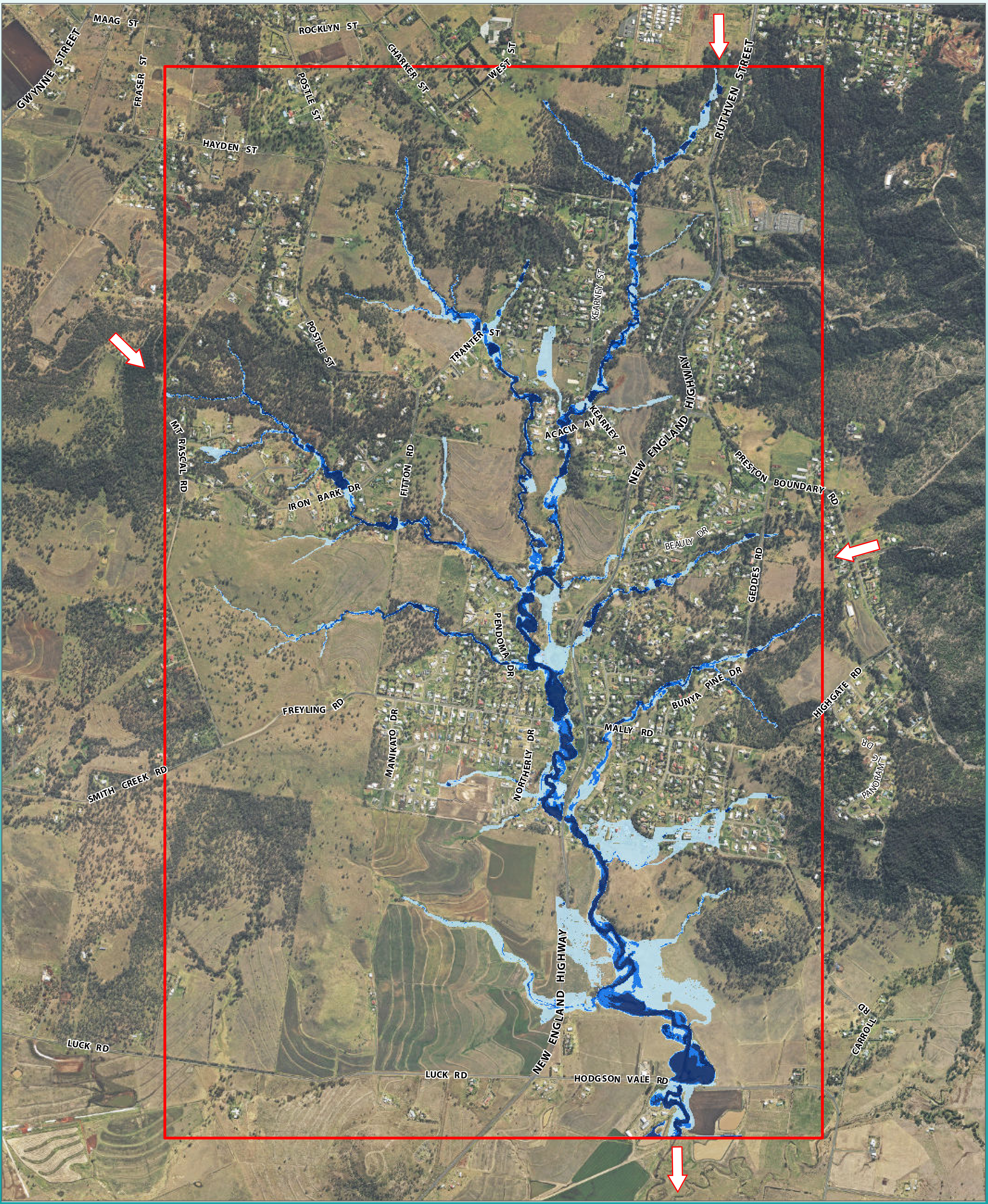
MOUNT RASCAL-TOP CAMP-HODGSON VALE



TOOWOOMBA REGIONAL COUNCIL

1:19,000 (at A3)

0 200 400 600 800

Metres

N

1% AEP FLOOD DEPTH RIVERINE

Water Depth (m)			
0 - 0.5		Model Extent	
0.5 - 1		DirectionFlow	
1+		Emergency Services	
		School	

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Flood Studies

TOOWOOMBA REGION
Rich traditions. Bold ambitions.

2D Flood Study for Mount Rascal, Top Camp and Hodgson Vale

September 2014 • *Endorsed on 25 February 2015*

GENERAL NOTE

These reports/documents are a base source of information that will be continually refined over time.

DISCLAIMER

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Distributed To	Date issued
V01	Final Report	AMD	AMD	GHD/TRC	10/03/2014
V02	Final Report	AMD	AMD	GHD/TRC	11/04/2014
V03	Final Report	AMD	AMD	GHD/TRC	19/05/2014
V04	Final Report	AMD	AMD	GHD/TRC	09/09/2014

PROJECT DETAILS

Project Name	SP051 Flood Studies – Work Package 6
Client	Toowoomba Regional Council
Client Project Manager	Chris Howell
Water Technology Project Manager	Alister Daly
Report Authors	Alister Daly/Luke McAvoy
Job Number	J2810-03
Report Number	R02
Document Name	Final Report

Cover Photo: Hodgson Creek overtopping Freylings Road during the Toowoomba flood event of January 2011 (Source – TRC)

EXECUTIVE SUMMARY

Significant rainfall associated with one of the strongest La Nina events on record occurred across a large portion of Queensland from late November 2010 through to January 2011, forcing the evacuation of thousands of people from towns and cities in the southeast corner of QLD and bordering NSW areas.

Subsequent to these unprecedented flooding events and the conditional approval of the Toowoomba Regional Planning Scheme (TRPS) by the State Government, Toowoomba Regional Council (TRC) appointed a number of organisations under Council contract number SP051 in order to revise and update flood mapping across the greater TRC administration area. TRC commissioned Water Technology Pty Ltd to undertake a flood study for the Work Package 6 of the overall SP051 project, which included namely the Mount Rascal, Top Camp and Hodgson Vale local areas. This study aims to define and map overland flow path corridors in the current and future development areas within the aforementioned localities as part of the 16.9km^2 area of the overall Mt Rascal catchment.

In order to assess the behaviour of overland flow path flooding within the study areas, catchment discharge estimates were required. Hydrologic modelling was used to estimate catchment discharges contributing to the study areas for design events pre-determined by TRC. This included the 2, 5, 10, 20, 50, 100, 200, 500 year Average Recurrence Interval (ARI) and Probable Maximum Design Flood (PMP-DF) events.

Hydraulic modelling of the study areas has been undertaken utilising DHI Software's MIKE FLOOD modelling system. The use of MIKE FLOOD was a specific requirement of the project as specified by TRC. Analysis was undertaken for the aforementioned design rainfall events. Additional analysis was also undertaken for model validation and sensitivity analysis purposes.

In order to calibrate the flow estimates for the Mount Rascal catchment, comparison of recorded flood levels for the 10th January 2011 flood event to the hydraulic model were undertaken in a joint hydrologic/hydraulic model calibration process. The historical flood level data sourced for the purposes of the model calibration comprised a mixture of data sources, including highest known flood level information that was nonspecific in respect to the date of occurrence, as well as recorded flood level data that corresponded to the January 2011 flood event. Good correlation was shown between the recorded flood data and the hydraulic model for the January 2011 event. The calibrated MIKE FLOOD model developed for Mount Rascal has been adopted as the basis on which to undertake the design flood event assessments. The calibrated hydraulic model has been adopted without change for the purpose of the design flood estimation.

Alternative hydrologic techniques have been undertaken to provide the best estimate for the 100 year ARI design event discharge for the Mount Rascal catchment. The adopted 100 year ARI discharge for the Mount Rascal catchment from the hydrologic techniques was then matched in the calibrated MIKE FLOOD model by adopting hydrologic design rainfall parameters (in the form of

losses) to achieve the required flow. The hydrologic model parameters were then applied to all other design storms.

Analysis of rainfall records from rain gauges near the study area suggest the rainfall burst that occurred on the 10th January 2011 was greater than 100 year ARI design event rainfall at the top of the Mount Rascal catchment. This reduced in intensity to approximately a 20 year ARI rainfall event in the lower reaches of the catchment. Significant antecedent rainfall and primed catchment conditions resulted in what was estimated to be a 150 year ARI flood magnitude for the Mount Rascal catchment for the January 2011 event.

Given the good correlation between model predictions of flood behaviour and anecdotal and recorded historical flood information and the subsequent approval of the MIKE FLOOD models by the TRC-appointed peer reviewer, analysis of the pre-determined design events (2, 5, 10, 20, 50, 100, 200, 500 year ARI and PMP-DF event) has been undertaken. The design event simulations have additionally included a variety of climate change scenarios as well as model sensitivity assessments including blockage assessments.

It is recommended that the model results developed from this study be adopted by Council and used for inclusion in Council's updated planning scheme and for the purposes of addressing the conditional approval of the scheme, as issued by the State Government on the 17th February 2012.

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ABBREVIATIONS

AEP	Annual Exceedence Probability
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DNRM	Department of Natural Resources and Mines
DFE	Defined Flood Event
DTM	Digital Terrain Model
DTMR	Department of Transport and Main Roads
GIS	Geographic Information System
LIDAR	Laser Detection and Ranging
NFRAG	National Flood Risk Advisory Group
NHMA	Natural Hazard Management Areas
QR	Queensland Rail
QRA	Queensland Reconstruction Authority
QFCI	Queensland Flood Commission of Inquiry
SPP 1/03	State Planning Policy 1/03
TRC	Toowoomba Regional Council
TRPS	Toowoomba Regional Planning Scheme

GLOSSARY (Note 1)
Annual Exceedance Probability (AEP) means the chance of a flood of a given or large size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (1 in 20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Bureau of Meteorology (the Bureau) is Australia's national weather, climate and water agency.
Australian Height Datum (AHD) means a common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI) means the long-term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see AEP).
Catchment is the land area drained by a waterway and its tributaries.
Climate change a change in the state of the global climate induced by anthropogenic change to the atmospheric content of greenhouse gases and that persists for an extended period, typically decades or longer (Note 2)
Culvert is a short passageway under a road, railway or embankment designed to allow stormwater to allow from one side to the other without being dammed.
Defined flood event (DFE) is the flood event adopted by a local government for the management of development in a particular locality.
Defined flood level (DFL) is the level of a flood that would occur during a defined flood event (DFE).
Discharge is the rate of flow of water measured in terms of volume per unit of time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving.
Essential services encompass electrical power, the provision of drinking water, sewerage, stormwater drainage, telecommunications and roads and rail.
Flood relatively high water levels caused by excessive rainfall, storm surge, dam break or a tsunami that overtop the natural or artificial banks of a stream, creek, river, estuary, lake or dam (Note 4)

Flood damage the tangible (direct and indirect) and intangible costs (financial, opportunity cost, clean-up) of flooding. Tangible costs are qualified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people and attributed to a flooding episode (Note 4)
Flood hazard potential loss of life, injury and economic loss caused by future floods events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, duration and rate of rise of floodwaters), topography, population at risk and emergency management (Note 4)
Flood hazard area, for the purposes of Queensland Development Code, proposed new part 3.5: 'Construction of buildings in flood hazard areas', 21 November 2011 , means an area, whether or not mapped, designated by a local government as a natural hazard management area (flood) under section 13 of the *Building Regulation 2006.*
Flood map is a map which depicts the extent of a particular flood or floods, for example the 1% AEP flood or a historical flood.
Flood overlay map is a map used in land planning to depict the land constrained by planning controls imposed by a council because of the flood risk associated with the land.
Floodplain is an area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by floodwater.
Flood risk is a term that usually embodies both likelihood of flooding and the consequences of flood.
Flow velocity means the speed and direction of flow, measured in metres per second (m/s). (Note 6)
Hydrodynamic (hydraulic) model uses data about the flow in streams and the terrain of a particular area to estimate flood heights, velocities and flow over time. In order to do this the hydrodynamic model solves the equations for the conservation of mass and momentum/energy.
Hydrograph a graph that shows for a particular location, the variation with time of discharge (discharge hydrograph) or water level (stage hydrograph) during the course of a flood (Note 4)
Hydrologic model (runoff routing model) uses rainfall data and estimates of the proportion of the rainfall which turns into runoff and the time which the runoff from each part of the catchment takes to flow into the stream to estimate flow in the stream over time.
Hydrology is the term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.

Major flooding is a term used by the Bureau of Meteorology to depict extensive flooding of rural areas and/or urban areas. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.
Major Overland Flow Path an overland flow path that drains water from more than one property, has no suitable flow bypass, and has a water depth in excess of 75mm during the major design storms, or is an overland flow path recognized as "significant" by the local government (Note 3).
Major Road a road whose primary function is to serve through traffic. These roads include Collector Roads, Sub-Arterial and Arterial Roads. Refer to Department of Main Roads or AustRoads for further definition (Note 3)
Minor flooding is a term used by the Bureau of Meteorology to depict flooding that occurs in low-lying areas next to watercourses where inundation may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.
Planning scheme is a local planning instrument for regulating development in Queensland. Planning schemes regulate what development must be assessed before it can be undertaken, the type of assessment required and the criteria used in an assessment in each council region. They also contain codes with which self-assessable development must comply.
Probable maximum flood is an estimate of the largest possible flood that could occur at a particular location, under the most severe meteorological and hydrological conditions.
Q100 is a probability-based design flood event discharge, aimed to reflect typical combinations of flood producing and flood modifying factors which act together to produce a flood event at a specific location of interest that has a I in 100 chance of being equalled or exceeded in any one year (1% annual exceedance probability - AEP): it is described as having an average recurrence interval (ARI) of 100 years. It is a theoretical flood model used to inform planning and policy (see AEP and ARI).
Stormwater is the rain water that has not yet entered a river system or soaked into the ground.
Stormwater flooding inundation by local runoff caused by heavier than usual rainfall. 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 urban stormwater drainage systems to overflow (Note 4).
Stream /river gauging station (gauge) a manual or automated gauge that measures the height of the water in a river at a particular location.

Watercourse as defined in the Sustainable Planning Regulation 2009 (Note 2): (1) Generally, watercourse means a watercourse as defined under the *Water Act 2000,* schedule 4. (2) Watercourse, for schedule 3, part 1, table 4, item 5(b)(iv), means a river, creek or stream in which water flows permanently or intermittently – (a) in a natural channel, whether artificially improved or not; or (b) in an artificial channel that has changed the course of the watercourse (3) Watercourse, for schedule 24, part 1, section 1(2) – (a) Means a river, creek or stream in which water flows permanently or intermittently – i) in a natural channel, whether artificially improved or note; or ii) in an artificial channel that has changed the course of the watercourse; and iii) Includes the bed and banks and any other element of a river, creek or stream confining or containing water.
Waterway as defined under the *Environmental Protection Act 1994* means any of the following (Note 5): • a creek, river, stream or watercourse • an inlet of the sea into which a creek, river, stream or watercourse flows • a dam or weir

Notes

(1) Unless otherwise noted, definitions have been taken from the QFCI Final Report.
(2) Definitions taken from SPP1/03.
(3) Definitions taken from the Queensland Urban Drainage Manual.
(4) Definitions taken from Floodplain Management in Australia, Best Practice Principles and Guidelines.
(5) Definitions taken from SPP4/10.
(6) Definitions prepared for this study.

1. INTRODUCTION

1.1 Background

The approval of the Toowoomba Regional Planning Scheme (TRPS) by the State Government on the 17 February 2012 was conditional on providing revised and updated flood information in response to the Queensland Floods Commission of Inquiry (QFCI) as well as the State Planning Policy 1/03 "Mitigating the Adverse Impacts of Flood, Bushfire and Landslide" (SPP 1/03). Following the conditional approval, TRC has since completed a "Scoping Plan for Flood Risk Studies" (Scoping Plan Study) in September 2012. Key aspects of this study included:

- The identification of areas with no flood information.
- Prioritising these areas for future upgrades to meet the statutory requirements for the TRPS.
- Defining work packages and general methodologies to inform the future flood studies.
- Providing budget costs and timelines for completion.

This study has formed the basis to TRC since appointing a number of organisations under Council contract number SP051 to undertake a range of technical works across a number of work packages in order to revise and update flood mapping works across the greater TRC administration area. The assessments of flooding for the Mount Rascal, Top Camp and Hodgson Vale catchment areas comprise the Work Package 6 component of works under SP051.

TRC has subsequently commissioned Water Technology Pty Ltd to undertake a flood study for the Mount Rascal, Hodgson Vale and Top Camp catchment areas (collectively referred to as Mount Rascal in this report). Work Package 6 requires the assessment of flooding associated with the several waterway tributaries within the greater Mount Rascal area to define and map flooding within current and future development areas.

This study is the first step in the development of Flood Risk Management Plans for the towns, and generally seeks to support land use and infrastructure planning, as well as providing information for emergency planning purposes.

This report details the works, methodologies and assumptions that have gone into the development of the computer-based models of the study areas associated with Work Package 6.

1.2 Study Objectives

The main objectives of the study are summarised as follows:

- Development of computer-based hydraulic models of the identified areas;
- Determination and documentation of catchment tributaries;
- Identification of critical infrastructure and emergency facilities for which safe operation may be disrupted by flood events;
- Preparation of detailed maps and GIS layers for inclusion in Council's databases;
- Detailed reporting of all elements of the Work Package and outcomes; and

- Provide emergency planning information to input into Council's Emergency and development planning information databases to assist Council in its emergency management, planning, preparedness and response.

This report details the works, methodologies and assumptions that have gone into the development of the computer based models of the study area associated with Work Package 6 being the Mount Rascal greater area.

2. DATA

Data utilised to determine flooding behaviour within the study areas has been obtained from a variety of sources during the course of the assessment process. The following sections summarise the base data sets that have been used for this study and provides detail on the sources and accuracy levels of the data sets as applicable.

2.1 Topographic Survey

The topographic dataset used in the study consists entirely of LiDAR survey supplied by TRC. This dataset was collected in 2010 and has a 1m resolution. Any recent localised changes to topographic variation by developments or other works within the study areas may not be represented in this dataset. This dataset has been used as the basis for the hydraulic models, as well as being the dataset used for catchment delineation.

A collection report was provided to accompany the 2010 LiDAR Capture Project dataset as prepared by Schlenker Mapping Pty Ltd (2010). The data was collected from the 29th June to the 16th July 2010. The report states that the accuracy achieved was 94% of points within +/- 150mm accuracy of ground controls. This is considered appropriate for adoption and was well within the accuracy specifications of the LiDAR Capture Project. The LiDAR data was used to developed 1m resolution Digital Elevation Models (DEMs) of the study areas for this project.

2.2 Aerial Imagery

High resolution 2010 aerial imagery has been supplied by TRC for use in this study. The study area has 12.5cm imagery available across its entirety.

Imagery has been used to identify specific hydraulic structures, confirm land uses and associated impervious values and to delineate floodplain roughness in conjunction with site observations, oblique photographic records and other imagery (i.e. Google Earth).

2.3 Land Use

Council have supplied a Digital Cadastral Database (DCDB) for use in this study in a Geographic Information System (GIS) format. This has been used to accurately determine catchment imperviousness based on an ultimate development scenario. Additionally, Council have also provided a GIS layer detailing the broadhectare mapping for future urban areas over a time horizon exceeding 10 years. The broadhectare mapping was used to supplement the DCDB land use for ultimate catchment development. Note that ultimate catchment development fraction impervious was only adopted for sensitivity analysis of the ultimate land use case.

In some cases the provided dataset did not cover areas in the eastern catchment, and hence a review of aerial photography and surrounding land uses was undertaken to develop likely land uses for these areas. These areas were isolated to areas around Preston Boundary Road (approx. 8.7ha).

The cadastral boundaries of these areas were delineated using Locker Valley Regional Council cadastral information.

In the case of the calibration and design run scenarios for the Mount Rascal catchment, land use has been determined from 2010 aerial imagery in conjunction with Mount Rascal ultimate land use to determine land use that would have likely occurred for the January 2011 event. A further discussion in relation to this aspect is provided in Section 4.5.

Land use mapping for both the January 2011 event in addition with the ultimate development scenario for the Mount Rascal catchment is included in Appendix A.

2.4 Rainfall Data

Design rainfall Intensity Frequency Duration (IFD) data was obtained from the Bureau of Meteorology website for the analysis of overland flow path assessments undertaken as part of this study. This online service automates the Australian Rainfall and Runoff (IEAust, 1998) datasets for each of the study areas.

Historical data sets for a number of rainfall gauges covering the areas of Work Package 6 has been sourced from the various organisations including the Bureau of Meteorology (BoM), the Department of Natural Resources and Mines (DNRM) as well as TRC. Historical rainfall data comprised both daily total rainfall data as well as 6 minute, half hour, and hourly interval pluviograph rainfall data and was sourced generally for the period December 2010 to January 2011. Of specific interest was the period extending from the 9th to 12th January 2011 which resulted in some of the largest flooding that occur across the study area. Historical rainfall data was sourced to aid in the model calibration tasks and to assess historical rainfall frequencies to aid in model validation. Historical rainfall frequency is discussed separately in Section 6.4.

2.5 Hydraulic Structures

Data for hydraulic structures in the study area including culverts, bridges as well as isolated stormwater drainage systems was identified and measured during the course of the site inspection works. This included the location, size, cover, material as well as any other relevant details from which a GIS hydraulic structure database was prepared to aid in the development of the hydraulic models. Oblique photographic records were also taken for each of the structures of interest during the site inspection works. The photographic record for all structures and model areas will be provided at the completion of the study as part of the digital data sets prepared for Council. Further details on hydraulic structure data for the respective model areas are discussed in Section 5.

2.6 General GIS Datasets

Base GIS information for the study areas were supplied by TRC to aid in the completion of the flood study. This information has been utilised for this study and specifically for catchment hydrology, hydraulic analysis and mapping tasks. Other freely available GIS information has also been sourced to assist in the study, and includes rail and road centreline information.

2.7 Historic Flood Level and Rainfall Information

Water Technology undertook a consultation program which was undertaken at the same time as the field inspection works. The consultation activities are documented in a consultation strategy, which was approved by TRC prior to embarking on the various consultation tasks. Part of this consultation strategy included contacting a number of long-term residents to assist in collecting historic flood and rainfall information for the Mount Rascal locality. Residents with information on flooding or rainfall were initially contacted via phone or email and interviewed at-site where appropriate. Where historic flood or rainfall data was identified, this was collected and recorded throughout the specific areas of interest to aid in model calibration tasks. Part of this consultation program included ad-hoc discussions and selective door-knocking with various local residents during the course of the field inspection works.

All historical flood or rainfall information sourced and collected as part of the consultation program has been recorded and has been used to assist in the completion of the flood study works. Specifically, this information has been used to aid in the model calibration tasks. In general, the historical data collected included the following: -

- Historical rainfall information which related specifically to the January 2011 event. This consisted primarily of daily rainfall totals and anecdotal rainfall information from within the Mount Rascal catchment.
- Historical flood level data which related specifically to the January 2011 flood event. This ranged from indicative flood depth estimates for the event through to surveyed flood level information; and
- Other historical data sets relating to the highest known flooding which occurred historically. This historical data was not related to any specific historical event rather was simply anecdotal information for the largest known flooding which may have occurred at the specific area. Some of this type of data represented anecdotal accounts passed down through the generations of long-term residents in the areas.
- Flood data through media sources i.e internet/video information of the January 2011 event. This includes YouTube footage posted from local residents during the event in the Mount Rascal catchment.

While the January 2011 event was one of the largest flood events on record for many of the areas under investigation, significant flooding occurred at discrete times throughout the entire period from December 2010 to the end of January 2011. No specific data was sourced as part of the consolation program for other significant flood events that may have occurred throughout this period other than for the largest event.

A more detailed summary of all data collected from the consultation program and the historical flood level data associated with Work Package 6 is presented in Section 6.4.

2.7.1 Data Limitations

Historical flood data has been collected for the study from a variety of sources. This includes data received from TRC being surveyed debris lines and marks that were visible and accessible at the time of recording after the January 2011 floods, accounts of witnesses, flood information collected through community consultation as well as estimated flood levels recorded during the time of field inspections. The flood data used in the Study is based on the information that was available to TRC and Water Technology at the time which may not be accurate or complete.

3. DESCRIPTION OF DECEMBER 2010 TO JANUARY 2011 EVENT

3.1 Introduction

Significant rainfall associated with one of the strongest La Nina events on record occurred across a large portion of Queensland from late November 2010 through to January 2011. This caused widespread flooding throughout much of Queensland, with the most destructive flooding occurring during the second week of January 2011, forcing the evacuation of thousands of people from towns and cities in the southeast corner of QLD and bordering NSW areas. Three-quarters of the state of Queensland was declared a disaster zone. Thirty-eight people in Queensland died in the 2010/2011 floods. (1)

On the 17th January 2011 a Commission of Inquiry into the Queensland Floods of 2010/2011 was established (termed the Queensland Flood Commission of Inquiry (QFCI)). The QFCI released its final report on 16 March 2012. The report made 177 recommendations across a broad range of issues including floodplain management, land use planning, building regulations, insurance, mines, emergency management and dam management. The QFCI was one of the catalysts to this current project.

3.2 Regional Rainfall

Toowoomba sits on the watershed of the Great Dividing Range and is some 700 metres above sea level. Significant rainfall over the greater Toowoomba region commenced in December 2010 and continued throughout January 2011.

(1) "Death Toll from Queensland Floods", Queensland Police Service, 24 January 2011

Table 3-1 shows selected rainfall totals for December 2010 and January 2011 across the gauges in the Toowoomba region and also includes a summary of maximum daily totals. The location of the selected rainfall gauges is shown in Figure 3-1.

Table 3-1 Local Rainfall Totals at Selected Locations for December 2010 to January 2011

Rainfall Gauge (BOM Gauge #)	December 2010		January 2011	
	Total Rainfall (mm)	Maximum Daily Total (mm)	Total Rainfall (mm)	Maximum Daily Total (mm)
Oakey (#041359)	304.2	67.6	265.4	78.8
Pittsworth (#041082)	413	114	149.4	49
Cambooya (#041011)	65.4	25.8	56.4	27.6
Greenmount (#041040)	159.6	48.2	179.2	89.2
Toowoomba (041529)	399.2	64.6	413	123.4

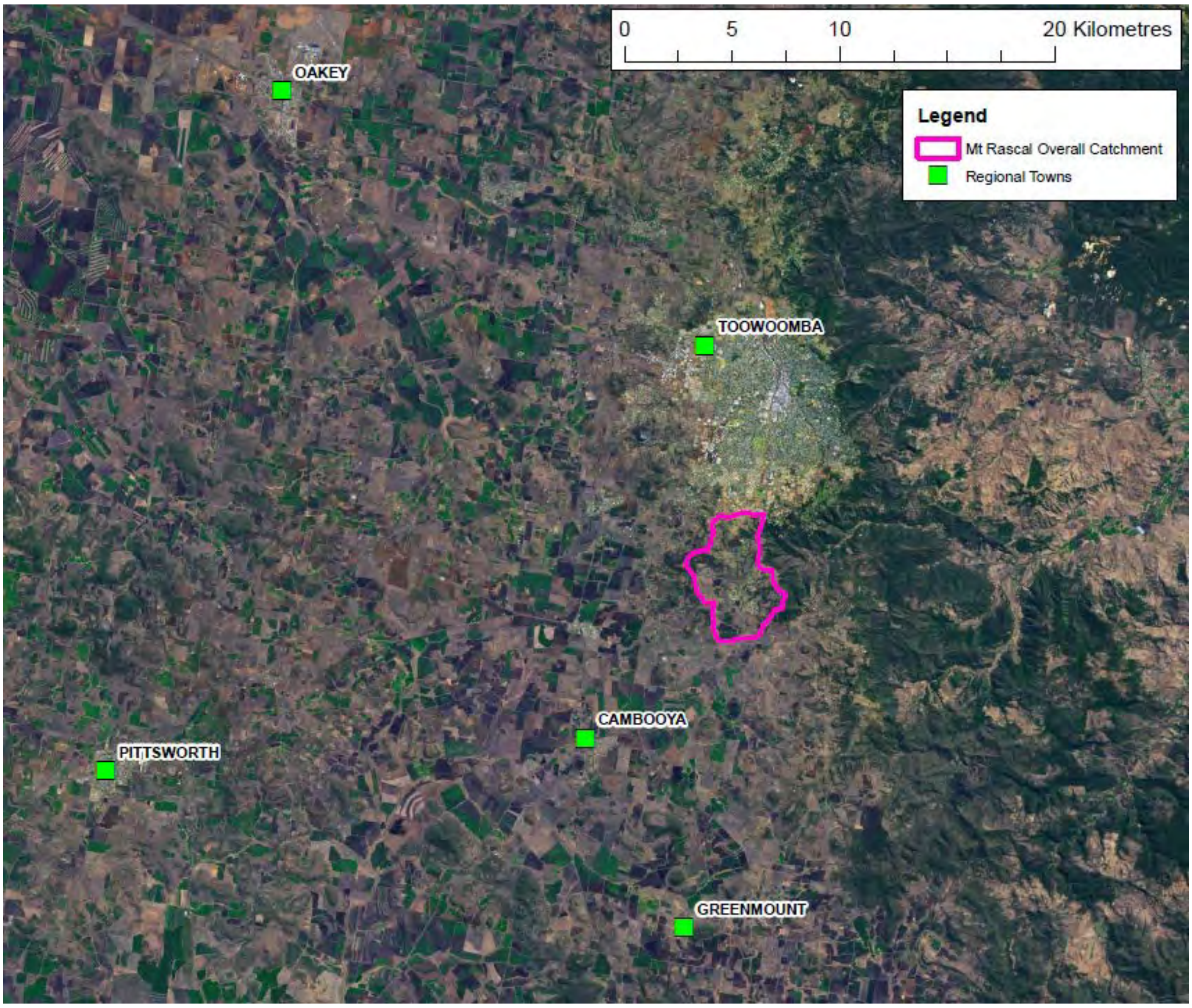


Figure 3-1 Selected Local Rainfall Total Locations for December 2010 to January 2011

Total rainfall depths which fell through December 2010 were significant and in some townships of TRC exceeded the monthly rainfall totals that fell in January 2011. Maximum daily total rainfall records show that the heaviest daily rainfall total was experienced in January 2011 in Toowoomba and this occurred on or about the 10th January 2011. The rainfall records also show that while high totals occurred in December 2010 resulting in some major flooding, the intense rainfall occurring on the 10th January 2011 was generally reported to result in the most significant flooding throughout the region. Figure 3-2 shows the cumulative rainfall totals that fell during the months of December 2010 and January 2011.

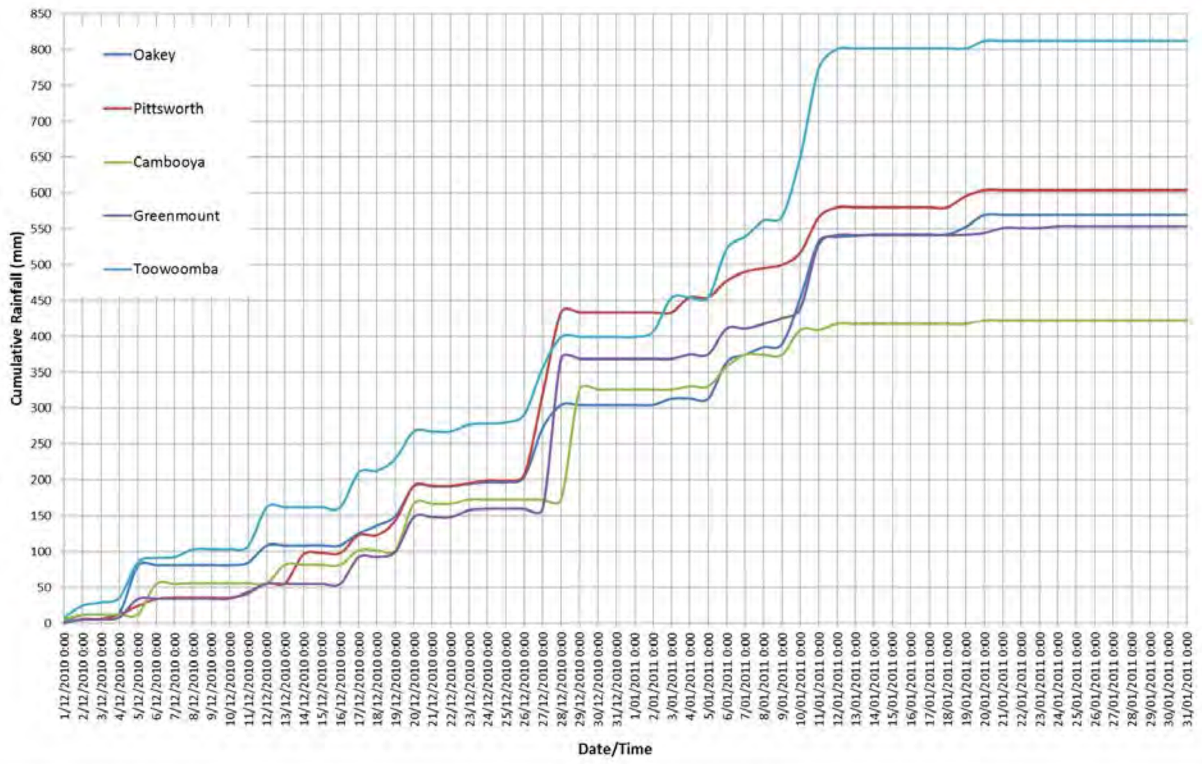


Figure 3-2 Cumulative Rainfall at Regional Locations for December 2010 to January 2011

The following comments are provided in relation to the cumulative rainfall totals at the various gauges presented in Figure 3-2:

Rainfall was gradually falling from the start of December 2010 through to approximately Christmas Day on the 25th December 2010. Rainfall totals for this period were approximately 200 – 300 mm across the various gauges.

- Significant rainfall totals were experienced over a 5 day period from the 25th December 2010 to the 29th December 2010. The rainfall totals for this period alone exceeded 200 mm at most gauges with the exception of Toowoomba.
- Rainfall steadily fell through the early part of January 2011 with significant rainfall occurring over a 5 day period from the 5th to 11th January 2011. Rainfall totals for this period were up to approximately 150 mm, with the exception of Toowoomba, which experienced approximately 350 mm total rainfall.
- Higher maximum daily rainfall was recorded for the 5th to 11th January 2011 period as opposed to the 25th to 29th December 2010 period for all gauges with the exception of Pittsworth (refer
- Table 3-1 previously).
- The rainfall falling during the 5th to 11th January 2011 period was recorded as a much larger magnitude event in Toowoomba than for the other towns in Figure 3-1.

The rainfall records occurring throughout December 2010 to January 2011 show that the rainfall occurring in December 2010 had left the catchment areas in a supersaturated state. While flooding across the broader TRC region is likely to have been experienced as a result of the rainfall totals in December 2010, further rainfall occurring in early January 2011, including an intense storm event occurring on about the 10^{th} January 2011, resulted in what was reportedly more severe and significant flooding in comparison to the December 2010 event.

3.3 Local Rainfall

From recorded and anecdotal rainfall and flood information, it was clear that the larger contributing event in the local Toowoomba area and including specifically the Mount Rascal catchment area was associated with the intense storm event occurring on or about the 10^{th} January 2011 (hereby referred to as the January 2011 event). This storm was therefore investigated in detail and adopted as the hydrologic calibration event for the Mount Rascal catchment.

The Mount Rascal catchment is located approximately 8.5km south of the Toowoomba CBD. The Mount Rascal, Top Camp and Hodgson Vale localities are located within the Mount Rascal catchment. There are no local or State-owned rainfall gauges situated within the Mount Rascal catchment that had data for the January 2011 event. The only pluviograph gauge located within the Mount Rascal catchment was the University of Southern Queensland (USQ) gauge. Upon enquiry to USQ, Water Technology was informed that rainfall data from this gauge for the relevant period was not available.

Both daily and pluviograph information from various sources was obtained for the January 2011 event for use in the hydrologic analysis. All gauge information considered most relevant to the January 2011 event in the Mount Rascal catchment was obtained for the study and is detailed in Table 3-2. This includes daily total rainfall information sourced from local residents situated within the catchment area and termed as “Kaiguna” and “86 Luck Road”. These records were sourced as part of the consultation program undertaken for this study. Figure 3-3 shows the Mount Rascal catchment in relation to the surrounding rainfall gauges. Daily rainfall totals and pluviograph rainfall accumulation for the January 2011 event are given in

Table 3-3 and Figure 3-4 respectively.

Apart from those gauges adopted in the study, there were other gauges also in close proximity to the site including a collection of TRC-owned pluviograph gauges. These gauges either did not have the required period of data (i.e. installation after January 2011) or, in the case of the TRC gauges, the closer gauges were deemed to not have data to the degree of accuracy required for the calibration (i.e. data gaps, irregularities in data, suspect low rainfall totals, etc).

TRC gauges to the north of the site are located approximately 1 – 5km from the catchment. Relevant gauges to the south and east of the site were located approximately 10 – 15km from the catchment respectively. Available rainfall data to the west of the catchment was such a distance away that it was not deemed applicable for use in the study.

Table 3-2 Local Rainfall Gauges adopted for January 2011 Event

Rainfall Gauge Station Name	Operating Agency (Gauge No)	Information Type	Period of Record
Gabbinbar Reservoir	TRC	Pluvio (Hourly/Half Hourly)	09:43 9/1/2011 – 23:43 16/1/2011
Alderley Street West Creek	TRC	Pluvio (Hourly)	09:37 9/1/2011 – 23:37 16/1/2011
Middle Ridge	TRC	Pluvio (Half Hourly)	14:46 9/1/2011 – 23:46 11/1/2011
Prescott and Goggs Street	TRC	Pluvio (Half Hourly)	14:46 9/1/2011 – 23:46 11/1/2011
Little Egypt Alert	BOM (#540170)	Pluvio (Alert)	1/11/2010 – 31/1/2011
Toowoomba Alert	BOM (#540162)	Pluvio (Alert)	1/11/2010 – 31/1/2011
Toowoomba Airport	BOM (#041549)	Pluvio (AWS)	1/1/2011 – 16/1/2011
Cambooya TM	DNRM (#42230974A)	Pluvio (Telemetry)	1/1/2011 – 31/1/2011
Moyola	BOM (#041369)	Daily	09:00 1/12/2010 – 09:00 31/1/2011
Mount Kynoch	BOM (#014096)	Daily	09:00 1/12/2010 – 09:00 31/1/2011
Withcott Alert	BOM (#040672)	Daily	09:00 1/12/2010 – 09:00 31/1/2011
Deverton Sawpit Gully Road	BOM (#040883)	Daily	09:00 1/12/2010 – 09:00 31/1/2011
“Kaiguna”[1]	Local Landowner	Daily	09:00 9/1/2011 – 09:00 12/1/2011
86 Luck Road[1]	Local Landowner	Daily	09:00 9/1/2011 – 09:00 12/1/2011

1. Local landholders indicated measurement was taken at arbitrary times in the morning. For these locations, we have adopted a 9:00am recording time for the purpose of this study.

