Greater Hume Shire Council

Walla Walla Floodplain Risk Management Study and Plan

Final Report

October 2017

Cover photograph: Flooding in Queen Street during October 2010. The Queen Street Drain is submerged between the road and the chain mesh security fence.

Preface

The NSW State Government's Flood Policy aims to provide solutions to existing flooding problems and ensure that new development within flood prone areas is compatible with the prevailing flood risk and does not create additional flooding problems in other areas.

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

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

- Flood Study – determines the nature and extent of the flooding problem
- Floodplain Risk Management Study – evaluates management options for the floodplain in respect of both existing and proposed development
- Floodplain Risk Management Plan – the formal plan adopted by Council for the management of the floodplain
- Plan Implementation – implementation of the various measures proposed by the Plan

This report documents the above second and third stages in the process (Floodplain Risk Management Study and Floodplain Risk Management Plan). It follows the completion of the Walla Walla Flood Study in early 2017.

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

Table of Contents

Table Index

Figure Index

Appendices

Executive Summary

The Walla Walla Floodplain Risk Management Study and Plan was commissioned by the Greater Hume Shire Council.

The study has been carried out in accordance with the NSW Government's Floodplain Development Manual (2005). 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 the risk of private and public losses resulting from floods.

The management of flood-prone land within urban areas remains the responsibility of local government. The NSW State Government provides funding to assist local councils with the development of floodplain risk management plans and their implementation.

The development of a Floodplain Risk Management Plan for Walla Walla follows the completion of the Walla Walla Flood Study in early 2017. The Flood Study report (GHD, 2017) documents flooding conditions at Walla Walla based on an assessment of historical records and computer modelling using detailed terrain data for the floodplain.

Community Consultation

Community consultation activities are documented in Section 2 of this report.

The project has been overseen by Council's Floodplain Risk Management Committee. The Committee met regularly during the project to review progress and provide direction for future activities. Three local community representatives from Walla Walla served on this Committee.

Both the 2017 Flood Study report and this FRMS&P report were placed on public exhibition in draft form to provide an opportunity for submissions from the public. Public forums were held during the public exhibition process. Consultation with directly affected landholders was also undertaken during the assessment of mitigation options.

Flooding Conditions and Impacts at Walla Walla

Flooding conditions and impacts are summarised in Section 3 of this report. Details are documented within the Walla Walla Flood Study report (GHD, 2017).

The hydraulic modelling carried out as part of the 2017 Walla Walla Flood Study has enabled detailed flood mapping to be prepared for a range of floods. Events modelled consist of the 5, 10, 20, 50, 100, 200 and 500 year ARI floods and an extreme event. Mapping prepared for each event defines the height, depth and extent of flooding.

As is typical for many small country towns within the NSW Riverina, during large flood events there is widespread shallow sheet flow inundation both within and outside the Walla Walla township. Depths of flooding outside the incised waterways and drains are generally less than 0.3 metre up to and including the 100 year ARI event. Consequently flooding conditions outside the incised waterway corridors are generally characteristic of Low Hazard conditions.

Serious flood impacts at Walla Walla are limited to the south (upstream) side of the railway line. The major source of serious flooding impacts is the inability of the Queen Street Waterway and downstream Queen Street Drain to confine flood flows leading to widespread flooding of existing developed properties between Queen Street and the railway line.

All of the roadways into Walla Walla are subject to flooding. Roads are therefore closed to light vehicular traffic for short periods until floodwaters recede.

Flood damage analysis undertaken identified that there are an estimated 23 properties subject to above floor flooding in a 100 year ARI event. Eleven of these properties are residential, with the remaining twelve commercial / industrial. The estimated average annual flood damage is $250,000 per annum. The average depth of 100 year ARI above floor flooding is 0.16 metre. The maximum depth of above floor flooding is 0.57 metre.

Floodplain Management Options – Planning and Development Controls

Property modification mitigation measures are described in Section 5 of this report.

Integral to all floodplain risk management plans is the development of flood based planning and development controls. These are important for ensuring that future development occurs in a manner which is compatible with the flood risk. This includes excluding development from high risk areas and imposing appropriate controls (e.g. minimum floor levels) in low risk areas. The planning and development controls largely based on flood mapping prepared as part of the 2017 Walla Walla Flood Study and refined as part of this Floodplain Risk Management Study.

The proposed flood based planning and development controls for Walla Walla are documented in Appendix A. Figures A1, A2 and A3 in Appendix A are the maps which define the respective areas which are subject to these controls.

Most of the areas subject to inundation at Walla Walla have been designated as Flood Fringe (refer to Figure A2) and Low Hazard (refer to Figure A3). Development controls for these areas are primarily in the form of minimum floor level requirements.

In contrast, development controls for areas designated as Floodway and High Hazard are very restrictive with development largely excluded. Areas designated as Floodway and High Hazard are however generally limited to the waterway corridors as shown on Figures A2 and A3.

Floodplain Management Options – Flood Response Improvement Measures

Flood response improvement mitigation measures are described in Section 6 of this report.

Flood response measures include improvements to the flood warning system and activities to increase the level of flood awareness in the local community.

Flood warning system improvements are not proposed given the small catchment size at Walla Walla which typically results in flooding occurring within less than one hour of the flood inducing rainfall. Telemetered rainfall and stream height gauges are more effective on larger catchments with sufficient time for residents to respond to gauge data.

The effectiveness of community awareness related measures is also limited by the short response times available. The following low cost measures are proposed:

- Provide detailed flood information on Council’s web site
- Inclusion of expanded flooding information on Section 149 certificates issued by Council

The SES will prepare a Local Flood Plan for the Shire once all of the Floodplain Risk Management Plans within the Shire have been completed. The Local Flood Plan will detail operations relating to flood preparedness, flood response measures and flood recovery measures.

It is important that flood data be collected in future large floods at Walla Walla. This includes recording peak flood heights and any instances of above floor flooding. The data will be most useful for assisting with any future updates of the Floodplain Risk Management Plan.

Floodplain Management Options – Flood Modification Measures

Flood modification mitigation measures are described in Section 7 of this report.

The assessment of mitigation options focused on potential measures to reduce the impact from flooding caused by the Queen Street Waterway. Runoff from the Queen Street Waterway catchment discharges to the Queen Street Drain which is not able to cope with the amount of incoming flow in large floods. The mitigation option assessment found that:

- Retardation of flows is not practical due to the extremely large storage volume which would be required to adequately reduce downstream peak flows through the town
- A major upgrade of the Queen Street Drain is not practical given there is very little if any room for further enlarging the existing drain along much of its route through town
- Extending the Queen Street Drain a further 200 metres upstream of where it currently terminates will provide some relief from grounds and other nuisance level flooding in small floods, however will not alleviate serious impacts in large floods
- Given the above, the diversion of flows from the Queen Street Waterway on the upstream side of town such that the diverted flow bypasses the town is the only practical means by which serious flooding impacts can be largely eliminated
- A number of Queen Street Waterway diversion channel routes were assessed. The preferred route (refer to Figure 12) involves a 2.4 km diversion channel located 400 m east of the sportsground which discharges to a natural depression on the downstream side of the town
- There are a number of complications with the preferred diversion channel route, notably the loss of native trees along the route

The only real alternative to providing flood relief to those residential properties currently at risk of above floor flooding, other than the diversion channel, is through voluntary house raising. A preliminary assessment of the practicality of raising the floor level of the houses at risk has however concluded that floor level raising is unlikely to be practical for most of them.

The following recommendations have therefore made in regards to flood modifications for Walla Walla:

- Incised channel to be established for 200 m upstream of the existing upstream limit of the Queen Street Drain with a low level berm positioned on the north side of the channel. This will confine flows to the Queen Street Drain in minor floods
- Walla West Waterway railway bridge to be removed and a 30 m opening in the railway established. This will reduce 100 year ARI flood levels on the upstream side of the bridge by 0.5 metre
- Diversion channel to be constructed along the proposed 2.4 km route subject to the results of a vegetation impact assessment study to be completed in advance of the detailed design. The diversion channel is expected to eliminate above floor flooding within Walla Walla except for one non residential property only

Floodplain Risk Management Plan

The Floodplain Risk Management Plan for Walla Walla is presented in Section 8 of this report. It summarises the adopted floodplain management measures. The adopted measure priorities, indicative capital costs and responsible implementation organisations are listed in Table 9.

Recommended floodplain management measures consist of:

- Implementation of the various land use planning and development control actions (e.g. incorporation of flood related controls into Council's LEP and DCP)
- Include expanded flooding information on Section 149 certificates issued by Council
- Preparation of a Local Flood Plan for the Greater Hume Shire
- Implementation of the other community awareness measures
- Implementation of the proposed flood modification measures

Council will be able to apply for funding assistance to implement the recommended floodplain management measures which do not form part of their core activities. Potential funding sources include the NSW State Government and Australian Commonwealth Government funding programmes for the implementation of flood risk mitigation measures and the SES for flood response improvement measures.

1. Introduction

The Walla Walla Floodplain Risk Management Study and Plan (FRMS&P) project has been undertaken to provide the Greater Hume Shire Council and other stakeholders with a Floodplain Risk Management Plan (FRMP) which documents flooding risks at Walla Walla and identifies preferred mitigation options for implementation to reduce future flood risks and associated damages.

The preparation of the Walla Walla FRMP follows the recent completion of plans for Culcairn, Holbrook, Henty and Jindera within the Greater Hume Shire. The FRMP for Walla Walla has been prepared in accordance with the NSW Government's Floodplain Development Manual (NSW, 2005).

Walla Walla is located approximately 30 km north of Albury and 1 km east of Petries Creek as shown on Figures 1 and 2. Petries Creek does not directly impact on flooding conditions within the town.

The town is affected by flooding from two local unnamed waterways (refer to Figure 2).

One of the two waterways is referred to as the Walla West Waterway in this report. This waterway skirts around the western and northern fringes of the town and has a catchment area of 18 km^2 where it crosses Lookout Road.

The other waterway which has a significant impact on Walla Walla is referred to as the Queen Street Waterway in this report. This natural waterway with a catchment area of 4 km^2 drains to the Queen Street Drain which is aligned through the town as shown on Figure 2. During large flood events much of the flow from the Queen Street Waterway inundates the town area between Queen Street and the railway line.

Most of Walla Walla is not affected by anything other than nuisance flooding. There are however some parts of Walla Walla which are at risk of serious flooding impacts (above floor flooding).

The FRMS is documented in Sections 4 to 7 of this report. The FRMS evaluates management options for the study area floodplain giving consideration to hydraulic, environmental, social and economic issues.

The FRMP is documented in Section 8 of this report. The FRMP outlines the adopted strategies to manage flood risk and flood management issues. The FRMP will also assist the Council and other government agencies to make appropriate decisions in relation to future land use planning.

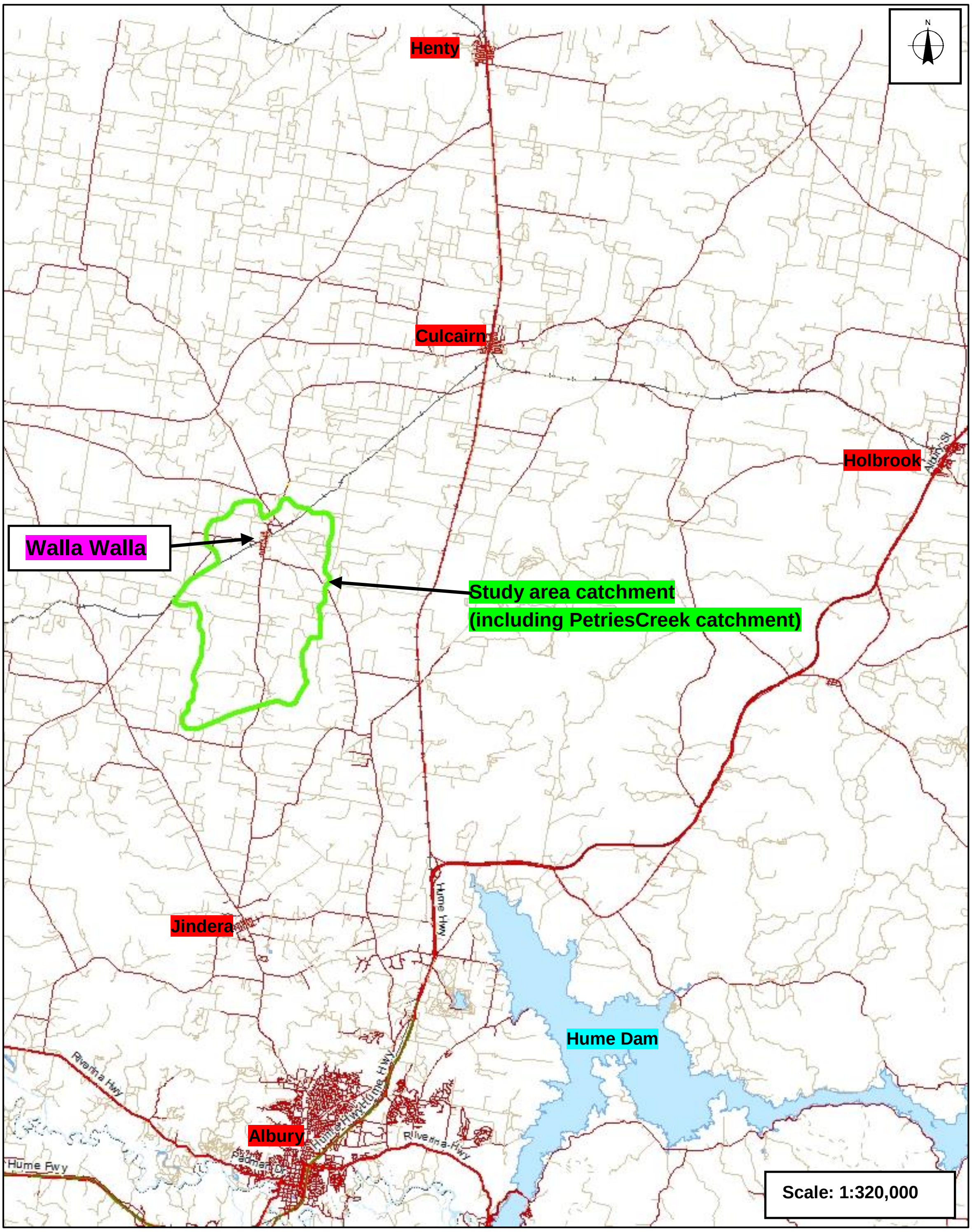


Figure 1 Walla Walla Locality and Catchment Plan

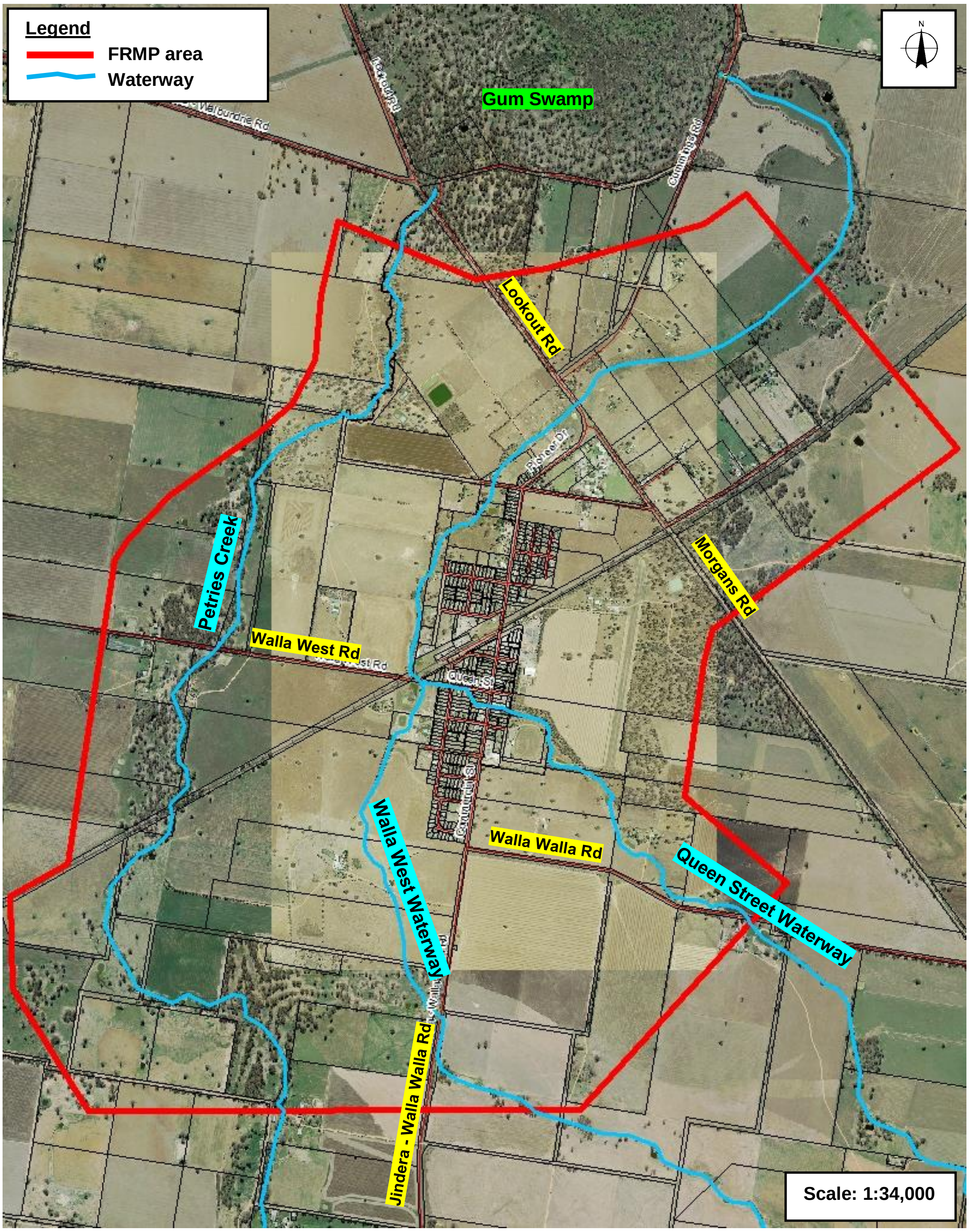


Figure 2 Walla Walla FRMP Area

2. Community Consultation

2.1 Overview

Community consultation forms an integral component of the floodplain management plan process. It is important that communities embrace ownership of the floodplain risk management plans and this requires their engagement during the preparation of the plans.

The objectives of the community consultation activities undertaken were as follows:

- To obtain any data held by the general public, local community groups or government agencies of relevance to the project
- To provide information to the community concerning the project including opportunities for the community to provide input into the development of the plan
- To seek feedback from the community on floodplain management issues and what views are held by the community in relation to flood mitigation options
- To seek feedback on the draft report documents produced including the Flood Study report and the FRMS&P report

2.2 Floodplain Risk Management Committee

Council established a Walla Walla Floodplain Risk Management (FRM) Committee to oversee the project. The FRM Committee included the following members:

- Three local community members
- Once Councillor (Committee chairperson)
- Two Council staff representatives
- Single representatives from OEH, SES, Department of Planning and the BOM

The FRM Committee inception meeting took place in February 2016. The Committee subsequently met in May, August and October 2016, and February, March and July 2017. The Committee provided feedback on progress reports, input into the nature of community consultation activities during the project, advice on local flooding conditions and past impacts, and discussion in relation to potential flood mitigation options.

2.3 Stage 1, 2 and 3 Community Consultation Activities

The following community consultation activities were undertaken during the Flood Study phase:

- Three meetings with the FRM Committee
- Community Engagement Guide distributed to all Walla Walla residents and businesses in March 2016
- Questionnaire distributed to all Walla Walla residents and businesses in March 2016
- Community flood forum meeting held at Walla Walla in April 2016
- Public exhibition of the draft Flood Study report in November / December 2016
- Community flood forum meeting held at Walla Walla in December 2016 as part of the public exhibition process

Further details are provided in the Flood Study report (GHD, 2017).

The Walla Walla Flood Study (GHD, 2017) report was placed on public exhibition in November 2016 and subsequently adopted by Council at the May 2017 Council monthly meeting.

2.4 Stage 4 Community Consultation Activities

Landholders directly affected by the proposed diversion channel option under consideration were contacted and subsequently individually briefed on this option, either at a meeting on site or via a phone discussion.

Council adopted the draft Walla Walla FRMS&P report at the August 2017 Council monthly meeting for the purpose of placing the draft report on public exhibition.

The draft FRMS&P report was subsequently placed on public exhibition in September 2017. The public exhibition process included:

- Posting of the draft document on Council's web site
- Hard copies of the draft FRMS&P document were made available for viewing at notified locations
- Community public information forum was held at Walla Walla on the 12 September 2017

No public submissions on the draft Walla Walla FRMS&P report were received by Council. The final Walla Walla FRMS&P report was subsequently adopted by Council at the October 2017 Council monthly meeting.

3. Flood Study Summary

3.1 Overview

The two waterways which most impact on flooding conditions at Walla Walla (Walla West Waterway and Queen Street Waterway) are shown on Figure 2.

Other smaller local waterways and drains at Walla Walla are shown on Figure 3.

The Queen Street Drain is the continuation of the Queen Street Waterway through the town. The drain is a concrete lined channel. A total of seven culvert crossings are present along the drain route. The Queen Street Drain discharges into the Walla West Waterway on the upstream (south) side of the Corowa-Culcairn disused railway.

The disused railway line remains in place, despite it being decommissioned in 1991. Much of the railway route through town is raised. It is therefore a notable influence on flooding conditions.

The other significant drain present is the Edward Street Drain. Roadside drains within the Walla Walla Road and the Jindera – Walla Walla Road discharge to the Edward Street Drain. The Edward Street Drain discharges westwards and into the Walla West Waterway.

In large floods, a relatively small proportion of flows carried by the Walla West Waterway overflows into Petries Creek on the upstream (south) side of Walla Walla. Petries Creek itself does not influence flooding conditions within the town with the exception of the PMF event.

All of the waterways at Walla Walla ultimately discharge into Gum Swamp on the north side of town (refer to Figure 2). Gum Swamp itself has not impact on flooding conditions within the town.

3.2 Details

The Walla Walla Flood Study (GHD, 2017) identifies flooding conditions for a range of varying size flood events. The flood study consisted of the following stages:

- LiDAR terrain survey of Walla Walla township and the surrounds obtained in 2013. Outputs from the survey included a 1 m grid digital elevation model (DEM) of the ground surface
- Estimation of design flows for the local waterways including Petries Creek, Walla West Waterway, Queen Street Waterway and the local catchments within the immediate town area. Design flows were estimated using the XP-RAFTS hydrologic model
- Estimation of design flood levels, velocities and extents for a range of flood events using the TUFLOW two dimensional hydraulic model
- Preparation of hydraulic category and provisional flood hazard mapping
- Reporting including the flood map outputs

The following flood mapping is included in the 2017 Walla Walla Flood Study report:

- Design Flood Extent and Depth maps for the 5, 10, 20, 50, 100, 200 and 500 year ARI events and the PMF
- Provisional Flood Hazard mapping for the 20 and 100 year ARI design events
- Hydraulic Category mapping for the 20 and 100 year ARI design events

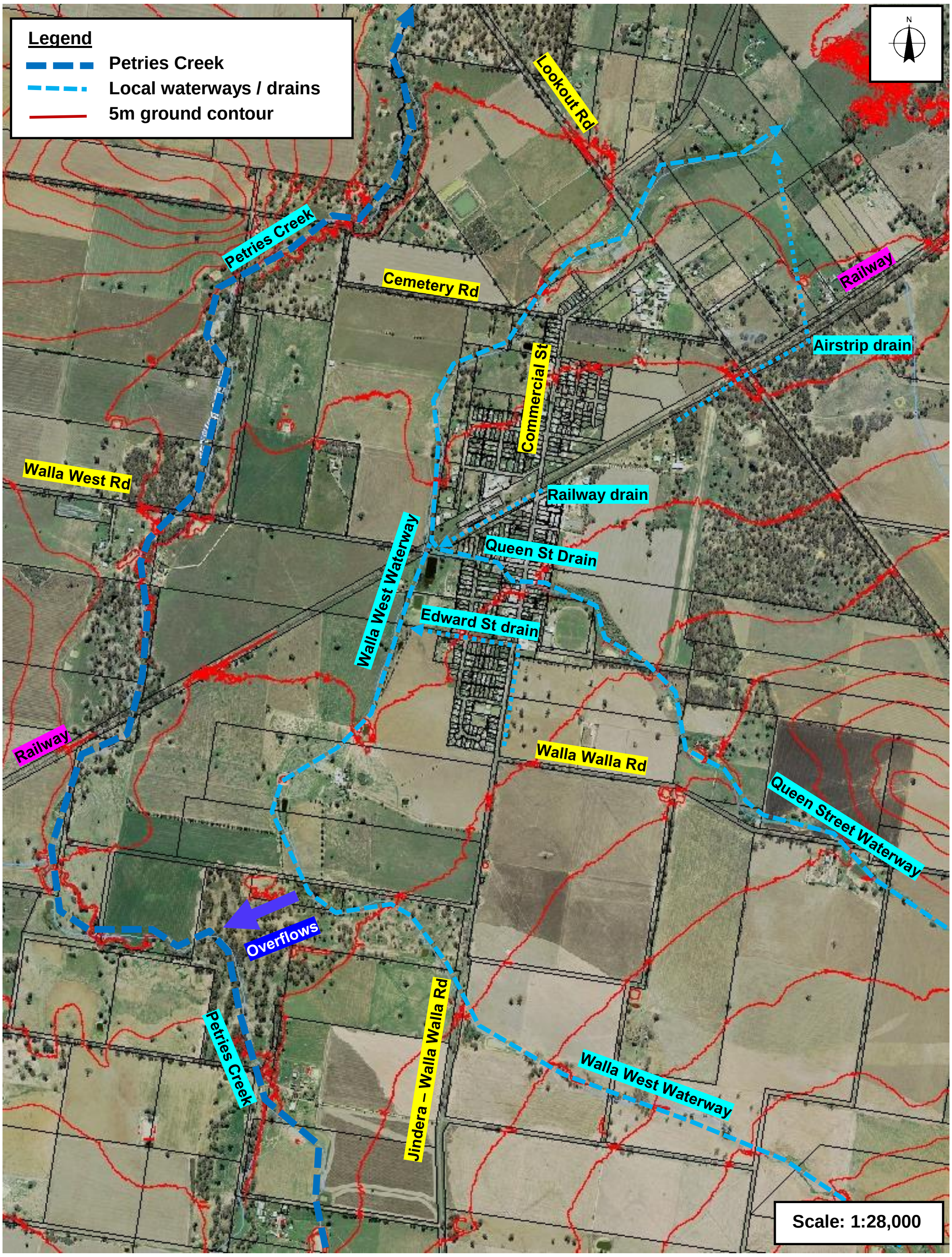


Figure 3 Local Waterways Plan

3.3 Key Outcomes

The hydrologic and hydraulic modelling carried out as part of the Flood Study identified that 3 m^3/s of flow from the Walla West Waterway discharges into Petries Creek in a 100 year ARI flood (equivalent to 20% of the Walla West Waterway peak flow) on the upstream side of Walla Walla (refer to Figure 3). This is the only location where there is an exchange of flows between the two waterways in a 100 year ARI flood, confirming that the town is not affected by Petries Creek in a 100 year ARI flood.

