


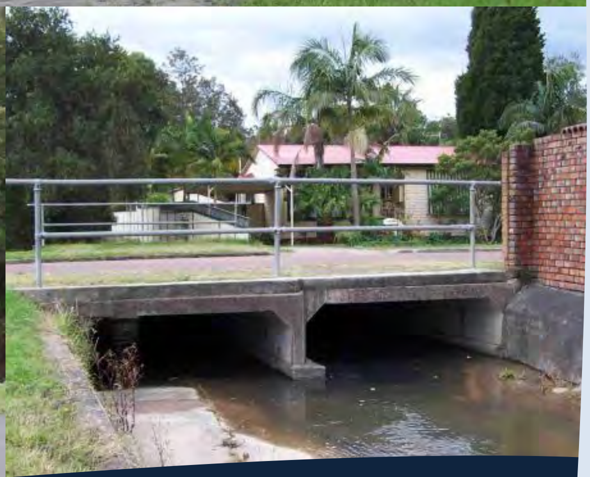

Stony Creek Floodplain Risk Management Study

Job Number LJ2597

Prepared for Lake Macquarie City Council

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Foreword

The NSW Government Flood Policy is directed towards providing solutions to existing flood 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.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee	Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.
2. Data Collection	The collection of data such as historical flood levels, rainfall records, land use, soil types etc.
3. Flood Study	Determines the nature and extent of the floodplain.
4. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Floodplain Risk Management Plan	Involves formal adoption by Council of a management plan for the floodplain.
6. Implementation of the Plan	This may involve the construction of flood mitigation works (eg culvert amplification) to protect existing or future development. It may also involve the use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Stony Creek Flood Study was completed by Cardno Lawson Treloar in 2005 to define flood behaviour in the catchment. This Floodplain Risk Management Study and Plan has been prepared for Lake Macquarie City Council and the Department of Environment and Climate Change by Cardno Lawson Treloar. This report forms the fourth and fifth stages of the management process for the Stony Creek catchment.

Executive Summary

Lake Macquarie City Council commissioned Cardno Lawson Treloar to prepare a *Floodplain Risk Management Study* and *Floodplain Risk Management Plan* for Stony Creek.

Flooding in the Stony Creek catchment can pose a high hazard to some residents living within close proximity to the creek. The purpose of this study is to identify and examine options for the management of flooding and make recommendations for actions to be adopted as part of the Floodplain Risk Management Plan.

The Stony Creek catchment has a total area of 46.4 km^2 discharging into Fennell Bay. The upper part of the catchment lies above the Newcastle-Sydney railway line and is primarily bushland area comprising Awaba State Forest. Downstream of the railway line is the industrial and residential area of Toronto and Blackalls Park. Stony Creek and Mudd Creek discharge downstream of Railway Parade into Edmunds Bay and Fennell Bay.

In the past, flooding in the catchment has caused property damage and posed a hazard to residents. A major flood occurred in February 1981, with more recent flooding occurring in June 2007.

The study area is exposed to two forms of flooding: Lake Macquarie flooding and local catchment flooding. Generally, areas downstream of Railway Parade experience more significant flooding due to Lake Macquarie than local catchment flooding. In contrast, areas upstream of Railway Parade are dominated by local catchment flooding. Full details of the flood modelling for the existing conditions can be sourced from the Stony Creek Flood Study (Cardno Lawson Treloar, 2005).

The table below summarises the number of properties that would be flooded in a range of design flood events together with the flood damage that is likely to occur under present conditions.

Flood ARI	Properties with Over-floor flooding	Flood Damage
5 Year ARI	0	$ 164,108
10 Year ARI	4	$ 497,645
20 Year ARI	10	$ 951,638
50 Year ARI	29	$ 1,855,372
100 Year ARI	57	$ 3,085,200
200 Year ARI	87	$ 4,389,976
PMF	295	$22,640,498
Average Annual Damage		$247,000

This Floodplain Risk Management Study investigates what can be done to reduce or manage the effects of flooding in the catchment. The Floodplain Risk Management Plan recommends a mix of strategies to manage the risks of flooding.

Using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (2005) and in consultation with the community, Council and state agency stakeholders, a number of potential options for the management of flooding were identified.

These options included:

- flood modification measures;
- property modification measures; and
- emergency response measures.

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The assessment found that the highest scored flood modification options to be recommended included:

- FM1.2 – Detention basin upstream of railway line – 1 site
- FM3.1 – Levee at West Toronto industrial area
- FM4.7 – Remove dis-used railway line at Railway Parade on Stony Creek and Mudd Creek

Property modification measures considered and recommended for the floodplain include:

- P1 – Planning controls – LEP update
- P2 – Building and development controls
- P8 – Flood proofing guidelines

Emergency response modification measures proposed for the floodplain include:

- EM1 – Information transfer to SES
- EM2 – Preparation and adoption of SES local flood plan
- EM3 – Flood warning system
- EM4 – Community flood awareness program
- EM5 – Flood depth markers

Data collection strategies proposed for the floodplain include:

- DC1 – Data collection following a flood event

The above listed flood, emergency and property modification measures ranked highly using a multi-criteria matrix assessment and have been selected for inclusion in the Draft Floodplain Risk Management Plan.

Those options selected for inclusion in the Draft Plan are based upon both their likely benefit and the funding available from Council and the State Government.

Based on the options recommended above, the cost of implementing the Plan would be an estimated capital cost of approximately $3,062,000 and an annual recurrent cost of approximately $27,200.

The draft Report was placed on public exhibition in September 2011 for comment by the public and stakeholders. This final Floodplain Risk Management Study document incorporates the one submission received during the exhibition period.

The final stages are the adoption and implementation of the actions in the Floodplain Risk Management Plan.

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Glossary

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
Design Flood	A significant event to be considered in the design process; various works within the floodplain may have different design events: some roads may be designed to be overtopped in annual flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain that causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river or drainage system.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.

Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of a river valley adjacent to the river channel, which is subject to inundation by the probable maximum flood event.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain 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 land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Possible danger to life and limb; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Integrated survey grid (ISG)	ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator.
Low hazard	Should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.

NPER	National Professional Engineers Register. Maintained by the Institution of Engineers, Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Terminology in this Glossary has been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedence Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AWE	Average Weekly Earnings
BoM	Bureau of Meteorology
CPI	Consumer Price Index
DCP	Development Control Plan
DECC	Department of Environment and Climate Change (formerly the Department of Environment and Conservation, now Office of Environment and Heritage)
DNR	Department of Natural Resources
FPL	Flood Planning Level
FRMC	Floodplain Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
GSDM	Generalised Short Duration Method
ha	hectare
IEAust	Institution of Engineers, Australia
IFD	Intensity Frequency Duration
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	metre
m^2	Square metres

m^3	Cubic metres
mAHD	Metres to Australian Height Datum
MHL	Manly Hydraulics Laboratory
MHWL	Mean High Water Level
mm	millimetre
m/s	metres per second
MSL	Mean Sea Level
NSW	New South Wales
OEH	Office of Environment and Heritage (formerly DECC)
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RAFTS	RAFTS proprietary software package
RTA	Roads and Traffic Authority
SEPP	State Environmental Planning Policy
SES	State Emergency Service

1 Introduction

A Floodplain Risk Management Study and Plan (FRMS&P) for the Stony Creek catchment has been prepared by Cardno Lawson Treloar for Lake Macquarie City Council. The FRMS&P identifies and examines options for the management of flooding within the Stony Creek catchment floodplain and is prepared in accordance with the NSW Government *Floodplain Development Manual* (2005).

A locality plan is included as **Figure 1.1**. The outline of the study area, shown in **Figure 1.2**, is defined for the purposes of this study as the main developed areas in the lower catchment that are affected by mainstream flooding.

1.1 Study Context

The Floodplain Risk Management Study and Plan forms two stages of the Floodplain Management process, which consists of the following steps, as defined in the *Floodplain Development Manual* (NSW Government, 2005):

1. Formation of a Floodplain Management Committee;
2. Data Collection;
3. Flood Study;
4. **Floodplain Risk Management Study**;
5. **Floodplain Risk Management Plan**; and
6. Implementation of Floodplain Risk Management Plan.

This study was jointly funded by Council and the Office of Environment and Heritage (OEH, formerly Department of Environment and Climate Change (DECC)). OEH also assists in the provision of specialist advice on flooding and related matters.

Previous flood studies include:

- Stony Creek Flood Study (Cardno Lawson Treloar, 2005)
- Lake Macquarie Floodplain Management Study (Webb McKeown & Associates, 2000)
- Lake Macquarie Floodplain Management Plan (Webb McKeown & Associates, 2001)

Further details of these studies are provided in **Section 2.1**.

1.2 Study Objectives

The overall objective of the FRMS&P is to devise a strategy that addresses the existing, future and continuing flooding issues in the Stony Creek catchment in accordance with the NSW Government's Flood Policy, as detailed in the NSW *Floodplain Development Manual* (2005).

Objectives of the Stony Creek Floodplain Risk Management Study and Plan are to:

- Ensure that the most up-to-date information is available on flood behaviour within the study area for the full range of flood events; including flood flows, velocities, levels, depths, flood hazard extents, rates of rise of floodwaters and the locations of floodways and flood storage areas. The Stony Creek Flood Study (Cardno Lawson Treloar, 2005) provides details for the 5 year ARI, 10 year ARI, 20 year ARI, 50 year ARI, 100 year ARI, 200 year ARI and the Probable Maximum Flood (PMF) events.
- Review Council's existing environmental planning policies and instruments, including Council's long term planning strategies for the study area.
- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events. Innovative solutions for the management of the flood hazards within the study area are being sought along with effective community consultation and participation throughout the undertaking of the study.
- Assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future.
- Consider whether the proposed works and measures could produce adverse effects (environmental, social, economic, or flooding) in the floodplain and, if so, whether they can be minimized.
- Examine and recommend measures to improve community flood awareness and emergency response measures in the context of the NSW State Emergency Service's disaster planning requirements.

1.3 Study Methodology

The report format follows the study methodology, which involved:

- Community consultation (Section 3)
- Environmental and social characteristics of the catchment (Section 4)
- Defining the existing flood behaviour including assessment of the June 2007 storm event (Section 5)
- Assessment of economic impact of flooding (Section 6),
- Review of current emergency response arrangements (Section 7)
- Review of flood planning levels (Section 8)
- Assessment of floodplain risk management options (Section 9)
- Economic assessment of options (Section 10)
- Multi-criteria assessment of options (Section 11)
- Floodplain risk management plan (Section 12)

2 Data Collation and Inputs to the Study

The majority of the data collated for this study was sourced from Lake Macquarie City Council. The data included planning documents, previous reports and mapping for the study area. A brief description of the data used in this study is presented below.

2.1 Previous Reports

A number of reports have previously been prepared that have relevance to the current study:

- Stony Creek Flood Study (Cardno Lawson Treloar, 2005)
- Flood Study for Proposed Development in Lake Street, Blackalls Park, Sinclair Knight, Reference 9339.2 (September 1991)
- Title Unknown (Flood Study in Stony Creek catchment), Sinclair Knight, Reference 8345.3 (Date Unknown ~October 1990)
- Lake Macquarie Floodplain Management Study (Webb McKeown & Associates, 2000)
- Lake Macquarie Floodplain Management Plan (Webb McKeown & Associates, 2001)

The Stony Creek Flood Study, completed by Cardno Lawson Treloar in December 2005, was reviewed as part of this Study and relevant information incorporated. The Flood Study of the Stony Creek catchment defined the nature and extent of flooding in the area for a range of design flood events. Sinclair Knight studies of flooding within the Study Area were reviewed with greater detail provided in **Appendix C**. Other previous reports and studies in the Study Area reviewed for the Stony Creek Flood Study (2005) are listed in the Flood Study Report.

The Lake Macquarie Floodplain Management Study and Plan reports (Webb McKeown & Associates 2000-2001) defined flood behaviour within and adjacent to Lake Macquarie. A plan of management for flood liable lands adjacent to the Lake was developed including measures for flood mitigation, property modification, response modification, and planning measures.

2.2 Planning Documents

A review of Council's planning documents relevant to floodplain risk management in the Stony Creek catchment was also conducted. This included a review of the following documents:

- Lake Macquarie Development Control Plan (2004)
- Lake Macquarie Local Environmental Plan (2004)
- Lake Macquarie Lifestyle 2020 Strategy (2000)

Further information regarding planning documents and policies is provided in **Section 4.13**.

2.3 Available Data

A description of data supplied by Lake Macquarie City Council for the Stony Creek Catchment is included in the Stony Creek Flood Study (2005). This data included:

- Aerial photography
- Cadastral data in GIS format
- Catchment contours
- Ground survey of Stony Creek and Mudd Creek

- Property floor level survey
- Survey of historical flood levels

The XP-RAFTS hydrological model and SOBEK hydraulic model developed for the Stony Creek Flood Study (2005) was reviewed for use in this Study.

3 Community Consultation

3.1 Community Questionnaire

A resident survey was undertaken in April 2007 by delivering questionnaires to residential and commercial properties within the catchment. About 1200 surveys were delivered within the Toronto and Blackalls Park area bounded by:

- Properties on Awaba Road and The Boulevarde to the south – including additional lots adjoining Carleton Drain and Farrell Drain;
- Toronto industrial area to the west;
- Properties on John Street, Faucett Street to the north including properties adjoining Edmunds Bay;
- Properties on Anzac Parade to the east.

The questionnaire sought information on flooding awareness and preferences for options to manage the flooding/drainage problems. **Appendix A** contains a copy of the questionnaire.

Of the distribution, 112 responses were received (approximately 10% return rate). The average time of residing in the catchment for respondents was 23 years with 46% having been there for 20 years or more. Eleven percent of respondents indicated they were not aware of flooding, with two respondents having lived in the area for 10-20 years. This may be due to the most significant flooding event occurring over 25 years ago in February 1981 and potentially due to the positioning of their residence away from the main creek corridor. About 28% percent indicated their property was flooded or they were inconvenienced by flooding.

A number of responses to the questionnaire provided comments on the proposed management options. These responses are collated in **Appendix A** (note that the names and addresses of the respondents are not included to maintain privacy). **Table 3.1** lists the preferences to the general management options included in the questionnaire. Preferences for the specific structural options presented in the questionnaire are listed in **Table 3.2**. Note that not all respondents indicated a preference (generally 70-80% of respondents indicated a preference).

Table 3.1: Community Survey Summary – General Options

Remedial Measure	Preference Ranking
Stormwater harvesting	1
Improved flood flow paths	2
Planning controls	3
Education	4
Retarding or detention basins	5
Culvert/ bridge enlarging	6
Infiltration basins and trenches	7
Levee banks	8

Stormwater harvesting was ranked as the preferred option but would have limited effect on flood mitigation, as specifically noted by some respondents. The preference for this option may be based more on the current drought affecting potable water supplies, rather than addressing flooding issues in the Stony Creek catchment.

The second most preferred measure was the improvement of flood flow paths. The dredging of deposited silt from Stony Creek, Mudd Creek, and their outlets to the bays was specifically listed by some respondents as likely to reduce flood impacts by improving the flow path. Maintenance of creeks and drains (also noting local drainage pits and pipes), such as clearing of debris (e.g. dead trees) and rubbish from the creeks, was identified. Notable other items were that a balance to flow path improvement needed to be established with maintaining riparian and in-stream vegetation for filtering and bank stabilisation reasons. Sediment and pollutant traps were also recommended upstream to limit silt build-up within the channels. It was noted by a respondent of the nature of flooding in the area, occurring potentially from flows in Stony Creek and also levels from Lake Macquarie.

Table 3.2: Community Survey Summary – Specific Options

Remedial Measure	Preference Ranking
Construction of a detention basin upstream of the North Rail Line	1
Enlarge culvert on Mudd Creek at Railway Parade	2
Enlarge the bridge over Stony Creek at Cook Street	3
Construction of a levee around properties on Fennell Crescent.	4

Planning control measures were ranked highly due to the recognition of development within the catchment affecting the flow behaviour within the catchment. Planning controls may include controls applied to new developments, including on-site detention, restrictions on impervious areas, or raised floor level requirements. On-site detention within Toronto and Blackalls Park may mitigate local overland flooding issues, but may not reduce the extent of mainstream flooding from Stony Creek. Floor levels above a specified flood level, would reduce the potential damages from flood events.

Education items noted by respondents included general flooding information for new and recent residents identifying the flood risk in the area and what to do before, during, and after a flood.

Generally detention basins were considered to be potentially effective for flood mitigation, but issues were raised regarding the potential size of basins required (and hence their safety), future maintenance of basins to ensure effectiveness, and the preference for the catchment to be retained in a ‘natural’ state. The Main Northern Railway Line was noted for two primary matters – as a potential detention basin, and also suspected as the cause of 1981 flood. An assessment of the 1981 event indicated that the rainfall was in excess of the 100 year ARI event and thus overtopping and damaging to the rail lines (Cardno Lawson Treloar, 2005).

Several respondents noted that flood mitigation benefits would result from improvements to the culvert/ bridge crossings of the creeks at Railway Parade. Of particular note, was a response from 1993 by Council regarding the measurable benefit to flood levels of removing (or raising) the Toronto-Fassifern rail line crossing. The culvert of Carleton Drain at Carleton Street was identified as being under capacity and resulting in local flooding in the vicinity of Beckley Street.

Comments regarding infiltration basins were limited, other than noting potential resultant increases to mosquito breeding habitat. The issue of infiltration generally was noted in respect of planning controls to mitigate changes resulting from additional impervious areas within the catchment.

The questionnaire indicates that levees were the least favoured of potential management options.

In some cases, respondents were unsure of the nature of the listed remedial options and would require more information to rank measures. It is noted that the flood planning process includes an exhibition period for specific measures proposed. It is recommended that during the exhibition period that input from the residents is obtained on their opinion of the recommended options.

The resident questionnaire and a summary of the responses are included in **Appendix A**. Following the initial questionnaire, a major flood event occurred in June 2007. Following this flood event, a new questionnaire was distributed to residents, and is described in **Appendix B**.

3.2 June 2007 Storm Event Questionnaire

Following the initial questionnaire, a major flood event occurred in June 2007. Following this flood event, a new questionnaire was distributed to residents, and is described in **Appendix B**.

3.3 Public Exhibition

The draft report of this Stony Creek Floodplain Risk Management Study and Plan was placed on public exhibition during September 2011. One submission from a resident of Farrell Avenue was received. Comments of the submission and response for the Floodplain Management Process are listed in Table 3.3.

Table 3.3: Public Exhibition Comment and Response

Comment	Response
What affects the level of the water in Stony Creek is air pressure. When the area is covered by a high pressure cell, the level of the creek is low. When there is a low pressure cell over the area the creek is high. If it is a very low pressure cell, I have observed that the water backs up the Farrell drain (between Farrell Ave and William St) all the way to the small concrete barrier that diverts the water from the drain into the mini wetland. The difference between the highest level and the lowest level of the creek under normal variations seems to be about 30 to 40 cm.	The modelled scenarios use a combination of ARI event flooding of Lake Macquarie and from catchment runoff. This analysis considers the joint probability of an elevated Lake level during storm events.
Flooding is accentuated because heavy rain results from low pressure cells, the water has risen as a result of the low pressure cell, then the rain water running into the creek adds to the water in the creek.	Refer to previous response regarding model scenarios.
The water table rises during periods of high rainfall. Some yards in Farrell Ave are inundated several times a year by the water table rising above ground level. It usually occurs when there is 50 mm or more of rain over a short period. Properties are on an infilled area which has sunk to a level below the surrounding roads, so the water from downpipes cannot drain out to the road drains!	Noted. The Study investigated mainstream flooding behaviour from Stony Creek itself and from Lake Macquarie. Localised overland flow behaviour was not explicitly evaluated.

4 Environmental and Social Characteristics

4.1 Catchment Layout and Topography

The Stony Creek catchment is located within the Local Government Area (LGA) of Lake Macquarie City Council. The catchment has an area of 46.4km^2 and drains into the northern end of Lake Macquarie at Fennell Bay. Lake Macquarie is a large coastal lake connected to the Tasman Sea at Swansea Heads. The catchment extends to the west of Fennell Bay and there are several large tributaries that contribute to the flow of Stony Creek. The upper reaches of the catchment are mainly forested with the catchment headwaters originating within the Awaba State Forest.

The F3 freeway bisects the upper and lower reaches of the catchment. There is a large bridge under which the major tributary of Palmers Creek flows, and a series of culverts allowing for the crossing of other minor creeks. Two other major controls, both in the upper catchment, are the Newstan Eraring Private Coal Road (known as Coal Haul Road; an elevated private road) and the Metro North Railway (Railcorp).

The topography of the catchment is quite varied with the elevation of the catchment changing from 0m at Fennell Bay up to a relief of approximately 300m along the ridgeline of the Sugarloaf Ranges in the north-west of the catchment. Rolling hills are found in the south of the catchment and have an average maximum relief of 80m. The lower urbanised reaches of the catchment are relatively flat with gentle undulations.

4.2 Catchment Land Use

The upper half of the catchment is mostly naturally vegetated with little development. The Lake Macquarie Local Environment Plan (LEP) 2004 shows the majority of this land to be zoned as either a natural resources zone, or as a zone with a level of environmental protection (**Figure 4.1**). There is also some rural land use in the mid to upper reaches of the catchment.

The purpose of land zoned as natural resources is to integrate the economic and ecological value of the land (LMCC, 2004). Awaba State Forest makes up a significant portion of the western part of the catchment and is zoned as a natural resources zone (9) managed by NPWS and State Forests. A notable portion of land is also zoned as “Conservation (Secondary)” and “Environmental (General)”. The main objective of a secondary conservation zone is to protect, conserve and enhance land of environmental value and to only enable development that does not compromise these values (LMCC, 2004). The objective of the general environmental zone is similar, however, requiring a lower level of protection.

In the lower reaches, the catchment is mostly residential with some industrial and commercial areas. The industrial centre is located in western Toronto, while residential development dominates Blackalls Park, eastern Toronto, Awaba and part of Fassifern. Residential areas are medium to low density and located in the low-lying land surrounding Stony Creek.

4.3 Creek Characteristics / Drainage Network

4.3.1 Stony Creek

The headwaters of Stony Creek are in the south-west of the catchment (**Figure 4.2**); south of Awaba. The creek flows under the Metro North Railway through culverts and then passes under an old timber road bridge on Wilton Road. From this bridge the creek flows north parallel to Wilton Road and passes under Awaba Road and the Metro North Railway to end up on the western side of the line. There are three main culverts under the Metro North Railway to convey flows towards Toronto, with an additional smaller culvert slightly to the south. Just downstream of the Metro North Railway the creek passes under the Coal Haul Road. Downstream of the Coal Haul Road the creek flows into a broad floodplain and flows past the West Toronto Industrial Area. Just downstream of the industrial area, at High Street, a weir across the creek forms the tidal limit for Lake Macquarie waters (**Figure 4.3**). Further downstream the creek flows on the southern side of Blackalls Park Sewage Treatment Plant (operated by Hunter Water) before entering a wide floodplain, where the majority of the flood-affected properties are located. Past this location a series of hydraulic controls exist in the form of pipeline bridges, a disused railway bridge, a pedestrian bridge and the Railway Parade Bridge. The urban areas in the catchment discharge to Stony Creek via either piped conduits or concrete-lined channels.

4.3.2 Palmers Creek

Palmers Creek is the major tributary of Stony Creek. The headwaters of this creek are in the west of the catchment near Freemans Waterhole. This catchment is largely undeveloped and includes large tracts of bushland and rural pastoral land. Palmers Creek joins Stony Creek east of the Metro North Railway (**Figure 4.3**).

4.3.3 Mudd Creek

Mudd Creek (previously known as Saltwater Lagoon) was separated from Stony Creek in the 1940s (precise date uncertain) (Umwelt, 2002). This drastically reduced the catchment area and practically reduced the creek flow to nil except in wet weather events. In the 1960s Blackalls Park Sewage Treatment Plant began discharging into Mudd Creek, and this provided the main source of flow until 1993, when the plant stopped its discharges. At present the only flow comes from runoff from the immediate, low lying, urban residences and flow from a small pipe culvert from Stony Creek opened in 1993. The two creeks flow roughly parallel and are separated by a low floodplain. Mudd Creek discharges into Edmunds Bay.

4.3.4 Creek at Carleton Street

This nameless Creek at Carleton Street has its headwaters in the hills south of Toronto (**Figure 4.3**). The creek then passes through the urban development at the end of Forest Lake Way. The creek flows past Biraban Primary School and through the urban area of western Toronto, then enters a concrete channel (referred to as the Carleton Street Channel) and flows past the local swimming centre, Awaba Road, and a pedestrian bridge before opening out past Toronto High School. The creek joins Stony Creek just downstream of its crossing with Carleton Street (**Figure 4.3**).

4.3.5 LT Creek

LT Creek is not within the floodplain of Stony Creek; hence not within the study area. However, this creek also flows into Fennell Bay and from a water quality perspective may interact with Stony Creek. However, analysis in the Flood study suggests that there is minimal impact of this creek on the flood levels in Stony Creek.

4.4 Catchment and Creek Debris

Debris sources can include organic materials such as leaf litter, garden clippings and animal droppings and anthropogenic materials such as litter (newspapers, plastic bags and cigarette butts) that become entrained in flows. Other sources of debris include illegally dumped waste and even rubbish bins (if a flood event occurs on a waste collection night). Essentially, any items that are not fixed, and lie within the flow path, can become debris.

4.5 Receiving Waters – Lake Macquarie

Fennell Bay and Edmunds Bay form the downstream boundary of the study area. Edmunds Bay discharges into Fennell Bay, before they pass under the Fennell Bay Bridge and out into the eastern sections of Lake Macquarie.

A flood study carried out by MHL (1998) established the Lake Macquarie water levels for various design events. The impact of catchment runoff, elevated ocean water levels, local winds and the condition of the Swansea entrance channel was considered in the assessment of the flooding behaviour of the lake as a whole. As a compendium to the above study, MHL (1998) determined the design flood levels for the lake foreshore area, such as Fennell and Edmunds Bay. These approximate design levels were primarily based on the wave run-up process at the foreshore. The complete set of the design lake levels is provided in **Table 4.1**.

Table 4.1: Lake Macquarie Design Water Levels (MHL, 1998)

Storm Event (ARI)	Downstream Boundary Level (m AHD)
PMF	2.63
200 Year	1.55
100 Year	1.38
50 Year	1.24
20 Year	0.97
10 Year	0.80
5 Year	0.65
2 Year	0.45

Both Fennell Bay and Edmunds Bay have a limited and lagged tidal nature. The bays are a considerable distance from the ocean entrance to Lake Macquarie hence the tidal range is small and tidal flushing is slow. The narrow mouth under the Fennell Bay Bridge further limits this characteristic acting as a hydraulic control. Water levels within the bays are therefore a result of both tidal and riparian influences and include any combination of the following natural causes:

- Wind Set-up and the Inverse Barometric Effect;
- Wave Set-up;
- Wave Runup;
- Fresh Water Flow;
- Eustatic and Tectonic Changes;
- Greenhouse Effect; and
- Global Changes in Meteorological Conditions.

Edmunds Bay is the receiving water for Mudd Creek. As Mudd Creek only flows in high rainfall events, water levels are primarily tidal; however the narrow mouth of Edmunds Bay into Fennell Bay further limits water level fluctuations in the Bay.

Further details on Fennell Bay and Edmunds Bay can be found in **Section 4.7**.

4.6 Geology, Soils and Mine Subsidence

4.6.1 Soils

As outlined in **Section 4.1**, the topography of the Stony Creek catchment is quite variable, with steep vegetated slopes and valleys of higher relief draining to relatively flat floodplains and lower lying suburban areas of gentler gradient. Associated with the variable terrain of the catchment there are numerous soil landscape groupings as identified from the *Gosford – Lake Macquarie* (Murphy, 1993), *Newcastle* (Mattheri, 1995) and *Singleton* (Kovac & Laurie, 1991) *Soil Landscape Maps*. These maps were obtained in a digital format from OEH.

Figure 4.4 shows the classification of soil landscapes in the Stony Creek Catchment. There are eleven different soil landscapes present within the catchment, the most common being the Awaba, Warners Bay, Wyong and Doyalson groups.

Awaba (Erosional Landscape)

The rolling low hills of the southern reaches of the catchment (south of Awaba Station) consist predominately of the Awaba soil landscape (**Figure 4.4**), resulting in coarse-grained sediments derived from the Narrabeen Group and Newcastle Coal Measures. The local relief in the regions is between 20-80m and the land has a gradient of 10-25% with some steeper sections. The land is covered in mostly uncleared open forests and drainage lines are narrow and incised. The soils on the gentler slopes and drainage lines are shallow (<50cm) Soloths and Yellow Podzolic. Lithosol soils are found on the steeper slopes having a moderate depth of 50-150cm. The soils in this region are considered to have a high erosional potential.

Warners Bay

The Warners Bay soil landscape is dominant in the upper reaches of the catchment, along the undulating low rises and low hills of Palmers Creek (**Figure 4.4**), resulting in soils that are moderately deep (100cm) to deep (>150cm). The soils are Gleyed Podzolic and Yellow Podzolic with structured loams along broad drainage lines. The properties of the soils within the class are known to cause foundation problems. The region is extensively cleared open forests.

The Warners Bay soil type is characterised by a high erosion hazard from concentrated flows and strongly acid and low fertility soils.

Wyong

The Wyong soil landscape is dominant along the broad floodplain and alluvial flats of Stony Creek and Palmers Creek (**Figure 4.4**), comprising deep (>200cm) Quaternary sediments on the Central Coast Lowlands. The sediments are classified as Yellow Podzolic Soils, Brown Podzolic Soils and Soloths. The floodplain is of a gentle gradient, being less than 5% and the local relief less than 10m. Characteristics include low fertility, impermeable poorly drained soils, and severe stream bank erosion along major drainage channels.

Doyalson

In the lower mostly developed region of the catchment the most common soil landscape is the Doyalson landscape (**Figure 4.4**). The landscape has broad crests and ridges along gently inclined (<10%) undulating slopes that rise on Munmorah Conglomerate. Depending on the underlying geology there are two common soil profiles found in the landscape, including:

- On sandstones and conglomerates: Moderately deep (50-150cm) Yellow Earths, Yellow Podzolic Soils and Soloths; and
- On fine grained siltstones and claystone: Moderately deep (50-150cm) to deep (>150cm) Yellow Podzolic Sils, Soloths, Gleyed Podzolic.

The Doyalson soil type is characterised by strongly acid soils of low fertility, high run-on and high erosion hazard in concentrated flows.

4.6.2 Acid Sulfate Soils

Acid sulfate soils (ASS) are common along the NSW coast in estuaries and in coastal low-lands. ASS occur when soils containing iron sulfides are exposed to air and the sulfides oxidise producing sulphuric acid (DECC, 2008). This usually occurs when soils are disturbed through excavation of drainage works. The production of sulphuric acid results in numerous environmental problems, including extensive damage to the State's fishing industry (DECC, 2008). It is therefore important to be aware of the distribution of ASS within the catchment, so that potential management options are developed and assessed in a manner that is sensitive to the problem of ASS (potential and actual acid sulfate soils).

A significant portion of land in the lower reaches of the catchment is prone to acid sulfate soils (**Figure 4.5**). The extent of land having a probability of acid sulfate soil is confined to low lying areas, including the estuarine sediments of Fennell Bay and the alluvial sediments along the lower reaches of the main watercourse.

Land affected by acid sulfate soil along Stony Creek extends from Fennell Bay along the path of the creek bed upstream to the Awaba railway station. The probability of occurrence of acid sulfate soil materials within the soil profile graduates from a higher to a lower probability with an increase in land elevation. That is, the lower lying land has a higher probability of acid sulfate soil than land of higher elevation (**Figure 4.5**). For example the land adjacent to Edmunds Bay has a high probability of ASS, within 1m of the ground surface (severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing), as opposed to land near Awaba Railway Station where the probability is low and the depth to ASS is greater than three metres below the ground surface (low environmental risk if ASS materials are disturbed by activities such as deep excavations) (DLWC, 1997). If high risk materials were to be disturbed (e.g. dredging) there may be a severe environmental risk. Soil investigations would be necessary to assess these areas for acid sulfate potential should any flood management actions be proposed.

4.6.3 Contaminated Land

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the *Contaminated Land Management Act 1997*. The Office of Environment and Heritage (OEH) is authorised to regulate contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination.

A search of the DECC (now OEH) Contaminated Land Record on 27 July 2009 showed six known contaminated sites within the Lake Macquarie LGA. However, none of these sites are within the Stony Creek catchment. The Contaminated Land Record is not an exhaustive index, and there may be unreported contamination present within the catchment. Given the primarily residential history of the study area there is no reason to suspect the presence of broad-scale contamination.

4.6.4 Mine Subsidence

The Stony Creek catchment is wholly contained within the West Lake and Lake Macquarie Mine Subsidence Districts. Consequently, the potential for land subsidence needs to be included when considering potential management actions.

Mine subsidence is the lowering or settling down of the land's surface as a result of past, previous or future coal mining activities. The Mine Subsidence Board (MSB) was established under the *Mine Subsidence Compensation Act 1961*, and its responsibilities include providing compensation to affected property owners and minimising the risk of mine subsidence. There are controls imposed by the MSB on the types of buildings and improvements that can be undertaken in Mine Subsidence Districts (MSB, 2007). To assist in safe development in Mine Subsidence Districts the Board has prepared surface development guidelines to ensure that structures can tolerate the expected levels of subsidence. Any proposed flood modification actions will need to consider these guidelines.

4.7 Water Quality

The Stony Creek catchment covers an area of approximately 46km^2 and drains to the western shore of Lake Macquarie (Fennell Bay), passing through the urban areas of Awaba, Toronto and Blackalls Park (**Section 4.1**). The catchment is largely rural (agricultural and bushland) with the remainder comprised of light density residential housing and light industry (**Section 4.2**). The upper regions of the catchment (largely forested areas) are steeper; reaching elevations of 300m. The lower part of the catchment is moderately flat (approximately <1% gradient). The major drainage flow paths and drainage systems are described in **Section 4.3**.

4.7.1 Stony Creek and Mudd Creek

The water quality in Stony Creek is seen to be particularly poor in comparison with other discharge points into Lake Macquarie. High levels of Phosphorous, Nitrogen, Faecal Coliforms and bacteria have been recorded in the lower reaches of Stony Creek, particularly after rain events (Eyre, 2005). This likely reflects the urban-area stormwater run-off and possible sewer overflows. Algal numbers are not demonstrably worse than other creeks (Eyre, 2005). Substantial remediation works have been undertaken in the lower reaches to improve creek health. The upper reaches of the creek are in a relatively untouched state, surrounded by small scale agriculture and bushland.

Stony Creek runs parallel to Mudd Creek. The water quality within Mudd Creek is very poor. This is primarily driven by the creek's low flow rate and historical relationship/proximity to the sewage treatment plant (**Section 4.3**). Many cases of algal blooms, fish kills, sea grass decline, and bacterial growth were recorded in the 1980s and 1990s (Umwelt, 2002). Mudd Creek does not generally flow and requires several high rainfall events to create consistent flow (Umwelt, 2002). This allows stagnation, sediment build-up and eutrophication.

Sources of pollutants impacting upon water quality include:

- "Point" Sources – e.g. discharges from premises licensed by the OEH (EPA) within the catchment under the *Protection of the Environment Operations Act (1997)*; and
- "Non Point" Sources – e.g. discharges from diffuse sources (such as build up of pollutants on road surfaces, runoff from fertilised gardens).

A search of licences listed in the Public Register under the *Protection of the Environment Operations Act (1997)* (current to 1 June 2009) on 31 July 2009 indicated 4 licensed point sources within the Stony Creek catchment area, as listed in **Table 4.2** (DECC, 2009c).

4.7.2 Fennell Bay

The water quality of Fennell Bay is affected by freshwater input from catchment runoff and, to a lesser extent, the effects of wind re-suspension of the bay sediments. Fennell Bay is deep in parts (>2m) limiting wind re-suspension of sediments affecting the concentration of suspended solids, which has the potential to affect nutrient concentrations in the water column. Given the slow flushing rate of the Bay (**Section 4.5**), following rain events Fennell Bay acts as a large stilling basin. Most of the load of sediment and nutrients that is delivered from the catchment is trapped within the bays for sufficient time for fine sediment to settle on the bed and for nutrients to be taken up by algae and seagrass (Umwelt, 2002).

Limited monitoring of Fennell Bay (Blackalls Park, at the junction of Edmunds Bay, Fennell Bay and Stony Creek) has been conducted under the DECC (now OEH) Beachwatch / Harbourwatch program (DECC, 2007). The results show several occasions at which the faecal coliform and enterococci concentrations exceeded acceptable levels. The results also show a weak relationship between these elevated concentrations and rainfall events. This indicates that urban stormwater is a potential source of pollution at this site. Nutrient concentrations are seen to be within the range of other semi-enclosed bays around Lake Macquarie. Sediment nutrient concentrations, although variable, are also generally within range of other similar sites in Lake Macquarie, yet considerably worse than the open areas in the middle of the lake. Stony Creek and LT Creek have been identified as the most polluted discharge point into the Lake

Macquarie system (Eyre, 2005). Most of the post-rain freshwater flows from Stony Creek pass immediately under the Fennell Bay Bridge into Kooroora Bay without significantly impacting the water quality of Fennell Bay.

Table 4.2: Licensed Point Sources within Stony Creek Catchment (DECC, 2009c)

Licence No.	Accountable Party Name	Common Name of Premise	Street	Suburb	Fee-Based Activity
395	Centennial Newstan Pty Limited	Newstan Colliery	Wakefield Rd	Fassifern	Coal Washery Reject or Slag Landfilling
395	Centennial Newstan Pty Limited	Newstan Colliery	Wakefield Rd	Fassifern	Mining for Coal
443	Centennial Newstan Pty Limited	Awaba Colliery	Wilton Rd	Awaba	Mining for Coal
1127	Hymix Australia Pty Ltd	Hymix Australia Pty Ltd	361 Awaba Rd	Toronto	Concrete Works
5873	Lake Macquarie City Council	Awaba Waste Disposal Facility	60 Wilton Rd	Awaba	Waste Disposal (Application to Land)
5873	Lake Macquarie City Council	Awaba Waste Disposal Facility	60 Wilton Rd	Awaba	Composting

4.7.3 Edmunds Bay

Edmunds Bay has very poor fresh-water or tidal flushing, allowing substantial sediment build-up. The narrow mouth into Fennell Bay and the limited flow from Mudd Creek create a sediment trap within the bay. Mudd Creek has particularly poor creek health. Subsequently, what limited flow is passed into Edmunds Bay is often highly polluted. Subsequently, Edmunds Bay often falls below acceptable levels of nutrients and bacteria (Umwelt, 2002). As Mudd Creek has poor flow and high nutrient build-up, Edmunds Bay experiences significant rain-based pulses of nutrients. Consequently the bay also undergoes pulses of sea-grass growth and macro-algal blooms.

4.8 Flora, Fauna and Riparian Areas

With 75% of the total catchment area being vegetated, the Stony Creek catchment supports significant native flora and fauna areas, a significant proportion of which is protected (e.g. Awaba State Forest). The lower reaches of the catchment are predominantly urbanised, however substantial parklands and vegetative corridors (particularly alongside the major creeks) provide usable habitat for native fauna.

4.8.1 Flora

Figure 4.6 shows the distribution of vegetation within the catchment as distinguished into one of two classes; remnant native or partially cleared vegetation. The extent of vegetation in the LGA was mapped and classified in 2006 by Lake Macquarie City Council from 2004 aerial photographs. It can be seen that the majority of vegetation within the catchment is remnant native vegetation comprising of 94% of total vegetation, with partially cleared native vegetation comprising the remaining 6% (**Figure 4.6**). The defining characteristics of each class are as follows:

- Remnant native vegetation – Area of vegetation that is predominantly native and the canopy is complete. Can include heathland and wetland vegetation; and

- Partially cleared native vegetation – Area of vegetation that is not in an intact state. Can include areas that have had the canopy thinned, the under-storey mown or have a component of exotic trees and shrubs. Can also include regenerating areas.

The remnant native vegetation in the area largely consists of Coastal Plains Smooth-barked Apple Woodland. Dominant species within the woodland (*Eucalyptus capitellata*, *Eucalyptus umbra*, *Corymbia gummifera* and *Angophora costata*) compose an 8-12m canopy. Also common are the smaller trees of *Syncarpia glomulifera* and *Leptospermum trinervium*. The understorey of these woodlands generally comprise *Hakea bakeriana*, *Lambertia formosa*, *Tetratheca juncea*, *Epacris pulchella* and *Grevillia* species. Ground layer vegetation is dense with many native grasses.

A search of DECC's (now OEH) Atlas of NSW Wildlife on 27 July 2009 revealed eight threatened plant species listed under the *Threatened Species Conservation Act 1995* (TSC Act 1995) known to, or likely, to occur within the Stony Creek catchment (records date back to 1980). **Table 4.3** provides a list of these species. Given the large tracts of remnant native vegetation and occurrence of several endangered and vulnerable species, the Stony Creek Catchment can be considered to be of high environmental value. Any flood management actions will need to recognise this and comply with the fauna and flora legislative requirements outlined in **Section 0**. Although not endangered there are six Koala feed-tree species which are likely to be found in the area, based on a search of DECC's (now OEH) Atlas of NSW Wildlife on 28 July 2009, including:

- *Eucalyptus tereticornis* (Forest red gum);
- *Eucalyptus microcorys* (Tallowwood);
- *Eucalyptus punctata* (Grey Gum);
- *Eucalyptus haemastoma* (Broad leaved scribbly gum);
- *Eucalyptus signata* (Scribbly gum); and
- *Eucalyptus robusta* (Swamp mahogany).

These tree species are protected under State Environmental Planning Policy 44 – Koala Habitat Protection (SEPP 44).

4.8.2 Fauna

Given the extensive tracts of native vegetation within the catchment it is unsurprising that there are many species (threatened and unthreatened) in the locality. A search of DECC's (now OEH) Atlas of NSW Wildlife on 27 July 2009 revealed 31 threatened fauna species listed under the TSC Act 1995 that are known, or likely, to occur within the Stony Creek catchment (records date back to 1980). A list of these species is provided in **Table 4.4**. Given the large number of threatened species in the area, it would be expected that there is also a very large number of non-threatened species occurring within the catchment. The presence of all these species reflects the catchment's ecological importance. Any proposed flood modification actions should consider the number and type of species the modification may affect.

Table 4.3: Threatened Flora Species Listed Under the TSC Act 1995 in the Stony Creek Catchment (DECC, 2009a)

Family Name	Scientific Name	Common Name	Legal Status	Count
Elaeocarpaceae	*Tetratheca juncea*	Black-eyed Susan	Vulnerable	410
Fabaceae (Mimosoideae)	*Acacia bynoeana*	Bynoe's Wattle	Endangered	9
Myrtaceae	*Angophora inopina*	Charmhaven Apple	Vulnerable	25
Myrtaceae	*Callistemon linearifolius*	Netted Bottle Brush	Vulnerable	1
Myrtaceae	*Melaleuca biconvexa*	Biconvex Paperbark	Vulnerable	1
Myrtaceae	*Syzygium paniculatum*	Magenta Lilly Pilly	Vulnerable	1
Orchidaceae	*Cryptostylis hunteriana*	Leafless Tongue Orchid	Vulnerable	3
Proteaceae	*Grevillea parviflora subsp. parviflora*	Small-flower Grevillea	Vulnerable	30

Table 4.4: Threatened Fauna Species Listed Under the TSC Act 1995 in the Stony Creek Catchment (DECC, 2009a)

Family Name	Scientific Name	Common Name	Legal Status	Count
		Birds		
Accipitridae	*Pandion haliaetus*	Osprey	Vulnerable	13
Ardeidae	*Ixobrychus flavicollis*	Black Bittern	Vulnerable	5
Cacatuidae	*Callocephalon fimbriatum*	Gang-gang Cockatoo	Vulnerable	2
Cacatuidae	*Calyptorhynchus lathami*	Glossy Black-Cockatoo	Vulnerable	13
Ciconiidae	*Ephippiorhynchus asiaticus*	Black-necked Stork	Endangered	1
Climacteridae	*Climacteris picumnus*	Brown Treecreeper	Vulnerable	5
Haematopodidae	*Haematopus longirostris*	Pied Oystercatcher	Vulnerable	3
Jacanidae	*Irediparra gallinacean*	Comb-crested Jacana	Vulnerable	1
Meliphagidae	*Xanthomyza phrygia*	Regent Honeyeater	Endangered	2
Psittacidae	*Lathamus discolor*	Swift Parrot	Endangered	6
Psittacidae	*Neophema pulchella*	Turquoise Parrot	Vulnerable	1
Strigidae	*Ninox connivens*	Barking Owl	Vulnerable	1
Strigidae	*Ninox strenua*	Powerful Owl	Vulnerable	33
Tytonidae	*Tyto novaehollandiae*	Masked Owl	Vulnerable	37
Tytonidae	*Tyto tenebricosa*	Sooty Owl	Vulnerable	11

Family Name	Scientific Name	Common Name	Legal Status	Count
Mammals				
Dasyuridae	*Dasyurus maculatus*	Spotted-tailed Quoll	Vulnerable	10
Molossidae	*Mormopterus norfolkensis*	Eastern Freetail-bat	Vulnerable	17
Petauridae	*Petaurus australis*	Yellow-bellied Glider	Vulnerable	4
Petauridae	*Petaurus norfolcensis*	Squirrel Glider	Vulnerable	32
Phascolarctidae	*Phascolarctos cinereus*	Koala	Vulnerable	14
Pteropodidae	*Pteropus poliocephalus*	Grey-headed Flying-fox	Vulnerable	20
Vespertilionidae	*Chalinolobus dwyeri*	Large-eared Pied Bat	Vulnerable	5
Vespertilionidae	*Falsistrellus tasmaniensis*	Eastern False Pipistrelle	Vulnerable	3
Vespertilionidae	*Kerivoula papuensis*	Golden-tipped Bat	Vulnerable	2
Vespertilionidae	*Miniopterus australis*	Little Bentwing-bat	Vulnerable	35
Vespertilionidae	*Miniopterus schreibersii oceanensis*	Eastern Bentwing-bat	Vulnerable	36
Vespertilionidae	*Myotis adversus*	Large-footed Myotis	Vulnerable	3
Vespertilionidae	*Scoteanax rueppellii*	Greater Broad-nosed Bat	Vulnerable	12
Vespertilionidae	*Vespadelus troughtoni*	Eastern Cave Bat	Vulnerable	5
Reptiles				
Cheloniidae	*Chelonia mydas*	Green Turtle	Vulnerable	5
Elapidae	*Hoplocephalus stephensii*	Stephens' Banded Snake	Vulnerable	1

4.8.3 Fish

A variety of common fish species are likely to occur within the lagoon and riparian areas of the catchment. A desktop search of the Department of Primary Industries (NSW Fisheries) database revealed that there are no known threatened species listed in this catchment (DPI, 2009).

The modified nature of the Stony Creek system presents considerable barriers to fish passage. Several bridges cross the lower reaches of the creek and the upper reaches of Stony Creek have several culvert pipeline crossings of the Metro North Railway. Intrusions such as these can increase water flow rate, create potential harmful synthetic environments, and increase turbulence. Even non-intrusive barriers (e.g. raised bridges) can cause barriers to fish passage by limiting light penetration, generating extended darkened sections through which fish may be unwilling to travel (Fairfull and Witheridge, 2003). The major barrier to fish passage is the High Street Weir, separating the fresh and salt water ecosystems, and represents the upper bound of marine ingress, except during flood events in Lake Macquarie itself.

4.9 Recreational Use

Open space within the Stony Creek catchment provides the general public with the opportunity to participate in a variety of recreational activities. Recreational activities that were considered for the study area are those associated with the enjoyment of the watercourse, reserves and open spaces adjoining the watercourse, and other significant locations of recreational value within the PMF extent.

Recreational users can be categorised into 'active' users (those who require a vehicle, equipment or watercraft for their activity) or 'passive' users (those who do not require a watercraft, vessel or specialised equipment).

Common recreational uses of the creek and adjoining parklands include:

- Sightseeing;
- Picnicking;
- Walking/Jogging;
- Bird watching;
- Physical exercise (particularly in Keith Barry Park);
- Dog walking;
- Kayaking and other light craft water sports (lower catchment); and
- Shore-based recreational fishing.

Keith Barry Park is an open space of notable recreational value located in the lower catchment between Stony Creek and Awaba Road at Bridge Street. The park's facilities include two playing fields with lights and one minor field (**Figure 4.3**).

Awaba State Forest, which encompasses a significant part of the upper catchment, is also an important recreational area. This was confirmed by a web-based visitation survey undertaken by Forests NSW to reveal the State's most visited forests and the types of activities people like to do in State forests (DPI, 2005). Analysis of 1500 responses from late 2003 to mid 2005 showed that Awaba was one of the top 20 State forests visited out of some 700 in New South Wales. The survey also showed that the most common activities undertaken in NSW State forests include mountain biking, camping, picnicking, bushwalking, forest-driving and 4wd touring (DPI, 2005).

4.10 Aboriginal and Non-Aboriginal Cultural Heritage

4.10.1 Aboriginal Heritage

The *National Parks and Wildlife Act 1974* provides protection for Aboriginal heritage. The objective of the Act is to conserve heritage items of cultural significance to Aboriginal people and to promote public appreciation of these items. Proposed flood modification actions need to consider any potential impact on identified heritage items.

A preliminary investigation of indigenous heritage was undertaken by searching the NPWS Aboriginal Heritage Information Management System (AHIMS) in February 2007 for known or potential indigenous archaeological or cultural heritage sites within or surrounding the Stony

Creek floodplain. The AHIMS search results are shown on **Figure 4.7** and relevant sites are presented in **Table 4.5**, with five listed Aboriginal sites near the catchment outlet, located along the foreshore of Fennell Bay. Also notable, when considering future management options, is the Aboriginal site on Palmers Creek involving a water hole/well.

Table 4.5: Items Identified Under the NPWS Aboriginal Heritage Information Management System for Stony Creek

Site ID	Site Name	Site Type
38-4-0102	Palmers Creek: PC1	Axe Grinding Groove, Water Hole/Well
38-4-0187	Fennell Bay	Rock Engraving
38-4-0188-F	Fennell Bay	Isolated Find
38-4-0189	Fennell Bay	Axe Grinding Groove
38-4-0190	Fennell Bay	Midden
38-4-0191	Fennell Bay	Natural Mythological (Ritual)
45-7-0005	Awaba Railway Station: Toronto	Axe Grinding Groove, Shelter with Deposit
45-7-0241	Awaba 1	Not Classified

The following qualifications apply to an AHIMS search:

- AHIMS only includes information on Aboriginal objects and Aboriginal places that have been provided to OEH;
- Large areas of New South Wales have not been the subject of systematic survey or recording of Aboriginal history. These areas may contain Aboriginal objects and other heritage values which are not recorded on AHIMS;
- Recordings are provided from a variety of sources and may be variable in their accuracy. When an AHIMS search identifies Aboriginal objects in or near the area it is recommended that the exact location of the Aboriginal object be determined by re-location on the ground; and
- The criteria used to search AHIMS are derived from the information provided by the client and OEH assumes that this information is accurate.

It is likely that these identified items relate to the Awabakal people; the traditional owners of the Stony Creek Area. Consultation with community elders is required for any proposed modification to the creek system that may have an impact on these heritage items.

4.10.2 Non-Aboriginal Heritage

There are three different types of statutory heritage listings of non-Aboriginal origin; local, state or national heritage items. A property is a heritage item if it falls into a listings category. The category an item falls into depends on whether it is considered to be significant to the nation, state or a local area. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Aboriginal heritage was undertaken for the catchment. Searches were undertaken on a number of databases to determine the cultural heritage within this area. Databases searched include:

- NSW Heritage Office – State Heritage Register; and
- Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List; Register of the National Estate).

The State Heritage Register listed 282 heritage listed items within Lake Macquarie LGA (as at 27 July 2009), whilst the Lake Macquarie Local Environment Plan (LEP) 2004 list 321 heritage listed items. The State Heritage Register and Lake Macquarie LEP 2004 concurred 34 heritage items were located within the Stony Creek catchment boundaries, as indicated in **Table 4.6**.

The Lake Macquarie LEP 2004 also lists natural heritage items of significance under Schedule 5 of the LEP. The two items of significance within the Stony Creek Catchment are listed in **Table 4.7**.

A search of the Australian Heritage Database on 27 July 2009 found 34 items/locations listed as items of National Heritage within the Lake Macquarie LGA (33 on the Register of the National Estate (RNE) and 1 on the National Heritage List). Of these, 4 items on the RNE are located within the Stony Creek catchment:

- Fennell Bay Reserve (Public Reserve R 38237), Narara Street, Blackalls Park;
- Toronto Hotel, 74 Victory Parade, Toronto;
- Toronto Railway Station and Masters Room, Victory Parade, Toronto; and
- Toronto to Fassifern Rail Corridor, Victory Parade, Toronto.

Table 4.6: Local Heritage/Archaeological Items within the Stony Creek Catchment as Listed Under Schedule 4 of the LMCC LEP 2004

Suburb	Item Number	Significance	Item	Address	Property Description
	Heritage items other than of Aboriginal origins and including potential archaeological sites				
Awaba	AW-05	Local	Gatekeeper's Cottage	1 Wilton Rd	Lot 1, DP 817297
Blackalls Park	BK-02	Local	Railway Bridges	2 (over) Mudd Creek and 2 (over) Stony Creek	(also see RT-11)
Blackalls Park	BK-03	Local	Railway Station	26 South Pde	(also see RT-11)
Fassifern	FF-01	Local	Fassifern Railway Cottage	Wallsend Rd	Lot 1, DP 854050
Fassifern	FF-02	Local	Toronto Railway Overbridge	(over) Fassifern Rd	(also see RT-11)
Fassifern	FF-03	Local	Fassifern Railway Station	29 Fassifern Rd	
Toronto	TT-01	Local	House "Manuka"	182 Excelsior Pde	Lot 461, DP 589541
Toronto	TT-06	Local	House "The Moorings"	2 Jarrett St	Lot A, DP 368417
Toronto	TT-08	Local	Toronto Cemetery	354 Awaba Rd	MD 500 MS 3070

Suburb	Item Number	Significance	Item	Address	Property Description
Toronto	TT-09	Local	Toronto Hotel	74 Victory Pde	Lot 201, DP 549239
Toronto	TT-11	Local	Former Railway Station	16 Victory Row	Lot 22, DP 858519
Toronto	TT-12	Local	Frith's Store	66 The Boulevarde	Lot B, DP 390795
Toronto	TT-15	Local	Building Restaurant	24 Victory Pde	Lot 1, DP 301366
Toronto	TT-16	Local	Royal Motor Yacht Club Annexe	8 Arnott Ave	Lot 12 to 15, DP 456286
Toronto	TT-17	Local	Building Restaurant	6 Arnott Ave	Lot X, DP 406274, Pt Lot 424, DP 823708
Toronto	TT-18	Local	Boatman's Cottage Lakefront	4 Arnott Ave	Lot 1, DP 950464
Toronto	TT-19	Local	Boathouse and Winches Lakefront	4 Arnott Ave	Lot 1, DP 950464 PO 65/60
Toronto	TT-20	Local	House	4 Arnott Ave	Lot 1, DP 950464
Toronto	TT-21	Local	House "Burnbrae"	32 Renwick St	Lot 1, DP 122786
Toronto	TT-22	Local	Station Master's Cottage	98 Brighton Ave	Lot 1, DP 125979
Toronto	TT-23	Local	House "McGeachie's"	109 Brighton Ave	Lot 2, DP 515029
Toronto	TT-29	Local	Convent of Mercy	26 Renwick St	Lot 2, DP 314496
Toronto	TT-30	Local	House	23 Renwick St	Lot 2, DP 350492
Toronto	TT-38	Local	Cottage	6 Renwick St	Lot 21, DP 4236
Toronto	TT-42	Local	House	16 Hunter St	Lot 111, DP 596414
Toronto	TT-43	Local	Winn's House	19 Hunter St	Lot 100, DP 717511
Railways and Tramways	RT-03	Local	Great Northern Railway	Line passes through Lake Macquarie from Garden Suburb to Wyee	
Railways and Tramways	RT-11	Local	Fassifern to Toronto Branch Railway Line	Fassifern Railway Station to Toronto Railway Station and then Toronto Wharf	
	Potential archaeological sites other than of Aboriginal origins				
	3		Newstan Colliery	Fassifern Rd, Fassifern	
	AW-08	L	Railway Station	34 Brisbane St,	

Suburb	Item Number	Significance	Item	Address	Property Description
			cottage	Awaba	

Table 4.7: Natural Heritage Items within the Stony Creek Catchment as Listed Under Schedule 5 of the LMCC LEP 2004

Suburb	Item Number	Significance	Item	Address	Property Description
	Natural Heritage Items				
Blackalls Park	BK-01	L	Fossil Tree Sections	Venetia Ave	Lot 6, DP 12604
Blackalls Park	BK-04	L	Fossil Tree Reserve	40 Aldon Cr	Reserve 38237

Both the Toronto Railway Station and Masters Room, and the Toronto to Fassifern Rail Corridor have been proposed as potential areas of National Heritage but are awaiting formal acceptance (i.e. they are listed as Indicative Places as at 27 July 2009).

Part 6 of the Lake Macquarie LEP 2004 outlines the provisions which must be followed in relation to heritage items in the LGA. It is important to consult the LEP if development is intended in an area which may interfere with a heritage listed item, as there are development restrictions and procedures which need to be followed.

4.10.3 Land Rights and Native Title Claims

Land rights and Native Title are two different forms in which traditional land owners can gain access to land or claim compensation for previous dispossession of their land.

Under the *Aboriginal Land Rights Act 1983* local Aboriginal land councils can claim Crown lands provided the lands are vacant and not otherwise required for an essential pubic purpose. A search on the Land Claims Register maintained by the Office of the Registrar, *Aboriginal Land Rights Act 1983* (ORALRA), on 2 February 2007, found that more than 200 land claims had been lodged within the Lake Macquarie LGA.

A database search and inspection of the National Native Title Tribunal spatial map for NSW, ACT and Jervis Bay Territory (dated 30 June 2009) was undertaken on 27 July 2009 to determine whether there are any previous or pending native title claimant applications within the vicinity of the study area under the Commonwealth *Native Title Act 1993* (NNTT, 2009). The map indicated that although there are a number of claims within the area, there are no applications lodged concerning land within the catchment, the nearest application being in Pelican, Lake Macquarie.

If specific flood modification works were to proceed, any active claims in the development vicinity would need to be confirmed to ensure that an up to date evaluation of potential constraints is available.

4.11 Visual Amenity

The Stony Creek catchment is a semi-urbanised catchment in a scenic coastal setting. The landscape is dominated by relatively flat residential suburbs bordering Lake Macquarie with a backdrop of forested hills and mountains. In general, the Lake Macquarie LGA is a popular tourist destination with the pleasing visual amenity of the area being a major attraction. The mountains are a majestic backdrop to the urban landscape providing a scenic setting for the low density residential development. Lake Macquarie itself, the catchment outlet, is the second largest NSW estuarine waterway area (DNR, 2009).

Within the catchment the undeveloped upper reaches provide important state forests and areas of natural beauty (e.g. Awaba State Forest). In the lower reaches of Stony Creek, the creek itself (preserved in its natural state) and surrounding vegetative corridors and parks are areas of high visual amenity. The coastal sections of the catchment are also considered of high value due to the abundance of water and wildlife.

Areas around the Sewage Treatment Plant and Mudd Creek present areas of lower visual amenity.

4.12 Demographic Characteristics

A knowledge of demographic character assists in the preparation and evaluation of management options which are appropriate for the local community. For example, the data is relevant in the consideration of emergency response or evacuation procedures (e.g. information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community).

The demographic characteristics of the Stony Creek catchment presented in this report are based on the three suburbs of Toronto, Blackalls Park and Awaba. These suburbs were chosen as they are representative of the populated extent of the catchment affected by flooding. Population data for each suburb was sourced from the Australian Bureau of Statistics (ABS) 2006 Census. The data was then aggregated to produce an overall summary for the region of interest.

In summary, the 2006 Census data revealed that:

- The region had a significantly lower proportion of people in the 25 - 54 years age group and a slightly higher proportion of people in the 55 - 64 years age group than is typical of the general Australian population. The region also had a significantly higher proportion of people in the 65 year and over age group (**Table 4.8**);
- Approximately 93.4% of the region's population was Australian born. Those born overseas predominately emigrated from England (3.8%) followed by New Zealand (1.2%). Indigenous (Aboriginal and Torres Strait Islander) people comprised of 4.4% of the region's population;
- English was the only language spoken in approximately 98.6% of homes in the Stony Creek catchment. The remainder of languages spoken at home were diverse and included Spanish, German, Dutch and Italian; however there was no specific other language contributing to greater than 0.3% of the total (**Table 4.9**);
- Only 50% of the region's population was in the labour force. Of those who stated their employed hours 53% worked full-time and 31% worked part-time;

- Christianity was the dominant religion in the Stony Creek catchment, with 34.5% of the population identifying themselves as Anglican and 25% as Catholic. Following this, 22% of the region's population were of no religion;
- The average median weekly income for individuals in the region was $361, compared to the Australian average of $466. This trend of below average income for the region compared to the Australian average was also evident for family and household incomes (**Table 4.10**).

Table 4.8: Age Structure of Awaba, Blackalls Park and Toronto (ABS, 2007)

Age Group (Years)	Persons in Selected Region	% of total persons in Region	% of total persons in Australia
0 - 4	502	6.10%	6.30%
5 - 14	1111	13.40%	13.50%
15 - 24	983	11.90%	13.60%
25 - 54	2951	35.60%	42.20%
55 - 64	1075	13.00%	11.00%
65 +	1666	20.10%	13.30%
TOTAL	8288	-	-

Table 4.9: Languages Spoken at Home in Awaba, Blackalls Park and Toronto (ABS, 2007)

Languages Spoken at Home	Persons in Selected Region	% of total persons in Region	% of total persons in Australia
English Only	7,805	98.62%	78.50%
Spanish	23	0.29%	0.50%
German	17	0.21%	0.40%
Dutch	13	0.16%	0.20%
Italian	13	0.16%	1.60%
Khmer	11	0.14%	0.10%
Filipino	9	0.11%	0.20%
Dinka	7	0.09%	0.00%
Serbian	4	0.05%	0.30%
Balinese	3	0.04%	0.00%
French	3	0.04%	0.20%
Mandarin	3	0.04%	1.10%
Vietnamese	3	0.04%	1.00%

Table 4.10: Average Median Income of Awaba, Blackalls Park and Toronto (ABS, 2007)

Income (For Population Aged 15 Years and Over)	Selected Region	Australia
Average Median individual income (weekly)	$361	$466
Average Median household income (weekly)	$792	$1,027
Average Median family income (weekly)	$977	$1,171

4.13 Legislation, Policies, Plans and Codes

Legislation, policies and plans relevant to the Study are listed in **Table 4.11**. A brief description is given of those most relevant to the Stony Creek floodplain.

Table 4.11: Details of Relevant Legislation and Environmental Planning Instruments

Name of Legislation / Policy	Administrative Body	Details
NSW Flood Prone Land Policy 2001 *Floodplain Development Manual 2005*	OEH	The *Floodplain Development Manual 2005* incorporates the *NSW Flood Prone Land Policy 2001*. The Policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods. The policy also recognises the benefits of use, occupation and development of flood prone land. The Manual provides councils with the framework for implementing the Policy.
Lake Macquarie Local Flood Plan (1996)	SES	A detailed review of the Lake Macquarie Disaster Plan (DISPLAN) is provided in Section 7.
Water Management Act 2000	DWE	The Water Management Act 2000 replaced the repealed *Rivers and Foreshores Improvement Act 1948*, and regulates construction activities in close proximity to waterways. Principles set out in the Act generally aim to preserve and or restore water sources, floodplains, and water dependant ecosystems (including groundwater and wetlands). The Act also encompasses the protection of habitats, animals and plants which benefit from water or are potentially affected by managed activities. A Controlled Activity Approval (under Chapter 3, Part 3 of the Act) is required from DWE for any works to be carried out in, on or under waterfront land. The prescribed distance for waterfront land is currently 40m inland from the highest bank of a river/creek and 40m inland from the shore of a lake. However, it should be noted that Clause 39A (1) of the *Water Management (General) Regulation 2004* provides for all public authorities (other than Landcom) and local councils to be exempt from Section 91E (1) of the *Water Management Act 2000*, and hence are not required to obtain Controlled Activity Approval for controlled activities carried out on or under waterfront land.
Local Government Act 1993	Department of Local Government (DLG)	The *Local Government Act 1993*, primarily administered by DLG, gives local councils the power to control and regulate the drainage of land and to construct drains in their locality.
State Emergency and Rescue Management Act 1989 (SERM Act 1989)	SES	The SERM Act 1989 defines an emergency as an emergency due to an actual or imminent occurrence (such as fire, flood, storm, earthquake, explosion, accident, epidemic or

Name of Legislation / Policy	Administrative Body	Details
		warlike action) which: • Endangers, or threatens to endanger, the safety or health of persons or animals in the State; • Destroys or damages, or threatens to destroy or damage, property in the State; and • Hence requires a significant and co-ordinated response. The Act makes detailed provisions for planning and action during emergencies as outlined above.
Environmental Planning and Assessment Act 1979 (EP&A Act 1979)	DoP and Lake Macquarie City Council	The EP&A Act 1979 includes aims and objectives which set the tone for the application of the Act. Standard LEP templates are also included which provide standard guidelines, definitions and controls. A range of sections of the Act are relevant to floodplain management including Sections 117 and 149.
Protection of the Environment Operations Act 1997 (PoEO Act 1997)	OEH – EPA	The PoEO Act 1997 is administered by OEH and ultimately aims to protect, enhance and restore the quality of the environment in NSW, to reduce risk to human health and promote mechanisms that minimise environmental degradation through a strong set of provisions and offences. The PoEO Act 1997 enables the explicit protection of the environment policies (PEPs) and more innovative approaches to reducing pollution. The Act also provides a single licensing arrangement to replace the different licences and approvals under existing separate Acts. Integration of EPA licensing with the development approval procedures under the EP&A Act 1979 provides public participation in the environmental assessment of activities that may be licensed by the EPA. A licence is required from OEH if any activities to be undertaken are determined to be a "scheduled activity" under Schedule 1 of the Act.
Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act 1999)	Department of Environment and Water Resources (Commonwealth)	The EPBC Act 1999 establishes the obligation to preserve native species and ecological communities that are listed as endangered or vulnerable. This legislation requires that approval be obtained for any environmentally significant actions on Commonwealth Land, or actions that are likely to have a significant impact on nationally threatened species and ecological communities, RAMSAR wetlands and other nationally significant issues.
Threatened Species Conservation Act 1995 (TSC Act 1995)	OEH	The objectives of the TSC Act 1995 include: • To conserve biological diversity and promote ecologically sustainable development; • To prevent the extinction and promote the

Name of Legislation / Policy	Administrative Body	Details
		recovery of threatened species, populations and ecological communities; • To protect the critical habitat of those threatened species, populations and ecological communities that are endangered; • To eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities; • To ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed; and • To encourage the conservation of threatened species, populations and ecological communities by the adoption of measures involving co-operative management.
National Parks and Wildlife Act 1974 (NPW Act 1974)	OEH – National Parks and Wildlife Service	The NPW Act 1974, administered by OEH, is the primary legislation for the protection of Aboriginal cultural heritage in NSW. Part 6 of the Act provides specific protection for Aboriginal objects and places. A Section 87 Permit or a Section 90 Consent under the NPW Act, issued by the Director General of OEH, should be obtained if any impacts on Aboriginal objects and places are anticipated due to any activities. The Act also makes provision for the protection of native flora and fauna not listed as threatened or endangered.
Fisheries Management Act 1994	DPI – NSW Fisheries	The objectives of the *Fisheries Management Act 1994* are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations. In particular: • To conserve fish stocks and key fish habitats; • To conserve threatened species, populations and ecological communities of fish and marine vegetation; and • To promote ecologically sustainable development, including the conservation of biological diversity.
Noxious Weeds Act 1993	DPI – NSW Agriculture	The *Noxious Weeds Act 1993* aims to regulate the impacts and spread of noxious weeds throughout NSW. Declared noxious weeds are gazetted and must be disposed of in accordance with the guidelines.
Native Vegetation Act 2003	OEH	This Act is designed to protect native vegetation in non-urban areas. In general native vegetation must not be cleared except in accordance with: (a) A development consent granted in accordance

Name of Legislation / Policy	Administrative Body	Details
		with the Act; or (b) A property vegetation plan. The Act does not apply to the clearing of native vegetation: • Under Part 5 of the *Environmental Planning and Assessment Act 1979* (EP&A Act 1979); • On urban lands (i.e. land zoned 'residential'); or • That is, or is part of, designated development under the EP&A Act 1979 where development consent has been granted.
Contaminated Lands Management Act 1997	OEH	The *Contaminated Land Management Act 1997* outlines the assessment criteria and management of contaminated land which poses significant risk to human health or the environment. Under the Act, a person or persons or a public authority will be held responsible as an outcome of land contamination. OEH is responsible for declaring the land as 'Contaminated' and will give notice to end the declaration, once satisfied that the land poses no further risk.
State Environmental Planning Policy (Infrastructure) 2007	DoP	SEPP (Infrastructure) aims to facilitate the effective delivery of infrastructure across NSW by providing greater regulatory certainty in regards to infrastructure projects and consent conditions, and also allowing greater flexibility in the location of services and infrastructure. Clause 50 of the SEPP permits development for the purpose of flood mitigation works to be carried out by or on behalf of a public authority without consent on any land. Clause 111 of the SEPP permits development for the purpose of stormwater management systems under the same provisions. Part 2, Section 15 of SEPP (Infrastructure) contains provisions for public authorities to consult with local councils and other public authorities prior to the commencement of any development with impacts on flood liable land. SEPP (Infrastructure) details the consultation and environmental assessment categories required for infrastructure developments.
State Environmental Planning Policy (Housing for Seniors or People Living with a Disability) 2004	DoP	This SEPP permits housing for seniors or people with a disability wherever houses, flats, hospitals and special uses are permitted in urban areas or adjoining urban areas, except for some environmentally sensitive areas. It allows for the setting aside of local planning controls within guidelines outlined in the SEPP. Where inconsistencies occur this policy prevails over other planning instruments (e.g. LEP).

Name of Legislation / Policy	Administrative Body	Details
SEPP 14 – Coastal Wetlands	DoP	SEPP 14 is designed to ensure that coastal wetlands are preserved and protected for environmental and economic reasons. Under this SEPP any land clearing and drainage work conducted within a SEPP 14 listed wetland is required to obtain concurrence from DoP. Such development also requires an Environmental Impact Statement to be lodged with a development application.
SEPP 19 – Bushland in Urban Areas	DoP	SEPP 19 aims to protect and preserve bushland within certain urban areas contained in Schedule 1 of the SEPP. Lake Macquarie area is listed under Schedule 1 as an area of bushland that requires preservation because of its value to the community as part of the natural heritage of the area, its aesthetic value, and also its value as a recreational, educational and scientific resource. SEPP 19 specifically aims to protect habitats for native flora and fauna and protect wildlife corridors and vegetation links with other nearby bushland.
SEPP 26 – Littoral Rainforests	DoP	SEPP 26 aims to provide a mechanism for the consideration of applications for development that is likely to damage or destroy littoral rainforest areas with a view to the preservation of those areas in their natural state.
SEPP 44 – Koala Habitat Protection	DoP	SEPP 44 aims to protect areas of land that are 'core koala habitat' or 'potential koala habitat'. In this Policy 'core koala habitat' means an area of land with a resident population of koalas, evidenced by attributes such as breeding females (that is, females with young) and recent sightings of and historical records of a population. 'Potential koala habitat' means areas of native vegetation where the trees of the types listed in Schedule 2 of the Policy constitute at least 15% of the total number of trees in the upper or lower strata of the tree component. SEPP 14 applies to all local government areas (LGAs) listed in Schedule 1 of the Policy. Lake Macquarie LGA is listed in Schedule 1.
State Environmental Planning Policy 71 – Coastal Protection (SEPP 71)	DoP	SEPP 71 aims to ensure development assists in protecting, preserving and managing the coast of NSW. This Policy requires certain development applications to carry out development in sensitive coastal locations to be referred to DoP for comment. According to Coastal Zone Maps 2 and 3 (*NSW Coastal Protection Act 1979*), part of the Stony Creek catchment is classified as Coastal Protection Zone.
Lake Macquarie Local Environmental Plan 2004 (LM LEP 2004)	Lake Macquarie Council	The LM LEP 2004 determines the developmental capabilities and restrictions for all areas within the Lake Macquarie LGA. The LM LEP 2004 was developed out of and by-and-large replaces the

Name of Legislation / Policy	Administrative Body	Details
Lake Macquarie Lifestyle 2020 Strategy (2000)		LM LEP 1984. All land in the Lake Macquarie LGA is zoned for specific purposes in alignment with the perceived attributes and character of the area. In particular the LEP is designed in conjunction with the Lake *Macquarie Lifestyle 2020 Strategy*, and is aimed at promoting the goals set out in the Strategy. The Strategy outlines the plans necessary to manage the population and employment growth expected to occur in the Lake Macquarie LGA for the period until the year 2020. Detailed requirements of the zoning present in the Stony Creek catchment area are given in Section 4.2 (Figure 4.1) and Section 4.13.1. In the LM LEP 2004, Section 32 (Flood prone land) outlines that development on flood affected land is to be done with consent and designed to minimize impacts of flooding on property and have regard to the existing flood regime. Section 34 (Trees and native vegetation) of the LEP sets forth the consent requirements for modification of trees and native vegetation.
Lake Macquarie Development Control Plans 1 & 2 (2004) (DCP)	Lake Macquarie Council	The DCP supplements the LEP and provides greater development details. These may not specifically relate to the control or management of flooding but have been prepared under the framework of the LEP.
Lake Macquarie Environmental Action Plan (2004) (EAP)	Lake Macquarie Council	The EAP sets forth strategies to manage the urban environments of Lake Macquarie. The Plan was established in conjunction with the LM LEP 2004 and subsequent developmental controls.

4.13.1 LEP Zoning Objectives

The Stony Creek catchment covers 18 distinct LEP zones (**Figure 4.1**). The nature of compliant development of each zone and development restrictions, specifically relating to flood works, are described in **Table 4.12**.

Table 4.12: Lake Macquarie LEP 2004 Zoning Objectives within Stony Creek catchment

Locality	Objectives
Zone 1(1): Rural (Production) Zone	The objectives of this zone are to: (a) provide for economic and employment-generating agricultural activities, (b) provide for a range of compatible land uses that maintain and enhance the rural environment of the locality, (c) ensure development is carried out in a manner that improves the quality of the environment, including quality of design, and is within the servicing capacity of the locality, (d) encourage development and management practices that are sustainable, (e) encourage the development of good quality agricultural land for agriculture (other than intensive agriculture) to the greatest extent possible, (f) encourage the development of low quality agricultural land for intensive

Locality	Objectives
	agriculture, (g) provide for sustainable forestry practices, (h) avoid land use conflict by restricting or prohibiting development that has the potential to negatively affect the sustainability of existing agriculture, and (i) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP and agriculture (other than intensive agriculture). Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, extractive industries, roads, roadside stalls, signs, stormwater management facilities and sustainable generating works.
Zone 1(2): Rural (living) Zone	The objectives of this zone are to: (a) provide for the enjoyment of a rural lifestyle and the operation of small-scale rural and tourism activities, (b) provide for a range of compatible land uses that maintain the rural environment, (c) ensure development is carried out in a manner that improves the quality of the environment, and is within the servicing capacity of the area, (d) retain and enhance the rural character of land, (e) allow for the appropriate development of land presently within this zone so as to limit the need to rezone any more land to this zone, (f) avoid land use conflict by restricting or prohibiting development that has the potential to negatively affect the sustainability of existing agriculture, and (g) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, roadside stalls, signs and stormwater management facilities.
Zone 2(1): Residential Zone	The objectives of this zone are to: (a) permit development of neighbourhoods of low-density housing, (b) provide for general stores, community service activities or development that includes home businesses whilst maintaining and enhancing the residential amenity of the surrounding area, (c) ensure that housing development respects the character of surrounding development and is of good quality design, and (d) provide for sustainable water cycle management. Development permissible without development consent:

Locality	Objectives
	Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 2(2): Residential (Urban living) Zone	The objectives of this zone are to: (a) provide for medium and high density housing, (b) encourage development of good quality design within the zone, (c) provide an environment where people can live and work in home businesses and professional services whilst maintaining the residential amenity of the surrounding area, (d) provide residents with good access to a range of urban services and facilities, and (e) encourage amalgamation of existing lots to facilitate well designed medium and high density development, and (f) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, environmental facilities, roads, signs and stormwater management facilities.
Zone 3(1): Urban Centre (Core) Zone	The objectives of this zone are to: (a) provide land for commercial, retail, recreational and housing uses in a central location, (b) generate viable employment and economic activity, (c) create urban centres for safe and vibrant social, cultural and community activity, (d) create public spaces that are accessible, welcome all people and are a central focus for the community, and (e) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 3(2): Urban Centre (Support)	The objectives of this zone are to: (a) provide land for development that supports the viability of Urban Centre (Core) zoned land,

Locality	Objectives
Zone	(b) encourage good quality design within the zone, (c) provide land for mixed use development comprising residential uses in combination with commercial and retail uses, professional services and home based businesses, and (d) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 4(2): Industrial (General) Zone	The objectives of this zone are to: (a) provide land for light industries that can service surrounding community needs and provide local employment opportunities, and (b) enable ancillary retail/commercial uses, in conjunction with an approved development, providing it will not undermine the retail function and general amenity of existing and future urban centres, and (c) ensure that development is well designed, has minimal adverse impact on the environment and integrates with the urban environment, and (d) provide opportunities for high technology industries, scientific research and development, or similar activities, and (e) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 4(3): Industrial (Urban Services) Zone	The objectives of this zone are to: (a) provide land for light industries that can service surrounding community needs and provide local employment opportunities, (b) provide land for the wholesale or retail sale of bulky goods, (b1) provide land for research and development, and for applied technology, that can service surrounding community needs and provide employment opportunities, (c) support the role of existing and future urban centres while not undermining the retail and commercial functions and general amenity of these centres, (d) ensure that development is well designed, has minimal adverse impact on the environment and integrates with the urban environment, and (e) provide for sustainable water cycle management. Development permissible without development consent:

Locality	Objectives
	Exempt development as provided in Schedule 1 of the LEP. **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.**
Zone 5: Infrastructure Zone	**The objectives of this zone are to:** **(a) provide land for future infrastructure needs such as roads, drainage and other utilities,** **(b) provide land required for the expansion of existing community facilities or the development of new community facilities,** **(c) provide for limited development within the zone where it can be demonstrated that the development will not prejudice or have the potential to prejudice the intended future infrastructure development of that land,** **(d) ensure that development on adjacent or adjoining land zoned infrastructure does not prejudice future infrastructure development within that zone, and** **(e) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.**
Zone 6(1): Open Space Zone	**The objectives of this zone are to:** **(a) provide community owned land or land intended to be owned by the community (shown with crosshatching on the map) that is suitable for the passive and active recreation needs of the community, and** **(b) provide for a variety of facilities necessary to support use of this land including barbeque facilities, toilet facilities, sports administration and changing rooms, clubhouses, cycle ways, seating, lighting and the like, and** **(c) facilitate preservation of the environmental qualities of land identified in this plan for public ownership, and** **(d) provide for the use of public land leased from the Council where community benefit can be established and the use of the land is appropriate for its location, and** **(e) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management**

Locality	Objectives
	facilities.
Zone 6(2): Tourism and Recreation Zone	**The objectives of this zone are to:** **(a) provide land primarily for commercial recreation and tourist uses,** **(b) encourage good quality design within the zone,** **(c) provide land for good quality tourist development,** **(d) provide land for function and entertainment centres,** **(e) encourage tourism development that is sensitively designed to complement its location and minimise any adverse impacts on the environment, and** **(f) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.**
Zone 7(1): Conservation (Primary) Zone	**The objectives of this zone are to:** **(a) provide and conserve land having ecological, scientific, geological, educational, faunal, floristic or aesthetic values,** **(b) preserve and enhance areas of significant vegetation and habitat to promote the regeneration of ecosystems and eradication of invasive species that compete with native flora and fauna,** **(c) conserve, enhance and manage corridors to facilitate species movement, dispersal and interchange of genetic material,** **(d) exclude activities which would prejudice the ongoing conservation or rehabilitation of land,** **(e) encourage activities that meet conservation objectives,** **(f) protect land within this zone from impacts from development on adjoining zones, and** **(g) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, environmental facilities, roads, signs and stormwater management facilities.**
Zone 7(2): Conservation (Secondary) Zone	**The objectives of this zone are to:** **(a) protect, conserve and enhance land that is environmentally important,** **(b) protect, manage and enhance corridors to facilitate species movement, dispersal and interchange of genetic material,** **(c) enable development where it can be demonstrated that the development will not compromise the ecological, hydrological, scenic or scientific attributes of the**

Locality	Objectives
	land or adjacent land in Zone 7 (1), (d) ensure that development proposals result in rehabilitation and conservation of environmentally important land, and (e) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 7(3): Environmenta l (General) Zone	The objectives of this zone are to: (a) maintain and enhance biodiversity, scenic quality and native riparian vegetation and habitat, (b) protect, manage and enhance corridors to facilitate species movement, dispersal and interchange of genetic material, (c) ensure that development and land management practices do not have an adverse effect on water quality, land surface conditions and important ecosystems such as waterbodies, waterways, wetlands and rainforests, (d) protect and enhance natural, rural and heritage landscapes, (e) provide for sustainable water cycle management, and (f) encourage rehabilitation and conservation of environmentally important land. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP. Development, relating to flood works, permissible only with development consent: Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.
Zone 7(5): Environmenta l (Living) Zone	The objectives of this zone are to: (a) provide land with ecological, geological, scientific, scenic and biodiversity values that may accommodate minimal impact, low density residential and agricultural development, (b) manage development to minimise adverse impacts on those values, such as by encouraging appropriate use of disturbed land, (c) protect, enhance and manage corridors to facilitate species movement, dispersal and interchange of genetic material, (d) encourage rehabilitation and conservation of environmentally important land, and (e) provide for sustainable water cycle management. Development permissible without development consent: Exempt development as provided in Schedule 1 of the LEP.