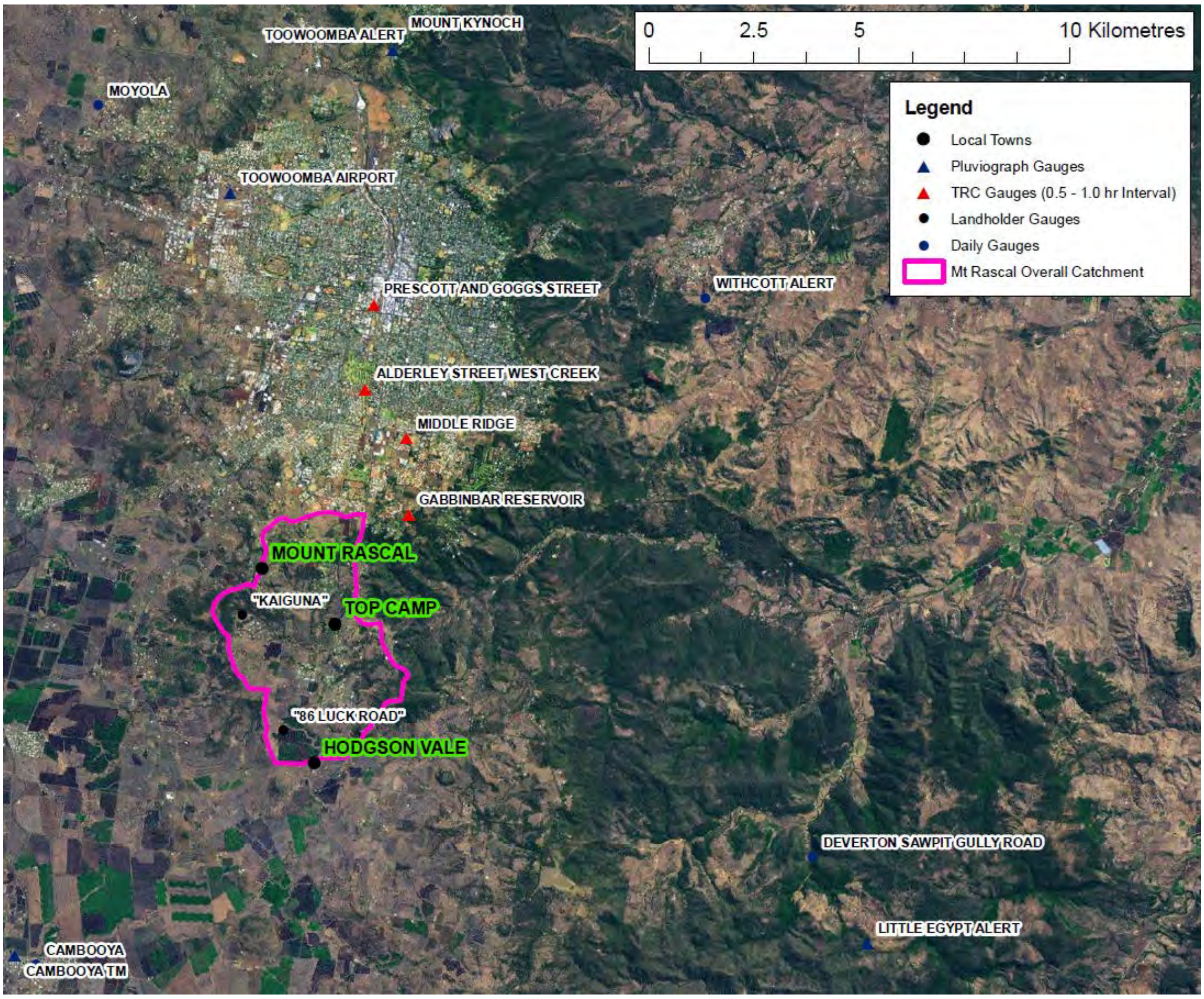


Figure 3-3 Mount Rascal Local Rainfall Gauge Locations and Mount Rascal Catchment Area

Table 3-3 Local Daily Rainfall Totals to 9:00am for January 2011 event

Rainfall Gauge Station Name	9/01/2011	10/01/2011	11/01/2011	12/01/2011
Gabbinbar Reservoir	0	61.7	107.9	31
Alderley Street West Creek	0	57	124.1	0.5
Middle Ridge (Daily Gauge)	3.4	80.8	149.6	42.2
Prescott and Goggs Street	N/A	74.4	153.9	22.7
Little Egypt Alert	1	25	97	31
Toowoomba Alert	9	80	116	22
Toowoomba Airport	3.2	89.6	121.8	26.6
Cambooya TM	0	26	91	33
Moyola	1.8	42.2	122.4	36.8
Mount Kynoch	12	104.2	143.2	36.4
Withcott Alert	26	61.8	180.8	15.6
Deverton Sawpit Gully Road	5.2	83.6	123.4	26.6
“Kaiguna”	N/A	23.5	128	46
86 Luck Road	N/A	30.5	74.2	61

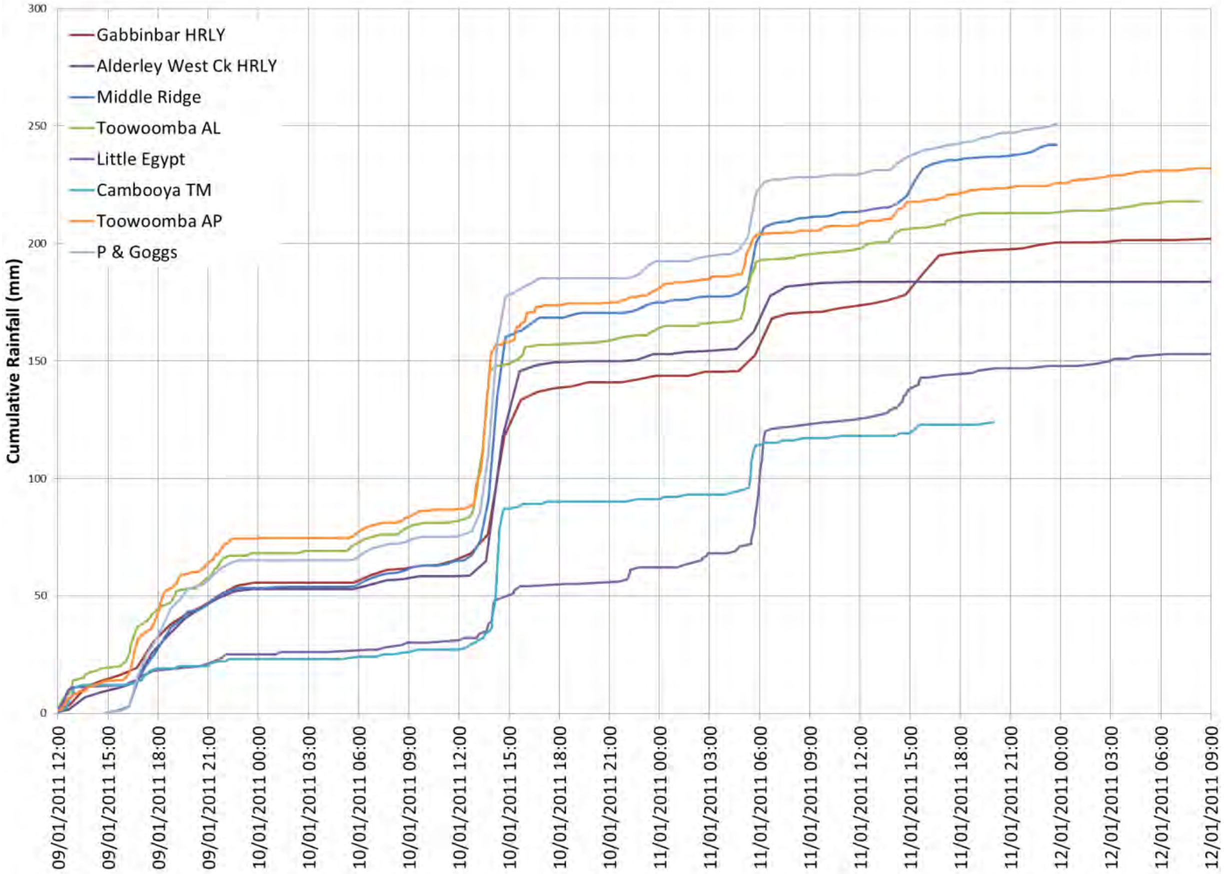


Figure 3-4 Cumulative Rainfall at Local Pluvio Locations for January 2011 event

3.4 Historical Flood Reports

The December 2010 rainfall totals were significant and especially over the Christmas period of 2010. This rainfall no doubt resulted in flooding occurring to some degree throughout the greater area. Reports from locals and information gathered as part of this study generally confirms and supports that flooding was experienced over this period throughout the broader Toowoomba area. The severity of flooding was however more pronounced on or about the 10th January 2011 with many accounts of significant flooding occurring at this time. Much of the anecdotal information collected and sourced from local residents for this study confirms that flooding which occurred as a result of the rainfall on or about the 10th January 2011 was to a higher level and was more severe in comparison to the December 2010 event. Much of the historical flood level information collected was associated with the January 2011 event. Indeed, it was this event which resulted in significant flooding in the City of Toowoomba itself and specifically East and West Creeks.

While the flooding that occurred throughout the region over December 2010 and January 2011 generally reflects the rainfall which occurred, flooding associated with the January 2011 event was disproportionately large and severe. This is likely due to antecedent rainfall occurring throughout December 2010 which resulted in supersaturated catchment conditions which ultimately contributed to the pronounced and significant flooding that occurred later in January 2011.

4. CATCHMENT HYDROLOGY

In order to assess the behaviour of flooding associated with the Mount Rascal catchment area, catchment flows and discharge estimates were required. The following sections detail the methodology and assumptions made during the derivation of these catchment discharge estimates.

4.1 Overland Flowpath Definition

Water Technology undertook the identification of the flowpaths across the Work Package 6 study area. The identification process included a CatchSIM analysis to define the various stream order tributary lines from which a set of flowpaths to be included in this study were identified for mapping. These included both local tributaries as well as larger creek and waterway catchment areas. These nominated flow paths were subsequently approved by TRC for assessment in this study.

4.2 Methodology

Catchment hydrology for this project was determined using an XP-RAFTS model in accordance with that specified in the project brief. For the purposes of calibration, the XP-RAFTS model was used to provide local catchment inflows for the two deliverable items:

(1) Calibration of the MIKE FLOOD hydraulic model to the January 2011 event.
(2) Estimation of the design event floods using the calibrated MIKE FLOOD hydraulic model.

That is, the XP-RAFTS model itself is not calibrated to represent routed catchment flows, but to provide local hydrograph inflows to the hydraulic model (at a local catchment level) as part of a joint calibration process. The hydraulic model calibration process and the XP-RAFTS parameters are detailed in Sections 6 and 7 respectively. Figure 4-1 shows the XP-RAFTS sub-catchment boundaries and study area location. Sub-catchment boundaries were established using the topographic data sets and was facilitated using a CatchSIM analysis with manual intervention as part of the review process and in order to better represent contributing sub-catchments to each of the identified flowpaths. A detailed summary of sub-catchment characteristics including area, fraction impervious and slope is included in Appendix B.

4.3 Catchment Descriptions

The Mount Rascal catchment is 1693ha in area with predominately rural or natural land uses. Discrete areas of urban development in the middle and lower areas of the catchment also exist primarily as part of the Hodgson Vale and Top Camp localities. Figure 4-1 illustrates the catchment extents and topographic variability across the study area.

4.4 Design Rainfall

Design rainfall patterns and intensities for the centroid of the Mount Rascal catchment were determined via the Bureau of Meteorology website for this analysis. This online service automates the standard procedures in Australian Rainfall and Runoff (IEAust, 1998).

4.5 Catchment Land Use

The January 2011 calibration model and the design event models have adopted existing land use/fraction impervious values as was directed by TRC. Table 4-1 presents the adopted fraction impervious values for the catchment for the existing condition as delineated using the 2010 aerial photography. We have assumed that the catchment conditions represented in the 2010 aerial photography are representative of the catchment conditions as at January 2011 and subsequently used for the January 2011 calibration event.

The fraction impervious values assigned across the catchment have been determined generally in accordance with QUDM provisions with visual inspection of the catchment. The fraction impervious values for each of the sub-catchment areas have been determined based on a weighted average of different land use types within the respective sub-catchment areas.

Land use descriptors and their adopted fraction impervious for ultimate land use conditions are summarised in Table 4-2. Appendix A provides a map of catchment land use applied for the January 2011 and ultimate land use model scenarios. Fraction impervious applied for each of the respective sub-catchments is detailed in Appendix B.

Table 4-1 Adopted Existing Condition Fraction Impervious Values

Land Use Description	Fraction Impervious
Urban Residential - Low Density	0.3
Rural Residential	0.15
Urban Residential - High Density	0.7
Transformers	0.9
Shop	0.7
Light Industry A	0.7
Horses	0.2
Open Space	0
Road	0.7
Creek	1

Table 4-2 Adopted Ultimate Condition Fraction Impervious Values

Land Use Description	Fraction Impervious
Abattoir	0.7
Animals Special	0.2
Body Corporate in any strata titled	0.85
Building Format Plan Primary Use Only	0.7
Car Parks	0.7

Caravan Parks	0.7
Cattle grazing	0
Cattle Grazing Breeding	0
Cattle Grazing Breeding and Fattening	0
Cattle Grazing Fattening	0
Cemeteries (Include Crematoria)	0.2
Child Care excluding Kindergarten	0.5
Church/Facilities	0.5
Combined Dwelling & Shops	0.9
Community Protection Centre	0.2
Community Purposes	0.2-0.5(1)
Creek	0.2
Dairy Cattle Milk	0.2
Educational include Kindergarten	0.5
Extractive Quarry / Industry	0.5
General Industry or Medium Industry	0.7
Grains	0
Heavy Industry	0.9
Horses	0.2
Hospitals, Convalescent Homes (Medical	0.7
Hotel/Tavern	0.7
Large Home Site Dwelling	0.15
Large Home Site Vacant	0.5
Library/Museum	0.9
Light Industry A	0.7
Light Industry B	0.9
Low density res	0.5
Motel	0.7
Multi Dwellings or Flats	0.85
Nurseries (Plants)	0.2
Open space	0
Other Clubs Non Business	0.2
Outbuildings	0.2
Outdoor Storage Area/Contractors Yard	0.7
Parks, Gardens	0
Pigs	0.2
Poultry	0.2
Professional Offices	0.7
Reservoir, Dam, Bores	1
Residential Choice	0.6
Residential Living	0.6
Restaurant/Function Centre	0.7
Retail Warehouse	0.7
Roads	0.7
Rural	0
Rural Vacant Land	0
Sales Area Outdoors (Dealers, Boats, Cars	0.7
Section 49 Valuation Vacant Urban Land	0.6
Service Station	0.7
Shop Single	0.7
Shopping Group (2-6 Shops)	0.7

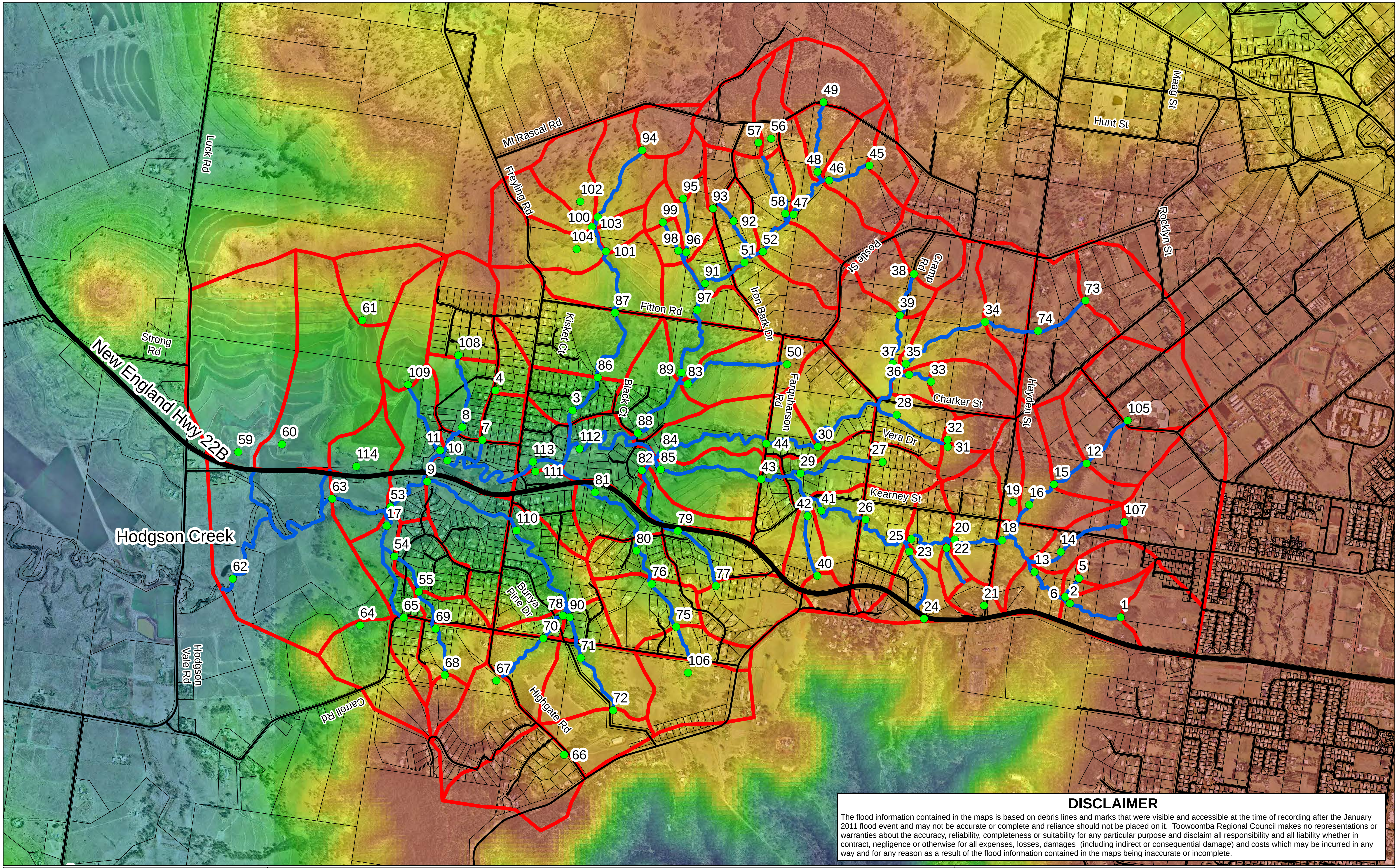
Show Ground, Race Course, Airfield	0.2
Single Unit Dwelling	0.7
Small Crops and Fodder Irrigation	0
Special Tourist Attraction	0.2
Sports Clubs/Dance Facilities	0.2
Township	0.2-0.6 (1)
Transformers	0.7
Transport Terminal	0.7
Urban Residential	0.7
Vacant Urban Land	0.6
Warehouse and Bulk Stores	0.9

4.6 Manning's' Land Use Sensitivity

The representation of catchment roughness for both pervious and impervious catchment areas in the hydrologic model was adopted based on a Manning's 'n' value of 0.04 applied consistently across the Mount Rascal catchment. A sensitivity assessment was also undertaken to assess the impact of varying the Manning's roughness coefficient to 0.015 for the impervious areas. The sensitivity test was undertaken based on both the January 2011 event in addition with the ultimate land use model scenarios. The sensitivity assessment on the Manning's n values showed the following results (based on sampled results taken at various points throughout the catchment): -

- There was a maximum increase in total flow of 2.6% at Acacia Avenue just upstream of ST24 (i.e. peak flows from 83 m^3/s to 85 m^3/s). This was due to a significant impervious area change that has occurred within a short distance upstream of the point of interest.
- All other locations tested including at various reaches throughout the catchment showed a negligible increase in flow of less than 0.7%.

In both cases it was found that varying the Manning's 'n' parameter in the hydrologic model resulted in insignificant differences in peak flow estimates and when analysed hydraulically would translate into negligible effects in water levels.



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 150 300 600
Meters

GDA 1994 MGA Zone 56

N

Legend

- Catchment Outlet ID
- Catchment Flowpaths
- Major Road Centre Lines
- Catchment Boundaries
- Cadastre

Topography

Value (mAHD)

High : 730

Low : 490

SP051 Flood Studies - Work Package 6

Mount Rascal Catchment Map

Figure 4-1

MTR-E-CATCHMENT.mxd
Author/Date: Ryan.dermek 4/04/2014

5. HYDRAULIC MODELLING

5.1 Model Description

Hydraulic modelling of the study area has been undertaken utilising DHI Software's MIKE FLOOD modelling system. The project brief required a 1D MIKE11 hydraulic model however this was later changed by agreement with TRC to a 2D MIKE FLOOD hydraulic model to better represent catchment flooding characteristics.

MIKE FLOOD combines the dynamic coupling of the one-dimensional MIKE 11 river model and MIKE 21 fully two-dimensional model systems. Through coupling of these two systems it is possible to accurately represent in and over-bank floodplain flood behaviour as well as sub-surface drainage flow behaviour through the application of a comprehensive range of hydraulic structures (including culverts, bridges, weirs, control gates etc).

5.2 Modelled Events

That this report summarises calibration of the hydraulic model to historic flood levels as well as the hydraulic modelling results for the design (2, 5, 10, 20, 50, 100 year ARI) , rare (200 and 500 year ARI) and extreme (Probable Maximum) flood events for the Mount Rascal study area.

5.3 Model Details

5.3.1 Model Area and Extents

The model areas and extents for the MIKE FLOOD model developed for this study is shown in mapping in the report Appendix and is discussed in the following chapter of this report.

5.3.2 Model Resolution

The model has utilised a 2m cell resolution. This was considered appropriate to both accurately represent the flooding behaviour of in-channel and overbank flows as well as maintaining realistic model simulation times. The model grid size adopted was also discussed and agreed with TRC.

5.3.3 Model Alignment and Orientation

The model is aligned in a traditional North/South orientation (0 degrees).

5.3.4 Hydraulic Structures

In a solely 2D modelling environment it is often not possible to accurately describe the hydraulic behaviour of structures such as culverts and bridges. This is due to the fact that grid cell sizes often exceed the dimensions of various structures and friction and specific hydraulic structure losses through the culvert cannot be modelled. As a result, hydraulic structures are often more accurately modelled in a 1D modelling environment (MIKE 11) within the 2D domain (MIKE 21), thus allowing prescriptive modelling of the exact characteristics of the various structures. Hydraulic structures within the study areas have therefore been incorporated within the MIKE 11 modelling domain.

As no survey information was available for the hydraulic structures, structure size and location details have been derived from field notes, LiDAR survey provided by TRC, the structure database prepared for this study as well as the oblique photographic records as described in Section 2.5. Invert levels for the structures were estimated from an assessment of the structure height/diameter and ground cover to the road crown as well as other topographic considerations based on the ALS survey data. This was then assessed in a GIS environment to determine the likely invert level of each structure from the DEM. Culvert slope was estimated from the DEM level at intake and discharge locations of the respective culvert structures.

Appendix C provides a summary of the hydraulic structures incorporated within the MIKE FLOOD model prepared for Mount Rascal. Appendix C additionally includes a map illustrating the locations of each of the hydraulic structures.

5.3.5 Model Duration and Timestep

The January 2011 event was run for the major storm burst on the afternoon of the 10th January 2011 from 12:00pm to 4:00pm (with the exception of the pre-wetting run). The identification of this burst is discussed further in Section 6. A 0.2 second timestep was adopted in both the 1D (MIKE 11) and 2D domain (MIKE 21) of the MIKE FLOOD model, with the exception of the Probable Maximum Flood event which adopted a 0.05 second timestep in both the 1D and 2D model domain to maintain stability.

5.3.6 Model Boundaries

Downstream Boundary

The downstream model boundaries were located a sufficient distance downstream from the furthest limit of mapping as to not impact on flood behaviour predictions within the areas of interest.

Iterative assessments of the peak water surface level and local topography longitudinal grades were undertaken to determine a suitable level for the tailwater model boundary. Boundary details are presented in Table 5-1. The chosen tailwater was not significantly influential of water levels upstream of the Hodson Vale Road crossing. Points to note regarding the downstream tailwater condition include:

- The existing Hodgson Vale Road crossing structure is raised to a higher level above the floodplain meaning the structure controls flood levels in the lower domain of the model.
- There are no regional watercourses within a sufficient distance downstream to control tailwater levels within the model domain.
- Regional levels of the tributary of Hodgson Creek just downstream of the model boundary have not been investigated due to the lack of influence on the area of interest.

- The relatively steep hydraulic grade line through the domain and at the downstream boundary limit the influence of the adopted constant tailwater for all design events.

Table 5-1 Adopted Downstream Boundary Conditions

Model Name	Boundary Location Description	Adopted Tailwater Level (m AHD)
Mount Rascal	Approximately 400 m downstream of Hodgson Vale Road	504.0

Inflow Boundaries

The local event hydrographs for each sub-catchment from the XP-RAFTS model were applied to the MIKE FLOOD 2D model domain (MIKE 21) by way of direct application at the respective sub-catchment inflow locations throughout the model domain. These inflows were source inflows applied throughout the model domain. Nodes were applied at or just upstream of sub-catchment outlets. Inflow nodes were split amongst adjacent hydraulic model cells to maintain stability where necessary and subject to the magnitude of the respective inflow. Overall, there were some 171 separate source points applied to the hydraulic model for design events up to and including the 200 year ARI events. For the 500 year ARI and PMP-DF events, a total of 504 source nodes were applied. Appendix D provides a detailed summary of the respective flow splits based on the source point scenarios outlined and the corresponding XP-RAFTS sub-catchment.

Initial Water Level

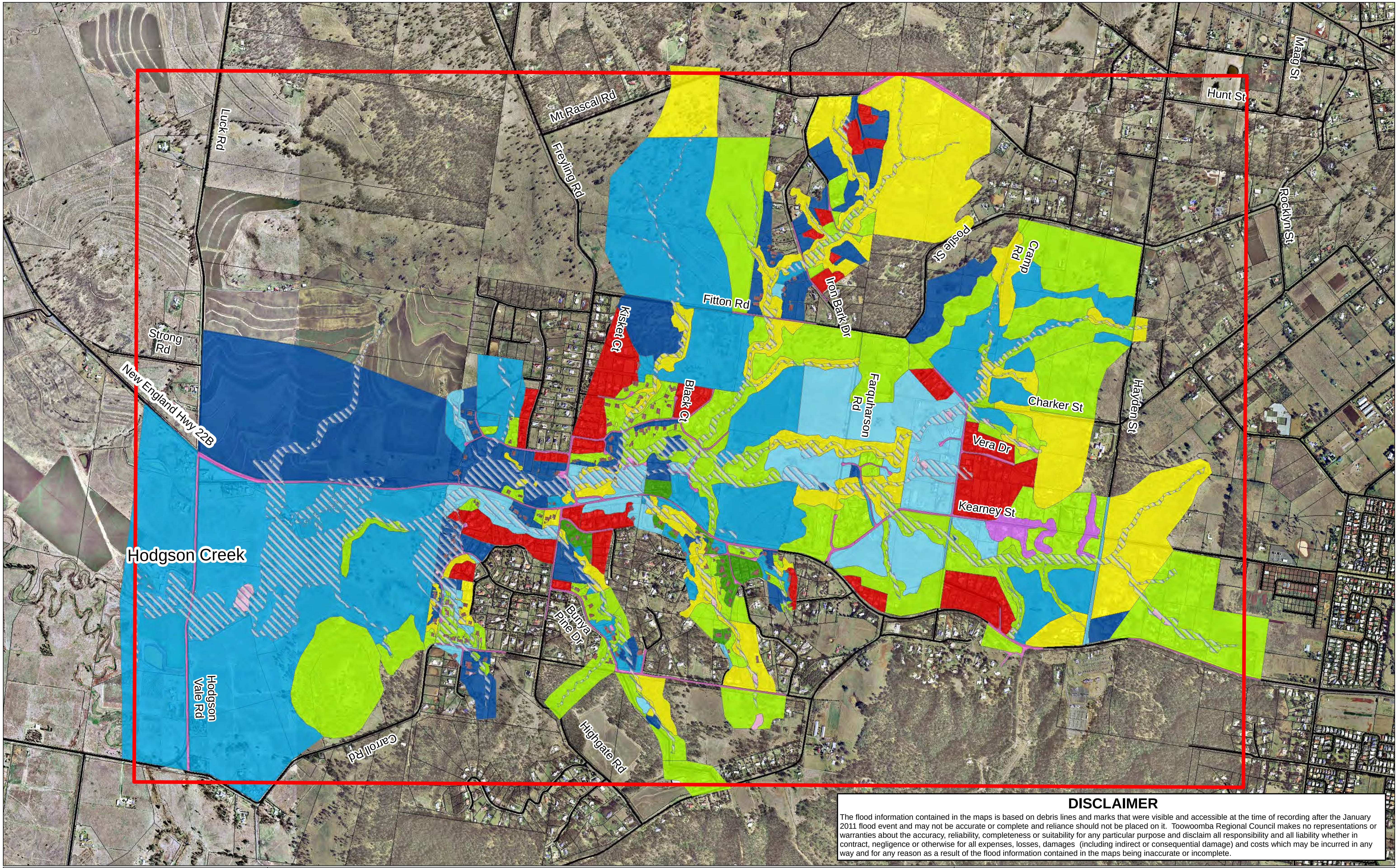
The hydraulic model domain was 'pre-wet' using the XP-RAFTS inflows which were run from the period 9:00am on the 9th January 2011 to 12:00pm on the 10th January 2011 (being the beginning of the major storm burst). The water level across the domain at 12:00pm on the 10th January 2011 was taken as the starting water level for all future model iterations. Note this was after a two-hour period of no rainfall, hence flow has been allowed to leave the model domain and water remaining represents storage areas. All design event iterations have also adopted this initial water level.

5.3.7 Floodplain Roughness

Floodplain roughness values were derived based on a review of the 2010 aerial photography, site notes and oblique photographic records as well as recommendations outlined in Table 10-1 of Project 15 of the AR&R review, namely 'Two Dimensional Modelling in Urban and Rural Floodplains' (IEAust, 2012). A summary of the roughness values adopted for the hydraulic models was prepared and provided to TRC for approval. The spatial application of the adopted roughness values is illustrated in Figure 5-1. A summary of the adopted roughness values is presented in Table 5-2. The roughness values applied are also consistent with the roughness values adopted for the other work packages being undertaken by Water Technology.

Table 5-2 Adopted Floodplain Roughness Values

Floodplain Description	Manning's 'n' Value
Culverts - Concrete	0.014
Concrete Lined Channels	0.017
Roads/Paved Areas/Carparks/Driveways	0.020
Gravel Road	0.025
Lakes/Dams/Water Bodies	0.025
Culverts - Corrugated	0.025
Railway	0.030
Waterways/Channels - Minimal Vegetation	0.040
Open Pervious Areas - Grassed	0.045
Wetlands/Marsh Areas	0.060
Open Pervious Areas - Shrubs	0.060
Waterways/Channels - General Vegetation	0.070
Open Pervious Areas - Treed	0.080
Cropping/Broad Hectare	0.080
Waterways/Channels - Thick Vegetation	0.100
Residential - Low Density	0.150
Residential - High Density	0.300
Industrial/Commercial	0.300
Buildings - Permeable	0.500



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- 100yr ARI Flood Extent
- Major Road Centre Lines
- Cadastre

Manning's 'n' Roughness

0.01, 0.02, 0.025, 0.04, 0.045, 0.06, 0.07, 0.08, 0.1, 0.15, 0.5

SP051 Flood Studies - Work Package 6

Mount Rascal Roughness Map

Figure 5-1

MTR-E-ROUGHNESS.mxd
Author/Date: Ryan.dermek 4/04/2014

5.3.8 Topographical Changes

Minor topographic changes have been made in all models to assist in accurate representation of flow behaviour and model stability around model boundaries.

Changes were typically limited to areas around MIKE 11 structures to aid in accurate representation of structure inverts and flow transference between the 1D and 2D model domains.

Minor changes to topography around model boundaries has also been undertaken to assist in model stability during the simulations. These changes have no effect on flood behaviour estimations in the areas of interest in these assessments.

Changes were also made to a particular area on Kearney Street in the model domain as part of the calibration process. This is detailed further in Section 6.

5.4 Model Calibration Event Nomenclature

The MIKE FLOOD naming nomenclature used for this study is in accordance with the TRC requirements.

6. HYDRAULIC MODEL CALIBRATION

6.1 Methodology

The project briefing requirements for model validation for Work Package 6 specified a methodology of calibrating a hydraulic model to the January 2011 event using the available historical flood information. Accordingly, we have applied a model calibration approach which is consistent with the project briefing requirements. The following approach was adopted to calibrate the hydraulic model: -

- One XP-RAFTS model was developed:
  - January 2011 catchment conditions. The catchment conditions were based on land use based on the 2010 aerial photography.
- One MIKE FLOOD model was developed:
  - January 2011 catchment conditions.
- Two HEC-RAS models were developed to validate flood levels and afflux at major structures:
  - Hodgson Creek crossing at Freylings Road (culvert crossing); and
  - Hodgson Creek at New England Highway (bridge crossing).
- The HEC-RAS model was used to verify structure performance and channel conveyance in the MIKE FLOOD model.
- The XP-RAFTS model was used as local input (i.e. routing in hydraulic model only) into the MIKE FLOOD model to calibrate the MIKE FLOOD model to historic flood information.
- The calibration process involved the refinement of the following parameters in the XP-RAFTS model: -
  - Spatial rainfall distribution of the January 2011 event.
  - Temporal rainfall distribution of the January 2011 event.
  - Initial and continuing losses.
- The calibration process involved the refinement of the following parameters in the MIKE FLOOD model:
  - Roughness (Manning's "n").
  - Topography.

The general approach undertaken for the calibration assessment against historical flood level information was as follows: -

- Where uniform or consistent under and over estimation of historical flood level information occurred, this was addressed through the adjustment of the XP-RAFTS hydrology; and
- For more localised historical flood level differences, these were addressed by local refinement and adjustment of the MIKE FLOOD hydraulic model.

The following provides further details on the calibration process.

6.2 Hydrologic Model

The calibration of the MIKE FLOOD model to the January 2011 event involved determining appropriate and representative inflows for the event as it occurred in the Mount Rascal catchment. This involved an iterative assessment of the XP-RAFTS model based on three key aspects: -

- Spatial rainfall distribution of the January 2011 event.
- Temporal rainfall distribution of the January 2011 event.
- Initial and continuing losses.

Each of these aspects is discussed in specific detail below.

6.2.1 Spatial Distribution of Rainfall

The spatial distribution of rainfall across the Mount Rascal catchment has been represented for the January 2011 event by the following methodology: -

- Selecting appropriate representative rainfall gauges for the January 2011 event using the available data sets.
- Spatially weighting the total depths of the gauges over the selected January 2011 event period.
- Iteratively running various spatially-weighted depths (in conjunction with other variables) to achieve calibration to recorded levels for the event using the MIKE FLOOD hydraulic model.

The selected period for hydrologic modelling was 9:00am on the 9th to 9:00am on the 12th January 2011. The total rainfall depths are summarised in Table 6-1 and the daily totals for the gauges can also be seen in Table 3-3 and Figure 3-4.

Table 6-1 Total Rainfall Depth for the period 9:00am 9/01/2011 to 9:00am 12/01/2011

Rainfall Gauge Station Name	Depth (mm)
Middle Ridge (Daily)	272.6
Prescott and Goggs Street[1]	251
Little Egypt Alert	153
Toowoomba Alert	218
Toowoomba Airport	232
Cambooya TM	124
Moyola	201.4
Mount Kynoch	283.8
Withcott Alert	258.2
Deverton Sawpit Gully Road	233.6
"Kaiguna"	197.5
"86 Luck Road"	167.1

1. Note Prescott and Goggs Street did not include entire record.

Note that two TRC pluvio gauges (namely Prescott and Goggs Street and Middle Ridge) did not include the entire rainfall record for this storm event. The Middle Ridge depths were therefore supplemented with Middle Ridge daily information (BOM Gauge #041553). The Prescott and Goggs Street gauge was not supplemented with additional rainfall, however temporal patterns at other local gauges indicate minimal rainfall for the period would have fallen outside of the recording of the Prescott and Goggs Street gauge.

The rainfall depths presented in Table 6-1 were spatially averaged using a simple natural neighbour surfacing technique to give a representation of rainfall depths falling across the Mount Rascal catchment during the selected January 2011 event period (i.e. 9:00am on the 9/1/2011 to 9:00am on the 12/1/2011).

It was noted that the two TRC gauges named Gabbinbar Reservoir and Alderley Street West Creek had significantly lower total rainfall depths for the January 2011 event in comparison to other TRC pluvio gauges close to the site (namely the Prescott and Goggs Street as well as Middle Ridge gauges). The resulting January 2011 event rainfall isohyet plot for the period 9:00am on the 9/1/2011 to 9:00am on the 12/1/2011 is presented in Figure 6-1. The discarded event rainfall isohyet plot adopting the Gabbinbar Reservoir and Alderley Street West Creek gauges is shown in Figure 6-2. Note the abnormal drop in isohyet rainfall gradients at the location of the two discounted gauges in comparison to the adopted smoother rainfall gradient shown in Figure 6-1.

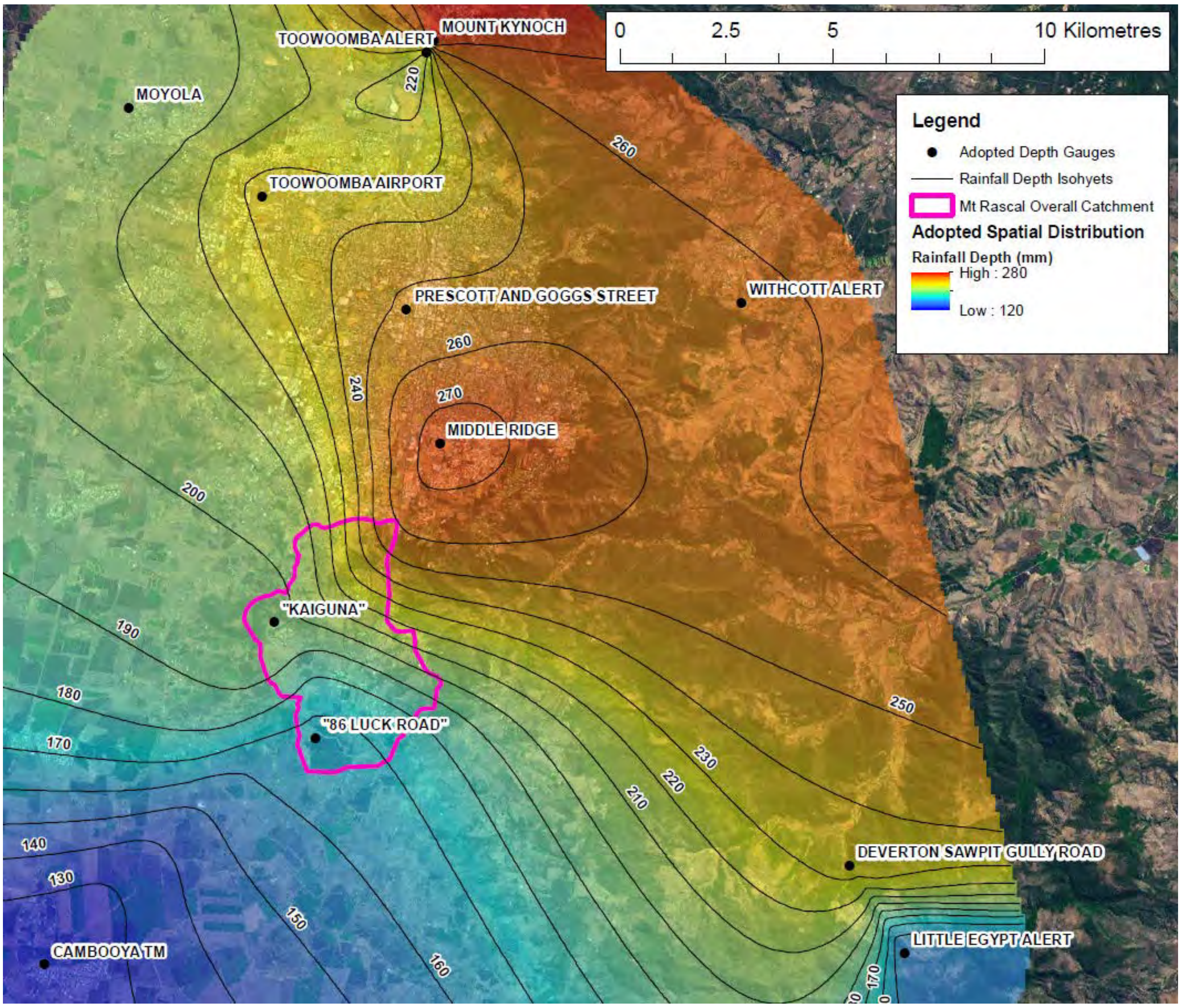


Figure 6-1 Adopted Mount Rascal Spatial Rainfall Distribution

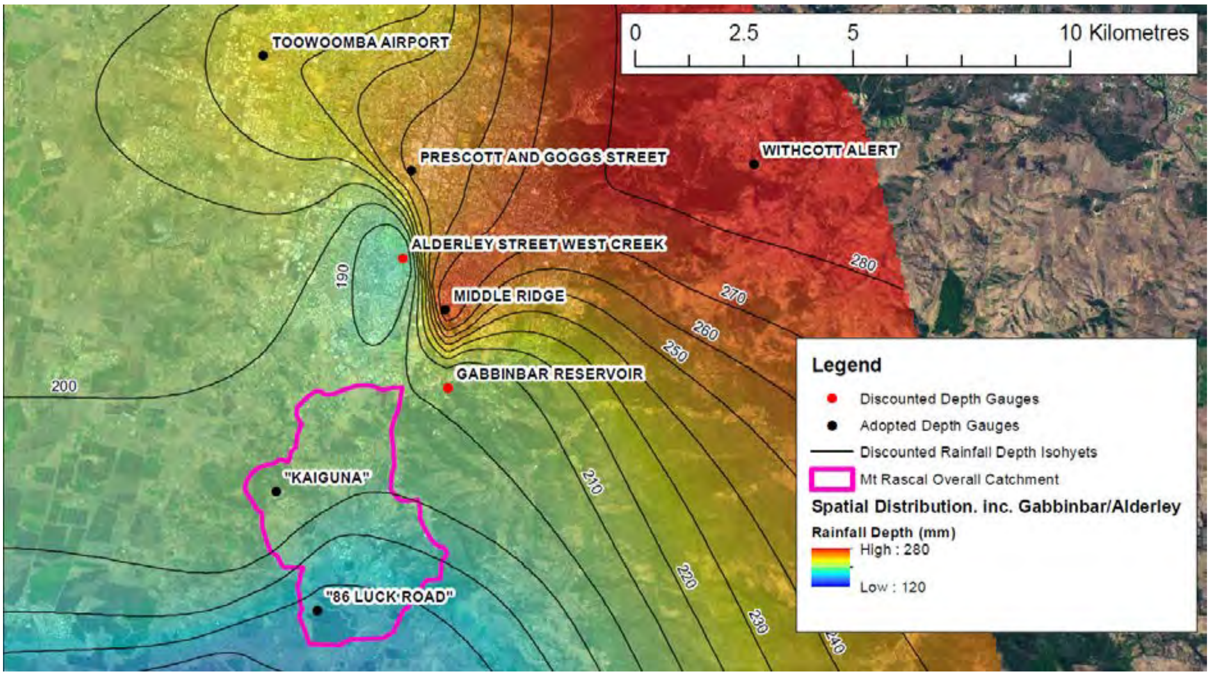


Figure 6-2 **Mount Rascal Spatial Rainfall Distribution inclusive of Gabbinbar Reservoir and Alderley Street West Creek**

Various combinations of spatial and temporal combinations (discussed separately in Section 6.2.2) were tested as part of the model calibration process. The rainfall depths at the Alderley Street West Creek and Gabbinar Reservoir gauges were also further investigated using the hydraulic model. As previously discussed, the total rainfall depth for the January 2011 event (i.e. 9:00am on the 9/1/2011 to 9:00am on the 12/1/2011) was adopted as a representative depth in the hydrologic model for input into the hydraulic model. Despite the adopted model losses (as discussed separately in Section 6.2.3), the hydraulic model was not able to reproduce observed flood levels of the January 2011 event with the inclusion of the Alderley Street West Creek and Gabbinar Reservoir gauge depths. As part of the calibration process and in order to replicate observed flood levels, these gauges were subsequently excluded as event rainfall depths in the hydrologic model.

It was determined to exclude the Alderley Street West Creek and Gabbinbar Reservoir gauge information in the estimation of spatial distribution of rainfall. We suspect that rainfall records at these gauges are erroneous for the January 2011 event in respect to the isohyets of total event depths and replication of observed flood levels for the same event based on the hydraulic model and calibration process.

It is important to note that the January 2011 incident storm direction has also been considered in the adoption of the representative spatial distribution for the catchment. Four major storm bursts are definable in the January 2011 event, the largest being that beginning around 1:00pm on the 10th January 2011 and which is the focus of the calibration event. Historical BOM radar imagery (Weatherchaser, 2013) showed that all storms generally travelled in a south south-easterly direction across the Toowoomba area (refer Figure 6-5). This indicates that the most spatially representative gauges for the headwaters of the Mount Rascal catchment would be the TRC gauges located towards the south of the Toowoomba township (north north-east of the Mount Rascal catchment). This has been reflected in the spatial distribution adopted for the catchment by the strong weighting of the Middle Ridge and Prescott and Goggs Street gauges near the top of the catchment.

Note that orographic effects must also be considered when defining the spatial distribution of rainfall of the 2011 event. Figure 6-3 shows an oblique view of the exaggerated elevation profile of the Mount Rascal catchment. It can be clearly seen that the upper reaches of the catchment are at a similar elevation to the TRC gauges located to the south of the Toowoomba CBD. The steep elevation change (in combination with the January 2011 storm direction) through the catchment indicates that these gauges would not ideally be representative of depths falling in the lower Mount Rascal catchment. This is reflected in the adopted rainfall spatial distribution, where the rainfall gradient drops away steeply from the top to the bottom of the catchment. This is also confirmed using the local landholder rainfall totals located within the catchment which confirms progressively less rainfall occurring moving downstream (south) along the catchment. This aspect is further validated in Section 6.2.2.

Figure 6-3 Relative elevations of local gauges to Mount Rascal catchment

6.2.2 Temporal Distribution of Rainfall

The temporal distribution of rainfall across the Mount Rascal catchment has been represented for the January 2011 event by the following methodology: -

- Selecting appropriate representative rainfall gauges for the January 2011 event.
- Temporally distributing the adopted spatial rainfall distribution over the selected January 2011 event period (9:00am on the 9th to 9:00am on the 12th January 2011) with the adopted gauge temporal pattern.

As outlined previously, the incident storm direction for the January 2011 event was predominately from the north north-east travelling in a south south-westerly direction across the Toowoomba area (refer Figure 6-5). This indicated that the adopted temporal pattern for the January 2011 event in the Mount Rascal catchment would be more representative using pluviograph gauges located in the storm path to the north north-east or the south south-west of the catchment. The applicable gauges using these criteria were listed as either being the TRC pluvio gauges, the Toowoomba Airport gauge or the Cambooya TM gauge. We note that there is no available pluviograph gauge information situated within the catchment area for the January 2011 event.

The storm burst of interest for the January 2011 event was the burst occurring from 1:00pm to 4:00pm on the 10th January 2011 in the Toowoomba region, as this recorded the most intense rainfall and produced the highest peak water levels according to anecdotal historical information and which was also confirmed using the hydraulic model. As part of the investigation, pluviograph data was plotted to determine the allocation of rainfall for the 4 main storm bursts of the January 2011 event in Toowoomba which is summarised in Table 6-2. The average hourly intensity at the selected pluviograph gauges for each burst is shown in Figure 6-4. It can be seen that for all gauges (with the exception of Little Egypt – the least representative gauge analysed), the hourly intensity of the storm burst on the 10th January 2011 is the highest. These storm burst magnitudes can also be seen in Figure 3-4 previously.

