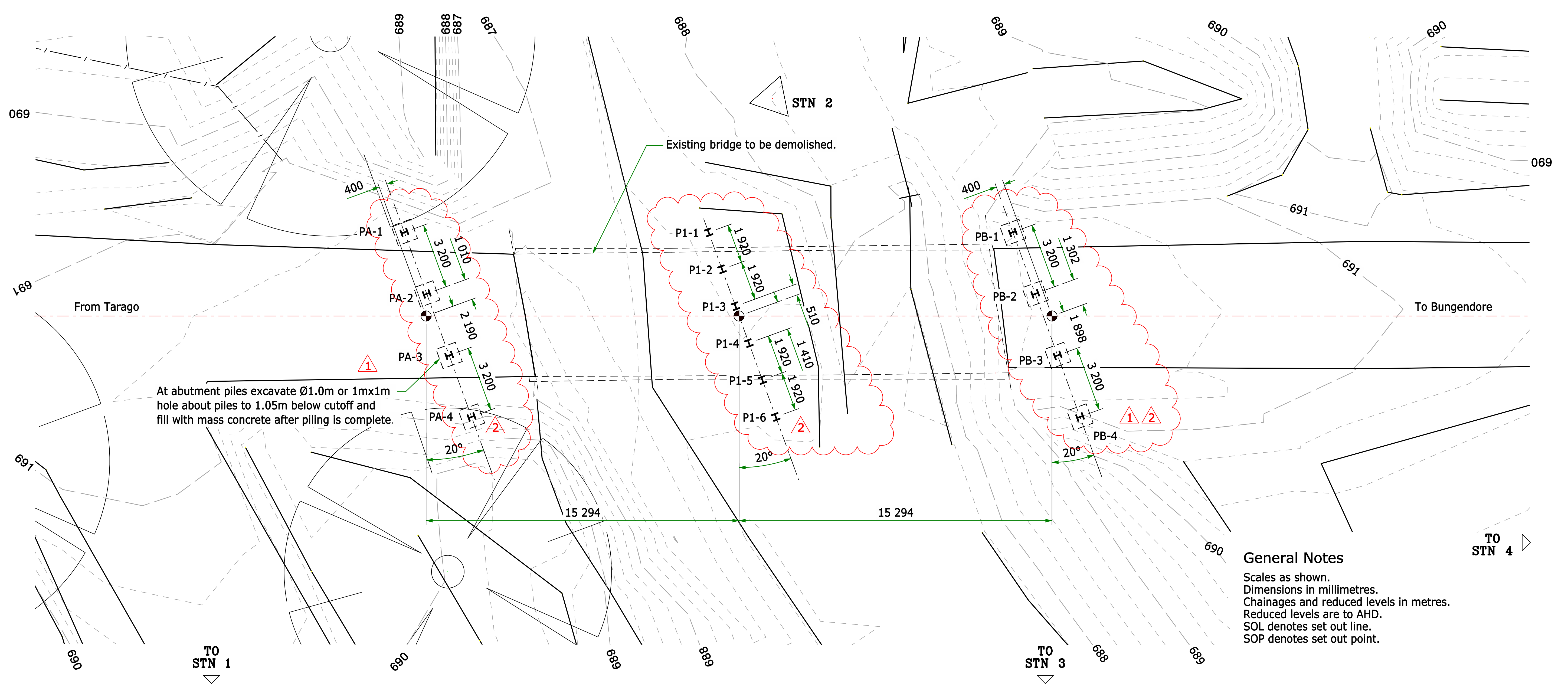
PALERANG COUNCIL

DESIGN BY:
jim alexander bridge design
PO Box 9140, WYOMING, NSW 2250
ABN 35 113 670 830 ph (02) 4329 0505, fax (02) 4328 4557

DESIGN: JRA
DRAWING: BNC
MANAGER JIM ALEXANDER BRIDGE DESIGN

Shire of Palerang Tarago Road MR268
BRIDGE OVER TURALLO CREEK
at Bungendore
GENERAL ARRANGEMENT

JOB NUMBER	DOCUMENT NUMBER	SHEET	REVISION
0712	D02	SHEET 2 OF 21	1



General Notes

Scales as shown.
Dimensions in millimetres.
Chainages and reduced levels in metres.
Reduced levels are to AHD.
SOL denotes set out line.
SOP denotes set out point.

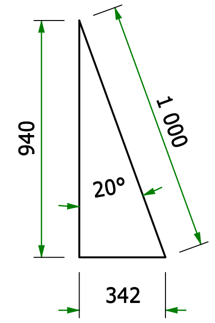
Pile number	Location		Design Ultimate vertical load Nu(kN)	Design Ultimate Bending load (kNm)	Cut off level	Anticipated founding level	Calculated set for 1.39*Nu (mm/10 blows)
	Easting	Northing					
PA-1	900.597	398.105	1 200	330	690.450	671.0	110
PA-2	897.434	397.625	1 200	330	690.450	671.0	110
PA-3	894.270	397.144	1 200	330	690.450	671.0	110
PA-4	891.106	396.663	1 200	330	690.450	671.0	110
P1-1	897.669	383.528	1 200	80	687.400	670.0	110
P1-2	895.770	383.239	1 200	80	687.400	670.0	110
P1-3	893.872	382.951	1 200	80	687.400	670.0	110
P1-4	891.974	382.663	1 200	80	687.400	670.0	110
P1-5	890.076	382.374	1 200	80	687.400	670.0	110
P1-6	888.177	382.086	1 200	80	687.400	670.0	110
PB-1	894.739	368.950	1 200	330	690.395	669.0	110
PB-2	891.575	368.469	1 200	330	690.395	669.0	110
PB-3	888.411	367.988	1 200	330	690.395	669.0	110
PB-4	885.247	367.508	1 200	330	690.395	669.0	110