Locality	Objectives
	Development, relating to flood works, permissible only with development consent: **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.**
Zone 9: Natural Resources Zone	**The objectives of this zone are to:** **(a) provide land that has dual values as an economic natural resource and for environmental protection,** **(b) recognise the dual values of the land and integrate economic use of the land with ecological sustainability,** **(c) acknowledge the economic value of its natural resources, particularly for extraction of coal, gravel and timber,** **(d) acknowledge the long term value of the land for the management and maintenance of biodiversity, threatened species habitat, and corridors by minimising the adverse impacts of resource development,** **(e) rehabilitate disturbed land to a natural state, reflective of its long term value,** **(f) minimise earthworks while enabling productive use of the land,** **(g) permit habitat disturbance to facilitate forestry, surface activities for underground mining and other extraction of mineral and gravel resources and energy generation works,** **(h) acknowledge the multiple use of State forests for tourism, conservation and sustainable harvesting of timber, and** **(i) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development, relating to flood works, permissible only with development consent:** **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, extractive industries, roads, signs and stormwater management facilities.**
Zone 10: Investigation Zone	**The objectives of this zone are to:** **(a) provide land for future development and/or conservation,** **(b) ensure that land in this zone is thoroughly assessed to identify and substantiate future uses,** **(c) provide for limited development of the land and allow that development only where it can be proven not to prejudice or have the potential to prejudice future protection or use of the land,** **(d) ensure that land is released in a strategic and efficient manner consistent with the Lifestyle 2020 Strategy,** **(e) require comprehensive local environmental studies to substantiate the capability and suitability of land in this zone proposed for rezoning, and** **(f) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.**

Locality	Objectives
	Development, relating to flood works, permissible only with development consent: **Development for the purpose of drainage, earthworks, emergency services facilities, environmental facilities, roads, signs and stormwater management facilities.**
Zone 11: Lakes and Waterways Zone	**The objectives of this zone are to:** **(a) recognise the importance of Lake Macquarie and its waterways as an environmental asset, not only to Lake Macquarie City, but to the Hunter and Central Coast Regions,** **(b) ensure that development of the Lake and its waterways occurs in a manner that is consistent with the principles of ecologically sustainable development,** **(c) ensure development does not adversely affect the ecology, scenic values or navigability of the Lake or its waterways,** **(d) ensure that aquatic and terrestrial habitats and their interface are protected and enhanced and are not adversely affected by the recreational use of the Lake or its waterways,** **(e) provide for sustainable and viable economic use of the Lake and its waterways, and** **(f) provide for sustainable water cycle management.** **Development permissible without development consent:** **Exempt development as provided in Schedule 1 of the LEP.** **Development for the purpose of aids to navigation required by the Maritime Authority of NSW, moorings (except commercial moorings) if in accordance with a Mooring Management Plan approved by the Maritime Authority of NSW.** **Development permissible only with development consent:** **Any development not listed as development permissible without development consent.**

5 Existing Flood Behaviour

5.1 Background

The Stony Creek catchment lies within the Lake Macquarie catchment situated to the north-west side of the Lake. The catchment headwaters are located in the west, incorporating the Awaba State Forest. The catchment outlet is at Fennell Bay within Lake Macquarie. There are several large tributaries of Stony Creek, as shown in **Figure 1.1**. The catchment has an approximate area of 46.4km^2.

The land use in the upper reaches of the catchment is rural or bushland. The F3 Freeway passes through the upper reaches of the catchment with a large bridge conveying flow on Palmers Creek and culverts conveying flow for all the minor creek crossings. Other major controls in the upper catchment are the Coal Haul Road and the Great Northern Railway.

In the lower reaches, the catchment is developed with low to medium density housing and some industrial and commercial areas. Mudd Creek is situated in the urban area downstream of the Sewage Treatment Works and flows parallel to Stony Creek discharging into Edmunds Bay.

5.2 Revision of Flood Study

A detailed flood study of Stony Creek was completed by Cardno Lawson Treloar in 2005. The flood study presented the flood extents and damage costs for a range of recurrence intervals based on hydrologic and hydraulic modelling completed. The SOBEK computer model used to assess flood behaviour for the flood study was reviewed for application to this Floodplain Risk Management Study.

In June 2007, a significant storm event occurred in the catchment resulting in flood inundation to properties within the catchment. This event provided an opportunity to review the calibration and the flood results from the model. Modelling and assessment of the June 2007 storm event concluded that the SOBEK model established for the Flood Study (2005) was representative for flood estimation for the catchment. **Appendix B** includes details for the June 2007 Storm Event and model calibration.

Two flooding investigation reports in the Stony Creek catchment were undertaken by Sinclair Knight in October 1990 and September 1991. Comparison of the results of these models to the SOBEK model used for the Flood Study (2005) showed the SOBEK model provided suitable results of flow behaviour in the catchment. Additional information for the review of these studies is included in **Appendix C**.

SOBEK modelling in the Flood Study (2005) demonstrated that blockage to culverts had a significant effect on flood behaviour in the catchment. Three additional culvert blockage scenarios were modelled and the results showed that the culverts and crossings at Railway Parade have a large impact on flood levels upstream. Further details of the culvert blockage modelling are included in **Appendix D**.

Flood modelling to assess the impacts due to potential climate change impacts are detailed in **Appendix G**.

The hydrology and hydraulic model used in the Flood Study (2005) are therefore utilised for this Floodplain Risk Management Study as these reviews show the models are suitable and significant changes to land-use have not occurred in the Stony Creek catchment.

Peak water levels for the recurrence intervals modelled are shown in the following figures:

- Figure 5.1 – PMF Peak Flood Levels
- Figure 5.2 – 200y ARI Peak Flood Levels
- Figure 5.3 – 100y ARI Peak Flood Levels
- Figure 5.4 – 50y ARI Peak Flood Levels
- Figure 5.5 – 20y ARI Peak Flood Levels
- Figure 5.6 – 10y ARI Peak Flood Levels
- Figure 5.7 – 5y ARI Peak Flood Levels

5.3 Flood Hazard

Flood hazard can be defined as the risk to life caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard (**Section 5.3.2**).

Hazard categorisation based on all of the above factors is part of establishing a Floodplain Risk Management Plan. Flood hazard may be defined on either the provisional or true flood hazard. These definitions are discussed in detail below.

5.3.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations (Appendix L; NSW Government, 2005). The Floodplain Development Manual (2005) defines two categories for provisional hazard – high and low.

Provisional flood hazard for the 5, 10, 20, 100, 200 year ARI and PMF flood events were completed as part of the Stony Creek Flood Study (Cardno Lawson Treloar, 2005). The provisional hazard is based on the hazard calculation at each location. Hazard calculations are undertaken conservatively using the peak depth and peak velocity of each duration for all ARI's presented. The provisional hazard for the PMF and the 100 year ARI events are presented in **Figures 5.8** and **5.9**.

5.3.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described above in **Section 5.3.1**, does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

- Size of the flood,
- Effective warning time,
- Flood readiness,
- Rate of rise of floodwaters,

- Duration of flooding,
- Ease of evacuation,
- Effective flood access, and
- Type of development in the floodplain.

In the Stony Creek floodplain many of the above factors are not applicable in terms of affecting hazard definition. However, to provide a thorough assessment process, all of the above factors have been considered in this report.

Figure 5.10 and **5.11** show the true high hazard areas cause by effective flood access in the PMF and 100y ARI events.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, flood hazard has been assessed for the PMF and 100 year ARI events. The PMF and 100 year ARI events were determined to be the appropriate events to categorise the "true" hazard for the Stony Creek Catchment.

Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuation). The effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures.

The critical duration storm in the main residential area of Toronto is generally the 36 hour event for the 100 year ARI. Durations of 4.5 hour and 9 hour are critical around Galbraith Avenue and Carleton Street respectively. The peak duration for the PMF event is about the 4 hour to 5 hour duration event.

The flow peak can take a couple of hours to occur in the urban area however there is currently no effective alert system for residents. Thus, the warning is not considered to decrease the flood hazard.

For the PMF peak event of 4 hours duration, surface water first occurs around the industrial area at Ada Street around 2 hours after start of storm. For Fennell Crescent, this is about 1 hour. Thus properties with above floor flooding in the PMF are coded as high true hazard (where high hazard due to depth-velocity does not already occur on the property).

Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient pattern to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The last major flood event occurred in June 2007 which had a storm equivalent to an event in excess of 50 year ARI. As a result, flood awareness is likely to be relatively high and no particular part of the catchment is likely to be any more prepared for a flood than another, thus flood readiness has not been considered in the preparation of hazard extents.

Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 200 mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 500 mm was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 500 mm flood depth is well within the range of available information as to when vehicles become unstable even with no velocity (Figure L1; NSW Government, 2005).

In the study area, there are no properties with flow behaviour of these constraints for the 100y ARI event. Several properties are identified in the PMF event with depth greater than 500mm and a rate of rise of 0.5 m /hr.

Depth and Velocity of Floodwaters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping for the PMF and 100 year ARI events were undertaken by Cardno Lawson Treloar (2005) and are presented in **Figures 5.9 and 5.10**. This provisional hazard mapping has been used as the base to determine true flood hazard.

Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations of over 6 hours occur in some locations for the 100 year ARI storm. In developing the true hazard, areas mapped based on water depth and velocity criteria (provisional hazard) included any areas that would be affected by duration of flooding criterion. On this basis, the provisional hazard effectively incorporated the flood duration criteria, and no modifications were made to the provisional hazard mapping.

Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

- The number of people requiring assistance,
- Mobility of those being evacuated,
- Time of day, and
- Lack of suitable evacuation equipment.

In developing the true hazard, areas mapped based on water depth and velocity criteria (provisional hazard) included any areas that would be affected by duration of flooding criterion. On this basis, the provisional hazard effectively incorporated the ease of evacuation criteria, and no modifications were made to the provisional hazard mapping.

Effective Flood Access

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Flood access issues vary across the catchment. For the purposes of this assessment properties were identified as being in one of four flood access categories:

- Site is flooded and evacuation required through a high hazard flooded roadway,
- Site is flooded and evacuation is required through a flooded roadway,
- Site is flooded and evacuation is possible through a non-flooded roadway directly from site,
- Site is flood free, however all road access is impeded by floodwaters.

To consolidate these categories and determine the implication of flood access issues on hazard mapping, criteria were set to establish effective flood access. It was determined that effective access is a road which is flooded by less than 300mm of water. For the purposes of this assessment 300mm is the threshold depth at which vehicles become unstable, even at very low velocities. However, further to this, a property or area is only considered to be without effective access, and hence has true high flood hazard, if the access is flooded by 300mm of water for more than 6 hours.

Type of Development

The degree of hazard to be managed is a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and may also change management strategies in existing development areas.

The land-use in the Study Area is generally residential and industrial but some facilities and infrastructure are located in the floodplain:

- Power substation on corner of Carleton Street and Fenton Avenue is in a high hazard area in the PMF event based on the velocity-depth criteria,
- Toronto Workers Club on James Street is near high hazard roadway in 100 year ARI event and is shown as high hazard in PMF event,
- Toronto High School in Field Avenue is not in a high hazard area for the 100 year ARI event but is high hazard in a PMF event,
- Sewage Treatment Works in Faucett Street is not inundated in less than a 200 year ARI event but is in a high hazard area in a PMF event.

5.4 Flood Categorisation

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The *Floodplain Development Manual* (2005) defines flood prone land into one of the following three hydraulic categories:

- 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.

Floodways were determined for the 100 year ARI and PMF by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below.

As a minimum, the floodway was assumed to follow the creekline from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway, based on Howells et al (2003):

- Velocity * Depth product must be greater than 0.25 m2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below.

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Flood Way or Flood Storage, but still within the flood extent are represented as Flood Fringe.

Figure 5.12 and **5.13** hydraulic categorisation for PMF and 100 year ARI events respectively.

5.5 Major Access Road Flooding

There are several primary access / transport corridors within the Stony Creek catchment potentially affected by flooding. **Table 5.1** lists peak flood depths across several roadways shown in **Figure 5.14.**

In the upper catchment the Great Northern Railway is overtopped in a 10 year ARI event. The main coal haul road just downstream of the railway embankment is only overtopped in the PMF event. Similarly, the Sewage treatment plant is overtopped in the PMF event but not the 200 year ARI event. Railway Parade at Stony Creek is not overtopped up to the 200 year ARI event but is overtopped at Mudd Creek starting at the 10 year ARI event.

Table 5.1: Major Access Corridor Flooding

Location	Maximum Depth of Flooding over Roadway at PMF (m)	Maximum Depth of Flooding over Roadway at 100y ARI (m)	Maximum Depth of Flooding over Roadway at 20y ARI (m)
1. Great Northern Railway	6.02	2.46	2.16
2. Railway Parade – at Stony Creek	1.40	0	0
3. Railway Parade – at Mudd Creek	2.20	0.50	0.28
4. Intersection of James St & Cook St	2.75	0.92	0.65
5. Fennell Cres – at Mudd Creek	3.28	1.33	1.07
6. Intersection of Galbraith Ave & William St	2.40	0.58	0.32
7. Awaba Road – intersection of Carleton St (peak in vicinity)	1.52 (2.47)	0.49 (0.49)	0.45 (0.45)
8. Awaba Road – intersection of Sunderland Rd	1.12	0	0
9. Intersection of Anzac Pde and Main Rd	1.36	0.17	0

6 Current Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. **Table 4.1** categorises various types of flood damages.

Table 6.1: Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social - increased levels of insecurity, depression, stress General inconvenience in post-flood stage

The direct damage costs, as indicated in **Table 4.1**, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as tangible costs. In addition to this there are also intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been used with assistance from OEH on the adoption of appropriate damage curves.

6.2 Floor Level and Property Survey

Floor level and property survey information was provided by Lake Macquarie City Council. The survey included details of each property within the known extent of the floodplain at the time of the survey. The property details included a floor level and property types. The survey is discussed in more detail in the Flood Study.

6.3 Damage Analysis

A flood damage assessment for the existing catchment conditions and several flood management options has been completed for the Stony Creek Floodplain Risk Management Study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchment is not available and recourse is generally made to damage curves from other catchments.

OEH has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties. The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

The following sections set out our methodology for the determination of damages within the Stony Creek Catchment.

6.3.1 Residential Damage Curves

The draft DNR Floodplain Management Guideline No. 4 *Residential Flood Damage Calculation* (2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground
- Single Storey, high-set.

The property survey did not categorise residential into these types, therefore the damage curve for single storey (slab on ground, floor level 0.5m above the ground) was utilised. No apartment buildings or townhouses were identified in the survey therefore no additional costs were apportioned based on these landuses.

Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for a damage of $9,045 (February 2009 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.5m below the floor level for slab on ground). The damage remains constant from the base of the house to the floor level of the house. A nominal value of $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped but only up to 0.5m below the floor of the house.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- Based on interrogation of the aerial photos, the average residential floor area in Stony Creek catchment is approximately 140m^2. A value of 150m^2 was adopted as a conservative estimate of the floor area for residential dwellings for the floodplain. With a floor area of 150m^2, the default contents value is $37,500 (November 2001 dollars).
- The Effective Warning Time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).
- Stony Creek catchment is a small part of the regional area and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in regional areas, where re-construction resources are limited and large floods can cause a strain on these resources. This effect, for example, may be pronounced during a Lake Macquarie Flood.

The adopted residential damage curves are shown in **Figure 6.1**.

Average Weekly Earnings

The OEH curves are derived for late 2001, and were updated to represent February 2009 dollars (shown in **Table 6.2**Error! Reference source not found.). General recommendations by OEH are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of this study was for February 2009. Therefore all ordinates in the residential flood damage curves were updated to February 2009 dollars. In addition, all damage curves include GST as per OEH recommendation. Note that the Stony Creek Flood Study prepared in 2005, was based on AWE data from February 2005.

While not specified, we have assumed that the curves provided in DNR guidelines were derived in November 2001, which allows us to use November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the Draft DNR guidelines, and February 2009 (and February 2005) AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au).

Table.6.2: AWE Statistics

Month	Year	AWE
November	2001	$676.40
February	2005	$788.50
February	2009	$916.10

Consequently, damages have been increased by 35.4% and GST has been included compared to 2001 values. The AWE value has increased by 16.2% compared to the February 2005 value used for the 2005 Flood Study.

6.3.2 Commercial Damage Curves

Commercial damage curves are adopted from the FLDamage Manual, Water Studies Pty Ltd (1992). FLDamage allows for three types of commercial properties:

- Low Value Commercial
- Medium Value Commercial
- High Value Commercial

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2009 dollars (this data was obtained from the Australian Bureau of Statistics website (www.abs.gov.au)). It was assumed that the Water Studies Pty Ltd data was in June 1990 dollars. Note that the

Stony Creek Flood Study prepared in 2005, was based on CPI data from June 2004. The CPI data is shown in **Table 6.3**.

Table 6.3: CPI Statistics

Month	Year	CPI
June	1990	102.50
June	2004	144.80
March	2009	166.20

Consequently, damages have been increased by 62.1% and GST has been included compared to 1990 values. The CPI value has increased by 14.8% compared to the June 2004 value.

6.3.3 Industrial Damage Curves

Cardno Lawson Treloar, as a part of the Allans Creek Floodplain Management Study, conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. We therefore have used these damage curves for this study.

The curves were prepared for three categories:

- Low Value Industrial
- Medium Value Industrial
- High Value Industrial (e.g. BHP steelworks in Wollongong).

Within the catchment, there are no properties considered to be representative of high value industrial properties, and hence these curves were not used.

The floor areas for the industrial properties were estimated from aerial photographs. To normalise the damages for property size, the curves have been factored to account for floor area.

The survey conducted only accounts for structural and contents damage to the property. Clean up costs and indirect financial costs were estimated based on FLDamage Manual. Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean up costs and indirect financial costs could be made. The values were adjusted to March 2009 dollars using the CPI statistics shown in **Table 6.4**. The Stony Creek Flood Study prepared in 2005, was based on CPI data from June 2004.

Table 6.4: CPI Statistics

Month	Year	CPI
June	1998	121.00
June	2004	144.80
March	2009	166.20

Consequently, damages have been increased by 37.4% and GST has been included compared to 1998 values. The CPI value has increased by 14.8% compared to the June 2004 value.

6.3.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6.1**. The commercial and industrial damage curves are for a property with a floor area of 100m^2.

6.4 Average Annual Damage

Annual Average Damage (AAD) is calculated on a probability approach, using the flood damages calculated for each design event.

Flood damages (for a design event) are calculated by using the 'damage curves' described in the sections above. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

The AAD value attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event (**Figure 6.2.**). For example, the 100 year ARI design event has a probability of occurring of 1% in any given year, and as such the 100 year ARI flood damage is plotted at this point on the AAD curve. AAD is then calculated by determining the area under this curve. Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (2005).

For this study, the damage resulting from a 50% AEP event (2 year ARI) was assumed to be zero for the AAD analysis. This value is based on the assumption that flows for the 50% AEP event are contained generally within the channel and thus do not result in inundation, and consequent damage to properties.

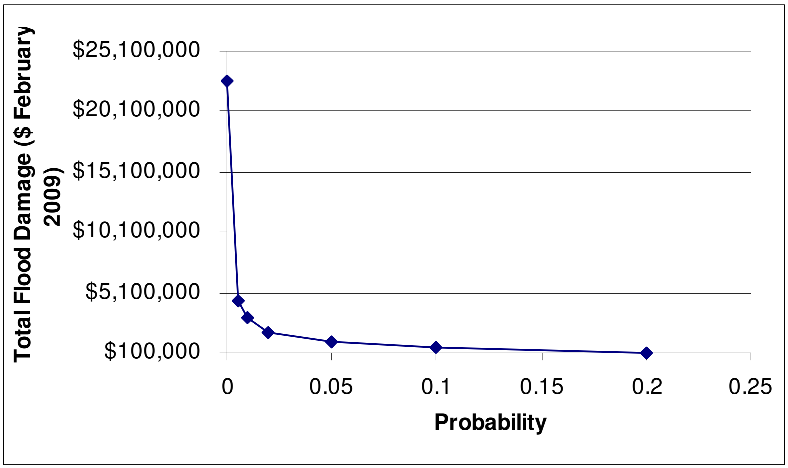

Figure 6.2 Annual Average Damage Curve for Stony Creek

6.5 Results

Table 6.5 shows the results of the flood damage assessments. Based on the analysis described in **Section 6.4** above, the average annual damage for the floodplain under existing conditions is approximately $247,000.

Table 6.5: Flood Damage Assessment Summary

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($February 2009) *
PMF					
Residential	247	1.18	2.56	262	$13,643,936
Commercial	11	1.73	2.66	12	$ 2,323,959
Industrial	37	1.98	2.81	37	$ 6,672,604
PMF Total	295			311	$22,640,498
200 year ARI					
Residential	66	0.68	0.78	177	$ 3,539,542
Commercial	3	0.51	0.40	8	$ 106,218
Industrial	18	0.85	0.65	30	$ 744,216
200 Year ARI Total	87			215	$ 4,389,976
100 year ARI					
Residential	41	0.19	0.66	165	$ 2,611,634
Commercial	3	0.26	0.30	6	$ 76,243
Industrial	13	0.15	0.67	26	$ 397,323
100 Year ARI Total	57			197	$ 3,085,200
50 year ARI					
Residential	20	0.18	0.52	147	$ 1,740,389
Commercial	3	0.15	0.20	6	$ 31,359
Industrial	6	0.12	0.42	21	$ 83,624
50 Year ARI Total	29			174	$ 1,855,372
20 year ARI					
Residential	7	0.21	0.37	98	$ 927,695
Commercial	2	0.08	0.10	5	$ 19,267
Industrial	1	0.09	0.09	3	$ 4,677
20 Year ARI Total	10			106	$ 951,638
10 year ARI					
Residential	3	0.12	0.16	59	$ 494,738
Commercial	0	-	-	2	$ -
Industrial	1	0.04	0.04	2	$ 2,907
10 Year ARI Total	4			63	$ 497,645
5 year ARI					
Residential	0	-	-	25	$ 164,108
Commercial	0	-	-	1	$ -
Industrial	0	-	-	1	$ -
5 Year ARI Total	0			27	$ 164,108

*values are expressed to the nearest dollar, but this is not indicative of the accuracy of the estimates

6.6 Assumptions and Qualifications

A significant assumption in the calculation of the Annual Average Damage is that the damages in the 2 year ARI design event are zero, with a linear increase in damage up to the 5 year ARI design event. Assuming a different design event for zero damages can significantly change the AAD (refer to Thomson et al. (2006) for more details). Note that modelling of flood inundation extents was not undertaken for events more frequent than the 5 year ARI. A 2 year ARI design event was considered to be a reasonable estimate of zero damage in the catchment, allowing for the potential capacity of the channel.

Note that not all properties within the floodplain as modelled had available level information to estimate damage costs, therefore the presented damages may be an underestimate as they may not account for properties on the periphery of the flood extent. Nevertheless, the information presented is considered to be representative of potential damages and is suitable for the purposes of this study.

7 Current Emergency Response Arrangements

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risk to the area. Current flood emergency response arrangements for managing flooding in the Lake Macquarie LGA are discussed below.

7.1 DISPLAN

Flood emergency management for the Lake Macquarie LGA is organised under the *Lake Macquarie Local Disaster Plan* (DISPLAN, 1996), which was issued under the authority of the *State Emergency and Rescue Management Act 1989.* The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- Preparedness measures,
- Conduct of response operations, and
- Co-ordination of immediate recovery measures.

The plan also consists of a series of appendices, which include details of vulnerable services and areas.

The DISPLAN identifies the flood hazard to be a high probability hazard with major consequences. A sub-plan to the local DISPLAN, termed the Local Flood Plan, has been prepared by the Hunter Region SES (1996) to effectively manage the flood emergency. The Local Flood Plan has been accepted by the Lower Hunter SES Division Controller and the Lake Macquarie Local Emergency Management Committee. The Local Flood Plan provides greater detail than the DISPLAN regarding the roles and responsibilities of agencies during all levels of flooding within the area.

The DISPLAN outlines the responsibilities and mitigation strategies for managing flood hazard as follows:

Lake Macquarie City Council	▪ Regulate property development and construction through the Local Environment Plan and Development Control Plan; ▪ Provide and maintain appropriate drainage infrastructure; ▪ Work in partnership with SES for flood education and amend SES responsibilities accordingly; and ▪ Implement Floodplain Risk Management Plans.
SES	▪ Prepare Local Flood Plan; ▪ Develop public education programs; and ▪ Coordinate management strategies and flooding responses with the Local Emergency Management Committee.

7.2 SES/Emergency Service and Operations

The Stony Creek Floodplain lies within the Hunter Region of the State Emergency Service (SES). The Hunter region office is located at 72 Turton Street, Metford. All service operations will be controlled from the local SES Headquarters Operations Centre at the corner of Creek Reserve Road and Fourth Street, Boolaroo. Furthermore the Cooranbong SES unit Headquarters is located at the corner of Martinsville Road and Freemans Drive, Cooranbong which is located approximately 4kms from the lower portion of Stony Creek.

Emergency operations will be controlled from the local emergency Operations Centre at the Lake Macquarie City Council Office, Main Road, Speers Point, approximately 10 kilometres (by road) to Stony Creek.

The SES is primarily a volunteer organisation. In times of emergency, the SES operates a paging service for on-call volunteers. However, more experienced crew know when to mobilise based on their understanding of the local area.

Many of the emergency services for the area are located within surrounding districts such as Blackalls, Toronto and Awaba. Major hospitals (e.g. John Hunter hospital) are located in Newcastle to the north-east (approximately 15km from Stony Creek).

7.3 Flood Warning Systems

No flood warning system currently exists for Stony Creek. An option has been proposed in this report to establish a flood warning system for the floodplain. This is discussed in more detail in **Section 9.4**.

7.4 Evacuation

The critical duration of flooding ranges from 9 hours in the upper catchment to 36 hours in the lower for all design flood events. In this regard, the SES is likely to play a significant role in evacuation during a flooding event. SES Volunteers will generally be deployed into areas where evacuation assistance is needed i.e. lower floodplain. Furthermore, the SES will correspond and interact with other emergency services and Council to ensure emergency action is coordinated effectively.

The majority of floods within the area do not necessitate evacuation, but occasionally severe events may require large scale evacuations especially in the lower parts on the valleys surrounding Stony Creek. Some residents may make their own decision to evacuate and will move to alternate accommodation using their own transport. However, such practice is not recommended for the Stony Creek floodplain as the response during the flood emergency is likely to be uncoordinated, which can expose residents to a hazardous situation (particularly where access/egress roads are inundated). As such, the preferred approach is to remain within the property (sometime referred to as ‘shelter-in-place’) and move to the upper level of the residence, where available.

Table 6.5 indicated that there are a number of residential and commercial properties in all design events that experience over-floor flooding of equal to or greater than 0.2m. Several of the properties which experience over-floor flooding at the 5 year ARI event do not have a second storey on their house. In these cases “shelter-in-place” may not be appropriate. The SES should be notified which properties fall into this category and specific emergency procedures may need to be developed for these properties to manage the risk to life.

7.5 Recovery

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long-term welfare of the affected community. However, the immediate action is likely to be undertaken through the SES Local Emergency Operations Controller and support agencies including Police Services, Ambulance Services, Health Services and the Fire Brigade. Details and responsibilities of agencies are outlined in the DISPLAN.

The Local Flood Plan also provides greater details of the recovery operation in the aftermath of a flood event. As detailed within the plan evacuees will be advised to go to the nearest accessible evacuation centre which generally comprise local schools including:

- Glendale High School, Oakland Street Glendale.
- Cardiff High School, Boronia Street Cardiff, and
- Toronto High School, Field Avenue, Toronto.

Additional evacuation centres within the local area are listed in the Lake Macquarie Local Flood Plan, 1996.

The closest high school to the Stony Creek Floodplain is Toronto High School. The other schools recommended in the Local Flood Plan are further away, and would likely result in the need to cross other floodplains. It is noted that the Toronto High School is actually inundated in the 100 year ARI event, and is located within the floodplain. It is therefore recommended that this school be removed from the Local Flood Plan.

Alternative evacuation centres in the area might include the Toronto RSL Memorial Club, located at 41 the Boulevarde Street, Toronto. This particular RSL club is outside of the floodplain, unlikely to be affected by Lake Macquarie flooding, and would potentially have the capacity to hold displaced residents. The potential for this RSL club to be utilised as an evacuation centre would need to negotiated with the club. Further investigations would also be required to assess the capacity of the club and its ability to act as an evacuation centre.

For properties to the north of Stony and Mudd Creeks, it is not recommended that the evacuation route should cross Mudd Creek and Stony Creek, as this access may potentially be cut-off. An investigation of the local area has not identified any potential evacuation centres in this location. Further north, Fassifern Road crosses LT Creek, which itself may be under flood. A potential option may include the construction of a grandstand on the soccer fields of the Waterboard Oval. This would at least allow a sheltered location away from the rainfall for the local residents in the area. It is recommended that potential alternative locations be discussed with the local community and the SES.

These evacuation centres act as temporary accommodation for flood affected residents. However, if it is expected that flooding will extend for longer than a 24hour duration, evacuees will be encouraged to leave the evacuation centres if they have alternative accommodation, otherwise alternative accommodation will be arranged where possible.

8 Flood Planning Level Review

8.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 100 year ARI flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 - 0.5 m for residential properties, and can vary for industrial and commercial properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (2005) identifies the following issues to be considered:

- risk to life
- long term strategic plan for land use near and on the floodplain
- existing and potential land use
- current flood level used for planning purposes
- land availability and its needs
- FPL for flood modification measures (levee banks etc.)
- changes in potential flood damages caused by selecting a particular flood planning level
- consequences of floods larger than the flood planning level
- environmental issues along the flood corridor
- flood warning, emergency response and evacuation issues
- flood readiness of the community (both present and future)
- possibility of creating a false sense of security within the community
- land values and social equity
- potential impact of future development on flooding
- duty of care.

These issues are dealt with collectively in the following sections.

8.2 Likelihood of Flooding

As a guide,

Table 8.1 has been reproduced from the Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in

Table 8.1 gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1 in 100 year event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1 in 100 year flood event as the basis for the flood planning level. Given the social issues associated with a flood event and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of people to floods.

Table 8.1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 years)

Likelihood of Occurrence in any year (ARI)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
1 in 10	99.9	99.3
1 in 20	97	86
1 in 50	75	41
1 in 100	50	16
1 in 200	30	5

Note that there still remains a 30% chance of exposure to at least one flood of a 1 in 200 year magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

8.3 Current FPL in Floodplain

Based on the existing DCP, Council currently utilises the 100 year flood level, as determined by the Stony Creek Flood Study. A freeboard allowance of 500mm is provided for residential properties while no freeboard is allowed for industrial properties.

Prior to the completion of the Stony Creek Flood Study, the 1981 flood event was utilised as the FPL. For residential properties, a freeboard of 300mm was utilised, while for industrial properties no freeboard allowance was provided.

8.4 Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A sensitivity analysis was undertaken for catchment runoff as a part of the flood study. This analysis showed that for a 20% increase in catchment flows, the maximum increase in water level in the 100 year ARI design event in Stony Creek and Mudd Creek was 0.16 metres and 0.13 metres respectively. The largest increases in the Stony Creek levels are located in the reach upstream of the confluence with Mudd Creek.

Changes to the land use can also result in changes in the assumed roughness of the floodplain. This can lead to changes in discharge characteristics and ultimately flood levels in the catchment. A sensitivity analysis was conducted as a part of the flood study that assessed the effect of varying the roughness by +/- 20%. The results of this analysis showed that the highest increase in water level in the 100 year ARI design event in Stony Creek and Mudd Creek was 0.15 metres and 0.10 metres respectively when the roughness was increased. Similarly to the flow sensitivity, the peak increase occurs in the reach of Stony Creek upstream of the confluence with Mudd Creek. A roughness reduction of 20% results in a peak increase in flood level of 0.15 metres within Carleton Drain (this is due to the accelerated response of the catchment resulting in coincidence of peak flows in Stony Creek). The reduced roughness generally resulted in a decrease in flood level within Stony Creek and Mudd Creek (by 0.15 metres at most) and only increased the level by a maximum of 0.01 metres at the outlet.

Consideration could be given to provide a free-board based on the results of this sensitivity analysis.

8.5 Damage Cost Differential Between Events

Based on the existing flood behaviour and the assessment of flood damages, the incremental difference in Annual Average Damage for different recurrence intervals is shown in **Table 8.2**. This table represents the incremental increase in AAD attributed to each design event.

Table 8.2 Damage Differential Costs

Recurrence Period	Incremental AAD	Properties with Overfloor Flooding	Average AAD per Property
Up to 5 Year ARI	$24,616	0	N/A
5 Year to 10 Year	$33,088	4	$8,272
10 Year to 20 Year	$36,232	10	$3,623
20 Year to 50 Year	$42,105	29	$1,452
50 Year to 100 Year	$24,703	57	$433
100 Year to 200 Year	$18,688	87	$215
200 Year to PMF	$67,576	295	$229
AAD (Total)	**$247,008**		

Table 8.2 indicates that the largest incremental increases in the AAD per property occur up to the 10 year ARI event. This suggests that the largest benefit to the community would be if the 10 year event were utilised in the setting of the FPL, as the savings in AAD per property would be the greatest (assuming that existing properties were replaced with similar properties set at the FPL).

8.6 Incremental Height Difference Between Events

Consideration of the average height difference between various design flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour (Section 3) the incremental peak height difference between events as averaged across the catchment for the existing case cross sections is shown in **Table 8.3**.

Table 8.3 indicates a dramatic difference in flood level of the PMF event compared to other events. The incremental difference between flood events is in the order 0.15m, except for the PMF. The adoption of the 100 year ARI event as the flood planning level is only marginally different from that of the 50 year ARI event (0.13m), but similarly different from the 200 year ARI event (0.13m). Therefore, the adoption of the 100 year ARI event would provide an increased level of risk reduction over the 50 year and the inclusion of a freeboard over 0.13m would likely increase protection for the 200 year ARI event. The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 100 year ARI event and may therefore potentially present an issue for the setting of flood planning levels in the catchment.

Table 8.3 Relative Differences Between Design Flood Levels

Event	Diff PMF (m)		Diff 200y (m)		Diff 100yr (m)		Diff 50yr (m)		Diff 20yr (m)		Diff 10yr (m)	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
200 year	1.86	0.45										
100 year	1.98	0.46	0.13	0.03								
50 year	2.11	0.48	0.25	0.05	0.13	0.03						
20 year	2.26	0.48	0.40	0.09	0.28	0.06	0.15	0.04				
10 year	2.43	0.51	0.57	0.11	0.45	0.09	0.32	0.06	0.17	0.05		
5 year	2.57	0.55	0.71	0.14	0.58	0.12	0.45	0.10	0.31	0.09	0.14	0.04

Avg = Average Difference; SD = Standard Deviation of Differences

With regard to an appropriate freeboard, the maximum difference between the PMF event and the 100 year ARI event is 2.60m. The 95 percentile difference (value for which 95% of the difference values for the catchment are below) is 2.12m. The difference between the 100 year ARI event and the PMF indicates that basing the flood planning level from the 100 year ARI level with a reasonable freeboard may not result in significant reduction in building inundation in the PMF event.

8.7 Consequence of Adopting the PMF as a Flood Planning Level

Analysis of the flood damages (**Section 8.5**) indicates that the choice of the PMF event over the 100 year ARI event as the FPL would result in significant economic benefits (in annualised terms) to the community. However, the difference in average flood levels between the 100 year event and the PMF event (Section 7.5) indicate that the use of the PMF as the FPL would result in significantly higher levels (1.98 metres on average), and as a result higher economic costs and inconvenience to the community. In addition, the incremental AAD per building from the 100 year to the PMF is relatively low. The economic costs may in fact outweigh the benefits of using the PMF event as the FPL. The use of the PMF level as the FPL may also conflict with other development/building controls in Councils control plans.

Given the risk of exposure outlined in

Table 8.1, it is recommended that emergency response facilities be located outside of the floodplain and any other likely critical facilities be limited to areas outside of the floodplain. Other critical facilities are suggested to have a floor level at the PMF.

8.8 Environmental and Social Issues

The FPL can result in housing being placed higher than it otherwise would be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring economic property rights. This may also lead to conflict with other development controls already present within the Council's development assessment process.

8.9 Climate Change – Sea Level Rise

The DECC (now OEH*) Practical Consideration of Climate Change* (2007b) provides guidance on expected ocean level rises. Three scenarios are recommended to be analysed:

- Low Level Rise (0.18 metres)
- Medium Level Rise (0.55 metres)
- High Level Rise (0.91 metres)

An assessment of the effects of sea level rise is detailed in **Appendix G**.

8.10 Climate Change – Change in Rainfall Patterns

Current research indicates that while annual rainfalls will decrease as a result of climate change, storm intensities will actually increase in some areas. The DECC (now OEH) guidelines (2007b) provide recommended ranges for the assessment of increase in peak rainfall intensities. The guidelines recommend analysis of three scenarios:

- 10% increase in peak rainfall and volume
- 20% increase in peak rainfall and volume
- 30% increase in peak rainfall and volume.

An assessment of the effects of modified rainfall intensities is included in **Appendix G**.

It should be noted that a percentage increase in rainfall intensity does not directly correlate with the same increase in peak flows. For a 20% increase in rainfall intensity, the maximum increase in peak 100 year ARI water levels is 0.16m, with an average of 0.10m.

8.11 Climate Change – Use in FPL

The selection of appropriate FPLs based on climate change is challenging. Unlike traditional flood analysis, which has a probability of occurring at any given time, increases in ocean levels and rainfall will occur over a longer timeframe. Therefore, while increases in peak rainfalls are expected to occur over the next 100 years and further out, in the next 5 years there is unlikely to be any change to the 100 year event.

This leads to challenges in the selection of FPLs and climate change. It may be appropriate to select a FPL incorporating climate change based on the design life of a proposed structure. For example, a residential property may have a 50 year design life, and as such a 50 year outlook might be appropriate in the selection of a freeboard.

An alternative option is to investigate the potential for mitigation over time. For example, a property with a 50 year design life may be set at a 25 year outlook at present. However, it may be designed such that the floor level of the property can be raised to accommodate future climate change.

These are broader policy implications that need to investigate not only the setting of an FPL, but the adaptation of the community over time to the implications of climate change.

8.12 Risk

The selection of an appropriate FPL also depends on the potential risk of different development types. For example, consideration should be given for different FPLs for industrial, commercial and residential properties, which have different implications should overfloor flooding occur.

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, has wider spread implications should inundation occur. As such, FPLs are typically selected for this types of structure higher than for residential, commercial or industrial properties.

8.13 Supplementary Factors

Two other factors need to be considered in FPL determination. They are:

- Change in flow regime from supercritical to subcritical flow in open channels and overland flowpaths.
- Impact of culvert/bridge blockage on design flood levels.

The first factor relates to the fact that local obstructions can cause supercritical flow (shallow fast flow) to become subcritical (deeper slower flow) with a resulting increase in design flood levels. This phenomenon can occur in the upper steeper parts of the catchment and is likely to be localised. In the lower, urbanised parts of the catchment, this phenomenon is also likely due to high flow velocity, particularly within the concrete drains discharging into Stony Creek. The impact of this phenomenon is generally considered in the selection of an appropriate freeboard for the FPL.

The second factor has come to prominence with flooding in Wollongong in the late 1990s and other similar catchments where reasonably large culverts were blocked from debris floating down the creek. In the lower parts of the catchment, the debris is likely to be a mixture of anthropogenic and natural sources. The natural sources would primarily be from the upper areas of the catchment, which are heavily vegetated.

Culvert blockage generally results in an increase to flood levels upstream of the culvert and a decrease downstream. A sensitivity analysis was undertaken in the flood study on a potential 100% blockage of all the culverts in the study area. The results of the 100 year ARI sensitivity analysis identified an increase of up to 0.67 metres on Stony Creek, 0.66 metres on Mudd Creek, 0.36 metres on Carlton Drain and 0.46 metres on Farrell Drain.

Three alternative culvert blockage scenarios are discussed in Appendix D. These scenarios assess impacts of selected culverts within the main residential area being blocked, in particular the culverts at Railway Parade and at Carleton Drain. The resultant peak water level rise in the 100 year ARI event based on these scenarios is:

- 0.15m at High Street
- 0.07m at Carleton Street
- 0.61m at Stony Creek just upstream of Railway Parade
- 0.46m at Mudd Creek just upstream of Railway Parade
- 0.06m at Day Street
- 0.09m at Venetia Parade

It is noted that a 100% blockage of culverts and bridge in the study area, particularly the Railway Parade Bridge over Stony Creek, may be unlikely. However, it is possible that a portion of the structure may be blocked, which would result in an increase in levels somewhat below the estimates above.

The impact of culvert blockage can partly be accommodated by specifying a freeboard for the FPL.

8.14 Freeboard Selection

As outlined above, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL. It should be realised that the freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. This consideration may result in the adopted FPL being higher than the PMF in certain cases. However, given the inherent purpose of freeboard, the FPL should still be used in such cases.

The freeboard may account for factors such as:

- changes in the catchment
- changes in the creek/channel vegetation
- accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area)
- model sensitivity
- local flood behaviour (e.g. due to local obstructions etc),
- wave action (e.g. such wind-induced waves or wash from vehicles or boats),
- culvert blockage,
- climate change (affecting rainfall and ocean water levels).

The accuracy of ground survey used in the modelling is generally of the order of ±0.01 m for each point surveyed, and approximately ±0.15 m for the aerial survey. The accuracy of the rainfall inputs is more difficult to translate to a level of accuracy. Instead, the effects of the overall hydrological response of the catchment on levels were considered via assessments of model sensitivity to changes in hydrological inputs and floodplain condition.

The model sensitivity was found to be a maximum increase of 0.28 metres for the 100 year ARI event as a result of a 20% increase in downstream boundary level during the flood study (Table 7.5), although it is noted that this is downstream of Railway Parade. The maximum increase in 100 year ARI levels upstream of Railway Parade is approximately 0.16 metres for flow sensitivity and 0.15 metres for roughness sensitivity.

Table 8.4 Model Sensitivity Statistics

Statistics	Model Boundary Sensitivity		Model Inflow Sensitivity		Model Roughness Sensitivity	
	+20%	-20%	+20%	-20%	+20%	-20%
Maximum	0.28	0.00	0.16	0.00	0.15	0.15
Minimum	0.00	-0.27	0.02	-0.40	0.01	-0.15
Average	0.14	-0.12	0.10	-0.27	0.09	-0.06

The impact of various elements factored into a freeboard can be summarised as follows:

- Uncertainty in flood modelling – it is difficult to provide an accurate estimate of the uncertainty in the modelling. However, the sensitivity analysis indicates that a variation of up to 0.16 metres might be expected, not allowing for downstream boundary variations.
- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (adopted from Gillespie (2005))
- Local wave action (allowances of ~0.1 m are typical) (truck wash etc)
- Culvert blockage analysis indicates that a maximum increase of 0.67 metres is possible under a 100% blockage of culverts in the study area, however a 100% blockage scenario is conservative. Roughly assuming a linear relationship, a 50% blockage might result in an increase of approximately 0.35 metres.
- Climate change - Sea Level Rise – from 0.18 metres to 0.91 metres, although the impact on 100 year ARI levels varies for properties upstream of Railway Parade.
- Climate Change – rainfall increases – estimated at up to 0.16 metres for a 20% increase in rainfall, although the impact of this is not significant downstream of Railway Parade.

The impact of potential wind waves for foreshore properties on Fennell Bay and Edmunds Bay is not included in the above analysis nor any allowance been made for the potential wind setup and wave run-up associated with the wind waves generated. The local waves and the wind waves along with the wave run-up are not likely to occur at the same time and as such the allowance for local waves can also serve to provide a partial allowance for wind waves/wave run-up, which are likely to produce much higher increase in the water level.

A number of Council's have currently adopted a two phase freeboard; one with an allowance for climate change and the second with an allowance for the other factors addressed above. As climate change has not been assessed directly in the flood study, this is likely to be the most appropriate method for Stony Creek. The two phase freeboard recommendations are presented below:

- Freeboard – Council currently adopts a 500mm freeboard for residential properties and a 0mm freeboard for industrial properties. The 500mm freeboard for residential properties would appear to be reasonable based on the above analysis. A 0mm freeboard for industrial properties may be appropriate based on the risk profile.
- Freeboard – Climate Change. For areas upstream of Railway Parade, an allowance of 0.2 metres might be appropriate, allowing for increase in flows as well as some allowance for increases in the downstream boundary. For areas downstream of Railway Parade, it is recommended that Council's preferred climate change ocean level rise be adopted, potentially allowing for adaptation over time.

Note that the provision for climate change is recommended for review on a periodic basis (at least every 5 years), as new information from research becomes available.

8.15 Flood Planning Level Scenarios

A selected number of FPL scenarios have been assessed, to test the implications on the floodplain, in regards to the number of existing buildings which are below this level as well as the flood protection provided in various design events.

Table 8.5 summarises potential benefits for the setting of various flood planning levels (FPL) options with freeboards. Note that vacant lots are not included in floor level calculations and the results do not differentiate between the floor levels of residential properties compared to commercial or industrial buildings. The 1981 flood, which was utilised as the FPL prior to the completion of the flood study, is provided for reference.

The results indicate that a significant proportion of properties within the catchment area have floor levels that would need to be raised to satisfy the three FPL scenarios below. For the PMF event, the raised floor levels are not sufficient to prevent inundation of additional properties but the depth of flooding experienced is reduced, even though it remains high. Based on the number of properties presented, the most effective FPL is shown as 100 year ARI plus a 0.3m freeboard. This FPL results in significant reductions to flood affectation in the 100 year and 200 year ARI floods but affects fewer properties than the freeboard allowance of 0.5m. However, it should be noted that the selection of suitable freeboard is dependent on a number of additional parameters, as discussed **Section 8.14**.

Table 8.5 Selected Flood Planning Level Scenarios & Impact on Properties

Description	Current	FPL Scenario 100y + 0.3m	100y + 0.5m	200y + 0.5m	1981+ 0.3m
Total number of properties evaluated (Non-Vacant Lots)	346	346	346	346	346
Number of existing properties which are below the FPL	N/A	119	167	198	179
Percentage of Properties		34%	48%	57%	52%
PMF					
Properties flooded above floor level	295	295	295	295	295
Maximum depth of above floor flooding (m)	2.81	2.3	2.1	1.96	1.33
Average depth of above floor flooding (m)	1.39	1.18	1.08	0.99	0.91
200y					
Properties flooded above floor level	87	1	1	0	12
Maximum depth of above floor flooding (m)	0.78	0.27	0.27	0	0
Average depth of above floor flooding (m)	0.28	0.27	0.27	0	0.11
100y					
Properties flooded above floor level	57	0	0	0	2
Maximum depth of above floor flooding (m)	0.67	0	0	0	0.08
Average depth of above floor flooding (m)	0.22	0	0	0	0.05

8.16 Recommended Flood Planning Levels and Freeboard

Based on the preceding assessment, it is recommended that:

- The flood planning level (FPL) for residential, commercial and industrial areas be based on the 100 year event.
- A freeboard of 500mm would be appropriate for residential properties, allowing for the factors addressed in Section 8.14. This is equivalent to the existing planning policies.
- A freeboard of 0mm for industrial properties, as per existing planning policies.
- A climate change freeboard of 200mm upstream of Railway Parade, to allow for increase in rainfall. However, this might be adjusted to allow for adaptation over time. An alternative is to undertake climate change design runs for the full floodplain, to provide more refined estimates of flood planning levels.
- Climate change freeboard downstream of Railway Parade to be selected based on Council's preferred ocean level rise and given consideration to potential for adaptation.
- For properties where the adopted FPL is higher than the PMF, the FPL should be used.
- Emergency services and flood evacuation centres should be prohibited in the floodplain (i.e. outside of the PMF extent).

9 Floodplain Risk Management Options

9.1 Overview of Available Measures

Flood risk can be defined as being existing, future or residual risk:

- Existing flood risk - the existing problem refers to existing buildings and developments on flood prone land. Such buildings and development by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- Future flood risk - the future problem refers to buildings and developments that may be built on flood prone land in the future. Such buildings and developments may be exposed to a 'future' flood risk, i.e. a risk would not materialise until the developments occur.
- Continuing risk of flooding - the continuing problem refers to the 'residual' risk associated with floods that exceed management measures already in place, i.e. unless a floodplain management measure is designed to withstand the Probable Maximum Flood, it will be exceeded by a sufficiently large flood at some time in the future.

The alternate approaches to managing risk are outlined in Table 9.1 (after SCARM, 2000):

Table 9.1: Flood Risk Management Alternatives

Alternative	Description
Preventing/Avoiding risk	i.e. setting the planning level at the Probable Maximum Flood or not allowing development to be within the floodplain
Reducing likelihood of risk	i.e. relying on structural measures to reduce risk (possibly not viable for planning levels in the floodplain). The potential for implementation of flood modification options is limited by economic, social and environmental constraints)
Reducing consequences of risk	i.e. using development controls - design of structures to withstand flooding, allows a floodplain to be developed in lower areas
Transferring risk	via insurance - not viable given the non-insurability of most flood-prone areas
Financing risk	through natural disaster funding
Accepting risk	regardless of the options implemented, a continuing risk will be present.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. As a result, there are three types of measures for the management of flooding:

- Flood Modification Measures (for the existing risk)
- Property Modification Measures (for the future risk)
- Emergency Response Modification Measures (for the residual risk).

9.1.1 Options Identified by the Community

A community survey was undertaken by delivering questionnaires to residents as discussed in **Section 3**. The survey provided an insight into the community's awareness of flooding and allowed the residents to provide comments and suggestions on proposed flood management options. A summary of the responses to various management options is presented in **Section 3**.

9.2 Flood Modification Measures

A community survey was undertaken by delivering questionnaires to approximately 1200 residents in the Stony Creek catchment as described in Section 3. The survey provided an insight into the community's awareness of flooding and allowed the residents to provide comments and suggestions on the proposed flood mitigation options.

Based on the community survey, historical flood information, flood study results, and field inspections of the catchment, possible flood modification options (ie structural options) for various locations within the floodplain were identified. **Table 9.2** lists the potential flood modification options identified in the catchment.

9.2.1 Detention Basins

Detention basins constructed upstream of the railway and main Toronto residential area were identified in the resident questionnaire. Potential sites for storages include the area just upstream of the railway line and in various locations within the Awaba State Forest area.

Potential sites for detention basins are shown on **Figure 9.1**. These sites are selected based on their position along channels, and are referred to by their nearby RAFTS node from the hydrology modelling. **Table 9.3** lists these sites and their potential storage capacity estimated from the available contour information. These storages are situated on-line to the channels and storage estimated as the volume obtained by constructing a berm across the low-point and flooding the existing area behind, not by excavating additional storage. Thus the basins would result in temporary inundation to vegetation currently behind the embankment.

Table 9.2: Flood Modification Measures

Option	Location	Option Description
Detention Basins		
FM1.1	Upstream of railway line – 8 sites	Eight detention basins distributed across upstream catchment
FM1.2	Upstream of railway line – 1 site	One detention basin just upstream of the railway line
Carleton Drain		
FM 2.1	Carleton Street	Additional culvert
FM 2.2	Carleton Street	Augmentation of existing culverts and additional culvert
FM 2.3	Carleton Street and Awaba Road	Augmentation of existing culverts at Carleton Street and Awaba Road. Additional culvert at Carleton Street
Levee Banks		
FM 3.1	Toronto industrial area	Construct levee bank from Burleigh St to

Option	Location	Option Description
		May St
FM 3.2	Blundell Parade, Farrell Ave, and Galbraith Ave	Construct levee bank along Stony Creek
FM 3.3	Fennell Cres. Between Mudd Creek and Stony Creek	
FM 3.4	Adam St and Fennell Cres. (north of Mudd Creek)	
FM 3.5	Lake St and Venetia Ave	Construct levee bank to Edmunds Bay, Mudd Creek and Stony Creek
FM 3.6	Sara St and Day Street	Construct levee bank to Stony Creek
Railway Parade		
FM 4.1	Railway Parade – Mudd Creek	Augment culvert crossing of Mudd Creek
FM 4.2	Railway Parade – Mudd Creek	Augment culvert crossing of Mudd Creek. Remove railway line and crossings downstream of Railway Parade
FM 4.3	Railway Parade – Stony Creek	Augment culvert crossing of Stony Creek
FM 4.4	Railway Parade – Stony Creek	Augment culvert crossing of Stony Creek. Remove railway line and crossings downstream of Railway Parade
FM 4.5	Railway Parade – Stony Creek and Mudd Creek	Augment culvert crossings of Mudd Creek and Stony Creek
FM 4.6	Railway Parade – Stony Creek and Mudd Creek	Augment culvert crossings of Mudd Creek and Stony Creek. Remove railway line and crossings downstream of Railway Parade
FM 4.7	Railway Parade – Stony Creek and Mudd Creek	Remove railway line and crossings downstream of Railway Parade
FM 4.8	Railway Parade – Mudd Creek	Raise road crossing of creek
FM 4.9	Railway Parade – Stony Creek and Mudd Creek	Augment flow connection between Mudd Creek and Stony Creek
Rainwater Tanks		
FM 5.1	Catchment wide	Rainwater tanks installed to all properties
Infiltration Basins & Trenches		
FM 6.1	Across catchment	Construct infiltration basins and trenches to locations across catchment

Option	Location	Option Description
Lake Macquarie Measures		
FM 7.1	Swansea Channel	Dredging works at channel entrances and augmentation of Swansea Bridge
FM 7.2	Lake Macquarie Foreshore Levees	Construct levees around Lake Macquarie foreshore
Flood Flowpath Improvement		
FM8.1	Catchment Wide	Clearing debris from flowpaths and dredging of creeklines.

Table 9.3: Estimated Detention Basin Storages

Point	Location (RAFTS Node)	Estimated Storage (m^3)	Comment
1	P13	63,000	
2	DP7	51,000	Located just upstream of F3 Freeway
3	P19	26,000	Located just upstream of F3 Freeway
4	DP5	25,000	
5	DP4	28,000	
6	DAW3	21,000	
7	AW20	25,000	
8	AW14	18,000	
9	AW12	34,000	
10	AW10	10,000	
11	DW2	22,500	
12	DP0	53,000	Located just upstream of railway line
13	AW1	52,000	Located just upstream of Toronto industrial area

Two options for detention basin layouts were identified:

- Option FM1.1 includes detention basins distributed in eight locations in the upper catchment. The locations selected for basins in this option are RAFTS nodes P13, DP7, P19, DAW3, AW20, AW12, DP0, and AW1. A total storage volume of 325,000 m3 is distributed at the eight basins.
- Option FM1.2 requires construction of a single detention basin at RAFTS node DP0 with a storage capacity of 100,000 m3.

These detention basin options were modelled for the 100 year ARI 36 hour critical duration storm event. **Table 9.4** lists peak water level results at several locations. Results show a reduction of around 0.2-0.3m in areas upstream of Railway Parade with inclusion of the basins. The peak water level downstream of Railway Parade occurs due to the level in Fennell Bay which is not influenced by the detention basins upstream. Levels at Carleton Street are also generally unaffected as the detention basins are not located within the catchment to this location.

Table 9.4: Peak Water Levels for Detention Basin Options (100y ARI – m AHD)

Location	100y ARI Existing	Basin Option FM1.1	Diff. to Existing	Basin Option FM1.2	Diff. to Existing
High St weir	2.97	2.61	-0.36	2.67	-0.29
Stony Creek / Mudd Ck confluence	2.27	1.99	-0.27	2.04	-0.22
Carleton St – Beckley St intersection	3.45	3.44	-0.01	3.44	-0.01
Fennell Cres – crossing of Mudd Ck	2.18	1.90	-0.28	1.95	-0.23
Fennell Cres	2.08	1.78	-0.29	1.84	-0.24
Blundell Pde – Farrell Ave intersection	2.06	1.78	-0.28	1.83	-0.23
Cook St – James St intersection	1.98	1.70	-0.28	1.73	-0.25
Stony Ck – just upstream of Railway Pde	1.90	1.65	-0.25	1.65	-0.25
Mudd Ck - just upstream of Railway Pde	2.01	1.72	-0.29	1.78	-0.23
Lake St – Venetia Ave intersection	1.47	1.47	0.00	1.47	0.00
Sara St – Day St intersection	1.45	1.45	0.00	1.45	0.00

Assessment for all ARI storms was undertaken for Option FM1.2 as it was considered to be the best option applicable to the catchment. Option FM1.1, with eight basins, resulted in slightly lower flood levels compared to Option FM1.2, with a single basin. The single basin of Option FM1.2 was preferred due to its potential lesser impact to the upstream catchment as construction and maintenance would be restricted to a single site, though it may require a larger footprint than the basin in the same location per Option FM1.1.

9.2.2 Carleton Drain

In the 100 year ARI event, runoff flows overland from the channel at Carleton Street, near Beckley Street, toward the intersection with Awaba Road. A triple-cell box culvert is located at Carleton Street, shown in **Figures 9.2 and 9.3**, with each cell 2.13m wide by 0.72m high (surveyed by LMC^2 Consulting Group July 2004).

Figure 9.2 – Carleton Street culverts (upstream side)

Figure 9.3 – Carleton Street culverts (downstream side)

Three options for the augmentation of the Carleton Drain system were modelled in the 100 year ARI 36 hour critical duration event. **Figure 9.4** shows the location of drainage structures in the vicinity and the options reviewed are:

- Option FM2.1 – additional culvert (3.0m wide by 0.72m high) at Carleton Street and widen approaches to accommodate additional culvert,
- Option FM2.2 – per Option FM2.1 with culvert and channel inverts lowered by 0.7m, and
- Option FM2.3 – per Option FM2.2 with the culvert openings duplicated at Awaba Road (from 3.05m wide by 1.8m high) and the footbridge just downstream widened (from 3.3m wide to 6.3m wide).

Table 9.5 shows peak flood depths modelled in the 100 year ARI event at several locations. The additional culvert of Option FM2.1 only results in small benefits to flood depths at Awaba Road, but the larger culverts of Option FM2.2 and Option FM2.3 result in larger decreases in flood depth. Enlarging the culverts / openings of the structures at Awaba Road convey the additional flow in the channel just upstream resolving the slight increase in flood depth.

Augmentation of the Carleton Drain system does not result in benefits downstream as peak flood levels result from runoff from the Awaba State Forest or due to levels in Fennell Bay.

Table 9.5: Peak Flood Depths (m) for Carleton Drain Mitigation Options

Location	100y ARI 36h	Option FM2.1	Diff. to Existing	Option FM2.2	Diff. to Existing	Option FM2.3	Diff. to Existing
Just upstream of Carleton St culverts	0.29	0.25	-0.03	0.08	-0.20	0.08	-0.20
Carleton St road surface – at culverts	0.14	0.12	-0.02	0.03	-0.11	0.03	-0.11
Vegetated channel between Carleton St and Awaba Rd	0.20	0.21	0.01	0.22	0.03	0.19	0.00
Awaba Rd road surface at culverts	0.19	0.20	0.01	0.20	0.01	0.19	0.00
Awaba Rd – Carleton St intersection	0.33	0.30	-0.03	0.00	-0.33	0.00	-0.33

9.2.3 Levee Banks

Construction of levee banks was generally not a preferred measure to mitigate flood impacts based on responses from the community questionnaire. Several responses noted problems with levees retaining water from local runoff and also impact to the visual amenity of the creek. However, some responses were favourable toward the implementation of levees.

Levees can be an effective method of excluding floodwaters up to their design level but have the disadvantages of adverse impacts on visual amenity and access, and altering local catchment drainage conditions trapping water behind levees. Flood flaps could potentially be used to resolve the local catchment drainage issue.

Six sites were reviewed for potential implementation of levee banks:

- FM 3.1 Toronto industrial area
- FM 3.2 Blundell Parade, Farrell Ave, and Galbraith Ave
- FM 3.3 Fennell Cres. Between Mudd Creek and Stony Creek
- FM 3.4 Adam St and Fennell Cres. (north of Mudd Creek)
- FM 3.5 Lake St and Venetia Ave
- FM 3.6 Sara St and Day Street

FM 3.1 Toronto industrial area

An existing levee is partly constructed around parts of the industrial area. **Figure 9.5** shows the western end of Nicholson St and the existing levee bank.

A revised levee bank to provide protection to the industrial area properties in the 100 year ARI storm was evaluated. **Figure 9.6** shows the location of the levee. It is about 1000m in length and varies in height above the existing ground by up to an additional 2.1m.

Figure 9.5 – Nicholson Street – western end

FM 3.2 Blundell Parade, Farrell Ave, and Galbraith Ave

A levee to serve properties along Blundell Parade and Farrell Avenue by excluding flood waters from Stony Creek was not considered effective. The potential location for this levee was along the park between Blundell Parade and Stony Creek. A suitable site for the levee to Farrell Drain, behind Farrell Avenue properties, was not feasible to provide protection to properties. Control and bunding of local catchments from upstream of Galbraith Avenue also restricted potential effectiveness of a levee system. A levee in this location was thus not modelled explicitly.

FM 3.3 Fennell Cres. Between Mudd Creek and Stony Creek

A levee to protect houses on Fennell Crescent between Mudd Creek and Stony Creek was not considered feasible. An extensive levee bank would be required to isolate the houses in this area as buildings on the Stony Creek side are adjacent to the creek. Regrading of Fennell Crescent roadway would be required at both the east and west sides to provide the rise in level suitable to exclude floodwaters.

Significant impacts to properties and owners would likely occur due to loss of visual amenity, access to the creek and resultant disconnection from properties just outside the levee area. Thus this option was not explicitly modelled.

FM 3.4 Adam St and Fennell Cres. (north of Mudd Creek)

The concept for this levee is to exclude floodwaters from properties on Adam Street and Fennell Crescent on the northern side of Mudd Creek. **Figure 9.7** shows the layout of the option.

The levee is about 800m long with a top level of RL 2.3m AHD to exclude the 100 year ARI flood from these properties. This top level of the levee is up to 1.8m above the existing ground level. The Mudd Creek crossing of Fennell Crescent will be raised about 1m to form part of the levee allowing augmentation to the existing culverts.

FM 3.5 Lake St and Venetia Ave

To protect properties on Lake Street and Venetia Avenue, an extensive levee would need to be constructed around this peninsula. A levee 2500m long between Stony Creek and Lake Street, between Mudd Creek and Venetia Parade, and between Edmunds Bay and the rear of properties would be required. This levee would need to be up to 1.2m higher than the existing ground level to be at the 100 year peak Lake level. This option was thus not explicitly modelled due to extent and the potential impost on properties and visual amenity.

FM 3.6 Sara St and Day Street

A levee positioned between properties on Sara Street and Stony Creek just downstream of Railway Parade was reviewed and considered not to be feasible. A levee about 400m long from downstream of Railway Parade to behind properties fronting Day Street was envisaged. A major constraint to a levee on these sites is the restricted space available at the creek side of these properties on land currently being utilised by the businesses. Thus this option was not explicitly modelled.

9.2.4 Railway Parade

The crossings of Railway Parade were identified in the questionnaire as adversely impacting flood levels upstream and as items for potential modification to mitigate flood impacts. Flood modelling shows this area to be a constriction to flow.

At Railway Parade, both Mudd Creek and Stony Creek have a road crossing and a railway crossing downstream. There are also water main pipelines crossing both creeks and a separate footbridge at Mudd Creek. **Figure 9.8** is an aerial photograph showing the area around the Railway Parade crossings of Mudd Creek and Stony Creek.

FM4.1 – Enlarge Mudd Creek Culvert

The existing Railway Parade road bridge is a concrete span across the creek about 0.72m thick with a road surface level of RL 1.5m. The creek opening width is about 8.4m between the bridge abutments and the invert of the channel on the upstream side is -0.90m (surveyed by LMC2 Consulting Group July 2004). **Figure 9.9** shows the Mudd Creek culvert. In the 100 year ARI event, runoff spills over Railway Parade adjacent to Mudd Creek.

The enlargement of the culvert to an open span width of 16m, effectively duplicating the existing span, under the road has been assessed. To accommodate the culvert enlargement, the channel has been widened both upstream and downstream to allow flow to be conveyed into the culvert.

Figure 9.9 – Mudd Creek culvert at Railway Parade

FM4.2 – Enlarge Mudd Creek Culvert and Remove Railway Line

This option comprises the enlargement of the Mudd Creek bridge (per Option 1) and the removal of the downstream crossings. This would be removal of the dis-used Toronto to Fassifern railway crossing (shown in **Figure 9.10**) and realignment of the footbridge and pipeline crossings.

The railway bridge over Mudd Creek has a width of about 32m spanning the creek with six columns (surveyed by LMC2 Consulting Group July 2004). The top of the sleepers is RL 1.72m, with the underside of the deck at RL 1.0m and invert of the channel at RL -0.81m. The railway crossing is state infrastructure and potentially a heritage item so removal may require specific approvals. The watermain pipelines and footbridge, shown in **Figure 9.11**, would need to be modified to provide a clear opening of 16m similar to the enlarged roadway bridge span.

Figure 9.10 – Mudd Creek Railway Crossing just downstream of Railway Parade bridge

Figure 9.11 – Pipelines crossing Mudd Creek just downstream of Railway Parade bridge

FM4.3 – Enlarge Stony Creek Culvert

The roadway crossing of Stony Creek is significantly larger than Mudd Creek with a larger conveyance area underneath. The bridge is about 50m wide with a road surface level of RL 2.5m and the underside of the bridge is RL 1.75m (surveyed by LMC2 Consulting Group July 2004). Three columns support the bridge across the creek which has an invert of RL -1.78m. **Figure 9.12** shows the bridge.

This option assesses the widening of the culvert opening to about 65m wide and channel widening for the approaches to the bridge just upstream and downstream. Figure 7 shows the concept layout of this option.

Figure 9.12 – Railway Parade roadway crossing of Stony Creek

FM4.4 – Enlarge Stony Creek Culvert and Remove Railway Line

Two structures cross Stony Creek downstream of the Railway Parade bridge. **Figure 9.13** shows the water main pipelines and **Figure 9.14** shows the dis-used railway track.

The twin 700mm diameter watermain pipelines have a top level of 1.85m AHD (surveyed by LMC2 Consulting Group July 2004). The structure has four supporting columns with a minimum channel invert of RL -2.05m AHD. The railway crossing is about 63m wide with twelve supporting columns. The surface level of the railway track sleepers is 1.55m, the underside of the bridge is RL 1.0m and the lowest invert level of the channel is RL -2.01m AHD.

This option assesses the impact of the enlargement of the road crossing and the removal of these structures downstream. The channel was also widened to 65m between top of banks downstream to the railway structure.

Figure 9.13 – Pipeline crossing of Stony Creek

Figure 9.14 – Railway crossing of Stony Creek

FM4.5 – Enlarge Mudd Creek Culvert and Stony Creek Culvert

This option comprises the enlargement of both the Railway Parade bridge crossings of Mudd Creek and Stony Creek as detailed in the previous options.

FM4.6 - Enlarge Mudd Creek and Stony Creek Culverts and Remove Railway Line

This option comprises the enlargement of both the Railway Parade bridge crossings of Mudd Creek and Stony Creek, removal of the railway crossing and realignment of the pipeline crossings downstream as detailed in the previous options.

FM4.7 – Remove Railway Lines from Downstream

This option comprises the removal of the railway and pipeline crossings from downstream of Railway Parade crossings without enlargement of the roadway openings or channel approaches.

FM4.8 – Raise Railway Parade Crossing of Mudd Creek

In a 100 year ARI event, Railway Parade is overtopped resulting in a peak depth of up to 0.5m on the surface of the road. The current road surface level is 1.5m AHD across Mudd Creek compared to 2.5m AHD at Stony Creek. Overflow across Railway Parade in a 100 year ARI event spreads either side of the location of Mudd Creek, but does not inundate the roadway at the Stony Creek bridge.

Reconstruction of the Mudd Creek crossing above the 100 year ARI flood depth will not result in a flood-free route in this area as Fennell Crescent and Cook Street (up to Thorne Street) is inundated. The pipeline and railway track just downstream may also need to be reconstructed as the flow conveyance area with the modified Railway Parade bridge may be reduced resulting in higher peak flood levels upstream.

This option was thus not specifically modelled.

FM4.9 – Balance flow levels between Mudd Creek and Stony Creek

In a 100 year ARI flood event, the levels at the upstream side of Railway Parade at Mudd Creek and Stony Creek are different. At Stony Creek, the peak water level is about 0.15m lower than at the Mudd Creek bridge.

During the 100y ARI event flows from the two creek systems combine as water spills across the roadway at a depth up to 0.5m at the Mudd Creek bridge. This option was thus not specifically modelled.

Flood Modelling

These scenarios were modelled for the 100y ARI event (for 36h critical duration with 5 year tailwater) and the 5 year 36h rainfall with 100 year ARI tailwater in the lake, and results compared at several locations. Peak water level results at these locations are shown in **Table 9.6**.

The enlargement of the Mudd Creek bridge (Option FM4.1) shows only a small decrease to flood levels upstream and similarly the enlargement of the Stony Creek bridge (Option FM4.3) also results in a small decrease to flood levels upstream. Removal of the railway and pipeline structures downstream in Mudd Creek (Option FM4.2) results in an additional decrease compared to Option FM4.1, but all reference locations show a depth decrease of less than

0.1m. In Stony Creek, the removal of the railway and pipeline structures downstream combined with the bridge enlargement (Option FM4.4) results in decreases to water levels greater than 0.1m. These results indicate that the structures downstream of the Railway Parade roadway bridges are a significant constriction to flow, which is also demonstrated in Option FM4.7. Enlargement of both bridges at Railway Parade (Option FM4.5) improves flood levels upstream slightly compared to enlargement of a single bridge, but improvements greater than 0.1m occur with the removal of crossing downstream (Option FM4.6 and Option FM4.7).

Results from the low tailwater case, 100y ARI 36h rainfall modelled with a 5 year ARI tailwater, show a minor increase (~0.01m) to a couple of properties downstream of Railway Parade in Venetia Avenue with the implementation of Option FM4.1. Note that the peak level downstream of Railway Parade generally occurs due to the peak level from Lake Macquarie. In Option FM4.2, additional flow is conveyed down Mudd Creek adjacent to Venetia Avenue compared to decreased flow, and consequently flood levels, along Stony Creek downstream of Railway Parade. Flood levels along Venetia Avenue are estimated to rise by up to 0.08m as result from Option FM4.2.

In Options FM4.3 and FM4.4, representing changes to the Stony Creek bridge and structures, additional water is conveyed in Stony Creek downstream of Railway Parade compared to reduced flow in Mudd Creek. Flood levels increases only in the area just downstream of Stony Creek bridge by up to 0.02m for Option FM4.3. For Option FM4.4, the revised flow distribution results in levels along Venetia Avenue reducing by up to 0.04m and increasing along Stony Creek by up to 0.05m in Sara Street and up to 0.03m to properties in Lake Street.

Amplification of the Mudd Creek and Stony Creek bridges in Option FM4.5 shows a decrease in peak water levels upstream around 0.05m and does not increase levels downstream. The combination of Mudd Creek and Stony Creek bridge amplification and removal of the downstream structures in Option FM4.6, shows a decrease to upstream peak water levels of about 0.2m, but increases downstream in Mudd Creek adjacent to Venetia Avenue of up to 0.03m. Removal of the downstream structures on both creeks in Option FM4.7, shows decreases in peak water levels upstream of Railway Parade and downstream adjacent to Venetia Avenue (of about 0.02m), but increases peak levels downstream to Day Street along Stony Creek (by up to 0.03m to properties in Sara Street).

Based on this assessment of the 100 year ARI flood results, three options were modelled for all recurrence intervals:

- FM4.2 – Enlarge Mudd Creek Culvert and Remove Railway Line – shown in **Figure 9.15**
- FM4.6 - Enlarge Mudd Creek Culvert and Stony Creek Culvert and Remove Railway Line – shown in **Figure 9.16**
- FM4.7 – Remove Railway Lines from Downstream – shown in **Figure 9.17**

Table 9.6: Peak Water Level Difference for Railway Parade Options (100y ARI)

Location	Existing Peak WL (m AHD)	FM4.1	FM4.2	FM4.3	FM4.4	FM4.5	FM4.6	FM4.7
High St weir	2.97	-0.01	-0.02	-0.01	-0.02	2.96	-0.03	-0.02
Stony Creek / Mudd Ck confluence	2.27	-0.01	-0.04	-0.02	-0.07	2.24	-0.10	-0.07
Carleton St – Beckley St intersection	3.45	0.00	0.00	0.00	0.00	3.45	0.00	0.00
Fennell Cres – crossing of Mudd Ck	2.18	-0.02	-0.06	-0.02	-0.09	2.14	-0.13	-0.08
Fennell Cres	2.08	-0.02	-0.07	-0.02	-0.11	2.03	-0.18	-0.11
Blundell Pde – Farrell Ave intersection	2.06	-0.02	-0.07	-0.03	-0.12	2.01	-0.18	-0.11
Cook St – James St intersection	1.98	-0.02	-0.08	-0.03	-0.17	1.92	-0.24	-0.16
Stony Ck – just upstream of Railway Pde	1.90	-0.02	-0.08	-0.05	-0.23	1.83	-0.25	-0.20
Mudd Ck - just upstream of Railway Pde	2.01	-0.02	-0.09	-0.03	-0.13	1.95	-0.21	-0.13
Lake St – Venetia Ave intersection	1.47	0.00	0.00	0.00	0.00	1.47	0.00	0.00
Sara St – Day St intersection	1.45	0.00	0.00	0.00	0.00	1.45	0.00	0.00

9.2.5 FM5.1 Rainwater Tanks

One of the options favoured by the community in the questionnaire (Section 3) was the use of rainwater tanks in the catchment. The benefit for using rainwater tanks would predominantly be for water conservation and any flood mitigation benefits would be expected to be low.

Available storage in rainwater tanks, even when being used for irrigation and internal purposes, would potentially be used up in the first part of the storm or from preceding rainfall events. Thus the rainwater tank may be effectively full at the main part of the storm, offering limited reduction in flood flows.

Flooding in the catchment generally results from runoff being conveyed for the large bushland catchment upstream in Awaba State Forest, or from Lake flood levels in areas downstream of Railway Parade. The application of rainwater tanks in the catchment would have limited influence on these flooding mechanisms.

9.2.6 FM6.1 Infiltration Basins & Trenches

Responses from the community questionnaire were not highly favourable of the use of infiltration basins or trenches for flood mitigation (Section 3). Similarly to the detention basins, large storages would be required to significantly reduce the flood impacts. Small infiltration trenches distributed around the catchment would potentially only have minor impacts to flood levels for frequent events. Some improvement to water quality may result from the use of infiltration systems.

9.2.7 Lake Macquarie Management Options

Flood inundation to properties downstream of Railway Parade, such as Lake Street and Venetia Avenue, are generally due to levels in Lake Macquarie rather than due to runoff from Stony Creek upstream for a particular recurrence interval. The Lake Macquarie Floodplain Management Plan (Webb McKeown, 2001) evaluates options for the management of flood risk for the Lake.

The following flood modification measures were given a low priority based on the assessment compared to other measures:

- Undertake a study to investigate dredging of the Swansea Channel,
- Dredge Swansea Channel to increase capacity (if recommended by the study),
- Upgrading of Swansea Bridge .

The Lake Macquarie Floodplain Management Study (Webb McKeown, 2000) noted community support for dredging works in Swansea Channel. The Study indicated that even a small reduction in the Lake flood level resulted in a large reduction in flood damages around the Lake. Disadvantages of the channel opening works were a high initial cost, adverse environmental impacts, and a potential increase to Lake levels due to increased ocean penetration. Swansea Channel works are referenced as Option FM7.1

A preliminary review for the Lake Macquarie Floodplain Management Study (Webb McKeown, 2000) indicated that no areas were particularly suitable for the construction of a levee. Disadvantages of a levee include reduction of visual amenity, high cost, trapping of local runoff, and low community support. Lake Macquarie levee works are referenced as Option FM7.2.

9.2.8 Flood Flow Paths

The improvement of flood flowpaths was a potential option preferred as noted in the community consultation (**Section 3**). Dredging of deposited silt from Stony Creek, Mudd Creek and their outlets to the bays was recommended for reducing flood impacts.

Potential reductions to peak flood levels from dredging the creeks is limited as the channels are a tidal system connected to Lake Macquarie. The dominant mechanism for flooding downstream of Railway Parade is due to Lake levels, rather than local catchment flooding.

Regular maintenance of the creeklines and culverts to remove debris would reduce the likelihood of blockages to the drainage network. The effect of blockages is described in **Appendix D**.

Sensitivity testing of modification to the roughness parameter in modelling of the catchment is detailed in the Flood Study Report (2005). The modelling showed that reducing the roughness across the entire study area by 20% resulted in a reduction to peak flood levels in the 100 year ARI event by 0.07m just upstream of Railway Parade.