There are two significant waterway obstructions along the Walla West Waterway route at Walla Walla. These are described as follows:

- Cemetery Road – the 100 year ARI afflux is approximately 1.0 metre. The elevated flood levels do not however result in inundation of the east side residential properties, other than some marginal grounds flooding at the rear of these properties.
- Railway – the 100 year ARI afflux is approximately 0.9 metres. The elevated flood levels do impact on a small number of residential developed properties within the afflux zone.

The Walla West Waterway overtops Lookout Road, Walla West Road and the Jindera-Walla Walla Road. This result in short duration periods when the roads are closed to light vehicular traffic.

The Queen Street Waterway causes the majority of the serious flooding impacts within Walla Walla. This is due to a combination of:

- Little or no incised waterway channel capacity on the waterway approach to the eastern fringe of town north of the town sportsground
- Consequently shallow sheet flow overflows to the north of the sportsground and through the town area north of Queen Street prior to the Queen Street Drain running at capacity
- The Queen Street Drain has a discharge capacity approximately equivalent to the 2 year ARI design flow assuming 25% culvert blockage is present. The drain capacity is therefore not large enough to cope with major (e.g. 100 year ARI) flooding

Flooding from the Queen Street Waterway overtops the railway line on the west side of Commercial Street. The railway line surface is close to natural ground levels at this location. Overtopping flows in a 100 year ARI flood are less than 1 m^3/s and are not though to cause serious impacts provided the house floor levels north of the railway line are elevated higher than 0.1 metre above the natural ground level.

The roadside drains in the southern portion of the town (e.g. Commercial Street, Edward Street) overflow in large floods. Similarly the town area to the north of the railway line is subject to shallow inundation from roadside drains overflowing. The resultant flooding is however characteristic of shallow sheet flow conditions which tends to limit impacts to grounds flooding, with any above floor flooding limited to buildings located at or just above natural ground level.

The anecdotal data and to a lesser extent the modelling results suggest that recent floods such as the October 2010 and March 2012 floods were most likely in excess of a 5 year ARI event. Anecdotal data also suggests that the January 1974 event was considerably more severe than these more recent floods.

3.4 Flooding Impacts

3.4.1 Summary

The floor level elevations of approximately 70 buildings located within the 100 year ARI flood affected area at Walla Walla were obtained during the Flood Study. The subsequent comparison with the modelled design flood levels enabled those buildings (i.e. houses or principle building on each property) which are subject to above floor flooding to be identified.

Flood damages were estimated using the outcomes from the comparison of building floor levels with flood levels and flood damage data.

The main outcomes were:

- There are four properties subject to above floor flooding in a 5 year ARI flood (smallest flood modelled)
- There are 23 properties subject to above floor flooding in a 100 year ARI flood. Twelve of these properties are residential and the remaining eleven commercial / industrial
- The average annual flood damage is $250,000 per annum
- The average height of 100 year ARI above floor flooding is 0.16 metre. The maximum depth of above floor flooding is 0.57 metre

A summary of the number of properties subject to above floor flooding is provided in Table 1 together with the flood damage estimates

Table 1 Flood Damage Estimates

Flood ARI (years)	Number of properties (buildings) potentially subject to above floor flooding		Estimated flood damage ($)
	Residential	Commercial / Industrial	
5	3	1	490,000
10	5	3	760,000
20	9	5	1,370,000
50	12	8	1,8300,000
100	12	11	2,370,000
200	15	12	2,790,000
500	17	14	3,280,000
PMF	65 combined		8,250,000
			AAD – $250,000/annum

Note:

1. Above floor flooding numbers relates to the main building on each property.

3.4.2 Specific Issues

The source of the serious flooding problems at Walla Walla can be attributed to two principle causes:

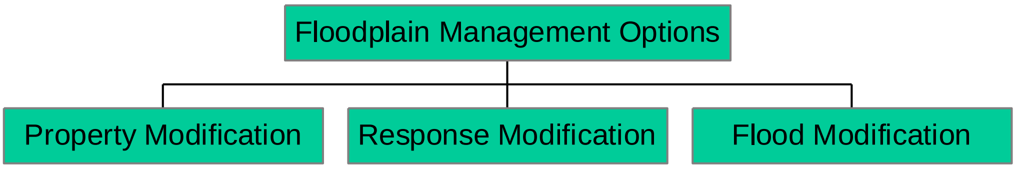
- Inability of the existing natural waterway and downstream man made drain to confine runoff flows from the Queen Street Waterway catchment as it discharges westwards through town on route to the Walla West Waterway
- Limited discharge capacity of the bridge opening through the railway line embankment for passing flows being conveyed by the upstream Walla West Waterway and the incoming Queen Street Drain

Consequently investigations to assess mitigation options to alleviate flooding impacts on existing development have focused on these two issues.

4. Floodplain Management Options – Preliminary Assessment

4.1 Overview of Types of Measures

The Floodplain Development Manual (NSW Government, 2005) documents how flood mitigation options can be categorised into the following three approaches:



Property modification measures are designed to avoid any future development within areas which have a high flood risk and to also reduce the damage inflicted on existing development by means of flood proofing. Property modification measures include:

- Land use planning including zonings and development control
- Voluntary house raising
- Flood proofing of buildings
- Improvements to flood access
- Voluntary purchase of high hazard properties

Response modification measures are designed to modify the response of the population at risk prior to, during and after a flood. Response modification measures include:

- Flood education and awareness
- Flood warning system establishment / improvements
- Flood response improvements
- Flood recovery improvements

Flood modification measures are designed to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from the area under threat. Flood modification measures include:

- Retarding basins
- Levees
- Waterway channel and structure modifications
- Bypass floodways
- Vegetation management and maintenance of creeks and culverts

The remainder of Section 4 documents the preliminary assessment of all of the above options in relation to their suitability for reducing flood impacts at Walla Walla.

The subsequent detailed assessments for Property Modification measures is provided in Section 5, Response Modification measures in Section 6 and Flood Modification measures in Section 7.

4.2 Property Modification Measures – Preliminary Assessment

4.2.1 Land Use Planning and Development Controls

Land use planning and development controls are an essential element in managing flood risk and the most effective way of ensuring future flood risk is managed appropriately. Planning not to develop land within high flood hazard or land that has the potential to impact flood behaviours in other areas represents an essential component of a floodplain risk management plan.

Land use planning controls can be achieved through zoning in the Local Environment Plan (LEP) and associated flood related controls incorporated into a Development Control Plan (DCP). Planning documents can be used as a floodplain management tool by controlling where development can occur and by specifying certain construction conditions (e.g. minimum floor levels).

The current land use zonings at Walla Walla are shown on Figure 4.

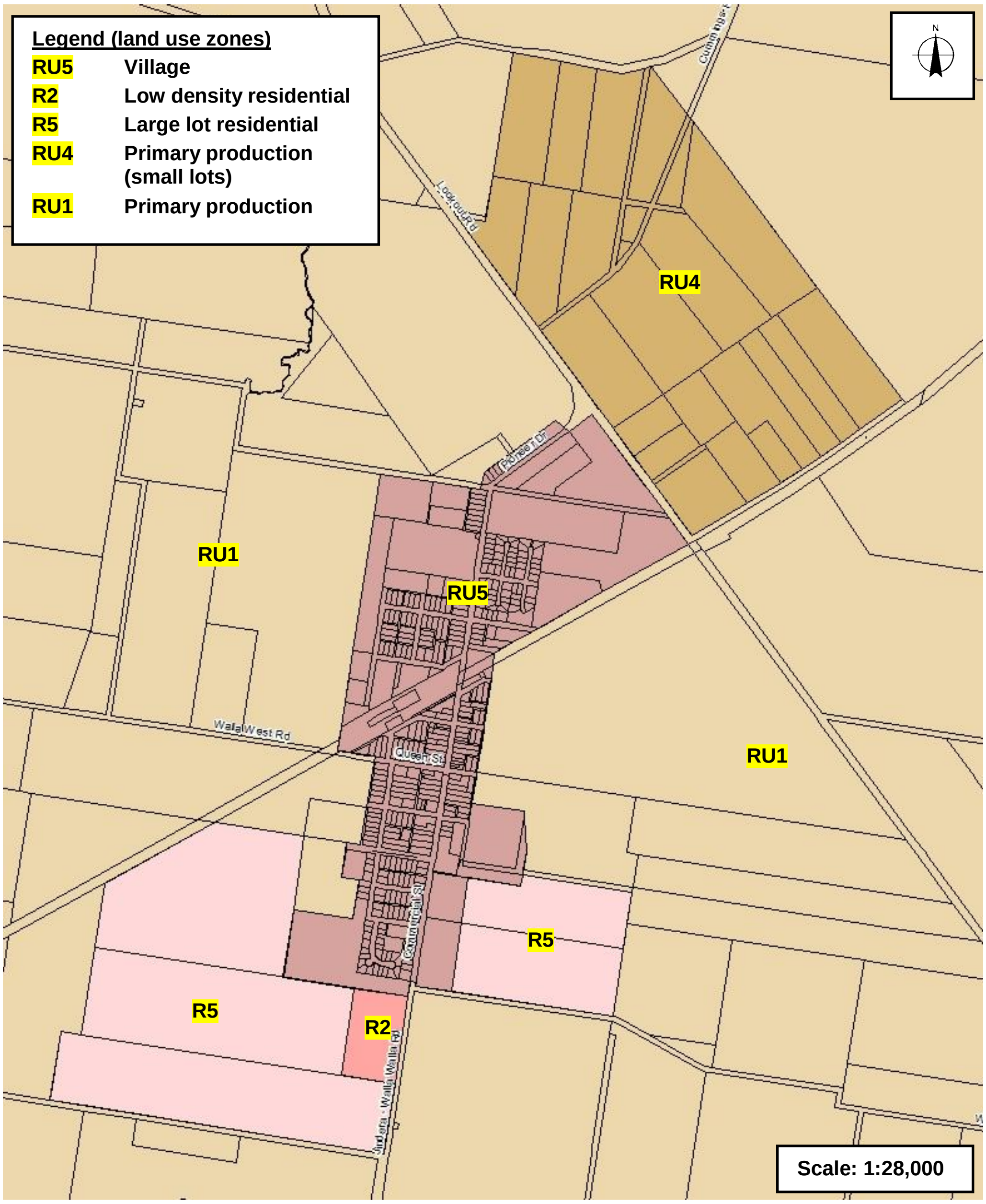


Figure 4 LEP Land Use Zonings at Walla Walla

The 2013 Greater Hume Local Environmental Plan (LEP) is the principal planning document which controls future development within the Shire. Clause 6.1A of the LEP relates to Flood Planning. The clause defines the Flood Planning Level as equal to the 100 year ARI flood level plus 0.5 metre freeboard.

The 2012 Greater Hume Development Control Plan (DCP) has a stand alone chapter on flood liable land (Section 8). This currently lists broad objectives and decision guidelines. Council is intending to expand this chapter of the DCP with the flood development controls forming part of the FRMPs for the towns within the shire, including Walla Walla, Jindera, Culcairn, Holbrook, and Henty.

Integral to the development of flood based land use planning and development controls for Walla Walla is the:

- Basis for the Flood Planning Levels (FPLs)
- Delineation of the Flood Planning Area (FPA)

The above is documented in Section 5.

4.2.2 Voluntary House Raising

House raising is generally only implemented in low hazard and / or flood fringe areas. House raising involves lifting building floor levels above the flood planning level to avert damage to buildings, improve personal safety and reduce stress and post-flood trauma. House raising is often a potential solution to flooding in rural areas for isolated houses, particularly for fibro or weatherboard dwellings positioned on stumps.

Consideration must be given to the type of house being raised, the level of hazard to be avoided, the duration of the flooding expected and social issues (access to balance of funding). An important consideration is that house raising will not mitigate flood risk entirely, since the effects of a flood of greater magnitude than the design flood (potentially up to the PMF) could still result in risk and damage.

Subsidised funding for raising of buildings is generally only available for residential properties.

Of the 23 buildings at Walla identified as subject to 100 year ARI above floor flooding, eleven are residential properties. Nine of these eleven houses are potentially suitable for floor level raising (i.e. building foundations are other than a concrete slab). All of the nine houses are positioned within low hazard / flood fringe areas. Voluntary house raising is therefore an option warranting further consideration.

4.2.3 Voluntary House Purchase

Voluntary purchase involves the acquisition of flood affected properties, in particular those inundated in high hazard areas, and the subsequent demolition of the building on the acquired property.

Voluntary purchase is not considered suited to any of the flood affected properties at Walla Walla, given the low severity and in most cases infrequent nature of above floor flooding. The houses at most risk are located within Low Hazard areas.

No further detailed investigations associated with voluntary house purchase are therefore recommended.

4.2.4 Flood Proofing of Buildings

Flood proofing includes the following scenarios:

- Achieved through the design and construction of the building (i.e. water resistant building materials, electrics positioned above the water line)
- Temporary flood barriers. This involves the use of plastic sheeting and sand bags at points of water entry (e.g. doorways, vents)

The available flood warning time for occupants of individual properties to set up barriers at points of entry will typically be very short at Walla Walla due to the small catchments and associated response times. This significantly reduces the practicality of flood proofing measures.

The potential use of flood proofing measures can be conveyed to the community as part of community awareness improvement measures.

No further detailed investigations into flood proofing options are recommended.

4.3 Response Modification Measures

Response modification measures are reactions to flooding that reduce potential social, economic and environmental damages from flooding. While response modifications will reduce the risk to life and may reduce direct damages, they will not prevent flooding. Therefore, they will not address all the social impacts and damages associated with flooding.

4.3.1 Flood Warning Systems

Depending on the warning time and resources available, flood warning systems and evacuation plans can be used to protect buildings, evacuate people, provide relief to evacuees and provide recovery assistance to those in flood affected areas.

The effectiveness of flood warning systems to aid flood response measures largely depends on the amount of flood warning time available. Flooding following rainfall on large catchments may not peak for days or even weeks following the flood inducing rainfall. Under these circumstances, flood warning systems are most effective.

The catchment areas draining to Walla Walla are relatively small. The Queen Street Waterway has a catchment area of 4 km^2. Flooding will therefore tend to commence within 15 minutes to one hour of the flood inducing rainfall burst. Although the Walla West Waterway catchment is larger (16 km^2 at the railway bridge) flooding is still expected to occur within two hours of the main rainfall burst. This leaves very little time for residents and flood response agencies to take actions to mitigate the resultant flooding impacts.

There are no rainfall pluviometer stations within the catchments draining to Walla Walla. The nearest rainfall pluvio station to Walla Walla is located at the Bowna Creek streamflow gauging station located downstream of the Gerogery Road, 19 km south east of Walla Walla. This pluviometer station is not a good indicator of rainfall within the catchment above Walla Walla.

Given the very limited amount of flood warning time available at Walla Walla, the expense associated with establishing and maintaining a pluviometer station at the town or within the upstream catchment is not warranted. Similarly establishing and maintaining a stream height gauge upstream of or at Walla Walla will not provide worthwhile flood warning system benefits.

No further detailed investigations into flood warning system improvements are therefore recommended.

4.3.2 Public Awareness Measures

Increasing public awareness of flooding risks assists in increasing the readiness of the community to prepare for and respond to floods. Measures to increase flood awareness within the local community could include:

- The dissemination of a Flood Information Pack that could be sent to all owners, business operators and residents of potential flood impacted properties
- The dissemination of flood certificates on a regular basis which would inform each property owner of the flood situation at their particular property, flood data and advice
- Signage or flood markers in flood prone areas giving notification of potential and historic flood levels.
- Providing a readily accessible flood information portal on Council's web site

Further investigations into potential ways to improve the level of flood awareness within the local community will form part of the detailed assessment of mitigation options (refer to Section 6).

4.4 Flood Modification Options

Flood modification measures are those that alter the flood conditions to reduce the flood hazard or change the flood behaviour. Flood modification is generally the only measures that will minimise both the social impacts and the risk to property and life.

Serious flooding impacts at Walla Walla (i.e. above floor flooding) are primarily due to the Queen Street Waterway. A man made drain (Queen Street Drain) conveys runoff from the Queen Street Waterway on the east side of town to the Walla West Waterway on the west side of town.

The Walla West Waterway railway bridge influences flooding conditions on the upstream side of the railway. This area is subject to some serious flooding impacts.

Most of Walla Walla is not subject to serious flooding impacts. This includes almost all of the town area north of the railway line and all of the town area south of William Street. Parts of these areas will be subject to shallow inundation, however not expected to be severe enough lead to above floor flooding.

Flood modification options which will alleviate serious flooding impacts are the focus of the flood modification measures under consideration.

An overview of flood modification options in relation to their potential application at Walla Walla is provided as follows.

4.4.1 Retarding Basins

Retarding or detention basins are temporary water storages which release flows at a controlled reduced rate in order to attenuate downstream peak flows and therefore flood levels.

Retarding basins tend to be used on smaller catchments such as local stormwater catchments as the amount of storage involved is able to be practically achieved. In larger catchments, the storage volume required to achieve worthwhile peak flow reductions becomes too large.

A retarding basin positioned on-line with the Queen Street Waterway on the upstream (east) side of town may provide some worthwhile benefits.

4.4.2 Waterway Improvements

This category of works is aimed at improving the hydraulic conveyance capacity of the waterway in order to reduce out of channel flooding and lower flood levels. It can involve:

- Removing vegetation and sedimentation which may be reducing (choking) the hydraulic conveyance of the waterway
- Enlarging the incised waterway through either bed lowering or widening
- Providing a secondary channel which activates in flood events, providing additional conveyance (i.e. bypass floodway channel)

In relation to the Walla Walla, waterway improvements will be central to the assessment of flood modification options. This will focus on the potential diversion of flows conveyed by the Queen Street Waterway on the eastern side of town and the upgrade of the discharge capacity of the Queen Street Drain.

4.4.3 Waterway Structure Improvements

Waterway structures typically represent a flow constriction which generates an energy loss leading to higher upstream flood levels.

All of the roadway culvert structures within the Walla Walla study area are overtopped in a 100 year ARI flood. Many of these structures have little influence on flooding conditions in large floods, as they become drowned out.

The waterway structure most influencing serious flooding impacts at Walla Walla is the Walla West Waterway railway bridge. An assessment of the benefits arising from the replacement of this structure was selected for detailed assessment.

4.4.4 Levees

The purpose of a levee is to mitigate flooding and associated economic and social consequences of flooding by preventing floodwaters from entering the area affected by flooding.

Whilst levees can be effective at reducing the impact of flooding, it is important to ensure that the flood risk for other areas outside the levee protected area is not significantly increased.

In relation to Walla Walla the following comments are made in regards to levees:

- Levees are required to incorporate a freeboard of typically 0.5 metre or more above the 100 year ARI flood level
- Although flooding depths at Walla Walla are generally less than 0.3 metre, the addition of the mandatory freeboard will result in a significant levee bank height

Levees are not suited to mitigating flooding impacts at Walla Walla. The principle source of the serious flooding problems (i.e. Queen Street Waterway) can be better addressed through waterway and waterway structure improvements.

There are some low level informal banks located within the Walla West Waterway floodplain upstream of Lookout Road. There banks are overtopped and or outflanked by relatively small floods (e.g. 5 year ARI flood) and are not thought to cause any adverse impacts. There are no plans therefore to modify or remove these banks.

4.5 Summary and Recommendations

From the preceding discussion, the various options and their status are listed in Table 2.

The flood modification measures are likely to be based around waterway and waterway structure improvements.

The detailed assessment of flood modification options is documented in Section 7.

Table 2 Preliminary Assessment of Flood Management Options

Option No.	Description	Recommended for further detailed assessment
1.	Define the basis for FPLs, FPA	**Yes**
2.	Develop draft Flood Policy for Walla Walla	**Yes**
3.	Voluntary house raising	**Yes**
4.	Voluntary house purchase – flood risks are too low	**No**
5.	Flood proofing of buildings. Only on an individual basis	**No**
7.	Improved flood warning system improvements	**No**
8.	Education and awareness measures	**Yes**
9.	Retardation	**Yes**
10.	Waterway Improvements	**Yes**
11.	Waterway structure improvements	**Yes**
12.	Levee banks	**No**

5. Property Modification Options – Detailed Assessment

5.1 LEP and DCP

Flood based planning and development controls aim to ensure that future development is compatible with the flood risk. To achieve this, Council's incorporate or link appropriate flood based planning and development controls to their Local Environmental Plans (LEPs) and Development Control Plans (DCPs).

The LEP guides land use and development through the zoning of land. Development is limited to complying land uses within each zone. Greater Hume Shire Council's LEP was adopted in 2012. The LEP includes a section on Flood Planning.

Greater Hume Shire Council adopted a DCP in 2013. The 2013 DCP lists objectives and broad decision guidelines in relation to flooding considerations.

5.2 Flood Planning Levels

5.2.1 Overview

The Flood Planning Level (FPL) is the combination of flood levels and freeboards selected for floodplain risk management purposes.

FPLs can vary depending on the intended application (e.g. minimum floor levels for development, minimum crest levels for levee banks). This section of the report relates to FPLs as they apply to future development.

The NSW Floodplain Development Manual states that in general the FPL for standard residential development is the 100 year ARI flood plus a freeboard of typically 0.5 metre.

The 100 year ARI flood is almost always adopted as the design flood for floodplain management purposes in NSW. The freeboard selected can however vary significantly depending on local flooding characteristics. Freeboard provides a factor of safety to provide protection against:

- Uncertainties in the estimation of flood levels
- Differences in water levels due to local factors
- Increases in flood level as a result of wave action
- Changes in rainfall patterns as a result of climate change

Individual FPLs can be specified for different types of development (e.g. residential, non-residential), for different flooding sources (e.g. riverine flooding, local overland flow) and for different locations (e.g. very broad floodplain reach, very confined floodplain reach). Selecting a higher FPL will reduce the risk of future flood impacts. It may also however result in a social and economic cost associated with the more restricted land use in flood prone areas.

Residential development tends to be viewed as warranting a higher FPL due to the increased exposure associated with habitable buildings including people being present at the time of flooding.

Commercial and industrial development can be less sensitive to flooding with property owners tending to be willing to take on a higher risk. Allowing commercial and industrial buildings to have reduced minimum floor levels whilst require flood proofing to the residential FPL is also an option.

Some types of especially vulnerable development (e.g. hospitals, critical infrastructure, senior's housing) can be assigned a higher freeboard than that for other development types.

5.2.2 100 Year ARI Flood Levels

The 100 year ARI flood levels at Walla Walla are those derived from modelling undertaken as part of the Walla Walla Flood Study (GHD, 2017).

The hydraulic model used for the Walla Walla modelling is a four metre grid two dimensional TUFLOW model. The appropriate flood level for a development site will require careful consideration given there will be a flood gradient across the site. The appropriate 100 year ARI flood level should be the highest flood level on the proposed building footprint.

5.2.3 Freeboard for Development FPLs

The freeboard is a factor of safety added to the design flood level. The individual factors which are taken into account when selecting an appropriate development control freeboard are described as follows with respect to flooding conditions at Walla Walla.

Uncertainties in the estimation of flood levels. The variation in design flood levels at Walla Walla with increasing flood ARI is relatively compressed. This is because local flooding conditions are typically characteristic of local overland flow with shallow sheet flow over a very broad area. This includes the Walla West Waterway and the Queen Street Waterway which both have minimal incised channel definition. Given these flooding condition, an allowance of 0.10 metre is considered adequate for this factor.

Differences in water levels due to local factors. This factor accounts for afflux due to waterway blockages and other local disturbances not able to taken into account by the hydraulic model. The afflux can increase as a result of blockages within waterway structures (e.g. culvert and bridge openings). All of the waterway road and rail crossings at Walla Walla are subject to significant overflows in a 100 year ARI event. The 100 year ARI flood levels are not therefore particularly sensitive to the extent of any blockage present. The 0.10 metre allowance for 'uncertainties in the estimation of flood levels' is considered adequate to cater for any additional affects due to 'local factors'.

Wave action. Waves can be generated by wind and by trucks and other vehicles. An allowance of 0.10 metre is considered appropriate.

Climate Change. Climate change impacts, particularly for a very large catchment system such as the Murray River are subject to a high level of uncertainty. Possible changes in rainfall vary from small reductions to increases of up to 30% (DECC, 2007). Given the relative insensitivity of flood levels to increasing flow, an allowance of 0.10 metre is considered appropriate for accommodating potential climate change effects.

The above suggests that a cumulative freeboard of 0.3 metre may be appropriate (i.e. 0.10 metre for 'uncertainties in the estimation of flood levels', 0.10 metre for 'wave action' and 0.10 metre for 'climate change').

A 'rule of thumb' approach taken into account when considering what freeboard to adopt for the FPL is based on the height difference between the 100 and 500 year ARI flood levels. A height difference of say less than 0.3 metre adds support for the adoption of a freeboard of 0.3 metre. If the height difference is in excess of 0.3 metre, this suggests that a freeboard greater than 0.3 metre is advisable.

In the case of Walla Walla, the 500 year ARI flood levels are typically less than 0.2 metre above the 100 year ARI flood level as documented in the Flood Study report. This includes those areas subject to considerable afflux (e.g. upstream of Cemetery Road, upstream of railway at Walla West Road) due to the overtopping threshold being lower than the 100 year ARI flood.

On the basis of the above, the proposed approach is for the FPLs at Walla Walla to coincide with the 100 year ARI flood level plus 0.3 metre of freeboard.

5.3 Flood Planning Area

The flood planning area (FPA) is the area subject to flood related development controls. Properties falling within the FPA are also identified as such on Section 149 (2) certificates issued by Council.

