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LT Creek Flood Study

Final Report

R.N1355.001.03

April 2011

Lake Macquarie

LT Creek Flood Study
Final Report

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Title :	LT Creek Flood Study –Final Report
Author :	Darren Lyons
Synopsis :	Report for the LT Creek Flood Study covering the development and calibration of computer models, establishment of design flood behaviour and flood mapping.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	18/08/09	PEH		DJL	
1	07/06/10	DJL		DJL	
2	20/08/10	DJL		DJL	
3	19/05/11	DJL		DJL	

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EXECUTIVE SUMMARY

Introduction

The LT Creek Flood Study has been prepared for Lake Macquarie City Council (Council) to define the existing flood behaviour in the LT Creek catchment and establish the basis for subsequent floodplain management activities.

LT Creek is a tributary of Lake Macquarie draining a catchment area of some 7.5km^2, extending north/north-west of the township of Fassifern. The catchment is drained by LT Creek and a number of unnamed tributaries, discharging to Fennel Bay, a semi-closed embayment of the broader Lake Macquarie waterway.

Catchment Description

Land use within the catchment primarily consists of bushland (60%), Newtsan Colliery (25%) and urban development (10%). The catchment is traversed by a number of transport corridors including the main-north railway, coal haulage routes associated with the Newstan operations and local roads.

The urban communities of Fassifern and parts of Fennell Bay occupy the lower floodplain of LT Creek and represent the existing development subject to potential flood risk. This lower region of the floodplain is also largely affected by Lake Macquarie flooding.

Historical Flooding

There is an evident high flood risk exposure to the Fassifern community at the lower end of LT Creek. Major flood events resulting in substantial inundation to property have occurred in 1949, 1981, 1990 and most recently in June 2007.

The February 1981 event is the largest recorded flood event within the catchment in which approximately 350mm of rainfall fell over a 6-hour period. Whilst a lower rainfall event, the June 2007 flood conditions were largely dominated by the flood water level in Lake Macquarie, estimated to be of the order of a 20-year return period. Similarly, the 1949 and 1990 flooding events were largely driven by Lake Macquarie flooding.

Community Consultation

Community consultation undertaken during the study has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to floodplain management activities to follow. It has provided an opportunity to collect information on their flood experience, their concern on flooding issues and to collect feedback and ideas on potential floodplain management issues within the catchment. The key elements of the consultation process have included distribution of a questionnaire relating to historical flooding, a community information session held at Lake Macquarie City Council offices in the evening of Tuesday 2nd December 2008, and public exhibition of the Draft Flood Study incorporating a second community information session held at Lake Macquarie City Council offices in the evening of Thursday 16th September 2010.

A key issue identified during the community information session was the ongoing water quality and sedimentation issues in the lower LT Creek channel. A detailed investigation of these issues was undertaken in the LT Creek Catchment Water Quality Management Plan (Umwelt, 2008) and is beyond the scope of the current flood study. Nevertheless, the potential sedimentation of the channel and therefore reduced channel carrying capacity has some relevance in regard to local flooding. Sensitivity tests on reduced channel capacity were found to have minor influence on design flood behaviour across the catchment.

No formal responses were received on the Draft Flood Study following public exhibition.

Model Development (and additional survey)

Development of hydrologic and hydraulic models has been undertaken to simulate flood conditions in the catchment. The hydrological model developed using RAFTS-XP software provides for simulation of the rainfall-runoff process using the catchment characteristics of LT Creek and historical and design rainfall data. The hydraulic model, simulating flood depths, extents and velocities utilises the TUFLOW two-dimensional (2D) software developed by BMT WBM. The 2D modelling approach is necessary to model the complex interaction between channels and floodplains and converging and diverging of flows through structures and urban environments.

The floodplain topography is defined using a high resolution digital elevation model (DEM) derived from LiDAR survey for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas. To supplement the LiDAR data, additional cross section survey of the LT Creek channel and significant hydraulic structures was acquired during the course of the study.

Calibration

The LT Creek catchment is ungauged and accordingly there is no available data for streamflow calibration. However, there is a reasonable database of peak flood levels within the Fassifern area for both the February 1981 and June 2007 events to enable some hydraulic calibration. The latter event data was collected as a component of the questionnaire issued to residents.

A reasonable model calibration has been achieved given the available data for the catchment. The developed models provide a sound representation of the flooding behaviour of the catchment, as demonstrated through comparison of recorded peak water levels for the historical events simulated.

Design Event Modelling and Output

The developed models have been applied to derive design flood conditions within the LT Creek catchment. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). A range of storm durations using standard AR&R (2001) temporal patterns, were modelled in order to identify the critical storm duration for design event flooding in the catchment.

The design events considered in this study are summarised in Table S1. These simulations cover a range of design event magnitudes including both catchment dominated flooding (runs 1 to 7) and combined catchment and Lake Macquarie flooding (runs 8 to 10). Given that wider Lake Macquarie flooding has been assessed in previous studies, the focus of the LT Creek Flood Study has been rainfall derived catchment flooding.

Table S1 – Modelled Design Event Scenarios

Run No.	Catchment Flooding Condition	Lake Flooding Condition
1	20% AEP	20% AEP
2	10% AEP	20% AEP
3	5% AEP	20% AEP
4	2% AEP	20% AEP
5	1% AEP	20% AEP
6	0.5% AEP	20% AEP
7	PMF	20% AEP
8	5% AEP	1% AEP
9	1% AEP	1% AEP
10	PMF	1% AEP

The model results for the design events considered have been presented in a detailed flood mapping series for the catchment. The flood data presented includes design flood inundation, peak flood water levels and peak flood depths.

Flood hazard categorisation in accordance with Figure L2 of the NSW Floodplain Development Manual (2005) has also been mapped for the 20% AEP, 1% AEP and the PMF events.

The hydraulic categories (floodway, flood fringe and flood storage) for flood affected area has been mapped for the 20% AEP, 1% AEP and the PMF events also.

Climate Change Scenarios

Projected sea level rise in Lake Macquarie, as adopted by Council policy, is 0.40m to the year 2050 and 0.90m to the year 2100. These numbers are comparable to the benchmark values recently provided in the draft NSW Sea Level Rise Policy. Accordingly, the consideration of potential sea level rise is in an integral component in the flood planning process.

Sensitivity tests on the design 1% AEP flood condition for the LT Creek catchment have been undertaken using a projected 50-year and 100-year sea level rise scenarios for the Lake Macquarie water level boundary condition. The sea level rise has been applied to the design 20% AEP flood level for Lake Macquarie applied as the boundary condition.

The design Lake Macquarie water level alone provides for significant inundation in the lower parts of the LT Creek catchment. Coupled with major LT Creek catchment flooding, the potential for extensive property inundation has been identified.

Potential increases in design rainfall intensity have also been assessed in the climate change sensitivity tests. Increases of 10%, 20% and 30% as recommended in the State Government Practical Consideration of Climate Change Guideline have been applied.

Property Inundation

Assessment of potential property inundation and damage has been undertaken as part of the flood study. A property database derived from Council's cadastral and floor level data has been established. Design flood levels calculated from the TUFLOW model were queried from TUFLOW's GIS output at each property reference point. The resulting output was used to identify flooding characteristics such as the frequency of inundation, the depth of inundation and number of properties affected.

A summary of the number of properties affected by flooding (i.e. above floor level) for a range of flood magnitudes is shown in Table S2.

Table S2 – Property Inundation Results

Design event	No. of properties with above floor flooding*
5% AEP Catchment Flood	0
1% AEP Catchment Flood	0
0.5% AEP Catchment Flood	0
1% AEP Catchment Flood with 0.4m sea level rise	0
1% AEP Catchment Flood with 0.9m sea level rise	15
1% AEP Lake Flood	7
1% AEP Lake Flood with 0.4m sea level rise	39
1% AEP Lake Flood with 0.9m sea level rise	85
PMF Catchment Flood	52
PMF Catchment Flood with 0.9m sea level rise	53
PMF Lake Flood	108
PMF Lake Flood with 0.9m sea level rise	131

Conclusions

The primary objective of the Flood Study is to define the flood behaviour of the LT Creek catchment through the establishment of appropriate numerical models. The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular design flood level information that will be used to set appropriate flood planning levels for the study area. The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain management process. Accordingly, the adoption of the flood study and predicted design flood levels is recommended.

The flood risk to existing development as a result of catchment rainfall derived flooding for LT Creek is relatively low. However, coupled with major Lake Macquarie flooding and potential sea level rise scenarios, the flood risk is substantially increased. Sea level rise adaptation is expected to be a key component of floodplain management in the LT Creek catchment given the potential impact on design flood conditions in the lower parts of LT Creek as demonstrated in this study.

Given the significant influence of Lake Macquarie flooding on the predicted flood behaviour of the lower LT Creek catchment, future flood studies and floodplain management studies relating to the broader Lake Macquarie waterway should feed back into the LT Creek floodplain management process. Floodplain management in the LT Creek catchment should be a dynamic process and respond to changes in available flood information, catchment changes and future development, and Council and State government policy in an appropriate manner.

A number of additional flooding risks within the LT Creek catchment have been identified during the course of the study. These include the potential failure of the Newstan Southern Reject Emplacement Area Dam and failure of one or more of the existing road/rail embankments within the catchment. It is recommended that future floodplain management activities in the catchment investigate in further detail these risks.

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GLOSSARY

annual exceedance probability (AEP)	The chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e. a 1 in 20 chance) of a peak discharge of 500 m^3/s (or larger) occurring in any one year. (see also average recurrence interval)
Australian Height Datum (AHD)	National survey datum corresponding approximately to mean sea level.
Astronomical Tide	Astronomical Tide is the cyclic rising and falling of the Earth's oceans water levels resulting from gravitational forces of the Moon and the Sun acting on the Earth.
attenuation	Weakening in force or intensity
average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as (or larger than) the selected event. For example, floods with a discharge as great as (or greater than) the 20yr ARI design flood will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event. (see also annual exceedance probability)
catchment	The catchment at a particular point is the area of land that drains to that point.
design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100yr ARI or 1% AEP flood).
development	Existing or proposed works that may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
discharge	The rate of flow of water measured in tems of vollume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
flood	Relatively high river or creek flows, which overtop the natural or artificial banks, and inundate floodplains and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
flood behaviour	The pattern / characteristics / nature of a flood.
flood fringe	Land that may be affected by flooding but is not designated as floodway or flood storage.
flood hazard	The potential risk to life and limb and potential damage to property resulting from flooding. The degree of flood hazard varies with circumstances across the full range of floods.
flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".

flood liable land	see flood prone land
floodplain	Land adjacent to a river or creek that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation by the probable maximum flood (PMF) event.
floodplain management	The co-ordinated management of activities that occur on the floodplain.
floodplain risk management plan	A document outlining a range of actions aimed at improving floodplain management. The plan is the principal means of managing the risks associated with the use of the floodplain. A floodplain risk management plan needs to be developed in accordance with the principles and guidelines contained in the NSW Floodplain Management Manual. The plan usually contains both written and diagrammatic information describing how particular areas of the floodplain are to be used and managed to achieve defined objectives.
Flood planning levels (FPL)	Flood planning levels selected for planning purposes are derived from a combination of the adopted flood level plus freeboard, as determined in floodplain management studies and incorporated in floodplain risk management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of landuse and for different flood plans. The concept of FPLs supersedes the "standard flood event". As FPLs do not necessarily extend to the limits of flood prone land, floodplain risk management plans may apply to flood prone land beyond that defined by the FPLs.
flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event. Under the merit policy, the flood prone definition should not be seen as necessarily precluding development. Floodplain Risk Management Plans should encompass all flood prone land (i.e. the entire floodplain).
flood source	The source of the floodwaters. In this study, Burrill Lake is the primary source of floodwaters.
flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
floodway	A flow path (sometimes artificial) that carries significant volumes of floodwaters during a flood.
freeboard	A factor of safety usually expressed as a height above the adopted flood level thus determing the flood planning level. Freeboard tends to compensate for factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
geomorphology	The study of the origin, characteristics and development of land forms.
gauging (tidal and flood)	Measurement of flows and water levels during tides or flood events.

historical flood	A flood that has actually occurred.
hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydrodynamic	Pertaining to the movement of water
hydrograph	A graph showing how a river or creek's discharge changes with time.
hydrographic survey	Survey of the bed levels of a waterway.
hydrologic	Pertaining to rainfall-runoff processes in catchments
hydrology	The term given to the study of the rainfall-runoff process in catchments.
isohyet	Equal rainfall contour
morphological	Pertaining to geomorphology
peak flood level, flow or velocity	The maximum flood level, flow or velocity that occurs during a flood event.
pluviometer	A rainfall gauge capable of continously measuring rainfall intensity
probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
probability	A statistical measure of the likely frequency or occurrence of flooding.
riparian	The interface between land and waterway. Literally means "along the river margins"
runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
stage	See flood level.
stage hydrograph	A graph of water level over time.
sub-critical	Refers to flow in a channel that is relatively slow and deep
topography	The shape of the surface features of land
velocity	The speed at which the floodwaters are moving. A flood velocity predicted by a 2D computer flood model is quoted as the depth averaged velocity, i.e. the average velocity throughout the depth of the water column. A flood velocity predicted by a 1D or quasi-2D computer flood model is quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.
water level	See flood level.

1 INTRODUCTION

The LT Creek Flood Study has been prepared for Lake Macquarie City Council (Council) to define the existing flood behaviour in the LT Creek catchment and establish the basis for subsequent floodplain management activities.

This project has been conducted under the State Assisted Floodplain Management Program and received State financial support.

1.1 Study Location

LT Creek is a tributary of Lake Macquarie draining a catchment area of some 7.5km^2, extending north/north-west of the township of Fassifern as shown in Figure 1-1. Land use in the upper catchment is dominated by the Newstan Colliery, whilst the lower area of the floodplain around the lake foreshore is occupied by the communities of Fassifern and Fennell Bay. The catchment is drained by LT Creek and a number of unnamed tributaries, discharging to Fennell Bay, a semi-closed embayment of the broader Lake Macquarie waterway.

Lake Macquarie is one of the largest saline coastal lakes on the east coast of Australia, with an area of some 110km^2, and a catchment area of 684km^2 (LT Creek contribution ~1%). The catchment of Lake Macquarie is relatively small compared to the size of the waterway, so volumetric set-up of water levels due to catchment runoff is generally small. When combined with elevated ocean levels, however, high lake water levels can inundate low-lying foreshores in many areas around the lake, including the lower reaches of LT Creek around Fassifern and Fennell Bay.

1.2 Study Background

There has been no previous detailed investigation of the flood behaviour of the LT Creek catchment. Nevertheless, there has been a history of flooding resulting in inundation of the lower floodplain including properties in Fassifern and parts of Fennell Bay. Significant flooding events to have occurred periodically over the past 60 years or so include the events in 1949, 1981, 1990 and 2007.

Some of these floods events, including 1949 and 2007, corresponded to major flooding in the broader Lake Macquarie waterway. Studies assessing the design water levels, wave climate and foreshore flooding of the Lake have been undertaken previously (MHL, 1998) providing the basis for the development of the Lake Macquarie Floodplain Management Study and Plan (Webb, McKeown and Assoc., 2000 and 2001).

Whilst not specifically dealing with flooding considerations, the most recent investigation of the LT Creek catchment was the Water Quality Management Plan (Umwelt, 2008). This study investigated in detail the apparent poor waterway health in LT Creek, which has been a source of concern to both Council and local residents for some time. The management study identified the principal sources of ongoing water quality problems in the catchment and recommended a suite of management measures to address these issues.

Title:
Study Locality

Figure: 1-1

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1.3 The Need for Floodplain Management at LT Creek

As evidenced in the recent June 2007 flood, a significant flood risk is posed to residents in the LT Creek catchment, particularly the existing development on the lower floodplain around Fassifern and Fennell Bay. The combination of local catchment flooding characterised by rapid response of the waterway to rainfall in the steeper upper catchments and elevated Lake Macquarie water levels contributed by catchment rainfall, storm surge and wave set-up, can result in significant inundation and large flood depths in parts of the existing developed area.

The potential for future sea level rise is now expected to be a major driver for floodplain management around coastal and estuarine systems such as Lake Macquarie. The issue of future sea level rise presents particular challenges to future development, as the risks associated with flooding will progressively increase during the lifetime of the development. It may be such that risks do not manifest until the development is nearing the end of its design life.

There also remains inherent uncertainty regarding the projected extents of sea level rise in the future. The NSW Government has recently released a draft policy that advocated consideration of increased sea levels by 0.4m by 2050, and 0.9m by 2100. However, there is potential for sea level rise to occur slower, or indeed faster, than these rates.

Adaptation is regarded as the main tool available for managing future sea level rise. Adaptation includes progressive changes, on an as-needs basis, to infrastructure and buildings associated with future development, as well as progressive changes to landuse planning and zonings controlling on-going development.

There is likely to be a future increase in development pressures across the wider Lake Macquarie LGA, including the LT Creek catchment to accommodate general population growth expectations. This in time will increase the number of people potentially exposed to flood risk, many of whom would be oblivious to existing flood risk given no previous experience of flooding in the catchment.

Floodplain risk management considers the consequences of flooding on the community and aims to develop appropriate floodplain management measures to minimise and mitigate the impact of flooding. This incorporates the existing flood risk associated with current development, and future flood risk associated with future development and changes in land use.

Accordingly, Council desires to approach local floodplain management in a considered and systematic manner. This study comprises the initial stages of that systematic approach, as outlined in the Floodplain Development Manual (NSW Government, 2005). The approach will allow for more informed planning decisions within the floodplain of LT Creek.

1.4 The Floodplain Management Process

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

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

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

Stages of Floodplain Management

	Stage	Description
1	Flood Study	Determines the nature and extent of the flood problem.
2	Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed developments.
3	Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4	Implementation of the Floodplain Risk Management Plan	Construction of flood mitigation works to protect existing development. Use of environmental plans to ensure new development is compatible with the flood hazard.

This study represents Stage 1 of the above process and aims to provide an understanding of flood behaviour within the LT Creek catchment.

1.5 Study Objectives

The primary objective of the Flood Study is to define the flood behaviour of the LT Creek catchment through the establishment of appropriate numerical models. The study will produce information on flood flows, velocities, levels and extents for a range of flood event magnitudes under existing catchment and floodplain conditions. Specifically, the study incorporates:

- Compilation and review of existing information pertinent to the study and acquisition of additional data including survey as required;
- Undertake a community consultation and participation program to identify local flooding concerns, collect information on historical flood behaviour and engage the community in the on-going floodplain management process;
- Development and calibration of appropriate hydrologic and hydraulic models;
- Determination of design flood conditions for a range of design event including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and extreme flood event; and
- Presentation of study methodology, results and findings in a comprehensive report incorporating appropriate flood mapping.

The assessment of design flood conditions in the catchment also includes:

- mapping of hydraulic categories and provisional flood hazards for a range of flood events;
- assessment of the potential impact of blockages of culverts and bridges on local flood behaviour;
- assessment of the potential impact of sea level rise; and
- quantification of the existing flooding problem through a flood damages assessment.

The principal outcome of the flood study is the understanding of flood behaviour in the catchment and in particular design flood level information that will be used to set appropriate flood planning levels for the study area.

1.6 About This Report

This report documents the Study's objectives, results and recommendations.

Section 1 introduces the study.

Section 2 provides an overview of the approach adopted to complete the study.

Section 3 outlines the community consultation program undertaken.

Section 4 provides information on the additional survey collected for this study.

Section 5 details the development of the computer models.

Section 6 details the model calibration and validation process including sensitivity tests.

Section 7 presents the design flood conditions and associated flood mapping.

Section 8 presents a preliminary property inundation and flood damages assessment.

2 STUDY APPROACH

2.1 The Study Area

2.1.1 Catchment Description

The LT Creek catchment occupies a total catchment area of 7.5km^2 on the western side of Lake Macquarie. The catchment extends north-west from Fassifern on the Lake Macquarie foreshore towards Wakefield and the Sydney-Newcastle Freeway.

The topography of the catchment is shown in Figure 2-1. From a high elevation of around 120m AHD at the top of the catchment, the topography grades relatively steeply from the upper slopes to the lower floodplain. Downstream of the Main Northern Railway, the channel bed drops below 2m AHD with much of the lower floodplain area, largely occupied by residential development in Fassifern also below this level.

The catchment is drained by LT Creek and a number of minor unnamed tributaries. The principal watercourses in the catchment, LT Creek north arm and south arm, drain the two major sub-catchments. The north arm and south arm of LT Creek converge in Fassifern, just downstream of the Bridge Street crossing.

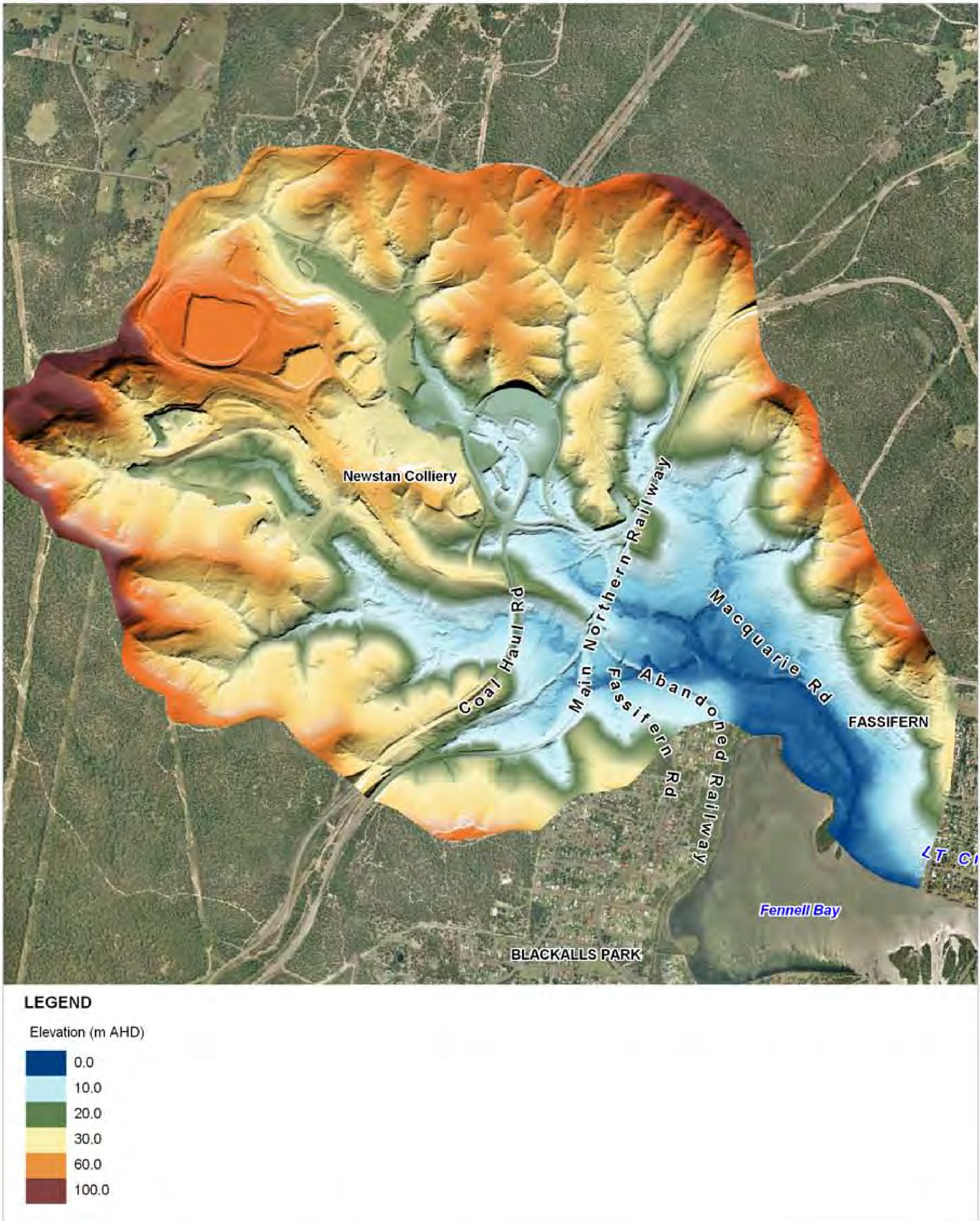
The watercourses upstream of the Main Northern Railway are typically small and heavily vegetated. As the channels cut through the lower floodplain, downstream of the railway, they gradually widen and deepen, with a corresponding increase in flow carrying capacity. Downstream of the confluence, the channel maintains a relatively uniform shape with a channel width of 20-30m.

The LT Creek catchment drains to Lake Macquarie through Fennell Bay, a semi-closed embayment of the broader Lake Macquarie waterway. The lower reaches of LT Creek therefore are subject to a tidal influence from Lake Macquarie. Tidal levels in the Lake typically vary between +/- 0.3m AHD with occasional higher spring/king tide events.

Land use within the catchment primarily consists of bushland (60%), Newtsan Colliery (25%) and urban development (10%). The Newstan site, operated by Centennial Coal, consists of a coal preparation plant, washing coal from other mine sites. There are numerous environmental management plans in place associated with these operations, including a water management plan and soil and erosion management plan which have some relevance to the flood study.

The urban communities of Fassifern and parts of Fennell Bay occupy the lower floodplain of LT Creek. The existing development is predominantly low to medium density residential development. Much of the recent construction has seen dwellings elevated above normal floodplain levels on building pads. There are also numerous properties fronting the LT Creek channel, many of which with buildings less than 20m from the channel bank.

The catchment is traversed by a number of transport corridors including the main-north railway, coal haulage routes associated with the Newstan operations and local roads. Many of these routes incorporate significant embankments across the LT Creek floodplain that are in evident in the catchment topography shown in Figure 2-1.



Title:

Topography of the LT Creek Catchment

Figure: **2-1**

Rev: **A**

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2.1.2 History of Flooding

There is an evident high flood risk exposure to the Fassifern community at the lower end of LT Creek. Major flood events resulting in substantial inundation to property have occurred in 1949, 1981, 1990 and most recently in June 2007.

The February 1981 event is the largest recorded flood event within the catchment in which approximately 350mm of rainfall fell over a 6-hour period. This was a regional flood event not confined to the LT Creek catchment, with major flooding experienced in neighbouring catchments on the western side of Lake Macquarie including Stony Creek, Dora Creek and Cockle Creek.

Whilst a lower rainfall event, the June 2007 flood conditions were largely dominated by the flood water level in Lake Macquarie, estimated to be of the order of a 20-year return period. Similarly, the 1949 and 1990 flooding events were largely driven by Lake Macquarie flooding. In each of these events, extensive flooding was experienced around the foreshore are of the entire Lake Macquarie waterway.

2.1.3 Previous Investigations

There has been no previous detailed investigation of the flooding characteristics of the LT Creek catchment. Some minor hydrological investigations associated with the Newstan Colliery operations have been undertaken, however, these generally do not consider the flooding characteristics of the wider catchment and indeed the potential flooding impact on the existing communities at the lower end of the catchment.

A detailed investigation of Lake Macquarie flooding was undertaken by MHL (1998). This study assessed design water levels, wave climate and foreshore flooding of the Lake. Webb McKeown and Associates (WMA) then prepared a Floodplain Risk Management Study (2000) and Floodplain Risk Management Plan (2001) based on the outcomes of the flood study modelling. No specific floodplain management measures were recommended for the LT Creek catchment, however various recommendations in regard to managing the foreshore flooding risk were recommended.

The most recent study undertaken in the LT Creek catchment is the Catchment Water Quality Management Plan (Umwelt, 2008). Flooding did not form any part of the scope of works for this study, which largely focused on the water quality objectives.

Further details of these previous investigations and their relevance in the context of the current flood study are presented in Section 2.2.1.

2.2 Compilation and Review of Available Data

2.2.1 Previous Studies

2.2.1.1 Lake Macquarie Flood Study (MHL, 1998)

Detailed modelling of the flooding processes was undertaken for this study to define flood levels in the Lake for a range of design magnitude conditions. The principal contributors to elevated water level conditions in the Lake include:

- Catchment rainfall – large depth/long duration rainfall (as experienced in June 2007) within the Lake catchment provides for a significant volume of inflow to elevate Lake levels;
- Ocean levels – elevated ocean levels are themselves driven by a number of processes including high tide conditions, storm surge and wave set-up;
- Swansea Channel dynamics – the interchange of water between the ocean and the main body of Lake Macquarie both under normal tide and flood conditions is controlled by Swansea Channel; and
- Wave set-up – local wind conditions and resulting wave climate can provide for increased flood levels along the foreshore areas.

Table 2-1 presents the predicted design flood levels in Lake Macquarie from the previous study. This data is relevant to the LT Creek flood study, providing downstream boundary conditions within Fennell Bay for consideration of coincident LT Creek catchment and Lake Macquarie flooding.

Table 2-1 Design Lake Macquarie Flood Level

Design Event	Still Lake Water Level (m AHD)
20% AEP	0.65*
10% AEP	0.80*
5% AEP	0.97
2% AEP	1.24
1% AEP	1.38
0.5% AEP	1.55*
0.2% AEP	1.75*
PMF	2.63

* - estimated as part of the Floodplain Management Study (WMA, 2000)

A number of sensitivity tests were undertaken on the model including ocean tailwater levels, catchment run-off volume, tidal conditions, wave conditions and entrance/channel conditions. The sensitivity analyses indicated that the Lake flooding condition was most sensitive to design ocean water levels. This has obvious implications when considering potential sea level rise scenarios for future conditions.

2.2.1.2 Lake Macquarie Floodplain Management Study (WMA, 2000)

The primary objectives of this study were to define the nature and extent of the flood hazard and identify appropriate measures to reduce the potential impact of flooding for both existing and future development.

The extent of the existing flood risk problem in Fassifern as a result of Lake Macquarie flooding is summarised in Table 2-2 considering properties affected by over-floor flooding for a range of design flood event magnitudes. No properties in Fassifern were identified at risk of over floor flooding for events up to the 5% AEP flood level, with only a relatively small number of properties up to the 0.2% AEP flood level.

Table 2-2 Fassifern Property Inundation from Lake Macquarie Flooding

Design Event	No. of properties with above floor flooding
5% AEP	0
2% AEP	2
1%	6
0.5% AEP	8
0.2% AEP	21
PMF	57

Given the scope of the study to address Floodplain Risk Management for the entire Lake Macquarie waterway, it is not surprising that no specific floodplain management measures for the LT Creek catchment were identified considering the relative size of the catchment and the relatively low number of potentially affected property.

2.2.1.3 Catchment Water Quality Management Plan (Umwelt, 2008)

This study was undertaken to identify the key threats to the health of the LT Creek waterway underpinned by a risk assessment of the full range of water quality processes which affect the capacity of the LT Creek to sustain diverse and healthy aquatic ecosystems (Umwelt, 2008).

The Catchment Water Quality Management Plan presents a prioritised suite of actions to address the most important risks to water quality and waterway health in the LT Creek catchment. The Plan addresses existing issues and the risks of future impacts associated with further development.

The study in general however does not consider major flooding. Whilst high sediment loads during rainfall events is identified as one of the key contributors to poor water quality in LT Creek, these rainfall events are generally at magnitudes significantly lower than those considered in the current flood study. It should be noted that over 99% of long term catchment runoff volumes occur for rainfall events up to the 1-year return period. Accordingly, water quality management objectives tend to address these more frequent events.

For rainfall events of the magnitude considered for the flood study i.e. 1 in 5-year and higher, the opportunity to provide effective improvement to long term waterway health is limited (due to their infrequency and magnitude).

The only water quality concern that has relevance from a flood management perspective is the potential siltation of the LT Creek waterway and any resulting reduction in flow carrying capacity of the channel. Siltation of the channel is a primary concern of the local residents, largely driven by the potential impact of poor water quality and navigation problems.

Nevertheless, given the level of community concern in relation to ongoing siltation issues in the LT Creek channel, additional modelling has been undertaken to investigate potential impact of reduced channel capacity on design flooding conditions. This modelling has been undertaken as a series of sensitivity tests described in Section 7.4.

2.2.2 Historical Flood Levels

Council's flood record database (prior to the June 2007 event) holds a reasonable record of historical flood levels in the LT Creek catchment, predominantly within Fassifern. The highest flood events on record are dominated by the 1981 and 1949 events. Figure 2-2 shows the flood event that has result in the highest recorded flood level at individual properties. The flood levels recorded for the properties are included in Appendix C.

From Figure 2-2 is evident that the highest recorded flood to have affected the western part of Fassifern was the 1981 event. As noted in Section 2.1.2, this was a major catchment rainfall event which resulted in significant flooding in neighbouring catchments such as Stony Creek and Dora Creek also.

The highest events in the lower part of the catchment correspond to the years of significant flooding of Lake Macquarie. Table 2-3 shows historical peak flood water levels in the Lake. The highest recorded flood level of the Lake of 1.25m AHD in 1949 corresponds to the highest flood water levels of approximately 1.2m AHD at the majority of property in the lower part of Fassifern (refer to Appendix C).

Table 2-3 Historical Flood Levels in Lake Macquarie

Date	Peak Lake Flood Level (m AHD)
June 1949	1.25
April 1946	1.2
June 2007	1.1
June 1930	1.1
February 1990	1.0
February 1981	0.8

Peak flood levels in Fassifern recorded for the June 2007 event were also approximately 1.1m AHD, corresponding to the general peak flood level in the Lake.

2.2.3 Rainfall Data

There is an extensive network of rainfall gauges across the wider Lake Macquarie and Newcastle areas operated by the Bureau of Meteorology (BoM), Hunter Water Corporation (HWC), Manly Hydraulics Laboratory (MHL) and Centennial Coal (Newstan Colliery). The Newstan Colliery gauge is the only operational rainfall gauge in the LT Creek catchment. Some 15 other gauges (continuous and daily read) are present in neighbouring catchments and the general locality of the north-western region of Lake Macquarie (within 5km of the LT Creek catchment). The full list of rainfall stations, including closed stations, is shown in Table 2-4 with their respective period of record. The location of the gauges is shown in Figure 2-3.

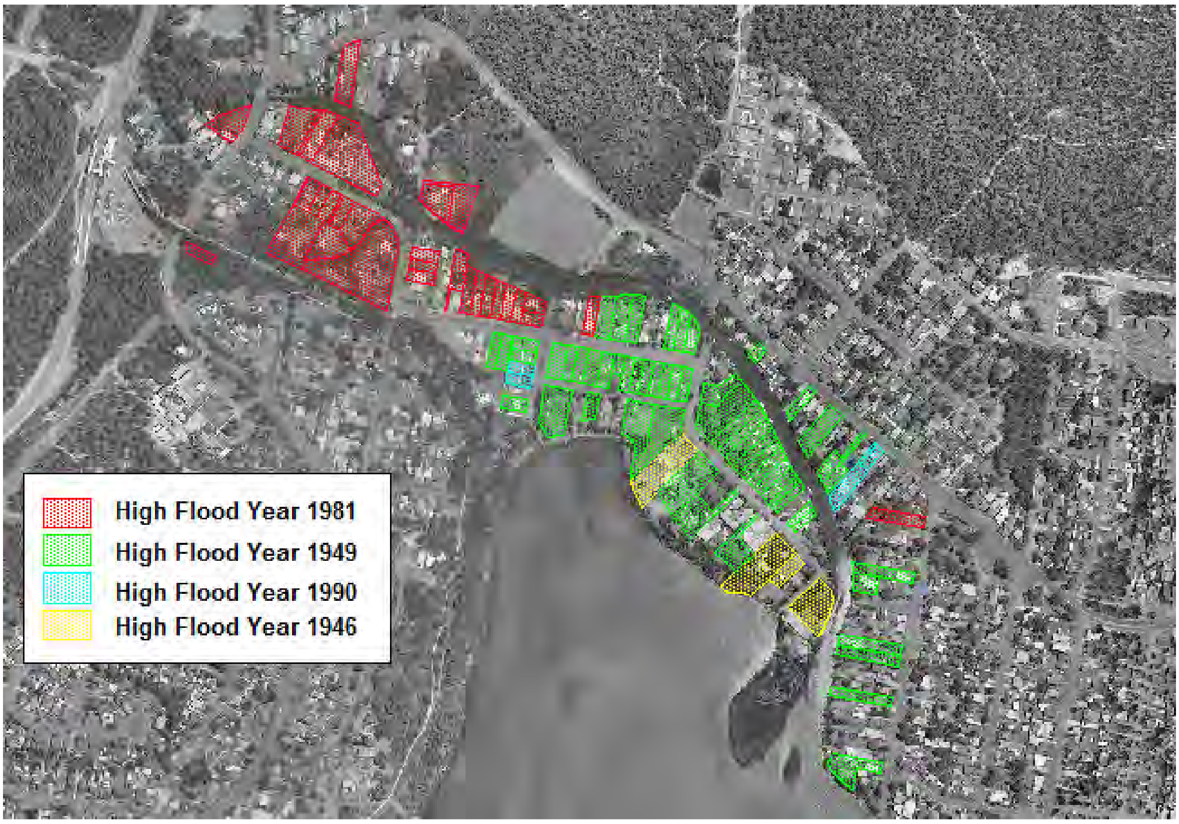


Figure 2-2 High Flood Year Records for Fassifern

Whilst there have been a large number of rainfall gauges installed in the catchment, unfortunately the length of record for most of the sites are short, and more significantly, tend not to correspond to periods in which major floods have occurred. From Council's flood database (refer Section 2.2.2), the three events for which the highest flood levels were recorded in Fassifern were June 1949, February 1981 and June 2007. The corresponding rainfall data available for these events includes:

- June 1949 event – daily rainfall totals for this event are available at a number of gauges with some 300mm of rainfall falling over a two day period. No temporal pattern data is available. For this event, however, the flooding in Fassifern was dominated by the high lake water level.
- February 1981 event – Daily rainfall totals for this event are available for Toronto, Bolton Point and Cockle Creek. The 1981 Sinclair Knight and Partners report on the storm event for the Stony Creek catchment provides detailed background and analysis of available rainfall data across the Lake Macquarie region for this event. Utilising various daily read totals and temporal pattern data from Eraring Power Station, the approximated isohyetal and temporal patterns for the region, including the LT Creek catchment are available in this report. This event data is considered the most appropriate to use in the current study.
- June 2007 event – significantly for this event, the Centennial Coal Newstan Colliery gauge, provides a continuous hyetograph of recorded rainfall within the catchment. The HWC Teralba gauge also has continuous data recorded for the event. As with the 1949 event however, despite the significant catchment rainfall the flood levels in Fassifern were again controlled by the Lake flooding conditions.

Further discussion on recorded rainfall data for historical events is presented with the calibration and validation of the models developed for the study in Section 6.

Table 2-4 Summary of Rainfall Gauges in the LT Creek Locality

Station No.	Name	Start Year	End Year	Years of Record
61370	Barnsley (Bendigo Street)	1990	current	29
61011	Cockle Creek (Pasminco Metals)	1900	current	109
61019	Fassifern	1924	1961	37
61133	Bolton Point (Kanimbla)	1962	1990	28
61322	Toronto (Home Port)	1972	1990	18
61322	Toronto WWTP	1972	current	37
Macq.-Tugg.	Barnsley	1989	current	30
Macq.-Tugg.	Fassifern	1992	1997	5
R12	Toronto WWTP	1989	current	20
R13	Valentine	1991	current	14
R34	Edgeworth	1995	current	14
R65	Edgeworth	1990	current	19
R67	Marmong Point	1990	1995	5
R7	Teralba BC	1994	current	15
R74	Toronto WWTP	1990	current	19
n/a	Newstan Colliery	2005	current	4

2.2.4 Streamflow Data

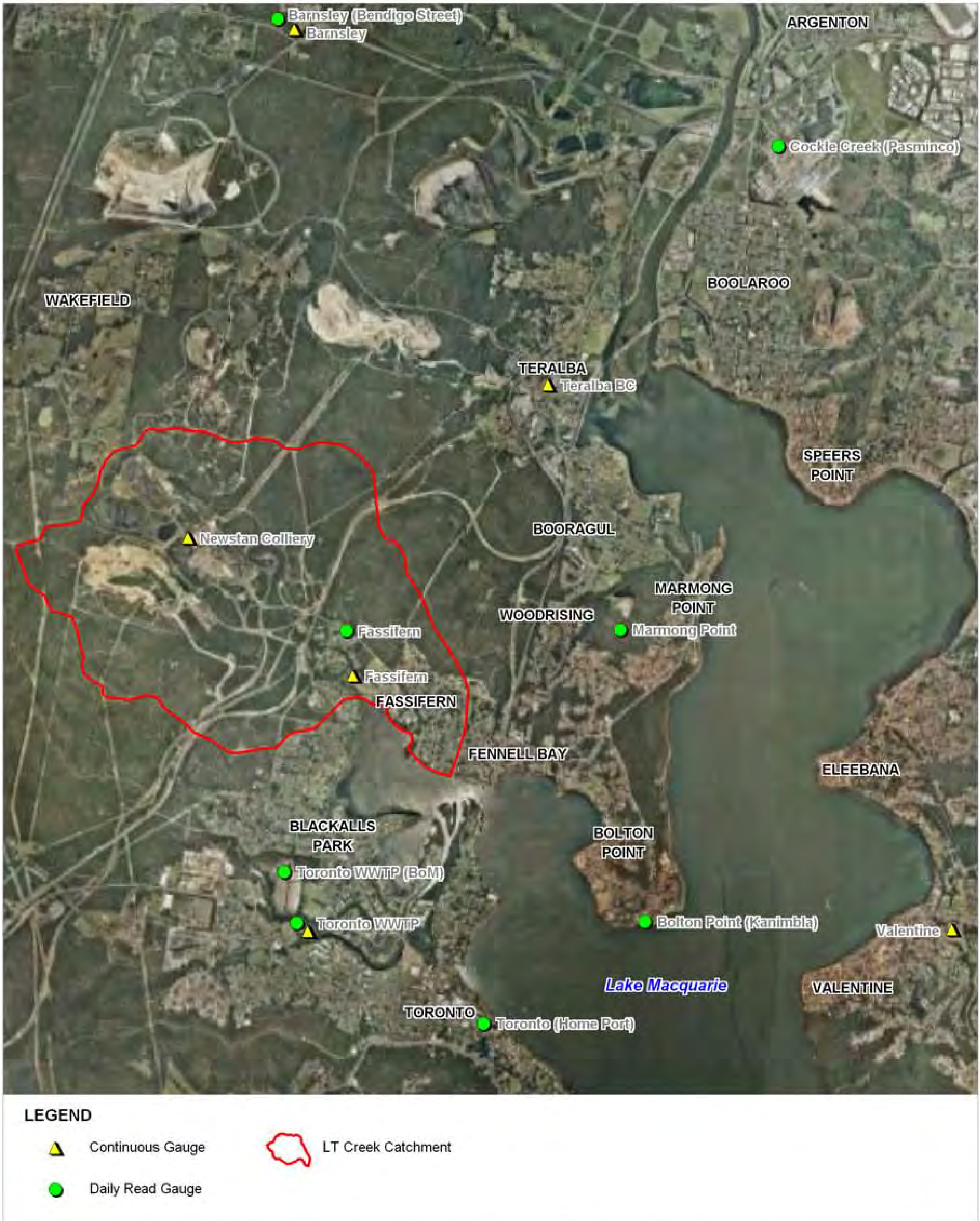
There are no streamflow gauges located on LT Creek. As part of the Newstan Colliery operations there are monitoring points related to the sites water management, however, given the location of the gauges and available data, there is little value provided to the flood study given the magnitude of flood events under consideration.

2.2.5 Lake Macquarie Water Level Data

Manly Hydraulics Laboratory (MHL) operates three continuous water level recorders in Lake Macquarie including:

- Swansea Channel – data from 1996 to present;
- Belmont – data from 1986 to present; and
- Marmong Point – data from 1986 to present.

The Marmong Point gauge on the western side of Lake Macquarie represents the most appropriate location for defining water levels in Fennell Bay (at the outlet of LT Creek).



Title:

Rainfall Gauges in the Vicinity of the LT Creek Catchment

Figure: 2-3

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2.2.6 Council Data

Digitally available information such as aerial photography, cadastral boundaries, topography, watercourses, drainage networks, land zoning, vegetation communities and soil landscapes were provided by Council in the form of GIS datasets.

A variety of relevant planning documents, where available, were also reviewed and considered as part of the study. These documents include Council's LEP, Council's Flood Policy, Lake Macquarie Sea Level Rise Preparedness Adaptation Policy, Development Control Plans, and SES Flood Plan.

LiDAR land survey data has also been made available for the floodplain relatively recently. Flood behaviour is inherently dependent on the ground topography. Advanced GIS analysis also allows the LiDAR imagery to be assessed in concert with spatial 2-D flood model data, facilitating mapping, categorisation, and overall flood management.

2.3 Site Inspections

A number of site inspections were undertaken during the course of the study to gain an appreciation of local features influencing flooding behaviour. Some of the key observations to be accounted for during the site inspections included:

- Presence of local structural hydraulic controls such as bridges, culverts, road embankments and natural topographical controls such as channel/floodplain constrictions or steep reaches;
- General nature of the river channel and floodplain noting river plan form, vegetation type and coverage and the presence of significant flow paths;
- Location of existing development and infrastructure on the floodplain.

This visual assessment was useful for defining hydraulic properties within the hydraulic model and ground-truthing of topographic features identified from survey.

An inspection within the operational area of Newstan Colliery was an important component of the site inspections undertaken given the large proportion of the study catchment area occupied by the site. This inspection was undertaken in accompaniment of Centennial Coal staff, providing access to all relevant areas of the site.

2.4 Additional Survey

The review of available topographic data identified the requirement for additional survey to be undertaken to provide the necessary coverage and detail required to build the hydraulic model. The additional survey incorporated:

- Cross sections of the LT Creek channel and major tributaries to supplement the existing LiDAR topographical data. Due to limitations in the aerial survey method, the detail of watercourses is often obscured (e.g. by standing water, vegetation etc). Ground survey is required to provide the required detail of the watercourses to integrate with the LiDAR data; and

- A number of flood drainage structures (including bridges and culverts) for which no existing details were available. These structures included those on both public and private access roads and the railway.

The acquisition of the additional survey is discussed in further detail in Section 4.

2.5 Community Consultation

The success of a floodplain management plan hinges on its acceptance by the community, residents within the study area, and other stake holders. This can be achieved by involving the local community at all stages of the decision-making process. This includes the collection of their ideas and knowledge on flood behaviour in the study area, together with discussing the issues and outcomes of the study with them.

The key elements of the consultation process in undertaking the flood study have been:

- Issue of a questionnaire to obtain historical flood data and community perspective on flooding issues;
- Community information session to provide feedback on the June 2007 flood, questionnaire, and direction of the flood study; and
- Public exhibition of Draft Report and community information session.

These elements are discussed in further detail in Section 3.

2.6 Development of Computer Models

2.6.1 Hydrological Model

For the purpose of the Flood Study, a hydrologic model (discussed in Section 5.1) was developed to simulate the rate of storm runoff from the catchment. The model predicts the amount of runoff from rainfall and the attenuation of the flood wave as it travels down the catchment. This process is dependent on:

- Catchment area, slope and vegetation;
- Variation in distribution, intensity and amount of rainfall; and
- Antecedent conditions of the catchment.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydrodynamic model. These hydrographs are used by a hydrodynamic model to simulate the passage of a flood through the LT Creek catchment to the downstream study limits at the outlet to Lake Macquarie (Fennell Bay).

2.6.2 Hydraulic Model

The hydraulic model (discussed in Section 5.2) developed for this study includes:

- two-dimensional (2D) representation of the LT Creek floodplain covering an area of approximately 3 km^2 of the lower catchment (approximately 40% of total catchment area), which includes all of the floodplain in the developed area of Fassifern east of the Main North railway; and

- one-dimensional (1D) representation of the main channels of LT Creek from the downstream model limit at Fennell Bay to approximately 2km upstream to the coal haulage road.

The hydraulic model is applied to determine flood levels, velocities and depths across the study area for historical and design events.

2.7 Calibration and Sensitivity Testing of Models

The hydrologic and hydrodynamic models were calibrated and verified to historical flood events to establish the values of key model parameters and confirm that the models were capable of accurately predicting real flood events.

The following criteria are generally used to determine the suitability of historical events to use for calibration or validation:

- The availability, completeness and quality of rainfall and flood level event data;
- The amount of reliable data collected during the historical flood information survey; and
- The variability of events – preferably events would cover a range of flood sizes.

The available historical information highlighted two floods with sufficient data to potentially support a calibration process. These floods were the recent June 2007 event and the February 1981 event being the largest recorded in the catchment to date.

The calibration and validation of the models is presented in Section 6. A series of sensitivity tests were also carried out to evaluate the model. These tests were conducted to examine the performance and determine the relative importance of different hydrological and hydrodynamic factors. The sensitivity testing of the models is detailed in Section 7.

2.8 Establishing Design Flood Conditions

Design floods are statistical-based events which have a particular probability of occurrence. For example, the 1% Annual Exceedance Probability (AEP) event, which is sometimes referred to as the 1 in 100 year Average Recurrence Interval (ARI) flood, is the best estimate of a flood with a peak discharge that has a 1% (i.e. 1 in 100) chance of occurring in any one year. For the LT Creek catchment, design floods were based on design rainfall estimates according to Australian Rainfall and Runoff (IEAust, 2001).

The design flood conditions form the basis for floodplain management in the catchment and in particular design planning levels for future development controls. The predicted design flood conditions are presented in Section 7.

2.9 Mapping of Flood Behaviour

Design flood mapping is undertaken using output from the hydrodynamic model. Maps are produced showing water level, water depth and velocity for each of the design events. The maps present the peak value of each parameter. Provisional flood hazard categories and hydraulic categories are derived from the hydrodynamic model results and are also mapped. The mapping outputs are described in Section 7.3 and presented in Appendix A.

3 COMMUNITY CONSULTATION

3.1 The Community Consultation Process

Community consultation has been an important component of the current study. The consultation has aimed to inform the community about the development of the flood study and its likely outcome as a precursor to subsequent floodplain management activities. It has provided an opportunity to collect information on their flood experience, their concern on flooding issues and to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process have been as follows:

- Meeting with, and presentations to, the Floodplain Management Committee;
- Distribution of a questionnaire to all landowners, residents and businesses within the study area;
- An information session for the community to present information on the progress and objectives of the flood study and details of the June 2007 flood; and
- Public exhibition of the draft Flood Study.

These elements are discussed in detail below.

3.2 The Floodplain Management Committee

The study has been overseen by the Floodplain Management Committee (Committee). The Committee has assisted and advised Council in the development of the LT Creek Flood Study. Members of the Floodplain Management Committee include representatives from the following:

- Staff from Lake Macquarie City Council;
- Staff from the Dept. Environment and Climate Change (DECC) Hunter Region;
- A representative from the State Emergency Service (SES); and
- Four (council to confirm) community representatives.

The Committee is responsible for recommending the outcomes of the study for formal consideration by Council.

3.3 Community Questionnaire

In October 2008, a short questionnaire was sent to all landowners, residents and businesses located within the study area. The questionnaire was sent to approximately 200 property holders, with Council receiving 32 responses.

The questionnaire asked residents to provide as much information as possible in regard to historical flood events within the catchment, with a focus on the June 2007 event.

A detailed summary of responses to the questionnaire is included in Appendix D. Provided hereunder is a summary of the key information and issues provided in the responses.

Historical Flooding

- Years of flooding – respondents were asked to acknowledge dates of previous flood events within the catchment from personal experience. The majority of respondents confirmed experience of the most recent significant flood events in the catchment being 2007, 1990 and 1981. Only 1 respondent noted the 1949 flood reflecting the lack of personal experience of this event by respondents, and not unexpected given the progression of time since the event.

- Flood marks – a key objective of the flood questionnaires was top obtain peak flood level reference points for model calibration purposes. The majority of flood information was provided for the June 2007 event, with little additional flood mark data obtained for other events. A total of 12 flood marks were identified in the responses largely derived from debris marks, marked posts, sheds, fences or other reference points on the property.

- Peak flood timing - a number of respondents were able to provide with confidence estimates of the timing of the peak flood level. These responses indicated that within the Fassifern area the water levels peaked at around 3am on Saturday 9th June. Other responses were generally spread over a few hour period in the early hours of the morning. It was noted that the water was slow to recede, with high water levels remaining for some time after the peak.

- Photographic/video record – a large database of photographs and video has been collated, courtesy of the respondents. The majority of this information was provided in digital format.