This flood modification measure, listed as Option FM8.1 in the multi-criteria assessment matrix in **Appendix F**, was therefore not modelled.

9.3 Property Modification Options

As outlined in Section 4.13, there are a number of opportunities for the use of planning legislation, plans, policies or guidelines for the management of flood liable areas of the catchment.

P1 - LEP Update

Local environmental plans prepared by councils guide planning decisions for local government areas. Through zoning and development controls, they allow councils to supervise the ways in which land is used.

Lake Macquarie Local Environment Plan 2004 (LEP) is the statutory planning instrument that establishes what forms of development and land use are permissible and/or prohibited on all land within the Lake Macquarie Local Government Area.

The relevant section of the LEP in regards to flooding is part 5, clause 32. In its current form, the LEP effectively refers to the controls within the relevant DCP.

The LEP in its current form is relatively recent and is unlikely to require an immediate update. However, it is recommended that the LEP be reviewed regularly to ensure that it is up to date. Changes would generally be associated with an update to the standard template, and as such this option is considered to be relatively minor. An allowance has been provided in the assessment of this option for regular reviews and updates of the LEP.

P2 – Building and Development Controls

Lake Macquarie's Development Control Plan flooding controls are provided in Section 2.1.7 of the DCP (Lake Macquarie City Council DCP No. 1, Revision 03, F2004/11035, adopted 9 February 2009). This DCP was established quite recently and many of the flood controls would not require significant updating. However, it is recommended that the controls in the DCP are regularly reviewed.

It is recommended that specific controls be established for the Stony Creek Floodplain, to address specific issues within the floodplain. This would be similar to the Dora Creek section of the DCP (Section 2.1.8), which outlines specific controls for Dora Creek. These controls would be additional to the controls in Section 2.1.7 of the DCP.

The proposed FPLs listed in Section 2.1.7 of the DCP are as follows:

- Residential lots – habitable floors at or above 100 year ARI plus 500mm freeboard. Non-habitable floors at or above the 20 year ARI.
- Commercial Lots – floor levels at or above the 100 year ARI plus 500mm freeboard.
- Industrial Lots – floor levels at or above the 100 year ARI.

These FPLs are generally consistent with the discussion provided in **Section 8** of this report, and are recommended for the Stony Creek Floodplain.

There are two primary areas in Stony Creek where evacuation is a potential issue:

- Fennell Crescent – in this area, both ends of the road are cut off by flood waters. In February 1981, there were reports of residents climbing onto their rooves in order to seek refuge from the floodwaters.
- Lake Street and Venetia Avenue – both of these areas are primarily affected by Lake Macquarie driven flooding. Unlike other foreshore areas, there is only one road access point which is cut-off during a flood event.

In these two areas, it is recommended that the following controls be applied:

- No intensification of development. This will prevent additional population be placed at risk in these areas.
- Encouragement of second storey development in the area, where the second storey is located above the PMF. This will provide a flood refuge for large flood events.

While there are other areas in Stony Creek where flooding is a significant issue, these areas are such that there are evacuation routes which rise away from the floodplain (either by car or foot).

Filling of land should not be permissible in the Fennell Crescent area. This area provides connectivity between Mudd Creek and Stony Creek during a flood event. Filling of this area has the potential to have significant impacts on flooding.

Filling may be permissible on the Lake Street and Venetia Avenue area, as this area is primarily governed by Lake Macquarie flooding. As such, any removal of storage would be considered negligible across the entire floodplain. However, a flood assessment should be undertaken for the proposed development to ensure that the filling does not adversely affect neighbouring properties.

P3 – House Raising

House raising is a possible option to reduce the incidence of over-floor flooding in properties. However, whilst house raising can reduce the occurrence of over-floor flooding, there are issues related to the practice including:

- Difficulties in raising some houses (such as slab on ground). In some slab on ground situations, it may be possible to install a false floor, although this is limited by the ceiling heights.
- The potential for damage to items on a property other than the raised dwelling (such as gardens, sheds and their contents, garages, cars, etc).
- Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists (i.e. there will be a residual risk).

- Evacuation may be required (e.g. medical emergency during a flood event) even if no above floor flooding occurs. This evacuation is likely to be hampered by floodwaters surrounding a property.
- The need to ensure the new footings and piers can withstand flood-related forces. House raising is generally only suitable for low hazard areas, however all properties have been considered as part of this assessment.
- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area (for properties to be raised a significant level, e.g. greater than 1m).

For a single storey, slab on ground property, the flooding damage that occurs for over-floor flooding of around 0 to 0.5 metres of depth is around $40,000. **Table 9.7** provides the approximate Annual Average Damage (excluding overground-only damage) for over-floor flooding commencing in different ARI events for individual residential properties. It assumes that over-floor flooding damage is constant at $40,000 for each over-floor event. This effectively provides a typical AAD for an individual property, and can be used as a guide.

Table 9.7 also demonstrates that properties with over-floor flooding in less frequent events are not exposed to flood damages as frequently, and hence the annualised damage for that property is not as significant. Properties that are exposed to over-floor flooding commencing in the 5 year ARI event, experience annualised damages of approximately $8,000, with a NPV (over 30 years) of approximately $99,300.

In Stony Creek, there are no properties with overfloor flooding in the 5 year ARI event. However, overfloor flooding does occur in the 10 year ARI event. **Table 9.7** provides an indication of the AAD if overfloor flooding was to commence in the 10 year ARI. It suggests an AAD of $4,000 and NPV (over 30 years) of $49,600 per property for properties where over-floor flooding commences in a 10 year ARI event.

Table 9.7: Estimates of AAD and NPV for Different Over-floor Flooding Scenarios

Event in which Over-floor Flooding Commences	Number of Properties with Over-floor Flooding*	Annual Average Damage per Property	NPV (30yrs) per Property
5yr	0	$8,000	$99,300
10yr	4	$4,000	$49,600
20yr	10	$2,000	$24,800
50yr	29	$800	$9,900
100yr	57	$400	$5,000
200yr	87	$200	$2,500
PMF	295	$0	$0

**based on number of residential properties, discussed in Economic Damage Analysis (Section 6)*

For the purposes of costing this option for assessment, it has been assumed that all houses that are inundated in the 10 Year ARI (4 houses) would be raised to the 20 year ARI level, at a cost of $80,000 per house (based on recent work undertaken by Pittwater Council). It is noted that this would unfairly disadvantage those properties which are inundated between the 10 year ARI and the 20 year ARI. This particular format has been assumed for assessment purposes only, as there are a number of different options available (such as the sliding subsidy scheme). If this option is considered viable, then these additional options could be considered by Council in establishing the scheme.

Funding for this option may occur jointly between Council, NSW Government and residents.

Table 9.8 shows the reductions in AAD from different house raising scenarios. In order for the scheme to be equitable, the house raising should only occur by raising floor levels up to the next ARI flood level. If it were to occur for a higher level, then it is arguable that the properties experiencing over-floor flooding in the next ARI storm would be disadvantaged. For example, if only those properties in the 10 year ARI event were raised to the 100 year ARI event, this would disadvantage properties who have over-floor flooding in the 20 year ARI event. In order to overcome this equity issue, it may be suitable to apply a sliding scale subsidy which applies to all properties which are affected by over-floor flooding in events more frequent than the100 year ARI.

For the purposes of costing this option for assessment, it has been assumed that all houses that are inundated in the 10 Year ARI (4 houses) would be raised to the 20 year ARI level, at a cost of $80,000 per house (based on recent work undertaken by Pittwater Council). It is noted that this would unfairly disadvantage those properties which are inundated between the 10 year ARI and the 20 year ARI. This particular format has been assumed for assessment purposes only, as there are a number of different options available (such as the sliding subsidy scheme). If this option is considered viable, then these additional options could be considered by Council in establishing the scheme.

Funding for this option may occur jointly between Council, NSW Government and residents.

Table 9.8: Reduction in AAD Resulting from Different House Raising Scenarios

Option	Number of Properties	Reduction in AAD (per property)	Overall Reduction in AAD	NPV of Reduction	Estimated Cost of Raising
10yr to 20yr	4	$2,000	$8,000	$99,272	$320,000
20yr to 50yr	10	$1,200	$12,000	$148,908	$800,000
50yr to 100yr	29	$400	$11,600	$143,945	$2,320,000
100yr to 200yr	57	$200	$11,400	$141,463	$4,560,000
200yr to PMF	87	$200	$17,400	$215,917	$6,960,000

P4 - House Rebuilding

Under a re-building scheme, the property owner would have the option of utilising the subsidy for house raising described above for re-construction instead. In a number of cases, the ability to raise properties can be difficult and therefore rebuilding may be the only option. The advantage of this option is that the new structure can also be built in a flood compatible way (such as including a second storey for flood refuge).

One of the issues associated with this option is that there is still a significant cost for the property owner to redevelop their land. In addition, this provides an inequitable situation for those properties that are subject to the subsidy and those that are not. It can have the effect of skewing the property redevelopment market, where those properties subject to the subsidy are more attractive for development than those properties that are not.

P5 – Voluntary Purchase

An alternative to the construction of flood modification options and for properties where house raising is not possible, is the use of voluntary purchase (VP) of existing properties. This option would free both residents and emergency service personnel and volunteers from the hazard of future floods. This can be achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to a flood compatible use, such as recreation or parkland or possibly redeveloped in a manner that is consistent with the flood hazard. However, this option should be considered after other, more practical options have been investigated and exhausted.

The recommended criteria to determine properties that are eligible for voluntary purchase are:

- property located in high hazard area for the 100 year ARI flood,
- occurrence of above floor flooding in the 5 year ARI flood event, and
- economic value of damages for a particular property is comparable to the property market value.

Typical prices of properties in the suburb of Toronto, and particular in the Stony Creek floodplain, are in the order of $300,000 (based on a search of the listed property prices for the area through www.realestate.com.au as at July 2009). The net present value of savings in average annual flood damages for removing one of the properties above from the floodplain is approximately $49,600 (as per **Table 9.7**). The cost of purchasing the properties in Stony Creek would therefore be significantly higher than the savings in terms of flood damages.

In addition, Voluntary purchase only benefits a few properties, and not the wider floodplain. This effectively results in an inequitable distribution of Council funds. By comparison, some of the flood modification options may in fact be less expensive and benefit the wider floodplain.

P6 – Land Swap

An alternative to pure voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area (e.g. an existing park) for the flood prone land with the appropriate transfer of park facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land rezoned to open space. The land swap approach may result in a significant saving on the land component of the voluntary purchase costs. It is recommended that this approach be investigated first before voluntary purchase proceeds and as such has not been included in the multi-criteria matrix assessment as a stand-alone option.

P7 – Council Redevelopment

This option also provides an alternative to the Voluntary Purchase (P5) scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them with a break even objective.

The following provides an estimate of the various costs involved for a single residential development, where Council redevelopment occurs only on those properties identified in for voluntary purchase. Reconstruction costs are estimated based on a single storey elevated building using the Allianz building express calculator (secure.cordell.com.au/valuer_residential/index.php?p=66, accessed on 25 June 2008). The purchase cost of the property is estimated as per P5 above.

- Purchase of Property = $300,000
- Reconstruction Costs = $200,000
- Reduction in Flood Damages = $49,600

The Council would need to sell the property at approximately $500,000 in order to break even on the development, in a one for one development approach. This excludes other expenses such as transaction expenses.

However, using a cost benefit analysis (and hence including the reduction in flood damages), then the development would need to resell at approximately $450,000 plus transaction costs in order for Council to break even.

Note that there are significant risks for Council in undertaking this option. In particular, the property market may vary during the construction period, resulting in a difficulty in re-selling the property or re-selling the property at a price lower than the purchase price. In addition, it requires a large upfront cost to Council. An alternative would be to consider the acquisition of multiple flood-affected properties, and redevelopment with a high density, flood compatible development where possible and as permitted in the zoning under the LEP.

In addition, as with Voluntary Purchase and Land Swap, this option, while reducing Annual Average Damages, only benefits a few properties, and not the catchment as a whole.

For the purposes of options analysis, it has been assumed that the properties sell for $50,000 more than the buying price ($350,000). This is likely to be a conservative approach.

P8 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property (and thus the damage caused by flooding). Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding. These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of flood proofing measures include:

- All structural elements below the Flood Planning Level shall be constructed from flood compatible materials;
- All structures must be designed and constructed to ensure structural integrity for immersion and impact of velocity and debris up to the level of the 100 year ARI flood event. If the structure is to be relied upon for 'shelter-in-place' evacuation then structural integrity must be ensured up to the level of the Probable Maximum Flood; and

- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the Flood Planning Level.

In addition to flood proofing measures that are implemented to protect a building, temporary/emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of a building (particularly in the case of a commercial property). These measures should be carried out according to a pre-arranged plan. These measures may include:

- Raising belongings by stacking them on shelves or taking them to a second storey of the building.
- Secure objects that are likely to float and cause damage.
- Re-locate waste containers, chemicals and poisons well above floor level.
- Install any available flood proofing devices (such as temporary levees and emergency water sealing of openings).

The SES business *Flash Flood Tool Kit* provides business with a template to create a floodsafe plan and to be prepared to implement flood proofing measures. It is recommended that this tool kit is distributed to all businesses in the Stony Creek floodplain.

In addition, it is recommended that draft *Flood Proofing Guidelines* for the Stony Creek Floodplain be prepared.

9.4 Emergency Response Modification Options

The following emergency response modification options are suitable for the floodplain:

- Information transfer to SES (EM1)
- Community flood awareness program (EM2)
- Flood warning system (EM3)

EM1 - Information Transfer to SES

The findings of the flood study and plan provide an extremely useful data source for the State Emergency Service. Information could be provided from the findings of the study in two forms:

- Electronic information (flood extent mapping and flood hazard mapping in GIS format)
- Laminated plans (hard copies of flood extent and hazard mapping) in laminated plan format for use in the operations centre to assist with directing teams to the most likely affected localities. This can also help to overcome any issues associated with power loss or difficulty with accessing information in an emergency.

EM2 – Update of Local Flood Plan

This option would update the local flood plan, in light of the information provided in this report. The update would incorporate the recommendations in **Section 7**.

EM3 - Flood Warning System

The critical duration and response times for flooding in the lower reaches of the catchment may mean the implementation of a flood warning system is feasible. The flow behaviour at three key locations was examined for potential application of a flood warning system. These nodes are:

- Just upstream of the F3 Freeway;
- Just upstream of the Coal Haul Road;
- On Stony Creek just upstream of the confluence with Mudd Creek (and upstream of Fennell Crescent properties).

The approximate channel distance is 5.5km from the F3 to the Haul Road, then an additional 2.5km to the Stony Creek – Mudd Creek confluence.

Peak flow and event times for the three locations indicate the time delay of the peak occurring at Stony-Mudd Creek from the peaks at the F3 and the Haul Road is about 4 hours and 2 hours respectively for the 100 year ARI event. Two hours may be insufficient time for preparation for flooding and thus this assessment focuses on the potential use of the F3 (Node 1) as a flow monitoring location for alerting at the Stony-Mudd Creek confluence (Node 3).

At the time of the peak flow occurring at Node 1, significant flows are already being conveyed at Node 3, prior to the peak occurring about 4 hours later. The largest coincident flows at Node 3, occur in the longer duration storms. For example, in a 100 year ARI 48 hour duration storm, the flow at Node 3 is equivalent to the peak flow of a 10 year ARI event (note that four properties experience overfloor flooding in this event) at the coincident time of the peak at Node 1. Thus Node 3 may already be experiencing flooding problems at the time an alarm would be triggered by flows from Node 1. This flow is due to the runoff from local subcatchments inundating Node 3 prior to the flow being conveyed from the upper parts of the catchment.

As an example to assess the effectiveness of a potential system, an alarm at Node 3 is triggered when the water level at Node 1 corresponds to a flow of about 50 m^3/s. This flow is equivalent to about the minimum peak flow at Node 1 in the 100 year ARI event for a range of durations. Notably this flow rate is less than the peak for the 10 year ARI event, and thus the alarm would not be triggered in storms up to this event. In the case of the PMF event (5 hour duration), this alarm configuration would trigger about 30 minutes prior to flows at Node 3 reaching 10 year ARI flood peaks, about 60 minutes prior to flood peaks approximately equivalent to 100 year ARI, and about five hours to the peak flow of the PMF.

Figures 9.15 and **9.16** show that there is only several hours from the peak of the storm to high flood depths across Fennell Crescent which would affect potential warning time of inundation.

EM4 - Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for their area. This includes the defence of their property and their evacuation in the flooding event, if required.

Flood awareness campaign should be an ongoing process and requires continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area. The more recent and frequent the flooding, the greater the awareness. The community consultation undertaken for the Flood Study (CLT, 2005), identified the most recent flood event recalled by residents was in 1990, with a major event in February 1981. More recently, the residents experience a large flood event in June 2007. The resident questionnaire described in **Section 3**, indicates a reasonable awareness of flooding amongst respondents (approximately 90%). Following the June 2007 event, an additional survey was distributed with 128 of the 138 respondents (91%) suggesting a knowledge of flooding (**Appendix B**). Given that the June 2007 event was relatively large and recent, it is expected that the community have a reasonable awareness of flooding.

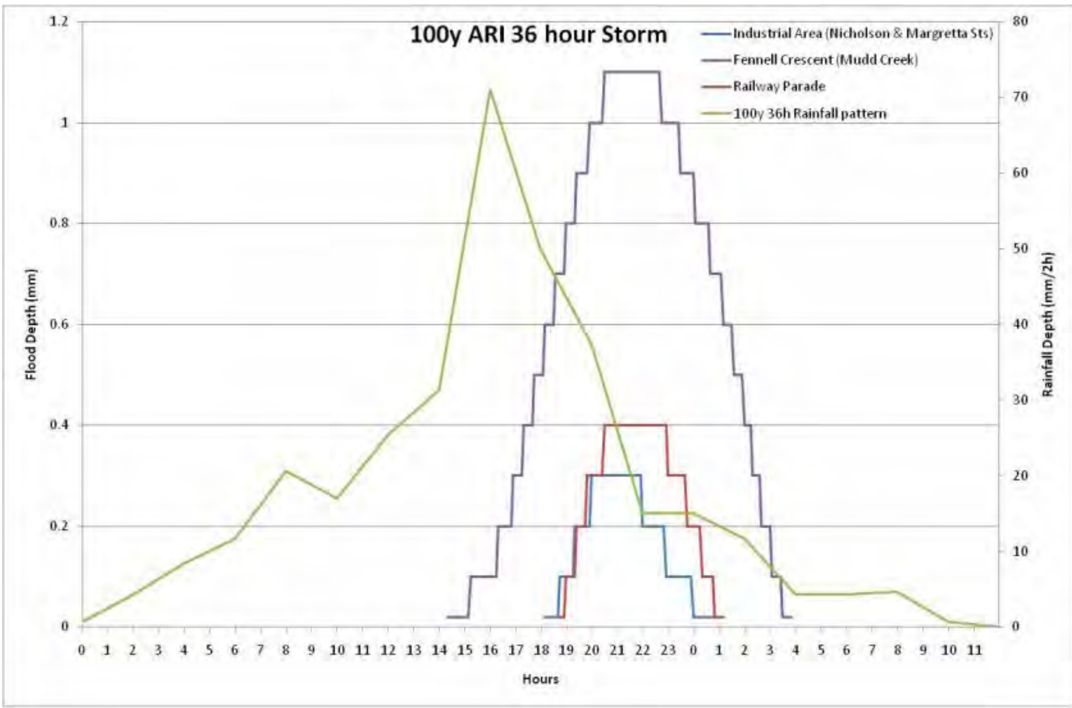

Figure 9.15 – 100y ARI 36h Storm and Flood Depths

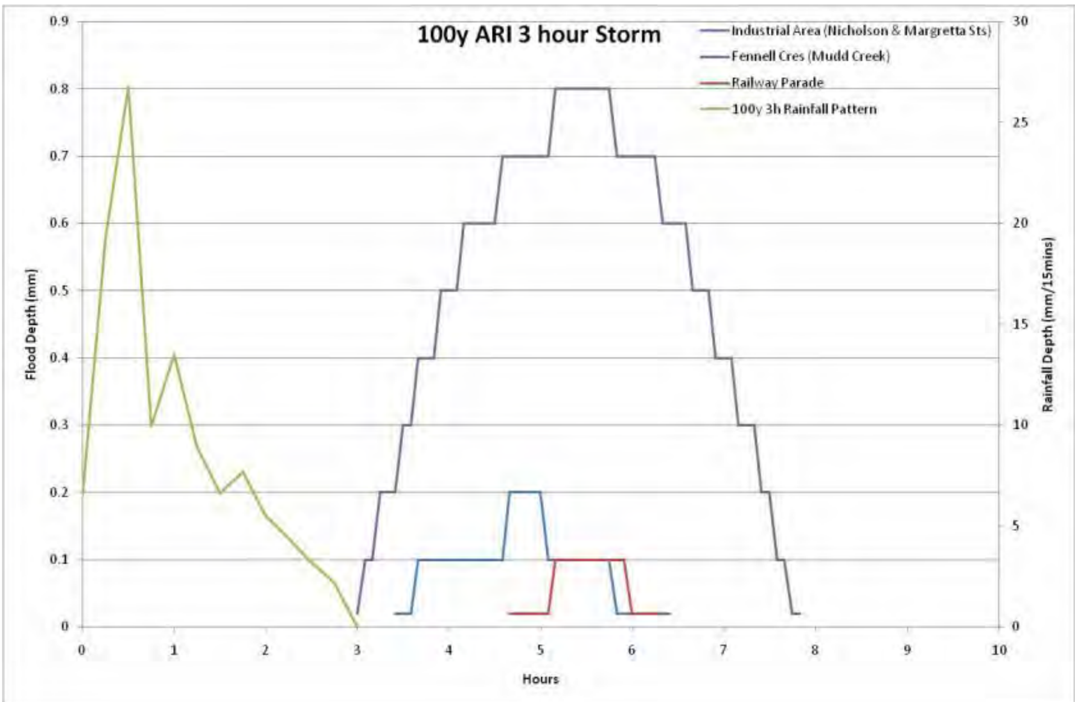

Figure 9.16 – 100y ARI 3h Storm and Flood Depths

However, for effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

It is recommended that the following awareness campaigns be considered for the floodplain:

- Preparation of a FloodSafe brochure. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information
- Development of a Schools Package from existing materials developed by the SES and distribution to schools accordingly. Education at schools is not only useful in educating the students, but can be useful in the dissemination of information to the wider community.

The meeting of local Community groups could be used to arrange flood awareness programs on regular intervals.

Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

Once prepared, the FloodSafe brochure can then be uploaded to the SES website (www.ses.nsw.gov.au) in portable document format (PDF) where it is available under the information for local communities section.

EM5 - Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding in the 100 year ARI event. It is therefore important that appropriate flood warning signs are posted at these locations. The following locations have been identified for flood signs:

- Keith Barry Oval at Bridge Street,
- Fennell Crescent at Mudd Creek – vicinity of Adam Street,
- Fennell Crescent at intersection with Railway Parade,
- James Street – near intersection with Cook Street.

Warning signs at the following locations may be prudent as these areas are classified as low hazard flooding in the 100 year ARI event, but are high hazard in the PMF:

- Industrial area north of Burleigh Street – potential sign location at intersection of High Street and Sunderland Road,
- Awaba Road – in the vicinity of Carleton Drain and Beckley Street,
- Water Board War Memorial Oval at Fennell Crescent,
- Railway Parade crossing of Mudd Creek,
- Lake Street at intersection with Railway Parade,
- Sara Street at intersection with Day Street,
- Main Road south of Fennell Bay Bridge.

EM6 – Fennell Crescent Evacuation Route

This area is potentially exposed to long duration inundation, with a number of properties experience overfloor flooding. In addition, a number of the properties are single level dwellings, providing minimal opportunity for vertical evacuation. Observations from the 1981 flood event suggested that residents resorted to utilising their rooves as refuges from the flooding.

This option would raise the Fennell Crescent crossing of Mudd Creek, to allow residents to evacuate in this direction and reach higher ground. This option could also be potentially combined with Option FM3.4.

It is noted that Fennell Crescent is relatively flat along its length. As such, a raising of the crossing over Mudd Creek would provide minimal benefits, particularly for those residents further to the east along Fennell Crescent. Evacuation would only be possible for as long as Fennell Crescent was not inundated. Therefore, this option is not considered viable.

It is recommended that two storey development be encouraged in this area, to allow for vertical evacuation during a flooding event.

EM7 – Lake St/ Venetia Avenue

Lake Street and Venetia Avenue become isolated during Lake Macquarie flooding. The only evacuation route is along Lake Street and then Railway Parade, both of which are cut-off during flood events.

Similar to Fennell Crescent, there is limited potential to raise a sufficient distance of these roads to provide an evacuation route. As such, this option is not considered viable.

As per Option EM5, it is recommended that two storey development be encouraged in this area, to allow for vertical evacuation during a flooding event.

DC1 - Data Collection Strategies

This would involve the preparation of a flood data collection form and use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

10 Economic Assessment of Options

10.1 Flood Damage Summary for Options

A summary of the flood damage assessments for the quantitatively assessed options is included in **Table 10.1** for the 100 year ARI event and in **Table 10.2** for the 20 year ARI event.

Table 10.1: Flood Damage Assessment Summary – 100 year ARI

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($February 2009) *
Existing					
Residential	41	0.19	0.66	165	$ 2,611,634
Commercial	3	0.26	0.30	6	$ 76,243
Industrial	13	0.15	0.67	26	$ 397,323
Existing Total	57			197	$ 3,085,200
FM1.2 - Detention Basin Upstream of Railway Line - 1 site					
Residential	**15**	**0.17**	**0.40**	**139**	**$ 1,598,890**
Commercial	**3**	**0.11**	**0.22**	**5**	**$ 41,284**
Industrial	**5**	**0.14**	**0.35**	**17**	**$ 123,384**
FM1.2 Total	**23**			**161**	**$ 1,763,557**
FM2.3 - Carleton Street and Awaba Road					
Residential	**40**	**0.19**	**0.66**	**161**	**$ 2,551,073**
Commercial	**3**	**0.24**	**0.28**	**6**	**$ 70,424**
Industrial	**13**	**0.13**	**0.53**	**25**	**$ 347,132**
FM2.3 Total	**56**			**192**	**$ 2,968,629**
FM3.1 - Toronto Industrial Area - Levee					
Residential	**40**	**0.19**	**0.66**	**159**	**$ 2,539,815**
Commercial	**1**	**0.22**	**0.22**	**2**	**$ 22,017**
Industrial	**3**	**0.09**	**0.13**	**8**	**$ 110,133**
FM3.1 Total	**44**			**169**	**$ 2,671,966**
FM3.4 - Adam St and Fennell Cres. (north of Mudd Creek)					
Residential	**32**	**0.16**	**0.67**	**136**	**$ 2,056,560**
Commercial	**3**	**0.25**	**0.29**	**6**	**$ 72,301**
Industrial	**13**	**0.14**	**0.53**	**25**	**$ 372,640**
FM3.4 Total	**48**			**167**	**$ 2,501,501**

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($February 2009) *
FM4.2 - Railway Parade - Mudd Creek Culvert Upgrade					
Residential	**29**	**0.18**	**0.58**	**137**	**$ 2,051,670**
Commercial	**2**	**0.23**	**0.23**	**3**	**$ 30,362**
Industrial	**8**	**0.10**	**0.22**	**19**	**$ 277,573**
FM4.2 Total	**39**			**159**	**$ 2,359,605**
FM4.6 - Railway Parade - Stony Creek & Mudd Creek Upgrade					
Residential	**22**	**0.17**	**0.47**	**151**	**$ 1,896,486**
Commercial	**3**	**0.24**	**0.28**	**6**	**$ 70,424**
Industrial	**12**	**0.14**	**0.53**	**25**	**$ 327,058**
FM4.6 Total	**37**			**182**	**$ 2,293,968**
FM4.7 - Railway Parade - Remove Downstream Railway Line and Crossings					
Residential	**27**	**0.18**	**0.53**	**156**	**$ 2,115,889**
Commercial	**3**	**0.24**	**0.28**	**6**	**$ 70,424**
Industrial	**12**	**0.14**	**0.53**	**25**	**$ 332,444**
FM4.7 Total	**42**			**187**	**$ 2,518,757**

*values are expressed to the nearest dollar, but this is not indicative of the accuracy of the estimates

Table 10.2: Flood Damage Assessment Summary – 20 year ARI

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($February 2009) *
Existing					
Residential	7	0.21	0.37	98	$ 927,695
Commercial	2	0.08	0.10	5	$ 19,267
Industrial	1	0.09	0.09	3	$ 4,677
Existing Total	10			106	$ 951,638
FM1.2 - Detention Basin Upstream of Railway Line - 1 site					
Residential	3	0.08	0.16	57	$ 435,803
Commercial	0	-	0.00	1	$ -
Industrial	1	0.03	0.03	3	$ 2,181
FM1.2 Total	4			61	$ 437,984

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($February 2009) *
FM2.3 - Carleton Street and Awaba Road					
Residential	7	0.21	0.37	98	$ 927,695
Commercial	2	0.08	0.10	5	$ 19,267
Industrial	1	0.09	0.09	3	$ 4,677
FM2.3 Total	10			106	$ 951,638
FM3.1 - Toronto Industrial Area - Levee					
Residential	7	0.21	0.37	94	$ 903,951
Commercial	0	-	0.00	2	$ -
Industrial	0	-	0.00	1	$ -
FM3.1 Total	7			97	$ 903,951
FM3.4 - Adam St and Fennell Cres. (north of Mudd Creek)					
Residential	4	0.26	0.38	77	$ 675,271
Commercial	2	0.08	0.10	5	$ 19,267
Industrial	2	0.22	0.35	11	$ 13,511
FM3.4 Total	8			93	$ 708,048
FM4.2 - Railway Parade - Mudd Creek Culvert Upgrade					
Residential	6	0.17	0.28	95	$ 803,432
Commercial	1	0.05	0.05	2	$ 4,099
Industrial	1	0.09	0.09	6	$ 4,677
FM4.2 Total	8			103	$ 812,208
FM4.6 - Railway Parade - Stony Creek & Mudd Creek Upgrade					
Residential	5	0.12	0.22	76	$ 619,991
Commercial	1	0.05	0.05	2	$ 4,099
Industrial	1	0.09	0.09	6	$ 4,677
FM4.6 Total	7			84	$ 628,767
FM4.7 - Railway Parade - Remove Downstream Railway Line and Crossings					
Residential	6	0.16	0.27	93	$ 814,119
Commercial	2	0.08	0.10	4	$ 19,267
Industrial	2	0.22	0.35	11	$ 13,511
FM4.7 Total	10			108	$ 846,897

*values are expressed to the nearest dollar, but this is not indicative of the accuracy of the estimates

10.2 Preliminary Costing of Options

A preliminary cost estimate of all proposed options has been prepared to assist with the comparative assessment of options. The costs were prepared (where appropriate) with the assistance of the Cordell Building Cost Guide.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the options, these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

The preliminary costing for all of the identified options is provided in the multi-criteria matrix provided in **Chapter 11.**

It is possible to quantitatively assess the economic benefit of some of the options (i.e. those which are hydraulically modelled and those with known benefits such as house raising). For those options, a benefit-cost ratio can be calculated.

A summary of the estimated capital costs for those options which have been quantitatively assessed is provided below in **Table 10.3**. Details of these costings are provided in **Appendix E**.

Table 10.3 Costs of Quantitatively Assessed Options

Option ID	Capital Cost Estimate	Recurrent Cost Estimate	Details
P3	$320,000	$0	House raising/rebuilding
P4	$1,200,000	$0	Voluntary purchase
P6	$2,000,000	$0	Council Redevelopment
FM1.2	$1,296,000	$5,000	Detention Basin Upstream of Railway Line - 1 site
FM2.3	$1,328,000	$5,000	Carleton Street and Awaba Road
FM3.1	$639,000	$5,000	Toronto Industrial Area - Levee
FM3.4	$1,166,000	$5,000	Adam St and Fennell Cres. (north of Mudd Creek)
FM4.2	$2,290,000	$5,000	Railway Parade - Mudd Creek Culvert Upgrade
FM4.6	$4,389,000	$10,000	Railway Parade - Stony Creek & Mudd Creek Upgrade
FM4.7	$1,001,000	$0	Railway Parade - Remove Downstream Railway Line and Crossings

An example of recurrent cost includes inspections and clearing of debris on an annual basis.

10.3 Average Annual Damage for Quantitatively Assessed Options

In a similar fashion to that discussed in **Section 6.3**, the total damage costs were evaluated for each of the options assessed by hydraulic modelling (quantitative assessment). The average annual damage (AAD) for each of the options is shown comparatively against the existing case ($247,000) in **Table 10.4**.

The results shown in **Table 10.4** indicate that the maximum reduction in average annual damage (AAD) is approximately $104,000 (compared with an existing case with an AAD of $247,000 (42%)). This reduction, for Option FM1.2 (detention basin upstream of railway) provides a significant decrease in damage value. Option FM4.6 (Railway Parade [Stony Creek & Mudd Creek Upgrade]) results in the next greatest reduction of AAD by $64,000 compared to the existing case.

Whilst the AAD is reduced to various degrees for different options, this reduction needs to be offset against the capital and recurrent costs of the option. This is described below.

10.4 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option.

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data reported in **Section 6** derived from a floor level and property survey along with damage curves derived for other, similar areas. The PMF, 200 year, 100 year, 50 year, 20 year, 10 year and 5 year ARI events were considered for this evaluation. Preliminary costs of each option were prepared (**Table 10.3)** and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 10.4: Average Annual Damage for Quantitatively Assessed Options

Option ID	Details	AAD	Reduction in AAD due to Option
P3	House raising/rebuilding	$239,000	$8,000
P4	Voluntary purchase	$231,000	$16,000
P6	Council Redevelopment	$231,000	$16,000
FM1.2	Detention Basin Upstream of Railway Line - 1 site	$143,000	$104,000
FM2.3	Carleton Street and Awaba Road	$243,000	$4,000
FM3.1	Toronto Industrial Area - Levee	$236,000	$11,000
FM3.4	Adam St and Fennell Cres. (north of Mudd Creek)	$211,000	$36,000
FM4.2	Railway Parade - Mudd Creek Culvert Upgrade	$207,000	$40,000
FM4.6	Railway Parade - Stony Creek & Mudd Creek Upgrade	$183,000	$64,000
FM4.7	Railway Parade - Remove Downstream Railway Line and Crossings	$211,000	$36,000

Table 10.5 summarises the overall economics for each option that was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

- Where the B/C is greater than 1 the economic benefits are greater than the cost of implementing the option.
- Where the B/C is less than 1 but greater than 0, there is still an economic benefit from implementing the option but the cost of implementing the option is greater than the economic benefit.

- Where the B/C is equal to zero, there is no economic benefit from implementing the option.
- Where the B/C is less than zero, there is a negative economic impact of implementing the option.

Table 10.5: Summary of Economic Assessment of Management Options

Option ID	AAD	Reduction in AAD due to Option	NPW of Benefit	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Option	B/C Ratio	Rank
P3	$239,000	$8,000	$99,000	$320,000	$0	$320,000	0.31	4
P4	$231,000	$16,000	$199,000	$1,200,000	$0	$1,200,000	0.17	9
P6	$231,000	$16,000	$399,000	$2,000,000	$0	$2,000,000	0.20	6
FM1.2	$143,000	$104,000	$1,290,000	$1,296,000	$5,000	$1,365,000	0.94	1
FM2.3	$243,000	$4,000	$52,000	$1,328,000	$5,000	$1,397,000	0.04	10
FM3.1	$236,000	$11,000	$131,000	$639,000	$5,000	$708,000	0.18	7
FM3.4	$211,000	$36,000	$444,000	$1,166,000	$5,000	$1,235,000	0.36	3
FM4.2	$207,000	$40,000	$497,000	$2,290,000	$5,000	$2,359,000	0.21	5
FM4.6	$183,000	$64,000	$795,000	$4,389,000	$10,000	$4,527,000	0.18	8
FM4.7	$211,000	$36,000	$449,000	$1,001,000	$0	$1,001,000	0.45	2

NPW – Net Present Worth is calculated using 7% interest over 30yrs.

The benefit-cost analysis shown in **Table 10.3** indicates that all the options have a benefit cost ratio less than 1. Thus they have varied levels of economic benefit and may provide other social and environmental benefits, which are accounted for in the multi-criteria matrix assessment in **Section 11**. Further, those options listed above that have a benefit-cost ratio less than 1, may have other limitations, such as minor flood level increases, environmental impacts and lack of community support.

10.5 Economic Assessment of Desktop Assessed Options

Given the overall benefits of those options where a desktop assessment was utilised (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. Instead, a judgement on the economic benefits of the options was made. This is described in **Section 9.3**.

11 Multi-Criteria Matrix Assessment

11.1 Overview

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the *Floodplain Development Manual* (2005). This approach to assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute "right" answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion as shown in **Table 11.1**.

11.2 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain outlined in **Section 4** as well as the community preferences outlined in **Section 3**. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion.

The criterion adopted includes:

Economic	Benefit Cost Ratio Capital and Operating Costs Reduction in Risk to Property
Social	Reduction in Social Disruption Reduction in Risk to Life Community Acceptance Council Support
Environmental	Meeting of River Flow and Water Quality Objectives Fauna/ Flora

The scoring system is shown in **Table 11.1** for the above criteria.

Table 11.1: Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio	2	0 to 0.5	0.5 to 1	1	1 to 1.5	>1.5
		Capital and Operating Costs	1	Extreme >$2 million	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Very Low $10,000 - $50,000
		Reduction in Risk to Property*	1	Major increase in AAD	Slight increase in AAD	No Improvement	Slight decrease in AAD	Major decrease in AAD
Social	1	Reduction in Risk to Life	1	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
		Council Attitude	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Community support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	1	Compatible with Water Quality and River Flow Objectives	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Fauna/Flora Impact	1	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit

*Values of likely AAD reduction assumed where actual assessment not undertaken

11.2.1 Economic Assessment Overview

The economic assessment involved an appreciation of:

- Benefit Cost Ratio;
- Capital and Operating Costs; and
- Reduction in Risk to Property.

Capital and operating costs for major structural options were assessed as described in **Section 10**, whilst a judgement of the likely capital and recurrent costs was made for the remaining options by experienced engineers.

It is noted that the Benefit Cost Ratio incorporates both the capital & operating costs, and the reduction in the Risk to Property. However, these are included to provide an overall measure of both the affordability of an option (the magnitude of the cost) as well as the overall benefit of the option. The Benefit Cost Ratio, while providing a representation of the economic efficiency of the option, does not provide this information.

11.2.2 Social Impact Assessment

The social impact assessment involved an appreciation, based on the information collated in **Section 4**, of:

- Reduction in Social Disruption;
- Reduction in Risk to Life;
- Council Attitude; and
- Community Support.

In general, there is a low level of flood awareness in the community. The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

The community support for a particular option was derived by converting the community responses received in the consultation period **(Appendix A)** discussed in **Section 3** into a numerical score.

The attitudes of Lake Macquarie City Council to different options were subjectively assessed based on discussions with representatives over the course of the study.

11.2.3 Environmental Assessment

The environmental impact assessment involved an appreciation, based on the information collated in **Section 4**, of both:

- Compatibility of the option with Water Quality and River Flow Objectives, and
- Fauna/flora impact.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system.

11.3 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix F**. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 11.1**. The overall score for the option is then calculated by the weights for each of the categories.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix F**.

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring shown in **Appendix F** is not “absolute” and the proposed scoring and weighting should be reviewed carefully as part of the process of finalising the overall Floodplain Risk Management Plan.

12 Floodplain Risk Management Plan

The implementation program developed from this Study is included in the Floodplain Risk Management Plan report.

13 Recommendations and Conclusions

This report presents the findings of the Floodplain Risk Management Study (**Sections 1 to 11**) for Stony Creek. The investigations and consultation undertaken as part of this process identified a number of issues for the floodplain. Based on these issues, a series of floodplain management measures were developed and have been recommended in the Floodplain Risk Management Plan (**Section 12**).

The assessment of management options provided in **Sections 8 to 11** facilitates the identification of the most beneficial options (in terms of hydraulics, economics, environmental and social issues). This assessment was based on a primarily technical review and consultation with the community working group. Further community and stakeholder feedback will be incorporated into the final report. This could lead to changes in the proposed options and their ranking.

Further public consultation is to be undertaken during the exhibition of this Study and Plan. Additional consultation and review will lead to the refinement of this Study and the final recommended floodplain risk management options for implementation.

14 Qualifications

This report has been prepared by Cardno Lawson Treloar for Lake Macquarie City Council and as such should not be used by a third party without approval.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts. Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The results of the study are based on the following assumptions / conditions:

- Legislation and planning policies are correct at the time of report issue but are subject to change,
- Cost estimates provided for options in this report are preliminary only and more detailed cost estimates should be prepared during the detailed design phase, and
- Data and modelling qualifications noted in the Stony Creek Flood Study (2005).

Study results should not be used for purposes other than those for which they were prepared.

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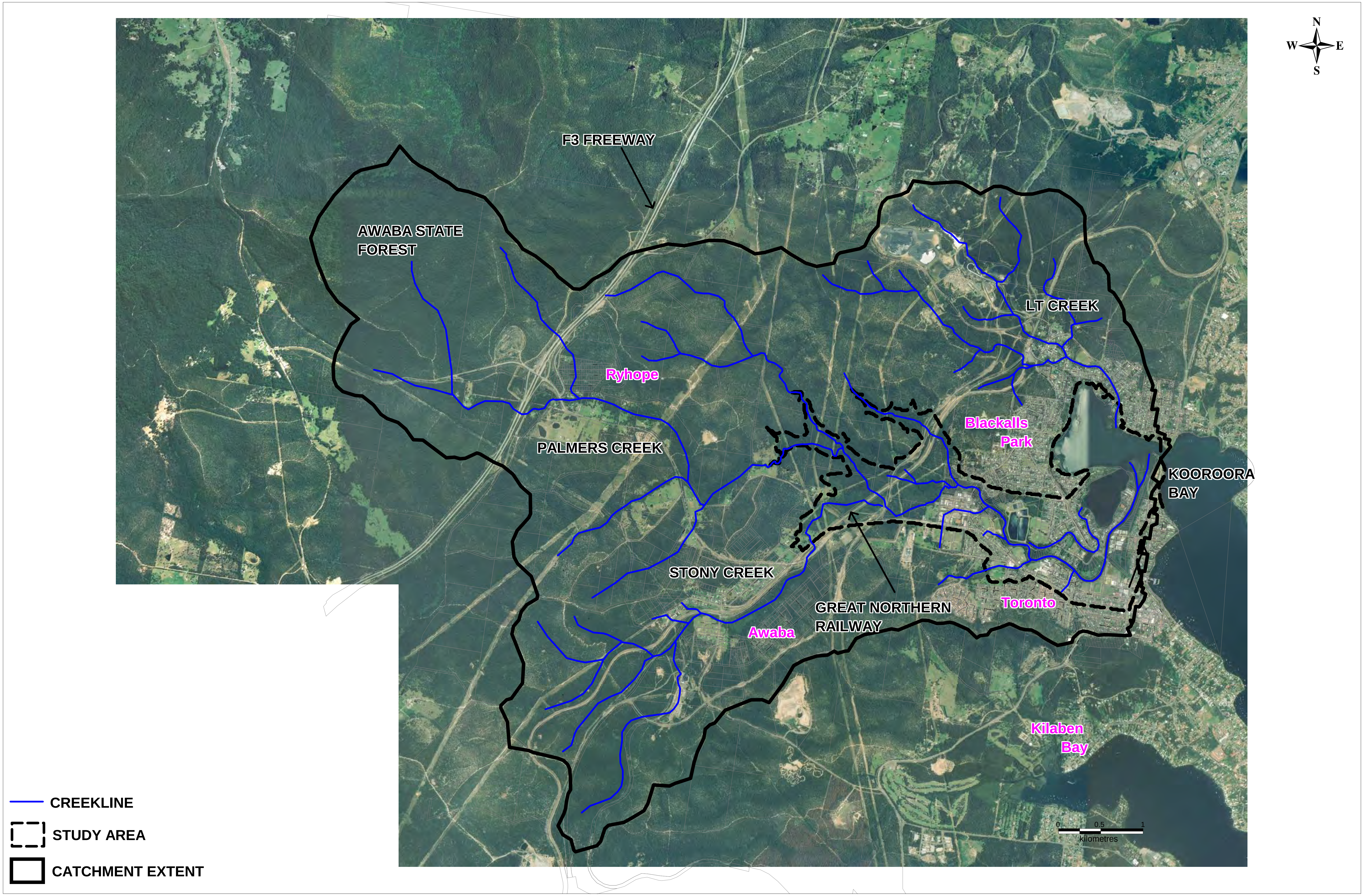
Figures



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J2597/V3
Dec 2011

FIGURE 1.1
LOCATION MAP

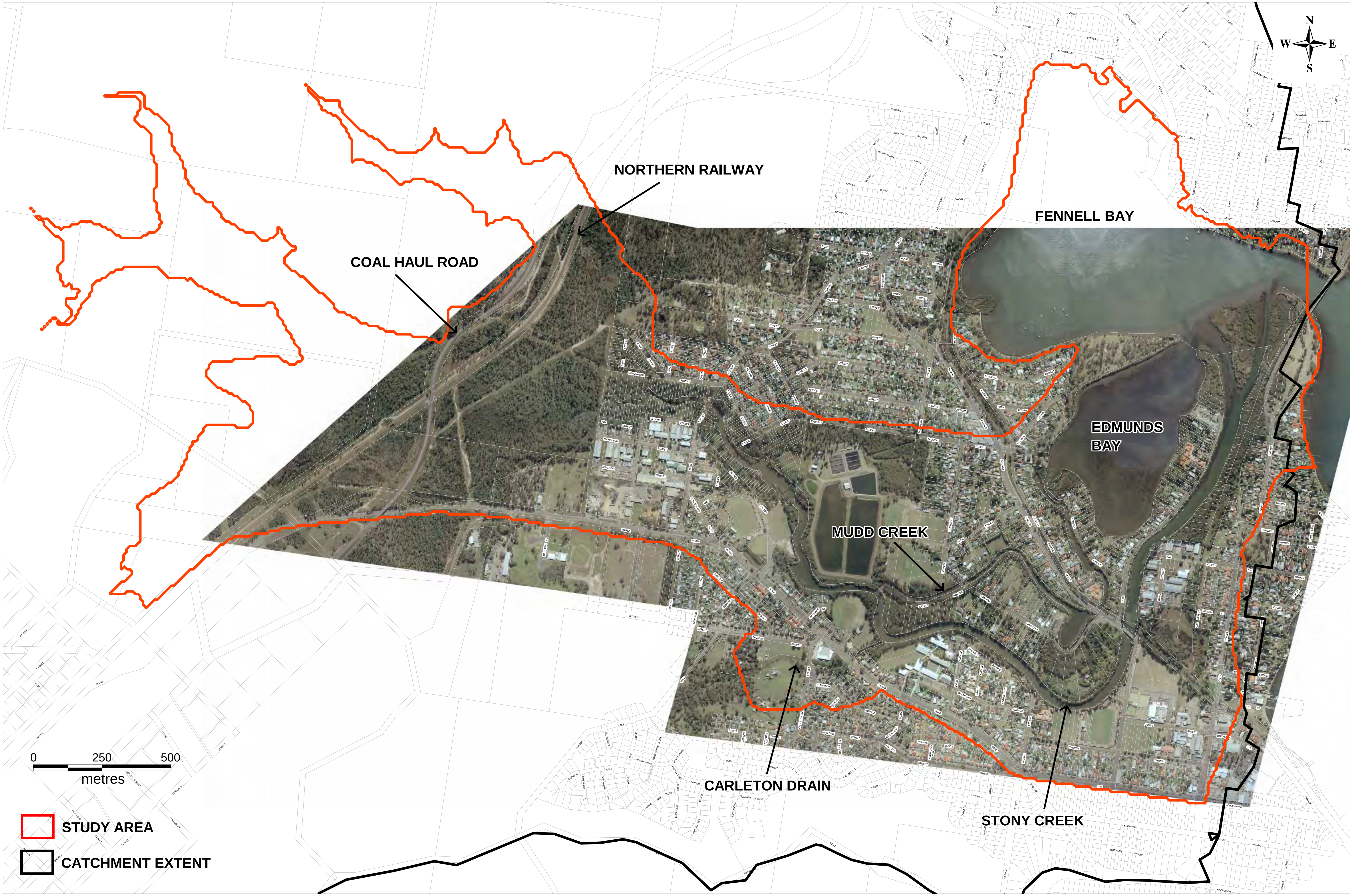

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FIGURE 1.2
STUDY AREA

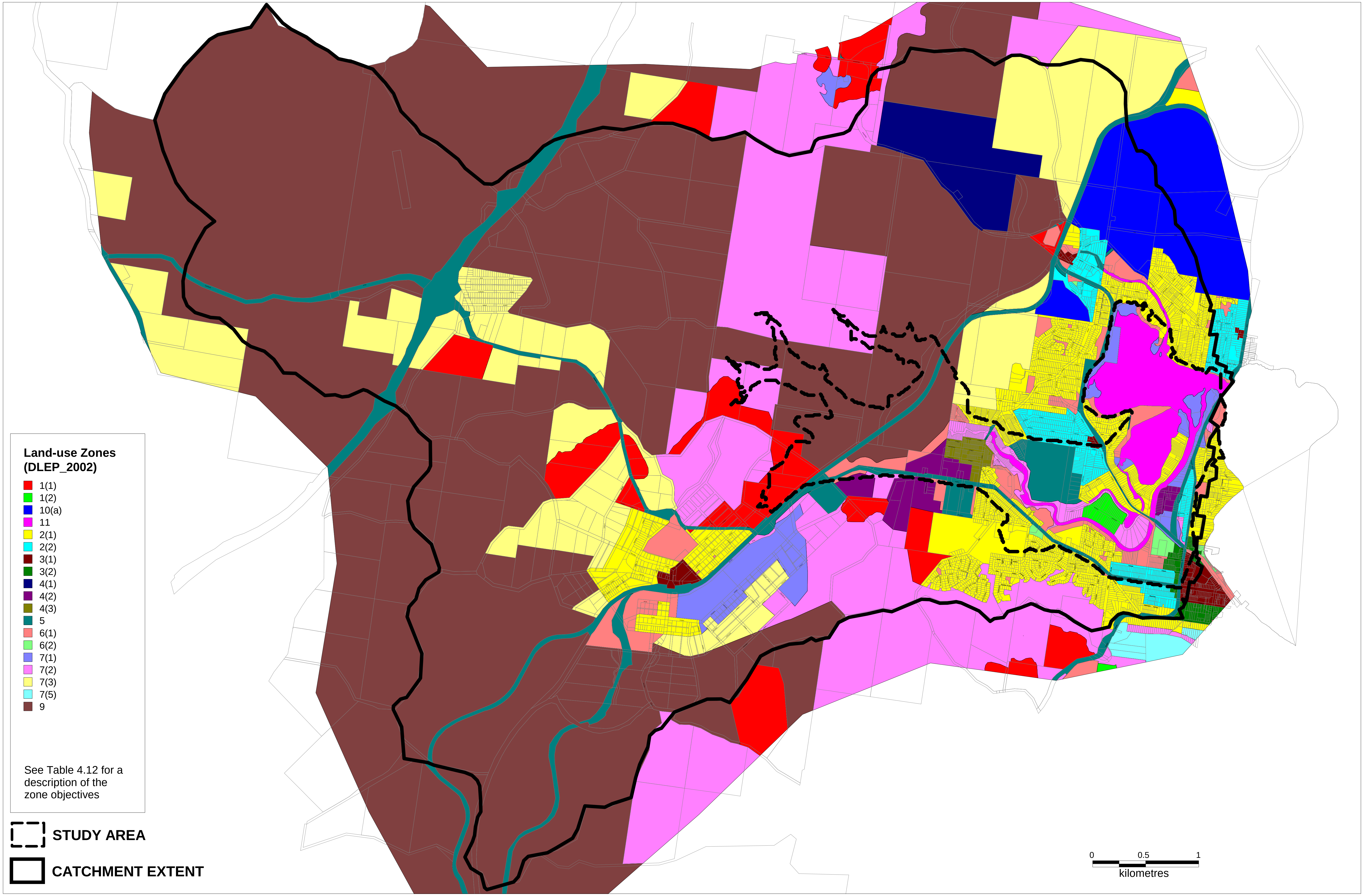

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FIGURE 4.1
LAND-USE ZONES

J2597/V3
Dec 2011

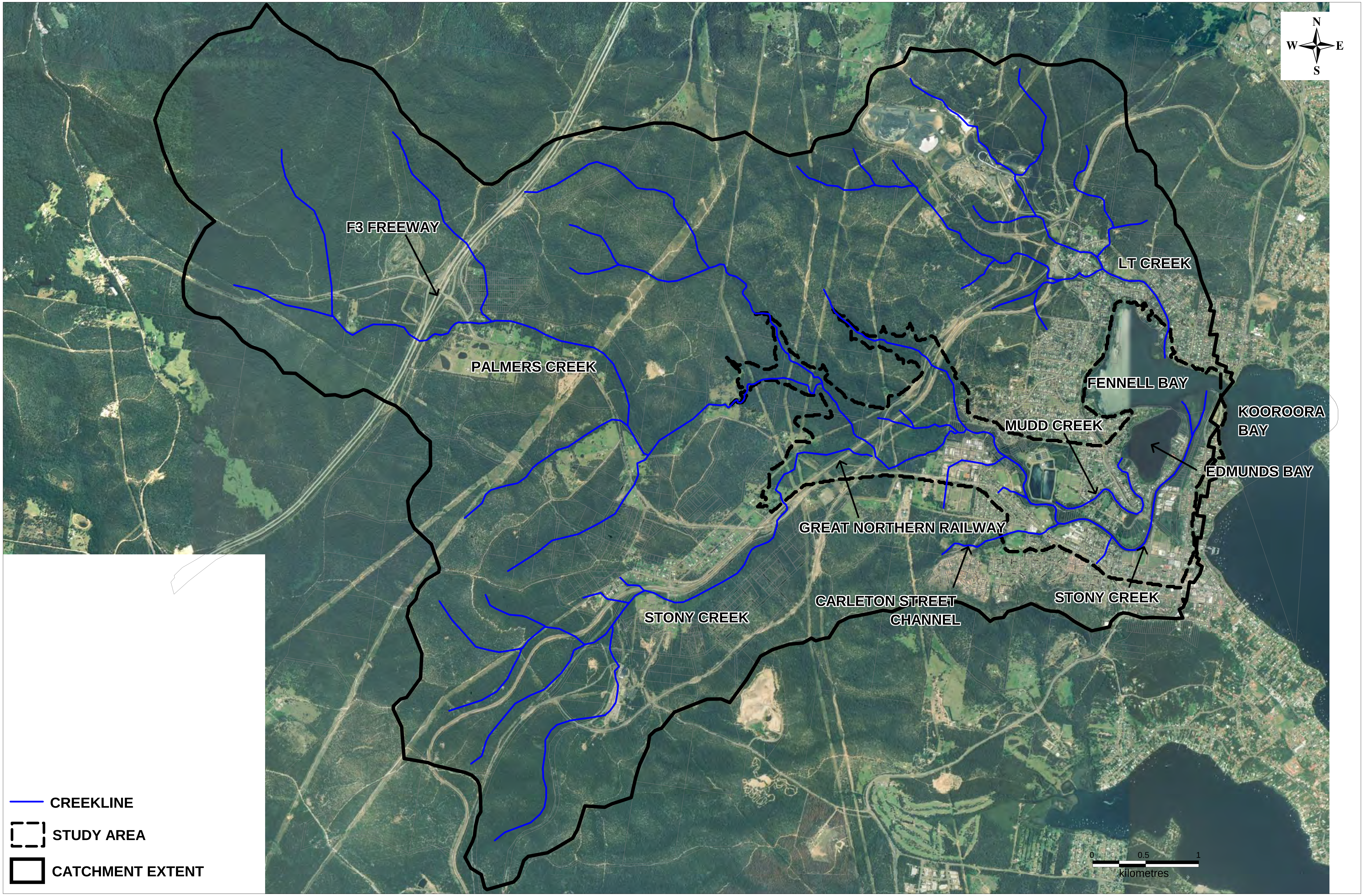

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FIGURE 4.2
STONY CREEK CATCHMENT

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FIGURE 4.3
DOWNSTREAM STONY CREEK STUDY AREA

J2597/V3
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Stony Creek Floodplain Risk Management Study

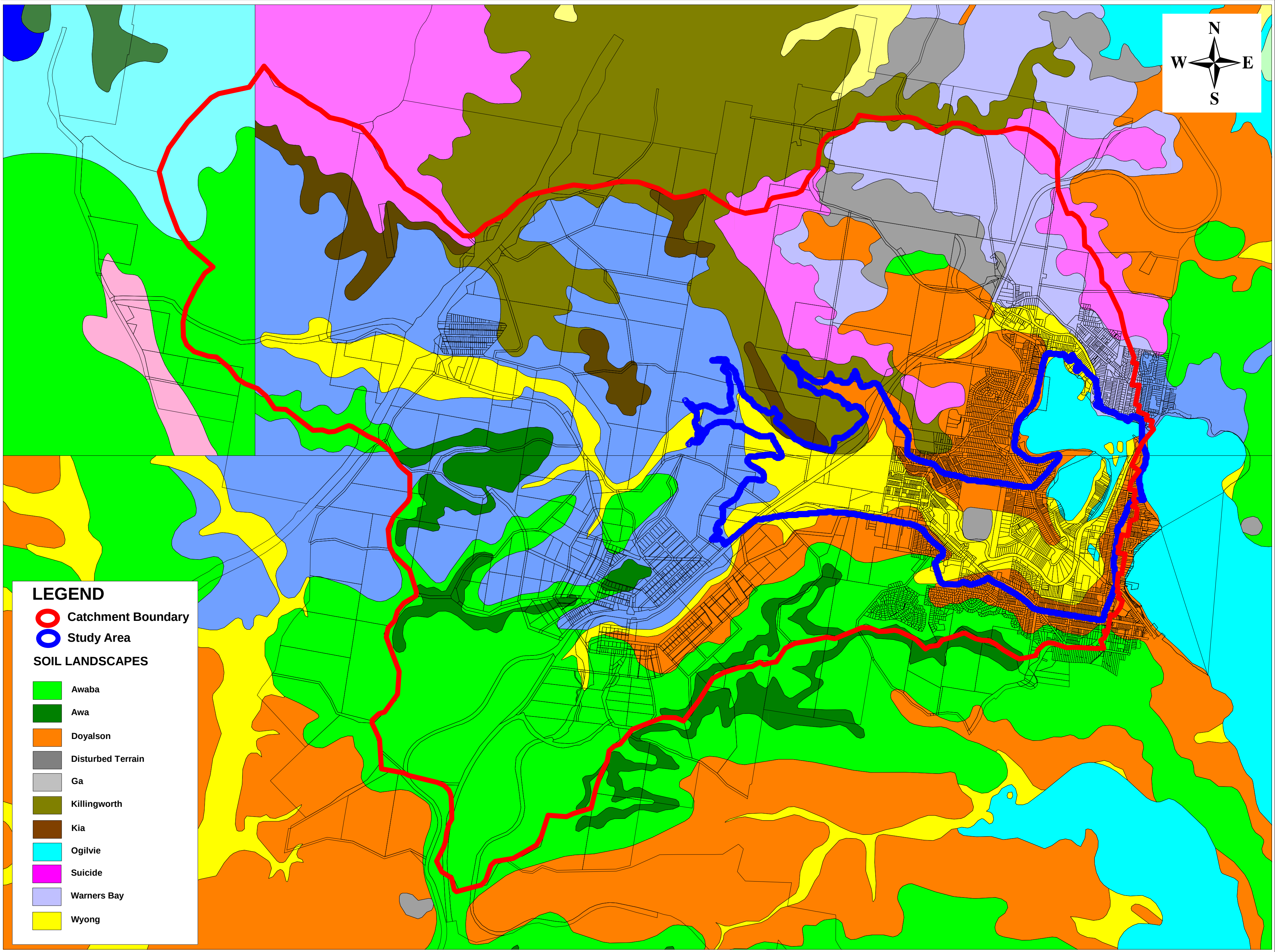

FIGURE 4.4
SOIL LANDSCAPES

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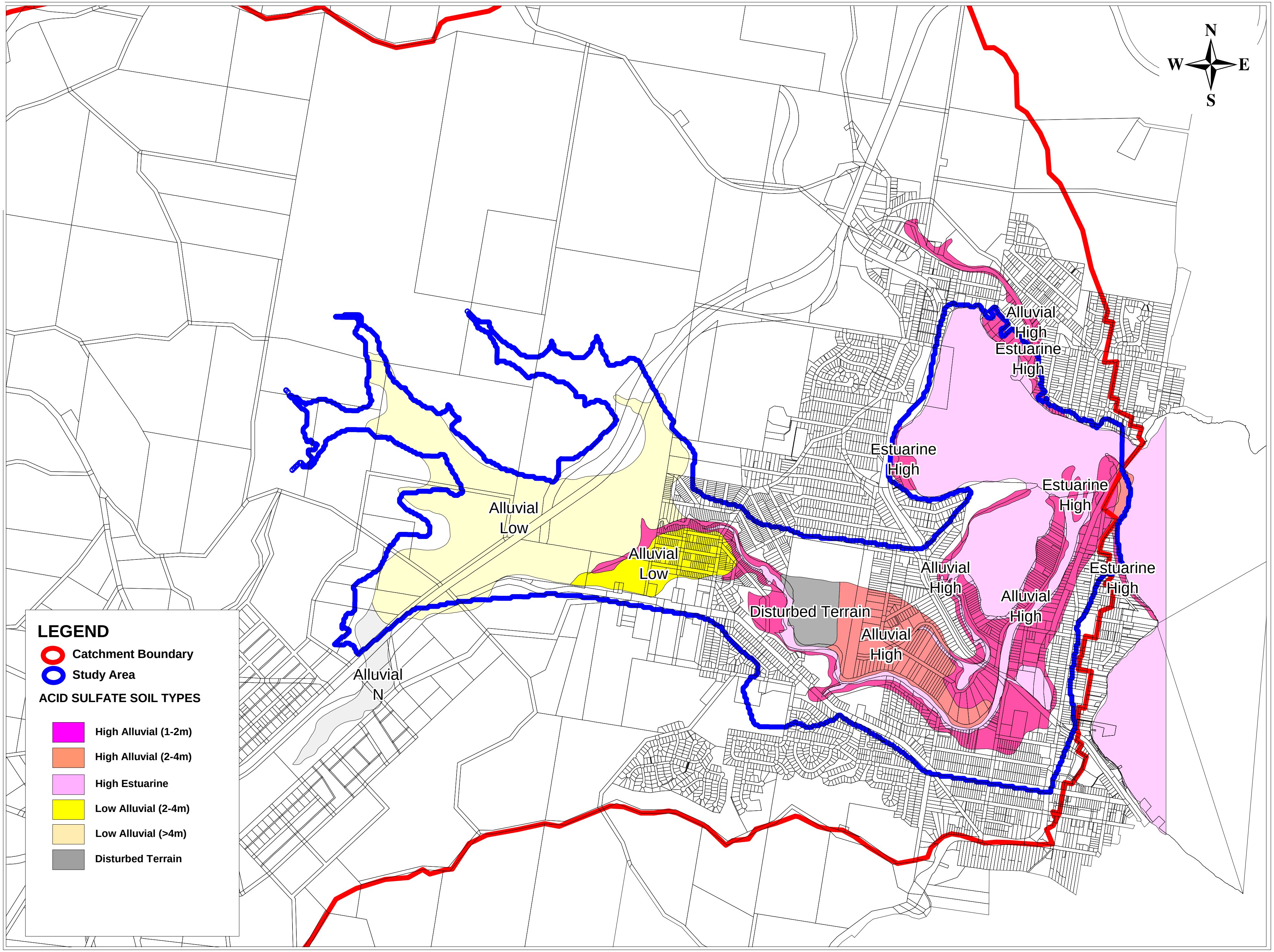
FIGURE 4.5
ACID SULFATE SOILS



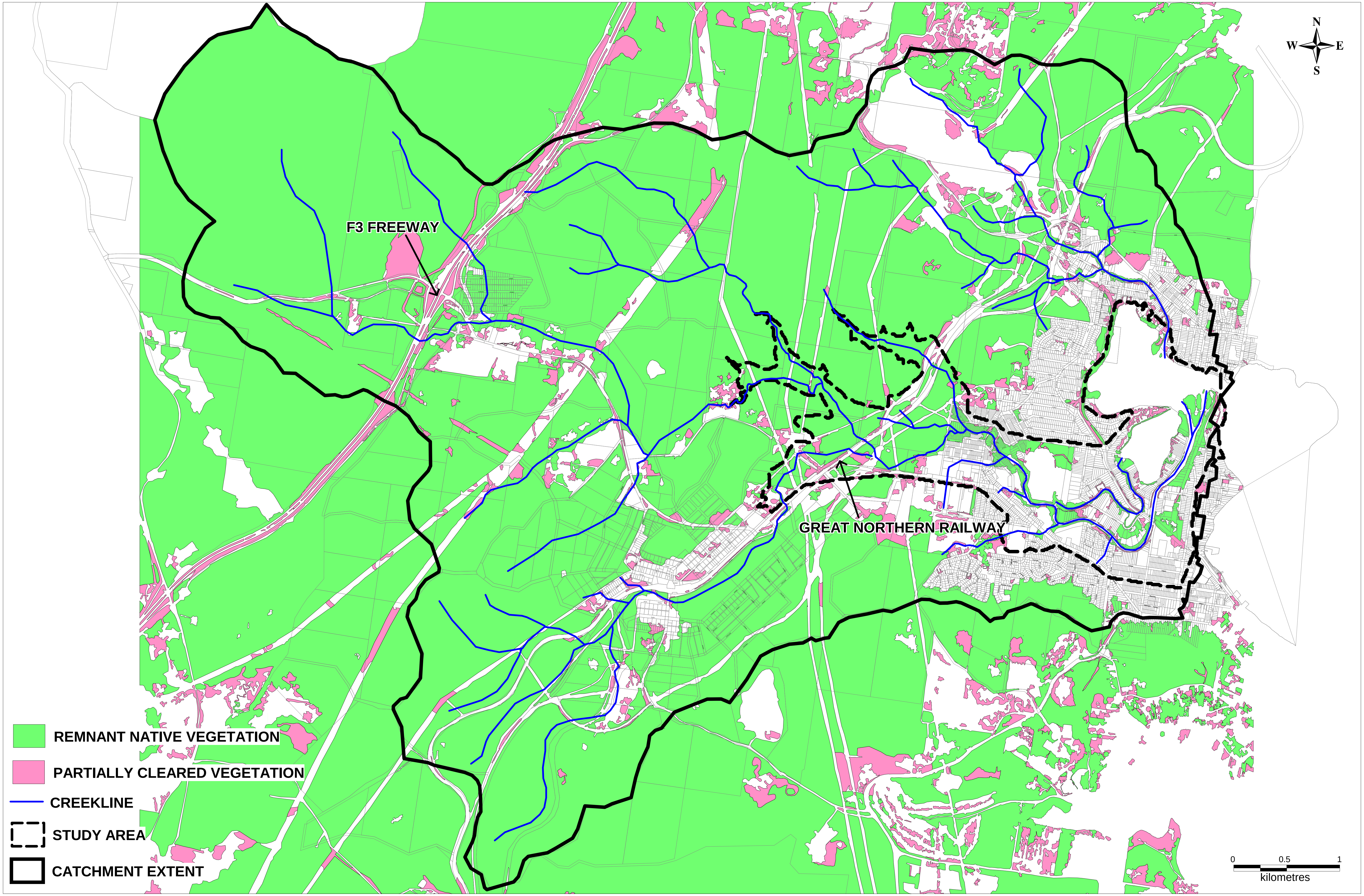


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FIGURE 4.6
STONY CREEK CATCHMENT - VEGETATION

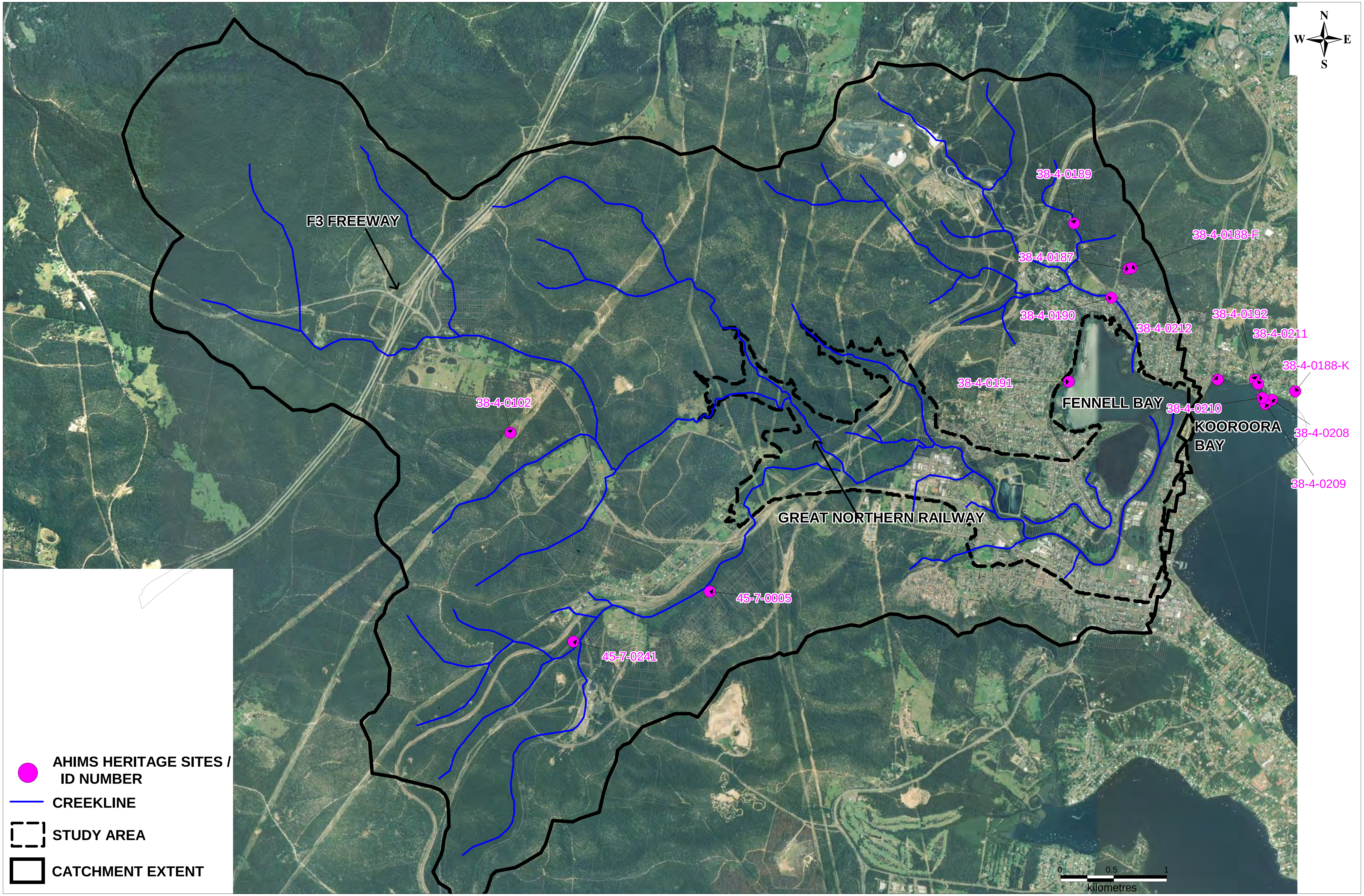

FIGURE 4.7
STONY CREEK CATCHMENT - A.H.I.M.S. HERITAGE SITES

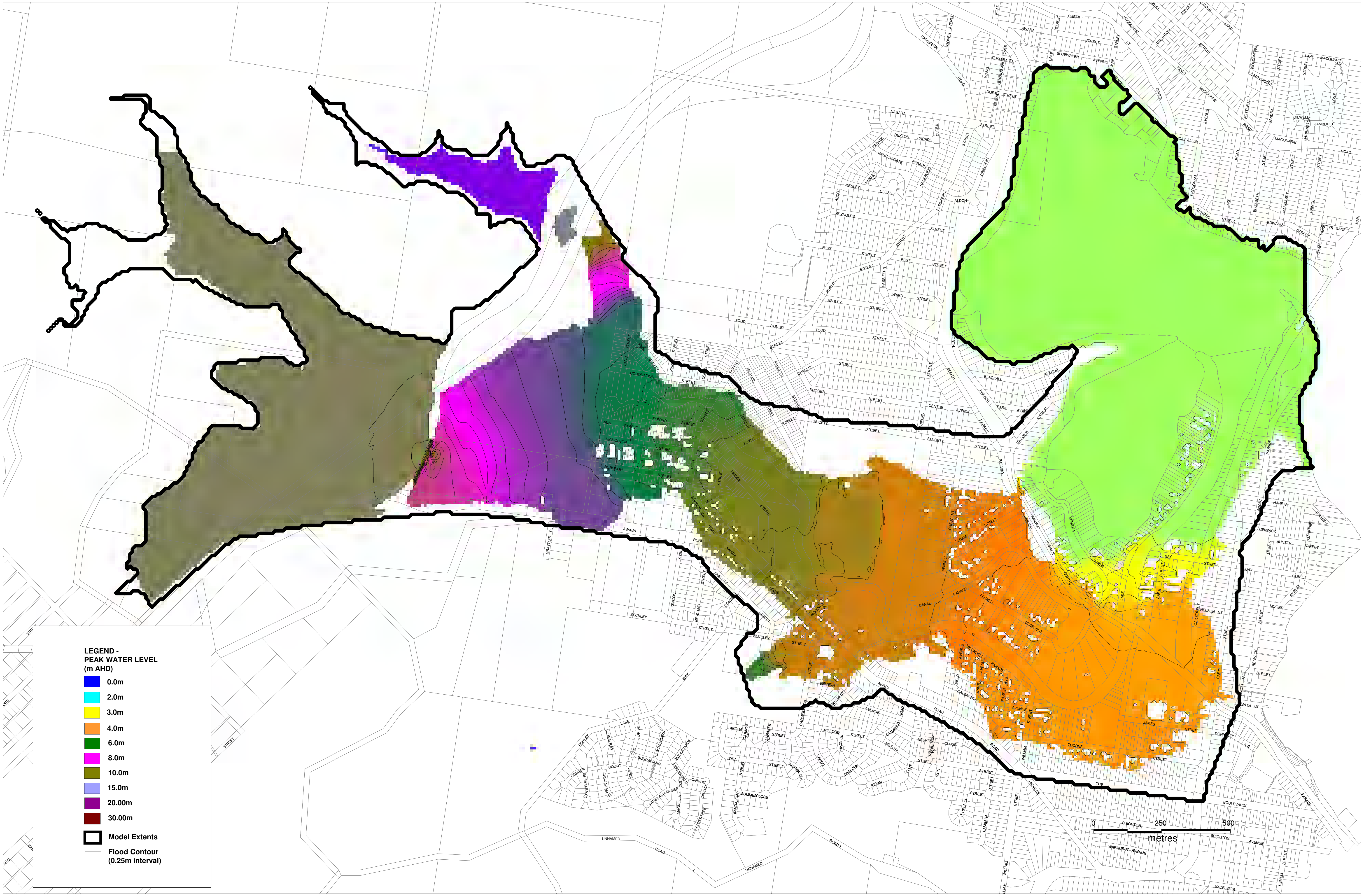

FIGURE 5.1
PMF PEAK WATER LEVEL

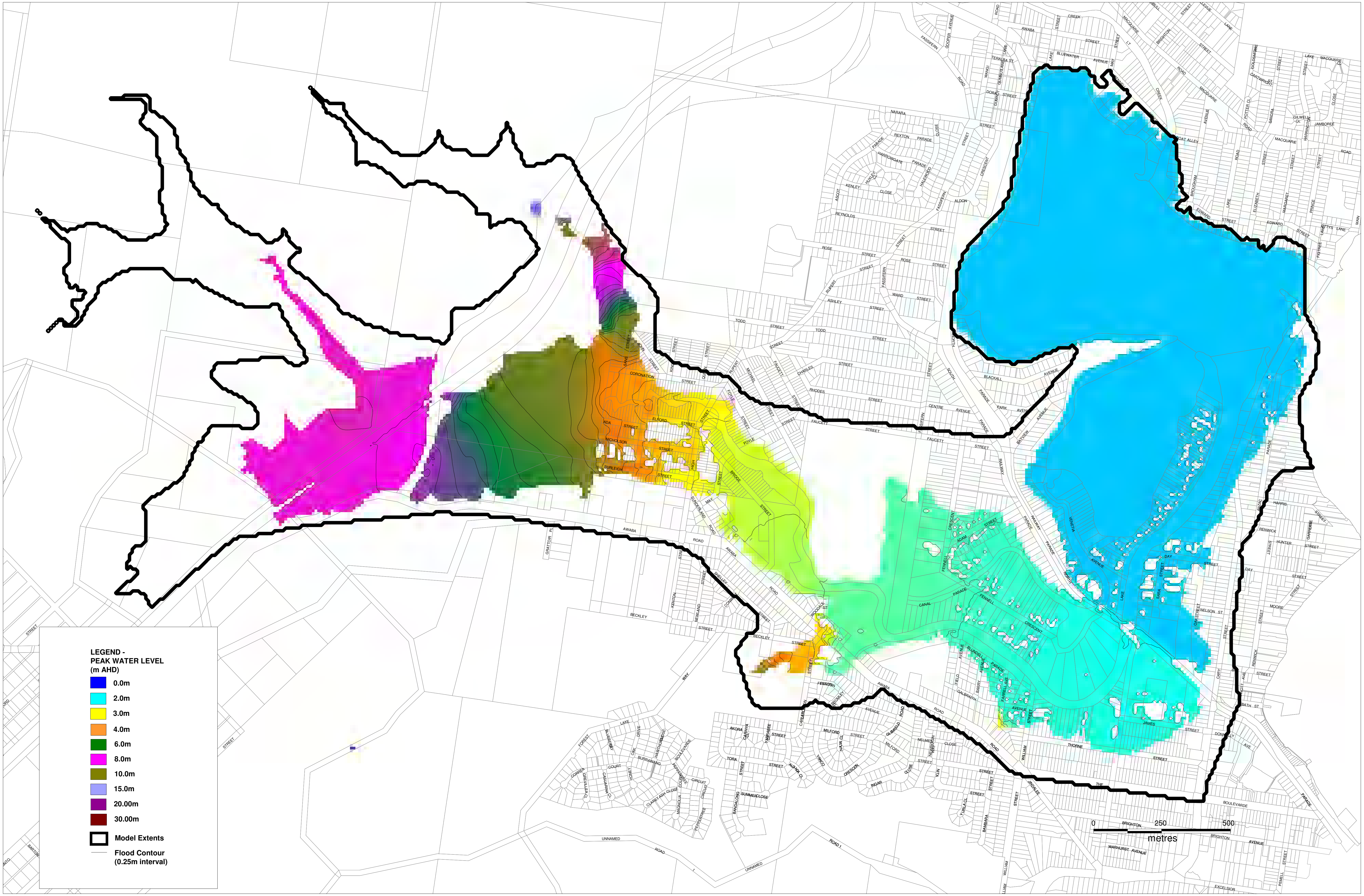

FIGURE 5.2
200 YEAR ARI PEAK WATER LEVEL

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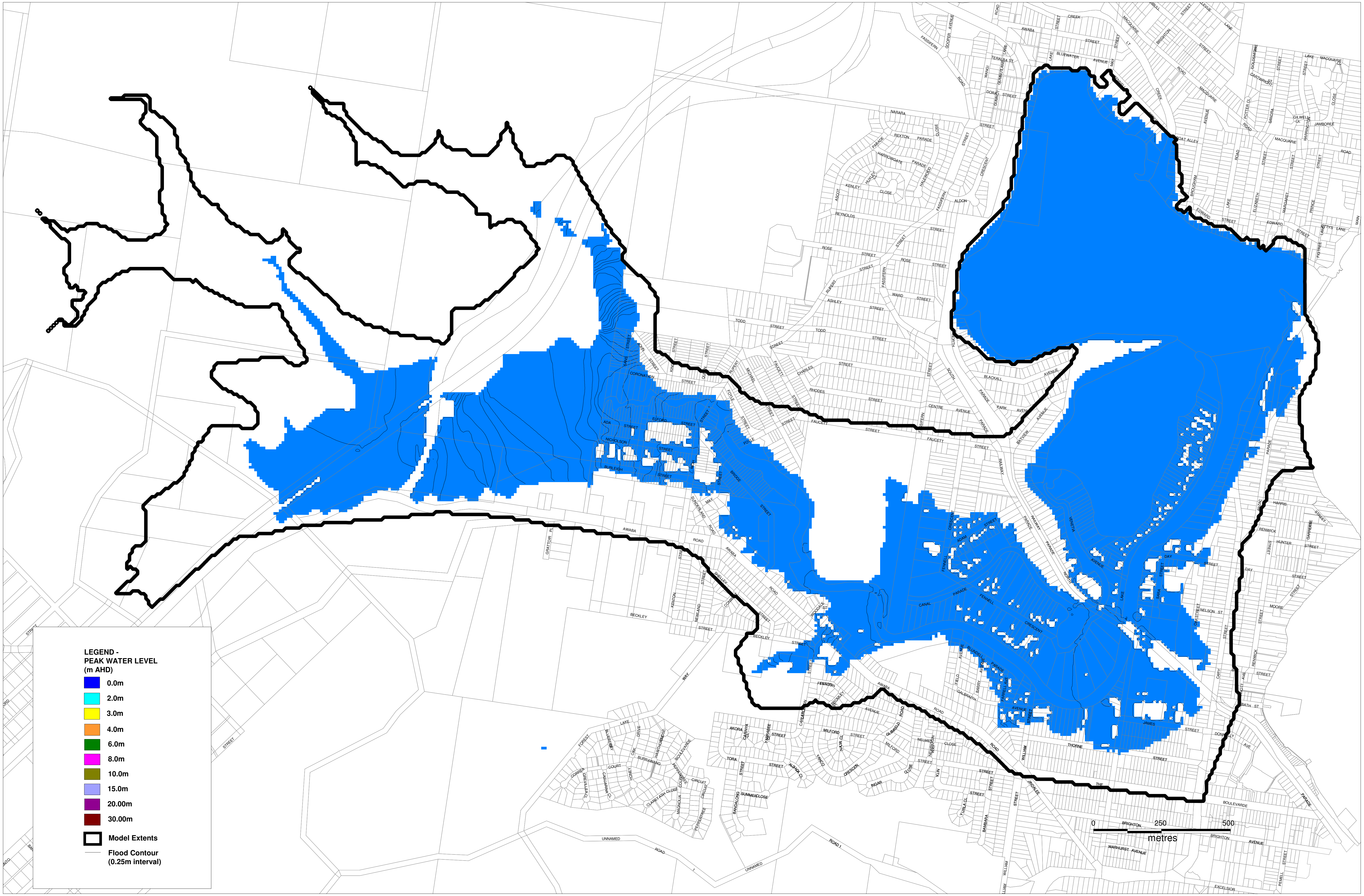