TABLE 1 - PILING DETAILS

Local coordinates are abbreviated MGA coordinates.
for MGA coordinates add 721 000E, 6 096 000N

	Easting	Northing	RL
SOP A	721 896.381	6 096 397.869	
SOP 1	721 893.368	6 096 382.874	
SOP B	721 890.355	6 096 367.880	
STN 1	721 857.027	6 096 396.127	689.408
STN 2	721 903.455	6 096 379.163	688.260
STN 3	721 862.727	6 096 367.437	688.075
STN 4	721 865.175	6 096 340.788	689.940
STN 5	721 875.394	6 096 312.456	689.749
STN 6	721 889.915	6 096 291.080	689.384

TABLE 2 - SETOUT



SKEW DIAGRAM

1:200 0 1m 2m 3m 4m 5m

Piling Notes

Piles shall be 310UC118 grade 300 steel piles.
The anticipated founding levels are estimates. As the contractor has elected to change the pile type, adjustments to contract length shall be made by comparing measured driving resistances from CAPWAP against the calculated performance of the tendered concrete piles.
The calculated sets are for a net driving energy of 50kJ and 18m length of pile.
The maximum net driving energy shall be 70kJ.
The minimum penetration depth of the piles shall be 12m below the soffit of pile cap/existing surface level

REV	DATE	COMMENTS	DFT	CHK
3	13/05/08	Missing pile coordinates added	JRA	JRA
2	01/05/08	Piling changed to driven steel	JRA	JRA
1	03/12/07	Mass concrete block added at abutments	JRA	JRA

PALERANG COUNCIL

DESIGN BY:
jim alexander bridge design
PO Box 9140, WYOMING, NSW 2250
ABN 35 113 670 830 ph (02) 4329 0505, fax (02) 4328 4557