- Rainfall records – one private rain gauge readings was provided to supplement the rainfall data for the catchment. The data provided indicated a total storm period rainfall of approximately 347mm generally across the study area. This reading was generally consistent with the Newstan Colliery total recorded for the catchment.

- Access closures – there were no confirmation of any access issues on the major routes into Fassifern (i.e. Macquarie Road and Fassifern Road). Inundation of local roads in the lower part of the catchment including Fennell Street and Bluewater Avenue.

General comments

Respondents were provided with the opportunity to add further comment on personal experiences or opinion in regard to the June 2007 flood or general flooding and floodplain management within the LT Creek catchment. The common themes from the responses given are summarised below.

- A number of respondents noted that yards were flooded for many of the older houses within the township, whilst acknowledging much of the newer development is raised and accordingly had little inundation.

- Issues related to water quality and silt deposition were noted by many residents. This re-iterates the ongoing concern within the community in relation to these issues. From a floodplain management perspective the erosion and deposition of bed material in the LT Creek channel warrants further consideration.

- Loss of electricity and other services were noted. The severity of storm coupling intense rainfall, high winds and flooding led to a loss of services. Again, from a floodplain management perspective, these issues may be considered further when addressing flood response and general flood preparedness within the community.

3.4 Information Session

A community information session was held at Lake Macquarie City Council offices in the evening of Tuesday 2nd December 2008 to:

- Provide the community with an overview of the study and objectives;
- Provide the community with a summary of the June 2007 flood event and the data collected and analysed to date; and
- Provide the study team with a means to obtain feedback from the local community on the direction of the study and additional information/comment arising from flooding in the catchment.

The information session was attended by approximately 25 community attendees in addition to Council staff and the consultant.

The primary issues and concerns raised by the community during the information session were the ongoing water quality and sedimentation issues in the lower LT Creek channel. A detailed investigation of these issues was undertaken in the LT Creek Catchment Water Quality Management Plan (Umwelt, 2008). Community workshops and other consultation were also undertaken within that study.

Further detailed investigation of the water quality and sedimentation issues is beyond the scope of the current flood study. Nevertheless, the potential sedimentation of the channel and therefore reduced channel carrying capacity has some relevance in regard to local flooding.

Other issues raised in relation to the general hydrology of the catchment include:

- water management at Newstan Colliery;
- stormwater drainage capacity; and
- runoff from new urban development.

The most relevant of the community concerns in relation to flooding (i.e. high flow regimes) as opposed to stormwater management (i.e. low flow regimes) is the sedimentation of the channel. Given the level of community concern in relation to ongoing sedimentation problems in the channel, sensitivity tests on reduced channel capacity have been incorporated into the flood study. The results of this analysis are provided in Section 7.4.

The Water Quality Management Plan recommends appropriate rehabilitation actions for the most degraded areas in the catchment and details a range of prioritised management actions for land managers and other stakeholders. Accordingly, no further comment or investigation in relation to erosion and sediment management is included in the flood study. However, it is recommended that these issues are acknowledged in the subsequent floodplain management study, to provide a more holistic catchment management approach by integrating the flooding, stormwater and water quality management in the LT Creek catchment.

3.5 Public Exhibition

The draft Flood Study was placed on public exhibition for the period September 6th 2010 to October 1st 2010. During this period, a community information session was held at Lake Macquarie City Council offices in the evening of Thursday 16th September 2010. No significant issues were raised by the community at the information session in relation to the flood study. Again most community concern related to water quality issues, particularly in relation to operations at Newstan Colliery.

No formal responses were received on the Draft Flood Study following public exhibition.

4 ADDITIONAL SURVEY

The following sections outline the additional survey data collected to supplement the existing data and enable the establishment of a suitable two-dimensional model representation of the LT Creek channel and floodplain.

4.1 Channel Cross Sections

The effectiveness of aerial data capture is often limited in the vicinity of the main creek alignment due to the presence of water and dense vegetation. In these instances cross-section surveys are required to accurately define the shape of the watercourse.

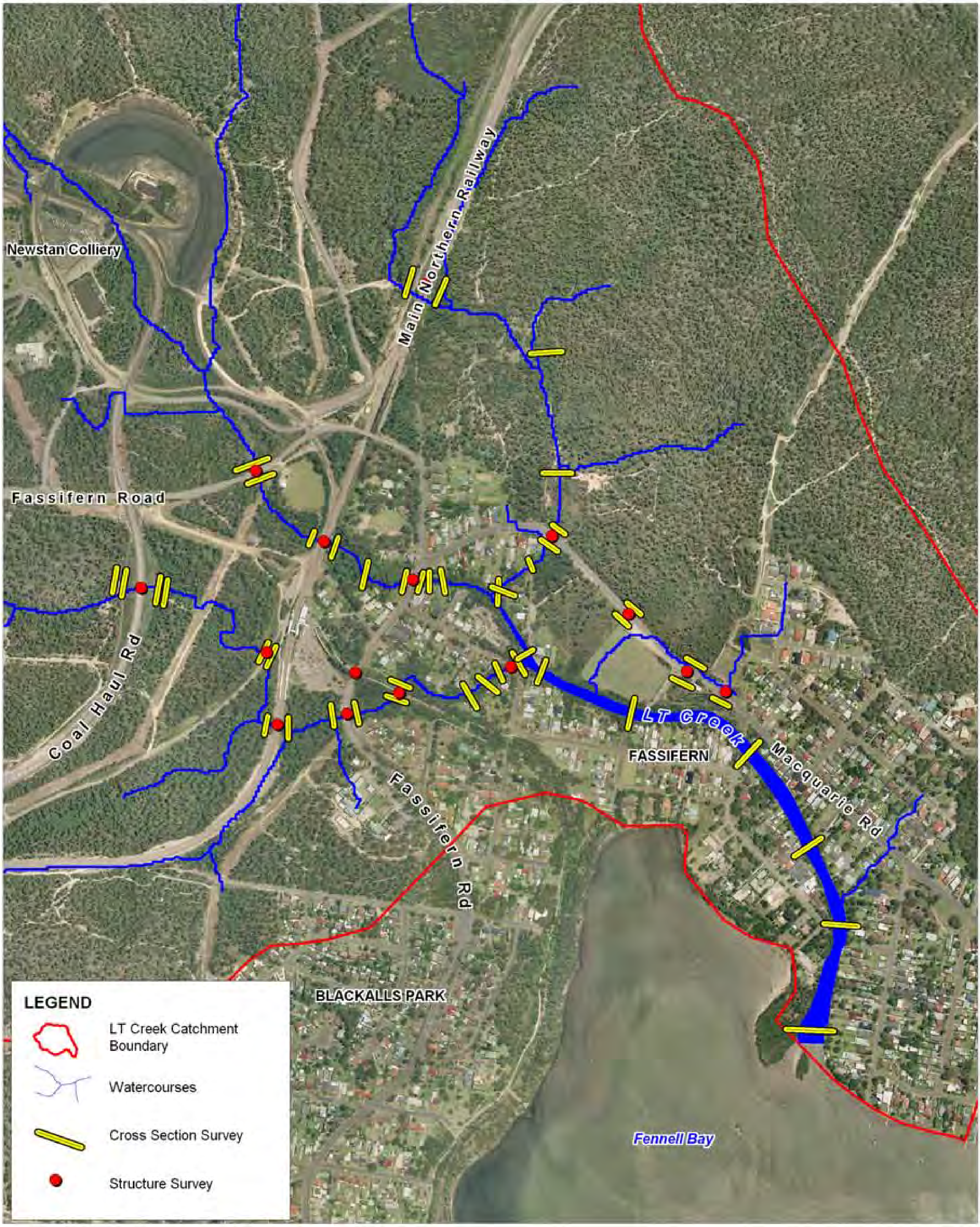
Figure 4-1 shows the location of cross sections that were surveyed by Council to provide additional waterway information for the LT Creek channel. Some of the deeper and wider sections in the lower LT Creek were surveyed by boat to provide appropriate representation of the waterway geometry.

The sections extend from the outlet of LT Creek at Fennell Bay to the Coal Haulage Road, Fassifern Road and the Main North Railway on the three main tributary alignments respectively. These limits correspond to the extent of the modelled 1D channel network. The distribution of cross sections shown represents an average cross section spacing of 200m along the main channel alignment in the lower part of LT Creek where the channel is relatively uniform. The cross section spacing on the upper reaches is somewhat smaller, generally coinciding with the location of major hydraulic structures as discussed in Section 4.2. This distribution and average spacing of cross sections was defined to provide an appropriate level of detail to develop the hydraulic model.

4.2 Structures

There are numerous hydraulic structures on the main channels within the study area for which limited existing survey detail was available. Accordingly, the ground survey undertaken by Council included the survey of numerous structures to provide the structure details required to build the hydraulic model such as dimensions, waterway areas and invert levels.

Fifteen (15) structures in total were surveyed including bridges and culverts on both the road and rail networks traversing the catchment. Further structure details and their respective model configuration are presented in Section 5.2.4.



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Location of Cross Section and Structure Survey

Figure: 4-1

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0 200 400m
Approx. Scale

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5 MODEL DEVELOPMENT

Computer models are the most accurate, cost-effective and efficient tools to assess a catchment's flood behaviour. For this study, two types of models were used:

- A hydrologic model of the entire LT Creek catchment; and
- A hydraulic model extending from just upstream of the coal haulage road to the downstream boundary of LT Creek at Fennell Bay.

The **hydrologic model** simulates the catchment rainfall-runoff processes, producing the river/creek flows which are used in the hydraulic model.

The **hydraulic model** simulates the flow behaviour of the channel and floodplains, producing flood levels, flow discharges and flow velocities.

Both of these models were calibrated interactively.

Information on the topography and characteristics of the catchments, watercourses and floodplains are built into the models. Recorded historical flood data, including rainfall, flood levels and river flows, are used to simulate and validate (calibrate and verify) the models. The models produce as output, flood levels, flows (discharges) and flow velocities.

Development of a hydraulic model follows a relatively standard procedure:

1. Discretisation of the catchment, watercourses, floodplain, etc.
2. Incorporation of physical characteristics (river cross-sections, floodplain levels, structures etc).
3. Establishment of hydrographic databases (rainfall, river flows, flood levels) for historic events.
4. Calibration to one or more historic floods (calibration is the adjustment of parameters within acceptable limits to reach agreement between modelled and measured values).
5. Verification to one or more other historic floods (verification is a check on the model's performance without further adjustment of parameters).
6. Sensitivity analysis of parameters to measure dependence of the results upon model assumptions.

Once model development is complete it may then be used for:

- establishing design flood conditions;
- determining levels for planning control; and
- modelling development or management options to assess the hydraulic impacts.

5.1 Hydrological Model

The hydrologic model simulates the rate at which rainfall runs off the catchment. The amount of rainfall runoff and the attenuation of the flood wave as it travels down the catchment is dependant on:

- the catchment slope, area, vegetation and other characteristics;
- variations in the distribution, intensity and amount of rainfall; and

- the antecedent conditions (dryness/wetness) of the catchment.

These factors are represented in the model by:

- Sub-dividing (discretising) the catchment into a network of sub-catchments inter-connected by channel reaches representing the creeks and rivers. The sub-catchments are delineated, where practical, so that they each have a general uniformity in their slope, landuse, vegetation density, etc;
- The amount and intensity of rainfall is varied across the catchment based on available information. For historical events, this can be very subjective if little or no rainfall recordings exist.
- The antecedent conditions are modelled by varying the amount of rainfall which is “lost” into the ground and “absorbed” by storages. For very dry antecedent conditions, there is typically a higher initial rainfall loss.

The output from the hydrologic model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood through the LT Creek channel and floodplain.

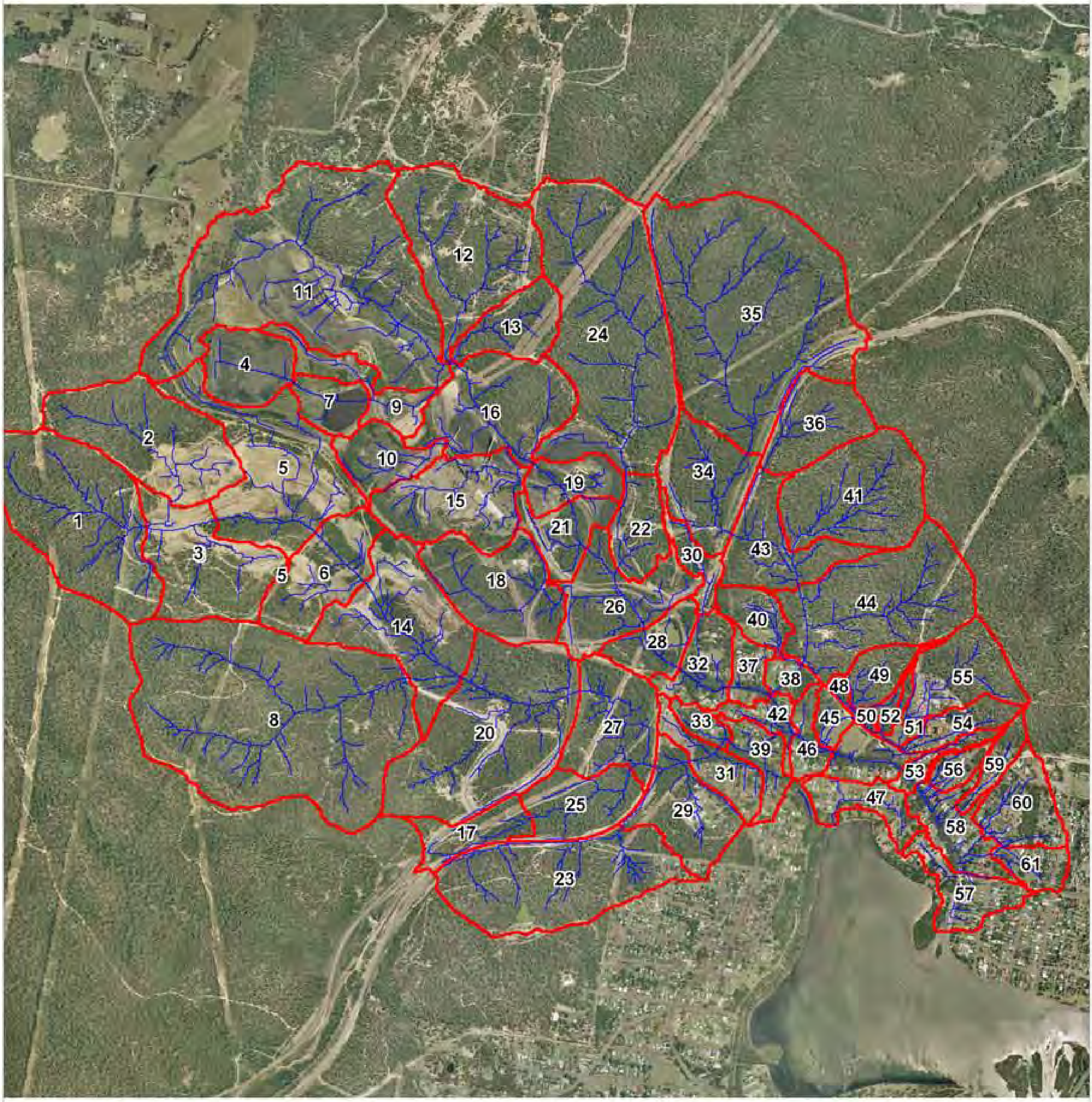
The RAFTS-XP software was used to develop the hydrologic model using the physical characteristics of the catchment including catchment areas, ground slopes and vegetation cover as detailed in the following sections.

5.1.1 Catchment Delineation

The LT Creek catchment drains an area of approximately 7.5km^2 to its outlet to Lake Macquarie at Fennell Bay. For the hydrological model this area has been delineated into 61 sub-catchments as shown in Figure 5-1.

The sub-catchment delineation provides for generation of flow hydrographs at key confluences or inflow points to the hydraulic model.

Table 5-1 summarises the key catchment parameters adopted in the RAFTS-XP model, including catchment area, vectored slope and PERN (roughness) value estimated from the available topographic information and aerial photography. The adopted PERN values considered the proportion of forested catchment to cleared/pasture area. As indicated in the table and evident from aerial photography, the greater proportion of the LT Creek catchment is largely forested.



LEGEND

17 RAFTS Sub-catchment

Stream Network

Title:
RAFTS Model Sub-catchment Layout

Figure: **5-1**

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Approx. Scale

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Table 5-1 RAFTS-XP Sub-catchment Properties

Catchment Label	Area (ha)	Slope (%)	PERN	Catchment Label	Area (ha)	Slope (%)	PERN
1	27.8	7.8	0.10	32	6.5	2.4	0.05
2	20.0	7.6	0.10	33	2.1	3.7	0.05
3	16.5	2.9	0.10	34	12.0	4.3	0.06
4	8.2	0.5	0.10	35	50.5	3.5	0.06
5	23.5	5.2	0.10	36	9.5	4.1	0.06
6	11.6	5.0	0.10	37	3.3	1.8	0.04
7	4.7	3.7	0.04	38	2.2	2.0	0.04
8	59.9	2.8	0.10	39	4.6	2.1	0.04
9	6.7	7.2	0.05	40	4.4	2.3	0.06
10	6.4	4.4	0.05	41	18.1	5.8	0.10
11	54.6	1.3	0.06	42	3.0	1.0	0.04
12	22.7	3.1	0.06	43	10.9	3.3	0.06
13	7.4	5.1	0.06	44	24.5	2.9	0.06
14	19.7	2.9	0.10	45	2.1	1.1	0.10
15	14.6	2.3	0.03	46	3.3	0.8	0.05
16	17.2	2.6	0.05	47	5.5	0.5	0.04
17	5.9	4.2	0.06	48	0.7	1.2	0.10
18	14.6	3.0	0.06	49	4.1	4.7	0.10
19	5.7	2.1	0.05	50	1.4	3.7	0.10
20	31.4	2.8	0.10	51	1.0	1.7	0.05
21	6.4	3.0	0.05	52	1.0	5.1	0.10
22	6.4	4.8	0.10	53	2.2	7.6	0.04
23	24.4	4.4	0.06	54	4.2	8.1	0.05
24	41.7	3.0	0.10	55	9.8	8.0	0.06
25	9.1	2.3	0.06	56	2.3	10.3	0.04
26	12.7	2.6	0.10	57	6.5	0.8	0.04
27	12.2	1.6	0.06	58	7.5	1.2	0.04
28	5.6	2.6	0.06	59	2.8	9.9	0.05
29	10.9	4.9	0.05	60	8.0	5.6	0.04
30	3.4	2.7	0.05	61	3.5	6.2	0.04
31	5.9	3.0	0.04				

5.1.2 Rainfall Data

Rainfall information is the primary input and driver of the hydrological model which simulates the catchments response in generating surface run-off. Rainfall characteristics for both historical and design events are described by:

- Rainfall depth – the depth of rainfall occurring across a catchment surface over a defined period (e.g. 270mm in 36hours or average intensity 7.5mm/hr); and
- Temporal pattern – describes the distribution of rainfall depth at a certain time interval over the duration of the rainfall event.

Both of these properties may vary spatially across the catchment.

The procedure for defining these properties is different for historical and design events. For historical events, the recorded hyetographs at continuous rainfall gauges provide the observed rainfall depth and temporal pattern. Where only daily read gauges are available within a catchment, assumptions regarding the temporal pattern may need to be made.

For design events, rainfall depths are most commonly determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in AR&R (2001). Similarly AR&R (2001) defines standard temporal patterns for use in design flood estimation.

The rainfall inputs for the historical calibration/validation events are discussed in further detail in Section 6 and design events discussed in Section 7.

5.2 Hydraulic Model

The scope of the flood study included the development of a two-dimensional (2D) hydraulic model for the LT Creek catchment. BMT WBM has applied the fully 2D software modelling package TUFLOW. TUFLOW was developed in-house at BMT WBM and has been used extensively for over fifteen years on a commercial basis by BMT WBM.

The 2D model has distinct advantages over 1D and quasi-2D models in applying the full 2D unsteady flow equations. This approach is necessary to model the complex interaction between rivers, creeks and floodplains and converging and diverging of flows through structures. The channel and floodplain topography is defined using a high resolution DEM for greater accuracy in predicting flows and water levels and the interaction of in-channel and floodplain areas.

5.2.1 Extents and Layout

Consideration needs to be given to the following elements in constructing the model:

- location of available data (eg. river section surveys);
- location of recorded data (eg. levels/flows for calibration);
- location of controlling features (eg. dams, levees, bridges);

- desired accuracy to meet the study's objectives; and
- computational limitations.

With consideration to the available survey information and local topographical and hydraulic controls, a linked 1D/2D model was developed extending from the outlet of LT Creek into Fennell Bay at the downstream limit, to approximately 2.5km upstream along the major tributary routes. A linked 1D/2D model was developed covering this extent. The major watercourses have been modelled as 1D branches cut through the 2D (floodplain) domain. This approach enables the hydraulic capacity of the channels to be accurately defined by surveyed cross sections, whilst enabling the floodplain area to be represented in 2D. The model layout is presented in Figure 5-2.

The floodplain area modelled within the 2D domain comprises a total area of some 2.5km^2 (up to approximately 12m AHD) which represents the lower third of the entire LT Creek catchment. A high resolution DEM was derived for the study area from the LiDAR data provided by Council. The ground surface elevation for the TUFLOW model grid points are sampled directly from the DEM's established for each model area.

A TUFLOW 2D domain model resolution of 5m was adopted for study area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 5m cell size results in DEM elevations being sampled every 2.5m. This resolution was selected to give necessary detail required for accurate representation of floodplain topography and its influence on out-of-bank flows, particularly in the developed part of Fassifern.

5.2.2 Topography

The ability of the model to provide an accurate representation of the flow distribution on the floodplain ultimately depends upon the quality of the underlying topographic model. For the LT Creek catchment, a high resolution DEM (2m by 2m grid) derived form LiDAR survey was provided by Council.

As discussed in Section 4.1, additional cross section survey of the watercourses was required to supplement the LiDAR data and provide the necessary detail on channel shape and dimensions for representation in the hydraulic model. The 1D model reaches were constructed to coincide with the locations of available cross section survey as presented in Figure 4-1.

5.2.3 Hydraulic Roughness

The development of the TUFLOW model requires the assignment of different hydraulic roughness zones. These zones are delineated from aerial photography and cadastral data identifying different land-uses (eg. forest, cleared land, roads, urban areas, etc) for modelling the variation in flow resistance.

The hydraulic roughness is one of the principal calibration parameters within the hydraulic model and has a major influence on flow routing and flood levels. The roughness values adopted from the calibration process is discussed in Section 6.

5.2.4 Structures

There are numerous bridge and culvert crossings over the main channel alignments within the model extents as detailed in Table 5-2 (refer to Figure 5-2 for locations). These structures vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these major hydraulic structures in the models provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

Table 5-2 Major Hydraulic Structures within Model Area

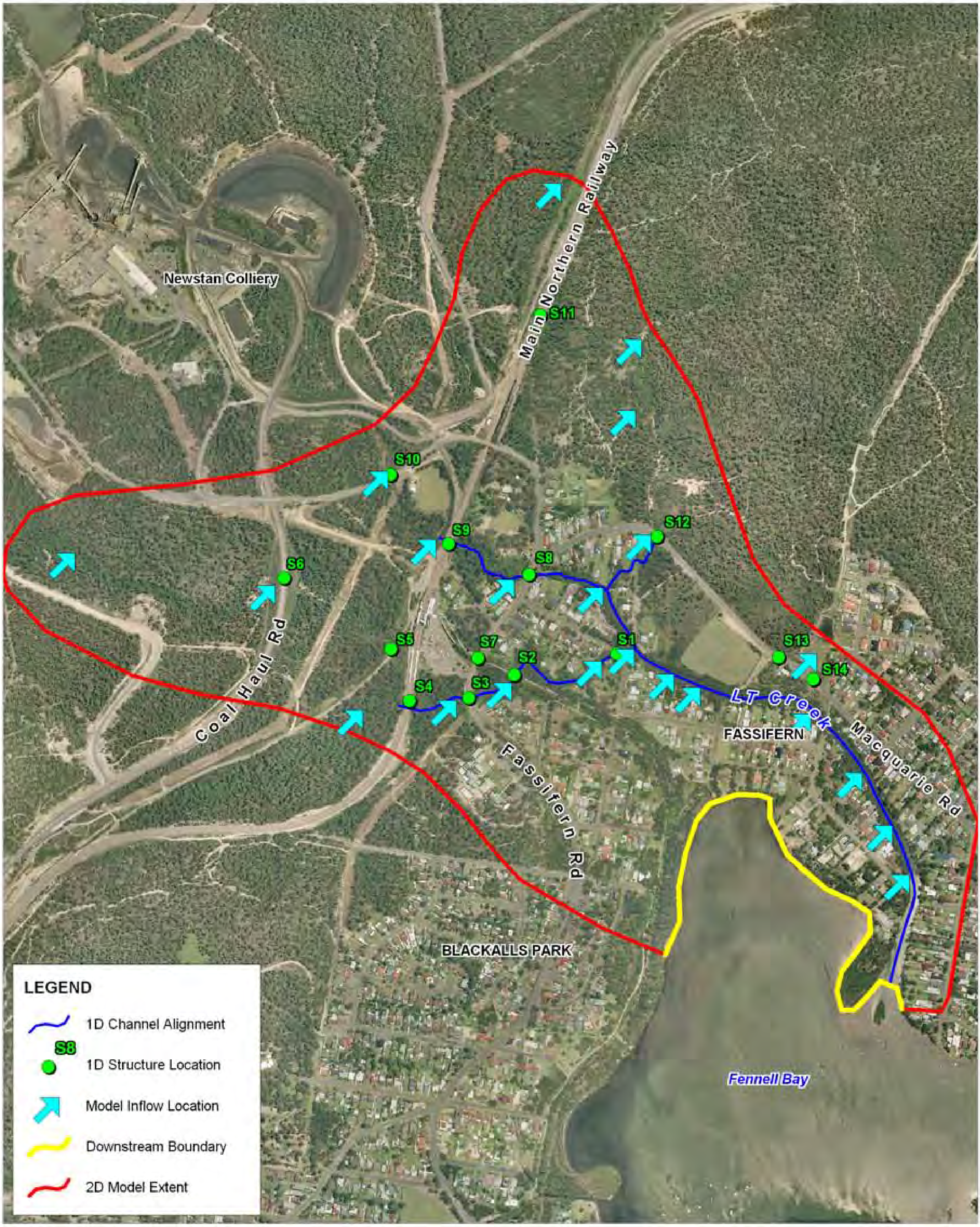
ID	Location	Structure
S1	Bridge Street bridge	Clear span bridge (approx. 13.6m clear width)
S2	Disused Railway box culvert	Box culvert 4.2m wide x 5.5m high
S3	Fassifern Road box culvert	Box culvert 4 cell 2.1m x 1.8m
S4	Main North Railway culvert	Box culvert 3.0m x 3.0m
S5	Private Access Road	Pipe culvert 1 x 1200mm diameter
S6	Coal Haul Road pipe culvert	Pipe culvert 4 x 1200mm diameter
S7	Fassifern Road Viaduct	Clear span bridge (approx. 5.8m clear width)
S8	Fassifern Road culvert	Box culvert 2 cell 2.4m x 1.2m
S9	Main North Railway culvert	Box culvert 3.7m x 3.6m
S10	Fassifern Road culvert	Box culvert 2 cell 2.4m x 1.8m
S11	Main North Railway culvert	Box culvert 2.4m x 2.4m
S12	Macquarie Road culvert	Box culvert 2 cell 2.0m x 1.2m
S13	Macquarie Road culvert	Box culvert 0.9m x 0.6m
S14	Macquarie Road culvert	Pipe culvert 1 x 525mm diameter
S15	Macquarie Road culvert	Pipe culvert 1 x 1050mm diameter

5.2.5 Boundary Conditions

The model boundary conditions are derived as follows:

- Inflows - the rainfall runoff calculated by the hydrologic model at major sub-catchment inflow points and along the modelled watercourse alignments of the LT Creek channel and significant tributaries. (refer Figure 5-2 for inflow locations); and
- Fixed Downstream Water Level– the downstream model limit corresponds to the discharge of LT Creek to Fennell Bay. Flood water levels in Fennell Bay are largely controlled by the flooding condition in the broader Lake Macquarie waterway. Accordingly the adopted downstream boundary conditions for both calibration and design events are representative of the Lake Macquarie flooding condition.

The adopted water levels for the downstream boundary condition (i.e. Lake Macquarie flood level) for the calibration and design events are discussed in Section 6 and Section 7 respectively.



Title:

Linked 1D/2D Model Layout

Figure: 5-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

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6 MODEL CALIBRATION AND SENSITIVITY TESTING

6.1 Selection of Calibration Events

The selection of suitable historical events for calibration of the computer models is largely dependent on available historical flood information. Ideally the calibration and validation process should cover a range of flood magnitudes to demonstrate the suitability of a model for the range of design event magnitudes to be considered.

Significant flooding in the LT Creek has occurred on numerous occasions, with the most severe events in recent times including 1949, 1981, 1990 and 2007. Of these events, the February 1981 and June 1949 events provide for the highest recorded flood levels in Fassifern. However, the nature of these events was quite different. The 1981 event was largely driven by high LT Creek catchment rainfall and subsequent mainstream flooding, whereas the 1949 event was dominated by the foreshore flooding associated with elevated Lake Macquarie water levels.

The February 1981 event is considered the most suitable of the historical events for model calibration. The principal objective of the flood study is the determination of design flood conditions predominantly driven by mainstream flooding of LT Creek, similar to what occurred in 1981. The availability of rainfall data and peak flood levels provides a sound dataset to enable calibration of the models.

Whilst the 1949 event provided for the next highest series of flood levels in Fassifern, it is not considered a suitable calibration event given limitations in available rainfall data for the event and the dominance of the Lake Macquarie water levels on the peak flood conditions in Fassifern.

Recorded rainfall is the key data requirement for historical flood simulation utilising rainfall-runoff modelling. In this regard the June 2007 event is considered a suitable calibration event given the availability of a recorded rainfall hyetograph within the LT Creek catchment (Newstan Colliery gauge). It is noted that June 2007 peak flood levels in Fassifern were again dominated by the Lake flooding condition, nevertheless, the catchment rainfall was significant totalling some 300mm in 24 hours including 250mm in a 12 hour period.

The model calibration and validation therefore is based on the historical data available for the February 1981 and June 2007 events. The available data, modelling approach and model results for each of these events are discussed in further detail in the following sections.

6.2 February 1981 Model Calibration

6.2.1 Rainfall Data

The distribution of rainfall gauge locations in the vicinity of the LT Creek catchment was shown in Figure 2-3 with their respective periods of record shown in Table 2-4. For the February 1981 event there is no pluviograph data for the catchment, with daily rainfall totals only available at Toronto and Bolton Point.

A report on the flood event was produced for the Stony Creek catchment by Sinclair Knight & Partners (1981). This included detailed analysis of available rainfall data including the Weatherex

Meteorological Report (1981) considering the distribution of the event rainfall across the wider Central Coast and Lake Macquarie regions. Estimated ishohyetal charts for the event covering nominal 6 hour and 24 hour periods were produced in the study, and included in Appendix E for reference. These isohyetal charts, coupled with temporal pattern data from Eraring Power Station form the basis of the event rainfall adopted in a number of previous flood studies in the western Lake Macquarie region, including Dora Creek (PWD, 1986) and Stony Creek (Cardno Lawson Treloar, 2005).

The adopted February 1981 event hyetograph for the LT Creek catchment is shown in Figure 6-1. The temporal pattern corresponds to the Eraring Power Station data as presented in Sinclair Knight & Partners (1981). In the absence of recorded data, no spatial or temporal variation in the adopted hyetograph was considered for the LT Creek catchment.

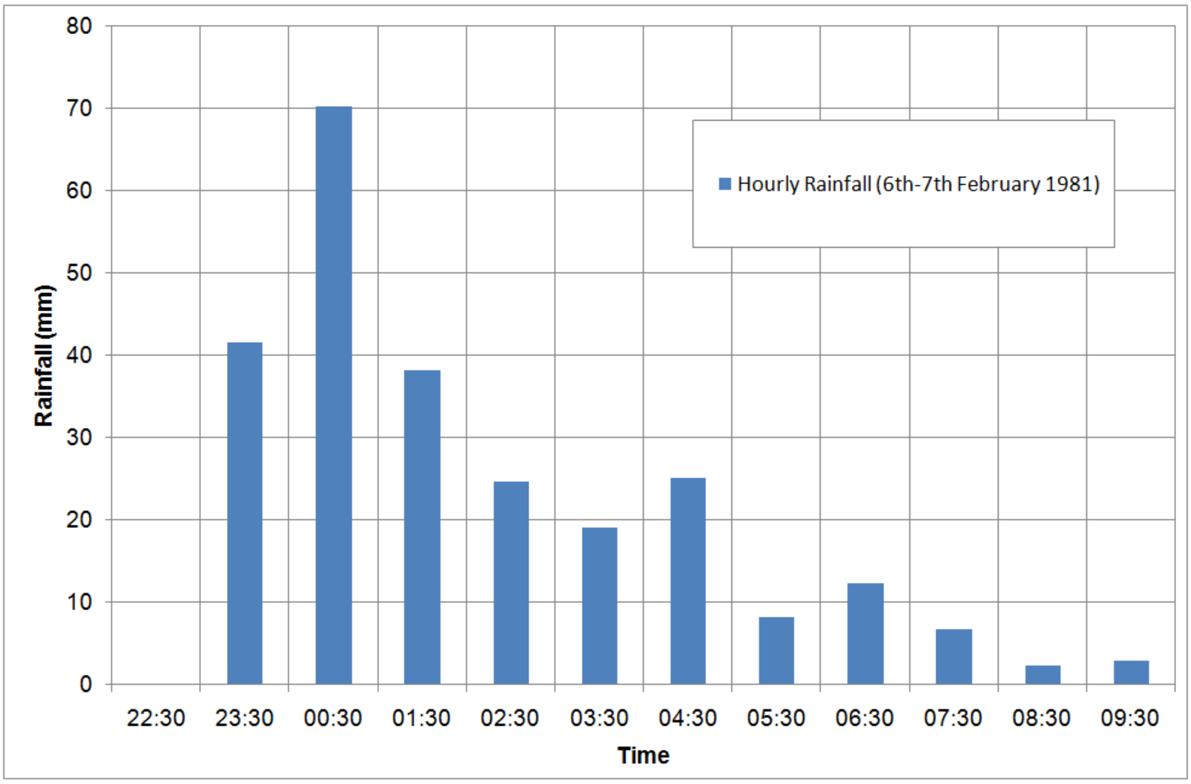


Figure 6-1 Adopted Rainfall Hyetograph for February 1981 Calibration Event

To gain an appreciation of the relative intensity of the February 1981 event, the adopted rainfall depths for various storm durations is compared with the design IFD data for the LT Creek catchment as shown in Figure 6-2.

The depth vs. duration profile for the February 1981 event shows it generally tracking well above the design 1% AEP (100-year ARI) rainfall. The adopted depths for the 6 hour and 12 hour periods are approximately 45% and 25% respectively higher rainfall than the 1% AEP design rainfall depth:

- 6-hour duration - 218mm recorded compared with 152mm design 1% AEP; and
- 12-hour duration - 250mm recorded compared with 204mm design 1% AEP.

Accordingly the February 1981 event is considered an extraordinary event with an estimated magnitude in excess of the 0.5% AEP (200yr-ARI) design event in comparison to the design IFD rainfall.

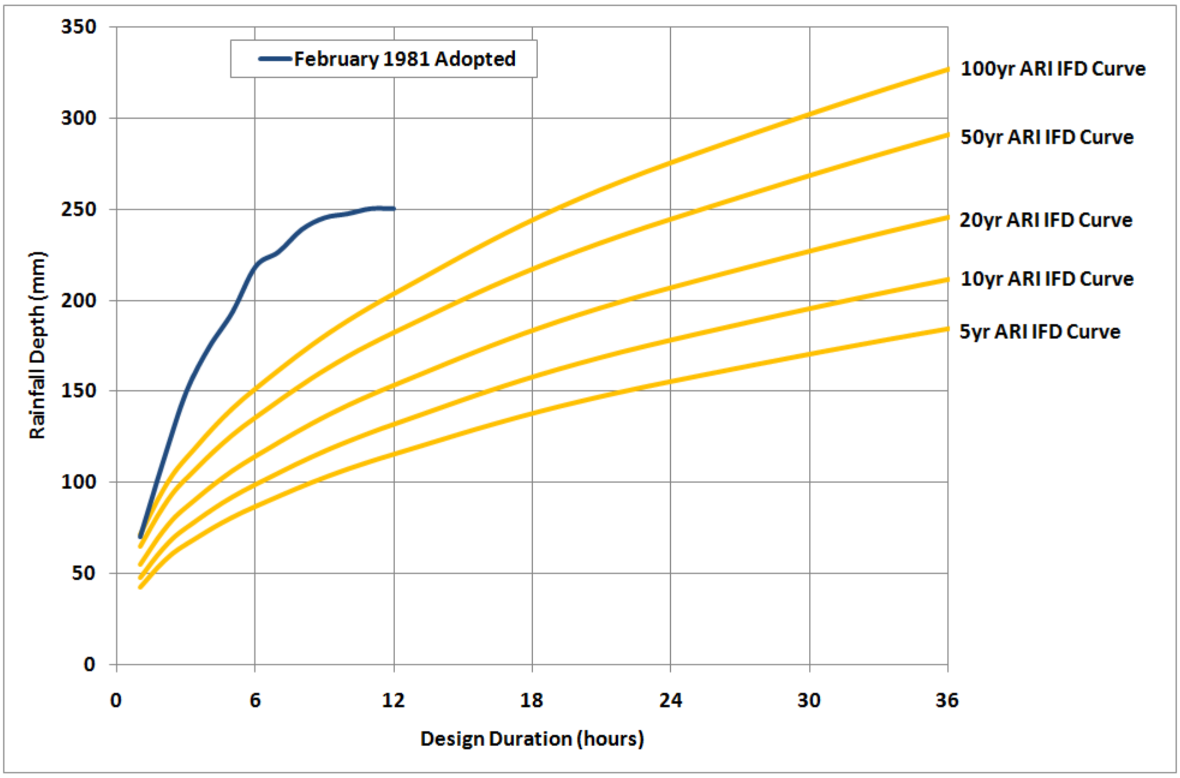


Figure 6-2 Comparison of Adopted February 1981 Rainfall with IFD Relationships

6.2.2 Antecedent Conditions

The antecedent catchment condition reflecting the degree of wetness of the catchment prior to a major rainfall event directly influences the magnitude and rate of runoff. The initial loss-continuing loss model has been adopted in the RAFTS-XP hydrological model developed for the LT Creek catchment. The initial loss component represents a depth of rainfall effectively lost from the system and not contributing to runoff and simulates the wetting up of the catchment to a saturated condition. The continuing loss represents the rainfall lost through soil infiltration once the catchment is saturated and is applied as a constant rate (mm/hr) for the duration of the runoff event.

Typical design loss rates applicable for NSW catchments east of the western slopes are initial loss of 10 to 35 mm and continuing loss of 2.5mm/hr (AR&R, 2001). For historical events however, the initial loss is indicative of the catchment wetness and prior rainfall to the modelled storm burst.

Figure 6-3 shows the monthly rainfall recorded at Toronto WWTW (assumed representative of LT Creek catchment) prior to the February 1981 event. Generally the months preceding the flood event were characterised by below average rainfall.

The main rainfall burst that occurred over the catchment between approximately 11pm February 6th and 9am February 7th 1981 was preceded by approximately 40mm of rainfall across the catchment in the 24 hours prior. In considering the catchment wetness condition at the start of the June 2007 event, an initial loss value of 20mm was adopted. This is similar to that adopted for design event conditions discussed in Section 7. It is noted that the adopted initial loss is slightly lower than values adopted in other catchment studies (Jigadee Creek 60mm (LMFS) , Stony Creek 50mm), however, there is significantly more uncertainty in total storm rainfall depths (>300mm) and temporal patterns over the catchment.

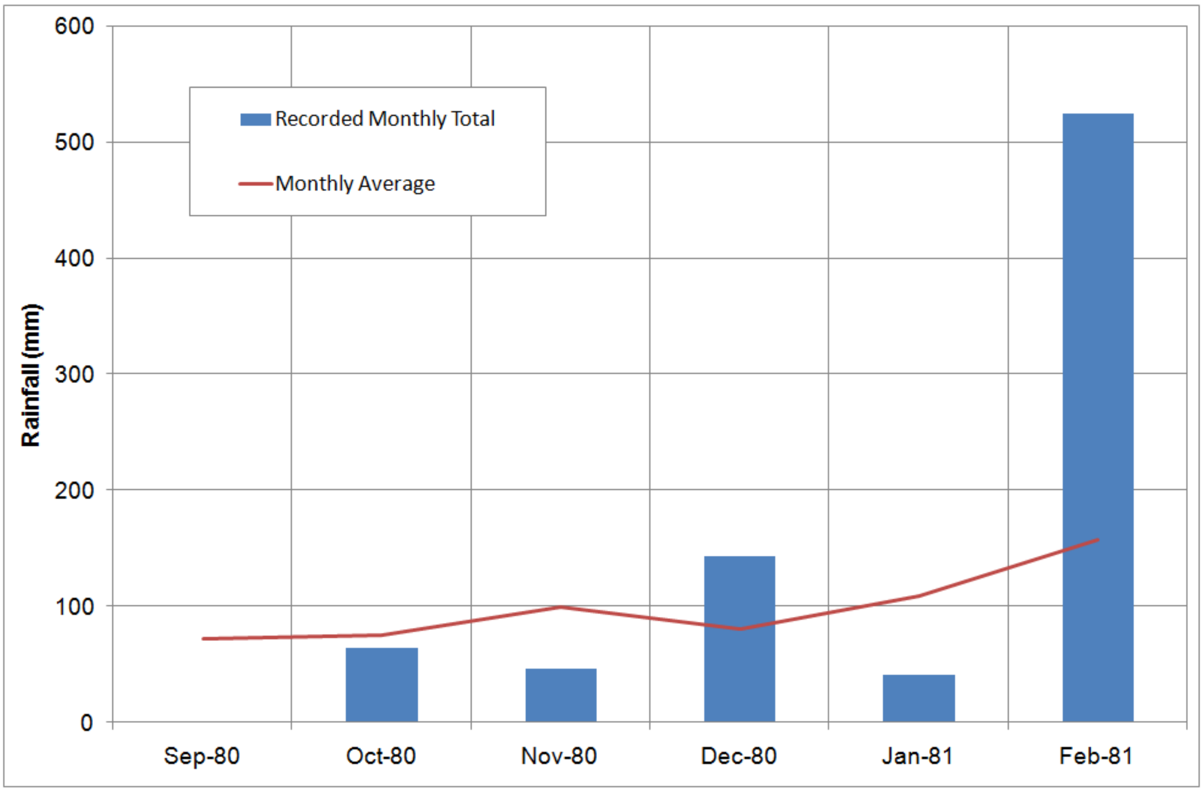


Figure 6-3 Monthly Rainfall Preceding February 1981 Event

6.2.3 Downstream Boundary Condition

The peak Lake Macquarie flood level for the February 1981 event was approximately 0.8m AHD. With reference to the design peak flood levels for the Lake as discussed in Section 2.2.1, this represents approximately a 10% AEP (or 1 in 10-year) event. In the absence of detailed information in regard to the timing of the peak flooding in LT Creek, particularly in relation to the rising Lake condition, the peak Lake flood level was adopted as a constant water level boundary for the simulation of the LT Creek flooding for the 1981 event.

It is unlikely that the peak (riverine) flood level coincided with the peak Lake level. However, in the absence of a recorded time series of water level in the Lake for the event, is considered the most appropriate assumption. Given that the peak Lake level is only 0.8m AHD, and peak flood levels in Fassifern are generally of the order 2.0m AHD for the event, the adopted Lake water level condition will have minimal influence on simulated flood behaviour.

6.2.4 Adopted Model Parameters

The model calibration centred around the adjustment of the rainfall losses, the sub-catchment PERN values and Bx storage routing factor (hydrological model parameters) and the Manning's 'n' values for the floodplain and channel (hydraulic model parameter). The final values adopted, as shown Table 6-1, were found to give a good result in representing observed peak flood levels in Fassifern. A plan showing adopted Manning's 'n' values across the modelled area is shown in Figure 6-4.

Table 6-1 February 1981 Model Calibration Parameters

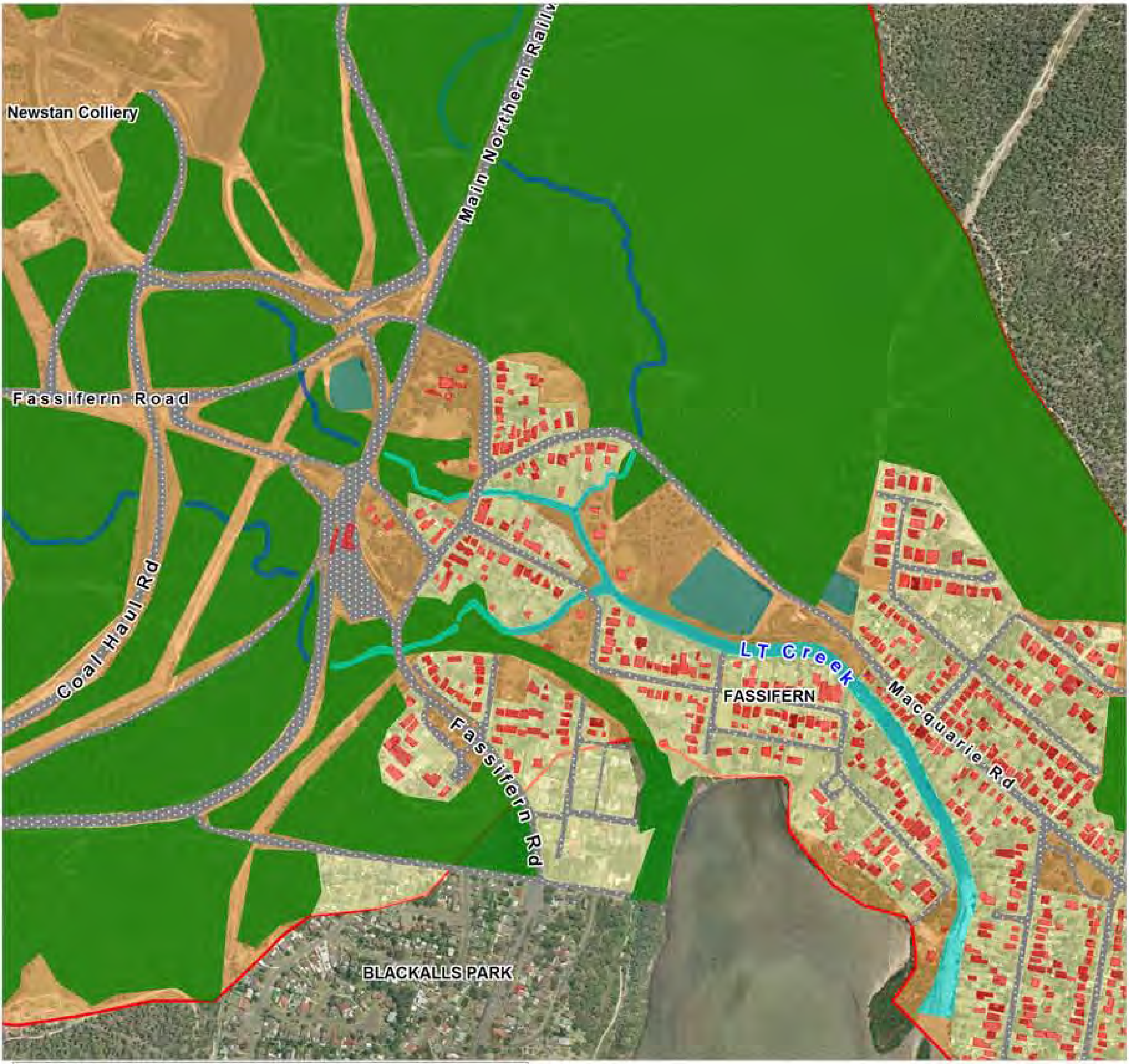
Parameter	Value	Comment
Initial Loss (mm): pervious area impervious area	 20 2	Approximately 40mm of rainfall fell over the catchment in the 24 hours preceding the main storm burst. Most of this will be removed as the initial loss for the modelled storm before the continuing loss is applied for the remainder of the storm duration.
Continuing Loss (mm/hr): pervious area impervious area	 2.5 0	Similar to adopted design continuing loss rate as recommended in AR&R (2001).
PERN: Forested Cleared Urban (pervious) Urban (impervious)	 0.1 0.06 0.04 0.02	The PERN factors are used to adjust the catchment routing factor to allow for catchment roughness. Catchment average values were estimated based on representative land use/ground coverage.
Bx (storage routing parameter)	1.5	Adopted value to calibrate catchment response in terms of relative timing.
Manning's n (channel)	0.025 – 0.08	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects degree of channel vegetation, channel size and sinuosity.
Manning's n (floodplain)	0.035 – 0.10	Variable adjusted locally (within reasonable bounds) to provide best fit for peak water level profiles. Variability largely reflects land use on the floodplain (cleared, forested, roads, urban lots)

6.2.5 Observed and Simulated Peak Flood Levels

Council's existing flood record database provides a series of flood levels for the 1981 event at individual properties in Fassifern. The available levels correspond to the properties in which the 1981 event resulted in the highest recorded flood level at the property. A comparison of simulated and observed peak flood levels in Fassifern for the February 1981 event are tabulated in Table 6-2 and shown in Figure 6-5 with the simulated inundation extent.

The results indicate a relatively good agreement between observed and simulated peak flood heights with some 80% of the locations having a simulated water level within +/- 0.3m of the observed value, and 100% within +/-0.4m.

The simulated inundation extent shown in Figure 6-5, in particular the extent of out of bank flooding in the western part of Fassifern, generally corresponds to the properties identified in Council's flood level database as having significant flood inundation for the 1981 event.



LEGEND

Building n=0.20	Light vegetation n=0.06
Urban Lot n=0.05	Heavy Vegetation n=0.10
Roads n=0.02	Channel n=0.025 to 0.05
Playing Field n=0.04	Channel n=0.08

Title:

Adopted Manning's 'n' Roughness Distribution

Figure: **6-4**

Rev: **A**

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Approx. Scale

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Table 6-2 Comparison of Observed and Simulated Peak Flood Levels February 1981

Location	Observed	Simulated	Difference
28A Fassifern Road Fassifern	4.23	4.1	-0.1
5 Fassifern Road Fassifern	3.26	3.4	0.2
106 Macquarie Road Fassifern	2.76	2.4	-0.4
7 Bridge Street Fassifern	2.64	2.3	-0.4
11 Bridge Street Fassifern	2.64	2.5	-0.1
6 Bridge Street Fassifern	2.50	2.2	-0.3
12 Bridge Street Fassifern	2.50	2.2	-0.3
2A Bridge Street Fassifern	2.28	2.2	-0.1
2 Bridge Street Fassifern	2.27	2.2	-0.1
9 Bridge Street Fassifern	2.26	2.4	0.2
4 Bridge Street Fassifern	2.26	2.2	-0.1
9 Bridge Street Fassifern	2.26	2.4	0.2
8 Bridge Street Fassifern	2.26	2.2	-0.1
10 Bridge Street Fassifern	2.26	2.2	-0.1
26 Wangi Road Fassifern	2.00	2.0	0.0
6 Wangi Road Fassifern	2.00	2.0	0.0
30 Wangi Road Fassifern	2.00	2.0	0.0
6A Wangi Road Fassifern	1.99	2.0	0.1
28 Wangi Road Fassifern	1.99	2.0	0.0
39 Awaba Street Fassifern	1.99	2.0	0.0
35 Awaba Street Fassifern	1.82	1.9	0.1
33 Awaba Street Fassifern	1.70	1.9	0.2
31 Awaba Street Fassifern	1.60	1.9	0.3
27 Awaba Street Fassifern	1.56	1.9	0.3
29 Awaba Street Fassifern	1.56	1.9	0.4
25 Awaba Street Fassifern	1.48	1.9	0.4
23 Awaba Street Fassifern	1.48	1.9	0.4
17 Awaba Street Fassifern	1.48	1.8	0.3
2 Lake Street Fassifern	1.48	1.9	0.4
3 Brougham Ave. Fennell Bay	0.94	1.2	0.2

Long section profiles of the simulated water levels along the main reaches of LT Creek from the outlet at Fennell Bay to upstream of the Main North railway are shown in Figure 6-6 and Figure 6-7 for the north arm and south arm of LT Creek respectively. The recorded peak flood levels from Council's database are shown for comparison. The profile again demonstrates the level of calibration achieved.