A very large FPA can cause considerable angst within the local community. Shallow sheet flow inundation is not generally viewed in the same way as mainstream flooding as increases in flooding severity can result in only marginal increases in flood level. In these circumstances there is therefore little or no risk of above floor flooding providing that building floor levels are elevated above the highest adjoining ground level. Currently the Australian Standard for residential slabs and footings (AS 2870, 2011) requires the minimum height of the slab above the finished ground to be 0.15 metre with some exceptions.

Consequently the FPA has in some recent past studies been defined in alternative ways to avoid the FPA encompassing a very large area, much of which is subject to very shallow 100 year ARI flooding.

The disadvantage of the above approach is that there remains a risk that above floor flooding may eventuate for unforeseen reasons in areas excluded from the FPA (e.g. building code floor levels not appropriately enforced, landscaping leading to poorly draining conditions).

There is a view that it is desirable for the floor level of all residential buildings to be elevated 0.3 metre above the adjoining finished landscaped ground level. The relatively small increase in the overall construction cost is arguably money well spent as it largely eliminates the risk of flooding associated with local runoff. This is commonly not seen that way however due to the tendency for home building companies to focus on construction cost saving whenever possible.

For mainstream flooding (i.e. waterways with significant incised channel capacity), the FPA is usually defined as the area below the FPL. For areas affected by local overland flow (i.e. flow on route to incised waterways), this approach can be problematic as it can lead to a very large FPA which can even in some circumstances encompass areas outside the PMF extent. This occurs in flat terrain areas where a freeboard of even 0.3 metre can result in a very large FPA.

All of the waterways at Walla Walla are more characteristic of local overland flow. Both the Walla West Waterway and the Queen Street Waterway have very limited channel incision.

There are large parts of Walla Walla which are subject to shallow overland flow (flooding depth less than 100 mm). The design event flood mapping included in the Flood Study report (GHD, 2017) coincides with the trimming of flood depths less than 0.1 metre consistent with the approach normally used.

The proposed FPA extent for Walla Walla is shown on Figure A1. The FPA extent coincides with the following:

- Petries Creek – area below the 100 year ARI extent plus 300 mm. Petries Creek has a significant incised watercourse channel. Flooding conditions are characteristic of main stream flooding.
- Walla West Waterway and Queen Street Waterway – 100 year ARI untrimmed extent. Both these waterways, particularly the Walla West Waterway, are more characteristic of depressions rather than incised waterways. The Walla West Waterway affects large undeveloped areas on the fringe of the existing town area. Maintaining the ability to impose flood based minimum floor levels in these areas for future development is desirable.
- Local overland flooding in town areas – 100 year ARI trimmed extent. Local runoff from stormwater catchment results in shallow inundation of large parts of the existing town to depths of less than 100 mm. Floor level control in the areas can be adequately governed by the building code. This approach avoids having large parts of the existing town within the FPA.

5.4 True Flood Hazard

Provisional flood hazard mapping is presented in the Flood Study report (GHD, 2017). The provisional hazard mapping is based on hydraulic conditions (i.e. depth and velocity of floodwaters) as determined using the Floodplain Development Manual (NSW Government, 2005).

The provisional flood hazard is reviewed during a FRMS, taking into account factors other than hydraulic conditions. Other factors taken into account include:

- Effective warning time. In regards to Walla Walla, there will generally be very little warning time available, typically less than 1 hour
- Flood readiness. The level of community flood awareness at Walla Walla is quite high given the relatively recent occurrence of significant floods in 2010 and 2012.
- Rate of rise of floodwaters. The rate of rise of floodwater at Walla Walla will be relatively rapid
- Duration of flooding. The duration of flooding at Walla Walla will normally be quite short, with flood levels remaining high for a few hours at most
- Evacuation access considerations. This is not a major consideration for Walla Walla given that there is insufficient warning time to initiate and complete a resident evacuation. Most streets will remain trafficable to heavy vehicles with flood depths not generally exceeding 0.4 metre

The final 100 year ARI flood hazard mapping is shown on Figure A3 in Appendix A.

The majority of the out of channel flooding remains designated as Low Hazard, unchanged from the provisional classification. Flooding conditions are characteristic of shallow sheet flow inundation. These conditions do not warrant a revision to High Hazard, notwithstanding the relatively short flood warning time available.

The High Hazard defined areas covering the waterway corridors have been adjusted in some places to provide improved connectivity along the waterway routes (i.e. Walla West Waterway and Queen Street Waterway).

5.5 Local Flood Policy

A preliminary draft Local Flood Policy for Walla Walla is included in Appendix A.

The key aspects of the Local Flood Policy are:

- Flood related development controls detailed in the Local Flood Policy apply to the FPA as defined by Figure A1
- The minimum floor levels for new residential buildings are to be at the FPL (i.e. 0.3 metre above the 100 year ARI flood levels)
- Commercial and industrial development. At Council's discretion, the minimum floor level is to be at the FPL or the building is to be flood proofed to at least the FPL

Council's DCP should be updated to incorporate the Local Flood Policy including the FPA map, the Hazard Category map and the Hydraulic Category map. Flood based development controls are to apply to the FPA. The LEP will also require updating as it currently specifies FPLs based on 0.5 metre of freeboard.

5.6 Comments on Future Development Areas

5.6.1 Overview

The more recent rezoned land at Walla Walla is located on the south side of the existing town area. These areas are shown on Figure 5 and are referred to as Sites 1 to 5 consistent with the 2007 Greater Hume Strategic Land Use Plan. These areas were rezoned with the introduction of the 2013 LEP.

There are also extensive undeveloped RU5 zoned areas north of the railway.

Comments on flooding conditions within the above future development areas are provided as follows.

5.6.2 Sites 1, 2 and 5 west of the Jindera – Walla Walla Road

Sites 1, 2 and 5 are shown on Figure 5.

Site 1 is zoned R5 (Large Lot Residential – 94 hectares), Site 2 is zoned RU5 (Village – 14 hectares) and Site 5 is zoned R2 (Low Density Residential – 12 hectares).

The Walla West Waterway is aligned though Site 1. The waterway is a broad depression through this area rather than an incised channel.

Most of Site 1 is located within the FPA and therefore minimum FPL floor levels will apply. Flooding conditions are predominantly Low Hazard and Flood Fringe with the exception of the central depression corridor (High Hazard and Floodway). Development should be excluded from the High Hazard and Floodway areas. Council should consider requesting a hydraulic study to accompany Development Applications for development within the remainder of the FPA (i.e. as per the draft Local Flood Policy in Appendix A).

Site 2 is located outside the FPA. There is some shallow local overland flooding through the site (depth less than 0.1 metre) which is outside the FPA.

The southern portion of Site 5 is located within the FPA. Minimum FPL floor levels will apply within the FPA area. The depth of flooding within this area is less than 0.1 metre and is characteristic of Flow Hazard and Flood Fringe.

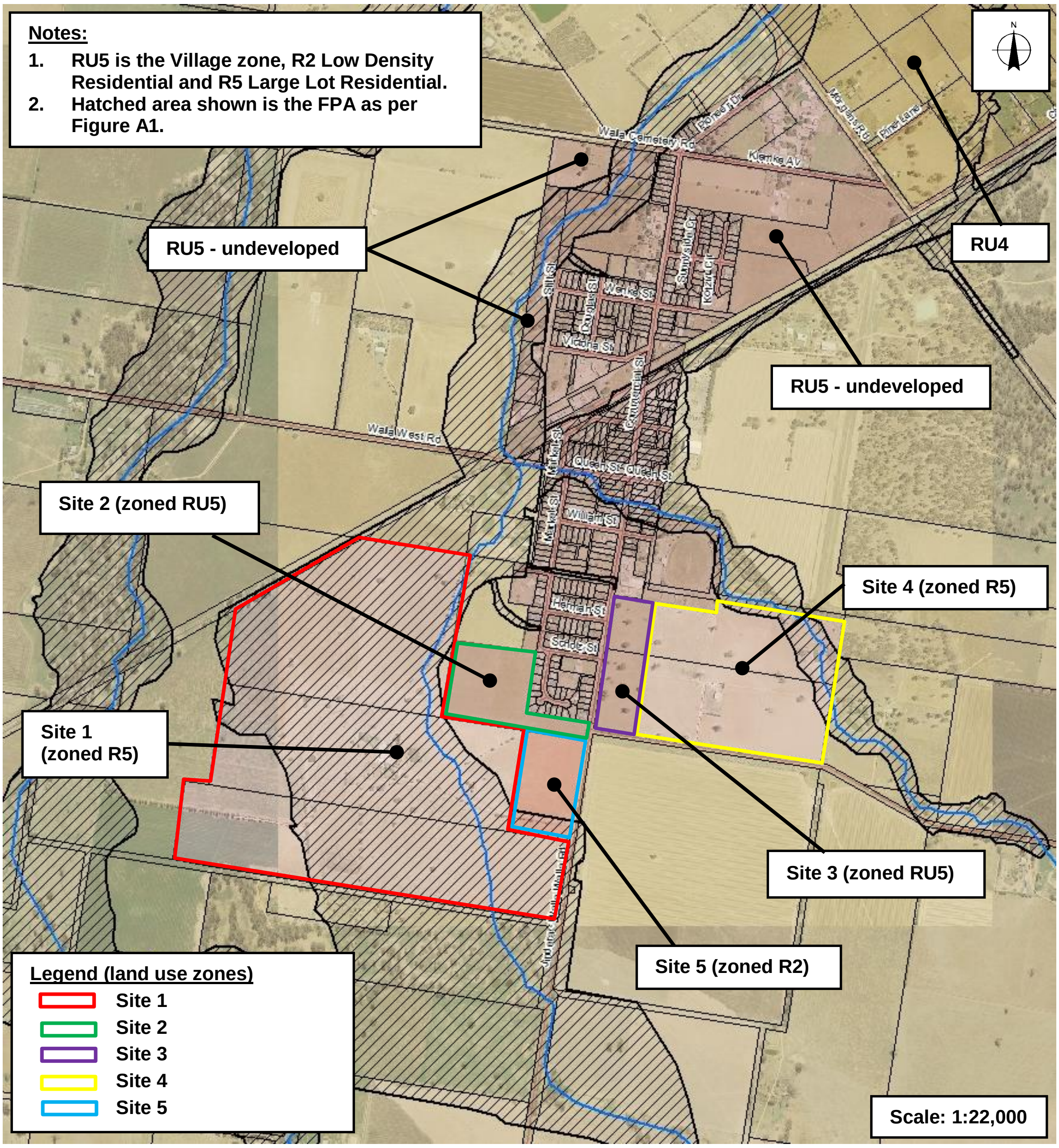


Figure 5 Future Development Areas

Although Sites 2 and 3 are both largely located outside the FPA and enforcement of minimum flood levels other than those associated with the building code is not therefore possible, it is preferable that residential building floor levels be elevated a minimum of 0.3 metre above the finished ground levels to guard against flooding. The down side of doing this is minimal (small increase in construction cost). The benefits are it largely eliminates the flood risk for unforeseen circumstances such as non or poorly draining low points adjoining houses created by poor landscaping.

5.6.3 Sites 3 and 4 east of the Jindera – Walla Walla Road

Sites 3 and 4 are shown on Figure 5. Both sites are on the north side of the Walla Walla Road.

Site 3 is positioned wholly outside the FPA. The site is subject to shallow overflows from the Walla Walla Road roadside drains (local overland flow). The depth of flooding is less than 0.1 metre which is why it is outside the FPA.

The Queen Street Waterway crosses the north eastern corner of Site 4. Development should be excluded from the High Hazard and Floodway corridor over the waterway alignment and the small area in the north east corner of Site 4 which would require access across the Queen Street Waterway. Minimum FPL floor levels will apply within the FPA area.

The remainder of Site 4 is located outside the FPA. Most of the site is however subject to shallow local overland flooding. The depth of flooding is less than 0.1 metre which is why it is outside the FPA.

As for Sites 2 and 3, it is preferable that residential buildings outside the FPA be elevated a minimum of 0.3 metre above the finished ground levels to guard against unforeseen circumstances (e.g. poor drainage following landscaping which may lead to increased flooding risks).

5.6.4 Areas north of the Railway – West of Commercial St / Pioneer Dr

RU5 zoned land north of the railway which remains undeveloped is shown on Figure 5.

Some vacant RU5 land is present on the west side of the existing urban limit. The Walla West Waterway is in some places aligned directly through the RU5 area (e.g. upstream side of Cemetery Road).

The areas affected by 100 year ARI flooding from the Walla West Waterway are located within the FPA. As such the controls applicable to the respective hydraulic category and hazard category will apply. These controls are described in Appendix A. Development in Floodway and / or High Hazard areas is generally excluded. Development within Flood Fringe and Low Hazard areas may be acceptable subject to meeting certain conditions (e.g. no adverse impacts on flooding on adjoining properties result from development as demonstrated by a hydraulic study, emergency access during flooding is satisfactory and minimum floor levels apply).

5.6.5 Areas north of the Railway – East of Commercial St

There is a substantial area of undeveloped RU5 zoned land enclosed by Commercial Street, Klemke Avenue, Morgans Road and the Railway.

This area is wholly outside the FPA. The raised Railway embankment prevents floodwater from the Queen Street Waterway impacting on this area. Floodwater on the south side of the Railway is diverted westwards or eastwards along the south side of the embankment.

There is insufficient local runoff to generate local overland flooding of this area, aside from very shallow flooding which typically occurs along the roadsides. Klemke Avenue is an example of where nuisance level flooding can occur due to the minimal grade along this road. Roadside drains consequently have minimal capacity which results in localised shallow surface inundation on parts of the road reserve during significant rainfall events. This has no implications for development other that the potential need to upgrade roadside drains as development proceeds in order to minimise nuisance flooding.

Although this area is located outside the FPA and enforcement of minimum flood levels other than those associated with the building code is not therefore possible or intended, it is preferable however that residential buildings be elevated a minimum of 0.3 metre above the finished ground levels. This is to guard against unforeseen circumstances (e.g. poor drainage following landscaping which may lead to increased flooding risks).

The school site north of Klemke Avenue is similarly outside the FPA. The same comments apply in regards to minimum floor levels.

5.6.6 Area east of Morgan Road and Pioneer Drive

This area between Chinatown Lane and Cummings Road is zoned RU4 (Primary Production – small lots). The Walla West Waterway is aligned through this area. The relevant FPA controls will apply including excluding most forms of development from the Floodway and High Hazard areas along the Walla West Waterway route.

Quite a large area is designated as Floodway and / or High Hazard based on the depth of flooding along the Walla West Waterway. The depth of flooding is influenced by backwater affects from the downstream Gum Swamp. Given the RU4 zoning, the FPA controls are however not particularly restrictive.

5.7 Voluntary House Raising

Of the 23 properties at Walla subject to above floor 100 year ARI flooding, 11 are residential properties located in low hazard / flood fringe areas. These 11 properties are therefore potentially suitable for voluntary flood level raising subject to the feasibility of being able to raise the individual buildings.

Data for the 11 properties is provided in Table 3. Comments are as follows:

- Properties 1 and 2 are not suitable for raising being slab on ground foundations. Both these houses will benefit from a proposed structural mitigation measure (removal of undersized railway bridge).
- The feasibility of raising the remaining three brick walled houses is considered extremely doubtful (Properties 3, 8 and 10).
- The existing floor levels of the six weatherboard and fibro walled houses are located quite close to the ground level. Under these circumstances, the practicality of house raising becomes very difficult given the need to gain access to the underside of the house for jacking up purposes.
- All of the six weatherboard and fibro walled houses have adjoining structures (e.g. verandahs, pergolas, carports etc) attached to the main house. Raising the main house will therefore necessitate modifications works to reattach the periphery structures to the elevated house.

Without further on-site investigations, the feasibility of raising the six weatherboard and fibro walled houses cannot be definitively established. Given the obvious difficulties (i.e. limited height from floor to ground, presence of peripheral attached structures) the average cost of raising is likely to be in the vicinity of $50,000.

Given the practicality issues above and the age and condition of the houses where floor level raising might be possible but at considerable cost, floor level raising is not considered to offer worthwhile benefits with the possible exceptions of Properties 4 and 5 in Table 3.

Table 3 Voluntary House Raising

Property ID	House description	Depth 100 year ARI above floor flooding (m)	Height to be raised (m)	Feasible for floor level raising	Reduction in AAD due to raising ($/annum)	PV of future reduced flood damages ($)
1.	Brick veneer on concrete slab	0.57	0.87	No	-	-
2.	Brick veneer on concrete slab	0.51	0.81	No	-	-
3.	Rendered stone on stumps	0.18	0.48	Most unlikely	10,100	95,000
4.	Weatherboard on stumps	0.19	0.49	Possibly	10,400	98,000
5.	Fibro & metal cladding on stumps	0.27	0.57	Possibly	14,000	136,000
6.	Weatherboard on stumps	0.10	0.40	Possibly	4,300	35,000
7.	Fibro on stumps	0.13	0.43	Possibly	6,000	53,000
8.	Brick veneer on stumps	0.08	0.38	Most unlikely	6,900	61,000
9.	Weatherboard on stumps	0.08	0.38	Possibly	5,100	42,000
10.	Brick on stumps	0.06	0.36	Most unlikely	2,400	13,000
11.	Weatherboard on stumps	0.04	0.34	Possibly	3,500	25,000

6. Response Modification Options – Detailed Assessment

6.1 Flood Warning System

As discussed in Section 4.2, the catchments draining to Walla Walla are relatively small. The lag time between any flood inducing rainfall and flooding at Walla Walla will therefore typically vary from 15 minutes to two hours.

Flood warning system infrastructure such as telemetered stream height / flow measurement stations and rainfall pluviometer station will not be effective at reducing flood damages given the minimal warning time available.

Consequently there are no recommendations to install additional flood warning system infrastructure at or in the catchment above Walla Walla.

6.2 Emergency Management

6.2.1 Local Flood Plan

It is the role of the SES to develop a Local Flood Plan for vulnerable communities. The Local Flood Plan is a sub plan of the Local Emergency Management Plan.

The Local Flood Plan details operations relating to flood preparedness measures, flood response measures and flood recovery measures.

Following the completion of the flood studies at Walla Walla, Jindera, Culcairn, Holbrook and Henty, the SES can proceed to prepare a Local Flood Plan for the Shire.

It is not envisaged that evacuation of residents from at risk areas would in general be able to take place at Walla Walla. There is too little flood warning time for this to be initiated and enacted.

Each flood at Walla Walla is likely to be different. This is because there are multiple local waterways impacting on different parts of the town. High intensity rainfall within the catchment draining into the Queen Street Waterway will cause most of the serious above floor flooding impacts. High intensity rainfall within the Walla West Waterway will not lead to as severe impacts with the possible exception of a small number of houses on the upstream side of the railway.

The random nature of rainfall areal variability combined with the small catchment sizes and short response times greatly limits any preparedness and response activities. Most of the operational activities covered by the Local Flood Plan in relation to Walla Walla may therefore focus on recovery actions (clean-up, temporary accommodation for above floor affected residents etc).

In relation to potential temporary evacuation sites, notable properties which are at very low risk of flooding at Walla Walla include:

- Sportsground site in William Street
- Lutheran Church site in Commercial Street
- Walla Walla Public School site in Commercial Street

6.2.2 SES Flood Data

There is no existing stream height gauge at Walla Walla. The consequence of an imminent flood cannot be reliably predicted given the small catchment sizes. The flood inundation maps included in the Walla Walla Flood Study report identify the expected extent and depth of inundation for the 5, 10, 20, 50, 100, 200 and 500 year ARI events and the PMF.

Given the short warning time available and the short duration of flooding, emergency response activities at Walla Walla are expected to be mainly focused on recovery related matters.

Most of the inundated affected areas at Walla Walla are characterised by relatively shallow sheet flow inundation up to and including a 500 year ARI event. Consequently, the flood affected areas at Walla Walla are expected to be characteristic of the following Emergency Response Planning (ERP) classifications:

- Areas with Overland Escape Routes – those areas which have access roads to flood free land crossing lower lying flood prone land
- Areas with Rising Road Access – those areas which have access roads rising steadily uphill and away from rising floodwaters

6.3 Flood Data

Comprehensive and up to date flood data is essential for effectively responding to flood events. With the completion of this FRMS&P, it is important that Council planning documents such as the DCP are updated to reflect the most up to date flooding information showing:

- Flood Planning Area (FPA) which represents the area which is subject to flood based planning and development controls
- Hydraulic Category maps defining the Floodway, Flood Storage and Flood Fringe areas
- Flood Hazard maps defining the Low Hazard and High Hazard flood areas

It is important that flood data be collected both during and in the aftermath of future flood events. The data can be used for future investigations associated with the update of the Walla Walla FRMP.

Future data collection should focus on:

- Large floods (i.e. where above floor flooding results)
- Photographs if possible at or near the peak of flooding. Where possible, photographs to be date and time stamped
- Recording reliable peak flood levels and their subsequent survey to the AHD datum
- Details of any instances of above floor flooding

Council may consider preparing a flood data collection strategy to more formally define the data collection process (type data, how it is to be recorded, roles and responsibilities).

6.4 Education and Awareness Measures

An overview of possible measures to increase the level of flood awareness in the community at Walla Walla is provided in Section 4.2.2. Of the various measures available, the following are considered most suited to Walla Walla:

- With the completion of the flood study and FRMS&P for Walla Walla, Council has detailed flood data available. Section 149 Certificates issued by Council should include the relevant flood information known to Council which impacts on the subject property. This would typically include with the issue of 149 (2) certificates whether the property is within the FPA, the Hydraulic Category of the property, the Hazard Category of the property and the subsequent flood based planning and development controls applicable to the property. Further detailed flood information could be provided if a Section 149 (5) is issued including frequency, level, depth and extent. This action is effectively a mandatory function that Council is required to perform as distinct from an optional activity
- Provide flood information on Council's web site including the Flood Study report, the FRMS&P report, Local Flood Plan, links to BOM and SES web sites and other flood warning and response information. It is easy to implement and maintain with minimal associated costs

7. Flood Modification Options – Detailed Assessment – Queen Street Waterway

7.1 Overview

Most of the serious above floor flooding problems at Walla Walla are caused by incoming flows from the Queen Street Waterway. This waterway has a catchment area of 4.0 km^2. The 100 year ARI design flow is 15 m^3/s on the upstream side of Walla Walla.

The Queen Street Waterway as it approaches the upstream limit of the Queen Street Drain has very little incised definition. Floodwater consequently spreads out and flows northwards towards the Railway and westwards through the town. This affects many properties within the intervening area between the Queen Street Drain and the railway with 23 identified properties subject to potential above floor 100 year ARI flooding.

The discharge capacity of the Queen Street Drain after allowing for 25% culvert structure blockage is equivalent to not much more than a 2 year ARI flood. Even if the 100 year ARI flow from the upstream Queen Street Waterway was able to be funnelled to the entry point of the Queen Street Drain, flooding would still occur along the drain route through the town.

There are a number of potential structural mitigation approaches to address flooding from the Queen Street Waterway. The results of detailed investigations into these options are documented as follows.

7.2 Retarding Basin Option

A retarding basin located on-line with the Queen Street Waterway was assessed. The site assessed is located on Figure 6 at the southern end of a private air strip.

The retarding basin assessment assumptions and outcomes are summarised as follows:

- Total storage volume below embankment crest level modelled - 30,000 m^3 (from embankment alignment as shown on Figure 6, embankment maximum height 3.0 metres)
- Storage volume below spillway sill level – 8,000 m^3
- Basin pipe outlet – discharge capacity 2 m^3/s consistent with the existing downstream Queen Street Drain capacity
- Basin spillway outlet – conveys all basin outflows exceeding the pipe outlet capacity – spillway assumed to be 25 metres wide, sill 1 metres below embankment crest
- 100 year ARI inflow volume (3 hour duration storm) – 180 ML.
- Peak 100 year ARI inflow – 13.5 m^3/s
- Peak 100 year ARI flow attenuation able to be achieved – less than 5%

The volume of storage available is small relative to the incoming 100 year ARI inflow volume. The basin was modelled using XP-RAFTS with the spillway positioned 1 metre below the embankment crest. This enables the 100 year ARI basin water level to be limited to 0.5 metres below the embankment crest based on the spillway size modelled. The storage volume below the spillway is therefore less than 5% of the incoming 100 year ARI runoff volume. The resulting attenuated peak basin outflow is less than 5% lower than the peak basin inflow.

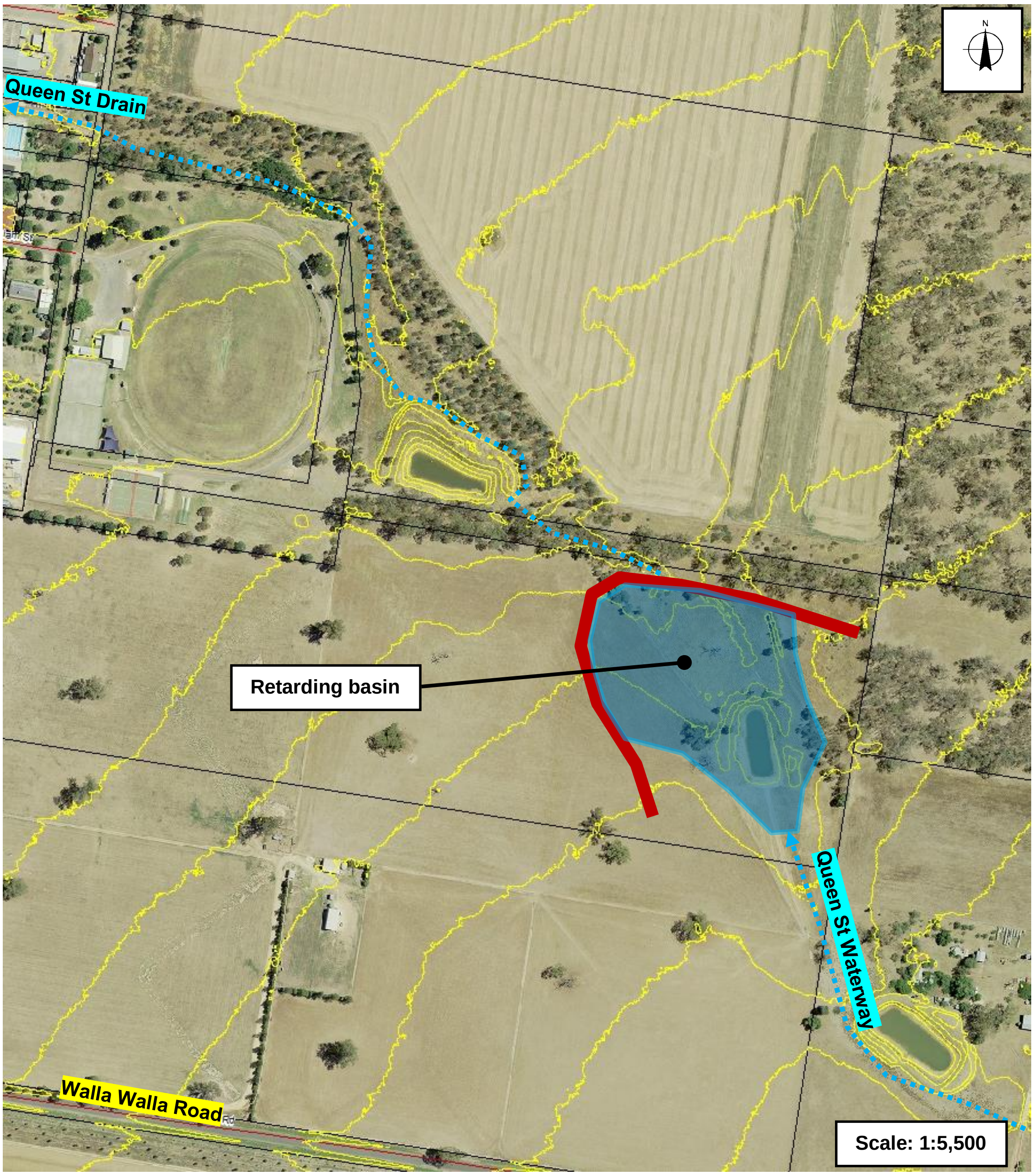


Figure 6 Walla West Waterway – Retarding Basin

The retarding basin is therefore ineffective as a flood mitigation measure. The basin would also need to be designed to cope with extreme floods, given that its failure in an extreme flood is not an acceptable risk.