FIGURE 5.3
100 YEAR ARI PEAK WATER LEVEL

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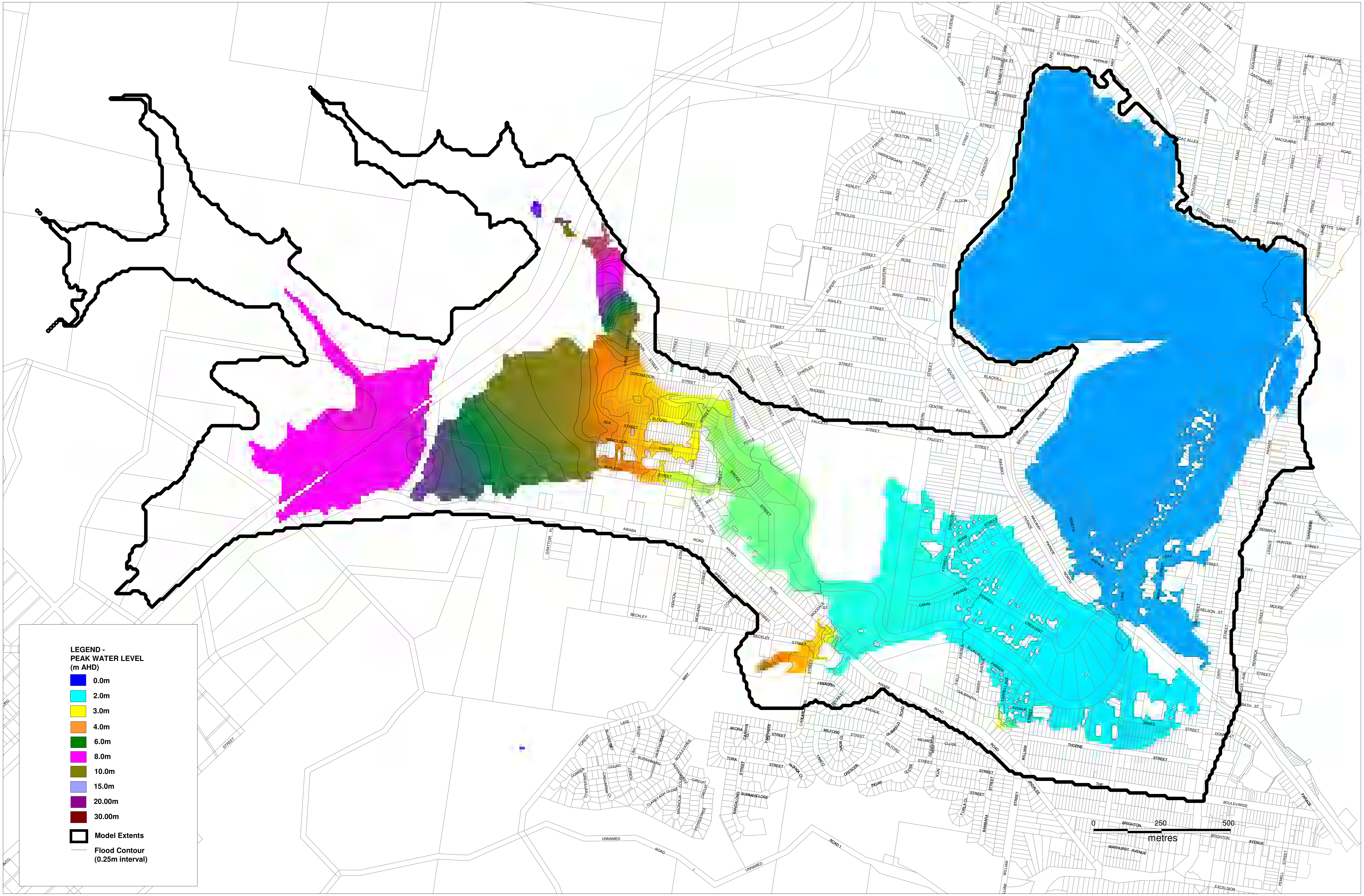

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FIGURE 5.4
50 YEAR ARI PEAK WATER LEVEL

Stony Creek Floodplain Risk Management Study

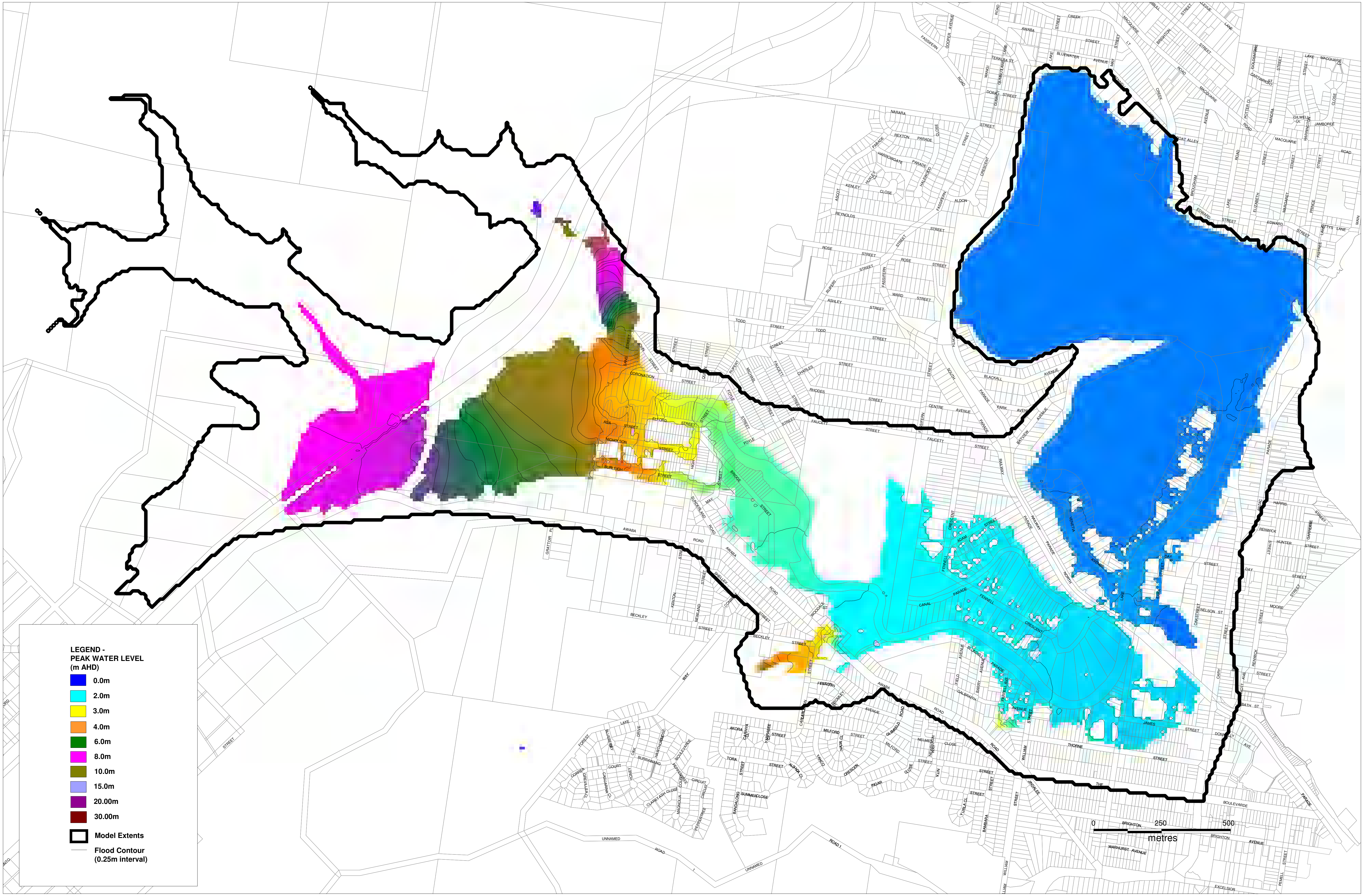

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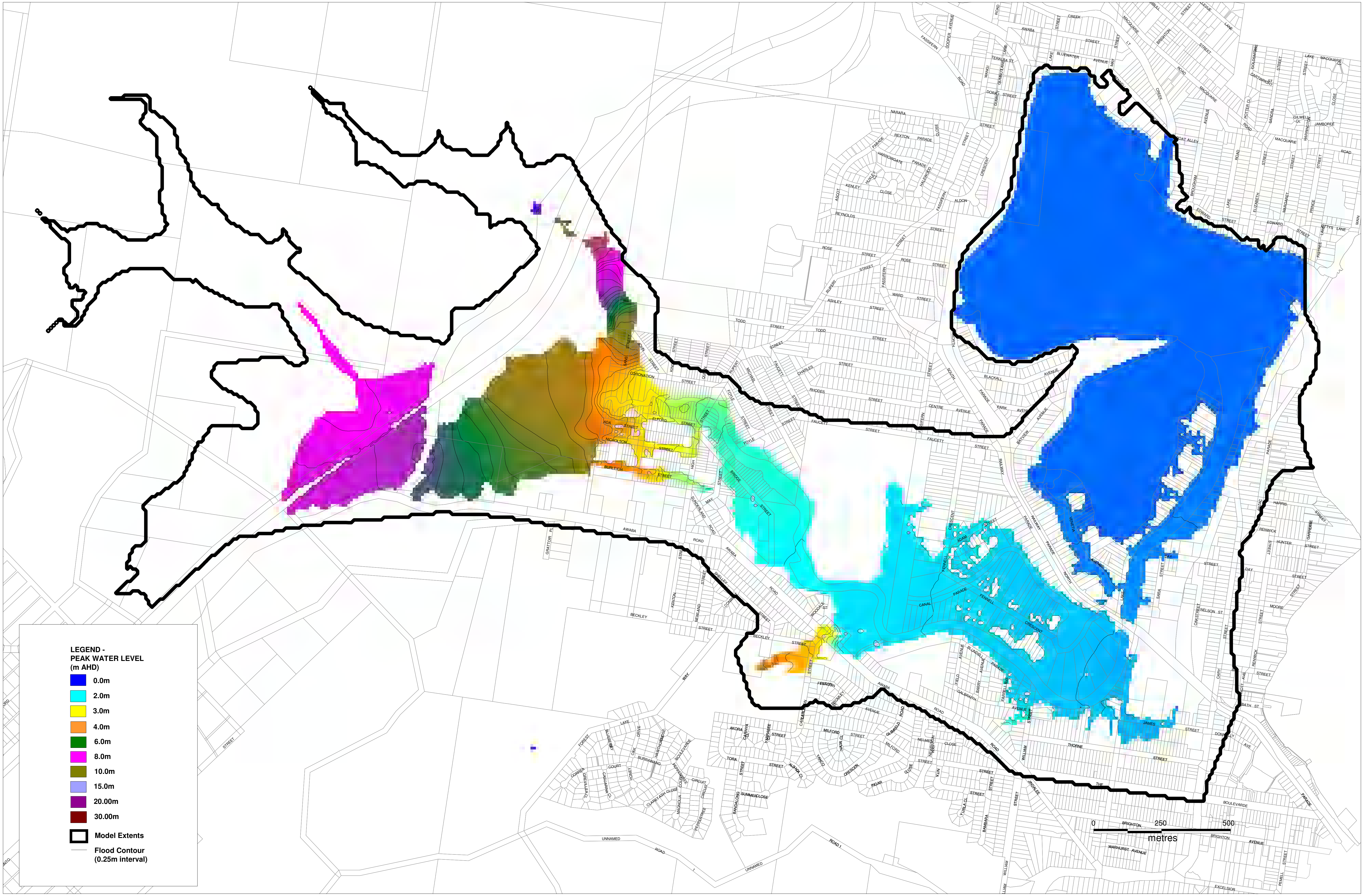
FIGURE 5.5
20 YEAR ARI PEAK WATER LEVEL



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Stony Creek Floodplain Risk Management Study

FIGURE 5.6
10 YEAR ARI PEAK WATER LEVEL

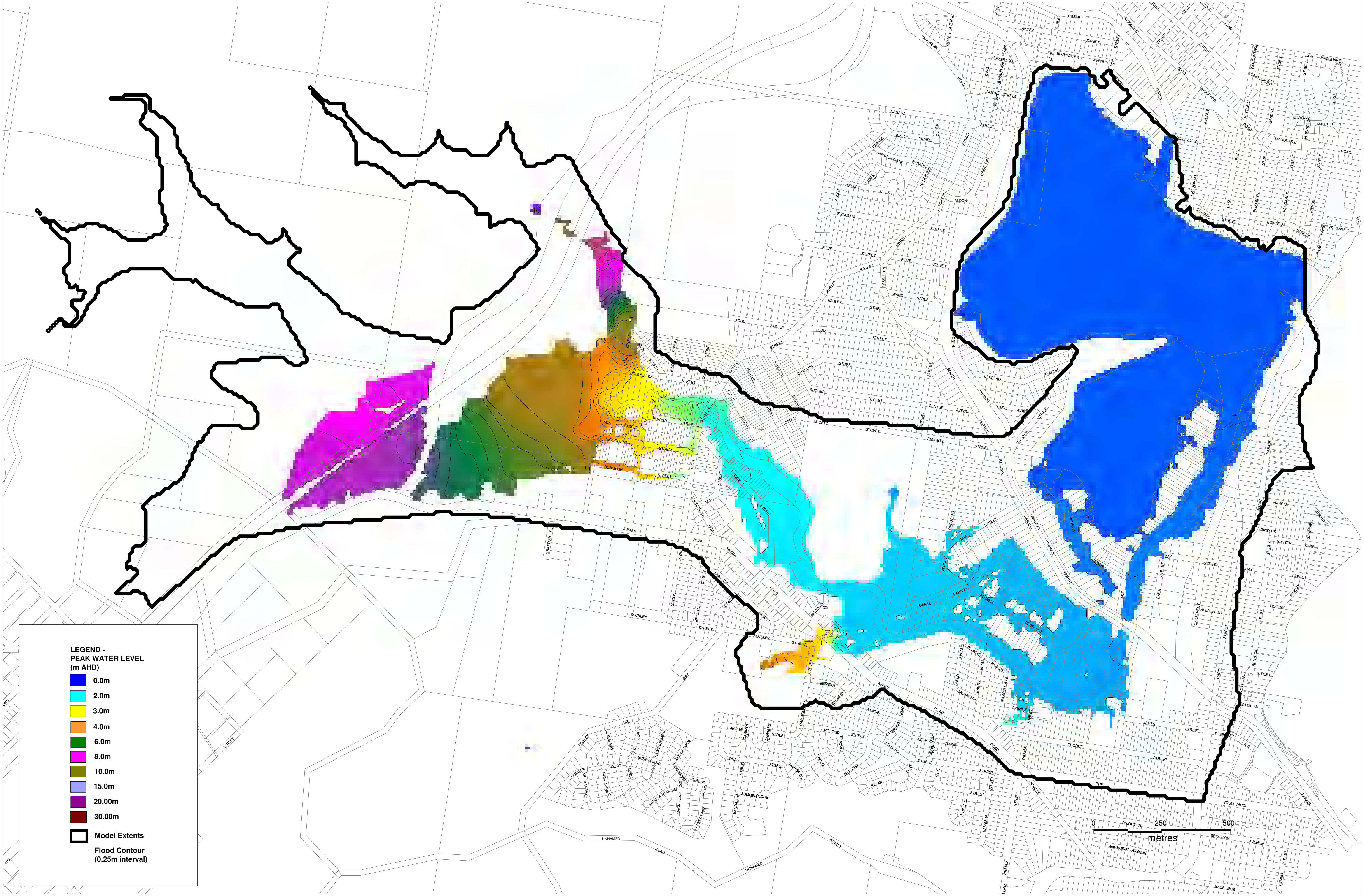

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FIGURE 5.7
5 YEAR ARI PEAK WATER LEVEL

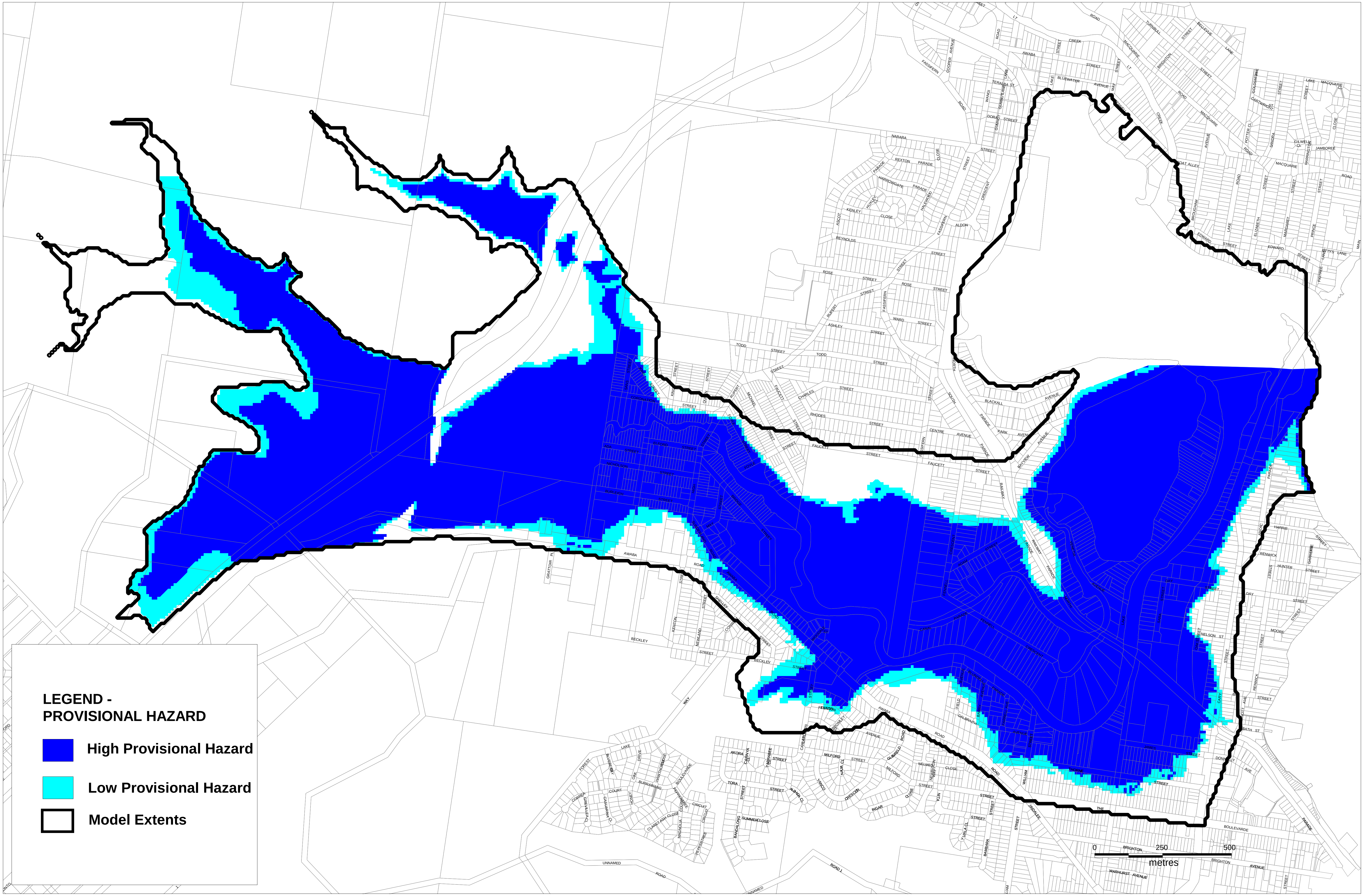

FIGURE 5.8
PMF PROVISIONAL FLOOD HAZARD

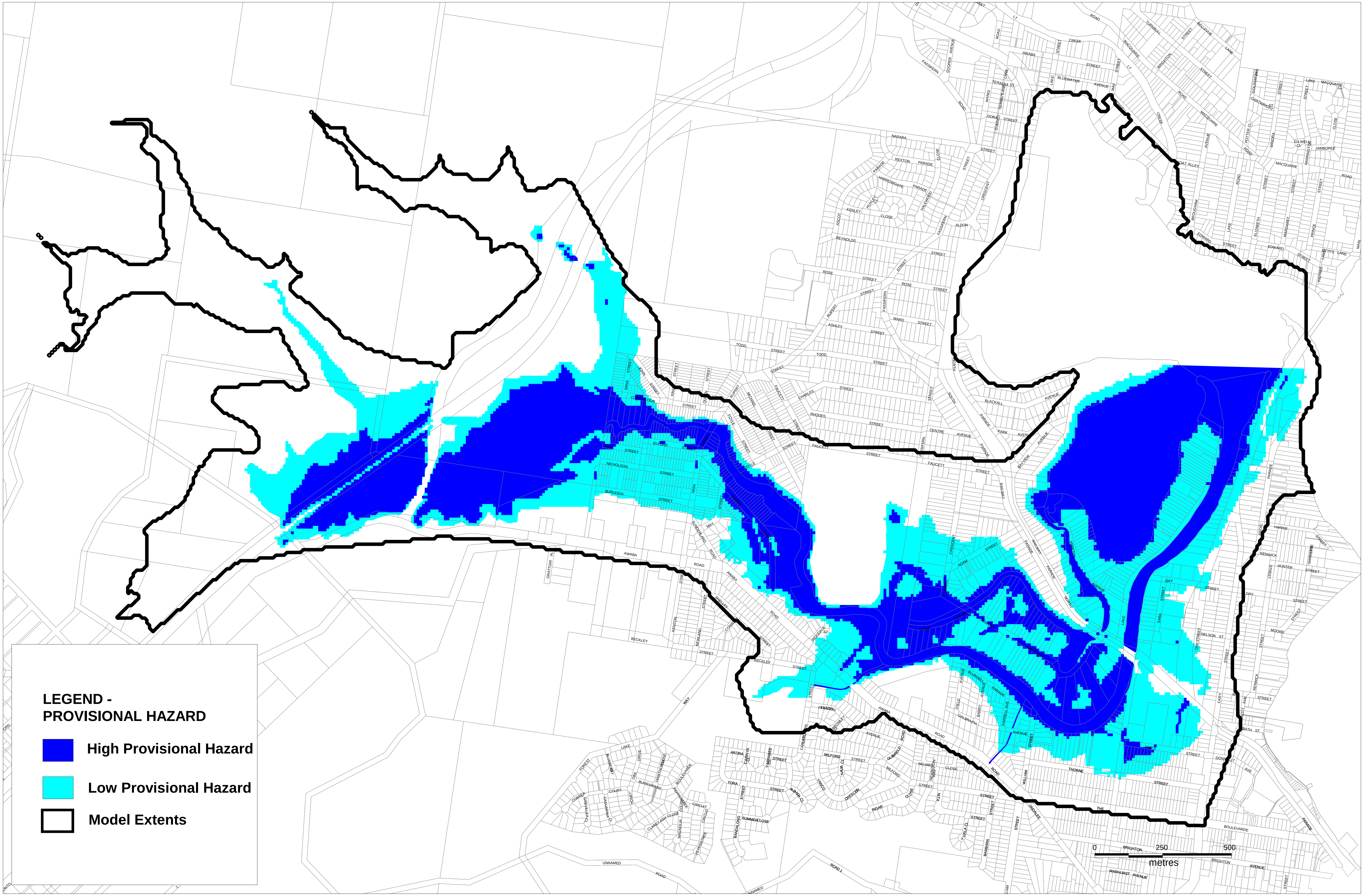

FIGURE 5.9
100y ARI PROVISIONAL FLOOD HAZARD

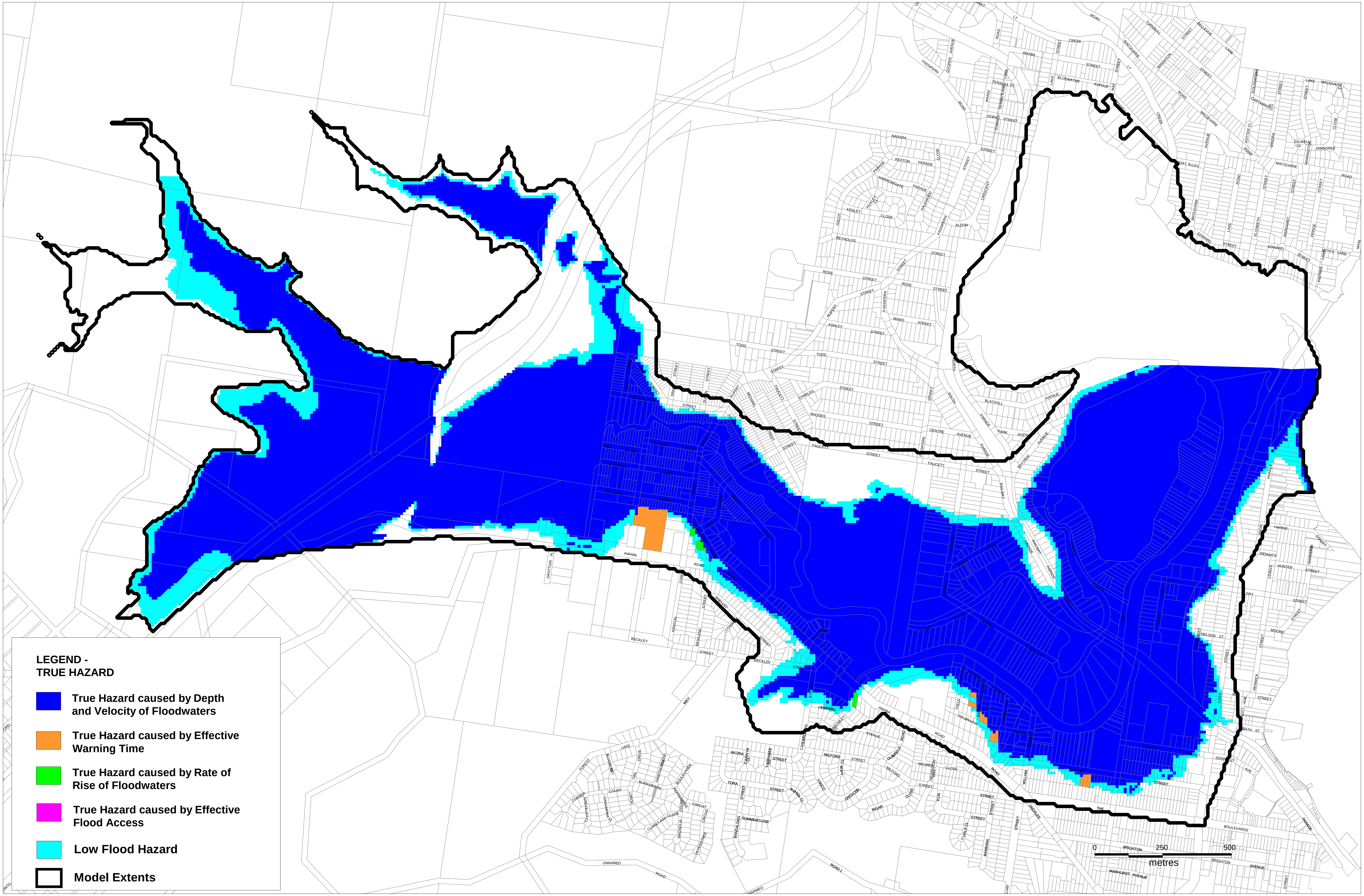

FIGURE 5.10
PMF TRUE FLOOD HAZARD

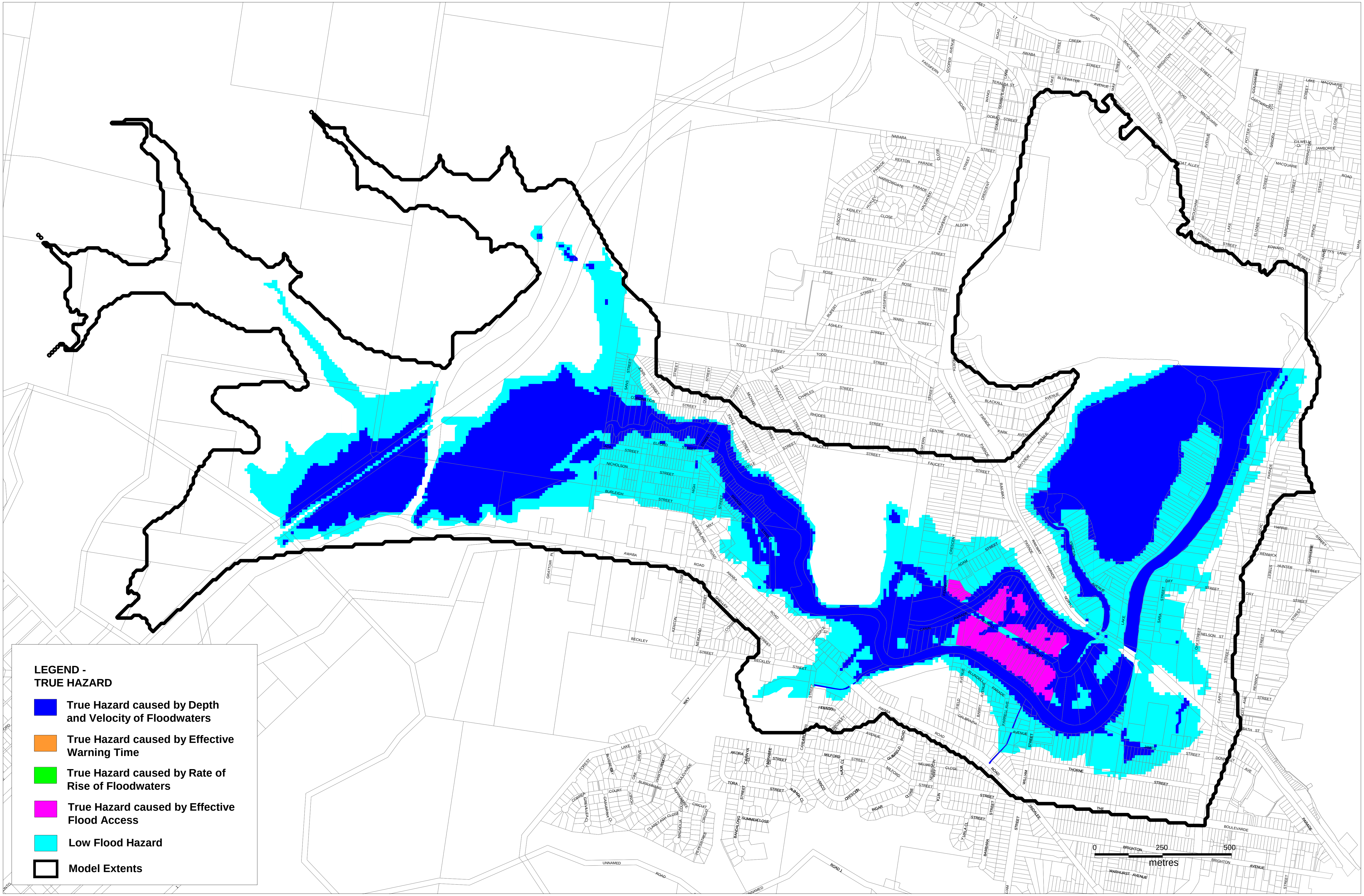

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FIGURE 5.11
100y ARI TRUE FLOOD HAZARD

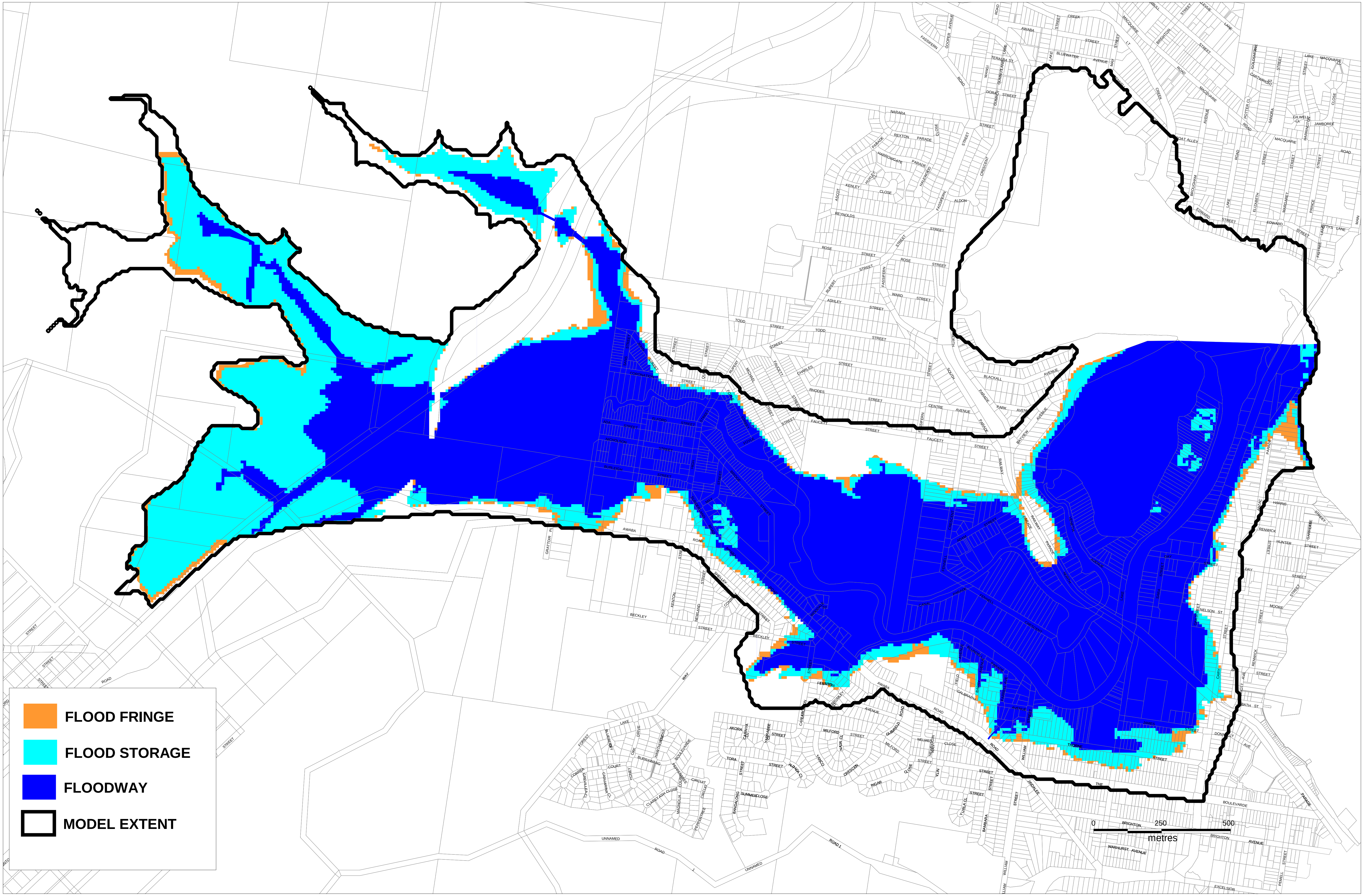

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FIGURE 5.12
PMF HYDRAULIC CATEGORIES

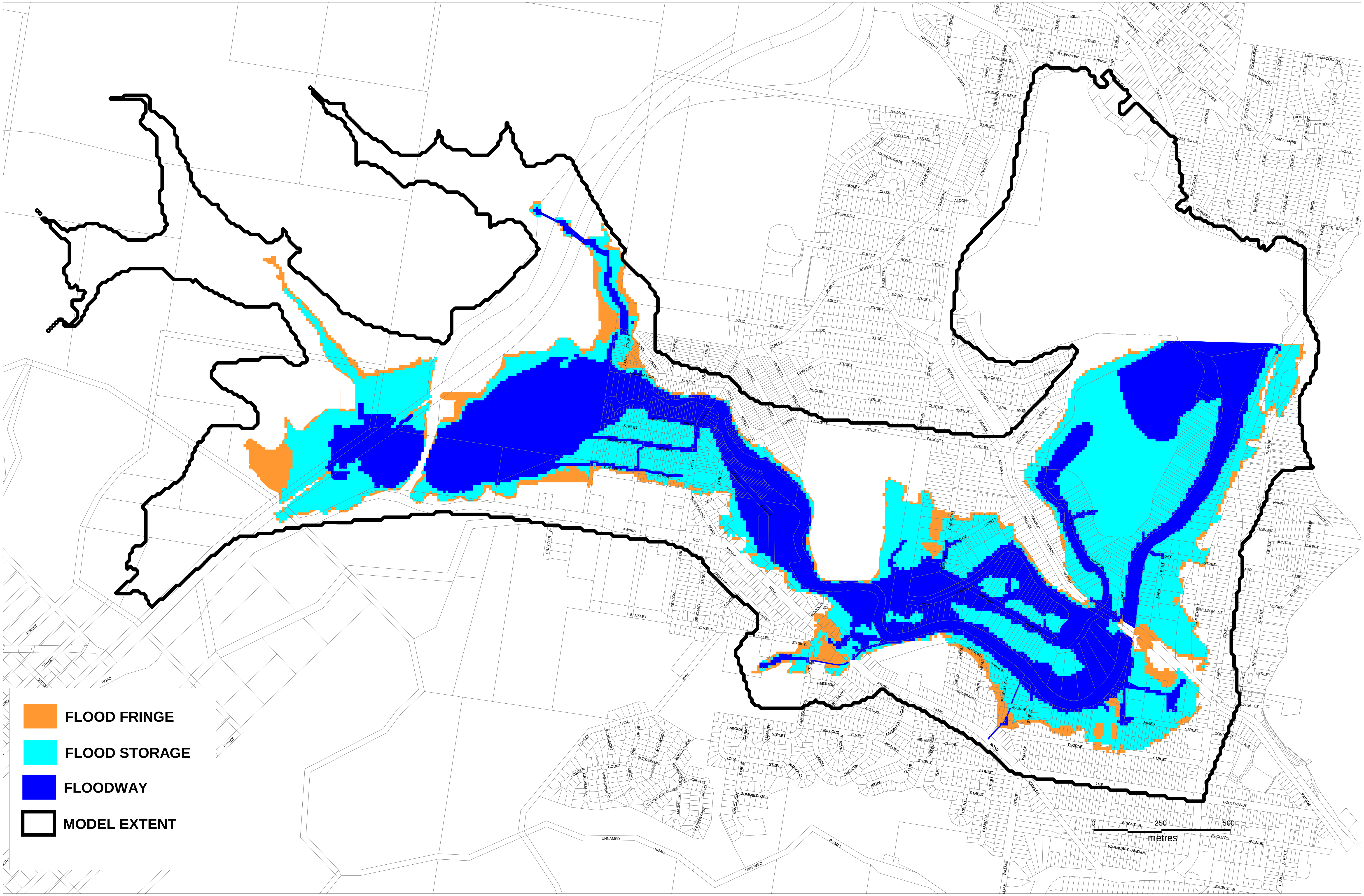

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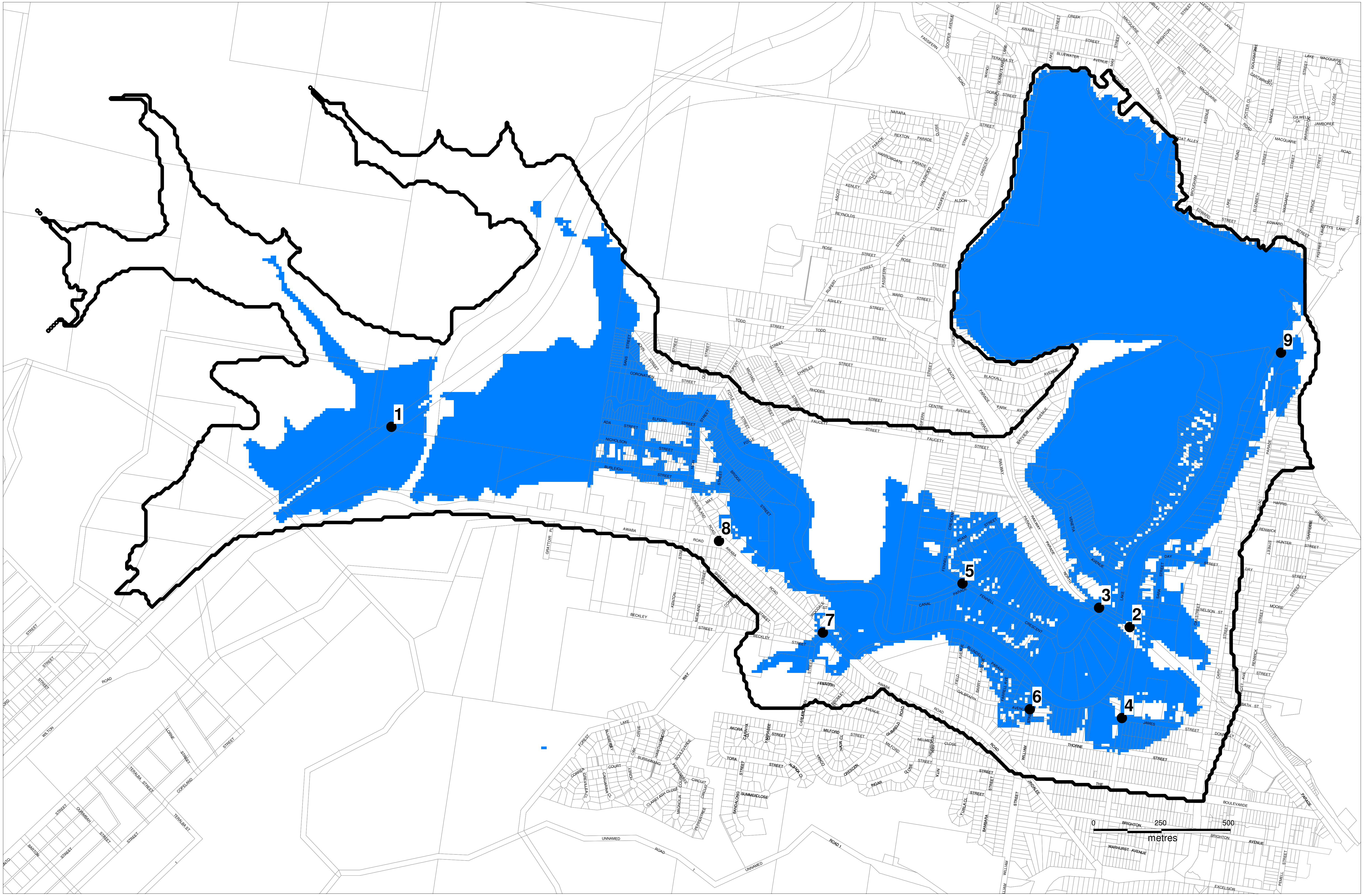
FIGURE 5.13
100 YEAR ARI HYDRAULIC CATEGORIES



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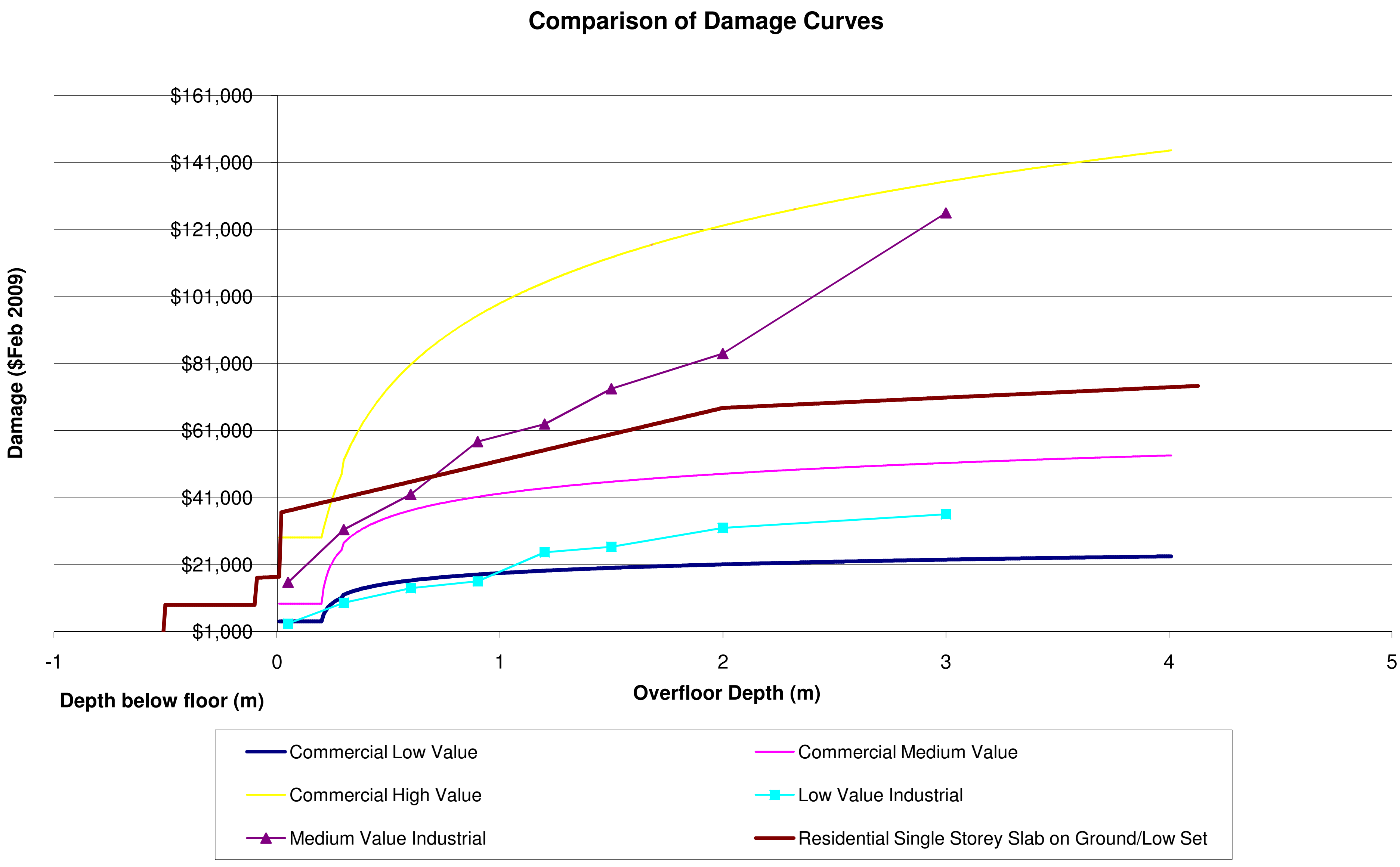
Stony Creek Floodplain Risk Management Study

FIGURE 5.14
MAJOR ACCESS ROAD FLOODING LOCATIONS
100 YEAR ARI FLOOD EXTENT


Comparison of Damage Curves
Damage ($Feb 2009)
$161,000
$141,000
$121,000
$101,000
$81,000
$61,000
$41,000
$21,000
$1,000
-1
0
1
2
3
4
5
Depth below floor (m)
Overfloor Depth (m)
Commercial Low Value
Commercial Medium Value
Commercial High Value
Low Value Industrial
Medium Value Industrial
Residential Single Storey Slab on Ground/Low Set

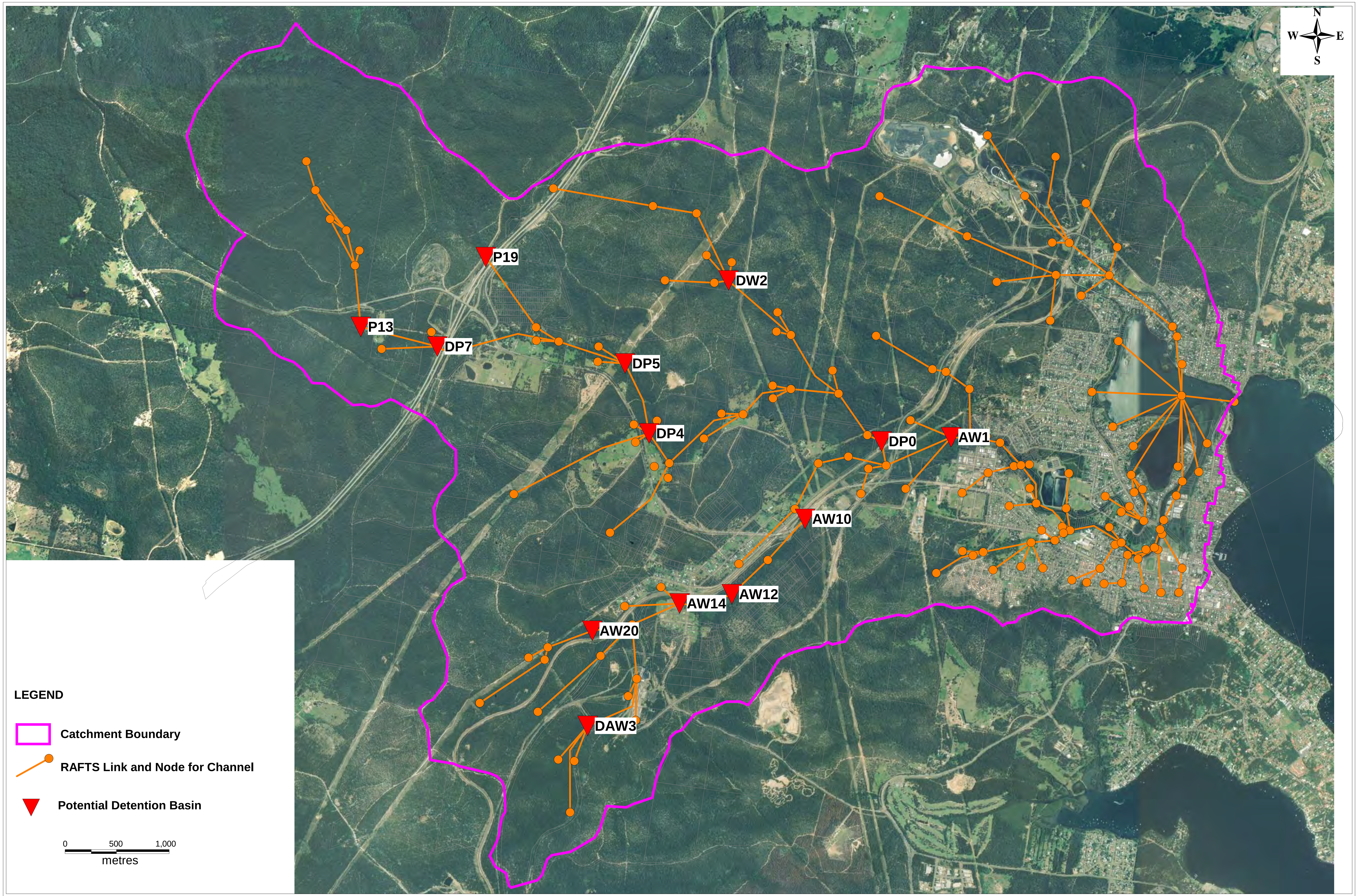


FIGURE 9.1
MITIGATION OPTIONS - DETENTION BASIN SITES

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FIGURE 9.4
MITIGATION OPTIONS -
CARLETON DRAIN

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FIGURE 9.6
MITIGATION OPTION FM3.1
LEVEE INDUSTRIAL AREA

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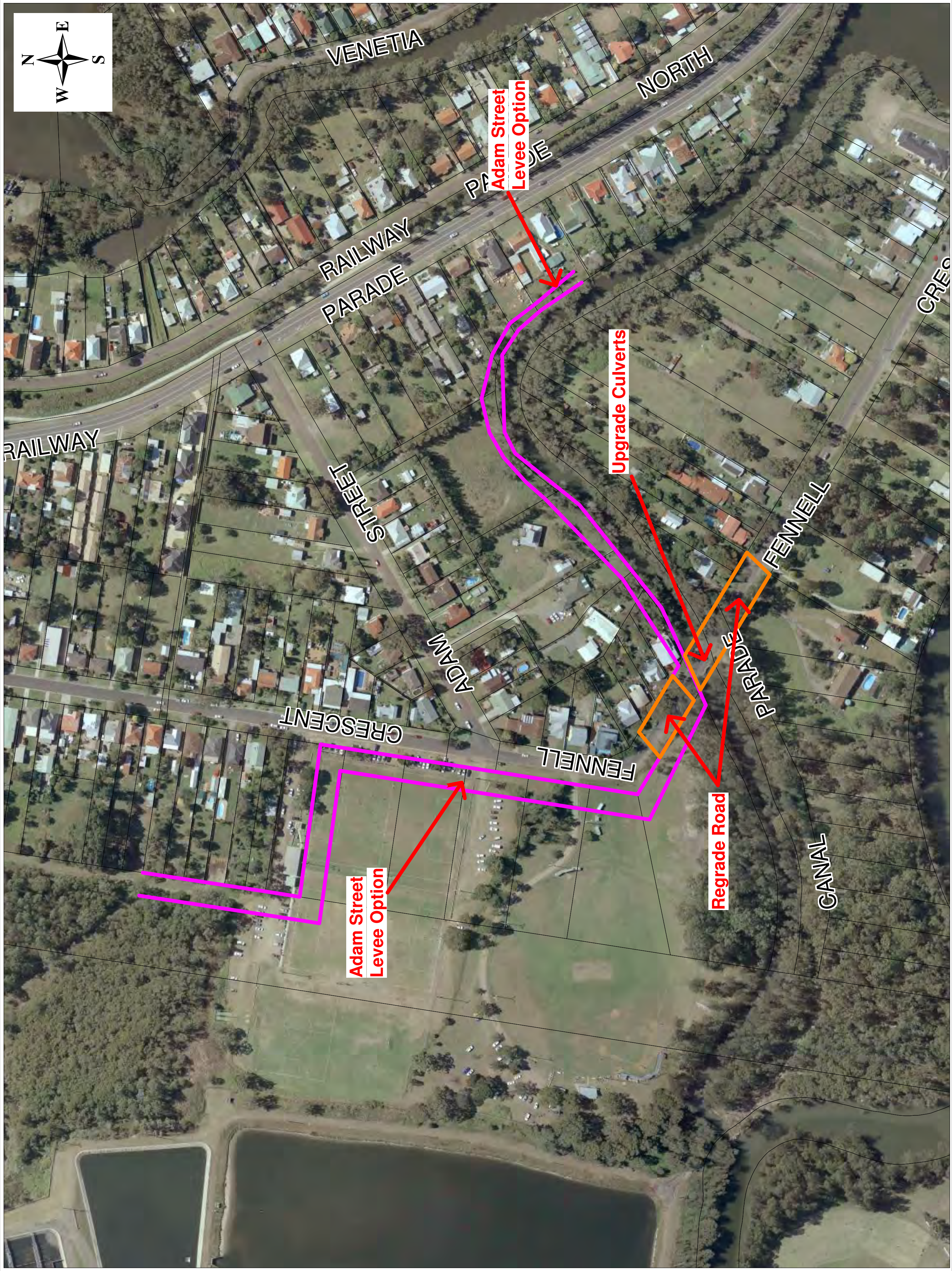

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FIGURE 9.7
MITIGATION OPTION FM3.4
LEVEE ADAM STREET

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FIGURE 9.8
RAILWAY PARADE LOCALITY

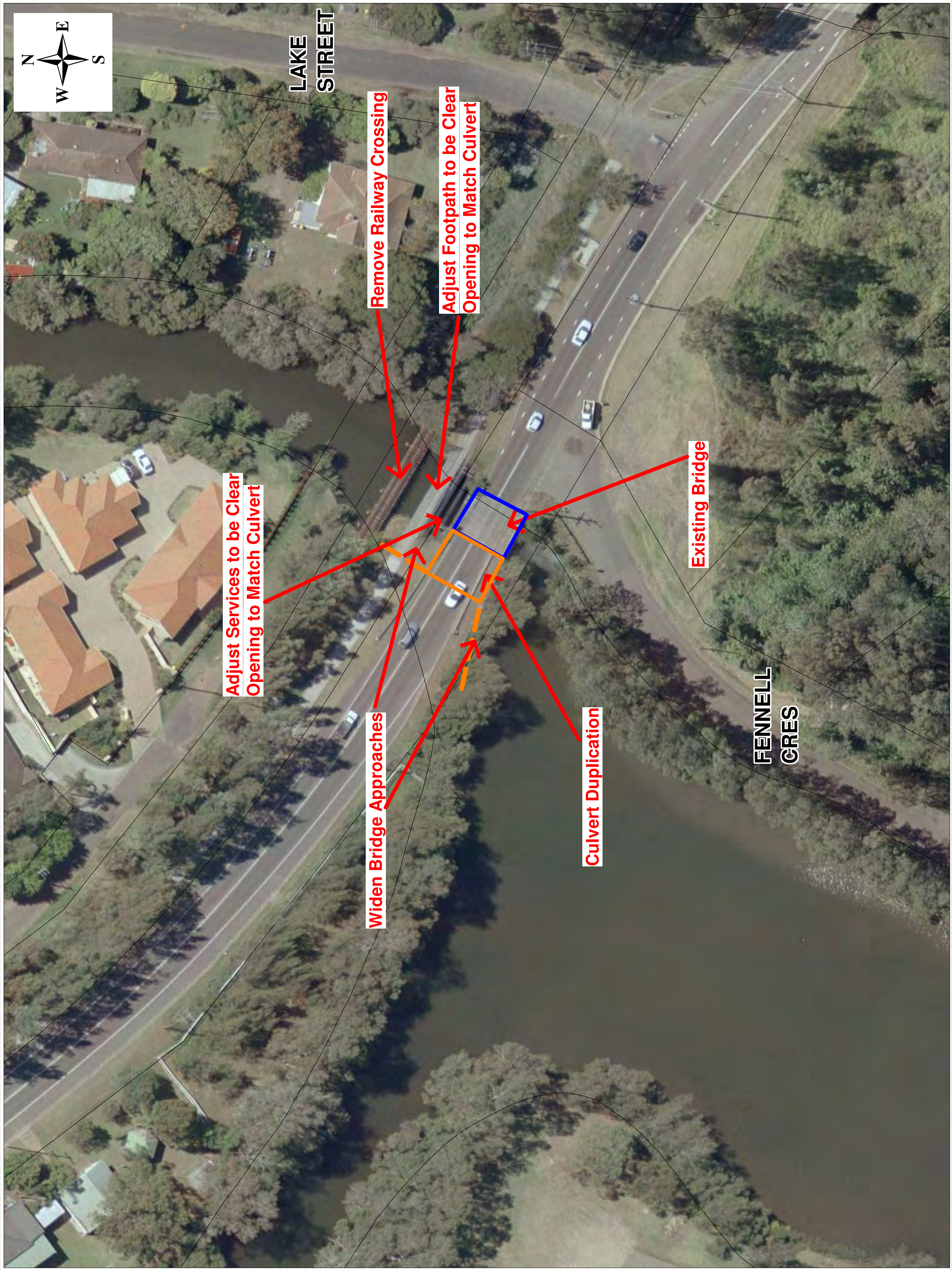

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FIGURE 9.15
MITIGATION OPTION FM4.1
MUDD CREEK AUGMENTATION

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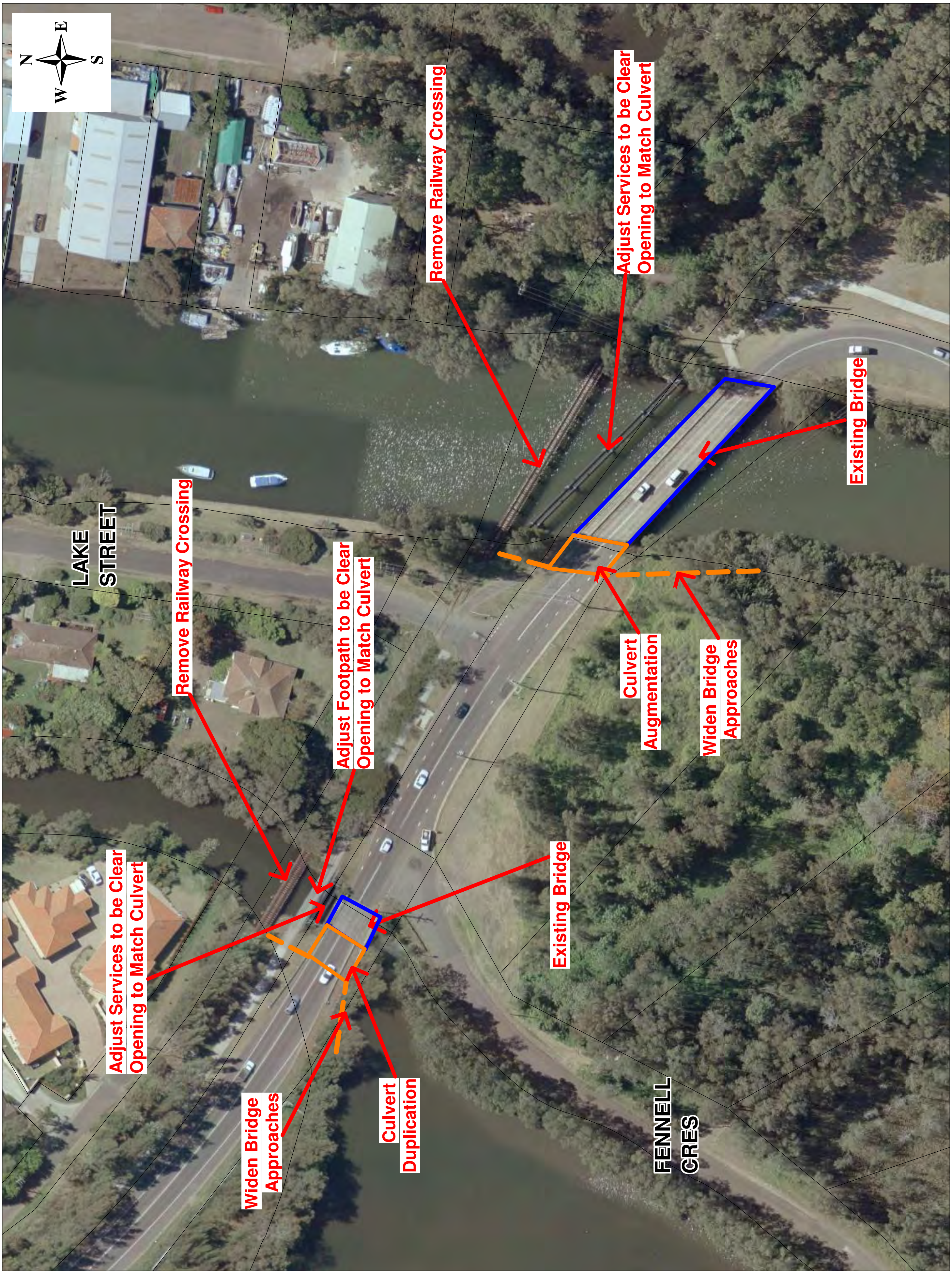

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Stony Creek Floodplain Risk Management Study

FIGURE 9.16
MITIGATION OPTION FM4.6
STONY CREEK AND MUDD CREEK AUGMENTATION

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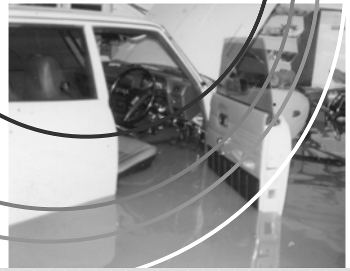
FIGURE 9.17
MITIGATION OPTION FM4.7
RAILWAY LINE REMOVAL

Appendix A

Community Questionnaire



COMMUNITY GUIDE
Stony Creek, Lake Macquarie: Floodplain Risk Management Study and Plan

COMMUNITY CONSULTATION PROGRAM

Community involvement is important in all stages of the Floodplain Management Process. Residents' local knowledge of the catchment and personal experiences of flooding provide an invaluable source of data to define the nature and extent of flooding. Also, it is important to gain community input and feedback so that the management solutions meet the needs of the local community.

Under the current stage of the process, the community consultation program includes this brochure (for dissemination of project information) and a questionnaire (for collection of vital flood data).

HOW CAN YOU GET INVOLVED?

As aforementioned, you can fill out the questionnaire that accompanies this brochure. Then, a draft copy of the Floodplain Risk Management Study and Plan will be placed on public exhibition for comments and questions prior to finalisation. During exhibition, public submissions can be made, and where appropriate they will be incorporated into the final document.

You will be informed of the date in due course.

FURTHER DETAILS?

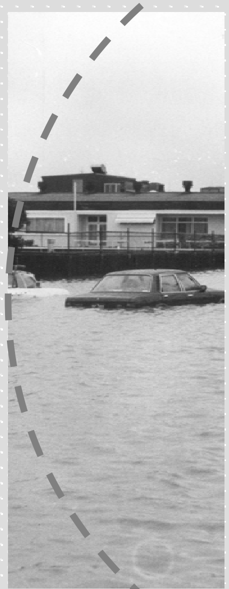
Should you require further details, please contact:

Lake Macquarie City Council- Greg Jones, 4921 0406

Cardno Lawson Treloar- Rhys Thomson, 9499 3000

CITY OF Lake Macquarie

Cardno Lawson Treloar


INTRODUCTION

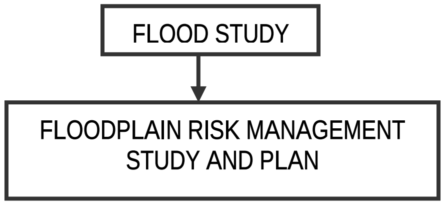
The Stony Creek Catchment has an approximate area of 46.35km^2. It lies within the Lake Macquarie Catchment, to the northwest of the lake. The upper reaches of the catchment are rural or bushland, while the lower reaches are low to medium density housing, with some industrial and commercial areas.

In the past, flooding in the Stony Creek Catchment has caused property damage and posed a hazard to the residents living close to the major drainage channels and creeks. The most notable historic flood for the Stony Creek Catchment was in 1981.

ACTION

Under the NSW Government Flood Prone Land Policy, management of flood prone land is, primarily, the responsibility of Councils.

Lake Macquarie City Council began to address this responsibility through the completion of a Flood Study for Stony Creek in 2005. This Study predicted the location, frequency, and magnitude of flooding along Stony Creek. Now Council are developing a Floodplain Risk Management Study and Plan. The Risk Management Study will investigate options to manage the risk of flooding, and the Risk Management Plan will be a strategy that Council will adopt to fulfil the management options.



This Community Guide is to inform you of the Floodplain Risk Management Study and Plan and invite you to contribute by completing the questionnaire attached.

OBJECTIVES

The objectives of the Floodplain Risk Management Study and Plan are:

- To manage flooding as an integral part of the planning and development process;
- To characterise hazard levels and assess actual/potential flood damages;
- To prepare a strategic task list to manage the existing flood problem and reduce future flood damages;
- To ensure sustainable development principles are achieved through implementation of flood management measures;
- To maintain and enhance, where possible, the quality of the Stony Creek Floodplain; and
- To involve the community in the decision making process.

WHY IS THIS IMPORTANT?

The implementation of sound flood management practice is an important process that can be used to optimise development potential, and to obtain social and economic benefits from the reduction in flood damages.

FLOOD MANAGEMENT MEASURES

A number of flood management measures may be adopted as part of the Floodplain Risk Management Plan:

Retarding or Detention Basins- serve a large catchment area by initially holding back floodwaters, then releasing floodwater slowly from the basin after the main peak flows have passed.

Stormwater Harvesting- involves diverting runoff from the roof to a rainwater tank, which reduces the amount of water entering the centralised drainage network. The water can be reused in the garden and possibly for toilet flushing and laundry water.

Improved Flood Flow Paths- involves the creation of formal land depressions that can direct water away from an area when the piped stormwater system capacity is exceeded.

Culvert/ Bridge Enlarging- involves increasing the amount of water conveyed through the structure and therefore reduces the frequency of flooding.

Levee Banks- help keep the flood waters away from the areas they protect.

Infiltration Basins and Trenches- small water storage areas with a permeable base that can collect flow, allow it to pond, and then percolate slowly away through the ground water table.

Planning Controls- implemented at the property development or redevelopment stage to ensure properties and buildings will be less likely to flood, and also that particular types of development do not worsen flooding to other properties.

Education- would include a pamphlet to educate your community about things such as flood risk areas, how to prepare for a flood, and flood response actions (eg. evacuation procedures).

The aforementioned flood management measures are listed in the questionnaire and you can comment on which options you might prefer for your community.

STONY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

QUESTIONNAIRE

Please answer the following questions as best as you can. Please return these pages in the enclosed "reply paid" envelope by Friday the 4th May 2007. YOUR PERSONAL INFORMATION WILL REMAIN COMPLETELY CONFIDENTIAL. A map is attached showing the study area of the project.

If you have any queries, please contact:

Greg Jones – LAKE MACQUARIE CITY COUNCIL Ph: 02 4291 0406 Email: gdjones@lakemac.nsw.gov.au
Rhys Thomson – CARDNO LAWSON TRELOAR Ph: 02 9499 3000 Email: rhys.thomson@cardno.com.au

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Question 1
Could you please provide us with the following details? We may need to contact you to check some of the information with you.

Name: ……………………………………………………… Daytime Ph: ……………………………………….

Address: …………………………………………………… Email:……………………………………………….
…………………………………………………………….
…………………………………………………………….

Question 2
How long have you lived in this locality?

………… Months ……….. Years

Question 3
How aware are you of flooding in the catchment? (PLEASE CIRCLE ONE)

Aware Some knowledge Not Aware

Question 4
Have you ever been inconvenienced, or has your property been flooded because of uncontrolled floodwater in this locality?

(Your property may have been flooded inside or in your backyard, or you might have been stopped from getting to work)

Please Tick: PROPERTY FLOODED YES ……….. NO ………..

INCONVENIENCED YES ……….. NO …………

Question 5
As a local resident and (probably) having witnessed a number of flooding/drainage problems you may have your own ideas on how to solve the problems. The following general management options are briefly explained in the brochure. Which would you prefer (1=least preferred, 5=most preferred)? Please also provide comments.

Proposed Option	Preference (Please Circle)	Comments
Retarding or Detention Basins	1 2 3 4 5	
Stormwater Harvesting	1 2 3 4 5	
Improved Flood Flow Paths	1 2 3 4 5	
Culvert/ Bridge Enlarging	1 2 3 4 5	
Levee Banks	1 2 3 4 5	
Infiltration Basins and Trenches	1 2 3 4 5	
Planning Controls	1 2 3 4 5	
Education	1 2 3 4 5	
Other	1 2 3 4 5	

Question 6
The specific structural options mentioned in the table below are under consideration. Which of the following would you prefer (1=least preferred, 5=most preferred)? Please also provide comments.

Proposed Structural Option	Preference (Please Circle)	Comments
Construction of a detention basin upstream of the North Rail Line.	1 2 3 4 5	
Enlarge the bridge over Stony Creek at Cook Street.	1 2 3 4 5	
Enlarge culvert on Mudd Creek at Railway Parade.	1 2 3 4 5	
Construction of a levee around properties on Fennel Avenue.	1 2 3 4 5	

Further Comments:
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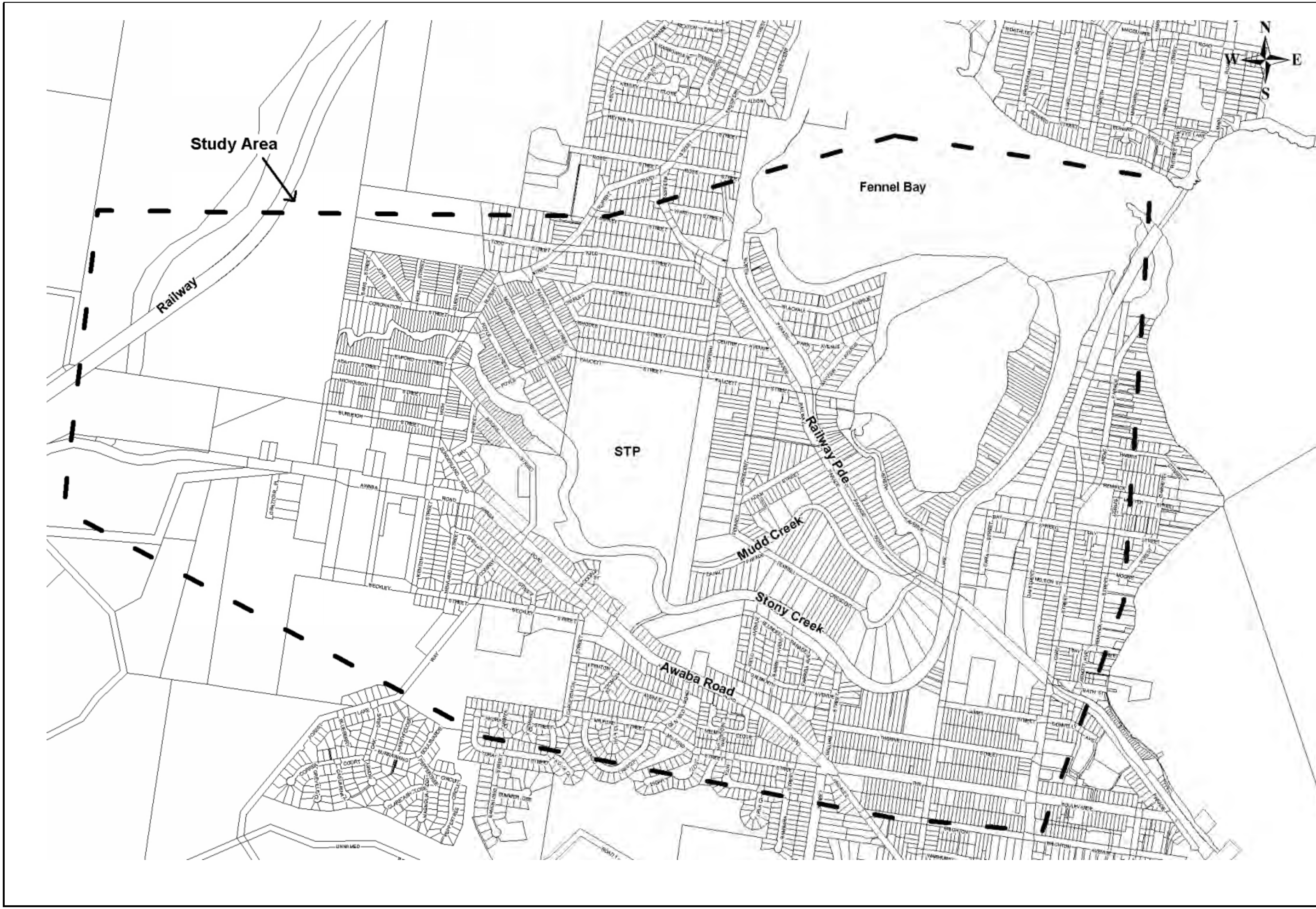
Thank you for providing the above information. Please remember to put it back in the reply paid envelope. A representative from Cardno Lawson Treloar may contact you in the near future to discuss your response.



