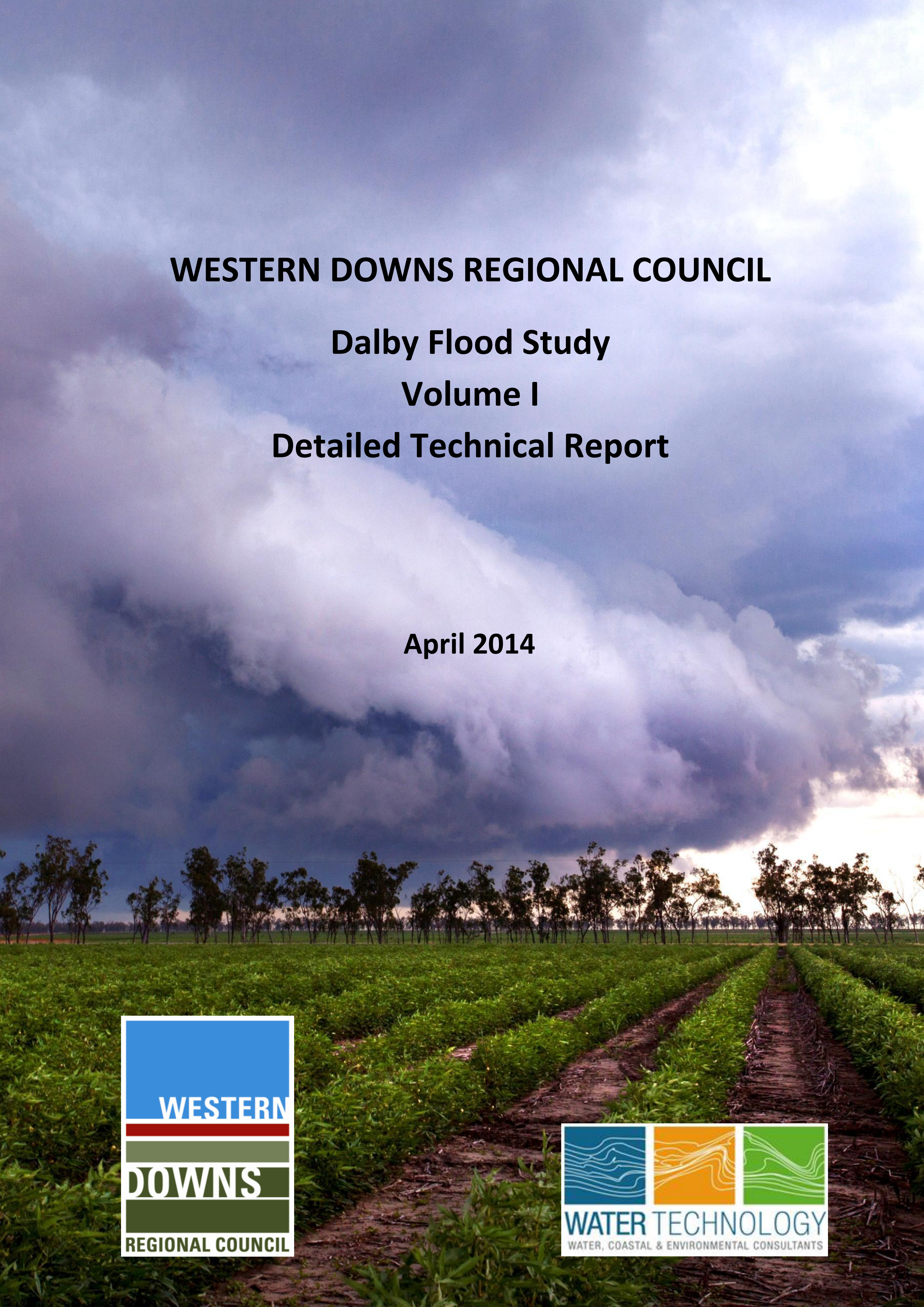

WESTERN DOWNS REGIONAL COUNCIL

Dalby Flood Study
Volume I
Detailed Technical Report

April 2014

WESTERN DOWNS REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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PROJECT DETAILS

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Executive Summary

Background

The Dalby Flood Study is a Western Downs Regional Council (WDRC) initiative aimed at understanding the risks associated with flooding in Dalby. Once the flood risks posed to the residents and businesses of Dalby are understood, ways to manage these risks may be developed.

The Dalby Flood Study is being undertaken as part of the full WDRC Planning Scheme review currently being undertaken to create one Planning Scheme for the Western Downs Region.

The Flood Study

A flood study is a comprehensive technical investigation of flooding behaviour that defines the extent, depth and velocity of floodwaters for floods of various magnitudes. This information is the principal technical information from which flood overlays for the Planning Scheme are formulated.

There are two principal components to a flood study:

- Hydrologic analysis or the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and hydrographs for a range of floods.
- Hydraulic analysis refers to the detailed description of flow down a watercourse or through a rural or urban floodplain or a combination of both to determine the extent, depths and velocities of flooding.

It is usual to undertake hydrologic and hydraulic analyses using computer modelling systems. Data about the catchments, floodplains, rivers, structures (e.g. bridges and culverts), land use (e.g. rural or urban) are all fed into the models. Once all the data is in the models, the models are "calibrated" to historic events to ensure that rainfall and floodplain processes are able to be accurately reproduced.

Following model calibration a series of theoretical "design" events are applied to the models with the aim of determining the flood hazard for flood events ranging from common (floods that could be expected to occur, on average every few years) to extreme (floods that could be expected to occur, on average once in a generation or even less frequently; e.g. the 1981 flood).

Flood Hazard

Flood hazard refers to the 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. Flood hazard is typically defined in the following terms:

- **Low** – there are no significant evacuation problems. If necessary, children and elderly people could wade to safety with little difficulty; maximum flood depths and velocities along evacuation routes are low; evacuation distances are short. Evacuation is possible by a sedan-type motor vehicle, even a small vehicle. There is ample time for flood forecasting, flood warning and evacuation.
- **Medium** – fit adults can wade to safety, but children and the elderly may have difficulty; evacuation routes are longer; maximum flood depths and velocities are greater. Evacuation by sedan-type vehicles is possible in the early stages of flooding, after which 4WD vehicles or trucks are required.

- **High** – fit adults have difficulty in wading to safety; wading evacuation routes are long again; Motor vehicle evacuation is possible only by 4WD vehicles or trucks and only in the early stage of flooding. Boats or helicopters may be required.
- **Extreme** – boats or helicopters are required for evacuation; wading is not an option because of the rate of rise and depth and velocity of floodwaters. Extreme hazard is produced when flood depths exceed 1.0m, velocities exceed 1.5m/s or the combination of depth and velocity exceeds $0.6m^2/s$.

Work undertaken for the Dalby Flood Study

There have been several previous investigations into flooding in Dalby. These previous investigations have been reviewed for this current study, as well as a significant amount of further research and data gathering by WDRC and the project team. This further research was undertaken in the form of:

- Community consultation,
- Research by the Dalby Family Historical Society, the Chinchilla Museum and the Miles Museum,
- Research by Council officers, and
- Interviews with residents.

Data gathered included:

- Official records (e.g. Bureau of Meteorology).
- Previous flood study reports.
- Newspaper articles.
- Photos.
- Recorded flood height records by long-term town residents.
- Flood marks on buildings and other structures.
- Anecdotal evidence/family histories of flood heights on structures (e.g. for floods that occurred over 80 years ago where there is a family history of how high the flood occurred on the house; which is still standing).

WDRC also commissioned highly accurate, aerial survey over Dalby, which has been a vital component of this study and will continue to be a valuable resource for the Dalby community into the future.

Based on the historic flood information gathered by WDRC and the community, a significant amount of technical analysis was undertaken. This is discussed in detail in this document.

Study Update

The initial Dalby Flood Study report was submitted in November 2012. Since then a significant amount of additional work has been undertaken including:

- Extensive community consultation and additional data gathering,
- Extensive investigations of historic (and specifically the 1893) events,
- Detailed modelling of flow distributions (on the basis of LIDAR data acquired in mid 2013) in the Mocatta's corner area,

- A revised Flood Frequency Analysis using the latest available techniques (as currently being developed through the revision of Australian Rainfall and Runoff).

Through these additional investigations, an increased level of confidence in flood magnitude at Dalby has been gained, and the design flood levels (including 1 in 100 AEP level) have been revised. The revised 1 in 100 AEP discharge estimate is approximately 20% lower than the Nov 2012 discharge estimate.

In most locations the reduction in design flows has lead to a reduction in the 1 in 100 AEP level. However, due to the complexity of the floodplain in and around Dalby, these reductions are larger in some areas (eg the southern flowpath) than others (eg at the Patrick St Gauge). There are also some areas where there have been increases in levels due to the change in flow distribution from the more accurate modelling of Mocatta's Corner.

Dalby Flood Study – Lessons Learned

The Dalby Flood Study has provided an increased understanding of floods and flood hazard for Dalby. Specific lessons learned include:

- The Myall Creek floodplain in and around Dalby is complex with numerous overland flowpaths that are activated during large floods.
- There is substantial flood hazard in and around Dalby due to major Myall Creek overland flowpaths running through and around the town.
- There has been a substantial amount of development in and around Dalby over recent decades. In many cases, this development has partially blocked the overland flowpaths through and around the town.
- The reduction in capacity of the overland flowpaths has meant that were previous floods (e.g. the 1981 flood) to occur again, the flood levels through and around the town would be higher than originally experienced.
- Road embankments and the railway embankment are key "controls" of the Myall Creek floodplain in and around Dalby. In particular, the railway embankment on the upstream side of town prevents a substantial amount of floodwater from flowing to the south of Dalby for lower flood magnitudes. However, for larger floods, the railway embankment overtops and flow to the south of Dalby increases substantially.
- A key outcome of the Dalby Flood Study has been the definition of the event usually adopted as the Design Flood Event (DFE), the 1 in 100 AEP flood. The DFE in Dalby has been defined as the 1 in 100 AEP flood with ultimate levels of development (i.e. the development levels defined by the zonings in the WDRC Planning Scheme).
- The 1 in 100 AEP flood for Dalby has been calculated as having a peak flow slightly larger than the 1981 flood.
- The DFE flood levels for Dalby are higher than those recorded during the 1981 flood. The increases in flood levels are due to several factors including:
  - A slight increase in discharge between the 1981 and 1 in 100 AEP floods.
  - An increase in development in Dalby since 1981 that has reduced the capacity of overland flowpaths.
  - Overtopping of the railway line for the 1 in 100 AEP flood which considerably increases the flood flows through the south of Dalby.

Outcomes of the Dalby Flood Study

Outcomes of the Dalby Flood Study that will have direct benefit to the Dalby community include a series of maps detailing flood hazard for:

- Myall Creek floods, and
- Local stormwater floods.

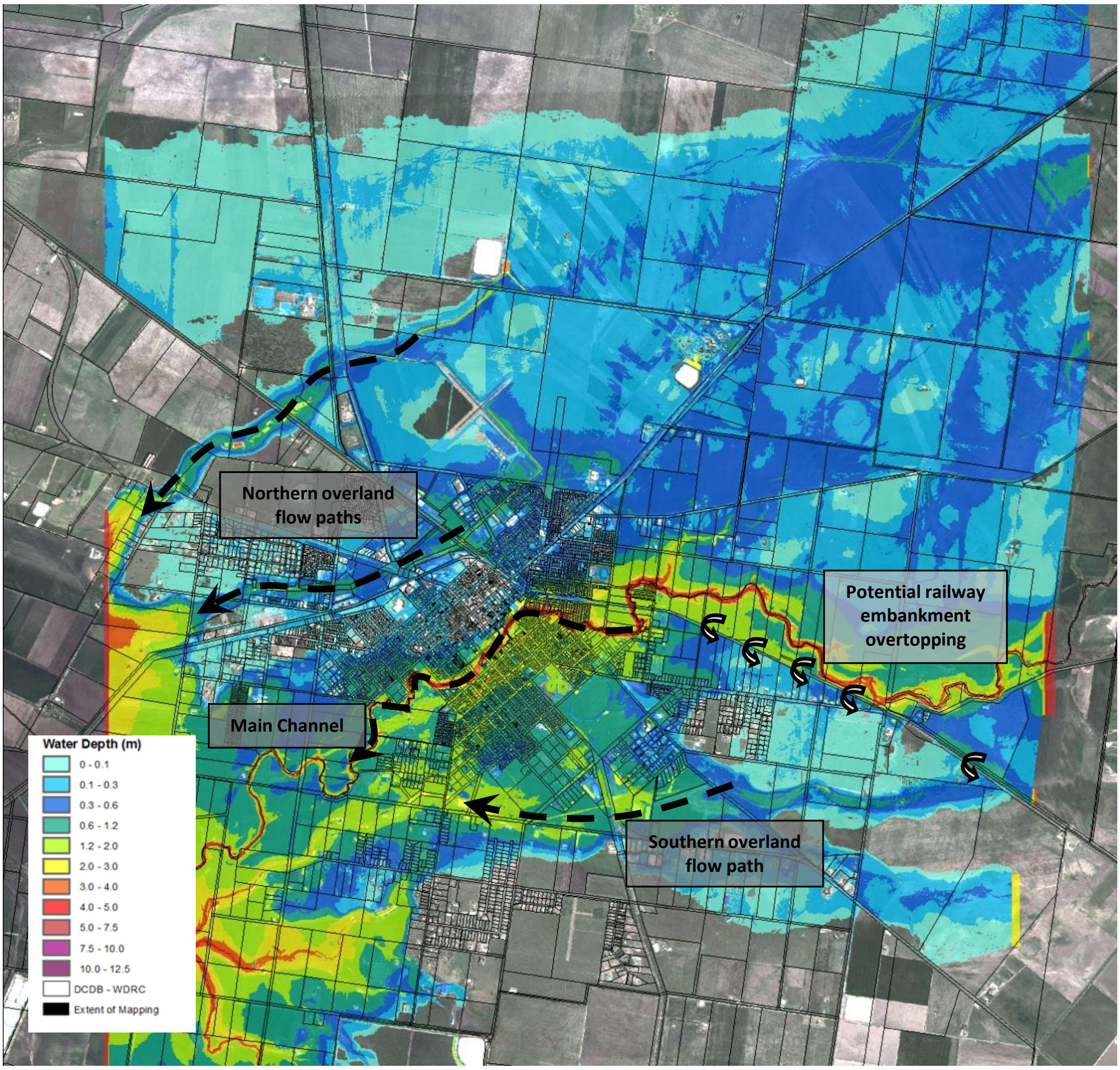
The maps will be an invaluable tool to ensure appropriate development that does not affect the proposed development (through flooding) or existing properties or residents (e.g. by blocking of overland flowpaths and/or redirecting stormwater onto nearby properties)

Other outcomes of the study include a consolidated set of historic flood data that will be of ongoing value to the community and detailed survey information for the town.

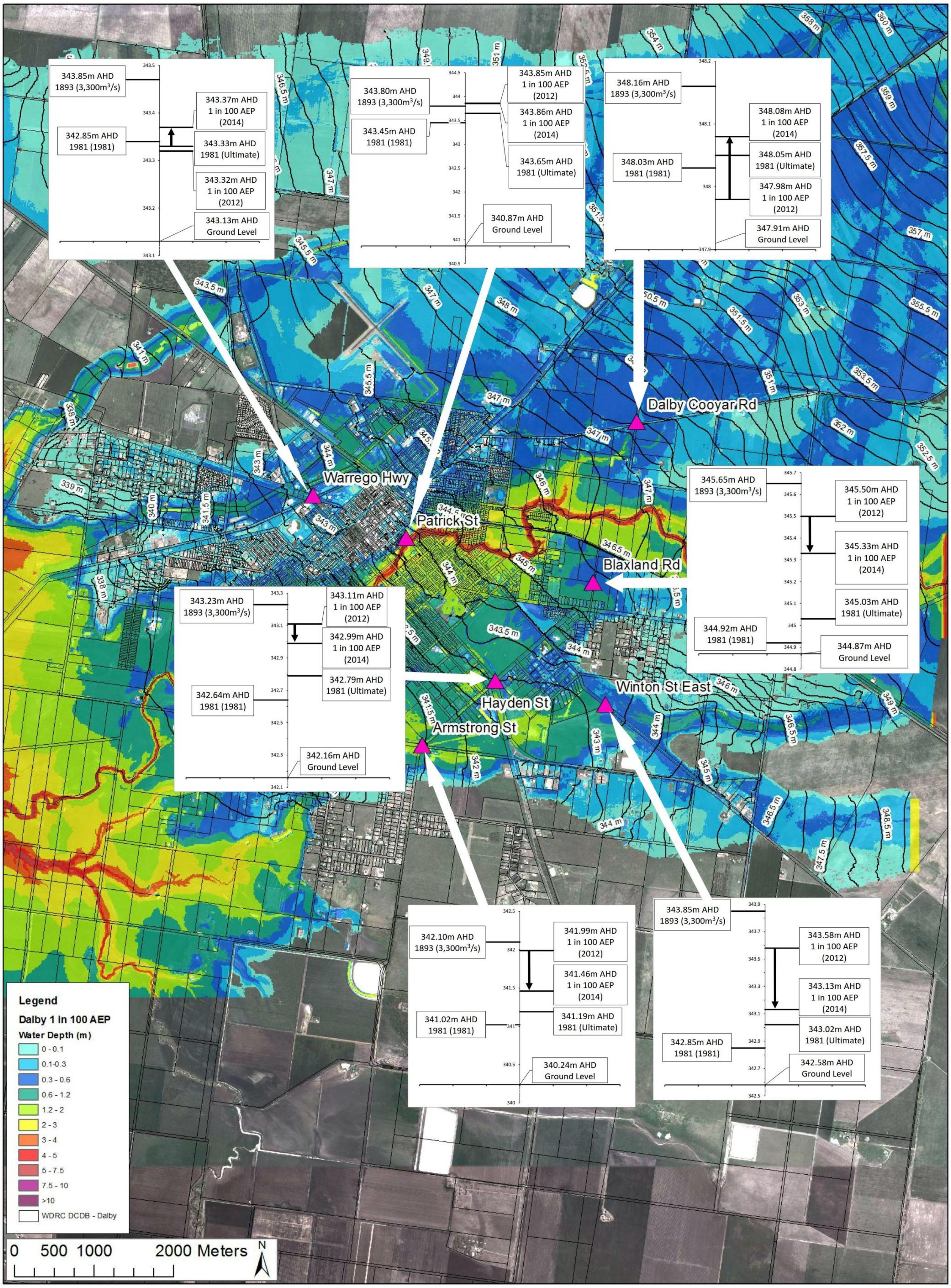
Report Format

For convenience, this report consists of two volumes:

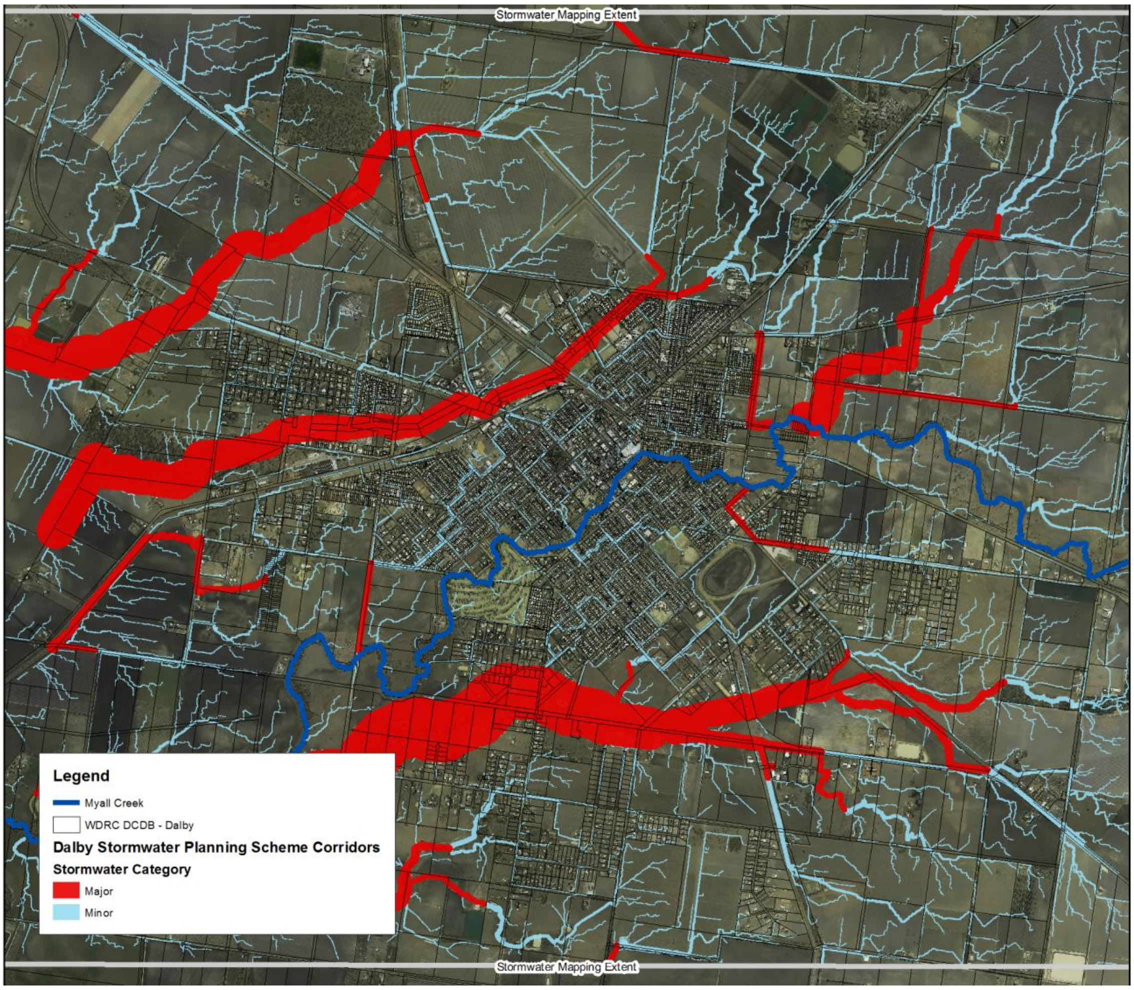
- Volume I: Dalby Flood Study Detailed Technical Report (this document).
- Volume II: Dalby Flood Study Maps.



Dalby 1 in 100 AEP Riverine Flood Depth



Dalby 1 in 100 AEP Riverine Flood Depth with indicators of key historic and design flood levels



Dalby 1 in 100 AEP Stormwater Flowpath Overlay

Please note that the Stormwater Flowpath Overlay Map shows the "flowpaths" or "corridors" which are used to assist stormwater planning; these are **not** stormwater flood widths.

Acknowledgements

This study would not have been possible without the support of the following people and organisations:

- The residents of Dalby (past and present).
- The Dalby Family Historical Society.
- The Chinchilla Museum.
- The Miles Museum.
- WDRC Councillors.
- WDRC Officers.

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Abbreviations

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
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
EWS	Energy and Water Supply, Queensland Government
GIS	Geographic Information System
LIDAR	Light Detection and Ranging
NFRAG	National Flood Risk Advisory Group
NHMA	Natural Hazard Management Areas
NRW	Natural Resources and Water (Queensland Government)
QR	Queensland Rail
QRA	Queensland Reconstruction Authority
QFCI	Queensland Flood Commission of Inquiry
SPP 1/03	State Planning Policy 1/03

Glossary

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 m3/s has an AEP of 5%, it means that there is a 5% chance (1 in 20 chance) of a 500 m3/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 (m3/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)

Glossary cont.

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 rakes 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.

Glossary cont.

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.

1 INTRODUCTION

1.1 Planning Scheme Review

Western Downs Regional Council (WDRC) was created in March 2008 after the amalgamations of local government areas throughout Queensland. WDRC contains six former local government areas and six different Planning Schemes. The former local government areas include Dalby Town Council, Wambo Shire Council, part of Taroom Shire Council, Chinchilla Shire Council, Murilla Shire Council and Tara Shire Council. A full Planning Scheme review is currently being undertaken to create one Planning Scheme for the Western Downs Region to resolve conflicts between the six different Planning Schemes within the Western Downs Regional Council.

WDRC proposed to undertake flood studies of six towns in the region in conjunction with the Planning Scheme review. There are two components to the flood studies; riverine flooding and stormwater flooding. The purpose of the riverine flood studies is to identify areas of risk of flood inundation, their impact upon current and future development and to identify flood hazard categories for the inundation areas for the defined flood event (DFE). The purpose of the stormwater flood analysis is to define and map stormwater corridors within current and future development areas. The six towns included in the study were Dalby, Chinchilla, Miles, Wandoan, Jandowae and Tara. .

Figure 1.1 shows the WDRC area and the location of the six towns where flood studies have been undertaken as part of the current planning scheme review.

This report presents the technical analysis undertaken in support of the flood study for Dalby.

This report consists of two volumes:

- Volume I: Dalby Flood Study Detailed Technical Report (this document).
- Volume II: Dalby Flood Study Maps.

Figure 1.1 Western Downs Regional Council Area

(Red dots represent towns where a flood study has been undertaken as part of the planning scheme revision)

2 PREVIOUS INVESTIGATIONS

2.1 Previous Studies

There have been several previous flooding investigations for Dalby. These are summarised in Table 2-1. Further details with regard to the SKM (2007) study are provided in the following section.