The water level profiles indicate that the LT Creek catchment rainfall and subsequent mainstream flooding was the dominant flooding mechanism for the February 1981 event. The downstream fixed water level boundary adopted in the model simulation of 0.8m AHD corresponds to the observed peak Lake Macquarie flood level for this event. No significant backwater influence is simulated for this downstream boundary condition.

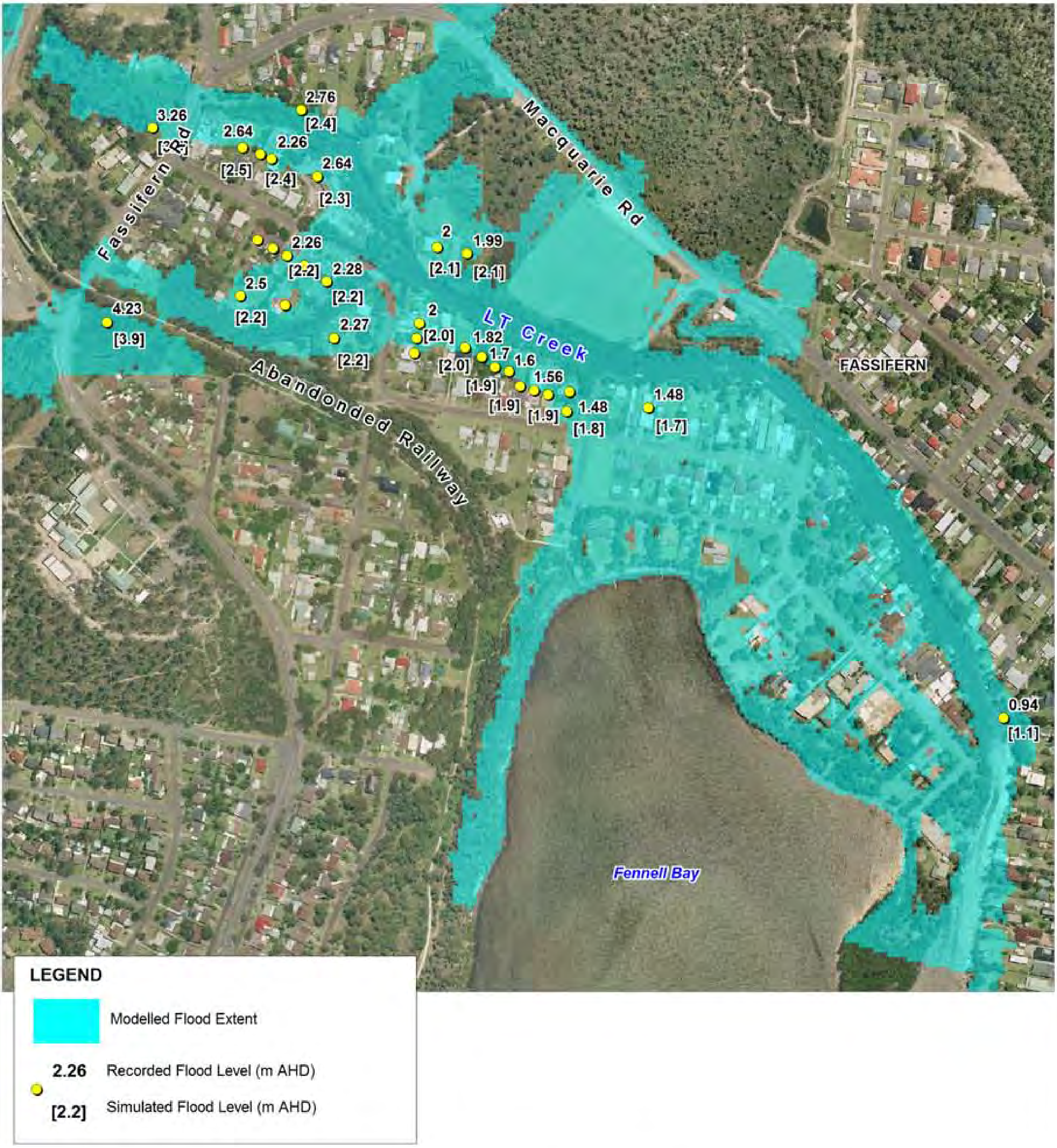
The recorded peak flood level points show a distinct change in water level profile between Lake Street and the confluence. In this vicinity, a change in peak flood level of some 0.5m occurs over a relatively short distance of 100 metres as represented by the recorded peak levels. A corresponding change in peak levels however has not been simulated. There does not appear to be any major hydraulic controls in this location that would provide for such a rapid head loss. The active floodplain width is constrained on the right bank by the natural high ground that extends between Wangi Road and Lake Street. There is a general broadening of the floodplain around Lake Street, however, these changes in natural topography are relatively gradual, and accordingly it is expected that flood water profiles would exhibit a similar “gentle” gradient.

It is noted that some local filling on the right bank floodplain associated with house construction may have occurred subsequent to 1981. A general raising of floodplain levels will provide for a local increase in peak flood levels given the reduction in floodplain conveyance capacity. However, it is estimated that a much more significant floodplain constriction or even main channel constriction would be required to simulate the relatively steep water level profile as indicated by Council’s peak flood level database.

In reviewing the topographical information, the main hydraulic control in this vicinity is at the confluence of the north and south arms of LT Creek. The simulated peak flood level of approximately 2.0m AHD matches the historical record in Council’s flood level database.

Fassifern Road provided for a significant control of peak flood water levels on the north arm of LT Creek as indicated in the peak water level profiles for the 1981 event. At this location the culvert structure capacity is exceeded with flood waters building up behind the embankment and eventually overtopping the road. Accordingly, there is a large water level difference simulated across Fassifern Road, which is also reflected in the historical flood records.

On the south arm however, the Fassifern Road culvert is effectively drowned out by the backwater influence form the abandoned railway culvert approximately 100m downstream. The railway embankment provides for a complete obstruction to flow on the floodplain (crest level approx. 6m AHD), thereby reducing the total flood conveyance to the culvert structure only. Subsequently, there is a significant backwater influence with simulated flood levels of around 4.0m AHD at Fassifern Road. As indicated in Figure 6-5, there is a flow connection the through the viaduct (abandoned railway) on Fassifern Road. The backwater influence from the abandoned railway is eventually relieved by overtopping of Fassifern Road and flow through the viaduct to the north. This flow through the viaduct eventually rejoins the south arm of LT Creek downstream of the abandoned railway.



Title:	Figure:	Rev:
February 1981 Simulated Peak Inundation Extent in Fassifern	**6-5**	**A**

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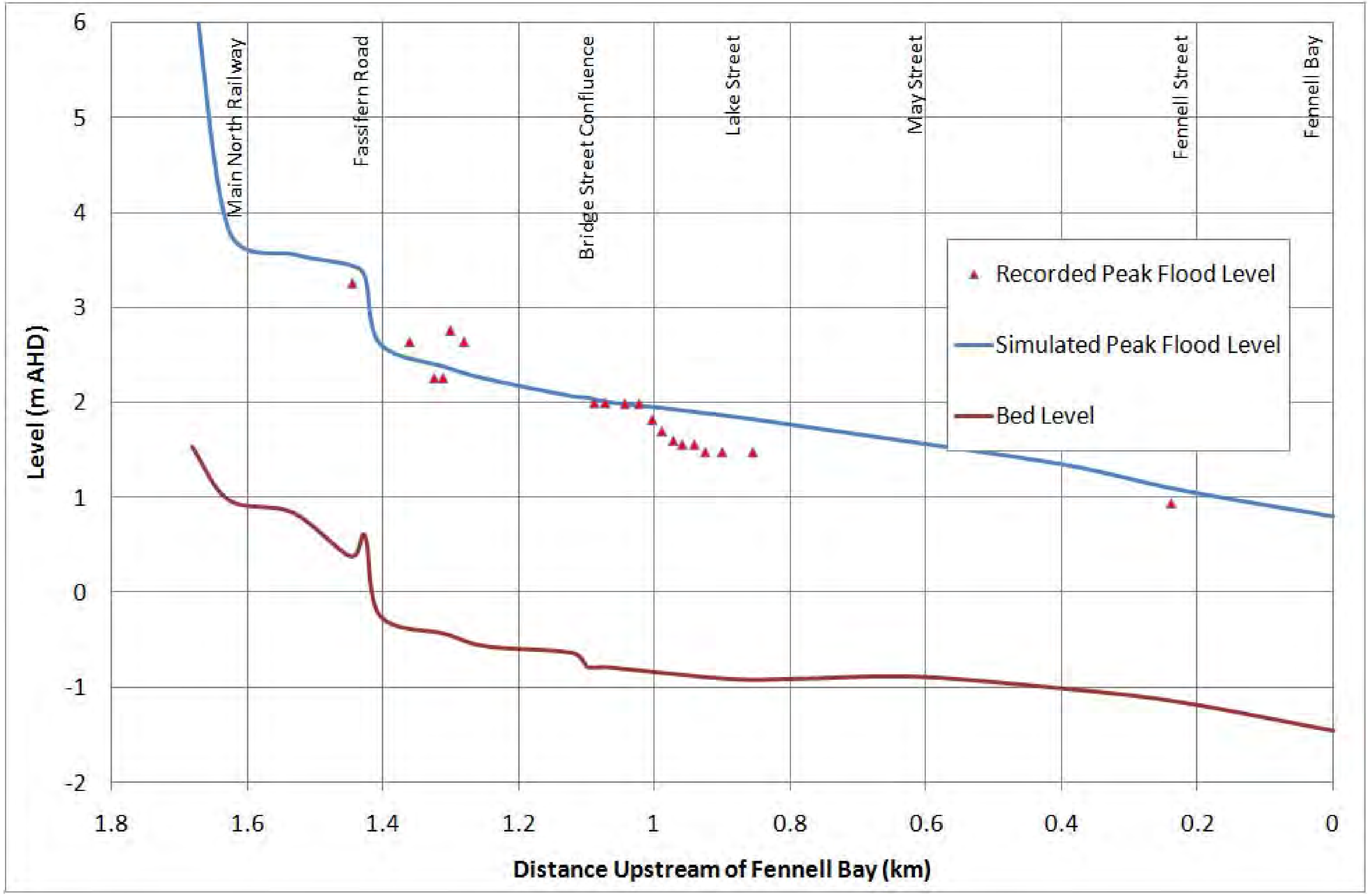


Figure 6-6 February 1981 Peak Water Level Calibration (North Arm)

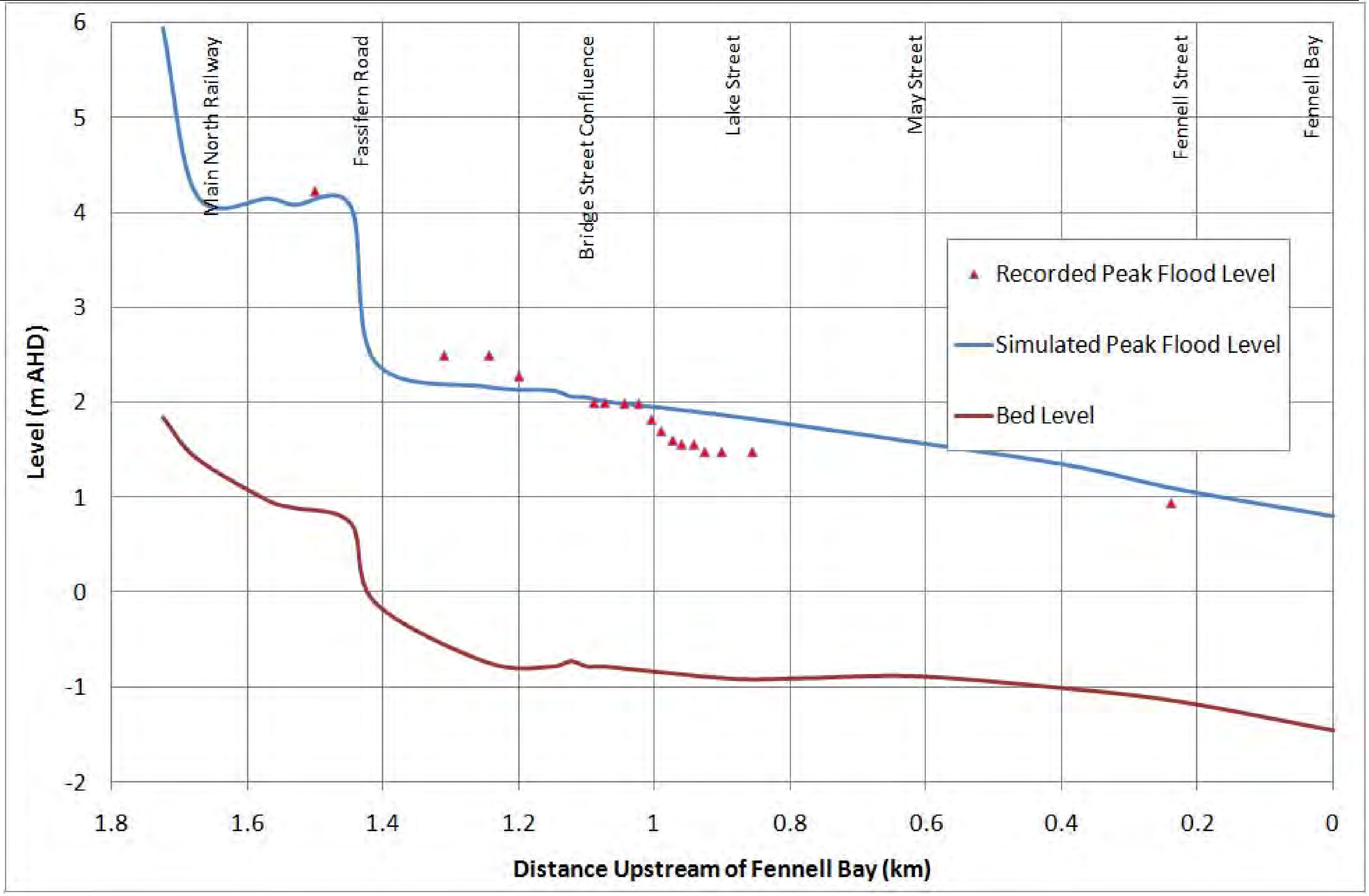


Figure 6-7 February 1981 Peak Water Level Calibration (South Arm)

6.2.6 Simulated Hydrographs

Whilst there is no recorded streamflow data in order to calibrate the simulated hydrographs, comparison of the peak flows from the simulated historical and design events provide an indication as to the relative magnitude of each event.

Figure 6-8 shows simulated hydrographs for the February 1981 calibration event at three key locations in the LT Creek catchment being, just upstream of the confluence on both the south and north arms of LT Creek, and the combined flow downstream of the confluence. The two hydrographs upstream of the confluence enable comparison of the relative flow contribution from the main south and north arms of the LT Creek catchment.

The north catchment provides for a greater contribution to the combined peak at the confluence, both in terms of peak flow and flow volume. This is reflective of the greater catchment area of the north arm, approximately 30% greater than the south arm. The timing of the peak flows in both catchments is similar given similar mainstream flow lengths, however, the south arm shows some attenuation of the flow associated with the embankment and culverts at the coal haulage road (structure S6 refer to Table 5-2) and the private access road (structure S5).

This feature of the catchment is significant, such that the peak flows in the two arms of LT Creek occur within an hour of each other. As discussed, in the absence of detailed rainfall data, the same rainfall depth and temporal pattern was applied across the entire LT catchment for the 1981 event. Therefore assuming consistent rainfall conditions across the catchment, it is the nature of the catchment for peak flows in both the north and south catchments to occur relatively simultaneously at the confluence.

Consistent rainfall depth and temporal patterns across the catchments is also generally adopted for the design event simulation. Given the major contribution of the north arm catchment, the simulated critical design flood conditions for the developed parts of Fassifern generally coincide with the peak flows emanating from this catchment.

The peak flow at the discharge point to Fennell Bay at the downstream model boundary is also shown in Figure 6-8. The hydrograph at the outlet approximates the summation of the two contributing north and south hydrographs at the confluence, given minor variances for local inflows downstream of the confluence, attenuation for routing in the short reach from the confluence to the outlet, and minor overland flows (out-of-bank) discharging directly to the Fennell Bay foreshore.

The rainfall hyetograph adopted for the 1981 event was shown in Figure 6-1. The majority of the rainfall fell within a couple of hours of the onset of major rainfall, including over 110mm in the first hour. Given this high intensity rainfall, coupled with a relatively small catchment with steep responsive upper reaches, the simulated hydrographs show very little available warning time for residents in Fassifern. The rapidly rising hydrographs peak within 2 to 3 hours for the simulation. Given that this event occurred during the middle of the night, this represents a significant flood risk to residents in the lower part of the floodplain. This potential for minimal flood warning to affected residents should be considered in future floodplain management studies.

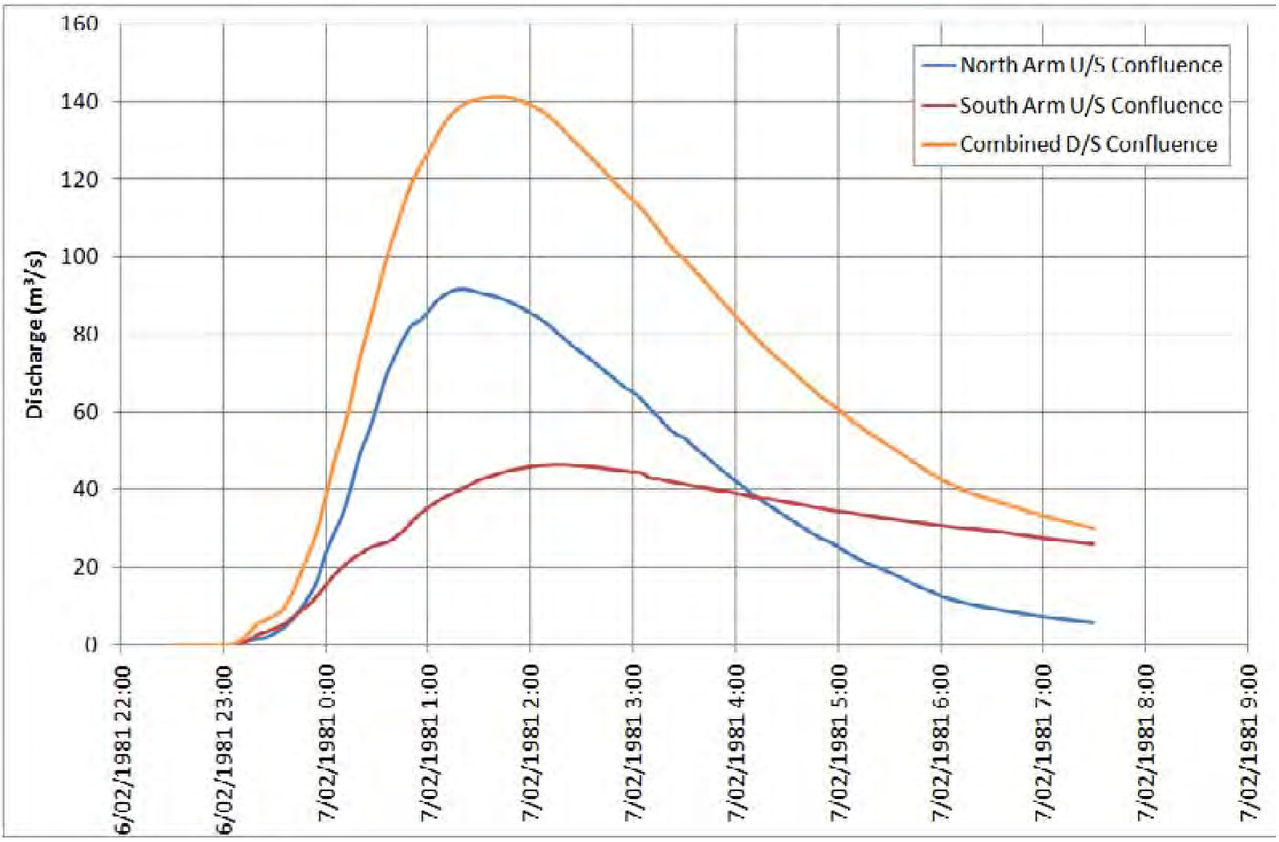


Figure 6-8 Simulated Hydrographs February 1981 Event

6.3 June 2007 Model Validation

The objective of the model validation was to test the appropriateness of the adopted calibration parameters for a different historical event. Based on available data, the June 2007 flood event was selected for this purpose. As previously discussed, the June 2007 flooding of the Fassifern area was largely dominated by the peak flood condition in the broader Lake Macquarie waterway. Nevertheless, the rainfall recorded of some 300mm 12 hours (refer Section 6.3.1) indicates a major catchment rainfall event also.

Whilst there is little historical data available, it is envisaged that there has been no major changes in the LT Creek waterway in the period between the February 1981 and June 2007 events. Accordingly, the same cross-sectional information acquired for this study and used to build the hydraulic models has been applied for both the 1981 and 2007 events.

Within the lower floodplain of LT Creek, there have been some minor changes to floodplain largely associated with development in Fassifern. Some minor re-development of some urban lots are noted, including developments to the north of Macquarie Road, however, for the greater majority of the lower floodplain there have been no major changes that would substantially influence flood behaviour.

The upper catchment remains largely undeveloped, with the exception of the Newstan Colliery. No doubt there have been changes of the land use within Newstan Colliery associated with ongoing operations. There are numerous minor storage and drainage works within the Colliery associated with the sites water management. Possible changes in local water management over the years however are not expected to have significant impact on flood event magnitudes. On-site storages for water management would typically be assumed to be full and have little attenuating affect on local catchment runoff.

The most significant change in the catchment with potential to impact on flood conditions is the construction of the Southern Reject Emplacement Area – Main Tailings Dam. The dam construction will provide storage for progressive disposal of tailings and coarse reject from the Colliery. The dam is proposed in stages with an initial starter embankment constructed to a finished height of 30m AHD, with a final height of 52.5m AHD.

One of the design criterion of the dam is to provide emergency flood storage for up to the 1 in 100,000-year ARI event (Parsons Brinckerhoff, 2006). Accordingly, the finished dam will have a substantial impact on flood volumes emanating within this sub-catchment.

At the time of the June 2007 event however, the dam was only partially constructed. The effective dam wall height at June 2007 was 22m AHD. Figure 6-9 shows the corresponding dam wall at the June 2007 event, with the Stage 2 completed wall also shown as at May 2008. Through discussions with Centennial Coal, it was confirmed that the structure was overtopped during the June 2007 event.

At a wall height of 22m AHD, as at June 2007, the flood storage provided is relatively minor in comparison to total catchment runoff volumes. Accordingly, only minor attenuation of peak catchment flows would be anticipated for the June 2007 event. As the wall height is progressively increased, however, the additional flood storage volume may have a greater impact on the flood flow contribution from this sub-catchment. This is considered further in the design event analysis presented in Section 7.5

6.3.1 Rainfall Data

The Newstan Colliery rainfall gauge operated by Centennial Coal provides the best data of recorded rainfall for the LT Creek catchment for the June 2007 event. Continuous 10-minute interval rainfall data was provided by Centennial Coal.

Figure 6-10 shows the recorded hourly rainfall total at Newstan Colliery for the period 6pm June 7th and 3am June 9th 2007. The most intense period of rainfall in the LT Creek catchment through the evening of 8th June 2007, including a periods of 100mm in 3 hours, 170mm in 6 hours and 245mm in 12 hours. In total 387mm of rainfall was recorded at the Newstan Colliery in the period 4am June 7th and 09am June 10th 2007

To gain an appreciation of the relative intensity of the June 2007 event, the recorded rainfall depths for various storm durations is compared with the design IFD data for the LT Creek catchment as shown in Figure 6-11.

The recorded depth vs. duration profile for the June 2007 events shows it generally tracking above the design 1% AEP (100-year ARI) rainfall. The recorded depths for the 12 hour and 18 hour periods generally recorded approximately 15-20% higher rainfall than the 1% AEP design rainfall depth:

- 12-hour duration - 245mm recorded compared with 204mm design 1% AEP; and
- 18-hour duration - 281mm recorded compared with 245mm design 1% AEP.

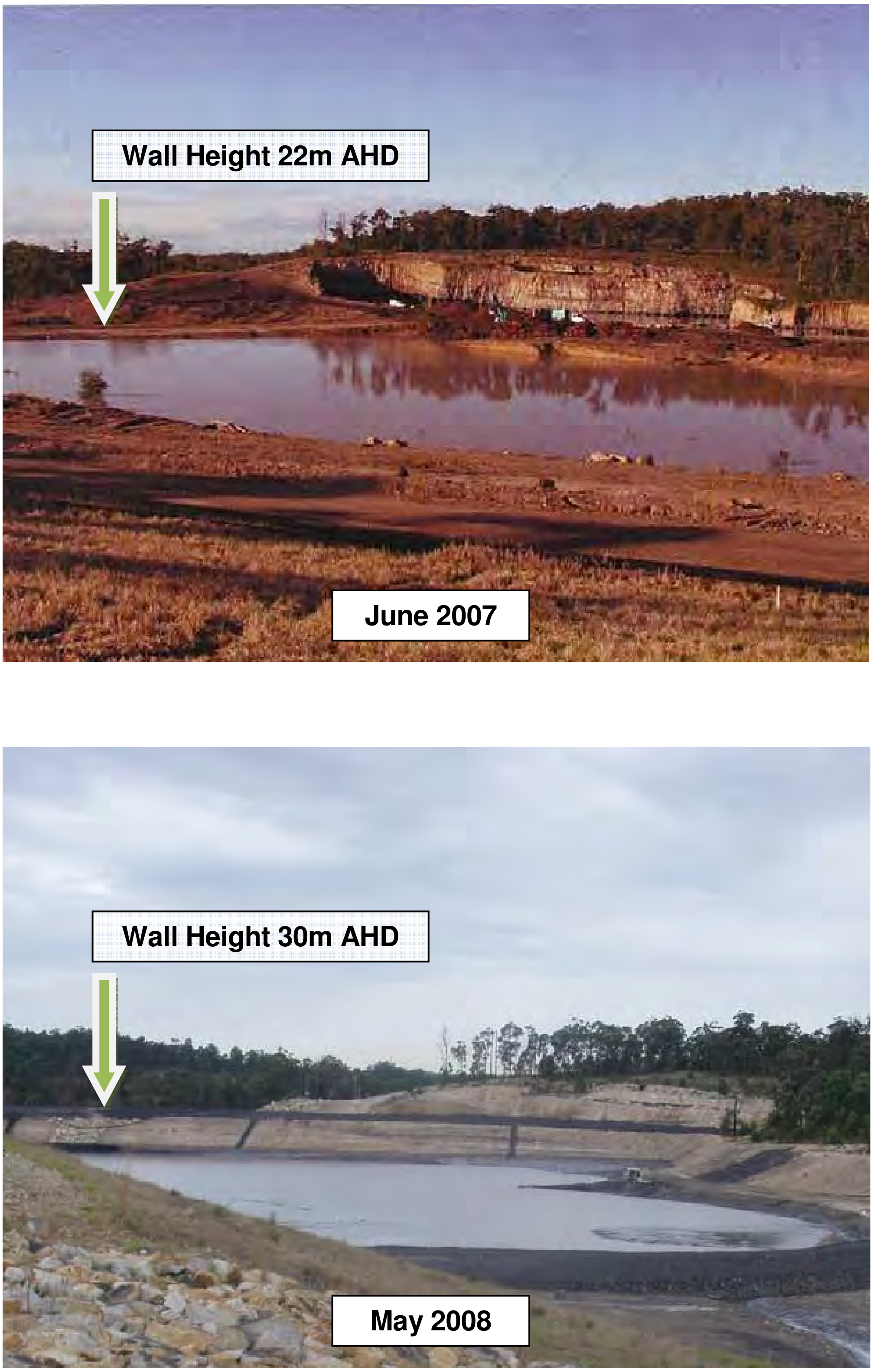


Figure 6-9 Construction Stages of the Newstan Tailings Dam

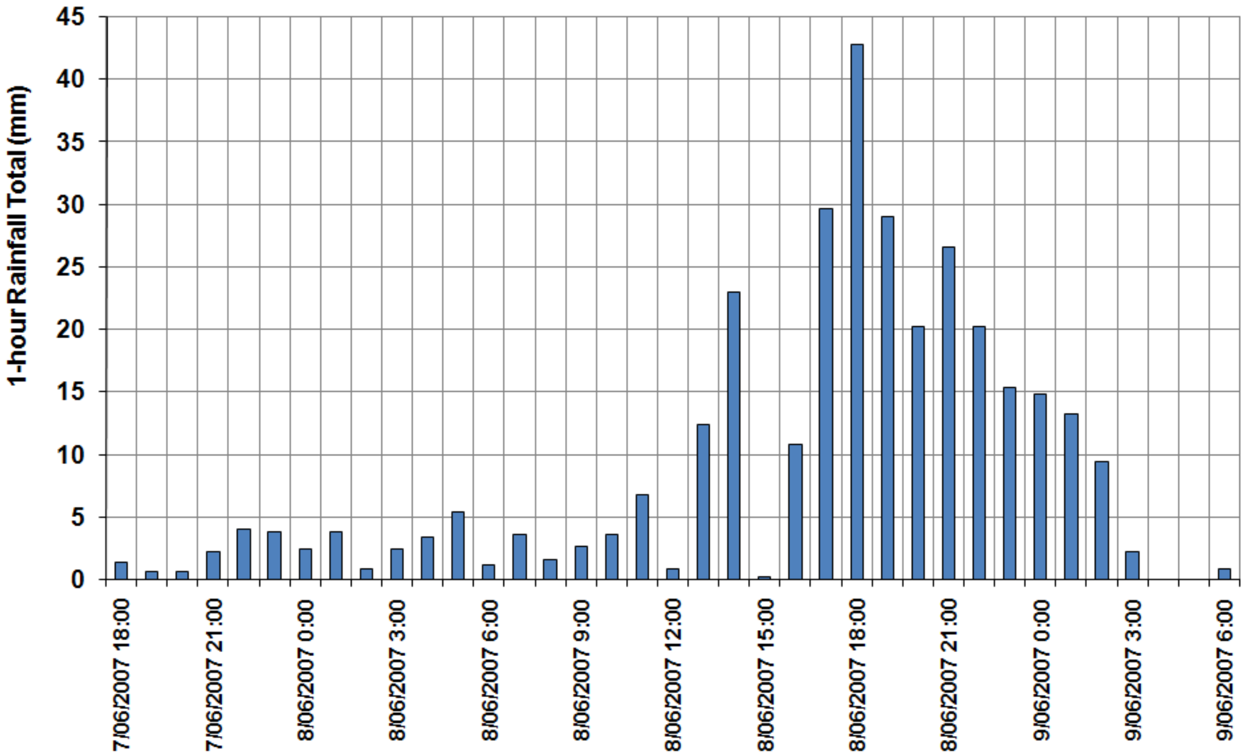


Figure 6-10 Recorded Rainfall at Newstan Colliery for June 2007 Event

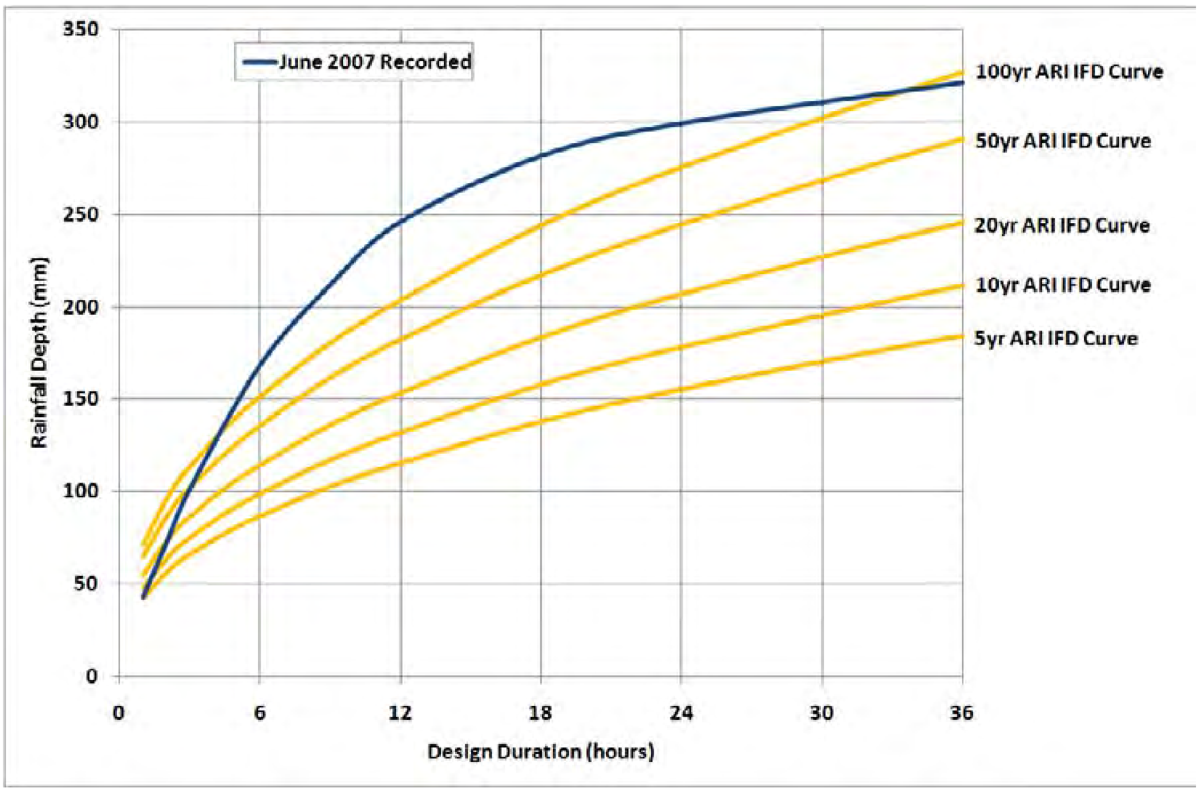


Figure 6-11 Comparison of Recorded June 2007 Rainfall with IFD Relationships

6.3.2 Antecedent Conditions

The antecedent catchment condition reflecting the degree of wetness of the catchment prior to a major rainfall event directly influences the magnitude and rate of runoff.

Figure 6-12 shows the monthly rainfall recorded at Toronto WWTW (assumed representative of LT Creek catchment) prior to the June 2007 event. May 2007 represented slightly below average rainfall, whilst generally the months preceding were characterised by above average rainfall.

As shown in Figure 6-10 the main period of rainfall occurred over the catchment between approximately 1pm June 8th and 3am June 9th 2007. In the 24-hour period prior to this, approximately 60mm of rainfall was recorded at Newstan Colliery. In considering the catchment wetness condition at the start of the June 2007 event, an initial loss value of 20mm was adopted.

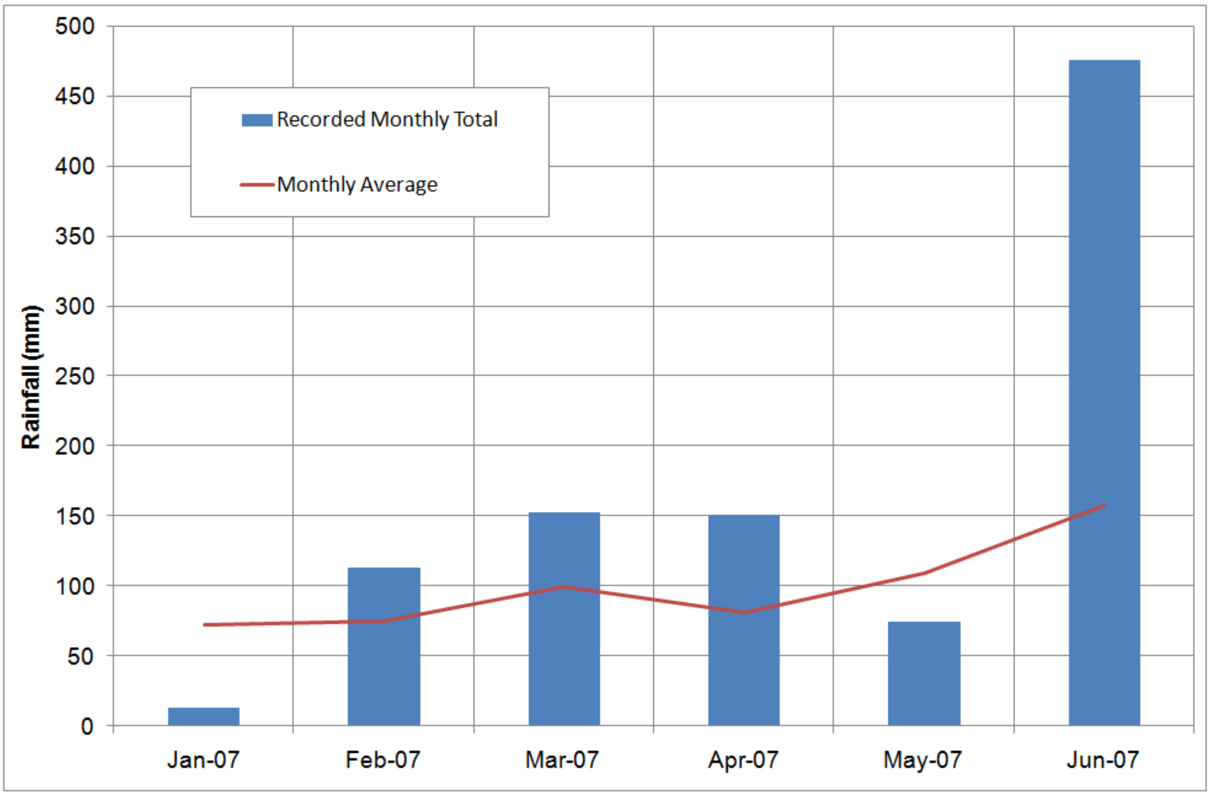
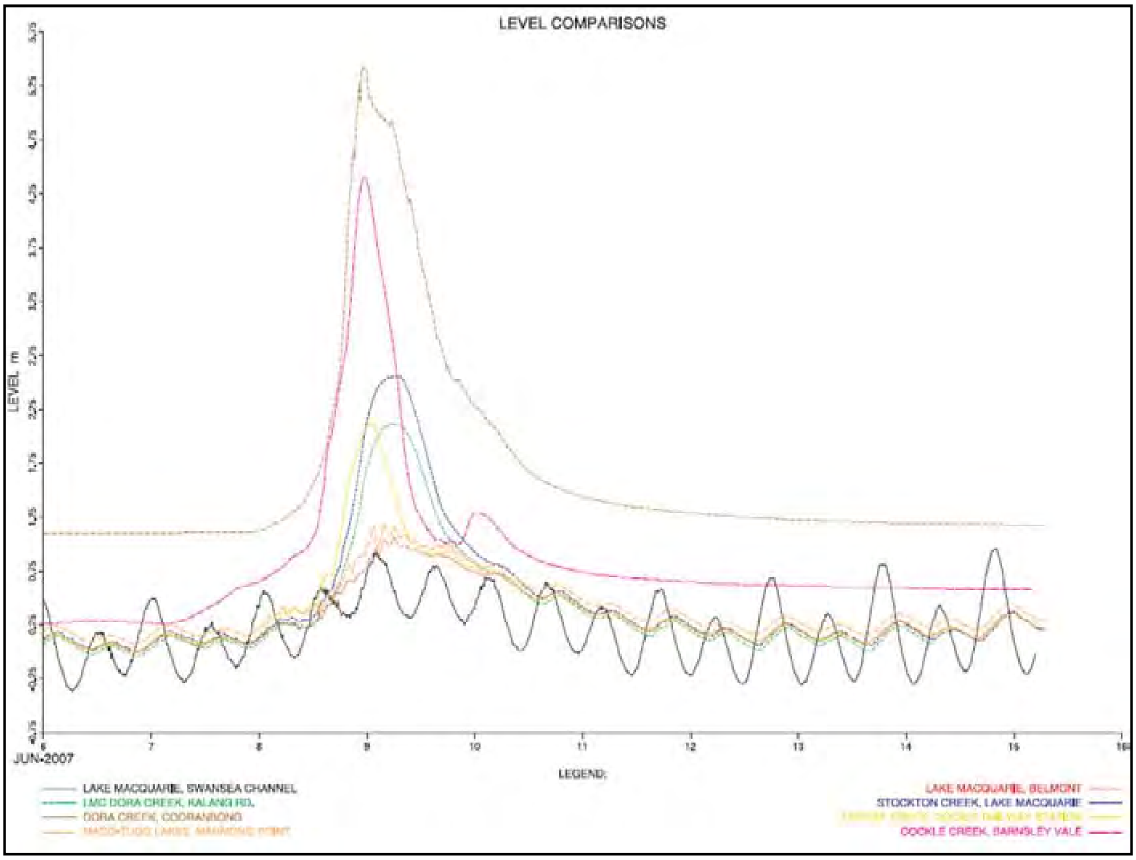


Figure 6-12 Monthly Rainfall Preceding June 2007 Event

6.3.3 Lake Macquarie Water Level

Manly Hydraulics Laboratory (MHL) operates numerous continuous water level recorders in the broader Lake Macquarie system including on some major tributary channels such as Dora Creek and Cockle Creek. The recorded water levels in the system for the June 2007 event are shown in Figure 6-13.

A summary of the recorded peak levels and timing at the gauge locations is shown in Table 6-3.



Source: Manly Hydraulics Laboratory (2007)

Figure 6-13 Lake Macquarie Water Levels June 2007 Event

Table 6-3 Lake Macquarie Peak Levels June 2007 Event

Location	Peak Level (m AHD)	Timing
Swansea Channel	0.93	02:00 09/06/07
Dora Creek (Kalang Rd)	2.12	05:45 09/06/07
Dora Creek (Cooranbong)	5.43	23:15 08/06/07
Marmong Point	1.19	03:45 09/06/07
Belmont	1.06	06:00 09/06/07
Stockton Creek	2.56	06:45 09/06/07
Cockle Creek (Railway Stn)	2.12	01:00 09/06/07
Cockle Creek (Barnsley)	4.41	23:30 08/06/07

The Marmong Point gauge on the western side of Lake Macquarie represents the most appropriate location for defining water levels in Fennell Bay (at the outlet of LT Creek) and the recorded water level hydrograph at this gauge has been adopted for the model boundary conditions. The peak water level at Marmong Point of approximately 1.19m AHD was recorded at 03:45am on 9th June 2007.

A significant observation from the peak flood level data presented in Table 6-3 is the timing of the peak at Dora Creek (Cooranbong) and Cockle Creek (Barnsley). Both of these sites are beyond the influence of the water levels in the broader Lake Macquarie waterway as indicated in the water level hydrographs shown in Figure 6-13. The sites peaked around 23:30pm on the 8th June 2007 and may be indicative of the general timing of the peak fluvial flooding conditions for the western Lake Macquarie tributaries. These “fluvial” peaks occur well before the general Lake level peaks as indicated at Marmong Point and Belmont. The LT Creek catchment is also significantly smaller than Cockle Creek and Dora Creek, such that the peak fluvial flooding condition in LT Creek may be expected to occur earlier than the other catchments.

6.3.4 Observed and Simulated Peak Flood Levels

The community questionnaire distributed to residents in Fassifern as part of the community consultation process targeted peak flood level information for the June 2007 event. A number of respondents provided descriptions and photographs of peak water level marks on their property.

The peak flood level indicated at each property all represent a water level of approximately 1.2m AHD. Significantly, this corresponds to the peak water level in Lake Macquarie. It is apparent therefore that the dominant flooding mechanism for June 2007 at these properties was the elevated Lake Macquarie water levels rather than the local catchment derived flooding of LT Creek.

The dominance of the elevated Lake Macquarie water level for the June 2007 event in determining peak flood heights in the lower part of Fassifern was confirmed by the model results. A comparison of simulated and observed peak flood levels in Fassifern for the June 2007 event is shown in Figure 6-14. The simulated results conform to the observed peak flood heights corresponding to the observed peak level at the Marmong Point gauge (approximately 1.2m AHD).

The simulated inundation extent shown in Figure 6-14 indicates the majority of out-of-bank flooding generally occurs along the riparian corridor of the LT Creek channel alignment. However, towards the lower floodplain of LT Creek, both Bluewater Avenue and Fennell Street are subject to significant floodwater inundation. These two streets are characterised by relatively low road levels, with much of the road corridor generally below the 1.2m AHD peak water level that occurred within Fennell Bay and the broader Lake Macquarie.

Long section profiles of the simulated June 2007 flood water levels along the main reaches of LT Creek from the outlet at Fennell Bay to upstream of the Main North Railway are shown in Figure 6-15 and Figure 6-16. The recorded peak flood levels identified from the community questionnaire are shown for comparison. Both the flood water level profile and observed flood marks again confirm the peak level generally achieved in the lower parts of Fassifern (i.e. downstream of the Bridge Street confluence) was driven by the Lake flooding.

As indicated in Table 6-3, the peak Lake water level at the Marmong Point gauge occurred at approximately 03:45am on 9th June 2007. However, the fluvial peak (i.e. flows emanating from the LT Creek catchment runoff) occurred much earlier and at a lower level than the Lake flooding for the lower parts of Fassifern. The peak flood water level profile considering only the fluvial flooding is also shown on Figure 6-15 and Figure 6-16. Note that upstream of the Bridge Street confluence, the peak flood levels for the event correspond to the fluvial peak.

Title:

June 2007 Simulated Peak Inundation Extent in Fassifern

Figure: 6-14

Rev: A

N

0 100 200m
Approx. Scale

BMT WBM
www.wbmpl.com.au

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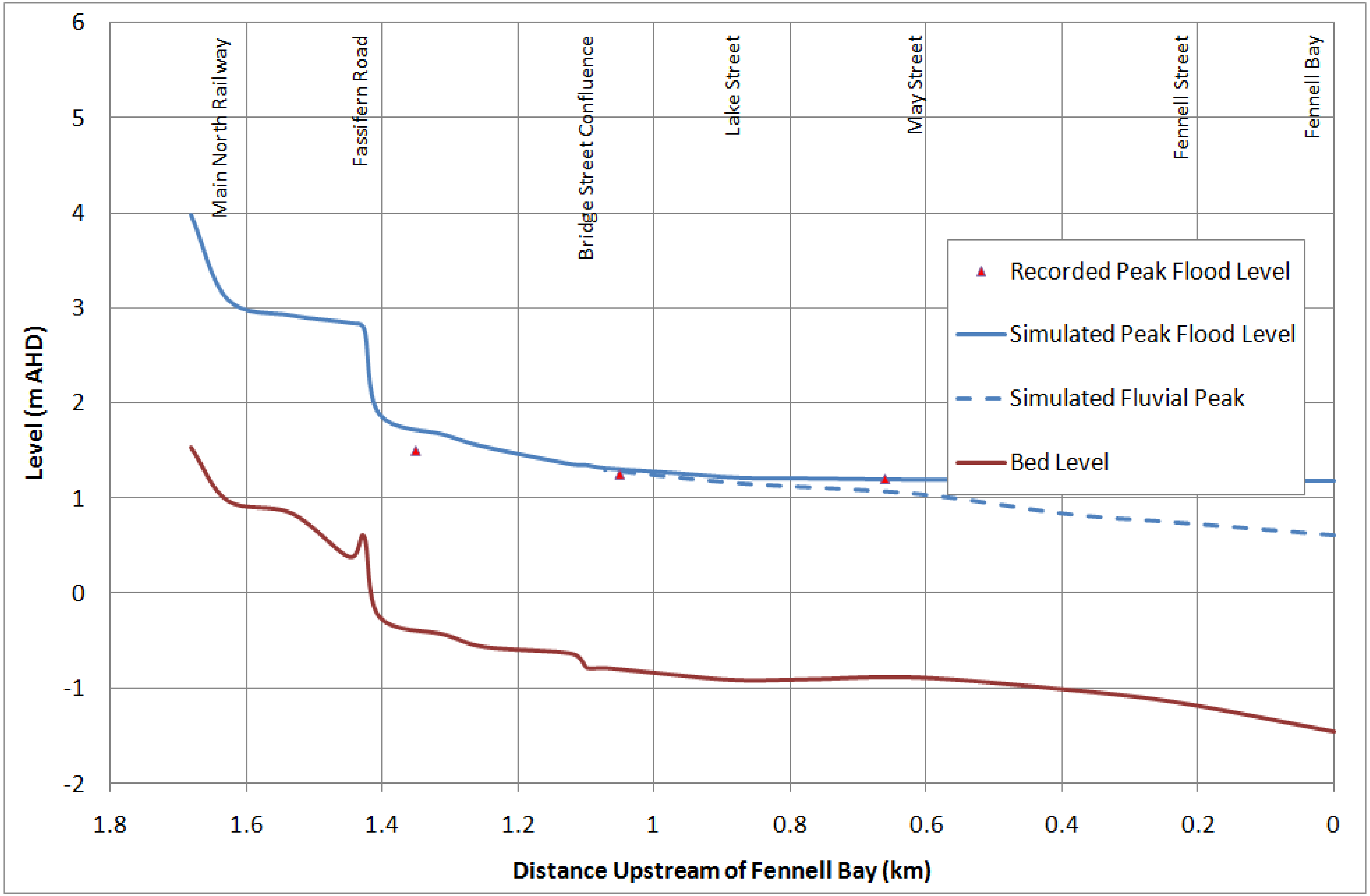


Figure 6-15 June 2007 Peak Water Level Calibration (North Arm)

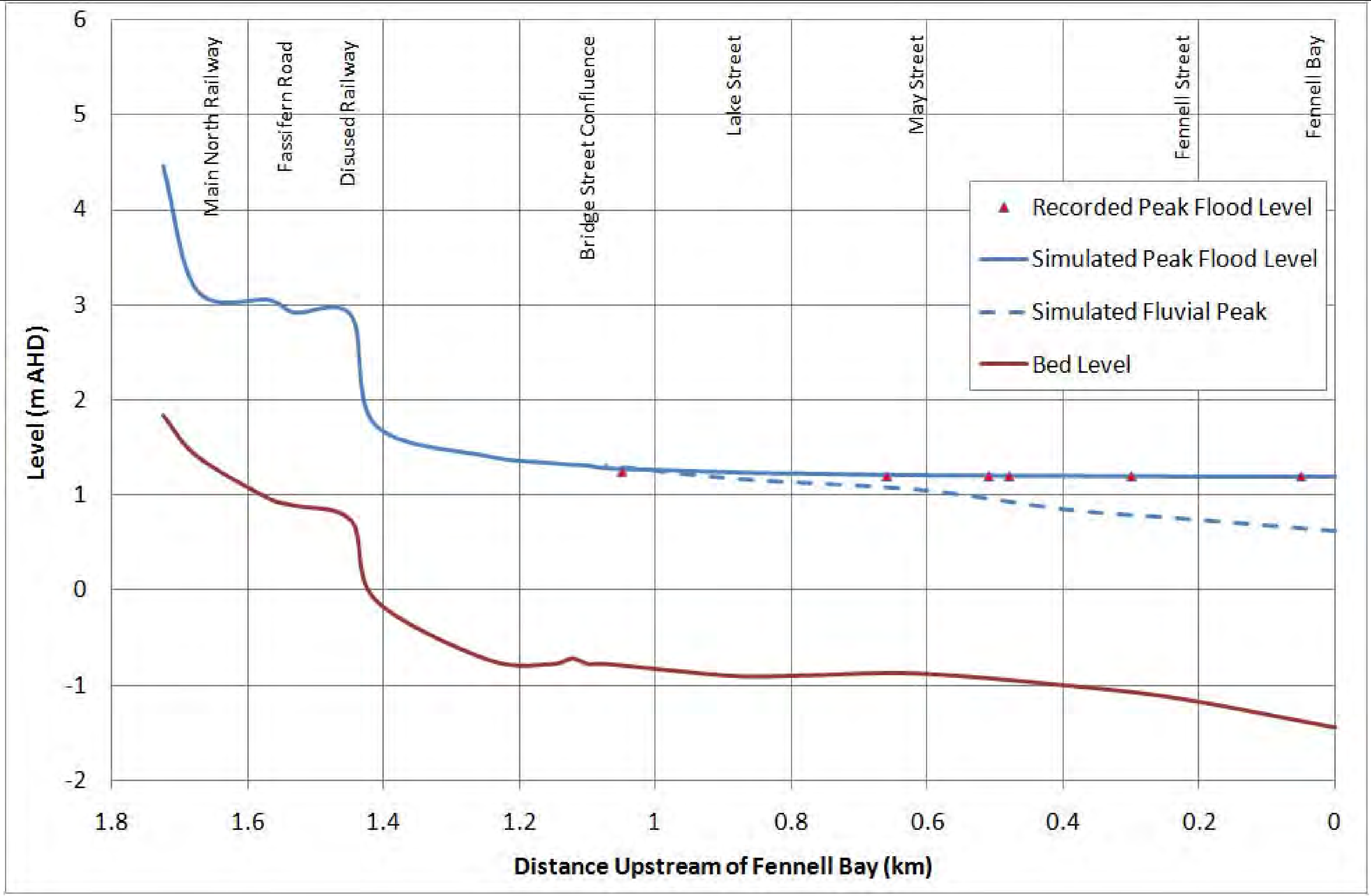


Figure 6-16 June 2007 Peak Water Level Calibration (South Arm)

Various timings of the peak of the event were provided in the community questionnaire responses. The relative timing of the peak of the event is dependent on the location within the catchment. Various reports indicated the flood peak in Fassifern is estimated to have occurred around approximately 3:00am on Saturday 9th June which corresponds to the peak Lake flooding. Other reports however noted a significantly earlier peak in the late evening of the 8th June. LT Creek, being one of the smaller contributing catchments to Lake Macquarie is expected to peak earlier than the main body of the Lake, given the lag expected in major inflows from larger catchments such as Dora Creek and Cockle Creek.