Retarding basins are better suited to smaller stormwater catchments where inflow volumes are lower and the necessary storage volume to achieve worthwhile peak flow reductions is consequently lower.

7.3 Queen Street Drain Upgrade

The existing Queen Street Drain is shown on Figures 7 and 8. There are seven culvert structures along the drain route (four roadways and three driveways crossings). A footbridge is located on the upstream side of the Commercial Street culvert structure.

The capacity of the existing drain is approximately 2 to 3 m^3/s (refer to Table 4). This is equivalent to approximately a 2 year ARI flood. This coincides with the smallest culvert structures along the route with the exception of culvert C7 (refer to Figure 7) which is a low flow culvert only located at the downstream limit of the drain.

The western (downstream) half of the Queen Street Drain is positioned within the Queen Street road reserve as shown in Figure 8 (Photographs 3 and 4).

There is no incised channel upstream of the upstream limit of the Queen Street Drain (refer to Figure 8, Photograph 1). Consequently not all minor flood flows are funnelled to the Queen Street Drain with flows discharging northwards towards Railway Street.

The following points are made in regards to constraints associated with an upgrade of the Queen Street Drain:

- An upgrade will be very costly due to the large number of culvert structures along the drain route
- There little or no space available within the Queen Street road reserve to allow for any widening of the drain to achieve 100 year ARI capacity
- A drain upgrade would need to include the formation of an incised waterway channel extending well upstream of the current drain upstream limit to capture flows which currently discharge northwards and into the town
- The existing typical drain depth is 0.9 metre. Assuming a design flow of 15 m^3/s (100 year ARI peak design flow), a 25% design blockage allowance and 1.2 x 0.75 metre box culvert cells, a total of 12 culvert cells would be required at each culvert site

Given the above constraints and preliminary design details, it is concluded that a 100 year ARI capacity upgrade to the existing Queen Street Drain is not feasible.

The following comments are made in regards to potential improvement measures for the drain:

- The two smallest capacity culverts are the two downstream most culverts in Queen Street (C6 and C7). There is little to be gained by upgrading these two culverts other than reducing the frequency of roadway flooding given their location on the outskirts of town. These overflows only impact on the road however with no impacts on residential properties. No changes (upgrades) are therefore suggested for these two culverts.
- Culverts C2 to C5 are all relatively similar in size / capacity. Upgrades given space and drain depth constraints will be problematic.

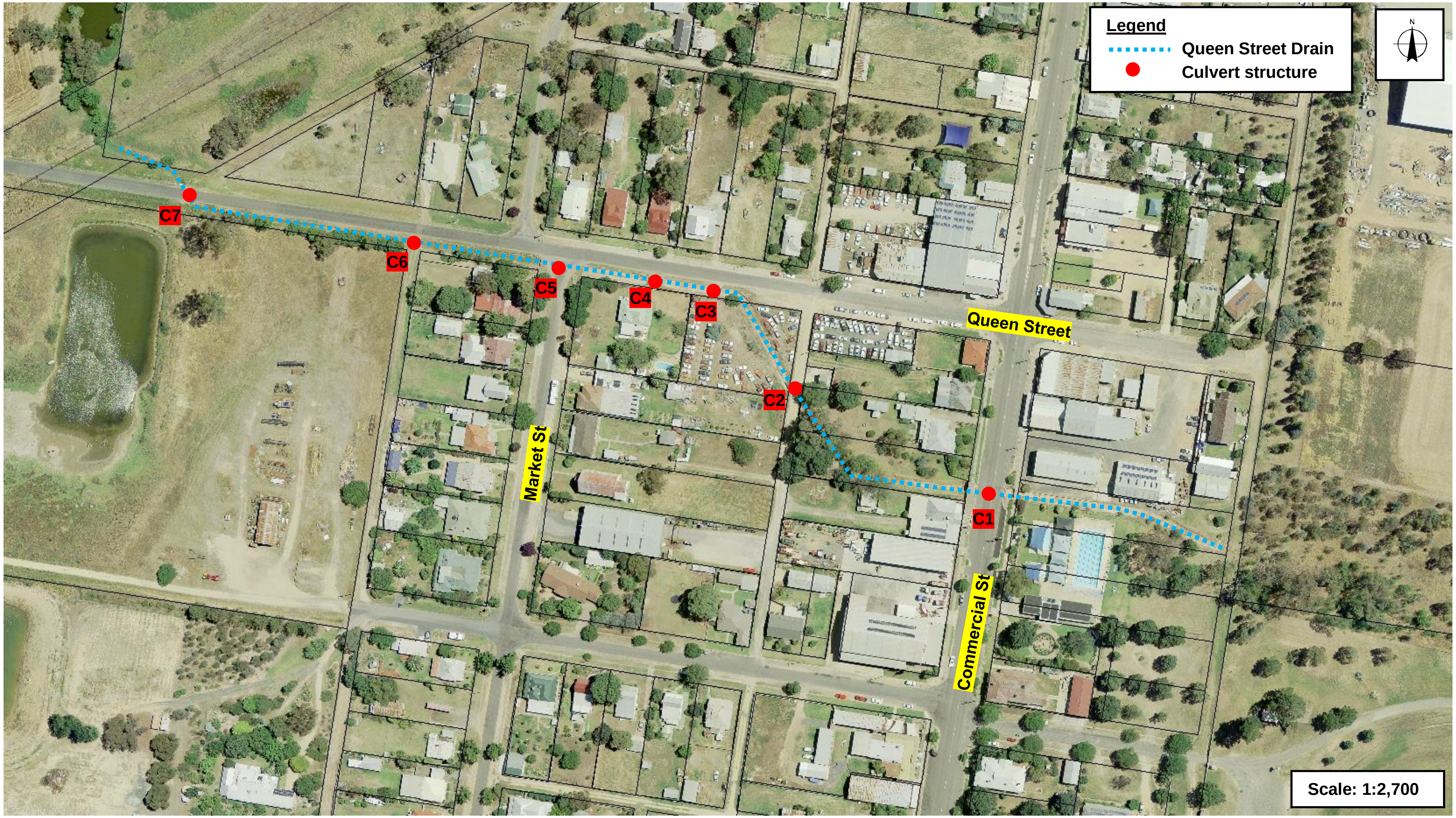


Figure 7 Queen Street Drain

Table 4 Queen Street Drain – Existing Capacity

Culvert Number (refer to Figure 7)	Existing Drain		
	Culvert Size (m)	Waterway Area (m^2)	Capacity (m^3/s)
C1	1 No. 3.6 x 0.75 BC	2.7	5
C2	2 No. 1.5 x 0.75 BCs	2.3	3
C3	2 No. 1.5 x 0.65 BCs	2.0	2
C4	2 No. 1.5 x 0.8 BCs	2.4	3
C5	2 No. 1.5 x 0.8 BCs	2.4	3
C6	2 No. 1.2 x 0.6 BCs	1.4	2
C7	1 No. 0.9 x 0.3 BC	0.3	0.4
Upstream C1	Open drain	-	7
C1 to C3	Open drain	-	6
C3 to C6	Open drain	-	4

Photo 1 – upstream limit of drain

Photo 2 – View looking upstream from Commercial St (C1)

Photo 3 – View looking downstream at C3

Photo 4 – View looking upstream at Market St (C5)

Figure 8 Queen Street Drain Photographs

7.4 Queen Street Drain – Upstream Extension and Berm

Extending the Queen Street Drain upstream of the existing drain upstream limit will assist in confining low and minor flood flows to the drain. A drain extension for approximately 200 metres to the north east corner of the sportsground would be beneficial in relation to reducing nuisance flooding (refer to Figure 9).

A drain extension will unfortunately require the removal of recently established vegetation along the waterway route. An alternative to a drain extension could involve the construction of a low level berm (e.g. 0.3 metre high) for directing flows to the existing Queen Street Drain entry point.

The following works were modelled to better assess the resulting flood mitigation benefits:

- Extension of the Queen Street Drain 200 metres upstream of the upstream limit of the existing drain
- Provision of a 0.3 metre high berm on the north side of the drain extension (berm height 214.7 metre AHD)

The modelling results indicate that the berm will be overtopped in a 5 year ARI flood. Benefits will therefore be limited to confining and funnelling low flows to the Queen Street Drain in minor flood events. The works will assist in reducing the frequency of nuisance level flooding which currently occurs (grounds flooding of properties north of the existing Queen Street Drain). The works have limited affect in a 5 year ARI flood (smallest flood modelled) as shown on Figure B1 in Appendix B.

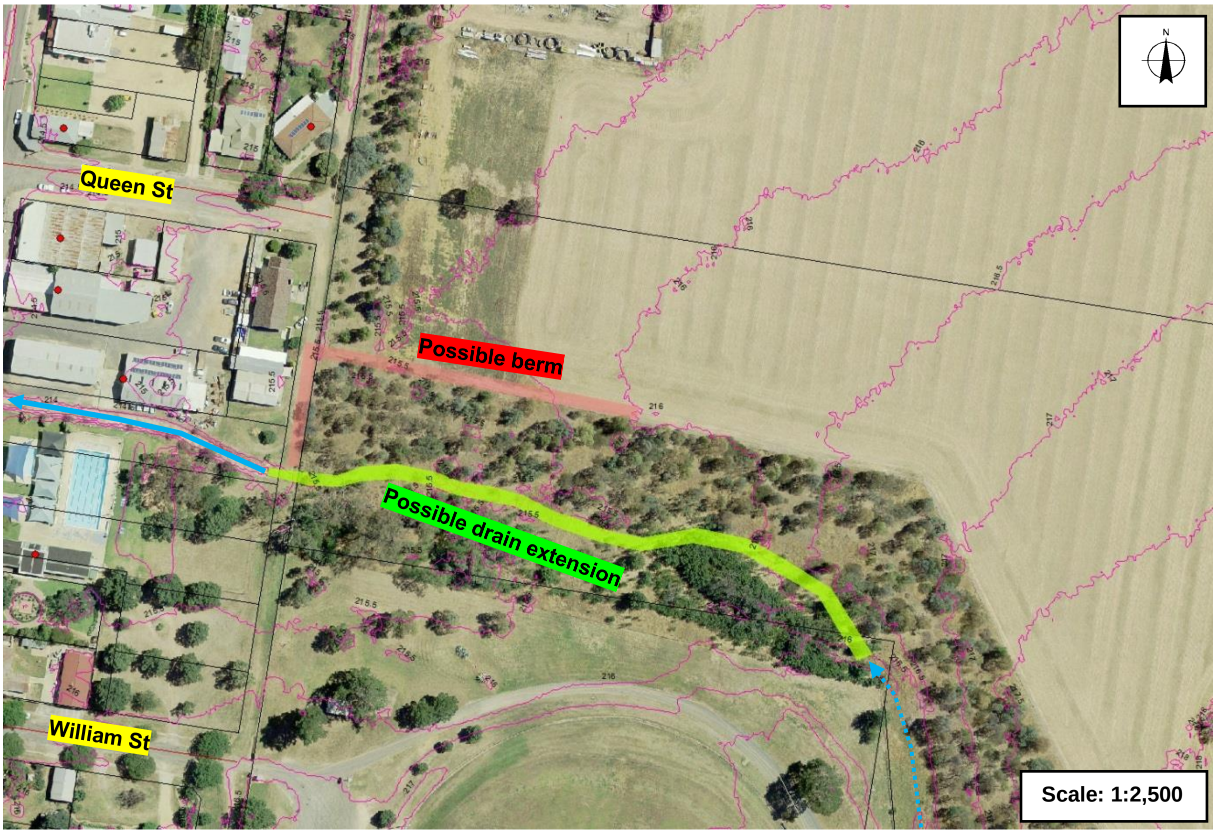


Figure 9 Queen Street Drain Extension

7.4.1 Impacts

The Queen Street Drain extension and berm works are expected to have the following impacts:

- Flooding – no impacts in a 100 year ARI flood, low and minor flood flows will be directed to the existing Queen Street Drain entry point resulting in a reduction in the frequency of grounds flooding, particular for properties on the north side of the existing drain entry point.
- Environmental – there will be a loss of vegetation involved in establishing the drain and adjoining berm. The vegetation present is the result of relatively recent plantings.
- Social – no adverse social impacts are expected.

The loss of immature native vegetation is the main negative outcome resulting from this option.

7.4.2 Economic Assessment

The benefits of the works in terms of reduced future flood damages are limited to reducing nuisance levels flooding in minor flood events. The works will not have a measurable benefit in large flood events.

Benefit cost details are given in Table 7. The benefit cost ratio for the Queen Street Drain extension and berm works is a favourable 1.65.

7.5 Waterway Diversions - Overview

Local residents have advised that a diversion of the Queen Street Waterway was previously considered by Council in the aftermath of some severe floods in the mid 1970s.. The diversion considered at that time involved a channel route down the south side of Walla Walla Road crossing under the Jindera-Walla Walla Road and continuing westwards into the Walla West Waterway (route shown on Figure 10). Ultimately Council did not decide to proceed with the diversion.

A review of terrain elevation data confirms that a Queen Street Waterway diversion on the east side of Walla Walla is feasible.

One such feasible alternative is the previously considered route in the 1970s (Walla Walla Road route – refer to Figure 10). This route diverts flows from the Queen Street Waterway into the Walla West Waterway on the upstream side of Walla Walla.

An alternative diversion route involves diverting flows northwards to the railway line and then eastwards on the upstream side of the railway embankment to the large railway bridge at the eastern end of Chinatown Lane (refer to Figure 10). This effectively diverts the Walla West Waterway floodwater to the downstream side of Walla Walla, as distinct from the upstream side of town as per the Walla Walla Road route.

Diversions can be problematic. This usually occurs as a result of increased flood risks for those properties along the diversion route. There are also direct disturbance impacts to those properties on which the diversion works are located. Diversions can however provide a very effective means for mitigation flooding impacts.

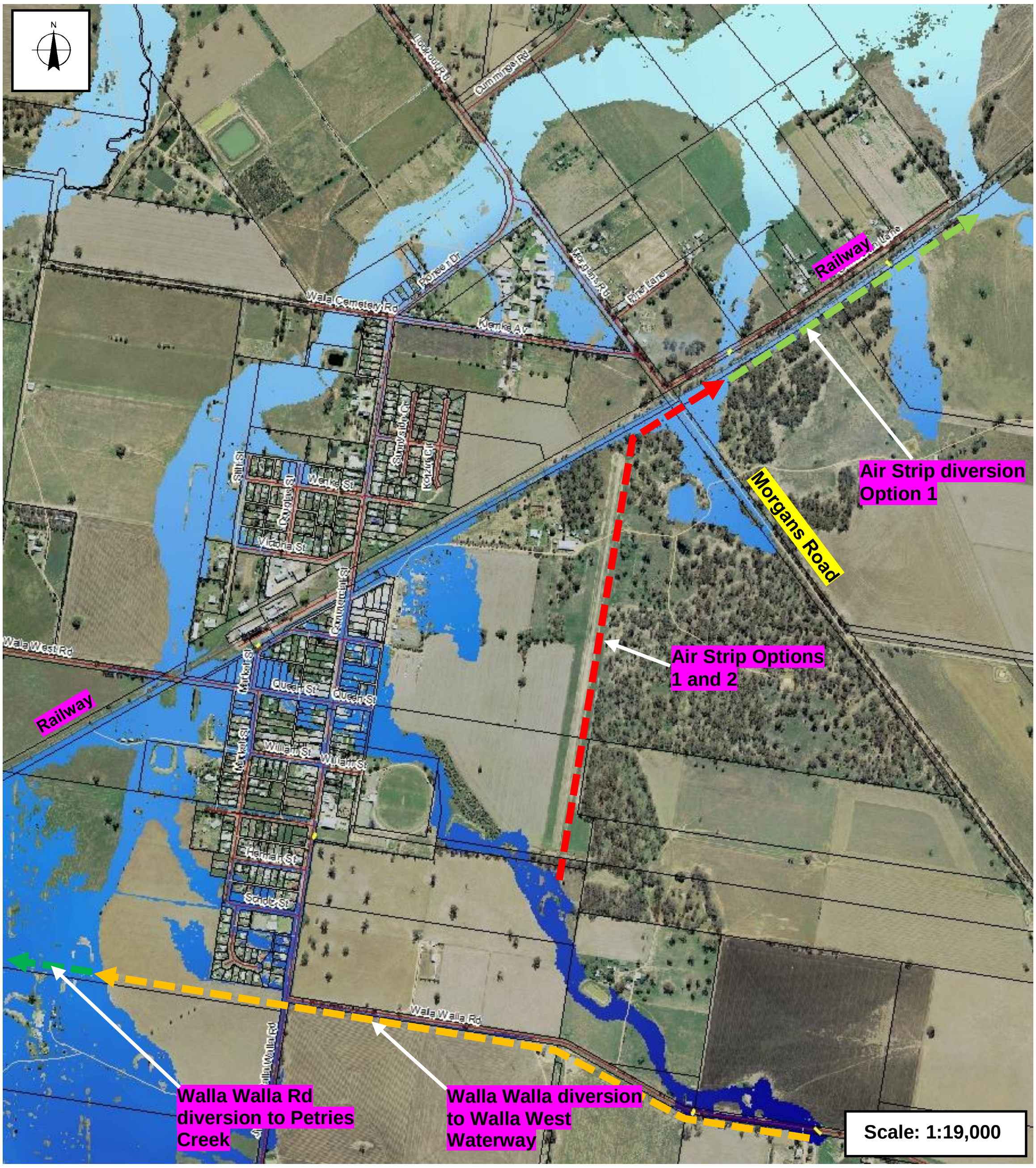


Figure 10 Queen Street Waterway - Diversion Options

Diversion options are listed as follows (refer to Figure 10):

- Walla Walla Road Diversion to Walla West Waterway
- Walla Walla Road Diversion to Petries Creek
- Air Strip Diversion Route 1 (to railway bridge 1.0 km downstream of Morgans Road)
- Air Strip Diversion Route 2 (to railway culvert 0.15 km downstream of Morgans Road)

7.5.1 Walla Walla Road Diversion

This diversion directs floodwater from the Queen Street Waterway westwards parallel with the south side of the Walla Walla Road, across the Jindera-Walla Walla Road and then westwards to the Walla West Waterway (refer to Figure 10).

Indicative diversion drain details are summarised as follows:

- Overall route length 2,100 metres
- Natural fall along the diversion route 0.7%.
- Assuming a trapezoidal shaped drain, 4 metre bed width, 6:1 batters and 0.3 metre of design freeboard, a drain depth of 1.2 metre and top width of 18.4 metre is required.

The Walla Walla Road diversion route is not favoured for the following reasons:

- It transfers floodwater to the upstream side of Walla Walla. Although flooding from the Walla West Waterway does not cause any serious impacts aside from the railway bridge choke, the diversion of a significant amount of additional floodwater into the waterway on the upstream side of town will increase nuisance flooding along the waterway route. A diversion which is able to transfer floodwater to the downstream side of town is preferred.
- A house, driveway and farm dam are located at the upstream end of the diversion route. This will lead to design complications and increased costs.
- One further vehicle access cross over is located on route to the Jindera-Walla Walla Road potentially requiring a high capacity, high cost culvert structure.
- The diversion channel route on the downstream (west) side of the Jindera-Walla Walla Road is through land zoned large lot residential (R5) which is earmarked for future development.

7.5.2 Walla Road Diversion to Petries Creek

Petries Creek is located a further 1,000 metres west of the junction of a possible Walla Walla Road diversion channel and the Walla West Waterway. A possible extension of the diversion through to Petries Creek would need to cross 700 metres of flat terrain on the west side of the Walla West Waterway.

A Walla Walla Road diversion extending a further 1,000 metres west to Petries Creek is not favoured for the following reasons:

- It will tend to exacerbate flooding along Petries Creek downstream of the diversion inflow point.
- The depth of the channel west of the Walla West Waterway is likely to exceed 3 metres. A diversion channel as large as this is not desirable.
- The same reasons as flagged above for the Walla Walla Road diversion terminating at the Walla West Waterway.

7.5.3 Waterway Diversion – Air Strip Route - Option 1

The favoured diversion route on the east side of Walla Walla is shown on Figure 10. The 2.5 km route is initially down the east side of a private airplane landing strip (1.3 km) and then down the south side of the railway (1.2 km).

The advantages of this route are:

- There is favourable continuous fall along the diversion route (varies from 0.3 to 0.9%)
- There is no flood sensitive development (e.g. buildings) along the diversion route
- The railway bridge receiving the diversion has sufficient capacity to pass the additional flow

The main complicating issues associated with the diversion are listed as follows:

- Native vegetation impacts along the diversion channel route. The railway section of the route is covered with low to medium density native woodland
- The probable need to allow low and minor flood flows to continue along the existing Queen Street Waterway course downstream of the diversion offtake (i.e. to supply the storage dam used for irrigating the sportsground)
- The probable need to allow low and minor flood flows to continue down an existing natural drainage course on the north side of the railway and Chinatown Lane (i.e. drainage course along the Option 2 receiving waterway route)
- Morgans Road crossing. A large culvert structure will be required
- An increase in flooding on the property immediately downstream (north) of the railway bridge at the downstream end of the diversion channel

7.5.4 Waterway Diversion – Air Strip Route – Option 2

Option 2 directs the diversion flows through an existing railway culvert crossing (four 1.2 x 0.8 m box culverts – refer to Photograph 3 in Figure 11) 150 metres downstream of Morgans Road as shown in Figure 10 and subsequently down a natural depression through properties on the north side of Chinatownn Lane to the Walla West Waterway.

This alternative route is not considered as favourable as the Option 1 route for the following reasons:

- The existing railway culvert structure would require a major upgrade as compared to the railway bridge option which has sufficient capacity to accommodate the diversion flows without the need for a new larger structure
- The Chinatown Lane crossing is problematic. It would require deepening of the overland flow path to allow for a large waterway structure under the road which would require further deepening on the downstream side of the road. There are no public road crossings on the downstream side of the preferred railway bridge Option 1 route, although there is a private vehicle access track
- This depression is aligned through multiple properties. There are two houses and multiple farm sheds located within or on the fringe of the overland flow path (depression)

The above complications are considered to make Option 2 less attractive than Option 1.

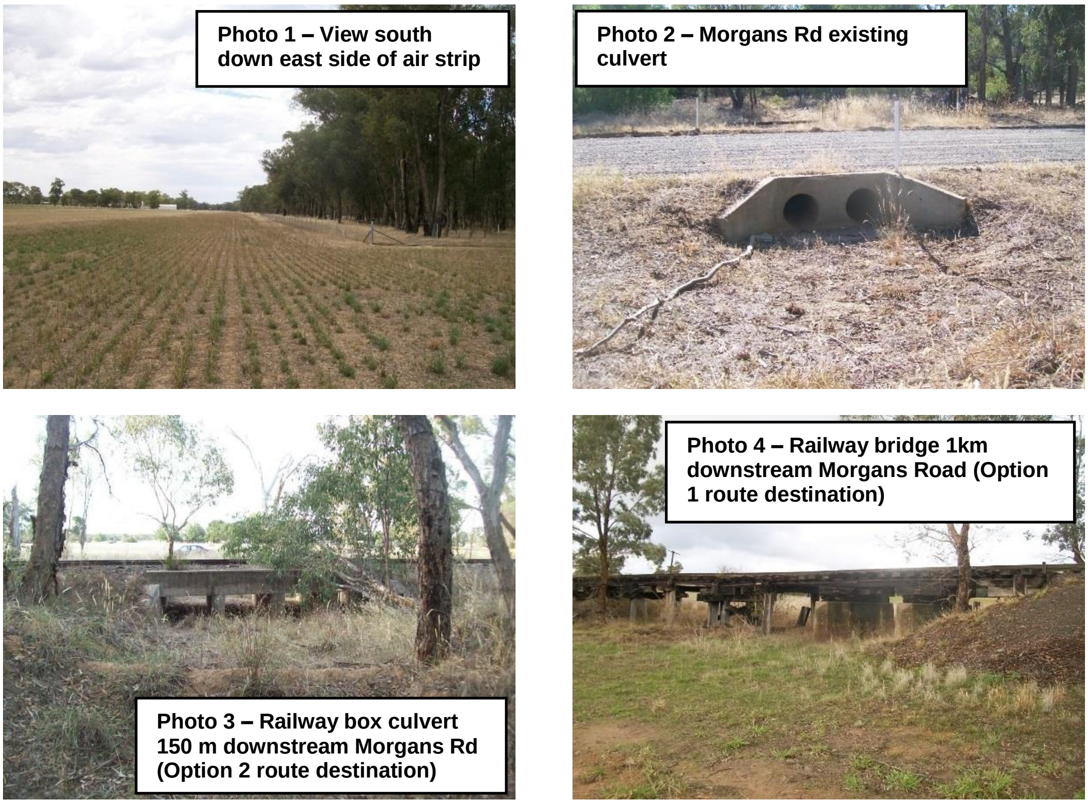


Figure 11 Air Strip Diversion Channel Route Photographs

Preferred Diversion Route

The preferred diversion route is the Air Strip Option 1. The principle reasons why this route is preferred are as follows:

- Diverted flows are discharged to the downstream side of Walla Walla in contrast to the Walla Walla Road route where diverted flows are discharged to the upstream side of town
- Flooding impacts within the receiving waterways will not be significantly exacerbated as a result of the diversion. The same cannot be said for the Option 2 Air Strip route with multiple small rural properties along the receiving waterway route downstream of Chinatown Lane affected
- Although the Option 1 Air Strip route is longer compared to Option 2, it does not require large waterway structures at the railway line and possibly Chinatown Lane as would be the case if the Option 2 route was selected

7.5.5 Preliminary Design Details – Preferred Route

The initial 1.1 km of the diversion channel route is parallel to a private air strip (refer to Figure 12). A close to uniform grade of 0.9% is present along this section of the route. It would be possible to position the drain within a cleared approximately 20 m wide strip on the east side of the air strip. If this was not possible (e.g. for safety reasons associated with the use of the air strip) then vegetation (native tree) clearing would be required in order to position the diversion channel on the east side of the current cleared zone.