Table 6-2 January 2011 Storm Bursts

Storm Burst	Approx. Duration in Toowoomba
1	12:00pm 9th – 12:00am 10th January 2011 (12 hrs)
2	1:00pm 10th – 4:00pm 10th January 2011 (3 hrs)
3	4:00am 11th – 7:00am 11th January 2011 (3 hrs)
4	1:00pm 11th – 5:00pm 11th January 2011 (4 hrs)

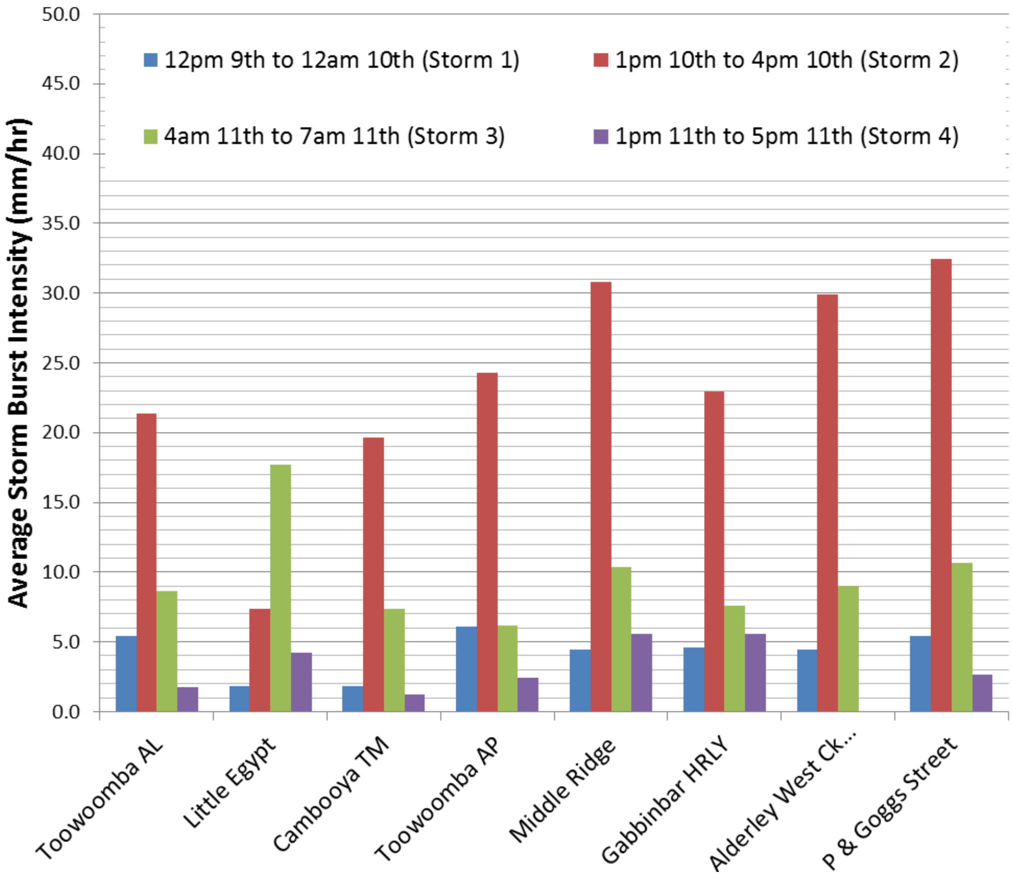


Figure 6-4 January 2011 Event Storm Burst magnitude

The weighting of the temporal pattern for each gauge across the event was also further investigated. Of particular interest was the percentage of the total rainfall at each gauge that fell in the burst on the afternoon of the 10^{th} January 2011. Table 6-3 details the fraction of total rainfall for each gauge contained in the burst on the 10^{th} January from 1:00pm to 4:00pm (i.e. Storm burst 2).

Table 6-3 Fraction of Total Rainfall in 10^{th} January 1:00pm – 4:00pm Storm Burst

Pluvio Gauge Name	Total Rainfall Depth (mm)	Storm 2 Burst Rainfall Depth (mm)	Fraction
Toowoomba AL	218.0	64.0	0.29
Little Egypt	153.0	22.0	0.14
Cambooya TM	124.0	59.0	0.48
Toowoomba AP	232.0	72.8	0.31
Middle Ridge	241.9	92.3	0.38
Gabbinbar Reservoir HRLY	202.5	68.8	0.34
Alderley Street West Creek	183.8	89.6	0.49
Prescott and Goggs Street	251.0	97.3	0.39

It can be seen that the fraction of rainfall in the burst at the Gabbinbar Reservoir gauge is lower than the three other TRC Gauges located to the north-east of the Mount Rascal catchment. Middle Ridge (0.38), Alderley Street West Creek (0.49) and Prescott and Goggs Street (0.39) all have a higher fraction of rainfall falling in the 1:00pm to 4:00pm January 11th 2011 burst.

Considering that Alderley Street West Creek and Gabbinbar Reservoir had been disregarded during the estimation of spatial distribution of rainfall, they were also eliminated from the analysis as not being representative temporal distribution gauges.

Of the two remaining closest TRC gauges, the Middle Ridge and Prescott and Goggs Street were also both disregarded as the representative temporal distribution at the gauge was based on hourly interval rainfall and was not considered appropriate for use in model calibration.

The closest remaining pluvio gauges (both approx. 11km from the Mount Rascal catchment centroid) were the Toowoomba Airport and Cambooya TM gauges. In order to determine the most appropriate temporal pattern for the Mount Rascal catchment, the orographic and spatial characteristics for the January 2011 event at the two gauges were compared to the Mount Rascal catchment.

The Toowoomba AP, Mount Rascal catchment centroid and Cambooya TM Gauges are located at elevations of approx. 632mAHD, 564mAHD and 463mAHD respectively. This does not give a particular indication in itself of which gauge to adopt as there is a significant topographical and rainfall gradient in the Mount Rascal catchment between these gauges. Of note is the location and elevation of the Toowoomba AP gauge relative the headwaters of the Mount Rascal catchment. Rainfall in the headwater of a catchment has a greater influence on peak catchment flows which in-turn favours the adoption of the Toowoomba AP gauge as a representative temporal pattern.

Table 6-3 indicates that the fraction of the total event rainfall that fell in the afternoon burst of the 10th January 2011 at the Toowoomba AP gauge (0.31) was similar to the TRC gauge closest to the site being the Middle Ridge gauge with a fraction of 0.38. Cambooya TM had almost half of the total rainfall (0.48) fall in the burst. This is much greater than those gauges located closer to the Mount Rascal catchment. This gave further weight to the consideration of the closer gauges to be more representative to the catchment.

The afternoon storm on the 10th January 2011 tracked in a general south-westerly direction across the Toowoomba region. Figure 6-5 shows intermittent radar images during this event and the location of the relevant townships. The approximate location of the Mount Rascal catchment centroid is also shown as a square red dot. This plot indicated that the intensities of the Toowoomba AP gauge were most like that which would have otherwise fell in the Mount Rascal catchment during the burst and particularly in the catchment headwaters. For the reasons discussed, the Toowoomba AP gauge has been adopted as a representative temporal pattern for the January 2011 event. Note that the Toowoomba AP gauge was also selected given that this contained 1 minute interval rainfall totals for the January 2011 event and was more representative for the purposes of calibration and in preference to the TRC gauges which recorded rainfall depths at 30 and 60 minute intervals.

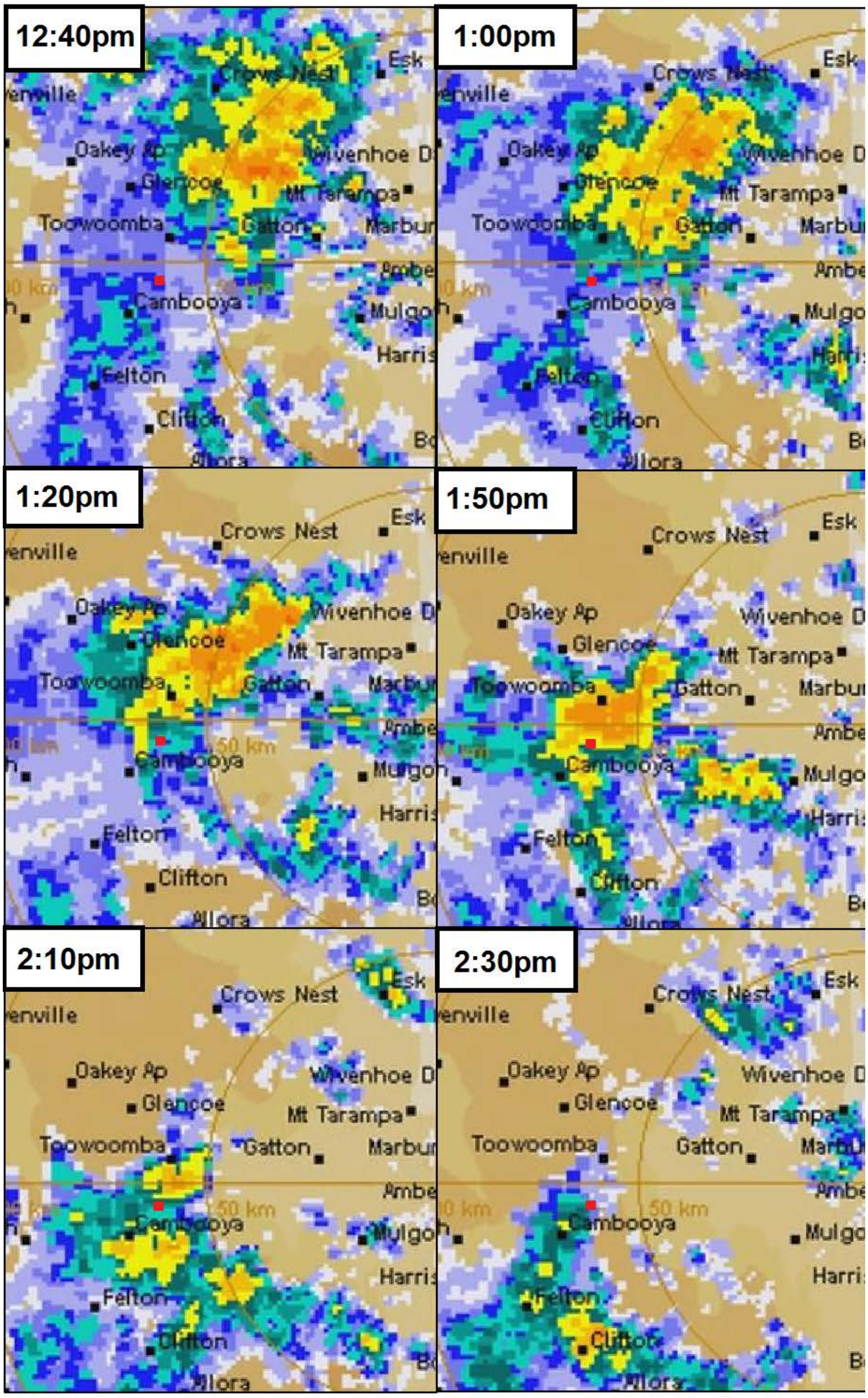


Figure 6-5 BOM Radar Incident Storm Direction – 10th January 2011

6.2.3 Initial and Continuing Losses

The adopted losses for the calibration run when utilising the Toowoomba AP temporal pattern were 0 mm initial loss (IL) and 0 mm continuing loss (CL). These values were determined through iterative analysis with the XP-RAFTS and MIKE FLOOD models and provided the best match to the historical flood level information. Although the losses may appear to be low in comparison to the typical values for hydrologic modelling, they are realistic for the January 2011 especially when considering the amount of antecedent rainfall in the catchment that occurred in December 2010 over the wider Toowoomba area and the saturated catchment conditions that predominated prior to the onset of the January 2011.

6.3 Hydraulic Model

The issues in replicating historic flood levels were addressed mostly through the logical refinement of hydrologic parameters as previously outlined. This was to be expected considering most parameters in the hydraulic model were based on physically quantifiable datasets. However, some areas within the model domain were noted to differ in magnitude of variance from the recorded flood levels to others which required local refinement to the hydraulic model including structure representation, Manning's "n" (magnitude and spatial distribution), local flowpaths and topography, etc. The calibration process involved the refinement of the above parameters in the MIKE FLOOD model as necessary and within realistic and appropriate ranges.

The area of particular note was an area in the upper north-east of the catchment associated with the Kearney Street culvert crossing. Figure 6-6 shows the Kearney Street crossing location in relation to the overall catchment. It was noted that when a good match using historical flood information was achieved across the greater catchment area, modelled flood levels at Kearney Street were considerably higher in comparison to the recorded surveyed levels. On further inspection, it was noted that the historic survey levels at Kearney Street were some 0.1 m to 0.2 m below the topographical levels otherwise represented in the LiDAR data.

Detailed "construction issue" drawings for the Kearney Street crossing were subsequently obtained from TRC and a copy of the relevant drawings are included in Appendix E. Figure 6-7 illustrates the longitudinal road profile for Kearney Street in the area of interest based on the LiDAR data versus that detailed using the construction issue drawings received from TRC. It can be seen that the construction issue drawings for Kearney Street show a lower road formation in comparison to the LiDAR data and in this case is up to some 200 mm. For the purposes of the hydraulic model, we have adopted the road profile levels as per the TRC construction issue drawing as this is considered to be more accurate in preference to the LiDAR data. Further discussion is provided in relation to the Kearney Street road profile in the calibration discussion included in Section 6.4.1.

Figure 6-6 Kearney Street Crossing location

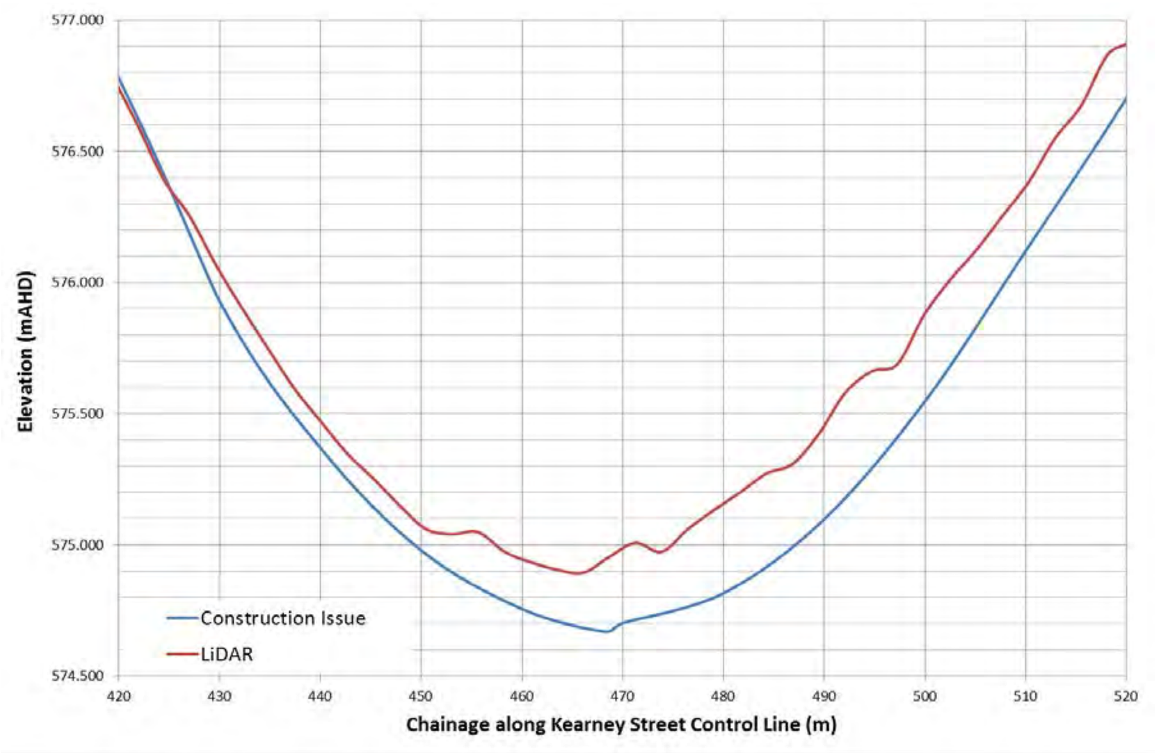


Figure 6-7 Kearney Street Topography Cross Section

6.4 Model Calibration Results

The hydraulic model calibration results prepared for this study for Mount Rascal are presented by way of tabulated information as well as a series of GIS maps. The GIS maps are included in Appendix G. All GIS maps prepared for this study have been undertaken based on the project specific technical requirements which include the mapping requirements and standards outlined in the project brief.

6.4.1 Calibration Flood Level Data

The model was calibrated to a total of 11 surveyed or estimated peak water levels for the January 2011 event at locations throughout the Mount Rascal catchment. Ten of these points were surveyed level information provided by TRC which are understood to have been surveyed following the January 2011 event. The other point was estimated by Water Technology using historical photos, anecdotal information and LiDAR topography data. The location of the calibration points is illustrated in Appendix G and are summarised in Table 6-4 against the modelled flood levels determined using the MIKE FLOOD hydraulic model. In additional to these points, there are several other locations were anecdotal information for the January 2011 event was also sourced. This additional information has also been used for further validation of the January 2011 calibration.

Table 6-4 January 2011 Event Calibration Results to Surveyed Levels

Point ID	Location Description	Survey Type	Survey Level (mAHD)	Modelled Level (mAHD)	Level Difference (m)
343	Iron Bark Drive	Level	582.82	582.84	0.02
344	Tranter Street	Extent	587.28	587.16	-0.12
345	Tranter Street	Extent	586.44	585.1	-1.34
346	Acacia Avenue US 1	Level	575.63	575.46	-0.17
347	Acacia Avenue US 2	Extent	575.38	575.38	0.00
348	Acacia Avenue US 3	Extent	575.54	575.75	0.21
349	Kearney Street	Extent	574.82	575.19	0.37
350	Kearney Street	Extent	574.55	575.2	0.65
370	Freyling Road	Extent	537.45	538.64	1.19
371	Freylings Road	Extent	538.74	538.67	-0.07
MR_FL_E06	Hodgson Vale Road	Level	510.80	510.72	-0.08

The following comments are made with regard to the calibration results outlined in Table 6-4: -

- The modelled flood heights at Kearney Street are consistently higher than the surveyed levels despite adopting the lower levels based on the TRC construction issue drawings. Despite the use of the "Construction Issue" drawings for the hydraulic model, one flood survey level at the Kearney Street crossing gave a level below the lowest sag crossing noted in the "Construction Issue" drawings with the other approximately 200mm above. This indicates a possible three issues:
  - The model topography at this location is still not accurate. This would infer inaccuracies with the construction issue drawing and/or that the actual road profile was not constructed as per the drawings. On a review of the drawings, we did notice that the culvert located at approx. chainage 420 on the drawings is shown as a 1500mm RCP in the longitudinal section but is nominated as a 1200mmRCP on the detail plan 33. By comparison, our site inspection measured this as a 1050mm RCP. On this basis, the accuracy of the drawings may be somewhat suspect and further review may be warranted.
  - The surveyed flood levels taken at the Kearney Street crossing for the January 2011 event are not accurate. If these were based on observed flood data, the observed data may have been higher during the event. The particulars and specific details associated with the survey collection are not known.
  - Of note with the plans are that these are for a construction issue and are not as-constructed survey plans. The discrepancy observed between the LiDAR data versus the construction issue drawings and the actual topography may be the cause for the higher water levels in the model. This could only be further confirmed by undertaking a detailed survey of the site.

- The historical water levels at Freylings Road were found to calibrate well at a point on the left bank. However, a flood level difference of over a metre occurred for the point located on the right bank. The survey level on the right bank was investigated through site specific investigation of available data (i.e. video footage, imagery, Google Earth (Google, 2013), topography, etc) and through further checks on the model performance. This aspect is discussed further in this report but the outcomes otherwise found that the historical level on the right bank to be inaccurate.
- The historical water levels at Tranter Street calibrated well at a point on the left bank. However, for the survey point recorded on the right bank, modelled results were over a metre lower. The survey level on the right bank was further investigated through site-specific investigation of available data (i.e. Google Earth (Google, 2013), imagery, topography, etc) and through further checks on the model performance (discussed further in the following sections of this report) and was found to be inaccurate. The surveyed point seems to lie on the kerb of Tranter Street downstream of the crossing and the flood data surveyed at this location is thought to be associated with local street drainage as opposed to being associated with the adjacent main creek.

Overall, the hydraulic model calibration at relevant survey points resulted in flood level comparisons in the order of ±0.2m from surveyed versus modelled levels. Where this accuracy was not achieved, the case for the discrepancy has been investigated and has been discussed. The flood level comparison achieved for the calibration is considered to be acceptable given the limitations in the study relating to data sets available for hydrological calibration as well as accuracy limitations of the hydraulic model owing simply to the topography dataset (i.e. LiDAR vertical variation of ±0.15m (Shlenker, 2010)).

6.4.2 Anecdotal Historic Flood Level Data

Anecdotal historical flood information sourced and collected as part of the consultation program has also been used to further validate the model calibration for the January 2011 event. In general, the historical data collected included the following: -

- Historical data which related specifically to the January 2011 flood event. This included indicative flood depth estimates at specific locations; and
- Other historical data sets relating to the highest known flooding which occurred historically. This historical data was not related to any specific historical event rather was simply anecdotal information for the largest known flooding which may have occurred at the specific area. Some of this type of data represented anecdotal accounts passed down through the generations of long term residents in the areas.

No specific data was sourced as part of the consultation program for other significant flood events that may have occurred throughout this period other than for the January 2011 event.

We note that the use of anecdotal historic flood level information has inherent inaccuracies that may impact on the accuracy of the historic flood levels provided.

Recollections of historic floods can be sometimes vague, (e.g. “I don’t think it never overtopped the railway bridge”), as well as respondents recalling different historic rainfall events or different flood magnitude for similar areas. Additionally, it may not be possible to determine whether the observed flood height represented the flood peak, or whether the flood was rising or receding at the time of observation.

As a result, the historic flood level information sourced as part of the consultation program and supplied by local residents should be viewed as a validation tool only, and has only been used to supplement the formal calibration of hydraulic model results.

6.4.3 Validation with Anecdotal Information

Historic Flood Levels

Historic flood levels for the Mount Rascal study area were supplied by a number of people with relevant history in the study area. The historic flood data for Mount Rascal was summarised in the consultation record sheet which was provided separately to TRC as part of the consultation notes. Where anecdotal flood information has been provided, these have been converted to an approximate representative point of interest where possible and compared to the January 2011 calibration model flooding results. The location of the anecdotal flood information validation points is illustrated in Appendix G and are summarised in Table 6-5 based on comments provided in relation to the performance of the MIKE FLOOD hydraulic model.

Table 6-5 Mount Rascal Validation to Anecdotal Flood Level Information

Flood Level ID	Description of Point and Source	January 2011 Hydraulic Model Performance
MR_FL_E01	Fitton Road - anecdotal reports. Local resident not sure if road overtopped.	Model shows Fitton Road crossing overtopped by approx. 0.2m in January 2011 event.
MR_FL_E02	Iron Bark Drive –anecdotal reports. Local resident not sure if road overtopped.	Model shows Iron Bark Drive crossing overtopped by approx. 0.2m in January 2011 event.
MR_FL_E03	Possible flooding to residences in this general area.	Model shows up to 0.2m flooding of property on Parkside Crescent adjacent to Hodgson Creek.
MR_FL_E04	Significant flooding occurred in and around this area in Jan 2011 event - no specific levels provided.	Model shows significant inundation in the area including complete inundation (> 0.1m) of the oval.
MR_FL_E05	Not known to be ever flooded to above road crest level.	Model shows crossing not overtopped, by Hodgson Creek. However, smaller tributary on downstream side was shown to slightly overtop (<0.1m) just upstream of highway crossing of Hodgson Creek.
MR_FL_E06	Hodgson Vale Road was flooded to an estimated 500mm deep over road crest in Jan 2011 event. (Approx. 510.8mAHD Flood level estimated based on LiDAR – See Table 6-4)	Model shows good match to estimated levels at the road crest (510.72mAHD flood level).
MR_FL_E07	Wide flood extent in this area - water spreads out over floodplain.	Model confirms wide flood extent in this area with multiple breakouts of Hodgson Creek.
MR_FL_E08	Wide flood extent in this area - water spreads out over floodplain.	Lower floodplain areas are downstream from model boundary.
MR_FL_E09	Fitton Road - anecdotal reports from adjacent property owner at 54 Fitton Rd of road being overtopped in 2011 event - unknown depth but road damaged.	Model shows Fitton Road crossing overtopped by approx. 0.2m in January 2011 event. Maximum velocity across road crest greater than 2.0m/s, indicating possibility for damage.
MR_FL_E10	Fitton Road - anecdotal record. Local resident recalled that this road crossing was washed away in 2011 event.	Model shows Fitton Road crossing overtopped by approx. 0.2m in January 2011 event. Maximum velocity across road crest greater than 2.0m/s, indicating possibility for damage.
MR_FL_E11	Anecdotal record indicates that from local resident's memory this road crossing has never been overtopped.	Model shows crossing not overtopped by main stream of Hodgson Creek. However, smaller tributary on downstream side was shown to slightly overtop (<0.2m) just upstream of highway crossing of Hodgson Creek which leads to some pondage across the bridge deck.

Flood Level ID	Description of Point and Source	January 2011 Hydraulic Model Performance
MR_FL_E12	Reports that highway in this area has been overtopped with flood waters - likely to be 2011 event.	Model confirms overtopping of the highway to approximately 0.3m with maximum overtopping velocity around 1 m/s.
MR_FL_E13	This road was overtopped in Jan 2011 event - depth unknown but was damaged.	Model confirms overtopping of the highway to approx. 0.3m - maximum overtopping velocity around 1 m/s – could possibly cause damage.
MR_FL_E14	Floodplain areas was one big lake in Jan 2011 event.	Lower floodplain areas are downstream from model boundary.
MR_FL_E15	Floodplain areas was one big lake in Jan 2011 event.	Lower floodplain areas are downstream from model boundary.
MR_FL_E16	Mally Road area - not aware of any flooding issues in this area or with road crossing. Inference is road not overtopped.	Model indicates road overtopping up to 0.2m in January 2011.
MR_FL_E17	Reported fast flowing water not able to walk across in Jan 2011. Flood width - could possibly jump over.	Model shows crossing overtopped by approx. 1.0m in January 2011 event with a maximum velocity of 1.3m/s. Shows flow width approximately 15m wide at peak (not jumpable) however rises and falls quickly.
MR_FL_E18	Iron Bank Drive - crossing is high and to local resident's knowledge water did not go over crossing in Jan 2011 event.	Model shows Iron Bark Drive crossing overtopped by approx. 0.2m in January 2011 event. Note that TRC surveyed point in this area indicates that road was overtopped.
MR_FL_E19	Flooding over the road reported. Did not seem to hinder vehicle access. Jan 2011 event.	Model shows Fitton Road crossing overtopped by approx. 0.2m in January 2011 event. Maximum velocity across road greater than 2.0m/s, indicating at peak may not have been traversable. Flood rises and falls quickly however, indicating vehicle access may be noted pre/post peak level.
MR_FL_E20	Local resident has not seen flooding over the road at this location.	Model shows crossing not overtopped by main stream of Hodgson Creek. However, smaller tributary on downstream side was shown to slightly overtop (<0.2m) just upstream of highway crossing of Hodgson Creek which leads to some pondage across the bridge deck.
MR_FL_E21	Mally Road - No flooding issues of concern. Inference is no road flooding.	Model indicates road overtopping up to 0.3m in January 2011.

Model Result Validation to Anecdotal Historic Flood Levels

Based on the outcomes of the model validation summarised in Table 6-5, the January 2011 calibration model in general showed a good match to the anecdotal accounts of historical flooding throughout the catchment. The January 2011 calibration model is considered to be representing the event with a good degree of accuracy.

6.4.4 Validation with HEC-RAS Modelling

The January 2011 calibration model was also further checked in respect to head loss and water levels at several major structure locations. This approach makes use of an alternative hydraulic model for the purposes of providing a further independent check on the performance of the MIKE FLOOD model. In this case we have used a HEC-RAS 1D model to confirm flood levels and head loss at 2 major structures throughout the catchment. The structures included Freylings Road and the New England Highway crossing. These crossings have been selected as they represent 2 different structure types (culvert versus bridge crossing) as well as being subject to major flooding during the January 2011 event. The HEC-RAS structure validation is discussed separately below.

Freylings Road Crossing

A steady-state HEC-RAS model was created using LiDAR for the Hodgson Creek crossing at Freylings Road as verification of the January 2011 MIKE FLOOD model hydraulics. The model was created to represent the crossing structure in 1D HEC-RAS as per the MIKE11 component of the hydraulic model. Table 6-6 below tabulates the comparison of both the HEC-RAS and MIKE models and additionally includes the surveyed historical data recorded at Freylings Road for the January 2011 event for comparative purposes.

Table 6-6 Freylings Road - HEC-RAS Validation of MIKE Results

Model	US WSL Elevation (mAHD)	DS WSL Elevation (mAHD)	Afflux through Structure (m)	Structure Discharge (m^3/s)	Maximum Structure Velocity (m/s) (1)	Historical Jan 2011 Level (m AHD)
MIKE	538.67	535.56	3.11	34.4	5.8	538.74
HEC-RAS	538.78	535.78	3.00	31.9	5.4	

Note (1) Velocity determined through continuity equation.

New England Highway Crossing

A steady-state HEC-RAS model was created using LiDAR for the Hodgson Creek crossing at the New England Highway as verification of the January 2011 MIKE FLOOD model hydraulics. The model was created to represent the crossing structure in 1D HEC-RAS as per the MIKE11 component of the hydraulic model.

Table 6-7 below tabulates the comparison of both the HEC-RAS and MIKE models. Although no surveyed historical data was recorded at this structure, anecdotal records indicated that this structure has never been overtopped.

Table 6-7 New England Highway HEC-RAS Validation of MIKE Results

Model	US WSL Elevation (mAHD)	DS WSL Elevation (mAHD)	Afflux through Structure (m)	Structure Discharge (m^3/s)	Maximum Structure Velocity (m/s)	Anecdotal Record
MIKE	530.07	528.77	1.30	174.0	4.0	Did not overtop. Road crest = 530.2 m AHD
HEC-RAS	529.76	528.34	1.42	175.2	4.4	

Note (1) Velocity determined from immediate downstream model grid.

Summary

The independent hydraulic model checks undertaken using the HEC-RAS models have shown very good correlation with the MIKE results at both structures. Additionally, there is also very good correlation with both the surveyed and anecdotal accounts of flooding at these locations. The MIKE model was therefore found to be performing to an acceptable level of accuracy.

We also note that while the independent check using HEC-RAS has only been performed at 2 selected structure locations, the modelling approach undertaken for hydraulic structures throughout the Mount Rascal catchment has employed a consistent methodology in the MIKE model. Given that the HEC-RAS results are consistent to the MIKE results and using a consistent structure modelling approach in MIKE, it can be reasonably expected that hydraulic performance for other structures in the model are also appropriate. Flow results at all model structures for the 100 year ARI event can be found in Appendix F.

6.4.5 Validation with Alternative Hydrologic Methods

As part of the review of the adopted methodology and to ensure reasonable model performance across the Mount Rascal catchment, the hydraulic model flows have been compared to those estimated using alternative hydrologic methods. The Rational Method has been adopted as an indicative hydrological estimation method to verify hydraulic model flows. Table 6-8 below summarises the Rational Method discharge with MIKE model discharge at varying locations through the Mount Rascal catchment.

Table 6-8 Rational Method Validation of MIKE Results

Location	Catchment Area	Time of Concentration	Rational Method Discharge	MIKE Discharge	Difference
	(ha)	(minutes)	m^3/s	m^3/s	%
Kearney Street	287	36.2	44	48	8.1
Fittons Road	193	29.4	34	28	-18.7

Freylings Road	1119	55.7	132	161	18.0
New England Highway	1212	58.3	139	163	15.0

6.4.6 January 2011 Historical Validation to Design Rainfall

As described previously in this report, the calibration approach for the MIKE FLOOD model for Mount Rascal is based on a calibration to the January 2011 event and specifically the storm on the afternoon of the 10th January 2011.

As a further check and comparison of the model calibration results and in order to confirm or otherwise the recurrence interval of the calibration event, we have considered historical rainfalls for the January 2011 event in comparison to the design rainfall approaches as documented in Australian Rainfall and Runoff (IEAust, 1998). While this approach has been used as a further validation check, the approach is not technically correct as rainfall intensity (measured as ARI) is not directly correlated to the flood magnitude (also measured as ARI). This is because there are many other parameters that affect the magnitude of the flood event including antecedent rainfall, rainfall distribution, catchment area, etc. Therefore, the ARI of the January 2011 event rainfall will not directly correlate to an ARI of the flood discharge. That is, ARI neutrality is not preserved in such comparisons. Within this context, rainfall has been considered and is discussed separately.

The IFD plot of rainfall for the January 2011 event has been plotted for a selection of local pluviograph gauges as discussed previously in this report (refer Figure 3-3 for gauge locations). Rainfall data in the form of pluviograph data is required to undertake a historical rainfall frequency assessment especially for short duration events which typically dominate the overland flow under this study. The selection of gauges presented was chosen to give a representation of the variation in rainfall surrounding the Mount Rascal catchment. These IFD plots at different gauge locations are presented in Figure 6-8 to Figure 6-12.

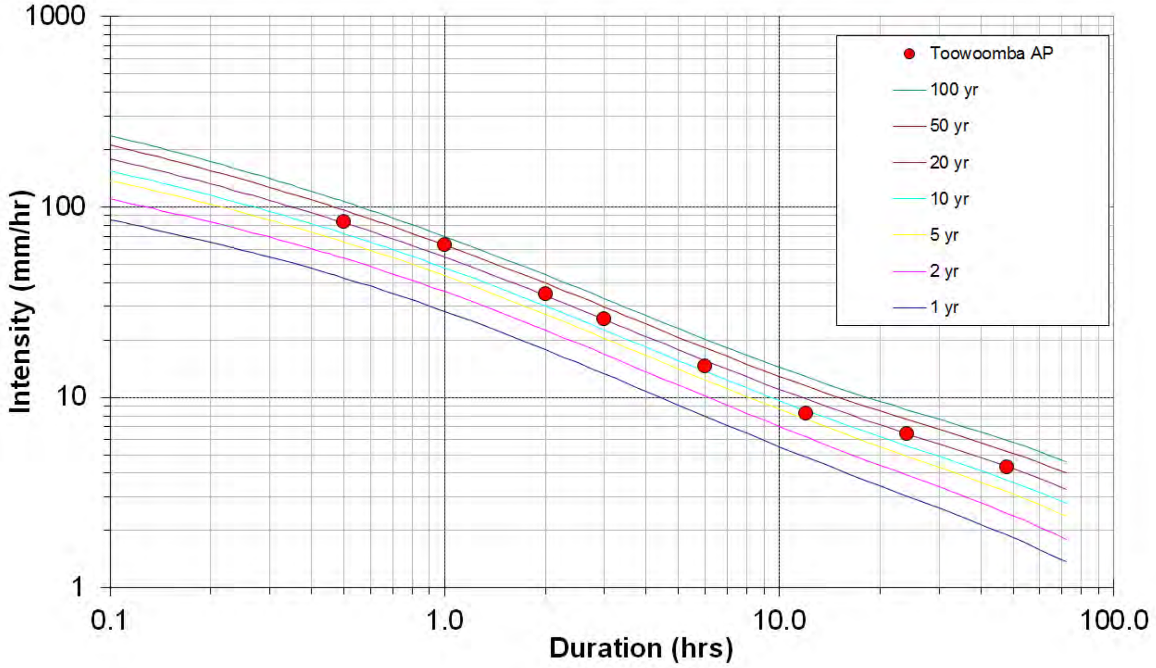


Figure 6-8 Intensity Frequency Duration Curves and rainfall intensities for Toowoomba Airport Gauge (BOM #041529) for the period 9th to 12th January 2011

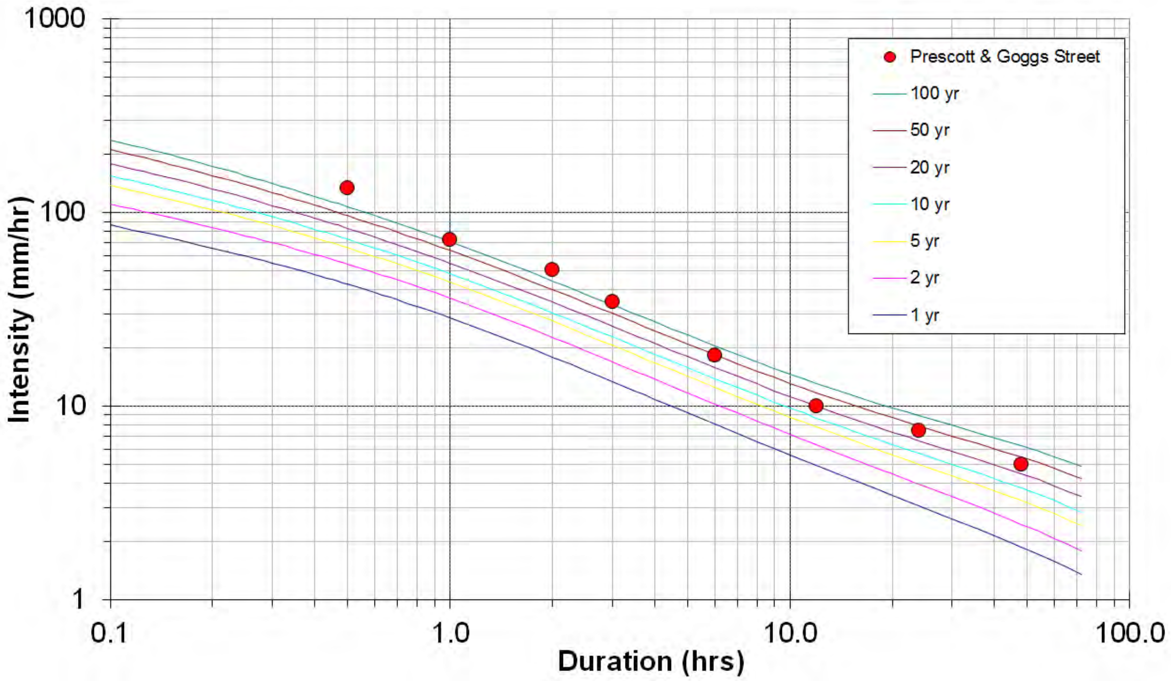


Figure 6-9 Intensity Frequency Duration Curves and rainfall intensities for Prescott and Goggs Street Gauge (TRC) for the period 9th to 12th January 2011

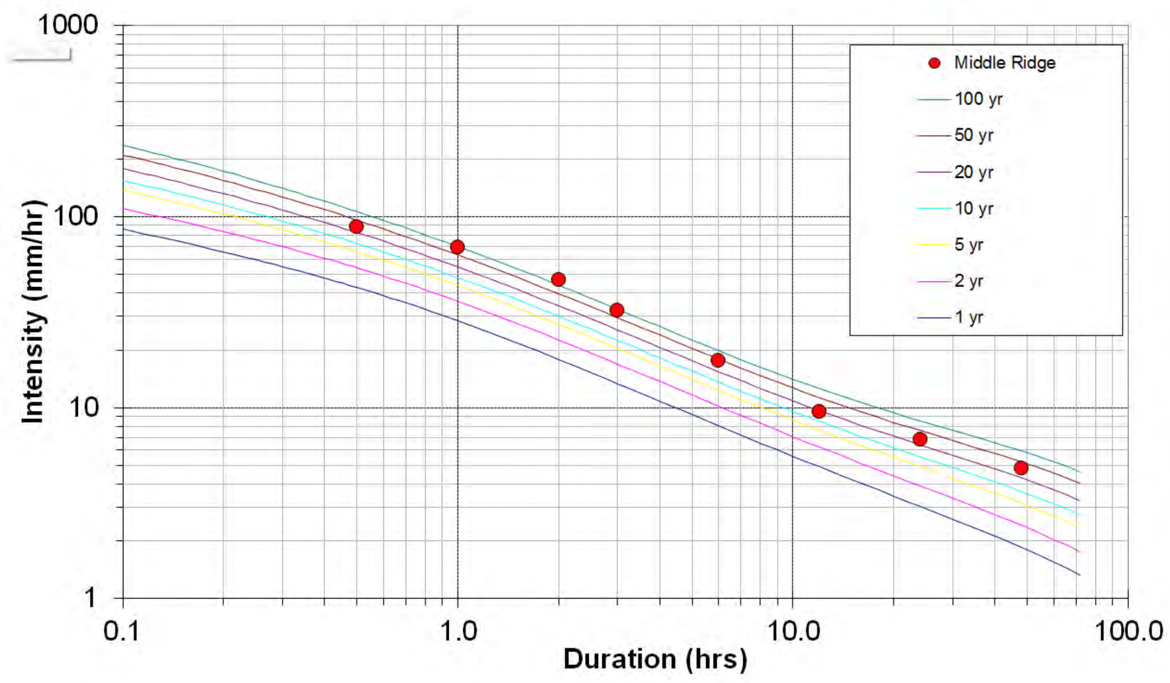


Figure 6-10 Intensity Frequency Duration Curves and rainfall intensities for Middle Ridge Gauge (TRC) for the period 9th to 12th January 2011

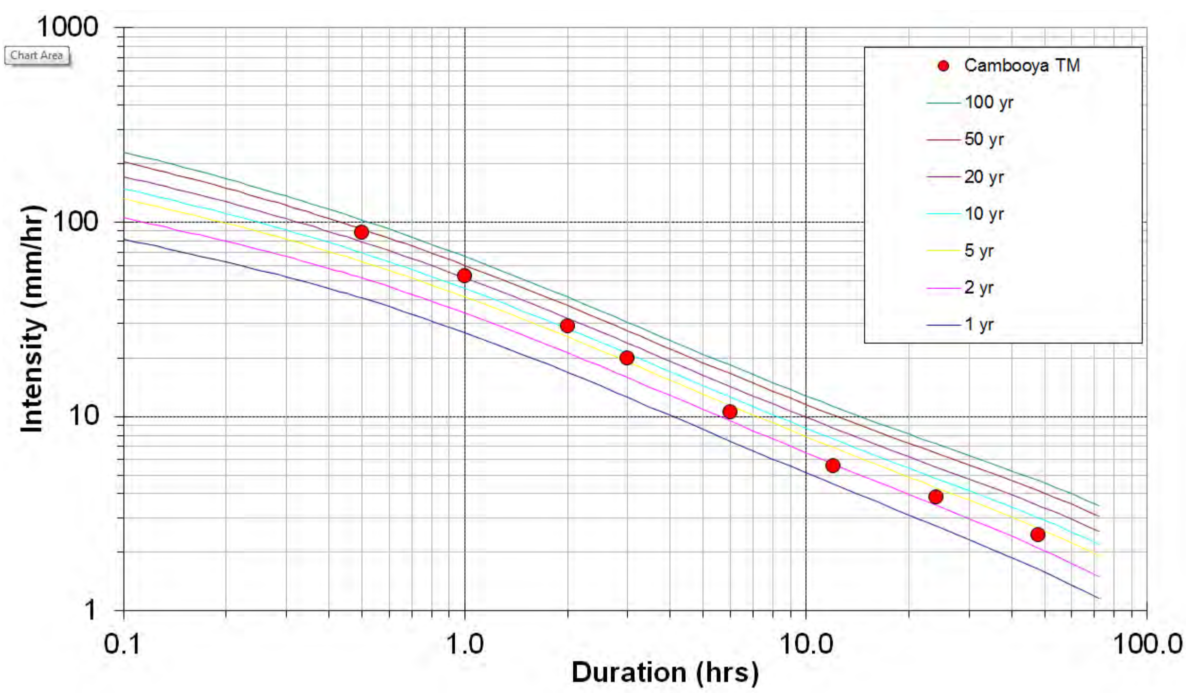


Figure 6-11 Intensity Frequency Duration Curves and rainfall intensities for Cambooya TM (DNRM #42230974A) for the period 9th to 12th January 2011

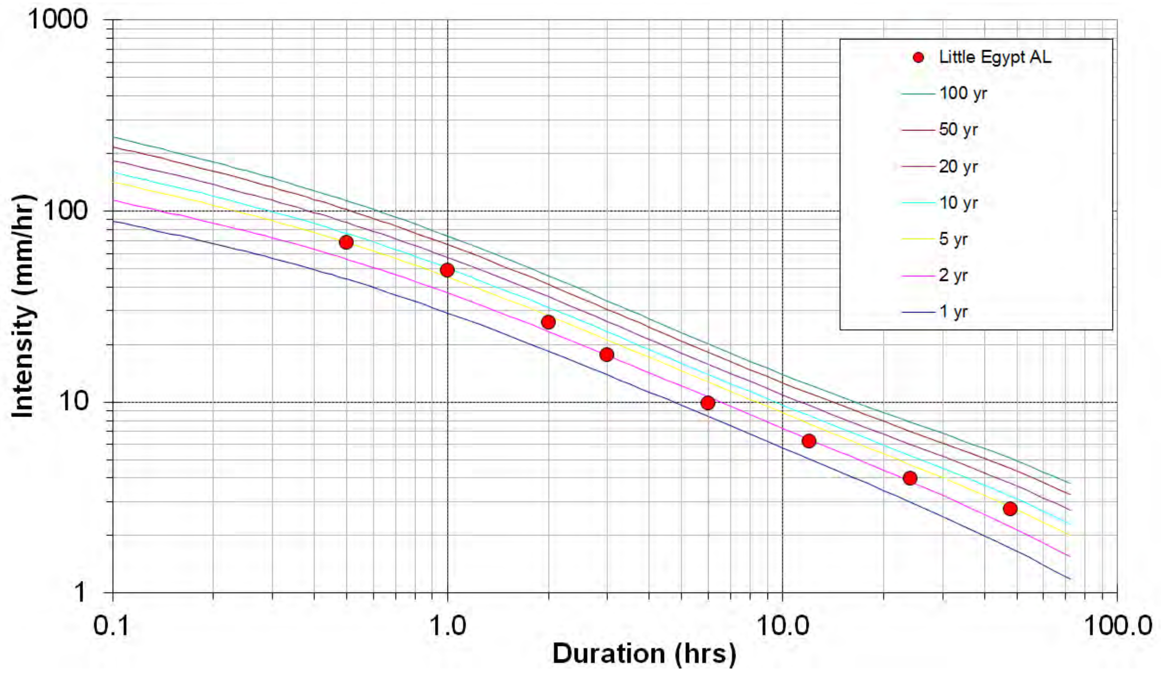


Figure 6-12 Intensity Frequency Duration Curves and rainfall intensities for Little Egypt (BOM #540170) for the period 9th to 12th January 2011

With the exception of the Little Egypt Gauge (the most non-representative gauged analysed), the highest ARI rainfall bursts for the shorter duration events (0.5, 1, 2, hour duration storms) at the selected gauges occurred during the 1:00pm – 4:00pm burst on the afternoon of the 10th January 2011. These storms are those expected to be most responsive in the Mount Rascal catchment considering area and the resulting critical storm duration for the catchment (approximately 1 hour from modelling and theoretical estimation). The two closest rainfall pluviograph gauges to the catchment are the Prescott and Goggs Street and Middle Ridge gauges. Both of these gauges indicate greater than 90 year ARI rainfall for the 0.5, 1 and 2 hour rainfall durations occurring between 12:00pm and 4:00pm on the 10th January 2011. This also confirms the adopted MIKE FLOOD calibration event simulation period.