DESIGN: JRA
DRAWING: BNC
MANAGER JIM ALEXANDER BRIDGE DESIGN

ISSUED FOR CONSTRUCTION

DRAWING SCALES TRUE AT A3

Shire of Palerang Tarago Road MR268

BRIDGE OVER TURALLO CREEK

at Bungendore

SUBSTRUCTURE SETOUT

JOB NUMBER	DOCUMENT NUMBER		REVISION
0712	D03	SHEET 3 OF 21	3

Appendix B

-

Impact of Measure 6 on Turalla Property

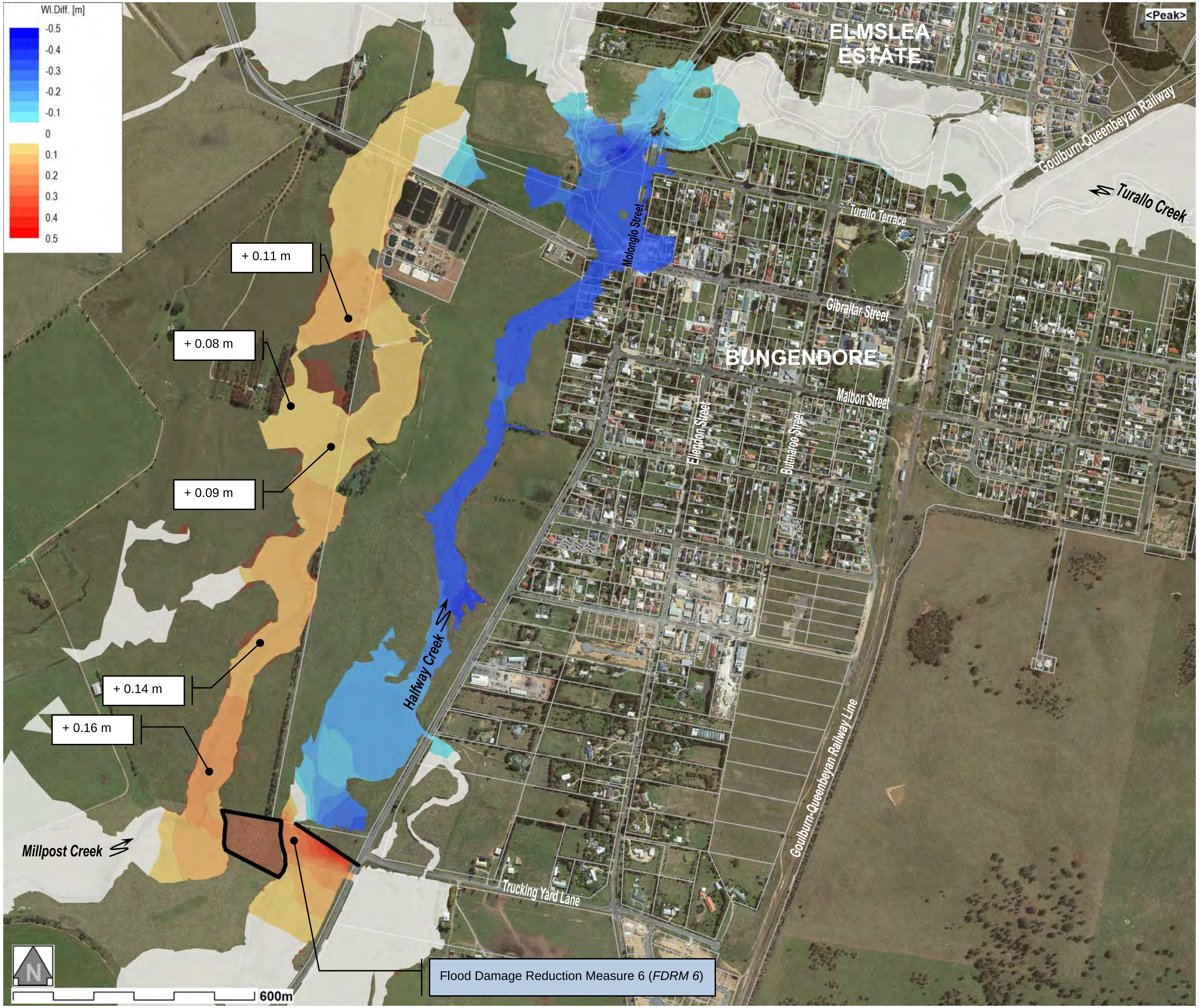
FIGURE B1

WorleyParsons
resources & energy

3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-figA1_Turalla Property.doc

TURALLA PROPERTY

FIGURE B2



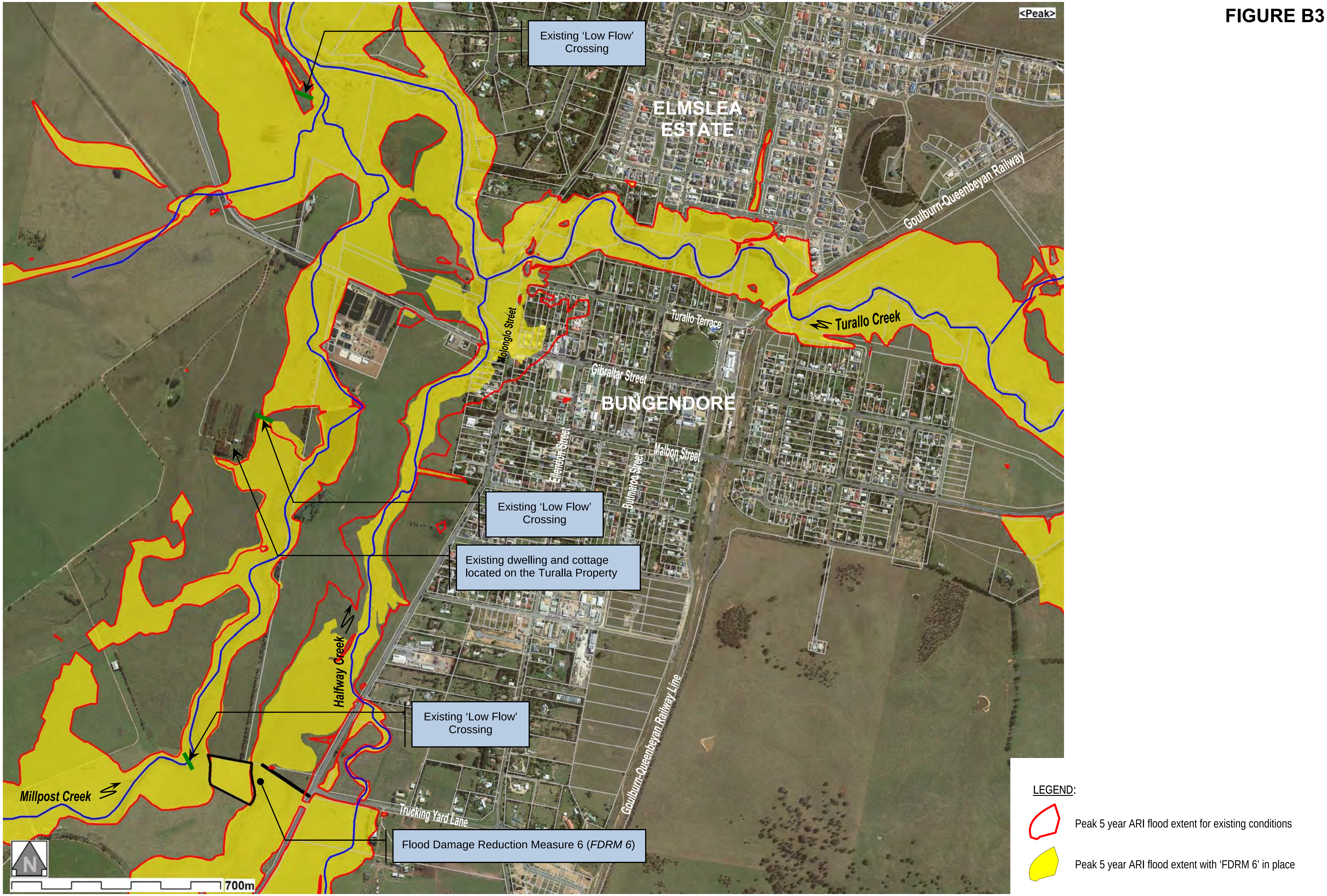
WorleyParsons

resources & energy

3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-fig1_FRM 6 Impacts (5yr).doc