Study Area
Railway
Fennel Bay
STP
Railway Pde
Mudd Creek
Stony Creek
Awaba Road
N
E
S
W

	A	E	F	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
1		Q1		Q3			Q4				Q5														
2	**Survey Ref. No**	**Street**	**Suburb**	**Aware of Flooding**	**Some Knowledge of Flooding**	**Not Aware of Flooding**	**Property Flooded (Y/N)**	**Comments**	**Inconvenienced (Y/N)**	**Comments**	**Retarding or Detention Basins**	**Comments**	**Stormwater Harvesting**	**Comments**	**Improved Flood Flow Paths**	**Comments**	**Culvert/ Bridge Enlarging**	**Comments**	**Levee Banks**	**Comments**	**Infiltration Basins and Trenches**	**Comments**	**Planning Controls**	**Comments**	**Education**
3	1			Y			N		N																
4	2	Woodale Street	Toronto	Y			Y		Y		5		5		5		5		5		5		5		5
5	3	Farrell Ave	Toronto		Y		Y	Man-made flood in 1981	Y	Inconvenienced every time heavier rain is experienced over a few days	4	Provided they don't become a breeding ground for mosquitoes	5	Water tanks should be encouraged	2		1		1		3		1		5
6	4	Thorne Street	Toronto		Y		N		N				5	Redirecting from higher elevation properties	5										
7	5	Awaba Road	Toronto			Y	N		N																
8	6	Beckley Street	Toronto		Y		N		N		5		5		5		5		5		5		5		5
9	7			Y			Y		Y		3		4		4		4		3		3		3		5
10	8	Nelmes Close	Toronto			Y	N		N		3		5		5		5		5		3		5		5
11	9	Nelmes Close	Toronto			Y	N		N																
12	10	Lake Street	Toronto		Y		N		N		4		5		3		4		2		3		4		4
13	11	Barry Ave	Toronto	Y			N		N		3		3		4		5		2		3		5		4
14	12	Blundell Pde	Toronto		Y		N		N		3		1		5		5		1		3		3		3
15	13	Foyle Street	Blackalls Park	Y					Y		1	Let nature take its course, creek at times needs flushing	1	Creek will only floog after a lot of rain and by this time water tanks already full	1		5		5		2		5		2
16	14	Foyle Street	Blackalls Park		Y		N		N		3		5		4		2		5		2		1		2
17	15	Galbraith Ave	Toronto	Y			N		N		5		5		5		1		1		5		5		3
18	16	Railway Pde North	Blackalls Park	Y			Y		Y		5		5		5		1		3		3				
19	17	Awaba Road	Toronto		Y				Y						3								3		
20	18	Nelmes Close	Toronto			Y	N		N				5		5		4		4		2		5		5
21	19	Galbraith Ave	Toronto	Y			Y				3		5		5		1		1		4		3		1
22	20	Park Ave	Blackalls Park	Y			N		N								3								
23	21	Lake Street	Blackalls Park			Y	N		N		5		5		5		4		2		5		5		3
24	22	Awaba Road	Toronto		Y		N		N		5		5		5		3		3		5		5		5
25	23	William Street	Toronto	Y			Y		N			Not sure how this would work	5	Tanks supplied to res. Would be great idea.	5		5		1	L/banks would reduce access & asthetics	5		5		5
26	24	Faucett Street	Blackalls Park		Y		N		N		5		5		5		2		2		5		5		2
27	25	Beckley Street	Toronto	Y			N		N		4	Good idea	4	Should have been done years ago	5	Good idea	3		4	Good idea	4		5		3
28	26				Y		N		N		1		2		1		1		5		5		1		1
29	27	Sunderland Rd	Toronto West	Y					Y																
30	28	Lake Street	Blackalls Park	Y			N		N										5	Creek banks are in serious danger of further undermining. Levee banks would help contain potential flooding. The timber walls are the only stable part of creek banks.					
31	29	Anzac Pde	Toronto	Y			N		N		4		5		4		2		4		2		3		3
32	30	Awaba Road	Toronto	Y			Y		Y						5	Path obstructed by mound behind playground should not have been done	5	Shown officers problem on 2 occasions							
33	31	Fennell Cres.	Blackalls Park	Y			Y		N		5		5		5		5		5		3		5		5
34	32	Lake Street	Blackalls Park	Y			N		Y				5	Should be rebate for householders supplying own tanks	5	Deepen natural depressions tomake scenic environmentaly friendly lake area	3		1	Should not be build in this area	4		5	Most important for future	5
35	33	Ingar Close	Toronto			Y	N		N				5		5						5		5		5
36	34	North Pde	Blackalls Park	Y			N		N		1		3		5		3		5		3		5		3
37	35	Nicholson St	Toronto			Y	N		N		5		5		4		1		1		4		4		5
38	36	Farrell Ave	Toronto	Y			Y		Y																
39	37	Anzac Pde	Toronto		Y		N		N				3	Because better drainage	4	Stop overflow			5	Not at moment	3	In certain places	5		5
40	38	Barry Ave	Toronto	Y			N		N		5	Already have this and is working well	4		3		2		1		4		5		3
41	39	William Street		Y			N		N		5		5		5		5		5		5		5		5
42	40	Lake Street	Blackalls Park	Y			N		N																
43	41	Burleigh St	Toronto			Y	N		N		4		2		5		3		4		3		4		4
44	42	Awaba Road	Toronto	Y			Y		Y		3	In the Awaba ares	3				4	Good idea because of debris blocking flow	5	Area marked on map (ie at STP)			4		4

	A	E	F	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
45	43	Oak St	Toronto	Y			N		N		4		4		4		1		1		2		3		3
46	44	Awaba Road	Toronto		Y		N		N		4		5		4		3		5		3		4		4
47	45	Awaba Road	Toronto	Y			Y		Y		3	Previous serious flooding washed out rail embankments through retained floodwaters.	4		5	Only effective if properly mainained	5	Need to be combined with dredging of Stony Creek entrance.	3	Huge job			4		3
48	46	Blundell Pde	Toronto		Y		N		N		1		1						1				1	Research & studies for effective controls preventing flooding	1
49	47	Awaba Road	Toronto	Y			N		Y		5		5		5		5		5		5		5		5
50	48	Anzac Pde	Toronto	Y			N		N						5				5						
51	49	North Pde	Blackalls Park			Y	N		N		3		5	Subsidies would assist.			5		1		3		1		5
52	50	Lake Street	Blackalls Park	Y			Y		N		3		3		4		4		4		4		3		3
53	51	Yanco St	Toronto		Y		N		N				1		1						1				1
54	52	Lake Street	Blackalls Park	Y			N		N		4				4										
55	53	William Street	Toronto		Y		N		N						5								5		5
56	54	May Street	Toronto		Y		N		N		5		3		5		3		4		3		5		5
57	55	Lake Street	Blackalls Park																						
58	56	Anzac Pde	Toronto	Y			Y		Y																
59	57	Akora St	Toronto		Y		N		N				5												
60	58	John St.	Blackalls Park			Y	N		N		1		5		5		5		1			What are these?		What's this?	5
61	59	Newland St.	Toronto	Y			N		N		1		1		3		4		4		3		5		
62	60	Nelmes Close	Toronto	Y			N		N		3		5		5		5		3		2		5		4
63	61	Beekley St	Toronto	Y			Y		Y		4	Can't hold all stormwater during severe events.	5	Extensive rainwater tanks should be installed on all new dwellings.	2	Unfortunately all natural depressions have been developed.	5	Culvert on Carlton St. needs enlarging	1		5		5	But will planning controls affect existing dwellings.	2
64	62				Y		Y						5		5		1		3		2		2		5
65	63	William St.	Toronto		Y		N				1		5		1	Stormwater flowing across Awaba Road	1		2		2		1		2
66	64	Railway Parade	Blackalls Park		Y		N		N		1	Could be a danger to children	5		5		5		1		1		4		1
67	65	Beckley St	Toronto	Y					Y		1		5		3		4		5		4		5		5
68	66	Lake St	Blackalls Park	Y					Y		2		3	Would like Council to supply tanks	5	Dredging needed	4	Clearing fill when creek was narrowed to buld them	2						
69	67	Galbraith Ave	Toronto		Y		N		N		3		5		4		5		4		5		5		5
70	68	Rupert St	Blackalls Park	Y			N		N		4		5	Too much water wasted.	4		5		2		3		2	Increased burden & costs on home builders puch up costs.	5
71	69	Faucett St	Blackalls Park	Y			N		N		5	Would have to be large areas	5	All houses etc. would need tanks relative to roof & paved areas.	5	Towards the end of both creeks	3	May help	5	Above town to restrict amount of water coming down	5	At the head of all gullys and drains	5	In all new subdivisions	5
72	70	William St.	Toronto		Y		N		Y														5		5
73	71	Blackall Ave	Blackalls Park		Y		N		N																
74	72	Fennell Cres.	Blackalls Park		Y		Y		Y		5		5		5		5		5		5		5		5
75	73	Cook St.	Toronto	Y			N		N				5		5				5						
76	74	May St.	Toronto	Y			N		N		4		5		4		3		3		3		4		3
77	75	Cnr. High & Burleigh St.	Toronto	Y			Y								5		3		3						
78	76	Blundell Pde	Toronto	Y			Y				1		1		5				1				1	If Council cleaned drains out it would make better	5
79	77	Anzac Pde	Toronto	Y			Y		Y		4		5		5		3		3		3		5		4
80	78	Anzac Pde	Toronto		Y				Y			Not enough information		Not enough info.		Not enough info.		Not enough info.		Not enough info.		Not enough info.		Not enough info.	5
81	79	Forest Lake Way	Toronto	Y			N		N		4	Would have to be large to slow water flow	4	Difficult to manage - too much open area around here	4	Flooding occurs behind Biraban School through property to underpass below Awaba Rd.									
82	80	Foyle Street	Blackalls Park	Y			N		Y		5		5		5		5		5		5		5		5
83	81	Awaba Road	Toronto		Y		N		N		5		5		5				1		5		5		5
84	82	Anzac Pde	Toronto	Y			Y								5										
85	83	Oak St	Toronto	Y			N		N																
86	84	Park Ave	Blackalls Park	Y			N		N		3		3		5		5		2		4				
87	85	Bridge St	Fassifern	Y			Y		Y		5		5		5		3		3		5		5		5

	A	E	F	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF
88	86	Forest Lake Way	Toronto		Y		N		N		5		5		2		2		1		4		5		1
89	87	Lake St	Blackalls Park	Y							5		5	Works until tanks full & overflow	5		5		5		5		5		5
90	88	Anzac Pde	Toronto	Y			N		N		5		5		5		4		1		3		3		1
91	89	Galbraith Ave	Toronto	Y			N																		
92	90	Anzac Pde	Toronto		Y		N		N		5		5		5		3		5		5		5		
93	91	Thorne Street	Toronto	Y			N		N		5		5		4		1		4		4		5		5
94	92	Blackall Ave	Blackalls Park	Y			Y		Y		1		5	Stormwater harvesting is needed but not for controlling floods	5	Ensure Mudd & Stony Creeks are clear	5	Mudd Creek bridge was replaced with new bridge which will help dam flood water & flood Fennell Cres.	5		1		5		3
95	93	The Boulevarde	Toronto	Y			N				5		3		4		4		2		3		5		3
96	94	Railway Pde North	Blackalls Park		Y		Y		N		3		3		4		4		3		4		4		2
97	95	Woodale Street	Toronto	Y			Y		Y		4		4		4		4		2		3		3		4
98	96	Foyle Street	Blackalls Park	Y			N		N		1		1				5	Seems the best option for established housing areas	5	For highly flood prone areas	1		5		4
99	97	Galbraith Ave	Toronto		Y		N		N		1		5		1		1		1		1		1		5
100	98	Yanco St	Toronto			Y	N		N		4		5		4		4		3		5		4		5
101	99	Lake Street	Blackalls Park		Y		Y																		
102	100	Anzac Pde	Toronto	Y			Y		N		1	Not the answer -they fill and water still has to get away uncontrolled	5	Tanks will help but not solve problem	5	Needs upgrading	1		1	Holds water in as well as out	3	Breeding ground for mosquitos	5		2
103	101	Milford St	Toronto			Y	N		N		1		1		1		1		1		1		1		1
104	102	Railway Pde North	Blackalls Park	Y			Y		Y		3		5		2		4		3		2		5		5
105	103	Anzac Pde	Toronto		Y		N		N		3		5		3		2		2		4		4		4
106	104	William St	Toronto	Y			N		N		5		5				5		5		5				
107	105	Awaba Road	Toronto	Y			Y																		
108	106	Venetia Ave	Blackalls Park	Y	Y		N		N		4								1		3		2		3
109	107	Blackall Ave	Blackalls Park	Y			N		N		4		5		5		5		3		3		3		3
110	108	Lake St	Blackalls Park		Y		N		N		5		4		4		2		1		2		4		4
111	109	Fairlands Rd	Medowie	Y			Y		Y		5	Detention basin upstream of Syd.Newcstle railway embankment will have long term effect	2		4	Removal of Toronto-Fassifern Railway line embankment & bridge will lower flood level by up to 0.5m	5	Removal Toronto/Fassifern Railway bridges	2		1		4		2
112	110	Anzac Pde	Toronto		Y		N		N		5	A graduated form of filtering barriers culd be effective	4		2		3				1				
113	111	North Pde	Blackalls Park		Y				N						5		5								
114	112	Fennell Cres.	Blackalls Park		Y		N		N		3		5		4		5		2		3		3		5

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
1				Q6								Further Comments	Further (non-flood) Comments
2	**Comments**	**Other**	**Comments**	**Construction of a detention basin upstream of the North Rail Line**	**Comments**	**Enlarge the bridge over Stony Creek at Cook Street**	**Comments**	**Enlarge culvert on Mudd Creek at Railway Parade**	**Comments**	**Construction of a levee around properties on Fennel Avenue**	**Comments**		
3													
4		5		5		5		5		5		Bad flooding experienced in late 70s early 80s, causing significant damage to property, includind inside house	
5			Minimise covering the land so water can soak in naturally and not be concentrated into drains	1	Embankment break caused manmade flood in 1981	1				1	One man-made flood doesn't warrant levee construction. Would also diminish aesthetics of area.	One man-made flood in 1981 does not mean this is a flood-prone area. Heavy/terrential rain causes innundation of property as it lies below the road and nature strip. Photos included - this scenario takes place approx 2-4 times a year. Water retreats within 36 hours.	
6													
7												Have not experienced flooding.	
8		5		5		5		5		5			
9				5		5		5		3			
10		5		5		5		5		5			
11												Have not experienced flooding, have no knowlede of flooding in the area over period of residence.	
12		3	Dredging the opening of the creek into the lake	4		5		5		4			
13				4		5		5		3		Storm water should be allowed to enter the lake.	
14		5		3		5		5		1		Clean rubbish and dredge built-up silt to improve water flow. Silt traps required further upstream to prevent silt entering creek.	
15				1		5		5		5	Must be in conjunction with enlarged bridge and enlarged culverts		Bike path needed from Foyl Street to the industrial area in Toronto West
16				1		4		3		3			
17				5		2		2		2			
18				5		1		5		3			
19								3					
20				3		5		4		4			
21		1				5							
22				3		3		3		5		Have not experienced flooding.	
23													
24		5			Not familiar with this area	5			Not familiar with this area	3		Have never experienced flooding in this side of the lake	
25				5		5		5		1			
26				5	Needs to be maintained regularly	1	Would not solve the problem requiring update in future	1	Would not solve the problem requiring update in future	2	Would create problems with sediment flow & more water under culvert & bridge & into lake		
27	For those in the flood area			4		3		3		3			
28				4		1		5		3			
29				1		5							
30													
31				4		2		4		4			
32													
33				5		5		5		5			
34	Good idea			1	Only if water in basin can be used constructively	5		5		1	Last resort. Levees upset environment.	Councils must stop being influenced by big building companys to the detrement of environment. There must be a very long term approach to any construction be it popular or not.	
35				5		5		3		4		White ants are a problem!!!	
36				5				4		5		Have often seen water rise almost to fences on xxxx North Pde. In March 84 almost all of the reserve was covered by flood water and our jetty was fully submerged. Feel that lake edge could have higher levees to reduce risk of flooding. Sometime ago creek bank was raised but the lake and drainage waters just go around it.	
37		4		5		5		5		5			
38												Council built a wetland (swamp) at corner of Blundell St & Farrell Ave. - overrun by reeds - water doesn't flow in/out - mosquitos - rats. The walkway to High School still floods with heavy rain. Have lived here for 31 years - flood 26 years ago was freak flood.	
39										5	Because low lying		
40				4		1	little effect	2		1	Too expensive		
41		5		5		5		5		5			
42						5		5					
43												How can one comment without details - do a proposal first.	
44				3		1						Good cleanout of Creek would reduce risk of flooding + removal of some trees North of William St. & High St. plus dredging shallow areas.	

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
45				3		3		3		3			
46				4		5		4		3			
47	If applied to Council planners			4	Would have to be much stronger than exist.rail line embankment.	4	Only effective if Creek widened or deepened.	4	As previous	2	Would have to completely surrund properties or area.	Experienced major flood some years ago. Have also experienced regular flooding and driveway washouts which happens after heavy downpours - caused by water from William & Bambara Sts. Across Awaba Rd. through properties. Cleaning out and maintainng exisitng drains & creeks would be a great help.	
48										1			
49				5		5		5		5			
50						5		5				In 1967 the depth of water in Stony Creek 6ft. From bank was 7-8 ft.is now 2ft deep -something should be done now.	
51				4		5		3		2			
52				2		2		3		5			
53				5		5		5		5			
54												Most of these options are unnecessary if entrance to Stony Creek and Edmunds Bay are deepened.	
55				5									
56				5									
57												Lived here only 6 months so don't feel confident to answer questions.	
58												After every decent fall of rain road and park are flooded - not enough drains - our is lowest property so continually flooded halfway up driveway and can't access road. Have written to Council - no response. Grate near property is too small and continually blocked with leaves. Too elderly to cope with cleaning drains constantly.	
59				5									
60	How do we find out how likely it is to flood?			1		5		5		1		Don't know about flooding - who's problem is it if our property floods?	
61				3		4		1		3		Circled area on back of questionaire lacks drainage - feeds into creek. With mod. Rainfall leeds to flooding. Area - Beckley St, Awaba Rd. Intersection and back of school grounds.	
62				5								Retention basin (existing) Nelmes Close needs constant maintenance -mowing etc.	
63		5	Consider effects of new development on the catchment.	5		4		3		1	May channel stormwater elsewhere & increase flooding effects.	New development upstream of Biraban Public School has resulted in hydrological changes downstream even during small rainfall events culvert on Carlton St. struggles to cope. No construction as yet on this site (86 lots) but when completed I predict flooding caused by this development.	
64				3	Only if kept natural	1	Will destroy natural flows	1	Leave as it	1	Will be paid for by owneres - No?		
65				1		2		2		2		Stormwater from Jindalee St. runs across Awaba Rd. then flows down William St. to the Creek. Water flows from Milford St. Across Awaba Rd into open drains that overflow. There is no kerb & gutter along North side of Awaba Rd.	
66		5	Dredging waterways to get more flow.	1		3		5		1		Last year dredging done around Mud Creek & Fennel Bay but not enough. This improved water flow in Mud Creek with heavy rainfalls.	
67		5	New housing estates have piped natural water ways and creeks. This stops water from seeping into ground and stops creeks & rivers from being cleaned out.	1		3		5		1		Piping & concreting everythins is a recipe for disaster. Building too close to creeks, rivers & lakes also stops a lot of natural water flows as some people build up their land.	
68				2	How big? Could be a danger	4	What about sewerage pipe & railway bridge	4	As previous	3		The cement drain near Toronto School released clay and gravel into Stoney Creek. Drain alongside railway tracks should not be cleared as rushes filter rubbish. Have marked island on map on questionaire - right hand side allows 'Alkira' to exist but left hand side is full of mud.	
69				4		5		5		5		Not lived in area long enough to experience flooding. Appreciate wetlands in nearby areas.	
70	Make community aware			5		3		3		1		Flooding shown on community guide would not have happened but for railway causing problems further up the creek.	
71	Of all new buyers in flood prone areas.			5	Would have to be higher than rail line.	1	Remove old railbridge this is the bottleneck	3	Open up end of Mudd Creen at Edmonds Bay			Used to live at 11 Ventia Ave. and was flooded in 1981. Caused by railway (North coast line) old sleepers & debris washed against culvert. We got no compensation for all the damage done.	
72												The Department of Housing is planning to build new housing at xxxx William St. When they built new housing at xxxxWilliam St. in 1991 plans did not adequately allow for run off onto their site during storms. Sent photos to LMCC showing creek flow through yard in severe storm and as a result their drainage system was amended. We suggest drainage plans for the new buildings on xxxx William St. Toronto be carefully checked by an engineer.	Natural vegetation has been destroyed by motor bikes using tracks that start at the south end of William St. This causes erosion and ultimately sediment to flow into Stony Creek and Lake Macquarie.
73						5		5					
74		5		5		5		5		1			
75										5			
76		5	Fully subsidised water tanks for houses.	5		3		3		3		Property opposite flooded in 1981. This problem was not so apparent before the railway alignment was built over the natural basin of Stony Creek upstream nearer Awaba.	
77				4		3		3				Photo & news article attached (18.2.81) Toronto Bus Service depot was flooded to approx. 1 metre- 30 buses out of service - office equipment and doucments destroyed.	
78		5	Get rid of train bridge at Stony Creek & Mud Creek	1	Would not help	5	May make a difference	5	As previous	1		Flood in 1981, I believe, was caused by debris collecting at rainway bridge.	
79		5	Plan maintenance for drainage systems	4		2		3		3		Drainage infront of xxxxAnzac Pde is constantly blocked - siltation. The lower area of Anzac Pde have their property flooded even after limited rain due to poor water run off strategies.	
80		5											
81												Flooding behind Biraban School primarily from Creek running alongside Forest Lake Way thru to new retention basins for new estate, although water has crossed road in dip of Forest Lakeway, it has been passable. Same applies at junction of Awaba Rd/Beckley St. Buildup of water is affected by tides in Lake, so retention basins etc. would have to be very large to slow water flow.	
82				4		4		4		3			
83				5		5		5		5		The houses opposite us are always flooding and there are children, perhaps someone could come and evaluate the situation.	
84												No. xxxx & xxxx Anzac Pde have been flooded at times due to stormwater silt. Traps and pipeline which runs thru xxxx - blocked most of the time. The pipe ends just outside rear fence and floods area between fence lines & creek bank. Main problem is flooding under house at xxxx and down drive to xxxxat rear.	
85												Don't know enough to comment other than I remember flooding in 1981 but were quite safe in Oak Street.	
86				4		3		5	Road Bridge at Mudd Cr. Caused much more water backup in 1981 than 1949 & 1955				
87		5	Cleanout LT Creek as wall	2	What happens if banks break?	3		5		3			

	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS
88				5		2		2		4		Q1 - Own property West Toronto Industrial Area. Q4 Aware of problems in industrial estate before my ownership. Would like to be kept up to date with any developments on studies that may affect Industrial Estate area.	
89				5		5		5		5		Any disturbing rise in water levels has happened in extreme wet weather when level of Lake Macquarie in Edmunds Bay & Fennel Bay cause Stony Creek to back up & block storm water drains.	
90		1		5		1		1		1		Copy of letter to Council attached plus photograph. In March 2006 Stony Creek flooded - sewage from Blackalls Prk ran into Stony Creek - Creek treated by Hunter Water - water left Creek, passed under Fennel Bay Bridge and winds blew rubbish & treated water onto foreshore in Kooroora Bay. 50 years ago before Lions Park heavy rain water would reach edge of road in park - when Stony Crk flooded natural flood plain helped. Retaining basins upstream would help but runoff from Toronto/Toronto West is a big problem. Perhaps western side of Stony Crk's mouth could be marsh floodplain to catch silt & rubbish.	
91												1981 flood due to drainage not being attended to by Council.	
92	Info would be more valuable for potential buyers.			5		5		3		5			
93				5		1		1		4			
94	Maps showing flooding history areas affected & depth.		Dredge Mudd Creek, install levee/raise roadheight in Venetia Avenue	1		1		5		5		Improve flow in Mudd Creek & Edmunds Bay and entrances of Stony Creek.	
95				5		4		4		2			
96				3		4		3		4			
97		2		4		4		4		2			
98				1		1		5	These seem to be the two main areas for consideration at present	5	As previous		
99				5		1		1		1		Were not inconvenienced by 1981 surge. Believe this flood was caused by electrification of railwayline and natural waterway was impeeded.	
100				5		5		4		4			
101												Don't know enough to comment apart from the fact that culvert out the front to my place cannot cope with amount of water that passes through it.	
102				1	With the volume of water experiences in the past - not the answer	5	Bridge & approaches needs upgrading	1		1		All new homes should have 1,000 L tanks (Gov.grant). Improved flood flow paths good idea. Don't agree to Levee Banks. Heavy rainfall + high tides will always induce flooding somewhere.	
103		1		1		1		1		1			
104				3		5		5		3			
105				2		2		2		2			
106				5		5		5		5		Experienced flooding when living at North Pde. Flood water came up to foundations of verandah.	
107													
108				5		5		1		1		Major problem is restriction caused by Stony Creek from Cook St. Bridge towards Toronto Bridge - poor flow nature of Mudd Creek from railway Pde to Edmunds Bay. Dredging would assist with flow when heavy rain falls happen.	
109				4		4		5		3			
110				5		1		2		1		Main concern with Stony Creek is water undermining banks and road causing trees to topple into creek taking large quantities of soil with them. Worst spot is where culvert crosses the road outside of xxxx the dual carriageway is only 4m wide not enough to have 2 cars pass. This is a danger to traffic and local community.	
111				5	Good idea	5	Remove railway bridges & embankment will lower upstream flood levels	5		2		Enclosed copies of letters to & from Lake Macquarie Council for reference. Removal of Stony Ck Rail bridge & embankment would lower upstream flooding. Also by providing a detention basin upstream of Northern Rail line would virtually ensure that lower areas could not flood.	
112				5	Include some form of filtering system	4		3		1		My property is often affected by dumping of a variety of flotsom & effluent scum coming from Fennel Bay during rain & mild flooding. This causes a build up of silt which is accumulating and not clearing - apart from neighbours manually removing problem in a limited way.	
113						4		4					
114				5		3		5		2			

Appendix B

June 2007 Storm Event

B Model Verification to the June 2007 Storm Event.

A significant storm event occurred in the Hunter Region from 7th to 10th June, 2007. Council and Department of Environment and Climate Change determined that this would be a suitable event for verification of the SOBEK model used for the 2005 Stony Creek Flood Study and hence further improve the confidence in the model for use in the current Stony Creek Floodplain Risk Management Study.

B.1 Storm Data

Rainfall data was collated for the period of the storm from various sources for locations around the Stony Creek catchment, with the sites selected for assessment listed in **Table B.1**. The rainfall gauge locations are shown in **Figure B.1**.

Table B.1: Rainfall Gauge Sites

Location	Source	Station Number	Details available
Toronto WWTP	Bureau of Meteorology	061322	Daily rainfall
Wyee	Manly Hydraulics Laboratory		Pluviograph (1 minute time intervals)
Eleebana	Hunter Water	TR100	Tipping bucket (0.2mm depth timestep)

The Toronto WWTP is the only gauge situated in the catchment and thus best represents the rainfall falling in the catchment for the event. This site however only has daily data which is insufficient for undertaking the modelling for Stony Creek Catchment, which requires rainfall data at more frequent sub-daily intervals. The nearest site with more frequent rainfall recordings was the Eleebana site operated by Hunter Water. **Table B.2** lists the precipitation in the 24 hours before 9am for the three sites.

Table B.2 Rainfall Depth in 24 hours up to 9am on the day (mm)

Location	7/6/07	8/6/07	9/6/07	10/6/07	Comment
Toronto WWTP	23	35	251	30	
Eleebana	28.4	45.4	297.6	16.8	Rainfall depths are only available from 02:24 7/6/07 to 23:41 9/6/07
Wyee	21	55.5	180.5	38	

The above rainfall totals show that Wyee received significantly less rainfall than the Toronto and Eleebana stations. The rainfall time-series graphs at Toronto, Eleebana and Wyee stations are shown in **Figures B.2, B.3 and B.3B** respectively. At Eleebana, a significant amount of rainfall occurred prior to the peak of the event falling between midday 8 June to early morning 9 June. The most intense rainfall occurred during 3:40PM and 9:40PM on 8 June, with the total rainfall depth of 218 mm. Over the approximately 70 hour duration of the storm, the catchment received 338mm of rainfall.

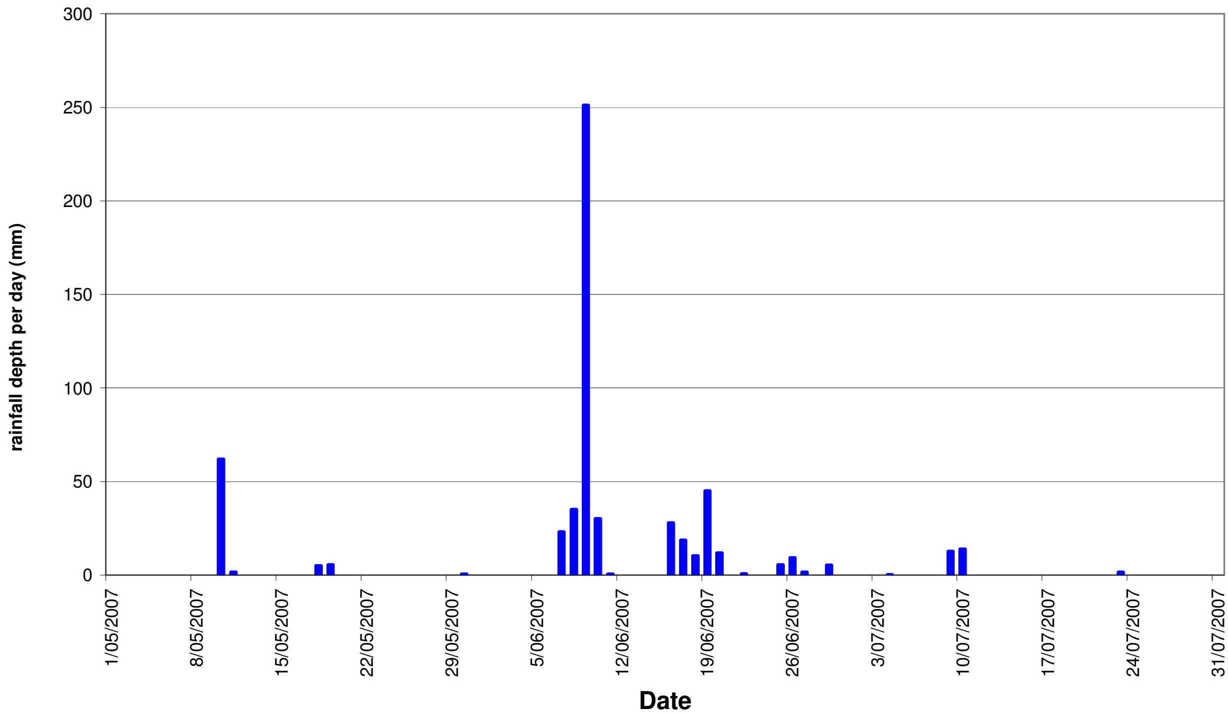


Figure B.2 Toronto WWTP Daily Precipitation (mm) [data from Bureau of Meteorology]

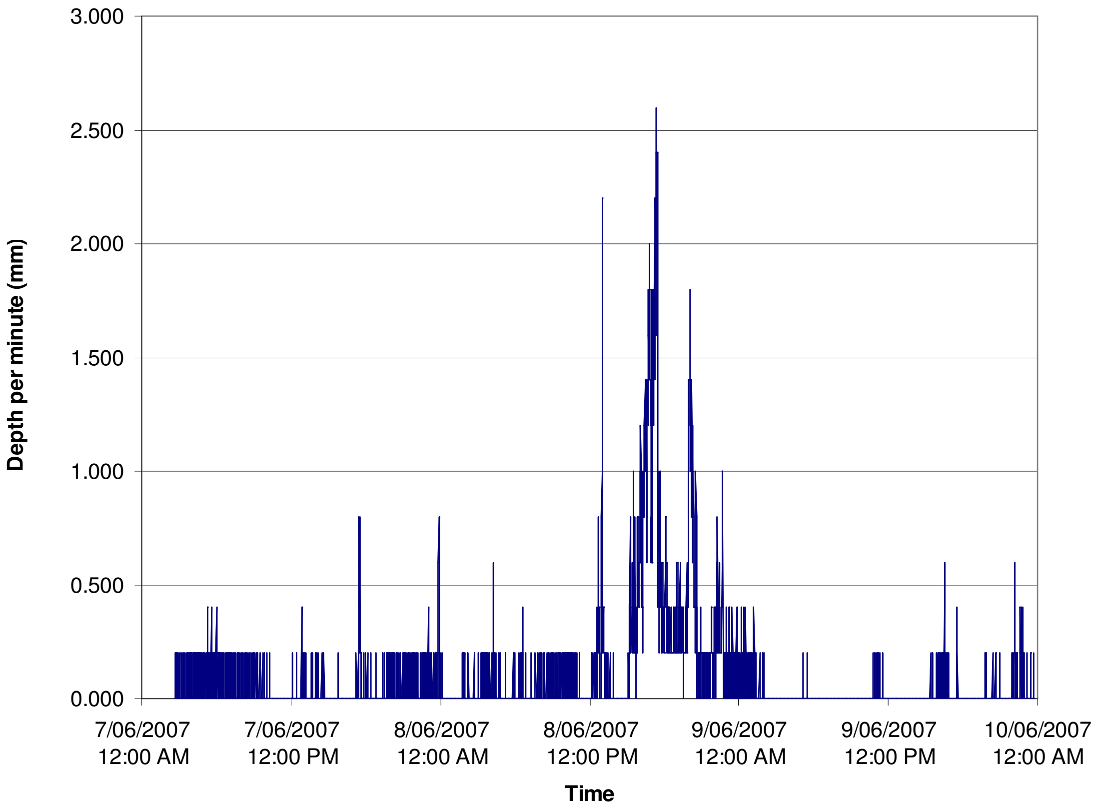


Figure B.3 Eleebana Precipitation (mm per minute) [data from Hunter Water]

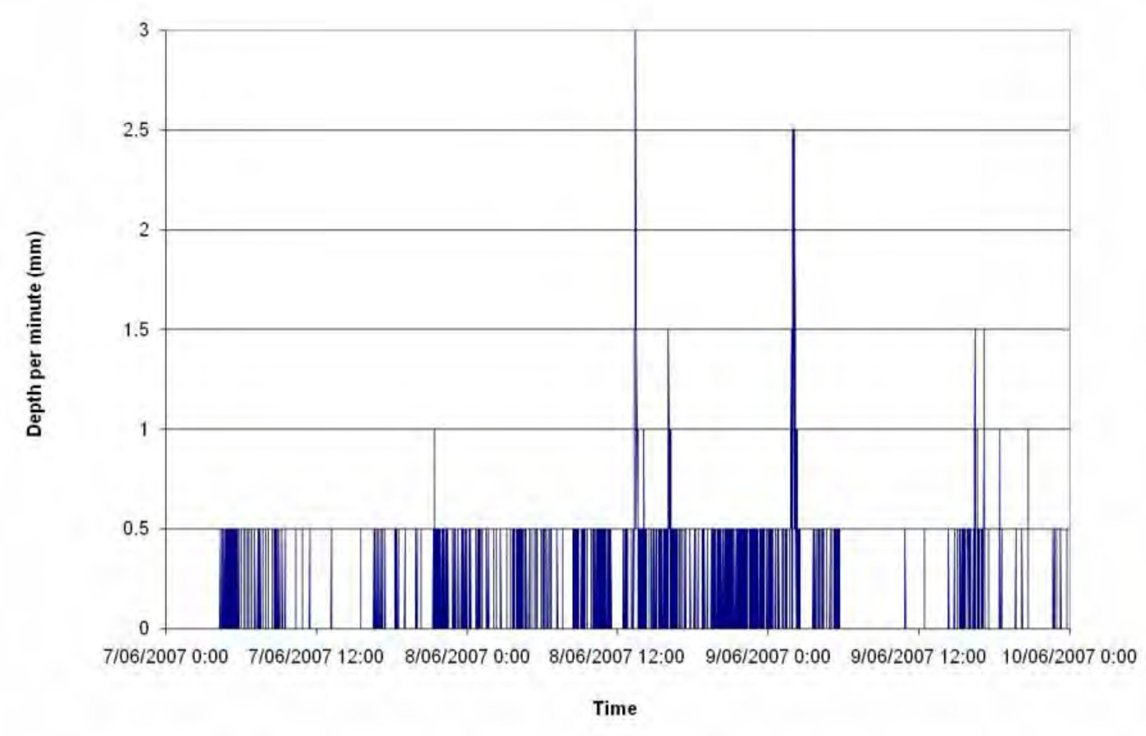


Figure B.3B Wyee Precipitation (mm per minute) [data from Manly Hydraulics Laboratory]

The Lake Macquarie levels influence flooding behaviour in the lower parts of the Stony Creek catchment. The water level height record for Lake Macquarie was obtained from Manly Hydraulics Laboratory gauge at Marmong Point (identified on **Figure B.1**). The gauge records the level every 15 minutes and the peak recorded level over the June long weekend was 1.14m AHD at 3:45AM 9 June. The water levels at the Marmong Point gauge are shown in **Figure B.4.**

B.1.1 Rainfall Data Processing

The Eleebana depths have been adjusted by dividing by 1.15 to better represent the daily rainfall depths of the Toronto WWTP daily precipitation.

The Eleebana depths factored to represent Toronto WWTP were examined to determine the Average Recurrence Interval (ARI) of the storm. The ARI for various durations are listed in **Table B.3** and shown graphically on **Figure B.4B**. The critical duration based on the previous modelling for the lower reaches of the Stony Creek catchment around the main residential area of Toronto is 36 hours. Thus the June 2007 event represents a 50 year ARI rainfall event for the lower reaches of Stony Creek. However, for the upper reaches of the study area, where the critical duration is about 9 hours, the June 2007 event represents a greater than 100 year ARI rainfall event.

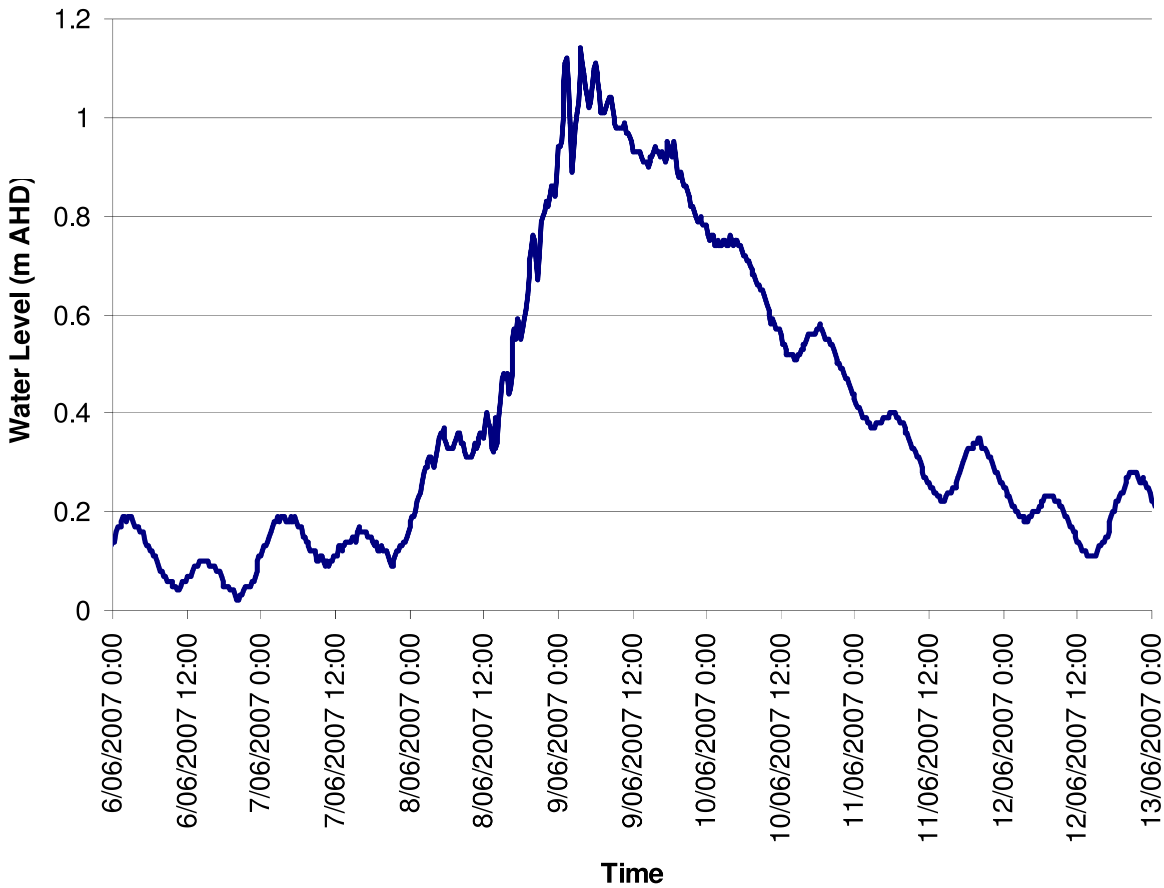


Figure B.4 Marmong Point Water Level (m AHD) [data from Manly Hydraulics Laboratory]

Table B.3 Rainfall Depth in 24 hours up to 9am on the day (mm)

Duration	Maximum Intensity (mm/hr)	ARI
10 min	116	~10
30 min	84	20-50
60 min	77	>100
2 hour	56	>100
3 hour	44	>100
6 hour	32	>100
9 hour	25	>100
12 hour	20	>100
24 hour	11	50-100
36 hour	8.2	~50
48 hour	6.7	20-50
72 hour	4.5	~20

B.2 Community Questionnaire

To collect data for the June 2007 storm event, a questionnaire was distributed in September 2007 to residents in the catchment enquiring about their experience of flooding during this event. The purpose of the questionnaire was to compile the experiences of residents during this event and to enable model calibration.

A total of 138 replies were received from approximately 1200 questionnaires issued. The questionnaire and a summary of responses from each questionnaire are attached. Selected photographs forwarded by residents are also attached.

B.2.1 General Experiences

128 of the respondents indicated they experienced the flood event of 7-10 June 2007. Some of the respondents noted they were away from home for the weekend but detailed the resultant effects to their property.

Respondents noted if they were affected in regards to the descriptors listed in **Table B.4**. Note that responses were not confined to an individual item, and most responses included multiples items.

Table B.4 Response of Flood Impact

Description	Number of Responses	Percent of Total Responses
We were without electricity	106	77
Our house/ property was flooded	65	47
We were frightened (worried)	49	36
We could not travel very easily/ access was affected	77	56
Our belongings were damaged	49	36

A majority of respondents noted they were without electricity for a variety of durations from several days to over a week.

Vehicular travel was affected during the flood event. Respondents noted that they experienced delays getting home, that roads were impassable (except in some cases for four-wheel drive vehicles), and some felt marooned within their homes.

The damage to belongings is naturally dependent on individual circumstances, such as degree of inundation and location of stored possessions. Common items listed were:

- garages and sheds – including stored lawn mowers, garden tools, freezers, toys, books;
- damages to fences – from flow of water or fallen trees/ branches;
- septic tanks being inoperable or overflowed;
- carpets and furnishings within the house;
- air conditioning units;
- cars;

- spoiled food due to the power outage – similarly unable to cook and hot water unavailable;
- garden beds and yard – fallen trees/ branches, debris, slime/ silt, sewage onto yard, swimming pools;
- rescuing pets – such as chickens from coops.

B.2.2 Flood Extent

The extent of flooding noted in the resident responses for different locations is listed in **Table B.5**.

The depth of flooding noted is dependent on the individual circumstances of the particular location thus a summary of levels is not presented. It is also likely most of the depths would be estimated from a distance by different respondents. The deepest above-floor flooding for a residence was noted to be 0.5m.

Figure B.5 shows the locations of the questionnaires returned and the reported degree of inundation experienced at that site.

Table B.5 Extent of Inundation

Location	Response Indicated Area Inundated	Percent of Total Responses
Parks	60	43
Roads	97	70
Residential (backyard)	86	62
Residential (frontyard)	66	48
Residential (above floor level)	14	10
Residential (below floor level)	32	23
Commercial (above floor level)	5	4
Commercial (below floor level)	8	6
Industrial	8	6

B.2.3 Culvert Blockage

Forty-six (33%) of the respondents advised they had noticed bridges/ culverts as blocked. The responses varied for the percent blockage, noting that in some cases the culvert was overtopped. This makes it difficult to determine if the culvert was blocked or undersized for the flow. Some comments were made regarding a general feeling that street drainage and culverts are undersized. The materials identified as blocking the culverts (or pipes) were woody debris, rubbish, garden furniture, reeds/ vegetation, silt build-up, fence / metal pieces, a car, or just that the flow of water was too much for the capacity of the drainage system.

Particular locations of blocked culverts identified were:

- Beckley Street / Carleton Street intersection;
- James Street (and Toronto Workers Club);
- Railway Parade (over Mudd Creek especially and Stony Creek), also noting the disused railway line blocking flow (also on Stony Creek which also occurred in the 1981 flood event);
- Awaba Road open drain
- Fennell Crescent (at Water Board Park end);
- Mudd Creek inlet from Stony Creek;
- Siltation limiting flow on Mudd Creek at Railway Parade and outlet to Edmunds Bay;
- Lake Street.

These locations are shown on **Figure B.6**.

B.2.4 Time of Flooding

The duration of flooding is dependent on the individual's location within the catchment. However, a general flooding window of the afternoon of Friday 8th June to the morning of Sunday 10th June is presumed. Some respondents noted flooding starting on Thursday 7th or Friday morning, and others noted that the water had generally receded by Saturday morning.

The time of the peak is also dependent on the location within the catchment and also the observation time of the respondent. A significant number of responses indicate a time between 10pm on Friday to 3am on Saturday. One respondent was taking regular measurements at their home and identified the peak as 1:45am on Saturday.

B.2.5 General Comments

Some general comments received from the questionnaires were:

- Related to the foul smell following receding of water – due to inoperative/ overflowing septic tanks, surcharging of sewer mains, or discharges/ overflows from the sewage treatment on Mudd Creek. Also sludge remained on yards after flooding.
- Dredging required in Edmunds Bay, Fennel Bay.
- Appreciated information on ABC radio.
- A recognition that other people were worse affected than they were.
- Mudd Creek channel capacity reduced by closing confluence with Stony Creek, inadequate culverts at Fennell Crescent and Railway Parade, and siltation within the creek itself and at the outlet to Edmunds Bay.
- The old railway bridge at Railway Parade should be removed to improve flow.
- Work of SES, electricity people and other volunteers was appreciated.
- Kerb and guttering works should be completed.
- Undersized or lack of street drainage (particularly Nelmes Close).
- Should some particular areas have been built on in the first place?
- Loss of electricity was biggest problem for some respondents.
- Rapid rate of rise of flood was unexpected.
- Unable to leave house during time of flooding.

B.3 Hydrologic Modelling

The rainfall depths for a 1 minute timestep for the adjusted Eleebana site data (refer to **Section B.1**) were input into the RAFTS model of the catchment. Though the storm event may not have been consistent across the catchment, specifically within both the Awaba State Forest area and the residential areas of Toronto, it was considered that this conservative approach was appropriate. The flow hydrographs developed in RAFTS were input into the SOBEK model.

As a preliminary comparison, the flow arriving at the Railway Line / Haul Road (Node DP0 shown on **Figure B.7**) was examined. The peak runoff generated from the rainfall of the June 2007 event at this location was 222 m^3/s (shown in **Figure B.8**, compared to the 100 year ARI design storm peak of 177 m^3/s and the 200 year ARI design peak of 200 m^3/s (both 9 hour duration). Thus, the RAFTS modelling at this location indicates the June 2007 storm may have been of event rarer than the 200 year ARI.

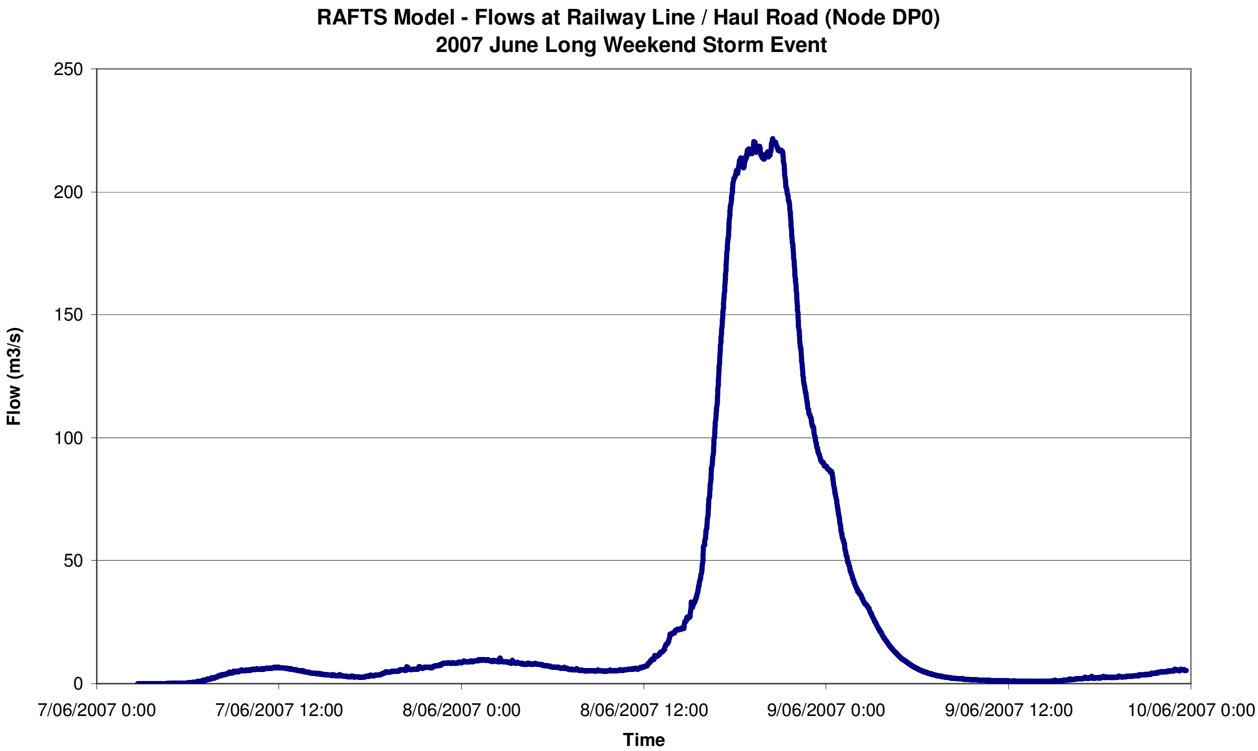


Figure B.8 RAFTS Node DP0 Flow Hydrograph for June 2007 Event

RAFTS Node S19 (refer to **Figure B.7**) at Awaba Road near Carleton Drain has a smaller contributing catchment area than Node DP0 but similarly indicates the June 2007 event was of recurrence interval greater than 200 years. The RAFTS peak 200 year ARI flow at this node is 3.66 m^3/s (for the 3 hour duration storm) compared to the RAFTS peak of 3.98 m^3/s for the June 2007 event.

These locations are effectively above the hydraulic model extent which commences at the Railway Line / Haul Road and includes an inflow node near Carleton Drain. This comparison is a guide only, and the hydraulic modelling results are likely to be different as the model takes account of storages and routing of the flows and covers the whole catchment downstream of these sites.

B.4 Hydraulic Modelling

The flow hydrographs for the June 2007 storm event generated by RAFTS and the Marmong Point water level time series was input into the SOBEK hydraulic model. The flood extent from the SOBEK model for the June 2007 event is shown in **Figure B.9**. Note that the inundation for Fennell Bay has been excluded for the figure for clarity.

For comparison purposes, the 100 year ARI and 200 year ARI extents as developed in the Stony Creek Flood Study (2005) are also shown on **Figure B.9**. These results indicate, similar to the RAFTS results described in Section 4, that the June 2007 storm was an event of around 100 year / 200 year ARI.

B.4.1 Verification to Surveyed Levels

Lake Macquarie City Council surveyed 17 flood-mark levels within the catchment following the June 2007 storm event. Exact locations of the surveyed points were not available, but the approximate position of the levels is shown in **Figure B.10**. These levels were used to verify the accuracy of the SOBEK modelling for this event. **Table B.6** lists the surveyed levels and the corresponding SOBEK modelled levels.

The majority of the SOBEK levels are within ±0.1m of the corresponding surveyed flood level (for 12 out of the 17 locations). Note that the location of the surveyed levels was not known exactly and thus some variation is expected.

The surveyed levels along Lake Street have a significant difference in levels (up to 0.27m). This amount of variation is attributed to anomalies from street drainage flooding as the modelled levels are expected to show a similar flood level along this creek reach. Note the representative peak level of the Lake was 1.14m AHD during the storm event. The SOBEK modelled levels showed reasonable agreement to the levels in the industrial area of Sara Street and Day Street which are downstream of Railway Parade. The two sites in the upstream area near May Street also showed reasonable agreement.

The surveyed levels on the upstream side of Railway Parade show some variation to the modelled levels. Reference sites 5, 6, and 7 show more variation than reference sites 3 and 4 which are situated further to the west. The calibration of the model to the 1981 flood event, detailed in the 2005 Flood Study, indicated similar over-estimation of flood levels in the model to the observed data. In this case it was presumed that this was due to errors in recollections for the observed data or changes to catchment conditions since 1981. The surveyed levels show a “step” in levels at Fennell Crescent not shown in the modelling for the 2007 event and 1981 event (eg points 3 and 4 compared to points 5 and 6). The model however shows a consistent flood level across this location. It is noted that point 7 is identified as “mark on top of fence” and thus may not represent the highest flood level.

The table shows the 50 year ARI SOBEK flood levels are generally within ±0.1m of the corresponding surveyed level at the sites (for 15 of the 17 cases). These results suggest that the June 2007 storm event is of 50 year recurrence interval. As the critical duration for peak flood levels from the SOBEK model within the areas of the surveyed sites is 36 hours, this is consistent with the results of the rainfall assessment indicating a recurrence interval of 50 year ARI for the 36 hour rainfall duration (refer to **Table B.3**).

B.4.2 Verification to June 2007 Questionnaire Responses

Responses from the questionnaire were mapped into three categories depending on the reported inundation to the individual property. The responses are shown in **Figure B.5** for the three classifications:

- Above-floor flooding;
- Flooding to yard; and
- No flooding experienced.

The distribution area for the community questionnaire covered an area larger than the extent of the SOBEK model to integrate responses from those residents near to the area but not necessarily within it.

Table B.6 June 2007 Storm Event Surveyed Flood Levels

Site	Address	Surveyed Level (m AHD)	SOBEK Level June07 (m AHD)	Diff (m) (Modelled to Surveyed)	SOBEK Level 50y ARI (m AHD)	Diff (m) (50y to Surveyed)
1	21 May Street	2.72	2.68	-0.04	2.61	-0.07
2	23 May Street	2.70	2.69	-0.01	2.62	-0.07
3	50 Fennell Crescent	2.00	2.02	0.02	1.99	-0.03
4	51 Fennell Crescent	1.96	2.05	0.09	2.01	-0.04
5	82 Fennell Crescent	1.74	1.97	0.23	1.93	-0.04
6	85 Fennell Crescent	1.81	1.95	0.14	1.91	-0.04
7	29 Thorne Street	1.66	1.91	0.25	1.86	-0.05
8	25 Sara Street	1.42	1.37	-0.05	1.37	0.00
9	11 Sara Street	1.30	1.33	0.03	1.35	0.02
10	27 Day Street	1.20	1.27	0.07	1.34	0.07
11	9 Venetia Avenue	1.30	1.18	-0.12	1.27	-0.03
12	23 Venetia Avenue	1.19	1.16	-0.03	1.27	0.08
13	35A Venetia Avenue	1.23	1.16	-0.07	1.27	0.04
14	57 Lake Street	1.23	1.18	-0.05	1.28	0.05
15	35 Lake Street	1.50	1.17	-0.33	1.28	-0.22
16	25 Lake Street	1.49	1.15	-0.34	1.27	-0.21
17	3 Lake Street	1.25	1.15	-0.10	1.26	0.01

A total of 114 responses have been received from residents within the SOBEK model extent. **Table B.7** lists the number of responses in each of the flooding classifications and the results for the same property based on the model results.

Table B.7 Questionnaire Responses of Flood Affectation

Classification	Received responses	Model results
Above floor flooding	6	5
Yard flooding	77	32
No flooding	31	63

The potential representativeness of the model to the received responses is listed in **Table B.8**.

Table B.8 Comparison of Modelled and Questionnaire Response

General condition	Number
Model shows worse flooding	2
Model shows less flooding	46
Similar result	57
No levels	9
Above-floor flood affectation	
Reported but not modelled	4
Modelled but not reported	4

Anecdotal responses of flood inundation from the questionnaire (detailed in the following section) were reviewed to assess the validity of the model results. Details of modelled flood levels are summarised in **Table B.9**. Reference is made to inundation of floors, as approximate depths in front and backyards are not readily verifiable due to the imprecise location that the depth was indicated and the potential variation of depth.

Within the community questionnaire there are some discrepancies to the extent of flooding reported. Respondents may have different interpretations for noting the varied degree of inundation to their property. For example, within the 'yard flooding' there may be instances of responses for inundation due to overland flow or localised ponding on the property which is not accounted for in the model which focuses on flooding from the main channels. This may be a contributing factor to the higher number of 'yard flooding' responses compared to the modelled results. The peak of the mainstream flooding may also occur at night when respondents are not monitoring inundation. It is noted that indications of flood extents, such as debris marks, would be evident after the event. Above-floor inundation is definitive evidence of the flood extent, however the floor level utilised in this assessment refers to the habitable floor level within the house and not to garages which may be at lower levels which may be reported as inundated by respondents. Redevelopment of some houses may also have occurred following the floor level survey which was undertaken for the Flood Study completed in 2005.

Responses may also vary for neighbouring properties particularly in regard to the flood inundation witnessed. Two examples are listed in **Table B.10**.

Table B.9 Selected June 2007 Storm Event Responses

Address	Inundation Response	House Floor Level (m AHD)	SOBEK Flood Level (m AHD)	Comment
South side of Stony Creek to Awaba Road				
3 Farrell Avenue	Yard inundated	2.16	1.98	Satisfactory as modelled water level below floor
2 Farrell Avenue	Not above floor level	1.86	1.96	High estimate
18 Blundell Parade	Garage flooded	2.5	1.98	Satisfactory as modelled water level below floor
8 Barry Avenue	Below floor level	2.57	2.01	Satisfactory as modelled water level below floor
2 Blundell Parade	Yard flooded	2.60	2.03	Satisfactory as modelled water level below floor
3 Galbraith Avenue	Shed under water	2.2	1.96	Satisfactory as modelled water level below floor
2 Galbraith Avenue	Below floor	2.2	1.96	Satisfactory as modelled water level below floor
1 William Street	Below floor	1.99	1.96	Satisfactory as modelled water level below floor
3 William Street	Below floor	2.83	1.96	Satisfactory as modelled water level below floor
Fennell Crescent – north side of Mudd Creek				
44 Fennell Crescent	Below floor	3.92	2.03	Satisfactory as modelled water level below floor
42 Fennell Crescent	Below floor (25mm)	2.18	2.10	Modelled level is slightly low
Fennell Crescent – between Stony Creek and Mudd Creek				
53 Fennell Crescent	Above floor	1.67	2.03	Satisfactory as modelled water level above floor

Address	Inundation Response	House Floor Level (m AHD)	SOBEK Flood Level (m AHD)	Comment
61 Fennell Crescent	Below floor	2.09	2.02	Satisfactory as modelled water level below floor
67 Fennell Crescent	Yard not flooded	2.46	2.0	Up to 0.6m depth modelled in yard. Modelled level is consistent with other responses.
69 Fennell Crescent	Above floor	2.33	1.99	Neighbours have lower floor levels and were not inundated. Modelled level is consistent with other responses.
79 Fennell Crescent	Below floor	2.42	1.97	Satisfactory as modelled water level below floor
83 Fennell Crescent	Yard flooded	2.81	1.98	Satisfactory as modelled water level below floor
91 Fennell Crescent	Below floor	2.01	1.97	Satisfactory as modelled water level below floor
82 Fennell Crescent	Below floor	1.95	1.97	Satisfactory as modelled level only slightly high
80 Fennell Crescent	Below floor	2.15	1.98	Satisfactory as modelled water level below floor
72 Fennell Crescent	Below floor	2.21	1.98	Satisfactory as modelled water level below floor
62 Fennell Crescent	Yard flooded	2.19	1.99	Satisfactory as modelled water level below floor

Table B.10 Differences in Responses for Neighbouring Properties

Questionnaire Response	Modelled Extent	Modelled Water Level (m AHD)	Surveyed Floor Level (m AHD)
Site 1			
"no flooding"	Yard flooding	2.03	2.33
"above-floor flooding"	Yard flooding	2.05	2.46
Site 2			
"no flooding"	Yard flooding	1.16	1.78
"above-floor flooding"	Yard flooding	1.18	1.78

The model therefore shows variations to flood inundation extents compared to the questionnaire responses but some variation is expected between the two sources. Accepting the flexibility of responses to the inundation classifications, the model results are considered to be representative.

B.4.3 Flood Event Timing

The duration of flooding is dependent on the individual's location within the catchment. However, a general flooding window of the afternoon of Friday 8th June to the morning of Sunday 10th June is presumed. Some respondents noted flooding starting on Thursday 7th or Friday morning, and others noted that the water had generally receded by Saturday morning (as described in **Section B.2**).

The time of the peak is also dependent on the location within the catchment and also the amount of times they observed the levels plus the time periods they observed it. A significant number of responses indicate a time between 10pm on Friday to 3am on Saturday. One respondent was taking regular measurements at their home and identified the peak as 1:45am on Saturday. A summary of peak times noted by residents categorised to position within the catchment is included in **Table B.11**. The Upper region is considered to be around Toronto Industrial Estate, Mid-catchment from the sewage treatment plant to around Fennell Crescent, and the Lower region as downstream of Railway Parade.

The timing of peaks from the model analysis are included in **Table B.12**. Generally, the peak of the flood event given by the SOBEK model occurs earlier than noted by residents.

Table B.11 Questionnaire Responses for Flood Peak

Street	Approximate Position in Catchment	Time Periods Noted
John Street	Upper	Fri 8/6 6:30PM
Sara Street	Upper	Level rising after 5:30PM Fri 8/6
Nicholson Street	Upper	Fri 8/6 9:30PM
High Street	Upper	Sat 9/6 3AM
Farrell Avenue	Mid-catchment	Fri 8/6 11:45PM to Sat 9/6 12:30AM
Fennell Crescent	Mid-catchment	Sat 9/6 1:45AM; also several responses ranging from 7:30PM Friday to 2AM Saturday
Adam Street	Mid-catchment	Friday 8/6 9PM to 10PM
William Street	Mid-catchment	Fri 8/6 11PM
Railway Parade	Mid-catchment	Fri 8/6 11PM to Sat 9/6 3AM
Lake Street	Lower	Sat 9/6 1AM to 10AM
Venetia Avenue	Lower	Fri 8/6 Midnight to Sat 9/6 4AM

In Fennell Crescent, the peak time indicated by the model is 9:45PM Friday compared to a resident's detailed measurements (every 15 minutes) reporting a time of 1:45AM Saturday. The change in flood depth between these two times in the model is about 0.45m (as a depth of 0.8m at 9:55PM and 0.35m at Saturday 1:45AM). The earlier peaks of the SOBEK model means that the peak water level in the Lake (based on the Marmong Point data) would be lower than the times reported by residents. The most specific peak times available are for Fennell Crescent, where the peak level time from SOBEK has a Lake water level of 0.81m compared to the level of 1.07m for 1:45AM on Saturday. In Lake Street, near Venetia Avenue, the SOBEK level peak around 10:45PM has a Lake level of 0.84m compared to the questionnaire response of around 2AM Saturday which has a Lake level of 0.99m. However, the peak flood level from the SOBEK model is about 1.3m AHD and the increase in Lake level would not necessarily result in an equal rise in the flood level.

Table B.12 Modelled Time for Flood Peak

Description	Location	Time of Peak
Peak rainfall depth (per minute rate)	N/A	Fri 8/6 5:19PM (majority of rainfall fell Fri 8/6 3:42PM to 9:42PM)
Peak overflows along Stony Creek	Upper - Toronto Industrial Estate (Margaretta Street)	Fri 8/6 9:15PM
Peak flood level in Fennell Crescent	Mid-catchment - Near 69 Fennell Crescent	Fri 8/6 9:45PM
Peak overflows along Stony Creek	Lower - Just downstream of Railway Parade	Fri 8/6 10:45PM
Peak level Lake Street	Lower - Near 89 Lake Street	Peak flood level shown on the Stony Creek side of properties between Fri 8/6 9:30PM to Sat 9/6 12:30AM. A lower level peak on the Edmunds Bay side occurs between 1:30AM and 7:00AM on Saturday.
Peak overflows along Stony Creek	Just upstream of outlet to Fennell Bay	Fri 8/6 11:25PM
Peak level of Level (at 1.14m AHD)	MHL gauge at Marmong Point	Sat 3:45AM (sharp rising of level from Fri 8/6 2:30PM)

These results suggest that the RAFTS model could have longer lag times incorporated in its reaches between nodes, however this would likely reduce the peak flows. This is due to the runoff from local sub-catchments peaking at around 6PM Friday (around the peak of the rainfall depth), but the peak flow in the creek occurring later and thus the co-incident flows would likely be lower. Changes to the flows would thus affect the flood levels which currently show reasonable correlation to the levels obtained from the 2007 June event.

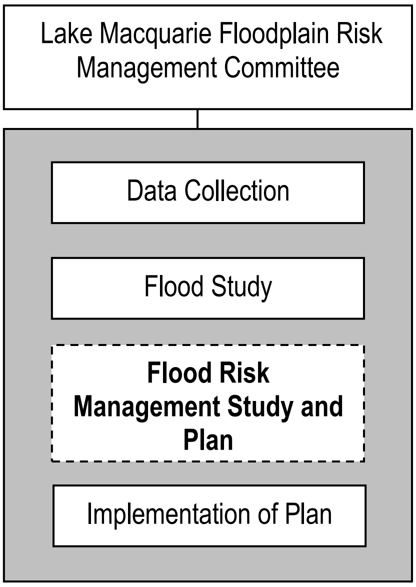
The maximum water level and peak depths for the June 2007 storm event are shown on **Figures B.11 and B.12** respectively. Flow depth profiles along Stony Creek and Mudd Creek are shown on **Figures B.13 and B.14** respectively.

B.5 Conclusion

The event of 7th-10th June 2007 is estimated as a storm of between 50 and 100 years average recurrence interval, and flood inundation was extensive within the catchment as reported in the responses to the community questionnaire. The SOBEK model used to define flood inundation for the catchment was verified as suitably representative of this event based on the community responses and the surveyed locations.

STONY CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

QUESTIONNAIRE : JUNE LONG WEEKEND STORM/FLOOD EVENT, 2007



As you may be aware, Cardno Lawson Treloar is conducting a Floodplain Risk Management Study and Plan for Stony Creek on behalf of Lake Macquarie City Council. This project forms one of the stages in the floodplain management process, and follows the completion of the Flood Study (see flowchart). The purpose of the Risk Management Study and Plan is to identify and assess flood hazard within the Stony Creek catchment, and examine various options to manage that flood hazard.

As part of the Floodplain Risk Management Study, a questionnaire was distributed to residents in April 2007 to assess the community's preferred methods of flood mitigation. Cardno Lawson Treloar and Lake Macquarie City Council would like to thank those who responded; your comments have been summarised and will be incorporated into the final report.

A significant flood event occurred on Thursday 7th to Sunday 10th June, 2007 in the Lake Macquarie area. Considering the magnitude of the event, it is necessary that the mathematical model of the floodplain developed in the Flood Study is verified against the observed flood behaviour of this event. This would provide further confidence in the outcomes of the Flood Study and subsequent stages of the floodplain management process. The mathematical model is used to predict future flood events, and assess flood mitigation options, so its accuracy is a priority.

The aim of this questionnaire is to gather information on the 2007 June long weekend storm/flood event (ie. 7-10th June). You may have witnessed the storm and/or the associated floods, which is vital information for verification purposes.

Please answer the following questions as best as you can. Please return these pages in the enclosed "reply paid" envelope by the 13th October 2007. **YOUR PERSONAL INFORMATION WILL REMAIN COMPLETELY CONFIDENTIAL**. A map is attached showing the study area of the project.

If you have any queries, please contact:

Greg Jones – LAKE MACQUARIE CITY COUNCIL Ph: 02 4291 0406 Email: gdjones@lakemac.nsw.gov.au
Andrew Reid – CARDNO LAWSON TRELOAR Ph: 02 9499 3000 Email: andrew.reid@cardno.com.au

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Question 1
Please provide us with the following details. We may wish to contact you to discuss the information you supply.

Name: ……………………………………………………… Daytime Ph: ……………………………………….

Address: ………………………………………………… Email:……………………………………………….

…………………………………………………………….

…………………………………………………………….

Question 2
How long have you lived in this locality?

…………….Months …………….Years

Question 3
Did you experience the June long weekend storm/flood event (ie. 7-10th June)?

…………….YES ……………NO

If YES, how were you affected by the storm/flood event? (*You may tick more than one*)

………… We were without electricity
………… Our house/property was flooded
………… We were frightened
………… We could not travel very easily/access was affected
………… Our belongings were damaged (*please give details and approximate value of any flood damages*)
……
……
………… Other (*please give details*)
……
……

Question 4
If any, what type of areas did you see flooded, and how deep was the water? (*Please also mark specific locations on the map that is attached*)

Location	Flooding Present? (*Please tick*) YES	NO	Approximate Depth of Flooding
Parks	…………	…………	…………………………..
Roads	…………	…………	…………………………..
Residential (backyard)	…………	…………	…………………………..
Residential (front yard)	…………	…………	…………………………..
Residential (above floor level)	…………	…………	…………………………..
Residential (below floor level)	…………	…………	…………………………..
Commercial (eg. shops) (above floor level)	…………	…………	…………………………..
Commercial (below floor level)	…………	…………	…………………………..
Industrial (eg. factories)	…………	…………	…………………………..

Question 5
Did you notice any bridges and/or culverts to be blocked during the event?

…………….YES ……………NO

If YES, please provide details (please mark the location on the map if possible), and how blocked would you say it was? (eg. 50% blocked, 80% blocked)

……
……….

If YES, what was causing the blockage? (eg. woody debris, shopping trolley, vehicle)

……
……

Question 6
What would you say was the duration of the flooding? (*If you can, please give a time and date eg. 10am Thursday 7th June to 12pm Sunday 10th June*)
………
………..

Question 7
When would you say was the peak of the flood (ie. the flood water reached its maximum depth)? (*If you can, please give a time and date eg. 11am Saturday 9th June*)
………
………..

Question 8
Do you have any information (such as observations, photos, videos, flood marks) regarding the June long weekend storm/flood event (any records from 7-11th June)?

……………YES ……………NO

If YES, please give as much detail as possible:
………
………
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………
………

If there is any additional information regarding the June long weekend storm/flood event (7-10th June), please include it in the space below:
………
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Thank you for providing the above information. Please remember to put it back in the reply paid envelope. A representative from Cardno Lawson Treloar may contact you in the near future to discuss your response.

N
E
S
W
Study Area
Fennel Bay
Railway
STP
Railway Pde
Mudd Creek
Stony Creek
Awaba Road

Survey Ref. No	Q1 Street	Q1 Suburb	Q2 Years at Address	Q3 Experience Flooding Y/N	Q3 How were you affected: We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Q4 Flooding present/depth of flooding: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Q4 Approximate Depth: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Q5 Bridges / culverts blocked	How blocked	What caused blockage	Q6 Duration of Flooding	Q 7 Peak of Flood	Q8 Any records of flood	Details	Additional Information
1	Adam St	Blackalls Park	26	Y	Y	Y	Y	Y	Y	In our garage the mower & whippersnipper were underwater. A storage box containing books was destroyed. Our hot water heater was partly submerged, our septic tanks were rendered inoperable	N	Y	Y	Y	Y	N	N	N	N		hip deep	hip deep	hip deep	neighbours homes under. our home to floorboards					No - unable to leave home to see any of this			June 8 7pm to ealry hours following day (Saturday)	10pm 8 June (Friday)	Y	People driving their 4 wheel drives flooded homes with water from the flood waters (even though told by SES to stay away). Some families had to evacuate because their homes were flooded.	Because we were without power for 2.5 days we were unable to pump out our septic tanks which had overflowed because of stormwater. Because of this we could not flush our toilet or take showers.
2	Awaba Rd	Toronto West	34	Y	Y	N	Y	N	N	Backyard & frontyard above level, above the lawn	N	N	Y	Y	N	N	N	N	N										N					N		We were without electricity for three days (7-10 June). There was a tree on the rods was holding up the traffic on Awaba Rd going to Tornonr. The rain was very heavy that night.
3	Beckley St	Toronto	14	Y	Y	Y	Y	Y	N		N	Y	N	Y	N	Y	N	N	N										Y	Flood	Flood water reached its maximum depth		Friday 5pm	N		
4	Railway Pde	Blackalls Park	22	Y	Y	Y	N	Y	Y	Our belongong were damaged - $3000 worth. I found it very difficult to get home from work	Y	Y	Y	N	N	N	Y	Y	N	1M	2M	1M				1M	1M		Y	90% blocked	Water, woody debris	Friday afternoon to Sunday	Friday evening/early hours Sat morning	Y	All areas were impossible to pass through. James St Toronto near Toronto Workers Club. Stony Creek bridge was passable, Mudd Creek brigde & all areas surrounding this was impossible only 4 wheel drives were able to pass through. The force of the water made it impossible to wade through.	Mudd Creek needs to be dredged properly. It was supposedly dredged previously but I feel this was not carried out sufficiently to allow water to flow easily into Edmonds Bay & Fennell Bay. Edmonds Bay needs further dredging as it is sitting up aswell. Mudd Creek bridge on Railway Pde should be lifted to allow water to flow through - this may have caused the water to back up increasing the flood areas.
5	Rupert St	Blackalls Park	24	Y	N	Y	N	Y	N	Our house/property was flooded not from flood rain, but blocked drains	Y	Y	Y	Y	N	N	Y	N	Y	0.5M	1M	1M	0.5M					1M	Y	50%	Woody debris, rubbish	2:30pm Fridy 8 June to 12pm Sunday 10 June	Midnight Friday 8 June	Y	I had to drive to Toronto at about 5pm on Friday. I noticed major flooding along James St, Toronto, parts of Railway Pde, Fennel Cres & Adam St. As soon as the heavy rain stopped the flooding dissapated very soon after. I was surprised at the moment of flooding around the Toronto Workers Club & surrounds, this seemed to happen exceedingly fast.	
6	Lake St	Blackalls Park	7	Y	Y	N	Y	Y	N	Our house was not flooded - front garden, driveway & road was - all were underwater. Driveway between 7 & 9 was underwater	Y	Y	N	Y	N	N	N	N	N	05.M	0.5M		Slopes so varied depths						N			Started Friday morning until Sunday morning	Early Saturday morning	N		It was a worry * inconveient without power but appreciated the ABC's courage so we knew what was happening (thanks to having a bettery operated radio). However we realised we were lucky compared to others who fared so much worse than we did & congratulations to the efforts of the SES, electricity workers & a;; who volunteered their services to help others.
7	Newbiggin Way	Toronto	9	Y	Y	N	Y	N	N		N	N	Y	Y	Y	N	N	N	N										Y	50% to 80%	Woody debris	Friday 8 June to Saturday 9 June		N		Milford Rd was flooded, cars couldn't go through because of flooding from culvert & the water was washing all the debris over the footpath impossible to walk down Milford Rd. Very bad flooding in Nelmes Cl homes flooded inside No17 very badly afected, No 15, 17 & 19 were all damaged. Fences blown down as the flood water & the wind gales first took all the fences down.
8	Railway Pde	Blackalls Park	8	Y	Y	N	Y	Y	N	It took us 4 hours to get home from the Junction	Y	Y	Y	N	N	Y	N	N	N	1M	1M	1M			1M				Y	The viaduct at Fassi Station	Could not see in the pitch dark & torrential rain, I thought the water could simply not get away quickly enough.	The flood water was in our yard for several days	In our backyard I think Saturday afternoon	Y	A photo of the flood water in our backyard	I would like to add that the floo water in our yard smelled foul, & that it left behind a thick sticky sludge which is still damp
9	Lake St	Blackalls Park		Y	Y	N	N	Y	N		N	Y	N	N	N	N	N	N	N		1M								N			Friday am to Sunday pm	The level didn't change from Friday to Sunday	N		
10	Lake St	Blackalls Park	6	Y	Y	Y	Y	Y	Y	pot plants floated away as well as kids yard toys & balls. Lawn mower, whippersnipper, blower vac, drills deep freezer, washing machine were in garden shed and all water damaged, not working. The cost is ongoing to try to fix these things & replace toys, now about $2000	N	Y	Y	Y	N	Y	N	N	N		1-2FEET	2-3FEET	0.5FOOT		2-3FEET				Y	80-100%	Debris	My property was flooded from 5pm Fri to 10pm Sunday. My street was flooded from 6-7pm Fri to Sunday am.	Saturday 3-4pm	Y	Video footage of my yard, nextdoors yard & Lake St at front of my house. Photo's of Lake St & my yard.	My observation in 6.5 years living in Lake St is that only once in May 2001 after a week of rain did my yard get flooded & it was only half way up my yard & not very deep (from Edmonds Bay). Stony Creek never broke the banks at that time. Since the rock wall was built on Stoney Creek the water has come up over the bank many times after alot of rain. Almost to the road. The June flood only took 1 day of rain to break the banks of Stoney Creek.
11	Railway Pde	Blackalls Park	5	Y	Y	Y	N	N	N		N	Y	Y	Y	N	N	N	N	N		60CM	60CM	60CM						Y	80%	Plastic bags, McDonald containers	Backyard partially flooded June 8-11	11 & 12 June	Y	Photos & observation	
12	Sunderland Rd	Toronto	11	Y	N	Y	N	Y	Y	Fences fell down, $1000 costs	Y	Y	Y	Y	N	N	N	N	N	1-2M	1-2M	12INCHES	12INCHES						Y	80%	Water	4:30 to 7pm Friday	7-8 Friday	N		

Survey	Q1		Q2	Q3							Q4																		Q5			Q6	Q7	Q8		
					How were you affected						Flooding present/depth of flooding									Approximate Depth																
Ref. No	Street	Suburb	Years at Address	Experience Flooding Y/N	We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Bridges / culverts blocked	How blocked	What caused blockage	Duration of Flooding	Peak of Flood	Any records of flood	Details	Additional Information
13	Ingal St	Toronto	35	Y	Y	N	N	Y	N	Tree branches blown down-big enough to cause real damage. I worked 4 days in a nursing home without power.	N	Y	Y	Y	N	N	N	N	N			CHEST HEIGHT	WAIST HEIGHT									1-2 days on roads		N		
14	Thorne St	Toronto	60	Y	Y	N	N	N	N																				N					N		As we live on the high side of Thorne St we had no trouble other than the electricity off for 4 days & the water ran through our garage, as it does in any heavy rain. We know it flooded on the corner of James & Cook Sts as it always does in heavy rain.
15	Awaba Rd	Toronto	10	Y	N	Y	N	Y	Y	carpets, timber furniture was damaged, fridge. Water flows across Awaba Rd from Glenfield Rd down onto our property.	Y	Y	Y	Y	Y	Y	Y	Y	Y	1M	1M	1.2M	1.2M	30CM	40CM				Y	Bridge near workers club. Open drain Awaba Rd. Park. JR Hill Oval. High School,.	Workers club is so low it floods when Stoney Creek breaks its banks. 1981 we were flooed out & so was workers club.	24hours	7pm	N		I have seen plans at workers club for retirment home & other development. If these go ahead land will be built up & will cause more flooding as I have seen the land flooded * club building with water in building in 1981 & 2007. The land at workers blub should never be built on.
16	Fennell Cres	Blackalls Park	50	Y	Y	Y	N	Y	Y		N	Y	Y	N	N	N	N	N	N		1M	1M							N			4 days	midnight			
17	Nelmes Cl	Toronto	8	Y	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		We were not affected but neighbours up the cul de sac were.
18	The Boulevard	Toronto	9	Y	Y	N	N	N	N		Y	N	N	N	N	N	N	N	N	150MM									N			6pm Friday to 10am Sunday	Unsure	N		
19	Fennell Cres	Blackalls Park	48	Y	Y	Y	Y	N	N		N	Y	Y	N	N	N	N	N	N			5INCHES							N			1:40am Friday, subsided by 8am Saturday	2am Friday	N		
20	Fennell Cres	Blackalls Park	54	Y	N	N	Y	Y	N		Y	Y	Y	Y	Y	Y	N	N	N										Y	Areas shown in green on map are trouble spots	Narrowing of natural flow of Mudd Creek & Stoney Creek causing extreme siltation	Due to slow rush off in excess of 24 hours				Many years ago I sighted an old Parish map showing a confluence of Mudd Creek with Stoney Creek (shown in green on map). After the sewage treatment works was established I believe that this junction was blocked off to provide a convenient outflow of excess effluent from the treatment works & causing major siltation. A small culvert at Stoney Creek later at this point is ineffectual. Mudd Creek was further degraded by a shallow concrete culvert at Fennell St thus impeding natural flow. Similarly further narrowing at Railway Pde to facilitate a road brudge again narrows Mudd Creek. Edmunds Bay is badly silted as well, impeding effective runoff of floodwater. Sewage from STP now piped to Ocean outfall. Most previous siltation remains.
21	Fennell Cres	Blackalls Park	18	Y	Y	N	N	Y	Y	$6700 to freezer, fridge, sound system, mower, etc	N	Y	Y	Y	N	N	N	N	N			House Side had 250mm, 1340mm at creek edge							Y	Couldn't see bridge at all over Mudd Creek		Friday & Sat	7:30pm Friday	Y		The flood came in two peaks. The first was the high one, the second was 240ml lower as witnessed by the tidemarks they left. Whilst trying to save chickens we waded through water at 5pm up to our knees & was very brown & smelled like treatment works
22	Farrell Ave	Toronto	7	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N																	My yard was inundated, nothing was damaged as my garage had been demolished & its replacement has yet to be built, & when I extended my house I added on at the floor level & not onto a slab. Neighbours had problems because their garages & extensions were on concrete slabs. Mine & two neighbours yards are regularly inundated when there is heavy rain-our yards are below street level & there is no runoff-we just wait for the watertable and go down again.
23	Galbraith Ave	Toronto		Y	Y	N	N	Y	N		Y	Y	Y	N	N	N	N	N	N	200MM	200MM	200MM							N			Friday 8th June to Saturday 9th June (not sure of time flooding subsided)	Friday 8th June 8pm	Y	We have photos of the flooding of the backyard of the people close to the creek near our house-the flooding softened the groung & caused the tree to fall on their house. We also have photos of the flooding of the park & road near the Toronto Workers Club.	
24	William St	Toronto	10	Y	Y	Y	Y	Y	Y	About $1200 worth of contents damage. Tree fell on house, possile pier damage. Water pipe busted, soil & gardens washed away or damaged.	Y	Y	Y	Y	N	Y	N	N	N	3-4FEET	3-4FEET	3-4FEET	3-4FEET		3-4FEET				Y	Bridge over Stoney Creek about 80% mainly due to the useless rail bridge that is still there, it was still very blocked the next afternoon.	Mainly woody debris, although there are some other items of debris in the creek.	Flood started Friday night on sunset until about Sunday afternoon.	Water level peaked about 11pm Friday. Water at our place reached our floor level. About 3-4 feet deep.	Y	We have many photos & flood marks around our residence.	In my opinion, the drains around Stoney Creek need cleaning out. The old rail bridge needs to be taken away as there was a lot of debris built up against it. Therefore not allowing the water to get away. Also the mouth of the creek needs to be widened & dredged deeper to allow water to get awat quicker.