The storm path shown previously in Figure 6-5 can be seen from the relative IFD rainfall intensities. The gauges under the most intense path of the afternoon 10th January 2011 recorded the highest ARI for associated shorter duration storms. The gradient of rainfall in the IFD plots corresponds well with the storm path shown in Figure 6-5 and adopted spatial rainfall distribution shown in Figure 6-1.

The Prescott and Goggs Street and the Middle Ridge rainfall gauge only recorded data at half hour intervals. This means the specific period of most intense rainfall for all durations may fall within the recording interval of the gauges (note that this would be less of an issue with increasing event duration). Therefore, the peak burst rainfall ARI at these gauges may be higher than that shown in Figure 6-9 and Figure 6-10.

It is also worth noting from the historical rainfall totals for the December 2010 to January 2011 event (discussed previously in Section 3) that a significant amount of antecedent rainfall fell in the catchment prior to the January 2011 event, resulting in a supersaturated catchment condition. A greater portion of rainfall that fell in the January 2011 event would therefore be readily converted to discharge given the comparatively lower catchment losses. This is also reflected in the initial and continuing rainfall losses determined for the January 2011 event from the XP-RAFTS model.

The results from the hydraulic model calibration undertaken at Mount Rascal found that the January 2011 flood magnitude was greater than the 100 year ARI design flood event. The flood validation to IFD rainfall has indicated pluviograph rainfall gauges closest to the Mount Rascal catchment experienced greater than 100 year ARI rainfall at durations close to that most responsive in the catchment. Note that this assessment is based on design rainfall only. The recurrence interval of the January 2011 event is further investigated with respect to flood discharge and is discussed separately in Section 7.

7. DESIGN FLOOD EVENT ANALYSIS

7.1 Introduction

The previous sections of this report have described in detail the MIKE FLOOD model development and calibration assessments that have been prepared for this study. The calibrated MIKE FLOOD model also used to provide an estimate of design, rare and extreme flood events.

7.2 Methodology

The calibrated MIKE FLOOD model developed for Mount Rascal has been adopted as the basis on which to undertake the design flood event assessments. The calibrated model has been adopted without change for the purpose of the design flood estimation.

The catchment flow for the 100 year ARI event has been estimated based on the existing catchment conditions as per the study requirements and direction provided by TRC. As outlined previously in this report, this has been based on land use information taken from the 2010 aerial photography as being representative of the current catchment conditions. Alternative hydrologic techniques have been undertaken to provide the best estimate for the 100 year ARI design event discharge for the Mount Rascal catchment.

The adopted 100 year ARI discharge for the Mount Rascal catchment adopted flow at the Mount Rascal outlet from the hydrologic techniques was then matched in the calibrated MIKE FLOOD model by adopting design rainfall parameters (in the form of losses) in the XP-RAFTS model to achieve the required flow. The XP-RAFTS outputs were then used as local catchment inflows to the MIKE FLOOD model. The losses in the XP-RAFTS model were then applied to all other design storms.

Further details on the approach are discussed below.

7.3 100 year ARI Design Event Flow Estimate

7.3.1 Overview

In order to determine the 100 year ARI design flow estimates for the Mount Rascal catchment, design discharge estimates were undertaken using industry-accepted hydrologic estimation techniques. The following estimation techniques have been considered in this study to arrive at an appropriate 100 year ARI design event flow for the Mount Rascal catchment and without otherwise having a stream gauge within the catchment: -

- The Rational Method (IEAust, 1998).
- The Australian Regional Flood Frequency Model (ARFF) (IEAust, 2012).
- The Design Rainfall Technique ((IEAust, 1998).
- Local Flood Frequency Analysis (FFA) estimates on the Gowrie Creek at Cranley Gauge (inc. Grayson Catchment Transposition, (Grayson et al, 1996)).

The alternative to using these estimation techniques is to use the January 2011 XP-RAFTS rainfall-runoff model used as a local inflow source to the January 2011 calibration hydraulic model. This approach does not consider the changes in catchment conditions, routing, storm duration, temporal pattern and the relative magnitude of the event when directly adopting hydrologic parameters from the January 2011 XP-RAFTS model. That is, new hydrologic parameters (in the form of initial and continuing losses) must be determined to match flows estimated by alternative hydrologic methods (i.e. the Rational method, ARFFM) with flows estimated in the MIKE FLOOD hydraulic model to determine appropriate design flows.

A summary of the various hydrological estimation techniques outlined above and the respective discharge estimates are discussed and presented separately below.

7.3.2 January 2011 Calibration

As an indication of flood magnitude, the calibrated MIKE FLOOD hydraulic model peak discharge for the January 2011 event was estimated to be 218 m^3/s at the outlet of the Mount Rascal catchment. The XP-RAFTS flow for this same event and at the same outlet location was 308 m^3/s. The difference in the flows is due to routing within the hydraulic model.

7.3.3 Design Rainfall Technique

Discharge estimates based on the design rainfall technique as outlined in Australian Rainfall and Runoff (IEAust, 1998) were undertaken. The January 2011 land-use XP-RAFTS model of the Mount Rascal catchment was run in accordance with design rainfall with varying initial loss (IL) and continuing loss (CL) parameters in order to test rainfall loss sensitivity on model discharge. A summary of design flows (using the design rainfall technique) at the catchment outlet under varying rainfall loss conditions is presented in Table 7-1. As can be seen, the model is quite sensitive to the selection of rainfall losses.

Table 7-1 100 Year ARI Discharge Estimates

Method	Discharge (m^3/s)
XP-RAFTS - 10 IL,0.5 CL	410
XP-RAFTS - 20 IL,1.5 CL	338
XP-RAFTS - 30 IL,2.5 CL	256

7.3.4 The Rational Method

A combination of the Friend's Equation and the Stream Velocity Method were used to determine the time of concentration for the Mount Rascal catchment. This is the recommended methodology for rural catchments of less than 25 km^2 in area (Mount Rascal = 16.9km^2) as outlined in Section 4.06.11 of the Queensland Urban Drainage Manual (QUDM, 2008).

The average maximum velocity along the longest flowpath length (Hodgson Creek) was extracted from the calibrated January 2011 MIKE FLOOD model for adoption as the average stream velocity. This was deemed acceptable due to the large magnitude of both the 10^{th} January 2011 event and the 100 year design event.

The estimate of a coefficient of discharge (C) is required for the Rational Method to adequately represent factors influencing peak catchment discharge such as infiltration and other losses. The C_{10} values as outlined in Table 4.05.3 (a) and 4.05.3 (b) of QUDM were adopted for use in this assessment based on the associated fraction impervious values as determined from the assessment of the 2010 aerial photography land use. A fraction impervious C_{10} value of 0.49 was adopted for the Mount Rascal catchment considering the low fraction imperviousness of the catchment (approx. 12%).

The parameters adopted in the Mount Rascal Rational Method calculations are summarised in Table 7-2. The 100 year ARI design flow was estimated to be 161 m^3/s.

Table 7-2 Adopted 100 year ARI Rational Method Parameters

Parameter	Value
Area (ha)	1689
C_{10} (f_i)	0.49 (0.12)
Catchment Manning's "n"	0.04
Slope (m/m)	0.043
Flowpath Length (m)	8750.00
Av. Channel Velocity (m/s)	2.1
Time of Concentration (mins)	77

7.3.5 The Australian Regional Flood Frequency (ARFF)

The Australian Regional Flood Frequency Model (ARFF) (IEAust, 2012) has been considered as part of this study. The ARFF is recommended for use on rural catchments between 20 and 1000 km^2 (Mount Rascal = 16.9km^2) (IEAust, 2012). However studies undertaken both internally and external to Water Technology indicate that the ARFF method can be a reliable estimation tool for both smaller and considerably larger catchments.

It should be noted that the ARFF method was developed for use with data from mostly rural (pervious) catchments. Considering the fraction impervious (12%) of the Mount Rascal catchment, the method is deemed to be applicable however should be treated as a lower bound of the design discharge estimate for the catchment.

The ARFF was used to check the flood magnitude estimates for the Mount Rascal catchment outlet. The ARFF estimate for the 100 year ARI event was estimated at 161 m^3/s.

7.3.6 Local Flood Frequency Analysis including Grayson Catchment Transposition

No stream gauging station exists in the Mount Rascal catchment and consequently an at-catchment Flood Frequency Analysis (FFA) could not be undertaken. However, previous investigations in the Toowoomba area have included an FFA for the Cranley Gauge on Gowrie Creek (DNRM Gauge 422326A). This gauge has a contributing catchment area of 47km^2 (Mount Rascal = approx. 17km^2) and is located to the north of the Toowoomba CBD. The investigation included an FFA of the Cranley gauge for the period to the ARFF estimate (to 2006) (IEAust, 2012) and also included the period to 2013. The 100 year ARI discharges estimated from the analysis of the Gowrie Creek at the Cranley Gauge is summarised in Table 7-3.

Table 7-3 Gowrie Creek at Cranley 100 year ARI Discharge Estimates

Estimation Method	**Discharge (m^3/s)**
FFA on Gauge Record to 2006 (37 years)	240
FFA on Gauge Record to 2013 (44 years)	420
ARFF Estimate (to 2006)	360

Note that the ARFF estimate is considerably higher than the at-gauge FFA estimate. This is due to the ARFF method which includes statistical weighting of adjacent gauges in the determination of the 100 year ARI discharge estimate.

When there is no available stream gauging station located at the location of interest, transposition techniques are required to estimate the flood frequency at the site from those recorded at other sites. Transposing ARI discharge estimates from gauged to ungauged locations and catchments needs to account for the following processes: -

- Spatial variation in catchment characteristics and climate;
- Variation in catchment areas;
- Spatial variation of rainfall.

That is, assuming that catchment characteristics and climate are similar: -

- Larger catchments will produce larger discharges (for a given ARI) than smaller catchments, due to the larger contributing catchment area; and
- There will be greater spatial variation in rainfall across larger catchments - the so-called areal reduction factor. That is, for a small catchment, a given rainfall event is likely to fall over the entire catchment area with the percentage of the catchment receiving rainfall decreasing with increasing catchment area. This tends to introduce non-linearity in the catchment area – discharge relationship.

There is very little available methodology for transposing discharges between catchments in Queensland. The only applicable method is provided in Grayson et al. (1996):

$$\frac{Q_C}{Q_G} = \left(\frac{A_C}{A_G}\right)^{0.7}$$

Where:

Q = Discharge (m^3/s)

A = Area (hectares)

C = ungauged catchment

G = gauged catchment

The Grayson transposition technique between the Cranley and Mount Rascal catchment was undertaken on the Cranley Gauge for the 44 years of record to 2013. The resultant 100 year ARI discharge estimate is 205 m^3/s using the full gauge record.

It is also noted that the catchment upstream of the Cranley Gauge (Gowrie Creek) is heavily urbanised in comparison to the Mount Rascal catchment. East and West Creeks (the headwaters of Gowrie Creek) drain the majority of the City of Toowoomba. Compare this to Hodgson Creek having the rural localities of Top Camp and Hodgson Vale as its most heavily urbanised areas. For this reason, a higher discharge per unit area is expected to occur for the Gowrie Creek catchment in comparison to the Cranley Gauge. It is therefore considered that the FFA estimates transposed to the Mt Rascal catchment from the Craney Gauge represent an upper bound of the design discharge estimate.

7.3.7 Summary and Discussion of 100 year ARI Discharge Estimate Magnitude

The 100 year ARI discharge using the analysed hydrologic methods at the Mount Rascal outlet are summarised in Table 7-4.

Table 7-4 100 year ARI Discharge Estimate Summary

Method	Discharge (m^3/s)
ARRF	161
Rational Method	161
Design Rainfall - XP-RAFTS - 10 IL,0.5 CL	410
Design Rainfall - XP-RAFTS - 20 IL,1.5 CL	338
Design Rainfall - XP-RAFTS - 30 IL,2.5 CL	256
Cranley Grayson Transposition	205

It can be seen the design rainfall technique gives unrealistically large estimates of the 100 year ARI flood when compared to other methods. This is expected as the model is not calibrated and is shown to be an indicator only. In any case, as noted in Ball et.al (2011) and Walton et. al (2014), the uncertainties in the application of the design rainfall techniques mean it should never be used as a standalone method of flood estimation.

The Rational Method is currently the primary simplified hydrologic estimation technique for Queensland. It is recommended that the application of the Rational Method be limited to rural catchments with a catchment area less than 25 km^2 and for urban catchments less than 5 km^2 in area (QUDM, 2008). The Mount Rascal catchment (area of 16.9 km^2) is within the limits of this recommendation. The Rational Method has been adopted in this study as an appropriate design flow estimation technique for the Mount Rascal catchment for the following reasons:

- The Rational Method does not allow for flow attenuation/catchment storage; the estimates are therefore likely to be conservative and are considered as being appropriate for a planning scheme study.
- The Rational Method gives some guidance on the discharge magnitude. The only alternative to using the Rational Method would be to have an un-calibrated XP-RAFTS model (i.e. the January 2011 hydrologic model). It is considered this would have considerably greater uncertainty than the use of the Rational Method.

It is important to note that the record length of the Cranley gauge is 34 years (from 1970 to 2004) (IEAust, 2012). Flood frequency estimates on a period of this length can be dramatically affected by the inclusion of large and extreme flood discharges. The issue then arises that the FFA period of the ARRF estimate does not include the significant flooding events of 2010-2011 in the Toowoomba area which are known to be significant and resulted in some of the largest flooding that has occurred throughout the greater area. It can be seen that the inclusion of the additional 5 years of records (including the large magnitude flood events) that the FFA at Cranley has greatly increased the 100 year ARI FFA discharge (approximately a 75% increase). It is therefore expected that the most recent 100 year ARI ARRF (1970 – 2013) estimate would be larger than the given value of 161m^3/s using the records from 1970 – 2005. This indicates that the ARFF value should be taken as being a lower bound for the 100 year ARI flood estimate. It is understood the ARFF database is currently being updated to include this data but at the time of writing these updates were not currently available. The fact that the ARFF estimation tool is based on rural catchments (i.e. 0% impervious) also indicates the estimate should be taken as a lower bound in the Mount Rascal catchment (12% impervious).

Considering all of the hydrological methods outlined and based on the range of results obtained, the adopted 100 year ARI discharge for the Mount Rascal catchment outlet for use in this study is selected to be approximately 200m^3/s. Note that this discharge represents the hydraulically routed flow at the catchment outlet – the XP-RAFTS flow for the 100 year ARI event was 337m^3/s.

Due to the lack of "in catchment" FFA estimation, the ARI of the January 2011 event can be approximated by applying and extrapolating the ARFF curve from the estimated 100 year ARI discharge (circa 200m^3/s) to the catchment discharge for the calibrated January 2011 event (218m^3/s). Using this approach, the January 2011 event flood magnitude in the Mount Rascal catchment is estimated to be approximately a 150 year ARI flood event.

7.3.8 January 2011 versus 100 Year ARI Event

As outlined above, we have selected a 100 year ARI discharge for the Mount Rascal catchment of circa 200m^3/s (n.b. the actual hydraulically routed flow at the catchment outlet was 192m^3/s). The hydraulic model extraction location is located at the downstream catchment boundary (approx. 250m upstream of Hodgson Vale Road). The catchment outlet extraction location is illustrated in Figure 7-1. The adopted 100 year ARI discharge in the MIKE model translates into a XP-RAFTS discharge of 337m^3/s. By comparison, the XP-RAFTS flow for the January 2011 calibration event was found to be 308 m^3/s. This is lower than the 100 year ARI estimate despite our assessment of the magnitude of this event being approximately a 150 year ARI flood event.

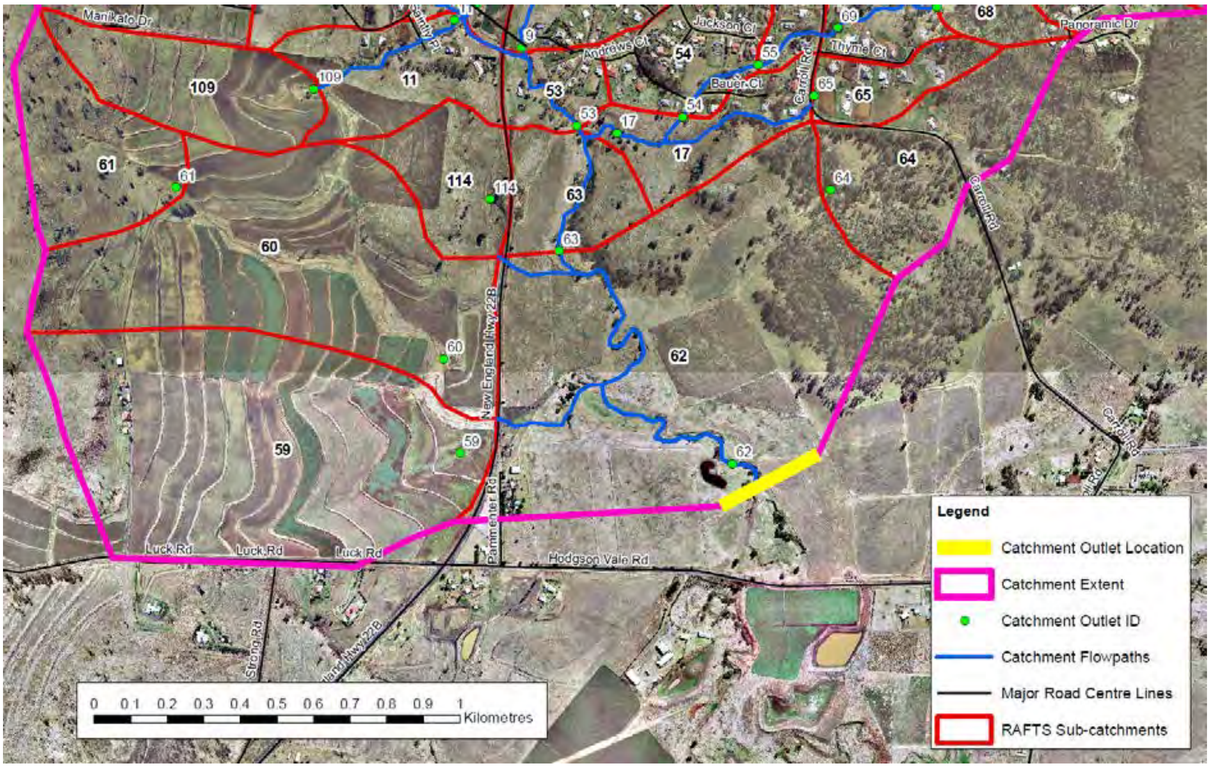


Figure 7-1 Mount Rascal– Catchment Outlet/Hydraulic Model Extraction Location

It should be noted that the January 2011 calibration model utilises spatially-weighted rainfall depths over the catchment. These rainfall depths (isohyets) are presented in Figure 6-1. The rainfall depth at the top of the catchment was approximately 260mm and is weighted to the Middle Ridge gauge. Moving south through the catchment, the total rainfall depth reduces to around 165 mm. As a result, during the January 2011 event, the bottom of the catchment is receiving rainfall that is less than a 100 year ARI event.

Contrast this to the design rainfall approach in XP-RAFTS for the 100 year ARI event. Using this approach, all sub-catchments in the model regardless of where they are in the overall catchment receive a 100 year ARI design rainfall storm event in accordance with the Australian Rainfall and Runoff (IEAust, 1998) procedures. Therefore, the entire catchment is receiving 100 year ARI rainfall for the critical duration.

It would therefore be expected that solely based on rainfall alone, the January 2011 event would result in a lower peak flow at the outlet.

7.4 Hydraulic Model Design Events

7.4.1 XP-RAFTS Design Flows

The XP-RAFTS model has been used to generate all design flows for inclusion in the hydraulic model. The model has incorporated design rainfall in accordance with the Australian Rainfall and Runoff (IEAust, 1998) procedures. Design rainfall depths adopted in the hydrologic model are tabulated in Table 7-5. The IFD information was extracted using the BOM automated service (BOM, 2013). The extraction location was the Mount Rascal catchment centroid (-27.625S, 151.925E).

Table 7-5 Design Event Depths (Extracted from BOM, 2013)

Duration	ARI						
	1 Year	2 years	5 years	10 years	20 years	50 years	100 years
5 Mins	7.6	9.8	12.2	13.7	15.8	18.6	20.8
6 Mins	8.5	10.9	13.6	15.3	17.6	20.8	23.3
10 Mins	11.6	14.8	18.3	20.5	23.7	27.8	31.2
20 Mins	17.2	21.9	26.7	29.6	33.7	39.3	44.0
30 Mins	21.1	26.7	32.4	35.8	40.8	47.4	52.5
1 Hr	28.1	35.5	42.8	47.2	53.5	62.0	68.7
2 Hrs	35.2	44.6	53.4	58.8	66.6	77.0	85.2
3 Hrs	39.3	49.8	59.7	65.7	74.4	85.8	95.1
6 Hrs	47.4	60.0	72.0	79.2	89.4	103.2	114.0
12 Hrs	57.5	72.8	88.2	97.3	110.6	128.4	142.8
24 Hrs	71.0	91.0	112.3	125.8	144.5	169.7	189.6
48 Hrs	86.9	112.8	144.0	163.7	191.5	229.0	259.2
72 Hrs	94.3	122.4	159.8	182.9	215.3	260.6	297.4

As the discharge for the 100 year ARI event at the catchment outlet has been selected with consideration of various hydrological methods as well as the hydraulic routing as outlined previously, the rainfall losses were adjusted in the XP-RAFTS to match with the required 100 year ARI discharge. These losses were then applied to all ARI design flow estimates. The adopted losses for the design event XP-RAFTS models are summarised in Table 7-6.

Table 7-6 Adopted XP-RAFTS Rainfall Losses for Design Events

ARI	Initial Loss (IL) (mm)	Continuing Loss (CL)
ALL	20	1.9

7.4.2 Hydraulic Model Events

The 100 year ARI event has been analysed for a range of storm durations in the MIKE-FLOOD model. The critical durations assessed through the catchment using hydraulic routing are summarised in Table 7-7.

Table 7-7 Modelled Design Event Durations

ARI	Duration (mins)
100	25, 30, 45, 60, 90

A critical duration assessment was undertaken across all 5 events. The dominant storm events were the 45 minute and 60 minute events. There were a few discrete and isolated areas in the hydraulic model which were dominated by either the 25 minute or 30 minute storm events. However, these areas were found to be very localised with a maximum water level difference of only 5 mm to 10 mm. A summary of hydraulic model flows at the catchment outlet for the tested storm durations are presented in Table 7-8. A map illustrating the critical duration storms throughout the catchment model area for all design events are presented in Figure 7-2. For overall simplicity, only the dominant 45 minute and 60 minute storm events have been adopted for the purposes of preparing the flood envelopes for the catchment for each of the design events analysed as part of this study. Note that in all cases a 100 percent blockage factor was applied to all crossing structure handrails and guardrails in the hydraulic model as per direction from the TRC-appointed peer reviewer.

Table 7-8 Modelled Design Events - Catchment Outflow

Event ARI	Duration (mins)	Catchment Outflow (m^3/s)
100	25	112
100	30	130
100	45	164
100	60	192
100	90	188
50	45	139
50	60	162
20	45	104
20	60	125
10	45	79
10	60	98
5	45	60
5	60	80
2	45	49
2	60	33

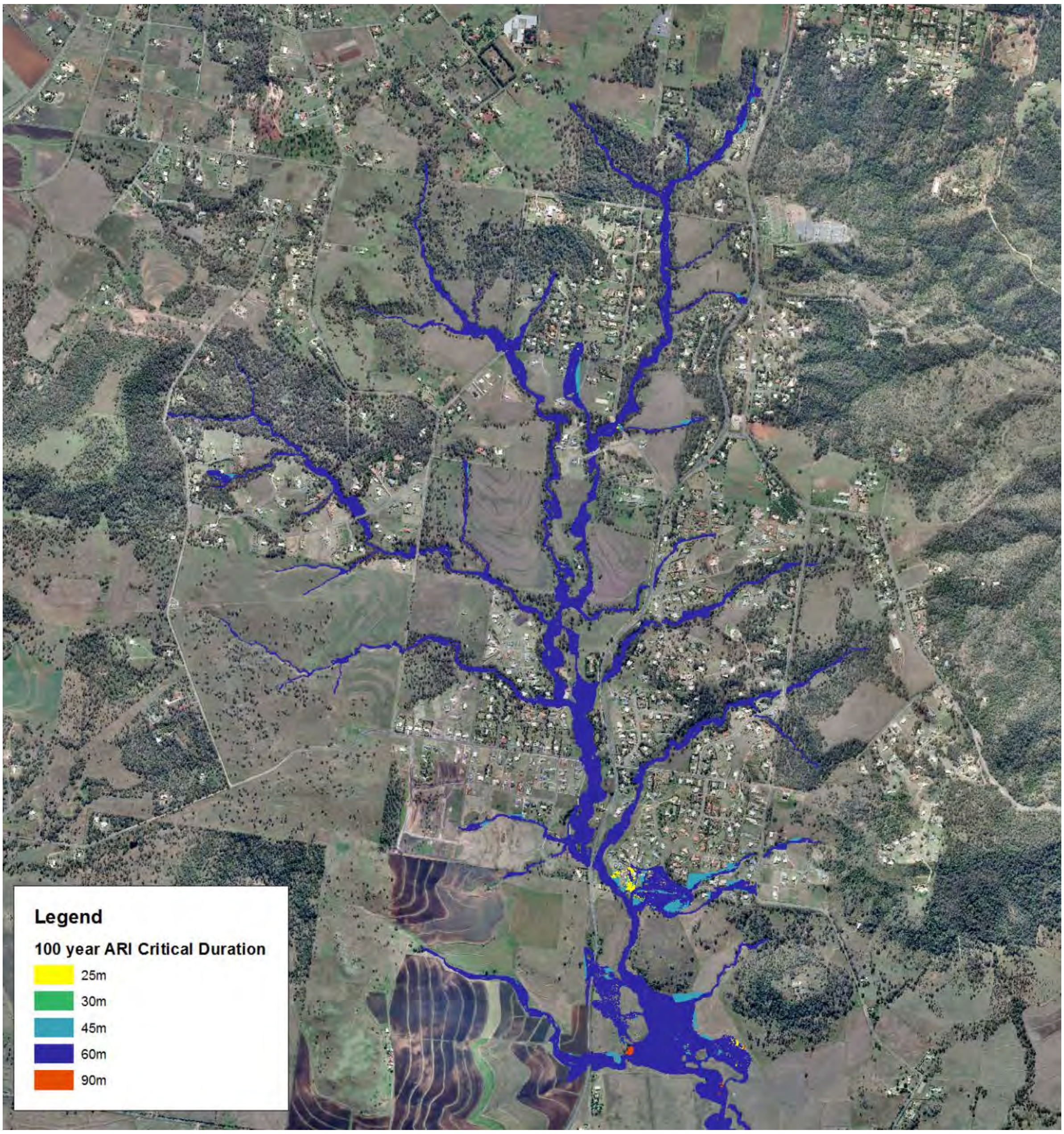


Figure 7-2 100 Year ARI design storm Critical Duration throughout Mount Rascal catchment

7.5 Rare Event Discharge Estimate

In order to determine the 200 and 500 year ARI rare event flow estimates for the Mount Rascal catchment, discharge estimates were undertaken using hydrologic estimation techniques provided in ARR Book VI (IEAust, 1998) and the CRCFORGE Method for Queensland (Hargreaves et al, 1999).

CRCFORGE is a design point rainfall estimation technique for use in Queensland. CRCFORGE is a statistical (regional) analysis method that provides estimates of rare rainfall events at individual stations using a conventional plotting position formula.

The point rainfall gauge data used for the CRCFORGE analysis was within 24km of the catchment centroid. It should be noted that the 45 and 90 minute duration storm rainfall (as identified to be the critical durations for the catchment as outlined above) are not standard CRCFORGE outputs. Consequently, it has been necessary to interpolate these intermediate rainfall durations from an intensity/duration curve fit to the CRCFORGE output as illustrated in Figure 7-3. The standard GDSM Temporal Pattern (BOM, 2003a) was adopted as the design temporal pattern. Rare rainfall depth outputs from CRCFORGE adopted in the XP-RAFTS model are summarised in Table 7-9.

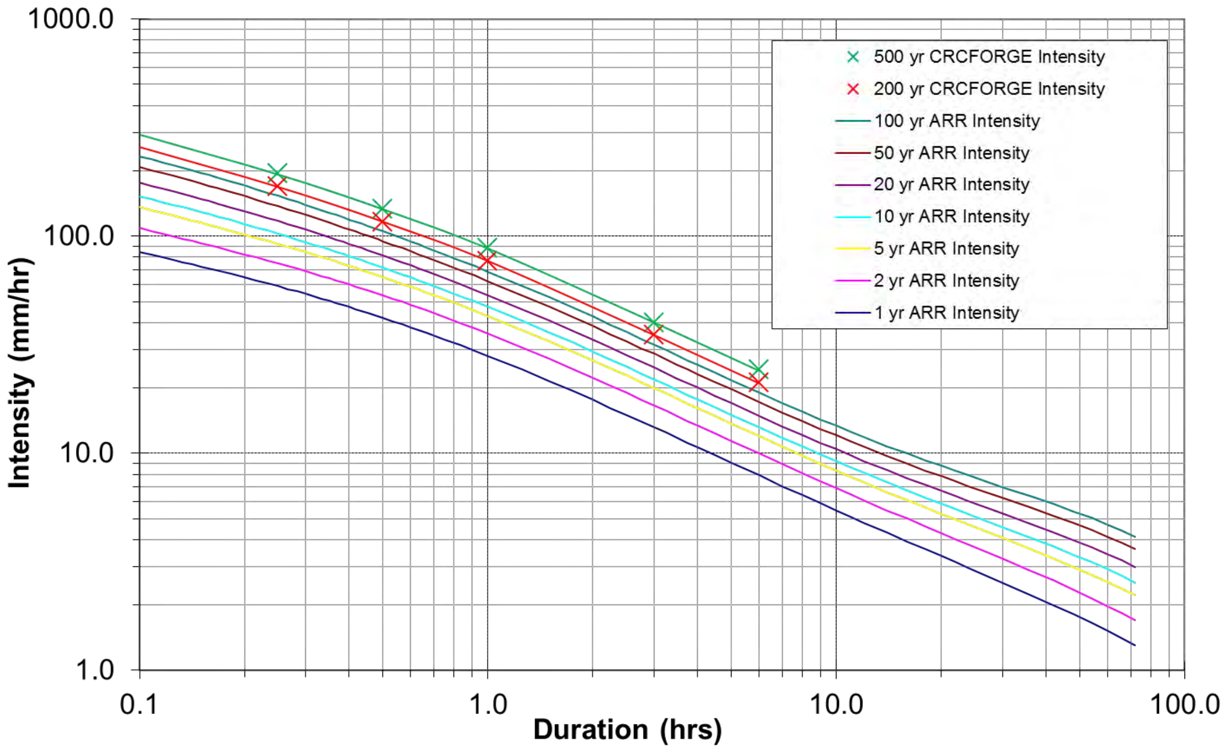


Figure 7-3 Interpolation of non-standard duration CRCFORGE rainfall intensity

Table 7-9 Rare Event Depths

Duration (mins)	Depth (mm)	
	200 year ARI	500 Year ARI
15	42.3	48.4
30	58.3	66.7
45 (Note 1)	69.8	79.5
60	77.0	88.0
90 (Note 1)	82.5	94.5
180	105.2	120.2
6	126.8	145.0

Note (1) – The 45 and 90 minute storm rainfall for rare events have been interpolated from standard CRC-FORGE output duration rainfall.

7.6 Hydraulic Model Rare Events

7.6.1 XP-RAFTS Rare Flows

The XP-RAFTS model has been used to generate all rare event flows for inclusion in the hydraulic model. The model has incorporated rainfall in accordance with the procedures outlined in Section 7.5. The rainfall losses in the XP-RAFTS design flow estimates outlined previously in Table 7-6 were also applied to the rare events.

7.6.2 Hydraulic Model Events

The 200 and 500 year ARI events have been analysed for a range of storm durations in the MIKE-FLOOD model. The critical durations assessed through the catchment using hydraulic routing are summarised in Table 7-10.

Table 7-10 Modelled Rare Event Durations

ARI	Duration (mins)
200	15, 30, 45, 60, 90, 180
500	30, 45, 60

A critical duration assessment was undertaken across all events for the 200 year ARI event as a critical duration check. The dominant storm events were the 30, 45 minute and 60 minute events. There were a few discrete and isolated areas in the hydraulic model which were dominated by the 15 minute storm event. However, these areas were localised with a maximum water level difference of mostly 5 mm with a small area up to 18 mm. For overall simplicity, only the dominant 30, 45 and 60 minute storm events were used to prepare the flood envelopes across the catchment study area for the rare events. A summary of hydraulic model flows at the catchment outlet (refer Figure 7-1) for the tested storm durations are presented in Table 7-11. Note that the peak catchment outflow in the hydraulic model provides further confirmation to the estimation of the January 2011 event as being approximately a 150 year ARI flood event. A map illustrating the critical duration storms throughout the catchment model area for the 200 year ARI event is illustrated in Figure 7-4. Note that in all cases a 100 percent blockage factor was applied to all crossing structure handrails and guardrails in the hydraulic model as per direction from the TRC-appointed peer reviewer.

Table 7-11 Modelled Rare Events - Catchment Outflow

Event ARI	Duration	Catchment Outflow (m^3/s)
200	15	90
200	30	157
200	45	207
200	60	231
200	90	216

200	180	179
500	30	209
500	45	272
500	60	302

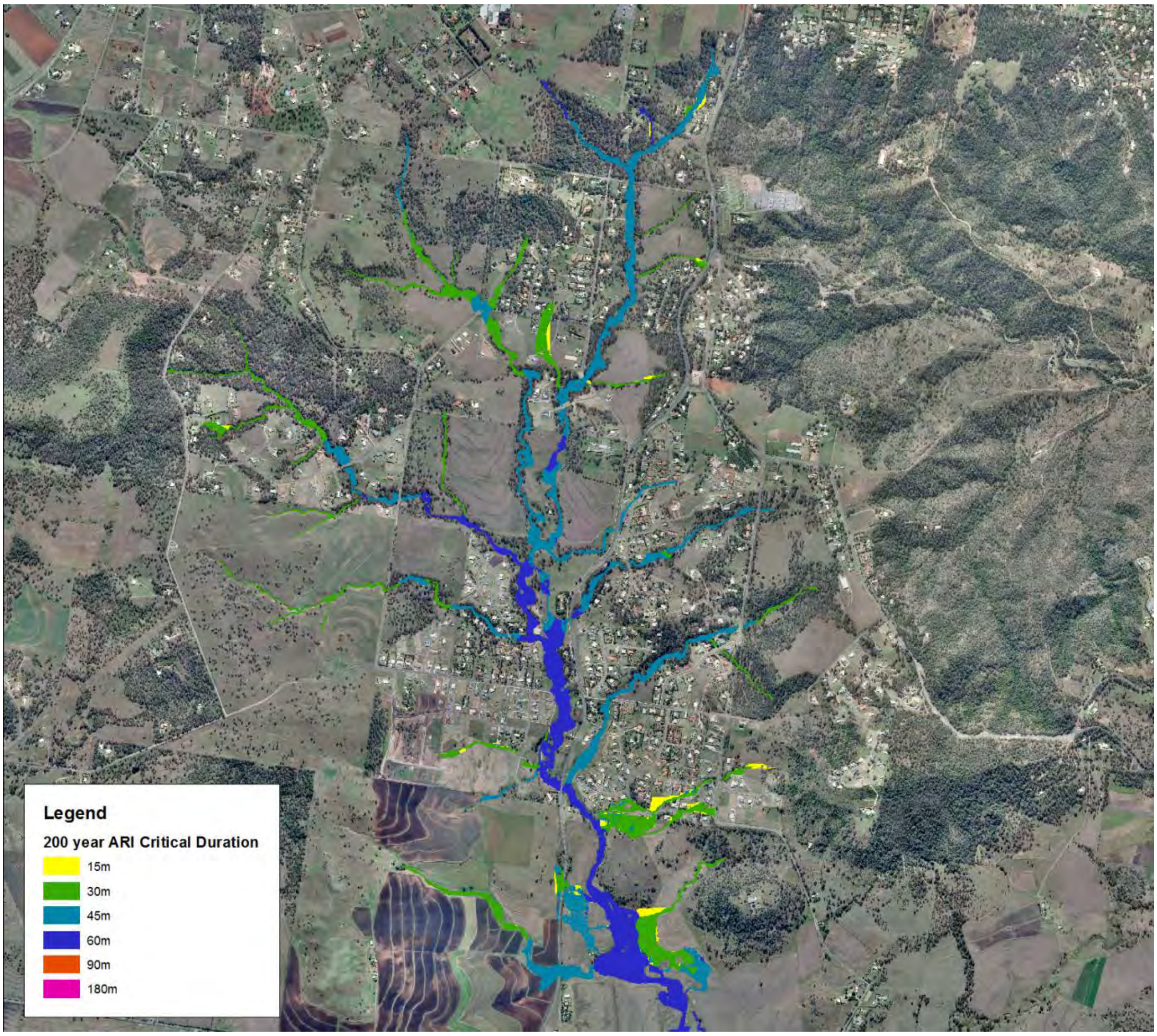


Figure 7-4 200 Year ARI Rare Event Critical Storm Duration throughout the Mount Rascal catchment model area

7.7 Extreme Event Discharge Estimate

7.7.1 Methodology

The Probable Maximum Precipitation (PMP) is defined in (WMO, 2009) as *"the theoretical maximum precipitation for a given duration under modern meteorological conditions"*.

Probable Maximum Flood (PMF) is defined in (WMO, 2009) as *"the theoretical maximum flood that poses extremely serious threats to the flood control of a given project in a design watershed".*

The Probable Maximum Precipitation Design Flood (PMP-DF) is the flood discharge determined through estimation and hydrologic routing of the Probable Maximum Precipitation (PMP). This is based on the assumption of AEP neutrality i.e. the assumption that the AEP of the flood estimate is the same as the AEP of the design rainfall event that produces it.

The adopted methodology for estimating the extreme event discharge within the Mount Rascal catchment is consistent with estimation techniques to determine the PMP-DF. This approach is deemed acceptable considering the uncertainty associated with any estimate of such rare events (in most areas a purely theoretical event) and the project objectives being of a planning nature. In any case, the variation in and extreme event due to the accuracy of the modelling established for the study (i.e. model calibration to a single historical event) would be comparable to the variation between PMP-DF and PMF estimates.

The PMP-DF varies from the Probable Maximum Flood in the following aspects:

- The AEP neutrality assumption is rejected in favour of adopting conservatively high estimates. That is, the PMF is not assigned the recurrence interval given to the PMP.
- Temporal patterns are standardised for the PMP-DF. The estimation of the PMF however requires the adoption of various temporal patterns including application of observed temporal patterns.
- Rainfall losses are acceptable in the PMP-DF whereas by definition hydrologic modelling of the PMF should not include a loss model.
- The broad range of considerations in deriving the PMF include pre-burst rainfall, flood frequency analysis, evidence from very large floods in similar catchments, extrapolation and supplementation of data for extreme events and adjustment of model parameters for extreme event discharge estimation.