The subsequent 1.2 km of the diversion channel route is parallel to the decommissioned railway line. The preliminary drain longitudinal grade reduces to 0.34% downstream of Morgans Road. There is 10 to 15 metres of space available from the toe of the decommissioned railway embankment to the south side reserve boundary. This will be insufficient to wholly locate the diversion channel within the railway reserve. Subject to negotiation outcomes with the rail authority during detailed design, it may be necessary to wholly locate the diversion channel outside the railway reserve on approximately 25 metres wide easement.

Low flow culvert structures are likely to be required for internal farm access across the diversion channel at two points along its route.

Preliminary design details for the diversion channel are given in Table 5.

7.5.6 Hydraulic Assessment

The hydraulic model was used to quantify the effect of the Walla West Waterway diversion. The following preliminary design arrangement was adopted at the diversion channel offtake:

- Embankment across the creek course immediately downstream of the diversion (100 year ARI flood level 221.15 m AHD)
- Entry into the diversion channel – weir sill set at 220.1 m AHD
- Single 0.75 metre diameter low flow culvert through embankment – 100 year ARI flow of 1.3 m^3/s discharges via this culvert into the downstream Queen Street Drain

The low flow culvert will allow for the continued discharge of low flow inflows into the dam adjoining the sportsground (used for irrigation).

Limiting the culvert to a single cell 0.75 metre diameter pipe will also ensure that 100 year ARI post diversion flows are confined to the Queen Street Drain. Inflows into the dam adjoining the sportsground during large flood events will be significantly reduced compared to pre diversion conditions.

The modelled change in 100 year ARI flood level with the diversion channel in place is shown on Figure B2 in Appendix B.

There are no locations along the diversion channel route where increases in 100 year ARI flood levels are predicted to occur which will impact on existing buildings or other flood sensitive development.

Increases in the flood depth of up to 0.5 metre will occur at the railway bridge at the downstream end of the diversion channel. The extent of flooding is not significantly affected however both upstream and downstream of the bridge with flows relatively well confined by the natural terrain.

The model indicates that there will be some increase in flow through the railway culvert structure 150 m downstream of Morgans Road. This results in an afflux of up to 0.05 metre within the receiving natural depression downstream of Chinatown Lane. This could easily be addressed if required by closing one of the three railway box culvert cells to reduce the flow through this structure back to existing condition levels.

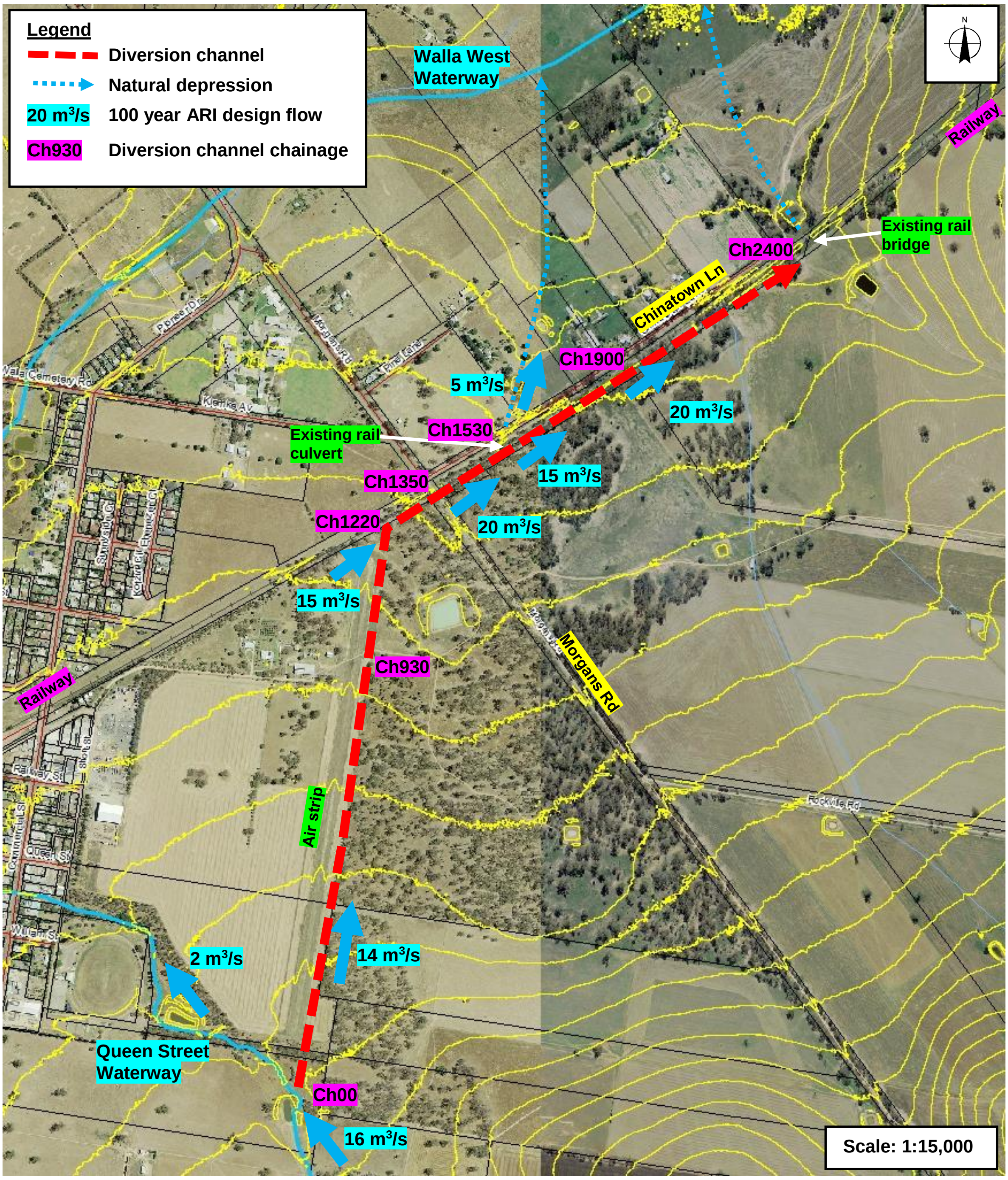


Figure 12 Queen Street Waterway – Preferred Diversion Route

Table 5 Queen Street Waterway Diversion – Preliminary Design Details

Chainage (m) (Refer to Figure 12)	Drain Details				Comments
	100 year ARI flow (m^3/s)	Grade (%)	Depth (m)	Top width (m)	
00	14	-	-		Inlet Weir – sill 220.1 m AHD – waterway bed approx. 219.4 m AHD
00-130	14	0.90	1.2	20	Located within cleared offset runway zone
130 - 1220	14	0.90	1.2	20	20 m wide cleared strip on east side of runway, farm access crossing at Ch 930
Ch 1220 - 1350	15	0.90	1.2	20	South side of railway –base rail embankment to boundary approx. 15 m
Ch 1350	18	-	-		Morgans Road – indicative structure – ten cells 1.5 m (W) x 0.9 m (H) BCs
Ch 1350 - 1530	20	0.34	1.6	24	South side of railway – expanded reserve area to Ch 1480
Ch 1530	20	-	-	-	Existing rail culvert – works may be required to maintain flow characteristics
Ch1530 – 1900	15	0.34	1.5	23	South side of railway – base rail embankment to boundary approx. 10 m
Ch1900 - 2400	20	0.34	1.6	24	South side of railway – base rail embankment to boundary approx. 10 m
Ch2400	25	-	-	-	Dilapidated bridge structure – capacity > 30 m^3/s – no works proposed
Downstream Ch 2400	25	-	-	-	Broad depression – no works proposed

Depth includes 0.3 m freeboard, 5.0 m bed width, 6:1 batters

7.5.7 Environmental Impacts

It may be possible to position the diversion channel in the cleared strip adjoining the east side of the air strip (refer to Figure 11, Photograph 1). If this is the case, there will be no native vegetation losses along this section of the route. If not and the channel is positioned on the east side of the cleared strip, a significant amount of native vegetation (woodland) will require removal.

The railway segment will necessitate the clearing of native vegetation (woodland) along the channel route. This is a major adverse impact associated with this option.

An assessment of the environmental value of the vegetation along the diversion route has not been carried out to date. An assessment should be undertaken prior to detailed design.

7.5.8 Social Impacts

The works are spread over four privately owned properties. The property most affected is the air strip property. The diversion channel will however convey flow infrequently and for short periods of time. The diversion channel is also a relatively shallow broad waterway (batters 6 (H) to 1 (V), base 5 m, 100 year ARI flow depth adjoining air strip only 0.9 m).

The impacts on the other three properties will be less. The diversion channel will occupy a relatively narrow strip adjoining the railway reserve. The width of the strip will depend on whether the channel can be partly located within the railway reserve. Past experience would suggest that it may be necessary to wholly locate the diversion channel outside the rail reserve given the complications associated with works within railway reserves, even those which have been decommissioned. An easement is generally the preferred approach compared to full acquisition.

Compensation would be payable to the owners of the properties on which the diversion channel is located. The compensation amount is generally determined by a Certified Valuer.

The five landholders directly affected by the diversion channel were consulted regarding their views on the impacts of the works.

One of the landholders is extremely concerned with the loss of native woodland vegetation which will result from the construction of the diversion channel as it parallels the railway. The other landholders also have varying degrees of concern in relation to the loss of trees which would result.

Another concern raised is the effect on flows within the depression downstream of the railway culvert, 150 metres downstream of Morgans Road (refer to Photograph 3, Figure 11). The bed of the diversion channel will be lower than the invert of the culverts therefore significantly reducing flows in the downstream depression including inflows into two farm dams.

The bed level of the diversion channel is likely to be approximately 0.5 metre below the railway culvert invert level. It is noted that there is currently an informal bank preventing low flows from discharging to this same railway culvert suggesting that at least one downstream property owner is not benefitting from receiving these flows. One landholder on the north side of Chinatown Lane has however made it known that he relies on the railway culvert flows to supply his farm dam.

It should be possible, if required, to direct low flows from within the base of the diversion channel down the Chinatown Lane depression. This may require a low flow pipe from the base of the diversion channel to the depression on the north side of Chinatown Lane. The details would be determined during detailed design.

7.5.9 Economic Impact

The diversion channel works will eliminate all above floor flooding at Walla with the possible exception of one property which remains affected by local runoff.

Benefit cost details are given in Table 7. The benefit cost ratio is 0.85. Although the tangible benefits are slightly outweighed by the costs, intangible benefits not taken into account such as those associated with reductions in the level of stress for town occupants and a potential boost in property values adds further support for the diversion channel option.

7.6 Walla West Waterway – Railway Bridge

7.6.1 Overview

There are two Walla West Waterway infrastructure crossings which cause significant increases in flood levels on the upstream side of each crossing.

One of these crossings is the Cemetery Road culvert. Although a 100 year ARI afflux of 0.9 metres is induced, this does not lead to any serious flooding impacts within the afflux zone (i.e. no buildings are located within the afflux zone). Given this, there is no need for the Cemetery Road culvert structure to be upgraded.

The other crossing is the railway bridge adjacent to Walla West Road / Queen Street. The existing dilapidated structure is show on Figure 13. The 100 year ARI afflux is 0.9 metre. There are existing houses located within the afflux zone (6 Queen Street and 8 Queen Street). Given this, changes to the existing structure to reduce the afflux have been assessed.

The railway was decommissioned in 1991. It is possible that the railway may be converted for use as a cycle / pedestrian trail at some point in the future.

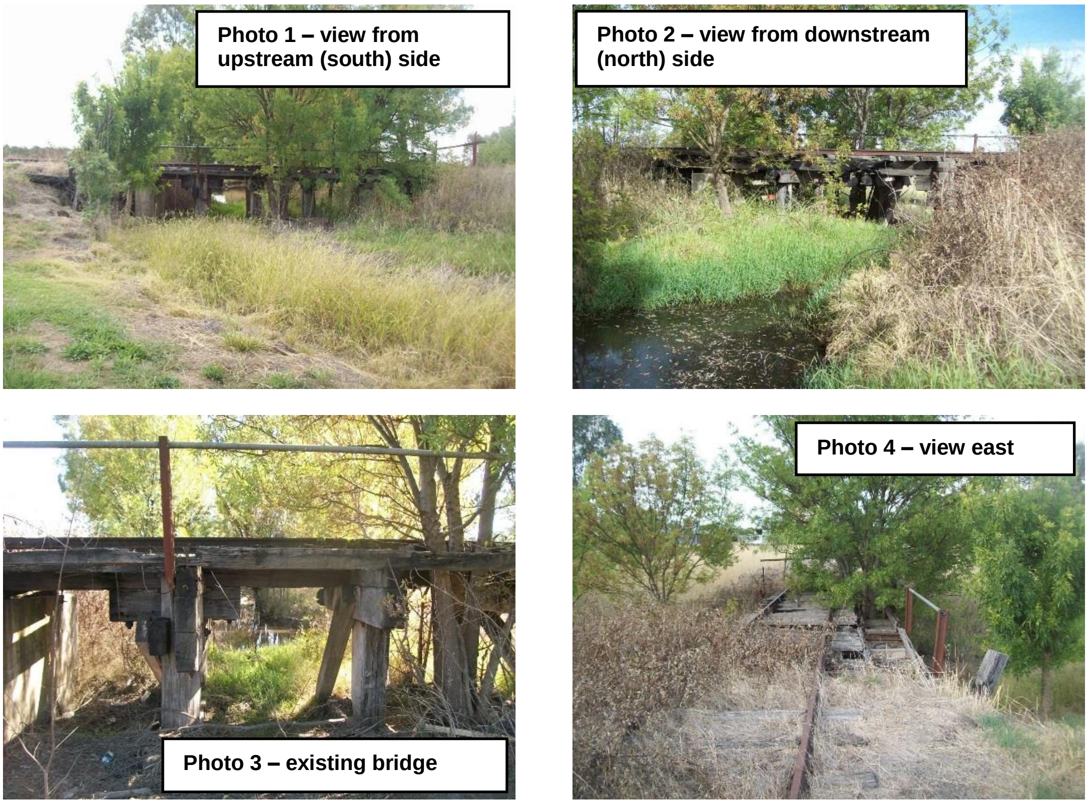


Figure 13 Walla West Waterway – Railway Bridge

The existing railway bridge structure details are:

- Span (abutment to abutment) – 10 metres
- Waterway opening area – 9 m^2 (after allowing for the five piers, zero blockage)
- 100 year ARI peak design flow 36 m^3/s
- 25% blockage assumed for design flood modelling
- 100 year ARI upstream flood level – 212.8 m AHD (top of railway 212.7 m AHD)

7.6.2 Modification Options

The following options were modelled all involving removal of the existing railway bridge:

- 10 m wide opening retained with some lowering of local ground levels
- 20 m wide opening
- 30 m wide opening
- 50 m wide opening

Modelling results are summarised in Table 6.

The nearest house within the afflux zone is located at 6 Queen Street. A 30 m wide opening in the railway embankment is required in order to reduce the railway afflux sufficiently such that 6 Queen Street is outside the afflux influence zone. The 100 year ARI flood levels at 6 Queen Street is reduced by 0.48 metre as a result of the bridge removal and widening of the embankment opening to 30 metres. Any further widening of the railway embankment beyond an opening width of 50 m is therefore not needed.

The 30 m wide opening option will:

- Reduce the 100 year ARI flood level at 6 and 8 Queen Street by 0.48 m and 0.41 m respectively (refer to Table 5)
- Flood levels up to and including the 10 year ARI event at 6 and 8 Queen Street remain unchanged however. The threshold of above floor flooding at these two properties (10 year ARI event) will as a result remain unchanged

The change in 100 year ARI flood levels coinciding with the removal of the railway bridge and the 30 m widening works is shown on Figure B3 in Appendix B.

If the Queen Street Waterway Diversion Channel option is implemented, the peak 100 year ARI flow at the Walla West Waterway railway bridge reduces to 26 m^3/s. Under these circumstances, a railway embankment opening of 23 metres is sufficient to reduce the afflux such that 6 Queen Street is outside the afflux influence zone.

Table 6 Railway Bridge Removal and Embankment Opening Widening

Scenario	100 year ARI Flood level (m AHD)				Velocity through opening (m/s)
	4 m upstream of bridge	6 Queen St (floor 212.33)	8 Queen St (floor 212.39)	10 Queen St (floor 212.84)	
Existing conditions	212.83	212.90	212.90	213.02	4.0
10 m wide opening – bridge removed	212.65	212.83	212.83	213.00	3.3
20 m wide opening – bridge removed	212.33	212.53	212.53	213.00	2.6
30 m wide opening – bridge removed	212.14	12.42	212.49	213.00	1.9
50 m wide opening – bridge removed	212.02	212.42	212.48	213.00	1.3

7.6.3 Impacts

The railway bridge modifications are relatively benign. There are expected to be no significant adverse impacts on:

- Flooding – downstream flow and flood level increases are small (refer to Figure B3 in Appendix B)
- Environmental – no adverse environmental impacts are expected
- Social – no adverse social impacts are expected. The existing bridge is dilapidated. If the railway is to be converted to a pedestrian / cycleway trail at some point in the future, a suitable structure can be installed at that time

7.6.4 Economic Assessment

The railway works will benefit two properties. These two properties are however two of the most vulnerable houses at Walla Walla. Benefit cost details are given in Table 7. The benefit cost ratio is 1.06.

7.7 Road Closures

All of the roads into and out of Walla Walla (Walla Walla Road, Walla Walla Jindera Road, Walla West Road and Lookout Road are subject to flooding from either the Walla West Waterway, Queen Street Waterway or Petries Creek.

None of the road crossings where flooding occurs cause problems with respect to flood damage impacts on adjoining development (e.g. due to afflux effects). The impacts are limited to any damage to the road pavement and the inconvenience associated with temporary road closures until floodwaters recede.

Road closures longer than 6 hours are not generally expected given the small catchment sizes and relatively rapid runoff response times.

Upgrading existing culverts to reduce the frequency of road overflows will be costly. It is also probable that other waterways will overtop the roadways further out from town, thereby negating the benefits of the road culvert upgrades.

The Walla Walla- Jindera Road for example has more than ten local gully culvert crossings within the first 7 km south of the Walla West Waterway crossing. Most of these crossings will experience infrequent short duration overtopping of the road in severe rainfall events. Upgrading the Walla West Waterway culvert structure will not therefore achieve a significant improvement in road access into and out of Walla Walla.

Give the above, no further detailed investigations were carried out into roadway waterway structure upgrades at the various waterway crossings on the outskirts of Walla Walla.

7.8 Summary and Discussion

7.8.1 Flood Modification Options

Serious flooding leading to potential above floor flooding at Walla Walla is primarily due to the unconfined discharge of flows from the Queen Street Waterway through the town between the Queen Street Drain and the railway.

The investigations documented in the preceding sections have found that the Walla West Waterway railway bridge adjoining the Queen Street / Walla West Road, although generating a large upstream afflux in a 100 year ARI flood, is not the controlling influence on the threshold of above floor flooding for any of the nearby properties.

A summary of the flood modification investigation outcomes is provided as follows:

- Retarding basin on-line with the Queen Street Waterway. Hydrologic modelling identified that the storage volume required is very large in order to achieve worthwhile peak flow reductions. This option is therefore unviable and has been discarded
- Queen Street Drain upgrade. The existing drain is aligned through the town. Upgrading will be very costly given the presence of seven culvert crossings along the route. Furthermore there is insufficient space to allow for a major upgrade, notably along the Queen Street Road reserve segment of the drain where the existing drain takes up all of the available space. This option (large increase in the drain capacity) is therefore considered to be practically and economically problematic and as such has been discarded
- Queen Street Drain Extension and Berm. The assessment of this option has found that it will assist in reducing the frequency of nuisance level flooding. It will have very little effect on flooding conditions in large floods. None the less the benefit cost ratio for this option is a relatively favourable 1.65 (refer to Table 7) due to alleviating impacts in minor flood events (e.g. mitigating grounds flooding property impacts).
- Queen Street Water Railway Bridge removal. This option will significantly lower 100 year ARI flood levels on the upstream side of the railway. The removal of the dilapidated bridge and widening of the opening to 30 metres reduces the upstream 100 year ARI flood levels by 0.5 metres. This option does not however reduce the threshold at which properties within the afflux zone are subject to above floor flooding (threshold is controlled by overflows from the Queen Street Drain). The befit cost ratio for this option is 1.06 (refer to Table 7)
- Queen Street Waterway Diversion – Walla Walla Road Route. A diversion westwards via the south side of the Walla Walla Road to the upstream side of town was assessed. This option will tend to exacerbate flooding along the Queen Street Waterway route as it skirts around the west side of Walla. There are also complications with respect to the route including the need to retain access to existing properties and conflicts with future development on the west side of the Walla Walla-Jindera Road. This option is therefore not the preferred diversion route
- Queen Street Waterway Diversion – Air Strip and Railway Route. This option diverts flows from the Queen Street Waterway to the downstream side of the town. There is favourable fall along the route. There are no buildings or other high value infrastructure along the route which will be affected by this diversion. This option is considered the most favourable diversion option and will eliminate almost all of the serious flooding within Walla Walla. The benefit cost ratio of this option is 0.85 (refer to Table 7)

There are some difficulties associated with the preferred Queen Street Waterway diversion option. It is predominantly aligned through privately owned rural land use properties. At least one of the affected landholders is very concerned with the loss of native vegetation which will result from the diversion channel construction. Other landholders also have concerns (e.g. impacts of flows into farm dams). The vegetation impacts should be subject to a detailed assessment prior to detailed design and pending the outcome of this assessment may determine if the detailed design proceeds.

The Queen Street Drain Extension will have very little impact in large floods. It will however reduce nuisance flooding in small floods. The down side is that native vegetation will be lost along the formed drain route. The native vegetation is immature vegetation which covers the waterway corridor following a revegetation and fencing project.

The benefits and costs of the preferred options are given in Table 7. The benefit cost ratios are relatively favourable given that the assessment of benefits excludes intangible benefits (e.g. reductions in stress and trauma) and potential benefits derived from more favourable property valuations given the reduced flood risk.

7.8.2 Alternative Approach – Voluntary House Raising

The alternative to relying on flood modification measures to mitigate flood impacts on existing development at Walla Walla is voluntary house raising (refer to Section 5.7).

Voluntary house raising funding subsidies are generally limited to residential properties in low hazard areas. The other major limiting factor is that many houses are not suitable for raising because of practical limitations (e.g. all houses on concrete slab foundations).

Voluntary house raising only provides benefits to those properties which have been raised. Grounds flooding will continue to occur to those properties where houses have been raised. Any stored contents below the raised floor will be vulnerable to flooding, particularly given the relatively short flood response time available at Walla Walla.

Commercial and industrial land buildings, and those residential houses not able to be raised will continue to be subject to above floor flooding.

A preliminary assessment of the feasibility of raising the eleven houses subject to above floor flooding has found that:

- It may be possible to raise up to six houses. None of these six houses is favourably suited to economical raising however given the low height between the ground and floor level
- The cost of raising any of the six houses, if feasible, will be significant given the presence of peripheral structures attached to the main house unit and the practical difficulties due to the limited space between the ground and existing floor
- Given the above practical difficulties and the age and condition of the subject houses, favourable economic outcomes are likely to be limited to raising of at most two houses only

Table 7 Economic Assessment of Flood Modification Options

Mitigation Option	QSD Extension and Berm	QSW Diversion Channel	Railway Bridge Removal	Composite Works
Existing conditions AAD ($/annum)	250,000	250,000	250,000	250,000
Existing conditions – number of buildings subject to 100 year ARI above floor flooding	23	23	23	23
Post mitigation works AAD ($/annum)	238,000	87,000	245,000	81,000
Post mitigation – number of buildings subject to 100 year ARI above floor flooding	23	1	23	1
Reduced AAD post mitigation ($/annum)	12,000	163,000	5,000	169,000
Present value of future benefits ($)	127,000	1,727,000	53,000	1,790,000
Capital cost of mitigation works ($)	70,000	1,840,000	50,000	1,960,000
Future maintenance costs ($/annum)	700	18,400	0	19,100
Present value of future maintenance costs ($)	7,000	195,000	0	202,000
Present value of total costs (capital plus maintenance)	77,000	2,035,000	50,000	2,162,000
Benefit / cost ratio	1.65	0.85	1.06	0.83

Notes:

1. Future annual average maintenance costs assumed to be 1% of the capital costs.
2. Present values of future flood reduction benefits and levee maintenance costs assume a discount rate of 7% and a design life of 20 years.

7.9 Recommended Approach

Given the limitations associated with the house raising option, the recommended approach for mitigating flood impacts on existing development at Walla Walla is to pursue the implementation of the preferred flood modification measures as listed in Table 8. The implementation of the flood modification options will:

- Eliminate almost all serious above floor flooding at Walla Walla (only one remaining property subject to above floor flooding due to local runoff)
- Provide potential improvements in property valuations (not factored into the benefit cost figures)
- Potentially allow for a reduction in the size of the Queen Street Drain

The major proposed mitigation measure is the Queen Street Waterway Diversion Channel. The main adverse impact associated with this measure is the loss of vegetation. It is recommended that a detailed vegetation impact assessment be completed prior to detailed design. This could be undertaken as part of a broader concept design assessment and would encompass confirmation of the channel alignment and easement footprint, identification of any required access crossing structures and local drainage structures required along the route.