The simulated water levels through the June 2007 event at various locations in the lower part of Fassifern are shown in Figure 6-17. The water level time series shown for the north arm of LT Creek at Fassifern Road generally represents the timing of the fluvial (catchment derived) flooding condition in LT Creek. Moving downstream to the confluence and further to the outlet to Fennell Bay, the influence of the Lake flooding condition is seen to increase and be the dominant mechanism in terms of the peak flood level attained. The simulated water levels for the reach between the Bridge Street confluence and Fennell Street show a first fluvial peak between say 8:00pm to 10:00pm on the 8th June, followed by a second peak in the early hours of the 9th June corresponding to the rise in the Lake flood levels. This condition was also reported in the questionnaire responses in some locations.

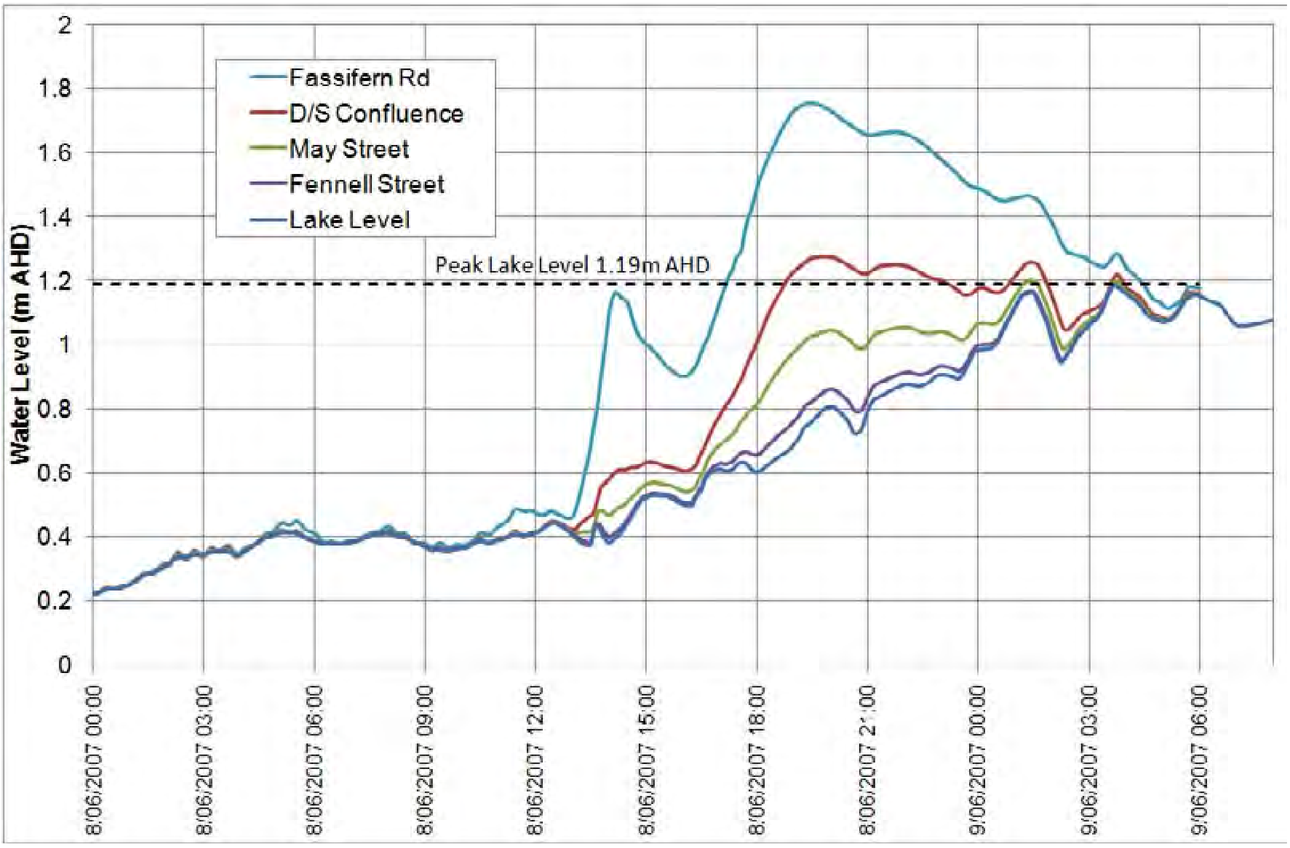


Figure 6-17 Timing of Peak Water Levels in Fassifern for June 2007 Event

The dominance of the Lake flooding condition in the lower parts of the LT creek catchment is further highlighted considering that the LT Creek catchment rainfall for the June 2007 event was in excess of a 1% AEP event, and the Lake Macquarie level corresponds to approximately a 5% AEP event. This is significant for Council when considering the appropriate design flood conditions for development control in the lower parts of Fassifern, including coincident LT Creek and Lake Macquarie flooding.

6.3.5 Simulated Hydrographs

As discussed previously, there is no recorded streamflow data in order to calibrate the simulated hydrographs. However, comparison of the peak flows from the simulated historical and design events provide an indication as to the relative magnitude of each event.

Figure 6-18 shows simulated hydrographs for the June 2007 validation event at three key locations in the LT Creek catchment being, just upstream of the confluence on both the south and north arms of LT Creek, and the combined flow downstream of the confluence. The two hydrographs upstream of the confluence enable comparison of the relative flow contribution from the main south and north arms of the LT Creek catchment.

As with the 1981 event simulation, the simulated hydrographs for the June 2007 event show a greater flow contribution from the main north sub-catchment of LT Creek. However the attenuation of the flow in the south arm is much less pronounced than for the 1981 event, given the lower magnitude of the 2007 event, and the corresponding greater proportion of the flow conveyed within the main channel.

Also shown for reference is the combined peak flow downstream of the Bridge Street confluence. The simulated peak flow of some 51m^3/s is considerably less than that simulated for the February 1981 event (141m^3/s) reflective of the relative magnitudes of the two events. Further discussion on the magnitudes of the 1981 and 2007 events with respect to design event magnitudes is provided in Section 7.3.2.

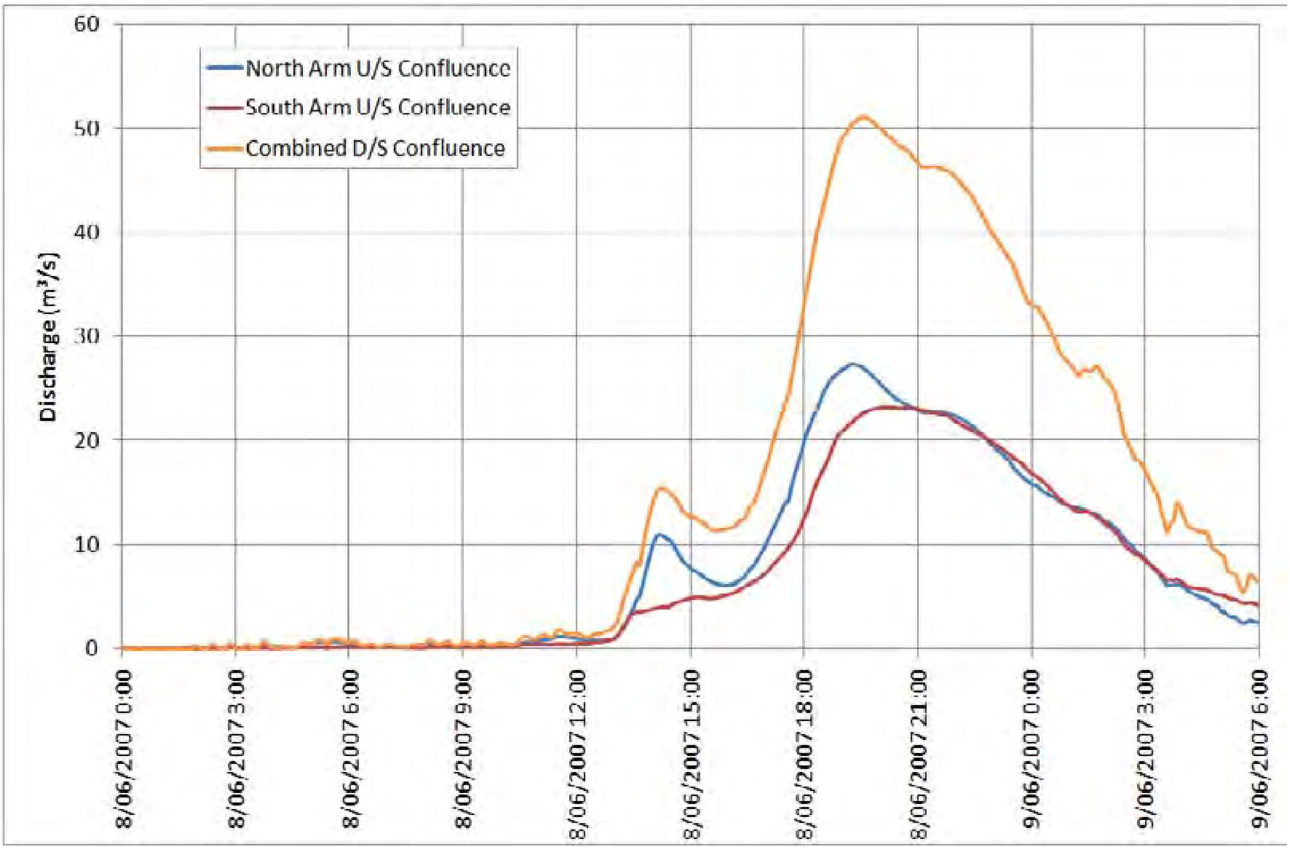


Figure 6-18 Simulated Hydrographs June 2007 Event

6.4 Determination of Design Model Parameters

In calibrating the models emphasis was placed on reaching agreement between recorded and simulated flood conditions with respect to observed peak flood water levels and relative timing of occurrence. In the absence of available streamflow data, no calibration with respect to flow magnitude and hydrograph shape could be undertaken.

The model calibration achieved good agreement in regards to observed peak water levels. The model calibration centred around the adjustment of the rainfall losses, the sub-catchment PERN values, routing adjustment parameter (BX value) and the Manning's 'n' values for the channel and floodplain. The final values adopted, as shown in Table 6-1, were found to give an adequate result. All of these parameters have been kept within normal bounds generally considered for a catchment study of this nature.

The adopted parameters have been maintained (as per the calibration events) for design event simulation.

7 DESIGN FLOOD CONDITIONS

Design floods are hypothetical floods used for planning and floodplain management investigations. They are based on having a probability of occurrence specified either as:

- Annual Exceedance Probability (AEP) expressed as a percentage; or
- Average Recurrence Interval (ARI) expressed in years.

This report uses the AEP terminology. Refer to Table 7-1 for a definition of AEP and the ARI equivalent.

Table 7-1 Design Flood Terminology

ARI[1]	AEP[2]	Comments
5 years	20%	A hypothetical flood or combination of floods which represent the worst case scenario likely to occur on average once every 5 years or a 20% chance of occurring in any given year.
10 years	10%	As for the 20% AEP flood but with a 10% probability or 10 year return period.
20 years	5%	As for the 20% AEP flood but with a 5% probability or 20 year return period.
50 years	2%	As for the 20% AEP flood but with a 2% probability or 50 year return period.
100 years	1%	As for the 20% AEP flood but with a 1% probability or 100 year return period.
200 years	0.5%	As for the 20% AEP flood but with a 0.5% probability or 200 year return period.
500 years	0.2%	As for the 20% AEP flood but with a 0.2% probability or 500 year return period.
Extreme Flood / PMF[3]		A hypothetical flood or combination of floods which represent an extreme scenario.

1 Average Recurrence Interval (years)
2 Annual Exceedance Probability (%)
3 A PMF (Probable Maximum Flood) is not necessarily the same as an Extreme Flood.

In determining the design floods it is necessary to take into account:

- The critical storm duration of the catchment (small catchments are more prone to flooding during short duration storms while for large catchments longer durations will be more critical. For example, considering the relatively small size of the LT Creek catchment, it is potentially more prone to higher flooding from intense storms extending over several hours rather than a couple of days); and
- The relative timing and magnitude of flooding in Lake Macquarie in relation to LT Creek catchment flooding.

7.1 Coincident Catchment and Lake Flooding

The coincident catchment and Lake flooding condition is an important consideration in defining design flood event conditions for the LT Creek catchment. As discussed previously, some of the significant flood events in the Fassifern locality have been primarily driven by Lake Macquarie flooding. Table 7-2 presents a comparison of observed peak flood levels in Lake Macquarie for historical events and design flood levels provided in Lake Macquarie FRMS (WMA, 2000).

Of the historical events included in Table 7-2, only the February 1981 event has a significant mainstream flooding component as a result of high LT Creek catchment rainfall. As previously discussed, this high catchment rainfall was not confined to LT Creek for this event, but affected the majority of the western catchment of Lake Macquarie. The corresponding peak flood level that resulted in the Lake is estimated to be of the order of a 10% AEP (10-year return period) magnitude.

Table 7-2 Comparison of Historical and Design Event Flood Levels in Lake Macquarie

Event	Lake Level
PMF	2.63m AHD
0.2% AEP	1.75m AHD
0.5% AEP	1.55 AHD
1% AEP	1.38m AHD
June 1949	*1.25m AHD*
2% AEP	1.24m AHD
June 2007	*1.1m AHD*
February 1990	*1.0m AHD*
5% AEP	0.97m AHD
10% AEP	0.80m AHD
February 1981	*0.8m AHD*
20% AEP	0.65m AHD

In order to gain a full appreciation of catchment derived flooding conditions, design event scenarios have been run without significant influence from adopted tailwater conditions. In these scenarios, a design 20% AEP Lake Macquarie flooding condition has been adopted. The range of design events considered are summarised in Table 7-3, with runs 1 to 7 representing the above tailwater assumptions.

There is however the potential for major coincident flooding of both Lake Macquarie and catchment derived LT Creek flooding. Additional design event simulations (runs 8 to 10) have been undertaken by adopting a design 1% AEP flood level within Lake Macquarie coinciding with design 5% AEP, 1% AEP and PMF design rainfall in the LT Creek catchment.

7.2 Design Rainfall

Design rainfall parameters are derived from standard procedures defined in AR&R (2001) which are based on statistical analysis of recorded rainfall data across Australia. The derivation of location specific design rainfall parameters (e.g. rainfall depth and temporal pattern) for the LT Creek catchments is presented below.

Table 7-3 Modelled Design Flood Scenarios

Run No.	Catchment Flooding	Lake Flooding
1	20% AEP	20% AEP
2	10% AEP	20% AEP
3	5% AEP	20% AEP
4	2% AEP	20% AEP
5	1% AEP	20% AEP
6	0.5% AEP	20% AEP
7	PMF	20% AEP
8	5% AEP	1% AEP
9	1% AEP	1% AEP
10	PMF	1% AEP

7.2.1 Rainfall Depths

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

The Probable Maximum Precipitation (PMP) is used in deriving the Probable Maximum Flood (PMF) event. The theoretical definition of the PMP is "the greatest depth of precipitation for a given duration that is physically possible over a given storm area at a particular geographical location at a certain time of year" (AR&R, 2001). The ARI of a PMP/PMF event ranges between 10^4 and 10^7 years and is beyond the "credible limit of extrapolation". That is, it is not possible to use rainfall depths determined for the more frequent events (100 year ARI and less) to extrapolate the PMP. The PMP has been estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology.

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered included the 1-hour, 1.5-hour, 2-hour, 3-hour, 4.5-hour, 6-hour, 9-hour, and 12-hour durations.

Table 7-4 shows the average design rainfall intensities based on AR&R adopted for the modelled events. The full IFD table with durations from 5-minutes to 72-hours derived for the LT Creek catchment is included in Appendix F.

Areal Reduction Factor

The areal reduction factor takes into account the unlikelihood that larger catchments will experience rainfall of the same design intensity (eg 1% AEP) over the entire area. Areal reduction factors typically apply to catchments significantly larger than LT Creek and no reduction factor is required for the study area catchment of 7.5km^2.

Table 7-4 Average Design Rainfall Intensities (mm/hr)

Duration (hours)	Design Event Frequency					
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP
1	41.9	47.4	55	64	72	79
1.5	33.2	37.6	43.4	51	57	63
2	28.0	31.8	36.7	43.2	48.1	53.2
3	22.0	25.0	28.9	34.0	38.0	42.0
4.5	17.3	19.6	22.7	26.8	29.9	33.1
6	14.6	16.6	19.2	22.6	25.3	28.0
9	11.4	13.0	15.1	17.8	19.9	22.1
12	9.65	11.0	12.7	15.1	16.8	18.7

7.2.2 Temporal Patterns

The IFD data presented in Table 7-4 provides for the average intensity (or total depth) that occurs over a given storm duration. Temporal patterns are required to define what percentage of the total rainfall depth occurs over a given time interval throughout the storm duration. The temporal patterns adopted in the current study are based on the standard patterns presented in AR&R (2001).

The same temporal pattern has been applied across the whole catchment. This assumes that the design rainfall occurs simultaneously across each of the modelled sub-catchments. The direction of a storm and relative timing of rainfall across the catchment may be determined for historical events if sufficient data exists, however, from a design perspective the same pattern across the catchment is generally adopted.

7.2.3 Rainfall Losses

The hydrologic model parameters adopted for the design floods were similar to those used in the hydrologic model calibration and verification. For the initial and continuing rainfall losses, values of 20mm and 2.5mm/h were used. These are consistent with the recommended ranges for design event losses in AR&R (2001).

7.3 Design Flood Results

A range of design event durations were simulated to determine the critical duration for flooding along LT Creek. In general, the model simulations indicated the peak water levels in the channel and inundated areas of Fassifern corresponded to the 9 hour duration (4-hour for the PMF event).

This conforms to the general rainfall pattern occurring during the June 2007 event. The design results presented in the remainder of the report are for the 9-hour critical duration for events up to the 0.5% AEP event and 4-hour duration for the PMF.

7.3.1 Peak Flood Levels, Depths and Velocities

The design flood results are presented in a flood mapping series in Appendix A. For the key simulated design events including the 5% AEP (20-year ARI), 1% AEP (100-year ARI) and PMF events, a map of peak flood depth, velocity and hydraulic hazard is presented covering the modelled area including the entire developed Fassifern locality.

Predicted flood levels at the selected locations shown in Figure 7-1 are summarised in Table 7-5 for the full range of design event magnitudes considered. All of the locations refer to in-channel water levels on both the north and south arms of the LT Creek waterway. Longitudinal profiles showing predicted flood levels along LT Creek are also shown in Figure 7-2 and Figure 7-3 respectively.

Figure 7-1 Reported Flood Level Locations

A key reference point for flood levels, particularly in relation to historical events, is the confluence of the main north and south catchment tributaries in the vicinity of Bridge Street. Recorded flood levels at this location for the February 1981 and June 2007 events were 2.0m AHD and 1.3m AHD respectively. Comparison of these historical peak levels can be made with the design flood results in Table 7-5 to gauge the relative severity of the flood. Flood levels at the confluence for the 1981 event lie some 0.7m above the 1% AEP flood level. The estimated return period of the 1981 flood on the basis of the predicted peak water level is in excess of 200-years (0.5% AEP). The June 2007 event peak flood level lies between the predicted 2% AEP and 1% AEP flood levels. This level is approximately 0.1m below the 1% AEP flood level.

Table 7-5 Estimated Peak Flood Levels for Design Events (with 20% AEP Lake Flooding)

Location	Design Event Frequency						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
Fennell Bay (LT Creek)	0.65	0.65	0.65	0.65	0.65	0.65	0.98
Fennell Street	0.67	0.68	0.70	0.72	0.74	0.77	1.36
May Street	0.75	0.79	0.86	0.94	1.00	1.06	1.93
Lake Street	0.82	0.88	0.98	1.08	1.15	1.23	2.30
Confluence	0.90	0.98	1.10	1.22	1.30	1.39	2.59
North Arm							
Fassifern Road	1.96	2.11	2.33	2.69	2.82	2.90	3.96
Main North Railway	3.10	3.30	3.51	3.75	3.92	4.11	10.14
South Arm							
Cooper Avenue	2.06	2.26	2.54	2.73	2.86	2.97	4.74
Fassifern Road	2.36	2.49	2.73	2.91	3.03	3.13	4.76
Main North Railway	3.52	3.78	4.10	4.30	4.45	4.59	7.91

As discussed for the model calibration and validation events, the major embankments associated with the Coal Haulage Road, a private access road, the Main North Railway, and Fassifern Road form significant controls. This impact is clearly evident with the change in simulated peak flood levels across the respective embankments on both the north and south arms of the channel as shown in Figure 7-2 and Figure 7-3. On the south arm, the abandoned railway embankment also forms a dominant control downstream of Fassifern Road.

Downstream of Fassifern Road there is a gradual flattening of the water level profile on the lower floodplain also reflected by the bed profile. The profiles show relatively small changes in peak flood level between the respective flood magnitudes. This feature is a result of the effectiveness of the main LT Creek channel to convey simulated flood discharges. The LT creek channel, particularly the lower reaches downstream of the Bridge Street confluence, has a relatively high conveyance capacity in relation to the catchment area. The LT Creek catchment area is only some 7.5km^2 with a main channel width of some 20 to 30m in the lower reaches. Peak flood levels in the lower reaches are also somewhat limited by the activation of alternative flow paths for major overbank flows, providing for direct drainage to the Fennell Bay foreshore via routes such as Lake Street, Bluewater Avenue and Fennell Street.

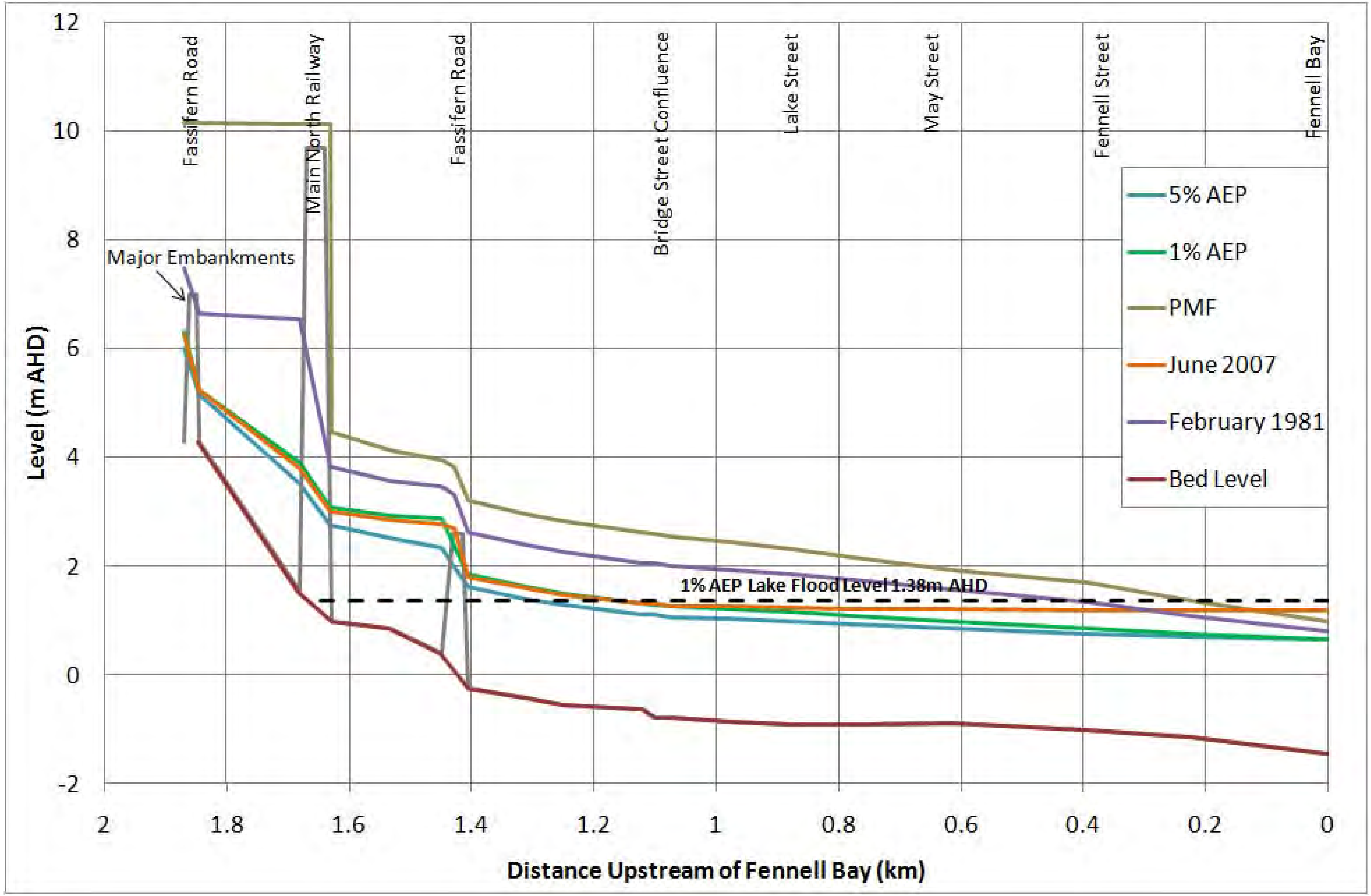


Figure 7-2 Design Flood Level Profiles for LT Creek (North Arm)

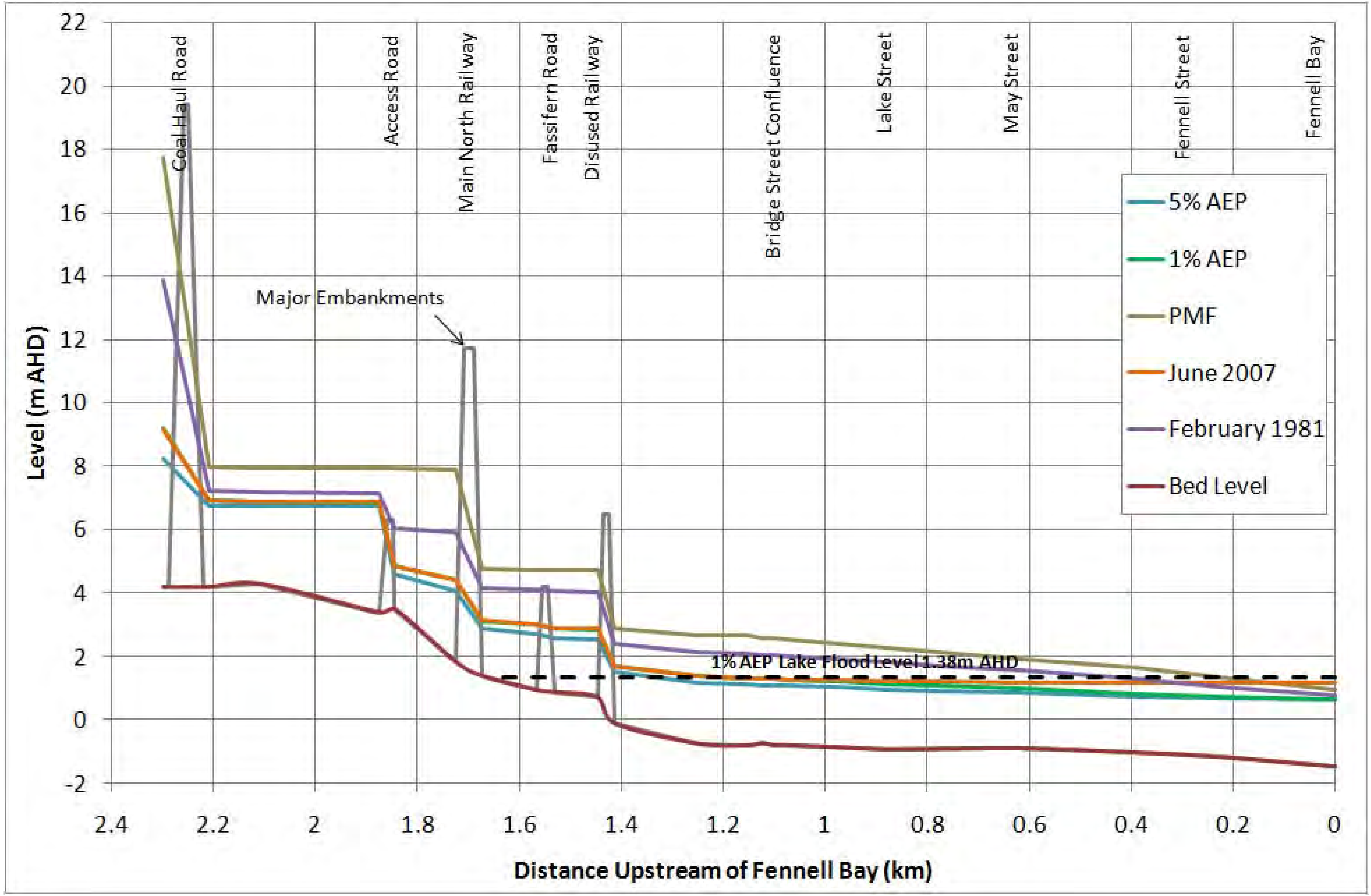


Figure 7-3 Design Peak Flood Level Profiles for LT Creek (South Arm)

The simulated flood inundation extents in the LT Creek catchment for the 5% AEP, 1% AEP and PMF events are shown in Figure 7-4 for comparison. There is only a small increase in the inundation extent for the 1% AEP event compared with the 5% AEP extent. Again this is representative of the general capacity of the main LT Creek channel to convey flood discharges derived for catchment rainfall.

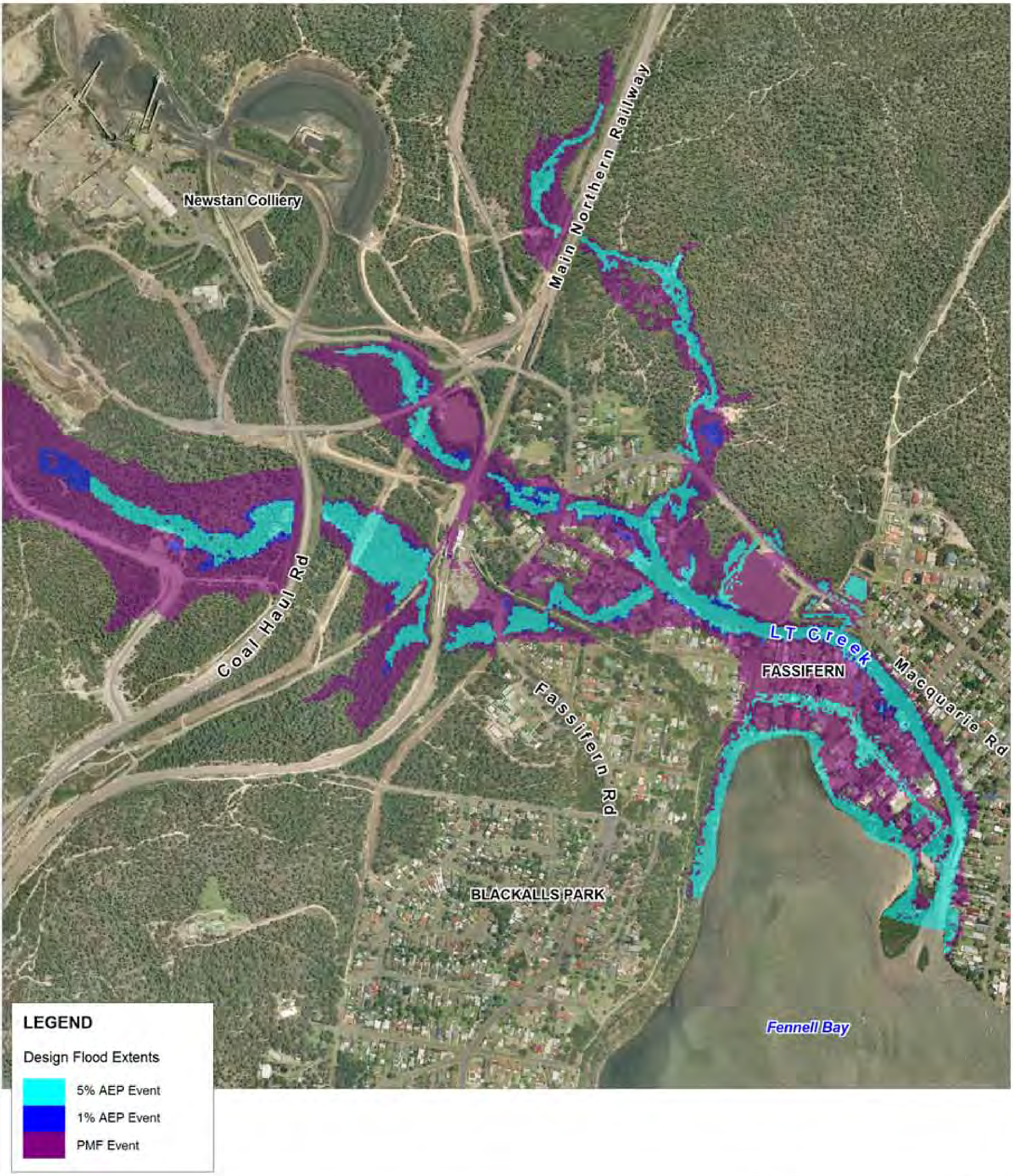
Significantly, the simulated extents for events up to the 1% AEP event show little property inundation. Floodwaters are effectively conveyed within the main channel and fringing floodplain, with inundation of some roads including Lake Street, Bluewater Avenue and Fennell Street. The properties along these inundated roadways are generally at a higher level than the road, having been constructed on elevated pads, accordingly there is minimal inundation to buildings.

With the majority of floodwater conveyed in-channel for events up to the 1% AEP event, flood velocities on the floodplain are typically less than 0.5m/s. Conversely, the in-stream velocities are of the order of 2m/s for most of the LT Creek channel.

For the simulated PMF event, there is large scale inundation across the study area. In much of the existing developed areas of Fassifern, flood depths for this event are of the order of 1 to 2 metres. The corresponding peak flow velocities on the floodplain typically exceed 3m/s, with local higher simulated velocities associated with major constrictions of the flow. The majority of affected development is contained within the floodplain corridor between Macquarie Road to the north and the abandoned railway line to the south. Generally beyond these limits, the natural topography rises relatively steeply, thereby limiting inundations in these parts, and controlling the extent of flooded width on the LT Creek floodplain.

The simulated peak water levels for the PMF event upstream of the Main North Railway correspond to significant flood depths upstream of the railway embankment (refer to mapping in Appendix A). For this extreme event, the capacity of the existing cross drainage structures is well exceeded, resulting in substantial ponding upstream of the railway embankment. Simulated peak head differences across the embankment are of the order of 5m. This large hydraulic pressure raises the possibility of embankment failure.

Similarly, and perhaps of greater significance, is the depth and extent of ponding behind the Coal Haul Road. The height of this road embankment is of the order of 15m. The upstream catchment is drained by a 4x1200mm diameter pipe culvert. Once the capacity of this culvert is exceed, the floodwaters begin to backup behind the embankment as flow is controlled by the culvert capacity. For the PMF event, where design flows in the catchment far exceed the culvert capacity, flood levels rapidly build behind the embankment, eventually to a point when the Coal Haul Road is overtopped.



Title:
Design Flood Inundation Extents for LT Creek

Figure: 7-4

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 200 400m
Approx. Scale

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Rapid failure of an embankment, with a significant volume of floodwater stored behind it, may result in a damaging flood wave propagating through to Fassifern with little or no warning. Accordingly, it is recommended that the risk of embankment failure be considered in future flood investigations in the catchment including subsequent floodplain management studies.

The model results and discussion presented above relate to the design model runs 1 to 7 (refer Table 7-3) for which a 20% AEP design Lake Macquarie flooding condition was adopted for the downstream water level boundary.

The peak flood level results presented in Table 7-5 and Table 7-6 below utilise a design 1% AEP Lake Macquarie flood condition of 1.38m AHD (WMA, 2000), representing runs 8 to 10 (refer Table 7-3).

Table 7-6 Estimated Peak Flood Levels for Design Events (with 1% AEP Lake Flooding)

Location	Design Event Frequency		
	5% AEP	1% AEP	PMF
Fennell Bay (LT Creek)	1.38	1.38	1.38
Fennell Street	1.39	1.39	1.54
May Street	1.42	1.46	1.95
Lake Street	1.46	1.52	2.30
Confluence	1.50	1.59	2.59
North Arm			
U/S Fassifern Road	2.33	2.82	3.96
U/S Main North Railway	3.51	3.92	10.14
South Arm			
Cooper Avenue	2.54	2.86	4.74
U/S Fassifern Road	2.73	3.03	4.76
U/S Main North Railway	4.10	4.45	7.91

Comparing the peak flood level results in and Table 7-6 for the 20% AEP and 1% AEP Lake flooding condition respectively, the limit of backwater influence form the adopted downstream condition lies between the confluence and Fassifern Road depending on the design flood event magnitude. Upstream of Fassifern Road, the adopted boundary conditions have no impact on simulated peak flood levels. Downstream of Fassifern Road, the design peak water level profiles for the 5% AEP and 1% AEP LT Creek design events exhibit relatively flat water level gradients from the downstream boundary.

The design 1% AEP Lake Macquarie flood level of 1.38m AHD was included on the peak design water level profiles shown in Figure 7-2 and Figure 7-3. From these figures it can be seen that the Lake water level extends as far upstream as the Main North Railway. Indeed, elevated water levels at Fennell Bay from broader Lake Macquarie flooding is the dominant flooding mechanism for the 1% AEP event (compared to LT Creek catchment derived flooding) for most parts of Fassifern, particularly downstream of the confluence. For the PMF event, the adopted tailwater condition has no impact on peak flood water levels upstream.

The sensitivity testing for the adopted downstream boundary condition emphasises the significance of the Lake Macquarie flooding condition in determining design peak flood levels along LT Creek.

7.3.2 Flood Hydrographs

The simulated design hydrographs at the confluence of north and south arms of LT Creek, just downstream of the Bridge Street crossing, are shown in Figure 7-5. This is a useful reference point for comparison of peak flows simulated for historical events. In terms of peak flow magnitude, the 1981 flood was approximately 100% greater than the 1% AEP design flood. Similarly, the 2007 flood was estimated to be approximately 5% lower than the 1% AEP design flood in terms of peak flow magnitude. It is re-iterated that no calibration of the flows were able to be undertaken as part of the study due to lack of recorded streamflow data. The simulated 1981 and 2007 event hydrographs are shown for reference in Figure 7-5.

The estimated return period of the February 1981 flood is in excess of 200 years (i.e. greater than the 0.5% AEP design event) based on the peak flow estimates. The estimated return period of the June 2007 flood is of the order of 80 years (i.e. less than the 1% AEP design event) on the basis of the simulated peak flows.

Both the north and south arms of LT Creek provide for a relatively simular contribution to the peak flow at the confluence as summarised in Table 7-7. Also shown for reference is the combined peak flow at the discharge point to Fennell Bay at the downstream model boundary.

Table 7-7 Design Peak Flows for LT Creek

Sub-catchment	Design Event Frequency						
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	PMF
North Arm	14.9	17.8	21.7	26.0	30.0	34.4	179
South Arm	11.2	14.2	17.9	20.8	23.0	24.8	62
Combined D/S Confluence	26.1	32.0	39.7	46.8	53.0	59.2	241

An example of the relative timing of the contributions from the north and south arms of the LT Creek catchment and the combined flow downstream of the confluence is shown in Figure 7-6 for the 1% AEP design event.

As previously discussed, the similar mainstream lengths of the main north and south sub-catchments of LT Creek provide for the peak flows from each sub-catchment to occur relatively simultaneously at the confluence.

The 9-hour design event has been simulated as the critical duration event for the LT Creek catchment (4-hour for the PMF), resulting in the highest peak flow conditions in the lower floodplain where existing development is concentrated. The simulated hydrographs shown in Figure 7-6 have a relatively rapid rise. This has consequences in terms of flood warning and response which should be considered in future floodplain management investigations.

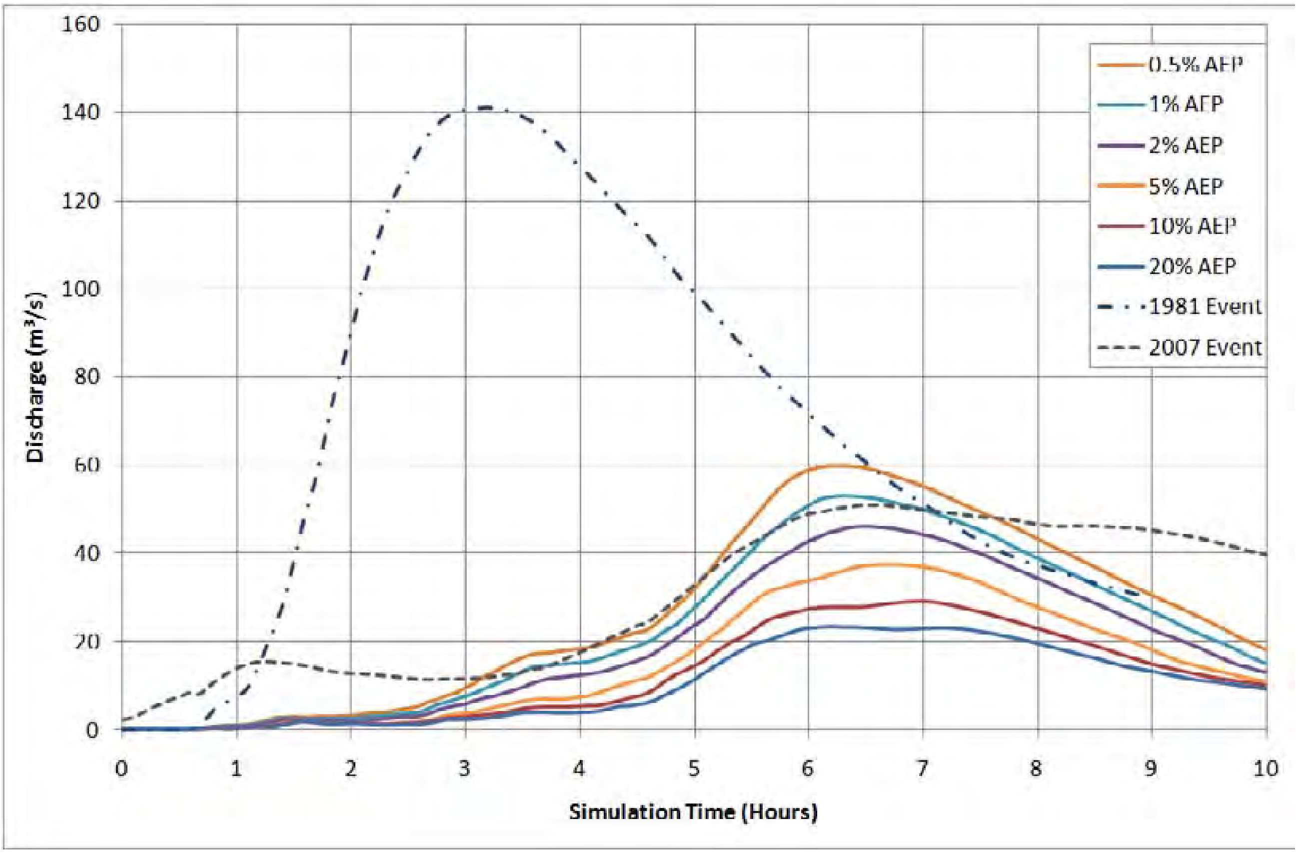


Figure 7-5 Design Flood Hydrographs for LT Creek (D/S Bridge St Confluence)

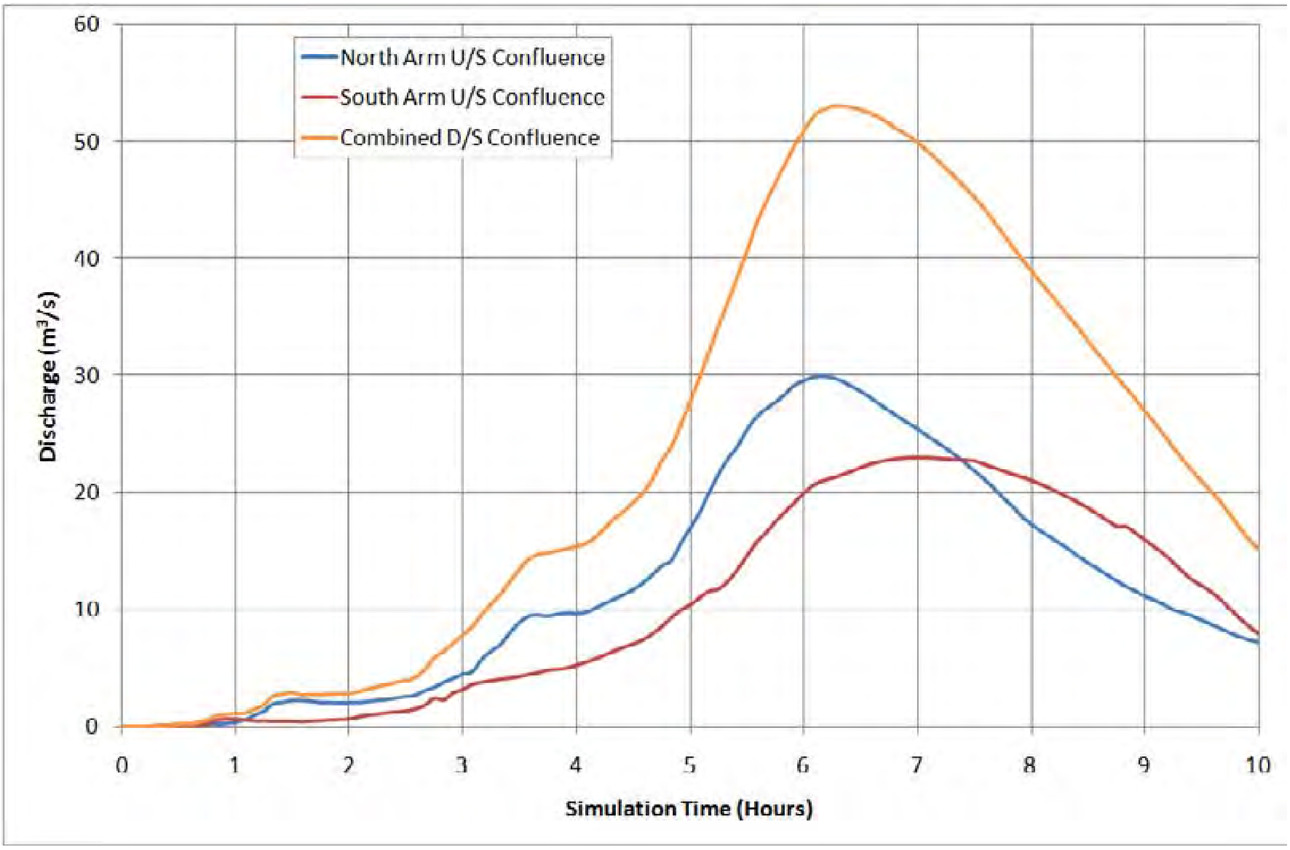


Figure 7-6 Timing of Design 1% AEP Hydrographs for LT Creek

7.3.3 Hydraulic Categorisation

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (NSW Government, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic categories as defined in the Floodplain Development Manual are:

Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.

Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant affect on the flood pattern or flood levels.

A number of approaches were considered when attempting to define flood impact categories across the LT Creek catchment. Approaches to define hydraulic categories that were considered for this assessment included partitioning the floodplain based on:

- Peak flood velocity;
- Peak flood depth;
- Peak velocity * depth (sometimes referred to as unit discharge);
- Cumulative volume conveyed during the flood event; and
- Combinations of the above.

The definition of flood impact categories that was considered to best fit the application within the LT Creek catchment, was based on a combination of velocity*depth and depth parameters. The adopted hydraulic categorisation is defined in Table 7-8.

Hydraulic category mapping for the design events considered is included in Appendix A. It is also noted that mapping associated with the flood hydraulic categories may be amended in the future, at a local or property scale, subject to appropriate analysis that demonstrates no additional impacts (e.g. if it is to change from floodway to flood storage).

Table 7-8 Hydraulic categories

Floodway	Velocity * Depth > 0.5	Areas and flowpaths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	Velocity * Depth < 0.5 and Depth > 1.0 metres	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	Velocity * Depth < 0.5 and Depth < 1.0 metres	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

7.3.4 Provisional Hazard

The NSW Government's Floodplain Development Manual (2005) defines flood hazard categories as follows:

High hazard – possible danger to personal safety; evacuation by trucks is difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings; and

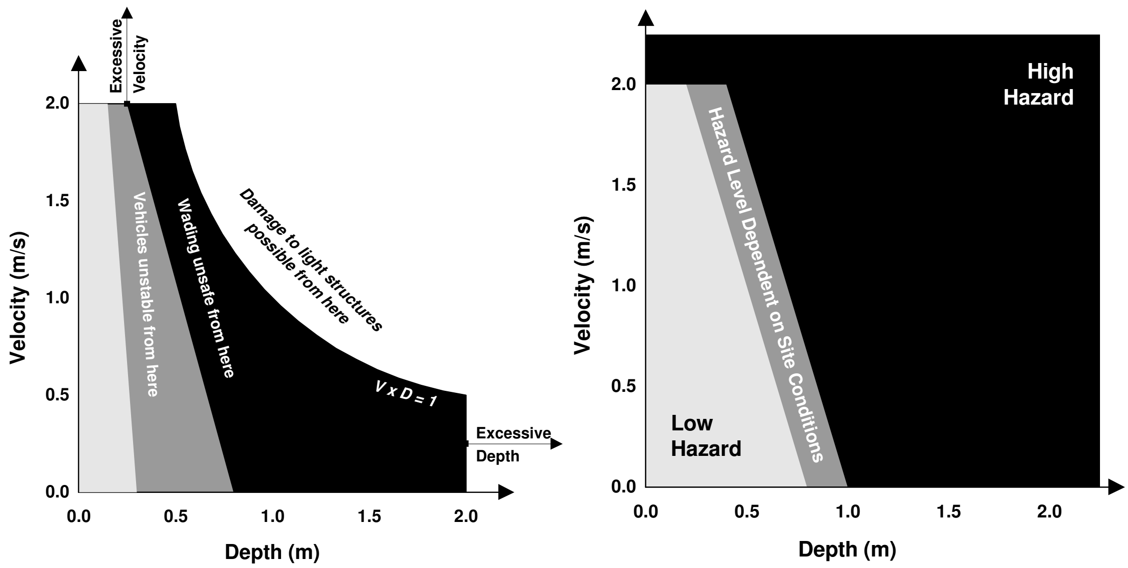
Low hazard – should it be necessary, trucks could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities have no major threat.

Figures L1 and L2 in the Floodplain Development Manual (NSW Government, 2005) are used to determine provisional hazard categorisations within flood liable land. These figures are reproduced in Figure 7-7.



Velocity Depth Relationships **Provisional Hazard Categories**

Figure 7-7 Provisional Flood Hazard Categorisation

The provisional hydraulic hazard is included in the mapping series for each simulated design event provided in Appendix A.