Table 2-1 Previous Flood Studies - Dalby

Flood Study
Munro Johnson and Associates (1981) Report on Dalby – Wambo Flood Mitigation • This study presents an assessment of the February 1981 floods, a flood study and a preliminary assessment of flood mitigation options.
Munro Johnson and Associates (1987) Dalby Region Flood Management Study • This study represents a significant undertaking for a flood study of its time. The report shows extensive consideration of the Myall Creek flooding mechanisms. Most of the technical output from this study is now superseded due to the limitations in computing model power, and terrain information that were available at the time.
Blain Johnson (1990) Dalby Region Flood Study, Myall Creek Stream Improvements, Preliminary Design Report. • A preliminary report detailing possible Myall Creek stream modifications.
Parsons Brinkerhoff (2002) Dalby Flood Mitigation Update Study • This study was an update of the 1987 study. It was based on the previous analyses, updated to reflect the 2002 costs, economic circumstances and technical practices. This study makes recommendations for flood mitigation options for Dalby based upon previous modelling investigations.
Parsons Brinkerhoff (2004) Myall Creek at Dalby: Flood Impact Assessment, Proposed Redevelopment of Dalby Central Shopping Centre • This study assessed the potential change in flooding in Myall Creek as a result of the proposed redevelopment of the Dalby Central Shopping Centre.
SKM (2007) Myall Creek Flood Study • This study used high quality LIDAR topographic data, an URBS hydrology model and a MIKE-21 hydraulic model. The study was used to derive the design flood levels for planning purposes at that time.

2.2 SKM (2007) Myall Creek Flood Study Review

2.2.1 Overview

Being the most recent investigation undertaken, the Myall Creek Flood Study (SKM, 2007) was reviewed in detail. It was concluded that a number of areas of both the hydrology and hydraulic modelling undertaken for the 2007 study would benefit from additional analysis and model development. Further, it was considered that the adopted discharges based on this investigation were likely to be underestimated.

2.2.2 Hydrology

The Bureau of Meteorology (BoM) had previously developed an URBS hydrology model of the Condamine River. The SKM (2007) investigated built on the Condamine River BoM URBS model by Adopting the Myall Creek component of the BoM model (the Myall Ck URBS Model) without modification.

The SKM (2007) study compared the results of a “regional” flood frequency analysis (FFA) for the Condamine River against output from the Myall Ck URBS model and concluded that flood magnitudes estimated by the FFA and URBS modelling were similar. No details of the regional FFA were presented. On the basis of this comparison, the SKM (2007) study concluded that the Myall Ck URBS model was appropriate

The Condamine River catchment that the Condamine River BoM URBS model represents is substantial. While the relatively course representation of the Myall Creek catchment within the Condamine River BoM URBS model is appropriate for consideration of Condamine River flood events, it is necessary to incorporate further detail into the model when analysing Myall Creek in and through Dalby.

The SKM (2007) study used design rainfall in the URBS model to obtain design discharges to describe the full range of design events. The Uniform Proportion loss model with URBS was used for both the historic and design event simulations. This parameters adopted for this loss model were an initial loss (IL) of 50mm and a proportional runoff (PR) of 0.75. While sensitivity testing is described, no evaluation of the sensitivity of discharge predictions to the adopted loss model is presented.

2.2.3 Hydraulics

A key assumption of the SKM (2007) study was the adoption of an assumed flow “split” upstream of the town. The basis for this flow split is not presented. Table 2-2 reproduces the adopted flow splits from SKM (2007).

Table 2-2 Hydraulic Model Flow Splits (reproduced from SKM (2007))

Inflow Node name	Description	Proportion of Myall Creek catchment
33TA	Myall Creek Main Channel	85%
33TB	Myall Creek North of Bunya Highway	10%
33TC	Myall Creek South of Mocatta's Corner Road	5%

The results of the historic event calibration are presented in Table 2-3. Note for a relatively "flat" topography, differences in predicted flood heights of between 0.1 to over 0.2m represents potentially significant differences.

Table 2-3 Calibration Model Results (reproduced from SKM (2007))

Historical Event	Recorded Height at Patrick Street Gauge (mAHD)	Modelled Height at Patrick Street Gauge (mAHD)	Difference (m)
February 1981	343.5	343.34	-0.16
June 1983	342.8	342.91	0.11
May 1996	341.9	342.12	0.22

2.2.4 Implications for current study

Based on the review of the SKM (2007) study, the following implications for the current study were drawn:

- A more detailed description of the Myall Creek catchment leading to Dalby was required,
- Specific investigations into the sensitivity of the hydrologic analysis to the adopted loss model was required,
- The assumed flow "split" at Mocatta's corner is a significant assumption with implications for the flow distribution through Dalby and a more accurate assessment of this "split" was required,

3 AVAILABLE DATA

3.1 Topographical Survey

The survey data adopted for this study are:

- A LIDAR survey of the six study towns undertaken by WDRC in 2010 was adopted for:
  - Hydraulic modelling of both riverine and stormwater flooding
  - Catchment delineation for stormwater modelling.
- Topographic data with a resolution of 3 arc seconds was used to estimate the catchments for the riverine flood studies.
- A Lidar survey of the Mocatta's Corner area was provided by WDRC in 2013.

3.2 Rainfall

Table 3-1 lists and Figure 3.1 shows the location of the available rainfall stations throughout the study area.

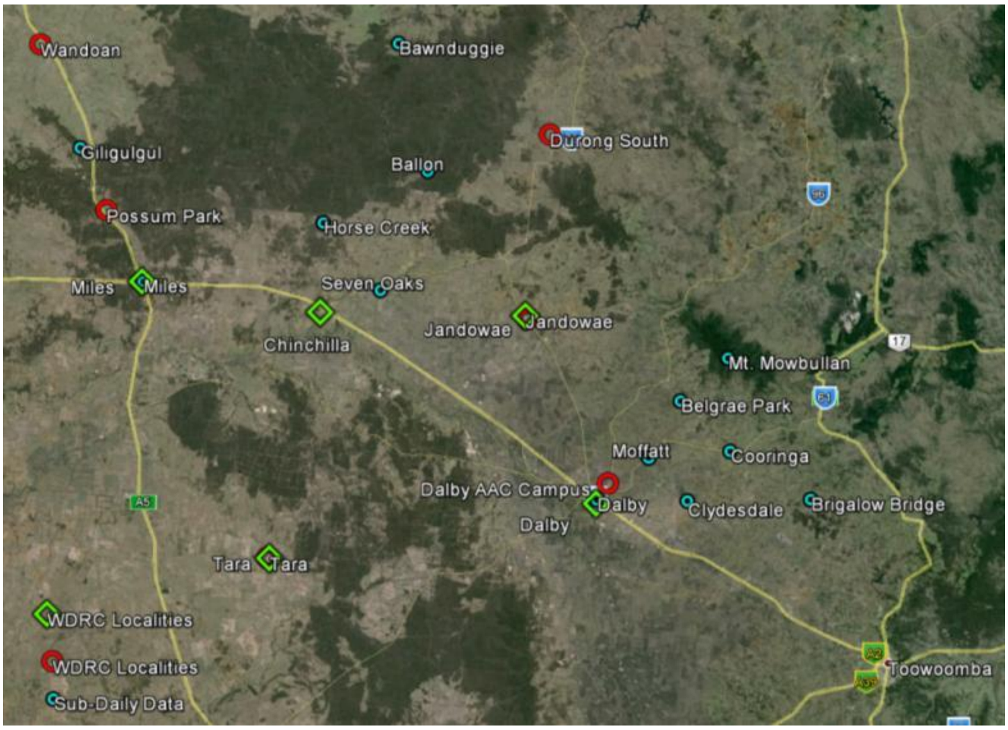

Figure 3.1 Available Rainfall Gauging Stations

(Red markers represent daily stations and blue markers represent sub-daily stations)

Table 3-1 Available Rainfall Stations

Station		
Name	**Number**	**Type 1**
Miles	042112	AWS
Possum Park	042004	Daily
Seven Oaks	041020	TM
Ballon	041092	TM
Bawnduggie	042036	TM
Durong South	040071	Daily
Horse Creek	042025	TM
Giligulgul	035039	TM
Wandoan	035014	Daily
Jandowae	041050	Daily
Dalby	541041	Alert
Moffatt	541042	Alert
Clydesdale	541043	Alert
Tara	041009	Daily
Belgrae Park	041551	Alert
Cooringa	541044	Alert
Mt Mowbullan	541046	Alert
Brigalow Bridge	041490	TM
Dalby AAC Campus	041497	Daily

Note 1
Daily – Rainfall Stations report rainfall amount received in the 24 hours prior to 9am each day.
Alert – Rainfall and/or stream gauging stations that communicate every one millimetre of rainfall over radio network to Flood Warning Centre
AWS – Automatic Weather Station. Sub hourly data
TM – Rainfall station connected to the public phone network, polled regularly during periods of heavy rain

3.3 Stream Gauges

Table 3-2 presents the available stream gauge records for Myall Creek, while Figure 3.2 shows the location of the available stream gauging stations for Myall Creek.

Table 3-2 Available Stream Gauging Stations

Station		Period of Record	Comments
Name	Number		
Myall Ck @ Patrick Street Bridge 1	041478 / 541041 (BoM)	1/09/1981- 28/04/1993	Manual gauge board readings on western side of Myall Creek.
Myall Ck @ Patrick Street TM 1	041478 / 541041 (BoM)	28/04/1993 – present	Automatic water level recorder 150m downstream of Patrick Street Bridge.
Clydesdale Alert Myall Ck (Main Branch)	041466 / 541043 (BoM)	1/11/1977 – Present	Water level only – not rated

Notes:

1) BoM use data from the two sites interchangeably. There is some confusion in the BoM record and other historical records as to where water level measurements were taken. See text for details.

Figure 3.2 Available Stream Gauging Stations – Myall Creek

3.3.1 Patrick Street Gauge Dalby

Figure 3.3 shows the location of the Patrick Street stream gauging stations in Dalby. There are two sites, a manual site at the bridge and an automatic water level recorder 170 m downstream of the bridge. BoM use data from the two sites interchangeably. There is some confusion in the BoM record and other historical records as to where water level measurements were taken. The differentiation between these two sites is important as there is approximately a 0.16 m difference in water level between the sites during a large flood. Given Dalby's flat topography, this represents a considerable difference in discharge.

Note also that water levels at the Patrick Street Bridge are read off gauge boards in the location shown in Figure 3.3. The correct location of this point is important as there is a difference in water level between the gauge board location and the centre of the creek. This makes a measurable difference when estimating flood levels from the hydraulic model.

3.4 Hydraulic Structures

Details for all major hydraulic structures were provided by WDRC. Minor structures, for example culverts under private driveways, were not included in the hydraulic analysis. Hydraulic structure locations are presented in Appendix A.

3.5 Historical Data

Extensive research was undertaken as part of the study to identify and list historical floods for Dalby with over 60 pieces of evidence being put forward by the community including approximately 30 historic newspaper articles. This research also included:

- Community consultation.
- Research by the Dalby Family History Society, the Chinchilla Museum and the Miles Museum.
- Research by Council officers.
- Interviews with residents.

The data collected generally consisted of:

- Official records (e.g. Bureau of Meteorology).
- Previous flood study reports.
- Newspaper articles.
- Photos.
- Recorded flood height records by long-term town residents.
- Flood marks on buildings and other structures.
- Anecdotal evidence/family histories of flood heights on structures (e.g. for floods that occurred over 80 years ago where there is a family history of how high the flood occurred on the house; which is still standing).

The data was collated and assessed for accuracy and usefulness to the study. That is, was it possible to identify a flood height taken at the flood peak on a structure that was still present? Topographical survey was undertaken of the identified historical flood marks to provide an estimate of the flood height. The historic levels used in calibration are presented in Appendix G superimposed on modelled flood surfaces for the historic events.

Figure 3.3 Dalby Stream Gauging Stations

3.6 Available Historical Flood Data Sets

Flood levels for selected large historical floods in Dalby is provided in Table 3-3. The data was sourced from:

- WDRC.
- The Department of Environment and Resource Management (DERM).
- The Bureau of Meteorology (BoM).
- Historical research undertaken as part of this study.
- Modelling results from this study.

3.7 Historic Topography and Land Use

Five historic hydraulic roughness and land use maps were developed to model the range of historical and ultimate land uses in Dalby. The five years/levels of development were:

- 1929.
- 1958.
- 1981.
- 2010.
- Ultimate development in accordance with planning scheme zones.

The four years mapped were the only ones with sufficient data available to determine land use (i.e. aerial photographs, survey, cadastre). These historical land use and roughness maps were used in the Dalby hydraulic model to simulate historical floods. The ultimate development maps were used to model the design flood levels for planning purposes.

Appendix B and Appendix C contain the Dalby historic surface roughness and topography difference maps, respectively.

3.8 Regional Flood Frequency Estimates

Software supporting the Australian Regional Flood Frequency (ARFF) estimates was released in November 2012 (Engineers Australia, 2012). This software was developed as part of the review of the Australian Rainfall and Runoff (ARR) guide to flood estimation. ARFF provides a regional estimate of discharge anywhere in Australia. The ARFF estimates were used as an additional piece of information in the determination of flood discharge magnitude for the six towns in the current study. The ARFF estimates for Dalby are presented and discussed further in Section 8.2.

Table 3-3 Dalby Historical Floods – Myall Creek at Patrick Street

Date	Patrick Street Bridge		Patrick St TM Gauge Ht (m)	Source
	Gauge Ht [1,2,3] (m)	Height (m AHD)		
July 1876 [5]	4.04	343.04		Current Study – based upon historical flood research and hydraulic modelling.
Feb 1893 [4]	>4.50	>343.50		
18 Mar 1908	4.15	343.15		Munro Johnson and Associates (1987) Dalby Region Flood Management Study
10 Feb 1942	3.56	342.56		
12 Feb 1954	3.66	342.66		
10 Feb 1956	3.77	342.77		
2 Feb 1971	3.54	342.54		
23 Feb 1971	3.30	342.30		
27 Jan 1974	3.34	342.34		
7 Feb 1981	4.50	343.50		
23 Jun 1983	3.80	342.80		
28 Jul 1984	3.10	342.10		
12 Feb 1988	3.10	342.10		Readings from Patrick Street at Dalby Manual Gauge
3 May 1996	3.07	342.07	2.90	Gauge Ht Readings from Dalby Alert at Patrick Street Automatic Gauge
20 Dec 2010	3.11	342.11	2.94	
27 Dec 2010	3.70	342.70	3.54	
10 Jan 2011	3.87	342.87	3.74	

Notes:

1) Gauge data:
   a. Gauge No 041478/422939 Dalby 1/09/1981 to 28/04/1993 datum = 340m AHD
   b. Gauge No 541041/422947 Dalby Alert 28/04/1993 to present datum = 339m AHD
2) For clarity, all gauge hts assume the present (339m AHD) datum
3) Gauge Height estimated for dates prior to 1/9/1981
4) Historical research indicates this flood was larger than the 1981 flood. However, it is difficult to determine an exact magnitude.
5) Estimate only. Exact height unclear.

4 FLOOD ANALYSIS APPROACH

4.1 Overview

The flood analysis of Myall Creek to Dalby was undertaken using a combination of hydrologic and hydraulic modelling techniques.

4.2 Hydrologic (Rainfall/Runoff) Analysis

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.

A 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 enter into the stream or watercourse over time. The 'RAFTS' runoff-routing model (XP Software, 2001) was used to model hydrologic processes for Myall Creek to Dalby.

4.3 Hydraulic (Flow) Analysis

Hydraulics (in this context) refers to the detailed description of flow down a watercourse or through a rural or urban floodplain or a combination of both.

A hydraulic (or hydrodynamic) model uses data about the flow in streams and the terrain of a particular area to estimate flood heights, velocities and flow over time. Hydraulic modelling of the Myall Creek floodplain through Dalby has been undertaken utilising DHI Software’s MIKE FLOOD modelling system. MIKE FLOOD combines via dynamic coupling 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.).

4.4 Catchment Area

The adopted catchment area for all discharge estimation was 1,420 km2. This is the adopted RAFTS model catchment size. The downstream catchment boundary does not align with any particular creek location (e.g. a gauging station); the size is a based upon an area of convenience for modelling.

For clarity, this catchment is named the “RAFTS Catchment” in this report.

5 JOINT CALIBRATION OF THE 1981 AND 2011 DALBY FLOODS

Joint hydrologic/hydraulic model calibration of the February 1981 and 10 January 2011 Dalby floods was undertaken. The 1981 and 2011 flood models used the 1981 and 2010 land use and roughness layers, respectively. The model was calibrated against recorded water levels and (for the 2011 flood) a flood level hydrograph at Patrick Street. The model showed good calibration for both floods.

Appendix G contains the hydraulic model calibration results for these floods. The following is of note:

- The 2011 hydrograph calibration at the Patrick Street gauge is shown in Figure 5.1.
- No hydrograph was available for the 1981 flood.
- The 1981 and 2011 flood models used the 1981 and 2010 land use and roughness layers, respectively.

The 2011 calibration results showed an area west of the main town (just left of centre in Figure G.4, Appendix G) where the modelled water levels are consistently lower than the recorded levels.

- Figure G.5, Appendix G shows an enlarged view of the area of interest showing the difference between modelled and observed water levels.
- Further investigation of this area was undertaken. In particular, an assessment of the modelled extent of flooding against historical extents (rather than the recorded depth provided by WDRC) was undertaken.
- WDRC door knocked residents in (or next door to) the properties with red outlines in Figure G.5, Appendix G.
  - The modelled flood extent was compared with the Google Earth image dated 29 January 2011 (which clearly showed the brown areas of the flood extent)
  - A YouTube video (taken by a media helicopter during the flood) which included the area of interest was viewed.
- Of note, an additional 0.4m of water (as indicated by the historical data) would result in a substantial increase in flood extent; given the flat topography of Dalby.
  - All three surveys confirmed that the modelled flood extent is an accurate representation of the actual extent. It was concluded that, in this small area, the WDRC data is not a correct representation of the flood extent.
  - WDRC have investigated this and the reason for the discrepancy between the WDRC and other is unclear.
  - The modelled results were adopted.

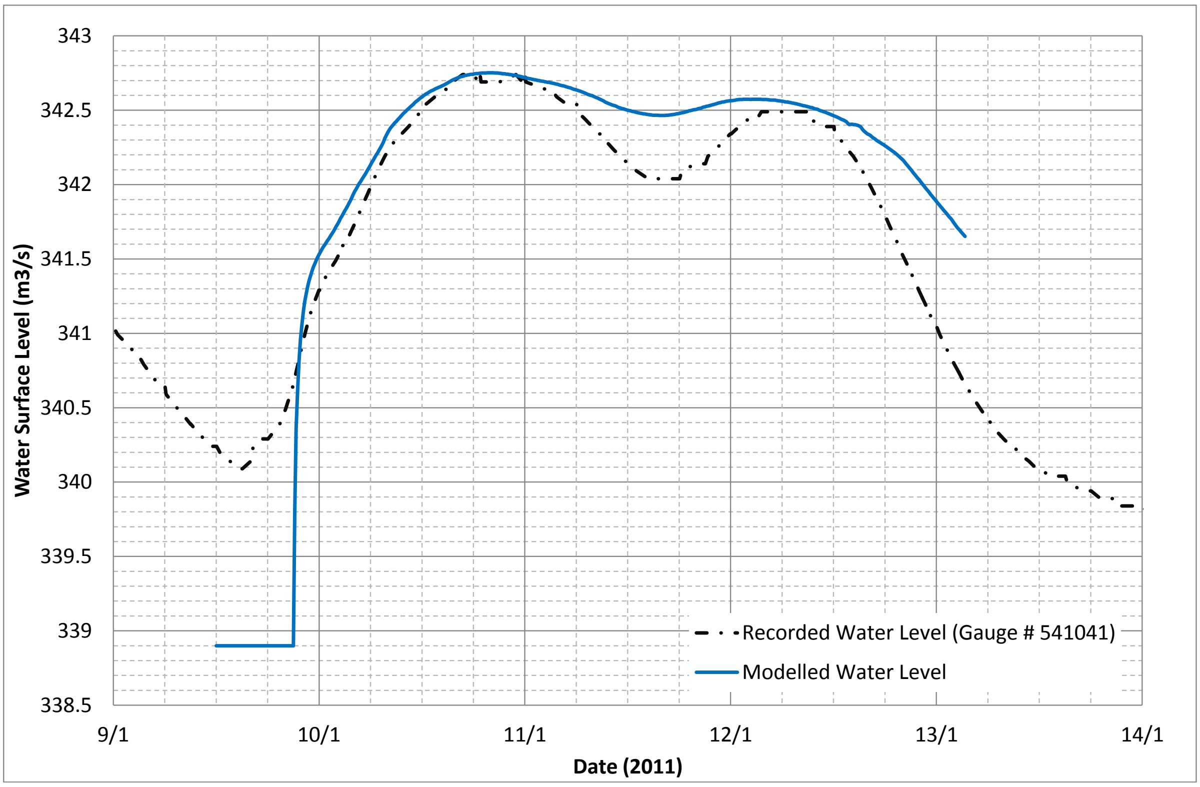

Figure 5.1 Dalby 2011 Flood Hydraulic Model Calibration

6 THE 1893 FLOOD

6.1 Introduction

Anecdotal evidence indicated that the 1893 flood was possibly the highest flood in Dalby since European settlement. If true, this flood would have a substantial impact on the flood frequency analysis. Given this importance, and the uncertainty in the 1893 flood level data, substantial analysis was been undertaken to compare the 1893 and 1981 flood magnitudes.

The limited data available included:

- Recorded Rainfall Data
- Historic newspaper articles regarding the water level at Dalby Station
- Historic newspaper articles regarding the water level at Queen's Hotel.
- Historic newspaper articles regarding the water level at Dalby Convent.

Full details of the assessment are provided in Appendix H.

6.2 Results Summary

Table 6-1 shows the results summarised along with sensitivity estimates. Figure 6.1 shows the range of discharges possible using the available information, including the best estimate.

Table 6-1 1893 Discharge Estimates based on recorded flood levels

Location	Level	Estimated Discharge (m3/s)
Dalby Station	2ft above railway track level -100mm	900
	2ft above railway track level	1,436
	2ft above railway track level +100mm	2,283
	2ft above platform level	~8,000
Queens Hotel	2ft above Lowest point of flat portion of the SE site	570
	2ft above Mable St road level adjacent to the SE site (indicative of floor level of Queen's hotel)	1,768
	2 ft above Mable St road level adjacent to the NW site (indicative of floor level of Queen's hotel)	6,435
Dalby Convent	4ft above the lowest point on the site	796
	4ft above Myall St level (indicative of historic convent floor level)	1,628
	4ft above the highest point on the site	2,110

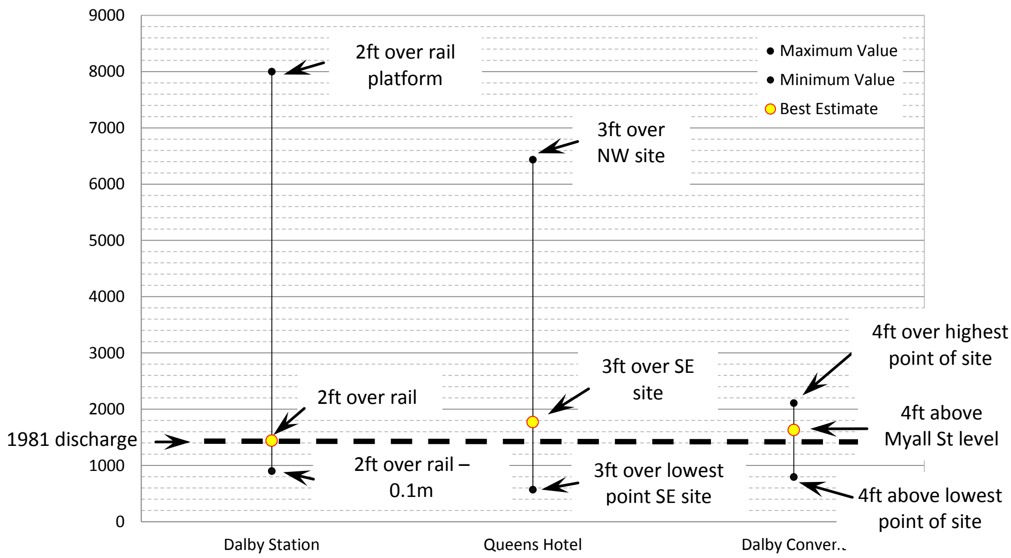

Figure 6.1 Dalby 1893 Flood Estimates

6.3 Discussion

While investigations into the 1893 event have been conducted, there is still significant uncertainty regarding the discharge to be assigned to the 1893 event. If the best estimates of flow for each of the three data points (Dalby Station, Queens Hotel and Dalby Convent) are averaged, an estimate of 1,645 m3/s results.

There are a number of uncertainties associated with the discharge estimates. Along with the unknown catchment rainfall and sensitivity to reference levels for the recorded depths, the following is of note:

- The Dalby train station recorded level was presented as 2ft above the station platform. The modelling results suggested that the discharge magnitude required to attain this level was significantly larger than any previously recorded flood event. More specifically the flow corresponding to a level of 2ft above the station platform has been estimated to be approximately 8,000 m3/s. This flow is approximately six times the flow of next largest flood (the 1981 flood of the order of 1,400m3/s). Sensitivity testing was carried out by interpreting the level described as 2ft above the station platform as being 2ft above the rail tracks at that location.
- The Queens hotel's location is uncertain. Historic maps show the hotel on the north-western side of Marble Street in Dalby while historic aerial photographs label a building on the south-eastern side of Marble Street as the location. As the ground level rises as distance from Myall Creek increases, if the depth at the Queen's hotel is interpreted as occurring at the south-eastern location, this depth is smaller, leading to a decreased estimate for the 1893 discharge when compared to the discharge obtained if the north western location is used.
- Historic photographs suggest that the Queen's hotel underwent significant structural changes between 1865 and 1930. The original layout of the Queen's hotel is a single storey slab structure with the floor level most likely at ground level. A photograph from 1930 shows the

Queen's hotel as a 2-storey structure with the floor level raised approximately 2-3 feet above the ground level.

- Newspaper reports from 1942 and 1975 suggest that tail water level of the Myall Creek in 1893 was higher than in other floods, possibly increasing levels. Modelling undertaken during this investigation suggests that the amount of influence from the Condamine River is minimal within the town of Dalby. However, there remains the possibility that extreme levels within the Condamine River may have had an impact.
- Newspaper reports from 1922 and 1942 suggest that the 1893 flood was the greatest experienced up until this time, being greater than the 1908 event which was approximately 1,100 m3/s.