Table 8 Summary Proposed Flood Modification Measures

Option / Description	Estimated Cost ($)	B/C Ratio	Ranking / Priority	Implementation Issues
Extend Queen Street Drain upstream	70,000	1.65	Medium	• Lower value vegetation impact issues
Removal of Railway Bridge and widen opening to 30 metres	50,000	1.06	Medium	• Approval from rail authority required. • Consider possible future pedestrian / cycleway rail trail uses. • Reduced opening of 23 metres required if Diversion Channel is implemented.
Queen Street Waterway air strip diversion	1,840,000	0.85	Medium	• Vegetation impact issues require further detailed assessment prior to detailed design. • Consultation with rail authority required. • Design issue with maintaining flows into the first north side natural depression on the east side of Morgans Road. • Design for continued flow access to dam adjoining sportsground.

Note:

1. Indicative cost estimates are provided in Appendix C. Cost estimates should be updated following detailed design.

8. Floodplain Risk Management Plan

8.1 Overview

This Floodplain Risk Management Plan (FRMP) applies to the Walla Walla township and adjoining area as defined by Figure A1.

An unnamed waterway referred to by this report as the Walla West Waterway skirts around the western and northern fringes of Walla Walla.

A second waterway referred to as the Queen Street Waterway by this report enters the town on the north side of the Sportsground. This waterway reverts to a man made drain (Queen Street Drain) within the town, discharging into the Walla West Waterway just upstream of the railway.

Petries Creek to the west of Walla Walla does not impact directly on flooding conditions within the town.

Serious flooding impacts within Walla Walla are primarily caused by flow from the Queen Street Waterway. This affects the area between the Queen Street Drain and the railway further north. Flooding is due to the limited discharge capacity of the Queen Street Drain and the lack of confinement of flows on the eastern fringe of town. Most of the remainder of Walla Walla is free from serious flooding impacts.

Walla Walla has been affected by flooding most recently in 2010 and 2012. More severe flooding occurred during 1973 and 1974.

Due to the small catchment areas draining to Walla Walla, the lag time between rainfall and peak flooding is short, typically 30 minutes to one hour. Flooding durations are similarly short, lasted for typically less than two hours.

Flood modelling undertaken as part of the Walla Walla Flood Study (GHD, 2017) identified that there are an estimated 23 buildings at risk of 100 year ARI above floor flooding. The average depth of above floor 100 year ARI flooding for these 23 buildings is 0.16 metres.

Flooding impacts are therefore likely to be confined to property damage, with depths and velocities through developed properties not high enough to create the risk of serious injury or, worse case, loss of life.

The average annual flood damage at Walla Walla is estimated to be $250,000 per annum.

Flood mitigation measures which can be used to reduce flooding impacts are:

- **Property modification measures** which are designed to avoid future development within areas which have a high flood risk or to reduce damages by flood proofing existing development
- **Response modification measures** which are designed to modify the response of the population at risk prior to, during and after a flood
- **Flood modification measures** which are designed to modify flooding conditions by lowering flow rates, flood levels or velocities and excluding floodwaters from protected areas

Almost all of the 23 properties identified as at the highest risk of above floor flooding are clustered in the intervening area between William Street and the railway line. Mitigation options to alleviate flooding impacts in this area were assessed with respect to their effectiveness (reduced future flood damages compared to their cost) and any adverse hydraulic, environmental and social impacts.

The recommended mitigation measures are a mixture of property modification, response modification and flood modification measures.

8.2 Recommended Mitigation Measures

The recommended floodplain management plan measures are listed in Table 9. The recommended measures have assigned priorities based on a subjective assessment of the costs and benefits.

8.2.1 Property Modification Measures

Implementing appropriate land use planning and development controls is an integral component of all floodplain risk management plans. In relation to Walla Walla, the following measures are recommended:

- Adoption of Flood Planning Levels (FPLs) for residential development based on the 100 year ARI flood level plus 0.3 metre of freeboard
- Adoption of a Flood Planning Area (FPA) as defined on Figure A1 of Appendix A
- Update of the Greater Hume Shire LEP such that it is consistent with the proposed Local Flood Policy for Walla Walla
- Update of the Greater Hume Shire DCP to incorporate the Local Flood Policy planning and development controls for Walla Walla (refer to Appendix A)

Although the FPA covers a significant size area, the associated flood based development controls are not particularly restrictive unless the site in question is located within a Floodway defined area (refer to Figure A2) and / or a High Hazard defined area (refer to Figure A3). The Floodway and High Hazard areas are primarily restricted to the waterway corridors (e.g. Walla West Waterway, Queen Street Waterway and the Queen Street Drain).

Most of the FPA area is designated as Flood Fringe and Low Hazard. The main development control applied to these areas is minimum floor levels for new development.

8.2.2 Response Modification Measures

The catchment draining to Walla Walla is relatively small. Installing telemetered rainfall and streamflow gauges is therefore not proposed given the very limited flood warning time available to respond to an imminent flood.

Subsequent to the completion of the FRMPs within the Shire, a Local Flood Plan (LFP) for the Greater Hume Shire should be prepared by the SES. The LFP will detail operations relating to flood preparedness measures, flood response measures and flood recovery measures.

The following community awareness measures are recommended:

- Establishment of a flood information facility on Council's web site where flood response information (e.g. Local Flood Plan), detailed flood information (e.g. reports and maps from this project) and other useful information relating to flooding can be accessed by the community
- Inclusion of expanded flooding information on Section 149 certificates issued by Council

It is important that flood data be collected both during and in the aftermath of future flood events. The data can be used for future investigations associated with the update of the Walla Walla FRMP. Future data collection should focus on:

- Large floods (i.e. where flooding leads to above floor flooding)
- Photographs if possible at or near the peak of flooding
- Recording reliable peak flood levels and their subsequent survey to the AHD datum
- Details of any instances of above floor flooding (e.g. address, date, height above floor)

Flood Modification Measures

Flood modification measures to alleviate flooding risks to those properties with the greatest risk of above floor flooding were assessed as part of the FRMS.

Council will be responsible for the implementation of the flood modification measures subject to its own funding constraints. Some funding may be available through the NSW Government's Floodplain Risk Management Program.

The focus of the proposed flood modification measures listed in Table 9 is to mitigate the serious (above floor) flooding impacts. The serious impacts are caused by flooding from the Queen Street Waterway.

The existing Queen Street Drain is not sufficiently large to cope with major floods. There is also a lack of channel incision on the east side approach to the drain. Limited space along the Queen Street Drain alignment does not allow for a major upgrade of the drain.

The proposed flood modification measures are:

- Relatively low cost works to form a defined approach channel upstream of the Queen Street Drain which will better confine low and minor flood flows thereby reducing nuisance level floodin
- Low cost works to remove a choke in the railway embankment at the Walla West Waterway adjacent to the Walla West Road. The works will significantly lower 100 year ARI flood levels on the upstream side of the railway.
- Major works involving the construction of a Queen Street Waterway diversion channel on the east (upstream) side of Walla Walla. The 2.4 km diversion channel will divert the majority of flow from the Queen Street Waterway such that it bypasses the town thereby eliminating almost all of the serious flooding at Walla Walla

A vegetation impact assessment and concept design study associated with the diversion channel should be undertaken in advance of the detailed design. Pending the outcome of the study, detailed design of the diversion channel would then proceed.

Voluntary house raising was considered as an alternative to flood modification options. Limitations associated with funding access (i.e. limited to residential properties only) and only a small number of houses being practical for raising meant that this option would not achieve a significant reduction in the risks to existing development.

Table 9 Recommended Floodplain Management Plan Measures

Measure Description	Priority	Indicative Capital Cost ($)	Funding Sources
Property Modification Measures			
- Endorse land use planning approach outlined in Plan	High	Nil	Council
- Refine & incorporate flood planning and development controls into LEP & DCP	High	Nil	Council
Response Modification Measures			
- Include expanded flooding information on S149 certificates	High	Ongoing	Council
- Develop and maintain flood information on Council's web site	High	5,000	Council / OEH / SES
- Prepare a Local Flood Plan	Moderate	10,000	SES
- Data collection and documentation in future floods	Moderate	Ongoing	Council / OEH / SES
-			
Flood Modification Measures			
- Queen Street Waterway Diversion Channel Vegetation Impact and Concept Design Study	High	40,000	Council / OEH
- Extend Queen Street Drain further 200 m upstream	Medium	70,000	Council / OEH
- Removal of Walla West Waterway railway bridge & establish 30 m opening (23 m if Diversion Channel is implemented)	Medium	50,000	Council / OEH
- Queen Street Waterway Diversion Channel	Medium	1,800,000	Council / OEH

Note:

1. Costs are indicative only and should be reviewed following any further design or investigation activities.

8.3 Implementation/Funding

There are a number of possible funding sources that could be considered by Council to assist with the implementation of the Floodplain Risk Management Plan. Potential funding sources include:

- Council contributed funds
- NSW State Government and Australian Commonwealth Government funding programmes for the implementation of flood risk mitigation measures
- SES for flood response improvement measures

The majority of NSW State Government financial assistance is likely to come via the NSW Government Floodplain Management Program (the Program). The Program is administered by OEH. Applications under the most recent round of funding within this Program were also eligible for funding assistance under the jointly funded NSW and Commonwealth Government's Natural Disaster Resilience Program.

Funding for vegetation management works could be sourced via the NSW Environmental Trust through OEH. The Environmental Trust offers a range of grant programs that rehabilitate or regenerate the environment. Funding for vegetation management works could also be available through the NSW LLS.

Funding under the Program is not available for assistance with measures associated with the applicant's core activities. This would include implementing land use planning and building development controls for example which is a core local government task. Eligible measures include implementing structural mitigation works, flood warning systems, evacuation management, voluntary house raising and voluntary purchase. Applicants are required to provide a certain level of funds for every $1 of grant funding. Funding of investigation and design activities is available. Funding for maintenance activities is generally not available.

9. Acknowledgements

The Greater Hume Shire Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

The project has been completed with the assistance of the Greater Hume Shire Council's Walla Walla Floodplain Risk Management Committee, Council's staff, Office of Environment of Heritage's staff, NSW SES staff and the other government agency and local residents who have had involvement in the project. The assistance which has been provided is very much appreciated by Council.

10. Abbreviations and Glossary

10.1 Abbreviations

AAD	Average annual damage
AEP	Annual exceedance probability
AHD	Australian height datum
ARI	Average recurrence interval
BOM	Bureau of Meteorology
DEM	Digital elevation model
EMPLAN	Emergency Management Plan
LEP	Local Environmental Plan
LLS	Local Land Services
FDM	Floodplain Development Manual (2005)
FPA	Flood planning area
FPL	Flood planning level
FRMS	Floodplain Risk Management Study
FRMS&P	Floodplain Risk Management Study and Plan
FRMP	Floodplain Risk Management Plan
OEH	Office of Environment and Heritage
PMF	Probable maximum flood
SES	State Emergency Service

10.2 Glossary

Annual Exceedance Probability (AEP) - AEP (measured as a percentage) is a term used to describe flood size. AEP is the long-term probability between floods of a certain magnitude. For example, a 1% AEP flood is a flood that occurs on average once every 100 years. It is also referred to as the '100 year ARI flood' or '1 in 100 year flood'.

0.2% AEP sometimes referred to as the 500 year ARI event

0.5% AEP sometimes referred to as the 200 year ARI event

1% AEP sometimes referred to as the 100 year ARI event

2% AEP sometimes referred to as the 50 year ARI event

5% AEP sometimes referred to as the 20 year ARI event

10% AEP sometimes referred to as the 10 year ARI event

20% AEP sometimes referred to as the 5 year ARI event

50% AEP sometimes referred to as the 2 year ARI event

Afflux - The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.

Australian Height Datum (AHD) - A common national plane of level approximately equivalent to the height above sea level. All flood levels; floor levels and ground levels in this study have been provided in meters AHD.

Average annual damage (AAD) - Average annual damage is the average flood damage per year that would occur in a nominated development situation over a long period of time.

Average recurrence interval (ARI) - ARI (measured in years) is a term used to describe flood size. It is a means of describing how likely a flood is to occur in a given year. For example, a 100-year ARI flood is a flood that occurs or is exceeded on average once every 100 years.

Catchment - The land draining through the main stream, as well as tributary streams.

Development Control Plan (DCP) - A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.

Design flood level - A flood with a nominated probability or average recurrence interval, for example the 100 year ARI flood is commonly use throughout NSW.

OEH (formerly DECCW, DECC, DNR, DLWC, DIPNR) - Office of Environment and Heritage. Covers a range of conservation and natural resources science and programs, including native vegetation, biodiversity and environmental water recovery to provide an integrated approach to natural resource management. The NSW State Government Office provides funding and support for flood studies.

Discharge - The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s) or megalitres per day (ML/day). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving.

Effective warning time - The time available after receiving advice of an impending flood and before the 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.

Flood - A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.

Flood awareness - An appreciation of the likely effects of flooding and knowledge of the relevant flood warning, response and evacuation procedures.

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.'

Flood hazard - The potential for damage to property or risk to persons during a flood. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.

Flood level - The height of the flood described either as a depth of water above a particular location (e.g. 1m above a floor, yard or road) or as a depth of water related to a standard level such as Australian Height Datum (e.g. the flood level was 77.5 m AHD). Terms also used include flood stage and water level.

Flood liable land - Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood prone land. Note that the term flood liable land now covers the whole of the floodplain, not just that part below the flood planning level, as indicated in the superseded Floodplain Development Manual (NSW Government, 2005).

Flood Planning Area (FPA) – the area of land below the FPL and thus subject to flood related development controls.

Flood Planning Levels (FPLs) - The combination of flood levels and freeboards selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.

Flood prone land - Land susceptible to flooding up to the Probable Maximum Flood (PMF). Also called flood liable land.

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 Study - A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.

Floodplain - The area of land that is subject to inundation by floods up to and including the Probable Maximum Flood event, that is, flood prone land or flood liable land.

Floodplain Risk Management Study – Studies carried out in accordance with the Floodplain Development Manual and assess options for minimising the danger to life and property during floods.

Floodplain Risk Management Plan - The outcome of a Floodplain Management Risk Study.

Floodway - Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

Flows or discharges - It is the rate of flow of water measured in terms of volume per unit time.

Freeboard - A factor of safety expressed as the height above the design flood 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.

High flood hazard - For a particular size flood, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.

Hydraulics Term - given to the study of water flow in waterways, in particular, the evaluation of flow parameters such as water level and velocity.

Hydrology Term - given to the study of the rainfall and runoff process; in particular, the evaluation of peak discharges, flow volumes and the derivation of hydrographs (graphs that show how the discharge or stage/flood level at any particular location varies with time during a flood).

Local catchments - Local catchments are river sub-catchments that feed river tributaries, creeks, and watercourses and channelised or piped drainage systems.

Local Environmental Plan (LEP) – A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.

Local overland flooding - Local overland flooding is inundation by local runoff within the local catchment.

Local runoff - local runoff from the local catchment is categorised as either major drainage or local drainage in the NSW Floodplain Development Manual, 2005.

Low flood hazard - For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.

Overland flow path - The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left — they may be diverted to another watercourse.

Peak discharge - The maximum flow or discharge during a flood.

Probable Maximum Flood (PMF) - The largest flood likely to ever occur. The PMF defines the extent of flood prone land or flood liable land, that is, the floodplain.

Risk - Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

Runoff - the amount of rainfall that ends up as flow in a stream, also known as rainfall excess.

SES - State Emergency Service of New South Wales

Velocity - the term used to describe the speed of floodwaters, usually in m/s (metres per second). 10km/h = 2.7m/s.

Water surface profile - A graph showing the height of the flood (flood stage, water level or flood level) at any given location along a watercourse at a particular time.

11. References

Department of Environment & Climate Change (2007). *Flood Emergency Response Planning Classification of Communities.*

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GHD (2016). *Walla Walla Flood Study*. Prepared for Greater Hume Shire Council.

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NSW Government (April 2005). *Floodplain Development Manual.*

Appendices

Appendix A – Local Flood Policy

Draft Local Flood Policy

Figure A1 – Flood Planning Area

Figure A2 – Hydraulic Category Plan

Figure A3 – Hazard Category Plan

Draft Local Flood Policy

1. Land to which these Development Controls Applies

The development controls in this Local Flood Policy apply to the Flood Planning Area at Walla Walla as defined by Figure A1.

2. Objectives

The floodplain development controls are intended to:

- Guide the development of flood prone land, applying balanced strategies to economically, socially and environmentally manage the potential flood risk to life and property
- Ensure that sufficient land is set aside to convey and/or store floodwaters and to protect and enhance the riparian zone
- Ensure that development, when considered both individually and in the context of cumulative development trends, will not cause unreasonable adverse flooding impacts in other locations

3. Definitions

Floodway	Those parts of the floodplain where a significant discharge of water occurs during floods. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Flood Storage	Those parts of the floodplain important for the temporary storage of floodwaters during the passage of a flood.
Flood Fringe	The remaining area of land affected by flooding, after floodway and flood storage areas have been defined.
Low Flood Hazard	Those parts of the floodplain where able bodied adults would generally have little difficulty wading and trucks could evacuate people and their possessions should it be necessary.
High Flood Hazard	Those parts of the floodplain where there would be a possible danger to personal safety, able bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be potential for significant structure damage to buildings.
Flood Planning Area (FPA)	Represents the area below the FPL and thus subject to flood related development controls.
Flood Planning Levels (FPLs)	Is the combination of flood levels and freeboards selected for floodplain risk management purposes.
Flood Prone Land	Land susceptible to flooding by the Probable Maximum Flood event. Flood prone land is synonymous with flood liable land.
Freeboard	Refers to a designated height above the design flood which is stipulated to incorporate a suitable factor of safety into development.

4. Site Classifications

- Flood Planning Area means land as defined by the attached Figure A1.
- Residential development Flood Planning Levels coincide with the 100 year ARI flood level plus 0.3 metre as determined by this FRMS&P.
- Floodway, Flood Storage and Flood Fringe Areas means land as defined by the attached Figure A2.
- Low Hazard and High Hazard Areas means land as defined by the attached Figure A3.

5. General - Development within the Flood Planning Area

General Development Standards applicable to the Flood Planning Area are as follows:

a) All development within the Flood Planning Area requires the consent of Council.

b) All development shall be generally assessed in accordance with the latest edition of the NSW Floodplain Development Manual as issued by the NSW Government.

c) Development will not be permitted unless Council is satisfied that the proposed development will not increase the flood hazard rating or likely flood damage to any other property.

6. Development within Floodway Areas

Development Standards applicable to Floodway Areas are as follows.

High Hazard Floodway Areas

Development within High Hazard Floodway areas is generally discouraged. Council may consider granting permission to minor developments including extensions provided the requirements for Low Hazard Floodway areas can be met.

Low Hazard Floodway Areas

a) No alteration in ground levels by more than 0.1 metre will be permitted, whether by excavation or filling, without the submission of a hydraulic study and prior development consent.

b) The erection of any new habitable structure on land within Floodway Areas will only be permitted if the land is outside the High Hazard area and supported by a hydraulic study demonstrating that the works will have no adverse flooding effect on any other property.

c) Extensions. Extensions of up to 60 m^2 to dwellings are permissible. The floor level of the extension is to be as high as practical without requiring modification to the existing roof line.

d) Fencing. Fences of a continuous (impermeable) design, such as metal cladding, shall not be permissible. Post and rail fences will be permitted providing they are designed to permit the unimpeded flow of floodwater.

7. Development within Flood Storage Areas and Flood Fringe Areas

Development Standards applicable to Flood Storage Areas and Flood Fringe Areas are as follows.

High Hazard Flood Storage and Flood Fringe Areas

The same requirements as those listed under Low Hazard Floodway Areas apply.

Low Hazard Flood Storage and Flood Fringe Areas

a) Development consent is required to be obtained prior to any work or building activity being carried out within the Flood Planning Area. A hydraulic study may be required to be submitted with any Development Application at the discretion of Council.

b) The minimum floor level of any new residential building is to be at the FPL (i.e. 0.3 metres above the 100 year ARI flood level).

c) Commercial and industrial development. At Council's discretion, the minimum floor level is to be at the FPL or the building is to be flood proofed to at least the FPL.

d) Extensions to existing residential buildings.

   i. Where the area of the extension is less than 50% of the existing floor area, the floor level of the extension may be constructed to the same level as the existing floor level.

   ii. Where the extension is greater than 50% of the existing floor area, the minimum floor level of the extension is to be at the FPL.

e) Extensions to existing non-residential buildings. Extensions to existing non-residential buildings may be constructed at the same level as the existing building. At Council's discretion, the complete building is to be flood proofed to the FPL.

f) Carports and open sheds. Carports and open sheds may be constructed at existing ground levels. They must be constructed from flood compatible materials.

g) Fencing. Fencing of a continuous design (e.g. metal cladding) shall be permissible.

8. Development Application Requirements

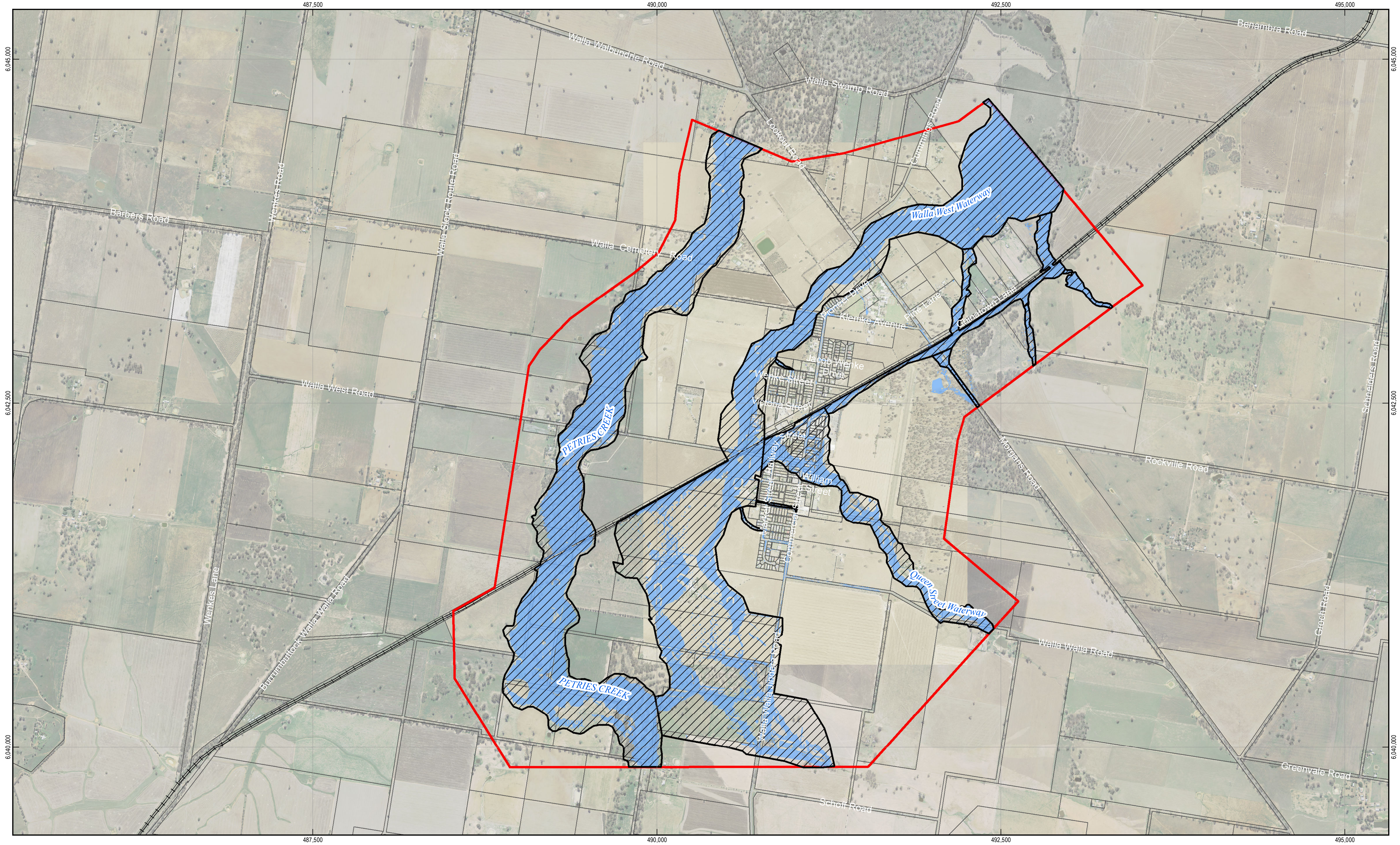
A development application lodged for development within the Flood Planning Area is to be accompanied by:

a) Existing ground levels of the subject site certified by a registered surveyor.

b) Floodway and / or High Hazard Areas only:

   a. A report from an accredited Consulting Engineer detailing any adverse effects of the proposed development on potential flood damages to the subject property and any other property as a result of the development.

   b. An evacuation plan for the development accompanied by evidence that the local division of the SES has been consulted in the formulation of the plan.