	Q1		Q2	Q3							Q4																		Q5			Q6	Q 7	Q8		
Survey	Street	Suburb	Years at	Experience	How were you affected						Flooding present/depth of flooding									Approximate Depth									Bridges / culverts blocked	How blocked	What caused blockage	Duration of Flooding	Peak of Flood	Any records of flood	Details	Additional Information
Ref. No			Address	Flooding Y/N	We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial								
25	Awaba Rd	Toronto	15	Y	N	Y	Y	N	Y	Water & mud through our shed. Side gate damaged.	N	Y	Y	N	Y	N	N	N	N		200MM								N			During the night with a torrential runoff from Awaba Rd	8am Saturday	N		Our residence is on northern side of Awaba Rd & it would have been a huge help if the road had kerbing & guttering which is way overdue, from Catalina Motel towards town, linked with existing kerb & guttering there. The flooidng only washed out potholes on side of road & made the edges even more sharp & rough. The water from some of the properties ran through & flooded the high school grounds.
26	Anzac Pde	Toronto	40	Y	Y	Y	Y	N	N	Only 3 feet of carpet in loungeroom which ive soken up with towels & dried out with heaters	Y	Y	Y	Y	N	N	N	N	N										Y	100% blocked, this drain has been a continual headache to neighbours , it overflowed from No15 across 13 under our fence into the airvents, in brickwork & all along loungeroom wall.	Runoff from main road. The property at No19 Anzac Pde. The backyard was like a swimming pool at least 2feet deep on Saturday & Sunday. Stoney Creek came up to our back fence, the track to creek was about 2feet deep.	Not sure	The day it started, only just got out of workers club, water up to bonnet of car, flooded Anzac Pde.	N	The water was up to wheels of caravan at xxxx, this water flooded across & under our fence. This Council drain only goes to back fence. It is always a problem.	
27	Venetia Ave	Blackalls Park	5	Y	Y	Y	N	Y	N		N	Y	N	Y	N	N	N	N	N		20-30cm								Y	80% blocked	Debris, shopping trolleys, poor outlet to Edmunds Bay	Friday night rising until about midnight , dropping Saturday gradually during the morning	Midnight Friday to 4am Saturday	Y	I have photos on Sat morning from about 9-10am, it shows levels of where debris were deposited on edge of block, etc	On Sat morning, water on the road from xxxx to end of street about 30cm deep. No11 had some water in front fence to about 20 metres (shallow)-cms only. xxxx has water to front gate. No 15 onwards had water front to bay. Mudd Creek needs to have all the debris & tree branches which are growing into it removed. It needs to be opened up-dug deeper from the bridge on the main road to the mouth on Edmunds Bay-this could be done in the majority with a mchine working from the side of the road in Venetia Ave.
28	Lake St	Blackalls Park	10	Y	Y	N	Y	Y	N	Disabled & confined to a wheelchair, my concern was rising water levels & entrapment.	Y	Y	Y	Y	N	N	N	N	N										Y	100%-all of Lake St	Debris	3 days		Y	Photos	
29	Park Ave	Blackalls Park	44	Y	Y	N	N	N	Y	$200 food lost (without power)	Y	N	N	N	N	N	N	N	N										N					N		I only drove to a nearby neighbour who had power still on to shower & have a meal. Used candles for a little light therefore I didn't see much of the flooding etc until it was over.
30	Nelmes Cl	Toronto	8	Y	N	N	Y	N	N		N	N	Y	N	N	N	N	N	N										N			Friday 6pm-8pm	Friday about 7pm	N		
31	Railway Pde	Blackalls Park	12	Y	Y	Y	N	N	Y	Contents of storage shed e.g. lawn mower, welders, tools, etc - $5500	Y	Y	Y	N	N	Y	N	N	N	1m	1m	700mm			700mm				N			8:30pm Friday to Saturday	11pm Friday	Y	Photos, flood mark on retaining wall	
32	Fennell Cres	Blackalls Park	11	Y	Y	Y	N	Y	Y	Because we have a highset house it affected the laundry, shed, cars & whatever was kept or stored under the house. We claimed $1500 but lost a lot more of setimental not monetary value, The cars were awash to the bottom of the seats but not enough to maker a claim.	Y	Y	Y	Y	N	Y	N	N	N	1m	1m	70cm	70cm-1m		50-70cm				N			Friday 7pm to Sat 3pm	Sat 12:30am	Y	Photos, flood marks	
33	Adam St	Blackalls Park		Y	Y	Y	N	Y	Y	Garden tools kept in the yard were damaged. We only lost a lownmower & leaf blower valued at about $400. We had to clean up & bag a lot of debris, leaf little, paper, etc	Y	Y	Y	Y	N	Y	N	N	N	1m	50cm	1m	50cm		10-15cm				N			Yard flooded from 7:30pm Friday to 5pm Saturday. Mudd Creek banks broken from 4pm Friday until approx 4am Monday	Between 9pm & 10pm Friday	Y	I have photos from Friday (around 9am) to Saturday am of flooding in & around my property	We live on Mudd Creek but flooding appeared to originate from the bottom of Adam St (around the Fennell St intersection). Even though the water level in Mudd Creek was rising, the major flooding came from Adam St & flowed down our driveway into Mudd Creek. Water levels rose very suddenly around 7pm Friday. We live in a block of villas. Once Adam St flooded, our units driveway seemed to be an escape route for the water. Flooding seemed ti stop at our driveway as Railway Pde seemed unaffected.
34	John St	Blackalls Park	4	Y	N	N	N	N	N	Took a couple of weeks to tidy up our backyard, no loss of any services	Y	N	N	N	N	N	N	N	N	1.1m									N			10am Thursday to 12pm Sunday		N		
35	Railway Pde	Blackalls Park	54	Y	Y	N	N	Y	N		Y	Y	Y	N	N	N	N	N	N	800mm	800mm	800mm							N			Thrusday to Tuesday	Friday night to late Saturday	N		
36	Nelmes Cl	Toronto		Y	N	Y	N	N	Y	Carpets, timber flooring, items of furniture & personal colelctables & bedding, books paintaings etc stored in garage. Sewing machine, whippersnipper, $17-18K	N	Y	Y	Y	Y	N	N	N	N		ankle deep	ankle deep	ankle deep	below ankle deep					Y	Drain at end of street 100% blocked	Wood, leaves, & rubber car mat	Friday approx 6:30pm-7pm		N		Nelmes Cl has a severe lack of street drainage in our side of the road.
37	Galbraith Ave	Toronto	30	Y	Y	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		Being without electricity for over 36hours was a problem.

	Q1		Q2	Q3							Q4																		Q5			Q6	Q 7	Q8		
Survey	Street	Suburb	Years at Address	Experience Flooding Y/N	How were you affected						Flooding present/depth of flooding									Approximate Depth									Bridges / culverts blocked	How blocked	What caused blockage	Duration of Flooding	Peak of Flood	Any records of flood	Details	Additional Information
Ref. No					We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial								
38	Beckley St	Toronto	18	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	N	N	N	N	N	1m	1.3m	0.4m	0.4m						Y	80% blocked	Woody debris, fence panel from Biraban School	12pm Friday to Saturday 2am	5:30pm Friday	Y	Peak of the flooding occurred approx 5:30pm when over 1m of water was over the Beckley St intersection. Half a dozen cars had been submerged & the unnamed stream that flows under Carlton St had become 500m wide & flowing along Awaba Rd. This lasted until approx 6:30pm Friday.	
39	Railway Pde	Blackalls Park		Y	Y	Y	Y	N	N	Silt & salt in backyard-gardens & shed affected. Lawn covered with slime	N	Y	Y	Y	N	N	N	N	N		0.5m	0.5m	0.5m						N			Can't recall	Can't recall	Y	Photos-took before & after of backyard showing flooding	
40	Akora St	Toronto	13	Y	Y	N	N	N	N		Y	N	N	N	N	N	N	N	N	300mm									N			No idea	No idea	N		
41	The Boulevard	Toronto	70	Y	Y	N	Y	Y	N		Y	Y	Y	Y	Y	N	N	N	N										Y	80% blocked	Wood debris	Friday overnight, then as water subsided late Saturday	Friday midnight	N		The usual areas were blocked as with all previous floods the Stoney Creek/Lake St area. Blackalls Park was marooned by 8pm on Friday. This area being inaccessible creates undue stress as we are both elderly & rely on family who live in Blackalls Park for assistance.
42	William St	Toronto	23	Y	Y	Y	N	Y	Y	Lawnmower - $400	Y	Y	Y	Y	N	Y	N	N	N	500mm-1m	500mm	400mm	500mm		1m				Y	Railway Bridge	Woody debris	Friday stormwater 7pm & high tide 11pm peak. Water in yard all night.	11pm Friday	Y	Peak flood marks on shed & bird avaries. Some photos	
43	Anzac Pde	Toronto	4	Y	Y	Y	N	N	Y	Wind damage to verandah blinds, slight fence damage.	Y	Y	N	Y	N	N	N	N	N	50cm	30cm		1m						N			Midnight Sat to midday Sat	3am Sat	Y	Photo of water in Lions Park & over roadway. Photo of lake water 3m into yard.	
44	Railway Pde	Blackalls Park	50	Y	Y	N	N	N	N		Y	N	Y	N	N	N	N	N	N										Y	The easement which is now part of our property, caused minor flooding due to the sheer volume of water	I do not believe that there was any real blockage persay	Friday onward-but recovery came when the rain eased.	Sat morning	N	I do not believe that conditions were any worse than other events that have occurred over the past 50 years-however the volume of water being directed into the drainage system has obviously increased greatly (due to the increasing number of homes)	We owe a debt of gratitude to some of our neighbours who were able to assist us during the extensuece blackout of electricity which we expereinced (from early Friday 8 until 5:20pm Tuesday
45	Barry Ave	Toronto	1	Y	Y	N	Y	Y	N		Y	Y	Y	N	N	Y	N	N	N	300mm	500mm	300mm			300mm				N			12pm Sat to 12pm Sun	1am Sun	N		
46	Oak St	Toronto	30	Y	N	N	N	Y	N	We has access to local shopping area, but had to travel to Maitland for my husban to have a chest scan because Hunter Imaging was flooded at Toronto & Cardiff.	N	N	N	N	N	N	N	N	N										N							
47	Lake St	Blackalls Park	12	Y	Y	N	N	Y	N		N	Y	N	Y	Y	N	N	N	N										N			Friday front yard only	2am Friday	Y	Photos taken on Friday	
48	Thorne St	Toronto	10	Y	Y	N	N	N	N	Footpaths & gutters overflowing	Y	N	N	Y	N	N	N	N	N	2.5m			35cm						N				Was quite deep at 4pm Friday afternoon	N		
49	Railway Pde	Blackalls Park	81	Y	Y	N	N	N	Y	Window in garage broken. Frozen foods spoilt due to loss of electricity for 4.5 days.	N	Y	Y	Y	N	Y	N	N	N										N			4-5 days, Friday night to Tuesday		N		
50	Fennell Cres	Blackalls Park	43	N	N	N	N	N	N		Y	Y	N	N	N	N	N	N	N										Y	80%	debris			N		
51	Fennell Cres	Blackalls Park	44	Y	Y	N	Y	N	N		N	N	Y	Y	N	N	N	N	N										N			Friday				
52	Ingar Cl	Toronto	12	Y	Y	N	N	Y	N	Large gum tree in frontyard fell over, taking down power lines, no power for 6 days	Y	Y	N	N	N	N	N	N	N	6-8inches	6-10inches								N			Friday 6pm		N		The water was flowing like a river from every street going onto Milford, from Awaba Rd
53	The Boulevard	Toronto	43	Y	Y	N	N	N	N		Y	Y	N	N	N	N	N	N	N	50cm	50cm								N			5pm Friday to 10am Saturday	11pm Friday	N		
54	Railway Pde	Blackalls Park	1	N	Y	N	N	N	N		N	N	Y	N	N	N	N	N	N			1.5m							N					Y	Debris & water stain on fence 1.5m above normal creek level. Water had mostly receded by time we arrived home from vacation. Talked with neighbour who was home during event & discussed his observations in that time.	
55	Railway Pde	Blackalls Park	3	Y	Y	N	N	Y	Y	Minor (freezer was out for 3 days) Boat engine was covered in water.	N	Y	Y	N	N	N	N	N	N		900mm	8m							Y	Mudd Creek under Railway Pde was 80% blocked & the railway line	Mostly broken trees & garden furniture			Y	The highest part of the flood in Mudd Creek is still visible on wire fencing.	
56	Fennell Cres	Blackalls Park	9	Y	Y	Y	N	Y	Y	$2500 in garage stuff, also pool was filled with dirty water	Y	Y	Y	Y	N	N	N	N	N	2ft	2-3ft	2ft	2ft						N			My property was starting to flood around 4pm Friday, water kept rising till around 11pm when we took our tinny and got out.	11-12pm Friday	N		I live in a flood zone, yet other areas not considered flood zones were affected a lot more than I was.
57	Galbraith Ave	Toronto	50	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N		Debris in Creek			N		

Q1			Q2	Q3							Q4																		Q5			Q6	Q7	Q8		
Survey	Street	Suburb	Years at Address	Experience Flooding	How were you affected						Flooding present/depth of flooding									Approximate Depth									Bridges / culverts blocked	How blocked	What caused blockage	Duration of Flooding	Peak of Flood	Any records of flood	Details	Additional Information
Ref. No				Y/N	We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial								
58	High St	Toronto	4	Y	Y	N	N	Y	N		N	N	N	N	N	N	N	N	Y									30cm	N			Midnight Friday to 6am Saturday	3am Saturday	Y	The water came up to our premises along High St from the creek during the night of Friday/am Saturday. Our business was not flooded but businesses across the road were.	
59	Farrell Ave	Toronto	31	Y	Y	Y	Y	Y	Y	2 cars - Mazda 3 $29500, Commodore Exce $18500. Sunroom furniture, Tv etc $5000, Frozen food spoilt	Y	Y	Y	Y	N	Y	N	N	N	700mm	700mm	700mm	400mm		400mm				Y	80%	Wetland next door was blocked with reeds, tress etc	Couldn't get home until after 10:30pm Friday. Too late flooding already started.	Friday 11:45pm 12:30am	Y	Photos on my computer. Also had mud & tree branch in driveway under 2 cars 200-300mm	Had no power for up to 3 days, relied on our neighbour for hot water.
60	Beckley St	Toronto	44	Y	Y	N	N	N	N		N	Y	N	N	N	N	N	N	N										N			Friday 10pm		N		The playground on Biriban Scool was under about 1ft of water on Sat. The water went away pretty quickly when it stopped raining.
61	Awaba Rd	Toronto	6	Y	Y	N	N	Y	N	I found it difficult to get transport out of Toronto to Sydney	Y	Y	N	N	N	N	N	N	N										N			9am Friday				
62	Blundell Pde	Toronto	4	Y	Y	N	N	Y	Y	$1,200	Y	Y	Y	Y	N	N	N	N	N										Y	80%	Water running so fast in draining kerbs, couldn't get away.	9pm Friday, streets flooded- 1ft high		N		No electricity from Friday to Sunday late afternoon. The river opposite me flooded to the roadside & along Blundell Pde & Farrell Rd. Our garage was flooded.
63	Cary St	Toronto	55	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N							We live at xxxx Harris St Toronto & business at xxxx Gary St Toronto. These sites were not affected.
64	Nicholson St	Toronto West	7	Y	Y	Y	Y	Y			N	Y	N	N	N	N	N	Y	Y		1M								N			9:30pm Thursday to 12am Sunday	Friday 9:30pm	N		The water was running down Nicholson St - 1m deep & this water was coming over the bank at the end of Nicholson St - it was about 1m deep.
65	Awaba Rd	Toronto	5	Y	Y	Y	N	N	N	Unable to cook or bathe at home for this time & had to rely on friends. Not able to get to shops.	Y	Y	Y	Y	N	N	N	N	N	6inches	12inches	6inches	4inches						Y	Buildup of rubbish & debris at bridges & culverts not allowing 50% of water to get away.	Rubbish & woody debris	Friday 3pm to Saturday 1pm	Saturday 8am	N		Apart from the flooding, the inconvenience of no electricity from Friday night until Sunday afternoon & the loss of some food & not being prepared for this type of situation has now made me realise to be preapred for any future catastrophe
66	Awaba Rd	Toronto	17	Y	Y	N	N	N	N		Y	Y	Y	N	N	N	N	N	N										Y			20hours	back fence	N		
67	Railway Pde	Blackalls Park	6	Y	Y	N	Y	N	N		N	N	N	N	N	N	N	N	N										Y	30% blocked	Woody debris	8:30pm Thursday to 12pm Sunday	10am Saturday	N		
68	Sara St	Toronto	6	Y	N	N	N	Y	N		Y	Y	N	N	N	N	N	N	Y										N			3pm Friday to late Saturday.	Late Friday night. I left the workshop at approx 5:30pm Friday as the water level was rising.	Y	As in Q6-7 I left the workshop on Friday at approx 5:30pm as the roads were being covered in water & returned at Approx 11am Saturday to see what the situtation with the workshop was. The creek level was at the road.	
69	Awaba Rd	Toronto	7	Y	N	Y	N	N	Y	Garden beds & compost washed away, mower & tools, bags of fertiliser lost & damaged. Damage similar to this was caused & claim for damages was paid in March 06.	N	N	Y	N	N	Y	N	N	N			60cm			20cm				N			Approx 3 hours, 11pm-2am Saturday	11pm Saturday	Y	See claim for damage in March 2006, Council should have photos, if not I have copies. Drain at rear of our house causes water to backup in our yard.	
70	Awaba Rd	Toronto		N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		At the time of the flood I was living at xxxx Fenton Ave. We were not affected by the flood. However my daughter who lives at Arcadia Vale was stranded at my house for several hours because of flooding in Toronto Rd.
71	Forest Lake Way	Toronto	6	Y	Y	N	N	Y	N		N	Y	N	N	N	N	N	N	N										N			Friday night for a couple of hours		N		
72	Nelmes Cl	Toronto	8	Y	N	N	N	N	N	None were above mentioned, only through garage & that's it. No items were damaged, no loss of electricity	N	N	Y	N	N	N	N	N	N			10mm							N			Friday 8pm	Very small of less than 10mm Friday 8:20pm. Subsided by 8:40pm, gone by 9:30pm	N		Mr property escaped damage. Water only went through garage as my property is on a slope. Water receded very quickly due to good drainage, within 20mins of downpour.
73	Nicholson St	Toronto	7	Y	Y	N	N	Y	N	We were without power from 8th June to 19th June	N	Y	N	N	N	N	N	N	N										N			9pm Friday	as above	N		
74	Awaba Rd	Toronto	2	Y	N	N	Y	Y	N	My home is on piers, if it was on flat land then we would have had water in the house	Y	Y	Y	N	N	Y	N	N	N		1ft	1/4-1/2ft			1/4-1/2ft				Y	The water went over the bridge & would be sure that debris was some of the cause.		Friday 6pm	Don't know	N		Debris did not help with the flood. The account I have given is my own observations but a number of flood areas would have been evident in the study area.

Survey Ref. No	Q1 Street	Q1 Suburb	Q2 Years at Address	Q3 Experience Flooding Y/N	Q3 How were you affected: We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Q4 Flooding present/depth of flooding: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Approximate Depth: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Q5 Bridges / culverts blocked	How blocked	What caused blockage	Q6 Duration of Flooding	Q 7 Peak of Flood	Q8 Any records of flood	Details	Additional Information
75	Beckley St	Toronto	10	Y	Y	Y	N	Y	N		Y	Y	Y	Y	N	N	N	N	N			50mm	50mm						Y	Fully blocked behind sub-station, water overflowed into the bottom of Biraban School & across road at Bridge	Partial woody debris, but creek couldn't take the excess water, the creek always overflows into the schoolyard with heavy rain.	All day Friday		Y	The creek runs through property at the rear of Biraban School because of the volume of water it had nowhere to go & overflowed into the school yard, & across the road at Carlton St. The water in Beckley half covered the road at our place & got deeper near the corner so that 6 cars were pulled out of the water. Traffic was turned back until it cleared.	Our yard back & front was approx 50mm underwater & was racing down the driveway onto the road. The worst we have seen in 10years. We have a lot of water in this yard with heavy rain as we are at the bottom of the hill.
76	Galbraith Ave	Toronto	35	Y	Y	Y	Y	Y	Y	Goods in garage were damaged - $1000	N	N	Y	Y	N	Y	N	N	N			300mm	300mm		120mm				N			Friday 7:30pm	Fruday 10:30pm	N		My yard often gets flooded with heavy downpours
77	John St	Blackalls Park	5	Y	N	N	Y	Y	N		N	Y	N	N	N	N	N	Y	N		1M-1.5M								Y	Wangi Rd- Catholic Shool turnoff and creek back toward Toronto Golf Club	Car & small turck washed into creek/d`rain	6-7pm Friday	6:30pm Friday	N		We were very fortunate at our address, with trees falling but not bringing down any power lines. Other members of the household had problems getting access via Railway Pde & the road past the Toronto Workers Club. This was at the same time 6pm Friday
78	Thorne St	Toronto		Y	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		The only thing I noticed was 2inches of water flowing from yards (higher at back of block) through property I own for a couple of days.
79	Thorne St	Toronto	33	Y	Y	N	N	Y	N		N	N	N	N	N	N	N	N	N										N			Friday night	During Sat night	N		
80	William St	Toronto	56	Y	Y	N	N	Y	N		N	Y	N	Y	N	N	N	N	N		50cm		20cm						N			5:30-7:30pm Thursday	6:30-7pm Thursday	Y	All the water from top half of William St combines with water from Bambara St & Milford St enters Awaba Rd causing Awaba Rd to flood.	
81	Fennell Cres	Blackalls Park	2	Y	Y	Y	Y	Y	Y	A storage & garden shed was flooded destroying most contents & a back room. Tools, lawnmower, whippersnipper etc destroyed - $1500 Had to rescue my 20 chickens & guard dog, 2 chickens drowned.	Y	Y	Y	Y	N	Y	N	N	N	3ft	3ft	3ft	3ft		3ft				Y	80% blocked at road crossing at water board park end of Fennell Cres	Debris	About 12hours from 10pm Thursday to Friday morning	10pm Thursday	Y	We did have flood marks but washed them away, clean up took weeks	Should this area have really been built on at all? The pollutants that were washed into our lake must have been in large amounts.
82	Park Ave	Blackalls Park	65	Y	Y	N	Y	N	Y	Food spoilt in fridge, battery in alarm needed to be replaced.	N	N	N	N	N	N	N	N	N										N					N		
83	Field Ave	Toronto		N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		I experienced the flooding but in a different suburb. I used to live in Bulraba & got flooded out, that's why I moved to Toronto
84	The Boulevard	Toronto	12	Y	Y	Y	Y	Y	N		N	Y	Y	Y	N	Y	N	N	N										N				About 9pm Friday	N		The amount of rain was unlikely to be contained by any drains but this property had to open garage doors at front & back to allow the water to continue on its way. It was flowing about 15cm deep across the back properties & about 30cm deep from the neighbours properties. I examined the area from Boulevard, Cook St & Brighton St & found the water continuous at approx 15cm. In the front of Boulveard the water reached up to 45-60cm. From the footpath which may be about 1m plus over the road surface. All properties were running a similar amount down their driveway. The road had a central kerb, this was covered by water continuing directly across the road about 40cm deep.
85	Park Ave	Blackalls Park	45	Y	Y	N	N	N	N		Y	Y	N	N	N	N	N	N	N	1M	0.5M								N					N		
86	Awaba Rd	Toronto	40	Y	Y	Y	Y	Y	Y	Electric welder, mower, whippersnipper, drill, grinder - $2500-3000	N	Y	Y	Y	N	N	N	N	N		2FT	2FT	2FT						Y	The drain 2 houses up was underwater, 100% underwater	Not big enough to take the amount of water that is directed into it.			Y	Myself & some neighbours have already supplied Mr Piper with some information on the 1920's drainage out front. We copped it from the drain over flowing & the water that comes from drains, & runoff from hours marked on map.	All the roads & the drain I have marked in red on the map, all the runoff's go straight for us because we are lower than the road. The flood water was lapping at the door.
87	William St	Toronto	1	Y	Y	N	N	Y	N		Y	Y	N	N	N	N	N	N	N										N			Thursday to Friday morning	Midnight Thursday	N		
88	Faucett St	Blackalls Park	27	Y	Y	N	Y	N	N	Tree came down in neighbours property-took out part of fence	N	Y	N	N	N	N	N	N	N										N			I was without power for about 1 hour		N		Because I live over the road from Blackalls Park Water Treatment works, power was off for very short time.
89	Milford St	Toronto		Y	Y	N	N	Y	Y	Gravel & debris washed into yard	N	Y	N	N	N	N	N	N	N		1m								N			Friday 6pm to Sat 11am	Sat 1am	N		
90	Beckley St	Toronto		Y	Y	Y	N	N	N		N	N	N	N	N	N	N	N	N										N					N		On Friday the school experienced a blackout at approx 11:30 & we were later advised by our district office to evacuate the students. This was a slow process due to the school's phones not working. All students were eventually evactuated by 3pm. Staff left at 3pm aswell. Locals reported to us that the bottom section of our playground was flooded but this has receded by Tuesday when we returned to school. Only damage was to trees.

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91	Akora St	Toronto	19	Y	Y	Y	Y	Y	N		Y	Y	Y	Y	N	N	N	N	N	1M	1M								N			The flooding on my property was during the storm teself due to the inability of the drains to cope.		N		The drains could not cope with the water flow & it flowed along the front of my house & through the backyard. The water was within 2cm of giving in my front door & through the house. I was terrified & could not get the car out (because of the water pressure) The water was travelling extremely quickly.
92	James St	Toronto	30	Y	N	Y	N	N	N		Y	Y	Y	N	N	N	N	N	N	600mm	600mm	300mm							Y	100%	Flooding		4pm Friday	N	Y	
93	The Boulevard	Toronto	1	N	N	Y	Y	N	N		N	N	Y	N	N	N	N	N	N			6CM							N			Friday to Saturday		N		
94	Fennell Cres	Blackalls Park	3	Y	Y	Y	N	Y	Y	Contents of workshop/garage affected $550 damage. I salvaged electric motors & dried them out myself, reducing cost. Water reached to level of verandahs (house on piers), garden affected, mulch washed away, some plants lost, air conditioning unit required cleaning by engineer-$140.	Y	Y	Y	Y	N	Y	N	N	N			31.5CM	31.5CM				31.5CM		N			Observed entering garage 9pm Friday. Water drained away when we awoke 6:30am Sat.	Peak at 1:45am Sat. Level being measured every 15mins during previous 3hours.	Y	Marked level of flood in shed 20m from house in back garden, & at back verandah, & at garage door. Debris along edge of Mudd Creek caught in branches of mangroves, height above bank	Amazed at the speed of the rise in water level & the rate of flow towards the lake. Completely unable to walk in the garden or street safely.
95	Lake St	Blackalls Park	9	Y	Y	N	Y	Y	N	Completely marooned	Y	Y	Y	Y	Y	Y	N	N	N	700MM	600MM	600MM	600MM	300MM	300MM				N			3 days	2-3pm Friday	Y	A line was marked on colourbond fence running from Edmonds Bay through to Stoney Creek, between xxxx Lake St & adjoining property	
96	Lake St	Blackalls Park	21	Y	Y	Y	N	Y	Y	$4500 damages	Y	Y	Y	Y	N	Y	N	N	N										N			Friday to Monday	2am Sat	N		
97	Anzac Pde	Toronto	12	Y	Y	Y	N	N	Y	Fridge/freezer food-$400	N	N	Y	N	N	N	N	N	N										N					N		
98	The Boulevard	Toronto		Y	Y	N	N	N	Y	Food in freezer lost-$100. Phone cut off for nearly 2 weeks	N	N	Y	N	N	N	N	N	N										N			5pm Friday	12am Sat	N		
99	Lake St	Blackalls Park	21	Y	Y	Y	Y	Y	Y	$25000 damages	Y	Y	Y	Y	N	Y	N	N	N										N			Friday to Monday	2am Sat	N		
100	Awaba Rd	Toronto	18	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		The rain washes from the road into my yard at the back then runs through my neighbours back yard.
101	Fennell Cres	Blackalls Park	15	Y	Y	Y	Y	Y	Y	Approx $40000	Y	Y	Y	Y	Y	N	N	N	Y					50MM				400MM	Y	Woody debris on Stoney Creek Railway Bridge	Water was held back because of the low design of bridge (disused rail bridge)	Daylight Sat morning the flood water has left the house	Friday approx midnight	N	Stoney Creek broke its bank at the junction of Stoney Creek and Mudd Creek	
102	Lake St	Blackalls Park		Y	Y	Y	Y	Y	Y	My Daewoo was flooded & became a writeoff ($6000). It happened at the Tennis Club near the Toronto Workers Club.	Y	Y	Y	Y	Y	Y	N	Y	N	40-50cm	40cm	60-70cm	40-50cm	Unsure	Unsure		30cm		Y	100% blocked. The draining system didn't work at all anymore at the bottom of James St. A cause of the blockage couldn't be seen as everything was submerged in water.	I don't know. The draining canal crossing James St was in flood, running over & down James St.	Friday 4pm to Sunday afternoon	1am Sat	N		We couldn't get out from our garage from Friday 6pm until Sunday sometime in the afternoon as Lake St was not usable for a normal car
103	Fennell Cres	Blackalls Park		Y	Y	N	N	Y	N	Had to park car in Adams St	N	N	N	N	N	N	N	N	N										N					N		
104	Lake St	Blackalls Park	7	Y	Y	N	N	N	N		Y	Y	N	N	N	N	N	N	N	50CM	5CM								Y	The old railway bridge over Stoney Creek was blocked with debris threatening local flooding.	woody debris.	Friday night to Saturday morning		N		
105	Lake St	Blackalls Park	24	Y	Y	Y	N	Y	N	Combined with high tide-rear of property flooded to approx 18inches	N	Y	Y	Y	N	N	N	N	N			18INCHES	2FT						N			10pm Friday to 1pm Sunday	6am Saturday	N		At xxxx water crossed road to grassed verge in front-never witnessed this before. Suggest removal of railway lines through Mudd & Stoney Creeks-surely these are potential blocking agents-considering diamter of supports & position in water flow, trains will not run again.
106	Lake St	Blackalls Park	10	Y	Y	Y	N	Y	N		N	Y	Y	Y	N	N	N	N	N										N			Sat 1am to Sun 4:30pm	Sat 12pm	Y	Photo of driveway between Edmonds Bay & Stoney Creek. Flood mark on side of my unit	
107	Thorne St	Toronto	9	Y	N	Y	N	Y	Y	Water into garage, landscaping damaged hotwater tanks foundation loosened. Stormwater too powerful. Storm drainage at the front couldn't handle water. Unit at the front of me was also badly flooded.	N	Y	Y	Y	N	N	N	N	N										N			Friday 5pm-9pm. Flooded workers club. Storm drain & drains couldn't holt it-Blackalls Park Bridge flooded the Boulevard had intense water flooding down to Lake.	6-7pm Friday	N		My friends car was rapidly flooded in Workers carpark & could not drive out. Had it finally towed out Sunday morning.

Survey Ref. No	Q1 Street	Q1 Suburb	Q2 Years at Address	Q3 Experience Flooding Y/N	Q3 How were you affected: We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Q4 Flooding present/depth of flooding: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Approximate Depth: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Q5 Bridges / culverts blocked	How blocked	What caused blockage	Q6 Duration of Flooding	Q 7 Peak of Flood	Q8 Any records of flood	Details	Additional Information
108	The Boulevard	Toronto	13	Y	Y	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		
109	Blundell Pde		4	Y	Y	N	N	N	N		Y	Y	N	N	N	N	N	N	N										N			Friday night to Sat morning-tidal effects in creek. Road-still water on Monday near workers club		N		Blundell Pde Park flooding did not reach the road at highschool end. Peaked at hightide Friday night/Saturday morning
110	Awaba Rd	Toronto	6	Y	N	N	N	Y	N		Y	Y	N	N	N	N	N	N	N	200MM	500MM								N			1pm Friday to 8am Sunday	5-7pm Friday	N		
111	Railway Pde	Blackalls Park	3	Y	Y	Y	Y	Y	Y	Food spoilage due to electricity loss (6 days)	Y	Y	Y	N	N	N	Y	Y	N	2FT	1M	1.5M				1M	50CM		Y	100%	Water & debris	Friday 1pm to Monday 4pm	3am Saturday	Y	Photos of backyard	Silt buildup in Mudd Creek almost blocking mouth-still present. Previous dredging of Edmonds Bay has filled in with silt. Rubbish & debris still present along shoreline & in water.
112	Fennell Cres	Blackalls Park	20	Y	Y	Y	N	Y	N	Air conditioning & pool pumps fused along with sewer pumpout pump. Water level 25mm below floor, very lucky.	Y	Y	Y	Y	N	Y	N	N	N										N			Friday 8pm to Saturday 5pm	Friday night	Y	25mm belowe floor level	This is the second occasion I have seen this area flooded unfortunately no matter what is done regards to water retention.
113	Fennell Cres	Blackalls Park	4	Y	Y	Y	Y	Y	Y	Trees over debris all over yard. Some trees split & lost branches fell onto other trees.	Y	Y	Y	Y	N	Y	N	N	N										Y	On the corner of workers club	There was a car there but too much water to be able to run away.	Friday 5:30pm the water was so deep at the front of my house I didn't think I'd get the car out. Sat morning 8:30am walked through water unable to drive car.	Told by neighbour 2am Sat	Y	The water from Stoney Creek at back of yard came up the bank & left a water mark & debris on the fence. At the front there are large rocks which were submerged. The boat which was in the lower part of the yard still has the water mark on it.	When I walked out the front at 5:30pm the water was up to my knee. I stepped out both sides of the road to see if I could get the car out. It was deeper on Mudd Creek side & coming across the road from that side. The water was halfway up my leg. I took the risk & took the dog & left. It was a frightening experience. The boat & trailer floated away to a different position, heavy objects in the yard moved to other places. There was debris & rubbish all over the property.
114	Awaba Rd	Toronto	19	Y	Y	N	N	N	N		Y	Y	Y	N	N	N	Y	N	N	N									N					N		
115	Railway Pde	Blackalls Park	55	Y	Y	Y	Y	N	N		N	Y	Y	Y	N	Y	N	N	N										N			PM Thursday to AM Saturday		N		Didn't see flooding other than own property as couldn't leave house. Did see aftermath around area.
116	Nicholson St	Toronto West	10	Y	Y	Y	N	Y	Y	Caused the septic tank to overflow. Councils drainage inadequate for Nicholson St. Septic tanks overflowing is the worst, posing a health & environment risk. Connection to the sewerage system.	N	Y	Y	Y	N	N	N	Y	Y										Y	60% culverts	Debris	Friday 6-9pm	Friday 6:30pm	Y	Flood water 750mm above centre of road in front of factory at xxxx Nicholson St.	
117	Lake St	Blackalls Park	3	Y	Y	N	Y	Y	N	Yard & driveway flooded	N	N	Y	Y	N	Y	N	N	N			60cm	60cm		60cm				N			Approx 60hours. Midday Friday to Monday	6am Saturday	Y	Photos taken around 5/35 Lake Street (Yard, driveway, etc)	
118	Nelmes Cl	Toronto	9	Y	N	Y	Y	N	Y	Everything inside house had to be replaced - furniture, kitchen, carpets, gyprock in side fence. Approx $80000 damages.	N	N	Y	Y	Y	N	N	N	N			18inches	15inches	6 inches					N			Friday 5:30-6:30pm	6pm Friday	Y	Photos taken 24 hours later showing water level marks on fences inside house, air con, hot water service, etc	I had to move out of the house, & stayed at my daughters place for 7 weeks, then the insurance put me up at The Brighton at Toronto & have been there for about 10 weeks, at least another 2 weeks before I moving back to my house.
119	Awaba Rd	Toronto	38	Y	Y	N	Y	Y	N		N	Y	N	Y	N	N	N	N	N										N					N		There was first nowhere but for the water to go as it came from across the main road like a river & it first kept coming. My family came Sunday to get me as I has no power & the water has gauged out my driveway only a 4wheel drive could get into my house.
120	Nelmes Cl	Toronto	1	Y	N	Y	N	N	Y	$4000 damages	N	Y	Y	N	Y	N	N	N	N		30cm	40cm		8cm					N			1 to 2 hours	5:30pm Friday	Y	Just photos of back room after water subsided showing water level & muddy floor.	
121	Lake St	Blackalls Park	11	Y	N	N	N	N	N		N	Y	N	N	N	N	N	N	N		50cm								N			I day - Thursday		N		
122	Milford St	Toronto	22	N	N	N	N	N	N		N	N	N	N	N	N	N	N	N										N					N		
123	Lake St	Blackalls Park	30	Y	Y	Y	N	Y	Y	Mainly shed gear-mowers, air con, power tools, 2 small dingys, vehicle, washing machine, tumble dryer, etc.	N	Y	Y	Y	N	N	N	N	N										Y	100%	Flood gates under roadway not working or completely blocked.	Actually started to come into the yard from the lake. About 7am Thursday, still partially flooded on Monday.	Between midnight & 3am	Y	Video footage of flooding during the night & receding water next couple of days. Footage of sewage being pumped out of mains & into yards.	Clearning up after the flood was enough but having to put up with raw sewage, human faeces & toilet paper continually pumping into our yards for 2 days after, was a major health risk. It took about a week for someone to come out & all they did was throw a few shovel loads of sand on top & that was it. The flood gates mentioned in Q5 would not have stopped properties flooding but would have let water & sewage back out of properties once creek level dropped.
124	Lake St	Blackalls Park	4	Y	Y	Y	Y	Y	N		Y	Y	Y	Y	N	Y	N	N	N										Y	drains 100%	debris/mud			N		
125	Lake St	Blackalls Park	8	Y	Y	Y	Y	Y	N		N	Y	Y	Y	N	N	N	N	N										Y	80% blocked	too much water	Friday 6pm to Sunday morning	Early Saturday morning	Y		
126	Lake St	Blackalls Park	4	Y	Y	N	N	Y	Y	Our chest type freezer wouldn't start again after power failure approx 40hrs duration. Isurance paid out for freezer replacement & loss of food approx $600.	N	Y	Y	N	N	N	N	N	N										Y	Culvert & stormwater pipe across driveway to No41 Lake St, blockage approx 60%	Woddy debris	Approx 8pm Friday to approx 1pm Sunday	Saturday 10am	Y	At rear of our property during the night (heavy rain, gale force winds). Friday night/Saturday morning Edmonds Bay broke its banks, water came into backyard almost to our back stairs, at back fence depth approx 2ft.	Approx 1m depth over Lake St, only accessible by 4WD's all day Saturday & until 1pm Sunday, then subsided fairly rapidly due to a low tide.

Survey Ref. No	Q1 Street	Q1 Suburb	Q2 Years at Address	Experience Flooding Y/N	Q3 How were you affected: We were without electricity	Our house/property was flooded	We were frightened	We could not travel easily	Our belongings were damaged	Details	Q4 Flooding present/depth of flooding: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Approximate Depth: Parks	Roads	Residential (backyard)	Residential (frontyard)	Residential (above floor level)	Residential (below floor level)	Commercial (above floor level)	Commercial (below floor level)	Industrial	Q5 Bridges / culverts blocked	How blocked	What caused blockage	Q6 Duration of Flooding	Q7 Peak of Flood	Q8 Any records of flood	Details	Additional Information
127	Lake St	Blackalls Park	23	Y	Y	Y	Y	Y	Y	Damage was confined to garden areas as a direct cause of flooding. There was some roof damage caused by the storm & falling trees but this was minimal.	N	Y	Y	Y	N	N	N	N	N		70cm	40cm	40cm						Y	80% blocked this culver blocks after any substantial rain & causes nuisance flooding, see attached photos.	Woody debris, mud etc (culvert is the only storm water outlet & flows into Stoney Creek.	Saturday 2am to Sunday PM	9am Saturday	Y	Photos enclosed include images taken 9/6/07 as well as flooding of culvert even after general flooding has receded & the creek/lake is back to normal tidal flow. The blocked culvert is located at xxxx Lake St, but causes nuisance flooding to the front of properties xxxx & xxxx.	The rear of the property at 49 Lake St facing Edmonds Bay was flooded through to buildings above flood level as this land is not filled.
128	Blundell Pde	Toronto		Y	Y	Y	N	N	N	The gardens were deeply waterlogged	N	N	Y	Y	N	N	N	N	N			50mm	50mm						N			Friday evening to Saturday morning	Friday midnight	Y	Enclosed photos of Stoney Creek from Blundell Pde.	
129	Awaba Rd	Toronto	3	Y	Y	Y	Y	Y	Y		N	Y	Y	Y	N	N	N	N	N		2M	2M	2M						Y	50%	Metal, debris, etc	4 hours on Friday	4 hours on Friday	Y	Photos submitted to Lake Macquarie Council & to chief engineer	Y
130	Fennell Cres	Blackalls Park	46	Y	Y	Y	Y	Y	Y	Septic tank-flooded/sunk & had to be removed & replaced. Garages, sheds, doors, stairs, floors all flooded $30K damages. Devestation of orchards, gardens, fallen trees, air con. Playground area destroyed by water & fallen tree, sewerage water contaminted large amount of property.	Y	Y	Y	Y	Y	Y	N	N	N	50CM	50CM	1M	1.5M	50CM	1.5M				N			8pm Friday to 3am Saturday	11pm Friday	Y	Photos-of flood marks & damaged property.	Our property flooded firstly from the road as there is no stormwater drains, the land is flat & almost equal if not lower than the road. The creek is severly silted up behind our property & along our st. We believe that a lot of the sewerage that was in the floodwater came from Toronto Sewerage Works. We went to witness the affect of the flood on the sewerage works & we witnessed that the settling ponds had overflowed, this was on Saturday at 3-4pm. We feel that a Levy should be built around the works, to prevent it happening again.
131	Awaba Rd	Toronto	36	Y	Y	Y		Y		Equipment in back shed ruined. ($2K)	Y	Y	Y																Y	Near swimming pool Awaba Rd 100% for short time.	Bush debris	Fri late afternoon to early morning Sat.	Sat. 2.00 a.m. at backyard	Y	Stoney Creek again flooded to within 2m of back steps. Lots of junk at edges of creek after flood.	
132	Lake St	Blackalls Park	8	Y	Y	Y			Y	Items in garage, pool, spa, car fence, gardens approx $35K damages.		Y	Y	Y		Y						350mm	350mm		350mm				N			Fri. night to Sun 10th approx. as away for weekend.	Sat. am approx. as away for weekend.	Y	Video recording & photo's taken by neighbour. Flood level marks.	
133	Galbraith Ave	Toronto	47	Y	Y	Y	Y	Y	Y	Shed went under water.	Y	Y	Y	Y		Y													N			12 hrs	Midnight	Y	Have photo's, access to video.	
134	Galbraith Ave	Toronto	7	Y	Y	Y							Y			Y						9"							N			7-9th june	Backyard flooding continued during the time of heavy continuous rain.	N		
135	Adam St	Blackalls Park	27	Y	Y							Y									200mm								N			10am Friday 8th June, 7am Mon.11th June.	10am -12pm Fri 8th June	N		
136	Fennell Cres	Blackalls Park	57	Y						Mowers damaged with water ($500 approx)																										
137	Sara St	Toronto	3	Y	Y	Y	Y	Y	Y	We lost food in the freezer and fridge, all kids toys as we have extra large cubby house full of toys, damaged floor of cubby and tools in carport. Over $1000 damage.		Y	Y	Y				Y	Y		0.5m or more	0.5m or more	0.5m or more				0.5m or more	0.5m or more	N			Just on dusk Friday to late Saturday	1am Sat 9th June	Y	Video- it shows you can't even see the road at the end of the driveway.	
138	Railway Pde	Blackalls Park		Y	Y	Y						Y	Y								1 foot	3 feet							N			Late Fri.8.06.07	2am Sat. 9.06.07	Y	Digital photo of flooding in backyard. Sat 9.06.07 am. Video footae of backyard - 3 minutes.	

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Stony Creek Floodplain Risk Management Study

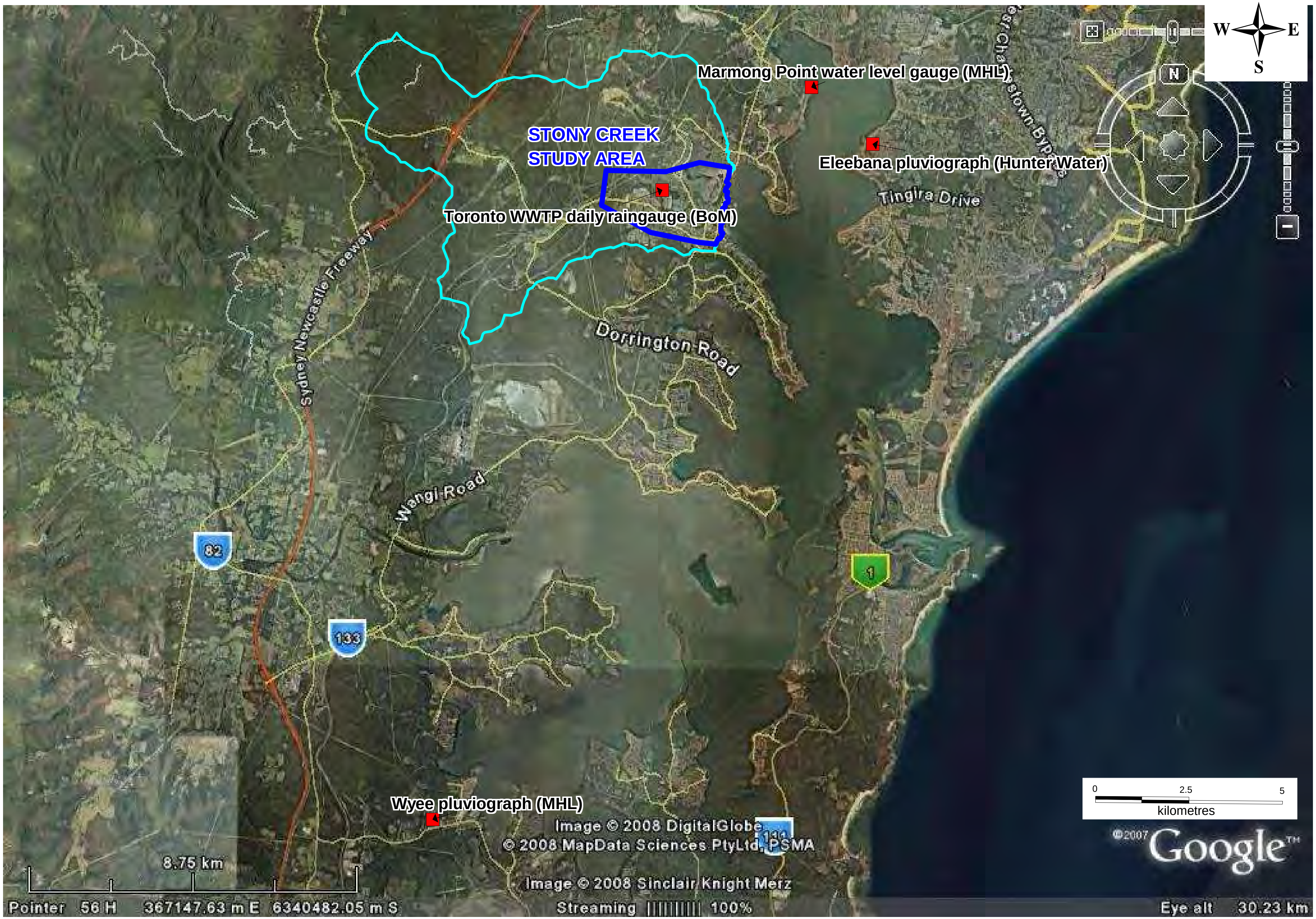

FIGURE B.1
RAIN GAUGE LOCATIONS

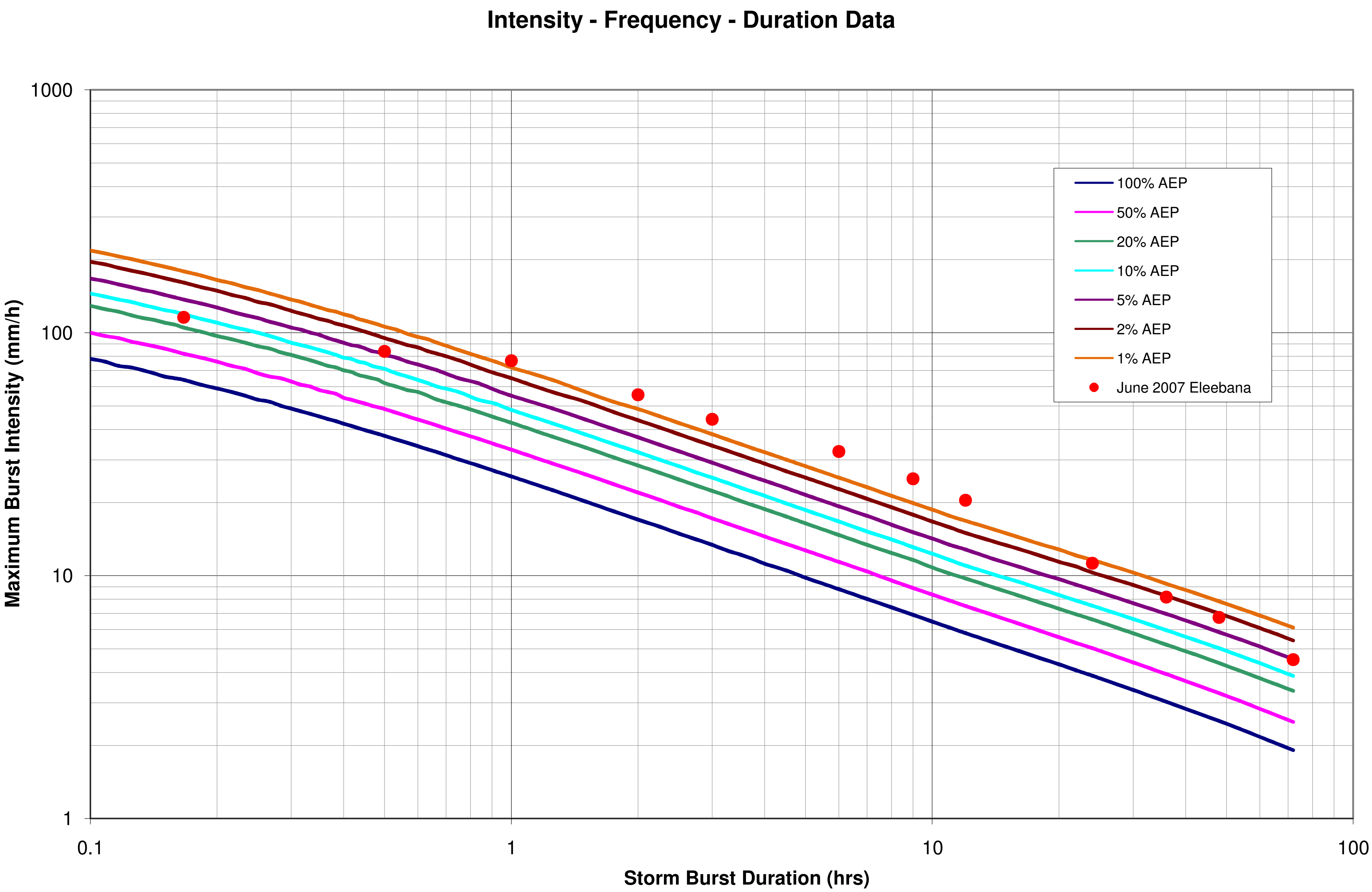

FIGURE B.4B
June 2007 Event and Design AEP Intensities

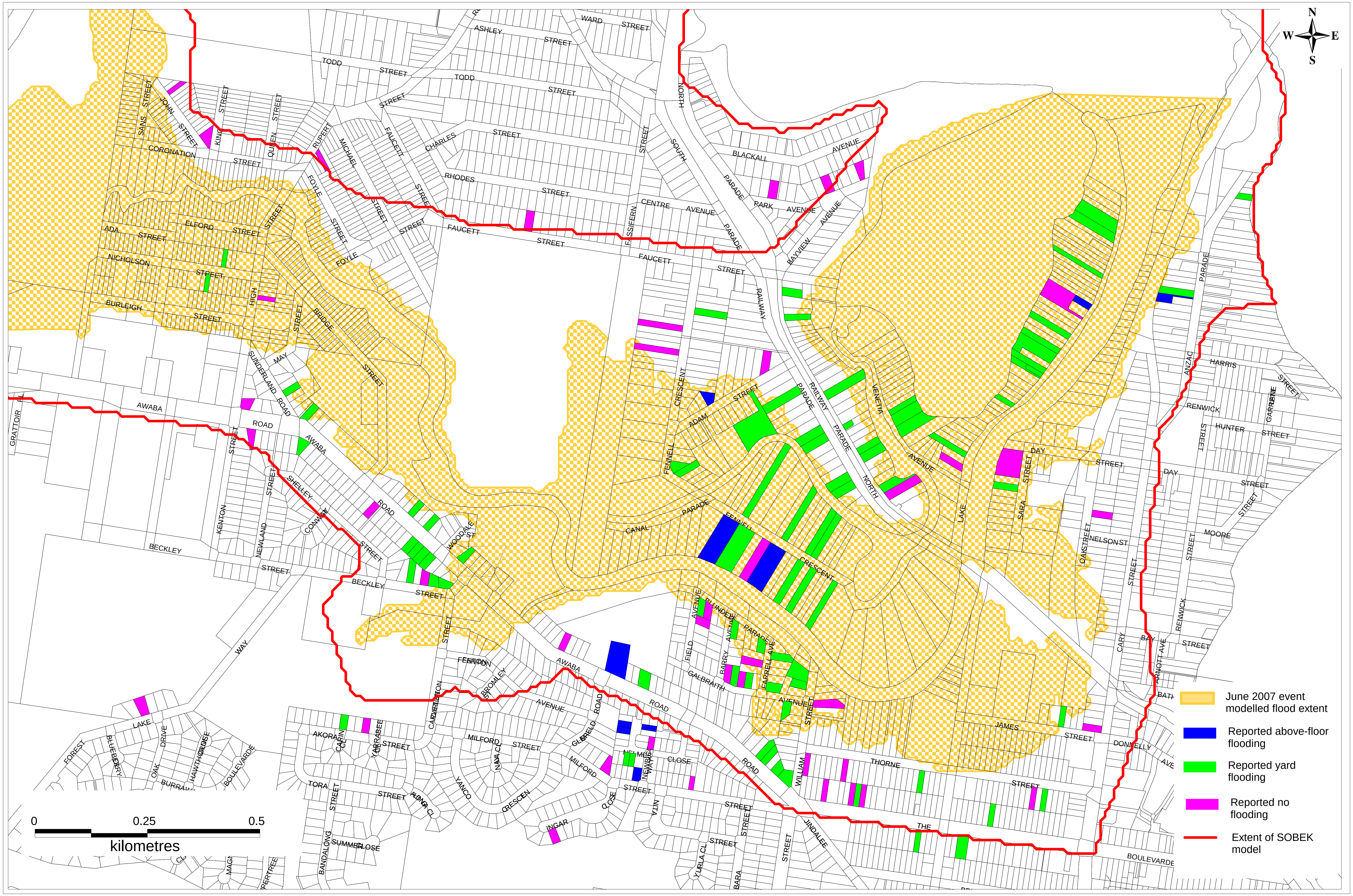

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FIGURE B_5
JUNE 2007 EVENT COMMUNITY RESPONSES

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FIGURE B_6
JUNE 2007 EVENT BLOCKAGE RESPONSES

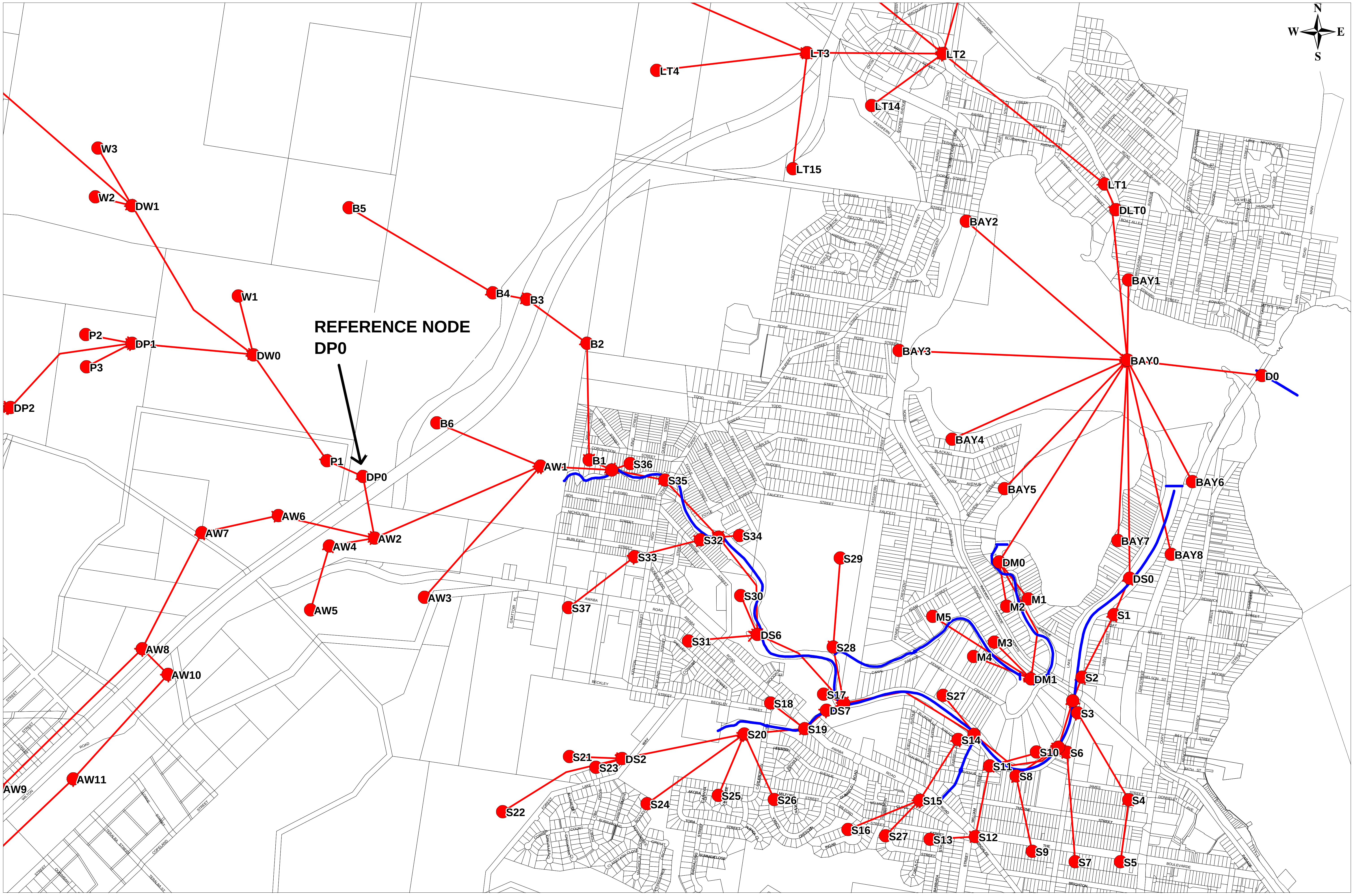

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FIGURE B_7
RAFTS NODE LAYOUT

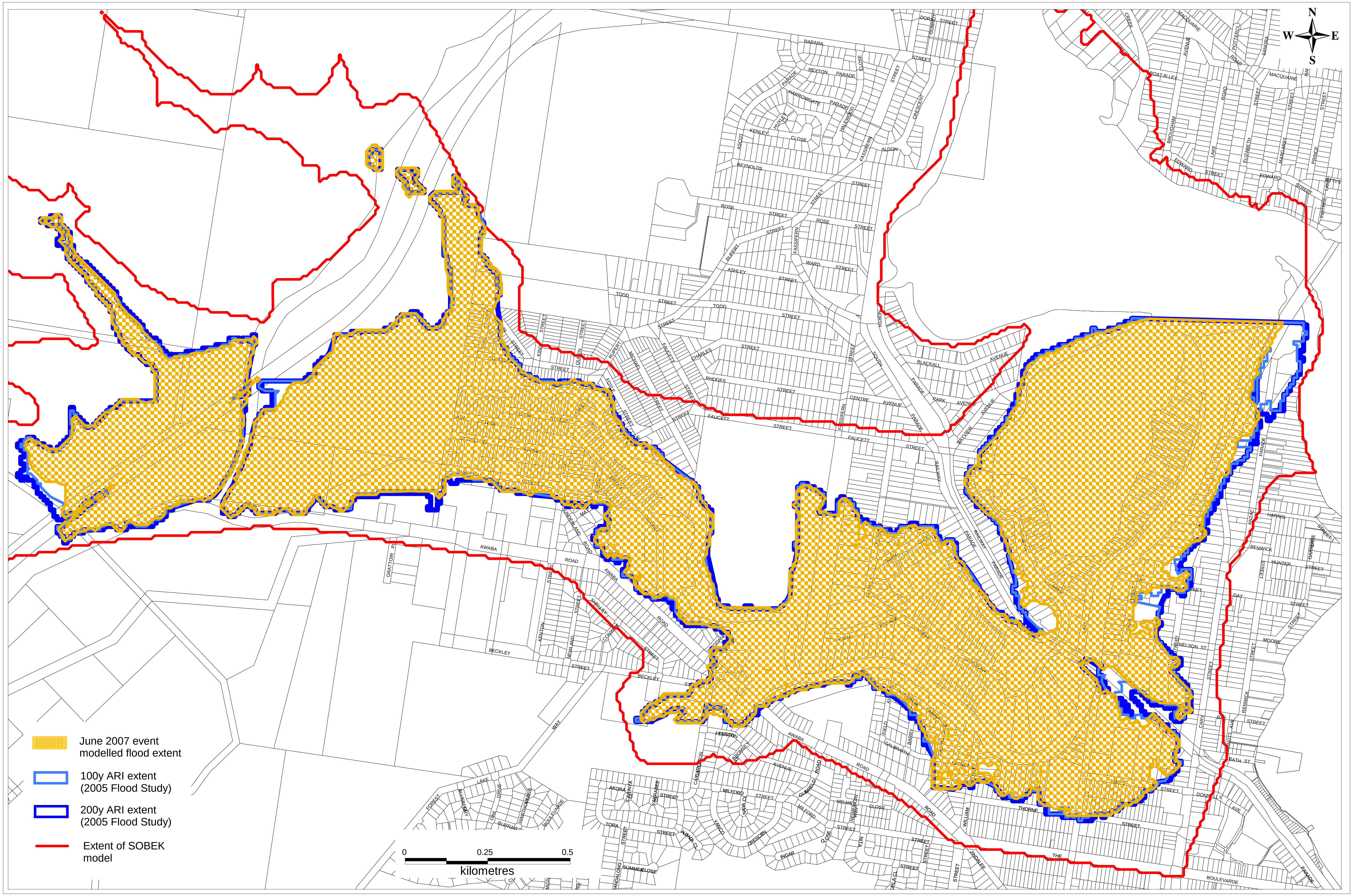

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FIGURE B_9
JUNE 2007 EVENT FLOOD EXTENT

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Stony Creek Floodplain Risk Management Study

FIGURE B_10
JUNE 2007 SURVEYED FLOOD MARKS

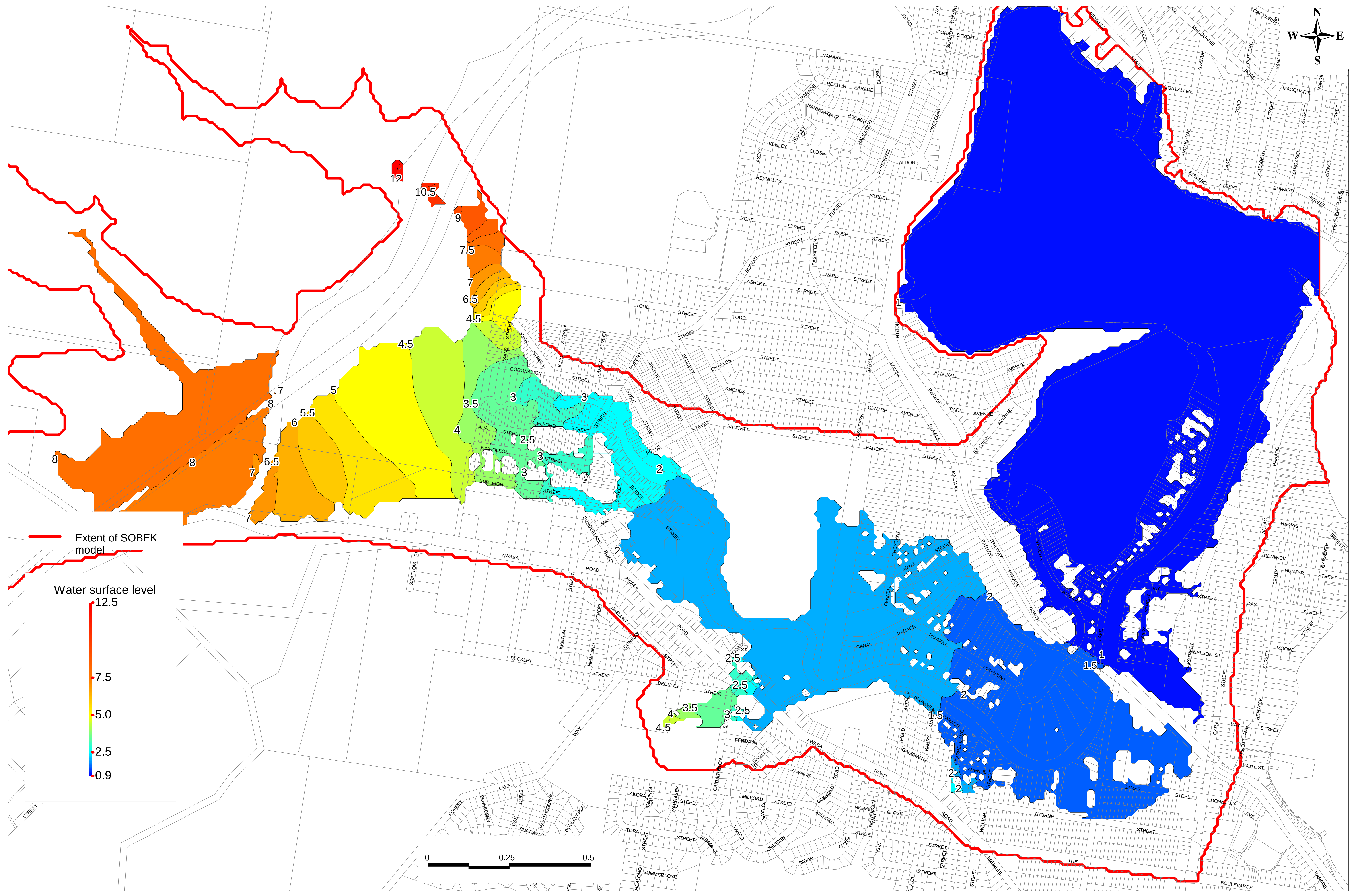

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FIGURE B_11
JUNE 2007 EVENT PEAK WATER LEVELS

Stony Creek Floodplain Risk Management Study

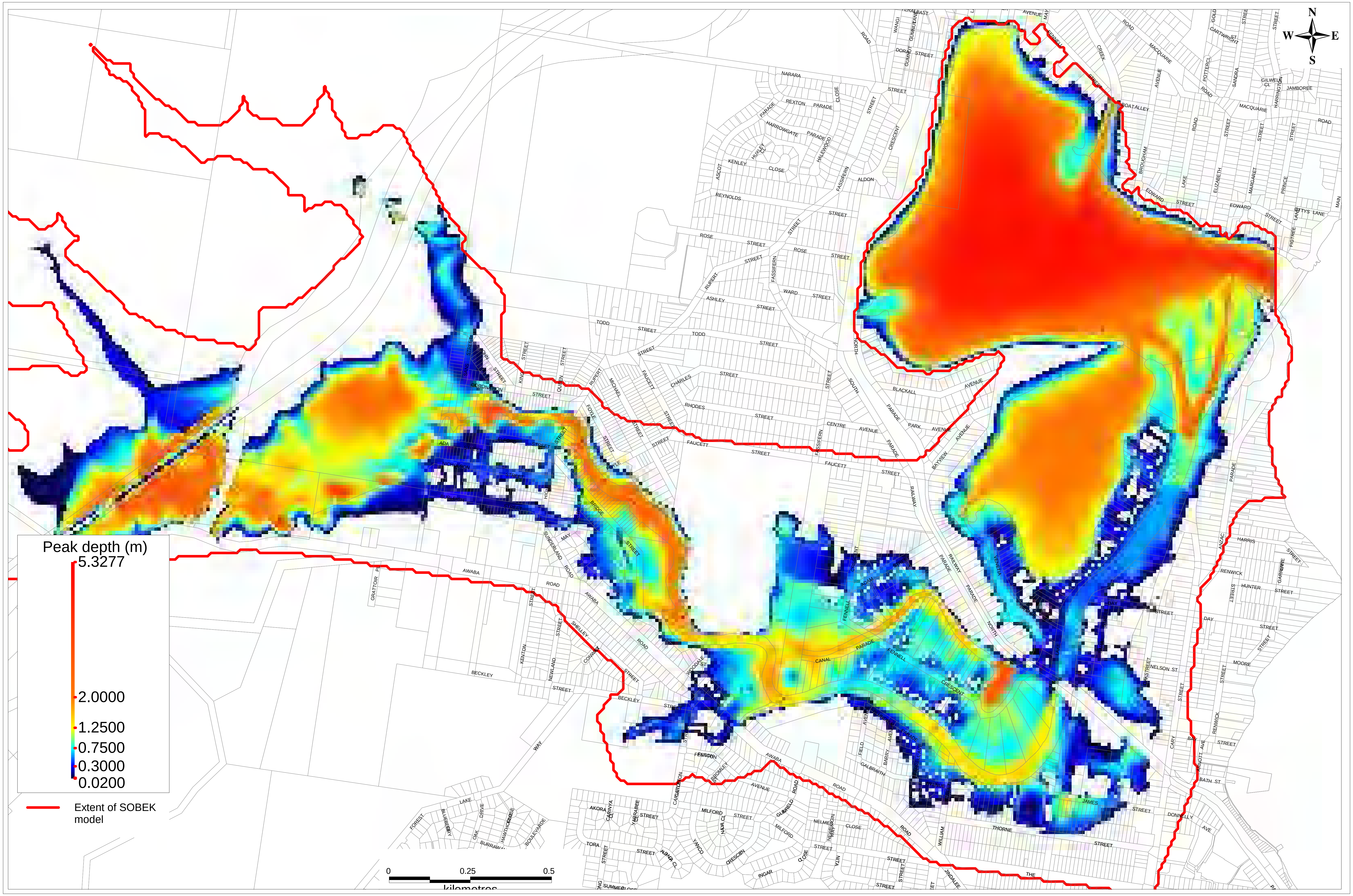

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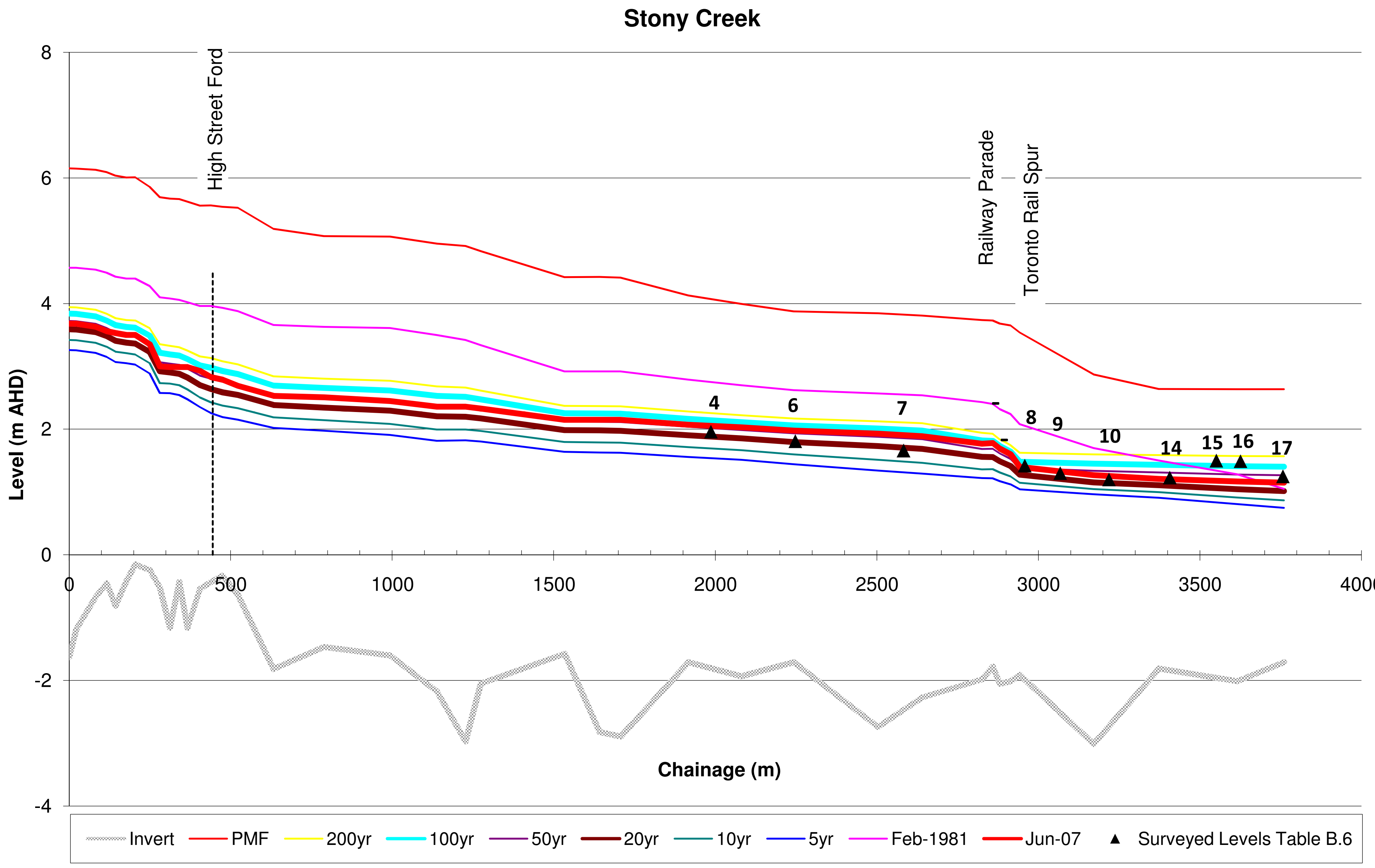
FIGURE B_12
JUNE 2007 EVENT PEAK DEPTH



Stony Creek
Level (m AHD)
8
6
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
3500
4000
Chainage (m)
High Street Ford
Railway Parade
Toronto Rail Spur
4
6
7
8
9
10
14
15
16
17
Invert
PMF
200yr
100yr
50yr
20yr
10yr
5yr
Feb-1981
Jun-07
Surveyed Levels Table B.6

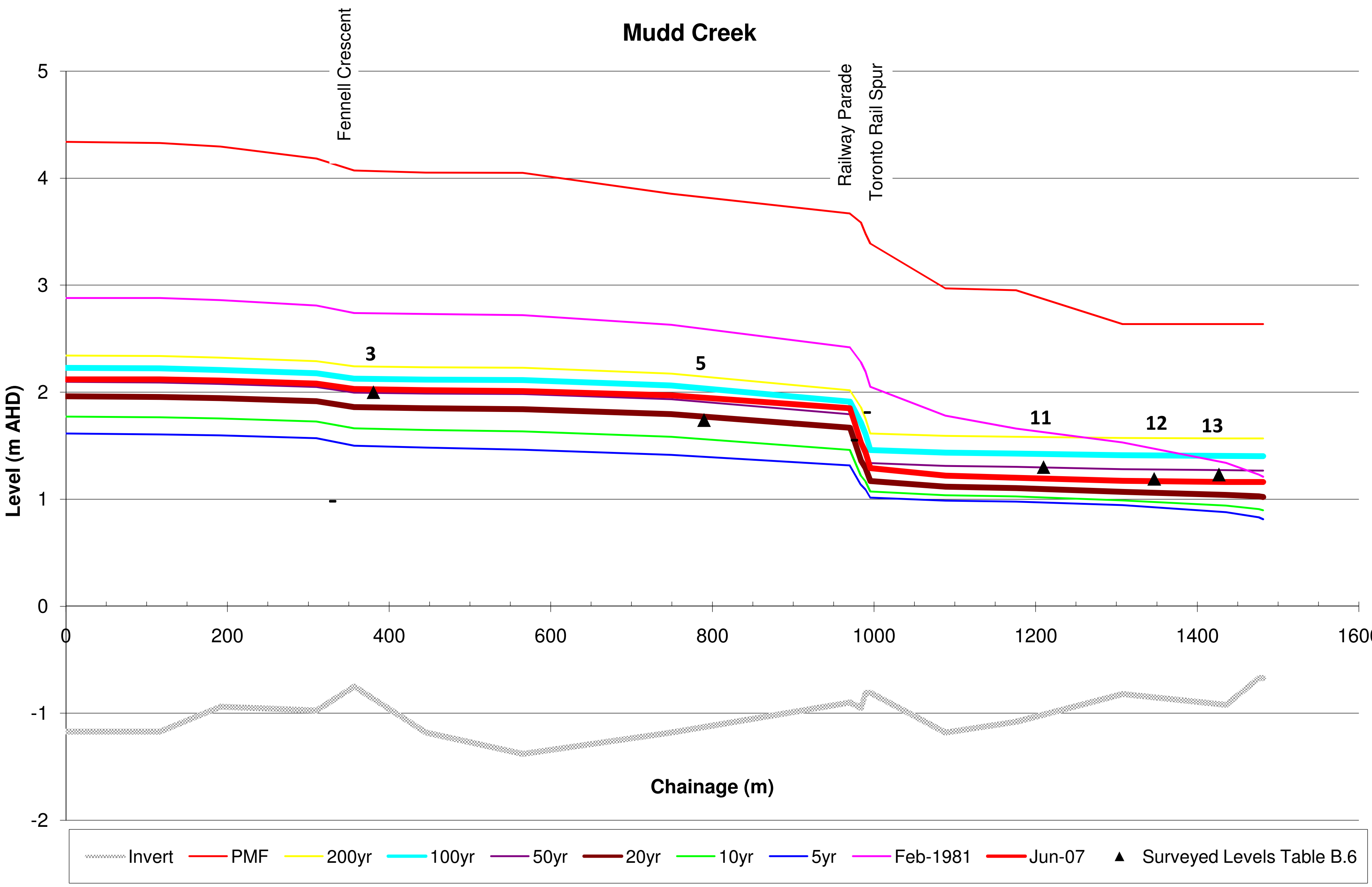


FIGURE B.14
MUDD CREEK FLOOD PROFILE

PHOTOGRAPHS FORWARDED WITH QUESTIONNAIRES BY RESIDENTS

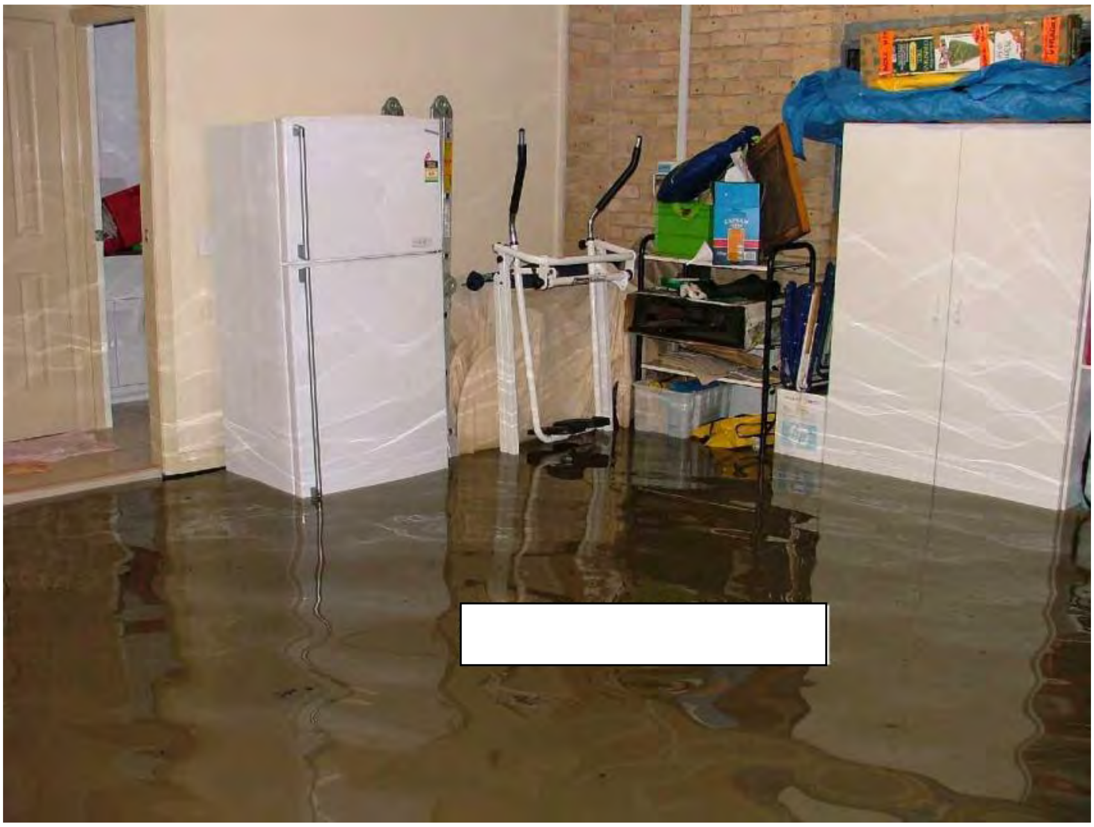
Day Street

Day Street – 7am Saturday 9/06/2007

Carleton Street

Debris at culvert Carleton Street

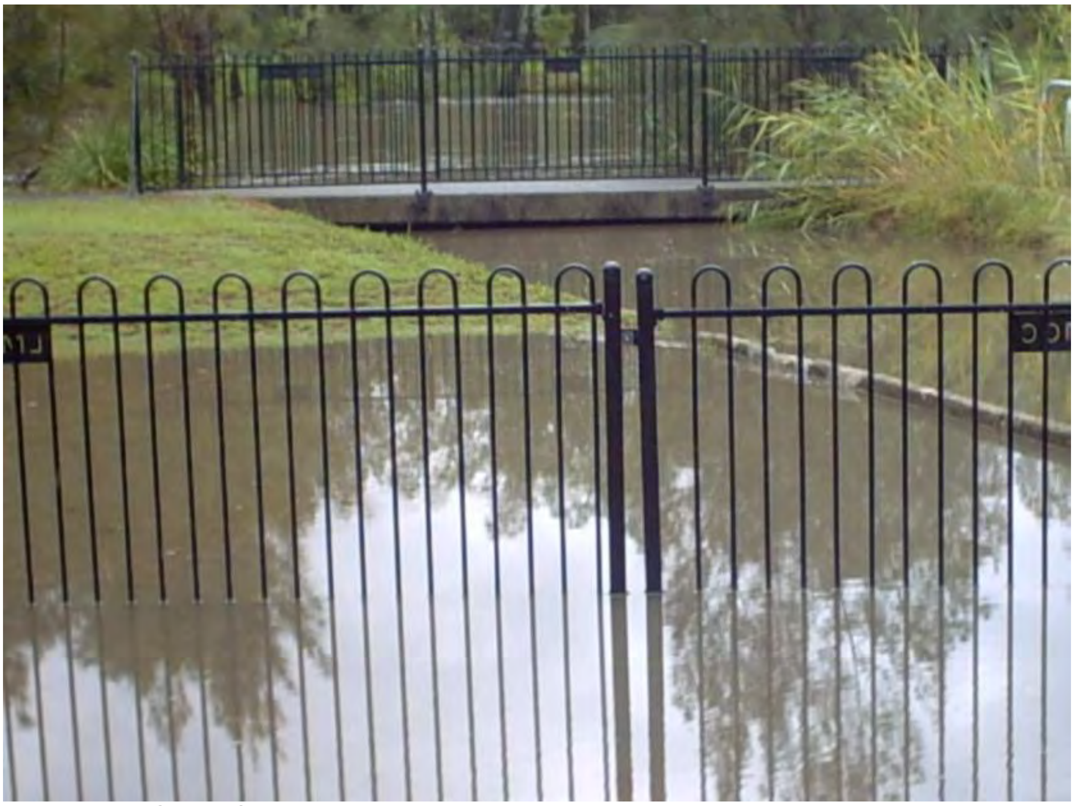
Adam Street



Friday 11:30PM 8/06/2007

Mudd Creek – Saturday 9:00AM 9/06/2007

Blundell Parade



Adjacent to Stony Creek

Adjacent to Stony Creek

Stony Creek

William Street

Stony Creek – Saturday 12:30PM 9/06/2007

James Street

Toronto Workers Club near Cook Street – Saturday 12:30PM 9/06/2007

Toronto Workers Club near Cook Street – Saturday 12:30PM 9/06/2007

Toronto Workers Club near Cook Street

Railway Parade

[Location not specified]

Lake Street

Saturday 9/06/2007 – facing Edmunds Bay

Facing Lake Street (and Stony Creek)

Residence A on Lake Street – During and After

Residence B on Lake Street – Before and After

Venetia Avenue / Mudd Creek

Appendix C

1990 & 1991 Report Review

C REVIEW OF SINCLAIR KNIGHT STUDIES

The references reviewed for the Stony Creek Flood Study (2005) included the Sinclair Knight and Partners "Report on the 7th February 1981 Flood in the Stony Creek Catchment" (1981). Following the 1981 Report, Sinclair Knight and Partners were commissioned to re-examine flooding in the catchment associated with redevelopment of the Toronto Wastewater Treatment Plant.