VARIATION IN PEAK 5 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF 'FDRM 6'

FIGURE B3



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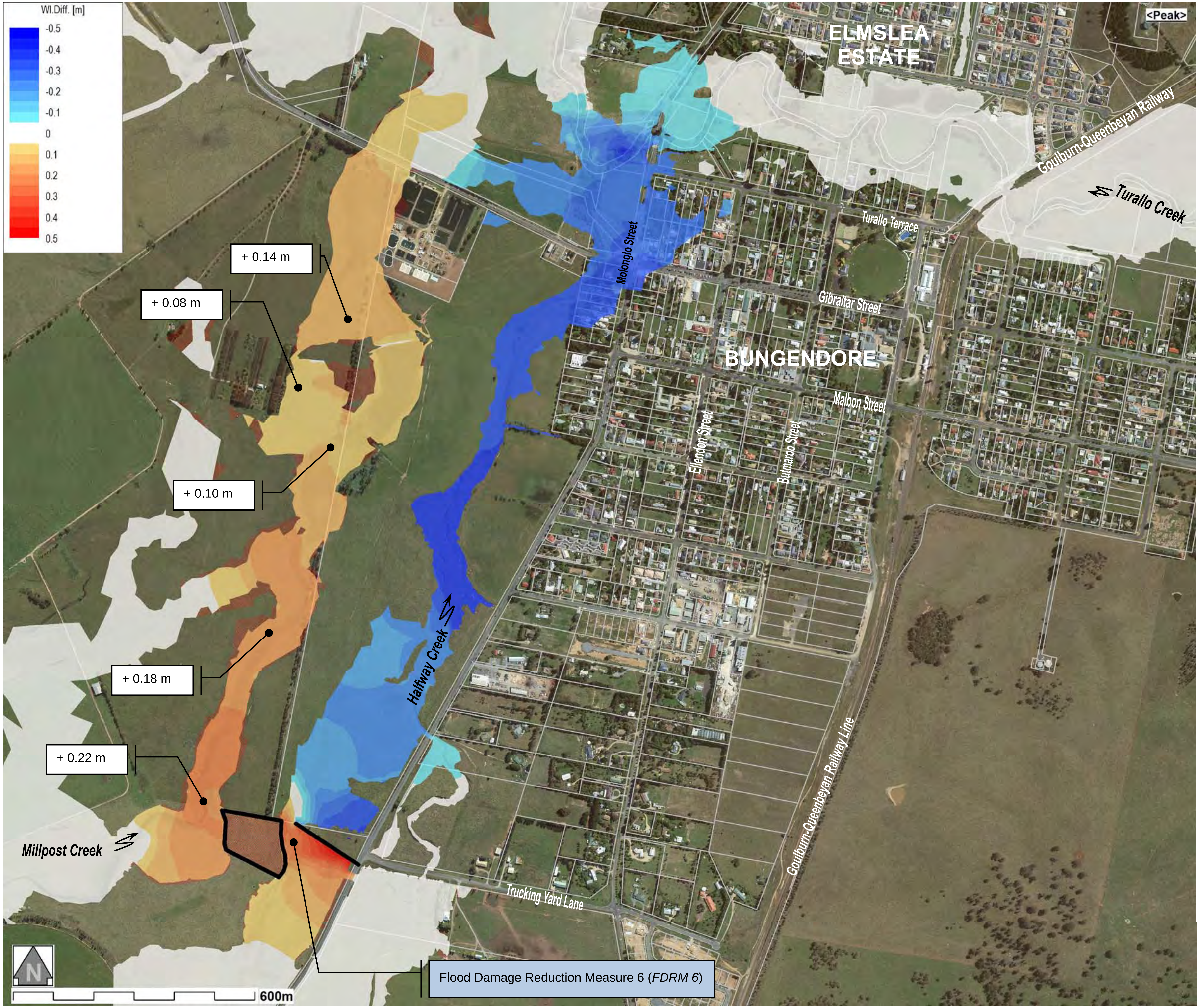
VARIATION IN PEAK 5 YEAR RECURRENCE FLOOD EXTENTS DUE TO INCROPORATION OF 'FDRM 6'