In order to determine the Probable Maximum Precipitation (PMP) and resulting PMP-DF estimate for the Mount Rascal catchment, discharge estimates were undertaken using hydrologic estimation techniques provided in ARR Book VI (IEAust, 1998) and the Generalised Short Duration Method (GDSM) Commonwealth Bureau of Meteorology (BOM) GDSM PMP estimation guide (BOM, 2003). Adopted parameters specific to the estimation of PMP are summarised in Table 7-12.

Table 7-12 Extreme Event Parameters

Parameter	Value
GDSM Duration Limit	1000km^2, 6 hours
Smooth Fraction	0
Mean Elevation	600
Elevation Adjustment	1.00
Moisture Adjustment	0.81

Rare rainfall depth outputs from BOM (2003) (rounded to the nearest 10mm) adopted in the XP-RAFTS model are summarised in Table 7-13.

Table 7-13 Extreme Event Depths

Duration (mins)	PMP Depth (mm)
15	160
30	240
45	310
60	360
90	460
120	540
150	600
180	650
240	750
300	820
360	880

7.8 Hydraulic Model Extreme Events

7.8.1 XP-RAFTS Design Flows

The XP-RAFTS model has been used to generate all extreme event flows for inclusion in the hydraulic model. The model has incorporated rainfall in accordance with the procedures outlined in Section 7.7. The rainfall losses in the XP-RAFTS design flow estimates outlined previously in Table 7-6 were also applied to the PMP event in the hydrologic model.

7.8.2 Hydraulic Model Events

The PMP-DF event has adopted the same critical storm durations for analysis identified in Section 0. This is deemed applicable due to the adoption of the GDSM temporal pattern (extreme event) in the rare storm event (200 year ARI testing) after hydraulic analysis and investigation of the PMP-DF hydrologic model output for various duration events. The critical durations assessed through the catchment using hydraulic routing is summarised in Table 7-14. A summary of hydraulic model flows at the catchment outlet for the tested storm durations are shown in Table 7-15. Note that in all cases a 100 percent blockage factor was applied to all crossing structure handrails and guardrails in the hydraulic model as per direction from the TRC-appointed peer reviewer.

Table 7-14 Modelled Extreme Event Durations

ARI	Duration (mins)
PMP	30, 45, 60

Table 7-15 Modelled Extreme Event Duration Catchment Outflow

PMP Event Duration	Catchment Outflow (m^3/s)
30	1898
45	2102
60	2058

7.9 Model Events

Flood events for the 2, 5, 10, 20, 50, 100, 200, 500 year ARI and PMP-DF events have been analysed for the Mount Rascal catchment. In addition, model sensitivity assessments have also been undertaken and specifically this includes the assessment of structure blockages, +/- 30% changes in inflow estimates, +/- 30% changes in floodplain roughness as well as a variety of climate change scenarios.

The sensitivity assessment for provision for blockages of cross-drainage culvert and bridge structures was undertaken for the 100 year ARI event. A pre-determined blockage factor of 50% was specified by TRC for the analysis. Technical advice provided from Council's peer reviewer specified that the blockages were to be applied based on a reduction in the flow conveyance areas with the respective inverts maintained at the same level. For box culverts, this involved a reduction in the structure width by 50% while for circular culverts, an effective diameter pipe size was determined and applied based on a 50% reduction in the culvert conveyance area. For bridge structures, the flow opening width was reduced by direct application of a 50% blockage ratio.

The sensitivity assessment for the +/- 30% change in flow and model roughness was undertaken for the 100 year ARI event. Model sensitivity for these scenarios was assessed using directly factored inflow estimates and floodplain roughness.

The sensitivity assessment for the climate change scenarios was based on a 5% increase in rainfall intensity per degree of global warming as recommended in advance of the review of State Planning Policy (SPP) 1/03 (Queensland Government, 2010b). This was incorporated into the 100, 200 and 500 year ARI flood events. The following temperature increases and planning horizons were adopted:

- $2^{o}C$ by 2050 (10 percent rainfall increase).
- $3^{o}C$ by 2070 (15 percent rainfall increase).

- 4^{o}C by 2100 (20 percent rainfall increase).

The MIKE-FLOOD naming nomenclature for the various scenarios undertaken for this work package have been prepared using Council's standard naming convention and a detailed summary is provided digitally as part of the model log provided for this project.

A summary of the flood event scenarios analysed using the two-dimensional MIKE-FLOOD models for the Mount Rascal catchment are presented in Table 7-16. Note that the actual number of model simulations analysed far exceeded the number outlined in Table 7-16 owing to the multiple storm duration events considered as part of this study as have been discussed previously.

Table 7-16 Mount Rascal (Work Package 6) Investigated Flood Event Summary

Event	Description
Calibration	January 2011 calibration event
2 year ARI	2 year ARI design storm event
5 year ARI	5 year ARI design storm event
10 year ARI	10 year ARI design storm event
20 year ARI	20 year ARI design storm event
50 year ARI	50 year ARI design storm event
100 year ARI	100 year ARI design storm event
200 year ARI	200 year ARI design storm event
500 year ARI	500 year ARI design storm event
PMP-DF	Probable Maximum Precipitation Design Flood event
100 year ARI + 30% discharge	100 year ARI design storm event with additional 30 % discharge sensitivity event
100 year ARI - 30% discharge	100 year ARI design storm event with 30 % discharge reduction sensitivity event
100 year ARI + 30% roughness	100 year ARI design storm event with 30 % increase in Manning's roughness sensitivity event
100 year ARI - 30% roughness	100 year ARI design storm event with 30 % decrease in Manning's roughness sensitivity event
100 year ARI - 50% structure blockage	100 year ARI design storm event with 50 % blockage factor applied to all structures
100 year ARI + 2	100 year ARI design storm event with 2 degrees

degrees climate change	climate change (2050) scenario (+10% rainfall)
100 year ARI + 3 degrees climate change	100 year ARI design storm event with 3 degrees climate change (2070) scenario (+15% rainfall)
100 year ARI + 4 degrees climate change	100 year ARI design storm event with 4 degrees climate change (2100) scenario (+20% rainfall)
200 year ARI + 2 degrees climate change	200 year ARI design storm event with 2 degrees climate change (2050) scenario (+10% rainfall)
200 year ARI + 3 degrees climate change	200 year ARI design storm event with 3 degrees climate change (2070) scenario (+15% rainfall)
200 year ARI + 4 degrees climate change	200 year ARI design storm event with 4 degrees climate change (2100) scenario (+20% rainfall)
500 year ARI + 2 degrees climate change	500 year ARI design storm event with 2 degrees climate change (2050) scenario (+10% rainfall)
500 year ARI + 3 degrees climate change	500 year ARI design storm event with 3 degrees climate change (2070) scenario (+15% rainfall)
500 year ARI + 4 degrees climate change	500 year ARI design storm event with 4 degrees climate change (2100) scenario (+20% rainfall)
Ultimate Land Use	100 year ARI design storm event assuming ultimate catchment development

7.10 Model Results

7.10.1 Design Flood Events

The model results prepared for the 2, 5, 10, 20, 50 and 100 year ARI events for Mount Rascal are presented as both a series of GIS maps as well as tabular information. Table 7-17 and Table 7-18 provide a summary of the peak hydraulic model flows and water levels respectively at selected key locations throughout the Mount Rascal catchment for the various design flood events. Flood maps for these events have also been prepared in a GIS format and are included in Appendix H. A summary of structure flows for the 100 year ARI design event is also included as Appendix F. All design flood event GIS maps prepared for this study have been undertaken based on the project specific technical requirements which include the mapping requirements, conventions and standards as outlined in the project brief.

Table 7-17 Design flood event peak flow summary at key locations

Location – Note 1	Design Event Peak Discharge (m^3/s)					
	2 year ARI	5 year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 year ARI
Iron Bark Drive (Upstream of ST19)	10	12	13	15	19	27
Tranter Street (Downstream of ST 21)	13	19	24	31	38	43
Acacia Avenue (Upstream of ST24)	13	21	26	33	42	52
Kearney Street (Upstream of ST 23)	12	19	23	31	39	48
Fittons Road (Downstream of ST 33)	10	13	14	16	18	28
Freyling Road (Upstream of ST25)	45	70	85	106	132	161
New England Highway Crossing (Upstream of ST1)	45	71	86	106	134	163
Catchment Outflow (At downstream catchment boundary)	49	80	98	125	162	192

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-18 Design flood event peak level summary at key locations

Location – Note 1	Design Event Peak Water Level (mAHD)					
	2 year ARI	5 year ARI	10 Year ARI	20 Year ARI	50 Year ARI	100 year ARI
Iron Bark Drive (Upstream of ST19)	580.10	581.10	581.66	582.34	583.01	583.16
Tranter Street (Downstream of ST 21)	587.61	587.64	587.70	587.81	587.89	587.97
Acacia Avenue (Upstream of ST24)	568.95	569.38	569.49	570.05	570.81	571.04
Kearney Street (Upstream of ST 23)	576.02	576.02	576.02	576.02	576.02	576.02
Fittons Road (Downstream of ST 33)	567.24	567.98	568.40	568.96	569.87	570.13
Freyling Road (Upstream of ST25)	538.03	538.27	538.40	538.55	538.73	538.92
New England Highway Crossing (Upstream of ST1)	529.61	529.67	529.70	529.74	529.78	530.16

Note (1) – Refer Appendix C for structure locations and flow reporting points

7.10.2 Rare and Extreme Flood Events

The model results prepared for the 200 and 500 year ARI events for Mount Rascal are presented as both a series of GIS maps included in Appendix I as well as tabular information. Table 7-19 and Table 7-20 provide a summary of the peak hydraulic model flows and water levels respectively at selected key locations throughout the Mount Rascal catchment for the rare and extreme flood events. All rare and extreme flood event GIS maps prepared for this study have been undertaken based on the project specific technical requirements which include the mapping requirements, conventions and standards as outlined in the project brief.

Table 7-19 Rare and extreme flood event peak flow summary at key locations

Location – Note 1	Rare and Extreme Event Peak Discharge (m^3/s)		
	200 Year ARI	500 Year ARI	PMP-DF
Iron Bark Drive (Upstream of ST19)	33	43	237
Tranter Street (Downstream of ST 21)	49	57	279
Acacia Avenue (Upstream of ST24)	59	73	400
Kearney Street (Upstream of ST 23)	53	66	354
Fittons Road (Downstream of ST 33)	37	50	293
Freyling Road (Upstream of ST25)	184	244	1487
New England Highway Crossing (Upstream of ST1)	194	254	1719
Catchment Outflow (At downstream catchment boundary)	231	303	2101

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-20 Rare and extreme flood event peak level summary at key locations

Location – Note 1	Rare and Extreme Event Peak Water Level (mAHD)		
	200 Year ARI	500 Year ARI	PMP-DF
Iron Bark Drive (Upstream of ST19)	583.26	583.41	584.00
Tranter Street (Downstream of ST 21)	587.99	588.10	589.00

Acacia Avenue (Upstream of ST24)	571.18	571.36	573.00
Kearney Street (Upstream of ST 23)	576.02	576.17	577.00
Fittons Road (Downstream of ST 33)	570.30	570.48	572.00
Freyling Road (Upstream of ST25)	539.12	539.32	542.00
New England Highway Crossing (Upstream of ST1)	530.66	531.43	534.00

Note (1) – Refer Appendix C for structure locations and flow reporting points

7.10.3 Climate Change Scenario Flood Events

The model results prepared for the 100, 200 and 500 year ARI climate change events for Mount Rascal are presented as both a series of GIS maps included in Appendix J as well as tabular information. Table 7-21, Table 7-22 and Table 7-23 provide a summary of the peak hydraulic model water levels respectively at selected key locations throughout the Mount Rascal catchment for the climate change scenario – including the 100, 200 and 500 year ARI base scenario for ease of comparison. It can be seen from the model results that the adopted climate change horizons show significant impact of flooding water levels which decreases with increase in event ARI. This is to be expected due to larger ARI events (and larger events generally) encroaching further into the floodplain and utilising additional storage at larger depths. Considering the increase in climate change impact on water levels in higher frequency events climate change should be considered an integral part of future land use planning.

All climate change event GIS maps prepared for this study have been undertaken based on the project specific technical requirements which include the mapping requirements, conventions and standards as outlined in the project brief.

Table 7-21 100 year ARI climate change scenarios flood event peak water level summary at key locations

Location – Note 1	100 year ARI Climate Change Scenario Peak Water Levels (mAHD)			
	100 year ARI	100 year ARI + 2 degrees Climate Change (+10% Rainfall)	100 year ARI + 3 degrees Climate Change (+15% Rainfall)	100 year ARI + 4 degrees Climate Change (+20% Rainfall)
Iron Bark Drive (Upstream of ST19)	583.16	583.26	583.37	583.42
Tranter Street (Downstream of ST 21)	587.97	588.04	588.07	588.10
Acacia Avenue (Upstream of ST24)	571.04	571.20	571.28	571.35

Kearney Street (Upstream of ST 23)	576.02	576.13	576.14	576.15
Fittons Road (Downstream of ST 33)	570.13	570.29	570.39	570.44
Freyling Road (Upstream of ST25)	538.92	539.13	539.20	539.29
New England Highway Crossing (Upstream of ST1)	530.16	530.70	530.88	531.04

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-22 200 year ARI climate change scenarios flood event peak water level summary at key locations

Location – Note 1	**200 year ARI Climate Change Scenario Peak Water Levels (mAHD)**			
	200 year ARI	**200 year ARI + 2 degrees Climate Change (+10% Rainfall)**	**200 year ARI + 3 degrees Climate Change (+15% Rainfall)**	**200 year ARI + 4 degrees Climate Change (+20% Rainfall)**
Iron Bark Drive (Upstream of ST19)	583.26	583.38	583.43	583.47
Tranter Street (Downstream of ST 21)	587.99	588.07	588.10	588.14
Acacia Avenue (Upstream of ST24)	571.18	571.31	571.38	571.44
Kearney Street (Upstream of ST 23)	576.02	576.15	576.17	576.18
Fittons Road (Downstream of ST 33)	570.30	570.42	570.49	570.53
Freyling Road (Upstream of ST25)	539.12	539.27	539.33	539.40
New England Highway Crossing (Upstream of ST1)	530.66	531.06	531.20	531.29

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-23 500 year ARI climate change scenarios flood event peak water level summary at key locations

Location – Note 1	**500 year ARI Climate Change Scenario Peak Water Levels (mAHD)**

	500 year ARI	500 year ARI + 2 degrees Climate Change (+10% Rainfall)	500 year ARI + 3 degrees Climate Change (+15% Rainfall)	500 year ARI + 4 degrees Climate Change (+20% Rainfall)
Iron Bark Drive (Upstream of ST19)	583.41	583.52	583.54	583.56
Tranter Street (Downstream of ST 21)	588.10	588.18	588.21	588.25
Acacia Avenue (Upstream of ST24)	571.36	571.50	571.56	571.61
Kearney Street (Upstream of ST 23)	576.17	576.19	576.20	576.23
Fittons Road (Downstream of ST 33)	570.48	570.57	570.62	570.68
Freyling Road (Upstream of ST25)	539.32	539.47	539.54	539.60
New England Highway Crossing (Upstream of ST1)	531.43	531.65	531.73	531.79

Note (1) – Refer Appendix C for structure locations and flow reporting points.

7.10.4 Sensitivity Assessment Flood Events

The model results prepared for the sensitivity assessments for Mount Rascal have been presented as tabulated summaries of peak flows and water levels at key locations. Results are presented by way of comparison of peak water levels to the 100 year ARI design event. Tabulated peak water levels for the Ultimate land use scenario, 50% structure blockage scenario, ±30% Manning's roughness sensitivity and ±30 discharge sensitivity and summarised in Table 7-24 through Table 7-27 respectively. No GIS maps for these scenarios have been prepared given the project specification requirements.

Table 7-24 Ultimate land use scenario flood event peak water level summary at key locations

Location – Note 1	Land Use Sensitivity Scenario Peak Water Level (mAHD)	
	100 Year ARI (January 2011 land use scenario)	100 Year ARI (Ultimate land use scenario)
Iron Bark Drive (Upstream of ST19)	583.16	583.26
Tranter Street (Downstream of ST 21)	587.97	588.07
Acacia Avenue (Upstream of ST24)	571.04	571.49
Kearney Street (Upstream of ST 23)	576.02	576.13

Fittons Road (Downstream of ST 33)	570.13	570.30
Freyling Road (Upstream of ST25)	538.92	539.25
New England Highway Crossing (Upstream of ST1)	530.16	530.95

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-25 50% structure blockage scenario flood event peak water level summary at key locations

Location – Note 1	50% Structure Blockage Sensitivity Scenario Peak Water Level (mAHD)	
	100 Year ARI	100 Year ARI 50% Structure blockage scenario
Iron Bark Drive (Upstream of ST19)	583.16	583.30
Tranter Street (Downstream of ST 21)	587.97	587.98
Acacia Avenue (Upstream of ST24)	571.04	571.28
Kearney Street (Upstream of ST 23)	576.02	576.13
Fittons Road (Downstream of ST 33)	570.13	570.36
Freyling Road (Upstream of ST25)	538.92	538.99
New England Highway Crossing (Upstream of ST1)	530.16	530.92

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-26 ±30% Manning's roughness scenario flood event peak water level summary at key locations

Location – Note 1	±30% Manning's roughness Scenario Peak Water Level (mAHD)		
	100 Year ARI	100 Year ARI +30% Manning's Roughness	100 Year ARI -30% Manning's Roughness
Iron Bark Drive (Upstream of ST19)	583.16	583.16	583.14
Tranter Street (Downstream of ST 21)	587.97	587.96	587.99
Acacia Avenue (Upstream of ST24)	571.04	571.02	571.01

Kearney Street (Upstream of ST 23)	576.02	576.18	576.02
Fittons Road (Downstream of ST 33)	570.13	570.16	570.16
Freyling Road (Upstream of ST25)	538.92	538.95	538.86
New England Highway Crossing (Upstream of ST1)	530.16	530.22	530.08

Note (1) – Refer Appendix C for structure locations and flow reporting points.

Table 7-27 ±30% Discharge scenario flood event peak water level summary at key locations

Location – Note 1	±30% Discharge Scenario Peak Water Level (mAHD)		
	100 Year ARI	100 Year ARI +30% Discharge	100 Year ARI -30% Discharge
Iron Bark Drive (Upstream of ST19)	583.16	583.42	582.33
Tranter Street (Downstream of ST 21)	587.97	588.10	587.81
Acacia Avenue (Upstream of ST24)	571.04	571.35	570.10
Kearney Street (Upstream of ST 23)	576.02	576.15	575.91
Fittons Road (Downstream of ST 33)	570.13	570.46	568.97
Freyling Road (Upstream of ST25)	538.92	539.29	538.56
New England Highway Crossing (Upstream of ST1)	530.16	531.14	529.70

Note (1) – Refer Appendix C for structure locations and flow reporting points.

7.10.5 Digital Flood Data

All model result files and associated results represent a project deliverable which has been provided to Council in a digital format at the completion of the flood study works. The digital data sets comprise detailed flood information in respect to flood levels, depths, velocities and flood hazards and can therefore inform the Planning Scheme revisions.

7.10.6 Emergency Management

As part of the assessment of flooding within the Mount Rascal catchment area, consideration has also been given to the likely impact of the predicted flood behaviour for each design event assessed on critical emergency management infrastructure. As there were no identified critical emergency management infrastructure located throughout the Mount Rascal catchment from the GIS data provided by TRC, only impacts on emergency egress (road access) within the study area have been assessed. Table 7-28 summarises the respective road flood immunities and time of road inundation achieved at each of the major access roads throughout the study area.

Table 7-28 Flood Impacts on Egress Routes

Critical Infrastructure Route (Note 2)	Flood Standard Achieved (Note 1)	Time of Road Inundation in 100 year ARI Event (mins)
Iron Bark Drive (ST19)	20 year ARI	30
Tranter Street (ST 21)	2 year ARI	35
Acacia Avenue (ST24)	20 year ARI	30
Kearney Street (ST 23)	20 year ARI	20
Fittons Road (ST 33)	20 year ARI	35
Freyling Road (ST25)	< 2 year ARI	65
New England Highway Crossing (ST1)	100 year ARI	Not Applicable

Notes

(1) Flood standard refers to the level at which the crossing first becomes inundated. Consequently, this does not consider road trafficability provisions in accordance with QUDM (NRW, 2007) Table 7.04.1

(2) Refer Appendix C for structure locations.

7.10.7 Property Inundation

The following street areas have been identified with inundated properties and significant hazard in the 100 year ARI flood event:

- Parkside Court
- Carinya Drive
- Hodgson Vale Sports Club

7.10.8 Assessment Uncertainties and Limitations

During the course of the assessment, various datasets have been used to assess flood behaviour for a number of design rainfall events. Given the multiple datasets that have been used in this assessment and their associated limitations and accuracies, there is an inherent limitation in the accuracy of the final model results and hence flood behaviour predictions. Datasets that will inherently impact on the accuracy of the model results are as follows:

- Design rainfall datasets have been derived from the procedures set out in Australian Rainfall and Runoff (IEAust, 1998). A new IFD dataset (IFD 2013) has been developed by AR&R with an additional 30 years of rainfall data as well as data from an additional 2300 rainfall stations. This dataset is not yet recommended for use by AR&R. As such, any changes to predicted design rainfall intensities as a result of the new AR&R IFD dataset will not be reflected in the results of this study.
- Baseline topographic data - The MIKE FLOOD models prepared as part of this study are based on the LiDAR dataset as supplied by TRC. The results are therefore inherently subject to the accuracy and detail of the topographic survey (94% of points within +/- 150 mm

accuracy of ground controls). Accuracy is reduced for areas under heavy vegetative cover and at derived points (from the DEM). Additionally, if changes have occurred to the topographic variation in the study areas due to development or other construction activities since the LiDAR data was collected, this will not have been accurately assessed in the model results.

- Where changes/upgrades to sub surface drainage features such as major culverts have been undertaken since the site visit, this will not be accurately represented within the model results.
- No detailed survey data has been collected for this project. Hydraulic structures included in the flood models prepared under this work package are based on site measurements. Invert levels for the culverts have been estimated using the DTM. In heavily vegetated areas, the levels from the DTM may not be accurate and accordingly hydraulic structure representation within the models may not be accurate and this may result in inaccuracies associated with flood level predictions.

Nonetheless, given the good replication of recent historic flood levels within the MIKE FLOOD models during the model verification stage, assessment of historic rainfall and model inflows, as well as model parameters being generally consistent with industry standards, the outcomes of this assessment are considered to be appropriate for the purposes of the project objectives.

8. CONCLUSION AND RECOMMENDATIONS

In order to assess the behaviour of overland flow path flooding within Mount Rascal, Top Camp and Hodgson Vale, catchment discharge estimates were required. Hydrologic modelling was used to estimate catchment discharges contributing to the study areas for design events pre-determined by TRC. This included the 2, 5, 10, 20, 50, 100, 200, 500 year Average Recurrence Interval (ARI) and Probable Maximum Precipitation Design Flood (PMP-DF) events.

Hydraulic modelling of the study areas has been undertaken utilising DHI Software's MIKE FLOOD modelling system. The MIKE FLOOD model calibrated to the January 2011 event had good correlation between model predictions of flood behaviour and anecdotal and surveyed historical flood information. The MIKE FLOOD model was adopted to undertake a range of design and sensitivity event flood assessments for the Mount Rascal catchment. The model performance and output were deemed acceptable and produced reasonable hydraulic results.

It is recommended that the model results developed from this study be adopted by Council and used for inclusion in Council's updated planning scheme and for the purposes of addressing the conditional approval of the scheme, as issued by the State Government on the 17th February 2012.

9. DISCLAIMER

While every care is taken by the Toowoomba Regional Council (TRC) and Water Technology to ensure the accuracy of the data used in the study and published in the report, TRC and Water Technology makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of data being inaccurate or incomplete.

10. REFERENCES

1. Australian Bureau of Meteorology (BOM), (2003), *The Estimation of Probable Maximum Precipitation in Australia – Generalised Short Duration Method*, 2003, Hydrometeorological Advisory Service

2. Australian Bureau of Meteorology (BOM), (2013), *Rainfall IFD Data System*, accessed 29/10/2013 via http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

3. Ball J.E., Babister M.K. and Retallick M.E. (2011), Revisiting the Design Flood Problem, 33rd Hydrology & Water Resources Symposium, 26 June - 1 July 2011, Brisbane, Australia, Engineers Australia

4. Catchment Simulation Solutions (2011) *CatchmentSIM Software*, Version 2.5.

5. EWS (2013), Queensland Urban Drainage Manual, Volume 1, Third Edition 2013 - Provisional, Department of Energy and Water Supply, Queensland Government.

6. IEAust (2012) *Australian Rainfall and Runoff Revision Project 5: Regional Flood Methods Stage 2 Report*, June, 2012

7. IEAust (2012) *Australian Rainfall and Runoff Revision Project 15: Two Dimensional Modelling in Urban and Rural Floodplains Stage 1 & 2 Report*, November, 2012

8. IEAust (1998), *Australian Rainfall and Runoff, A Guide to Flood Estimation, Volume 1 and 2,* Editor in Chief DH Pilgrim, Institution of Engineers.

9. IEAust (2012), *Australian Regional Flood Frequency Model,* Institution of Engineers.

10. Grayson R.B., Argent R.M., Nathan R.J., McMahon T.A. and Mein R.G. (1996), *Hydrological Recipes, Estimation Techniques in Australian Hydrology*, Cooperative Research Centre for Catchment Hydrology.

11. Hargreaves et al. (2009), Applicability of the CRCFORGE Method of Extreme Rainfall Estimation to Tropical and Sub-tropical Regions, Hydrology & Water Resources Symposium, 1999, Brisbane, Australia, Engineers Australia

12. NRW (2007), *Queensland Urban Drainage Manual*, Volume 1, Second Edition, Natural Resources and Water, Queensland Government.

13. Queensland Government (2003) *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide,* State Planning Policy (SPP) 1/03, June 2003 http://www.dsdip.qld.gov.au/resources/policy/spp-ifbl-guide.pdf

14. Queensland Government (2010a) *Healthy Waterways*, State Planning Policy (SPP) 4/10, December 2010 http://rti.cabinet.qld.gov.au/documents/2010/oct/state%20planning%20policy%20for%20healthy%20waters/Attachments/spp-healthy-waters%5B1%5D.pdf

15. Queensland Government (2010b), *Increasing Queensland's resilience to inland flooding in a changing climate: Final Report on the Inland Flooding Study*, 2010, http://www.ehp.qld.gov.au/climatechange/pdf/inland-flood-study.pdf

16. Queensland Government (2012) *Queensland Government response to the final QFCI report*, 7 June 2012 http://www.premiers.qld.gov.au/publications/categories/reports/response-to-flood-inquiry.aspx

17. SCARM (2000) *Floodplain Management in Australia. Best Practice Principles and Guidelines,* Agriculture and Resource Management Council of Australia and New Zealand, Standing Committee on Agriculture and Resource Management, Report No 73, CSIRO Publishing, Collingwood, Victoria.

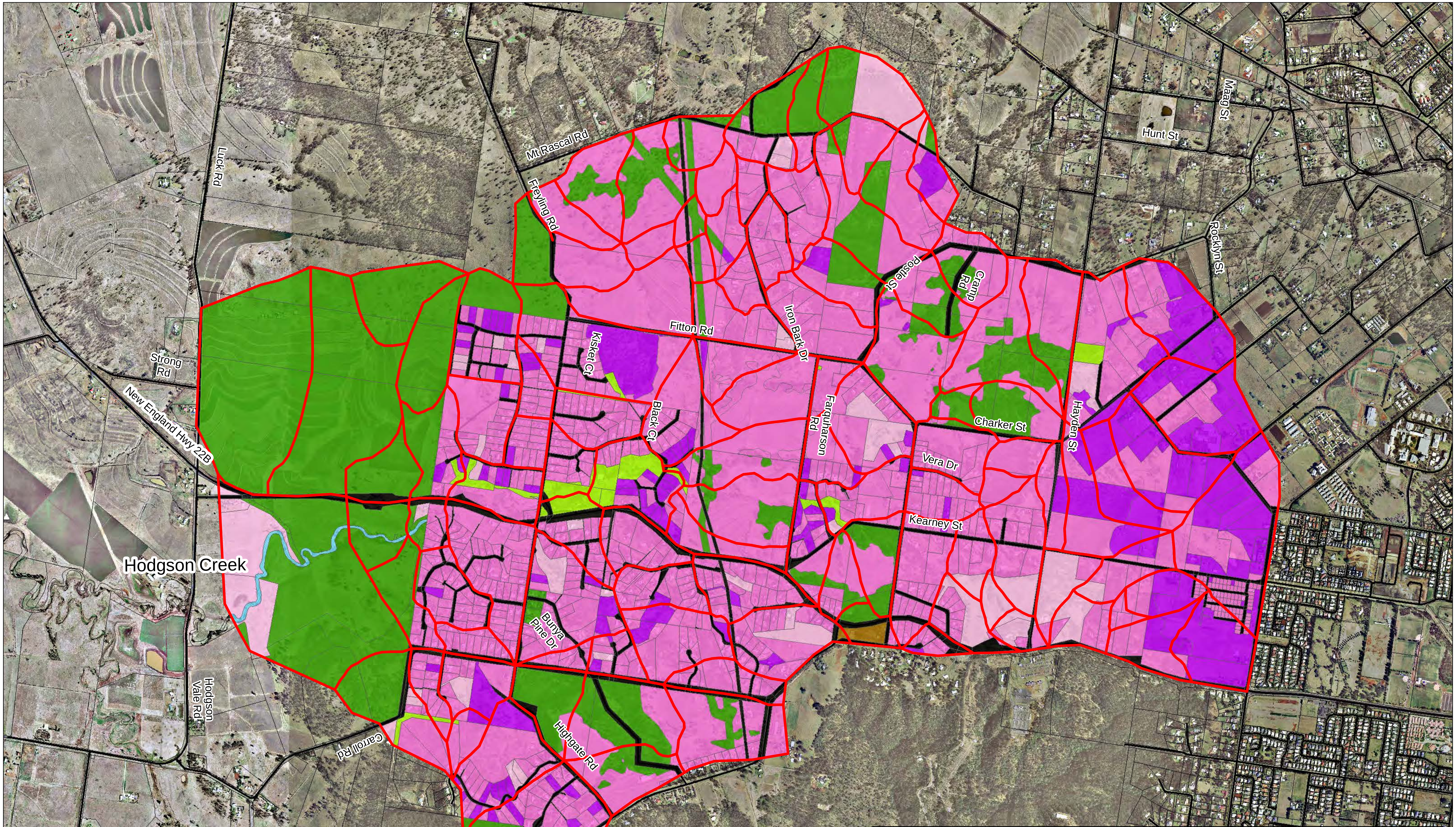
18. Shlenker Mapping Pty Ltd (2010), *Toowoomba Regional Council 2010 LiDAR Capture Project*, Schlenker Mapping

19. Walton R.S., McAvoy L.F., and Canning S.B. (2014) *If God Gave Us The Truth, What Would We Do With It? Reality Checking Flood Magnitude Estimates*, Hydrology & Water Resources Symposium, 2014, Perth, Australia, Engineers Australia.

20. The Weather Chaser (2011), Marburg Radar Loop, accessed 11/11/2013 via http://www.theweatherchaser.com/radar-loop/

21. World Meteorological Organization (2009), *Manual for Estimation of Probable Maximum Precipitation*, 3rd edition, WMO - No. 1045, Geneva, ISBN 978-92-63-11045-9

APPENDIX A LAND USE MAPS



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 150 300 600
Meters

GDA 1994 MGA Zone 56

N

Legend

- Catchment Boundaries
- Major Road Centre Lines
- Cadastre

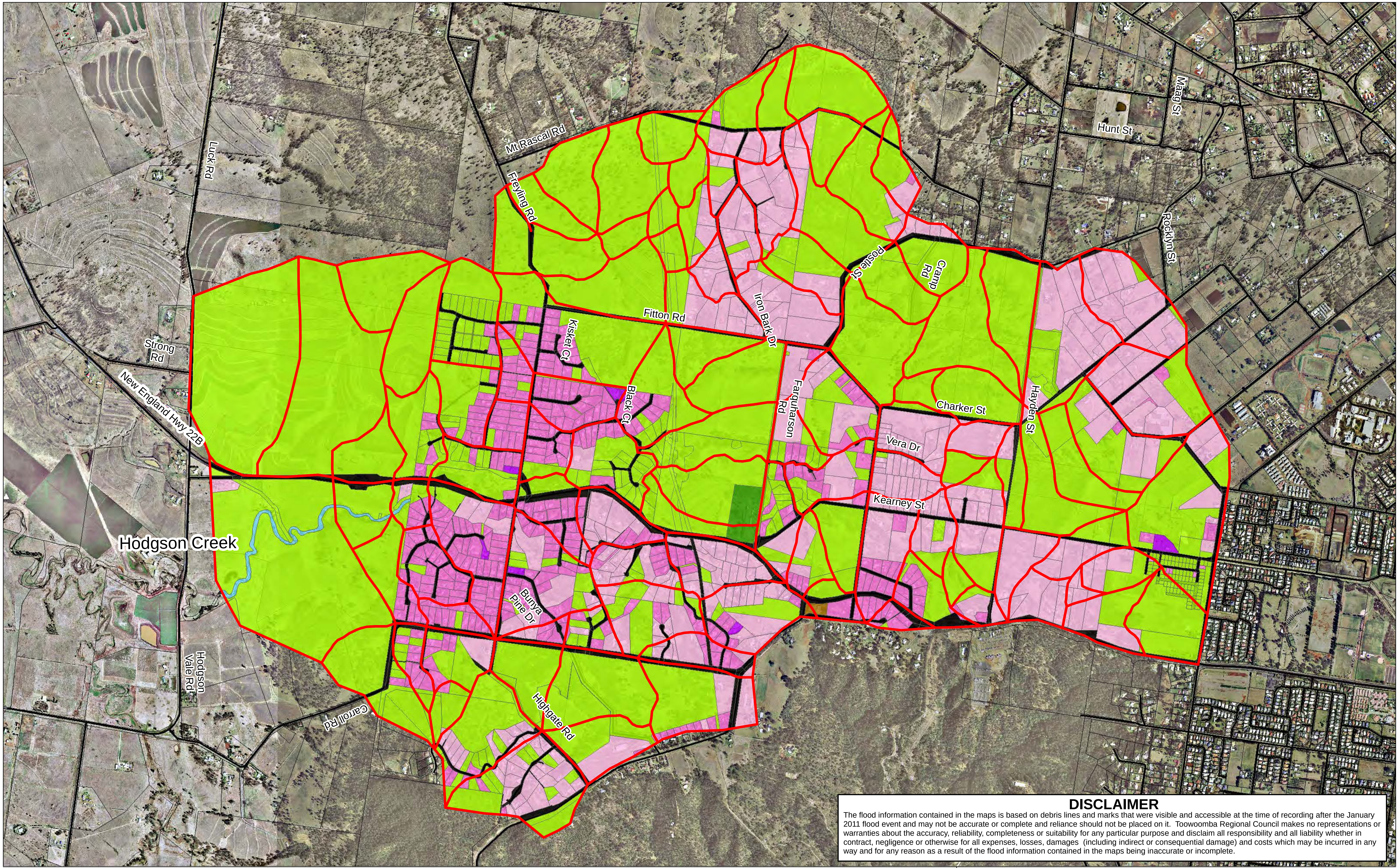
Ultimate Land Use

- Creek
- Agriculture
- Open Space
- Rural Residential
- Urban Residential - Low Density
- Urban Residential - High Density
- Light Industry
- Road

SP051 Flood Studies - Work Package 6

Mount Rascal Ultimate Land Use Map

MTR-D-LANDUSE.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 150 300 600 Meters

N

GDA 1994 MGA Zone 56

Legend

- Catchment Boundaries
- Major Road Centre Lines
- Cadastre

January 2011 Land Use

- Creek
- Agriculture
- Open Space
- Rural Residential
- Urban Residential - Low Density
- Urban Residential - High Density
- Light Industry
- Road

SP051 Flood Studies - Work Package 6

Mount Rascal Existing Land Use Map

MTR-D-LANDUSE.mxd
Author/Date: Ryan.dermek 4/04/2014

APPENDIX B CATCHMENT CHARACTERISTICS

XP-RAFTS ID	Total Area (ha)	January 2011 Land Use Fraction Impervious	Ultimate Land Use Fraction Impervious	Slope (%)
1	17.0	0.05	0.70	5.7
2	11.5	0.15	0.70	15.3
3	13.1	0.35	0.68	11.4
4	6.5	0.27	0.69	11.7
5	8.6	0.10	0.70	11.2
6	2.1	0.15	0.70	15.7
7	6.5	0.32	0.69	9.6
8	14.3	0.13	0.58	11.0
9	25.0	0.31	0.70	10.2
10	13.4	0.18	0.57	12.4
11	14.6	0.07	0.38	14.1
12	22.4	0.10	0.70	5.6
13	8.6	0.19	0.46	14.1
14	10.7	0.13	0.63	13.0
15	13.5	0.00	0.67	11.0
16	16.5	0.02	0.67	15.7
17	11.5	0.11	0.21	12.1
18	9.4	0.18	0.30	18.4
19	7.7	0.13	0.68	21.3
20	17.9	0.14	0.59	19.9
21	4.8	0.23	0.38	15.5
22	3.2	0.00	0.16	17.2
23	10.2	0.26	0.47	18.6
24	3.7	0.44	0.69	13.1
25	8.9	0.14	0.59	17.5
26	17.7	0.28	0.70	17.7
27	9.2	0.17	0.69	15.7
28	13.5	0.20	0.60	18.8
29	13.1	0.20	0.60	10.0
30	19.5	0.15	0.55	14.2
31	3.7	0.01	0.70	29.6
32	5.9	0.16	0.70	26.3
33	13.3	0.04	0.22	22.8
34	17.6	0.04	0.42	20.7
35	24.1	0.00	0.31	20.3
36	4.1	0.00	0.16	18.3
37	22.2	0.02	0.47	16.1
38	13.3	0.09	0.47	17.1
39	12.0	0.01	0.36	20.3
40	5.8	0.38	0.50	15.9
41	12.0	0.10	0.32	14.7
42	8.0	0.12	0.44	12.6

43	11.9	0.19	0.55	13.8
44	8.4	0.14	0.62	14.6
45	8.0	0.07	0.58	20.7
46	16.6	0.03	0.55	22.1
47	20.1	0.07	0.49	19.6
48	9.2	0.05	0.58	22.6
49	18.5	0.02	0.02	26.1
50	4.9	0.19	0.69	19.1
51	17.6	0.19	0.70	16.7
52	13.4	0.09	0.52	18.8
53	6.0	0.26	0.45	12.8
54	13.4	0.34	0.68	11.0
55	5.8	0.34	0.70	14.1
56	8.7	0.08	0.19	22.5
57	14.8	0.11	0.30	18.6
58	12.3	0.17	0.67	16.8
59	63.0	0.01	0.21	11.9
60	53.7	0.00	0.20	12.0
61	17.1	0.00	0.20	19.4
62	79.7	0.05	0.09	12.0
63	10.8	0.10	0.05	13.1
64	21.4	0.06	0.28	27.3
65	6.9	0.24	0.66	19.0
66	27.3	0.16	0.51	23.5
67	22.1	0.09	0.64	29.8
68	5.1	0.03	0.68	39.2
69	11.8	0.19	0.60	20.4
70	12.9	0.05	0.14	23.7
71	23.8	0.03	0.27	18.0
72	14.2	0.08	0.38	15.0
73	24.0	0.17	0.68	11.5
74	30.3	0.14	0.54	15.8
75	9.9	0.33	0.69	14.4
76	18.5	0.14	0.68	16.7
77	18.9	0.21	0.53	10.6
78	3.7	0.38	0.70	18.8
79	16.0	0.28	0.67	14.0
80	11.1	0.23	0.69	15.2
81	12.3	0.30	0.63	19.1
82	9.3	0.12	0.55	13.1
83	16.6	0.00	0.51	13.2
84	18.8	0.01	0.48	15.7
85	20.0	0.04	0.46	15.8
86	37.2	0.14	0.56	13.7

87	20.5	0.02	0.51	13.6
88	18.2	0.13	0.59	10.3
89	10.1	0.05	0.53	16.2
90	6.6	0.25	0.65	21.1
91	6.0	0.20	0.69	18.1
92	9.0	0.19	0.62	15.5
93	5.0	0.19	0.64	14.1
94	9.2	0.04	0.42	15.9
95	5.9	0.00	0.50	13.9
96	7.0	0.08	0.54	17.3
97	13.1	0.15	0.58	13.9
98	3.9	0.00	0.44	14.1
99	3.5	0.00	0.41	13.6
100	18.2	0.00	0.38	17.7
101	4.6	0.00	0.50	15.5
102	14.4	0.00	0.43	12.7
103	8.5	0.01	0.50	15.7
104	19.4	0.05	0.39	17.9
105	26.4	0.16	0.70	3.9
106	22.6	0.13	0.48	10.0
107	40.0	0.14	0.70	3.3
108	20.7	0.08	0.50	19.1
109	16.6	0.00	0.20	13.6
110	26.4	0.25	0.58	18.6
111	12.4	0.34	0.55	12.8
112	17.3	0.15	0.43	13.2
113	9.2	0.30	0.53	9.8
114	11.1	0.10	0.27	13.1

APPENDIX C HYDRAULIC STRUCTURE DETAILS

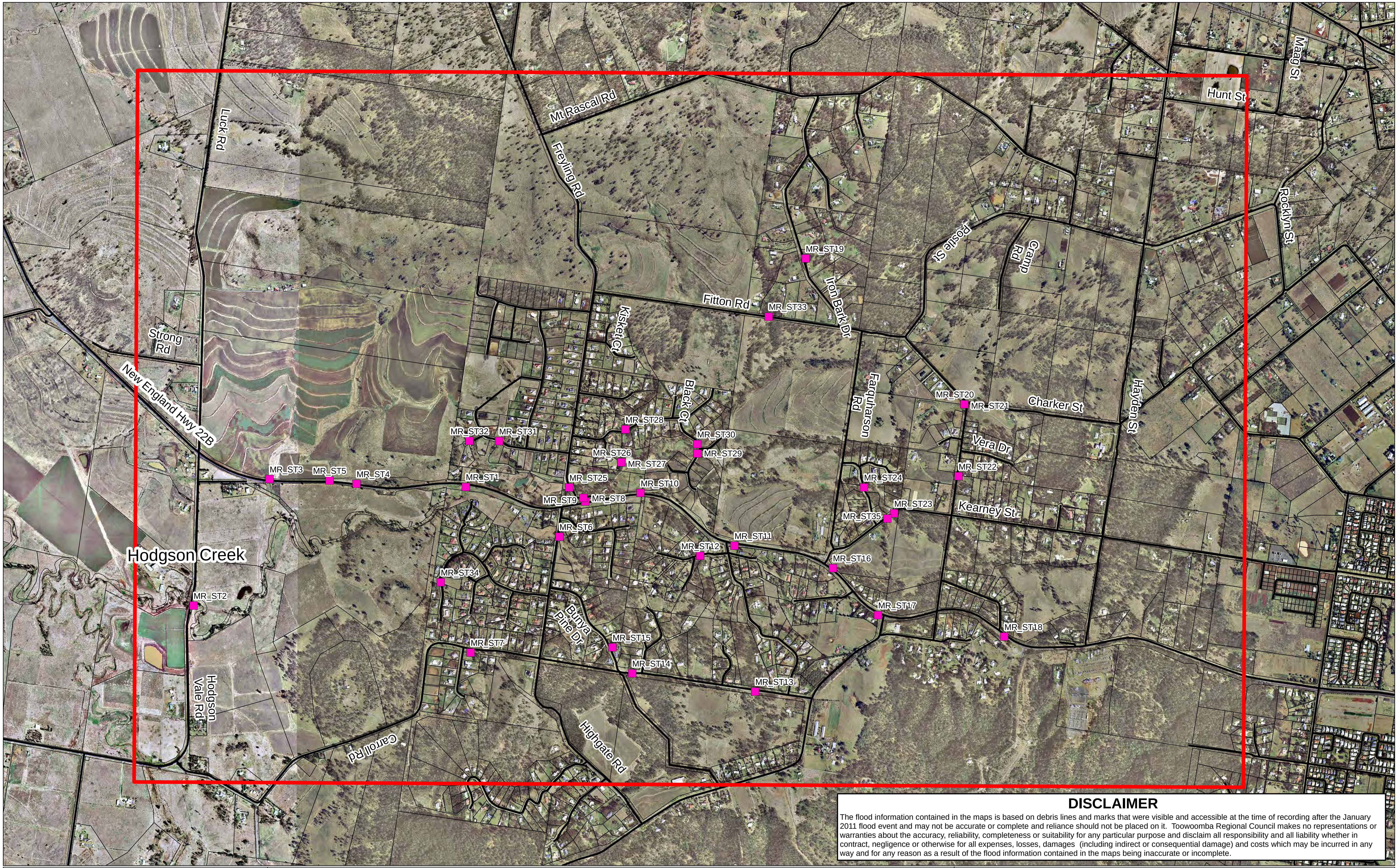
Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
MR_ST1	Mount Rascal	-27.6521	151.934	Bridge	concrete	1				3 Span bridge. Slight skew crossing. Refer site Notes.
MR_ST2	Mount Rascal	-27.6651	151.94	Pipe	corrugated	2	4200			Looks to be partially washed out and repaired. Refer site notes.
MR_ST3	Mount Rascal	-27.6614	151.934	Box	concrete	2	2100	1200	1500	u/s drop inlet structure. Refer site notes.
MR_ST4	Mount Rascal	-27.6573	151.934	Box	concrete	2	450	1200	600	Slight culvert skew. No handrail on crossing
MR_ST5	Mount Rascal	-27.6586	151.934	Pipe	concrete	2	450		1500	Nearly fully blocked
MR_ST6	Mount Rascal	-27.6476	151.937	Pipe	corrugated	1	2150		1300	Steel Handrail (1m). Refer site notes.
MR_ST7	Mount Rascal	-27.6519	151.943	Pipe	concrete	1	1200		2500	Timber fence 1.2m high
MR_ST8	Mount Rascal	-27.6464	151.935	Pipe	concrete	2	525		1300	Drop structure on inlet (depth 900, 2.6m wide) 1.3 off road wall.