Two of the subsequent reports prepared by Sinclair Knight and Partners were forwarded by Council and OEH:

- "Flood Study for Proposed Development in Lake Street, Blackalls Park", Sinclair Knight, September 1991, Reference 9339.2.
- Title Unknown, Sinclair Knight, Date Unknown, Reference 8345.3.

The "Untitled" Report was commissioned to examine aspects of flooding at Toronto and refers to a previous study by Sinclair Knight and Partners in 1989 of flooding in the Stony Creek Catchment. The 1991 Report refers to an October 1989 Report and an October 1990 Report. Therefore, the "Untitled" Report is assumed to be referred to as circa October 1990, however it is noted that an appendix to the Report is dated March 1991. The 1990 Study (as referred to for this current assessment) updated the model used in the previous study to allow for improvements in modelling procedures. This study was completed using the Field William Catchment Model (also known as "KinCat") developed at the University of Newcastle and the HEC-2 steady-state backwater program.

The 1991 Report is a flood study to investigate the effects of a medium density development in Lake Street, Blackalls Park. This Report is based on modifications to the 1989 model and recommends water surface elevations be obtained from the 1990 Report.

C.1 OCTOBER 1990 REPORT

The October 1990 Report re-examined Sinclair Knight's previous flood modelling for changes to catchment conditions and modelling processes. This Report presents flows and flood levels within the catchment and its results are compared to those of the Stony Creek Flood Study (2005).

C.1.1 Haul Road

The 1990 Report states that the coal haulage road (near the main railway line) was developed after the 1981 storm by the Electricity Commission. The roadway was identified as having a minimum elevation of approximately 9.85m AHD, and 29 multiple box culverts each 3.00m wide and 1.5m high. The 2005 Flood Study model had a similar level specified for the roadway. The culverts modelled was also similar, specifically 29 culverts each 3.15m wide by 1.53m high.

The calibration of the 2005 Flood Study model excluded the culverts and embankment of the haul road for the assessment of the 1981 storm event.

C.1.2 Storm Event Data

The figures of rainfall for the February 1981 event presented in the 1990 Report appear to be the same as those of the Weatherex report sourced for the 2005 Flood Study ("Stony Creek catchment Rainfall Study – Storm of 6/7 Feb 1981). The 1981 event was concluded as in excess of a 100 year ARI event, with approximately 400mm depth falling within the catchment primarily between 22:30 on 6 February and 09:00 on 7 February 1981. The 2005 Flood Study also identifies the 1981 Sinclair Knight study as a source for the rainfall data for the 1981 event.

For the Probable Maximum Precipitation event, the 1990 Report determined a rainfall depth for 3 hours duration of between 630 mm to 720 mm (varying smooth and rough catchment characteristics) based on the methodology in Australian Rainfall and Runoff. It was noted that a slightly lower estimate was given in the Weatherex report. The 2005 Flood Study PMP depths are considered comparable which used the Bureau of Meteorology Generalised Short-Duration Method (2003) to obtain depths for the 3 hour duration of between 490 mm and 650 mm (depending on the relative position within the spatial distribution ellipses).

C.1.3 Peak Flows Comparison

The hydrologic modelling in the 1990 Report lists peak flow estimates for various cases based on several calculation methodologies as listed in **Table C.1**. The peak flow of the 100 year ARI event for the 37 km2 catchment is estimated to be 165 m^3/s using the Regional Frequency Analysis method.

The 100 year and 20 year ARI design flows are applied to the hydraulic modelling of the 1990 Report, therefore these flows are considered to correspond to Stony Creek adjacent to Day Street within the 2005 Flood Study RAFTS modelling. The total catchment area for the hydrology modelling of the 1990 Report is 36.2 km2, which is similar to the 2005 Flood Study model catchment area of 35.9 km2. The 2005 Flood Study modelling shows comparative peaks flows from the RAFTS modelling of 506 m^3/s for the 1981 event, 191 m^3/s for the 100 year ARI event, 140 m^3/s for the 20 year ARI event, and 1313 m^3/s at the Haul Road for the PMP event.

The flows estimated for the 2005 Flood Study is considered reasonable for the catchment compared to those of the 1990 Report. Variations to peak flows may be attributed to a different sub-catchment layout and the different hydrology models utilised (RAFTS in 2005 and the Field Williams model primarily used for the 1990 Report). As no flow gauging stations are situated within the Stony Creek catchment, the hydrological model of the 2005 Flood Study could not be directly calibrated, but the RAFTS modelling was indirectly validated through the hydraulic model calibration.

Table C.1 - 1990 Report Peak Flowrates

Event	Peak flow recommended	Comment
February 1981 storm	380 to 460 m^3/s	Sensitivity analysis indicated range of between 380 and 610 m^3/s.
100 year ARI design	240 m^3/s	Range of between 164 and 240 m^3/s.
20 year ARI design	125 m^3/s	
Probable Maximum Precipitation	924 to 1040 m^3/s	Specified as flow at Haul Road and Railway Embankment

C.1.4 Flood Levels Comparison

The most suitable comparison of the 1990 Report to the 2005 Flood Study is based on resultant flood levels within the Catchment. Therefore the results of the hydrology modelling of the two studies, using the Field William model compared to RAFTS, is not assessed.

The flood levels for the 1990 Report are obtained using the HEC-2 program whereas the 2005 Flood Study modelling uses the SOBEK program. The HEC-2 program is a steady-state model that calculates flood levels based on a peak design flowrate at the specified cross-sections. The SOBEK program is more sophisticated determining two-dimensional flood behaviour over a continuous elevation grid (as opposed to discrete cross-sections). SOBEK also models unsteady-flow as the whole hydrograph of the storm flow is input. The elevation grid for SOBEK was developed from photogrammetry survey collected just prior to the study commencing, but it is noted that the in-bank sections of some creek locations for the one-dimensional model domain was supplemented by data obtained years prior to the 2005 Study.

Flood levels are tabulated in the 1990 Report however a complete figure showing the locations of the cross-sections was not available. The downstream half of a long-section for the creek was provided (effectively an A3 page trimmed to an A4 page size). This figure shows that the sewage treatment works occurs at cross-section 7A to 9 equivalent to chainages ~1606m and ~2136m respectively.

Additional cross-sections are incorporated in the results of the assessment of removing the old railway bridge piers. These have been added between cross-sections 2 and 3, suggesting that the railway bridge is located between these two sections. On the portion of the long-section figure available, Section 2 occurs at chainage 250m and section 3 occurs at chainage 545m. The 1991 report, also not available with a figure to relate cross-section numbers to landmarks or creek chainages, included an additional cross-section 0.5 downstream of section 1, presumably to cover the subject site on Lake Street, Blackalls Park.

The creek chainages adjacent to the sewage treatment plant does not readily correlate to those of the 2005 Flood Study: Ch. 1606 to 2136 (ie a distance of 530m) in the 1990 Report compared to Ch. 2020 to 2820 (ie 800m) in 2005 Flood Study. The length of creek between the old railway bridge and the STP is a better correlation: Ch. 1606 to ~500 (ie 1100m based on highest chainage) in 1990 Report; Ch. 2020 to 880 (ie 1140m) in 2005 Flood Study.

The levee around the Toronto Industrial Estate (in vicinity of Elford St) is indicated as between Cross-sections 11 and 15 in the 1990 Report.

The assumed cross-section locations of Stony Creek based on the 1990 Report are shown in **Table C.2**.

Table C.2 - 1990 Report Cross-section Locations

Location Description	1990 Report cross-section reference
Industrial Estate (west side)	15
Industrial Estate (east side)	11
Sewage Treatment Plant (west side)	9
Sewage Treatment Plant (east side)	7 (or 7A)
West of Railway Parade	3
East of Railway Parade	2
Adjacent Day Street	1
Stony Creek Outlet to Fennell Bay	-

C.1.5 1981 Flood Event

The 1990 Report presents two scenarios for the flood levels modelled for the 1981 storm event. One analysis models the case of catchment conditions circa 1981 compared to conditions circa 1990 where levee banks at the sewage treatment plant and West Toronto Industrial Estate as well as the haulage road have been constructed. A tidal level of 1.4m AHD was used as this level was observed during the storm event.

In modelling the 1981 storm event as a calibration event, the 2005 Flood Study model did not include the coal haul road as it was not present in the 1981 event. Thus it is recommended to compare the 2005 Flood Study levels to the 1981 conditions of the 1990 Report.

Results from the two Reports are listed in **Table C.3**.

Differences would be expected in comparing the 1990 Report and the 2005 Flood Study due to the different computer models and data used. There are some differences (both higher and lower) between the results of 1990 Report and 2005 Flood Study. However, the 2005 Flood Study showed good correlation to the observed flood levels reported for the 1981 storm event as shown on **Figure C.1**. Note that the presented comparison locations are not specifically defined in the 1990 SK Report so the locations are not considered identical. Also the 2005 Flood Study 1981 event results are based on a tailwater level of the Fennell Bay outlet of 0.0m AHD.

Table C.3 - 1981 Event Flood Levels (m AHD)

Location Description	1990 Report		2005 Flood Study
	1981 Conditions	1990 Conditions	
Industrial Estate (west side)	-	4.82	4.61
Industrial Estate (east side)	3.73	3.41	3.98
Sewage Treatment Plant (west side)	3.30	3.30	3.6
Sewage Treatment Plant (east side)	3.09	2.96	2.9
West of Railway Parade	2.37	2.36	2.5
East of Railway Parade	1.79	1.77	2.1
Adjacent Day Street	1.4	1.4	1.75
Stony Creek Outlet to Fennell Bay	-	-	0.75

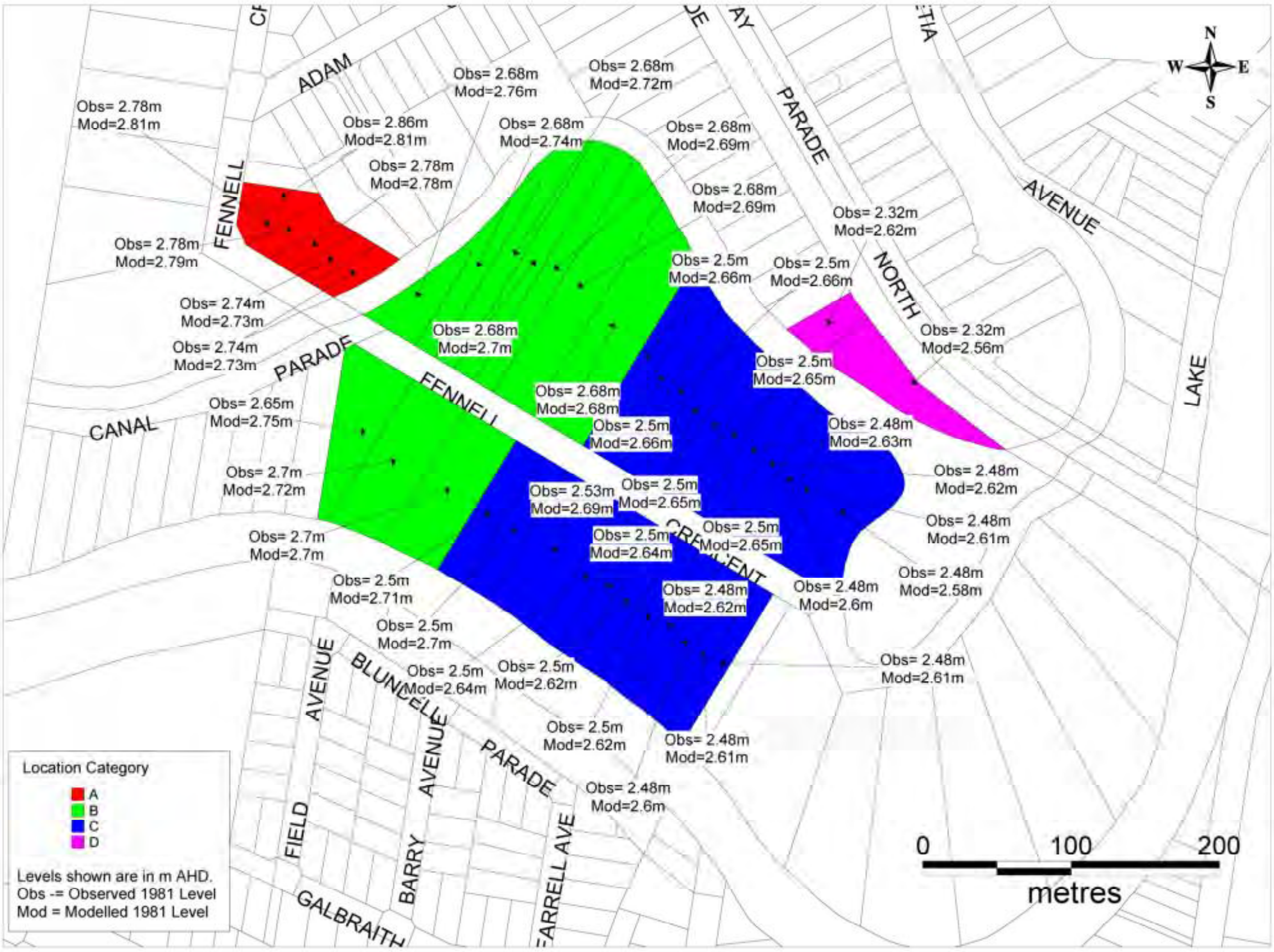


Figure C.1 – 2005 Flood Study Observed Flood Levels

C.1.6 Design Flood Levels

The 1990 Report recommends a design discharge of 240 m^3/s for the 100 year ARI design storm, and 125 m^3/s for the 20 year ARI design storm. Representative flood levels for Stony Creek from the 1990 HEC-2 modelling for the assumed cross-section locations are included in **Tables C.4 and C.5** with the levels from the 2005 SOBEK model. The location of the 2005 Flood Study sections are shown on **Figure C.2**.

Table C.4 - 1990 Report 100 year ARI Flood Levels

Location Description	1990 Report		2005 Flood Study	
	Cross-section reference	Flood Level (m AHD)	Node reference	Peak flood level (m AHD)
Industrial Estate (west side)	15	4.55	Dig-15	3.92
Industrial Estate (east side)	11	2.61	Dig-2	3.02
Sewage Treatment Plant (west side)	9	2.62	Stony-18	2.62
Sewage Treatment Plant (east side)	7	2.17	Stony-14	2.25
West of Railway Parade	3	1.81	Stony-6	1.82
East of Railway Parade	2	1.54	Stony-5	1.48
Adjacent Day Street	1	1.40	Stony-4	1.45
Stony Creek Outlet to Fennell Bay	-	-	Stony-1	1.01

Note for the sewage treatment plant east side, cross-section 7 is listed compared to cross-section 7A which is not presented in the 1990 Report results.

The 1990 Report used a tailwater level of 1.40m AHD at its downstream boundary (estimated to be at about Day Street) for both the 100 year ARI and 20 year ARI events compared to the resultant level of 1.01m AHD from the 2005 modelling.

The 100 year ARI results show reasonable correlation between the two models but the 20 year ARI results generally differ more.

Table C.5 - 1990 Report 20 year ARI Flood Levels

Location Description	1990 Report		2005 Flood Study	
	Cross-section reference	Flood Level (m AHD)	Node reference	Peak flood level (m AHD)
Industrial Estate (west side)	15	-	Dig-15	3.59
Industrial Estate (east side)	11	2.02	Dig-2	2.63
Sewage Treatment Plant (west side)	9	1.99	Stony-18	2.29
Sewage Treatment Plant (east side)	7	1.68	Stony-14	1.99
West of Railway Parade	3	1.52	Stony-6	1.56
East of Railway Parade	2	1.44	Stony-5	1.28
Adjacent Day Street	1	1.40	Stony-4	1.15
Stony Creek Outlet to Fennell Bay	-	-	Stony-1	1.01

C.1.7 Tide Levels

The 1990 Report indicates a tide level of 1.4m in the 1981 storm. Tidal levels of 1.1m AHD and 1.7m AHD were modelled for the 1981 storm event to assess the influence of tide on flood levels. The Report concluded that only the lowest reach of Stony Creek is influenced by significant variations in the tide level.

Similarly, the 2005 Flood Study reported that changes in the downstream boundary primarily affect the lower lying areas of the catchment. However, it is noted that a weir across the creek, just downstream of the industrial area, at the High Street Ford, forms the tidal limit for the Lake Macquarie waters. Comparative results to the 1990 Report are not applicable as the 2005 Flood Study assessed tidal sensitivity on the 100 year ARI and 5 year ARI events.

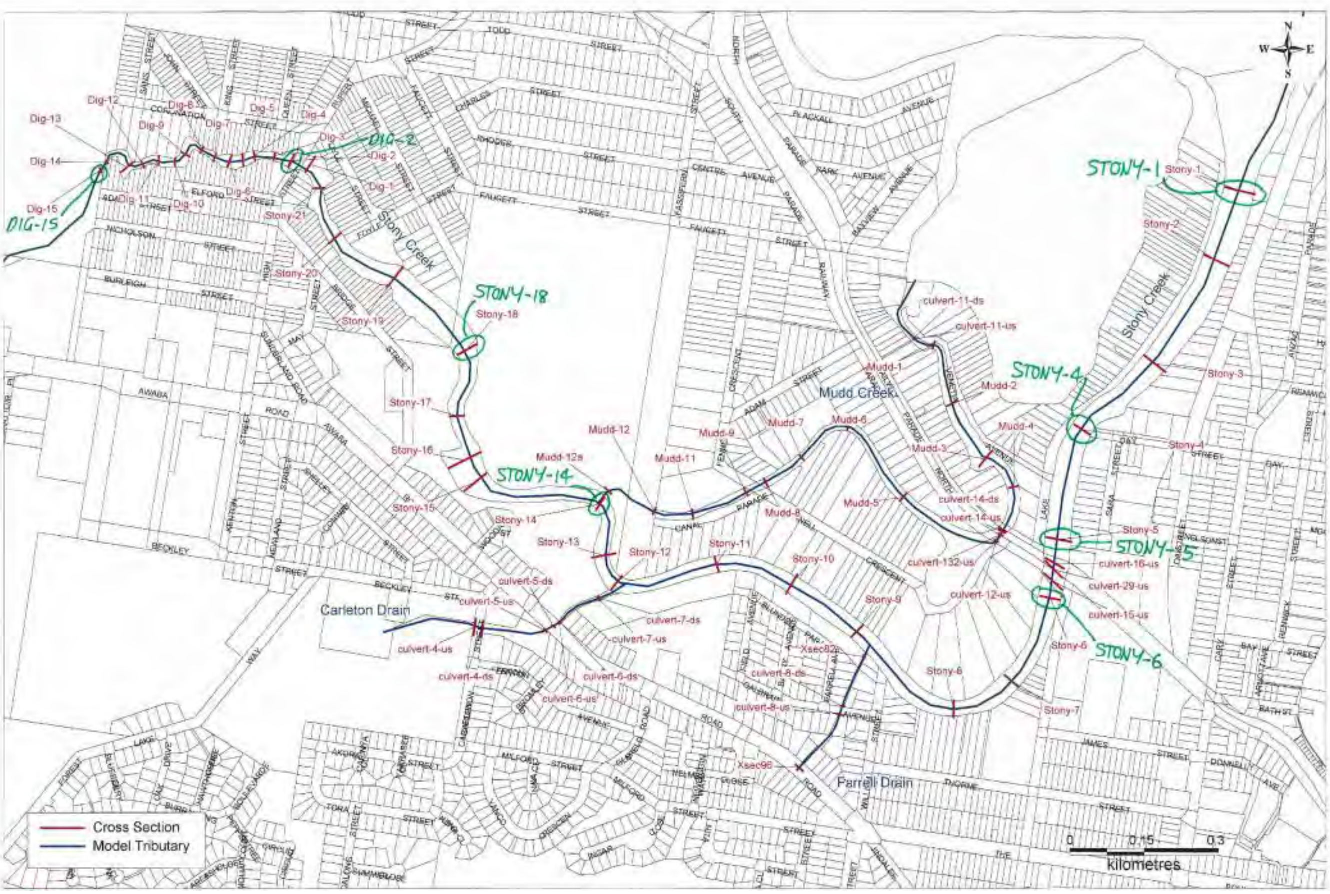


Figure C.2 - 2005 Flood Study Cross-section Locations

C.1.8 Removal of Railway Piers

The 1990 Report presented results for a model analysis incorporating the removal of 50% and also 100% of the piers of the old railway bridge. The results are shown in **Table C.6.**

The 1990 Report concludes the removal of the piers will have only marginal effects on levels in the main channel, noting 'reduction of the piers reduces the flood level by less than 50 mm'. However, the results tabled above suggest that complete removal of the piers results in a more significant decrease in levels between the sewage treatment plant and west of Railway Parade. Note that the flood levels at the Industrial Estate are influenced by the levee.

In 1993, Council responded to a query from a resident about the removal of the railbridge, citing results from the 1990 Report indicating that removal 'may lower upstream floodloads by 0.49 metres'. The State Rail Authority indicated at the time that it was 'reviewing options for the Toronto-Fassifern rail line'.

C.1.9 Greenhouse Effect

The 1990 Report acknowledged potential outcomes of the Greenhouse Effect, but the modelling of such changes was beyond the scope of the study. It was noted that potential changes may include:

- Increased tidal level causing further inundation of the lower areas of Stony Creek;
- Increased storm intensity may change the flood levels for a given storm recurrence interval.

Table C.6 - 1990 Report Railway Removal Scenario

Location Description	Cross-section reference	50% Piers Removed	100% Piers Removed
Industrial Estate (west side)	15	4.75	4.87
Industrial Estate (east side)	11	3.35	3.25
Sewage Treatment Plant (west side)	9	3.24	3.20
Sewage Treatment Plant (east side)	7	2.83	2.72
West of Railway Parade	3	2.36	1.87
East of Railway Parade	2	1.77	1.77
Adjacent Day Street	1	1.40	1.40
Stony Creek Outlet to Fennell Bay	-	-	-

C.1.10 General Conclusions

The 1990 Report also concluded:

- The 1981 storm event was in excess of 100 year ARI,
- The restriction of the Mudd Creek bridge opening compared to the former opening caused flood levels to rise by 0.02m,
- Local siltation in the creek bed did not cause substantial increases in flood level.

C.2 SEPTEMBER 1991 REPORT

The September 1991 Report "Flood Study for Proposed Development in Lake Street, Blackalls Park" was commissioned by Lake Macquarie City Council to investigate possible effects on flooding if a medium density was permitted along Lake Street.

C.2.1 Flood Modelling

The model used in the October 1989 Report, and hence generally equivalent to the October 1990 Report (discussed in previous section), was extended downstream from Cross-section 1. Presumably this added cross-section (labelled 0.5) is further along Lake Street closer to the outlet of Stony Creek into Fennell Bay. Flood levels from the 1991 Report for the existing scenario are listed in **Table C.7**.

Table C.7 - 1991 Report & 1990 Report Flood Levels (m AHD)

Location Description	Cross-section reference	1991 Report		1990 Report	
		100 year ARI	20 year ARI	100 year ARI	20 year ARI
Sewage Treatment Plant (east side)	7	2.26	1.71	2.17	1.68
West of Railway Parade	3	1.87	1.36	1.81	1.52
East of Railway Parade	2	1.62	1.29	1.54	1.44
Adjacent Day Street	1	1.51	1.21	1.40	1.40
Stony Creek Outlet to Fennell Bay	0.5	1.00	1.00	-	-

A tailwater level of 1.00m AHD was used for Section 0.5 for both the 100 year ARI and 20 year ARI. The 1991 Report states that the 1991 modelling results in a level of 1.51 at Section 1, compared to the (observed) level of 1.40 used for the 1990 modelling. It is recommended that the actual 100 year ARI flood level is between these two values. The 100 year ARI level of 1.45m AHD determined in the 2005 Flood Study for Section 1 is within this range. The 1991 Report states that actual water surface elevations should be obtained from the October 1990 Report.

Estimated flood levels from the 2005 Flood Study and the 1991 Report are listed in **Table C.8**. The 100 year ARI flood levels from the 1991 Report show good correlation to those of the 2005 Flood Study. However, similar to the 1990 Report review in the previous section, the 20 year ARI flood levels do not correlate as well, except for the downstream sections where the levels are similar.

Table C.8 - 1991 Report & 2005 Flood Study Flood Levels (m AHD)

Location Description	Cross-section reference	1991 Report		2005 Flood Study	
		100 year ARI	20 year ARI	100 year ARI	20 year ARI
Sewage Treatment Plant (east side)	7	2.26	1.71	2.25	1.99
West of Railway Parade	3	1.87	1.36	1.82	1.56
East of Railway Parade	2	1.62	1.29	1.48	1.28
Adjacent Day Street	1	1.51	1.21	1.45	1.15
Stony Creek Outlet to Fennell Bay	0.5	1.00	1.00	1.01	1.01

The 1991 Report identified that a Probable Maximum Precipitation (PMP) event would result in water level of 2.42m AHD, which is equivalent to a depth up to 1.7m within the development site. The specific location of this peak level is not known, however the 2005

Flood Study indicates a higher PMP flood level along Lake Street. The PMP flood level estimated in the 2005 Flood Study is 3.06m AHD at the intersection of Venetia Avenue, 2.86m AHD at equivalent Cross-section 1 and 2.64m AHD at the northern end of Lake Street.

C.2.2 Lake Street Development

Options for the medium-density development of an unspecified site within Lake Street were examined as it is categorised as high hazard based on the Floodplain Development Manual. Any works would also be required to not adversely affect flood levels upstream or downstream.

Hydraulic analysis of the site showed that the 100 year ARI flood level was 1.55m AHD. Filling of the site to this level (1.55m AHD) was then subsequently modelled. The peak flood level for the filled scenario increased the 100y ARI flood level to 1.62m AHD within the development and flood levels upstream increased by up to 0.18m. Differences in flood levels at several locations are shown in Table C.9. This filling option was not considered viable due to the resultant adverse effects to properties upstream.

Table C.9 - 1991 Report Filled Scenario

Location Description	Cross-section reference	100 year ARI		20 year ARI	
		Flood Level (m AHD)	Difference to Existing	Flood Level (m AHD)	Difference to Existing
Sewage Treatment Plant (east side)	7	2.31	0.05	1.71	0.01
West of Railway Parade	3	1.97	0.10	1.36	0.01
East of Railway Parade	2	1.70	0.08	1.29	0.03
Adjacent Day Street	1	1.57	0.06	1.21	0.02
Stony Creek Outlet to Fennell Bay	0.5	1.00	0	1.00	0

A second option of minimum floor levels above the 100 year ARI level combined with elevated footpaths to link buildings within the development and to provide access to safe high ground was examined. A minimum floor level of 1.56m AHD would need to be adopted for this option. This option was not recommended because of the dangers of residential areas in high hazard floodway areas.

Therefore, the 1991 Report concluded that this medium density residential development should not proceed. An industrial or commercial development was stated as more suitable for this site provided suitable flood proofing and compatible materials could be applied.

C.2.3 CONCLUSION

The computer models used to determine flood levels within the Stony Creek catchment, for the 1990 Report and the 2005 Flood Study are significantly different. Limited information was available for determining comparative locations of flood levels of the two studies. The two analyses showed some reasonable correlation in some locations, both noting the tidal influence is significant for the lower reaches. The 2005 Flood Study modelling is considered to supersede the 1990 Report due to the use of the more detailed SOBEK model.

The 1991 Report was completed to assess a development within Lake Street and recommends using the 1990 Report for obtaining flood levels within the catchment. Notably, the 1991 Report concludes that the proposed medium-density residential development within Lake Street was not suitable due to the flood hazards within the site and potential upstream adverse effects.

Changes to flood behaviour resulting from removal of the disused railway piers near Railway Parade and due to climate change will be examined in the Floodplain Risk Management Study.

Appendix D

Culvert Blockage Review

D Culvert Blockage Review

The potential effect of culvert blockage on flood levels in the catchment was assessed by modelling three additional scenarios to the sensitivity analysis in the Flood Study. Blockage to all culverts included in the model was assessed in the Flood Study.

The culverts included in the model are shown in **Figure D_1** and details listed in **Table D.1**.

Table D.1 – Culvert Structures Modelled

	Description
1	Box culvert
2	Three cell box culvert
3	Three cell box culvert
4	Three cell box culvert
5	Twenty-nine cell box culvert
6	Pipe
7	Two pipes
8	Arch-shaped culvert
9	Pipe
10	Three cell box culvert
11	Trapezoidal culvert
12	Bridge
13	Two cell box culvert
14	Two cell box culvert
15	Road crossing
16	Pipe crossing
17	Rail crossing
18	Road crossing
19	Footpath crossing
20	Rail crossing
21	Road crossing

The aim of the alternative scenarios modelled for this assessment was to assess flood levels for potential "worst case" combinations of blockage to particular culverts.

The culverts in the upstream section of the model, near the railway line and haul road, were not blocked for these assessment scenarios as this would result in runoff being retained in this upstream area resulting in lower waters downstream in the main residential and industrial areas within Toronto.

The downstream bridge in the model, Fennell Bay Bridge at Main Road is not expected to be the major control for the water levels in the residential areas. Significant blockage is also unlikely to this bridge due to its large open conveyance area and the large area of Edmunds Bay and Fennell Bay which are likely to disperse potential blockage debris.

The primary structures which are likely to influence flood levels are the crossings of the channels at Railway Parade and the pipe and railway crossings just downstream. Blockages to structures along the tributaries on the south side of Stony Creek near Galbraith Avenue and Carleton Street. Blockage to the small opening culverts on the branch lines is more likely as debris is washed from upstream areas into the single watercourse channel where it is conveyed to the culvert openings. Along Mudd Creek, potential blockage of the culverts along this reach is also potentially likely.

In the resident questionnaire, following the June 2007 storm event, responses received noted blockages to these culverts.

The blockage cases modelled are:

- Case 1 – Blockage to all the culverts / crossings at Railway Parade (locations 15, 16, 17, 18, 19, and 20);
- Case 2 – Blockage to all the culverts / crossings at Railway Parade (locations 15, 16, 17, 18, 19, and 20), Carleton Drain (locations 10, 11, and 12), Stony Creek – Mudd Creek confluence (location 9), and Galbraith Avenue (location 14) to model worst case for properties on the southern side of Stony Creek;
- Case 3 – Blockage to Mudd Creek culverts / crossings at Railway Parade (locations 18, 19, and 20) to model worst case for properties along Lake Street and Day Street.

The blockage cases were modelled for the 100 year ARI critical duration of 36 hours for the low tailwater condition (5 year ARI). Comparison results at reference locations shown in **Figure D_2** are listed in **Table D.2**. **Figures D_3, D_4, and D_5** show the difference in peak water levels for Blockage Cases 1, 2, and 3 respectively compared to the unblocked culvert scenario. **Table D.3** shows the comparative number of properties inundated for the blockage scenarios.

The results for Case 1 show significant increases to upstream water levels up to the industrial areas due to the blockage of the culverts at Railway Parade. Blockage of these culverts results in overflow across Railway Parade which results in increased levels along Mudd Creek adjacent to Venetia Avenue as flow spills across this part of the road first. Consequently, the flows along Stony Creek adjacent to Lake Street and Day Street are reduced as the additional flow is conveyed in Mudd Creek.

Blockage Case 2 modelling shows similar flood impacts around Railway Parade as for Case 1. Adjacent to Carleton Road, the runoff is conveyed across the road to Awaba Road in lieu of the blocked culvert carrying the flow.

The flood level increases upstream of Railway Parade are reduced compared to Case 1 and 2, but significant increases still result from the blockage of the Mudd Creek culvert /

crossings in Case 3. This blockage scenario results in additional flow being conveyed along Stony Creek adversely affecting properties in Lake Street and Day Street but reductions in flood levels occur along Venetia Avenue.

However, the reduced peak water levels downstream of Railway Parade are likely to be particularly affected by the storm event water level in Lake Macquarie which is around 1.4m AHD in the 100y ARI event. This is identified as being affected by the high tail water scenario modelling, which was not included in the blockage analysis.

Table D.2 Blockage Scenario Peak Water Levels (m AHD for 100y ARI 36h event)

	No Blockage	All Culverts Blocked	Diff. to Base Case	Blockage Case 1	Diff. to Base Case	Blockage Case 2	Diff. to Base Case	Blockage Case 3	Diff. to Base Case
1	8.02	10.84	2.82	8.02	0.00	8.02	0.00	8.02	0.00
2	2.97	3.09	0.13	3.12	0.15	3.12	0.15	3.00	0.03
3	2.62	2.85	0.23	2.86	0.24	2.86	0.24	2.67	0.05
4	2.27	2.61	0.34	2.60	0.33	2.60	0.33	2.34	0.07
5	3.45	3.52	0.07	3.45	0.00	3.52	0.07	3.45	0.00
6	2.18	2.57	0.39	2.55	0.38	2.55	0.38	2.26	0.08
7	2.08	2.52	0.44	2.50	0.43	2.50	0.43	2.18	0.10
8	2.06	2.51	0.46	2.50	0.44	2.50	0.44	2.16	0.10
9	1.98	2.49	0.51	2.47	0.49	2.47	0.49	2.09	0.11
10	1.90	2.47	0.58	2.45	0.56	2.45	0.56	2.02	0.12
11	2.01	2.49	0.48	2.47	0.46	2.47	0.46	2.12	0.12
12	1.35	1.51	0.16	1.58	0.22	1.58	0.22	1.26	-0.09
13	1.43	1.35	-0.08	1.33	-0.10	1.33	-0.10	1.48	0.06
14	1.38	1.32	-0.06	1.33	-0.06	1.33	-0.06	1.43	0.05
15	1.29	1.49	0.19	1.47	0.17	1.47	0.17	1.35	0.05
16	1.17	1.29	0.12	1.30	0.14	1.30	0.14	1.15	-0.02
17	1.13	1.07	-0.07	1.06	-0.08	1.06	-0.08	1.17	0.04

Table D.3: Blockage Scenarios Inundation Summary – 100y ARI

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding
Base Case				
Residential	41	0.19	0.66	165
Commercial	3	0.26	0.30	6
Industrial	13	0.15	0.67	26
Base Case Total	57			197
Blockage Case 1				
Residential	70	0.94	1.16	165
Commercial	4	0.59	0.34	7
Industrial	19	0.88	0.54	29
Case 1 Total	93			201
Blockage Case 2				
Residential	70	0.41	1.16	165
Commercial	4	0.29	0.34	7
Industrial	19	0.20	0.54	29
Case 2 Total	93			201
Blockage Case 3				
Residential	42	0.25	0.77	153
Commercial	3	0.22	0.29	6
Industrial	14	0.13	0.53	27
Case 3 Total	59			186

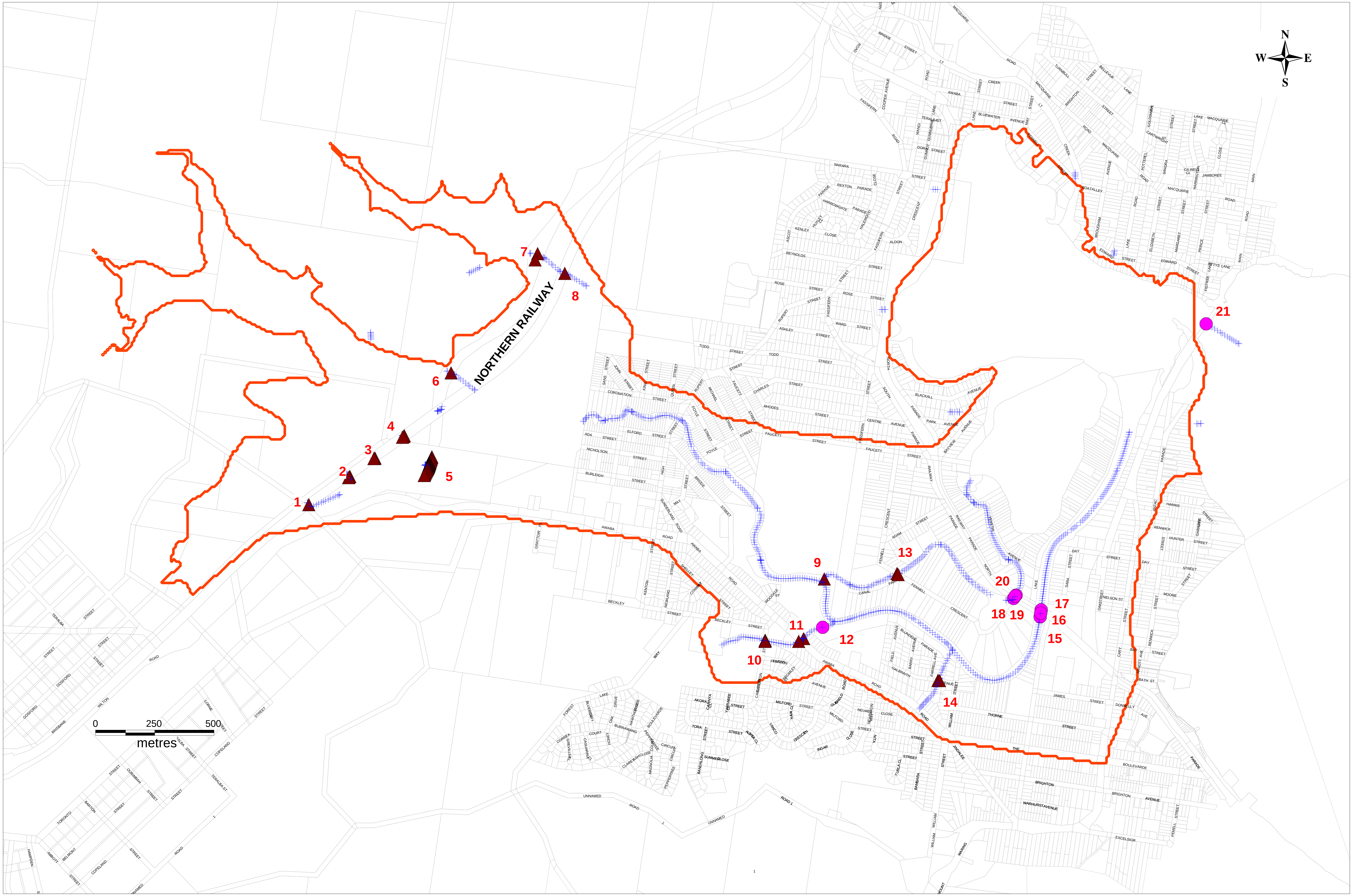


FIGURE D_1
CULVERT LOCATIONS

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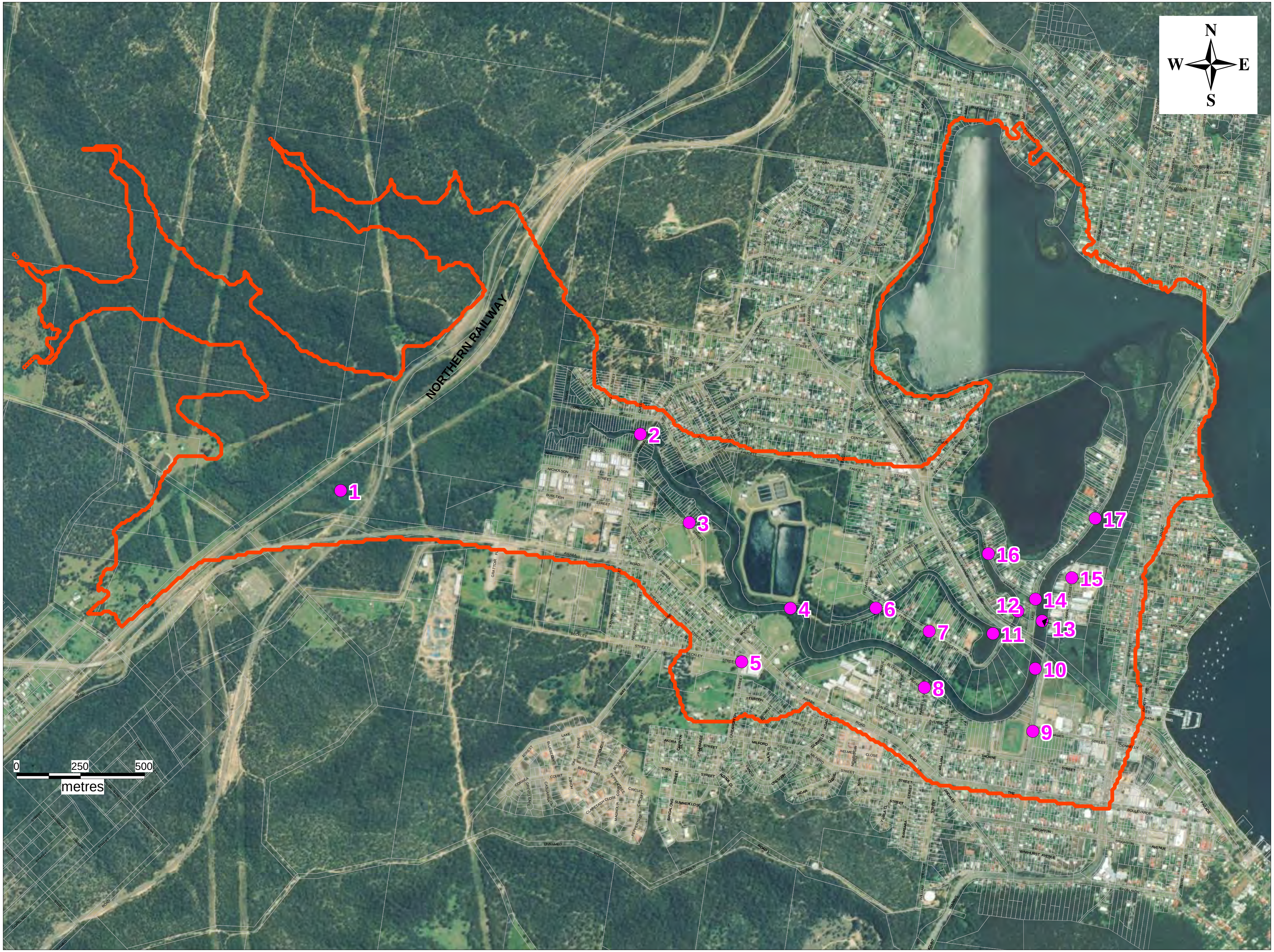
Dec 2011

J2597/V3
Dec 2011

Stony Creek Floodplain Risk Managment Study

FIGURE D_2
BLOCKAGE REPORT LOCATIONS



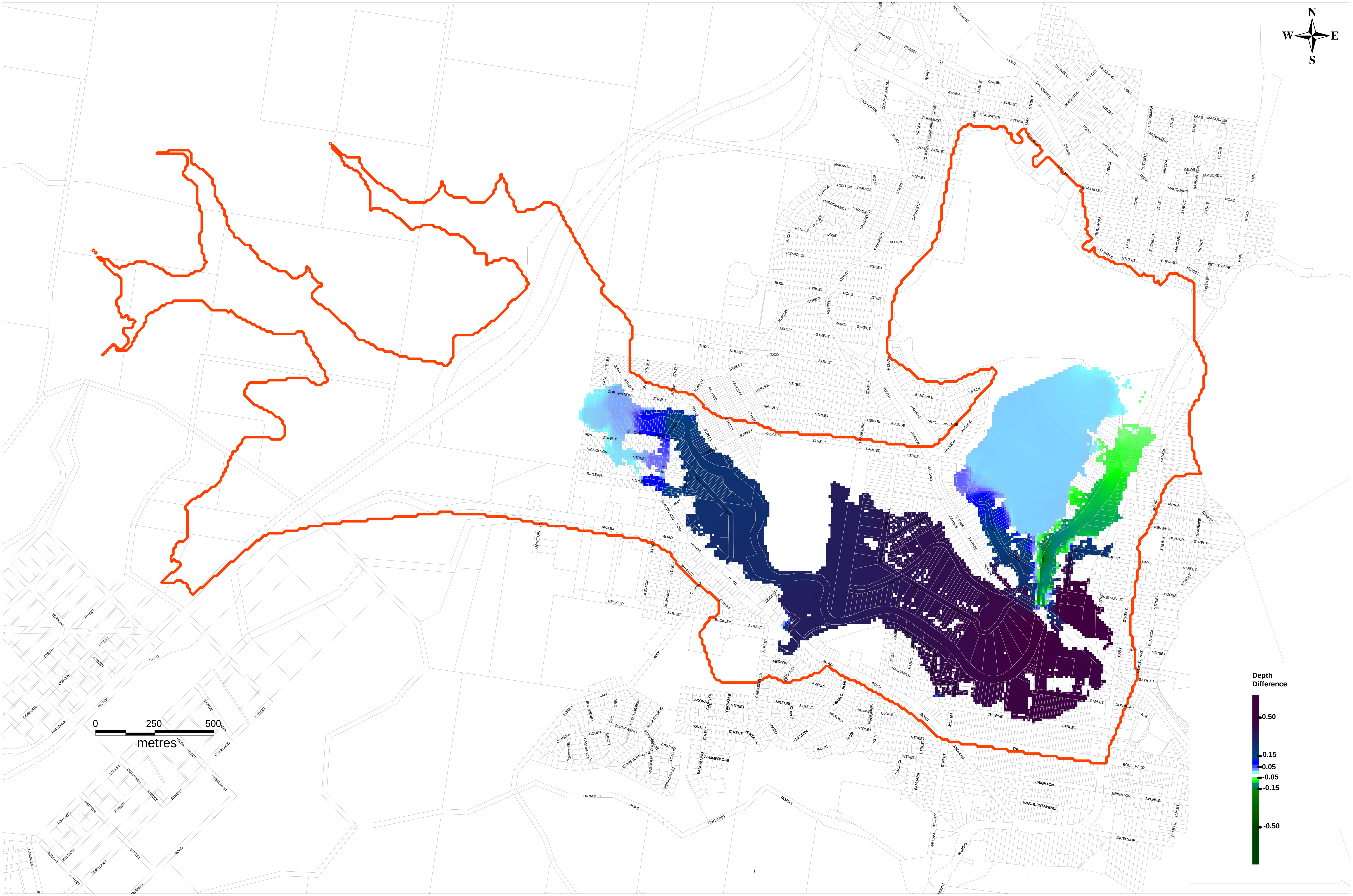


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FIGURE D_3
BLOCK CASE1 DEPTH DIFFERENCE

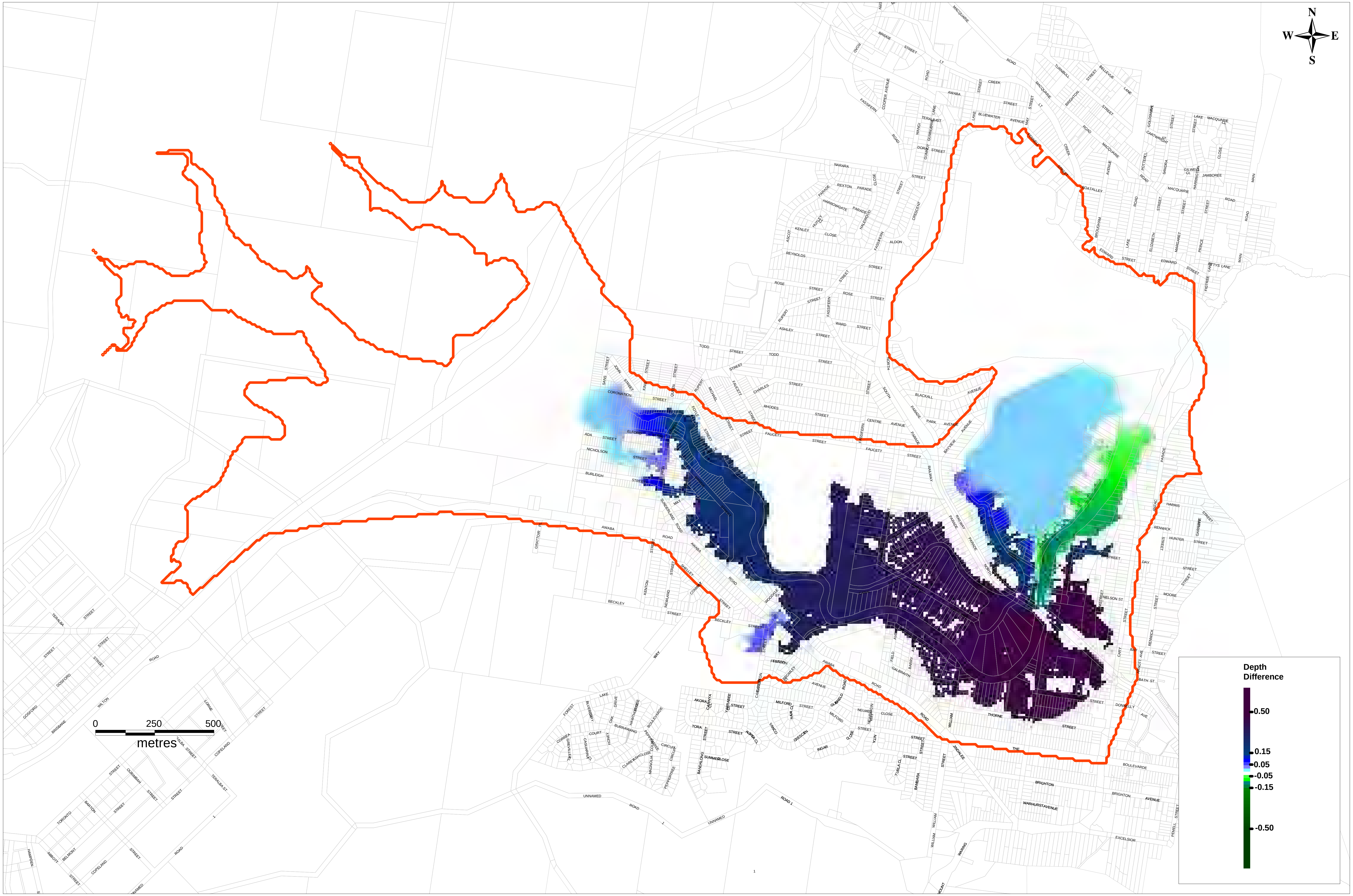
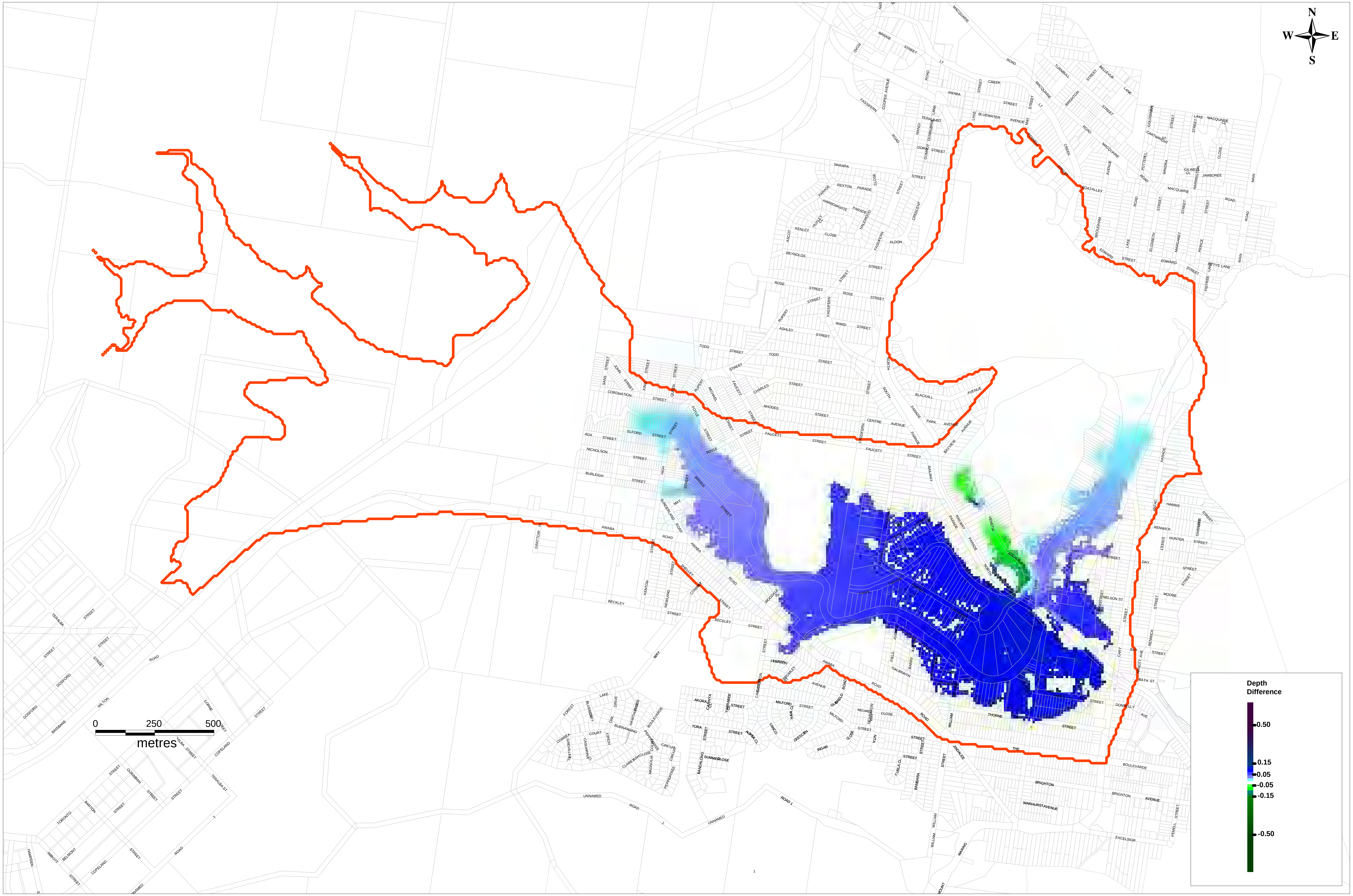


FIGURE D_4
BLOCK CASE2 DEPTH DIFFERENCE



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Stony Creek Floodplain Risk Management Study

FIGURE D_5
BLOCK CASE3 DEPTH DIFFERENCE

Appendix E

Cost Estimates for Qualitatively Assessed Options

MITIGATION OPTION FM1.2
DETENTION BASIN

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 10,000.00	$ 10,000
Site Establishment	1	each	$ 30,000.00	$ 30,000
Site Fencing	1,000	m	$ 30.00	$ 30,000
Geotechnical Testing / Survey	1	each	$ 20,000.00	$ 20,000
Erosion and Sedimentation Control	50,000	sq.m	$ 1.00	$ 50,000
2.0 Demolition				
Clearing and chipping of trees in enbankment footprint	50,000	sq.m	$ 10.00	$ 500,000
3.0 Earthworks				
Cut to fill	13,000	cu.m	$ 10.00	$ 130,000
Import place and compact fill	2,600	cu.m	$ 20.00	$ 52,000
4.0 Drainage				
4.2 wide x 1.8 high box culvert 25m long	2	m	$ 9,000.00	$ 18,000
Headwall for box culvert	2	each	$ 9,000.00	$ 18,000
Rock mattress for scour protection	84	sq.m	$ 400.00	$ 33,600
6.0 Roads				
Allow temporary access	1	item	$ 10,000.00	$ 10,000
5.0 Permits / Approvals				
Tree clearing	1	item	$ 5,000.00	$ 5,000
		SUB-TOTAL (Excl. GST)		$ 906,600
		Contingency 30%		$ 271,980
		TOTAL (Excl. GST)		$ 1,178,580
		GST		$ 117,858
		TOTAL (Incl. GST)		$ 1,296,438

DISCLAIMER:
This estimate of cost is provided in good faith using information available at this stage. This is not a Quantity Surveyor's estimate. This estimate of cost is not guaranteed, and Cardno (NSW) Pty Ltd will not accept liability in the event that actual costs exceed the estimate.

MITIGATION OPTION FM2.3
CARLETON ST & AWABA RD CULVERT AUGMENTATION

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 20,000.00	$ 20,000
Site Establishment	1	each	$ 20,000.00	$ 20,000
Site Fencing	200	m	$ 30.00	$ 6,000
Geotechnical Testing / Survey	1	each	$ 10,000.00	$ 10,000
Erosion and Sedimentation Control	1	item	$ 5,000.00	$ 5,000
2.0 Demolition				
Carleton St				
Dispose of existing culverts	1	item	$ 15,000.00	$ 15,000
Excavate a future 0.7m into concrete	96	cu.m	$ 500.00	$ 48,000
Remove and dispose existing road pavement	120	sq.m	$ 10.00	$ 1,200
Awaba Rd				
Remove and dispose existing road pavement	18	cu.m	$ 70.00	$ 1,260
3.0 Structural Elements				
Adjust walkway abutment to match extents of the widened culvert (downstream of Awaba Rd)	1	item	$ 100,000.00	$ 100,000
4.0 Earthworks				
Regrade channel	1	item	$ 20,000.00	$ 20,000
Scour	1	item	$ 50,000.00	$ 50,000
Carleton St				
Cut & dispose offsite	19	cu.m	$ 60.00	$ 1,140
Awaba Rd				
Cut & dispose offsite	150	cu.m	$ 60.00	$ 9,000
5.0 Drainage				
Divert water during construction	1	item	$ 50,000.00	$ 50,000
Carleton St				
3m x 1.5m box culvert 12m length	48	m	$ 6,800.00	$ 326,400
Construct headwall	2	each	$ 10,000.00	$ 20,000
Awaba Rd				
3m x 1.8m box culvert 12m length	18	m	$ 7,200.00	$ 129,600
Reconstruct headwall	1	each	$ 10,000.00	$ 10,000
5.0 Underground Services				
Adjust minor services	1	item	$ 50,000.00	$ 50,000
Relocate power pole	1	item	$ 10,000.00	$ 10,000
6.0 Roads				
Reconstruct Carleton St pavement above new culvert	80	sq.m	$ 100.00	$ 8,000
Reconstruct Awaba Rd pavement above new culvert	30	sq.m	$ 100.00	$ 3,000
7.0 Permits / Approvals				
Tree clearing	1	item	$ 5,000.00	$ 5,000
Part 3A	1	item	$ 10,000.00	$ 10,000
		SUB-TOTAL (Excl. GST)		$ 928,600
		Contingency 30%		$ 278,580
		TOTAL (Excl. GST)		$ 1,207,180
		GST		$ 120,718
		TOTAL (Incl. GST)		$ 1,327,898

NOTE:
Assume no property acquired

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MITIGATION OPTION FM3.1
INDUSTRIAL AREA LEVEE

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 2,000.00	$ 2,000
Site Establishment	1	each	$ 10,000.00	$ 10,000
Site Fencing	1,030	m	$ 30.00	$ 30,900
Geotechnical Testing / Survey	1	each	$ 15,000.00	$ 15,000
Erosion and Sedimentation Control	12,500	sq.m	$ 1.00	$ 12,500
2.0 Demolition				
Clearing and chipping of trees in embankment footprint	12,500	sq.m	$ 10.00	$ 125,000
3.0 Earthworks				
Import place and compact fill	7,450	cu.m	$ 20.00	$ 149,000
Vegetate	3,500	sq.m	$ 5.00	$ 17,500
4.0 Drainage				
Flood gates	1	item	$ 20,000.00	$ 20,000
Drainage through levee	1	item	$ 50,000.00	$ 50,000
5.0 Permits / Approvals				
Tree clearing	1	item	$ 5,000.00	$ 5,000
Part 3A	1	item	$ 10,000.00	$ 10,000
		SUB-TOTAL (Excl. GST)		$ 446,900
		Contingency 30%		$ 134,070
		TOTAL (Excl. GST)		$ 580,970
		GST		$ 58,097
		TOTAL (Incl. GST)		$ 639,067

NOTE:
Assume no access required over levee
Assume length, height, width all constant

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MITIGATION OPTION FM3.4
LEVEE ADAM STREET

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 20,000.00	$ 20,000
Site Establishment	1	each	$ 40,000.00	$ 40,000
Site Fencing	1,650	m	$ 30.00	$ 49,500
Geotechnical Testing / Survey	1	each	$ 10,000.00	$ 10,000
Erosion and Sedimentation Control	8,200	sq.m	$ 1.00	$ 8,200
2.0 Demolition				
Clearing and chipping of trees in embankment footprint	8,200	sq.m	$ 10.00	$ 82,000
Remove existing pavement	230	cu.m	$ 10.00	$ 2,300
Remove existing culverts	2	item	$ 10,000.00	$ 20,000
Property acquisition and demolition	450	item	$ 400.00	$ 180,000
3.0 Earthworks				
Import place and compact fill	4,137	cu.m	$ 20.00	$ 82,730
Regrade U/S & D/S of culverts	2	each	$ 10,000.00	$ 20,000
Scour	1	item	$ 20,000.00	$ 20,000
4.0 Drainage				
Upsize existing culverts (approx dim 2.8m x 1.5m)	26	m	$ 3,200.00	$ 83,200
Reconstruct headwall	4	each	$ 10,000.00	$ 40,000
Divert water during construction	1	item	$ 50,000.00	$ 50,000
5.0 Underground Services				
Adjust minor services	1	item	$ 50,000.00	$ 50,000
6.0 Roads				
Reconstruct Fennell Street	230	sq.m	$ 75.00	$ 17,250
Oval access at noth end of levee off Fennell Rd	1	item	$ 25,000.00	$ 25,000
6.0 Permits / Approvals				
Tree clearing	1	item	$ 5,000.00	$ 5,000
Part 3A	1	item	$ 10,000.00	$ 10,000
			SUB-TOTAL (Excl. GST)	$ 815,180
			Contingency 30%	$ 244,554
			TOTAL (Excl. GST)	$ 1,059,734
			GST	$ 105,973
			TOTAL (Incl. GST)	$ 1,165,707

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MITIGATION OPTION FM4.2
MUDD CREEK AUGMENTATION

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 20,000.00	$ 20,000
Site Establishment	1	each	$ 50,000.00	$ 50,000
Site Fencing	100	m	$ 30.00	$ 3,000
Geotechnical Testing / Survey	1	each	$ 10,000.00	$ 10,000
Erosion and Sedimentation Control	1	item	$ 10,000.00	$ 10,000
2.0 Demolition				
Remove existing bridge abutment	54	cu.m	$ 450.00	$ 24,480
Remove existing approach slab	68	cu.m	$ 450.00	$ 30,600
Decommission railway bridge	32	m	$ 3,500.00	$ 112,000
Remove and dispose existing road pavement	48	cu.m	$ 70.00	$ 3,360
3.0 Structural Elements				
Supply and placement of in-situ concrete deck for additional 8m length	68	sq.m	$ 3,000.00	$ 204,000
Reconstruct abutment at midpoint of widened bridge to support two 8m long concrete slabs	1	item	$ 150,000.00	$ 150,000
Construct approach slab for new works	68	sq.m	$ 3,000.00	$ 204,000
Construct abutment for new works	1	item	$ 150,000.00	$ 150,000
Adjust walkway abutment to match extents of the widened culvert	1	item	$ 100,000.00	$ 100,000
Adjust guard rails	1	item	$ 10,000.00	$ 10,000
4.0 Earthworks				
Cut & dispose offsite	400	cu.m	$ 50.00	$ 20,000
Scour	1	item	$ 20,000.00	$ 20,000
5.0 Underground Services				
Adjust watermains	1	item	$ 300,000.00	$ 300,000
Adjust existing minor services	1	item	$ 50,000.00	$ 50,000
Divert watermain during construction	1	item	$ 50,000.00	$ 50,000
6.0 Permits / Approvals				
Watermain shutdown	1	item	$ 50,000.00	$ 50,000
Approval for works in creek	1	item	$ 10,000.00	$ 10,000
Decommissioning railway bridge (Heritage listed)	1	item	$ 20,000.00	$ 20,000
		SUB-TOTAL (Excl. GST)		$ 1,601,440
		Contingency 30%		$ 480,432
		TOTAL (Excl. GST)		$ 2,081,872
		GST		$ 208,187
		TOTAL (Incl. GST)		$ 2,290,059

NOTE:
Watermain adjustment is significant and is expected to have long lead and approval times with strict restrictions upon the works
Removal of railway line subject to permission from relevant authority

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OPTION FM4.6
STONY CREEK & MUDD CREEK AUGMENTATION

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 50,000.00	$ 50,000
Site Establishment	1	each	$ 100,000.00	$ 100,000
Site Fencing	500	m	$ 30.00	$ 15,000
Geotechnical Testing / Survey	1	each	$ 30,000.00	$ 30,000
Erosion and Sedimentation Control	1	item	$ 20,000.00	$ 20,000
2.0 Demolition				
Mudd Creek				
Remove existing bridge abutment	54	cu.m	$ 450.00	$ 24,480
Remove existing approach slab	68	cu.m	$ 450.00	$ 30,600
Decommission railway bridge	32	m	$ 3,500.00	$ 112,000
Remove and dispose existing road pavement	48	cu.m	$ 70.00	$ 3,360
Stoney Creek				
Remove existing approach slab	13	cu.m	$ 450.00	$ 5,625
Decommission railway bridge	63	m	$ 5,000.00	$ 315,000
Remove and dispose existing road pavement	99	cu.m	$ 70.00	$ 6,930
3.0 Structural Elements				
Mudd Creek				
Supply and placement of in-situ concrete deck for additional 8m length	68	sq.m	$ 3,000.00	$ 204,000
Reconstruct abutment at midpoint of widened bridge to support two 8m long concrete slabs	1	item	$ 100,000.00	$ 100,000
Construct approach slab for new works	50	sq.m	$ 250.00	$ 12,500
Construct abutment for new works	1	item	$ 100,000.00	$ 100,000
Adjust walkway abutment to match extents of the widened culvert	1	item	$ 100,000.00	$ 100,000
Stoney Creek				
Supply and placement of in-situ concrete deck for additional 15m length	165	sq.m	$ 3,000.00	$ 495,000
Modify existing bridge abutment to support new in-situ concrete deck	1	item	$ 100,000.00	$ 100,000
Construct approach slab for new works	13	cu.m	$ 250.00	$ 3,125
Construct abutment for new works	1	item	$ 100,000.00	$ 100,000
4.0 Earthworks				
Cut & dispose offsite	890	cu.m	$ 60.00	$ 53,400
Bank works	1	item	$ 50,000.00	$ 50,000
Scour	1	item	$ 50,000.00	$ 50,000
4.0 Drainage				
Divert water during construction	1	item	$ 10,000.00	$ 10,000
Headwall for box culvert	1	item	$ 10,000.00	$ 10,000
5.0 Underground Services				
Minor service adjustments	1	item	$ 100,000.00	$ 100,000
Relocate power pole	1	item	$ 20,000.00	$ 20,000
Adjust watermains (Mudd Creek)	1	item	$ 300,000.00	$ 300,000
Adjust watermains (Stoney Creek)	1	item	$ 400,000.00	$ 400,000
6.0 Roads				
Reconstruct Cook St above new bridge deck	80	sq.m	$ 100.00	$ 8,000
7.0 Permits / Approvals				
Watermain shutdown	1	item	$ 100,000.00	$ 100,000
Decommissioning railway bridge	1	item	$ 20,000.00	$ 20,000
Part 3A	1	item	$ 20,000.00	$ 20,000
			SUB-TOTAL (Excl. GST)	$ 3,069,020
			Contingency 30%	$ 920,706
			TOTAL (Excl. GST)	$ 3,989,726
			GST	$ 398,973
			TOTAL (Incl. GST)	$ 4,388,699

NOTE:
Removal of railway line subject to permission from relevant authority
Assume no property acquired

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MITIGATION OPTION FM4.7
RAILWAY LINE REMOVAL

ITEM	QUANTITY	UNIT	RATE	AMOUNT
1.0 Preliminaries				
Traffic Control	1	item	$ 10,000.00	$ 10,000
Site Establishment	1	each	$ 50,000.00	$ 50,000
Site Fencing	500	m	$ 30.00	$ 15,000
Geotechnical Testing / Survey	1	each	$ 5,000.00	$ 5,000
Erosion and Sedimentation Control	1	item	$ 10,000.00	$ 10,000
2.0 Demolition				
Decommission railway bridge	2	each	$ 300,000.00	$ 600,000
3.0 Permits / Approvals				
Decommissioning railway bridge	1	item	$ 10,000.00	$ 10,000
		SUB-TOTAL (Excl. GST)		$ 700,000
		Contingency 30%		$ 210,000
		TOTAL (Excl. GST)		$ 910,000
		GST		$ 91,000
		TOTAL (Incl. GST)		$ 1,001,000

NOTE:
Removal of railway line subject to permission from relevant authority

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Appendix F

Multi-Criteria Assessment Matrix

Multi-Criteria Matrix

ID	Category of Measure	Location	Description	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 years)	Reduction in AAD	% reduction in c.f. to base case	NPV of Reduction in AAD	Benefit - Cost Ratio	Score on Benefit Cost Ratio	Capital and Operating Costs	Reduction in Risk to Property	Economic Score	Reduction in Risk to Life	Reduction in Social Disruption	Community Criteria	Council Support	Compatible with Policies and Plans	Social Score	Water Quality and Flow	Fauna & Flora	Environmental Score	TOTAL SCORE	RANK on TOTAL SCORE
P1	Property Modification	Lake Macquarie LGA	Planning Controls - LEP Update	$3,000	$1,000	$15,409	NC	N/A	N/A	N/A	2	2	2	**2.0**	2	1	1	2	2	**1.6**	0	0	**0.0**	**5.6**	**1**
P2	Property Modification	Lake Macquarie LGA	Building and Development Controls	$10,000	$1,000	$22,409	NC	N/A	N/A	N/A	2	2	2	**2.0**	2	1	1	2	2	**1.6**	0	0	**0.0**	**5.6**	**1**
P3	Property Modification	Selected locations throughout the floodplain	House raising	$320,000	$0	$320,000	$8,000	3.2%	$99,272	0.31	-2	0	1	**-0.8**	1	1	0	0	2	**0.8**	0	0	**0.0**	**-0.7**	**20**
P4	Property Modification	Selected locations throughout the floodplain	House Rebuilding	**An option for properties eligible for house raising**																					
P5	Property Modification	Selected locations throughout the floodplain	Voluntary purchase	$1,200,000	$0	$1,200,000	$16,000	6.5%	$198,545	0.17	-2	-1	1	**-1.0**	2	1	0	0	2	**1.0**	0	0	**0.0**	**-1.0**	**21**
P6	Property Modification	Selected locations throughout the floodplain	Land swap	**To be assessed for properties before voluntary purchase proceeds**																					
P7	Property Modification	Selected locations throughout the floodplain	Acquisition & Council Redevelopment	$2,000,000	$0	$2,000,000	$16,000	6.5%	$198,545	0.10	-2	-1	1	**-1.0**	2	1	0	0	2	**1.0**	0	0	**0.0**	**-1.0**	**21**
P8	Property Modification	Stony Creek Floodplain	Flood proofing guidelines	$10,000	$1,000	$22,409	NC	N/A	N/A	N/A	2	2	2	**2.0**	0	1	1	2	2	**1.2**	0	0	**0.0**	**5.2**	**3**
EM1	Emergency Response Modification	Lake Macquarie LGA	Information Transfer to SES	$2,000	$0	$2,000	NC	N/A	N/A	N/A	0	2	0	**0.5**	2	2	0	2	2	**1.6**	0	0	**0.0**	**2.6**	**5**
EM2	Emergency Response Modification	Lake Macquarie LGA	Preparation and Adoption of SES Local Flood Plan	$30,000	$2,000	$54,818	NC	N/A	N/A	N/A	0	1	0	**0.3**	2	2	0	2	2	**1.6**	0	0	**0.0**	**2.1**	**10**
EM3	Emergency Response Modification	Stony Creek Floodplain	Flood Warning System	$50,000	$10,000	$174,090	NC	N/A	N/A	N/A	0	1	1	**0.5**	2	2	1	1	2	**1.6**	0	0	**0.0**	**2.6**	**5**
EM4	Emergency Response Modification	Stony Creek Floodplain	Community Flood Awareness	$10,000	$2,000	$34,818	NC	N/A	N/A	N/A	0	2	1	**0.8**	2	2	1	2	2	**1.8**	0	0	**0.0**	**3.3**	**4**
EM5	Emergency Response Modification	Selected locations throughout the floodplain	Depth Markers at Street Crossings	$6,000	$200	$8,482	NC	N/A	N/A	N/A	0	2	0	**0.5**	2	2	0	1	2	**1.4**	0	0	**0.0**	**2.4**	**7**
EM6	Emergency Response Modification	Fennell Crescent	Fennel Crescent Evacuation Route	**Not Viable, refer to report**																					
EM7	Emergency Response Modification	Lake Street/ Venetia Avenue	Lake Street/ Venetia Avenue Evacuation Route	**Not Viable, refer to report**																					
FM1.1	Flood Modification	Upstream of railway line – 8 sites	Eight detention basins distributed across upstream catchment	$4,000,000	$15,000	$4,186,136	NC	N/A	N/A	N/A	-1	-2	2	**-0.5**	2	2	-2	-2	-2	**-0.4**	0	-2	**-1.0**	**-2.4**	**32**
FM1.2	Flood Modification	Upstream of railway line – 1 site	One detention basin just upstream of the railway line	$1,296,438	$5,000	$1,358,483	$103,949	42.1%	$1,289,904	0.95	1	-1	2	**0.8**	2	2	2	2	-1	**1.4**	0	-2	**-1.0**	**1.9**	**11**
FM 2.1	Flood Modification	Carleton Street	Additional culvert	$350,000	$5,000	$412,045	NC	N/A	N/A	N/A	-2	0	1	**-0.8**	0	1	-1	0	2	**0.4**	0	0	**0.0**	**-1.1**	**24**
FM 2.2	Flood Modification	Carleton Street	Augmentation of existing culverts and additional culvert	$500,000	$5,000	$562,045	NC	N/A	N/A	N/A	-2	-1	1	**-1.0**	0	1	-1	0	2	**0.4**	0	0	**0.0**	**-1.6**	**27**
FM 2.3	Flood Modification	Carleton Street and Awaba Road	Augmentation of existing culverts at Carleton Street and Awaba Road. Additional culvert at Carleton Street	$1,327,898	$5,000	$1,389,943	$4,199	1.7%	$52,107	0.04	-2	-2	1	**-1.3**	0	1	-1	0	2	**0.4**	0	0	**0.0**	**-2.1**	**31**
FM 3.1	Flood Modification	Toronto industrial area	Construct levee bank from Burleigh St to May St	$639,067	$5,000	$701,112	$10,522	4.3%	$130,567	0.19	1	-1	2	**0.8**	2	2	-2	2	2	**1.2**	0	-1	**-0.5**	**2.2**	**8**
FM 3.2	Flood Modification	Blundell Parade, Farrell Ave, and Galbraith Ave	Construct levee bank along Stony Creek	**Not Viable, potential negative impacts**																					
FM 3.3	Flood Modification	Fennell Cres. Between Mudd Creek and Stony Creek	Levee Bank	$1,748,561	$5,000	$1,810,606	NC	N/A	N/A	N/A	-1	-1	2	**-0.3**	2	2	-2	-2	2	**0.4**	0	-1	**-0.5**	**-0.6**	**19**
FM 3.4	Flood Modification	Adam St and Fennell Cres. (north of Mudd Creek)	Levee Bank	$1,165,707	$5,000	$1,227,753	$35,800	14.5%	$444,246	0.36	1	-1	2	**0.8**	2	2	-2	-2	2	**0.4**	0	-1	**-0.5**	**1.4**	**13**
FM 3.5	Flood Modification	Lake St and Venetia Ave	Construct levee bank to Edmunds Bay, Mudd Creek and Stony Creek	$1,597,668	$5,000	$1,659,713	NC	N/A	N/A	N/A	-1	-1	2	**-0.3**	2	2	-2	-1	2	**0.6**	0	-1	**-0.5**	**-0.4**	**18**
FM 3.6	Flood Modification	Sara St and Day Street	Construct levee bank to Stony Creek	$400,000	$5,000	$462,045	NC	N/A	N/A	N/A	0	0	2	**0.5**	1	1	-2	-1	2	**0.2**	0	-1	**-0.5**	**0.7**	**14**
FM 4.1	Flood Modification	Railway Parade – Mudd Creek	Augment culvert crossing of Mudd Creek	$2,100,000	$5,000	$2,162,045	NC	N/A	N/A	N/A	-1	-2	2	**-0.5**	2	2	-1	-1	2	**0.8**	0	0	**0.0**	**-0.2**	**17**
FM 4.2	Flood Modification	Railway Parade – Mudd Creek	Augment culvert crossing of Mudd Creek. Remove railway line and crossings downstream of Railway Parade	$2,290,059	$5,000	$2,352,104	$40,047	16.2%	$496,942	0.21	-1	-2	2	**-0.5**	2	2	-2	-1	-1	**0.0**	0	0	**0.0**	**-1.0**	**21**
FM 4.3	Flood Modification	Railway Parade – Stony Creek	Augment culvert crossing of Stony Creek	$2,500,000	$5,000	$2,562,045	NC	N/A	N/A	N/A	-2	-2	2	**-1.0**	2	2	-1	-1	2	**0.8**	0	0	**0.0**	**-1.2**	**25**
FM 4.4	Flood Modification	Railway Parade – Stony Creek	Augment culvert crossing of Stony Creek. Remove railway line and crossings downstream of Railway Parade	$2,700,000	$5,000	$2,762,045	NC	N/A	N/A	N/A	-2	-2	2	**-1.0**	2	2	-1	-1	-1	**0.2**	0	0	**0.0**	**-1.8**	**28**
FM 4.5	Flood Modification	Railway Parade – Stony Creek and Mudd Creek	Augment culvert crossings of Mudd Creek and Stony Creek	$4,000,000	$10,000	$4,124,090	NC	N/A	N/A	N/A	-2	-2	2	**-1.0**	2	2	-1	-1	2	**0.8**	0	0	**0.0**	**-1.2**	**25**
FM 4.6	Flood Modification	Railway Parade – Stony Creek and Mudd Creek	Augment culvert crossings of Mudd Creek and Stony Creek. Remove railway line and crossings downstream of Railway Parade	$4,388,699	$10,000	$4,512,789	$64,087	2.5	$795,253	0.18	-2	-2	2	**-1.0**	2	2	-2	-1	-1	**0.0**	0	0	**0.0**	**-2.0**	**30**
FM 4.7	Flood Modification	Railway Parade – Remove Downstream Railway Line and Crossings	Remove railway line and crossings downstream of Railway Parade	$1,001,000	$0	$1,001,000	$36,185	1.4	$449,016	0.45	1	-1	2	**0.8**	1	2	-2	0	-1	**0.0**	0	0	**0.0**	**1.5**	**12**
FM 4.8	Flood Modification	Railway Parade – Mudd Creek	Raise road crossing of creek	**Not Viable, refer to report**																					
FM 4.9	Flood Modification	Railway Parade – Stony Creek and Mudd Creek	Augment flow connection between Mudd Creek and Stony Creek	$300,000	$2,000	$324,818	NC	N/A	N/A	N/A	-2	0	0	**-1.0**	0	0	0	1	2	**0.6**	0	-1	**-0.5**	**-1.9**	**29**
FM 5.1	Flood Modification	Catchment wide	Rainwater Tanks	$0	$50,000	$620,452	NC	N/A	N/A	N/A	-2	-1	0	**-1.3**	0	0	2	2	2	**1.2**	2	1	**1.5**	**0.2**	**15**
FM 6.1	Flood Modification	Catchment wide	Infiltration Basins & Trenches	$0	$50,000	$620,452	NC	N/A	N/A	N/A	-2	-1	0	**-1.3**	0	0	2	2	2	**1.2**	2	1	**1.5**	**0.2**	**15**
FM 7.1	Flood Modification	Lake Macquarie measures	Swansea Channel	**Lake Macquarie Wide Option - Assessed as part of Lake Macquarie Floodplain Management Study**																					
FM 7.2	Flood Modification	Lake Macquarie measures	Levees	**Lake Macquarie Wide Option - Assessed as part of Lake Macquarie Floodplain Management Study**																					
DC1	Data Collection Strategies	Stony Creek Floodplain	Data collection following a flood event	$5,000	$2,000	$29,818	NC	N/A	N/A	N/A	0	2	0	**0.5**	0	0	2	2	2	**1.2**	0	0	**0.0**	**2.2**	**8**

** Indicates hydraulic model and detailed economic assessment used*

NC - Not Costed

Appendix G

Climate Change Assessment

G Climate Change Assessment

Changes to climate conditions are expected to have adverse impacts on sea levels and rainfall intensities. The NSW Department of Environment and Climate Change (DECC, now OEH) guideline, Practical Consideration of Climate Change (2007), provides advice for consideration of climate change in flood investigations. The guideline recommends sensitivity analysis is conducted for:

- Sea level rise – for low, medium, and high level impacts up to 0.91m
- Rainfall intensities – for 10%, 20%, and 30% increase in peak rainfall and storm volume

The Lake Macquarie City Council Policy, Lake Macquarie Sea Level Rise Preparedness Adaptation Policy (2008), details Council's framework for the assessment of climate change impacts. This includes:

- Sea level rise – adopted rise of up to 0.91m for the year 2100 as the basis for risk assessment and planning decisions. A linear increase in sea level between 2008 and 2100 is considered appropriate.
- Rainfall increase – adopt the upper level increase by 2100 of 30% resulting in a calculated rise of 0.18m in lake level for the 1% AEP event.