6.4 Changes in the Dalby Level of Development

Adjustments to the hydraulic model were made to represent differing historic floodplain configurations, based chiefly on available historic aerial photography. It is worth noting that with development progress in the town of Dalby (corresponding to gradually increasing overall "roughness" of floodplain) the discharge in 1893 would have to be greater than that of 1981 to attain the same flood level (due to the considerably different amounts of development).

6.5 Conclusion

The available data indicates that the 1893 flood had a higher discharge than the 1981 flood. It is possible that the 1893 flood was substantially larger; however there is considerable uncertainty regarding how much larger and to date it has not been possible to reduce this uncertainty. Based on work undertaken to date the 1893 flood was input into the flood frequency analysis for Dalby as a Censored Flow greater than 1,430 m3/s (1,430 m3/s being the 1981 flood magnitude). The flood frequency analysis is presented in Section 8.5.

7 THE 1981 FLOOD

7.1 Overview

The 1981 flood was a substantial, recent flood. As such, specific consideration of the 1981 flood in comparison with the 1% AEP flood is warranted. The following section provides an overview the recorded 1981 rainfall with reference to the 1% AEP rainfall.

7.2 Rainfall Excess

An assessment was made of the 1981 event rainfall and the 1% AEP design rainfall. The total 1981 event rainfall is similar to the 1% AEP design rainfall total, 210 and 213 mm, respectively. However, the peak discharges are different, 1430 and 1540 m3/s, respectively. Figure 7.1 shows the cumulative rainfall total and model rainfall excess for both events. Figure 7.1 clearly shows the difference in the rainfall temporal patterns, with the design rainfall being front loaded; compared to the 1981 event rainfall. Consequently, the design flood has higher rainfall intensity and rainfall excess at the start of the event. This results in a higher flood peak discharge. Of interest, the total rainfall excess is greater in 1981 than for the design event (151 vs 109 mm, respectively) however, it is the higher initial intensity that has the most influence on the flood peak, not the total rainfall excess.

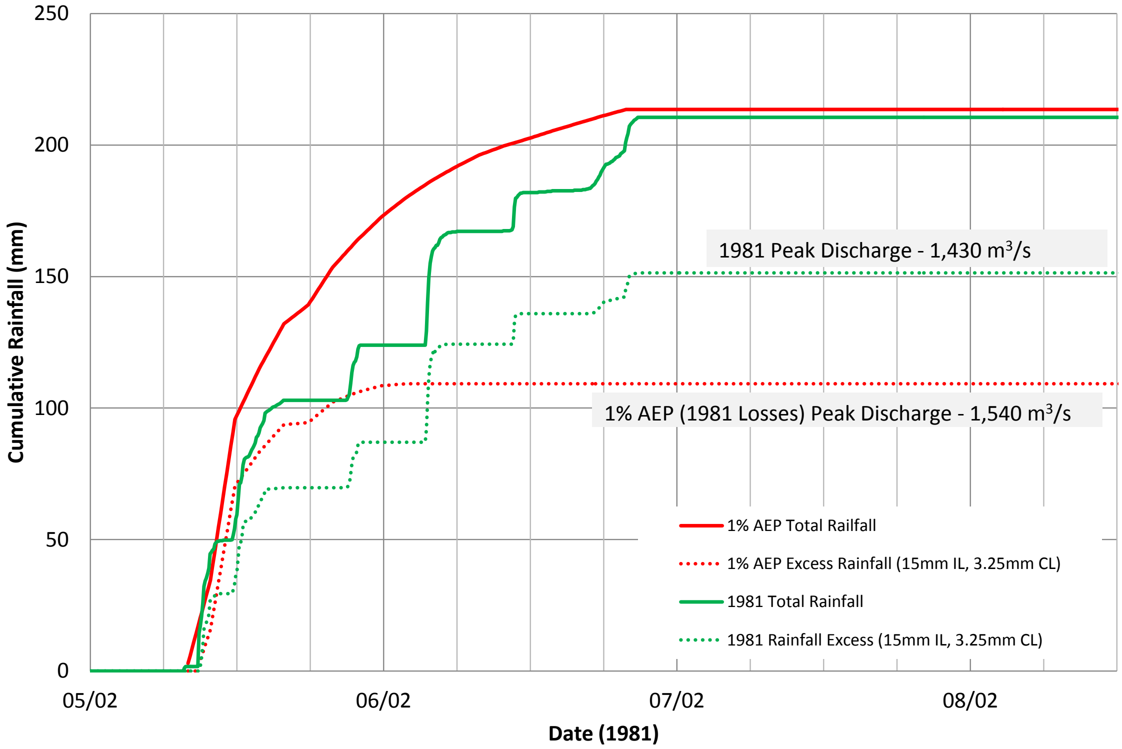

Figure 7.1 Relationship between the 1% AEP (1981 Losses) and 1981 Flood Rainfall for Dalby (RAFTS Catchment)

Table 7-1 Daily Rainfall – Dalby Post Office

Day	1980		1981		
	Nov	Dec	Jan	Feb	Mar
1	0	0	1.6	0	0.5
2	0	0	5.2	0	0
3	0	0	0	0	0
4	0	39.2	0	0	0
5	0	0.2	0	8.2	0
6	0	17.6	0	136	0
7	0	1	0	107	0
8	0	0	0	22	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	15.4
15	0	1	0	0.2	0
16	2.2	10.4	0	0	0
17	0	0	0	0	0
18	0	0	0.6	0	0
19	0	0	0.6	0	0
20	0	0	7.6	0	0
21	0	4	0	4.6	0
22	0	0	0	7	0
23	0	0	0	0	1.8
24	0	0	0	0	7.8
25	0	0	0	0	0
26	14.2	0	0	0	0
27	0	22	0	0	0
28	0	3	0	0	0
29	0	0	0		0
30	0	20	0		0
31		0	12.8		4
Total	16.4	118.4	28.4	285	29.5

7.3 Discussion

The total 1981 event rainfall is similar to the 1 in 100 AEP design rainfall total. However, the 1981 peak discharge is considerably lower than the 1 in 100 AEP design discharge. This is consistent with the data, which shows the following:

- The design rainfall has a different temporal pattern to the 1981 rainfall, with more rain falling at the start of the event (higher intensities) for the design rainfall. Therefore, the design rainfall produces more runoff than the 1981 rainfall.
- The catchment antecedent soil moisture conditions for the 1981 flood were low. Therefore, a considerable amount of the initial rain would have soaked into the soil before runoff commenced; reducing the size of the flood.

8 FLOOD HYDROLOGY

8.1 Overview

Uncertainty in flood magnitude estimation is a fundamental problem in flood hydrology. The geography of Myall Creek at Dalby (and the Myall Creek catchment generally) is hydrologically complex. The hydrological behaviour of the floodplain shows variation in space and time of infiltration characteristics, flowpaths, roughness and storage. Further, the extensive, flat floodplain introduces uncertainty into flow gauging and makes flood discharge estimation a complex task.

Given the uncertainty in discharge estimate, a number of techniques were employed in order to define the range of design events of Myall Creek at Dalby. These techniques included the following methods for determining design event discharges and are discussed in following sections:

- Australian Rainfall Regional Flood Frequency Analysis (ARFF).
- A regional discharge-area assessment.
- A Flood Frequency Analysis (FFA) using the FLIKE analysis package.
- The Design Rainfall technique.

8.2 Regional Flood Frequency

8.2.1 Australian Regional Flood Frequency

The Australian Regional Flood Frequency (ARFF) Model (Engineers Australia, 2012) was used to estimate Dalby flood magnitudes. Note that Engineers Australia (2012) recommends that the ARFF is applicable for catchments with areas between 20 and 1000 km2. The Dalby catchment (area 1420 km2) is outside this range. Notwithstanding this, the ARFF estimate is useful to provide an estimate to assist with flood magnitude selection. Table 8-1 shows the ARFF flood magnitude estimates for Myall Creek at Dalby.

Table 8-1 ARFF Discharge Estimates for Myall Creek at Dalby (RAFTS Catchment)

AEP (1 in x)	AARF
2	145
5	410
10	660
20	960
50	1,410
100	1,800

8.3 Regional Discharge Area Assessment

8.3.1 Overview

The regional discharge-area technique provides a way to check flood magnitude estimates. It identifies poor data, non-representative catchments, compares results from different techniques (e.g. design rainfall, ARFF) and provides catchment understanding. The method is described in full Walton et al. (2014).

8.3.2 Methodology

The regional discharge-area technique is applied in the following manner:

- Gauging stations in the vicinity of the study catchment are identified. Ideally, only geographically similar catchments with a reasonable record length are selected. In practice, however, there is usually a paucity of gauging stations in the general area, let alone stations with geographically similar catchments. Therefore, all stations are usually selected.
- The data is checked and flood frequency analyses are undertaken. As with site selection, while sites with reliable high discharge ratings and long record lengths (say >30 years) are desirable, the paucity of stations means that one cannot be too particular and poor quality stations are usually retained. These stations are noted, however, and their data quality is considered during the later analysis.
- Discharge estimates for the flood magnitude of interest (usually the 1% AEP) are plotted against catchment area.
- Additional discharge estimates for the station of interest, or other stations, may be added to the discharge-area plot. These estimates may include results from previous studies, other techniques (e.g. design rainfall) or regional estimates such as the Australian Regional Flood Frequency (ARFF) (Engineers Australia, 2012).
- An area-discharge curve is fitted to the data. This is the step that requires the most subjectivity or “professional judgement”. The area-discharge plot will usually show some scatter due to poor quality stations or a failure of the geographically similar assumption. Prior knowledge of the sites and data needs to be carefully applied at this step.

8.3.3 Curve Fitting

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

$$\frac{Q_C}{Q_G} = \left(\frac{A_C}{A_G}\right)^b \qquad \textbf{(8.1)}$$

Where:

Q = Discharge (m3/s)
G = gauged catchment (km2)
A = Area
b = exponent
C = ungauged catchment (km2)

Studies show that the exponent b ranges from 0.5 to 0.85. If no data is available Grayson et al. (1996) recommend a value of b=0.7. There appears to be no clear basis for the adoption of b=0.7 other than (if no data is available) it is approximately the average of the range of published values.

The gauge with the highest confidence is selected and applied to Equation (8.1). This provides a power function with an exponent b passing through point (AG, Qg). This function is added to the discharge-area plot of the selected gauges. The limitation of this method is that it is dependent upon the choice of the gauged catchment (G); which sets the function coefficient. In practice, all selected gauges may have limitations with no obviously "best" gauge. In this case, the power function can be fitted to a number of gauges. It is our experience that both methods tend to provide similar results.

8.3.4 Myall Creek

A number of stream gauging stations in the general vicinity of Myall Creek were selected. It was difficult to select geographically similar stations because any similar catchment to Myall Creek (with extensive floodplains) would also have similar gauging difficulties. Further, given the floodplain form of most catchments in the region, there is a paucity of gauging stations in general. Given the limited selection from which to choose, all nearby stations with adequate data were selected. Figure 8.1 shows the location of selected stations. Table 8-2 shows a summary of gauging station details.

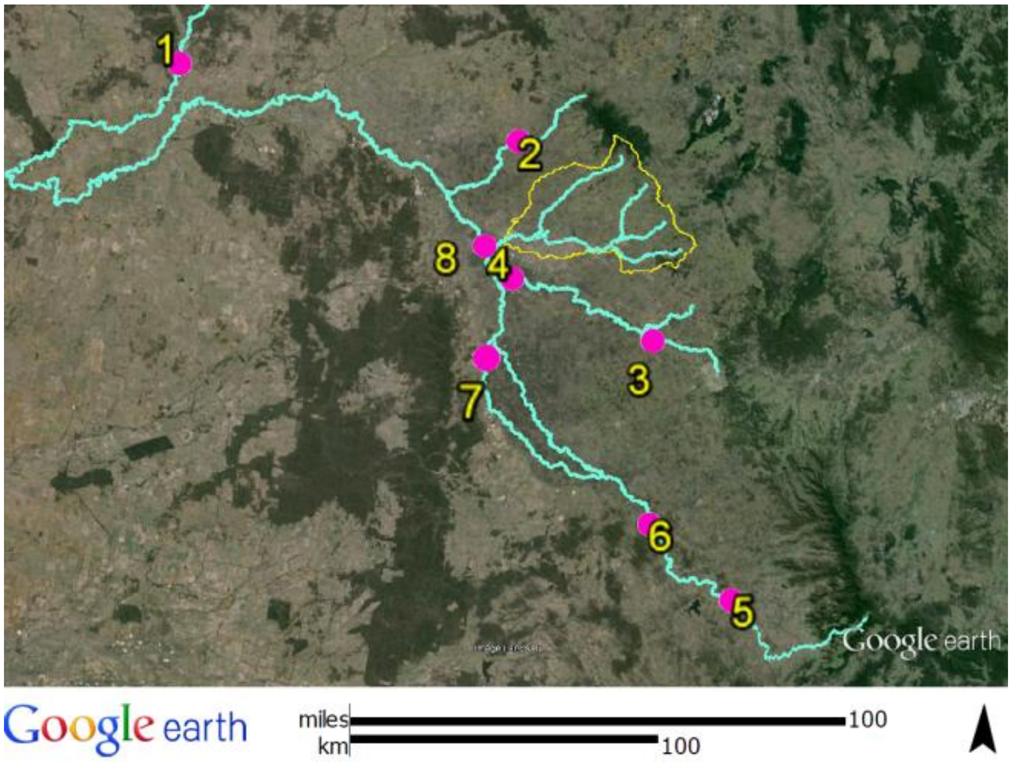

Figure 8.1 Myall Creek Catchment and Adopted Stream Gauges

Table 8-2 Adopted Stream Gauging Stations for the Myall Creek Catchment Assessment

No	Station Name (record; yrs)	Station No	Area (km2)	Qualitative Comparison with Myall Ck Catchment
1	Dogwood Ck at Gil Weir (62)	422202B	2875	High confidence. Rating curve checked with 2D hydraulic model. Steeper, limited floodplain, higher runoff coeff. ("harder" catchment). Expect higher flows.
2	Jimbour Ck at Bunginie (20)	422339A	235	Steeper topography. Expect higher flows.
3	Gowrie Ck at Oakey (19)	422332B	142	Steeper topography, higher rainfall, drains Toowoomba urban area. Expect higher flows.
4	Oakey Ck at Fairview (31)	422350A	1970	Floodplain, higher rainfall, drains Toowoomba urban area. Should be geographically similar but expect higher flows.
5	Condamine R. at Warwick (52)	422310C	1360	Steeper topography, higher rainfall, Expect higher flows than Myall Ck.
6	Condamine R. at Talgai Tailwater (23)	422355A	3105	Results indicated this catchment may be a "Myall Creek type" catchment. This assumption needs further supporting evidence
7	Condamine R. at Cecil Weir (38)	422316A	7795	Only low flow rating. Gauge located in a floodplain. FFA magnitude probably an underestimate. Expect lower flows than Myall Ck.
8	Condamine R. at Loudouns Bridge (40)	422333A	12380	Only low flow rating. Gauge located in a floodplain. FFA flood magnitude probably an underestimate. Expect lower flows than Myall Ck.

The 1 in 100 AEP flood was plotted. For each gauging station, an at-site flood frequency analysis was undertaken by fitting a Log Pearson Type III (LP3) distribution to the annual flood series using the method of moments in accordance with the procedures provided IEAust (1998).

Figure 8.2 also shows the ARFF estimates (Engineers Australia, 2012). While it is recommended the ARRF estimates are applicable to catchments with areas between 20 and 1,000 km2, the estimates are included as they are one more piece of information that can help reduce estimation uncertainty. Note that the catchment area for Myall Creek at Dalby is 1464 km2.

There was considerable uncertainty in the analysis as the catchments were, generally, not geographically similar. Further, the gauging data at a number of the stations was questionable due to the ratings and/or the length of record. Two different methods were used to estimate the discharge-area relationships; curves drawn "by eye" (Figure 8.2) and by fitting by regression to selected stations (Figure 8.3). Figure 8.2 shows two curves fitted "by eye", an upper and lower estimate, reflecting the uncertainty in the fitted curves. The curves do not follow any particular function. Instead, a subjective assessment of each catchment was undertaken to determine whether it would have a higher, similar or lower discharge-area relationship to Myall Creek.

A summary of the qualitative assessments is provided against each gauge in Table 8-2. Figure 8.3 shows two power functions; one fitted to all gauges excluding gauge 4 (coefficient = 200, exponent = 0.33) and one only fitted to gauges excluding gauges 4, 7 and 8 (coefficient = 140, exponent = 0.39).

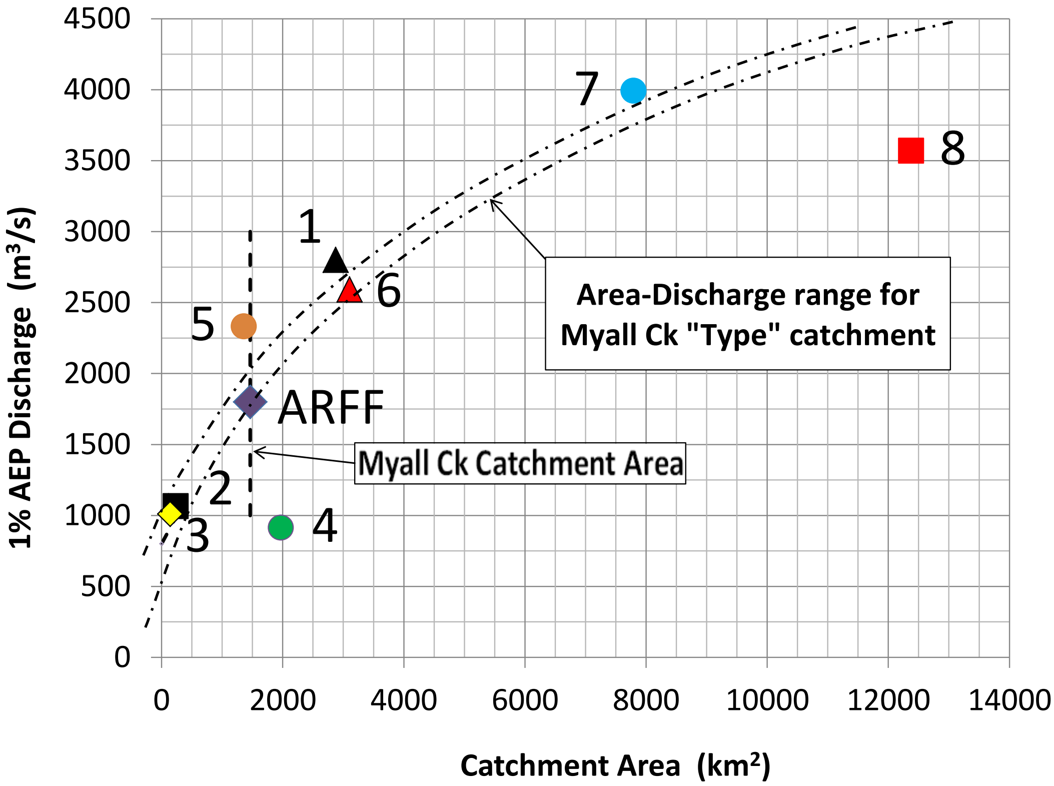

Figure 8.2 Discharge-Area Relationship (1% AEP) for Myall Creek (curves fitted "by eye")

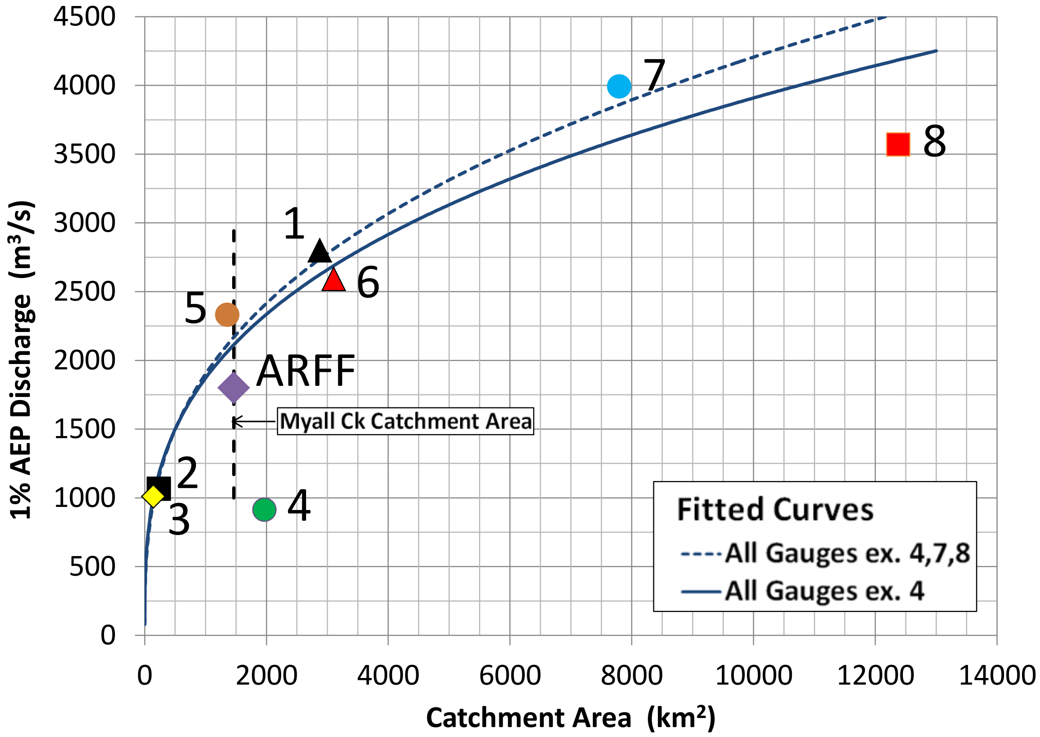

Figure 8.3 Discharge-Area Relationship (1% AEP) for Myall Creek (curves fitted by regression against data)

8.3.5 Discussion

A degree of professional judgement needs to be employed in assessing the results of the discharge-area relationship. When this technique is applied to geographically similar catchments, there is usually a clear relationship between discharge and area. Unfortunately, the available catchments for this study generally have different characteristics (e.g. rainfall, area, runoff coefficient, floodplain storage, topography); with none of them having "typical" Myall Creek characteristics. The uncertainty around the Myall Creek 1 in 100 AEP discharge estimate was reduced by "bracketing" the upper and lower flood magnitudes.

The following is of note:

- Lower boundaries:
  - Oakey Creek at Fairview:
    - This catchment is geographically similar to Myall Creek but with higher rainfall and urbanisation, it is expected to have a higher unit area discharge. However, it plots well below the fitted curves (i.e. a much lower unit area discharge). An inspection of the data showed the station was located in a floodplain with all recorded water levels truncated at a height just above top of bank. This resulted in a considerable underestimate of flood magnitude. It follows that the 1% AEP estimate derived from this data for this gauge should plot below the fitted curves, which it does.
      - Figure 8.4 shows discharge hydrographs for Gowrie Creek at Oakey and the downstream gauge of Oakey Creek at Fairview. It can be seen that the discharge data for Oakey Creek is poor because:
        - There is clearly a truncation of the hydrograph when the creek water flows over-bank at a discharge of approximately 300 m3/s.
        - The Gowrie Creek discharge is higher, even though there is a considerable difference in catchment areas; 142 km2 vs 1970 km2 for Gowrie Creek and Oakey Creek, respectively.
    - Therefore, the 1 in 100 AEP estimate for Oakey Creek is considered to be substantially lower than the "true" value.
  - Condamine River at Loudouns Bridge:
    - The Loudouns Bridge 1 in 100 AEP estimate is considered to be lower than the true value as rating has only been undertaken for low flows (Ken Klassen, DERM Hydrographer, Pers. Commun.). Further, the gauge is located in a broad flood plain therefore, it most likely does not accurately measure high flows.
    - It follows that the estimated 100 year ARI discharge (from FFA) at this gauge should be lower than that for a Myall Creek type catchment because the gauging data used in the FFA analysis is in error.
  - Condamine River at Cecil Weir:
    - The 1 in 100 AEP estimate for the Condamine River at Cecil Weir may be too low as the gauge is located in a broad flood plain therefore it does not accurately measure high flows; the highest recorded water level is well above the top of bank.
    - It follows that the estimated 1 in 100 AEP discharge (from FFA) at this gauge should be lower than that for a Myall Creek type catchment because the gauging data used in the FFA analysis is in error.