MR_ST9	Mount Rascal	-27.6465	151.935	Pipe	concrete	1	375		600	Located just d/s from structure 8 - service road entry to park/facilities
MR_ST10	Mount Rascal	-27.6438	151.934	box	concrete	2	2100	1200	1200	
MR_ST11	Mount Rascal	-27.6393	151.937	Pipe	concrete	2	1350		900	No guard rail. Side pipe inlet u/s headwall 450mm RCP - takes table drain from road. Refer Site notes
MR_ST12	Mount Rascal	-27.641	151.938	Pipe	corrugated	1	1500		2500	Handrail
MR_ST13	Mount Rascal	-27.6384	151.945	Pipe	concrete	2	900		2300	No handrail
MR_ST14	Mount Rascal	-27.6441	151.944	Pipe	concrete	2	1200		3000	No handrail
MR_ST15	Mount Rascal	-27.6451	151.943	Pipe	concrete	2	1350		2000	1100 high chainwire fence
MR_ST16	Mount Rascal	-27.6346	151.938	Pipe	concrete	1	600		nil	Overland will flow down road - no crest low point in road.(Drop Structure refer Site notes)

MR_ST17	Mount Rascal	-27.6325	151.941	Pipe	concrete	2	450			Overland will flow down road - no crest low point in road.(Drop Structure refer Site notes)
MR_ST18	Mount Rascal	-27.6265	151.942	Pipe	concrete	1	600		2000	No guard rail.
MR_ST19	Mount Rascal	-27.6359	151.922	Pipe	concrete	1	1650		6000	No guardrail, high embankment - Iron Bark Drive
MR_ST20	Mount Rascal	-27.6284	151.93	box	concrete	3	2400	900	600	Handrail on d/s headwall (1m). Refer site notes
MR_ST21	Mount Rascal	-27.6284	151.93	Pipe	concrete	2	600		600	Low point in road - refer site notes
MR_ST22	Mount Rascal	-27.6287	151.934	Pipe	concrete	2	357			Inlet pit and fence - refer site notes.
MR_ST23	Mount Rascal	-27.6317	151.936	box	concrete	4	2400	1500	500	No guardrail
MR_ST24	Mount Rascal	-27.6332	151.934	box	concrete	2	2400	1500	2000	Handrail both sides. (Photo 934 – observed on side of footpath)
MR_ST25	Mount Rascal	-27.6472	151.934	Pipe	corrugated	2	1950			Refer site notes

MR_ST26	Mount Rascal	-27.6447	151.933	Pipe	corrugated	1	1200		300	Crossing to sports centre. Refer site notes.
MR_ST27	Mount Rascal	-27.6447	151.933	pipe	concrete	1	300			Location approx. - is d/s of structure 26. Local pedestrian crossing at base of sports fields. Refer site notes
MR_ST28	Mount Rascal	-27.6445	151.931	Pipe	corrugated	4	1500	600		
MR_ST29	Mount Rascal	-27.6411	151.932	box	concrete	3	3600	2x1500h	1x1700h	Handrails 1100 high. refer site notes
MR_ST30	Mount Rascal	-27.6411	151.932	box	concrete	3	2700	2x1500h	1x1700h	Handrails 1100 high. refer site notes
MR_ST31	Mount Rascal	-27.6505	151.932	Pipe	concrete	1	1350			1800 diam. glory hole inlet. Grate on inlet - 50mm bars @ 150 centres. Handrail on inlet/outlet. "Z" shape pipe culvert alignment - refer site notes for details
MR_ST32	Mount Rascal	-27.6519	151.932	Pipe	concrete	1	1200		2600	cover approx.
MR_ST33	Mount Rascal	-27.6377	151.925	Pipe	concrete	1	1800		3000-4000	cover approx.

MR_ST34	Mount Rascal	-27.6533	151.939	Pipe	concrete	1	1200		2000	Co-ordinates approx. Extra culvert on subsequent visit. Windermere Drive crossing. Drop structure on US side 900x900 w/grate w/45mm bar spacing. Low flow pipe in us channel. Looks approx 600mm. Cover is approx. 2m. Cover was 1m from grated inlet
MR_ST35	Mount Rascal	-27.6321	151.935	pipe	concrete	1	1050		100	road crossing



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

- Structures
- Cadastre
- Model Domain Extents
- Major Road Centre Lines

SP051 Flood Studies - Work Package 6

Mount Rascal Structure Map

MTR-E-STRUCTURES.mxd
Author/Date: Ryan.dermek 4/04/2014

APPENDIX D HYDRAULIC MODEL SOURCE POINTS

Table D1 – 2 – 200 year ARI MIKE Source Nodes

XP-RAFTS ID	MIKE ID	MIKE (j,k)
1	1	(1501,2903)
1	2	(1501,2902)
2	3	(1461,2754)
3	4	(903,1296)
4	5	(1045,1018)
5	6	(1437,2746)
6	7	(1442,2740)
7	8	(1044,1012)
8	9	(954,972)
9	10	(1113,870)
9	11	(1114,869)
10	12	(1051,929)
11	13	(1022,908)
11	14	(1022,909)
12	15	(1051,2801)
12	16	(1051,2800)
13	17	(1370,2650)
14	18	(1310,2726)
15	19	(1113,2706)
16	20	(1173,2634)
16	21	(1172,2633)
17	22	(1243,753)
18	23	(1277,2554)
19	24	(1243,2586)
20	25	(1276,2416)
20	26	(1277,2417)
21	27	(1469,2503)
22	28	(1301,2392)
23	29	(1312,2283)
24	30	(1488,2304)
25	31	(1275,2289)
26	32	(1218,2155)
26	33	(1219,2156)
27	34	(1062,2201)
28	35	(911,2244)
29	36	(1084,1963)
30	37	(1005,2014)
30	38	(1006,2013)
31	39	(997,2382)

32	40	(990,2384)
33	41	(806,2340)
34	42	(638,2502)
34	43	(638,2501)
35	44	(762,2271)
35	45	(762,2270)
36	46	(794,2280)
37	47	(761,2232)
37	48	(762,2232)
38	49	(499,2293)
39	50	(620,2252)
40	51	(1384,2014)
41	52	(1193,2025)
42	53	(1209,1985)
43	54	(1102,1848)
44	55	(997,1863)
45	56	(182,2161)
46	57	(226,2043)
46	58	(226,2042)
47	59	(326,1939)
47	60	(326,1938)
48	61	(201,2009)
49	62	(7,2018)
49	63	(8,2018)
50	64	(762,1906)
51	65	(467,1797)
51	66	(467,1797)
52	67	(435,1850)
53	68	(1188,763)
54	69	(1333,775)
54	70	(1332,774)
55	71	(1437,847)
56	72	(104,1873)
57	73	(116,1836)
57	74	(116,1835)
58	75	(324,1915)
59	76	(1030,317)
59	77	(1031,317)
59	78	(1032,317)
59	79	(1033,318)
60	80	(1006,445)
60	81	(1006,444)

60	82	(1006,443)
60	83	(1006,442)
61	84	(654,652)
61	85	(655,651)
62	86	(1401,303)
62	87	(1402,303)
62	88	(1403,303)
62	89	(1404,302)
62	90	(1405,302)
63	91	(1165,593)
63	92	(1166,593)
64	93	(1536,676)
64	94	(1535,675)
65	95	(1511,806)
66	96	(1793,1418)
66	97	(1792,1418)
67	98	(1671,1116)
67	99	(1670,1117)
68	100	(1680,925)
69	101	(1545,898)
69	102	(1544,897)
70	103	(1571,1213)
71	104	(1628,1323)
71	105	(1627,1323)
72	106	(1781,1418)
73	107	(662,2661)
73	108	(662,2660)
74	109	(663,2657)
74	110	(664,2657)
74	111	(665,2657)
75	112	(1535,1602)
76	113	(1410,1530)
76	114	(1409,1530)
77	115	(1403,1714)
77	116	(1402,1713)
78	117	(1504,1270)
79	118	(1255,1605)
79	119	(1254,1604)
80	120	(1313,1484)
81	121	(1142,1362)
82	122	(1078,1499)
83	123	(824,1632)

83	124	(824,1631)
84	125	(1024,1560)
84	126	(1024,1559)
85	127	(1075,1554)
85	128	(1074,1554)
86	129	(806,1368)
86	130	(807,1367)
86	131	(808,1366)
87	132	(616,1418)
87	133	(617,1419)
88	134	(969,1487)
88	135	(970,1486)
89	136	(790,1614)
90	137	(1509,1290)
91	138	(530,1681)
92	139	(346,1764)
93	140	(342,1762)
94	141	(140,1495)
95	142	(281,1616)
96	143	(438,1626)
97	144	(607,1659)
98	145	(434,1603)
99	146	(351,1557)
100	147	(336,1366)
100	148	(337,1366)
101	149	(436,1390)
102	150	(291,1315)
103	151	(365,1349)
104	152	(430,1305)
104	153	(431,1306)
105	154	(1034,2815)
105	155	(1035,2814)
106	156	(1670,1637)
106	157	(1669,1636)
107	158	(1307,2739)
107	159	(1307,2738)
107	160	(1307,2737)
108	161	(750,961)
108	162	(749,961)
109	163	(864,830)
109	164	(865,831)
110	165	(1256,1133)

110	166	(1255,1132)
111	167	(1082,1187)
112	168	(1016,1316)
112	169	(1016,1317)
113	170	(1054,1180)
114	171	(1071,653)

Table D1 – 500 – PMP-DF year ARI MIKE Source Nodes

XP-RAFTS ID	MIKE ID	MIKE (j,k)
1	1	(1501,2903)
1	2	(1501,2902)
1	3	(1501,2901)
1	4	(1501,2900)
2	5	(1461,2754)
2	6	(1460,2754)
2	7	(1459,2754)
3	8	(903,1295)
3	9	(902,1295)
3	10	(901,1295)
3	11	(903,1296)
4	12	(1045,1018)
4	13	(1044,1018)
5	14	(1437,2746)
5	15	(1437,2747)
5	16	(1436,2746)
6	17	(1442,2740)
7	18	(1044,1012)
7	19	(1043,1012)
8	20	(954,972)
8	21	(954,973)
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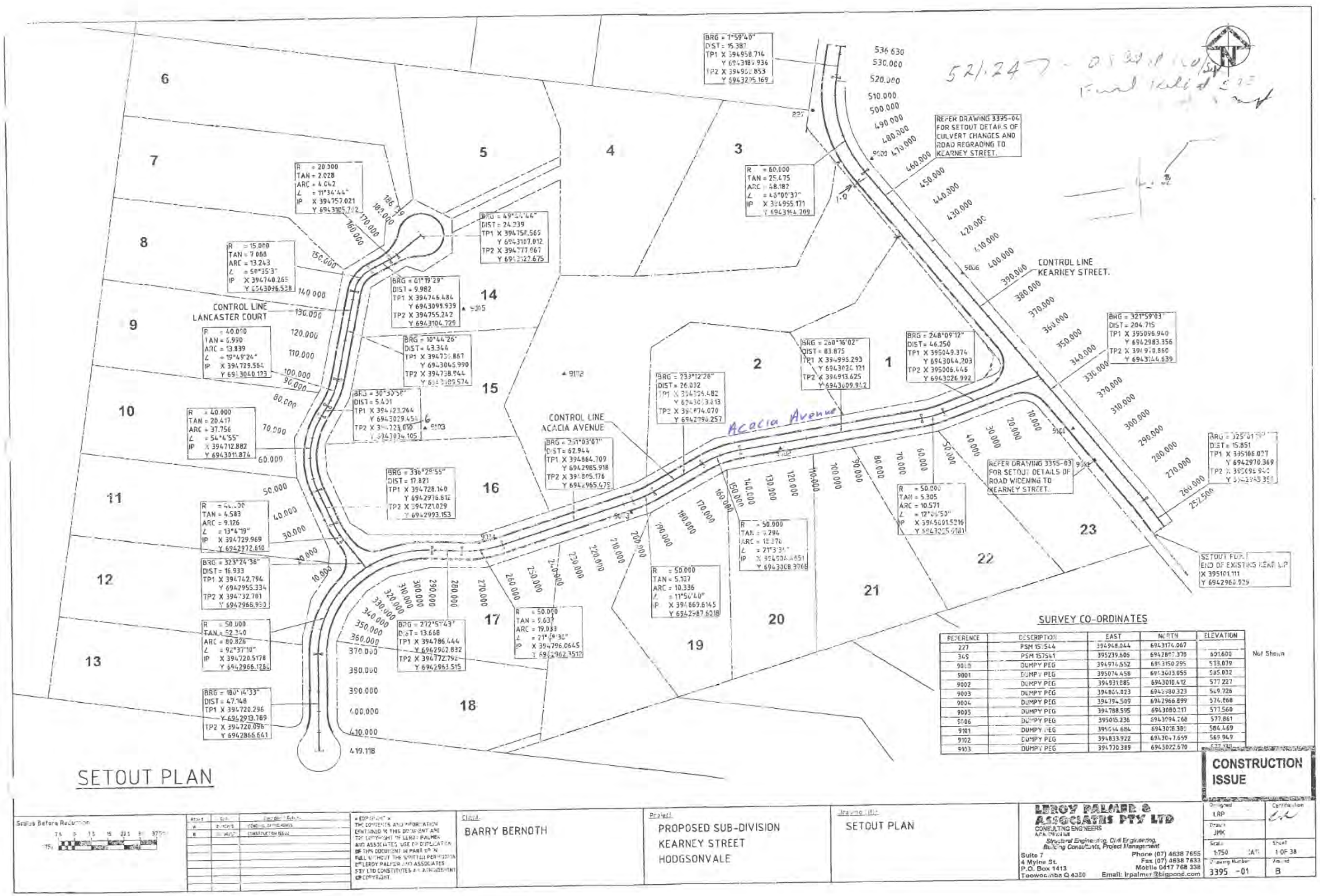
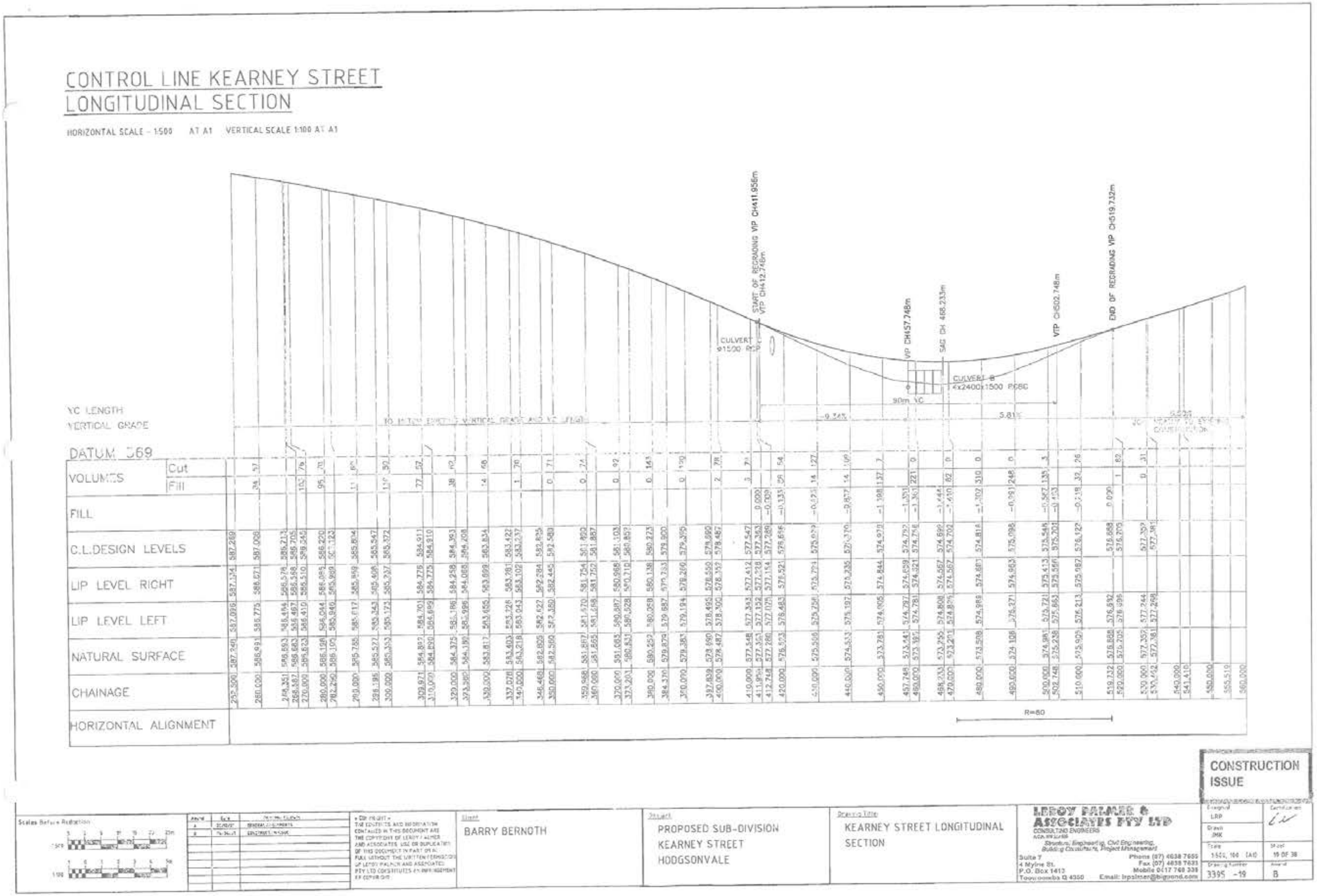
APPENDIX E KEARNEY STREET CONSTRUCTION ISSUE DRAWINGS


SETOUT PLAN
CONTROL LINE KEARNEY STREET.
CONTROL LINE LANCASTER COURT
CONTROL LINE ACACIA AVENUE
Acacia Avenue
REFER DRAWING 3395-04 FOR SETOUT DETAILS OF CULVERT CHANGES AND ROAD REGRADING TO KEARNEY STREET.
REFER DRAWING 3395-03 FOR SETOUT DETAILS OF ROAD WIDENING TO KEARNEY STREET.
SETOUT POINT END OF EXISTING KERB L/P
X 395101.111
SURVEY CO-ORDINATES
REFERENCE | DESCRIPTION | EAST | NORTH | ELEVATION
227 | PSM 157544 | 394948.044 | 6943174.067 |
345 | PSM 157541 | 395239.606 | 6942807.378 | 601.600 | Not Shown
9001 | DUMPY PEG | 395074.458 | 6943003.055 | 585.032
9002 | DUMPY PEG | 394931.885 | 6943010.412 | 577.227
9004 | DUMPY PEG | 394794.509 | 6942966.899 | 574.868
9005 | DUMPY PEG | 394788.595 | 6943080.217 | 577.560
9101 | DUMPY PEG | 395044.684 | | 584.469
9102 | DUMPY PEG | 394833.922 | | 569.949
9103 | DUMPY PEG | 394770.389 | 6943022.670 |
CONSTRUCTION ISSUE
Client BARRY BERNOTH
Project PROPOSED SUB-DIVISION KEARNEY STREET HODGSONVALE
Drawing title SETOUT PLAN
LEROY PALMER & ASSOCIATES PTY LTD
CONSULTING ENGINEERS
Structural Engineering, Civil Engineering, Building Consultants, Project Management
Suite 7 4 Myine St. P.O. Box 1413 Toowoomba Q 4350
Phone (07) 4638 7655
Fax (07) 4638 7633
Mobile 0417 768 338
Email: lrpalmer@bigpond.com
Designed LRP
Drawn JMK
Scale 1:750
Sheet 1 OF 38
Drawing Number 3395 -01
Amend B

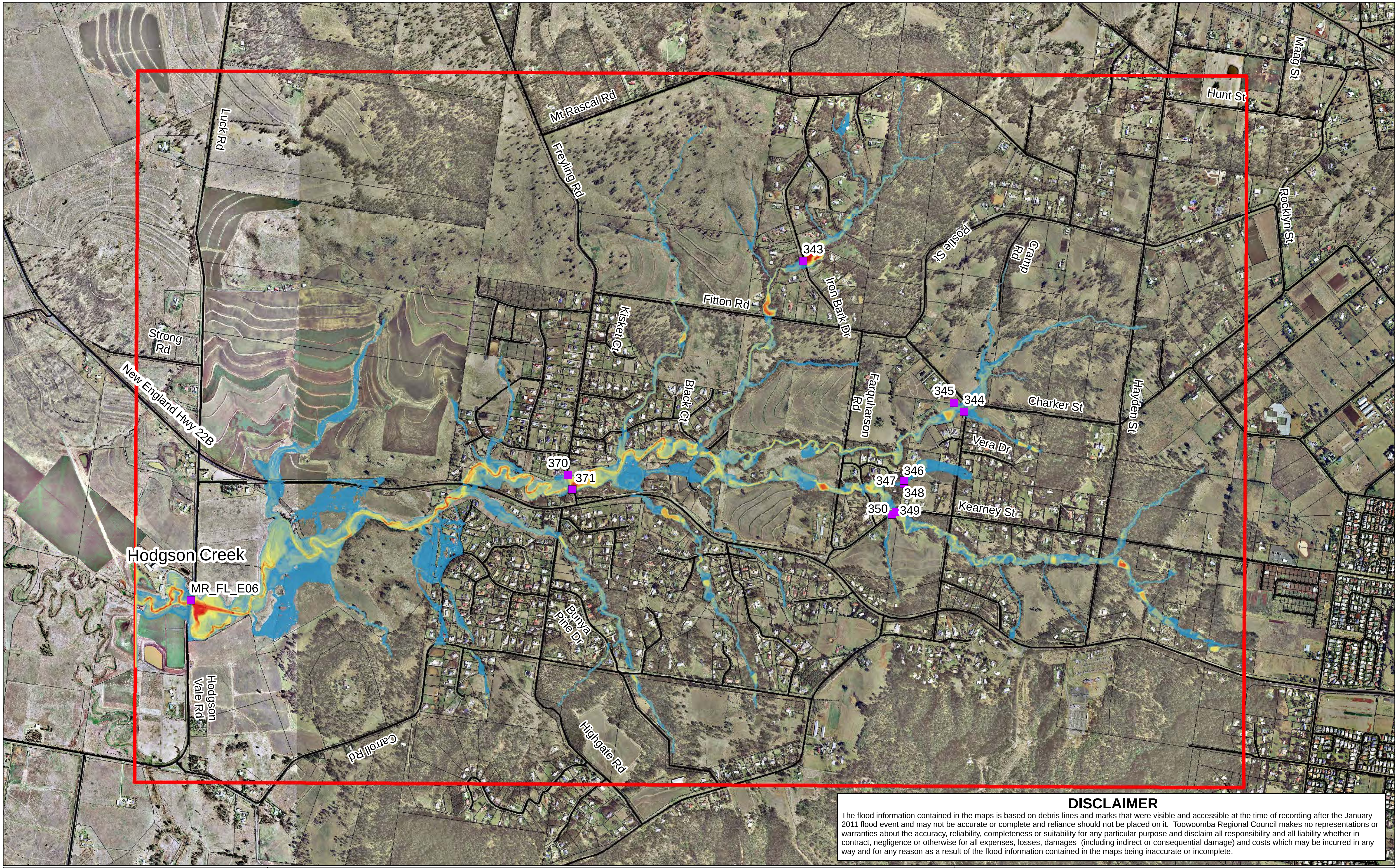

CONTROL LINE KEARNEY STREET
LONGITUDINAL SECTION
HORIZONTAL SCALE - 1:500 AT A1 VERTICAL SCALE 1:100 AT A1
START OF REGRADING VIP CH411.956m
VIP CH412.746m
VIP CH457.748m
SAG CH 468.233m
VIP CH502.748m
END OF REGRADING VIP CH519.732m
CULVERT
ø1500 RCP
CULVERT B
4x2400x1500 RCBC
90m VC
VC LENGTH
VERTICAL GRADE
DATUM 569
VOLUMES
Cut
Fill
FILL
C.L.DESIGN LEVELS
LIP LEVEL RIGHT
LIP LEVEL LEFT
NATURAL SURFACE
CHAINAGE
HORIZONTAL ALIGNMENT
R=80
CONSTRUCTION ISSUE
BARRY BERNOTH
PROPOSED SUB-DIVISION
KEARNEY STREET
HODGSONVALE
KEARNEY STREET LONGITUDINAL SECTION
LEROY PALMER & ASSOCIATES PTY LTD
3395 -19
B

APPENDIX F STRUCTURE PEAK FLOW SUMMARY

Structure ID (Note 1)	100 year ARI Peak Flow
MR_ST1	163.2
MR_ST2	145.3
MR_ST3	19.6
MR_ST4	1.6
MR_ST5	0.7
MR_ST6	18.4
MR_ST7	6.0
MR_ST10	12.9
MR_ST11	8.2
MR_ST12	10.1
MR_ST13	4.8
MR_ST14	13.2
MR_ST15	9.4
MR_ST19	15.6
MR_ST20	20.1
MR_ST21	1.9
MR_ST22	0.2
MR_ST23	40.0
MR_ST24	39.1
MR_ST25	34.9
MR_ST26	3.4
MR_ST28	28.4
MR_ST29	63.8
MR_ST30	34.6
MR_ST31	6.4
MR_ST32	4.7
MR_ST33	18.2
MR_ST34	6.2
MR_ST35	1.5

Note 1 – Refer Appendix A for structure locations.

APPENDIX G HISTORIC EVENT CALIBRATION/VALIDATION MAPS



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Calibration Points
- Model Domain Extents
- Major Road Centre Lines
- Cadastre

January 2011 Flood Depth

Depth Band (m)

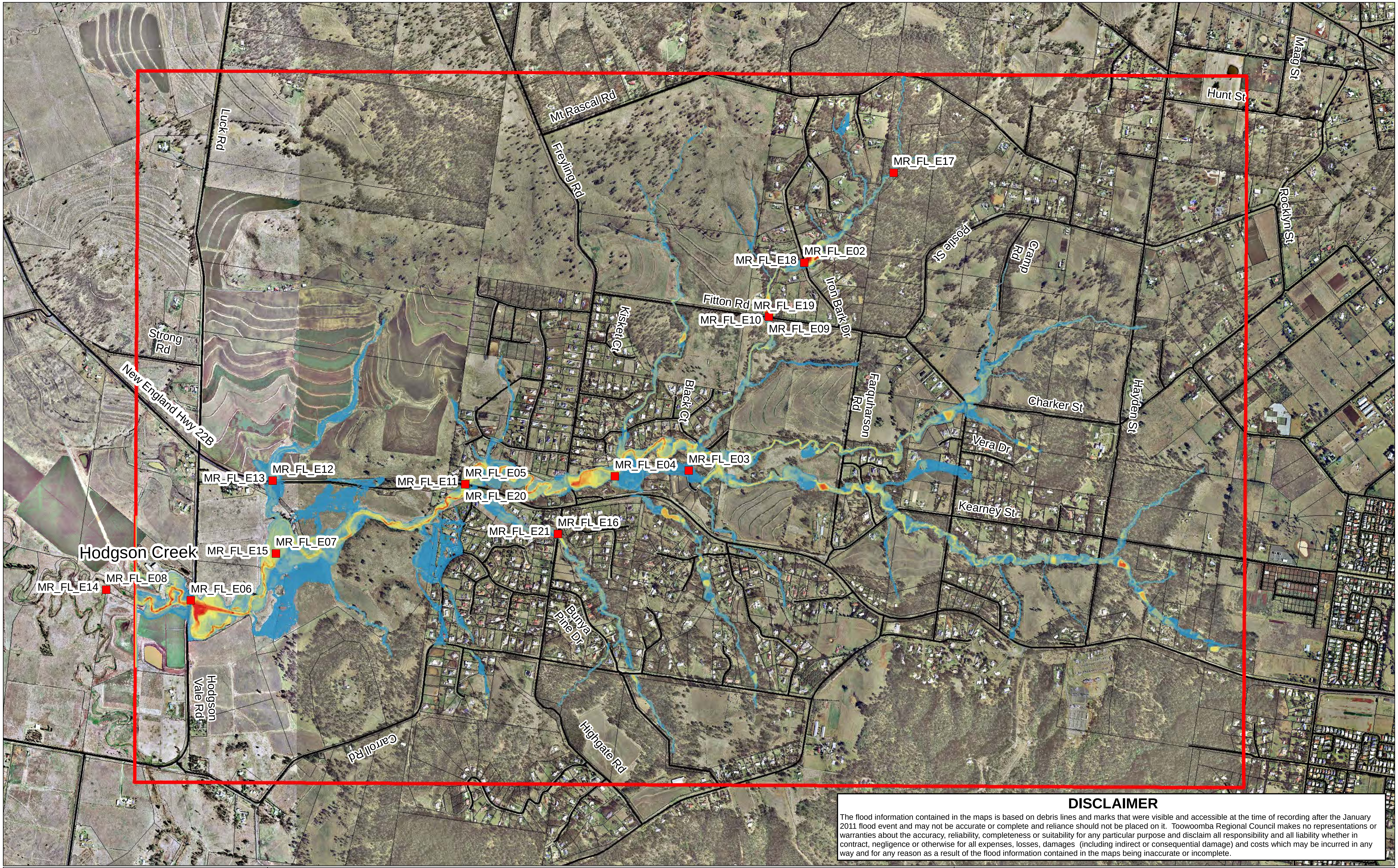
- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 6

Mount Rascal January 2011 Peak Flood Depth with Calibration Points

Disclaimer: Whilst all due care has been taken in the preparation of the plan and all information (the Plan and all information is referred to as "Plan information"), the accuracy of the Plan Information cannot be guaranteed. The Plan Information is provided as a guide and should not be relied upon in anyway whatsoever. Toowoomba Regional Council takes no responsibility for inaccuracies in the Plan Information and is not liable under any circumstances for any loss or damage whatsoever or howsoever caused arising directly or indirectly in connection with its use. The recipient must verify the Plan Information on site. Please refer any discrepancies to Toowoomba Regional Council - Information, Communications & Technology. No part of the Plan Information should be reproduced without the permission of the Coordinator GIS - ICT Branch, or other delegated representative of Council (131872).

MTR-E-CAL-PTS.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

Anecdotal Flood Records

Cadastre

Model Domain Extents

Major Road Centre Lines

January 2011 Flood Depth

Depth Band (m)

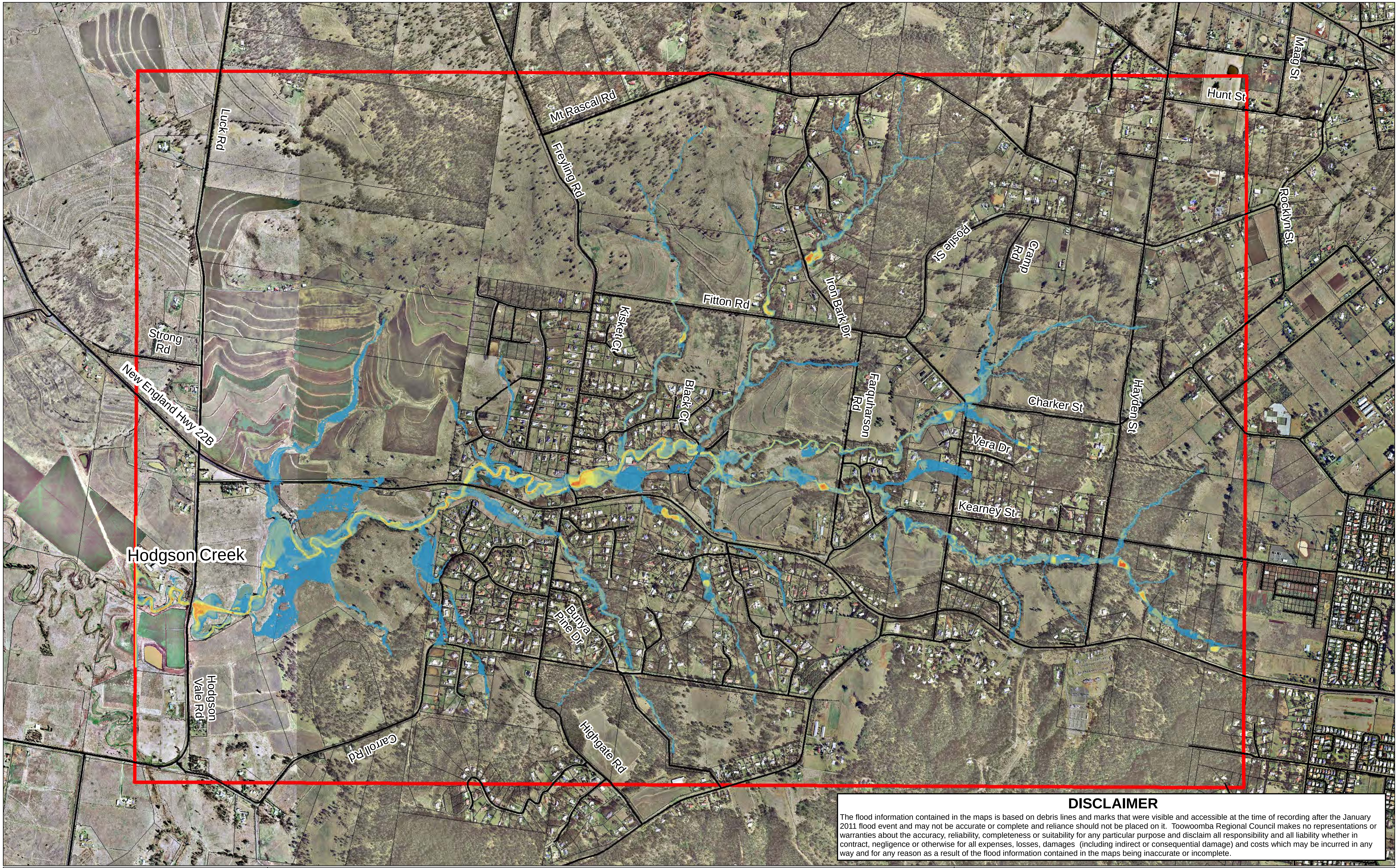
0.005 to 0.25	1.0 to 1.5	3.0 to 3.5	>5.0
0.25 to 0.5	1.5 to 2.0	3.5 to 4.0	
0.5 to 1.0	2.0 to 2.5	4.0 to 4.5	
	2.5 to 3.0	4.5 to 5.0	

SP051 Flood Studies - Work Package 6

Mount Rascal January 2011 Peak Flood Depth with Validation Points

MTR-E-VAL-PTS.mxd
Author/Date: Ryan.dermek 4/04/2014

APPENDIX H DESIGN EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

GDA 1994 MGA Zone 56

N

Legend

- Major Road Centre Lines
- Model Domain Extents
- Cadastre

Flood Depth

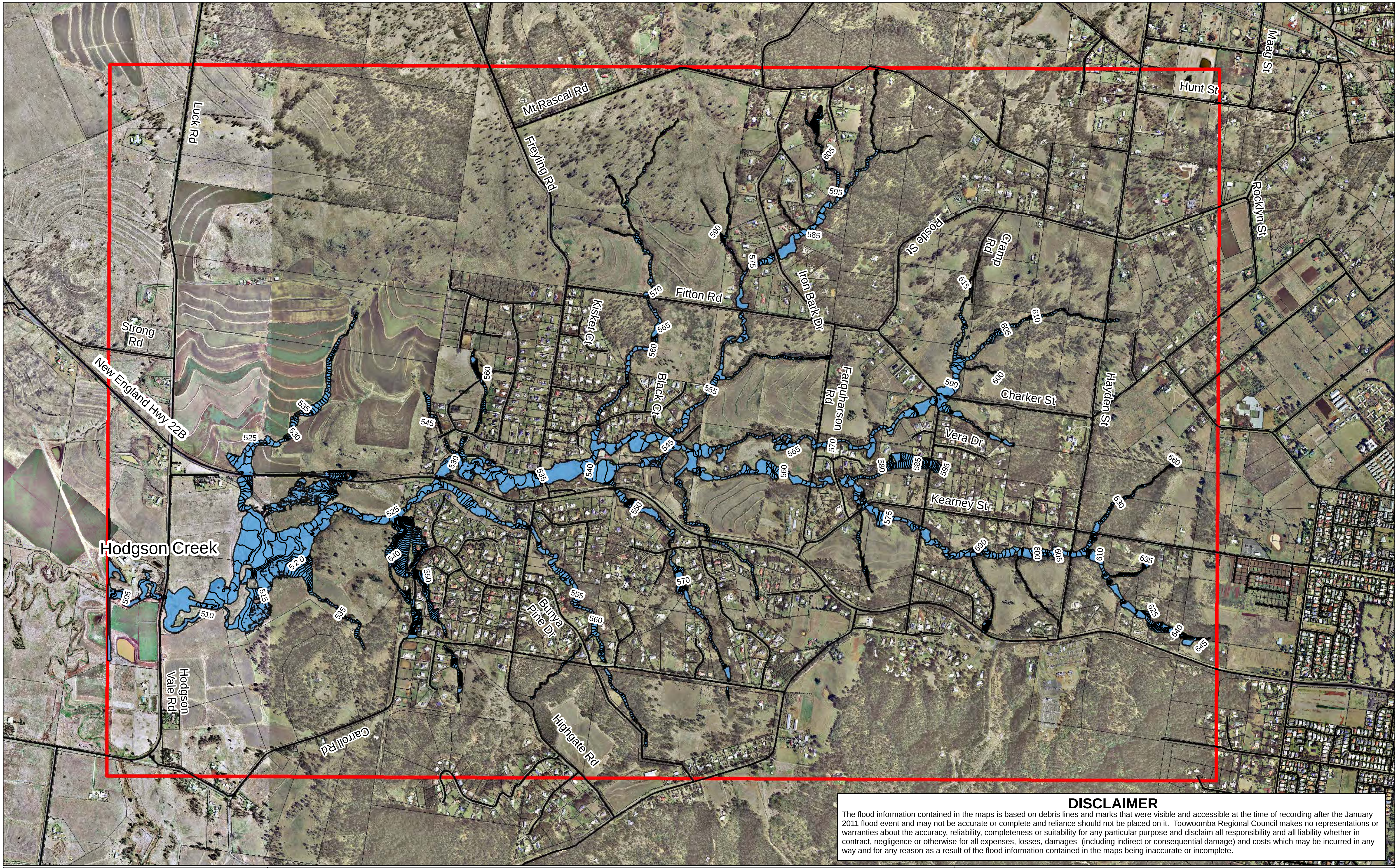
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 6

Mount Rascal 10 Year ARI Peak Flood Depth

MTR-E-Q10-D.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

Major Road Centre Lines
Model Domain Extents
Cadastre

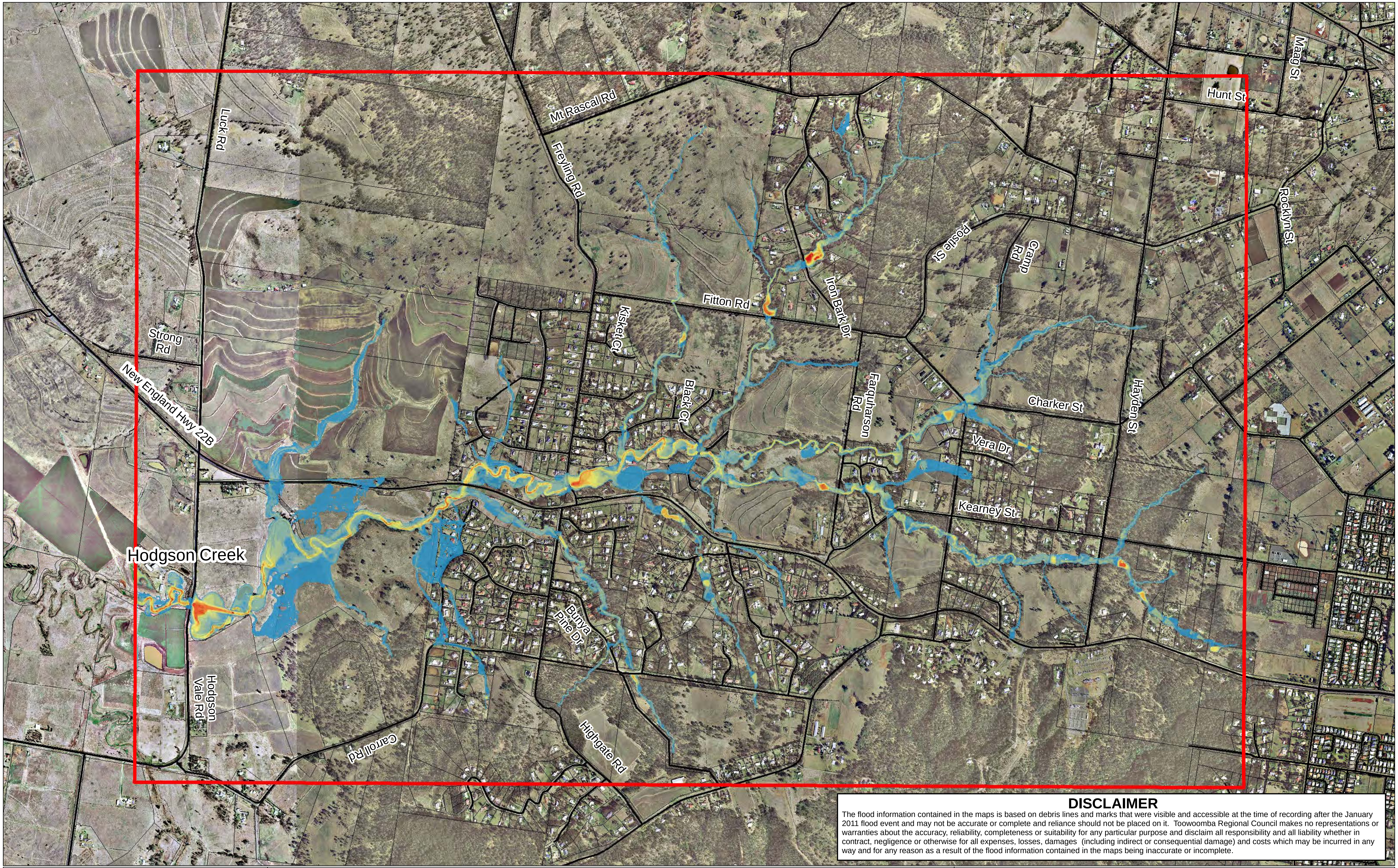
Flood Extent

10yr ARI
0.5m Flood Contours (mAHD)