FIGURE B4



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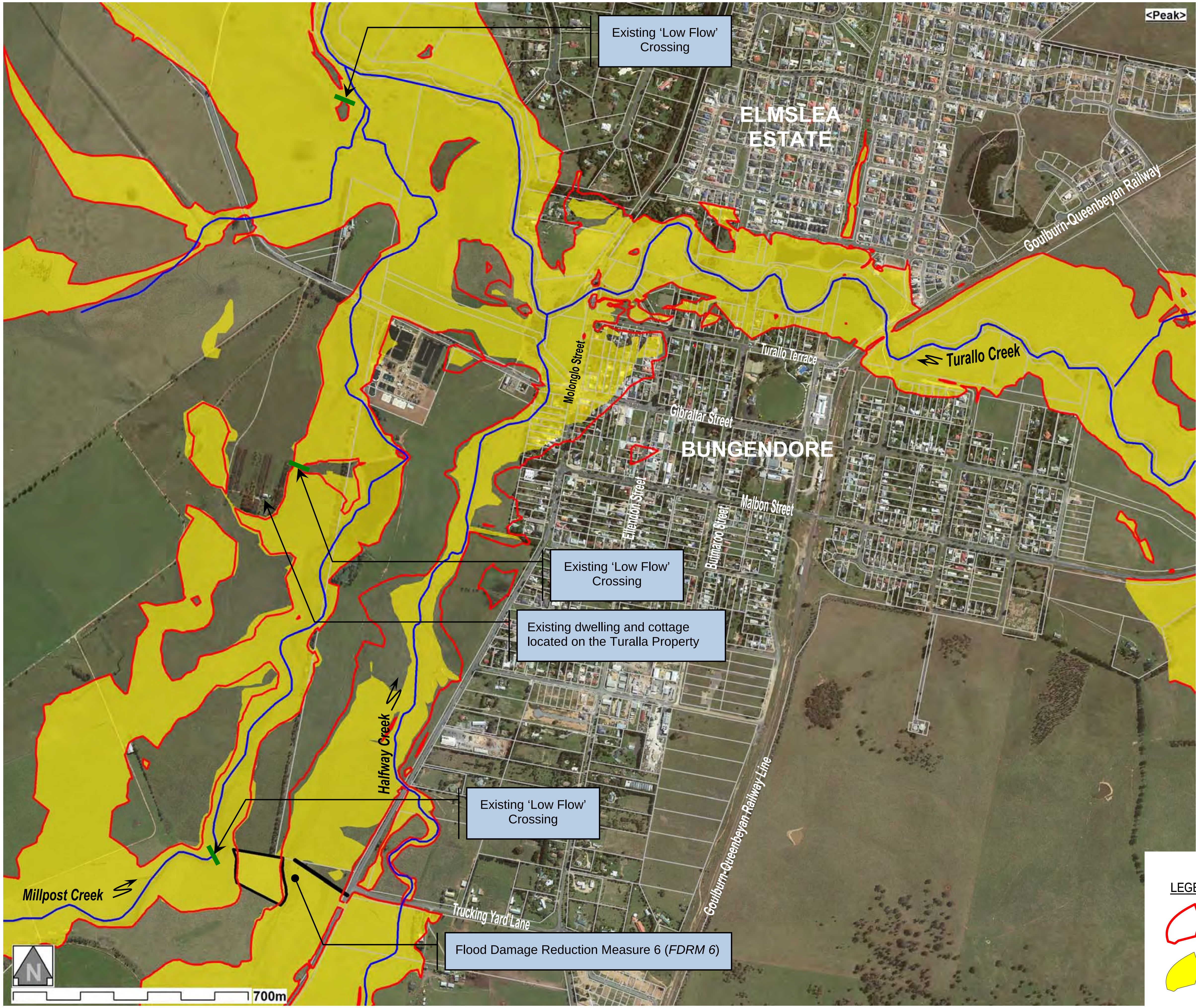
3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-fig3_FRM 6 Level DIFF (20yr).doc

VARIATION IN PEAK 20 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF 'FDRM 6'

FIGURE B5



LEGEND:

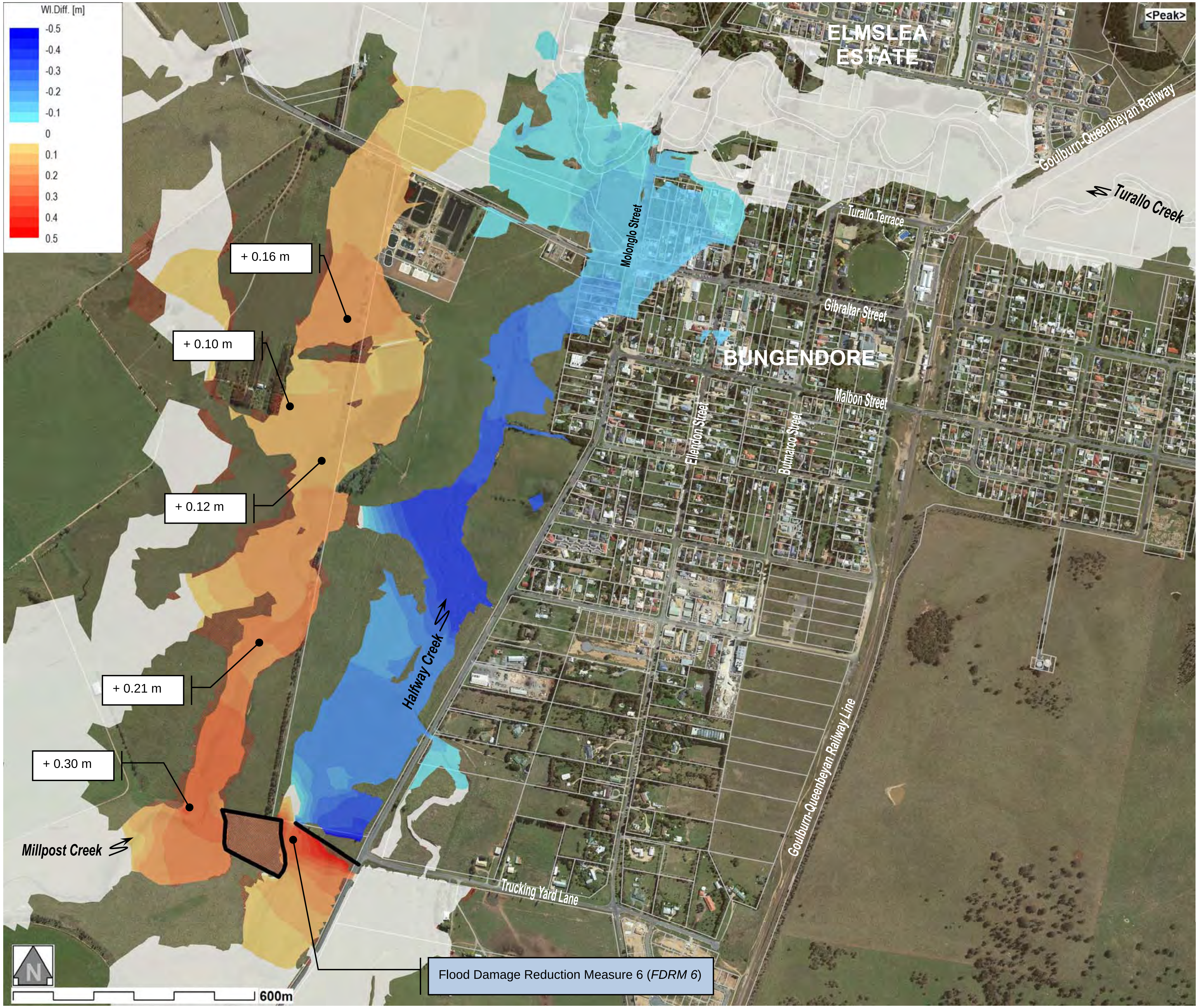
- Peak 20 year ARI flood extent for existing conditions
- Peak 20 year ARI flood extent with 'FDRM 6' in place

WorleyParsons
resources & energy

3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-fig6_FRM 6 Extent DIFF (20yr).doc

VARIATION IN PEAK 20 YEAR RECURRENCE FLOOD EXTENTS DUE TO INCROPORATION OF '<u>FDRM 6</u>'