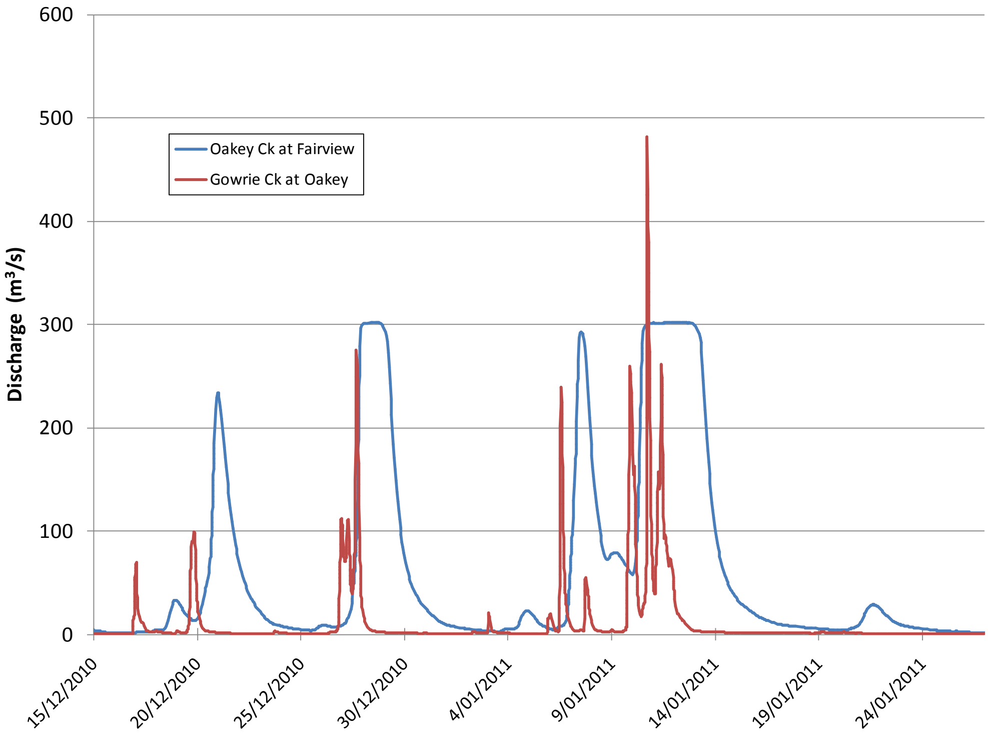

Figure 8.4 Comparison of Discharge Hydrograph for Oakey Creek at Fairview and Gowrie Creek at Oakey

- Upper boundaries:
  - Dogwood Creek at Miles (Gil Weir):
    - The fitted Myall Creek curves (Figure 8.2 and Figure 8.3) are below the Dogwood Creek at Miles (Gil Weir) discharge estimate.
      - This is expected as it is considered that, relative to the Myall Creek catchment, the Dogwood Creek catchment upstream of Gil Weir:
        - Is steeper.
        - Is more confined (has less flood plain); therefore less flow attenuation.
        - Has a higher runoff coefficient (i.e. is a "harder" catchment).
  - Gowrie Creek at Oakey:
    - The fitted Myall Creek curves are below the Gowrie Creek at Oakey data point.
      - This is expected as it is considered that, relative to the Myall Creek catchment, the Gowrie Creek catchment upstream of the Warrego Hwy:
        - Is steeper.
        - Has a higher runoff coefficient as it includes Toowoomba.
        - Is more confined (has less flood plain).
        - Has higher rainfall (the upper catchment takes in Toowoomba).
  - Condamine River at Warwick:
    - The fitted curves are below the Condamine River at Warwick estimate.
      - This is expected as it is considered that, relative to the Myall Creek catchment, the Condamine River catchment upstream of Warwick:
        - Is steeper.
        - Is more confined (has less flood plain).

            - Has higher rainfall (the upper catchment takes in Killarney).
- Jimbour Creek at Bunginie
    - The fitted curves are below the Jimbour Creek at Bunginie estimate.
        - This is expected as it is considered that, relative to the Myall Creek catchment, the Jimbour Creek catchment upstream of Bunginie:
            - Is steeper.
            - Is more confined (has less flood plain).
        - However, this gauge is only rated for low flows therefore the reliability of the gauged data is unclear (Ken Klassen, DERM Hydrographer, Pers. Commun.).
- Condamine R at Talgai Tailwater:
    - The 100 year ARI discharge for the Condamine R at Talgai Tailwater is within the Myall Creek curves.
    - This tends to indicate that the catchment upstream of the Condamine R at Talgai Tailwater gauge may be a "Myall Creek type" catchment. However, this assumption needs further supporting evidence.

8.3.6 2007 Flood Study

Of note, the SKM (2007) Myall Creek 1 in 100 year AEP discharge estimate of 915 m3/s is similar to that at the Oakey Creek at Fairview gauge. It has been shown that data from the Oakey Creek gauge has considerable error leading to an underestimation of the Oakey Creek 1 in 100 AEP discharge. This is compelling evidence that the 1 in 100 AEP discharge estimate from the 2007 study is too low.

8.3.7 Runoff Production per Unit Area for Regional Catchments

Figure 8.5 shows a graph of the runoff per unit area for the regional catchments used in the discharge-area scaling assessment.

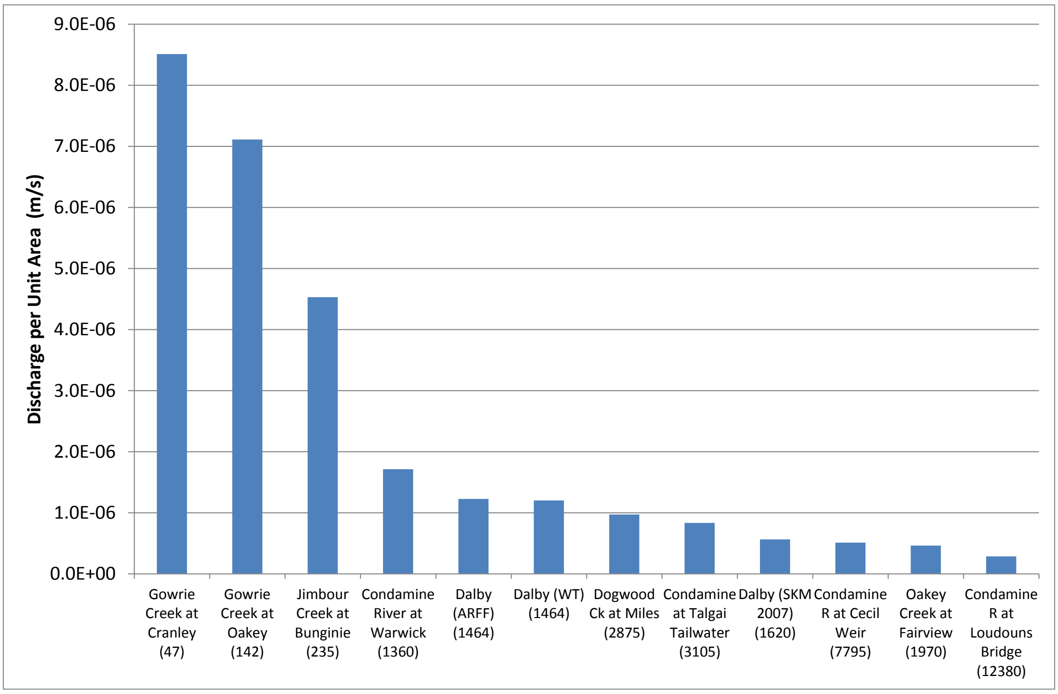

Figure 8.5 Discharge per Unit Area for Regional Catchments
(bracketed numbers are catchment areas in km2)

8.3.8 Conclusion

The regional area-discharge assessment indicates that the 1 in 100 AEP discharge estimate for Myall Creek at Dalby should be between approximately 1,800 and 2,350 m3/s.

8.4 Design Rainfall

The design rainfall technique (DRT) was applied to the Myall Creek catchment to provide a peak discharge estimate. The calibrated 1981 flood hydrology and hydraulic models were adopted. Table 8-3 shows the 1 in100 AEP RAFTS model discharges for a range of initial loss (IL) and continuing loss (CL). The following is of note:

- The calibrated 1981 flood IL and CL were 15 mm and 3.25 mm/hr, respectively.
- The 1 in 100 AEP design discharge estimate using the 1981 loss parameters was 1,560 m3/s.
- Changing the CL from 3.25 to 2 mm/hr (a reasonable assumption) results in a peak 1% AEP discharge of 1,860 m3/s.
- Different combinations of (reasonable) IL and CL result in 1% AEP discharge estimates of between (approximately) 1,560 and 2,100 m3/s.

8.4.1 General Comments on the Design Rainfall Technique

The DRT can be summarised as follows. A rainfall-runoff model is calibrated against one or more historical floods, the principal calibration parameters usually being the rainfall losses. These can vary greatly between calibration events; as much as an order of magnitude in large semi-arid catchments. Design rainfall of a given AEP is then applied to the calibrated model to produce design a discharge of the same AEP. The design rainfall losses are somewhat arbitrarily chosen; based upon the calibrated event losses, “experience” or “ARR recommendations”. The resulting design discharge are highly sensitive to these rainfall losses and there is thus significant uncertainty surrounding these design discharge estimates.

8.4.2 Results of the Design Rainfall Technique

The design rainfall technique has considerable limitations; especially when applied to large catchments. Notwithstanding this, the range of DRT discharge estimates do provide a check on results from other flood magnitude estimation techniques. The results of this study indicate that the 1% 100 AEP discharge for Myall Creek at Dalby is between 1,560 and 2,100 m3/s.

Table 8-3 Design Rainfall Technique Summary (RAFTS Catchment)

Event	Initial Loss (mm)	Continuing Loss (mm/hr)	Storm Duration (hrs)	Discharge (1 in 100 AEP) (m3/s)
1981	15	3.25	~36	1430
1% AEP	5	1	72	2250
	5	2	72	1970
	5	3	24	1730
	5	3.25	24	1680
	5	4	18	1560
	5	5	18	1420
	10	1	72	2190
	10	2	72	1910
	10	3	24	1670
	10	3.25	24	1620
	10	4	18	1490
	10	5	18	1360
	15	1	72	2130
	15	2	72	1860
	15	3	24	1610
	15	3.25	24	1560
	15	4	24	1430
	15	5	18	1290
	20	1	72	2070
	20	2	72	1800
	20	3	72	1550
	20	3.25	24	1490
	20	4	24	1370
	20	5	18	1230

8.5 Flood Frequency Analysis

8.5.1 Overview

A Flood Frequency Analysis (FFA) was undertaken for Myall Creek at Patrick St, based on the available gauge record using the FLIKE Flood Frequency Analysis package. FLIKE is a Flood Frequency Analysis tool that provides a comprehensive Bayesian analysis for a probability model fitted to gauged and censored historic data. Model outputs include probability plots showing data, quantiles and confidence limits, a text file summarising all the input data and results, and plots of the posterior density surface.

The Flood Frequency Analysis as applied to the Patrick St gauge record on Myall Creek is described in the following sections.

8.5.2 Myall Creek Flood Frequency Analysis

There is a long history of flooding in Dalby with the first known large flood during European settlement occurring in 1876. However, the available flood record is imprecise, with a manual water level gauge not being installed at Patrick Street until 1981 and an automatic gauge not installed until 12 years later in 1993.

It was not possible to undertake an acceptable flood frequency analysis of Myall Creek discharges between 1981 and 2013 for the following reasons:

- The period is too short.
- The period included extended periods of below average rainfall (i.e. periods of drought). This resulted in many years of very low to zero peak flow in Myall Creek.

While there are a number of stream gauges in the Myall Creek catchment, none of these are suitable for flood frequency estimation due to poor quality gauging data. That is, the lower section of the Myall Creek catchment is characterised by an extensive floodplain. The main channels of Myall Creek have a very low discharge capacity (less than a 1 in 2 AEP) with the majority of flow occurring either along anabranches or overland across paddocks. It is not possible to obtain quality stream gauging data in this landscape. Therefore, a low flow censored flood frequency analysis was undertaken.

8.5.3 Low Flow Censored Flood Frequency Analysis at Patrick Street Gauge

A low flow censored flood frequency analysis (FFA) was undertaken of the major historical floods in Dalby.

The following methodology was applied:

- The calibrated 1981 Dalby hydrology and hydraulic models were run with a range of discharges for four different historical development scenarios.
- A rating curve at the Patrick Street gauge was created for each of the four historical scenarios
  - A rating curve was also developed at other locations for the 1893 flood to assist with discharge estimation.
- The rating curves were used to estimate peak discharges at the Patrick Street Gauge for selected historical floods. The most representative (i.e. nearest in time) development scenario (topography and roughness map) was used.
- A low flow censored flood frequency analysis was undertaken of the adopted discharges using the FLIKE software.

An annual series of flows is not available at the Patrick St gauge as only flows that register as a "flood" are recorded. Consequently there is significant uncertainty regarding the frequency of occurrence of the lower flows present in the gauge record.

Through sensitivity testing, a value of $236m^3/s$ was adopted as the threshold value for low flow censoring within FLIKE. Adopting this value produced the best fit (as indicated by the confidence limits) of the available data.

8.5.4 Estimation of 1893 Flood Magnitude

As discussed previously, anecdotal evidence indicated that the 1893 flood was probably the highest flood in Dalby since European settlement. If true, this flood would have a substantial impact on the flood frequency analysis. Given this importance, and the uncertainty in the 1893 flood level data, considerable effort was applied to the investigation of the 1893 flood. The results of this assessment is provided in Section 6 of this report.

Based on work undertaken to date the 1893 flood was input into the FFA for Dalby as a Censored Flow greater than 1,430 m3/s (1,430 m3/s being the 1981 flood magnitude). Table 8-4 shows the historic events and discharges adopted for the flood frequency analysis.

Table 8-4 Adopted Flood Record for the Dalby Low Flow Censored Flood Frequency Analysis (RAFTS Catchment)

Year	Peak Discharge (m3/s)	Year	Peak Discharge (m3/s)
1876	1,000	1974	237
1879	500	1981	1,430
1893	>1,430 [1]	1983	456
1908	1,100	1984	168
1911	641	1988	136
1942	370	1990	297
1954	432	1996	126
1956	513	2011	369
1971	315	2013	197

[1] There is uncertainty associated with the discharge estimate for 1893. The most accurate representation for the flood frequency analysis was to characterise the 1893 discharge as greater than 1,430 m3/s.

8.5.5 Historic Flows

Historic flows greater than 237 m3/s were input as gauged flows with the exception of the flow for the 1893 event which was input as a censored flow greater than 1,430 m3/s. Table 8-5 shows the flow censoring adopted for FLIKE.

Table 8-5 FLIKE Censored Data

Threshold Value (m3/s)	Ungauged Years > Threshold (years)	Ungauged Years <= Threshold (years)
236	0	123
1,430	1	0

8.5.6 Distribution

A number of distributions were fitted to the data to assess the best fit. The Log-Normal distribution was adopted as clearly providing the best fit of the historic data set (based upon a visual assessment).

8.5.7 Results

Figure 8.6 show the adopted FFA results. Please note that the dashed arrow represents the significant uncertainty with regard to the 1893 event.

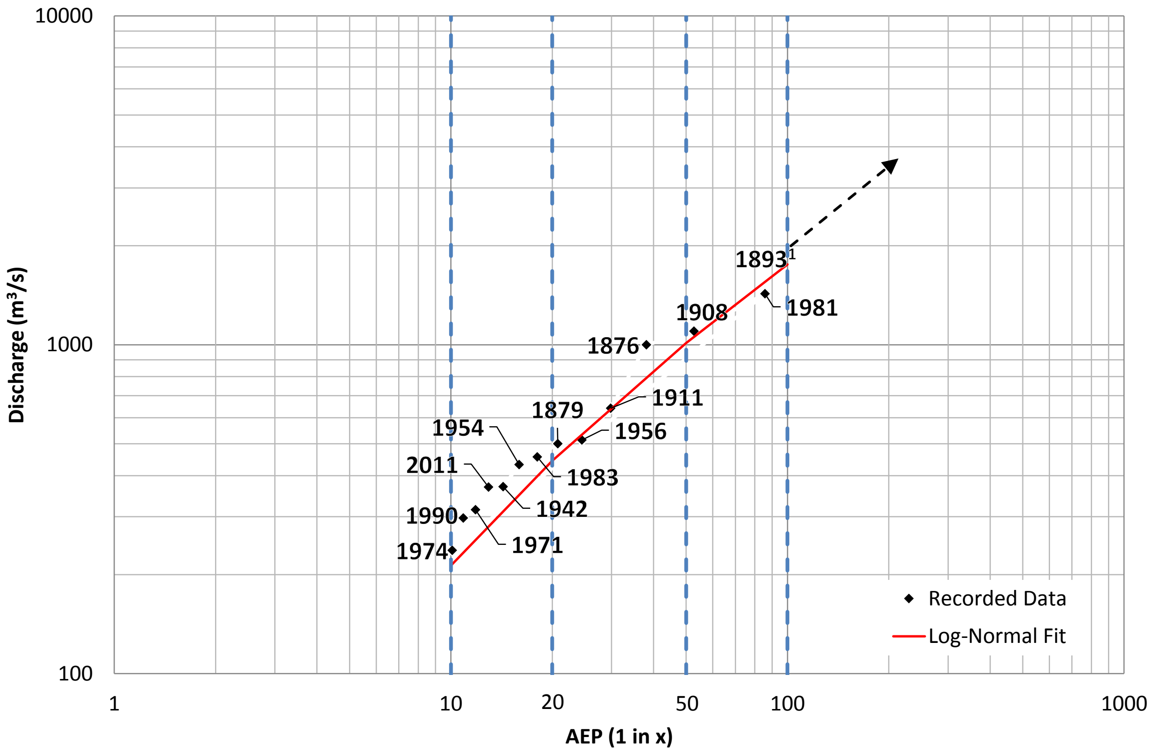

Figure 8.6 Adopted Flood Frequency Analysis Results – Dalby (Log Normal Distribution) (RAFTS Catchment)

Table 8-6 FFA Results (RAFTS Catchment)

AEP (1 in x)	Discharge (m3/s)
2	- a
5	- a
10	210
20	440
50	1010
100	1760

a) Discharge estimates for less than the 1 in 10 AEP flood are not applicable due to the low flow censoring used in the analysis.

8.6 Design Discharge Selection

8.6.1 1 in 100 AEP

Estimates for the 1 in 100 AEP discharge for Myall Creek at Dalby are:

- Australian regional flood frequency estimate: 1,800 m3/s.
- Regional discharge-area estimate: between 1,800 and 2,350 m3/s.
- Design rainfall technique: between 1,560 and 2,100 m3/s.
- Flood frequency analysis: 1760 m3/s.

It was considered that the flood frequency analysis provided the most accurate estimation of the 1% AEP discharge for this study. Further, the FFA estimate is within the range of other estimation techniques.

8.6.2 1 in 10 to 1 in 50 AEP

It was considered that the flood frequency analysis provided the most accurate estimation of the 1 in 10 to 1 in 50 AEP discharges. The following is of note:

- The low flow censoring threshold was 236 m3/s. This is slightly higher than the 1 in 10 AEP estimate of 210 m3/s.
- Generally, the low flow censoring threshold represents the lower limit of estimation.
- Given the absence of other more representative data, it is considered that the low flow threshold is close enough to the 1 in 10 AEP estimate to warrant the adoption of the FFA estimate.
- It follows that the FFA is unsuitable for estimation of the 1 in 2 and 1 in 5 AEP discharges.

8.7 Adopted Discharges

Table 8-7 shows the adopted 1 in 10 to 1 in 100 AEP discharges for Myall Creek at Dalby.

Table 8-7 Adopted 1 in 10 to 1 in 100 AEP Discharge Estimates for Myall Creek at Dalby (RAFTS Catchment)

AEP (1 in x)	Discharge (m3/s)
10	210
20	440
50	1010
100	1760

9 HYDROLOGIC MODELLING

The 'RAFTS' runoff-routing model (XP Software, 2001) was used to model hydrologic processes for Myall Creek to Dalby.

9.1 RAFTS Model Configuration

RAFTS requires several key parameters to accurately model hydrologic processes. Many of these have been derived through a joint calibration process which is described in detail in Section 5. A summary of the general RAFTS modelling approach adopted for this study includes:

- Use of the “one-subcatchment” model for all catchments,
- A catchment Manning’s n of 0.075 (based on calibration of the 1981 and 2011 events) was used for all catchments,
- A catchment percent imperviousness of 0% was adopted for all catchments at all locations. It was considered that the slight increase in imperviousness in the catchments that contained the towns would have an insignificant impact on discharges (due to the location in the catchment and the small area relative to the total catchment) and was therefore not included.
- The RAFTS Muskingum routing routine was used to model channel routing as follows:
  - The Muskingum K parameter was used as a calibration parameter during the joint calibration of the 1981 and 2011 Dalby floods.
  - The calibrated 1981 stream velocity was 0.5 m/s. This velocity was adopted to calculate the Muskingum K parameters for all design runs.
- A value of Muskingum x=0.2 was adopted for all streams.
- The RAFTSstorage coefficient ‘Bx’ = 0.95 was adopted from joint calibration of the 1981 and 2011 floods.
- The initial loss (IL) and (CL) were used as calibration parameters.

Figure 9.1 presents an overview of the RAFTS model layout

9.2 RAFTS Results

A full suite of design events was analysed using the RAFTS model. Table 9-1 shows the adopted design rainfall loss parameters.

Table 9-1 Design Rainfall Results for the 1 in 10 to 1 in 100 AEP Discharge Estimates for Myall Creek at Dalby

AEP (1 in x)	Initial Loss (mm)	Continuing Loss (mm/hr)	Discharge (m3/s)
10	46	4.1	210
20	44	4	440
50	31	3.2	1010
100	15	2.15	1760

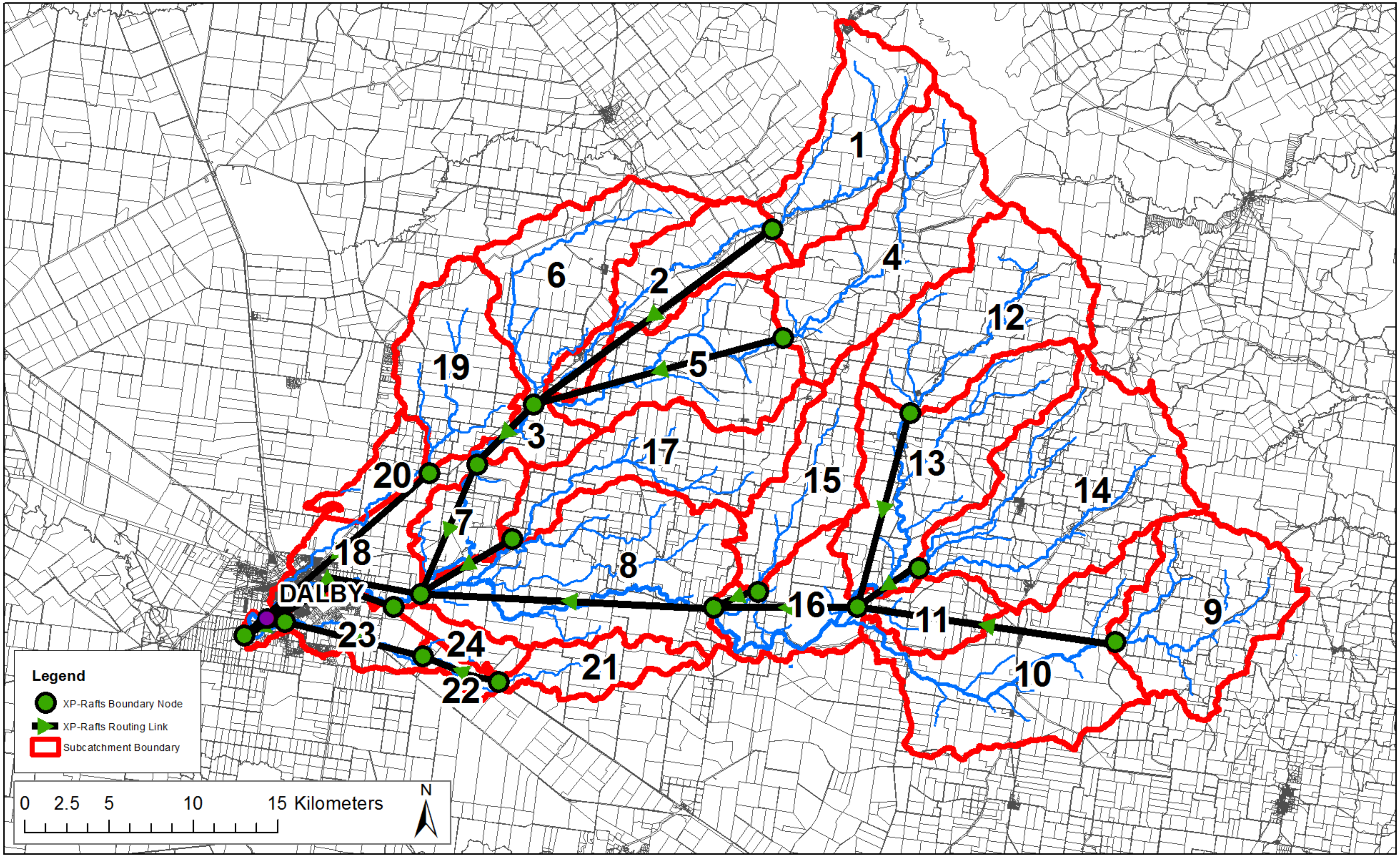

Figure 9.1 Myall Creek RAFTS Model Layout

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10 RIVERINE FLOODING ANALYSIS

10.1 Overview

The MIKE FLOOD model was used to estimate flood levels for Dalby. The 1% AEP flood was adopted as the defined flood event (DFE). This section describes the design event modelling process.

Model results are presented as maps of flood depth and flood hazard in Volume II of this report.

Figure 10.1 shows the topography and extent of the hydraulic model.

10.2 MIKE FLOOD Model Configuration

The model area and grid size were chosen to allow for practical model run times and to cover the area required. The Dalby MIKE FLOOD model developed for this investigation has the following characteristics:

- Model terrain based on available LIDAR data sets.
- 10m grid size covering an area 1.25km x 1.36km.
- 0.5s timestep.
- Velocity based eddy viscosity of 0.1m2/s.
- Inflow boundary conditions (from RAFTS).
- Fixed tailwater boundary condition.

A critical parameter within the hydraulic model is the hydraulic roughness. Hydraulic roughness is usually expressed in terms of the parameter Manning’s n and varied according to land use type. For this investigation, adopted Manning’s n values (corresponding to the various land use zonings within the revised planning scheme) are presented in Table 10-1.

Figure 10.2 shows the hydraulic roughness map used in the hydraulic model. The roughness is that for ultimate land use development in accordance with the planning scheme.

Appendix A shows the location of structures in the model.