SP051 Flood Studies - Work Package 6

Mount Rascal 10 Year ARI Peak Water Surface Level

MTR-E-Q10-H.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Flood Depth

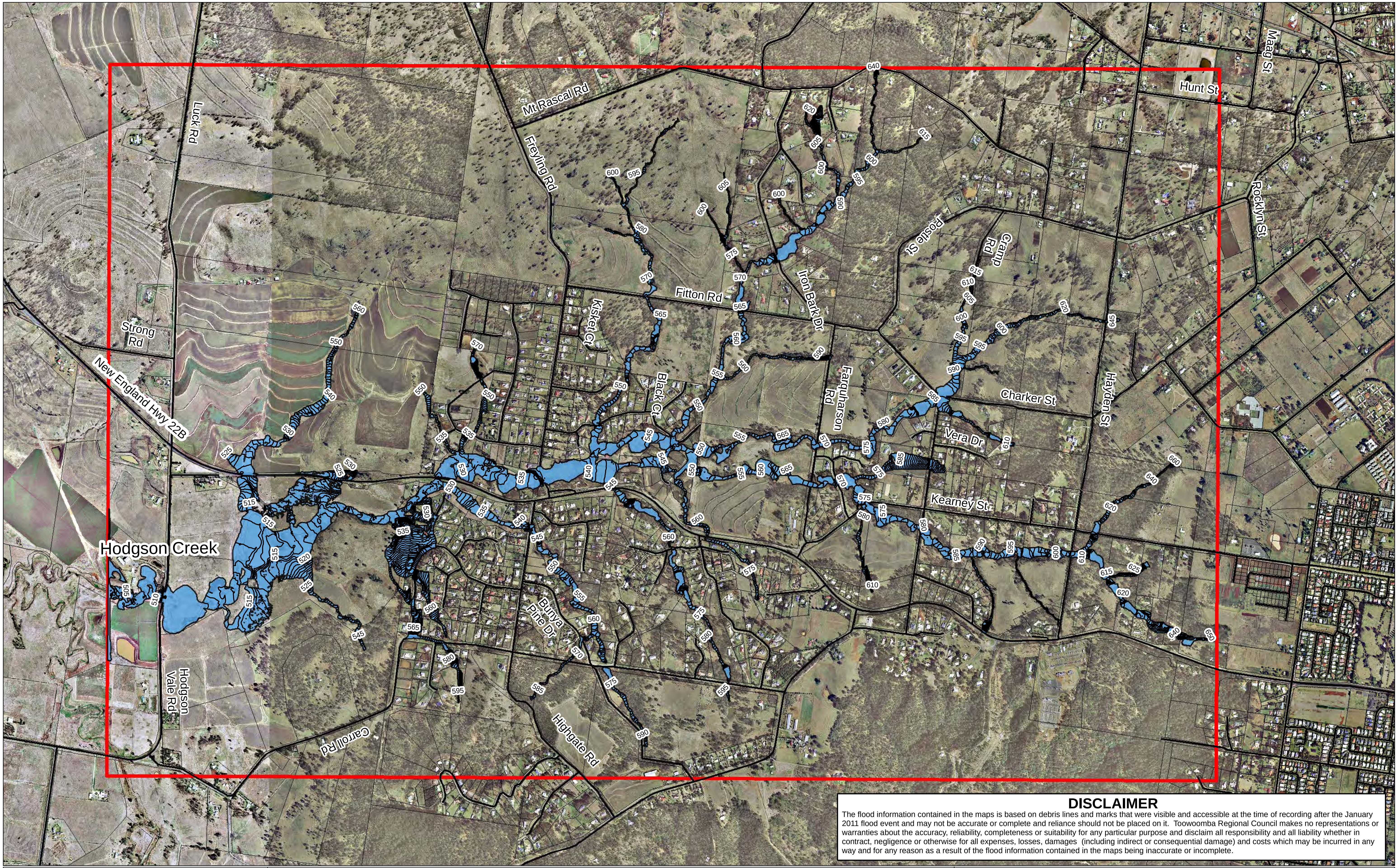
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 6

Mount Rascal 50 Year ARI Peak Flood Depth

MTR-E-Q50-D.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

GDA 1994 MGA Zone 56

N

Legend

- Major Road Centre Lines
- Model Domain Extents
- Cadastre

Flood Extent

- 50yr ARI
- 0.5m Flood Contours (mAHD)

SP051 Flood Studies - Work Package 6

Mount Rascal 50 Year ARI Peak Water Surface Level

MTR-E-Q10-D.mxd
Author/Date: Ryan.dermek 4/04/2014

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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- velleg2_plz
- Major Road Centre Lines
- Cadastre

Q100 Flood Depth

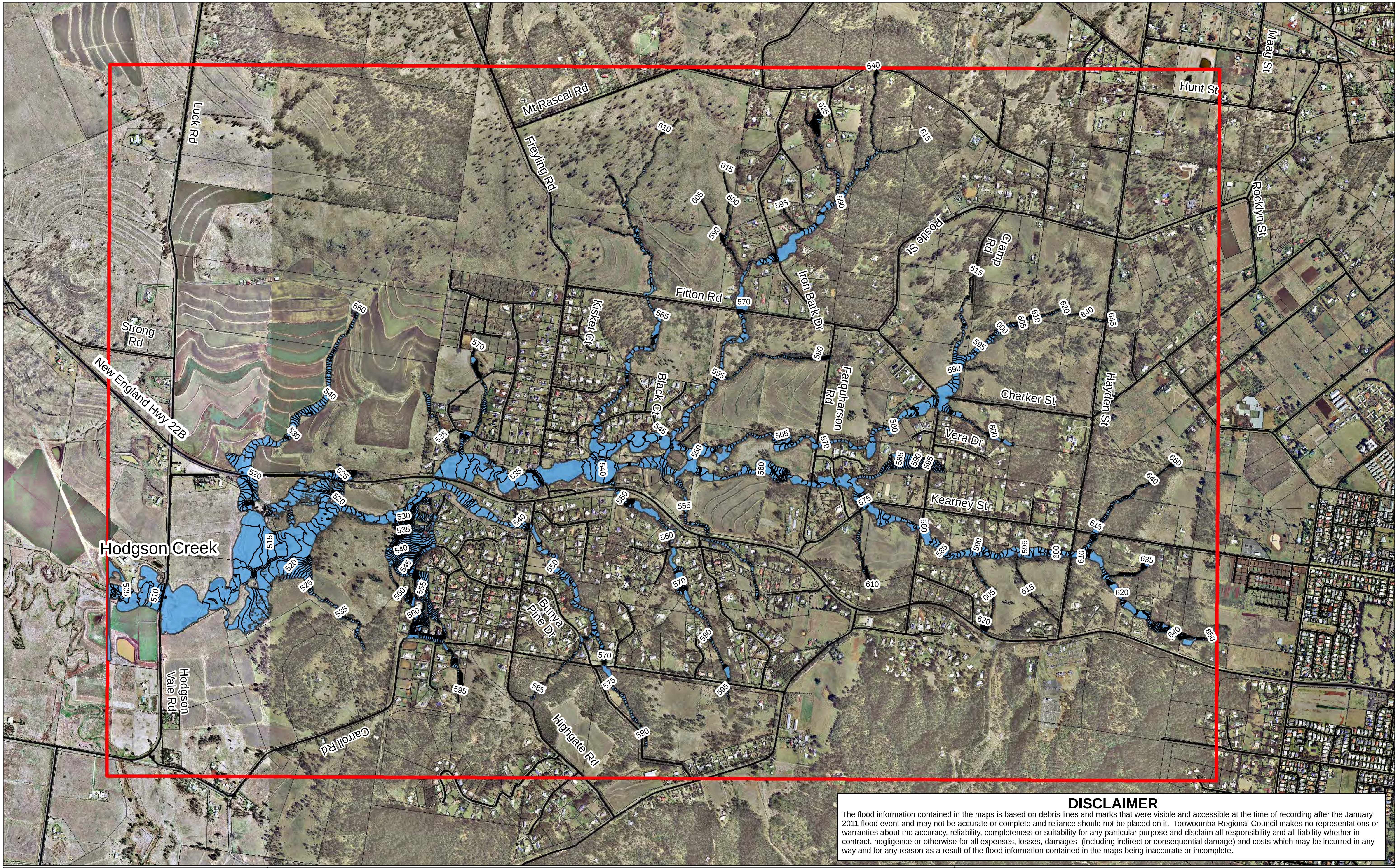
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0
- → Scaled Velocity Vector (1m/s)

SP051 Flood Studies - Work Package 6

Mount Rascal 100 Year ARI Peak Flood Depth

MTR-E-Q100-D.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

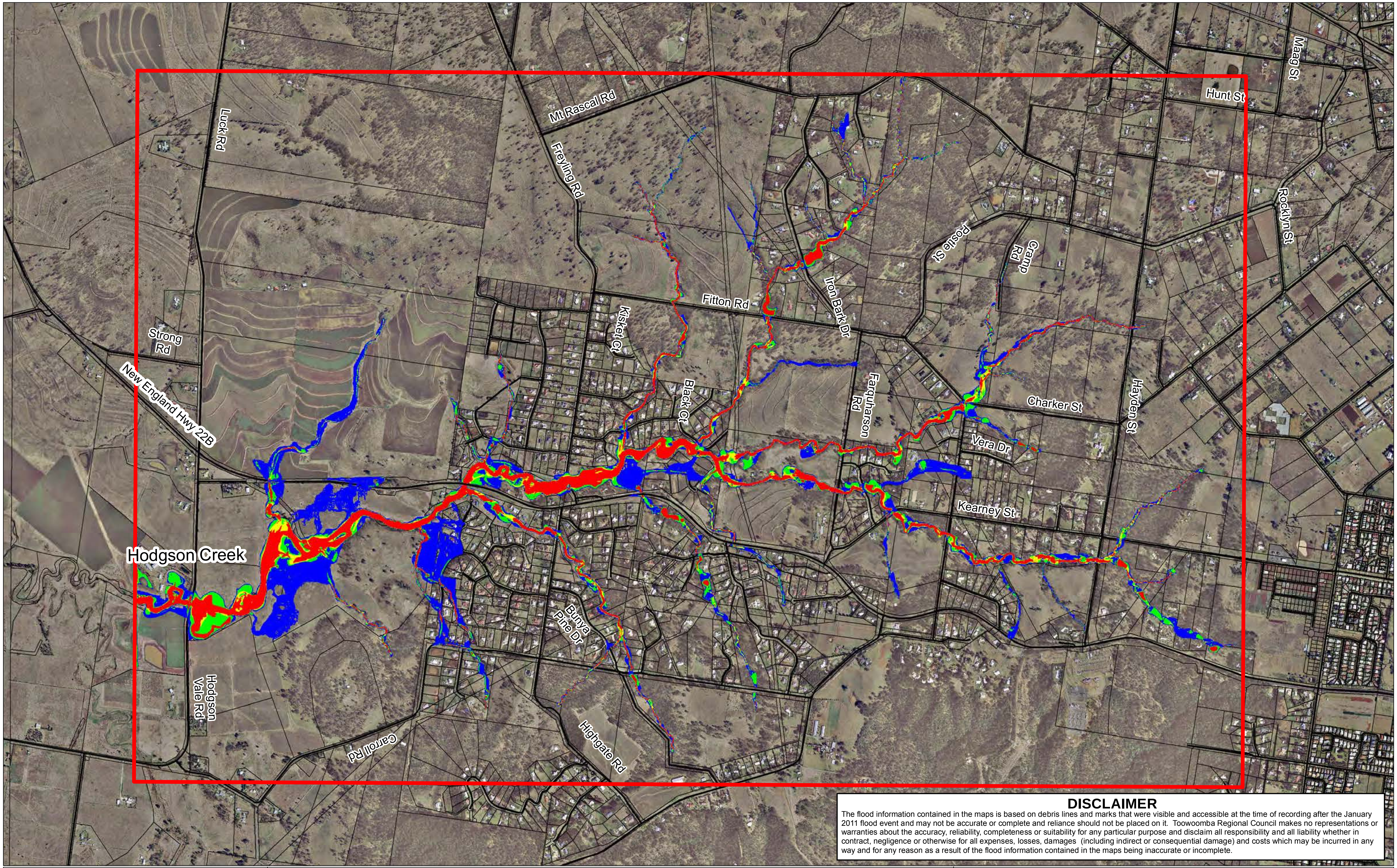
Flood Extent

- 100yr ARI
- 0.5m Flood Contours (mAHD)

SP051 Flood Studies - Work Package 6

Mount Rascal 100 Year ARI Peak Water Surface Level

MTR-E-Q100-H.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

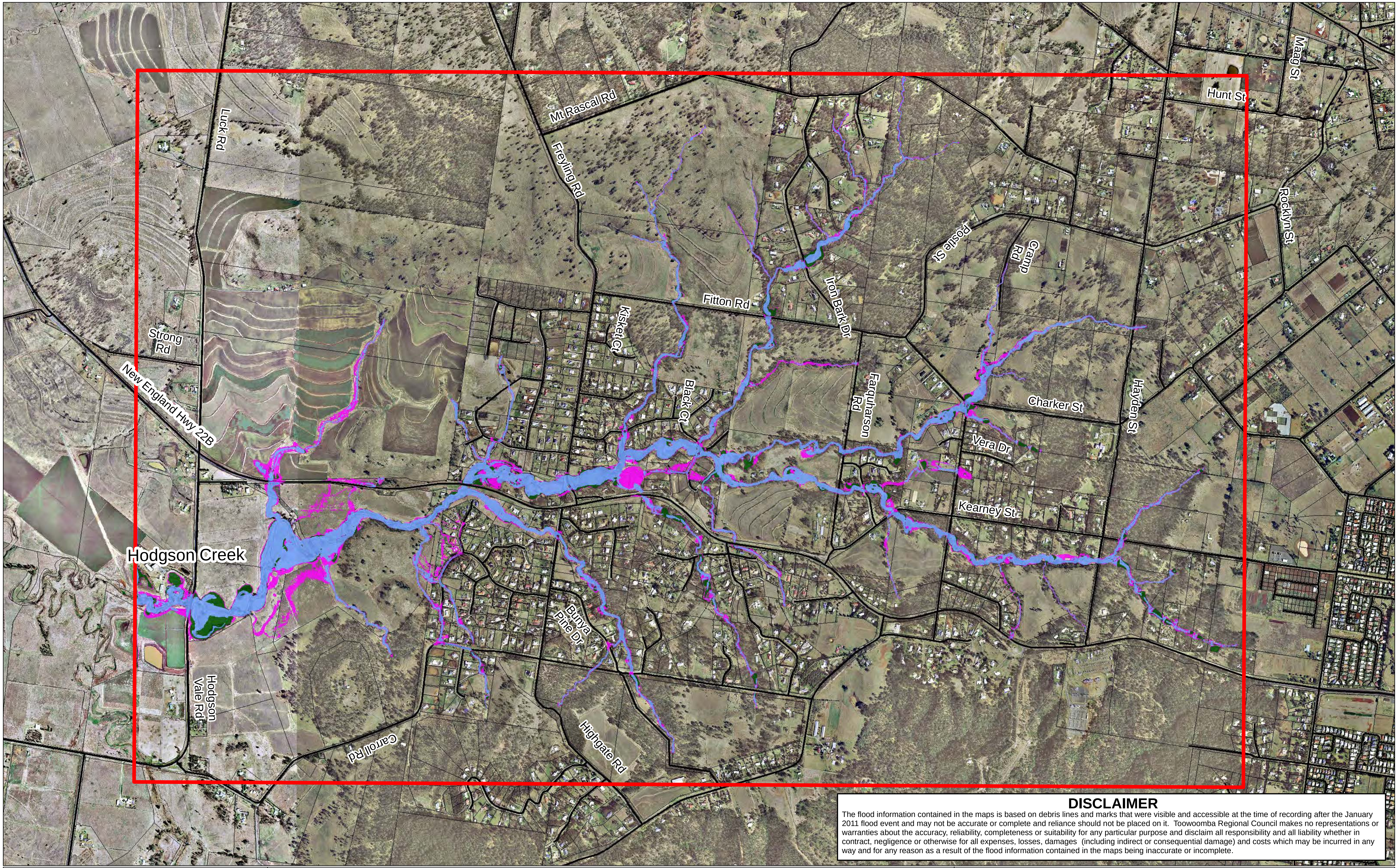
Hazard Category

- Low
- High
- Significant
- Extreme

SP051 Flood Studies - Work Package 6

Mount Rascal 100 Year ARI Flood Hazard

MTR-E-Q100-HAZ.mxd
Author/Date: blair.filer 8/09/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Hydraulic Category

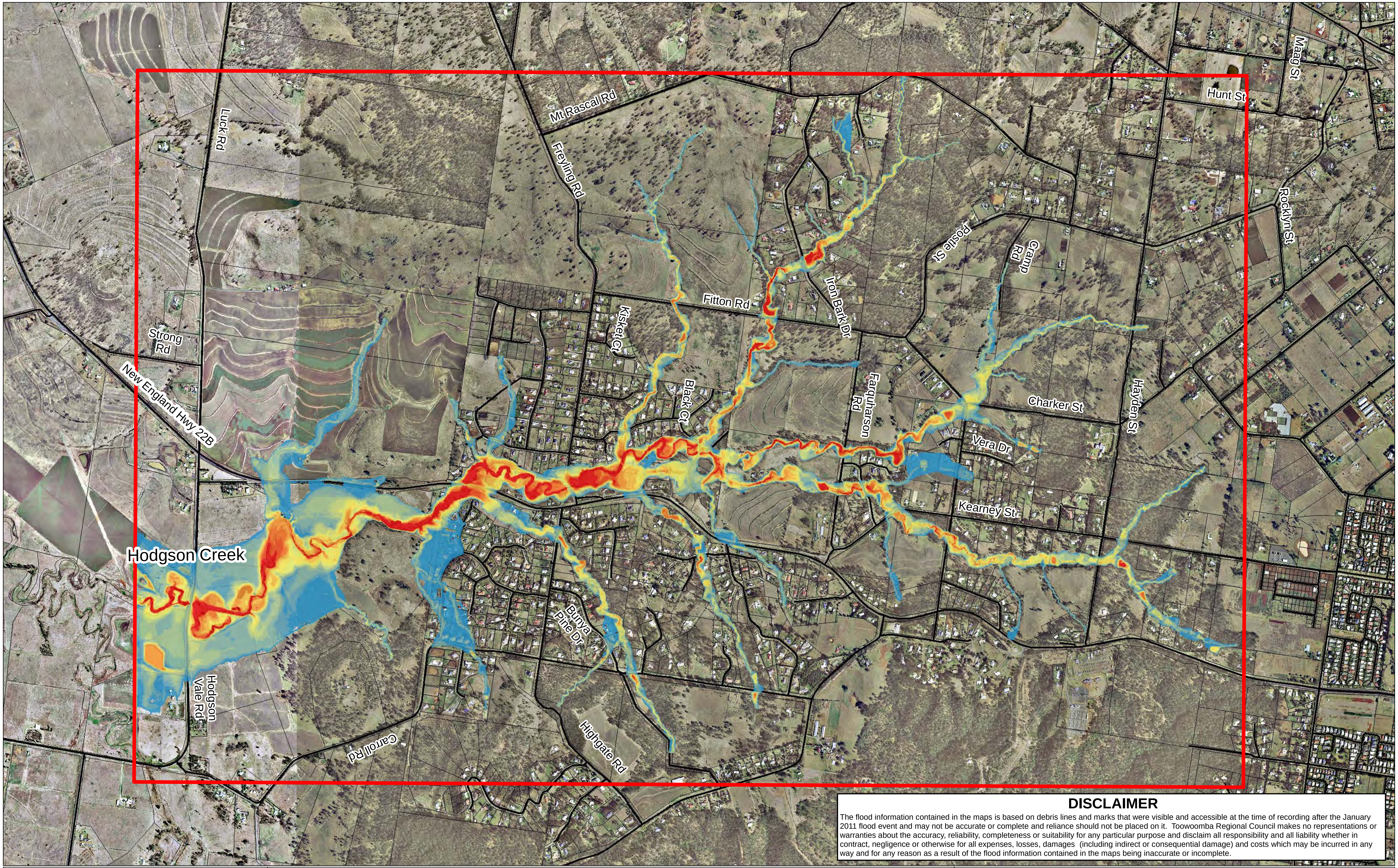
- Floodway
- Flood Fringe
- Flood Storage

SP051 Flood Studies - Work Package 6

Mount Rascal 100 Year ARI Hydraulic Category

MTR-E-Q100-HYD.mxd
Author/Date: Ryan.dermek 4/04/2014

APPENDIX I RARE AND EXTREME EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Flood Depth

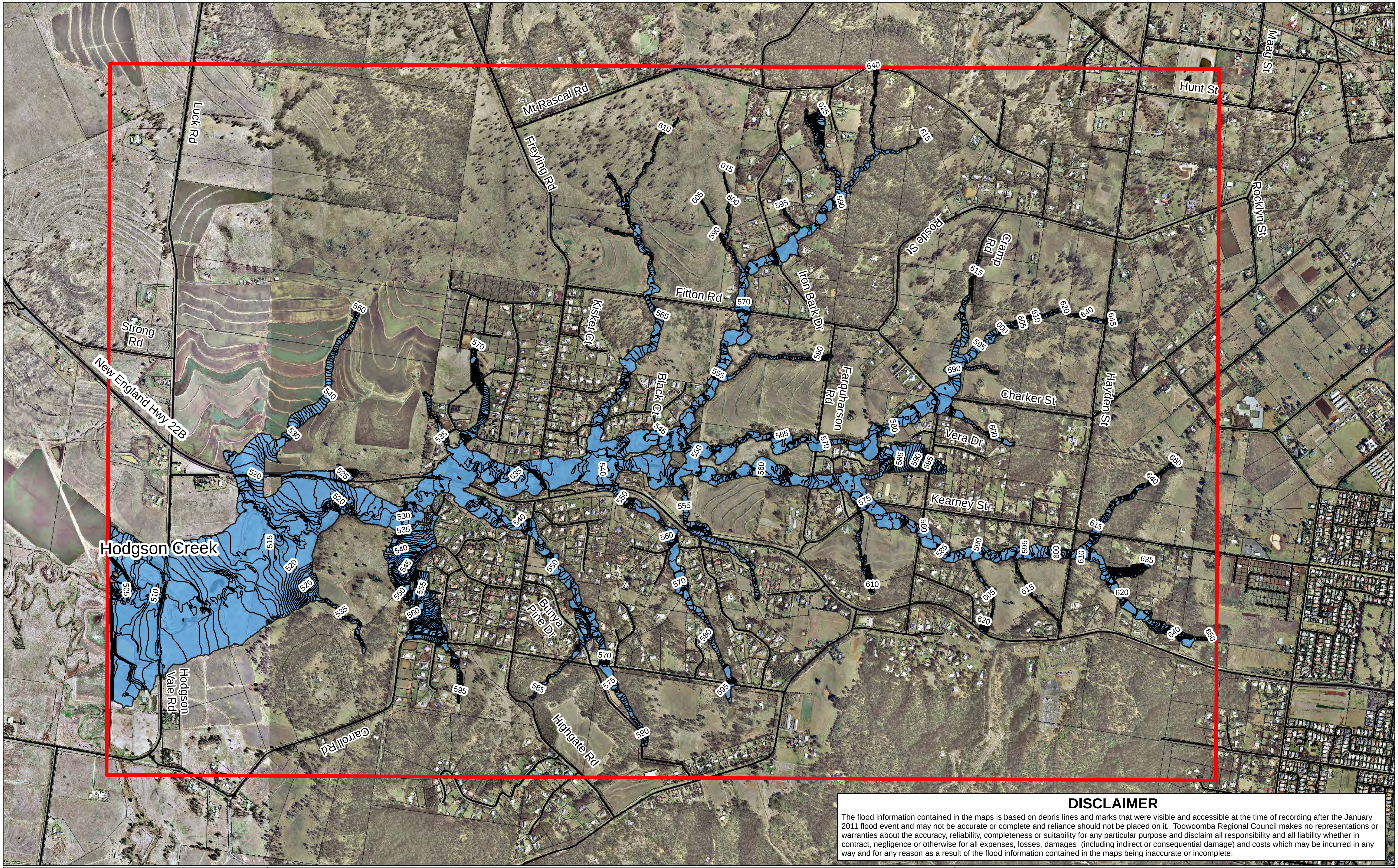
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 6

Mount Rascal PMF Peak Flood Depth

MTR-E-PMF-D.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

GDA 1994 MGA Zone 56

N

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

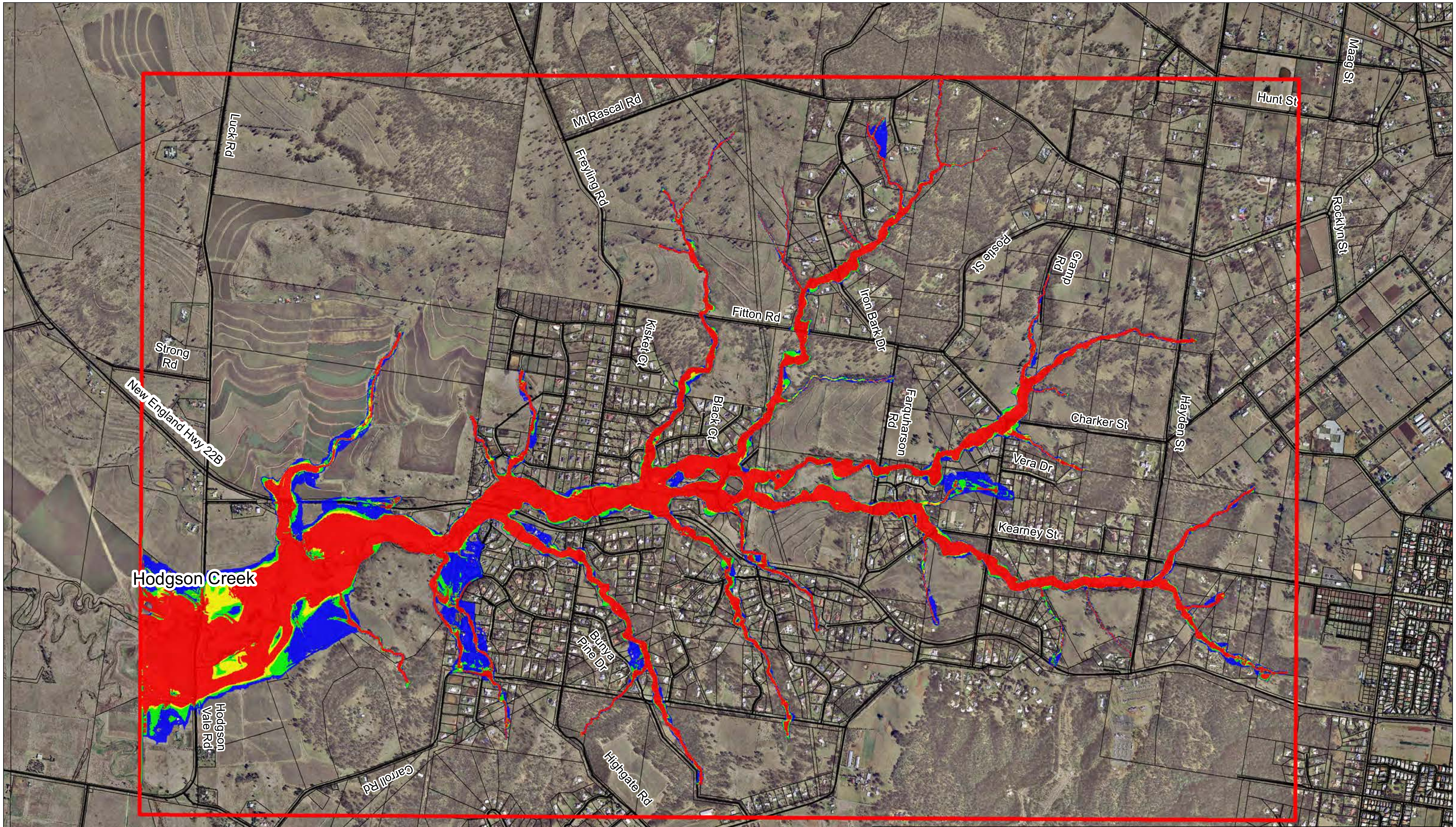
Flood Extent

- 0.5m Flood Contours (mAHD)
- PMF Event

SP051 Flood Studies - Work Package 6

Mount Rascal PMF Event Peak Water Surface Level

MTR-E-PMF-H.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550

Meters

GDA 1994 MGA Zone 56

N

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

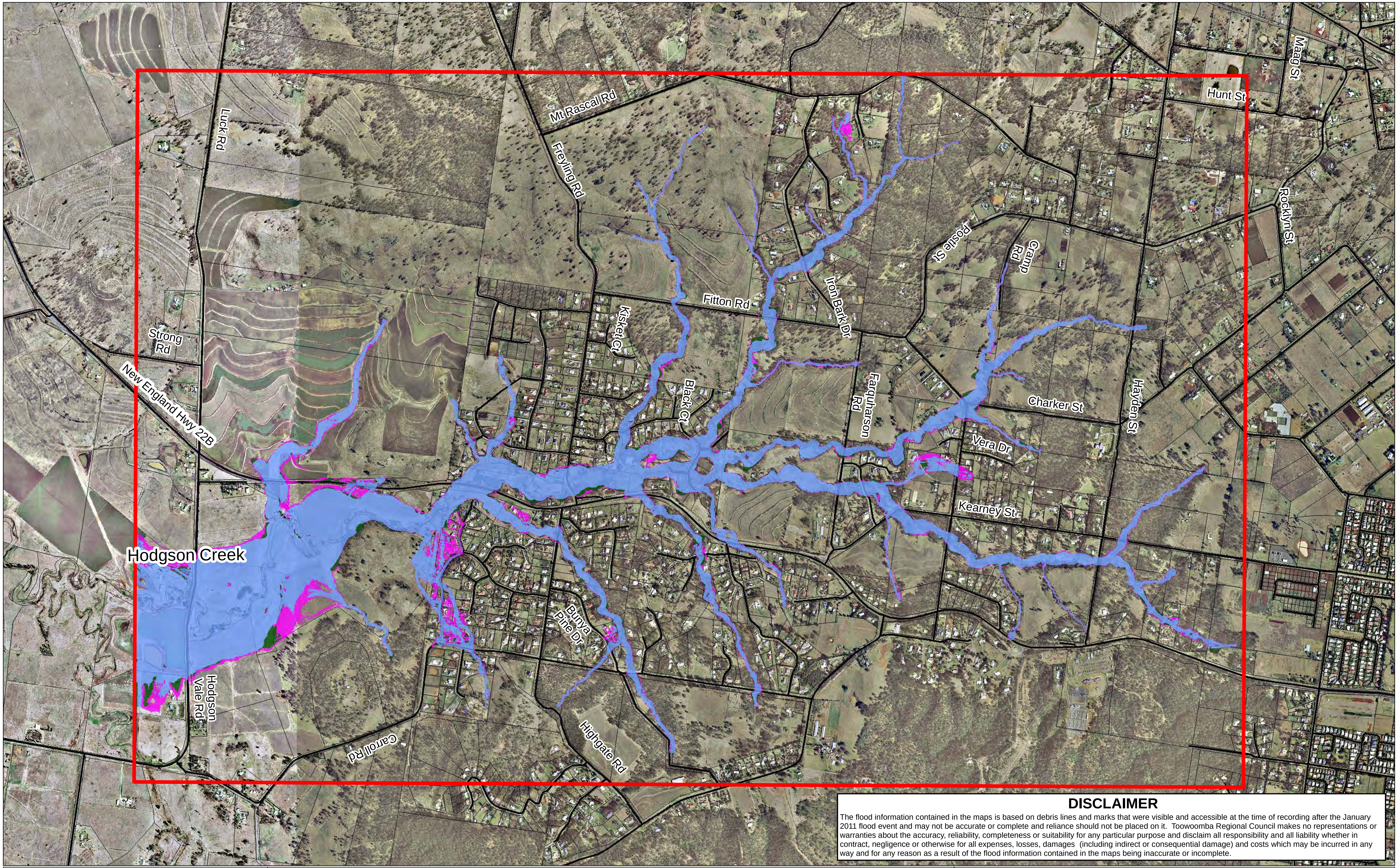
Hazard Category

- Low
- Significant
- High
- Extreme

SP051 Flood Studies - Work Package 6

Mount Rascal PMF Flood Hazard

MTR-E-PMF-HAZ.mxd
Author/Date: blair.filer 8/09/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

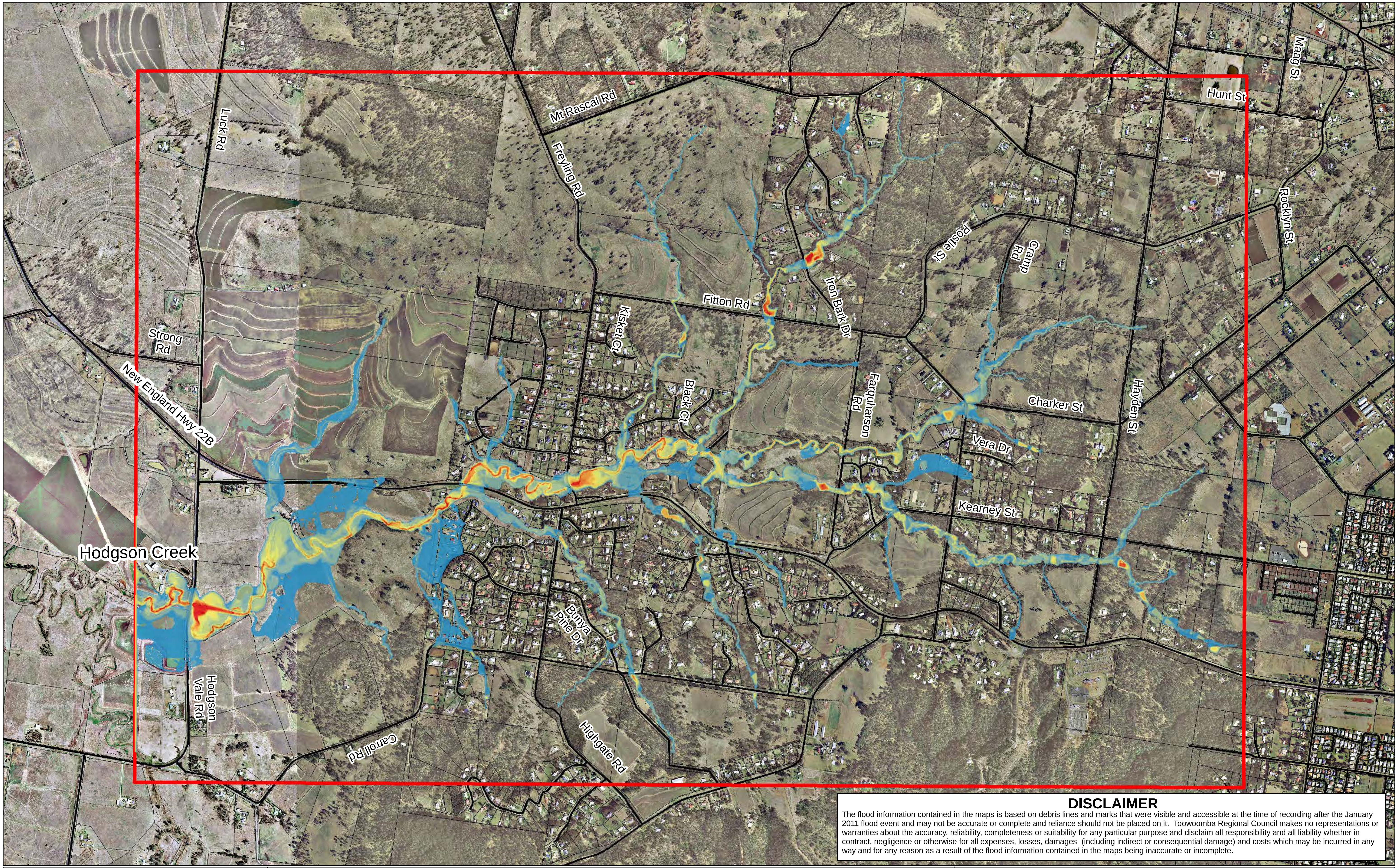
Hydraulic Category

- Floodway
- Flood Storage
- Flood Fringe

SP051 Flood Studies - Work Package 6

Mount Rascal PMF Hydraulic Category

MTR-E-PMF-HYD.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

Model Domain Extents
Major Road Centre Lines
Cadastre

Flood Depth

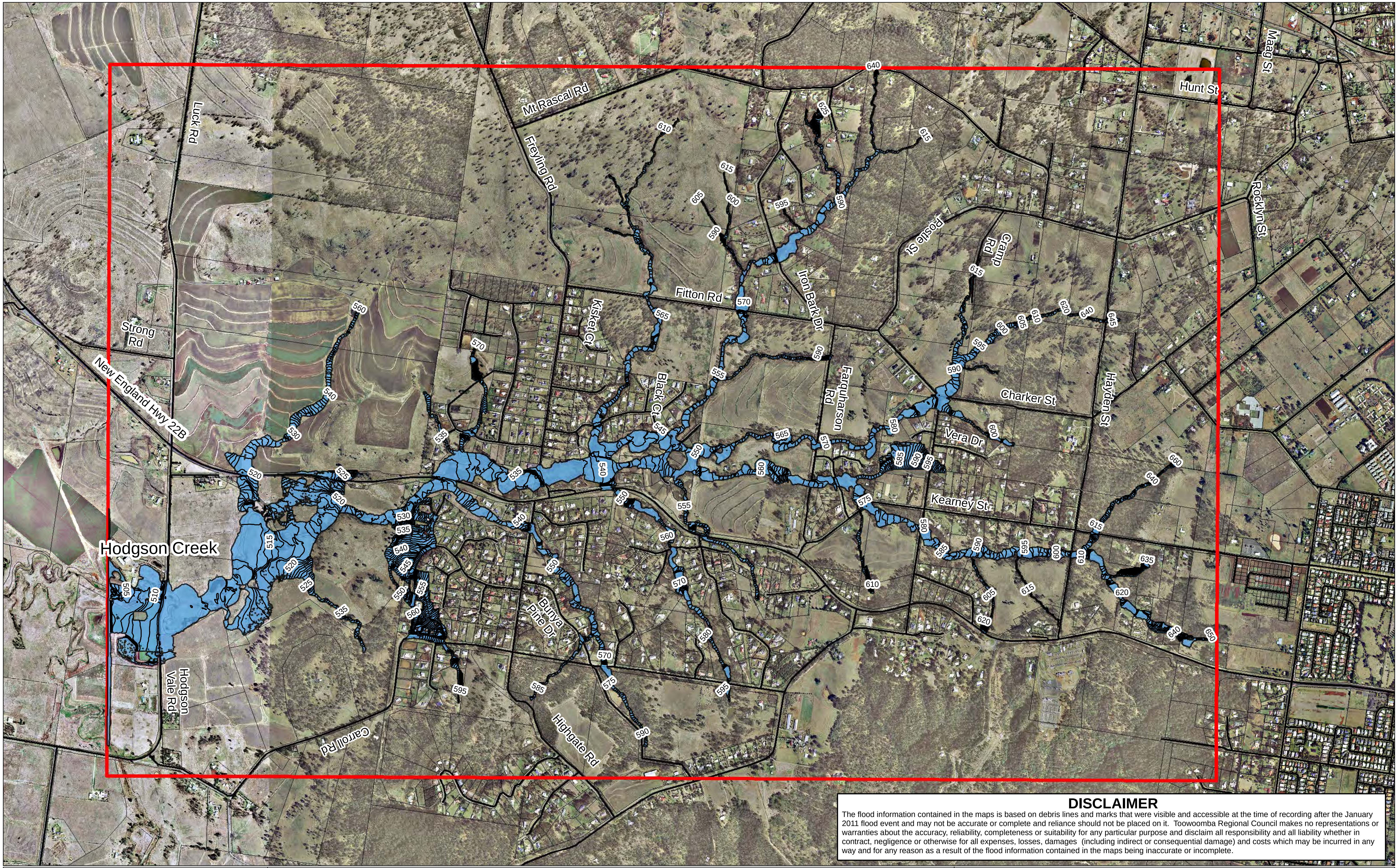
Depth Band (m)

0.005 to 0.25	0.5 to 1.0	2.0 to 2.5	3.5 to 4.0	>5.0
0.25 to 0.5	1.0 to 1.5	2.5 to 3.0	4.0 to 4.5	
	1.5 to 2.0	3.0 to 3.5	4.5 to 5.0	