FIGURE B6

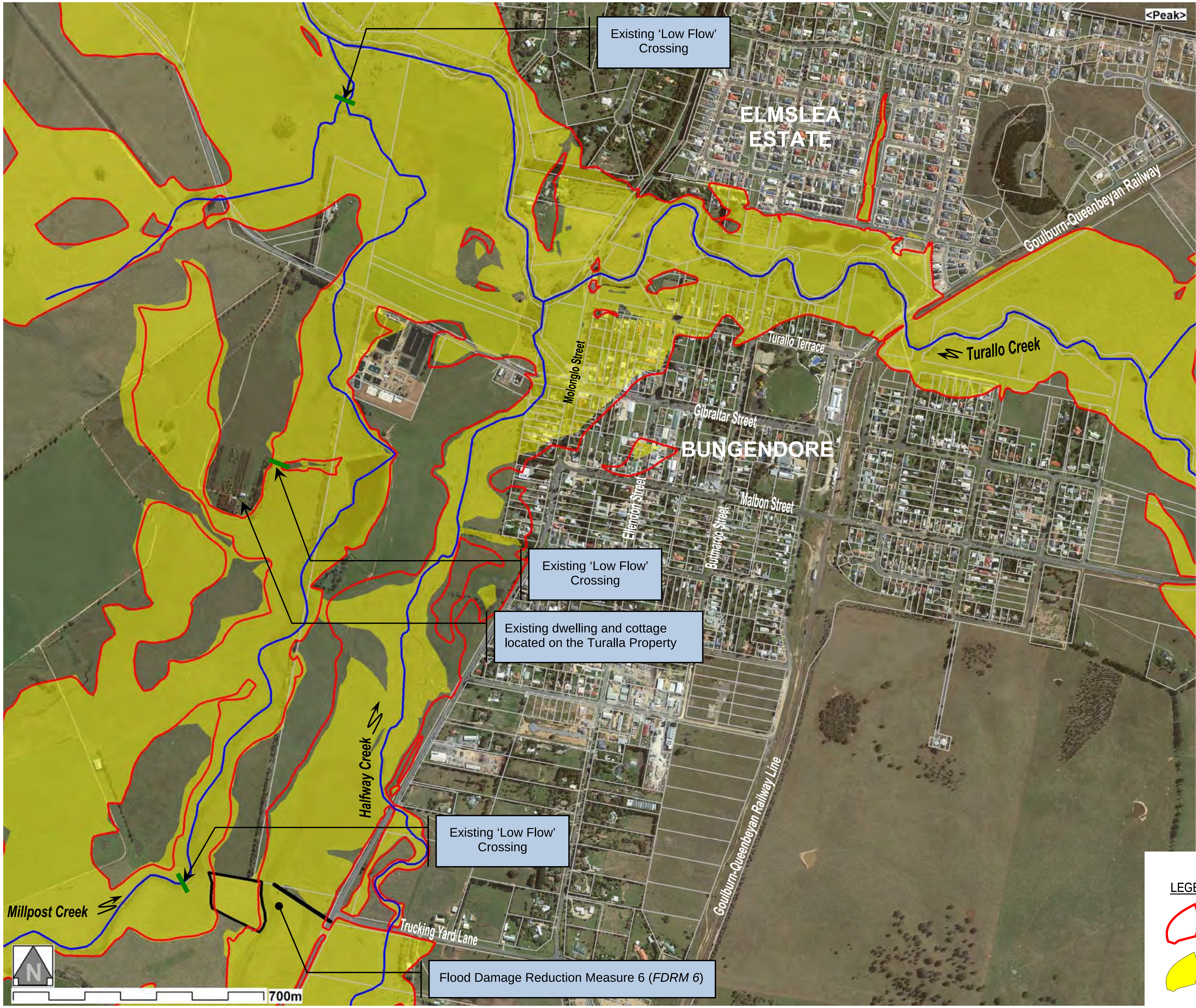


WorleyParsons
resources & energy

3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-fig5_FRM 6 Level DIFF (100yr).doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD LEVELS DUE TO INCROPORATION OF 'FDRM 6'

FIGURE B7



WorleyParsons
resources & energy

3777 - Bungendore Floodplain Risk Management Study
fg3777rg130325-fig6_FRM 6 Extent DIFF (100yr).doc

VARIATION IN PEAK 100 YEAR RECURRENCE FLOOD EXTENTS DUE TO INCROPORATION OF '<u>FDRM 6</u>'

Appendix C

-

Stage Damage Curves

TABLE C1 **Adopted Stage Damage Curves**

DEPTH (m)	DAMAGE COSTS WITH RESPECT TO DEPTH ($ AUD)						
	RESIDENTIAL R	COMMERCIAL LIGHT CL	COMMERCIAL MEDIUM CM	COMMERCIAL HEAVY CH	INDUSTRIAL LIGHT IL	INDUSTRIAL MEDIUM IM	INDUSTRIAL HEAVY IH
0	9,516	0	0	0	22,661	46,655	93,309
0.1	25,407	3,333	6,665	13,997	30,659	61,317	123,968
0.2	56,048	6,665	13,330	27,993	40,518	76,338	149,154
0.3	58,767	10,665	19,995	38,657	46,655	93,309	185,285
0.4	61,485	12,663	25,327	49,988	54,653	107,972	215,944
0.5	64,204	14,663	30,660	61,318	63,561	123,316	252,504
0.6	66,922	17,330	35,991	69,316	72,228	135,060	281,865
0.7	69,640	19,995	41,323	77,315	77,313	154,626	309,253
0.8	72,359	23,328	47,988	92,644	85,311	170,622	344,110
0.9	75,077	23,995	49,321	99,976	93,309	193,283	386,566
1	77,796	26,660	54,653	107,973	99,974	201,281	402,562
1.1	80,514	28,660	57,986	115,971	102,646	207,875	420,449
1.2	83,232	30,660	61,318	123,970	105,582	211,399	422,798
1.3	85,951	32,437	66,650	134,189	107,972	215,944	434,542
1.4	88,669	32,881	67,983	136,411	112,041	217,271	434,542
1.5	91,388	33,325	69,316	138,633	115,970	223,942	447,884
1.6	94,106	34,214	70,650	141,299	119,205	225,492	455,682
1.7	96,825	35,102	71,983	143,965	122,142	227,841	458,031
1.8	99,543	36,880	74,648	149,296	123,968	231,940	463,879
1.9	102,261	37,769	75,981	151,963	126,634	233,273	466,545
2	104,980	38,657	77,315	154,629	126,634	233,273	466,545
2.1	107,698	39,990	79,980	159,961	126,634	233,273	466,545
2.2	108,286	39,990	79,980	159,961	126,634	233,273	466,545
2.3	108,874	39,990	79,980	159,961	126,634	233,273	466,545
2.4	109,462	39,990	79,980	159,961	126,634	233,273	466,545
2.5	110,050	39,990	79,980	159,961	126,634	233,273	466,545
2.6	110,638	39,990	79,980	159,961	126,634	233,273	466,545
2.7	111,226	39,990	79,980	159,961	126,634	233,273	466,545
2.8	111,814	39,990	79,980	159,961	126,634	233,273	466,545
2.9	112,402	39,990	79,980	159,961	126,634	233,273	466,545
3	112,990	39,990	79,980	159,961	126,634	233,273	466,545
3.1	113,578	39,990	79,980	159,961	126,634	233,273	466,545
3.2	116,519	39,990	79,980	159,961	126,634	233,273	466,545
3.3	119,459	39,990	79,980	159,961	126,634	233,273	466,545

Appendix D

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Cost Estimates For Damage Reduction Measures