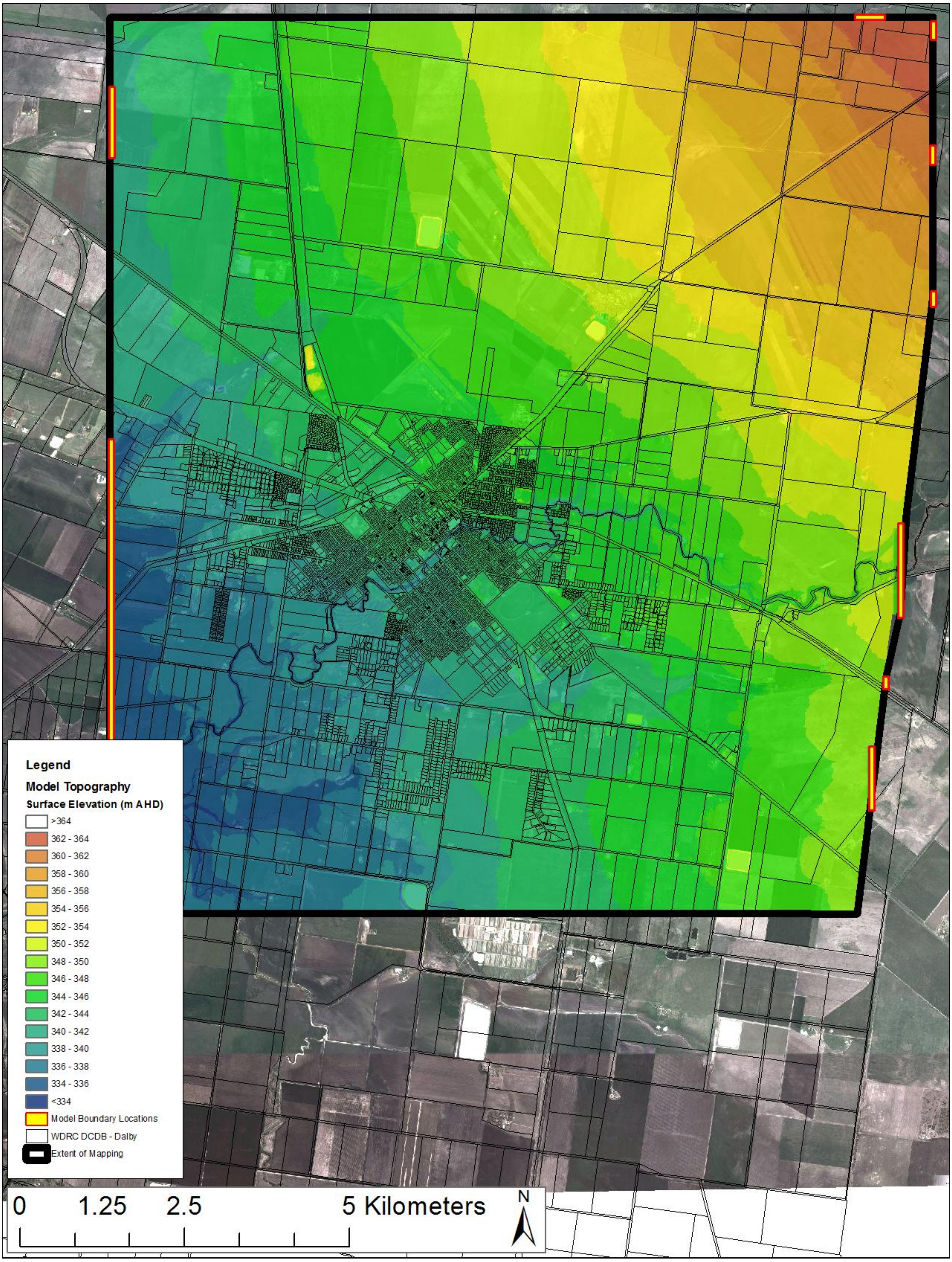

Figure 10.1 Hydraulic Model Extent and Topography

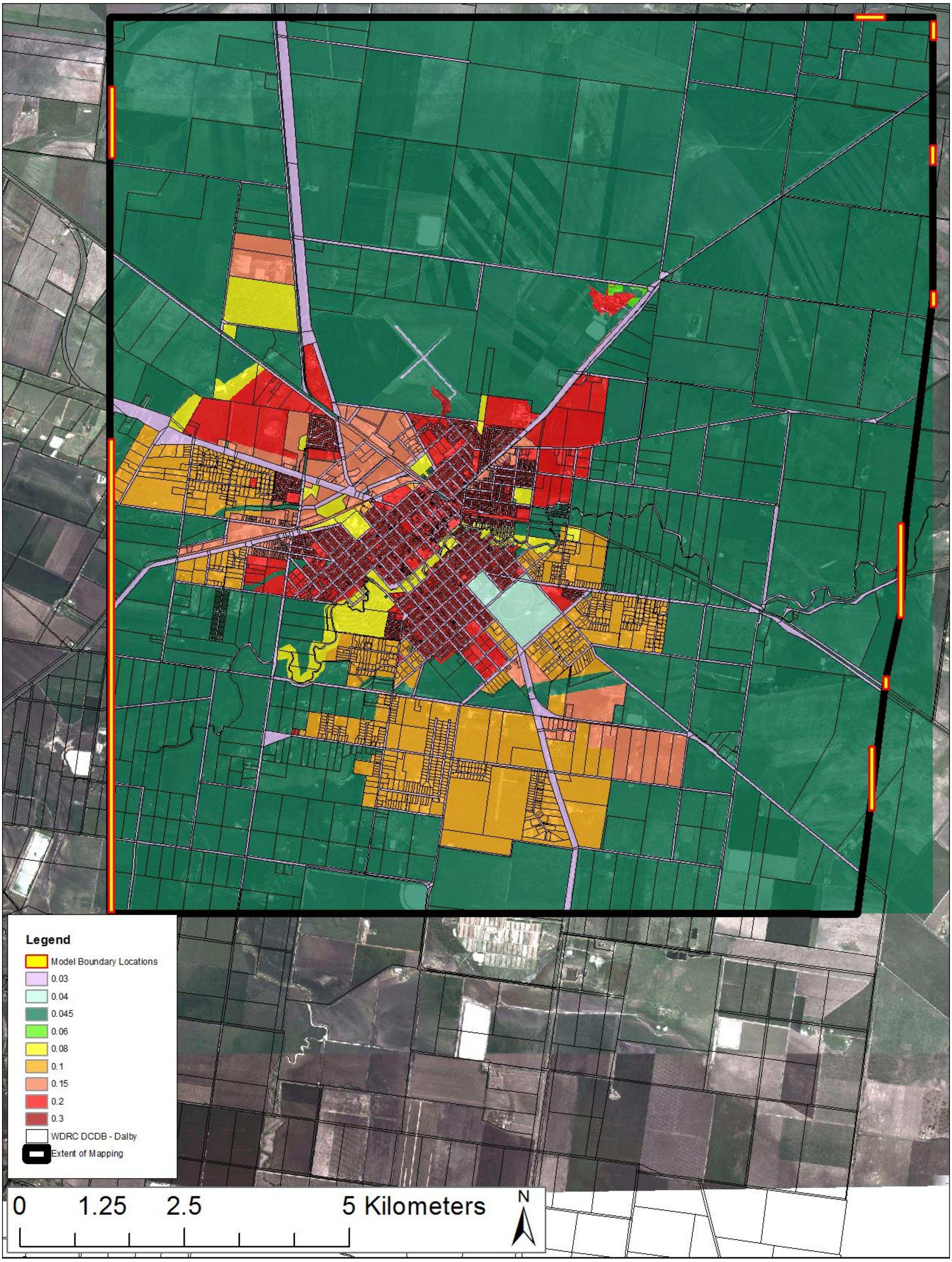

Figure 10.2 Hydraulic Model Roughness Map – Ultimate Development Conditions

Table 10-1 Adopted MIKE FLOOD Manning's n Values

Land Use	Manning's n
Roads	0.03
Cropping	0.045
Vegetation	0.08
Rural Residential	0.1
Industrial/Commercial	0.15
Dense Residential	0.2

10.2.1 Consideration of Mocatta's Corner

This study incorporated additional analyses to accurately define the flow split at Mocatta's corner, which has a substantial influence on the distribution of flow reaching the upstream side of Dalby.

Detailed LIDAR survey of the Mocatta's Corner area was obtained by WDRC in late 2013. This has allowed the current study to include accurate modelling of the hydraulic behaviour at Mocatta's Corner. This has been a substantial improvement in the model. This LIDAR survey was incorporated into the 10m MIKE FLOOD model grid and the model extended upstream to include the Mocatta's corner vicinity.

A series of model runs were completed with discharges ranging from 50 m3/s to 800 m3/s with the results being used to create a number of ratings at each of the following locations:

- Mocattas Corner Split between Myall Creek across Dalby Cooyar Road
- Mocattas Corner Road Levee
- Post Mocattas Corner Split between Myall Creek across Dalby Cooyar Road
- Split after Dalby Cooyar Road

Road culverts for the area of interested were also included in the model. Model results are provided in Table 10-2 (discharges) and Appendix I The flow splits show the portion diverted at each location shown. The proportion is is not necessarily based upon the total flow for the North Branch. For example, consider the 1 in 100 AEP Figure I.4 in Appendix I:

- 100% of the flow comes in along the north branch.
- At Mocatta's Corner, 59% of this flow heads west and 41% heads south.
- At Mocatta's Corner Road Levee, 43% (of the 59% from Mocatta's Corner) flows west and 74% flows south (back across the levee).
- Finally, at the downstream boundary of the model, the outflows are 30% within Myall Creek, 50% over the Dalby Cooyar Road and 20% to the north of Mocatta's Corner Road.

Table 10-2 Discharges for Mocatta's Corner Flow Splits

Location		Portion of Nth Branch Flow	Colour	Discharge Magnitude (m3/s) for given AEP			
				1 in 10	1 in 20	1 in 50	1 in 100
North Branch	Inflow	Total	Purple	104	221	473	795
Mocatta's Breakout	West	Total	Yellow	18	64	192	366
	South			86	156	281	429
Mocatta's Corner Road Levee	West	Portion	Green	18	43	97	158
	South			0	22	96	207
Dalby – Cooyar Road Crossing	South-West	Portion	Red	22	60	129	204
	South			65	96	152	225
Total Outflow	West	Total	Purple	18	42	97	158
	South-West			21	82	223	412
	South			65	96	152	225

The results show the following:

- There is considerable cross flow of water between the flow paths (in both directions).
- The breakout from Mocatta's corner increases with the flood magnitude.
- For all floods except low flows, the breakout water from Mocatta's corner flows along the northern side of the levee for a short distance before crossing back to the North Branch side of the levee.
- Water heading south from Mocatta's corner tends to overtop the Dalby-Cooyar Rd further down.

This is in contrast to the adopted the Mocatta's Corner flow split in the SKM (2007) (for all discharges) has the following characteristics:

- The flow split was 28% (west) and 72% (south).
- All breakout water heading west did not overtop the levee and re-join the North Branch. That is, it either entered Dalby west of the main town area or missed the town all together.

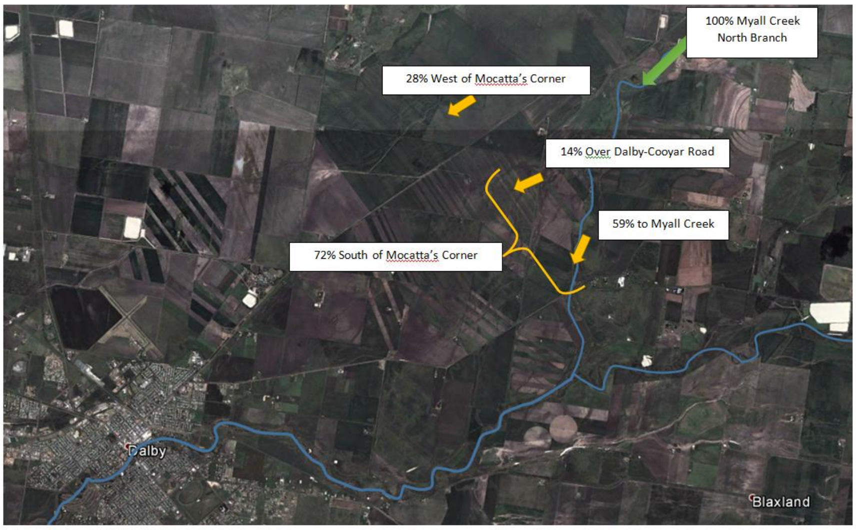

Figure 10.3 November 2012 Report Flow Distribution (1 in 10 AEP and 1 in 100 AEP)

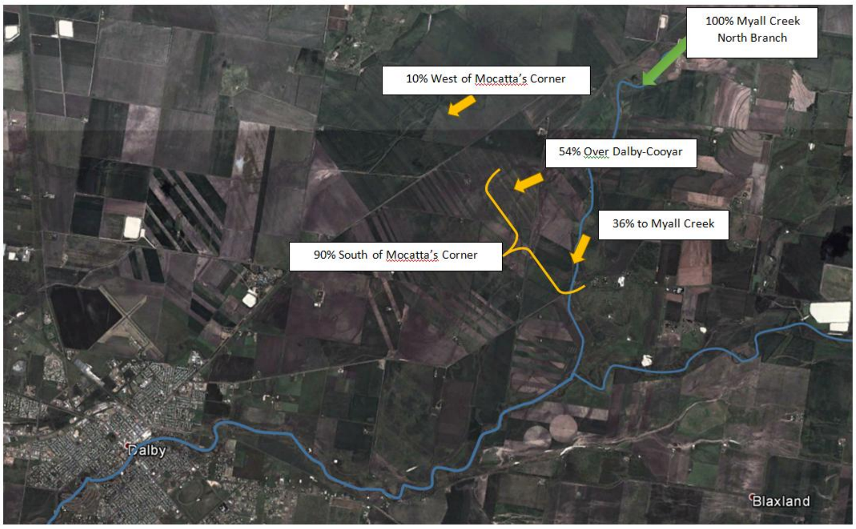

Figure 10.4 Revised Flow Distribution (1 in 10 AEP)

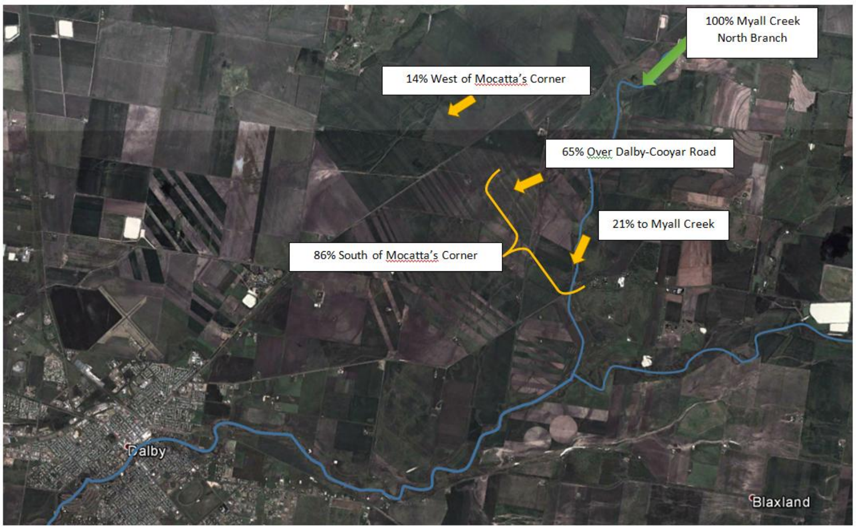

Figure 10.5 Revised Flow Distribution (1 in 100 AEP)

10.3 Mapping Conventions

10.3.1 Freeboard

A 300mm freeboard was added to the modelled defined flood level to create the Planning Scheme Overlay. The adopted freeboard is in accordance with the Queensland Urban Drainage Manual (NRW, 2007).

10.3.2 Hazard Mapping

Flood hazard categories were adopted from "Floodplain Management in Australia: Best Practice Principles and Guidelines" (CSIRO, 2000). Table 10-3 shows the adopted categories.

Table 10-3 Adopted Hazard Categories (CSIRO, 2000)

Criteria	Low	Medium	High	Extreme
Wading Ability	All including children and elderly (v*d <0.25)	Fit Adults (v*d <0.4)	Fit Adults have difficulty (v*d <0.6)	Wading not an option (v*d >= 0.6)
Max. Flood Velocity (m/s)	< 0.4	< 0.8	< 1.5	>1.5
Max. Flood Depths (m)	< 0.3	< 0.6	< 1.2	> 1.2
Typical Means of Egress	Sedan	Sedan early, but 4WD or trucks later	4WD or Trucks only in early stages, boats or helicopters	Large trucks, boats or helicopters

10.4 Hydraulic Results

Table 10-4 shows the seven different types of flood maps produced. Aerial photograph and cadastre are used as the background for all maps. These maps are presented in Volume II of this report.

Table 10-4 Riverine Flood Maps Produced

AEP (1 in x)	Flood Map Type	Description - Map Name
10	Extent + Depth	10% AEP riverine flood extent and depth
20	Extent + Depth	5% AEP riverine flood extent and depth
50	Extent + Depth	2% AEP riverine flood extent and depth
100	Extent + Depth	1% AEP riverine flood extent and depth
100	Extent + Hazard	Defined Flood Event (DFE): 1% AEP riverine flood hazard

11 DISCUSSION OF HYDRAULIC RESULTS

11.1 Overview

While the similarity in magnitude of the 1981 and the 1% AEP events has been noted earlier in this report, concern has been expressed in several forums that the design flood levels in Dalby (the 1% AEP flood) are considerably higher than those recorded during the 1981 flood. The increases in flood levels are due to several factors including:

- An increase in discharge between the 1981 and 1 in 100 AEP floods.
- An increase in development in Dalby since 1981.
- Overtopping of the railway line for the 1% AEP flood.

These factors are discussed in further detail in the following sections.

Figure 11.1 shows key flooding features for Dalby.

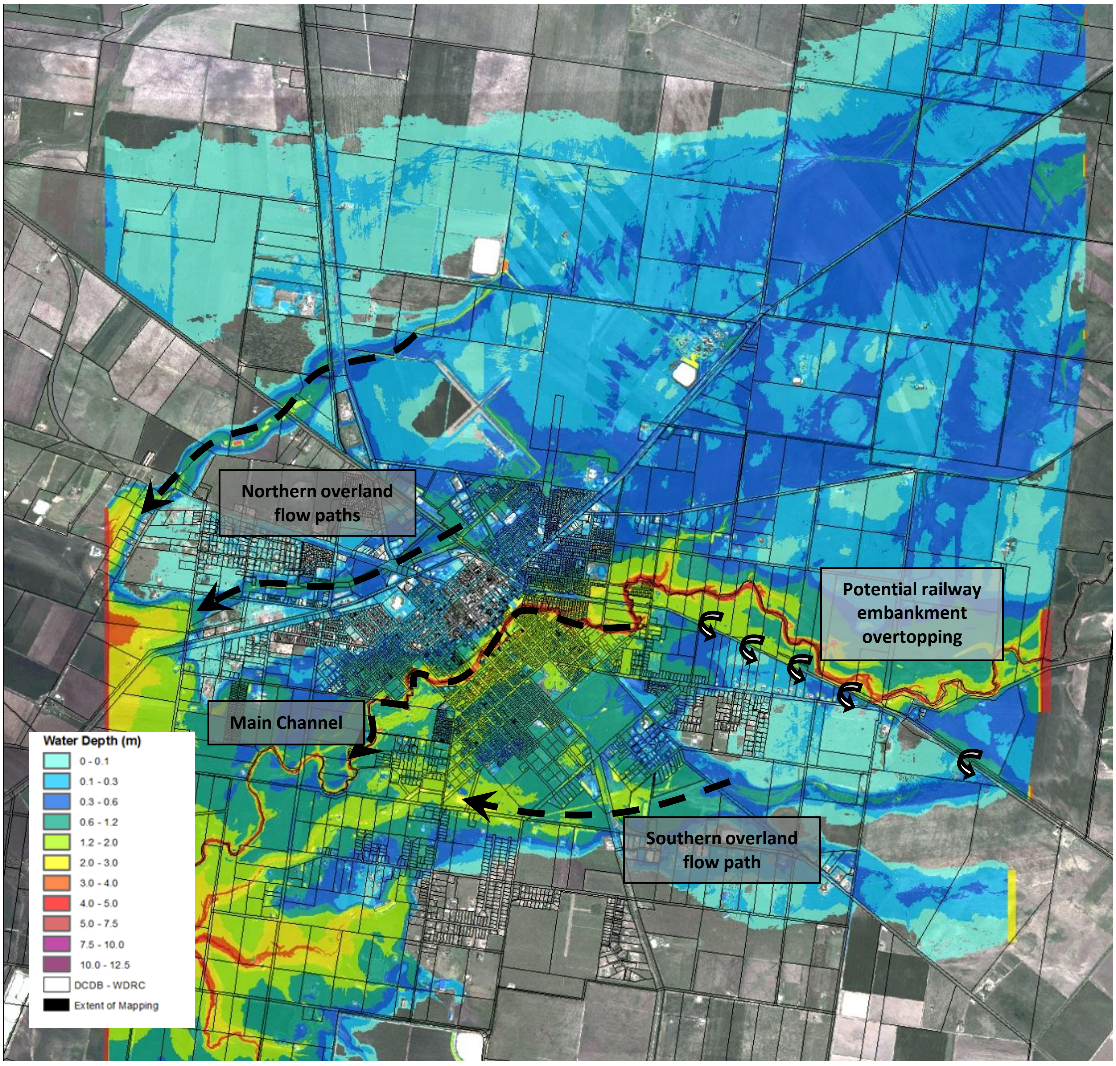

Figure 11.1 Dalby 1 in 100 AEP Riverine Flood Depth
(Arrows show key flooding features for the town).

11.2 Increase in Discharge

There is an increase in the discharge between the 1981 and the 1% AEP flood from 1,430 to 1,760 m3/s, respectively. This results in an increase in flood levels between the two floods.

11.3 Changes in the Level of Development

The DFE in Dalby is the 1% AEP flood with ultimate levels of development (i.e. the development levels defined by the zonings in the WDRC Planning Scheme). This change in development increases flood levels by:

- Reducing the area of flow by blocking (or partially blocking) existing broad overland flowpaths.
- Increasing the surface roughness over which the flood waters flow.

A comparison of flood levels at four locations in Dalby has been provided to assist with understanding of the impact of development on flood levels. Figure 11.2 shows the four adopted locations. Table 11-2 shows a comparison of flood levels (1981 and 1 in 100 AEP) and levels of development (1981, 2010 and ultimate) against 1981 flood levels. Table 11-2 shows the following:

- A substantial impact on flood levels in Dalby is the changes in land use between 1981, 2010 and the ultimate proposed level of development.
  - If the 1981 flood:
    - Occurred in 2010, it would be some 0.25 m higher at Patrick Street than it was in 1981.
    - Occurs under ultimate development conditions it will be:
      - Slightly lower than 2010 at Patrick Street (due to a slight blocking of flow by development)
      - Between approximately 0.1 and 0.24 m deeper at the other reporting locations.
  - If the 1 in 100 AEP flood:
    - Occurred in 1981, it would be between approximately 0.2 and 0.27m higher than the 1981 flood at the reporting locations.
    - Occurs under ultimate development conditions it will be between 0.39 and 0.44 higher than the 1981 flood.

Figure 11.3 and
Figure 11.4 show how flood levels would change if the 1981 flood occurred under current (2010 land use) and ultimate levels of development, respectively.

A range of different maps comparing the effects of different discharges (1981 and 1 in 100 AEP) and levels of development (1981, 2010 and Ultimate) have been prepared to assist with further analysis, if required. Table 11-1 shows the list of maps presenting this analysis.

Table 11-1 Index of Maps of to Compare the Effects of Historical and Ultimate Surface Roughness and Topography on the 1981 and 1 in 100 AEP Flood Levels

Appendix	Description
Appendix B	Dalby Historical Surface Roughness Difference maps
Appendix C	Dalby Historical Topography Difference maps
Appendix D	The Dalby 1981 flood with different levels of town development (1981, 2010 and Ultimate).
Appendix E	The Dalby 1 in 100 AEP flood with different levels of town development (1981, 2010 and Ultimate).
Appendix F	Comparison of the Dalby 1981 and 1 in 100 AEP floods with different levels of town development (1981 and Ultimate).

11.4 Overtopping of Railway

Anecdotal evidence indicates that the 1981 flood reached the height of the railway embankment on the northern side, but did not overtop. The modelling of the 1981 flood undertaken for this study supports this.

Further, the modelling of indicates that the 1 in 100 AEP flood overtops the railway. The majority of the additional water overtopping the railway enters the southern side of Dalby; in the Branch Creek area. This explains the greater increase between the 1981 and 1 in 100 AEP flood in South Dalby than elsewhere.