SP051 Flood Studies - Work Package 6

Mount Rascal 500 Year ARI Peak Flood Depth

MTR-E-Q500-D.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

GDA 1994 MGA Zone 56

N

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Flood Extent

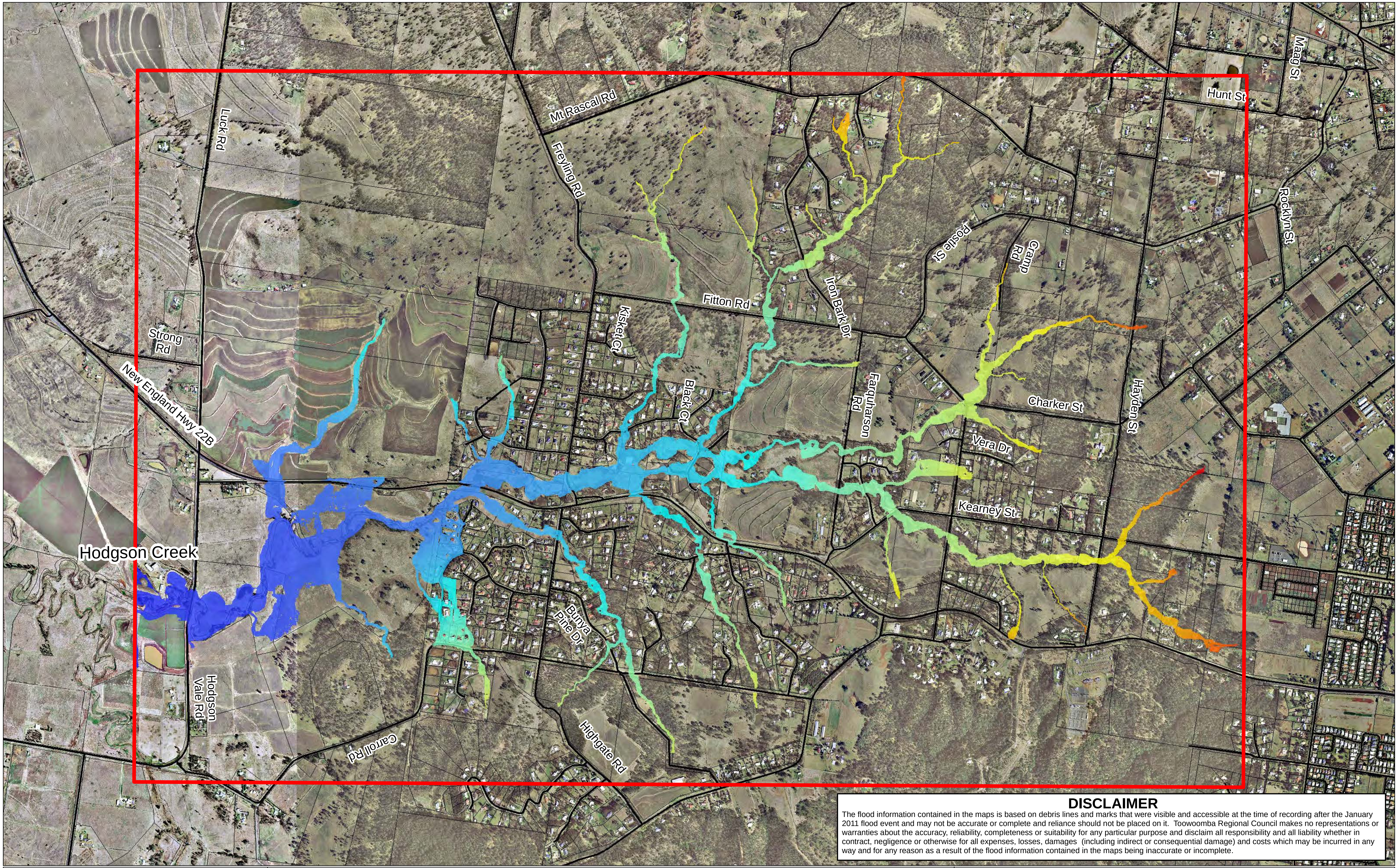
- 500yr ARI
- 0.5m Flood Contours (mAHD)

SP051 Flood Studies - Work Package 6

Mount Rascal 500 Year ARI Peak Water Surface Level

MTR-E-Q500-H.mxd
Author/Date: Ryan.dermek 4/04/2014

APPENDIX J CLIMATE CHANGE SCENARIO EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

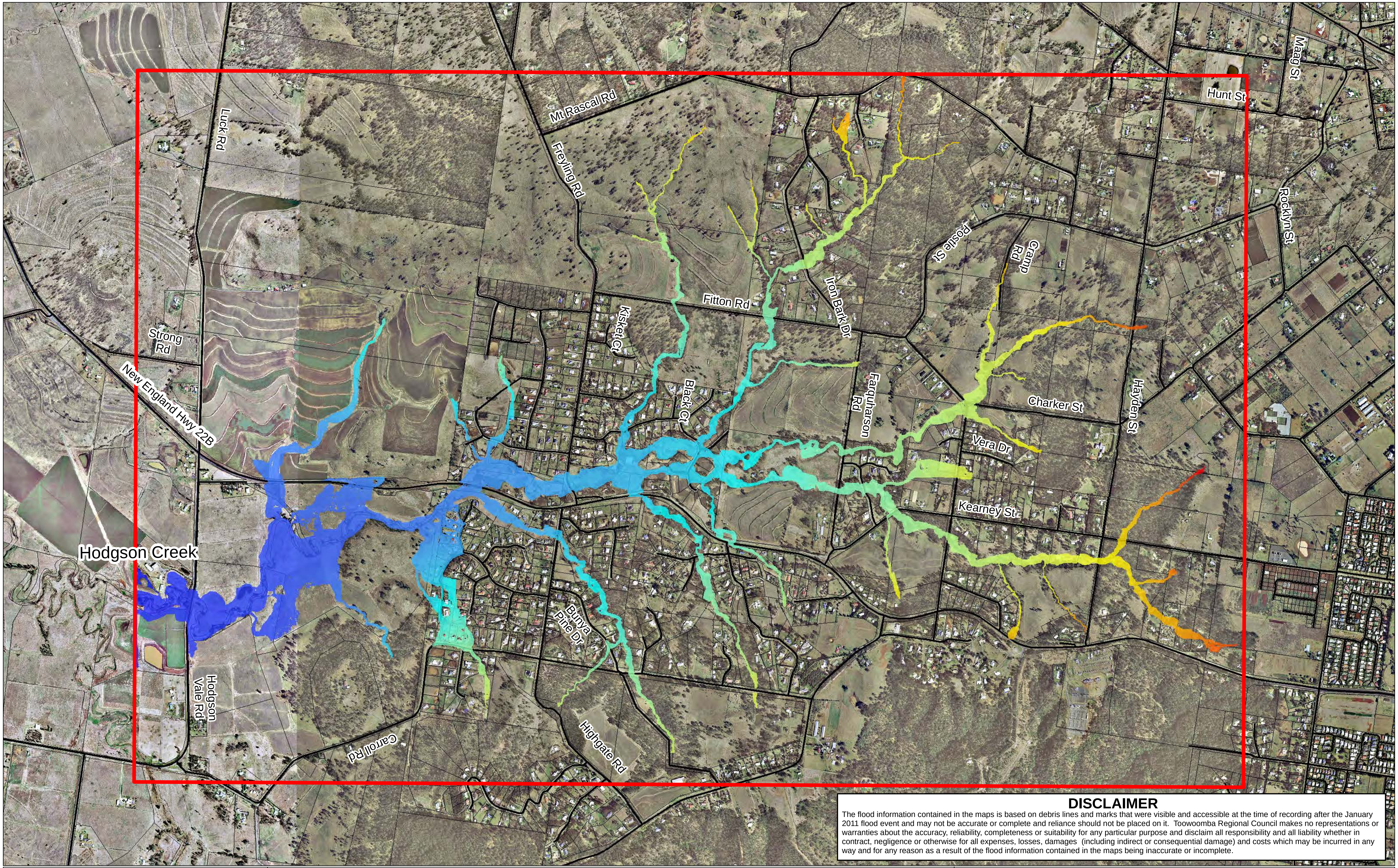
Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6
Mount Rascal 100 year ARI
2 Degrees (2050) Climate Change Scenario
Water Surface Level

MTR-E-Q100Y-2DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550 Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Surface Elevation

High : 660

Low : 500

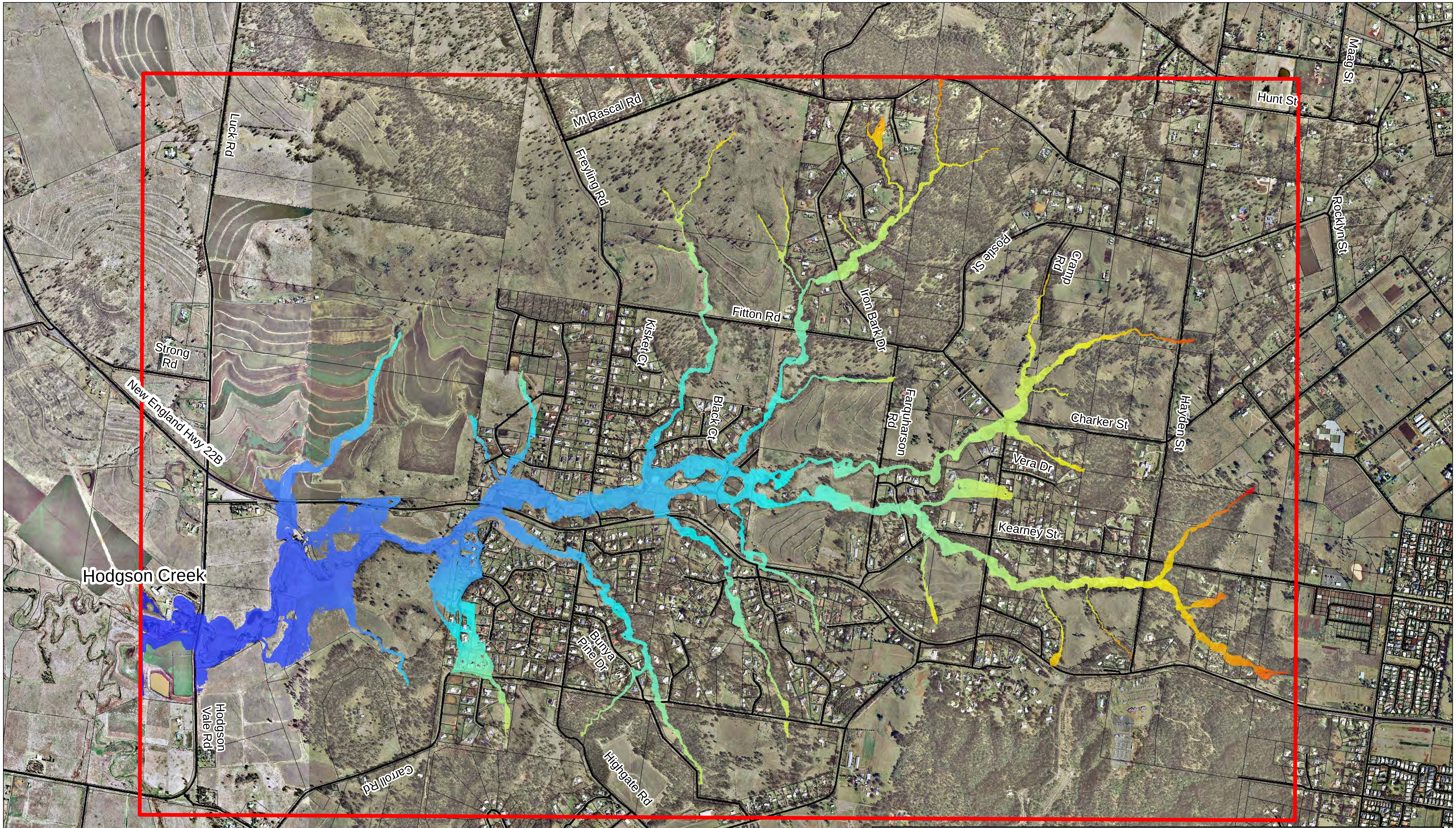
SP051 Flood Studies - Work Package 6

Mount Rascal 100 year ARI

3 Degrees (2070) Climate Change Scenario

Water Surface Level

MTR-E-Q100-3DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

Surface Elevation

High : 660

Low : 500

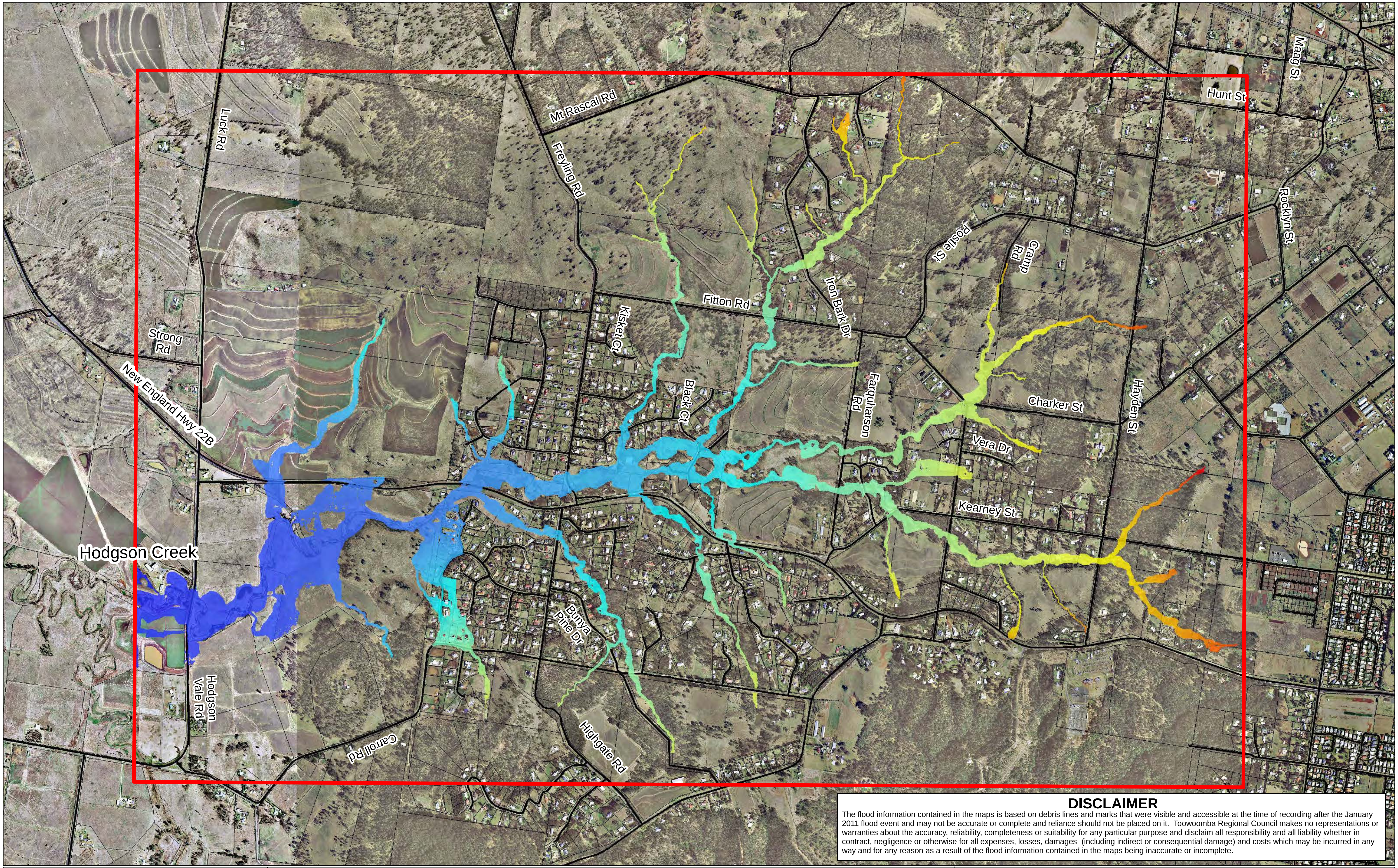
SP051 Flood Studies - Work Package 6

Mount Rascal 100 year ARI

4 Degrees (2100) Climate Change Scenario

Water Surface Level

MTR-E-Q100-4DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

Model Domain Extents

Major Road Centre Lines

Cadastre

Surface Elevation

High : 660

Low : 500

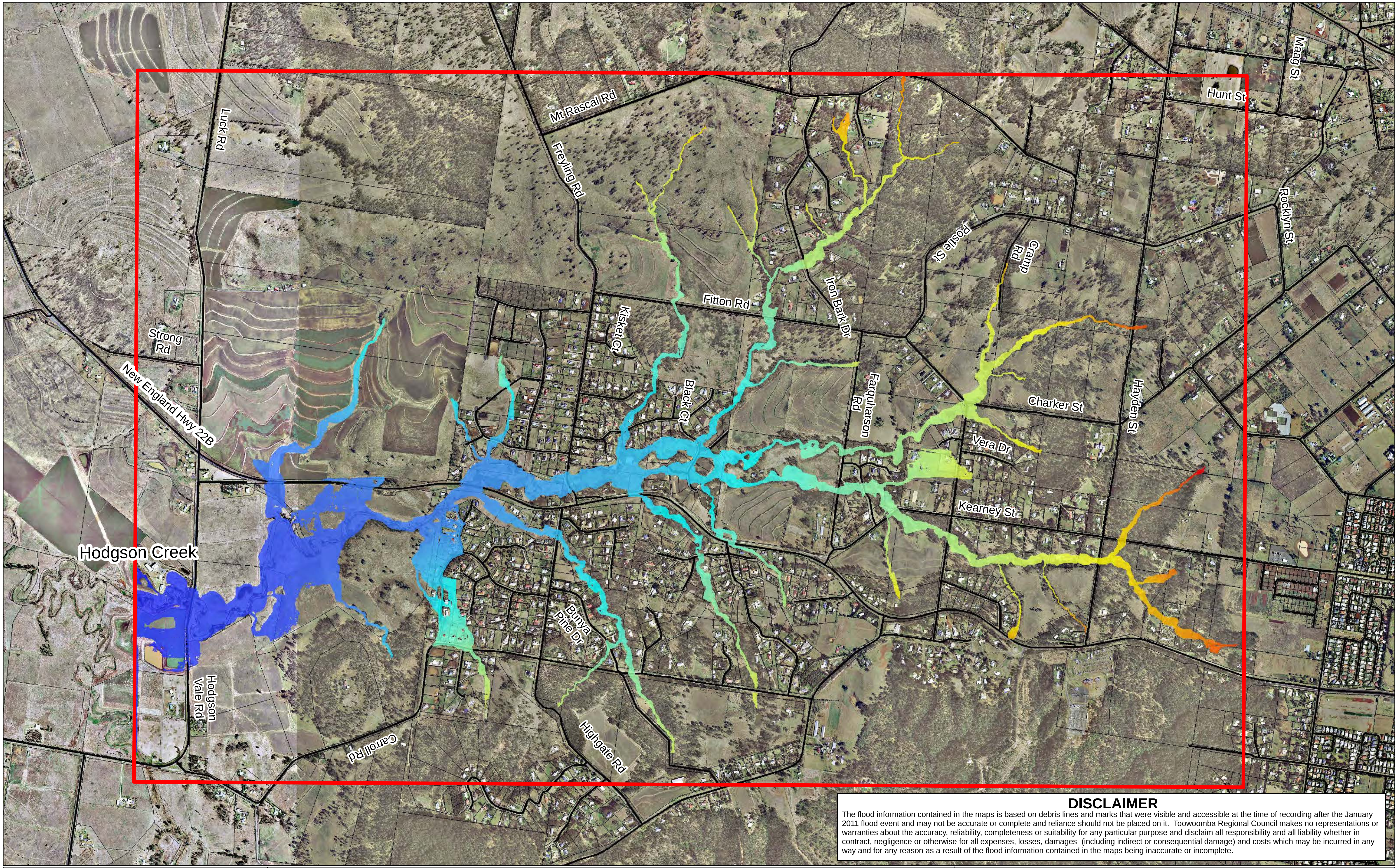
SP051 Flood Studies - Work Package 6

Mount Rascal 200 year ARI

2 Degrees (2050) Climate Change Scenario

Water Surface Level

MTR-E-Q200-2DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for any expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

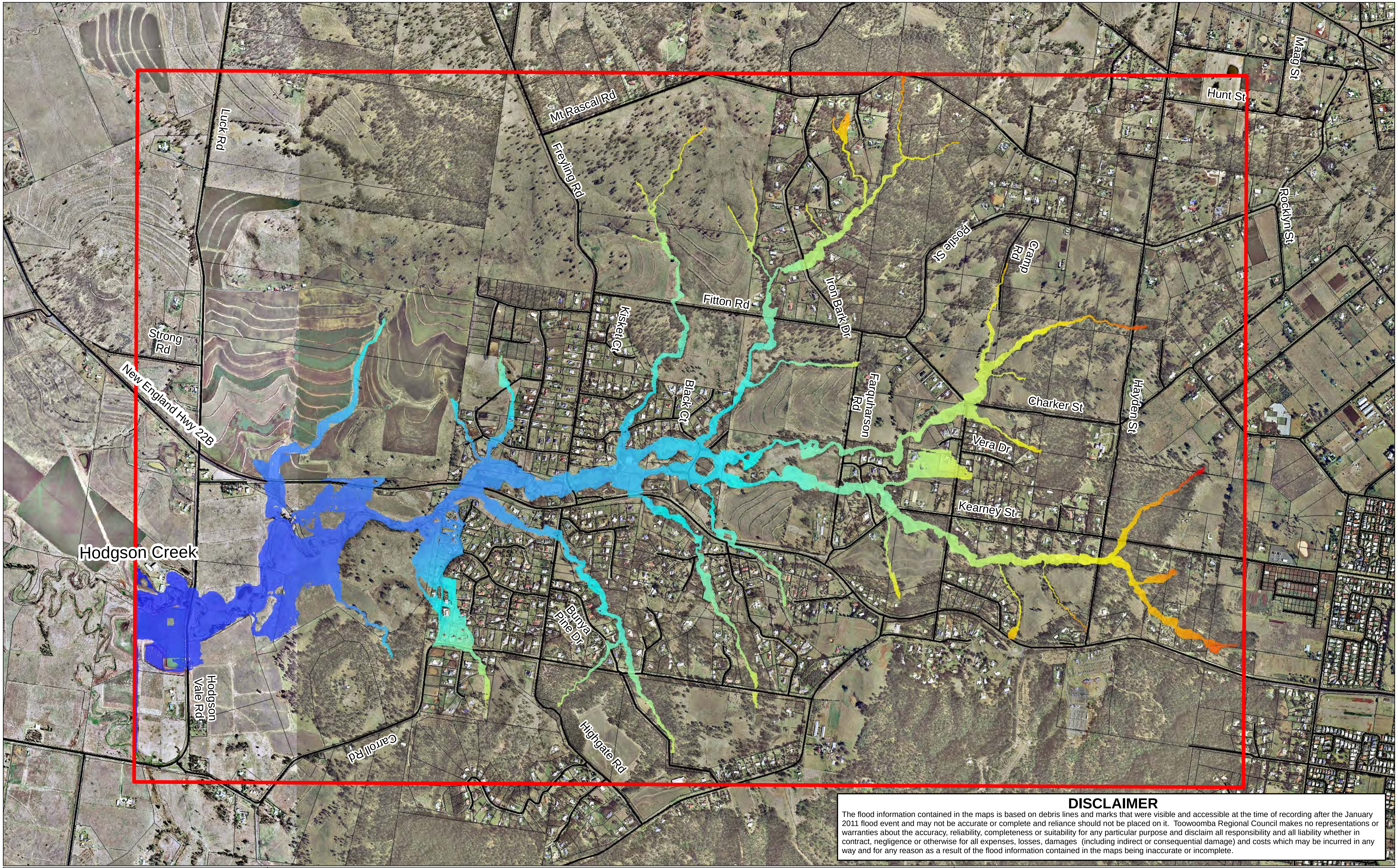
Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6
Mount Rascal 200 year ARI
3 Degrees (2070) Climate Change Scenario
Water Surface Level

MTR-E-Q200-3DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

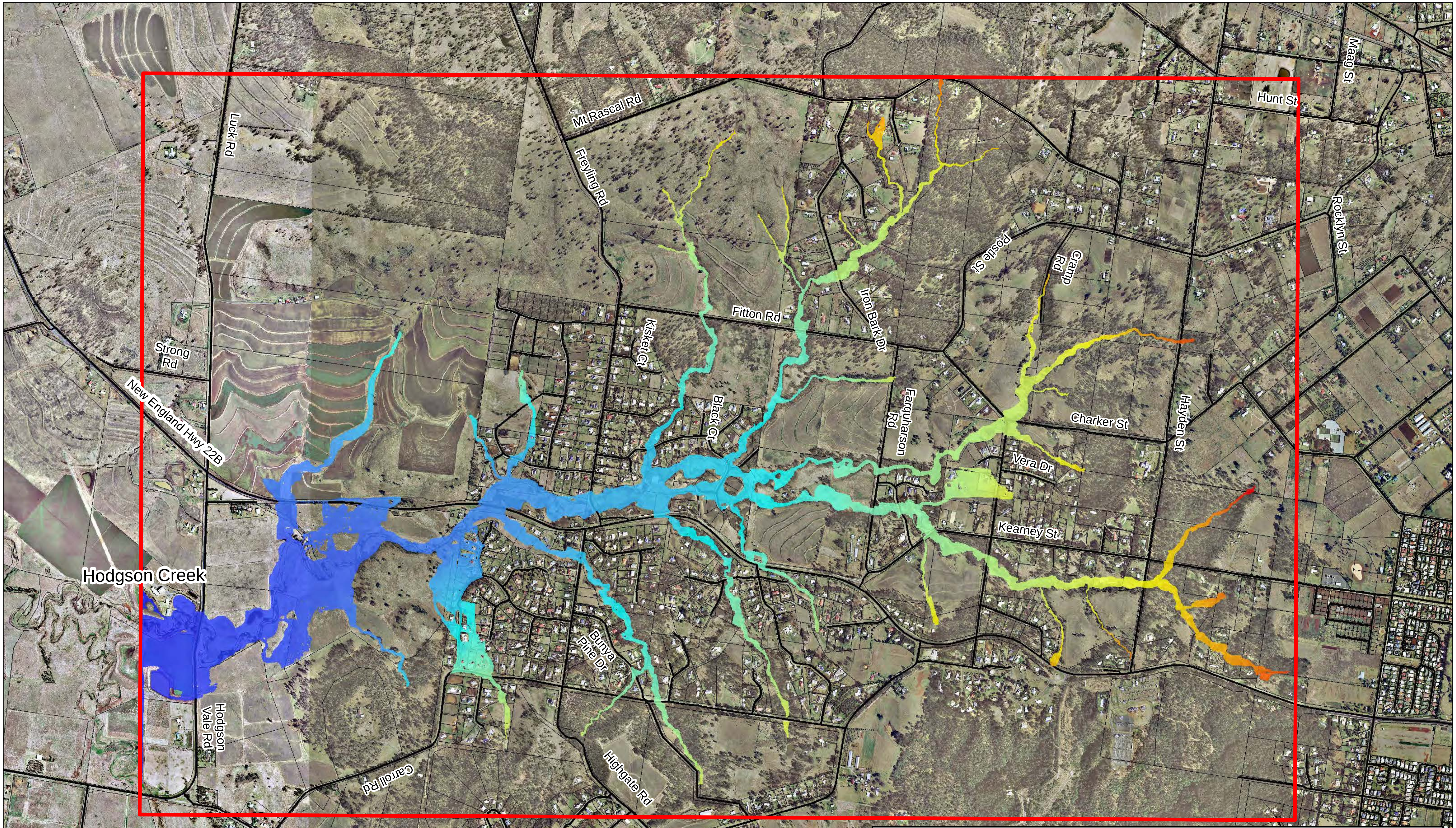
Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6
Mount Rascal 200 year ARI
4 Degrees (2100) Climate Change Scenario
Water Surface Level

MTR-E-Q200-4DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

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Meters

N

GDA 1994 MGA Zone 56

Legend

- Model Domain Extents
- Major Road Centre Lines
- Cadastre

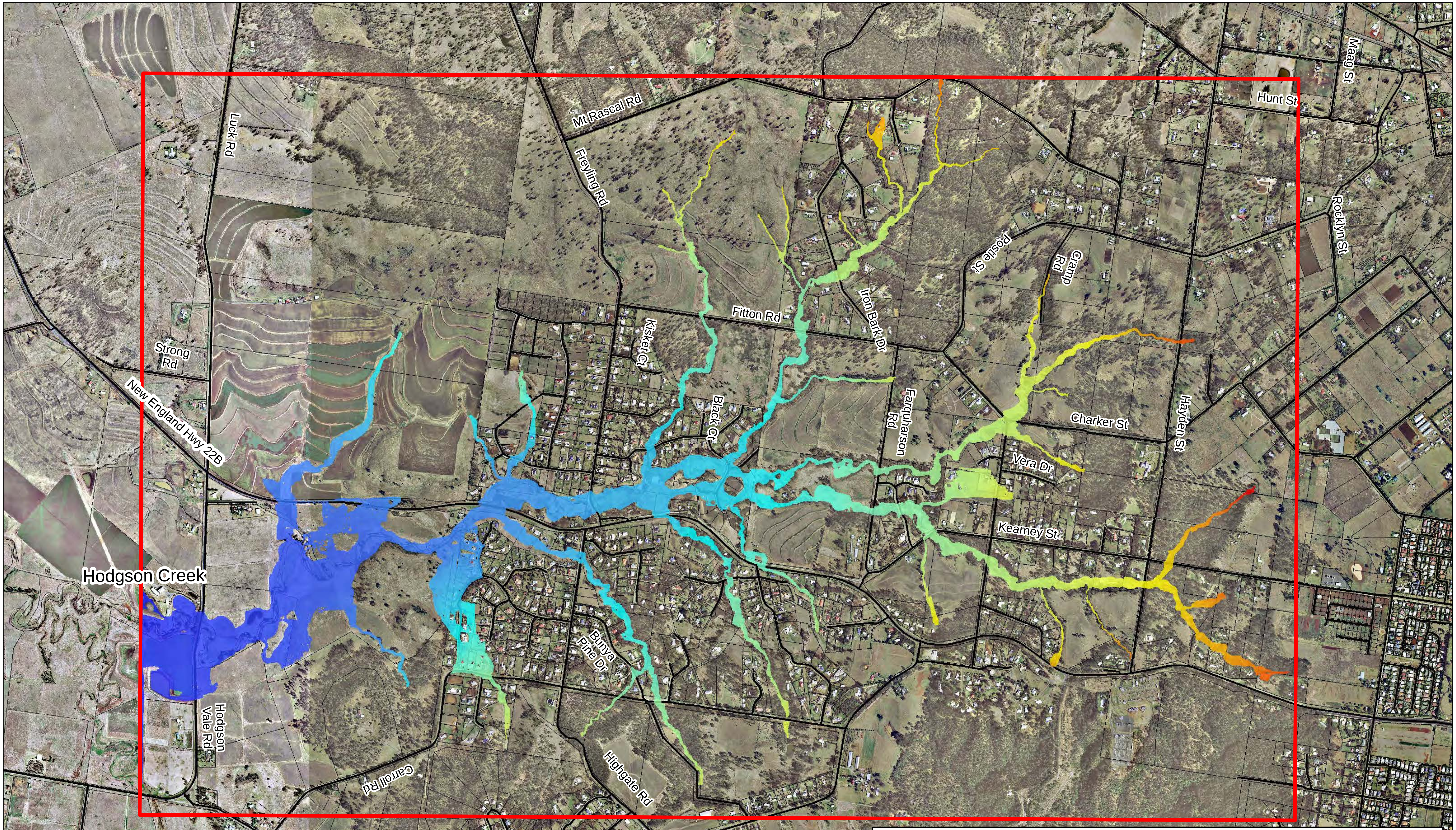
Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6
Mount Rascal 500 year ARI
2 Degrees (2050) Climate Change Scenario
Water Surface Level

MTR-E-Q500-2DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014



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TOOWOOMBA REGIONAL COUNCIL

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0 137.5 275 550
Meters

N

GDA 1994 MGA Zone 56

Legend

Model Domain Extents
Major Road Centre Lines
Cadastre

Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6
Mount Rascal 500 year ARI
3 Degrees (2070) Climate Change Scenario
Water Surface Level

MTR-E-Q500-3DEGCC.mxd
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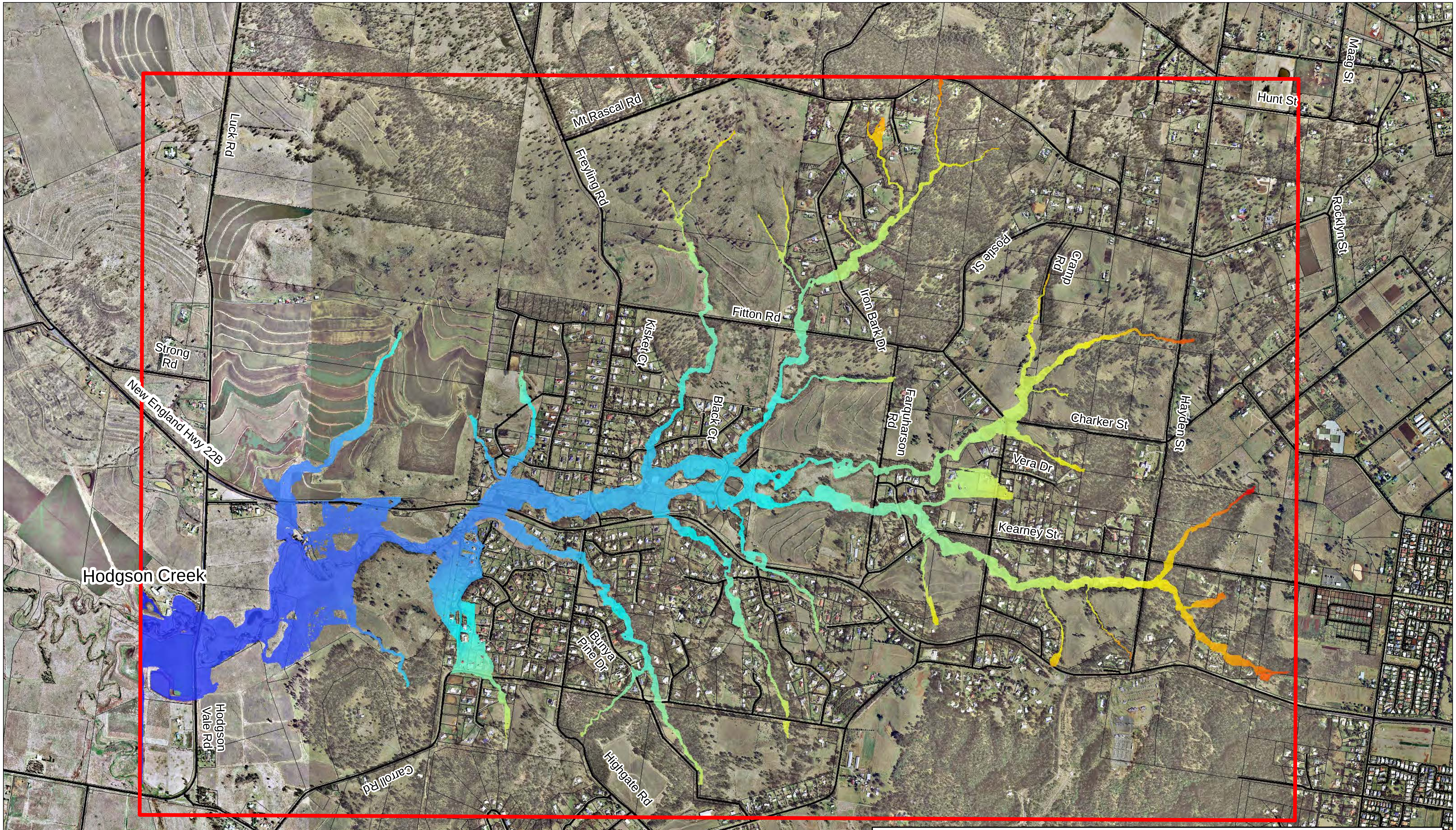

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Meters

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GDA 1994 MGA Zone 56

Legend

Model Domain Extents

Major Road Centre Lines

Cadastre

Surface Elevation

High : 660

Low : 500

SP051 Flood Studies - Work Package 6

Mount Rascal 500 year ARI

4 Degrees (2100) Climate Change Scenario

Water Surface Level

MTR-E-Q500-4DEGCC.mxd
Author/Date: Ryan.dermek 4/04/2014

TOOWOOMBA
REGION

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yoursay.toowoombaRC.qld.gov.au/flood-resilience

TOOWOOMBA REGION
Rich traditions. Bold ambitions.

Mount Rascal, Top Camp And Hodgson Vale Flood Studies Information Sheet

WHY UNDERTAKE FLOOD STUDIES?

Following extensive flooding across the Toowoomba region, we commissioned a number of flood studies to better understand how flooding can impact our communities. These studies are now complete and available on our website.

The flood studies found that flood behaviour can be complex and vary between locations, depending on landscape, infrastructure and rainfall pattern.

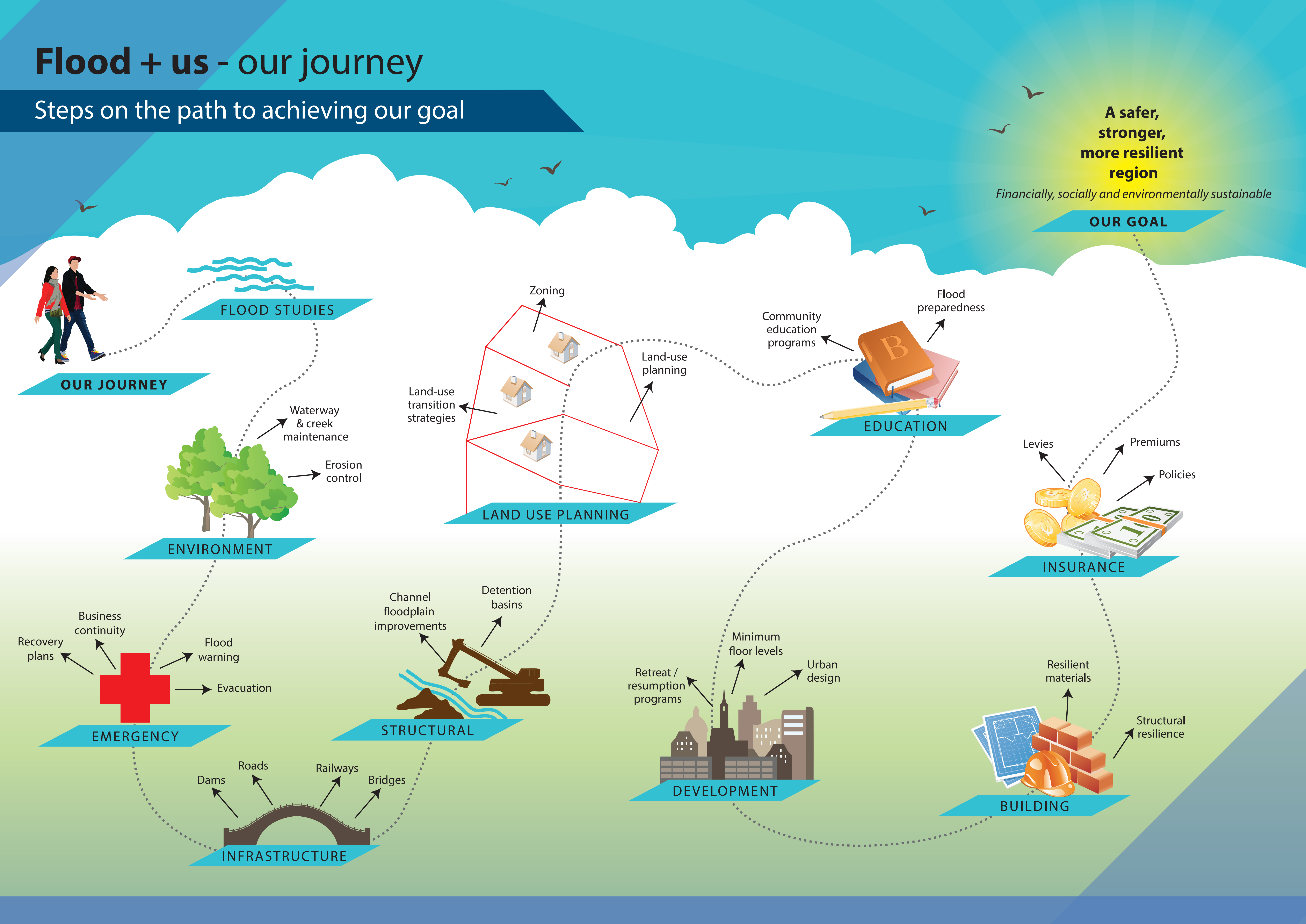
SOME BASIC FLOOD TERMS

1. **Overland flow** – short duration flooding of backyards, drainage paths, streets and rural properties caused by stormwater as it makes its way into the creek/river system;
2. **Creek flooding** – short to medium duration flooding caused by creeks rising and breaking their banks, which can then flood nearby homes, businesses and rural properties;
3. **River flooding** – longer duration flooding caused by significant rises in a river which can break its banks in the same way as smaller creeks.

Most of the studies undertaken or commissioned by Council relate to the first two types of flooding – overland flow and creek flooding. It's important to note that these types of flooding can occur separately or together.

KEY MESSAGES

1. Council has a legislative requirement to undertake flood management and the whole community needs to be involved.
2. Flood studies are a foundation and an essential step towards our goal of a safer, stronger, more resilient region.
3. Flood studies have been undertaken by specialist engineers and incorporate the latest data, modelling techniques and community input.
4. Community consultation enables two-way information sharing about the project to increase community awareness, enhance decision making and help achieve our goal of a safer, stronger, more resilient region.



Flood + us - our journey
Steps on the path to achieving our goal
A safer, stronger, more resilient region
Financially, socially and environmentally sustainable
OUR GOAL
OUR JOURNEY
FLOOD STUDIES
ENVIRONMENT
Waterway & creek maintenance
Erosion control
EMERGENCY
Recovery plans
Business continuity
Flood warning
Evacuation
INFRASTRUCTURE
Dams
Roads
Railways
Bridges
STRUCTURAL
Channel floodplain improvements
Detention basins
LAND USE PLANNING
Zoning
Land-use transition strategies
Land-use planning
EDUCATION
Community education programs
Flood preparedness
DEVELOPMENT
Retreat / resumption programs
Minimum floor levels
Urban design
INSURANCE
Levies
Premiums
Policies
BUILDING
Resilient materials
Structural resilience

Mount Rascal, Top Camp And Hodgson Vale Flood Studies Information Sheet

WHAT ARE MOUNT RASCAL, TOP CAMP AND HODGSON VALE'S FLOOD STORIES?

A flood study and flood maps are now available for Mount Rascal, Top Camp and Hodgson Vale residents. The primary source of flooding in the area is from overland flow and creek flooding. These communities are elevated and located at the headwaters of Hodgson Creek which flows to the south to meet with the Condamine River.

The flood study was prepared to quantify flood behaviour from the January 2011 event and to model other flood scenarios from relatively frequent events, through moderate to large, rare and extreme events for the catchment.

The January 2011 event was a significant event for the area. The primary cause of flooding is overland flow, given the communities are at the top of the Hodgson Creek catchment. Flooding during the January 2011 event generally followed the main channel running parallel to the New England Highway on its western side. A large number of smaller overland flow paths that drain to this main channel also flooded.

The study notes that significant lead-up rainfall and fully saturated catchment conditions contributed to the severity of the event in this catchment. The event is estimated to be approximately a 0.75% Annual Exceedance Probability event – meaning there is 0.75% chance in a year of a flood of this size event or larger occurring. This is larger and rarer than a 1% event.

The study identified some areas upstream of the Hodgson Vale Sports Club such as Parkside Court, Carinya Drive and the Sports Club to be flooded properties of significant flood hazard in the 1% event. Lower in the developed area some properties are subject to low flood hazard in the 1% event, such as Andrews Court and the southern part of Windermere Drive.

> Annual Exceedance Probability (AEP) means the chance of a flood of a given size or larger size occurring in any one year, usually expressed as a percentage.

COMMUNITY INVOLVEMENT

Improving the way we prepare for and respond to flooding as a community is very important to us. Many residents in our region contributed information to build and validate our flood knowledge during the region-wide consultation sessions and other flood studies engagement opportunities.

Community involvement with this project continues to help our region become safer, stronger and more resilient. We encourage you to access the flood study information online and stay up to date with the project by visiting the web address below.

GET INFORMED

You can access our region's current flood studies and maps by heading to
http://yoursay.toowoombarc.qld.gov.au/flood-resilience
For more information, please contact the project team by phone, email or post.

Phone: 131 872

Email: info@tr.qld.gov.au

Post: Strategic Planning & Economic Development,
Toowoomba Regional Council, PO Box 3021, Toowoomba Q 4350.

TOOWOOMBA REGION