Paper Size A3

0 212.5 425 850

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Flood Planning Area (FPL) Boundary
- Area Subject to 100 Year ARI Flooding
- Cadastre
- Floodplain Risk Management Plan Boundary
- Railway

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Walla Walla Floodplain Risk Management Study

Job Number	31-33591
Revision	A
Date	05 Jun 2017

100 Year ARI Flood Event

Flood Planning Area

Figure A1

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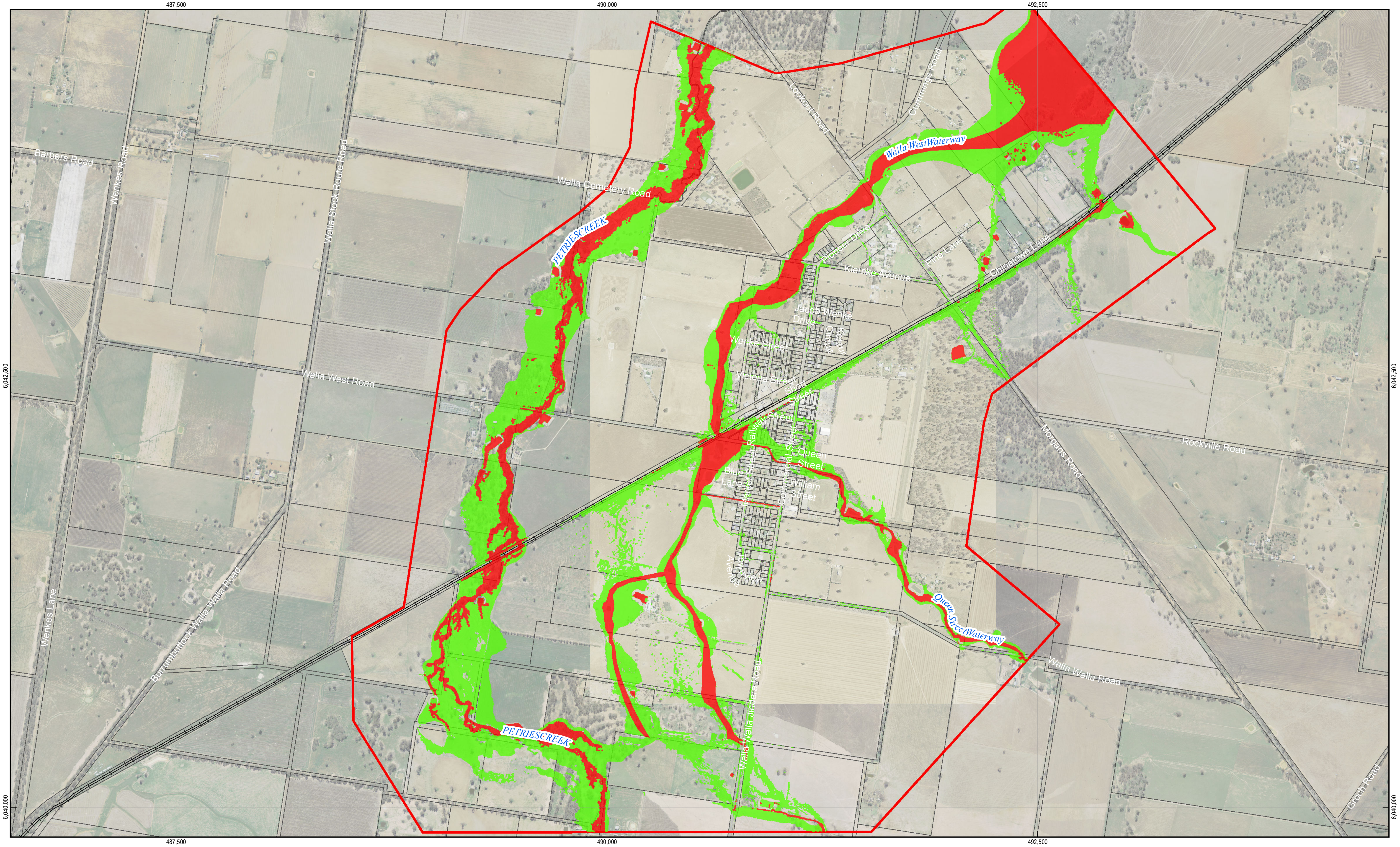
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas



Paper Size A3

0 170 340 680

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Low Hazard
- High Hazard
- Cadastre
- Floodplain Risk Management Plan Boundary
- Railway

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100 Year ARI Flood Event
Flood Hazard

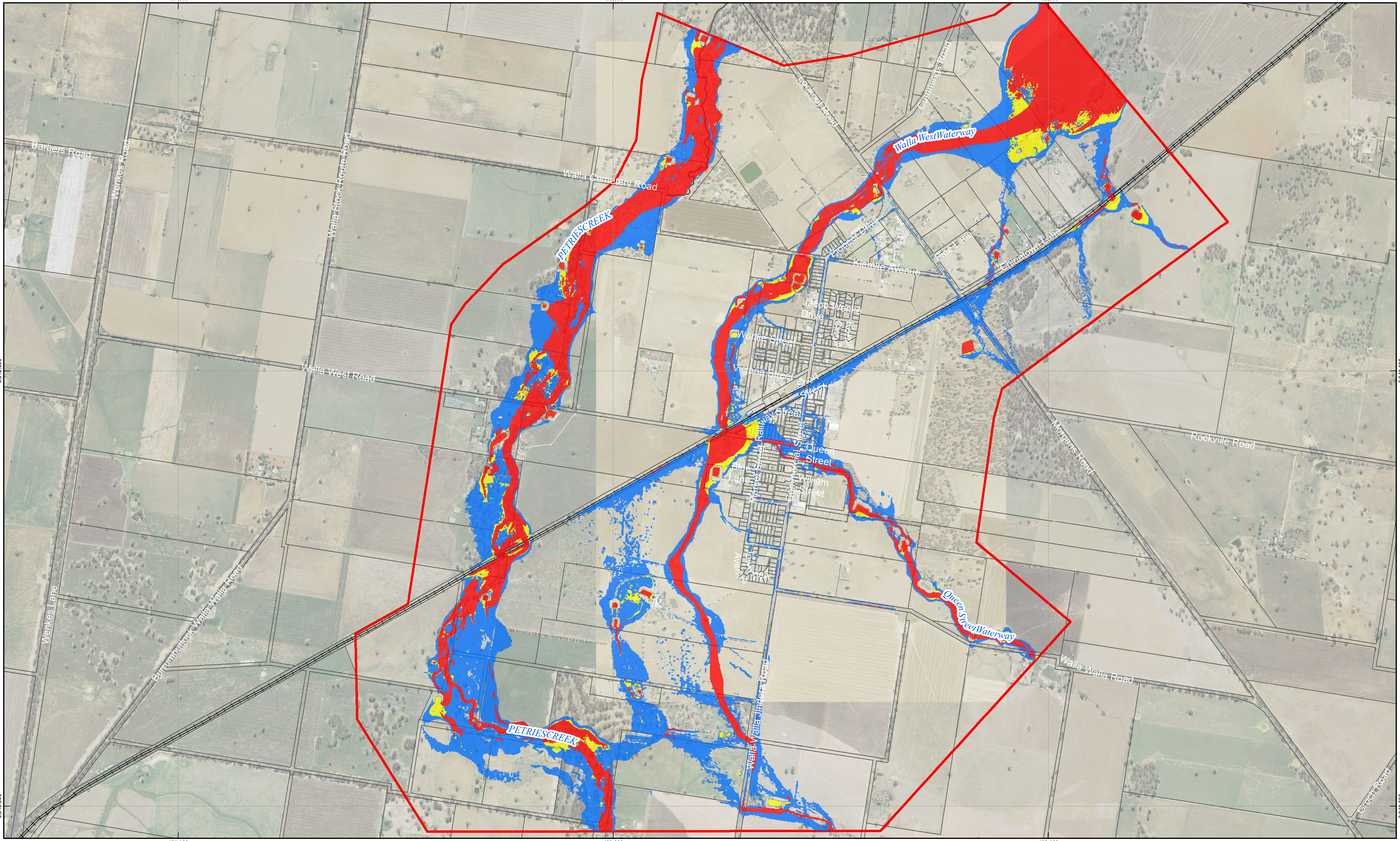
Job Number	31-33591
Revision	A
Date	05 Jun 2017

Figure A2

G:\31\33591\GIS\Maps\Deliverables\31_33591_Walla_FRMS_Fig_A2_100yr_Hydraulic_hazard_Rev_A.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas



Paper Size A3

0 170 340 680

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND
- Flood Fringe
- Flood Storage
- Flood Way
- Cadastre
- Floodplain Risk Management Plan Boundary
- Railway

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Walla Walla Floodplain Risk Management Study

Job Number	31-33591
Revision	A
Date	05 Jun 2017

100 Year ARI Flood Event Hydraulic Category

Figure A3

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas

Appendix B – Flood Modification Modelling Results

The figures in Appendix B show the change in flood level (afflux) associated with the particular mitigation option modelled.

Figure B1 – Post Queen Street Drain Extension – Change in 5 year ARI flood level

- Incised channel extended for 200 m upstream of where the Queen Street Drain currently terminates, 0.3 metre high berm established on the north side of the newly formed incised channel (refer to Figure 9)

Figure B2 – Post Air Strip Diversion Channel – Change in 100 year ARI flood level

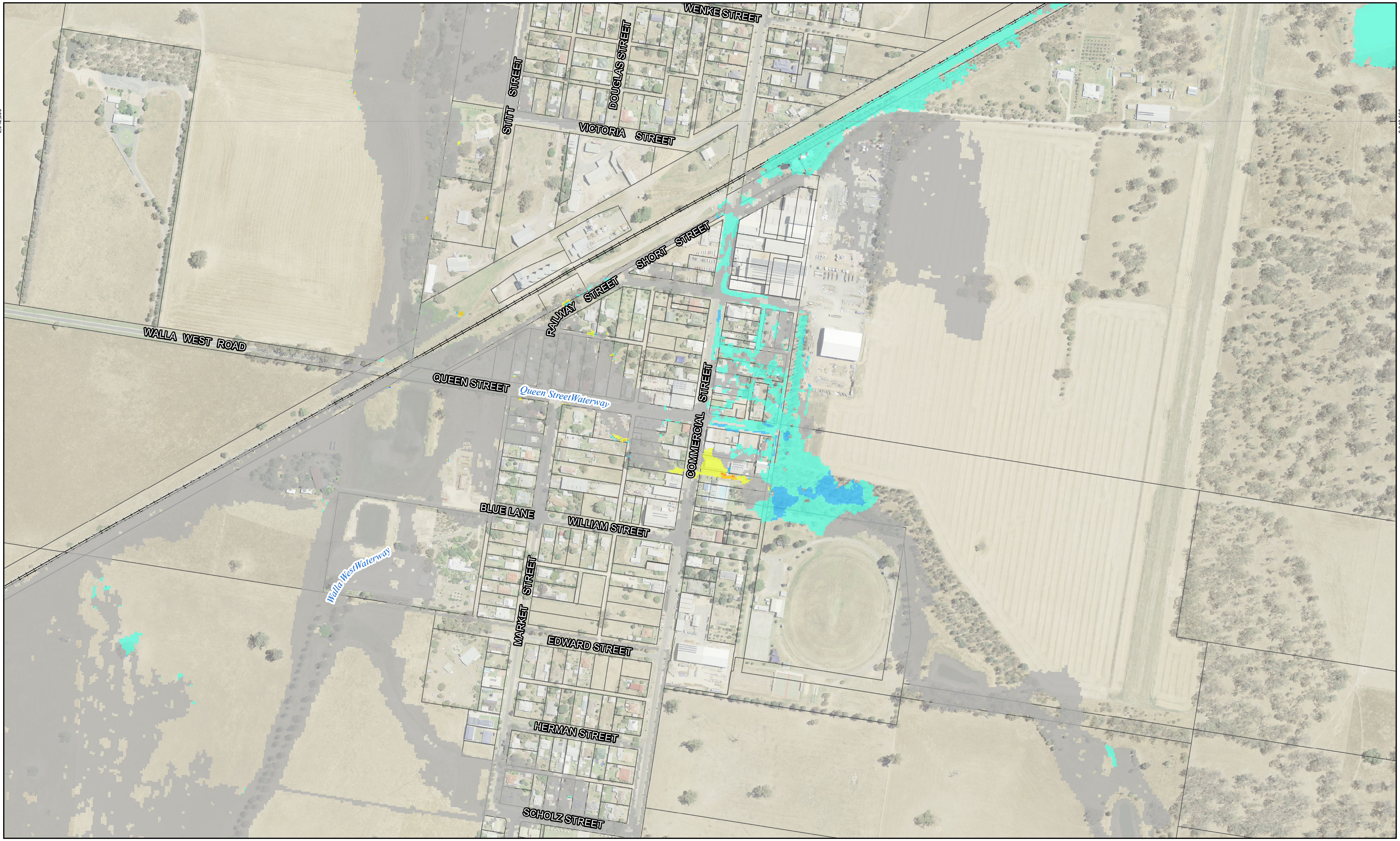
- Diversion channel route coincides with the preferred route terminating at an existing railway bridge 1.1 km downstream of Morgans Road
- The diversion channel is excavated below existing ground levels. The design 100 year ARI water level along much of the diversion channel route is below the existing ground surface. Figure B2 shows this as a decrease in water level.

Figure B3 – Post Railway Bridge Removal – Change in 100 year ARI flood level

- This coincides with full removal of the existing 10 m overall span bridge and widening of the railway opening to 30 m.

Figure B4 – Post Composite Mitigation Works – Change in 100 year ARI flood level

- Diversion Channel, Queen St Drain Extension and Berm, Railway Bridge Removal / 30 m Opening



Paper Size A3

0 40 80 160

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Cadastre

Hydraulic Modelling Extent

Railway

Change in Flood Level (m)

- > -0.50
- -0.50 - -0.20
- -0.20 - -0.05
- -0.05 - -0.015
- -0.015 - +0.015
- +0.015 - +0.05
- +0.050 - +0.20
- +0.20 - +0.50
- > +0.50

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Job Number	31-33591
Revision	A
Date	07 Jun 2017

Post Queen Street Drain Extension

5 Year ARI - Change in Flood Level

Figure B1

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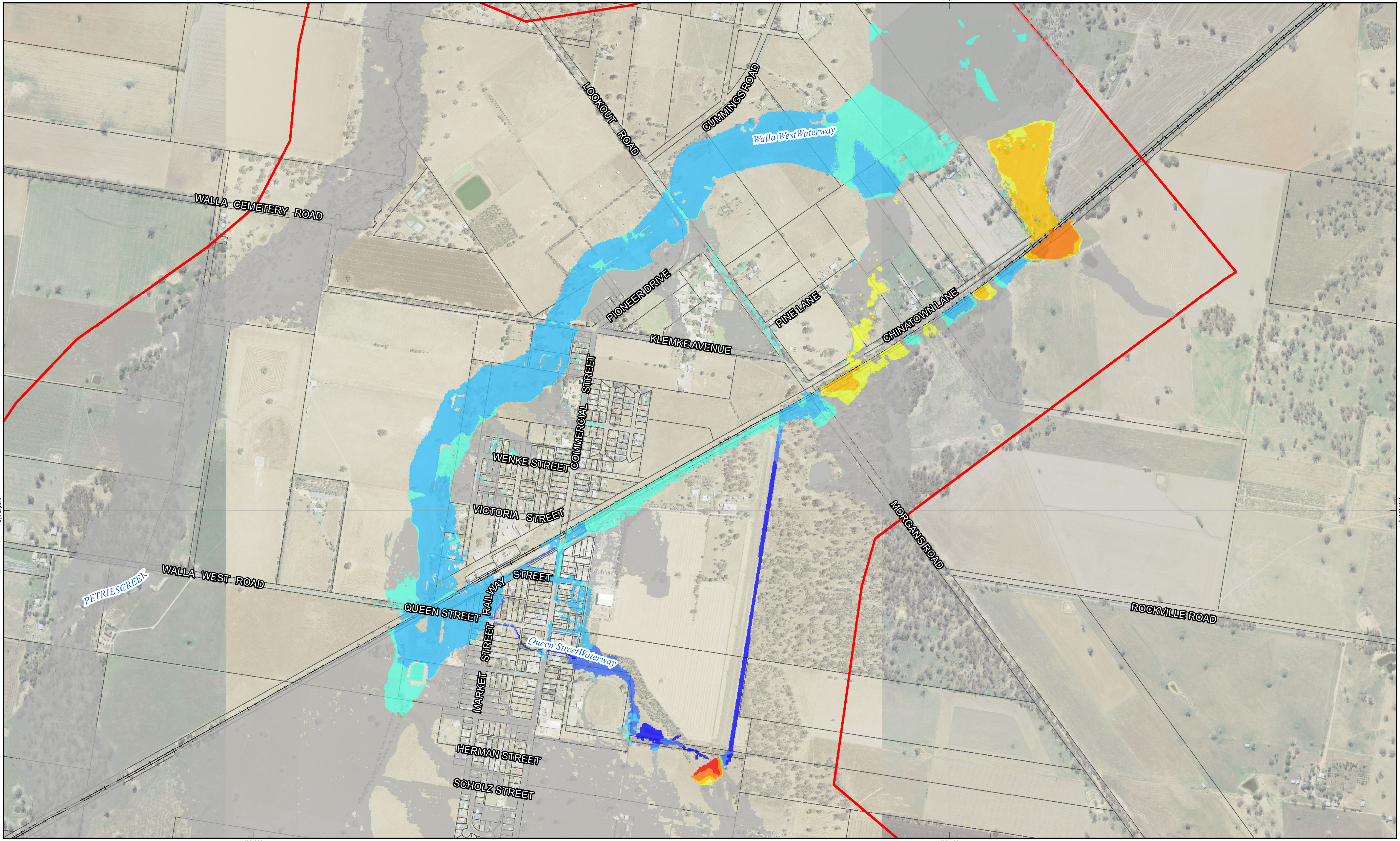
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas



Paper Size A3

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Cadastre
- Hydraulic Modelling Extent
- Railway

Change in Flood Level (m)

- > -0.50
- -0.50 - -0.20
- -0.20 - -0.05
- -0.05 - -0.015
- -0.015 - +0.015
- +0.015 - +0.05
- +0.050 - +0.20
- +0.20 - +0.50
- > +0.50

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Job Number	31-33591
Revision	A
Date	07 Jun 2017

Post Air Strip Diversion

100 year ARI - Change in Flood Level Figure B2

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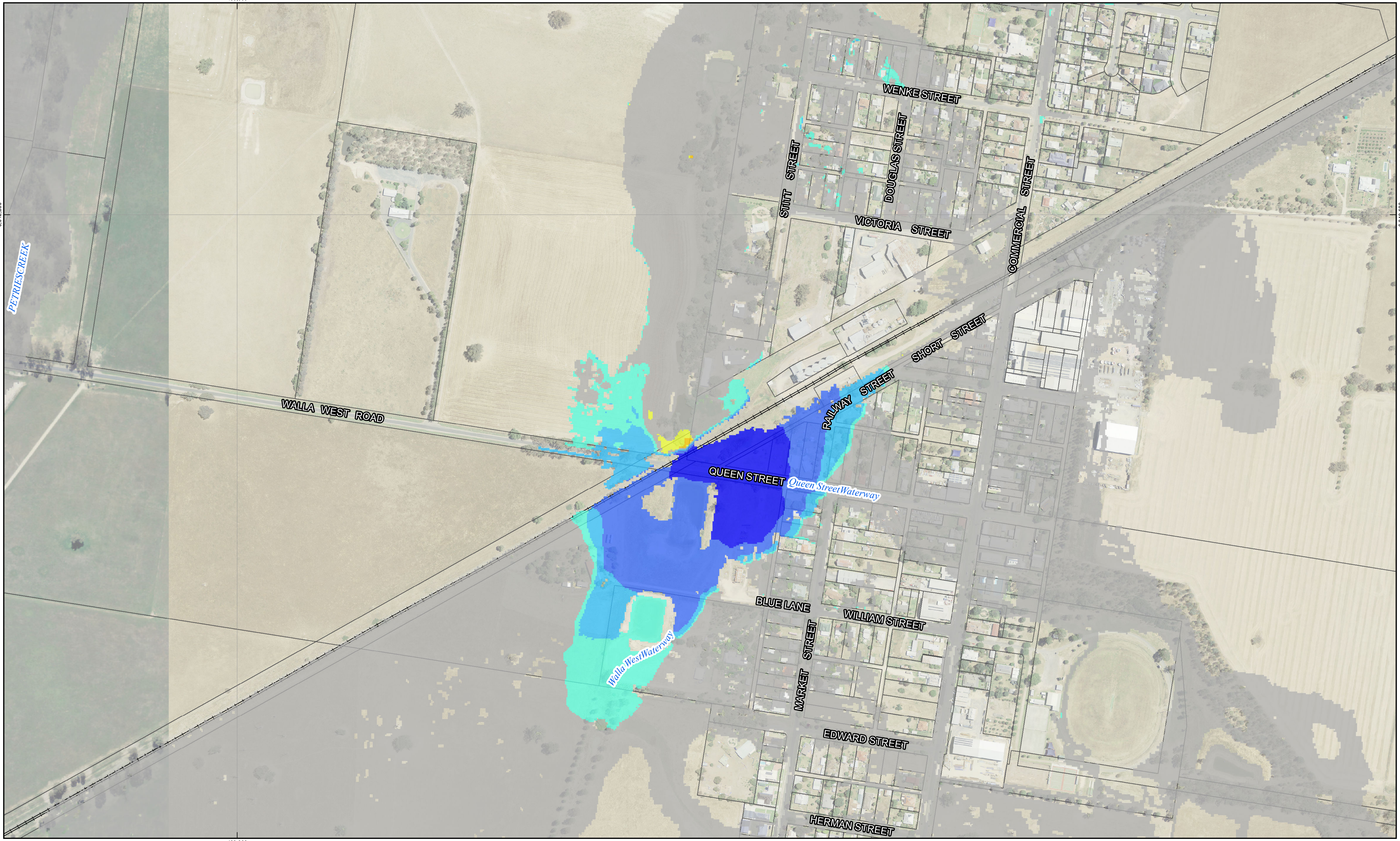
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas



Paper Size A3

0 40 80 160

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Cadastre
- Hydraulic Modelling Extent
- Railway

Change in Flood Level (m)

- > -0.50
- -0.50 - -0.20
- -0.20 - -0.05
- -0.05 - -0.015
- -0.015 - +0.015
- +0.015 - +0.05
- +0.050 - +0.20
- +0.20 - +0.50
- > +0.50

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Revision	A
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Post Railway Bridge Removal

100 Year ARI - Change in Flood Level **Figure B3**

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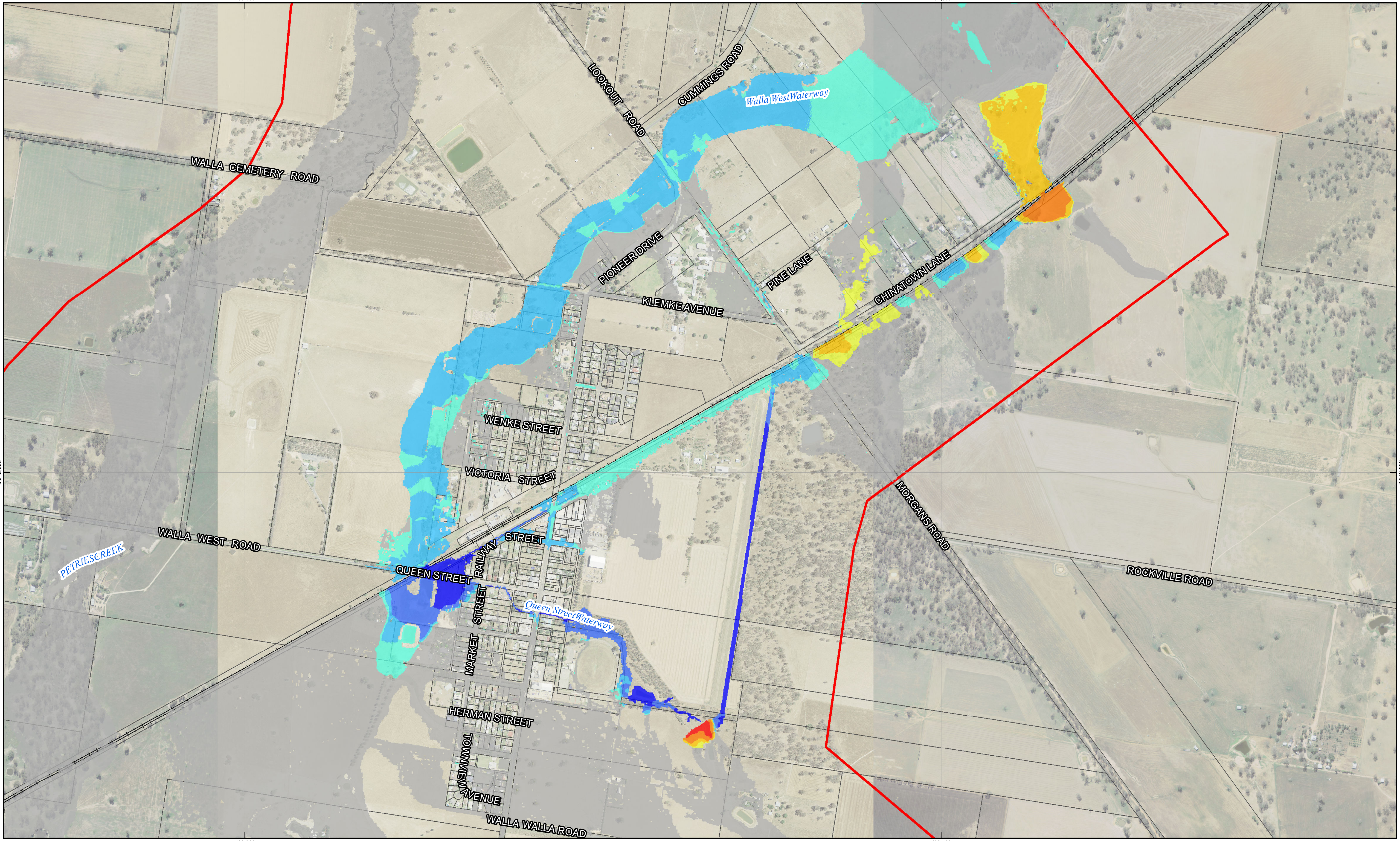
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas

490,000 492,500



6,042,500 6,042,500

490,000 492,500

Paper Size A3

0 105 210 420

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Cadastre

Hydraulic Modelling Extent

Railway

Change in Flood Level (m)

> -0.50

-0.50 - -0.20

-0.20 - -0.05

-0.05 - -0.015

-0.015 - +0.015

+0.015 - +0.05

+0.050 - +0.20

+0.20 - +0.50

> +0.50

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Job Number	31-33591
Revision	A
Date	07 Jun 2017

Post Composite Mitigation Works

100 Year ARI - Change in Flood Level Figure B4

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180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: Flood modelling data, GHD 2014, Imagery, Greater Hume Shire council, 2010. Created by:sldouglas