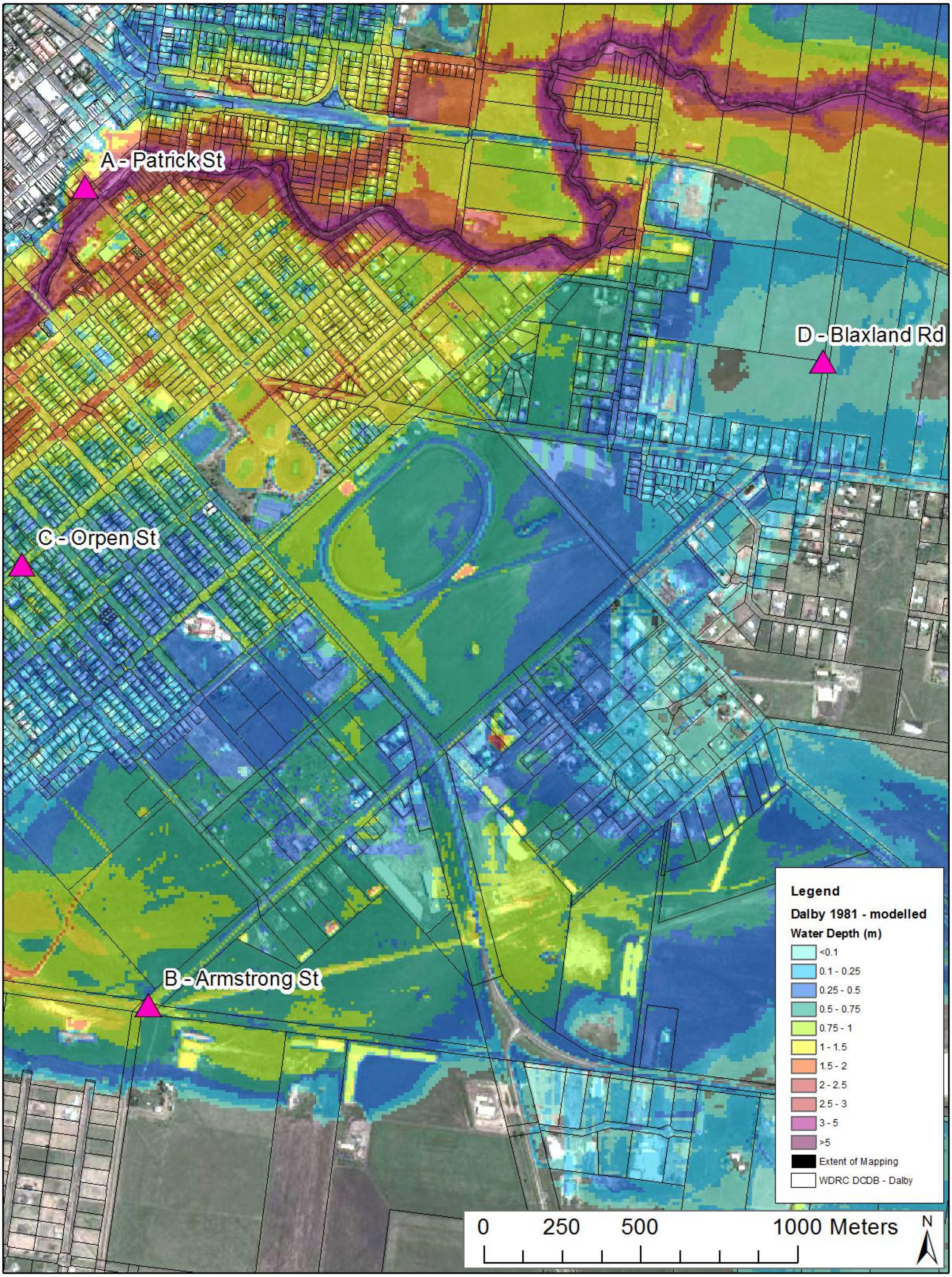

Figure 11.2 Adopted Locations for Dalby 1981 and 1% AEP Flood Level Comparisons

Table 11-2 Comparison of Flood Level Estimates against 1981 Flood Levels

Flood		Patrick Street		Armstrong Street		Orpen Street		Blaxland Road	
Flood	Level of Development	Water Level (m AHD)	Diff. to 1981 Flood (1981 Lev. of Dev.) (m)	Water Level (m AHD)	Diff. to 1981 Flood (1981 Lev. of Dev.) (m)	Water Level (m AHD)	Diff. to 1981 Flood (1981 Lev. of Dev.) (m)	Water Level (m AHD)	Diff. to 1981 Flood (1981 Lev. of Dev.) (m)
1981	1981	343.45	-	341.02	-	341.88	-	344.92	-
	2010	343.70	+0.25	341.12	+0.10	341.99	+0.11	344.96	+0.04
	Ultimate	343.65	+0.20	341.19	+0.17	342.12	+0.24	345.03	+0.11
1 in 100 AEP	1981	343.72	+0.27	341.28	+0.26	342.07	+0.19	345.14	+0.22
	2010	343.93	+0.48	341.33	+0.31	342.17	+0.29	345.18	+0.26
	Ultimate	343.85	+0.40	341.46	+0.44	342.28	+0.40	345.33	+0.41

Notes:

1) All differences are compared to the 1981 flood with the 1981 level of development.
2) The Patrick St water level is lower for the ultimate conditions compared with the 2010 conditions. This is because increased development (in accordance with the planning scheme (upstream of the railway) redirects water eastward (away from the main branch) increasing flows over the railway line.

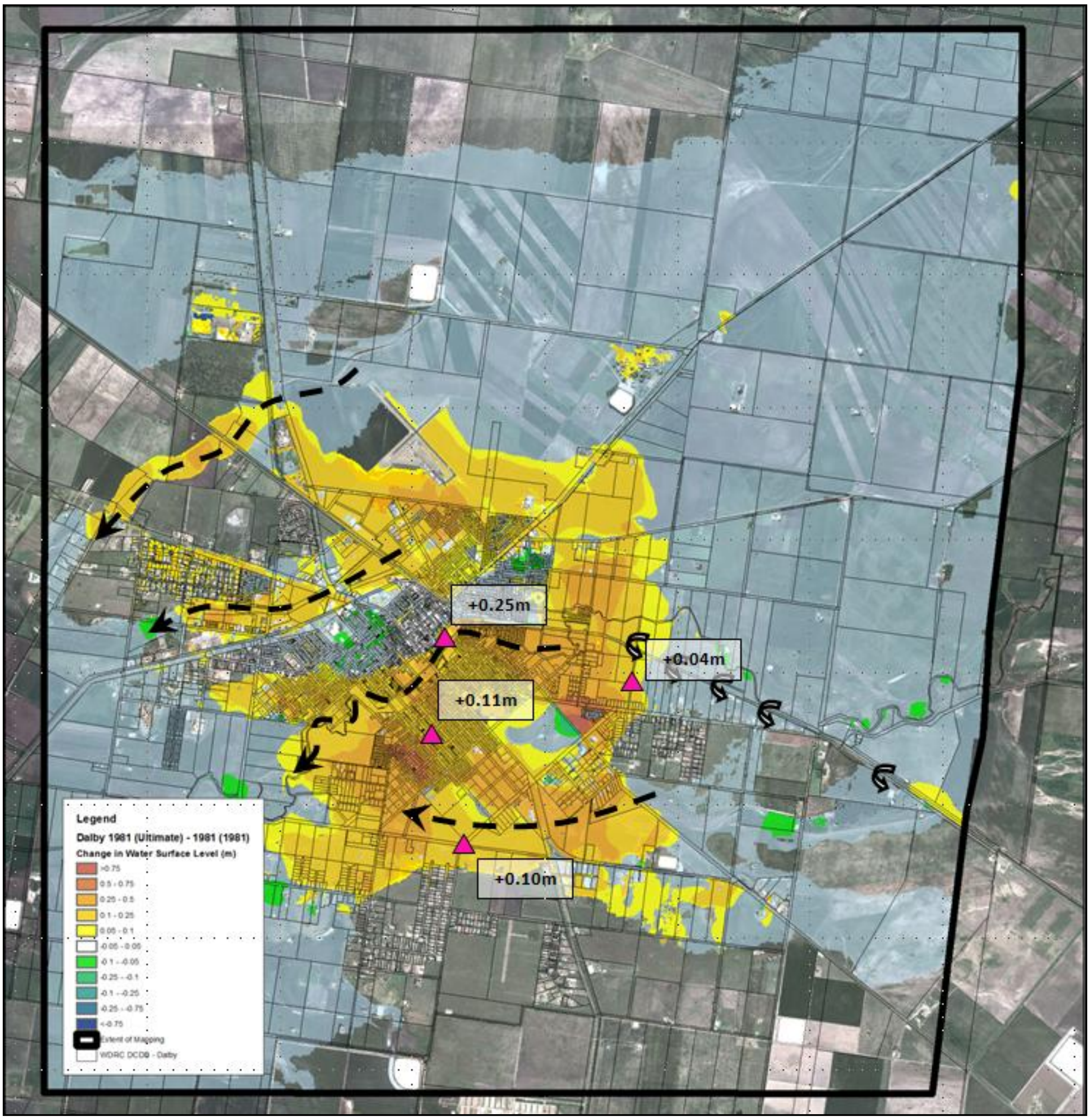

Figure 11.3 Flood Level Difference - 1981 Flood (1981 vs 2010 Level of Development)

Note that by reducing the capacity (by filling and intensifying land use) of the flowpaths to the North and South of the town centre, the flood levels in these areas have increased correspondingly.

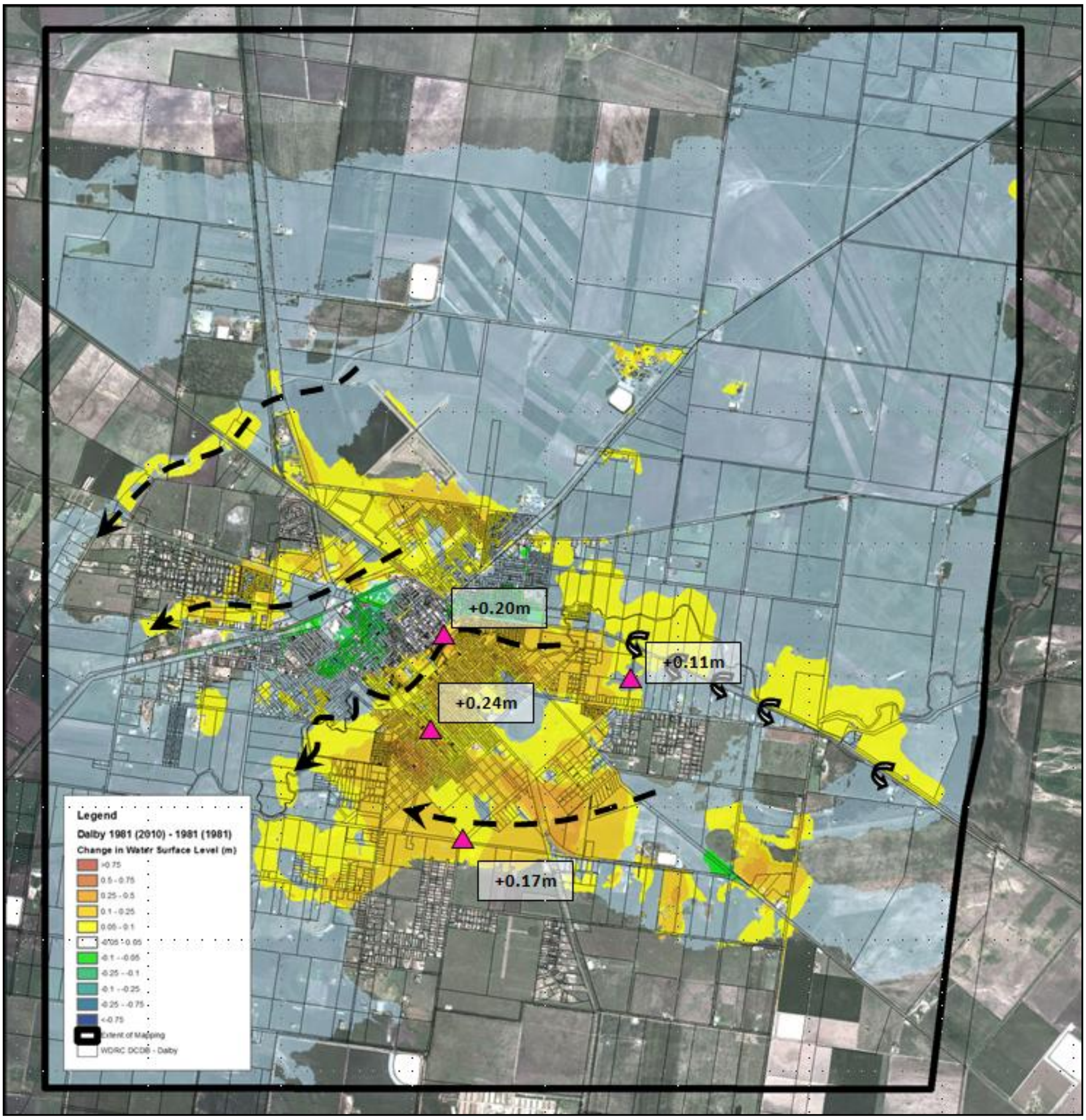

Figure 11.4 Flood Level Difference - 1981 Flood (1981 vs Ultimate Level of Development)

12 UPDATE TO THE NOVEMBER 2012 REPORT

The initial Dalby Flood Study report was submitted in November 2012. Since then a significant amount of additional work has been undertaking including:

- Extensive community consultation and additional data gathering,
- Extensive investigations of historic (and specifically the 1893) events, and
- Detailed modelling of flow distributions (on the basis of LIDAR data acquired in mid 2013) in the Mocatta's corner area,
- A revised Flood Frequency Analysis using the latest available techniques (as currently being developed through the revision of Australian Rainfall and Runoff).

Through these additional investigations, an increased level of confidence in flood magnitude at Dalby has been gained, and the design flood levels (including 1 in 100 AEP level) have been revised. The revised 1 in 100 AEP discharge estimate is approximately 20% lower than the Nov 2012 discharge estimate. In most locations the reduction in design flows has lead to a reduction in the 1 in 100 AEP level. However, due to the complexity of the floodplain in and around Dalby, these reductions are larger in some areas (eg the southern flowpath) than others (eg at the Patrick St Gauge). There are also some areas where there have been increases in levels due to the change in flow distribution from the more accurate modelling of Mocatta's Corner.

Table 12-1 and Table 12-2 below present comparisons of the design flows and associated levels for Myall Creek as presented in the Nov 2012 report and this current report for the Patrick St Gauge.

Table 12-1 Comparison between the previously adopted flows (Nov 2012 report) and current flows at the Patrick St Gauge, Dalby

AEP (1 in x) or historic event	Previous Discharge – Nov 2012 Report (m^3/s)	Revised Discharge - (m^3/s)
10	640	210
20	1000	440
50	1580	1010
100	2100	1760

As a result of the additional data gathering and the revised analysis, the 1 in 100 AEP design discharge previously proposed for Myall Creek at Dalby has decreased by approximately 20%. There have been proportionally larger decreases in the smaller design events. Previously the magnitude of the smaller design events was estimated using a regional flood frequency scaling analysis. The updated estimates are based on an updated Flood Frequency Analysis using the latest available techniques (available through the FLIKE software package).

Table 12-2 Comparison between adopted levels in 2012 and 2014 Report at Patrick St Gauge, Dalby

AEP (1 in x)	Previous Levels – Nov 2012 (m AHD)	Revised Levels (m AHD)
10	343.13	342.36
20	343.40	342.91
50	343.71	343.45
100	343.86	343.85

Please note that the levels presented in Table 12-2 (Patrick St Gauge) corresponding to the Nov 2012 report are slightly different from the levels actually presented in the November 2012 report. This is because the levels presented in the November 2012 report were calculated at the Patrick St TM Gauge which is at a slightly different location to the Patrick St Bridge Gauge.

Note that the impacts of the decrease in design flows and the changes in floodplain flow distribution are not distributed uniformly across the floodplain.

It is also worth noting that the predicted 1 in 100 AEP levels are universally lower than the study team's best estimates of the likely levels experienced during the 1893 event.

Another difference between the levels presented in the November 2012 report and this current report is that in the previous report, the Defined Flood Event (DFE) was defined as the 1 in 100 AEP event + an allowance for 1oC climate change (5% increase in rainfall intensity). For the purposes of this current report, the climate change allowance has not been included and the DFE has been defined as the 1 in 100 AEP event.

An appropriate freeboard allowance (300mm has previously been adopted) should be added to the 1 in 100 AEP event levels for planning levels.

Figure 12.1 and Figure 12.2 present:

- a comparison of flood levels from the November 2012 report and the current report,
- the 1 in 100 AEP flood depths, and
- indicators of the relative levels of historic events and the 1 in 100 AEP flood depths at indicative locations through the town.

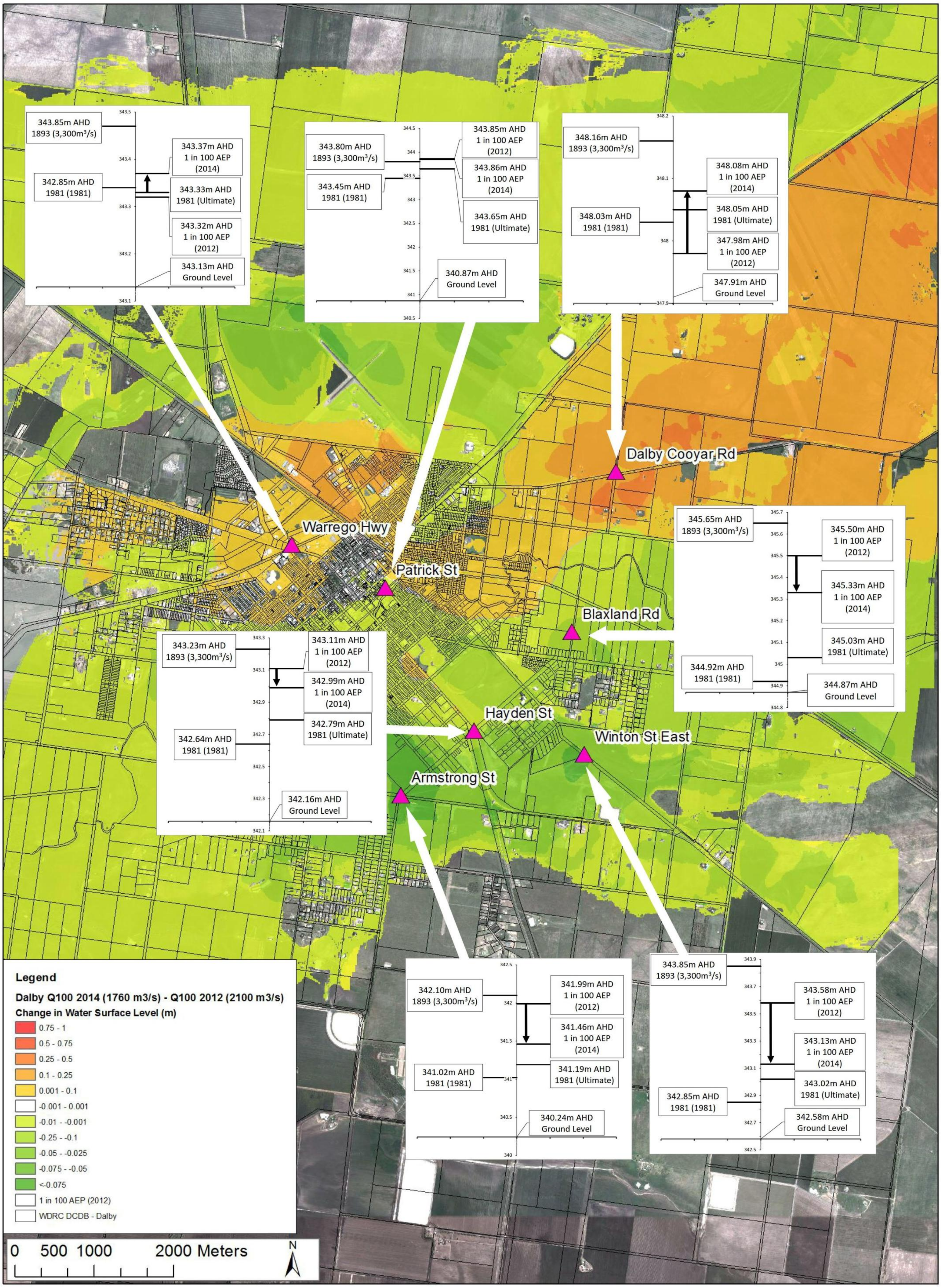

Figure 12.1 1 in 100 AEP flood level comparison – Revised flood levels compared to Nov 2012 flood levels

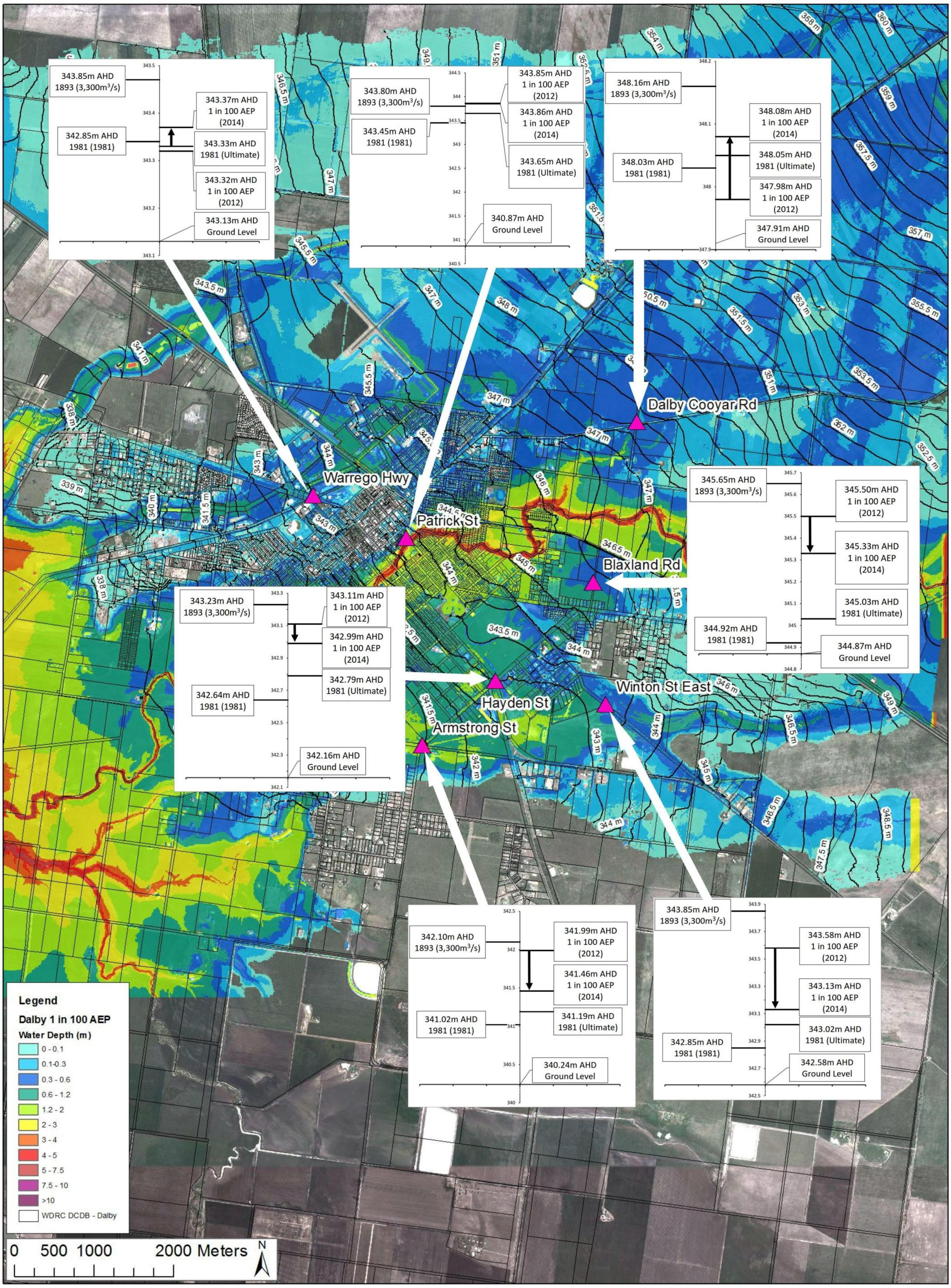

Figure 12.2 1 in 100 AEP depths with indicators of historic and design levels at key locations

13 STORMWATER FLOODING

13.1 Overview

Stormwater floods are local floods through the numerous overland flowpaths through the towns. These floods are short duration (an hour or so) and are usually the result of localised, short duration rainfall. These floods contrast with riverine floods, which are large regional floods from the creeks running through each town. These floods may last several days and are usually the result of widespread, long duration rainfall.

For the purposes of modelling stormwater, Dalby was divided into a number of stormwater catchments. The 1 in 10, 1 in 50 and 1 in 100 AEP stormwater floods were modelled.

Management of stormwater flowpaths in Dalby has historically been very difficult primarily because Dalby has very flat topography with many stormwater flowpaths difficult to identify (from maps and/or site inspection) due to their broad, shallow cross sections. Further, a number of large flowpaths run through Dalby that are both stormwater flowpaths and Myall Creek anabranches. As such, traditional stormwater management techniques are difficult to apply in Dalby. The aim of this current study was to provide a map of Dalby stormwater flowpaths and a simple and consistent methodology to estimate stormwater catchment areas and discharges. The following methodology was adopted:

- Streamlines and catchment areas were defined using CatchmentSIM software (CSS, v2.5).
- A Flow Width vs Discharge Relationship was defined:
- A number of stormwater flowpath cross sections were selected within the Dalby area which were considered to represent flowpath locations draining a range of different catchment areas.
- The 1 in 100 AEP peak discharge and flow width at each cross section was determined using the Rational Method and Manning's Equation, respectively.
- A regression equation was fitted to the flow width vs catchment area data (the flow width regression model).
- The flow width regression model was applied to all streamlines in Dalby.
- The model results were checked in selected locations against site specific flow width calculations.

It was found that there was considerable variation in the accuracy of the regression equation (with the equation both under and over predicting flow widths. However, a sensitivity analysis of different regression equations failed to provide a better solution, due to the inherent flowpath variability in Dalby. The adopted stormwater flowpath model was selected in consultation with WDRC. The chosen solution was to:

- Adopt the regression model, as it provided a clear and accurate representation of stormwater flowpaths.
- Use the WDRC Planning Scheme to overcome the inherent inaccuracy of the flowpath mapping by defining performance criteria and acceptable solutions so that development areas adjacent to the flowpaths (but not necessarily overlain by them) would be identified as sites that may be impacted by a stormwater flowpath.

Appendix J provides full details of the stormwater flowpath assessment for Dalby. Appendix K shows the adopted stormwater flowpaths.

13.2 How Results will be implemented

This section presents recommendations as to how the stormwater flowpath overlay maps and other catchment parameters adopted by this study may be used for development assessment in Dalby. Note that the ultimate adoption and method of use of the maps and parameters will be dependent upon the following:

- Council's adopted planning scheme.
- Changes, from time to time, in the accepted best practice for calculating stormwater discharges [e.g. updates to QUDM (NRW, 2007)].