Bungendore FPRMS Measure 1 - Turallo Terrace Levee Extension & Upgrade

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				
	- 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

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

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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	%	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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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	%	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

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 & Vegetation Removal				
	- equipment 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				
	- equipment 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 E

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Benefit-Cost Assessment

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Option S1

Measures 4 and 6

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	2041/42
Benefits (Damage Reduction)		-	50	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192	192
Vegetation Removal / Creek Re-shaping	278	278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Darmody Diversion	1,409	400	1,009	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		678	1,009	3	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Net Balance		- 678	- 959	189	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184

Present value of Benefits	2,079
Present value of Costs	1,600
Net Present Value	479
Internal rate return (%)	10.1%
Benefit Cost Ratio	**1.30**
Real Discount Rate (%)	7%

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Option S2

Measures 1, 4 and 6

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	2041/42
Benefits (Damage Reduction)		-	50	50	150	150	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217	217
Levee Upgrade + Extension	2,494	600	1,000	800	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetation Removal / Creek Re-shaping	278	278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Darmody Diversion	1,409	-	-	200	900	309	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	4	9	14	19	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		878	1,000	1,004	1,003	323	19	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Net Balance		- 878	- 950	- 954	- 853	- 173	198	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196

Present value of Benefits	2,109
Present value of Costs	3,683
Net Present Value	- 1,574
Internal rate return (%)	1.7%
Benefit Cost Ratio	**0.57**
Real Discount Rate (%)	7%

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Option S3A

Measures 1, 3, 4 and 6

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	*2013/14*	*2014/15*	*2015/16*	*2016/17*	*2017/18*	*2018/19*	*2019/20*	*2020/21*	*2021/22*	*2022/23*	*2023/24*	*2024/25*	*2025/26*	*2035/36*	*2036/37*	*2037/38*	*2038/39*	*2039/40*	*2040/41*	*2041/42*
Benefits (Damage Reduction)		-	**50**	**50**	**150**	**200**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**	**242**
Levee Upgrade + Extension	2,494	600	1,000	800	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overflow Channel - Tarago Road	595	-	-	200	395	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetation Removal / Creek Re-shaping	278	278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Darmody Diversion	1,409	-	-	-	409	1,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	4	9	14	19	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		**878**	**1,000**	**1,004**	**907**	**1,014**	**19**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**	**24**
Net Balance		**- 878**	**- 950**	**- 954**	**- 757**	**- 814**	**223**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**	**218**

Present value of Benefits	2,352
Present value of Costs	4,124
Net Present Value	- 1,772
Internal rate return (%)	1.6%
Benefit Cost Ratio	**0.57**
Real Discount Rate (%)	7%

Option S3B

Measures 2, 3, 4 and 6

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	*2013/14*	*2014/15*	*2015/16*	*2016/17*	*2017/18*	*2018/19*	*2019/20*	*2020/21*	*2021/22*	*2022/23*	*2023/24*	*2024/25*	*2025/26*	*2035/36*	*2036/37*	*2037/38*	*2038/39*	*2039/40*	*2040/41*	*2041/42*
Benefits (Damage Reduction)		-	**50**	**200**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**	**210**
Levee Upgrade	687	300	387	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overflow Channel - Tarago Road	595	300	295	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetation Removal / Creek Re-shaping	278	278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Darmody Diversion	1,409	-	400	1,009		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	4	10	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		**878**	**1,082**	**1,013**	**10**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**
Net Balance		**- 878**	**- 1,032**	**- 813**	**200**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**	**195**

Present value of Benefits	2,262
Present value of Costs	2,734
Net Present Value	- 473
Internal rate return (%)	5.0%
Benefit Cost Ratio	**0.83**
Real Discount Rate (%)	7%

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Option S4A

Measures 1, 3 and 4

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	2041/42
Benefits (Damage Reduction)		-	50	50	150	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232
Levee Upgrade + Extension	2,494	600	1,000	800	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overflow Channel - Tarago Road	595		-	-	595	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetation Removal / Creek Re-shaping	278	278	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	4	9	13	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		878	1,000	804	698	13	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Net Balance		- 878	- 950	- 754	- 548	219	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215	215

Present value of Benefits	2,292
Present value of Costs	3,033
Net Present Value	- 741
Internal rate return (%)	4.2%
Benefit Cost Ratio	**0.76**
Real Discount Rate (%)	7%

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Option S4B

Measures 2, 3 and 4

Values in $ '000 (Real Terms)		Year 1	2	3	4	5	6	7	8	9	10	11	12	13	14	24	25	26	27	28	29	30
		2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2035/36	2036/37	2037/38	2038/39	2039/40	2040/41	2041/42
Benefits (Damage Reduction)		-	**50**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**	**221**
Levee Upgrade	687	300	387			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Overflow Channel - Tarago Road	595	200	395	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vegetation Removal / Creek Re-shaping	278	278	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Maintenance		-	-	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Costs		**778**	**782**	**4**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**8**
Net Balance		**- 778**	**- 732**	**217**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**	**213**

Present value of Benefits	2,386
Present value of Costs	1,490
Net Present Value	897
Internal rate return (%)	12.8%
Benefit Cost Ratio	**1.60**
Real Discount Rate (%)	7%