7.4 Sensitivity Tests

A number of sensitivity tests have been undertaken on the modelled flood behaviour in LT Creek. These tests consider blockage of major hydraulic structures such as bridges and culverts, reduced channel capacity of the LT Creek channel associated with potential long-term sedimentation, increase/decrease in adopted roughness values, increase/decrease in adopted design peak inflow and the impact of rising Lake Macquarie water levels and increased rainfall intensities associated with climate change. The details of the sensitivity tests and results of the modelled scenarios are presented below. The impact of the sensitivity test on the standard design flood condition is also presented in Appendix B as a series of peak water level afflux diagrams.

7.4.1 Structure Blockage

Blockage of the structures upstream of the Main North Railway was not considered in the sensitivity assessment. Most of these structures are incorporated in major embankments such as the railway and the coal haulage road. A full or even partial blockage of these structures is likely to provide significant attenuation of peak flood flows as storage builds up behind the embankments. Significant attenuation of the LT Creek flows behind these embankments would lower the potential flood risk in the developed parts of Fassifern.

The more critical blockage scenarios for the major developed areas of Fassifern involve blockage of the structures downstream of the railway embankment. These blockages have the potential to substantially increase the magnitude and extent of property inundation through local increases in water level, redistribution of flows on the floodplain, and activation of additional flow paths.

The major hydraulic structures incorporated in the hydraulic model were summarised in Table 5-2. These structures vary in both size and configuration. The Fassifern Road viaduct, the Disused

Railway box culvert and the Bridge Street are all major structures with significant clear spans. For these major structures a 50% blockage has been applied. For all of the other structures (downstream of the railway only), a 100% blockage has been applied. Complete blockage of structures on the mainstream channel alignments would result in all flow being redistributed to the floodplain. The majority of the floodplain flow re-enters the main channel downstream of the blockage, with only a minor proportion of the flow found to be conveyed out-of-bank through the developed areas at the lower end of the LT Creek system.

The change in peak water levels with the assumed blockage conditions is summarised at key locations in Table 7-9 for the 20% AEP, 1% AEP and PMF events simulated. Mapping of the extents of the simulated afflux is included in Appendix B for each modelled scenario. Table 7-9 shows the simulated peak flood level with the assumed structure blockage, along with the change from the standard (no blockage) flood conditions shown in brackets.

Table 7-9 Peak Flood Levels with Structure Blockage

Location	Design Event Frequency		
	20% AEP	1% AEP	PMF
Fennell Bay (LT Creek)	0.65 (0.00)	0.65 (0.00)	0.98 (0.00)
Fennell Street	0.70 (0.00)	0.74 (0.00)	1.31 (-0.04)
May Street	0.85 (-0.01)	0.99 (-0.01)	1.87 (-0.06)
Lake Street	0.97 (-0.01)	1.14 (-0.01)	2.20 (-0.10)
Confluence	1.09 (-0.01)	1.29 (-0.01)	2.48 (-0.11)
North Arm			
Fassifern Road	3.11 (0.78)	3.20 (0.38)	3.82 (-0.14)
Main North Railway	3.55 (0.03)	3.92 (0.00)	9.99 (-0.15)
South Arm			
Cooper Avenue	3.64 (1.10)	4.08 (1.21)	5.45 (0.71)
Fassifern Road	4.07 (1.34)	4.19 (1.16)	5.45 (0.70)
Main North Railway	4.36 (0.26)	4.60 (0.15)	7.52 (-0.39)

Note: Bracketed value is change in peak flood level from standard design conditions (ref: Table 7-5)

The most significant impacts are associated with the blockage of the abandoned railway culvert (south arm of LT Creek). Given the crest level of the embankment of approximately 6m AHD, there is no available overflow of the embankment in the event of a total structure blockage. In this scenario, floodwater would back up behind the structure until relieved by the activation of an alternative flow path (at an elevation around 4m AHD) across Fassifern Road through the viaduct. For the 5% AEP and 1% AEP events simulated, the afflux upstream of the railway embankment exceeds 1m and extends some distance upstream of Fassifern Road.

The other significant impact is associated with blockage of the Fassifern Road culvert on the north arm. Afflux at this location is limited by the opportunity for floodwater to flow over the road in the event of structure blockage. Blockage of other structures (e.g. Macquarie Road culverts) generally results in only minor local impacts, and tends not to affect any existing development.

There is little impact of the blockage scenarios on the PMF flooding condition. At this magnitude event, the structures are largely drowned out and/or bypassed by the floodwater, thereby having little influence on the peak flooding condition.

For all magnitude events considered, the assumed blockage has minimal impact on flood conditions downstream of the confluence. In this regard, the assumed blockages do not change the broader flooding behaviour in the catchment, in particular the lower floodplain. The attenuation of peak flows resulting from structure blockages upstream may provide for minor reductions in peak flood levels in the lower floodplain as indicated in Table 7-9.

7.4.2 Channel Sedimentation

Sedimentation of the LT Creek channel and associated water quality was highlighted by the community as a major catchment issue. Given the level of community concern in relation to sedimentation of the channel, the potential impact on flood behaviour as a result of continued unmanaged sedimentation of the channel has been considered in this study.

Significant sedimentation on the bed of the LT Creek channel will reduce the bank-full channel capacity. This reduced channel carrying capacity may increase the propensity for out-of-bank flooding and increase the severity of inundation on the floodplain across a range of flood magnitudes.

To simulate the impact of potential sedimentation of the channel, the bed levels of LT Creek were raised by 0.5m. The depth of the existing channel varies across the model area, however, is generally of the order of 1 to 2m. Accordingly, a bed level increase of 0.5m represents a substantial reduction in channel capacity.

The peak water levels with the assumed blockage conditions and relative change from standard conditions is summarised at key locations in Table 7-10 for the 20% AEP, 1% AEP and PMF events simulated, with afflux mapping included in Appendix B.

Increases in peak flood water levels of 0.3 to 0.4m have been simulated in some of the lower reaches of LT Creek for the assumed channel siltation. There are no major changes to the existing flow patterns or activation of other flow paths, however, there would be a minor increase in flow depths on the floodplain (as more flow is conveyed out-of-bank) and corresponding increase in inundation extents.

At the major structures on Fassifern Road and the Main North Railway, the channel siltation provides for minimal change to existing peak flood levels. Peak flood levels at these locations are controlled by overflow across the embankments, such that changes in the channel formation have no significant influence.

Extensive siltation of the channel as represented in the sensitivity tests may result in increases in peak flood levels along LT Creek. The simulated condition represents a rise in bed levels for the entire reach of LT Creek downstream of Fassifern Road. Long term sediment accumulation is unlikely to be as uniform or extensive, however, the model simulation provide an indication of the relative sensitivity of the peak flooding condition to changes in the channel bed profile.

Table 7-10 Peak Flood Levels with Reduced Channel Capacity

Location	Design Event Frequency		
	20% AEP	1% AEP	PMF
Fennell Bay (LT Creek)	0.65 (0.00)	0.66 (0.01)	0.98 (0.00)
Fennell Street	0.82 (0.12)	0.92 (0.18)	1.51 (0.15)
May Street	1.14 (0.28)	1.30 (0.31)	2.03 (0.11)
Lake Street	1.34 (0.37)	1.54 (0.39)	2.46 (0.16)
Confluence	1.46 (0.36)	1.67 (0.36)	2.77 (0.18)
North Arm			
Fassifern Road	2.40 (0.07)	2.83 (0.01)	3.98 (0.02)
Main North Railway	3.54 (0.02)	3.92 (0.00)	10.14 (0.00)
South Arm			
Cooper Avenue	2.56 (0.02)	2.86 (-0.01)	4.72 (-0.01)
Fassifern Road	2.89 (0.16)	3.09 (0.06)	4.75 (0.00)
Main North Railway	4.10 (0.00)	4.44 (-0.01)	7.91 (0.00)

Note: Bracketed value is change in peak flood level from standard design conditions (ref: Table 7-5)

The impact of a reduced main channel capacity may be offset by the scour potential associated with major flood events. High in-stream velocities in the LT Creek channel, of the order of 1.5-2m/s, may mobilise the previously deposited bed sediment, once again increasing the carrying capacity of the channel.

7.4.3 Change in Adopted Hydraulic Roughness

Sensitivity tests on the hydraulic roughness (Manning's 'n') were undertaken by applying a 20% decrease and a 20% increase in the adopted values for the baseline design conditions. Whilst a calibration process has been undertaken with respect to available data, and adopted design parameters are within typical ranges, the inherent variability/uncertainty in warrants consideration of the relative impact on adopted design flood conditions.

The sensitivity tests have been undertaken for the 1% AEP catchment rainfall event (utilising a 20% AEP Lake flood boundary condition).The results of the sensitivity tests on hydraulic roughness for the 1% AEP design event are summarised in Table 7-11. The change in peak flood level conditions from the adopted design base case is also shown as afflux diagrams in Appendix B.

As expected, the model simulation results show general reductions in peak flood level for reduced hydraulic roughness, albeit relatively minor magnitudes (<0.15m). The main areas affected are the in-channel regions where the great majority of flow is conveyed for the 1% AEP event. The decrease in roughness has minimal influence on inundation extents in overbank areas.

Minor increases in peak flood level (generally < 0.15m) are simulated for the increased hydraulic roughness conditions applied in the sensitivity test. Again, the principal areas affected are the in-stream regions with only minor changes to the flood inundation extents.

Table 7-11 Peak 1% AEP Flood Levels for Hydraulic Roughness Sensitivity Tests

Location	Hydraulic Roughness Condition		
	Adopted	20% Decrease	20% Increase
Fennell Bay (LT Creek)	0.65	0.65 (0.00)	0.65 (0.00)
Fennell Street	0.74	0.71 (-0.03)	0.78 (0.03)
May Street	1.00	0.90 (-0.09)	1.08 (0.09)
Lake Street	1.15	1.03 (-0.12)	1.26 (0.11)
Confluence	1.30	1.17 (-0.14)	1.42 (0.12)
North Arm			
Fassifern Road	2.82	2.82 (-0.07)	2.82 (-0.06)
Main North Railway	3.92	3.91 (-0.01)	3.94 (0.02)
South Arm			
Cooper Avenue	2.86	2.88 (0.02)	2.86 (0.00)
Fassifern Road	3.03	3.02 (-0.01)	3.04 (0.01)
Main North Railway	4.45	4.47 (0.02)	4.45 (0.00)

Note: Bracketed value is change in peak flood level from standard design conditions

7.4.4 Change in Design Flow

Sensitivity tests on the simulated design inflow hydrographs were undertaken by applying a 20% decrease and a 20% increase in the design flows for the baseline design conditions. The sensitivity tests have been undertaken for the 1% AEP catchment rainfall event (utilising a 20% AEP Lake flood boundary condition). The results of the sensitivity tests on design inflows for the 1% AEP design event are summarised in Table 7-12. The change in peak flood level conditions from the adopted design base case is also shown as afflux diagrams in Appendix B.

LT Creek is an ungauged catchment and accordingly no calibration with respect to flood discharge magnitude has been possible. Sensitivity tests on design catchment inflows are therefore warranted to appreciate the relative impact of design flood discharge uncertainty on peak flood level conditions.

The 20% decrease and 20% increase in design flows show corresponding decreases and increases respectively in design peak flood level in the study area. The greatest impact of flow changes on peak flood levels (~0.3m) occurs in the upper reaches of both the south and north arm of LT Creek, where channel capacity is significantly lower. Downstream of the confluence, the capacity of the channel is significant, such that flow changes of the order of 20% only provide relatively modest changes in peak flood levels in the reach.

Significantly for the sensitivity tests undertaken, no change in the general flood inundation patterns are noted, with no activation of additional flow paths or major change in flow distribution across the lower catchment.

Table 7-12 Peak 1% AEP Flood Levels for Design Inflow Sensitivity Tests

Location	Design Inflow Condition		
	Adopted	20% Decrease	20% Increase
Fennell Bay (LT Creek)	0.65	0.65 (0.00)	0.65 (0.00)
Fennell Street	0.74	0.71 (-0.03)	0.78 (0.03)
May Street	1.00	0.90 (-0.09)	1.08 (0.08)
Lake Street	1.15	1.03 (-0.12)	1.25 (0.10)
Confluence	1.30	1.17 (-0.13)	1.41 (0.11)
North Arm			
Fassifern Road	2.82	2.52 (-0.36)	2.92 (0.04)
Main North Railway	3.92	3.63 (-0.29)	4.17 (0.25)
South Arm			
Cooper Avenue	2.86	2.64 (-0.23)	3.03 (0.17)
Fassifern Road	3.03	2.81 (-0.22)	3.19 (0.16)
Main North Railway	4.45	4.20 (-0.25)	4.65 (0.20)

Note: Bracketed value is change in peak flood level from standard design conditions

7.4.5 Climate Change Scenarios

Projected sea level rise in Lake Macquarie, as adopted by Council policy, is 0.4m to the year 2050 and 0.9m to the year 2100. These numbers are comparable to the benchmark values recently provided in the draft NSW Sea Level Rise Policy. Accordingly, the consideration of potential sea level rise is in an integral component in the flood planning process.

Sensitivity tests on the design 1% AEP flood condition for the LT Creek catchment have been undertaken using a projected 50-year and 100-year sea level rise scenarios for the Lake Macquarie water level boundary condition. The sea level rise has been applied to the design 20% AEP flood level for Lake Macquarie of 0.65m AHD. The adopted boundary water levels for the sea level rise scenarios are:

- 1.05m AHD – combining 20% AEP design Lake level and sea level rise to year 2050; and
- 1.55m AHD – combining 20% AEP design Lake level and sea level rise to year 2100.

The design Lake Macquarie water level alone provides for significant inundation in the lower parts of the LT Creek catchment. Coupled with major LT Creek catchment flooding, the potential for extensive property inundation has been identified.

The NSW Government has released a guideline for practical consideration of climate change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%. Accordingly, this increase in design rainfall will translate into increased design flood inundation in the LT Creek catchment, such that future planning and floodplain management in the catchment will need to take due consideration of this increased flood risk.

In consultation with Council and DECCW, a range of climate change sensitivity tests incorporating combinations of sea level rise and increased design rainfall intensity have been formulated as shown in Table 7-13. The sensitivity tests have been undertaken for the 1% AEP catchment rainfall event (utilising a 20% AEP Lake flood boundary condition) and the 1% AEP Lake flooding event (incorporating a 1% AEP catchment flood).

Table 7-13 Climate Change Sensitivity Tests

Run No.	Catchment Flood	Sea Level Rise (m)	Rainfall Increase
1	1% AEP	0	0
2	1% AEP	0	10%
3	1% AEP	0	20%
4	1% AEP	0	30%
5	1% AEP	0.4	0
6	1% AEP	0.4	10%
7	1% AEP	0.4	20%
8	1% AEP	0.4	30%
9	1% AEP	0.9	0
10	1% AEP	0.9	10%
11	1% AEP	0.9	20%
12	1% AEP	0.9	30%
Run No.	**Lake Flood**	**Sea Level Rise (m)**	**Rainfall Increase**
13	1% AEP	0.4	0
14	1% AEP	0.9	0

The results of the sensitivity tests are summarised in Table 7-14 to Table 7-17 with reference to the predicted peak flood level for the baseline conditions at selected locations. As with the other sensitivity tests, a map of predicted afflux for selected modelled scenarios is included in Appendix B.

Potential sea level rise has major flooding implications for the lower floodplain of LT Creek downstream of Fassifern Road. As indicated in Table 7-14, the design 1% AEP catchment rainfall event, coupled with possible future Lake Macquarie water levels, provides for significant increases in peak water levels estimates compared to existing conditions. As with other sensitivity tests on downstream boundary conditions, the impact of the sea level rise assumptions extends upstream of the confluence, gradually dissipating to no impact upstream of Fassifern Road.

Table 7-14 Peak 1% AEP Flood Levels with no Sea Level Rise

Location	Assumed Increase in Rainfall Intensity			
	0%	10%	20%	30%
Fennell Bay (LT Creek)	0.65	0.65 (0.00)	0.65 (0.00)	0.65 (0.00)
Fennell Street	0.74	0.76 (0.02)	0.78 (0.04)	0.81 (0.06)
May Street	1.00	1.05 (0.05)	1.10 (0.10)	1.15 (0.16)
Lake Street	1.15	1.22 (0.07)	1.28 (0.13)	1.35 (0.19)
Confluence	1.30	1.38 (0.07)	1.44 (0.14)	1.51 (0.21)
North Arm				
Fassifern Road	2.82	2.90 (0.08)	2.95 (0.13)	3.01 (0.19)
Main North Railway	3.92	4.09 (0.17)	4.24 (0.32)	4.44 (0.52)
South Arm				
Cooper Avenue	2.86	2.96 (0.10)	3.08 (0.22)	3.18 (0.32)
Fassifern Road	3.03	3.12 (0.09)	3.23 (0.20)	3.33 (0.30)
Main North Railway	4.45	4.58 (0.13)	4.70 (0.25)	4.81 (0.36)

Note: Bracketed value is change in peak flood level from standard design conditions

Table 7-15 Peak 1% AEP Flood Levels with 0.4m Sea Level Rise

Location	Assumed Increase in Rainfall Intensity			
	0%	10%	20%	30%
Fennell Bay (LT Creek)	1.05	1.05 (0.00)	1.05 (0.00)	1.05 (0.00)
Fennell Street	1.08	1.09 (0.01)	1.10 (0.02)	1.11 (0.02)
May Street	1.22	1.25 (0.03)	1.28 (0.06)	1.31 (0.09)
Lake Street	1.32	1.37 (0.05)	1.41 (0.09)	1.46 (0.14)
Confluence	1.43	1.48 (0.06)	1.54 (0.11)	1.59 (0.17)
North Arm				
Fassifern Road	2.82	2.90 (0.08)	2.95 (0.13)	3.01 (0.19)
Main North Railway	3.92	4.09 (0.17)	4.24 (0.33)	4.44 (0.52)
South Arm				
Cooper Avenue	2.86	2.96 (0.10)	3.08 (0.22)	3.18 (0.32)
Fassifern Road	3.03	3.12 (0.09)	3.23 (0.20)	3.33 (0.30)
Main North Railway	4.45	4.58 (0.13)	4.70 (0.25)	4.81 (0.36)

Note: Bracketed value is change in peak flood level from standard design conditions

Table 7-16 Peak 1% AEP Flood Levels with 0.9m Sea Level Rise

Location	Assumed Increase in Rainfall Intensity			
	0%	10%	20%	30%
Fennell Bay (LT Creek)	1.55	1.55 (0.00)	1.55 (0.00)	1.55 (0.00)
Fennell Street	1.56	1.56 (0.00)	1.56 (0.00)	1.56 (0.01)
May Street	1.60	1.61 (0.01)	1.61 (0.02)	1.63 (0.03)
Lake Street	1.65	1.66 (0.02)	1.68 (0.04)	1.71 (0.06)
Confluence	1.70	1.73 (0.03)	1.75 (0.05)	1.79 (0.09)
North Arm				
Fassifern Road	2.82	2.90 (0.08)	2.95 (0.13)	3.02 (0.19)
Main North Railway	3.92	4.09 (0.17)	4.24 (0.33)	4.44 (0.52)
South Arm				
Cooper Avenue	2.86	2.96 (0.10)	3.08 (0.22)	3.18 (0.32)
Fassifern Road	3.03	3.12 (0.09)	3.23 (0.20)	3.33 (0.30)
Main North Railway	4.45	4.58 (0.13)	4.70 (0.25)	4.81 (0.36)

Note: Bracketed value is change in peak flood level from standard design conditions

Table 7-17 Peak 1% AEP Catchment and Lake Flooding Condition Incorporating Sea Level Rise

Location	Sea Level Rise		
	0m	0.4m	0.9m
Fennell Bay (LT Creek)	1.38	1.78 (0.40)	2.28 (0.90)
Fennell Street	1.39	1.78 (0.39)	2.28 (0.89)
May Street	1.46	1.80 (0.34)	2.28 (0.83)
Lake Street	1.52	1.83 (0.31)	2.29 (0.77)
Confluence	1.59	1.87 (0.27)	2.31 (0.72)
North Arm			
Fassifern Road	2.82	2.82 (0.00)	2.85 (0.03)
Main North Railway	3.92	3.92 (0.00)	3.92 (0.00)
South Arm			
Cooper Avenue	2.86	2.86 (0.00)	2.86 (0.00)
Fassifern Road	3.03	3.03 (0.00)	3.03 (0.00)
Main North Railway	4.45	4.45 (0.00)	4.45 (0.00)

Note: Bracketed value is change in peak flood level from standard design conditions

7.5 Future Catchment Conditions

The determination of design flood conditions for the LT Creek catchment have been based on existing catchment development conditions. However, there are a number of possible developments in the catchment that have been identified which have the potential to impact on the existing flood behaviour. Whilst not a part of the scope of works for the current flood study, the impact of these developments on flood conditions may need to be considered in future flood studies or floodplain management studies of the LT Creek catchment. Some cursory comment on these developments is provided below.

7.5.1 Newstan Colliery Main Tailings Dam

The construction of the Southern Reject Emplacement Area –Main Tailings Dam at Newstan Colliery was briefly discussed with respect to the June 2007 model calibration in Section 6.3. The dam construction is proposed in stages with a final design height of 52.5m AHD (current height at Stage 2 completion 30m AHD).

The final design height represents a significant structure with a very large volumetric capacity. Indeed, one of the design criteria for the dam is the provision of emergency flood storage for up to the 1 in 100,000 year ARI event (Parsons Brinckerhoff, 2006). This storage capacity would provide for 100% capture of the dam's contributing catchment for many major rainfall events.

To gain an appreciation of the scale of the structure and potential impact on catchment flooding, Figure 7-8 shows the limit of the 52.5m AHD contour upstream of the structure. This extent approximates the potential extent of storage behind the embankment. The storage area occupies a significant proportion of the LT Creek catchment, with a contributing catchment area of some 0.73km^2 (Parsons Brinckerhoff, 2006) representing approximately 10% of the entire LT Creek catchment. Accordingly, some significant changes in the catchment hydrology may occur with construction of the dam to its final height.

It is noted that any major capture of catchment rainfall behind this structure will reduce flood flows downstream, such that the construction of the dam may reduce peak flood levels in some parts of the catchment. There is also the inherent risk of dam failure. Given the potential risks imposed to downstream areas, in particular the developed parts of Fassifern, further investigation of dam-break scenarios should be considered.

It is re-iterated that for the design flood conditions presented in this report, the assumption has been made that the tailings dam provides no attenuation/retention of flood flows. This is a conservative condition dependent upon the state of construction of the dam wall, however, the assumption is representative of a future condition in which the dam is decommissioned and the site is fully rehabilitated. This is considered the most appropriate scenario for future flood planning.

7.5.2 Mine Closure and Rehabilitation

The Newstan Colliery occupies a significant proportion of the LT Creek catchment. Mine closure and site rehabilitation will potentially change the landscape of this area with respect to current conditions. Whilst general catchment topography would not be expected to change, minor local filling or excavations may change local drainage characteristics and flowpath configurations. The ultimate developed state of the colliery is not expected to dramatically change the simulated design flood conditions in Fassifern, however, it is important to benchmark the flood study results with current catchment conditions.

The most significant feature of Newstan Colliery and possible changes following decommissioning will be the Main Tailings Dam as discussed in Section 7.5.1. Whilst not having a major impact in its current state on the design flood conditions presented in this study, subsequent flood investigations of the LT Creek catchment may assess future development conditions associated with this structure and timeframes involved in decommissioning which may include filling and capping.

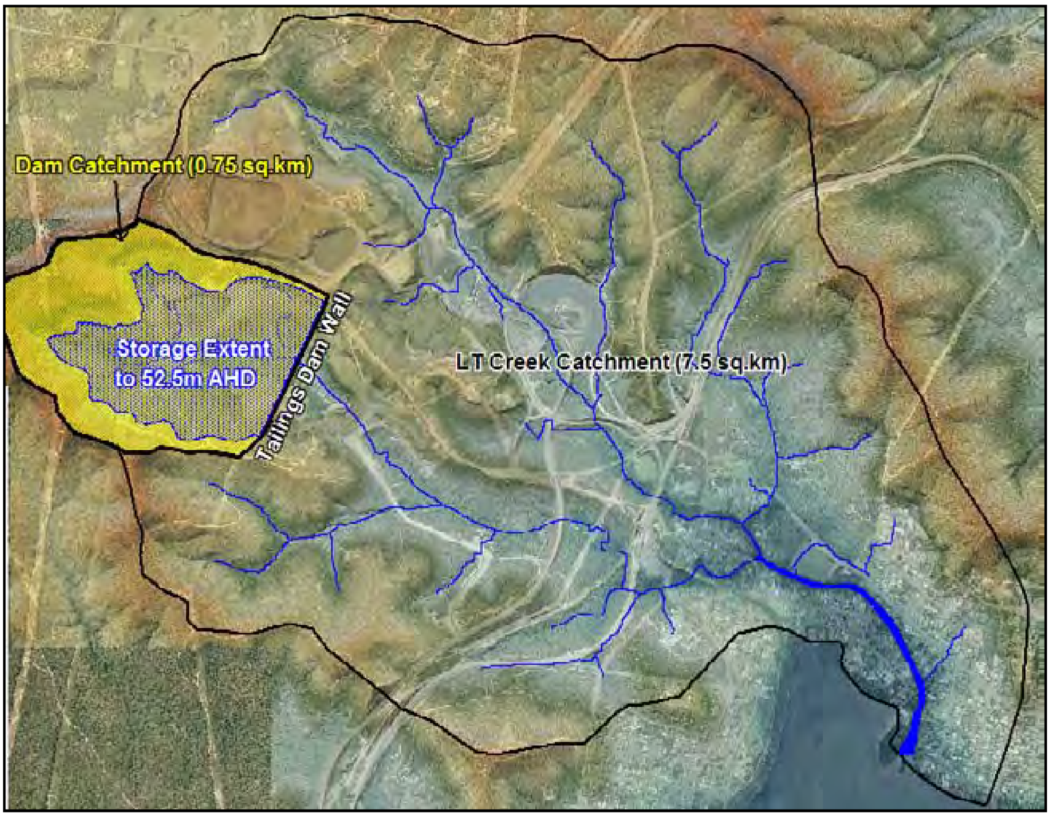


Figure 7-8 Newstan Main Tailings Dam Catchment Area

7.5.3 Future Urban Development

As with other parts of the Lake Macquarie LGA, the LT Creek catchment may be expected to undergo some future development to accommodate the growing population of the region. The majority of the upper catchment, upstream of the Main North Railway, is expected to remain unchanged in the near future. However further development in the lower catchment, adjacent to existing development may be anticipated.

The area north of Macquarie Road is noted on the current LEP as an investigation area. Whilst not expected to have significant impacts on the wider flooding characteristics of LT Creek, there are some implications for increased runoff potential and local flooding.

8 PROPERTY INUNDATION AND FLOOD DAMAGES

A preliminary flood damage assessment has been undertaken to quantify the extent of damages in economic terms for existing flood conditions. The general process for undertaking a flood damages assessment incorporates:

- Identifying properties subject to flooding;
- Determining depth of inundation above floor level for a range of design event magnitudes;
- Defining appropriate stage-damage relationships for various property types/uses;
- Estimating potential flood damage for each property; and
- Calculating the total flood damage for a range of design events.

8.1 Property Inundation

Assessment of potential property inundation and damage has been undertaken as part of the flood study. A property database derived from Council's cadastral and floor level data has been established. Design flood levels calculated from the TUFLOW model were queried from TUFLOW's GIS output at each property reference point. The resulting output was used to identify flooding characteristics such as the frequency of inundation, the depth of inundation and number of properties affected.

A summary of the number of properties potentially affected (i.e. above floor level) by LT Creek catchment and Lake flooding for a range of flood magnitudes is shown in Table 8-1. The distribution of affected properties within the catchment is shown in Figure 8-1 for the catchment flooding condition and Figure 8-2 for the Lake Macquarie flooding condition.

Table 8-1 Property Inundation Results

Design event	No. of properties with above floor flooding*
5% AEP Catchment Flood	0
1% AEP Catchment Flood	0
0.5% AEP Catchment Flood	0
1% AEP Catchment Flood with 0.4m sea level rise	0
1% AEP Catchment Flood with 0.9m sea level rise	15
1% AEP Lake Flood	7
1% AEP Lake Flood with 0.4m sea level rise	39
1% AEP Lake Flood with 0.9m sea level rise	85
PMF Catchment Flood	52
PMF Catchment Flood with 0.9m sea level rise	53
PMF Lake Flood	108
PMF Lake Flood with 0.9m sea level rise	131

Title:

Potential Property Inundation - Catchment Flooding

Figure: 8-1

Rev. A

N

0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

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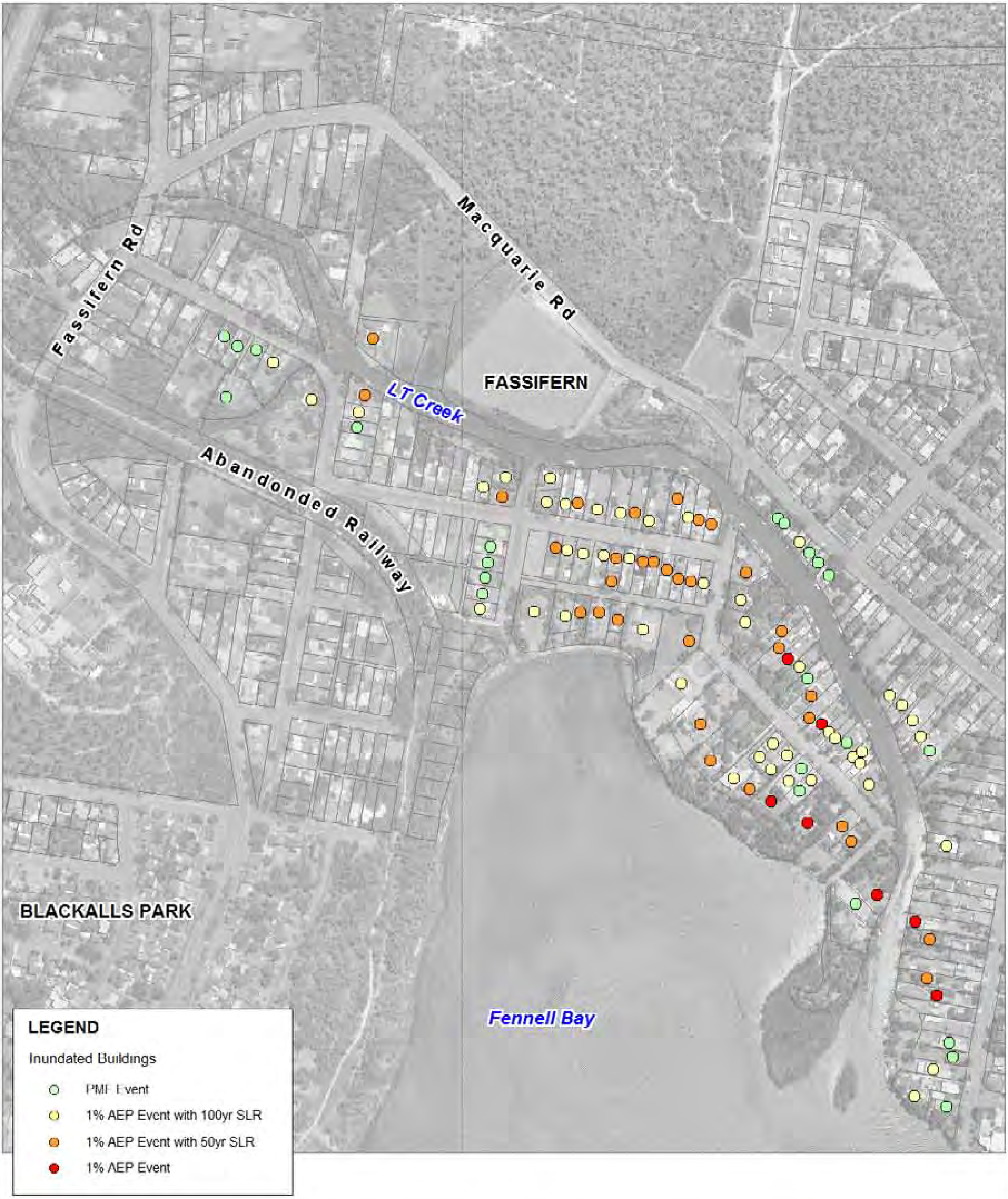

Title:
Potential Property Inundation - Lake Flooding

Figure:
8-2

Rev:
A

N

0 100 200m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_036_100604_Property_Inundation_Lake.WOR

No properties have been identified at risk of above floor flooding up the 1% AEP catchment rainfall event. As indicated, a small number of properties are identified from 1% AEP Lake Macquarie flooding however. The number of flood affected properties increases substantially considering both sea level rise scenarios and extreme event catchment flooding.

8.2 Basis of Flood Damage Calculations

Flood damages have been calculated using the database of potentially flood affected properties and stage-damage curves that relate the amount of flood damage that would potentially occur at different depths of inundation for various property types. The damages assessment has been limited to properties and does not include public infrastructure such as roadways, drainage systems etc.

Residential damage curves have been based on the DECC guideline stage-damage curves for residential property. Different stage-damage curves are generally derived for different type of residential dwelling size and construction type. In the absence of a comprehensive database of property classification in the study areas, the damage calculations are based on a single curve derived for the "Single Storey Slab on Ground/Low Set" category as defined in the DECC guideline. These assumptions may be reviewed/updated in formal floodplain management studies that may be undertaken in the future.

The adopted stage-damage curves and underlying assumptions are shown in Appendix F.

8.3 Summary of Flood Damages

The assessment of flood damages has considered LT Creek catchment flooding only; separate from the influence of broader Lake Macquarie flooding. The peak flood depth was determined at each property for the 5% AEP, 1% AEP and PMF events and the associated flood damage cost estimated from the stage-damage relationships. Total damages for each event were determined by summing the predicted damages for each individual dwelling. Table 8-2 provides a summary of the flood damage calculations for the study areas.

Table 8-2 Predicted Flood Damages for Catchment Derived Flooding

Design Event Frequency				Average Annual Damage
5% AEP	1% AEP	0.5% AEP	PMF	
$0K	$18K	$18K	$2.8M	$7K

The Average Annual Damage (AAD) is the average damage in dollars per year that would occur in a designated area from flooding over an extended period of time. It is estimated as the area under the damage versus probability curve. For the estimation of the AAD it was assumed a return period of 10,000 years was representative for the PMF.

The estimated damages reflect the relatively low flood risk posed to existing property from catchment rainfall derived flooding of LT Creek. However, as discussed, the number of properties affected by flooding and the associated damages increase with consideration of major flooding of the Lake Macquarie waterway and potential sea level rise.

9 CONCLUSIONS

The objective of the study was to undertake a detailed flood study of the LT Creek catchment and establish models as necessary for accurate flood level prediction. Central to this was the development of a two-dimensional hydraulic model of the floodplain for the lower catchment incorporating parts of Fassifern and Fennell Bay.

In completing the flood study, the following activities were undertaken:

- Collation of database of historical flood information for the LT Creek catchment including data from the June 2007 event;
- Acquisition of topographical data for the catchment including cross section and hydraulic structure survey;
- Consultation with the community to acquire historical flood information and liaison in regard to flooding concerns/perceptions and future floodplain management activities;
- Development of a hydrological model (using RAFTS-XP software) and hydraulic model (using TUFLOW software) to simulate flood behaviour in the catchment;
- Calibration of the developed models using the June 2007 and February 1981 flood events;
- Prediction of design flood conditions in the catchment, particularly around existing development at Fassifern, using the calibrated models,
- Production of design flood mapping series.

The flood study will form the basis for the subsequent floodplain risk management activities, being the next stage of the floodplain management process. Accordingly, the adoption of the flood study and predicted design flood levels is recommended.

Given the significant influence of Lake Macquarie flooding on the predicted flood behaviour of the Lower LT Creek catchment, future flood studies and floodplain management studies relating to the broader Lake Macquarie waterway should feed back into the LT Creek floodplain management process. Floodplain management in the LT catchment should be a dynamic process and respond to changes in available flood information, catchment changes and future development, and Council and State government policy in an appropriate manner. Sea level rise adaptation is expected to be a key component of floodplain management in the LT Creek catchment given the potential impact on design flood conditions in the lower parts of LT Creek as demonstrated in this study.

A number of additional flooding risks within the LT Creek catchment have been identified during the course of the study. These include the potential failure of the Newstan Southern Reject emplacement Area and failure of one or more of the existing road/rail embankments within the catchment. It is recommended that future floodplain management activities in the catchment investigate in further detail these risks.

10 REFERENCES

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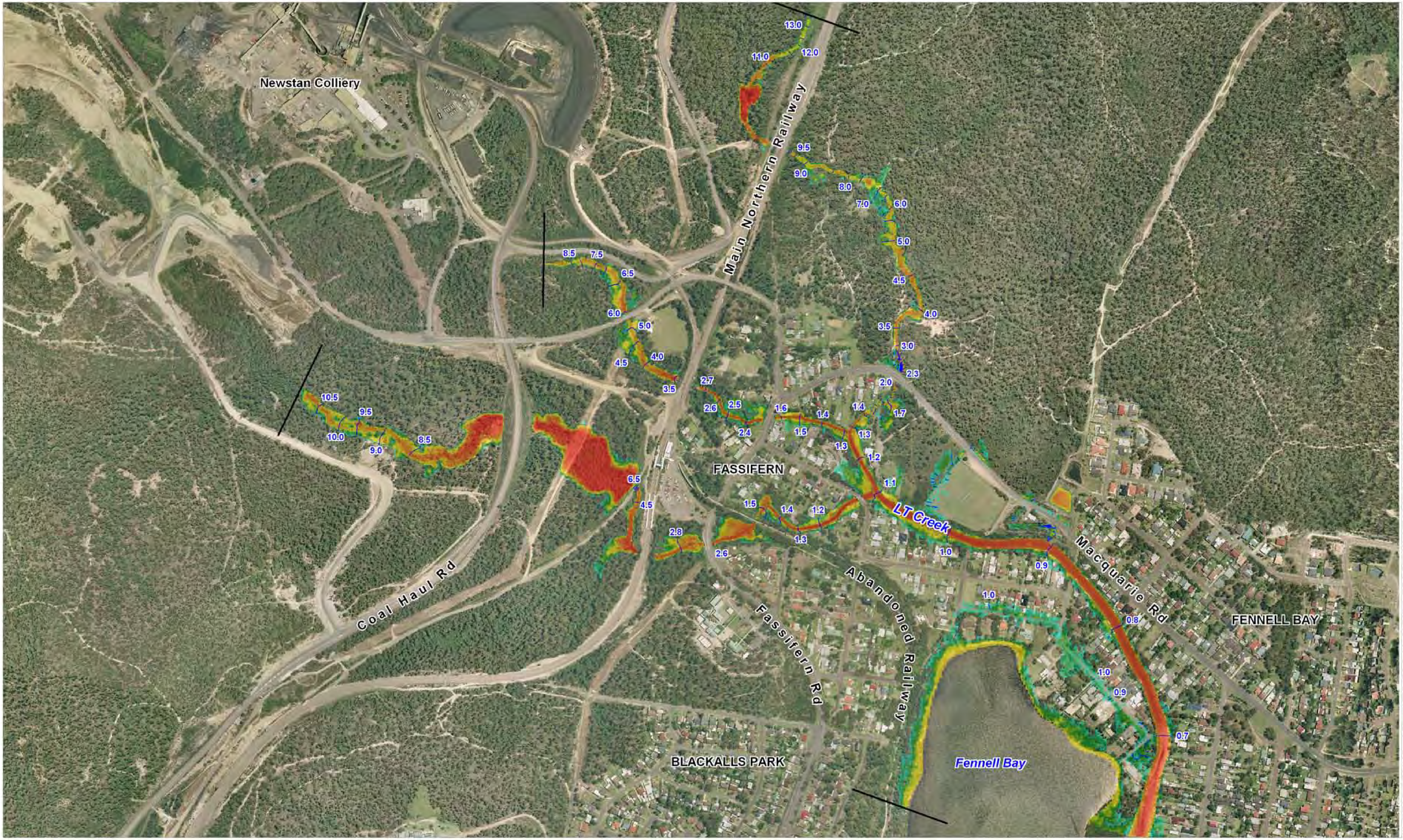
APPENDIX A: DESIGN FLOOD MAPPING



LEGEND

Maximum Flood Depth (m)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Water Level Contour (m AHD)

Note: Contour interval is 0.1m below 3m AHD and 0.5m above 3m AHD

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Depths and Water Levels: 5% AEP Event

Figure: **A-1**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

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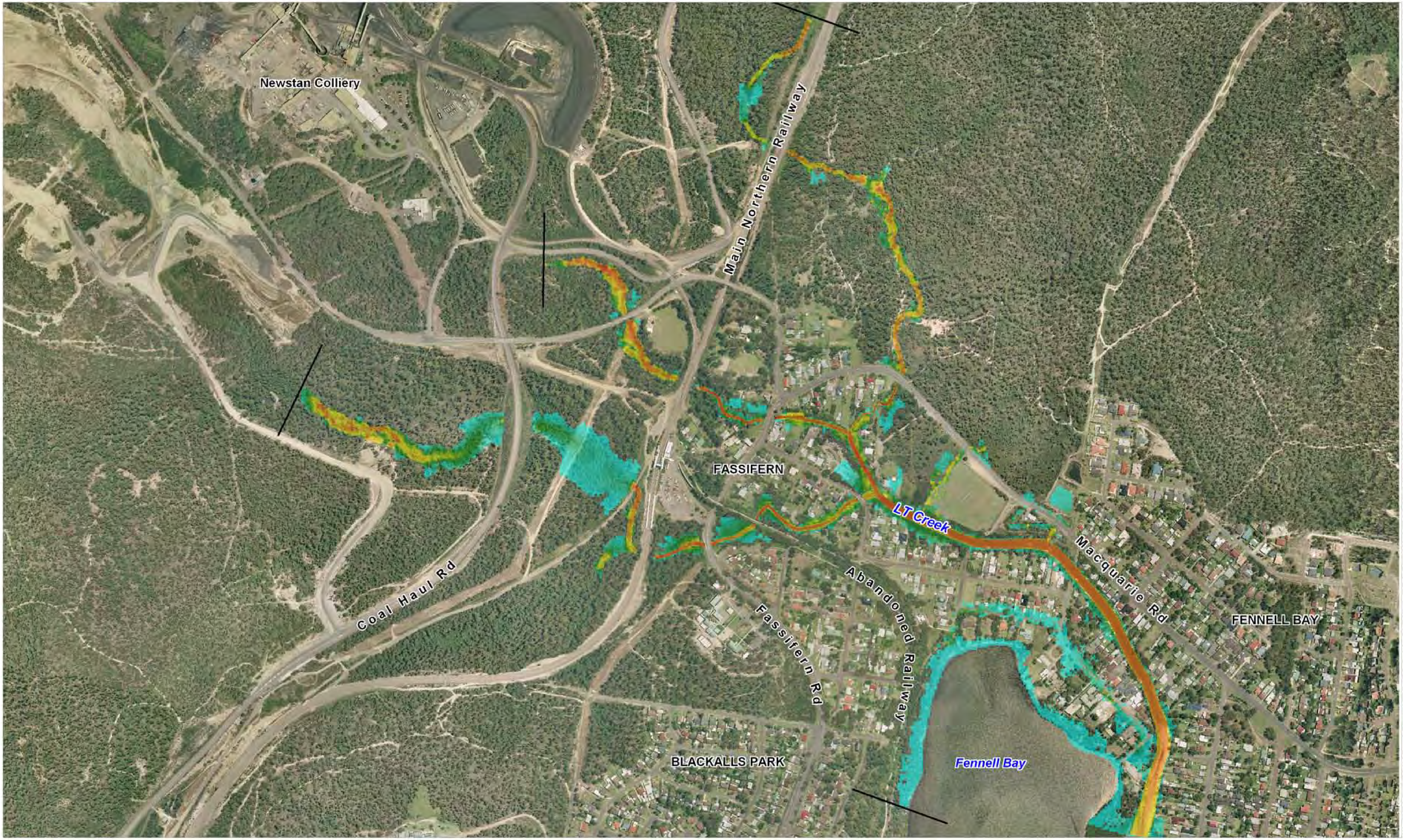

LEGEND

Maximum Flood Velocity (m/s)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Velocities: 5% AEP Event

Figure: **A-2**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

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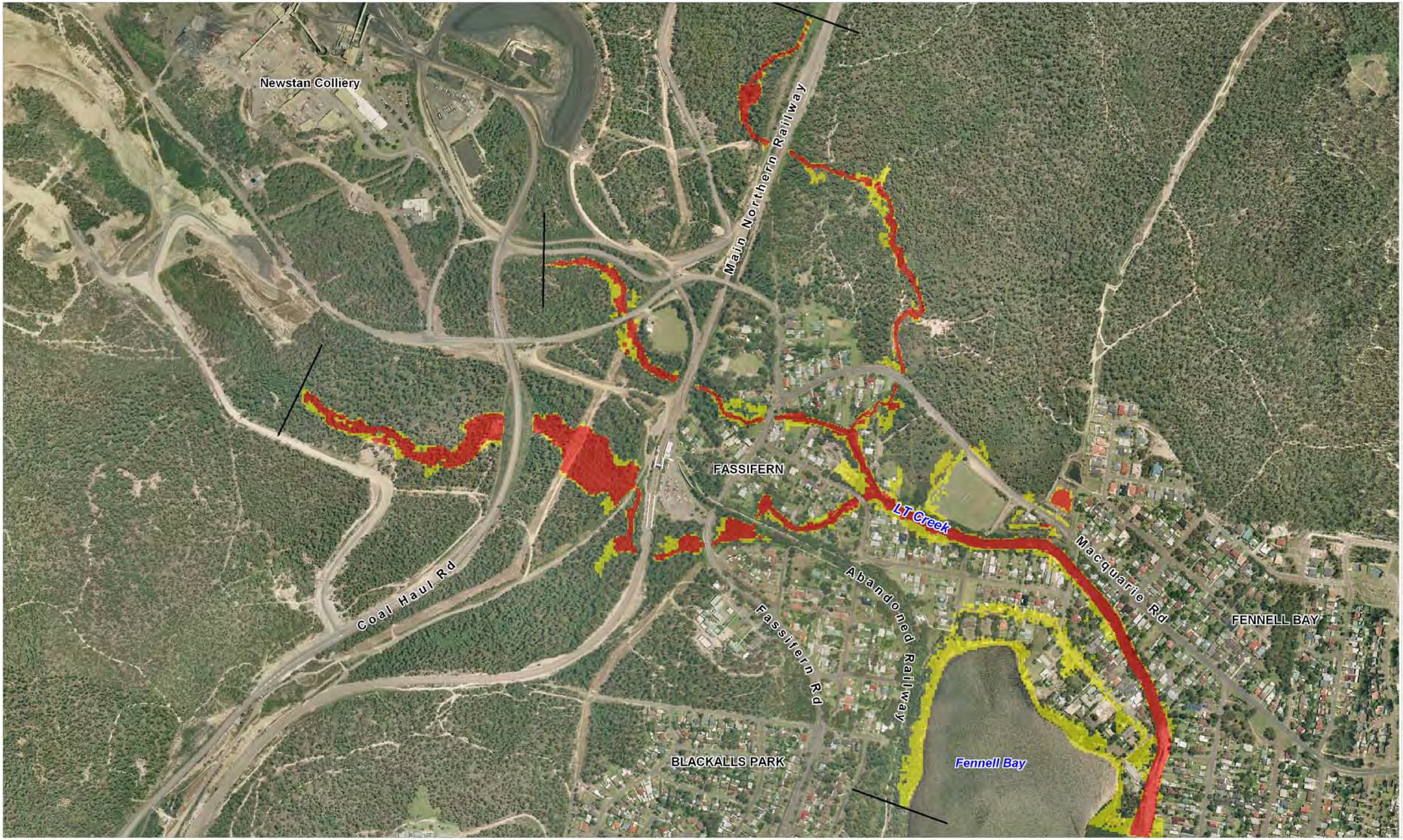

LEGEND

Maximum Flood Hazard

- Low Hazard
- High Hazard
- Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Hazard: 5% AEP Event

Figure: **A-3**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

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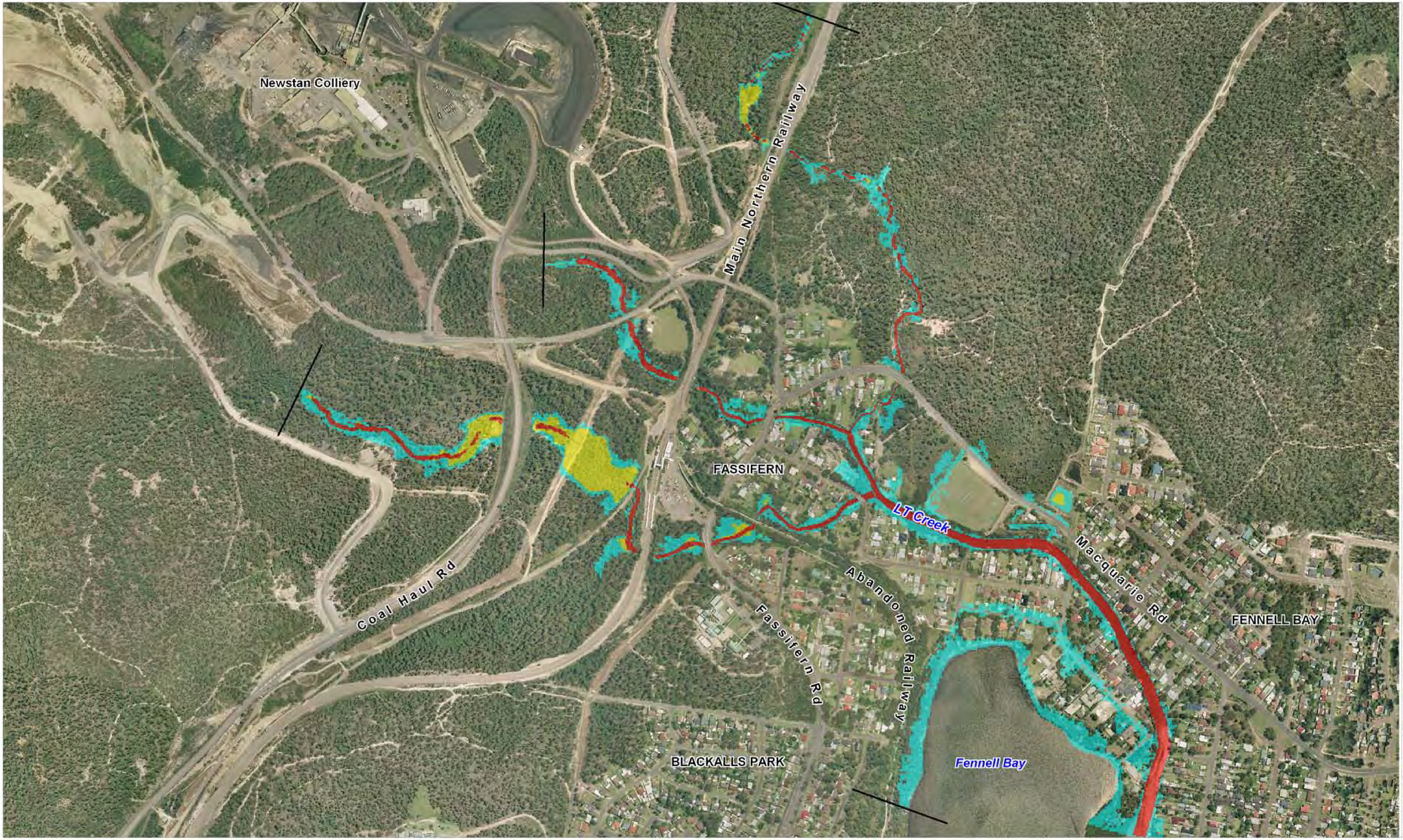