It is recommended that the Dalby stormwater modelling results be used in the following manner:

- The planning scheme (or a document referenced by the planning scheme) contains the stormwater flowpath overlay:
- The overlay shows the major and minor stormwater categories.
- The WDRC Planning Scheme defines performance criteria and acceptable solutions so that development areas adjacent to and/or intersected by the flowpaths will be identified as areas that may be impacted by a stormwater flowpath.
- If a proposed development triggers a stormwater flowpath assessment the proponent will have to undertake additional studies to better define the flow width of the identified flowpath(s) that the development may be impacting upon.
- Note that the stormwater flowpath overlay is only an approximate width for all streams with similar catchment area/stream length characteristics; not the exact flow width for that stream.
- The initial assessment is to be based upon the Rational Method and Manning's Equation:
- From the Council GIS, the proponent can obtain:
  - Catchment area.
  - Stream length.
  - The impervious percentage and runoff coefficient defined in Section Table 13-1 will be adopted.
- The proponent can apply the Rational Method with these values (with other data) to calculate the site specific discharge.
- The proponent can then use Manning's Equation to estimate the flow width.
- This will be a conservatively wide width (as the Rational Method does not account for catchment storage.
- If Rational Method/Manning's Equation calculations show that the development does not impact upon the flowpath then no additional assessment is required.
- If the Rational Method/Manning's Equation calculations show that the proposed development impacts upon the flowpath then the proponent has the option of undertaking more detailed modelling to refine the flow width estimate.
- Additional modelling will need to include 2D unsteady state hydraulic modelling at an appropriate scale and resolution. It is considered this is the only appropriate method to properly assess the complex stormwater flowpath storage behaviour in Dalby.

The adoption of the catchment stream lengths and areas together with runoff coefficients defined for this report will ensure consistency and transparency in development and assessment.

13.2.1 Runoff Coefficients

An impervious percentage was assigned to each land use category in the revised planning scheme based upon recommendations in NRW (2007) and discussions with WDRC. Each impervious percentage was converted to a C10 runoff coefficient for use with the Rational Method. The same impervious percentage – land use category relationships were adopted for all towns within the WDRC area. Table 13-1 shows the adopted impervious percentages and runoff coefficients for Dalby for each land use category.

Table 13-1 Adopted Rational Method C10 Runoff Coefficients - Dalby

Land Use	Impervious Percentage (%)	C10	Comments
Rural Zone	0	0.39	Negligible impervious area
Township Zone	60	0.7	Residential – Lot size >750m2
Recreation Zone	0	0.39	Open Space (eg Parks)
Community Purpose Zone	Vary according to proposal	Mixed	Open Space/Township
Rural Residential Zone	15	0.47	Rural – 2-5 dwelling per ha
Residential Living Zone	60	0.7	Residential – Lot size >750m2
Local Centre Zone	90	0.85	Commercial or Industrial
Emerging Communities Zone	60	0.7	Residential – Lot size >750m2
Major Centre Zone	100	0.85	Commercial or Industrial
Residential Choice Zone	60	0.7	Residential – Lot size >750m2
Medium Impact Industry Zone	90	0.85	Commercial or Industrial
Low Impact Industry Zone	90	0.85	Commercial or Industrial
Specialist Centre Zone	90	0.85	Commercial or Industrial
District Centre Zone	100	0.9	Central Business

14 CONCLUSIONS

Western Downs Regional Council (WDRC) was created in March 2008 after the amalgamations of local government areas throughout Queensland. A full Planning Scheme review is currently being undertaken to create one Planning Scheme for the Western Downs Region. WDRC proposed to undertake flood studies of six towns in the region in conjunction with the Planning Scheme review of which Dalby, the subject of this report was one. There were two components to the flood studies; riverine flooding and stormwater flooding. The purpose of the riverine flood studies was to identify areas of risk of flood inundation, their impact upon current and future development and to identify flood hazard categories for the inundation areas for the defined flood event (DFE). The purpose of the stormwater flood analysis was to define and map stormwater corridors within current and future development areas. The six towns included in the study were Dalby, Chinchilla, Miles, Wandoan, Jandowae and Tara.

Extensive research was undertaken as part of the study to identify and list historical floods for Dalby. This included:

- Community consultation.
- Research by the Dalby Family History Society,.
- Research by Council officers.
- Interviews with residents.

Two different types of floods were assessed; riverine and stormwater floods. Riverine floods are large regional floods from the creeks running through each town. These floods may last several days and are usually the result of widespread, long duration rainfall. Stormwater floods are local floods through the numerous overland flowpaths through the towns. These floods are short duration (an hour or so) and are usually the result of localised, short duration rainfall.

For the riverine flood, different flood magnitude estimation techniques were adopted for each town. This is a reflection of differences in the available data. In Dalby a number of different techniques were employed to reduce the estimation uncertainty. The 1% AEP flood was modelled. Results were presented as maps of flood depths and flood hazard. The 1 in 100 AEP flood was adopted as the defined flood event (DFE).

Stormwater flooding was also assessed in detail.

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APPENDIX A DALBY HYDRAULIC STRUCTURES

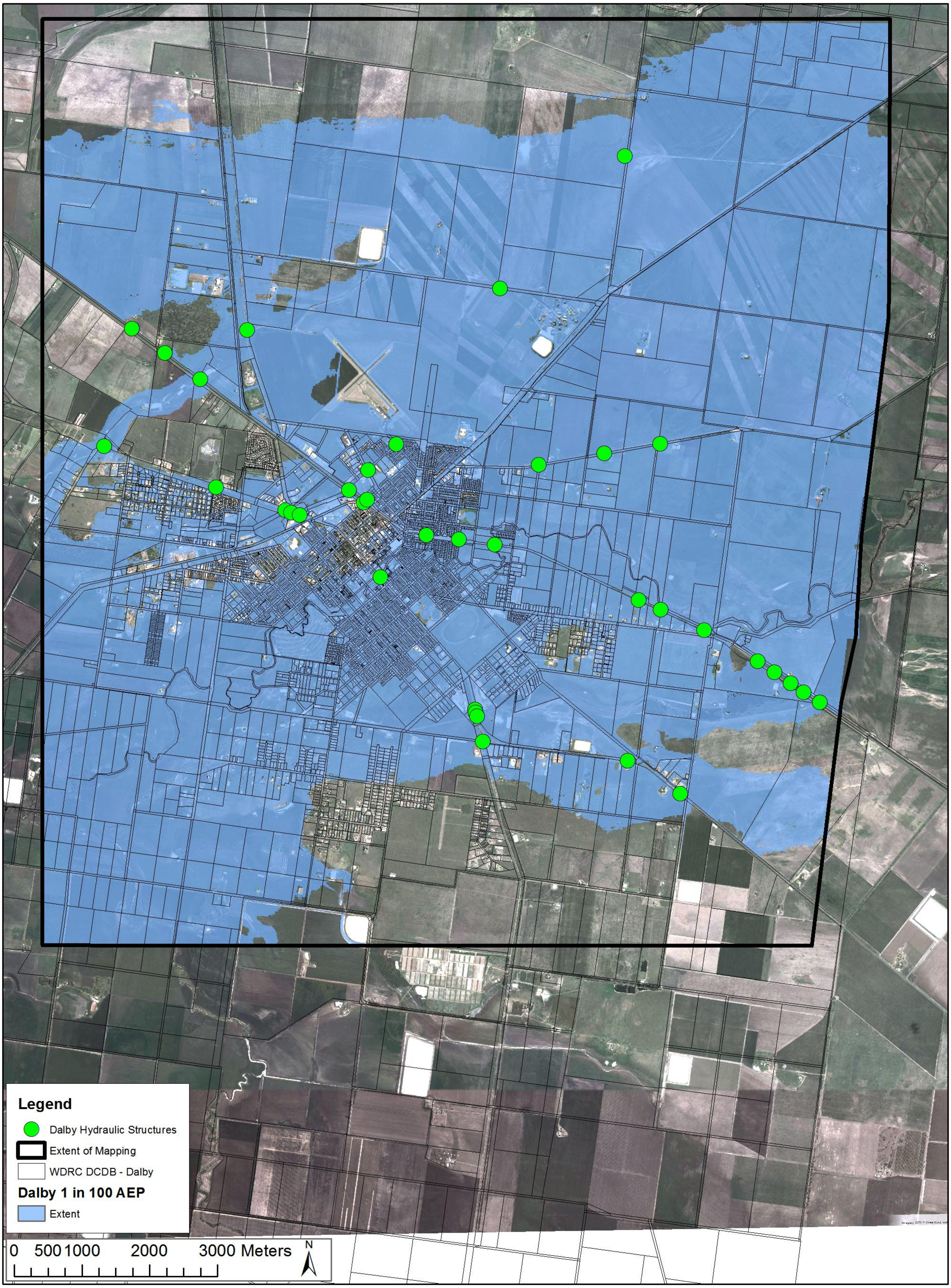

Figure A.1 Dalby Model Structures

APPENDIX B DALBY HISTORICAL SURFACE ROUGHNESS DIFFERENCE MAPS

Figure B.1 Change in Roughness between 1920 and 1950 in Dalby

Figure B.2 Change in Roughness between 1950 and 1980 in Dalby

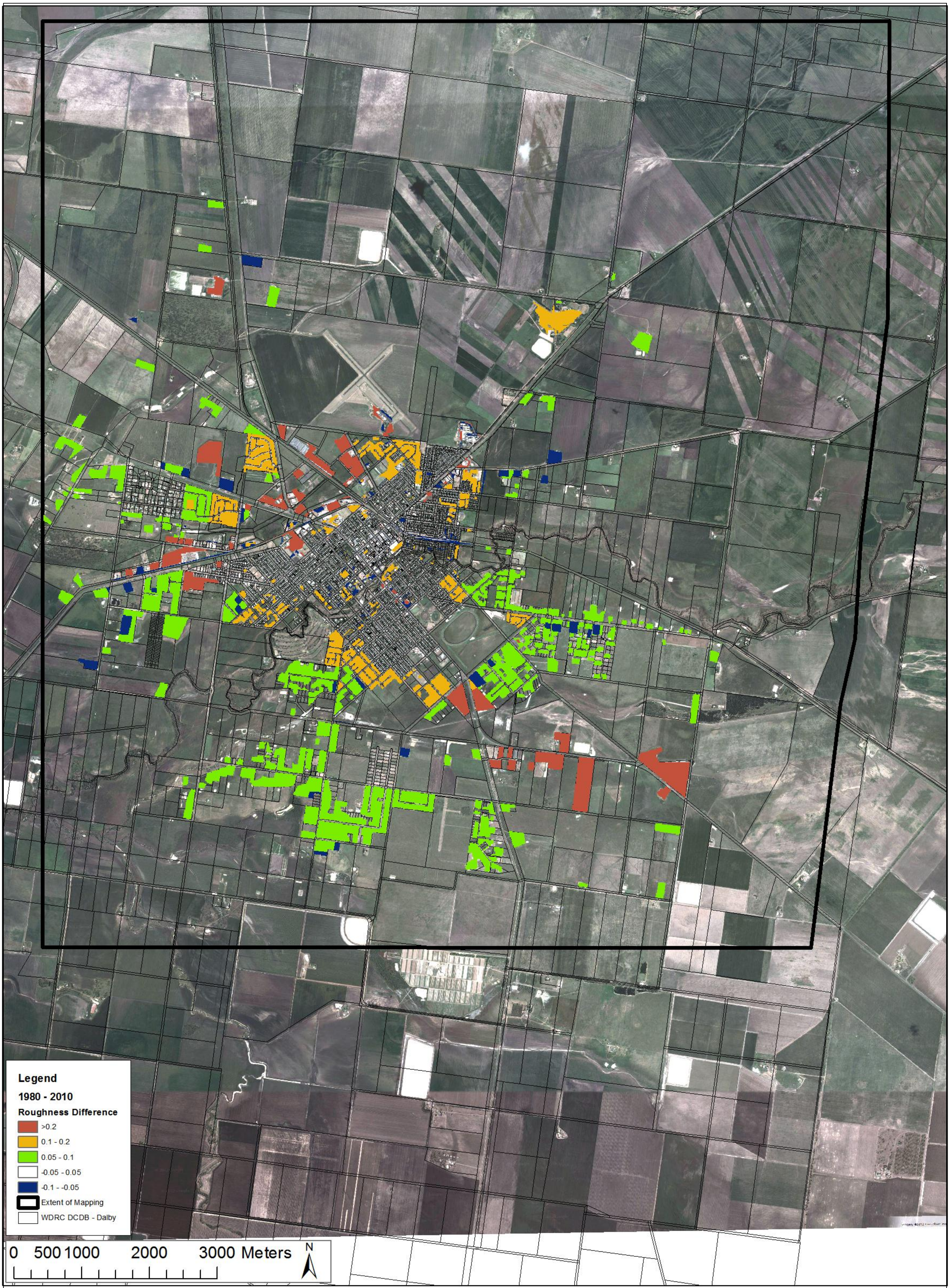

Figure B.3 **Change in Roughness between 1980 and 2010 in Dalby**

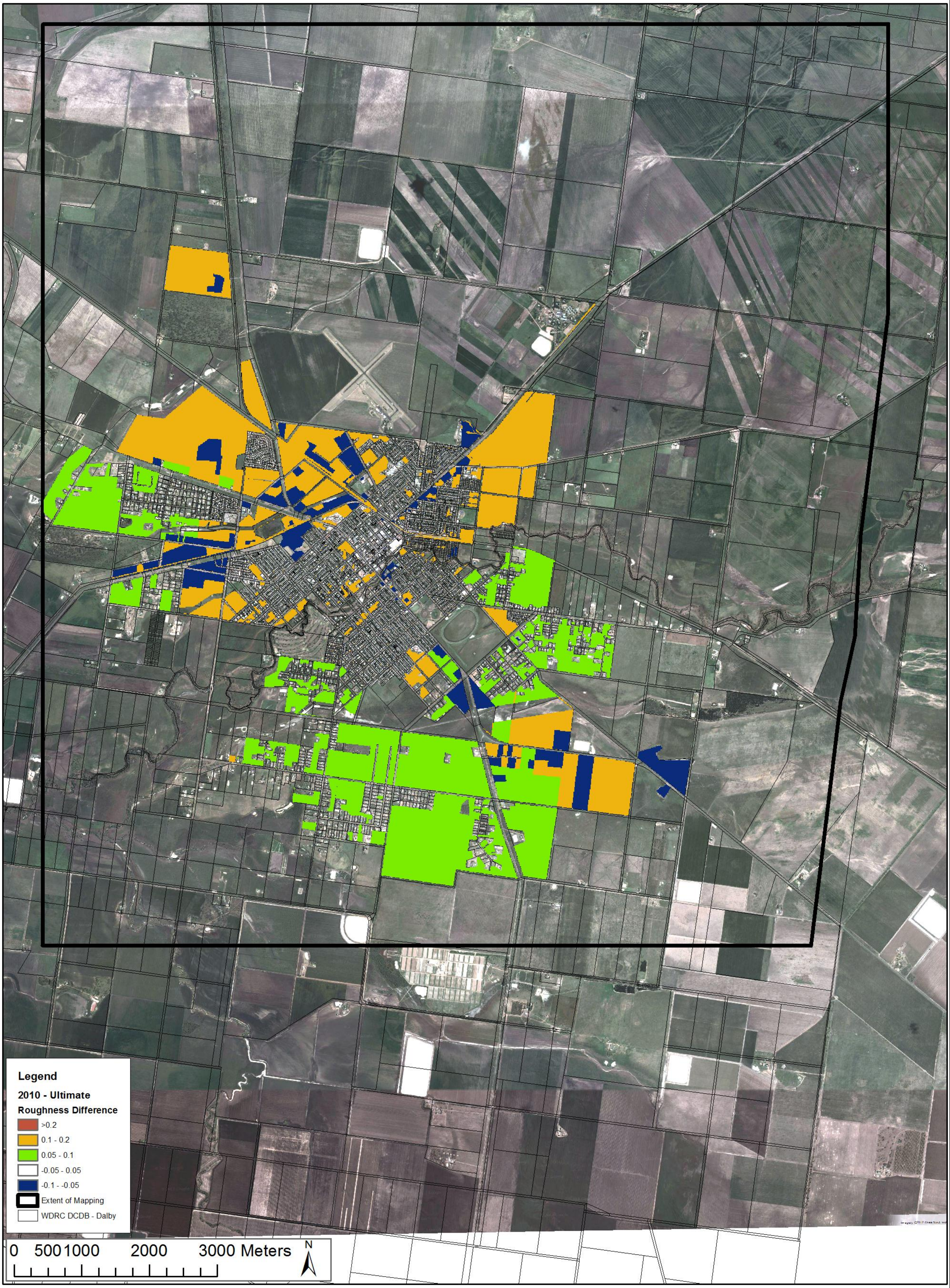

Figure B.4 Change in Roughness between 1920 and Ultimate Development Case in Dalby

APPENDIX C DALBY HISTORICAL TOPOGRAPHY DIFFERENCE MAPS

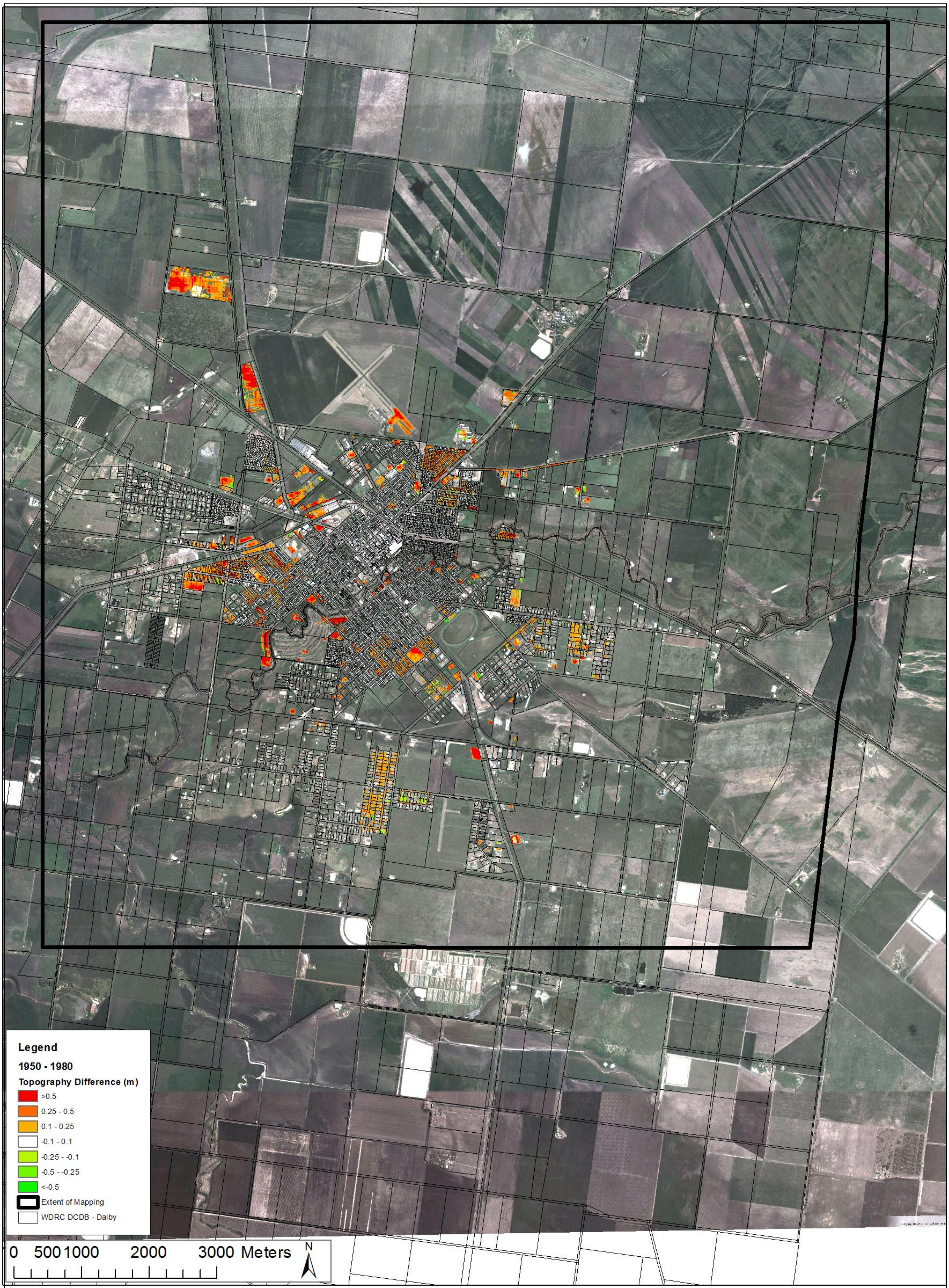

Figure C.1 Change in Topography between 1950 and 1980 in Dalby

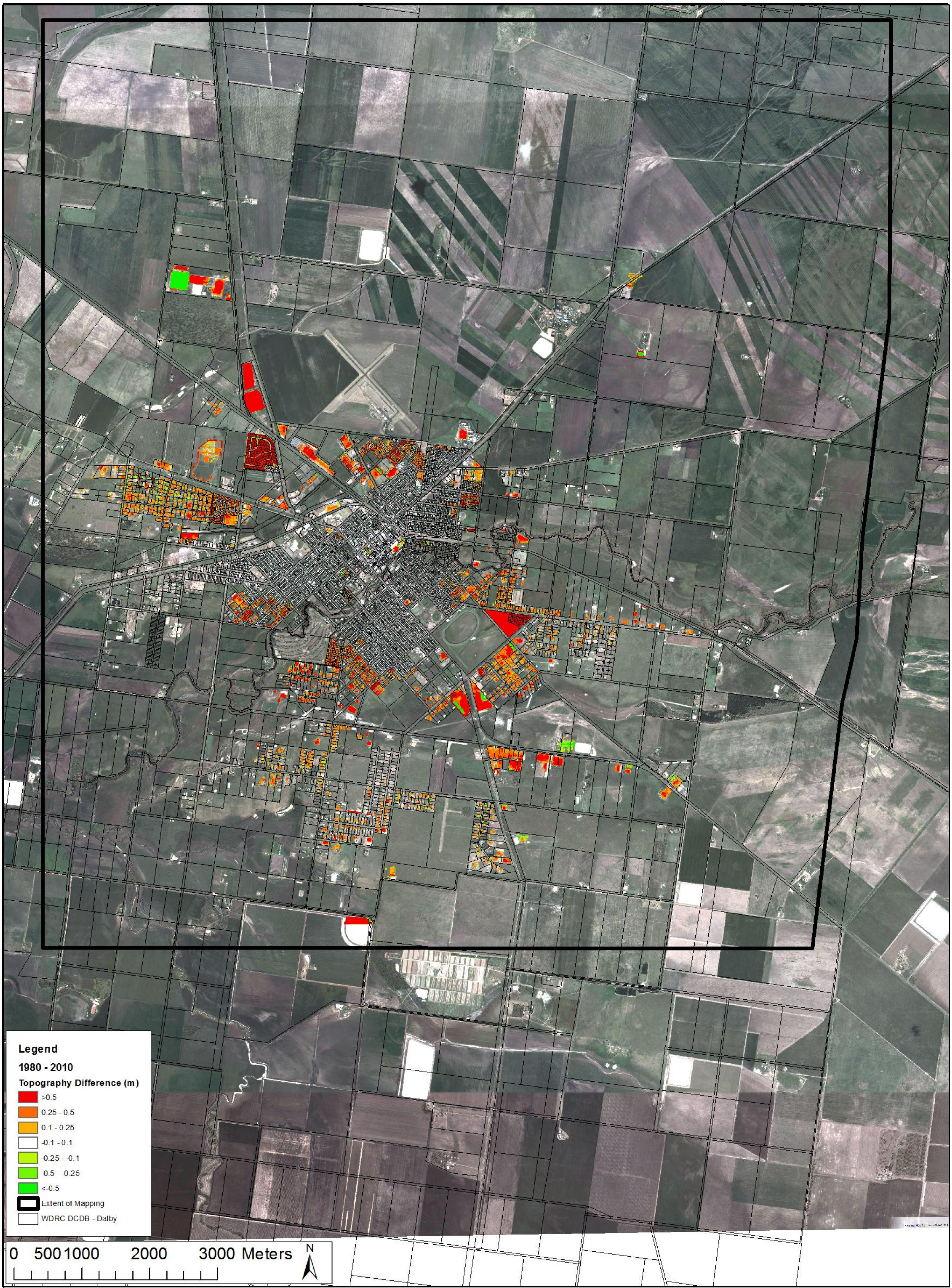

Figure C.2 Change in Topography between 1980 and 2010 in Dalby

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APPENDIX D THE DALBY 1981 FLOOD WITH DIFFERENT LEVELS OF TOWN DEVELOPMENT (1981, 2010 AND ULTIMATE)