Appendix C – Flood Modification Measures

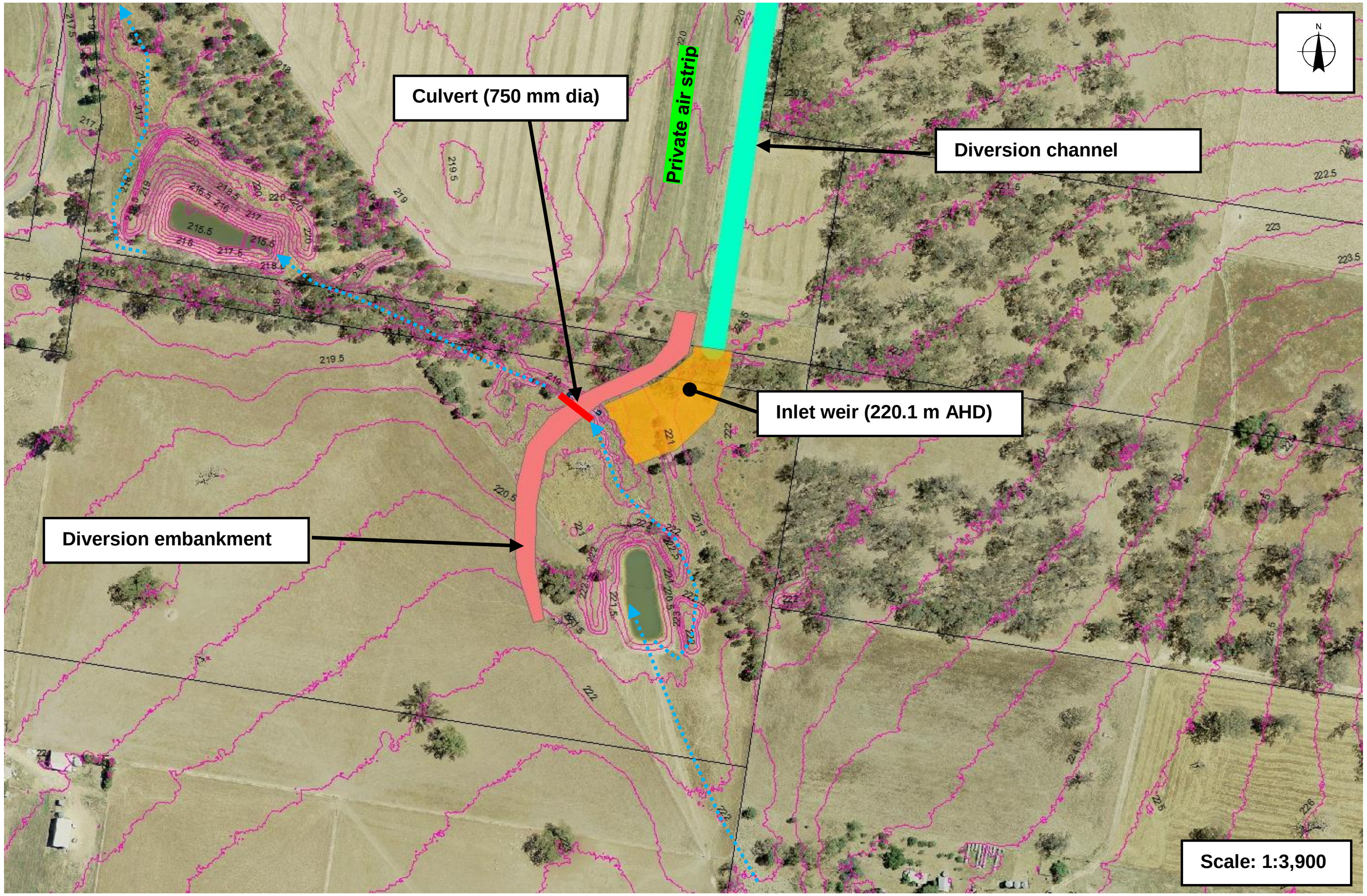

Figure C1 Queen Street Waterway Diversion Channel – Inlet Area

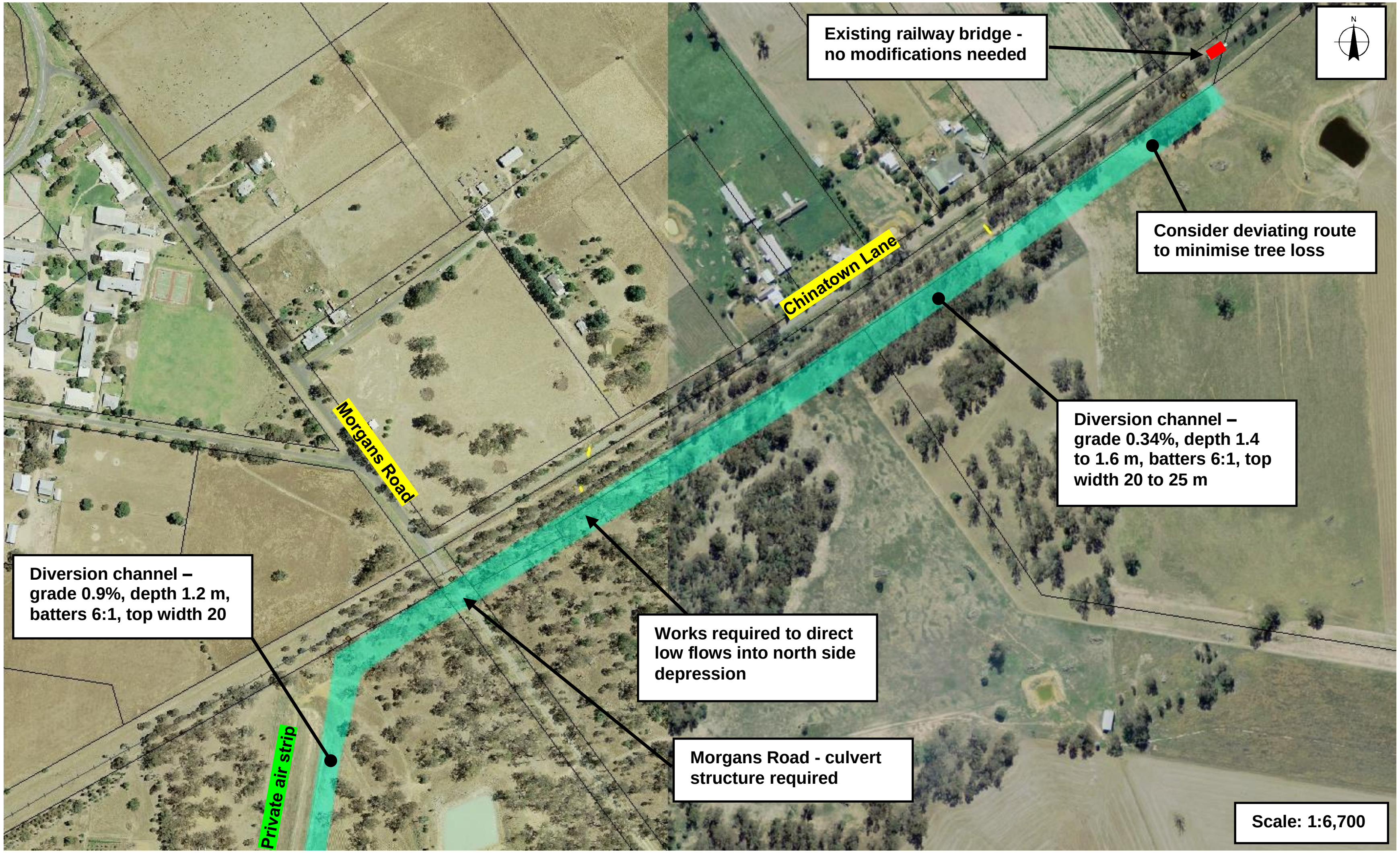

Figure C2 Queen Street Waterway Diversion Channel – Plan of Lower Route

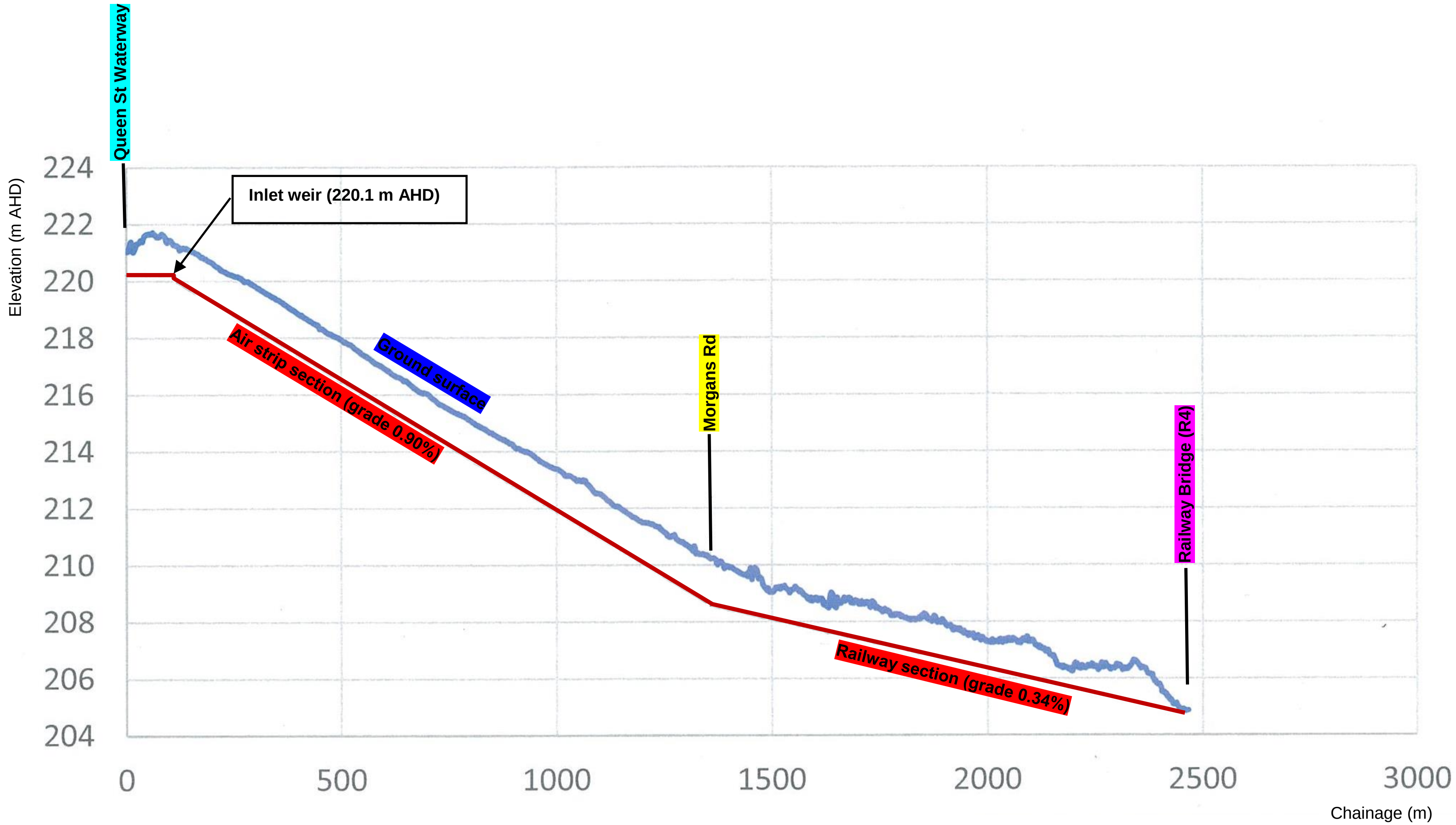

Figure C3 Queen Street Waterway Diversion Channel – Longitudinal Section

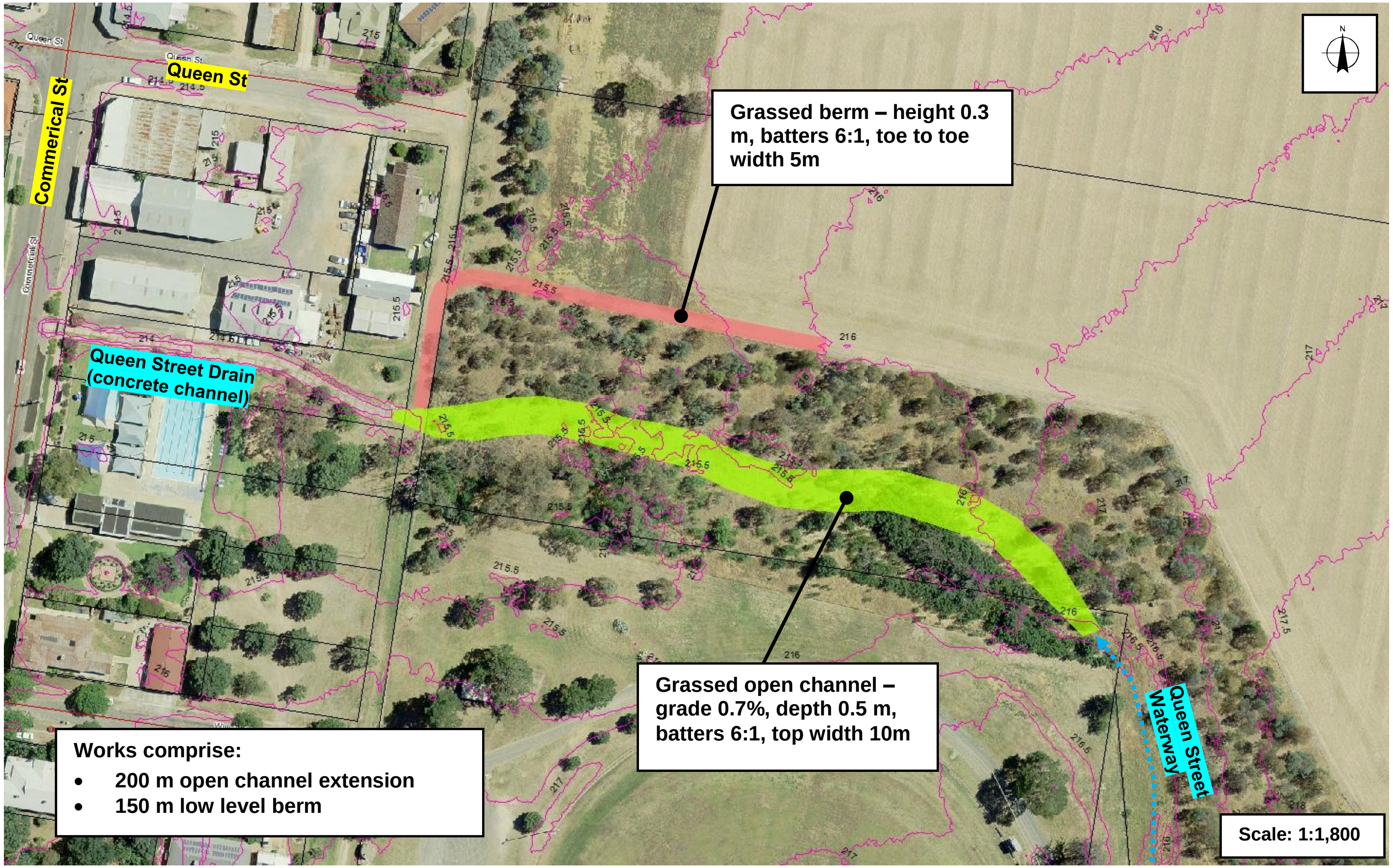

Figure C4 Queen Street Drain Extension and Berm

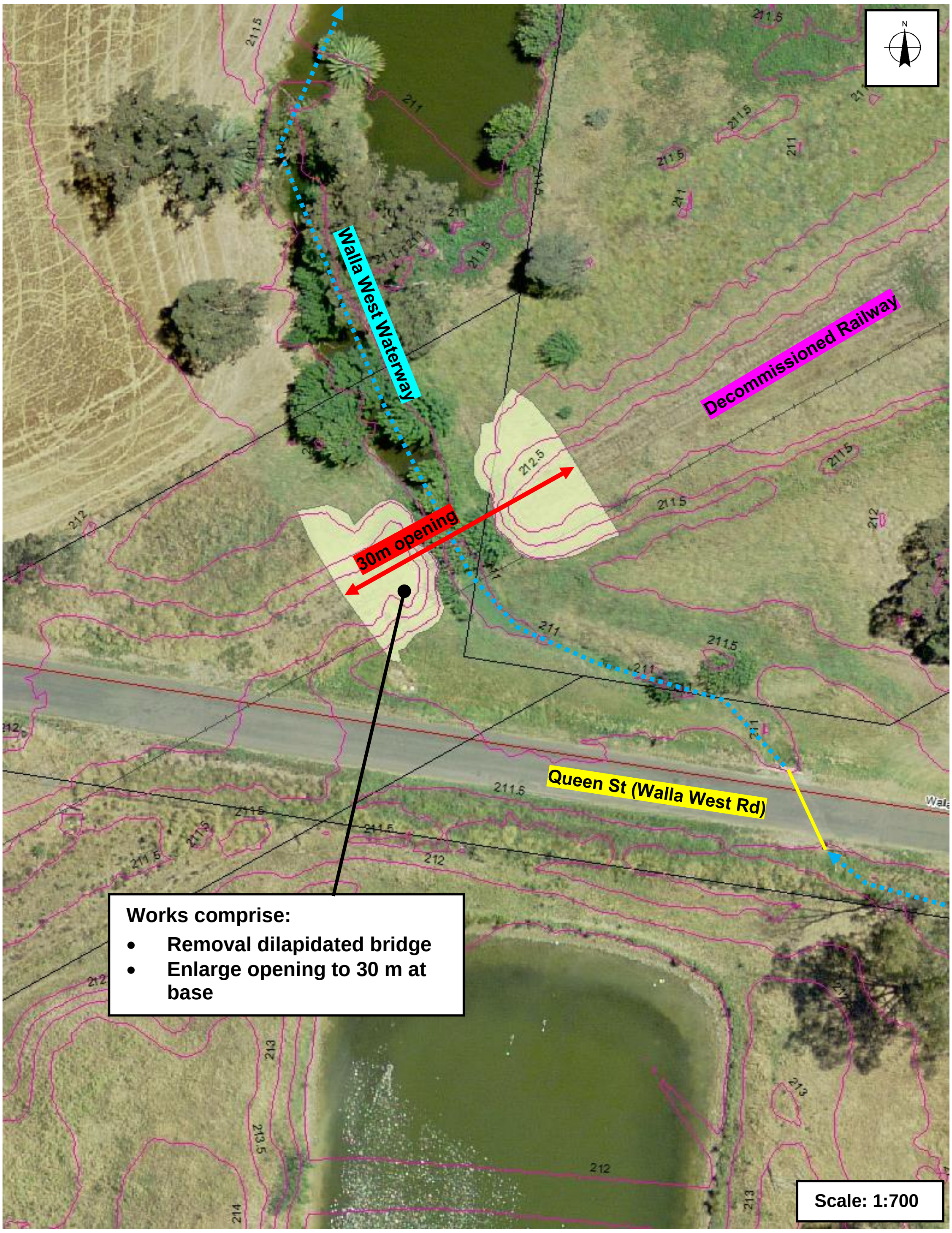

Figure C5 Walla West Waterway – Railway Bridge Removal & 30m Opening

Appendix D – Flood Modification Measures – Costs Estimates

Table D1- Cost Estimate - Queen Street Drain Extension and Berm Formation

TO: Greater Hume Shire Council — **Date** 6-Jun-17

FROM: GHD Pty Ltd — **Revision No.** 0

WORKS: **200 m Queen Street Drain Extension and berm formation** — **Job No.** 3133591

Element		Quantity	Unit	Rate (ex GST)	Amount	Contingency (%)	Contingency	Revised Fee
Preliminaries								
	Site survey - setout		Item	$4,000	$4,000	20%	$800	$4,800
	Project Management Costs		Item	$4,000	$4,000	20%	$800	$4,800
	Contractors Establishment		Item	$4,000	$4,000	20%	$800	$4,800
	Contractors Foreman Supervision	20	hrs	$90	$1,800	20%	$360	$2,160
	Contractors Engineer Supervision	40	hrs	$140	$5,600	20%	$1,120	$6,720
	Sediment and erosion control		Item	$1,000	$1,000	20%	$200	$1,200
	Environmental approvals		item	$5,000	$5,000	20%	$1,000	$6,000
	Easement acquisition	Item	Item	$0	$0	20%	$0	$0
	Traffic Control		item	$0	$0	20%	$0	$0
	Sub Total P				**$25,400**		**$5,080**	**$30,480**
Formation of open channel - earthworks								
	Clear trees	Item		$10	$5,000	20%	1,000	6,000
	Strip area under channel and bund and stockpile	200	m^3	$10	$2,000	20%	400	2,400
	Excavation, formation of open channel and form bund	650	m3	$25	$16,250	20%	3,250	19,500
	spread topsoil	200	m3	$5	$1,000	20%	200	1,200
	seed reserve	0.5	ha	$3,200	$1,600	20%	320	1,920
	Sub Total TS & S				**$2,000**		**$400**	**$25,020**
	COMBINED SUB-TOTALS ...				**$27,400**		**$5,480**	**$55,500**
	Design	**15**	%					**8,325**
	Total							**63,825**
	GST ...	**10**	%					**6,383**
	TOTAL incl GST ...							**$70,208**

Table D2- Cost Estimate - Queen Street Waterway Diversion Channel

TO:	Greater Hume Shire Council	**Date**	6-Jun-17
FROM:	GHD Pty Ltd	**Revision No.**	0
WORKS:	**2,400 m open channel diversion from Queen St Waterway to Rail bridge at east end Chinatown Lane**	**Job No.**	3133591

Element		Quantity	Unit	Rate (ex GST)	Amount	Contingency (%)	Contingency	Revised Fee
Preliminaries								
	Site survey - setout		Item	$10,000	$10,000	20%	$2,000	$12,000
	Project Management Costs		Item	$15,000	$15,000	20%	$3,000	$18,000
	Contractors Establishment		Item	$5,000	$5,000	20%	$1,000	$6,000
	Contractors Foreman Supervision	240	hrs	$90	$21,600	20%	$4,320	$25,920
	Contractors Engineer Supervision	120	hrs	$140	$16,800	20%	$3,360	$20,160
	Sediment and erosion control		Item	$5,000	$5,000	20%	$1,000	$6,000
	Environmental approvals	1	item	$20,000	$20,000	20%	$4,000	$24,000
	Easement acquisition and compensation	Item	Item	Item	$100,000	20%	$20,000	$120,000
	Traffic Control		item	$5,000	$5,000	20%	$1,000	$6,000
	Sub Total P				**$198,400**		**$39,680**	**$238,080**
Formation of open channel - earthworks								
	Clear trees		Item		$20,000	20%	4,000	24,000
	Strip area under channel and bund and stockpile	9,000	m^3	$5	$45,000	20%	9,000	54,000
	Excavation and formation of open channel	38000	m3	$10	$380,000	20%	76,000	456,000
	spread topsoil	9000	m3	$5	$45,000	20%	9,000	54,000
	seed reserve	6	ha	$3,200	$19,200	20%	3,840	23,040
	Sub Total TS & S				**$45,000**		**$9,000**	**$587,040**
Culvert structure - Morgans Road								
	Supply and deliver 1500 x900 BCs	122	m	$600	$73,200	20%	14,640	87,840
	Supply headwalls	2	Item	$5,000	$10,000	20%	2,000	12,000
	Base slab	210	m2	$60	$12,600	20%	2,520	15,120
	Excavator	120	hrs	$160	$19,200	20%	3,840	23,040
	Truck plus 4 man crew	120	hrs	$260	$31,200	20%	6,240	37,440
	Pavement over new culverts	150	m3	$60	$9,000	20%	1,800	10,800
	Sub Total B&CC				**$155,200**		**$31,040**	**$186,240**
Offtake works at Queen Street Waterway								
	Supply transport material to site, place and compact bank	2,140	m^3	$40	$85,600	20%	17,120	102,720
	Supply and deliver 750 mm diam pipes	40	m	$430.00	$17,200	20%	3,440	20,640
	Supply headwalls	2	Item	$2,000	$4,000	20%	800	4,800
	Weir works - sill slab	100	m2	$60	$6,000	20%	1,200	7,200
	Excavator	120	hrs	$160	$19,200	20%	3,840	23,040
	Truck plus 4 man crew	120	hrs	$260	$31,200	20%	6,240	37,440
	Sub Total B&CC				**$163,200**		**$32,640**	**$195,840**
Other works								
	Farm access crossings - allow for two	2		$30,000.00	$60,000	20%	12,000	72,000
	Modifications to railway culvert 200 m east of Morgans Road	1		$60,000.00	$60,000	20%	12,000	72,000
	Sub Total B&CC				**$120,000**		**$24,000**	**$144,000**
	COMBINED SUB-TOTALS ...				**$398,600**		**$79,720**	**$1,453,920**
Investigation & design (including veg impact assessment)		**15**	%					**218,088**
	Total							**1,672,008**
	GST ...	**10**	%					**167,201**
	TOTAL incl GST ...							**$1,839,209**

Table D3 - Rail bridge and embankment removal

TO:	Greater Hume Shire Council	Date	6-Jun-17
FROM:	GHD Pty Ltd	Revision No.	0
WORKS:	**Create 30 m wide opening in rail embankment at site of dilapidated bridge**	Job No.	3133591

Element		Quantity	Unit	Rate (ex GST)	Amount	Contingency (%)	Contingency	Revised Fee
Preliminaries								
	Site survey - setout		Item	$5,000	$0	20%	$0	$0
	Project Management Costs		Item	$15,000	$5,000	20%	$1,000	$6,000
	Contractors Establishment		Item	$5,000	$2,000	20%	$400	$2,400
	Contractors Foreman Supervision	0	hrs	$90	$0	20%	$0	$0
	Contractors Engineer Supervision	40	hrs	$140	$5,600	20%	$1,120	$6,720
	Sediment and erosion control		Item	$10,000	$2,000	20%	$400	$2,400
	Environmental approvals		item	$10,000	$0	20%	$0	$0
	Easement acquisition	1.3	Item	$10,000	$0	20%	$0	$0
	Traffic Control		item	$10,000	$2,000	20%	$400	$2,400
	Sub Total P				**$16,600**		**$3,320**	**$19,920**
Remove bridge and embankment								
	Removal of bridge structure	Item		$5	$5,000	20%	1,000	6,000
	Removal of embankment material	500	m3	$20	$10,000	20%	2,000	12,000
	Topsoil disturbed area	80	m3	$30	$2,400	20%	480	2,880
	Seed distubed area	Item		$500	$500	20%	100	600
	Sub Total TS & S				**$5,000**		**$1,000**	**$21,480**
		0	m	$700	$0	20%	0	0
		0	Item	$5,000	$0	20%	0	0
		0	m2	$60	$0	20%	0	0
		0	hrs	$160	$0	20%	0	0
		0	hrs	$260	$0	20%	0	0
		0	m3	$60	$0	20%	0	0
		0	m2	$15	$0	20%	0	0
	Sub Total B&CC				**$0**		**$0**	**$0**
	COMBINED SUB-TOTALS ...				**$21,600**		**$4,320**	**$41,400**
	Design	**10**	%					**4,140**
	Total							**45,540**
	GST ...	**10**	%					**4,554**
	TOTAL incl GST ...							**$50,094**

GHD

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	T Clark	R Berg		R Berg		23/6/2017
B	T Clark	R Berg		R Berg		7/8/2017
0	T Clark	R Berg		R Berg		30/10/2017

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