LEGEND

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

Limit of Modelled Area

Title:
LT Creek Flood Study
Hydraulic Categories: 5% AEP Event

Figure: A-4

Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
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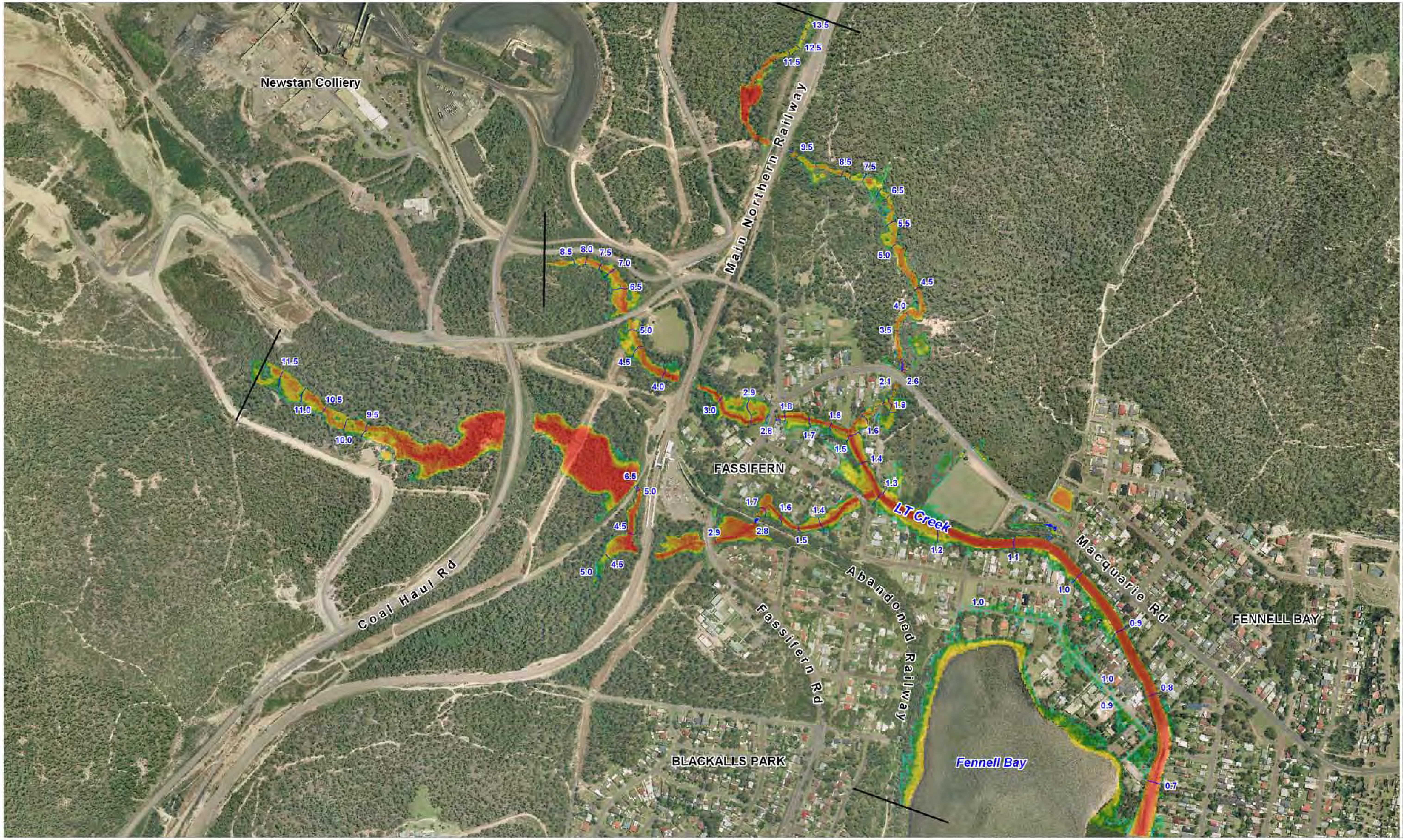

LEGEND

Maximum Flood Depth (m)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Water Level Contour (m AHD)

Note: Contour interval is 0.1m below 3m AHD and 0.5m above 3m AHD

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Depths and Water Levels: 1% AEP Event

Figure: **A-5**

Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

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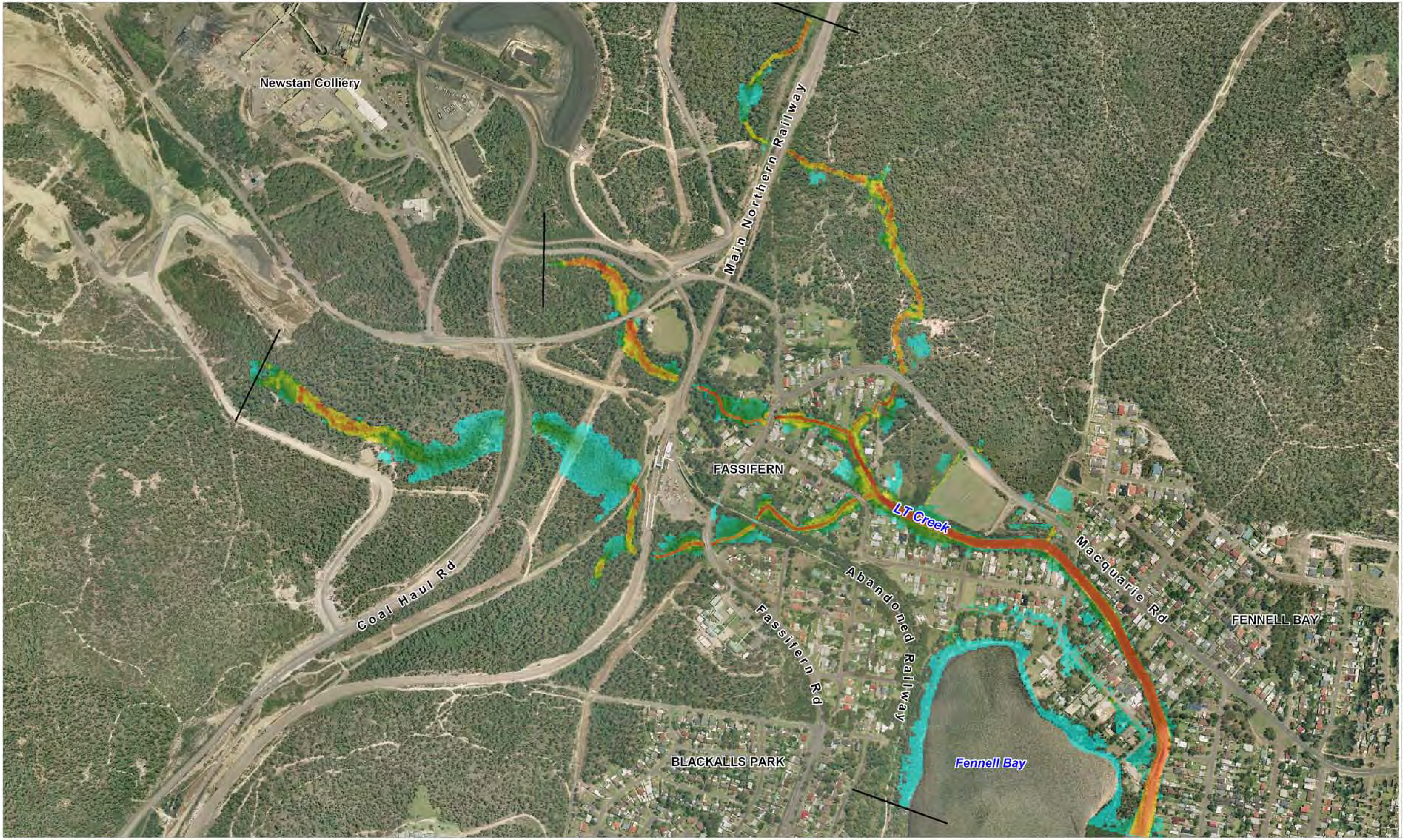

LEGEND

Maximum Flood Velocity (m/s)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Velocities: 1% AEP Event

Figure: A-6

Rev: A

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N

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Approx. Scale

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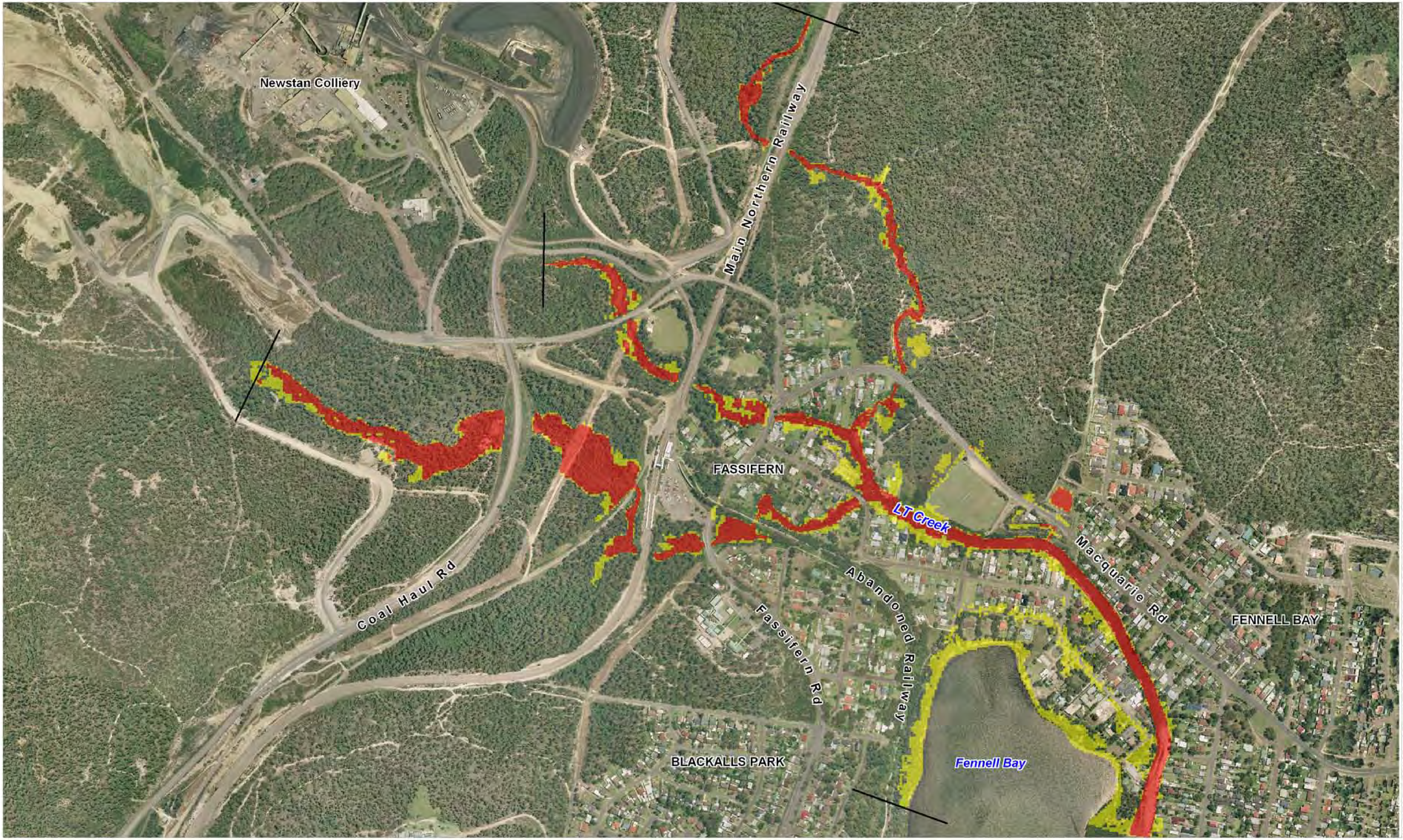

LEGEND

Maximum Flood Hazard

- Low Hazard
- High Hazard
- Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Hazard: 1% AEP Event

Figure: **A-7**

Rev: **A**

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N

0 125 250m
Approx. Scale

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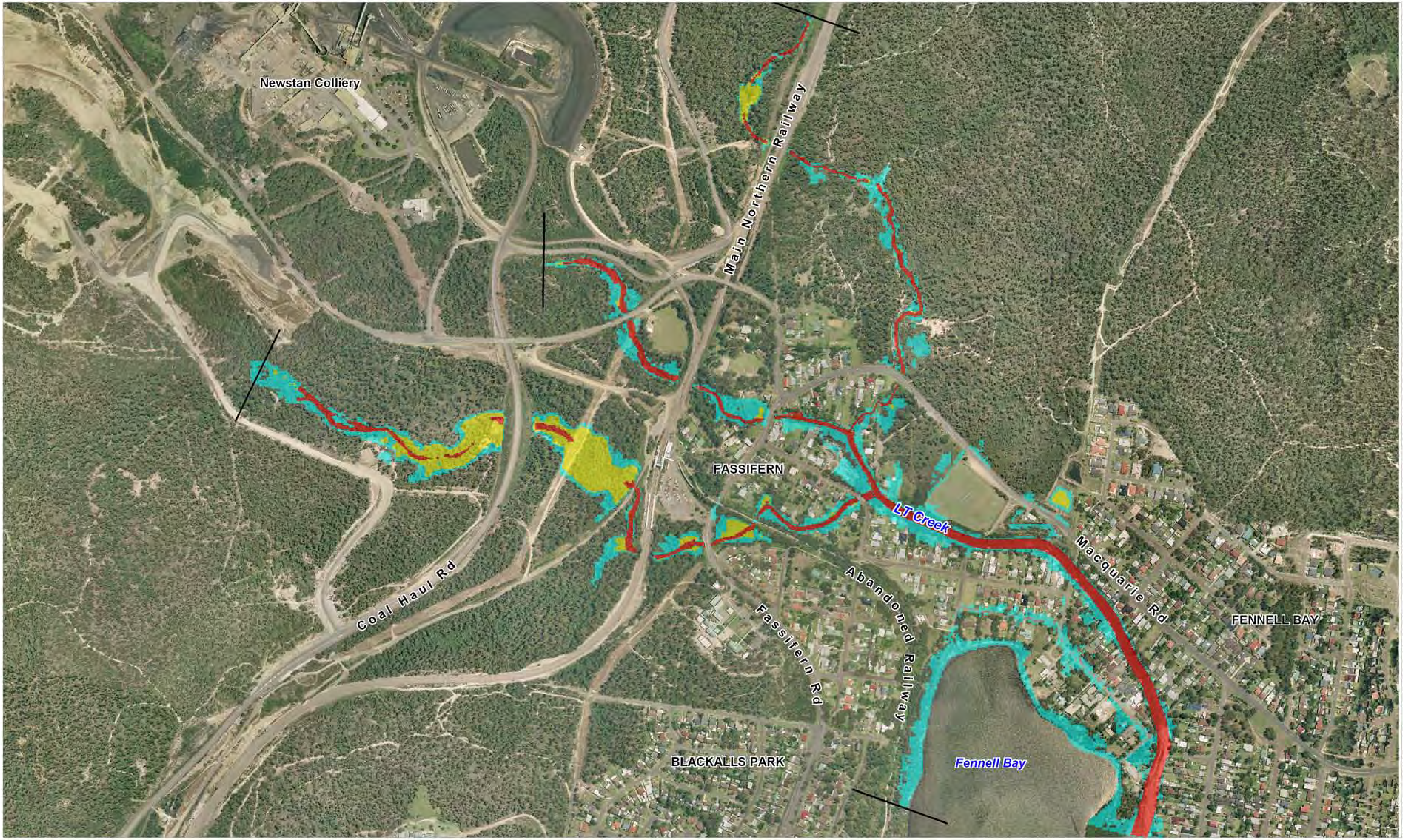

LEGEND

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

Limit of Modelled Area

Title:

LT Creek Flood Study
Hydraulic Categories: 1% AEP Event

Figure: **A-8**

Rev: **A**

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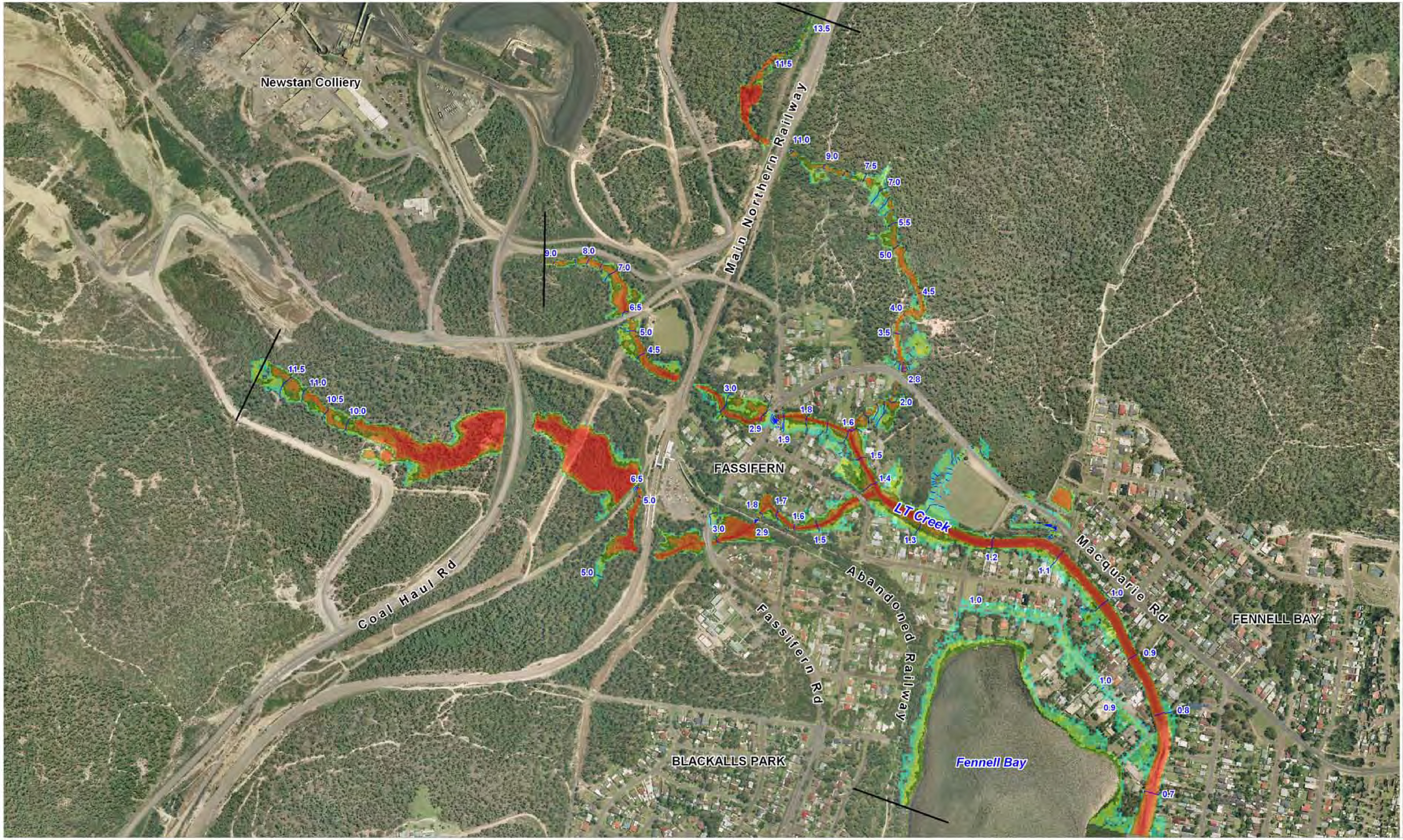
N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_024_090812_Hydraulic_Categories_100yr.WOR



LEGEND

Maximum Flood Depth (m)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

1.3 Water Level Contour (m AHD)

Note: Contour interval is 0.1m below 3m AHD and 0.5m above 3m AHD

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Depths and Water Levels: 0.5% AEP Event

Figure: **A-9**

Rev: **A**

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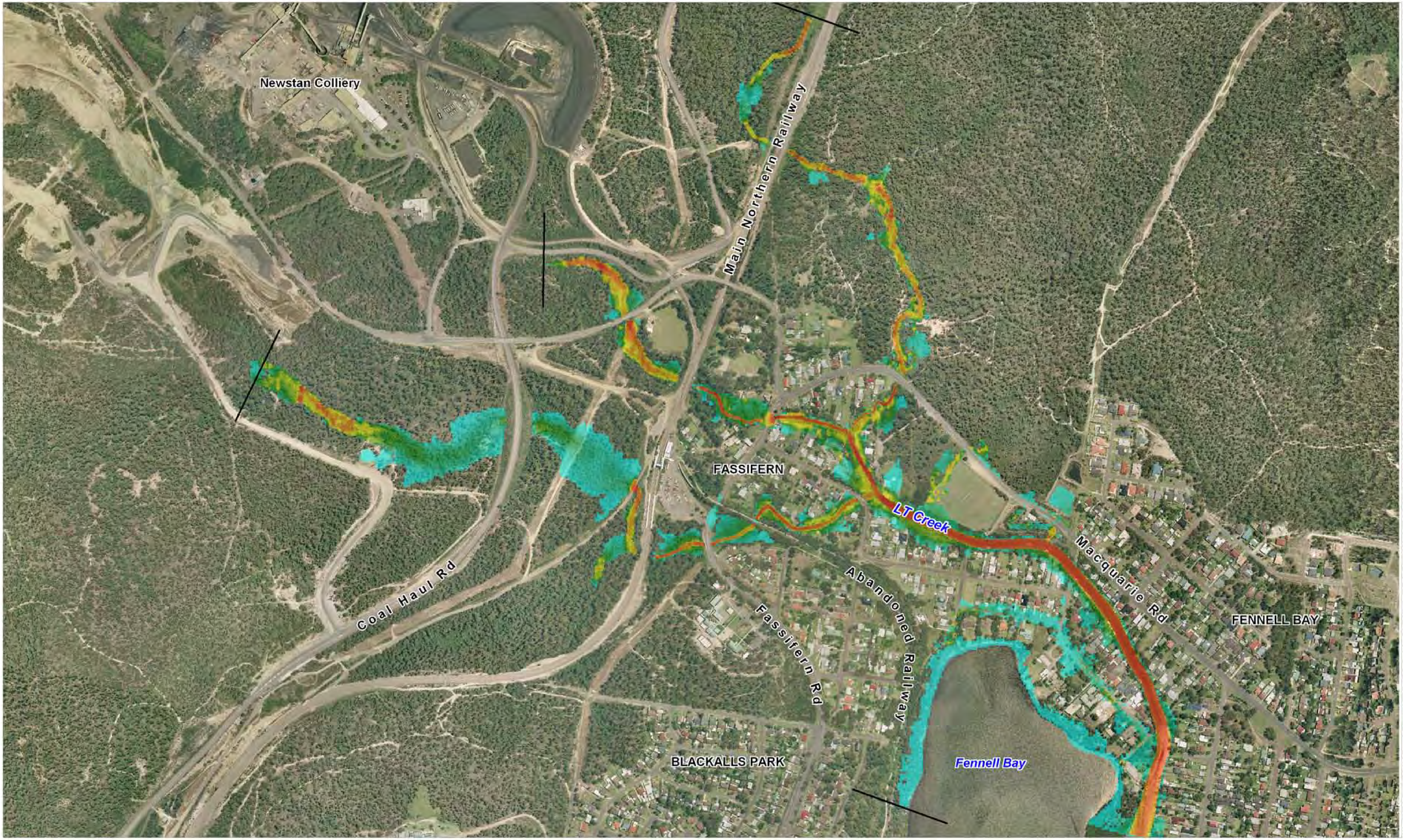
N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_037_100804_Flood_Depth_200yr.WOR



LEGEND

Maximum Flood Velocity (m/s)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Velocities: 0.5% AEP Event

Figure: **A-10**

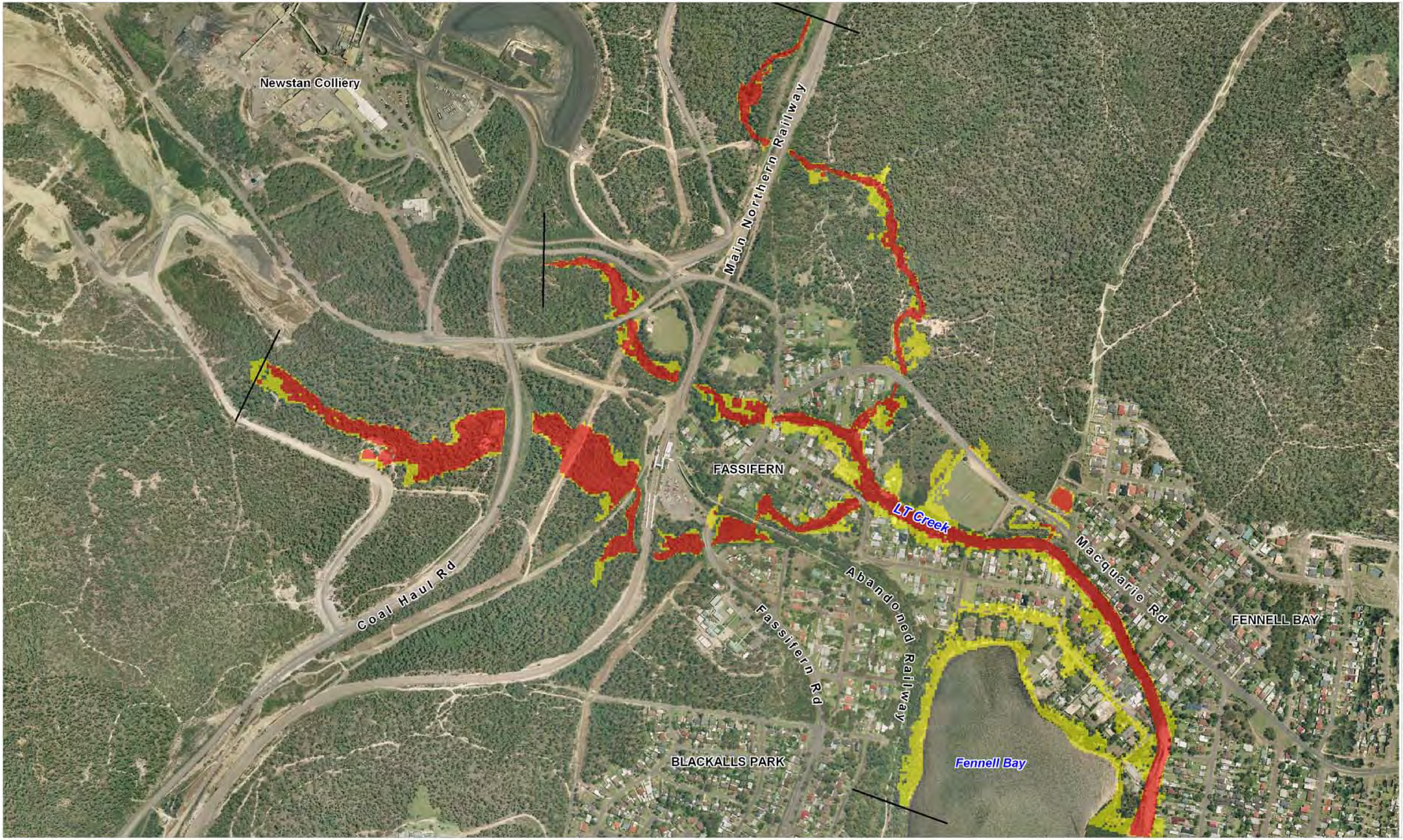
Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_038_100804_Flood_Velocity_200yr.WOR



LEGEND

Maximum Flood Hazard

- Low Hazard
- High Hazard
- Limit of Modelled Area

Title:

LT Creek Flood Study
Maximum Flood Hazard: 0.5% AEP Event

Figure: **A-11**

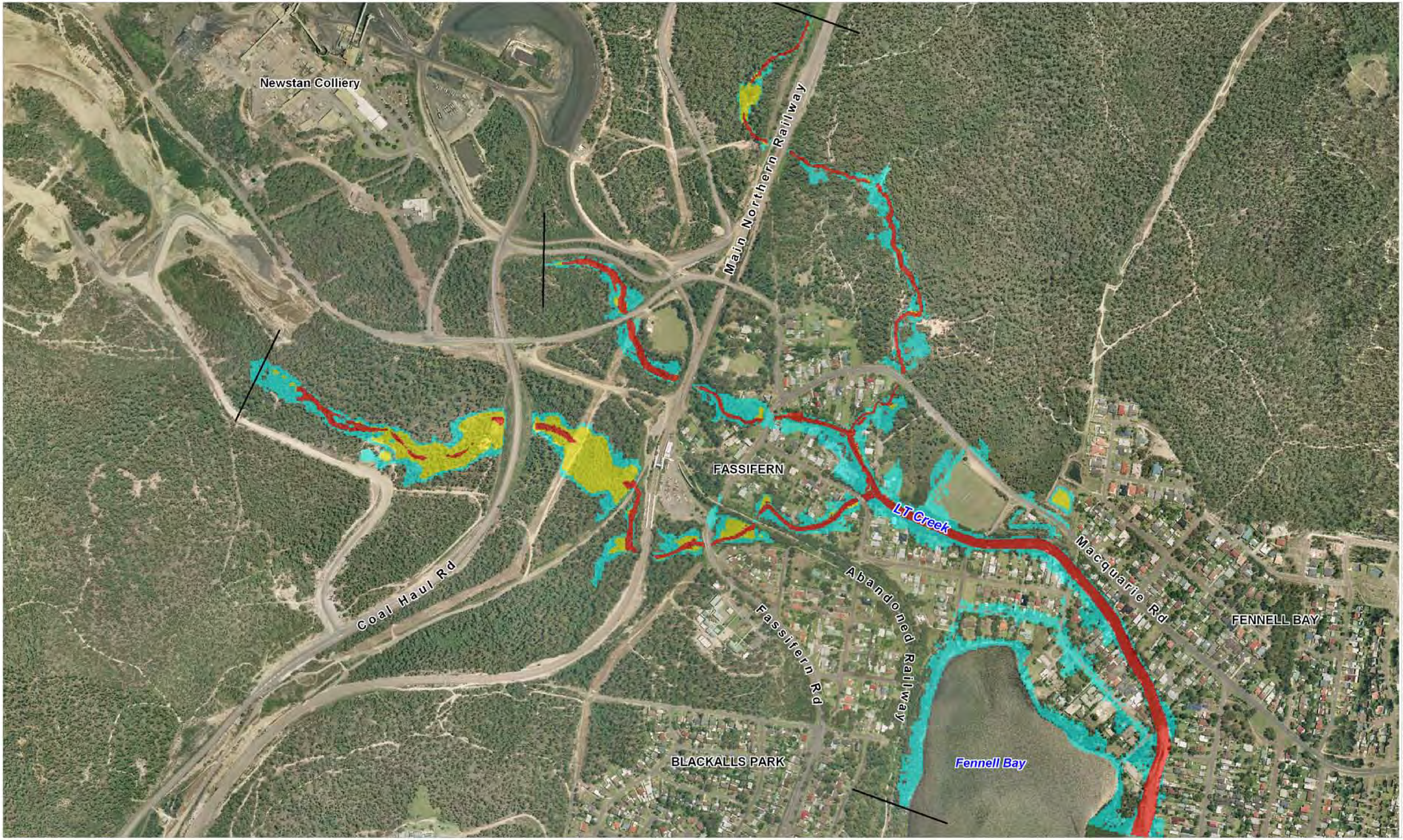
Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_039_100804_Flood_Hazard_200yr.WOR



LEGEND

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

Limit of Modelled Area

Title:

LT Creek Flood Study
Hydraulic Categories: 0.5% AEP Event

Figure: A-12

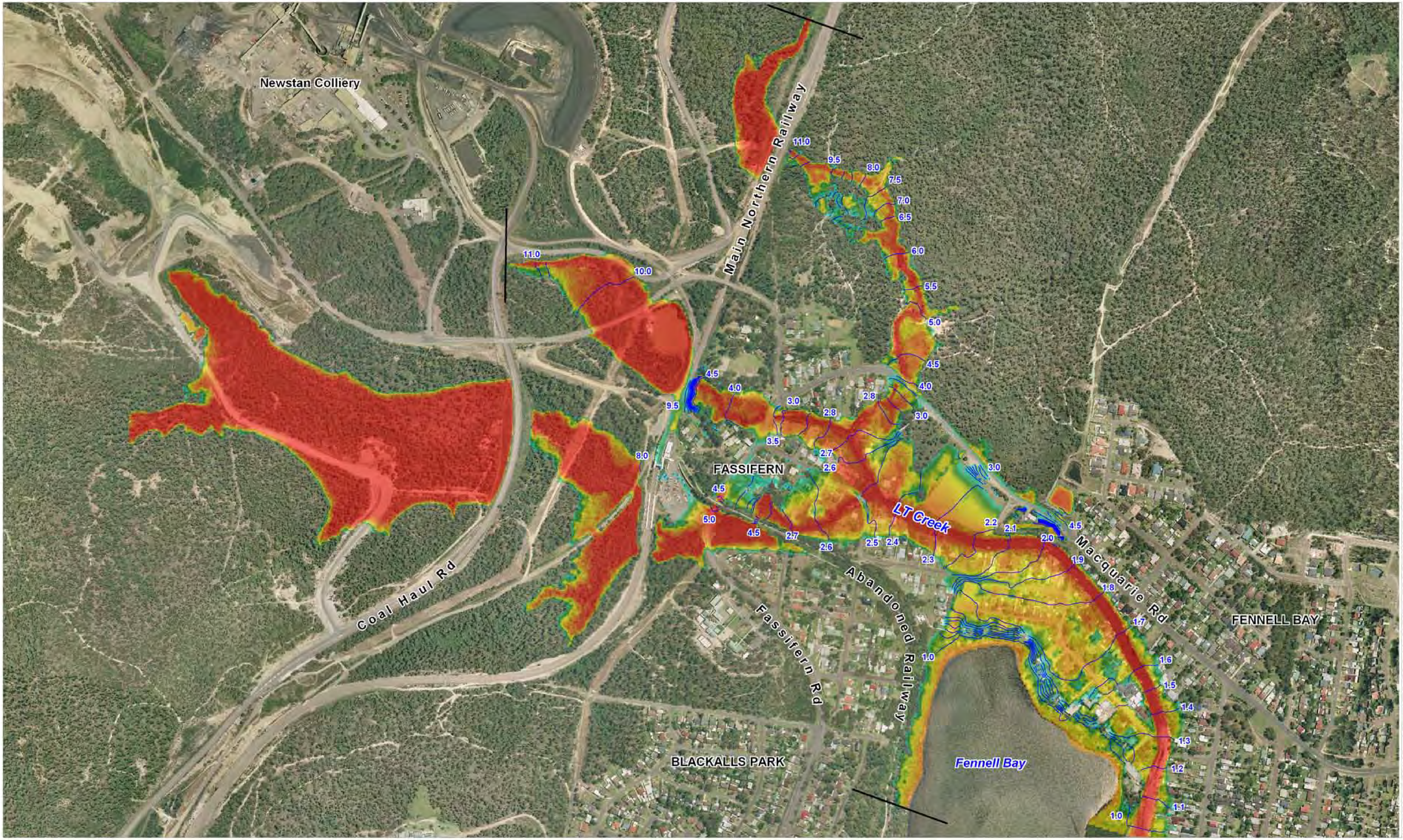
Rev: A

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_040_100804_Hydraulic_Categories_200yr.WOR



LEGEND

Maximum Flood Depth (m)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

1.3 Water Level Contour (m AHD)
Note: Contour interval is 0.5m

Limit of Modelled Area
Note: Flooding shown upstream of these locations is the backwater influence of structures located downstream

Title:
LT Creek Flood Study
Maximum Flood Depths and Water Levels: PMF Event

Figure: **A-13**

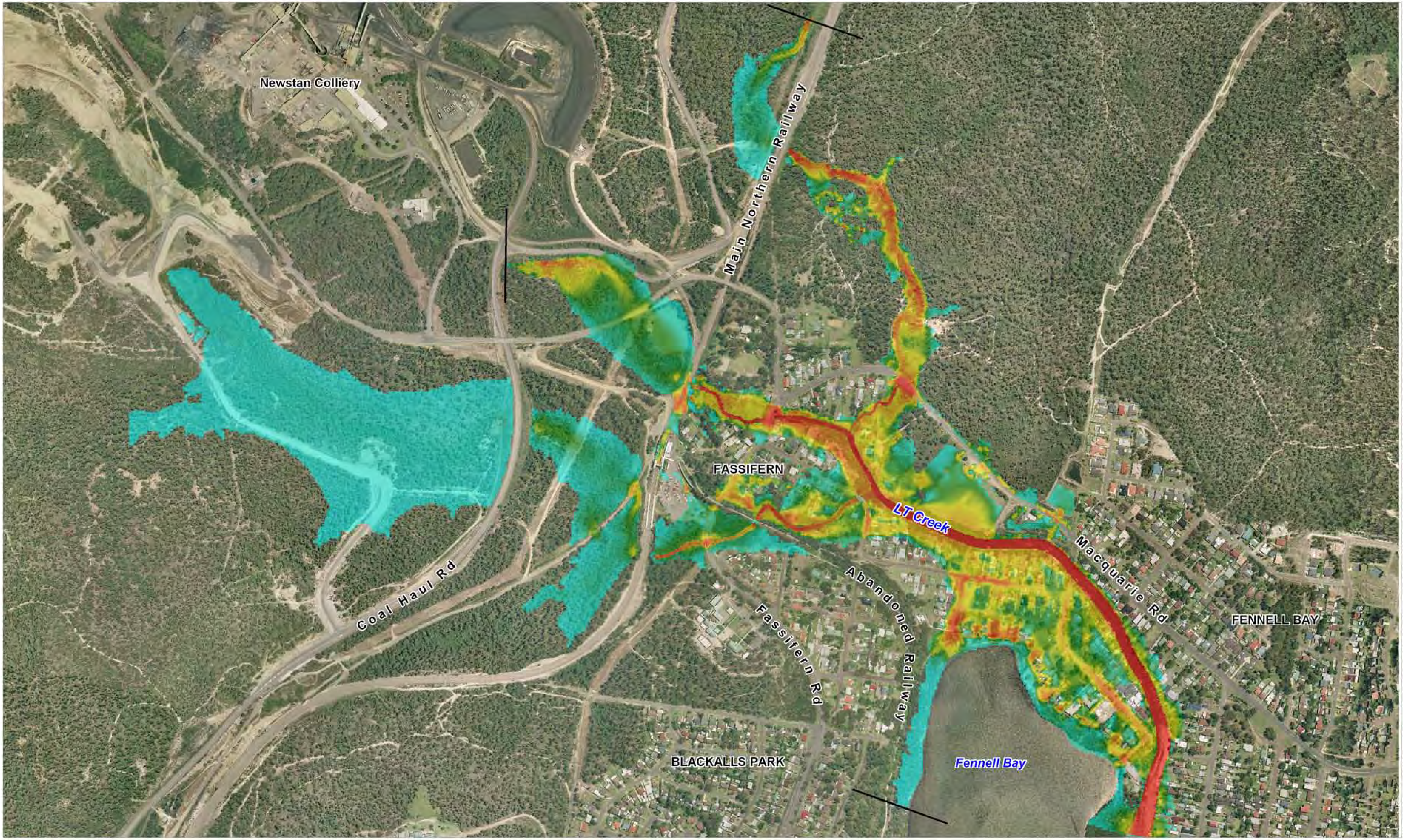
Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_017_090812_Flood_Depth_PMF.WOR



LEGEND

Maximum Flood Velocity (m/s)

- 0.10
- 0.25
- 0.50
- 1.00
- 2.00

Limit of Modelled Area

Note: Flooding shown upstream of these locations is the backwater influence of structures located downstream

Title:

LT Creek Flood Study
Maximum Flood Velocities: PMF Event

Figure: **A-14**

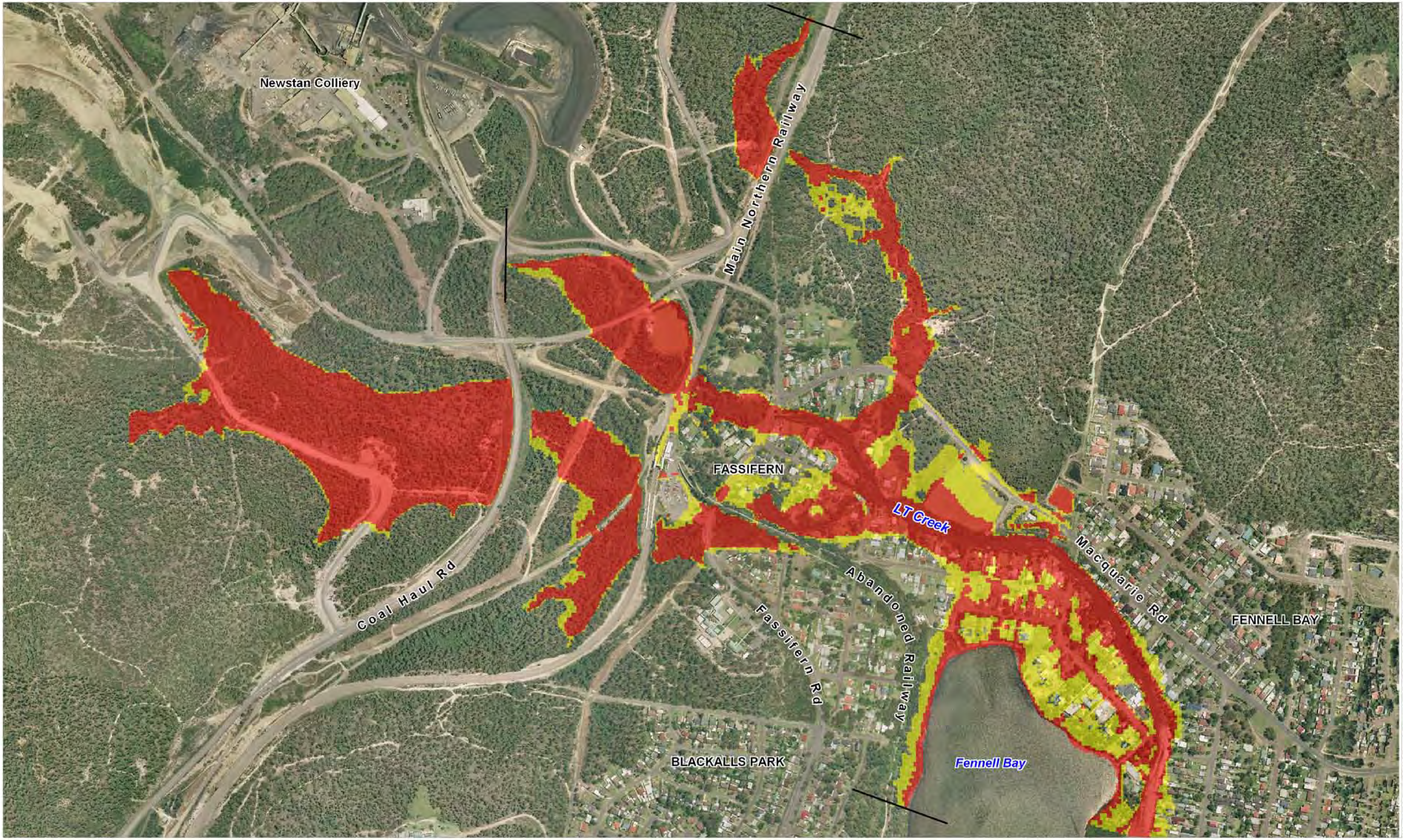
Rev: **A**

N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_020_090812_Flood_Velocity_PMF.WOR



LEGEND

Maximum Flood Hazard

- Low Hazard
- High Hazard

Limit of Modelled Area

Note: Flooding shown upstream of these locations is the backwater influence of structures located downstream

Title:

LT Creek Flood Study
Maximum Flood Hazard: PMF Event

Figure: **A-15**

Rev: **A**

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N

0 125 250m
Approx. Scale

BMT WBM
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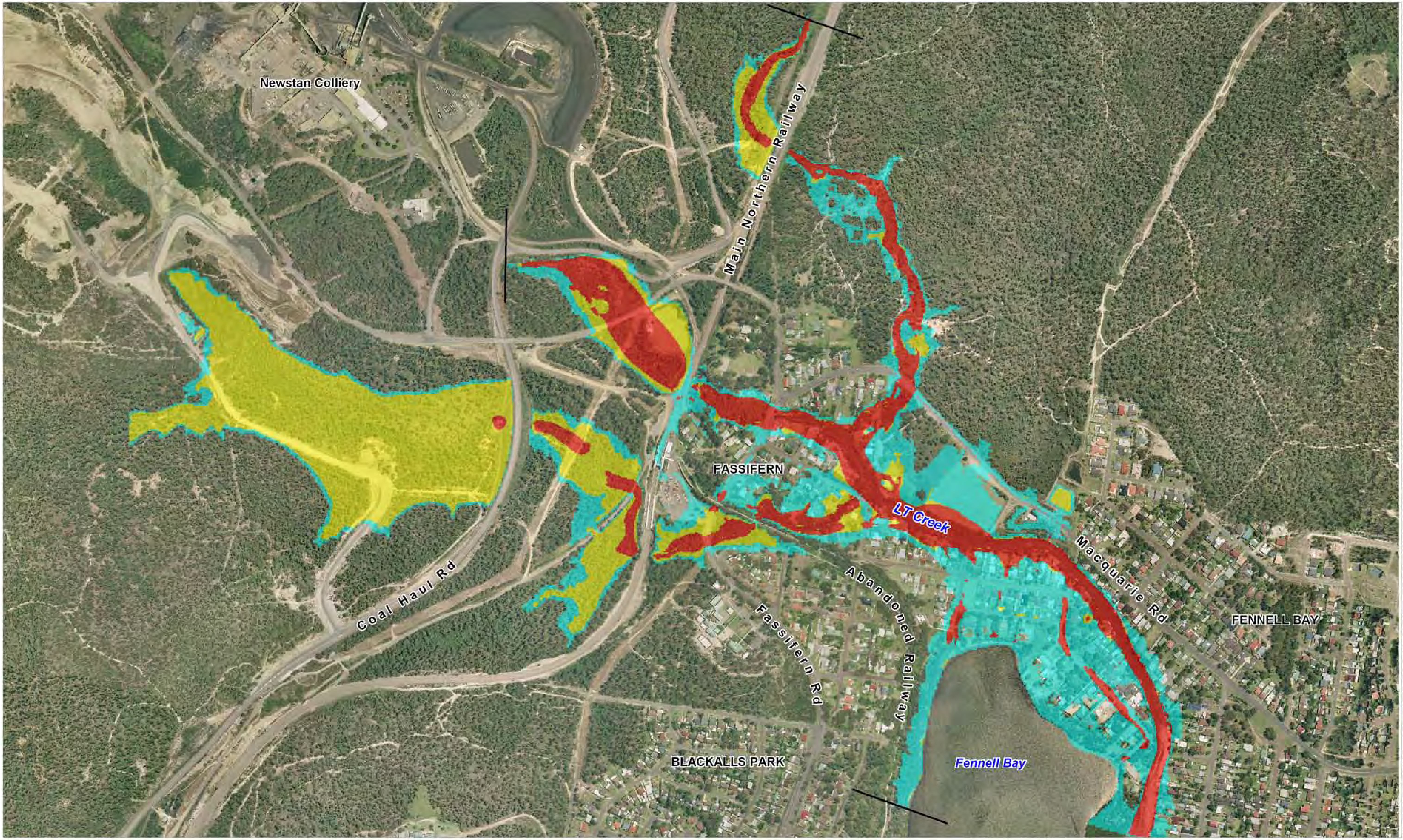
Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_023_090812_Flood_Hazard_PMF.WOR



LEGEND

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

Limit of Modelled Area

Note: Flooding shown upstream of these locations is the backwater influence of structures located downstream

Title:

LT Creek Flood Study
Hydraulic Categories: PMF Event

Figure: **A-16**

Rev: **A**

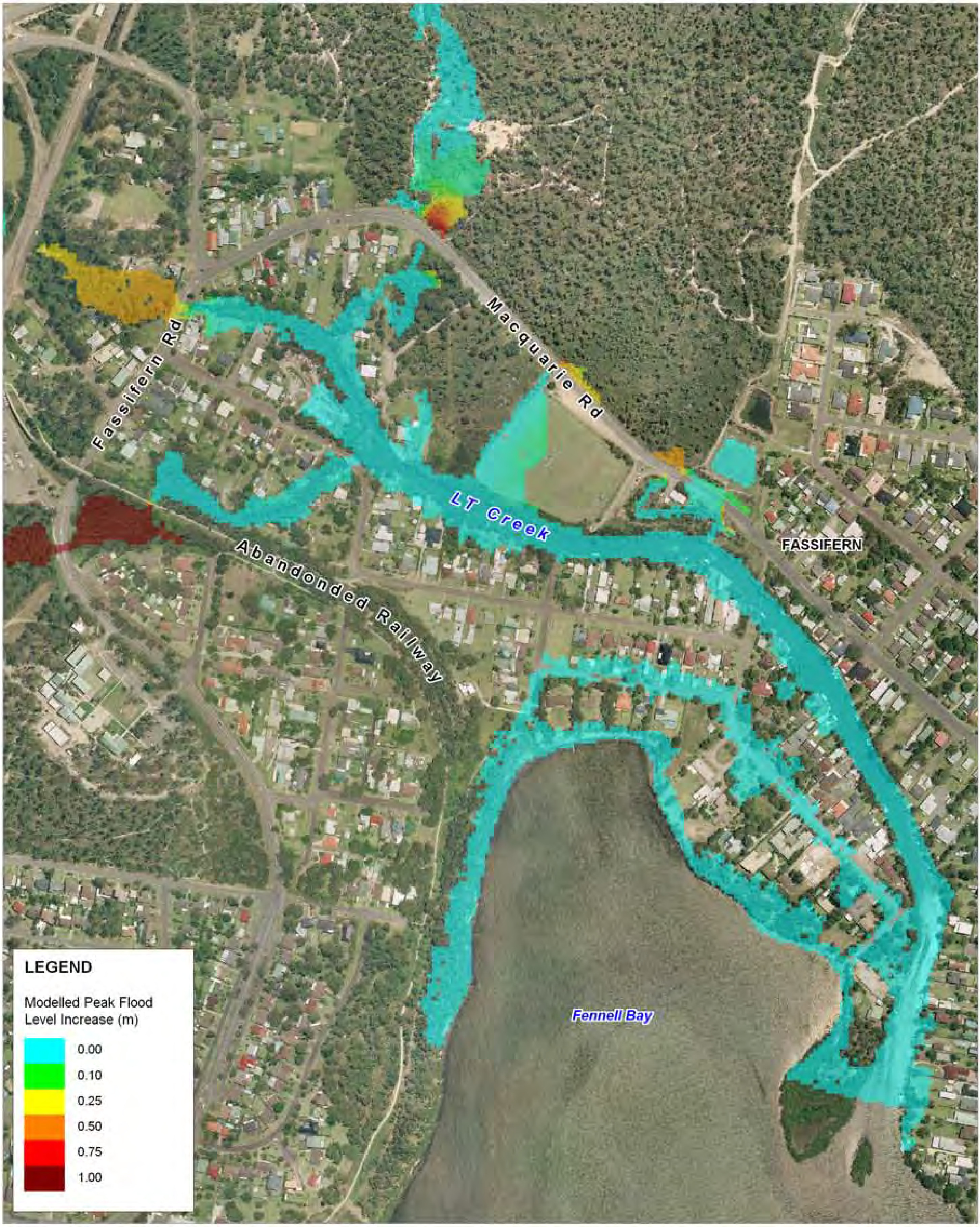
N

0 125 250m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_026_090812_Hydraulic_Categories_PMF.WOR

APPENDIX B: SENSITIVITY TESTS – FLOOD IMPACT MAPPING



Title:

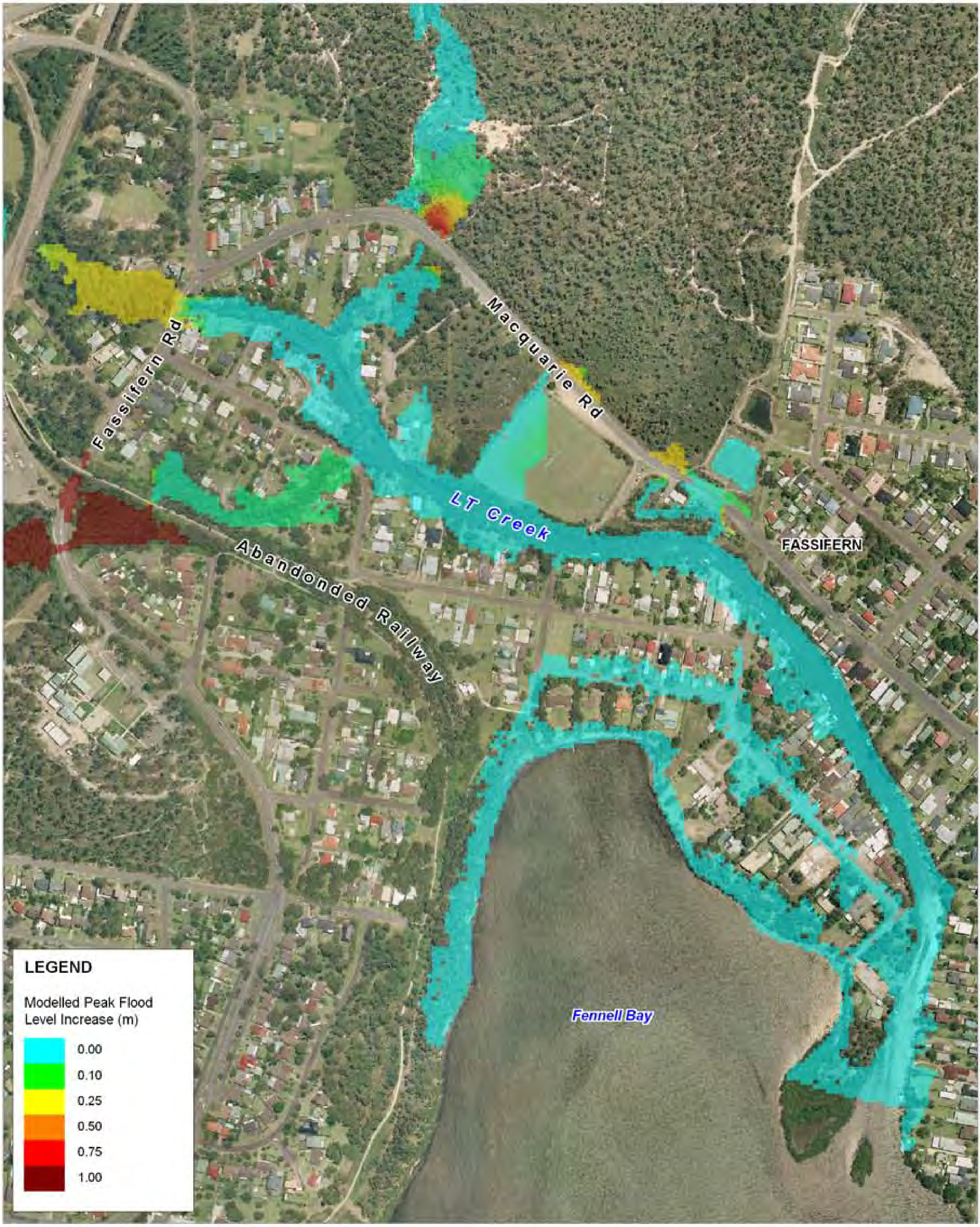
Peak Flood Level Afflux - Structure Blockage 5% AEP Event

Figure: **B-1**

Rev: **A**

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_031_090813_Afflux_20yr_Blockage.WOR



Title:

Peak Flood Level Afflux - Structure Blockage 1% AEP Event

Figure: **B-2**

Rev: **A**

N

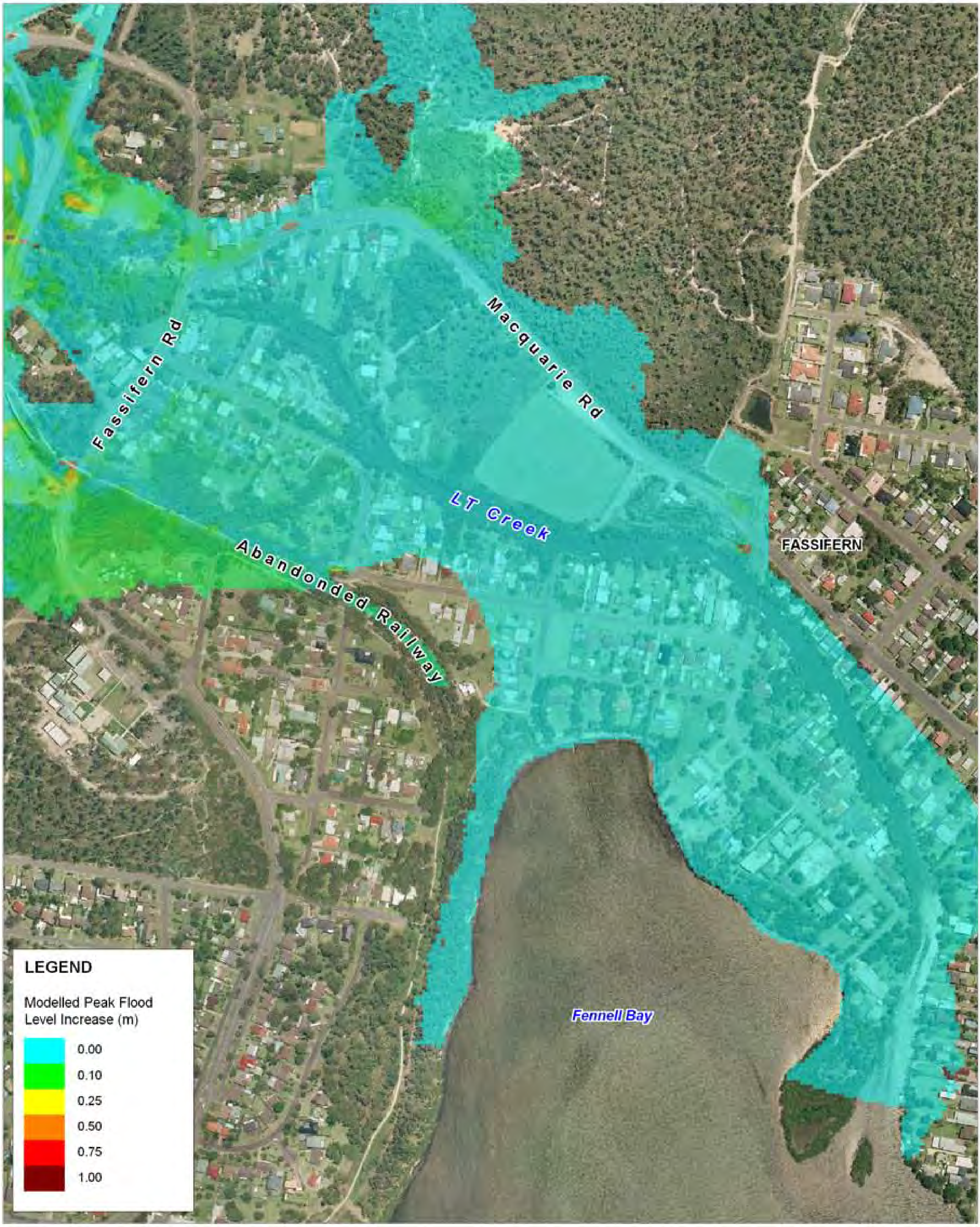
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_030_090813_Afflux_100yr_Blockage.WOR



Title:

Peak Flood Level Afflux - Structure Blockage PMF Event

Figure: **B-3**

Rev: **A**

N

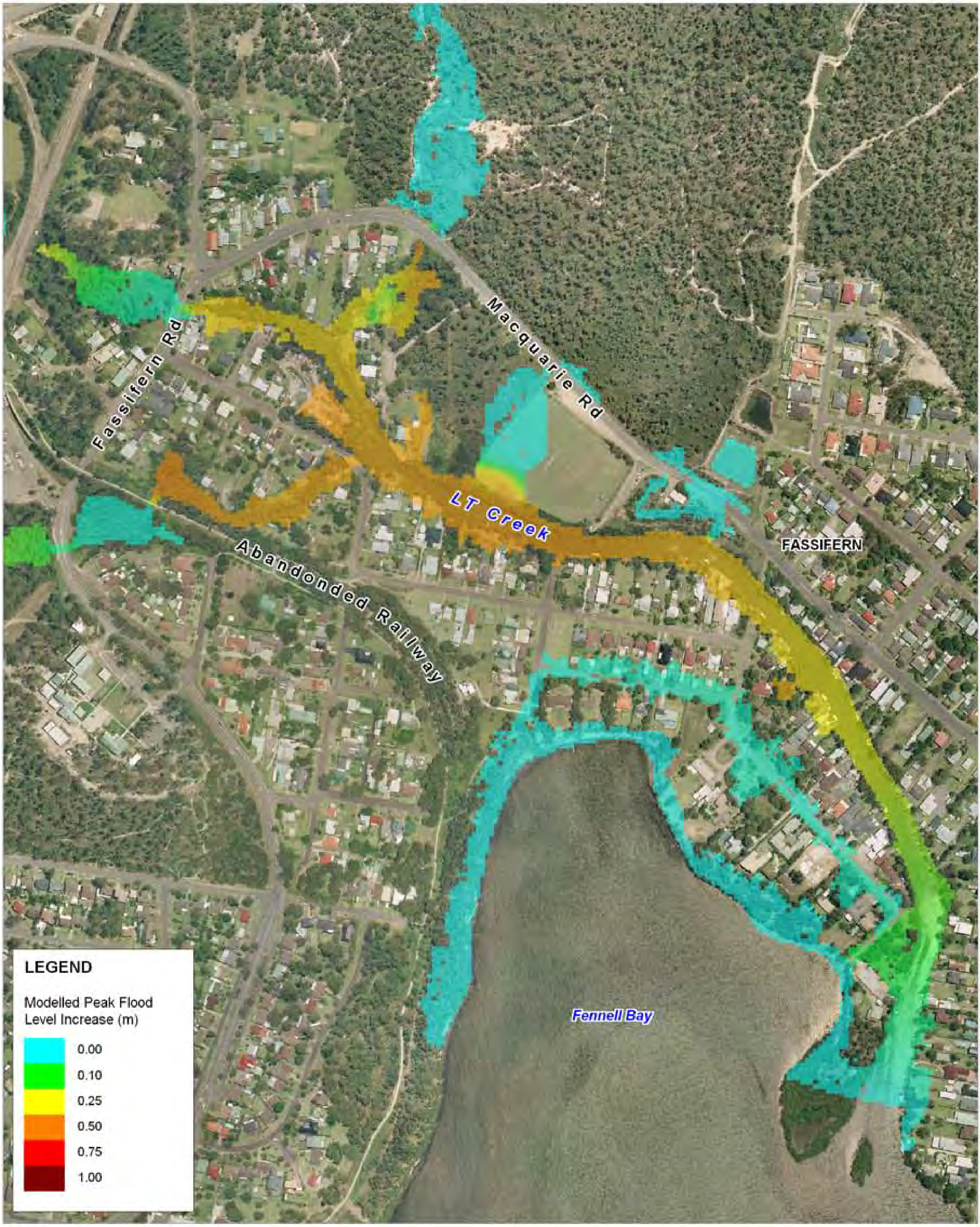
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_032_090813_Afflux_PMF_Blockage.WOR



Title:

Peak Flood Level Afflux - Channel Siltation 5% AEP Event

Figure: **B-4**

Rev: **A**

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N

0 100 200m

Approx. Scale

BMT WBM

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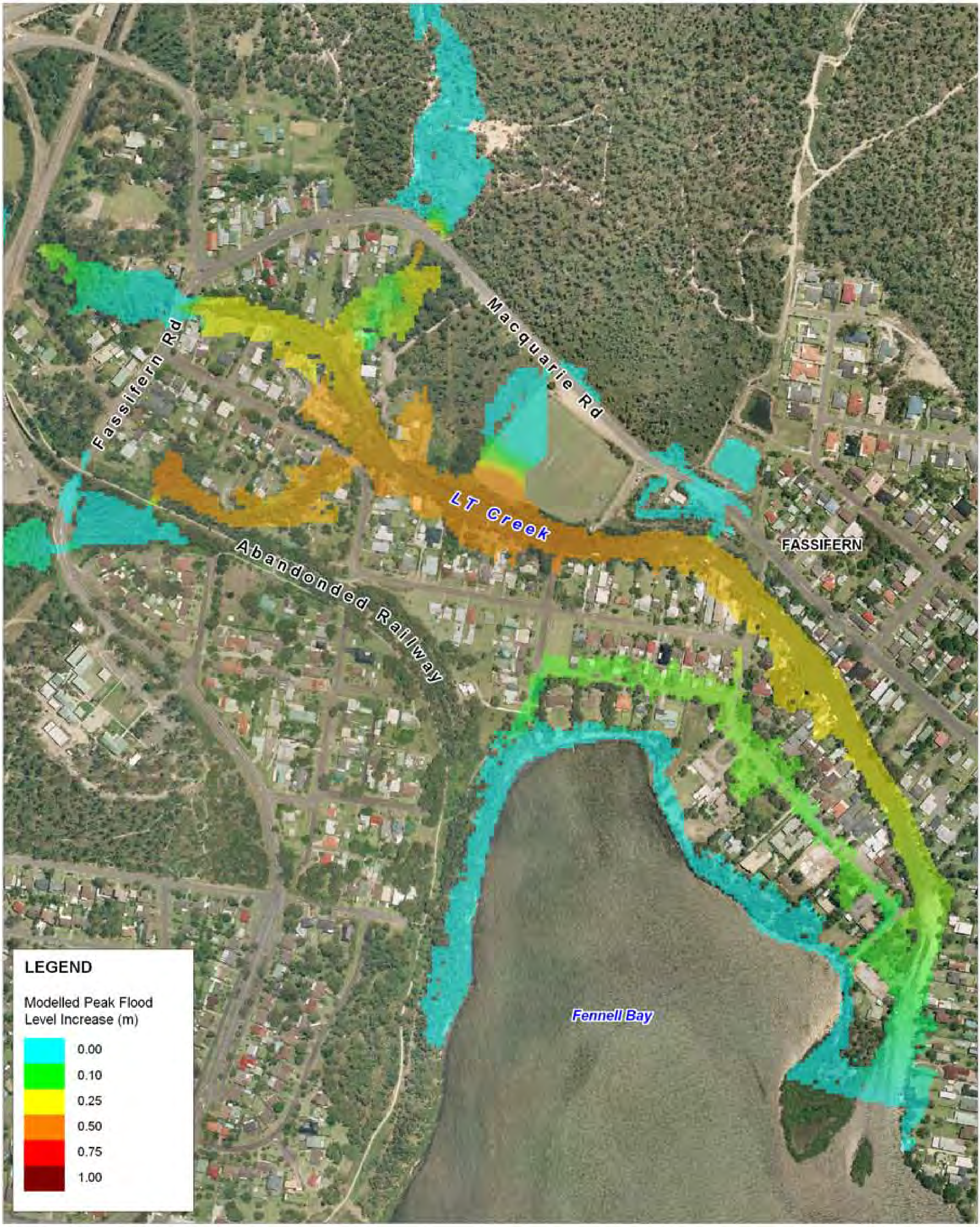
Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_028_090813_Afflux_20yr_Siltation.WOR



Title:

Peak Flood Level Afflux - Channel Siltation 1% AEP Event

Figure: **B-5**

Rev: **A**

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N

0 100 200m

Approx. Scale

BMT WBM

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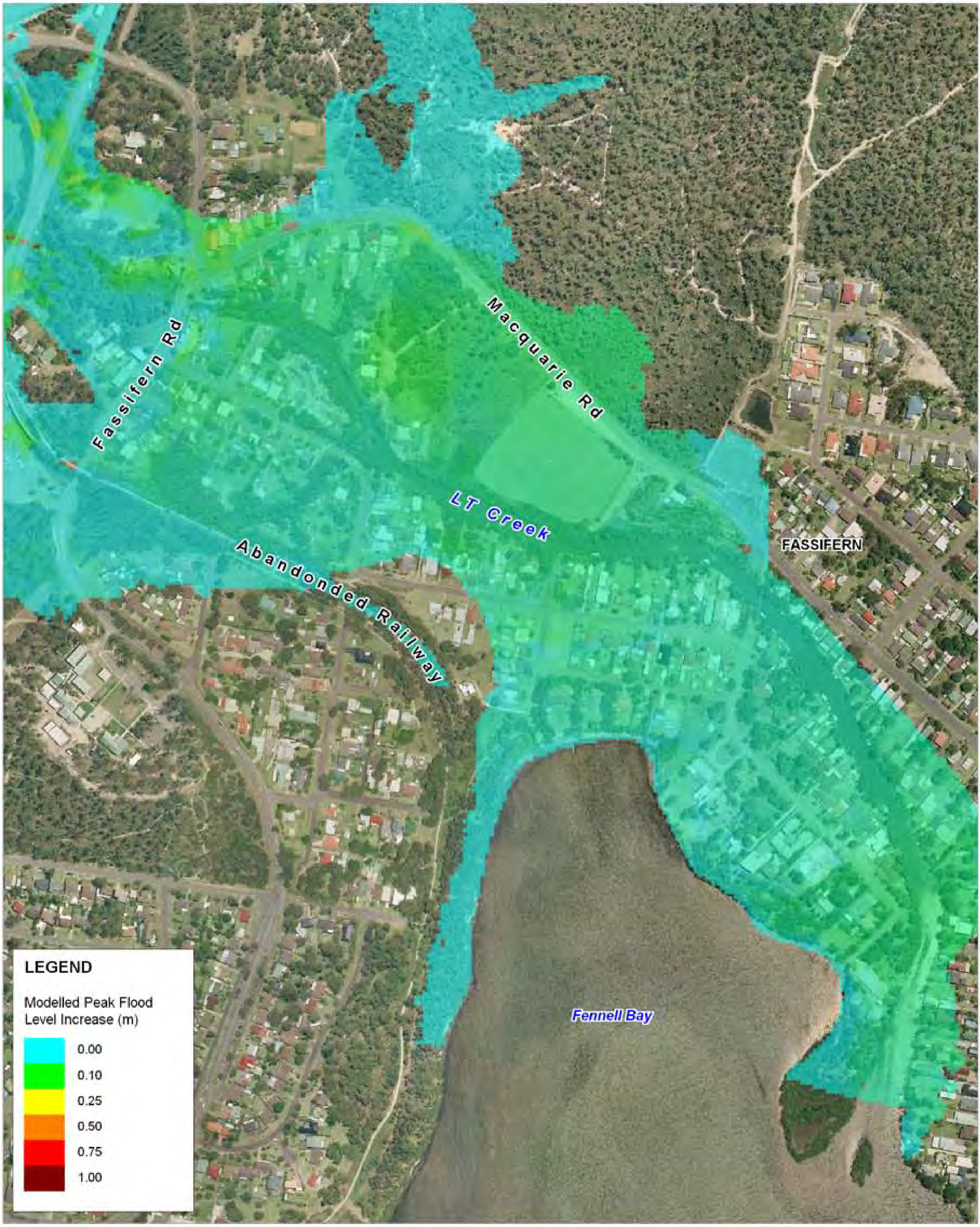
Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_027_090813_Afflux_100yr_Siltation.WOR



Title:

Peak Flood Level Afflux - Channel Siltation PMF Event

Figure: **B-6**

Rev: **A**

N

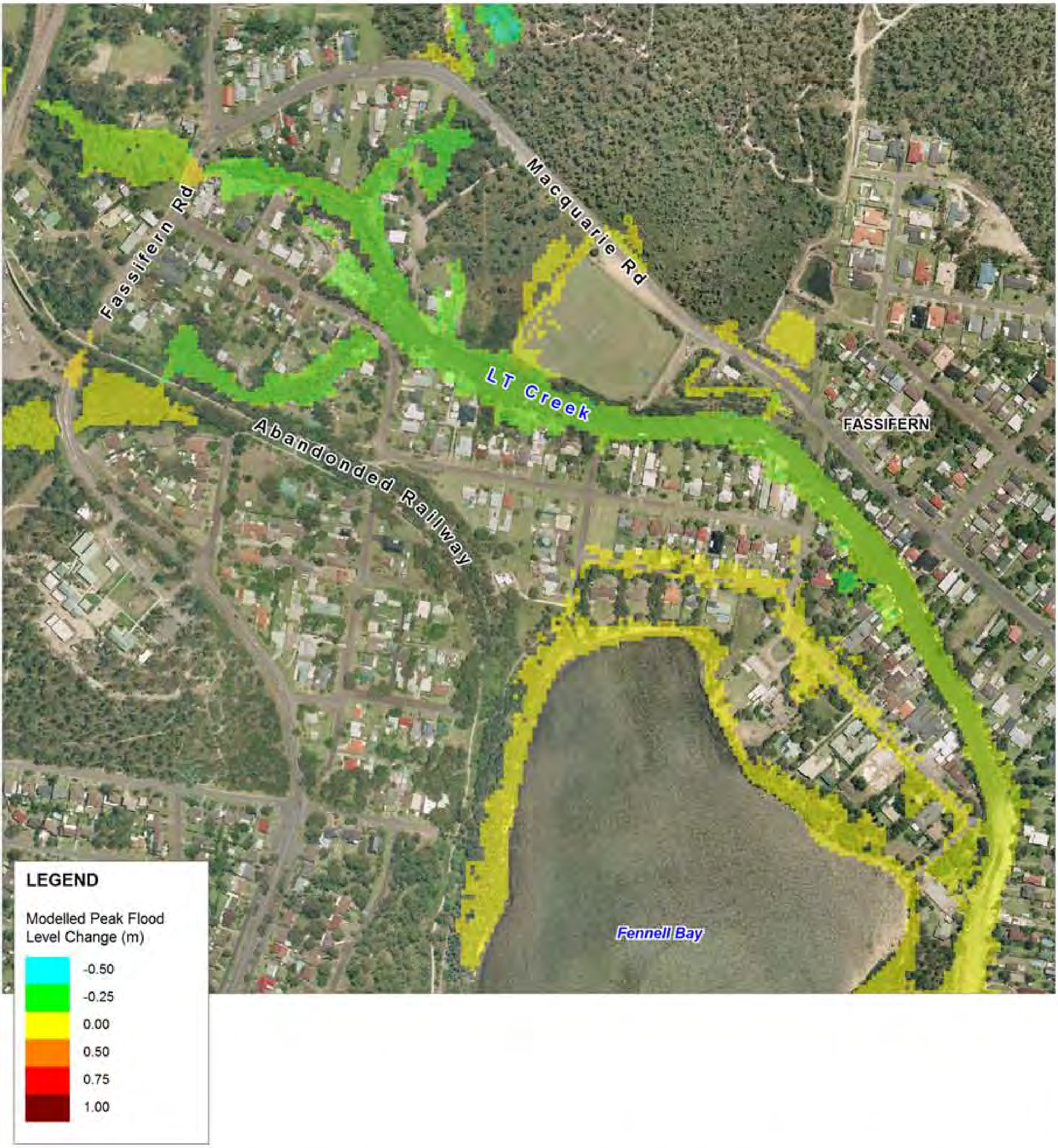
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_029_090813_Afflux_PMF_Siltation.WOR



Title:

Peak Flood Level Afflux - 20% Decrease in Design Roughness 1% AEP Event

Figure: B-7

Rev: A

N

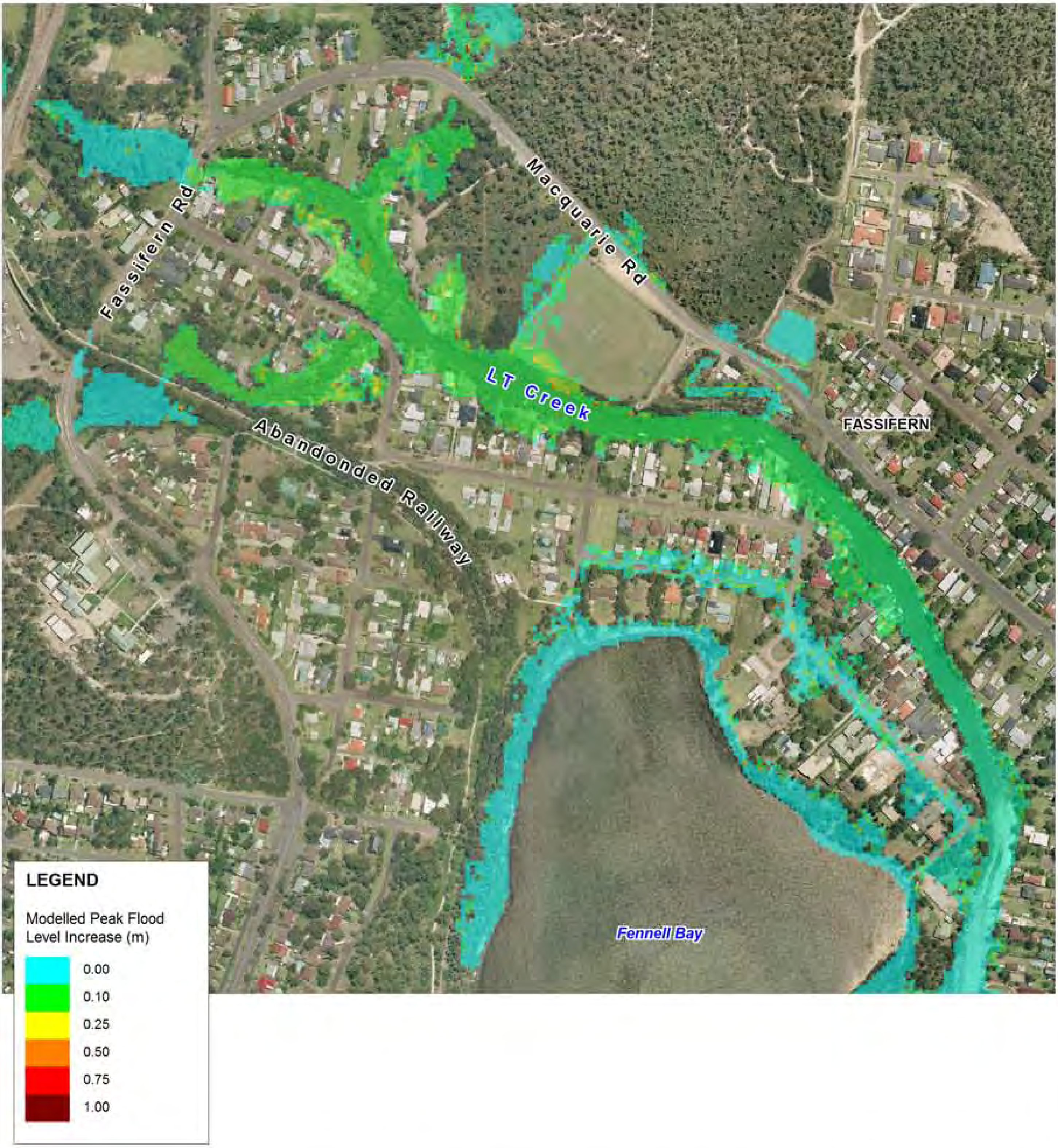
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_041_100811_Afflux_100yr_Roughness_dec.WOR



Title:

Peak Flood Level Afflux - 20% Increase in Design Roughness 1% AEP Event

Figure: **B-8**

Rev: **A**

N

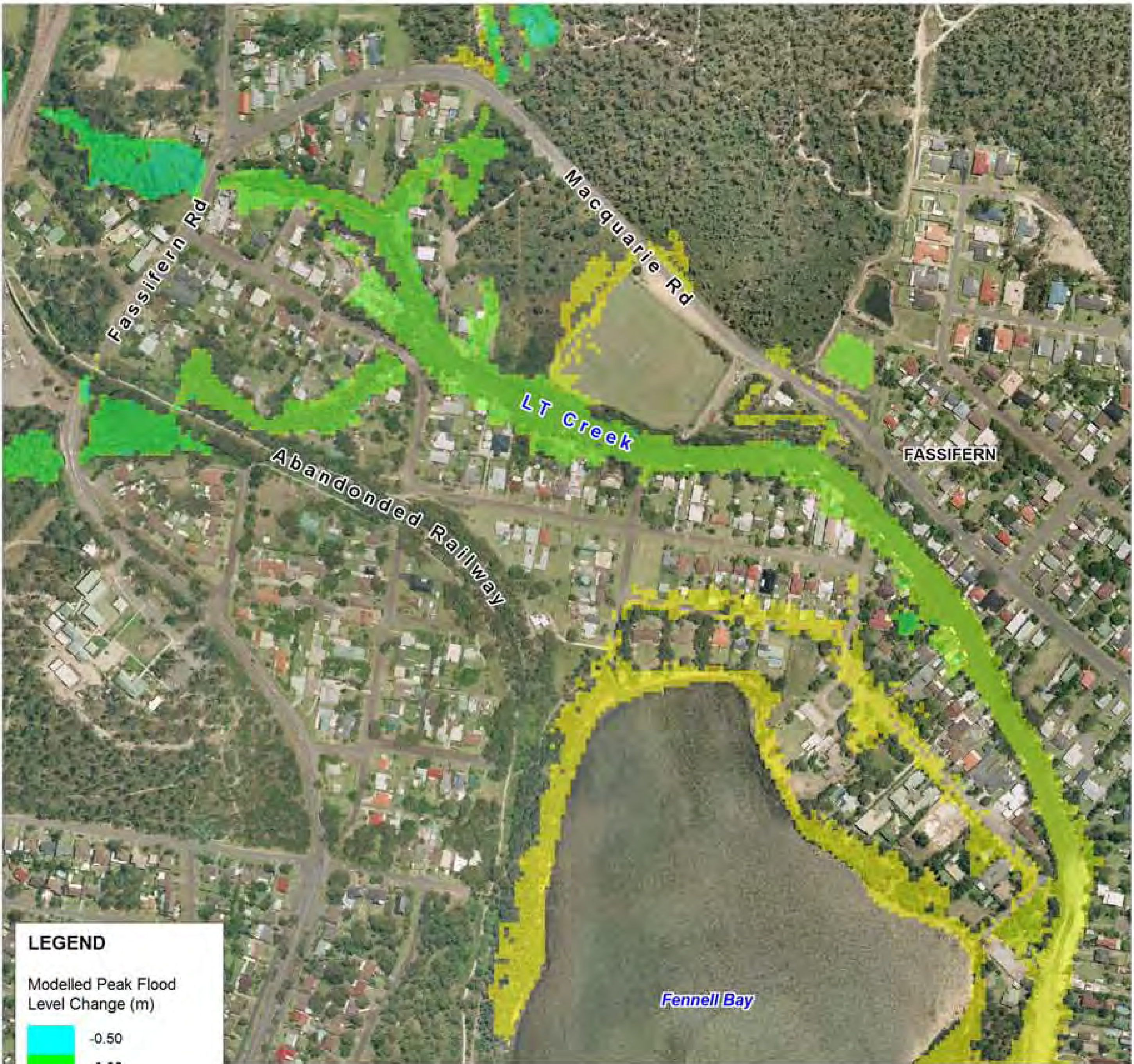
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_042_100811_Afflux_100yr_Roughness_inc.WOR



LEGEND

Modelled Peak Flood Level Change (m)

- -0.50
- -0.25
- 0.00
- 0.50
- 0.75
- 1.00

Title:

Peak Flood Level Afflux - 20% Decrease in Design Inflows 1% AEP Event

Figure: **B-9**

Rev: **A**

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N

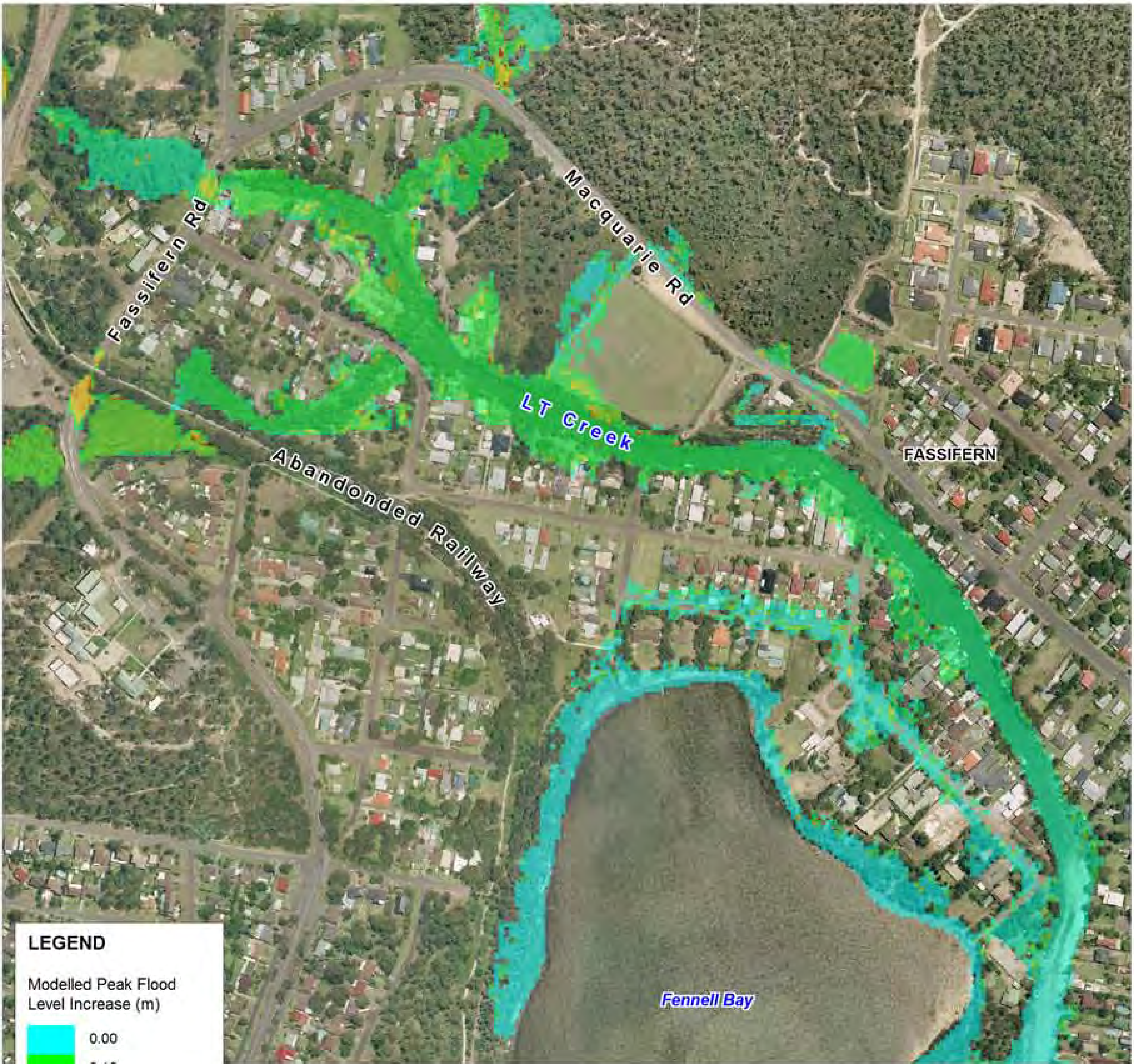
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_043_100811_Afflux_100yr_Q_dec.WOR



LEGEND

Modelled Peak Flood Level Increase (m)

- 0.00
- 0.10
- 0.25
- 0.50
- 0.75
- 1.00

Title:

Peak Flood Level Afflux - 20% Increase in Design Inflows 1% AEP Event

Figure: **B-10**

Rev: **A**

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N

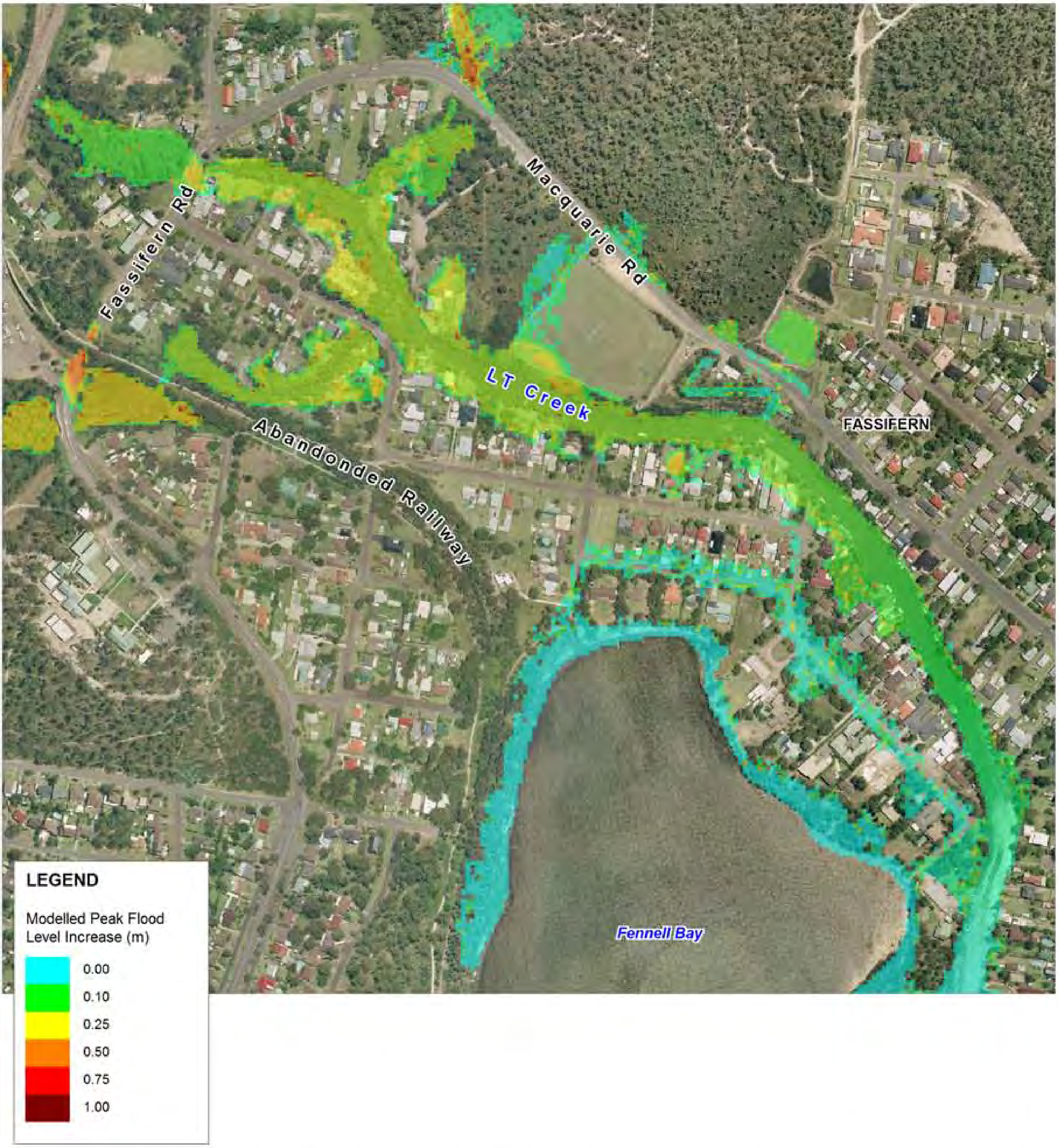
0 100 200m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_044_100811_Afflux_100yr_Q_inc.WOR



Title:

Peak Flood Level Afflux - 30% Increase in Design Rainfall 1% AEP Event

Figure: **B-11**

Rev: **A**

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BMT WBM
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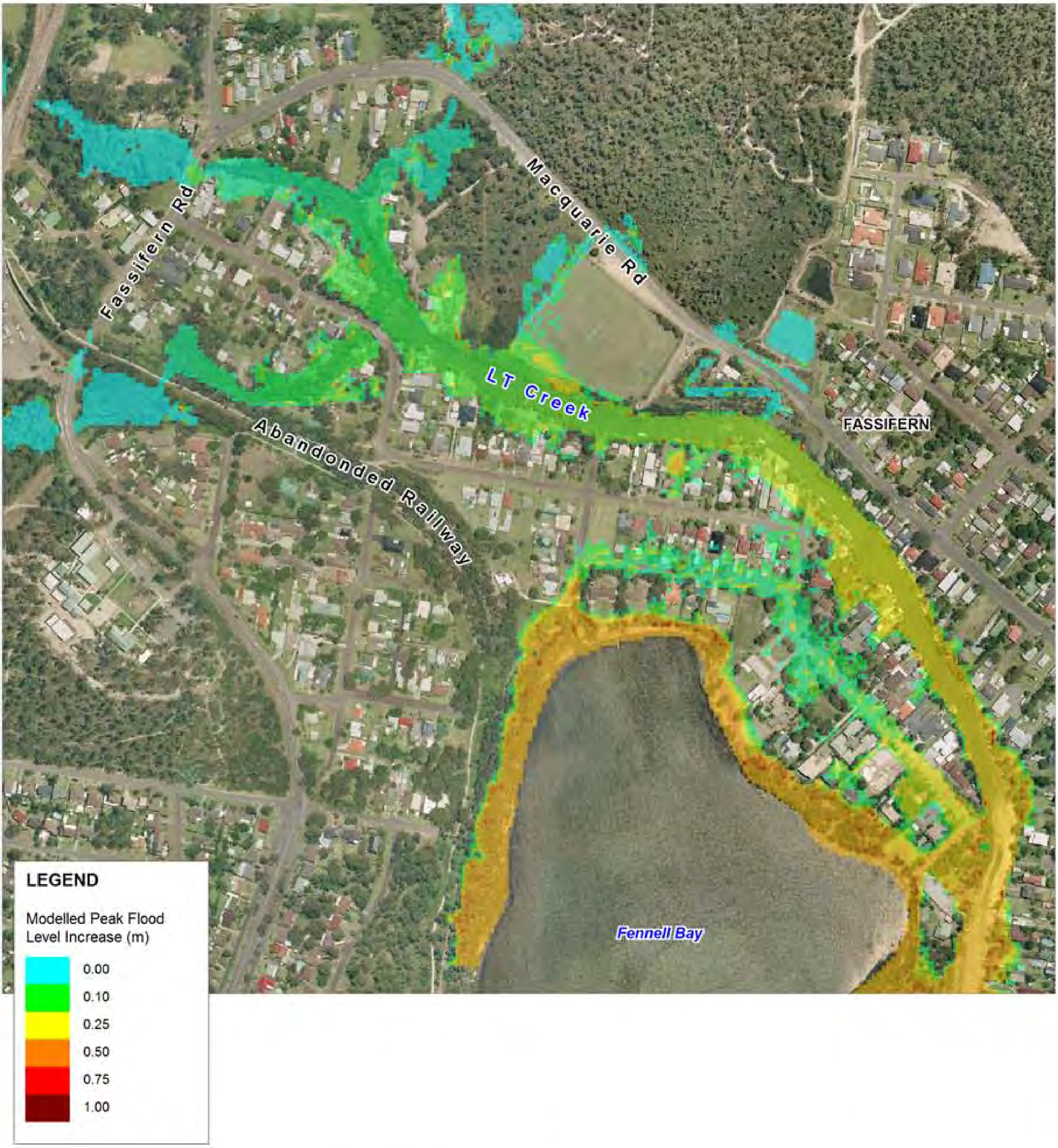
Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_045_100811_Afflux_100yr_30pcrain.WOR



Title:

Peak Flood Level Afflux - 0.4m Sea Level Rise 1% AEP Event

Figure: B-12

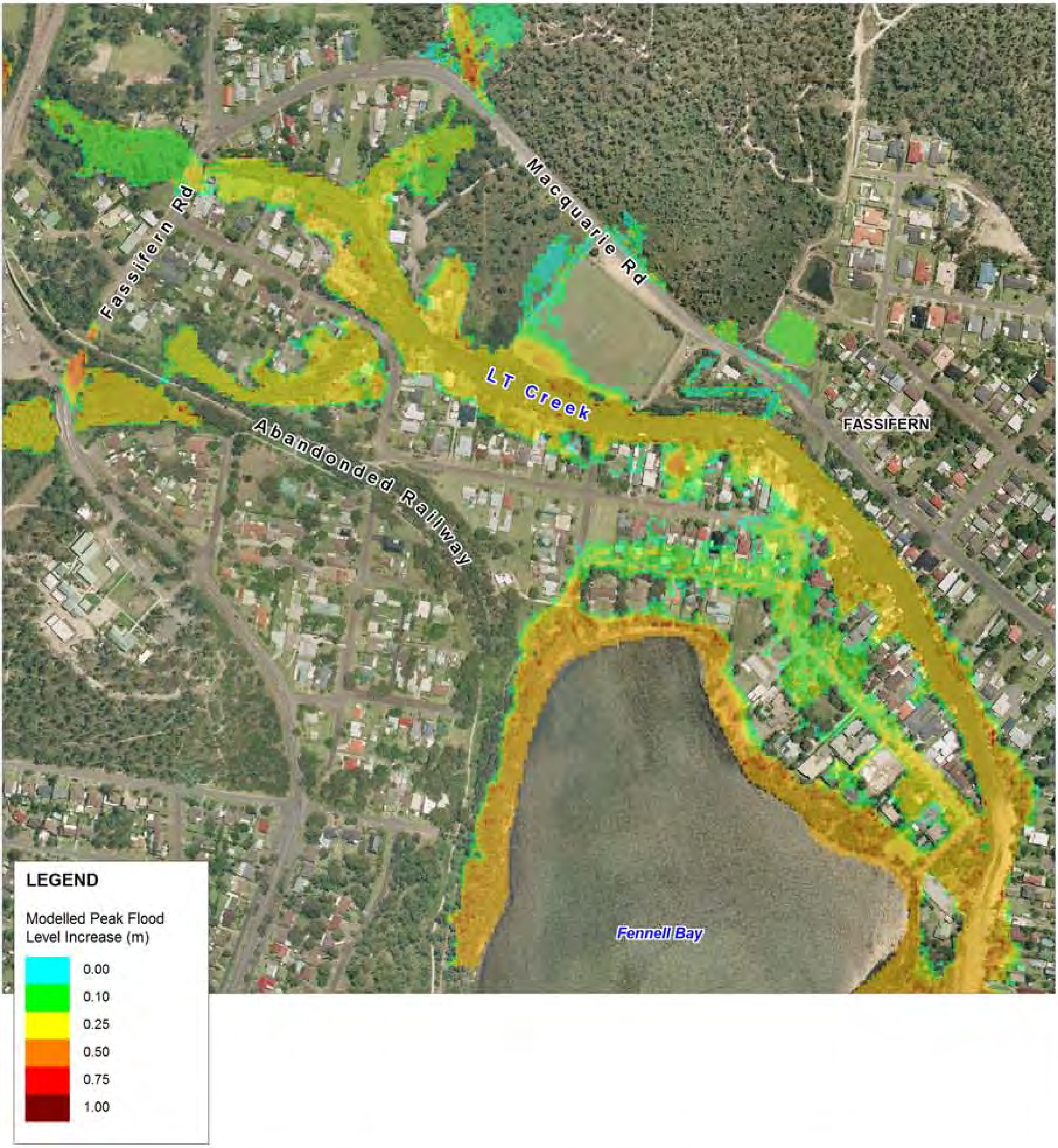
Rev: A

N

0 100 200m
Approx. Scale

BMT WBM
www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_046_100811_Afflux_100yr_50SLR.WOR



Title:

Peak Flood Level Afflux - 0.4m Sea Level Rise and 30% Increase in Design Rainfall - 1% AEP Event

Figure: **B-13**

Rev: **A**

N

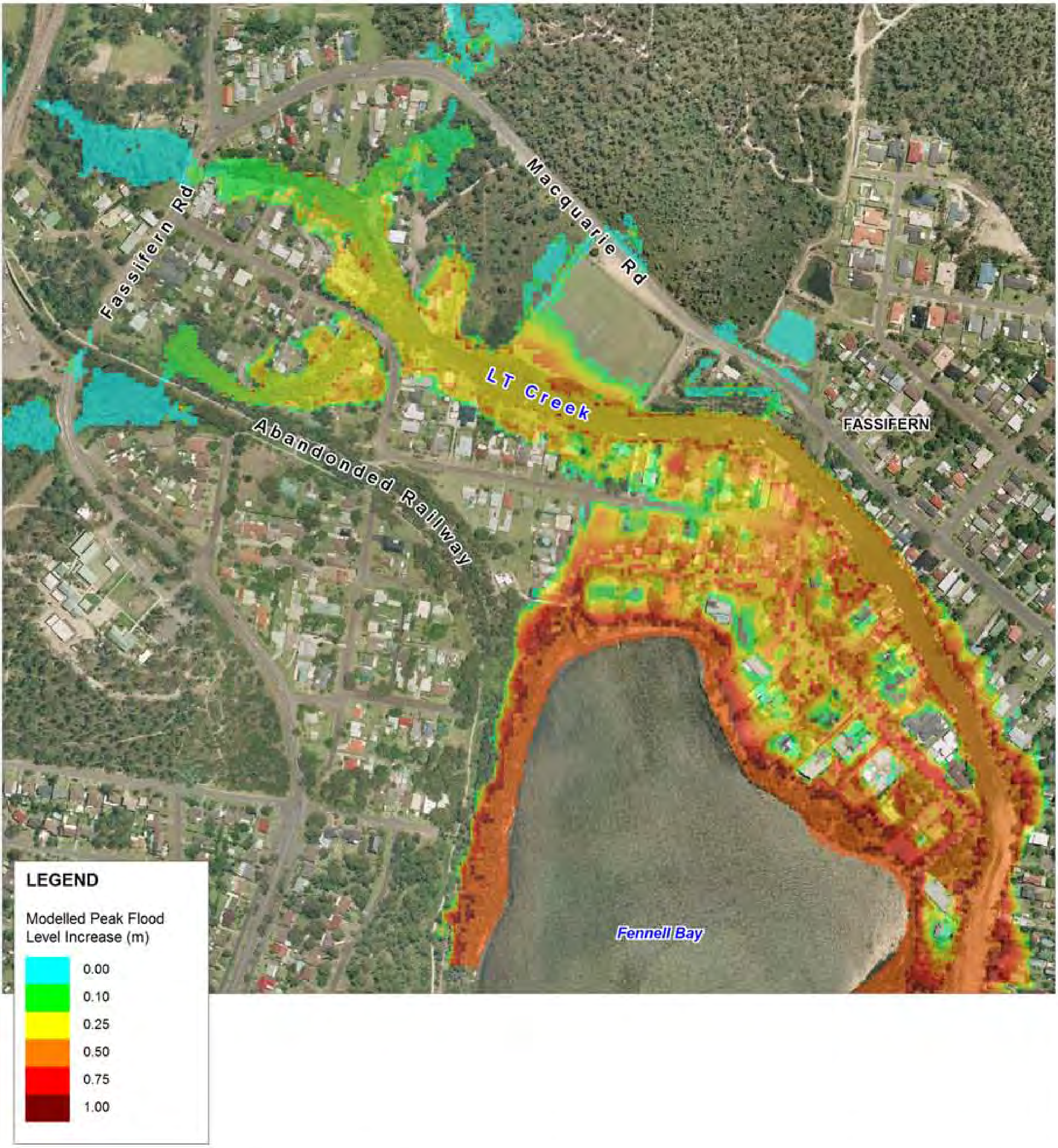
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_047_100811_Afflux_100yr_50SLR_30pc.WOR



Title:

Peak Flood Level Afflux - 0.9m Sea Level Rise 1% AEP Event

Figure: **B-14**

Rev: **A**

N

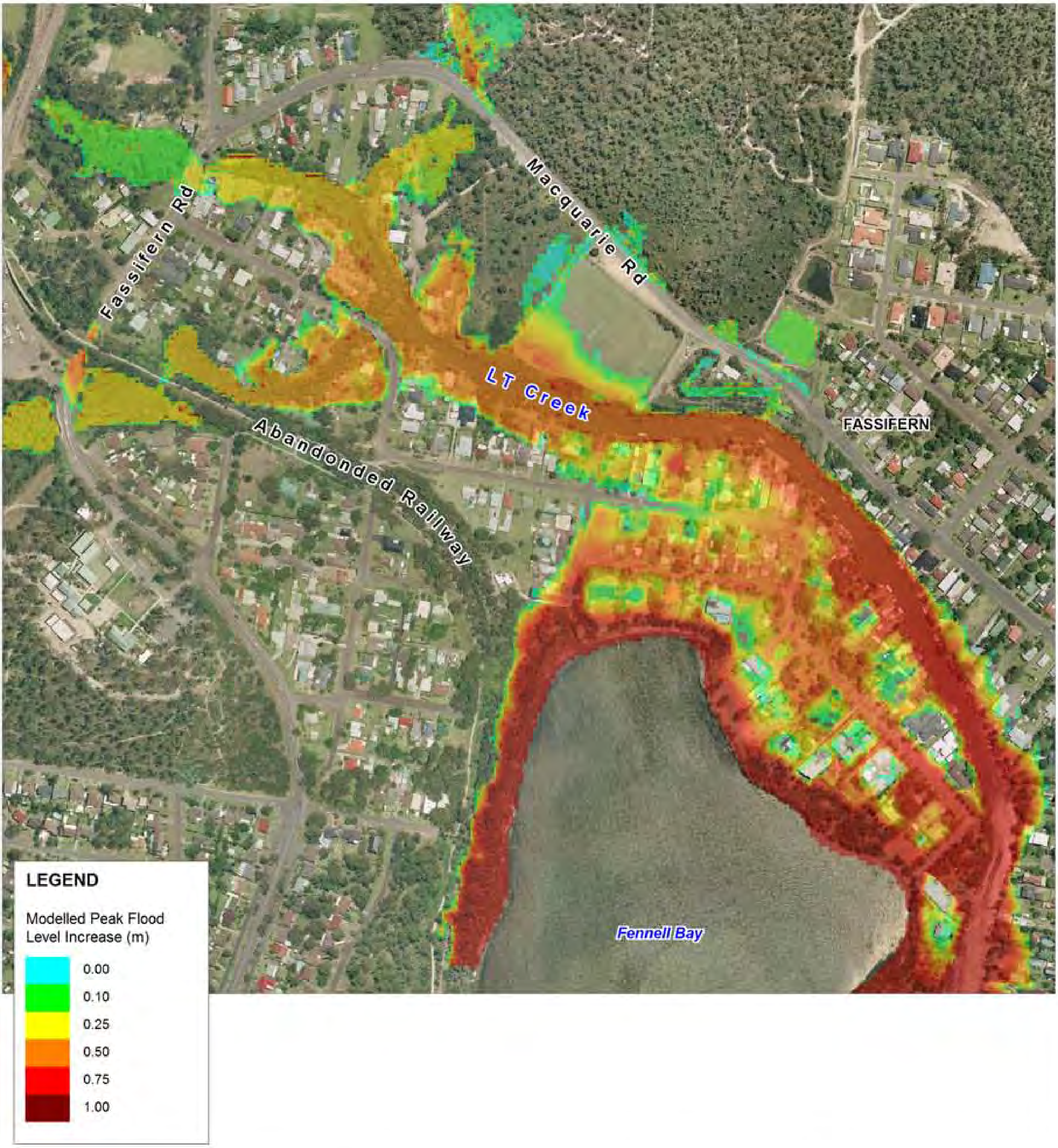
0 100 200m

Approx. Scale

BMT WBM

www.wbmpl.com.au

Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_048_100811_Afflux_100yr_100SLR.WOR



Title:

Peak Flood Level Afflux - 0.9m Sea Level Rise and 30% Increase in Design Rainfall - 1% AEP Event

Figure: **B-15**

Rev: **A**

N

0 100 200m

Approx. Scale

BMT WBM

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Filepath : K:\N1355_LT_Creek_Flood_Study\MI\Workspaces\DRG_049_100811_Afflux_100yr_100SLR_30pc.WOR

APPENDIX C: FASSIFERN PEAK FLOOD LEVEL DATABASE

Address	High Flood Level (m AHD)	Year	Address	High Flood Level (m AHD)	Year
28A Fassifern Road Fassifern	4.23	1981	26A Awaba Street Fassifern	1.21	1949
5 Fassifern Road Fassifern	3.26	1981	13 Awaba Street Fassifern	1.21	1949
106 Macquarie Road Fassifern	2.76	1981	6 Awaba Street Fassifern	1.21	1949
7 Bridge Street Fassifern	2.64	1981	35 Fennell Street Fassifern	1.21	1994
11 Bridge Street Fassifern	2.64	1981	44 Macquarie Road Fennell Bay	1.2	1949
6 Bridge Street Fassifern	2.5	1981	50 Macquarie Road Fennell Bay	1.2	1949
12 Bridge Street Fassifern	2.5	1981	15 Bluewater Avenue Fassifern	1.2	1949
2A Bridge Street Fassifern	2.28	1981	16 Awaba Street Fassifern	1.2	1949
2 Bridge Street Fassifern	2.27	1981	10 Fennell Street Fassifern	1.2	1949
9 Bridge Street Fassifern	2.26	1981	68 Macquarie Road Fennell Bay	1.2	1949
4 Bridge Street Fassifern	2.26	1981	42A Macquarie Road Fennell Bay	1.2	1949
9 Bridge Street Fassifern	2.26	1981	11A Brougham Avenue Fennell Bay	1.2	1949
8 Bridge Street Fassifern	2.26	1981	2 Boat Alley Fennell Bay	1.2	1949
10 Bridge Street Fassifern	2.26	1981	23 Brougham Avenue Fennell Bay	1.2	1949
26 Wangi Road Fassifern	2	1981	15 Awaba Street Fassifern	1.2	1949
6 Wangi Road Fassifern	2	1981	47 Brougham Avenue Fennell Bay	1.2	1949
30 Wangi Road Fassifern	2	1981	33 Brougham Avenue Fennell Bay	1.2	1949
6A Wangi Road Fassifern	1.99	1981	25 Brougham Avenue Fennell Bay	1.2	1949
28 Wangi Road Fassifern	1.99	1981	25 Fennell Street Fassifern	1.2	1949
39 Awaba Street Fassifern	1.99	1981	25A Fennell Street Fassifern	1.2	1949
35 Awaba Street Fassifern	1.82	1981	22 Fennell Street Fassifern	1.2	1949
33 Awaba Street Fassifern	1.7	1981	8 Bluewater Avenue Fassifern	1.2	1949
31 Awaba Street Fassifern	1.6	1981	29A Fennell Street Fassifern	1.2	1949
27 Awaba Street Fassifern	1.56	1981	29B Fennell Street Fassifern	1.2	1949
29 Awaba Street Fassifern	1.56	1981	11 Fennell Street Fassifern	1.19	1949
25 Awaba Street Fassifern	1.48	1981	14 Bluewater Avenue Fassifern	1.19	1949
6 Lake Street Fassifern	1.48	1981	13 Fennell Street Fassifern	1.19	1949
23 Awaba Street Fassifern	1.48	1949	7 Fennell Street Fassifern	1.19	1949
17 Awaba Street Fassifern	1.48	1981	9 Fennell Street Fassifern	1.19	1949
2 Lake Street Fassifern	1.48	1981	56 Macquarie Road Fennell Bay	1.19	1949

Address	High Flood Level (m AHD)	Year	Address	High Flood Level (m AHD)	Year
5 May Street Fassifern	1.21	1949	14 Lake Street Fassifern	1.19	1949
18 Awaba Street Fassifern	1.21	1949	2 Bluewater Avenue Fassifern	1.19	1949
28 Awaba Street Fassifern	1.21	1949	19 Fennell Street Fassifern	1.17	1949
2 Awaba Street Fassifern	1.21	1949	21 Fennell Street Fassifern	1.17	1949
14 Awaba Street Fassifern	1.21	1949	17 Fennell Street Fassifern	1.17	1949
20 Awaba Street Fassifern	1.21	1949	23 Fennell Street Fassifern	1.17	1949
8 Awaba Street Fassifern	1.21	1949	16 Fennell Street Fassifern	1.17	1949
24 Awaba Street Fassifern	1.21	1949	15 Fennell Street Fassifern	1.17	1949
10 Awaba Street Fassifern	1.21	1949	12 Lake Street Fassifern	1.06	1958
26 Awaba Street Fassifern	1.21	1949	33 Fennell Street Fassifern	1.05	1946
5 Awaba Street Fassifern	1.21	1949	30 Fennell Street Fassifern	1.05	1946
28 Awaba Street Fassifern	1.21	1949	26 Fennell Street Fassifern	1.05	1946
11 Awaba Street Fassifern	1.21	1949	8 Lake Street Fassifern	1.04	1990
4 Awaba Street Fassifern	1.21	1949	6 Fennell Street Fassifern	1.04	1946
22 Awaba Street Fassifern	1.21	1949	10 Lake Street Fassifern	1.04	1990
12 Awaba Street Fassifern	1.21	1949	40A Macquarie Road Fennell Bay	0.97	1990
1 Awaba Street Fassifern	1.21	1949	40 Macquarie Road Fennell Bay	0.97	1990
3 Awaba Street Fassifern	1.21	1949	3 Brougham Avenue Fennell Bay	0.94	1981

APPENDIX D: COMMUNITY QUESTIONNAIRE RESPONSES

LT Creek June 2007 Flood Questionnaire

	RETURN ID	1	2	3	4	5	6	7	8	9	10	11	12
1	Name or Business Name												
	Address												
	Contact Phone												
	Contact Email												
2	Do you have any flood marks indicating how high the water reached or are you able to indicate the level	No	No	Yes	No	No	Yes	Yes	No	Yes	No	Yes	Yes
	Description of flood mark			The base of a flag pole in our back yard		The water did not come anywhere near our house, the lake rose a little.	The floodmark 2m into driveway.	Water came to back wire fence. It didn't come into yard.		Brick course at front door		From storm water main hole on our block; it lifted in up spillway water in through shed. The pipe drain is too small to handle such volume. We have asked for the opening ti creek near the end of the pipe to be dredged deeper as it can't get away fast enough.	Known level
3	When did the highest water level occur?												
	Date:	9/06/2007					9/06/2007	9/06/2007	9/06/2007	9/06/2007			
	Time:						AM	8:00am	4:00am	1:00am		6:30 to 10:00pm	
	How sure of this time are you?												
	Within 1 hr							Yes	Yes	Yes			
	Could be more than an hour out												
	Don't know/unsure	Yes		Yes	Yes	Yes	Yes				Yes		Yes
4	Do you have any photographs, video or other information about the flood which you would be prepared to make available (on loan/copy)?	No		Yes	No	No	Yes	No	Yes	No	No		No
	Description (e.g. photos, videos)			Photograph			Photos of street flooded, can email these.		Photos - included		No		Photos
5	Do you have any rainfall records for the storm event	No		No	No	No	Yes		No	No	No		No
	Automated Weather Gauge												
	Rain Gauge						9/6/07 4pm 376mm	Rain gauge was over flowing					
6	Did access roads get flooded	No			Yes	Yes		No	Yes	Yes	No		
	Road				Fassifern Rd	Fennell St			Awaba St	Lake St			Part only
	Flooded Depth												
	Duration								Until daybreak				
	Comments				Flooded water was about 1 metre under the via duck on Fassifern Rd near railway	Fennell St had some water over it although we were still able to access our home.				Lake St was covered by water. 4WD could pass by noon, normal cars drove by			
7	Do you have information for other flood events?							No	No	Yes	No		
	1949	Yes											
	1981	Yes		Yes						Yes			
	1990	Yes				Yes				Yes			
	Other												
	Comments	Video		The water level in 1981 was app. 100mm higher then Jube 2007		I have a photo of the road - Fennell St - in Feb 1990							
8	Do you have any other comments regarding the flood?	We are subject to the licence requirements of New Stan Colliery, therefore in any major rain event millions of litres of dirty water are released from the mine cancelling out any benefit of a natural flush due to rain. The creek bed between Macquarie Rd and Croft Oval is devoid of marine life. It should be cleaned up.			I hope this sort of weather stays away from our mainland. Sorry I can't help much.		No power for 36hours, our street was underwater to a depth of app. 45cm. Older houses on LT Creek backyards were flooded; newer houses had been built up above flood.	Camphor laurels along back fence lost a lot of dead wood. They still need trimming vehicle access through our back yard.			I was on holidays at the time so not sure of what actually happened but we had no damage and no flooding.		The speed that water leaves the creek needs to be increased, shallow sloping banks allowed flood water to spread. Steep manmade sea walls coped with the excess water at a far better rate. If sea wall went all the way up the creek, flooding would have been prevented. Slow sloping banks spread the water over the land and allowed fooding in areas which would have had only run off if a seawall had been in place. The land which didn't have seawalls also stayed wet for a far longer time; up til the creek reached normal levels again (several days). Land protected by seawall dried as soon as level feel below seawall height, app. 18hrs.

LT Creek June 2007 Flood Questionnaire

	RETURN ID	13	14	15	16	17	18	19	20	21	22	23	24
1	Name or Business Name												
	Address												
	Contact Phone												
	Contact Email												
2	Do you have any flood marks indicating how high the water reached or are you able to indicate the level	No	No	Yes		No	No	No	No	Yes	Yes	Yes	Yes
	Description of flood mark			Water came up to end of our pavers which would be 400mm below our floorboards. Our house is 4 metres from LT Creek.					Didn't reach this block	Marked at front and back of property accurately	The high water reached the start of a garden wall and a joint in the concrete on a boat ramp.	Water marks on timber in boat shed and photos.	Inside house, outside walls of house, fence.
3	When did the highest water level occur?												
	Date:			9/06/2007							9/06/2007	8 or 9/6/07	8/06/2007
	Time:			2:00am							2:00 - 7:00am	2:45am	7:00pm
	How sure of this time are you?												
	Within 1 hr			Yes								Yes	Yes
	Could be more than an hour out										Yes		
	Don't know/unsure					Yes		Yes	Yes				
4	Do you have any photographs, video or other information about the flood which you would be prepared to make available (on loan/copy)?	No	No	Yes		No	No	No	No	Yes	Yes	Yes	Yes
	Description (e.g. photos, videos)			Photos - attached						Photos - attached. Photos of street, water showing levels both sides of street. Also levels on creek side.	Photos	Photos	Photos - Damage after flood, inside and outside.
5	Do you have any rainfall records for the storm event	No	No	No		No	No	No	No	No	No	No	No
	Automated Weather Gauge												
	Rain Gauge												
6	Did access roads get flooded	No	No	No		No	Yes	No	No	Yes	No	Yes	No
	Road						Fassifern Rd			Fennell St		Fennell St	
	Flooded Depth						18inches			3foot 6inches at South End, 1 foot 6inches - 2 feet at North End.		Parts of road flooded up to 300mm near sides and app. 100-150mm in middle.	
	Duration						2 hours					For a few days	
	Comments												
7	Do you have information for other flood events?	No	No	No		No		No	No		No	No	
	1949												
	1981												
	1990												
	Other												Yes
	Comments												Later part of 2007, 4-5 months (Nov/Dec 07) Photos of damage inside.
8	Do you have any other comments regarding the flood?			Was concerned about the sludge that covered our grass when flood receded. Hate to think what lies at the bottm of that creek.	We are unable to ansqwer any questions as the premises is rented. Our agents are LJ Hooker Toronto.			It was the furthest the water has ever come up the Yano but still wasn't a threat the to house.		We have been associated with this area since 1956 and this is the highest level experienced. The 1981 flood was exacerbated by bursting of dam effect on railway road, built to access building the electrification of rail above Fassifern Station.	The level of the creek and the depth of the water has become shallower since the flood, due to even more mud being deposited in it.	Lost power for a number of days. Lost app. $6000 of equipment without insurance paid due to rising water from LT Creek. Huge amount of silt deposited on ground when water subsided.	Please fix drainage of Macquarie Rd before another flood or heavy rain occurs. This has been allocated to 07/08 and now has been pushed back to 09/10 - NOT really good enough!

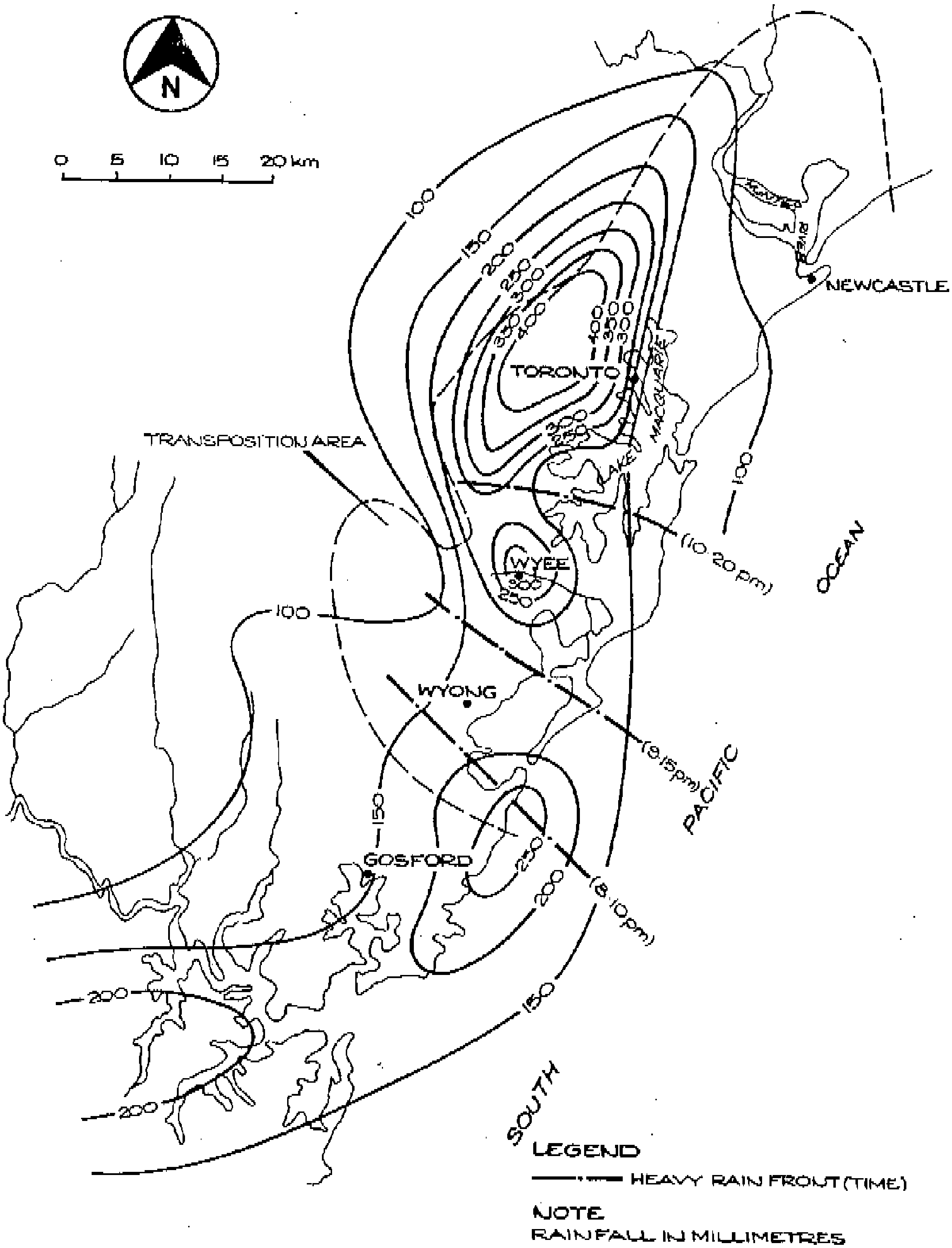
LT Creek June 2007 Flood Questionnaire

	RETURN ID	25	26	27	28	29	30	31
1	Name or Business Name							
	Address							
	Contact Phone							
	Contact Email							
2	Do you have any flood marks indicating how high the water reached or are you able to indicate the level	Yes	No	No	No	Yes	Yes	Yes
	Description of flood mark	Water rose to top of retaining wall.	The prooperty at Bridge St has never had flood water across the property, but is flat and becomes water logged. No water has entered the house, garage or shed.			Water reached up to and including 3rd and 4th course of bricks on letterbox. One car (parked on 'nature strip') flood damaged as water rose above chasis and entered through gap near doors.	We know height of water reached boats tied to house	To house side of boatshed, able to kayak in backyard. Sewer draining into lake from backyard
3	When did the highest water level occur?							
	Date:							9/06/2007
	Time:						1:00am	AM
	How sure of this time are you?							
	Within 1 hr							
	Could be more than an hour out							
	Don't know/unsure	Yes		Yes	Yes	Yes - Sometime overnight,	Yes	Yes
4	Do you have any photographs, video or other information about the flood which you would be prepared to make available (on loan/copy)?	Yes	No	No	No	Yes	No	No
	Description (e.g. photos, videos)	Digital images from creek downstream from us.				Photos - Of local streets	Son has photos	
5	Do you have any rainfall records for the storm event	No	No	No	No	No	Yes	No
	Automated Weather Gauge							
	Rain Gauge						12 inches - over several hours	
6	Did access roads get flooded	No		No	Yes	Yes	Yes	No
	Road				Fennell Street	Bluewater Ave, part of Fennell Street and end of Lake Street	Bridge on Bridge Street for several hours	
	Flooded Depth							
	Duration							
	Comments							
7	Do you have information for other flood events?	No		No		No	Yes	
	1949							
	1981		Yes				Yes	
	1990						Yes	
	Other							
	Comments		I did not own the propety at this time but I did know the person renting the property and the neighbours, they informed that when the tidal surge hit, the surge crossed the back of the property but was not near any building on the site.				Son has photos	
8	Do you have any other comments regarding the flood?	Water rose within overnight. It took several days to subside to below creek bank. Not much debri was left behind but we did have a 'swamp' snake on our path the next week. We have not seen a snake before or since.	From my account; the surge was caused by a massive amount of water from prolonged rain, trapped on the other side of the rail line at Awaba. When the line got washed away, a surge of water sweept down; plus the lake was at peak king tide. I was at the workers club in Toronto at the time and witnessed the water level rise from, level with the first step at the club to about a foot of water inside the club within minutes.	At my address I felt no adverse effects from the storm and LT Creek had no impact in my property at all.	Was in WA when flood occurred		Colour of water was black from the coal on grass at coal mine.	

APPENDIX E: FEBRUARY 1981 EVENT RAINFALL DATA

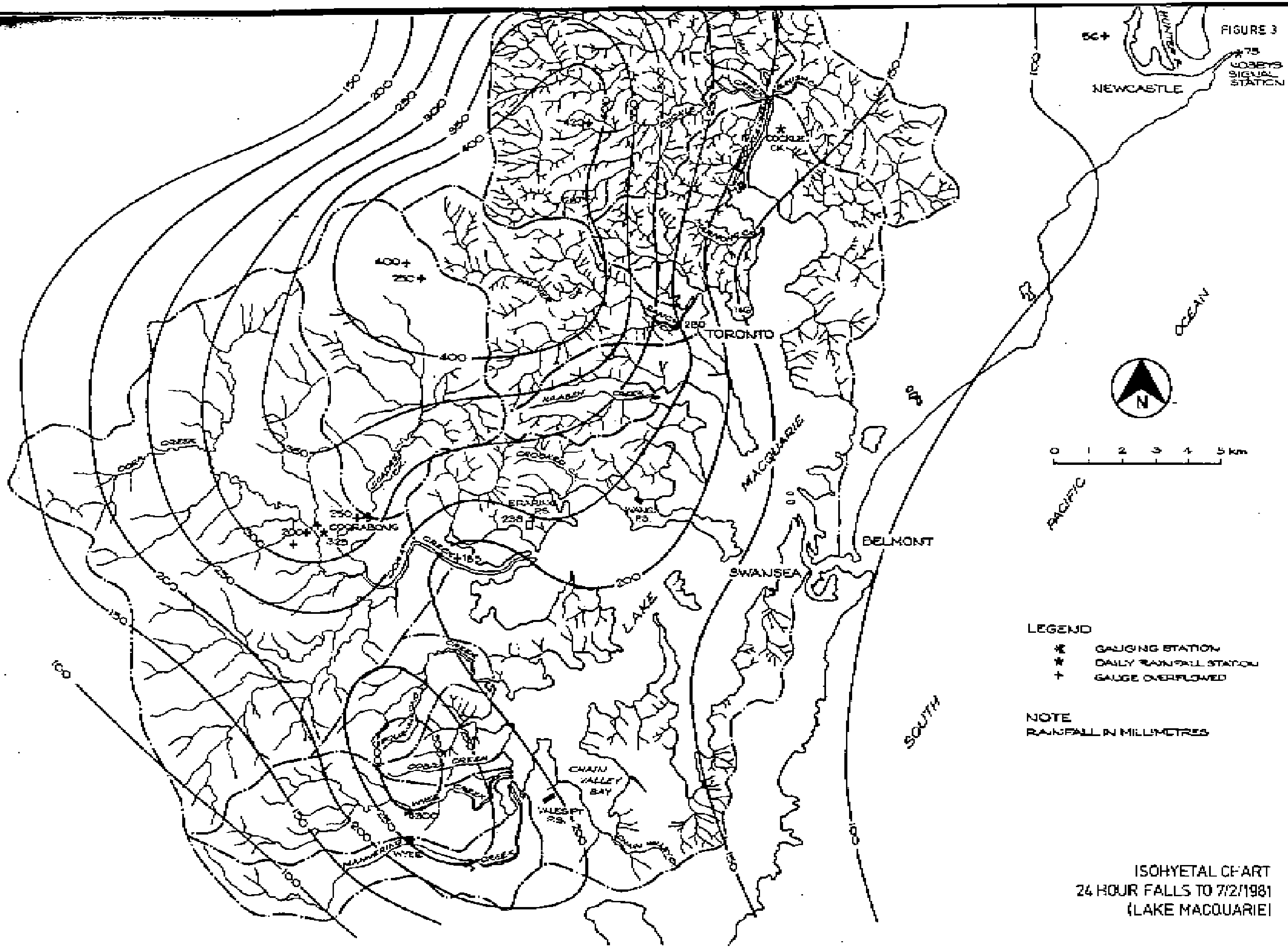
Isohyetal charts and temporal pattern data reproduced from "*Stony Creek – Report on Storm of February 1981 and Floodplain Management Plan"* (Sinclair Knight & Partners, 1981).

FIGURE 2



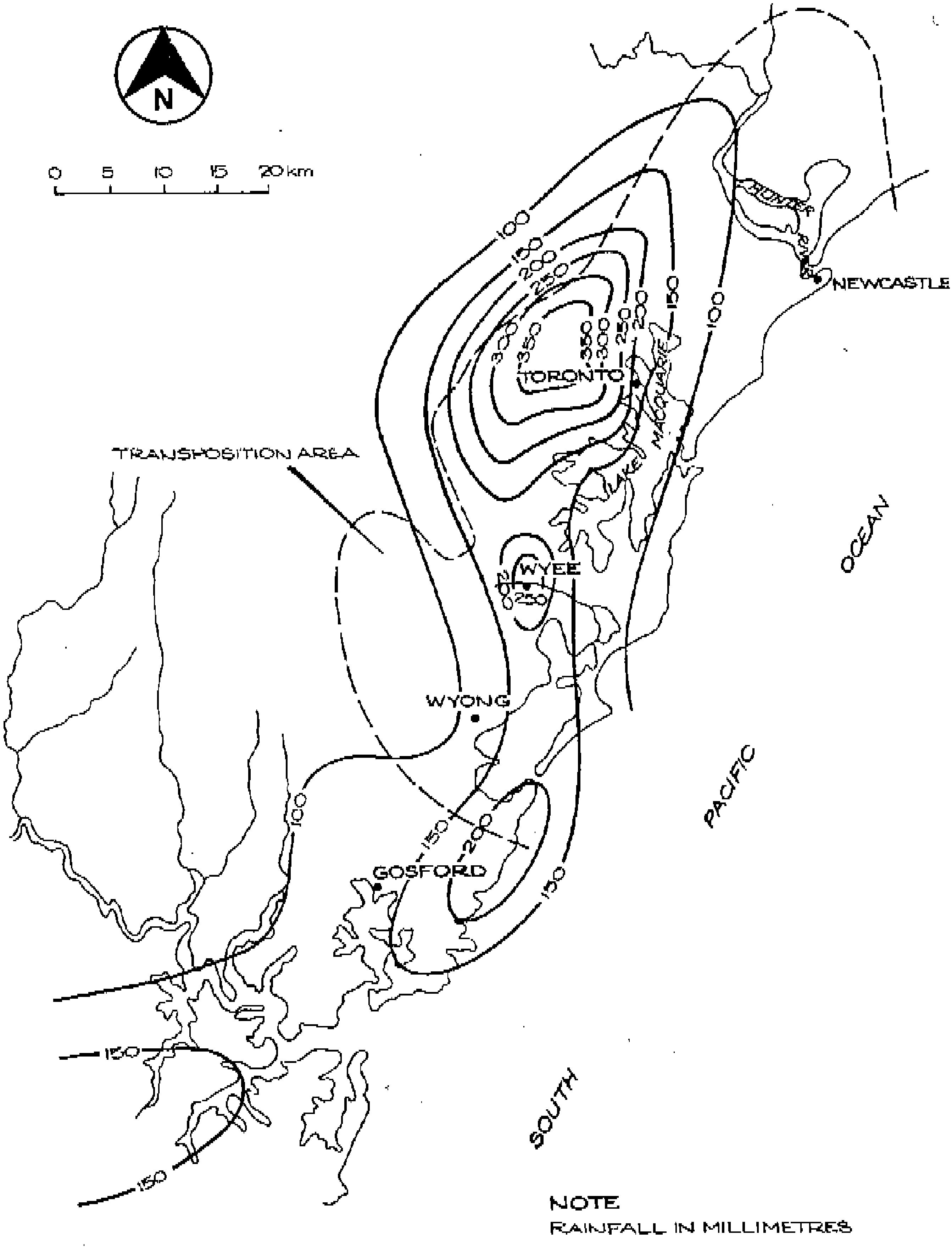
ISOHYETAL CHART
24 HOUR FALLS TO 9am 7/2/1981 (CENTRAL COAST)

FIGURE 3

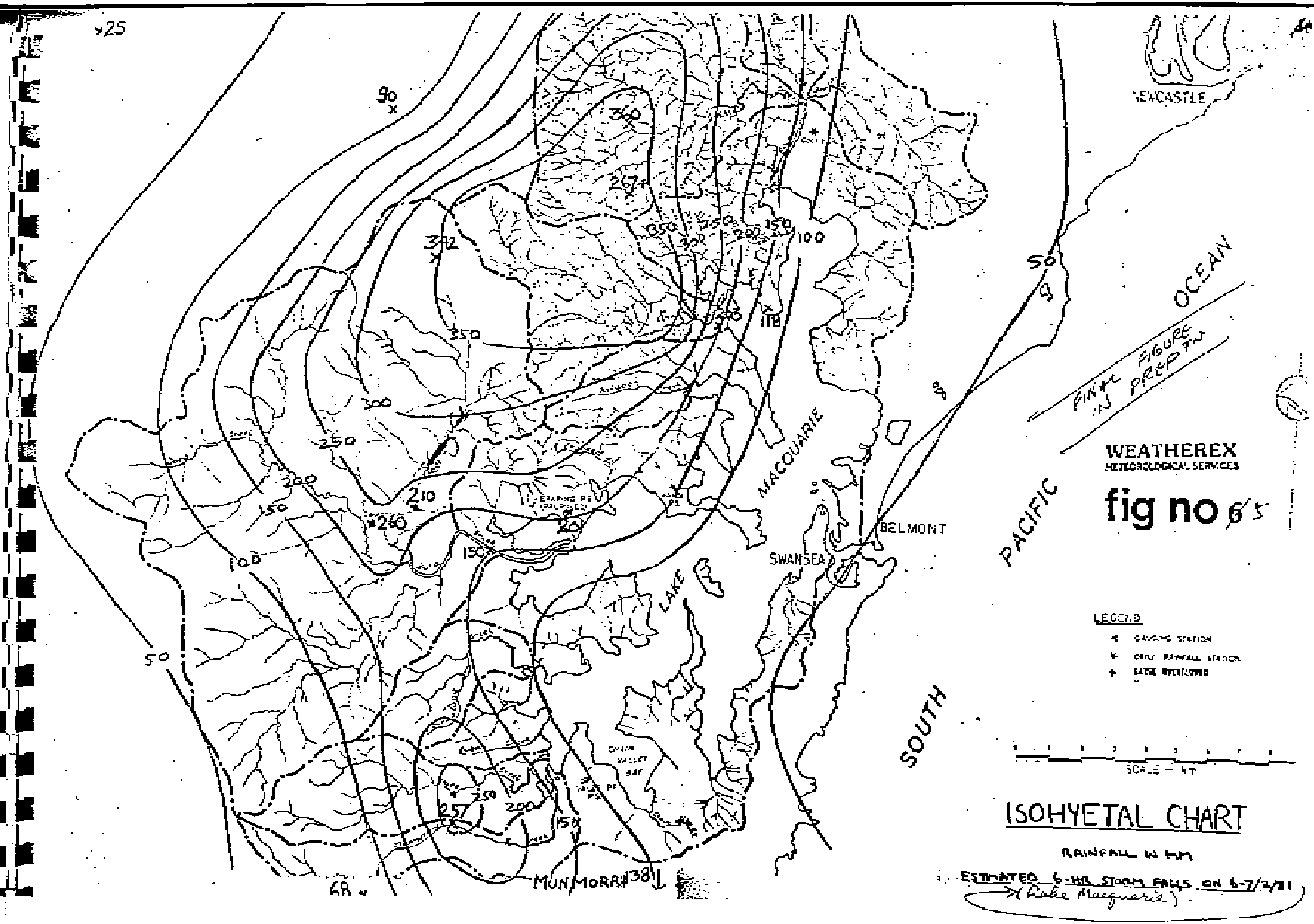


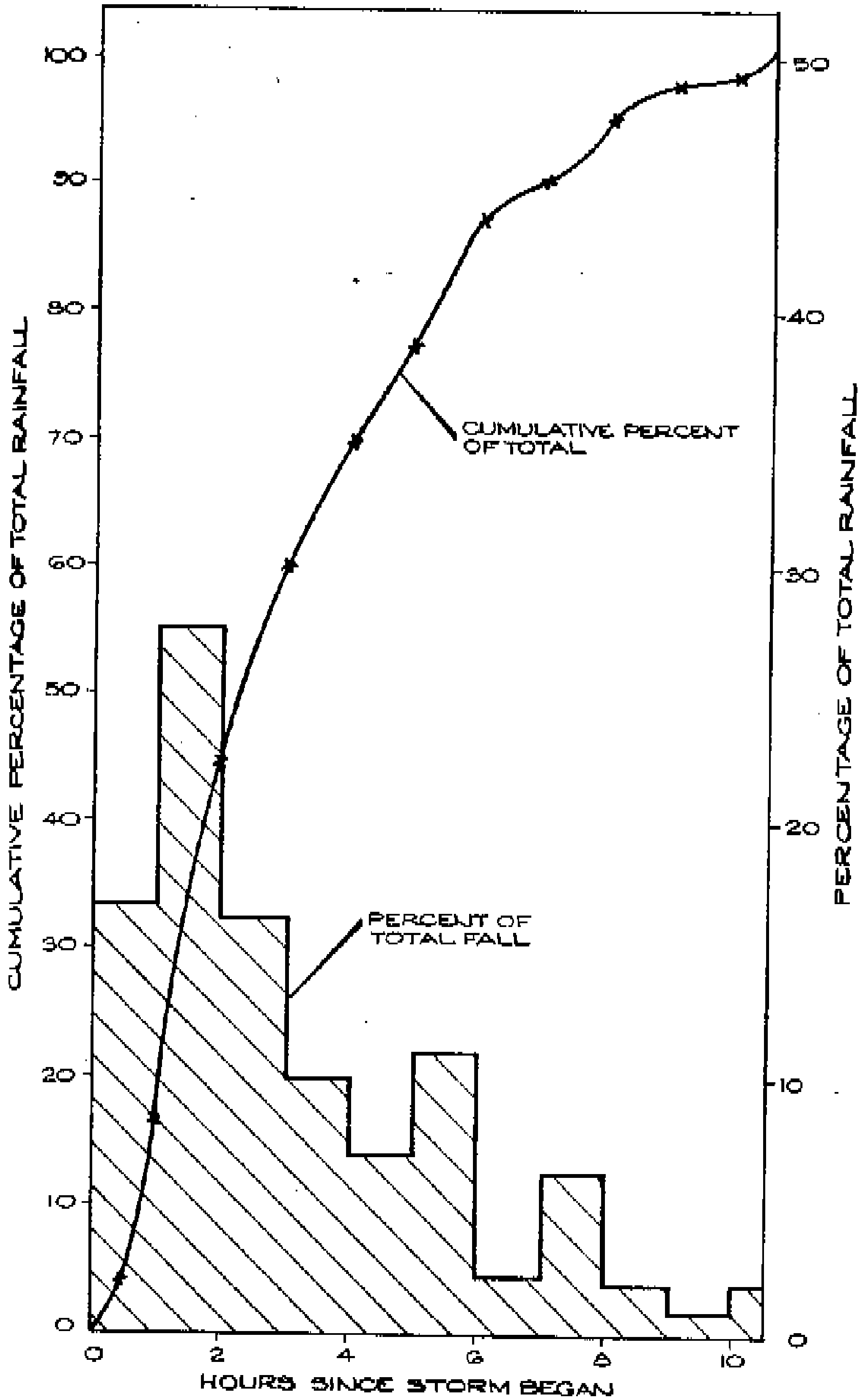
ISOHYETAL CHART
24 HOUR FALLS TO 7/2/1981
(LAKE MACQUARIE)

FIGURE 4



ISOHYETAL CHART
ESTIMATED 6 HOUR STORM FALLS
6/2/81 - 7/2/81 (CENTRAL COAST)


WEATHEREX
METEOROLOGICAL SERVICES
fig no 65
ISOHYETAL CHART
RAINFALL IN MM
ESTIMATED 6-HR STORM FALLS ON 6-7/2/81
(Lake Macquarie)
LEGEND
GAUGING STATION
DAILY RAINFALL STATION
SCALE - KM
FINAL FIGURE IN PREP'N
PACIFIC
OCEAN
SOUTH
NEWCASTLE
BELMONT
SWANSEA
LAKE
MACQUARIE
MUNMORAH 381
50
100
150
200
250
300
350
360
312
267
257
260
210
118
90
25
68



ERARING POWER STATION
TEMPORAL PATTERN
OF RAIN STORM 6/2/81- 7/2/81

APPENDIX F: IFD RAINFALL DATA

Rainfall Intensity for LT Creek, NSW

Duration	Average Recurrence Interval						
	1 Year (mm/hr)	2 Year (mm/hr)	5 Year (mm/hr)	10 Year (mm/hr)	20 Year (mm/hr)	50 Year (mm/hr)	100 Year (mm/hr)
5.0 m	82	105	136	153	177	207	231
5.5 m	79	102	131	148	171	200	223
6.0 m	77	99	127	144	166	194	216
6.5 m	74	96	123	139	161	189	210
7.0 m	72	93	120	136	156	183	204
7.5 m	70	91	117	132	152	179	199
8.0 m	69	88	114	129	148	174	194
8.5 m	67	86	111	126	145	170	189
9.0 m	65	84	109	123	142	166	185
9.5 m	64	83	106	120	138	162	181
10 m	63	81	104	118	135	159	177
11 m	60	78	100	113	130	153	170
12 m	58	75	96	109	125	147	164
13 m	56	72	93	105	121	142	158
14 m	54	70	90	101	117	137	153
15 m	52	67	87	98	113	133	148
16 m	51	65	84	95	110	129	144
17 m	49.3	64	82	93	107	125	140
18 m	48.0	62	80	90	104	122	136
19 m	46.7	60	78	88	101	119	132
20 m	45.6	59	76	86	99	116	129
21 m	44.5	57	74	84	96	113	126
22 m	43.5	56	72	82	94	111	123
23 m	42.5	55	71	80	92	108	120
24 m	41.6	54	69	78	90	106	118
25 m	40.7	52	68	77	88	104	115
26 m	39.9	51	66	75	86	102	113
27 m	39.1	50	65	74	85	100	111
28 m	38.4	49.5	64	72	83	98	109
29 m	37.7	48.6	63	71	82	96	107
30 m	37.0	47.7	62	70	80	94	105
32 m	35.8	46.1	59	67	78	91	101
34 m	34.6	44.6	58	65	75	88	98
36 m	33.5	43.3	56	63	73	85	95
38 m	32.6	42.0	54	61	71	83	92
40 m	31.7	40.8	53	60	69	81	90
45 m	29.6	38.2	49.3	56	64	76	84
50 m	27.9	36.0	46.5	53	61	71	79
55 m	26.5	34.1	44.0	49.8	57	68	75
60 m	25.2	32.5	41.9	47.4	55	64	72
75 m	22.1	28.5	36.9	41.8	48.2	57	63
90 m	19.9	25.7	33.2	37.6	43.4	51	57
105 m	18.1	23.4	30.3	34.4	39.7	46.7	52
120 m	16.8	21.6	28.0	31.8	36.7	43.2	48.1
135 m	15.6	20.2	26.1	29.6	34.2	40.3	45.0
150 m	14.7	18.9	24.5	27.8	32.2	37.9	42.3
165 m	13.8	17.9	23.2	26.3	30.4	35.8	40.0
180 m	13.1	17.0	22.0	25.0	28.9	34.0	38.0
195 m	12.5	16.2	21.0	23.8	27.6	32.5	36.2
210 m	12.0	15.5	20.1	22.8	26.4	31.1	34.7
225 m	11.5	14.8	19.3	21.9	25.3	29.8	33.3
240 m	11.0	14.3	18.6	21.1	24.4	28.7	32.1
270 m	10.3	13.3	17.3	19.6	22.7	26.8	29.9
5 h	9.65	12.5	16.2	18.5	21.4	25.2	28.1
6 h	8.65	11.2	14.6	16.6	19.2	22.6	25.3
7 h	7.88	10.2	13.3	15.1	17.5	20.7	23.1
8 h	7.27	9.42	12.3	14.0	16.2	19.1	21.3
9 h	6.78	8.78	11.4	13.0	15.1	17.8	19.9
10 h	6.36	8.24	10.8	12.2	14.2	16.8	18.7
11 h	6.01	7.78	10.2	11.6	13.4	15.9	17.7
12 h	5.70	7.39	9.65	11.0	12.7	15.1	16.8
14 h	5.22	6.77	8.87	10.1	11.7	13.9	15.5
16 h	4.83	6.28	8.24	9.41	10.9	13.0	14.5
18 h	4.52	5.87	7.72	8.82	10.3	12.2	13.6
20 h	4.25	5.52	7.28	8.33	9.70	11.5	12.9
22 h	4.02	5.23	6.90	7.91	9.21	10.9	12.3
24 h	3.82	4.97	6.57	7.53	8.78	10.4	11.7
30 h	3.35	4.36	5.79	6.65	7.77	9.25	10.4
36 h	2.99	3.91	5.21	5.99	7.01	8.36	9.41
42 h	2.72	3.56	4.75	5.48	6.41	7.66	8.63
48 h	2.50	3.27	4.38	5.05	5.93	7.09	7.99
54 h	2.31	3.03	4.07	4.70	5.52	6.61	7.46
60 h	2.16	2.83	3.80	4.40	5.17	6.20	7.00
66 h	2.02	2.65	3.57	4.14	4.87	5.84	6.60
72 h	1.90	2.50	3.37	3.91	4.60	5.53	6.25

The rainfall intensities shown above are calculated in accordance with Chapter 2, Australian Rainfall and Runoff - 1987 Edition.

LT Creek, NSW; [redacted]

25 June,2009

AUS-IFD
Ver 2.0, 2001

APPENDIX G: FLOOD DAMAGES INPUTS

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT

Version 1.00 | Queries to duncan.mcluckie@dipnr.nsw.gov.au

PROJECT	DETAILS	DATE	JOB No.

BUILDINGS

Regional Cost Variation Factor	1.00	*From Rawlinsons*					
Post late 2001 adjustments	1.34	*Changes in Avge Weekly Earnings - www.abs.gov.au*					
Post Flood Inflation Factor	1.40	*1.0*	*to*	*1.5*			
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*					

	Regional City			*Regional Town*		
	Houses Affected		*Factor*	*Houses Affected*		*Factor*
Small scale impact	*<*	*50*	*1.00*	*<*	*10*	*1.00*
Medium scale impacts in Regional City		*100*	*1.20*		*30*	*1.30*
Large scale impacts in Regional City	*>*	*150*	*1.40*	*>*	*50*	*1.50*

Typical Duration of Immersion	6	hours				
Building Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration flood*		*long duration flood*	
		Suggested range	*0.75*	*to*	*0.85*	
Average House Size	240	m^2	*240 m^2 is Base*			
Building Size Adjustment	1.0					
Total Building Adjustment Factor	**1.41**					

CONTENTS

Average Contents Relevant to Site	$ 60,000		*Base for 240 m^2 house*	*$*	*60,000*	
Post late 2001 adjustments	1.34	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*	*short duration flood*		*long duration flood*	
Sub-Total Adjustment Factor	0.85	*Suggested range*	*0.75*	*to*	*0.85*	
Level of Flood Awareness	low	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	2	hour				
Interpolated DRF adjustment (Awareness/Time)	0.93					
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**0.79**					
Total Contents Adjustment Factor AFD > TTBH	**0.85**					

Most recent advice from Victorian Rapid Assessment Method

Low level of awareness is expected norm (long term average) any deviation needs to be justified.

Basic contents damages are based upon a DRF of	*0.9*				
Effective Warning time (hours)	*0*	*3*	*6*	*12*	*24*
RAM AIDF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*
Site Specific DRF (SRF/0.9) for Awareness level for iteration	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*
Effective Warning time (hours)	*0*	*3*	*2*		
Site Specific iterations	*1.00*	*0.89*	*0.93*		

ADDITIONAL FACTORS

Post late 2001 adjustments	1.34	*From above*
External Damage	$ 6,700	*$6,700 recommended without justification*
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*
Likely Time in Alternate Accommodation	2	weeks
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*

TWO STOREY HOUSE BUILDING & CONTENTS FACTORS

Up to Second Floor Level, less than	2.6	m	70%	Single Storey Slab on Ground
From Second Storey up, greater than	2.6	m	110%	Single Storey Slab on Ground

Base Curves

AFD = Above Floor Depths

Single Storey Slab on Ground/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	0.0	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-1.50	m		
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Floodplain Specific Damage/Aftermath Curves

Allowance for Waves	0	m
Steps in Curve	0.1	m

Single Storey Slab on Ground/Low Set

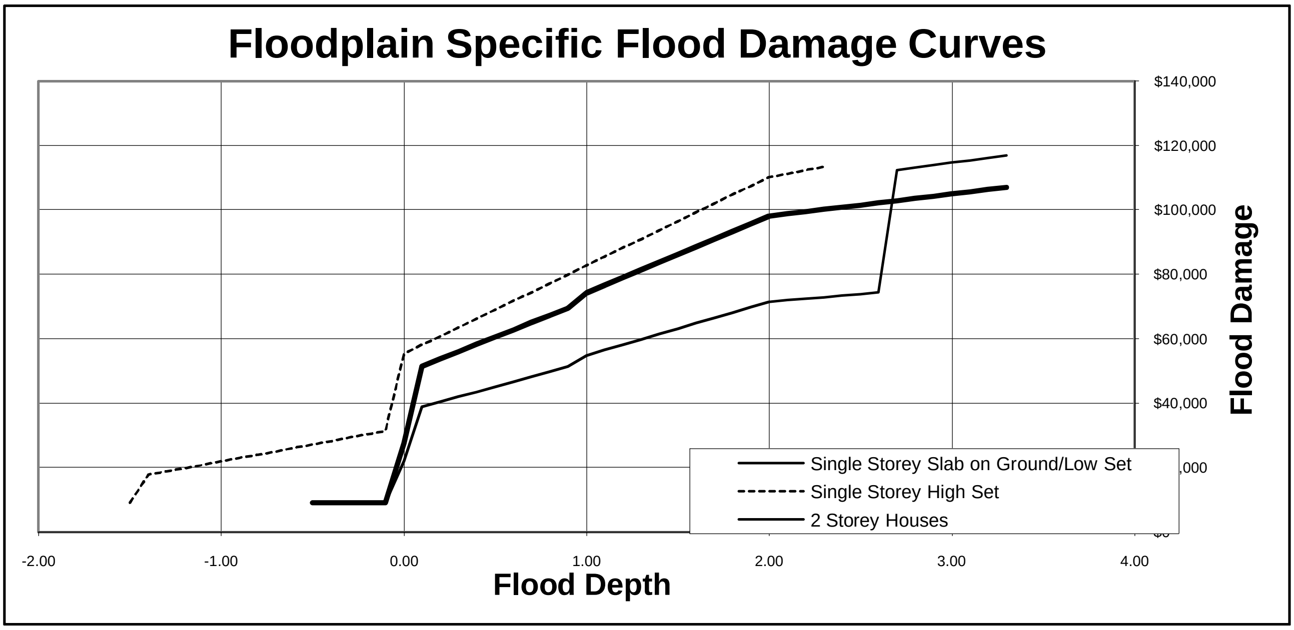
Static AFD	AFD + Wave Action	Damage
-0.50	-0.50	$ 8,978
-0.40	-0.40	$ 8,978
-0.30	-0.30	$ 8,978
-0.20	-0.20	$ 8,978
-0.10	-0.10	$ 8,978
0.00	0.00	$ 27,499
0.10	0.10	$ 51,449
0.20	0.20	$ 53,708
0.30	0.30	$ 55,968
0.40	0.40	$ 58,227
0.50	0.50	$ 60,487
0.60	0.60	$ 62,746
0.70	0.70	$ 65,005
0.80	0.80	$ 67,265
0.90	0.90	$ 69,524
1.00	1.00	$ 74,302
1.10	1.10	$ 76,687
1.20	1.20	$ 79,073
1.30	1.30	$ 81,458
1.40	1.40	$ 83,843
1.50	1.50	$ 86,229
1.60	1.60	$ 88,614
1.70	1.70	$ 90,999
1.80	1.80	$ 93,385
1.90	1.90	$ 95,770
2.00	2.00	$ 98,155
2.10	2.10	$ 98,841
2.20	2.20	$ 99,526
2.30	2.30	$ 100,211
2.40	2.40	$ 100,897
2.50	2.50	$ 101,582
2.60	2.60	$ 102,267
2.70	2.70	$ 102,953
2.80	2.80	$ 103,638
2.90	2.90	$ 104,323
3.00	3.00	$ 105,009
3.10	3.10	$ 105,694
3.20	3.20	$ 106,379
3.30	3.30	$ 107,065

Single Storey High Set

Static AFD	AFD + Wave Action	Damage
-1.50	-1.50	$ 8,978
-1.40	-1.40	$ 17,632
-1.30	-1.30	$ 18,681
-1.20	-1.20	$ 19,730
-1.10	-1.10	$ 20,778
-1.00	-1.00	$ 21,827
-0.90	-0.90	$ 22,876
-0.80	-0.80	$ 23,924
-0.70	-0.70	$ 24,973
-0.60	-0.60	$ 26,022
-0.50	-0.50	$ 27,071
-0.40	-0.40	$ 28,119
-0.30	-0.30	$ 29,168
-0.20	-0.20	$ 30,217
-0.10	-0.10	$ 31,265
0.00	0.00	$ 55,264
0.10	0.10	$ 58,013
0.20	0.20	$ 60,761
0.30	0.30	$ 63,510
0.40	0.40	$ 66,259
0.50	0.50	$ 69,007
0.60	0.60	$ 71,756
0.70	0.70	$ 74,505
0.80	0.80	$ 77,254
0.90	0.90	$ 80,002
1.00	1.00	$ 82,751
1.10	1.10	$ 85,500
1.20	1.20	$ 88,248
1.30	1.30	$ 90,997
1.40	1.40	$ 93,746
1.50	1.50	$ 96,495
1.60	1.60	$ 99,243
1.70	1.70	$ 101,992
1.80	1.80	$ 104,741
1.90	1.90	$ 107,490
2.00	2.00	$ 110,238
2.10	2.10	$ 111,287
2.20	2.20	$ 112,336
2.30	2.30	$ 113,384

2 Storey Houses

Static AFD	AFD + Wave Action	Damage
-0.50	-0.50	$ 8,978
-0.40	-0.40	$ 8,978
-0.30	-0.30	$ 8,978
-0.20	-0.20	$ 8,978
-0.10	-0.10	$ 8,978
0.00	0.00	$ 21,943
0.10	0.10	$ 38,708
0.20	0.20	$ 40,289
0.30	0.30	$ 41,871
0.40	0.40	$ 43,452
0.50	0.50	$ 45,034
0.60	0.60	$ 46,616
0.70	0.70	$ 48,197
0.80	0.80	$ 49,779
0.90	0.90	$ 51,360
1.00	1.00	$ 54,705
1.10	1.10	$ 56,375
1.20	1.20	$ 58,044
1.30	1.30	$ 59,714
1.40	1.40	$ 61,384
1.50	1.50	$ 63,054
1.60	1.60	$ 64,723
1.70	1.70	$ 66,393
1.80	1.80	$ 68,063
1.90	1.90	$ 69,732
2.00	2.00	$ 71,402
2.10	2.10	$ 71,882
2.20	2.20	$ 72,362
2.30	2.30	$ 72,841
2.40	2.40	$ 73,321
2.50	2.50	$ 73,801
2.60	2.60	$ 74,281
2.70	2.70	$ 112,350
2.80	2.80	$ 113,104
2.90	2.90	$ 113,858
3.00	3.00	$ 114,612
3.10	3.10	$ 115,365
3.20	3.20	$ 116,119
3.30	3.30	$ 116,873



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