G.1.1 Scenarios

The results were determined by calculating the peak of the two flooding mechanisms:

1. Riverine Flooding – 100y ARI storm of critical durations 9 hours and 36 hours with a 5y ARI Lake level increased due to climate change; and
2. Lake Flooding – 5y ARI storm of 36 hour duration (critical in the majority of the study area) with a 100y ARI Lake level increased due to climate change.

The scenarios modelled are listed in **Table G.1**.

Table G.1: Scenarios – 100 Year ARI Event

Scenario	100y ARI Lake Flood Level (mAHD)	Sea Level Rise (m) [1]	Lake Rise Due to Increased Rainfall (m) [2]	Resultant Modelled Lake Level (mAHD)
100y ARI with Rain+0%, SLR+0.4	1.38	0.4	0	1.78
100y ARI with Rain+10%, SLR+0.4	1.38	0.4	0.06	1.84
100y ARI with Rain+20%, SLR+0.4	1.38	0.4	0.12	1.90
100y ARI with Rain+30%, SLR+0.4	1.38	0.4	0.18	1.96
100y ARI with Rain+0%, SLR+0.91	1.38	0.91	0	2.29
100y ARI with Rain+10%, SLR+0.91	1.38	0.91	0.06	2.35
100y ARI with Rain+20%, SLR+0.91	1.38	0.91	0.12	2.41
100y ARI with Rain+30%, SLR+0.91	1.38	0.91	0.18	2.47

[1] – the sea level rise of 0.4m to the year 2050 and 0.91m to the year 2100 are expected to result in an equivalent increase in the level of Lake Macquarie.

[2] – the rise in the Lake level due to the increased percentages of runoff for the 100y ARI event was determined in the *Lake Macquarie Flood Risk Management Plan (2010).*

G.1.2 Model Results

Figures showing the impact to peak water levels of climate change for the 100y ARI event compared to the existing 100y ARI case are attached:

1. 30% increase in rainfall and 0.91m rise in Lake level,
2. 30% increase in rainfall and 0.4m rise in Lake level,
3. 0% increase in rainfall and 0.91m rise in Lake level, and
4. 0% increase in rainfall and 0.4m rise in Lake level.

In **Figure G.1**, the peak water level at the upstream side of the industrial estate has increased by about 0.3m. **Figure G.3** shows the extent of the increase to peak water levels from the 0.91m Lake level rise is up to just past the High Street weir.

For the 0.4m Lake level rise, **Figure G.4** shows the rise in peak water level extends upstream to the High Street Weir and but is less pronounced upstream of Railway Parade. In **Figure G.2**, the peak water level at the upstream side of the industrial estate has increased by about 0.29m.

Peak water levels for the 0.91m Lake level rise case for 30% and no rainfall increase are shown in **Figure G.5** and **Figure G.6** respectively. **Figures G.7** and **G.8** show peak water level profiles along Stony Creek for several climate change cases.

G.1.3 Lake Macquarie Inundation

The assessment of impact of Lake Macquarie inundation, through both tidal action as well as flooding, is an important consideration with sea level rise.

The mean high water of Lake Macquarie is approximately equal to +0.1m AHD (Lake Macquarie DCP No.1, 2009). A sea level rise of 0.91m would thus be expected to increase the mean high water level similarly to +1.01m.

Figure G.9 shows the extent of inundation to properties for various tidal ranges:

- <0.1m AHD (Mean High Water),
- 0.1 to 1.01m AHD (MHW plus 0.91m SLR),
- 1.01 to 1.66m AHD (5y ARI Climate Change Lake Level), and
- 1.66 to 2.47m AHD (100y ARI Climate Change Lake Level).

Note the figure shows the model grid elevations relevant for property allotments not of the creek invert elevations. Note the tidal range for the 5y and 100y ARI events excludes the riverine flooding extent, ie rainfall conveyed in Stony Creek from the upstream catchment.

Table G.2 provides a summary of the residential properties with overfloor and overground flooding under the scenarios listed above. It is noted that at mean high water level, forty residential properties experience overground flooding. This would occur very frequently, at least once a month.

When considering the 5 year ARI Lake Level incorporating sea level rise and a 30% increase in rainfall intensity, not only do a number of properties experience overground flooding, but also overfloor flooding. This would further create difficulties for residents due to the frequency of this flooding event.

One of the key areas impacted by tidal inundation and Lake Macquarie flooding is the Lake Street and Venetia Avenue area. This area represents a large portion of the Stony Creek floodplain which is primarily impacted by Lake Macquarie. Of the 80 properties located on Lake Street and Venetia Avenue, all properties would experience overground flooding in a 5 year ARI Lake Macquarie flood (with 30% increase in rainfall and 0.91m sea level rise) and 20 would experience overfloor flooding.

Table G.2 Lake Macquarie Inundation on Residential Properties

Lake Scenario	Water Level	Stony Creek Floodplain		Lake Street/ Venetia Avenue	
		Houses Inundated above Floor Level	Houses Inundated Overground	Houses Inundated above Floor Level	Houses Inundated Overground
Mean High Water	0.1	0	0	0	0
Mean High Water plus 0.91m Sea Level Rise	1.01	0	40	0	40
5y ARI plus 30% Increased Rainfall Event with 0.91m Sea Level Rise	1.66	28	147	20	80

G.2 Climate Change Mitigation Options

Potential structural options to mitigate the impacts of climate change, considering the recommended measures listed in the FRMS&P, are discussed following.

G.2.1 Railway Parade

Several options in the FRMS&P, namely FM4.1 to FM4.9, assessed the feasibility of upgrading the culverts at Railway Parade and/or removing the disused railway line and pipe crossings. Under the existing scenario, there is a head loss of approximately 0.4 metres across Railway Parade. However, in the sea level rise scenarios, there is not a significant drop in peak water level across Railway Parade as shown in **Table G.3**.

Thus, alterations to the Railway Parade culverts or crossings just downstream would not likely have significant benefits in the 100 year ARI event with climate change impacts.

Table G.3: Railway Parade Peak Water Levels

Flood ARI	Peak water level just upstream of Railway Pde	Peak water level just downstream of Railway Pde	Difference in level	Level in Fennell Bay
Base Case - 100y ARI with Rain+0%, SLR+0.0	1.89	1.48	0.41	1.38
100y ARI with Rain+0%, SLR+0.4	1.94	1.82	0.12	1.78
100y ARI with Rain+30%, SLR+0.4	2.20	2.04	0.16	1.96
100y ARI with Rain+0%, SLR+0.91	2.35	2.31	0.04	2.29
100y ARI with Rain+30%, SLR+0.91	2.55	2.51	0.04	2.47

G.2.2 Road Crossings

Figure G.10 shows the ground elevations from the SOBEK model. Significant areas, including private property are shown under RL 1.5, indicating they are particularly vulnerable to a Lake rise of 0.4m, and other properties below RL 2.0 being vulnerable to a sea level rise of 0.91m.

Many roads are also below these levels but the main priority may be to have roads passable in storm events such that people can evacuate to higher ground and the roads as high as possible (considering the surrounding landform) such that the frequency of inundation is reduced.

G.2.2.1 Awaba Road near Carleton Street

Awaba Road is a main east-west link and has a minimum level of about 1.95m near this intersection. The effect on nearby properties would need to be assessed in consideration of potentially raising the road at this location. Although areas above RL 3.0 are available on either side of this lowpoint, frequent inundation of this section of road may affect residents.

G.2.2.2 Anzac Parade – Main Road

Anzac Parade – Main Road is the primary connection north to south across Fennell Bay and is below RL 2.0 in places. Reconstruction of this road to a higher level is beyond the scope of this assessment and evacuation routes to locations above RL 3.0 are available to the south on Cary Street.

G.2.2.3 Railway Parade

Railway Parade and Cook Street are the primary evacuation route for Lake Street and Venetia Avenue. It is also the main road link across Stony Creek. The bridge over Mudd Creek is at RL 1.5 and the bridge over Stony Creek is at RL 2.5. Raising the level of the road over Mudd Creek will not necessarily be an advantage for improving the reliability of this road link during flood events as parts of Cook Street are below RL 1.5.

To facilitate a higher road link across Stony Creek, Cook Street would need to be raised such that it formed a levee for properties on the eastern side of Cook Street. Similarly part of the old railway corridor just to the north would need to be raised to from a levee.

G.2.2.4 Fennell Crescent

The culvert crossing of Mudd Creek on Fennell Crescent is at RL 0.7 and properties adjacent on Fennell Crescent are around RL 1.3. Thus the road level could be raised to about this level to provide a link that is less frequently inundated. It is noted that the 5 year ARI climate change Lake level is RL 1.66 (**Table G.4**).

G.2.3 Levee Options

A number of levees were considered as detailed in **Section 9.2.3**. These levees also have the potential to mitigate the impacts of climate change on the community. The following options were considered:

- **Industrial Area Levee** – this option was considered quite favourable as listed in **Section 10.4**, but would also assist in mitigating the impacts of increased rainfall and therefore increased inundation of this area.
- **Adam Street Levee** – this location is impacted by a combination of sea level rise and increases in rainfall intensities. A levee would assist in preventing inundation of the properties in this area. There would still be difficulties in the construction of this levee, particularly with the proximity to houses and the crossing of the road in this area.
- **Fennell Crescent Levee** – this location is challenging in that the levee would need to cross the road in two locations.
- **Sara/ Day Street Levee** – this location is primarily impacted by inundation from Lake Macquarie, as it is downstream of Railway Parade. It is noted that with climate change the inundation of this area will occur more frequently, as discussed in **Section G.1.3**.
- **Lake Street/ Venetia Avenue Levee** – This area is primarily affected by inundation from Lake Macquarie, and will only continue to worsen with the effects of climate change and sea level rise. As with both the Adam Street Levee and the Fennel Crescent levee, there are a number of challenges with this option as it would need to cross roads and would also cross the water frontages of up to 80 properties which would lead to difficulties. As it is primarily affected by flooding from Lake Macquarie, it is unlikely to have a significant impact on local catchment flooding. However, the implications of this type of option should be considered in the context of the overall Lake Macquarie floodplain and the associated impacts on storage.

G2.4 Filling within the Floodplain

Generally, filling within the floodplain would not be recommended. However, the Lake Street/ Venetia Avenue area is particularly prone to the impacts of sea level rise and Lake Macquarie flooding. Much of this area would be inundated due to the Lake level in a 5 year ARI event with 0.91m sea level rise and 30% increased rainfall intensity.

This would effectively result in this area being very challenging for local residents to occupy. If a levee were not constructed at this location, then an alternative may be to progressively fill the land as new development occurs. In this area, it is primarily impacted by flooding from Lake Macquarie, and is therefore likely to only have a minimal impact on local catchment flooding from Stony Creek. As noted above, however, this should be reviewed in respect to the overall Lake Macquarie floodplain.

G2.5 Construction of a Barrage

In the lower parts of the Stony Creek floodplain, a large portion of the impacts of climate change are a result of sea level rise. A potential option would therefore be to construct a barrage to prevent the effects of sea level rise on the floodplain. While this could be done locally within Fennell Bay, it is likely that it would be more economical across the Swansea channel as this would benefit the wider Lake Macquarie floodplain.

It is recommended that this option be considered as a part of the overall Lake Macquarie Floodplain Risk Management Study & Plan.

G.3 Economic Assessment

Section 6 of this Report details the estimation of potential economic damages to properties for flood events from 5 year ARI to a PMF event. Similarly, the potential damages for the worst case climate change scenario, 30% increase in rainfall and 0.91m increase in Lake level, was modelled for the average recurrence intervals listed in **Table G.4**.

Table G.4: Lake Water Level – 5 Year ARI to PMF

Scenario	ARI Flood Lake Level (mAHD)	Sea Level Rise (m)	Lake Rise Due to Increased Rainfall (m) [2]	Resultant Modelled Lake Level (mAHD)
5y ARI with Rain+30%, SLR+0.91	0.65	0.91	0.10	1.66
10y ARI with Rain+30%, SLR+0.91	0.80	0.91	0.12	1.83
20y ARI with Rain+30%, SLR+0.91	0.97	0.91	0.14	2.02
50y ARI with Rain+30%, SLR+0.91	1.24	0.91	0.16	2.31
100y ARI with Rain+30%, SLR+0.91	1.38	0.91	0.18	2.47
200y ARI with Rain+30%, SLR+0.91	1.55	0.91	0.2	2.66
PMF with Rain+0% [1], SLR+0.91	2.63	0.91	0	3.54

[1] – a 0% increase in rainfall is adopted on the basis that there is no current guidance on any expected changes to PMP values from the Bureau of Meteorology or any other agency.

[2] – estimated by volumetric analysis of catchment runoff volume and lake area based on change in Lake level for 100y rainfall increase advised by Council from the *Lake Macquarie Flood Risk Management Plan (2010).*

Peak water level profiles along Stony Creek for these modelled ARI events are shown in **Figure G.11.**

The resultant damages estimated are summarised in **Table G.5**. It is noted, as per **Section 6.4**, that the damages are assumed to be zero in a 2 year ARI event. However, as discussed in **Section G.1.3**, there are a number of properties which would experience overground inundation even under mean high water levels. Therefore, the following damages presented are likely to be a lower bound estimate.

A graph showing the relative damage estimates for the climate change and unmodified case are shown in **Figure G.12**.

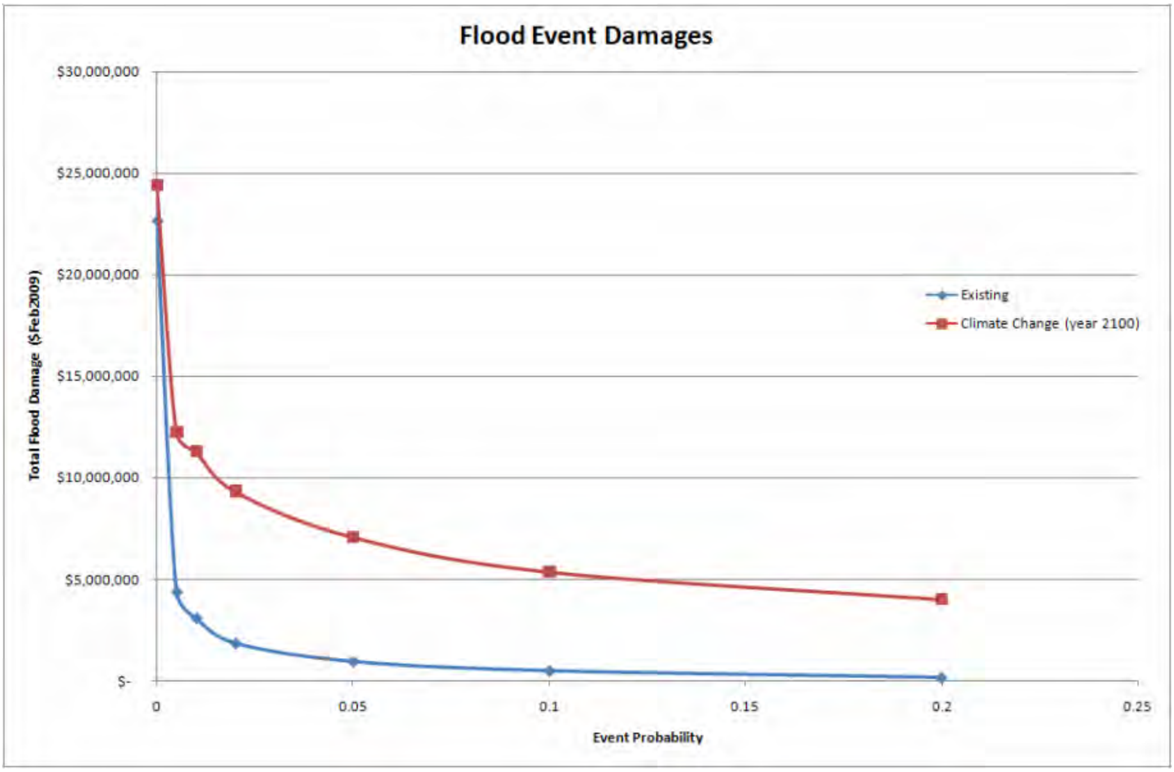


Figure G.12: Flood Event Damages

The equivalent average annual damage for the climate change and unmodified case are listed in **Table G.6**.

Table G.5: Flood Damage Summary – Climate Change (Plus 30% Rain, Plus 0.91m Sea Level Rise)

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with Overground Flooding	Total Damage ($February 2009) *
PMF					
Residential	258	1.43	2.56	273	$15,185,360
Commercial	11	1.79	2.66	12	$ 2,327,339
Industrial	37	2.06	2.82	37	$ 6,902,003
PMF Total	306			322	$24,414,703
200 year ARI					
Residential	159	1.41	1.62	186	$ 7,989,721
Commercial	4	0.94	1.46	8	$ 1,613,426
Industrial	27	1.29	1.36	32	$ 2,635,690
200 Year ARI Total	190			226	$12,238,836
100 year ARI					
Residential	157	0.62	1.44	192	$ 7,513,858
Commercial	5	0.57	1.27	10	$ 1,348,463
Industrial	28	0.51	1.18	33	$ 2,418,574
100 Year ARI Total	190			235	$11,280,896
50 year ARI					
Residential	151	0.50	1.29	186	$ 6,939,770
Commercial	4	0.55	1.12	8	$ 528,522
Industrial	24	0.44	1.02	32	$ 1,854,821
50 Year ARI Total	179			226	$ 9,323,113
20 year ARI					
Residential	127	0.32	1.01	176	$ 5,675,895
Commercial	3	0.48	0.84	7	$ 109,021
Industrial	21	0.29	0.75	28	$ 1,286,571
20 Year ARI Total	151			211	$ 7,071,487

10 year ARI					
Residential	**94**	**0.25**	**0.83**	**169**	**$ 4,528,536**
Commercial	**3**	**0.33**	**0.66**	**6**	**$ 68,691**
Industrial	**13**	**0.27**	**0.57**	**24**	**$ 767,586**
10 Year ARI Total	**110**			**199**	**$ 5,364,814**
5 year ARI					
Residential	**61**	**0.22**	**0.70**	**167**	**$ 3,458,990**
Commercial	**3**	**0.21**	**0.50**	**5**	**$ 64,727**
Industrial	**10**	**0.20**	**0.42**	**19**	**$ 482,102**
5 Year ARI Total	**74**			**191**	**$ 4,005,819**

*values are expressed to the nearest dollar, but this is not indicative of the accuracy of the estimates.

Table G.6: Average Annual Damage

Case	Average Annual Damage ($Feb2009)
Base – no rainfall increase and no sea level rise (refer to **Section 6.5**)	$247,000
Climate change - rainfall increase 30%, sea level rise 0.91m	$1,880,000

G3.1 Economic Damage Assessment of Mitigation Options

A summary of the economic analysis undertaken for each of the levee options is listed in **Table G.7**. It is noted that for some of the levee options (such as the Lake St/ Venetia Ave Levee), that modelling was not undertaken but instead the damage estimate was based on the protection that the levee would provide for those properties.

G.3.2 Economic Analysis of Options

An economic analysis on the levee options listed above, and the other options addressed, would either provide evacuation benefits (outside the scope of this economic analysis) or wider reaching benefits (such as the barrage option). It is assumed that the levees will provide up to a 100 year ARI event protection.

A capital cost was estimated for each of the options. Three alternatives were estimated:

- **Existing Protection Capital Cost** – A capital cost based on the level of the levee required to provide existing climatic condition protection for the area (i.e. provide protection up to the existing 100 year ARI flood event).
- **Retrofit Costs** – the cost of raising the levee from the existing protection level to the 2100 climate change level at some stage in the future. For the purposes of this analysis, this retrofit is assumed to occur in 2030 (20 years in the future).
- **Climate Change Protection** – a capital cost estimate assuming that the levee was constructed to the level required to protect the area at 2100.

Table G.7: Flood Damage Summary – Climate Change (Plus 30% Rain, Plus 0.91m Lake Rise) 100y ARI

Event/Property Type	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with Overground Flooding	Total Damage ($February 2009) *
100 year ARI Climate Change – no mitigation					
Residential	157	0.62	1.44	192	$ 7,513,858
Commercial	5	0.57	1.27	10	$ 1,348,463
Industrial	28	0.51	1.18	33	$ 2,418,574
No Mitigation Total	190			235	$11,280,896
Industrial Levee					
Residential	156	1.25	1.44	189	$ 7,461,556
Commercial	2	1.29	1.27	2	$ 1,269,115
Industrial	10	1.21	1.18	10	$ 1,566,116
Industrial Levee Total	168			201	$10,296,787
Adam St Levee					
Residential	136	0.64	1.44	163	$ 6,533,918
Commercial	5	0.58	1.27	10	$ 1,348,901
Industrial	29	0.50	1.18	33	$ 2,448,676
Adam St Levee Total	170			206	$10,331,496
Levee - Lake Street and Venetia Avenue					
Residential	87	0.51	1.44	121	$ 4,133,675
Commercial	5	0.57	1.27	10	$ 1,348,463
Industrial	28	0.51	1.18	33	$ 2,418,574
Levee – Lake St and Venetia Ave Total	120			164	$ 7,900,712
Levee - Sara and Day Streets					
Residential	144	0.61	1.43	179	$ 6,904,742
Commercial	4	0.40	0.72	9	$ 1,291,114
Industrial	19	0.32	0.71	24	$ 923,726
Levee – Sara St and Day St Total	167			212	$ 9,119,581
Levee - Fennell Crescent					
Residential	135	0.63	1.44	166	$ 6,494,759
Commercial	5	0.57	1.27	10	$ 1,348,463
Industrial	28	0.51	1.18	33	$ 2,418,574
Levee – Fennell Cres Total	168			209	$10,261,796

*values are expressed to the nearest dollar, but this is not indicative of the accuracy of the estimates.

Reductions in Annual Average Damages (AAD) were estimated for both now (2010) and for the year 2100. The 2010 AAD estimates are as per **Section 10**. The 2100 estimates were based on the 100 year ARI flood damages factored against the AAD estimated for the climate change scenario in 2100 with no mitigation option implemented. This is considered to be a reasonable estimate, particularly given the number of uncertainties in the analysis.

Three economic calculations have been undertaken for each of the options:

- **Upfront Protection** – Assume that the levee is constructed today to the full height required to provide 100 year ARI protection in 2100.
- **Retrofit in Future** – assume that the levee is constructed to the height required to provide 100 year ARI protection under existing conditions. Then, in 20 years time (2030), the levee is retrofitted to raise it to the 2100 100 year ARI level.
- **Deferred Works** – this analysis determines the year in which the construction of the levee to a full 2100 100 year ARI protection becomes economically viable (when the benefit cost ratio = 1).

Table G.8 lists the results of this analysis. The cost benefit analysis has been undertaken by assuming that the AAD values increases linearly from 2010 through to 2100. It is assumed that all levees have a design life of 50 years.

It is noted both the Sara/ Day Street Levee is economically viable if construction were to commence immediately. As such, it is recommended that this option be considered for inclusion in the Floodplain Risk Management Plan.

The Lake Street and Venetia Avenue levee is not currently viable at 2010, but due to the increase in AAD over time becomes viable in 2 years. However, as noted previously, there are a number of challenges of this option, including the street crossings and the construction of the levee across a number of properties. This may make this option difficult from both a social point of view and a practicality point of view.

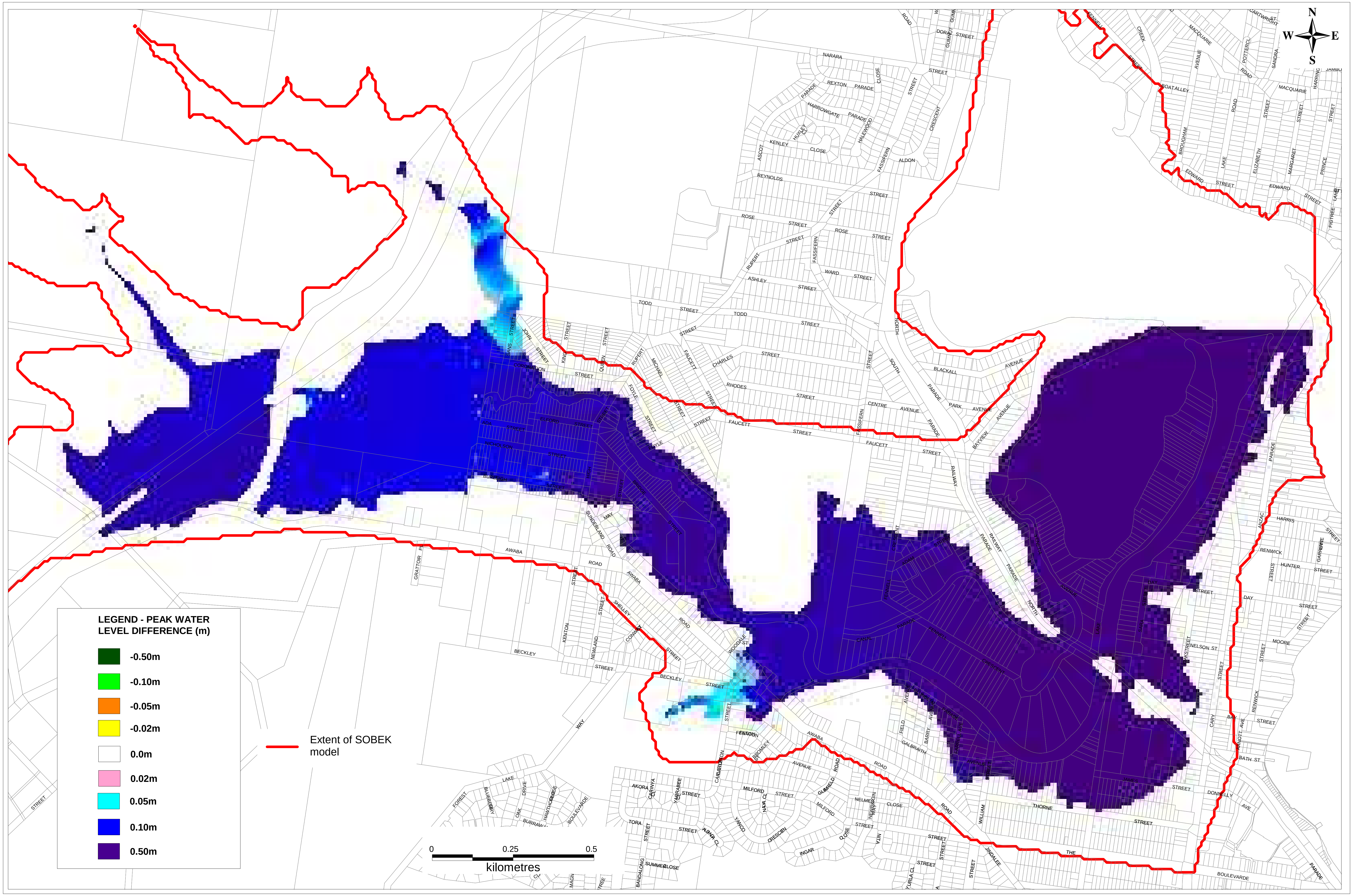
However, there will reach a period where these properties are becoming more and more frequently inundated, even from tidal action. Therefore, an option would need to be considered for this area, such as progressive filling of properties as discussed above. The other alternative is the potential for a barrage across Swansea Channel, as it is expected that this area is representative of a number of locations throughout the Lake Macquarie floodplain.

The Industrial Levee, which protects the industrial area in the upper portion of the floodplain, is currently not economically viable but will be viable in 2020. This option could therefore be incorporated into the plan as a long term implementation option.

Both the Adam Street Levee and Fennell Crescent Levee are currently not economically viable, and will not be for a number of years (2032 and 2045 respectively). These options would also have a number of logistical issues, such as road crossings and the construction of the levees within private properties. As such, it is recommended that these two options be re-visited as a part of a review of the Floodplain Risk Management Plan in the future. At this time, better estimates of climate change are also likely to be available.

Table G.8 Summary of Economic Analysis

		Industrial Levee	Adam St Levee	Fennell Cres Levee	Sara/ Day St Levee	Lake/ Venetia Levee
Capital Cost	For Existing Protection	$639,000	$1,166,000	$1,748,561	$400,000	$1,597,668
	For Climate Protection	$677,000	$1,195,000	$1,791,483	$433,000	$1,720,000
Retrofit Costs		$160,000	$300,000	$353,000	$89,000	$220,000
Maintenance		$5,000	$5,000	$5,000	$5,000	$5,000
Reduction in AAD	Existing	$10,514	$35,792	$42,373	$10,865	$30,984
	2100	$164,005	$158,221	$169,837	$360,191	$563,319
Benefit Cost Ratios	Upfront Protection	0.63	0.62	0.48	1.75	0.87
	Retrofit in Future	0.69	0.63	0.48	2.08	0.94
Year to Start Deferred Works (B/C=1)		2020	2032	2054	N/A	2012



Cardno Lawson Treloar

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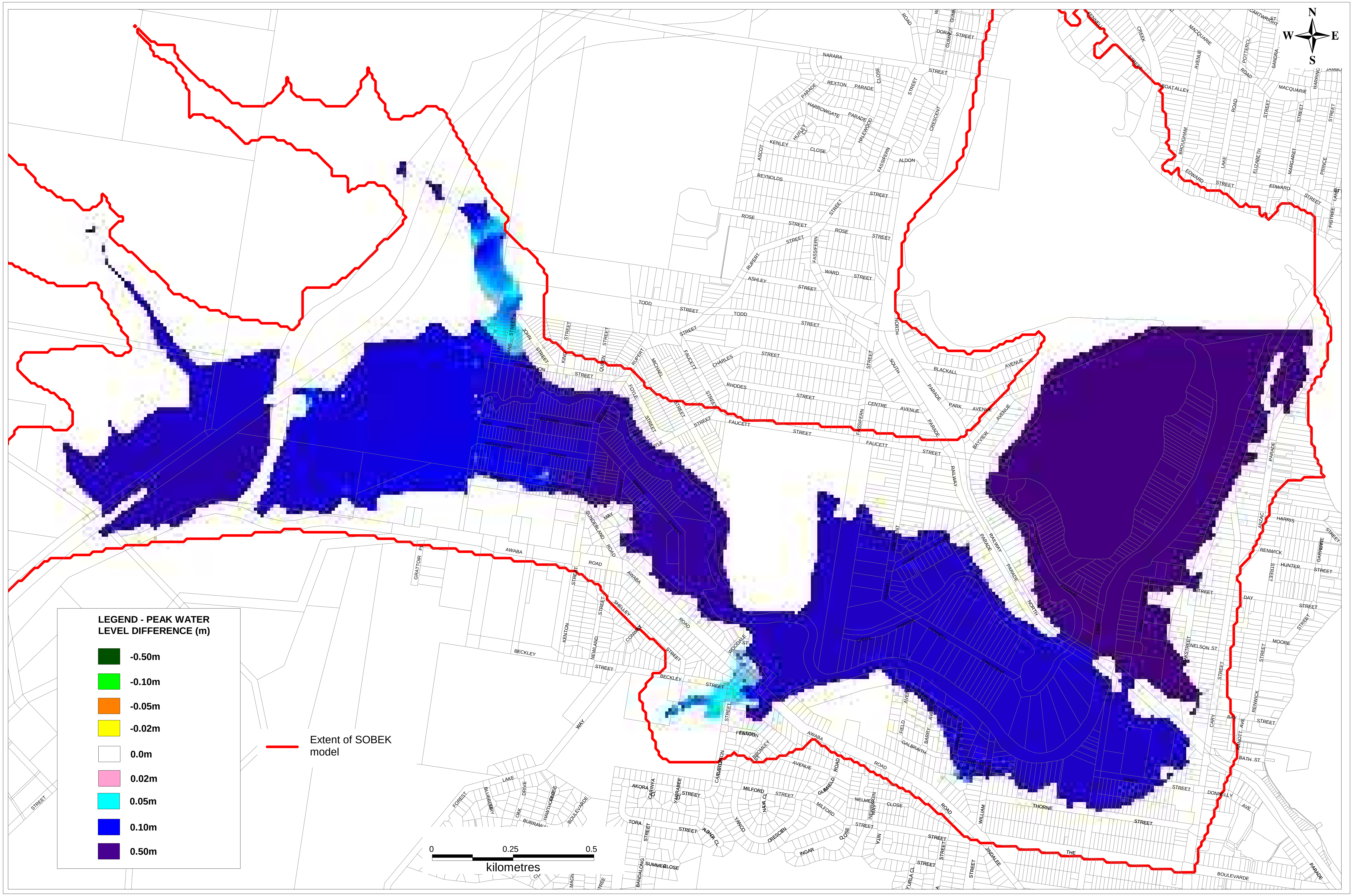
Dec 2011

Stony Creek Floodplain Risk Management Study

Climate Change Assessment
FIGURE G.1 Peak Water Level Difference
100y ARI +30% Rainfall +0.91m Lake Rise Less Existing



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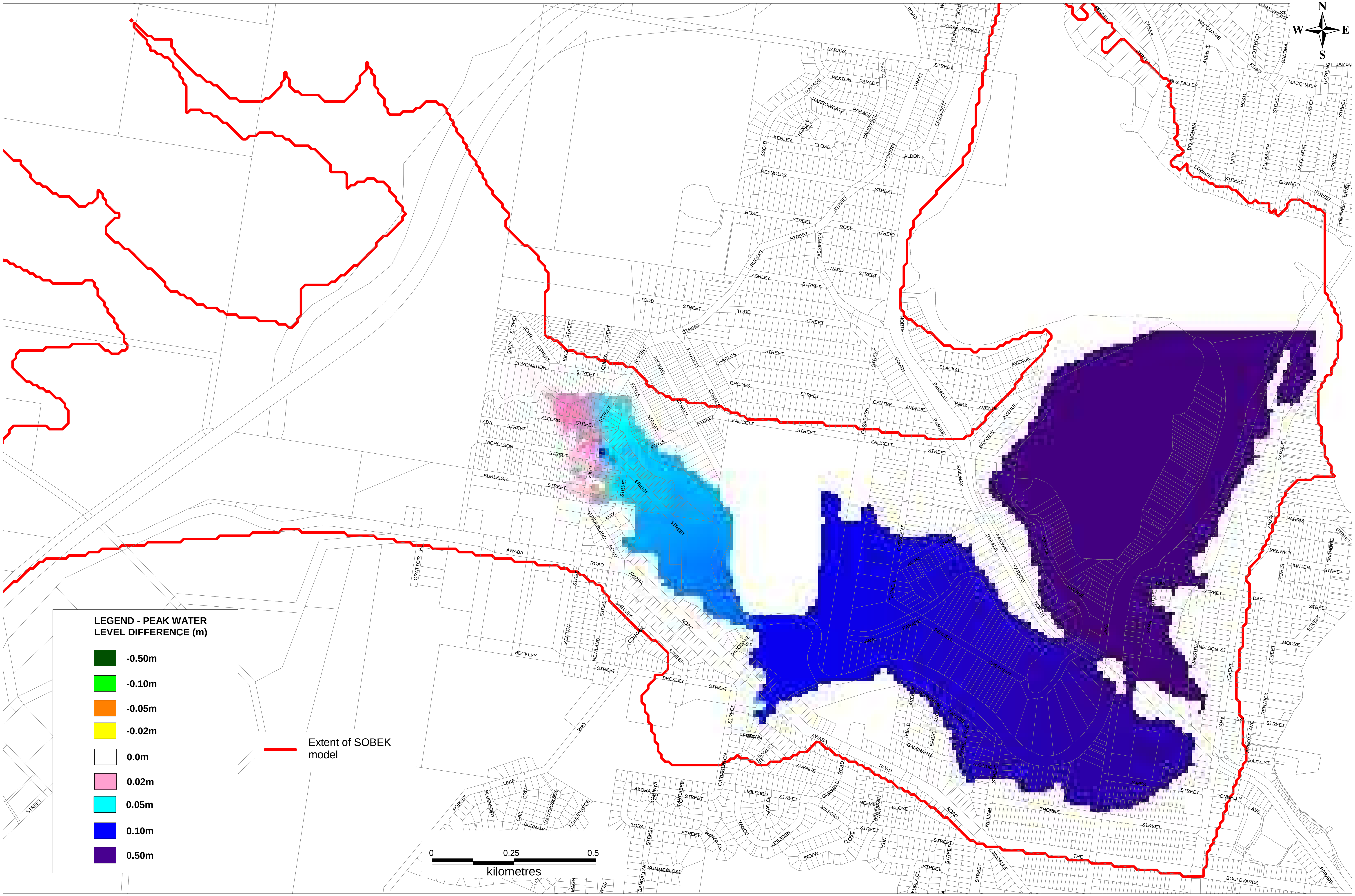
Dec 2011

Stony Creek Floodplain Risk Management Study

Climate Change Assessment
FIGURE G.2 Peak Water Level Difference
100y ARI +30% Rainfall +0.4m Lake Rise Less Existing



Climate Change Assessment
FIGURE G.3 Peak Water Level Difference
100y ARI +0% Rainfall +0.91m Lake Rise Less Existing

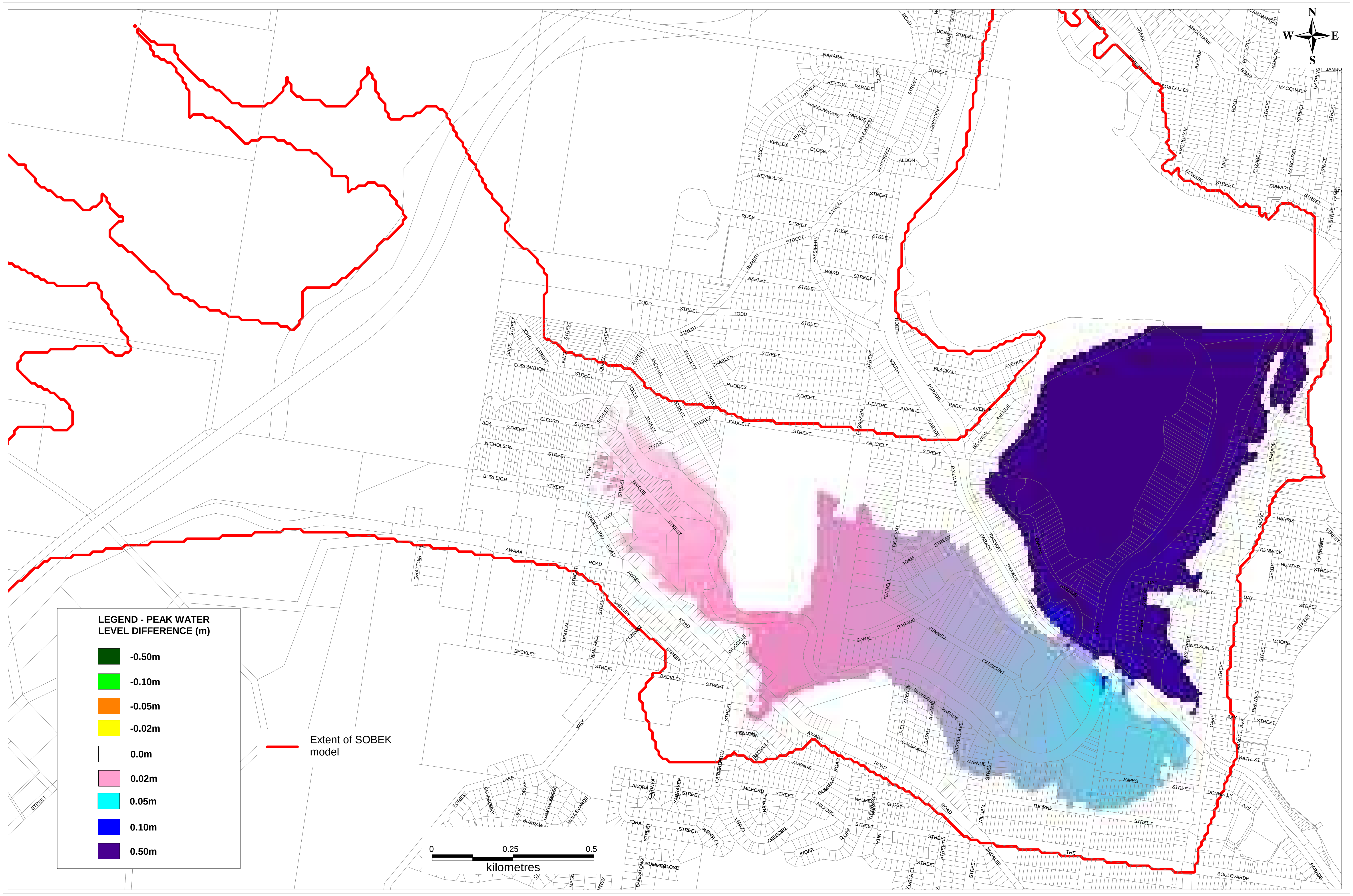


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FIGURE G.4 Peak Water Level Difference
100y ARI +0% Rainfall +0.4m Lake Rise Less Existing

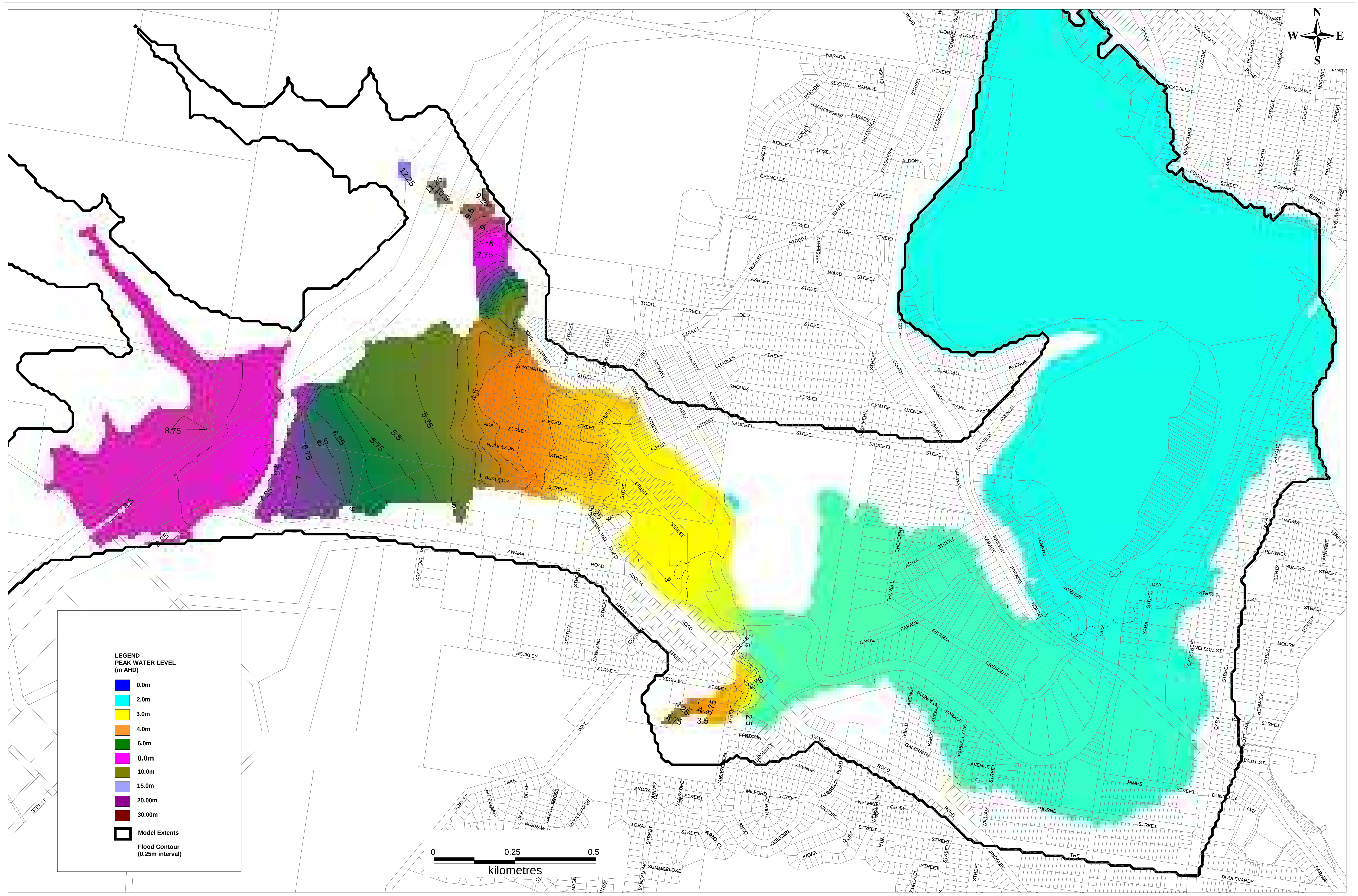

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FIGURE G.5 Peak Water Level
100y ARI +30% Rainfall +0.91m Lake Rise

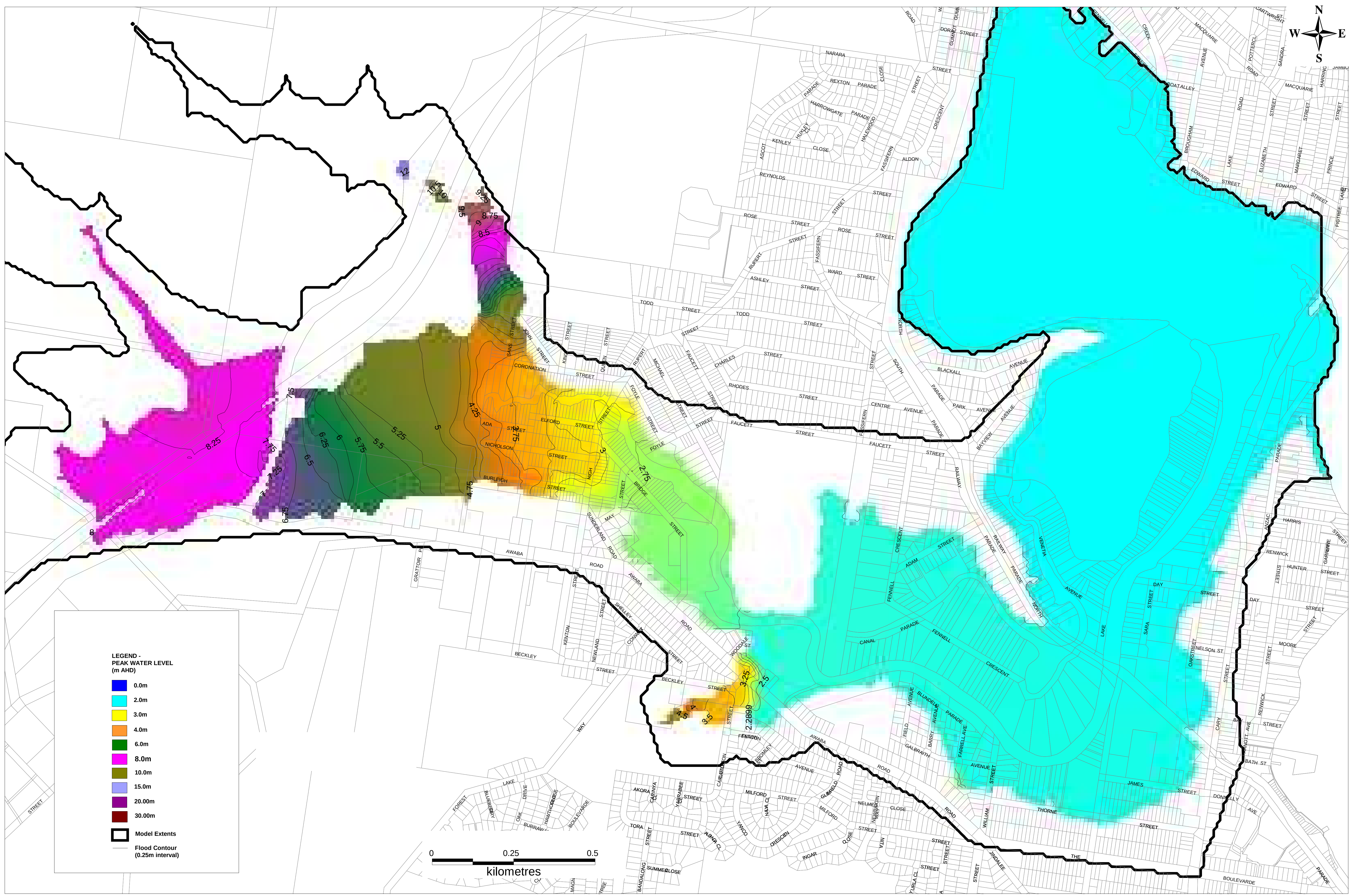

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FIGURE G.6 Peak Water Level
100y ARI +0% Rainfall +0.91m Lake Rise

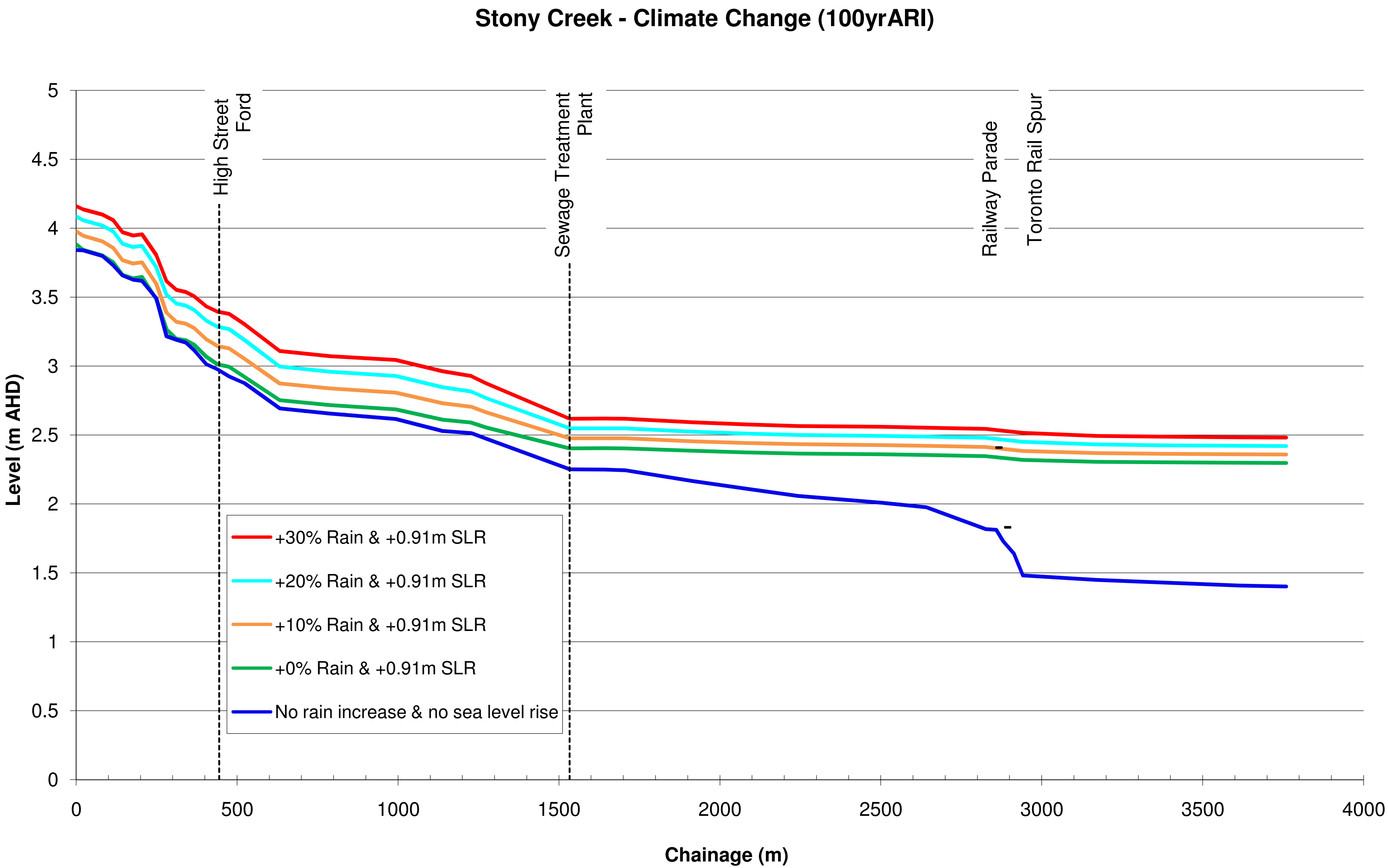

FIGURE G.7
STONY CREEK CLIMATE CHANGE FLOOD PROFILE

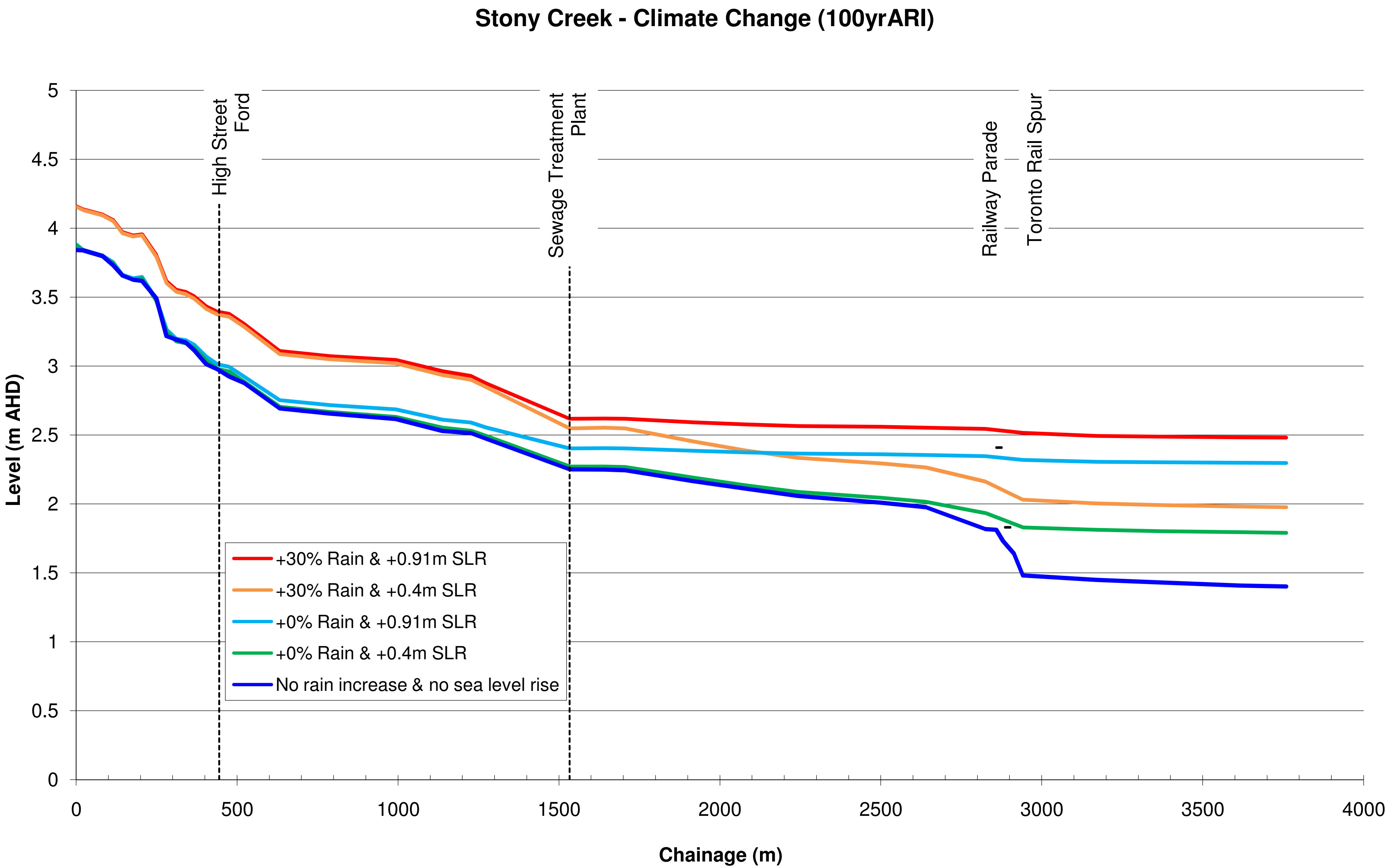

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FIGURE G.8
STONY CREEK CLIMATE CHANGE FLOOD PROFILE

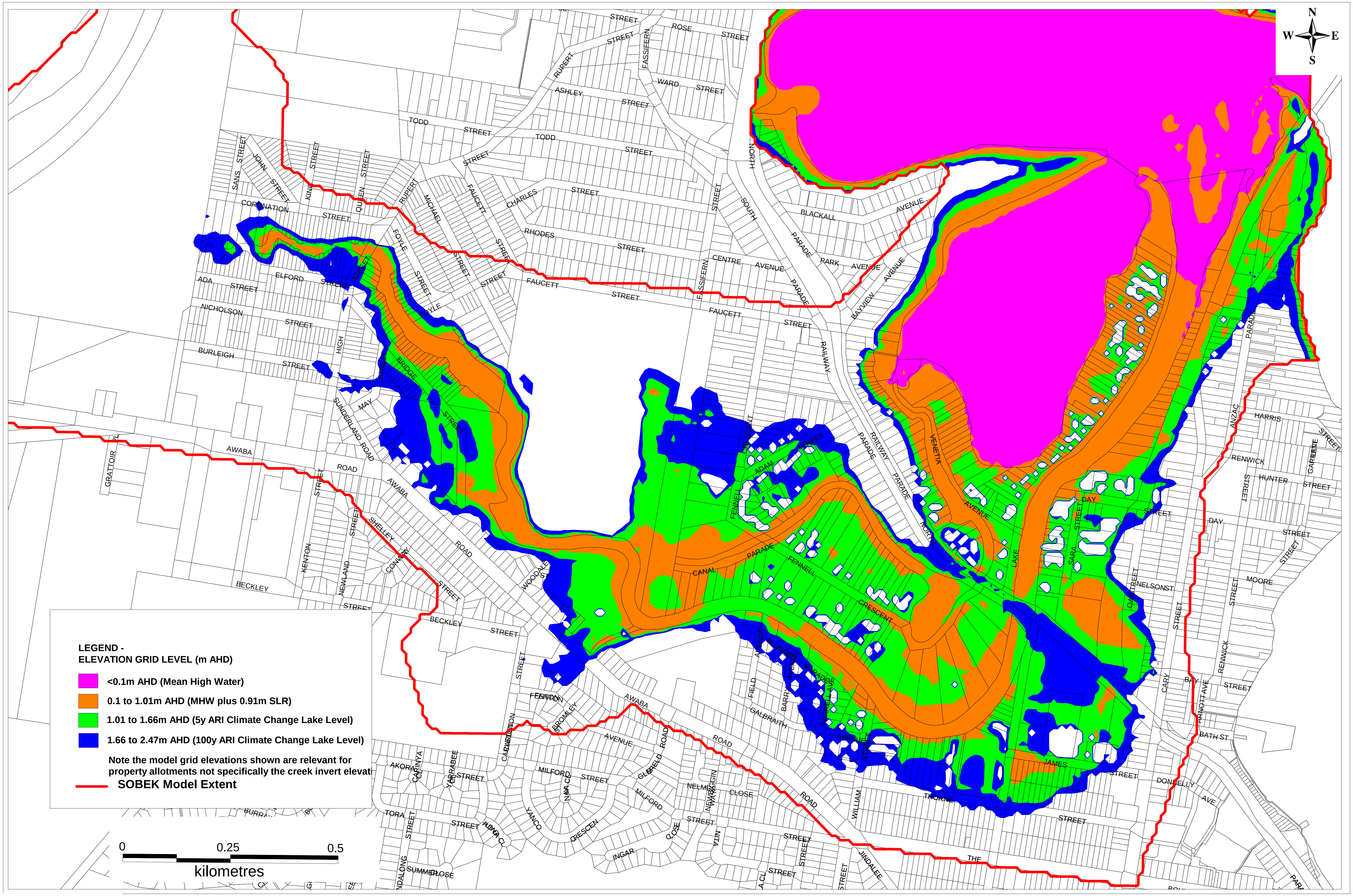

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FIGURE G.9 Tidal Inundation

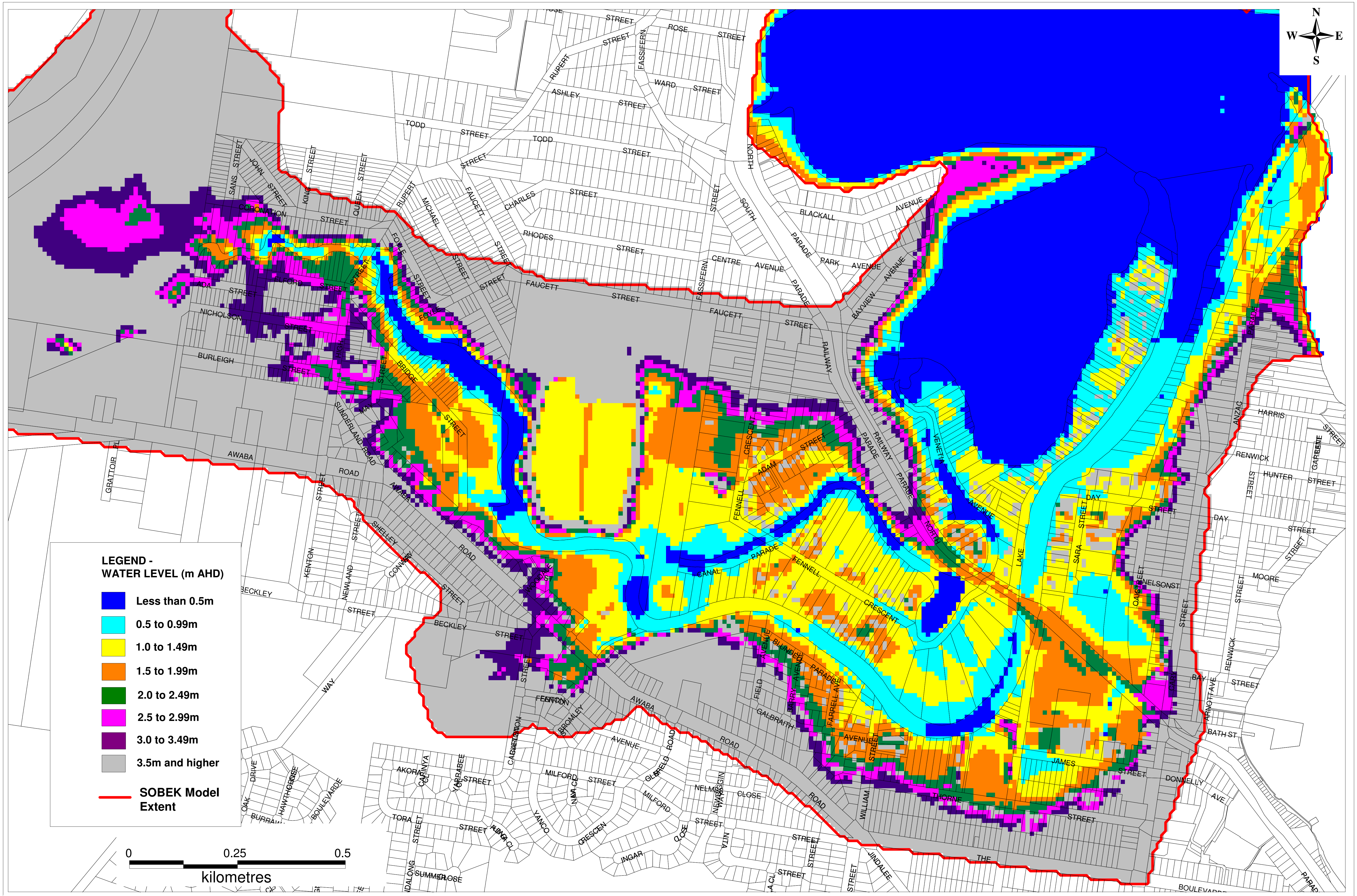

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FIGURE G.10 Ground Elevation

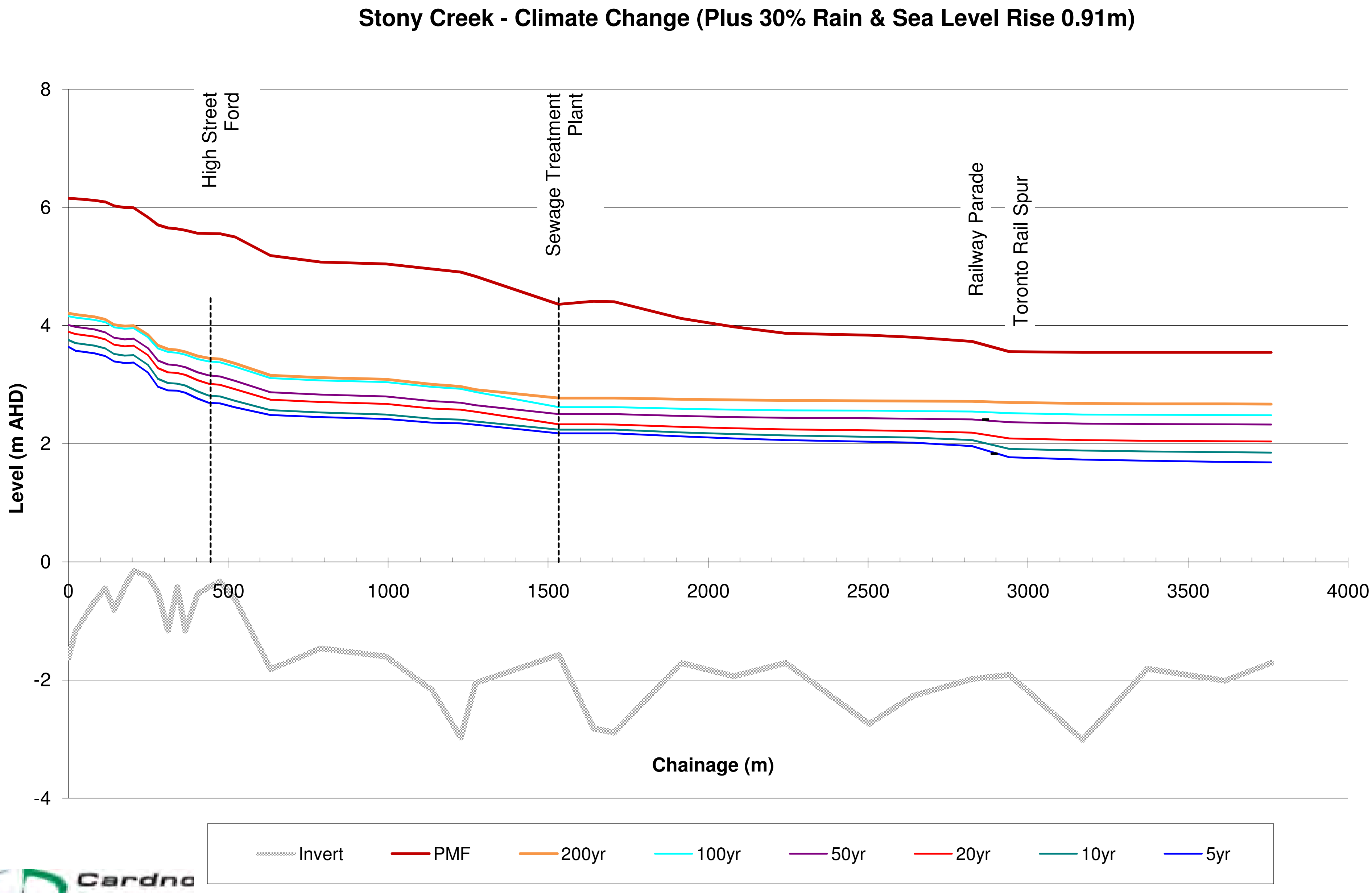

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FIGURE G.11
STONY CREEK CLIMATE CHANGE FLOOD PROFILE