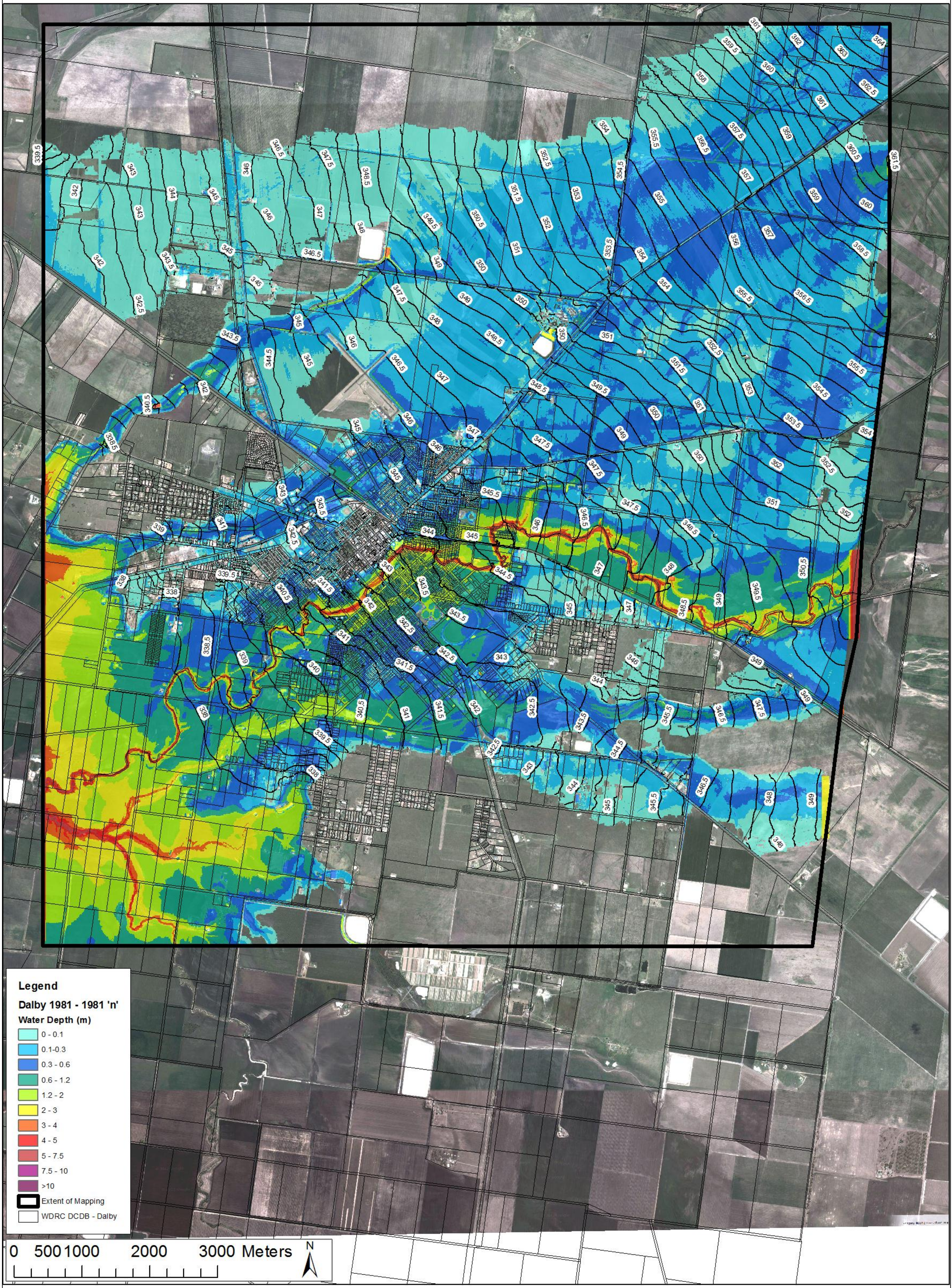


Figure D.1 **1981 Flood (1981 Level of Development)**

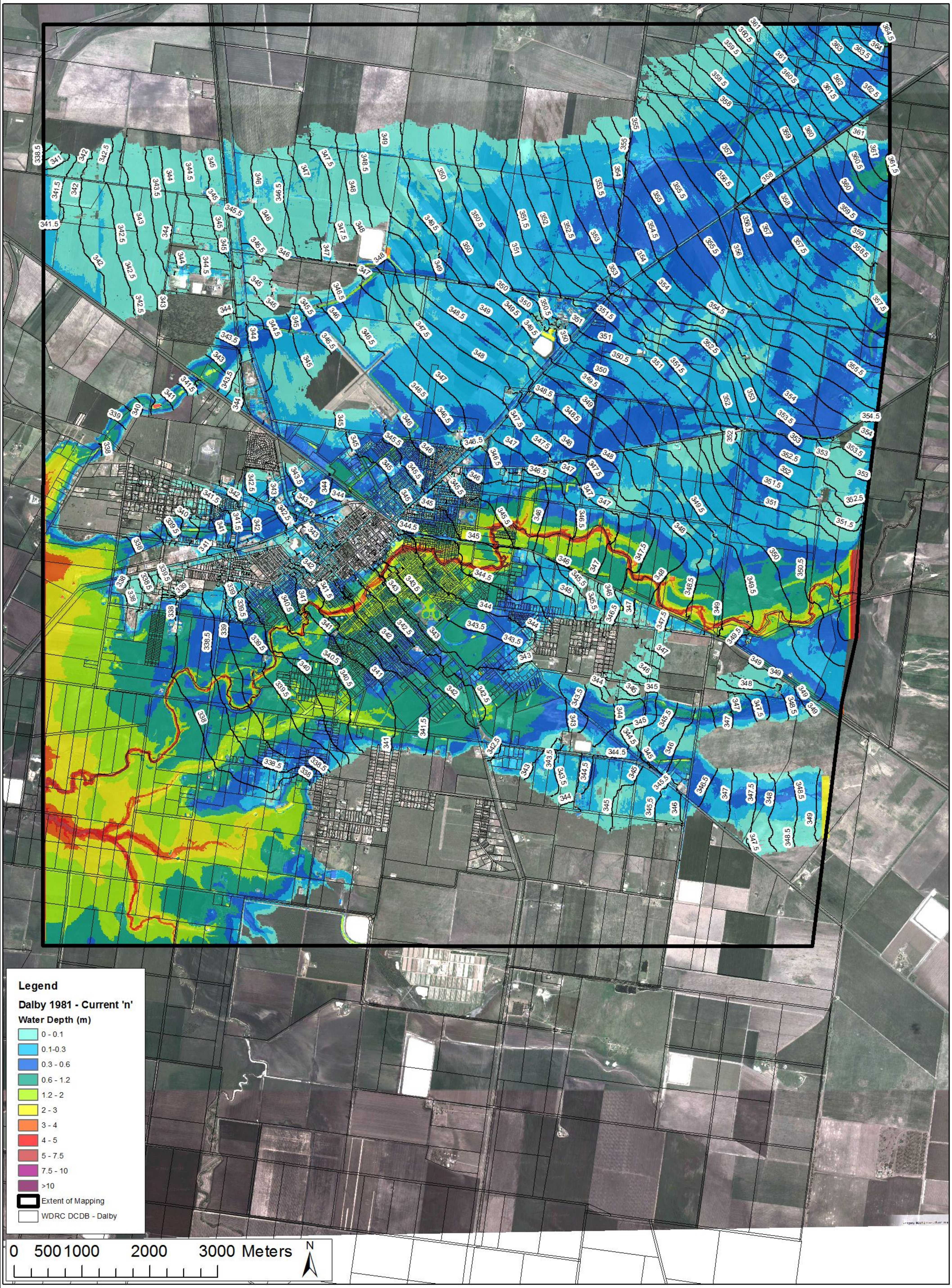


Figure D.2 **1981 Flood (2010 Level of Development)**

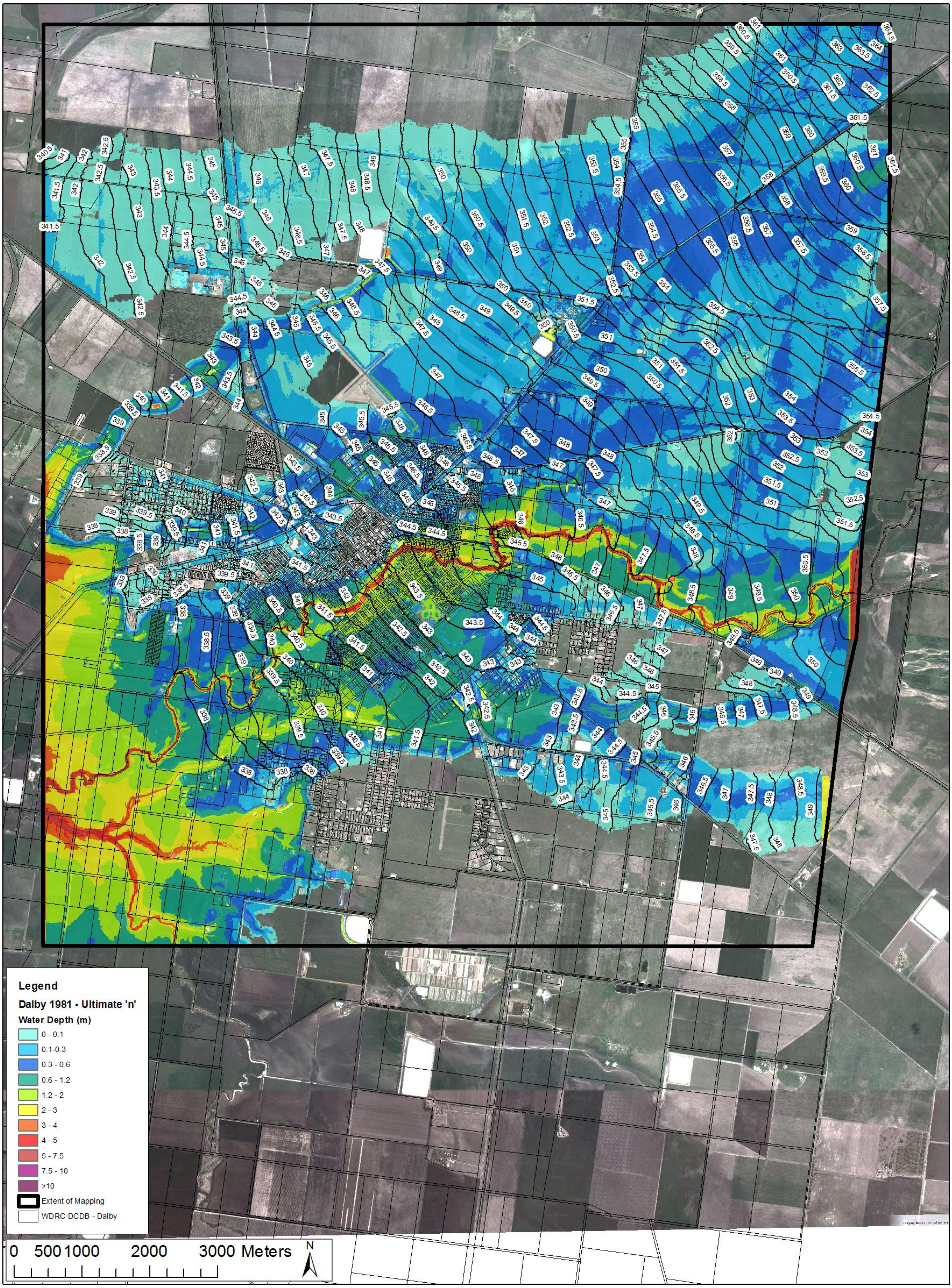


Figure D.3 **1981 Flood (Ultimate Level of Development)**

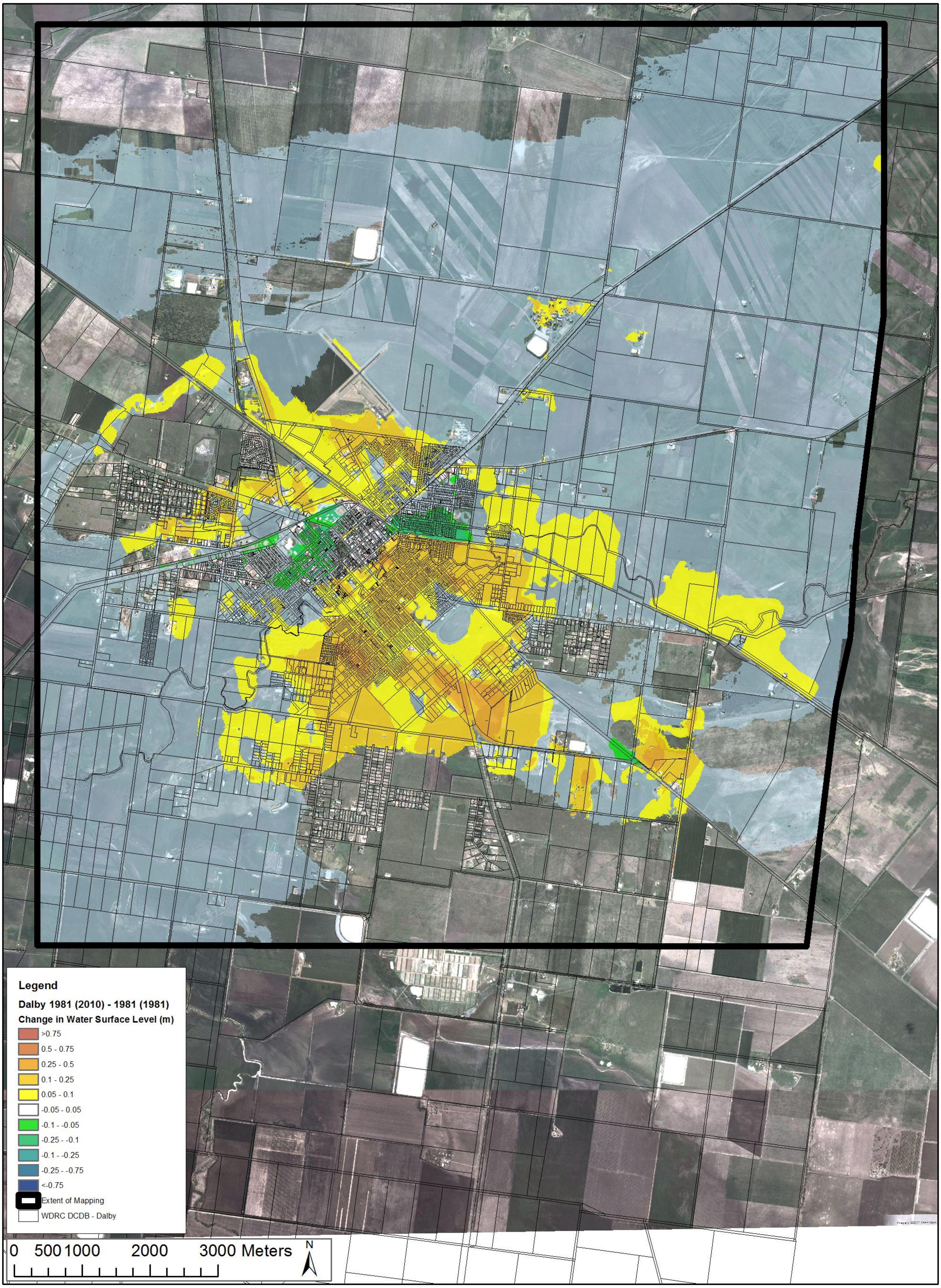


Figure D.4 Flood Level Difference - 1981 Flood (1981 vs 2010 Level of Development)

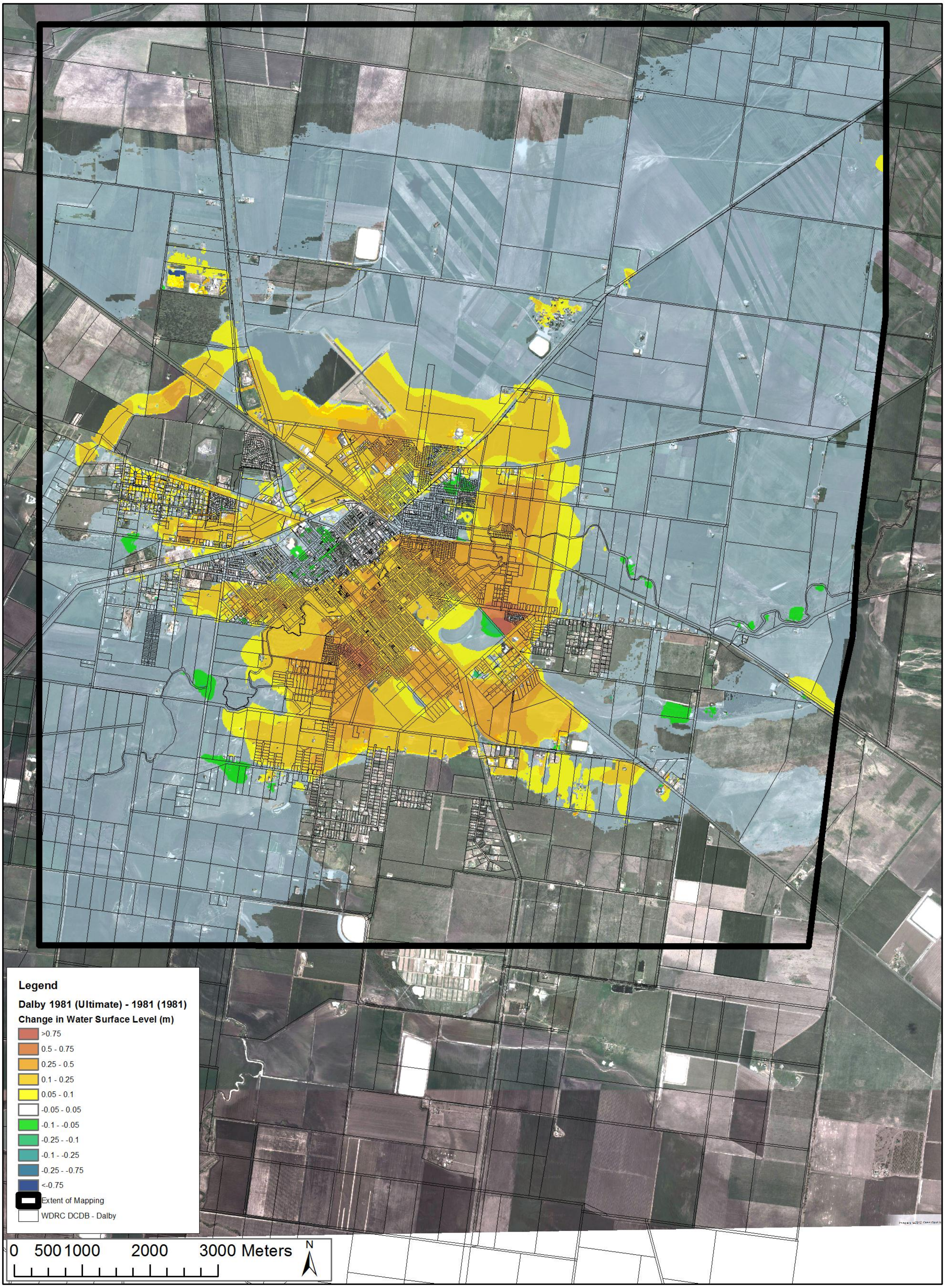


Figure D.5 Flood Level Difference - 1981 Flood (1981 vs Ultimate Level of Development)

APPENDIX E THE DALBY 1 IN 100 AEP FLOOD WITH DIFFERENT LEVELS OF TOWN DEVELOPMENT (1981, 2010 AND ULTIMATE)

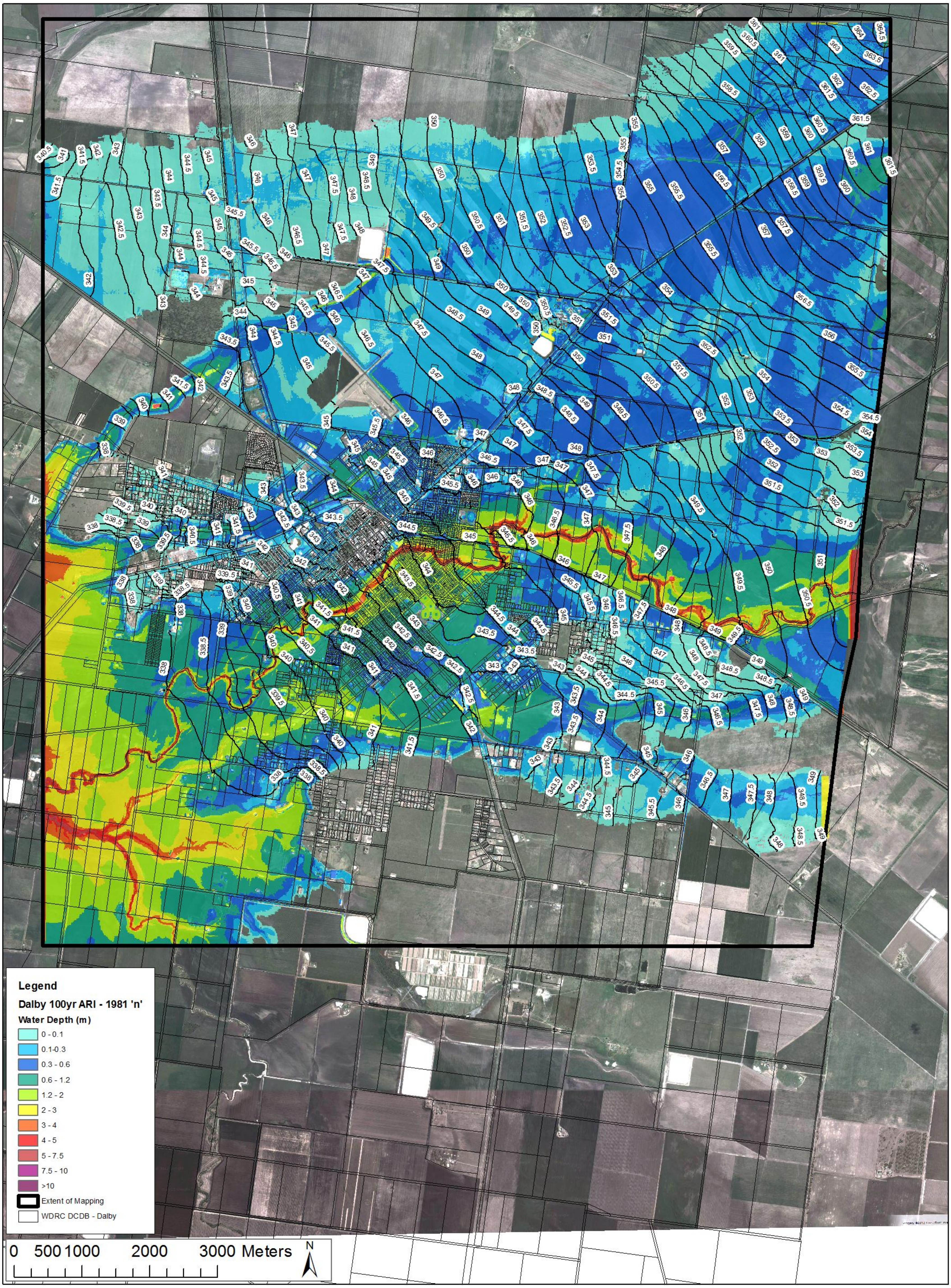


Figure E.1 **1 in 100 AEP Flood (1981 Level of Development)**

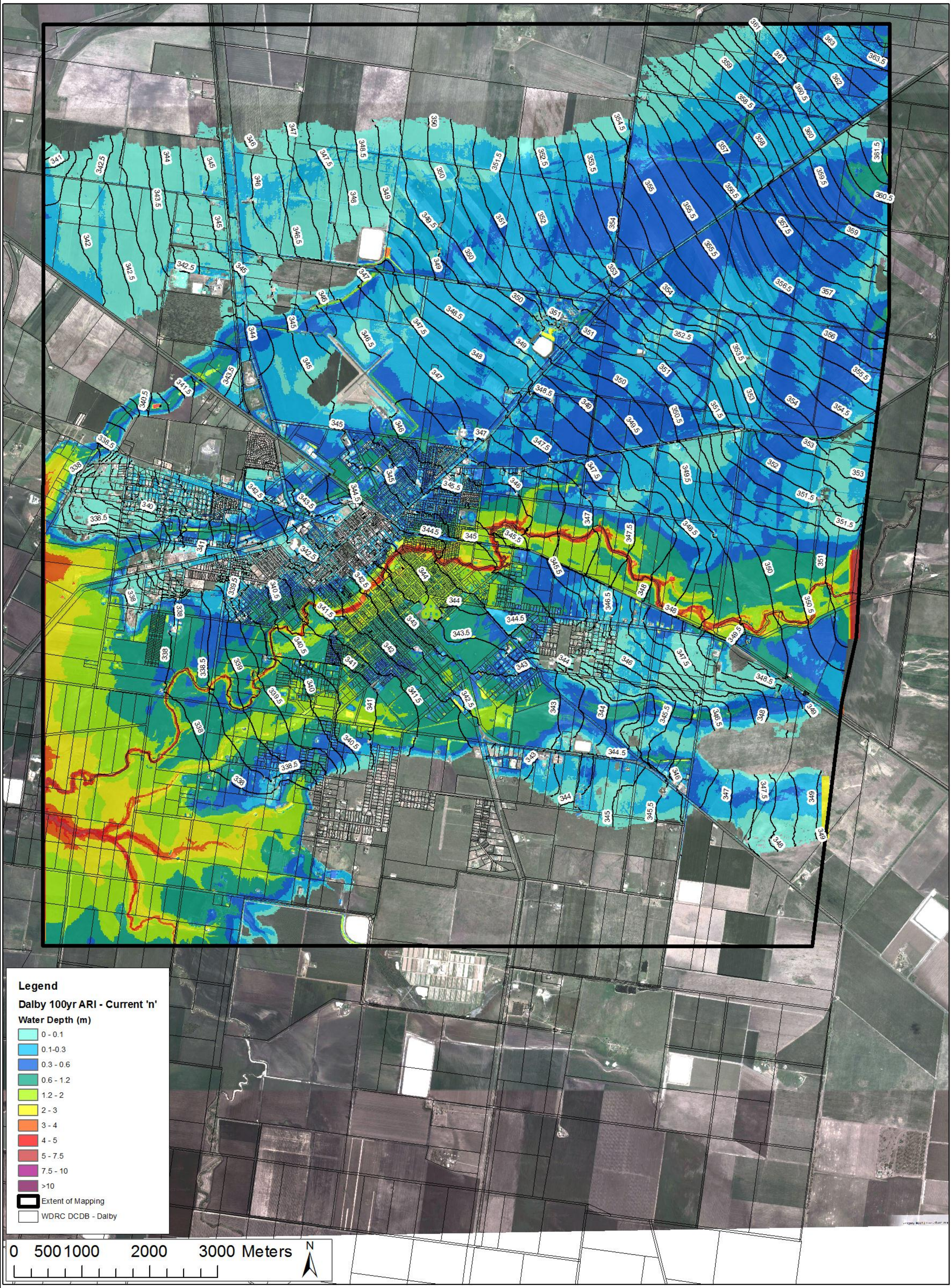


Figure E.2 1 in 100 AEP Flood (2010 Level of Development)

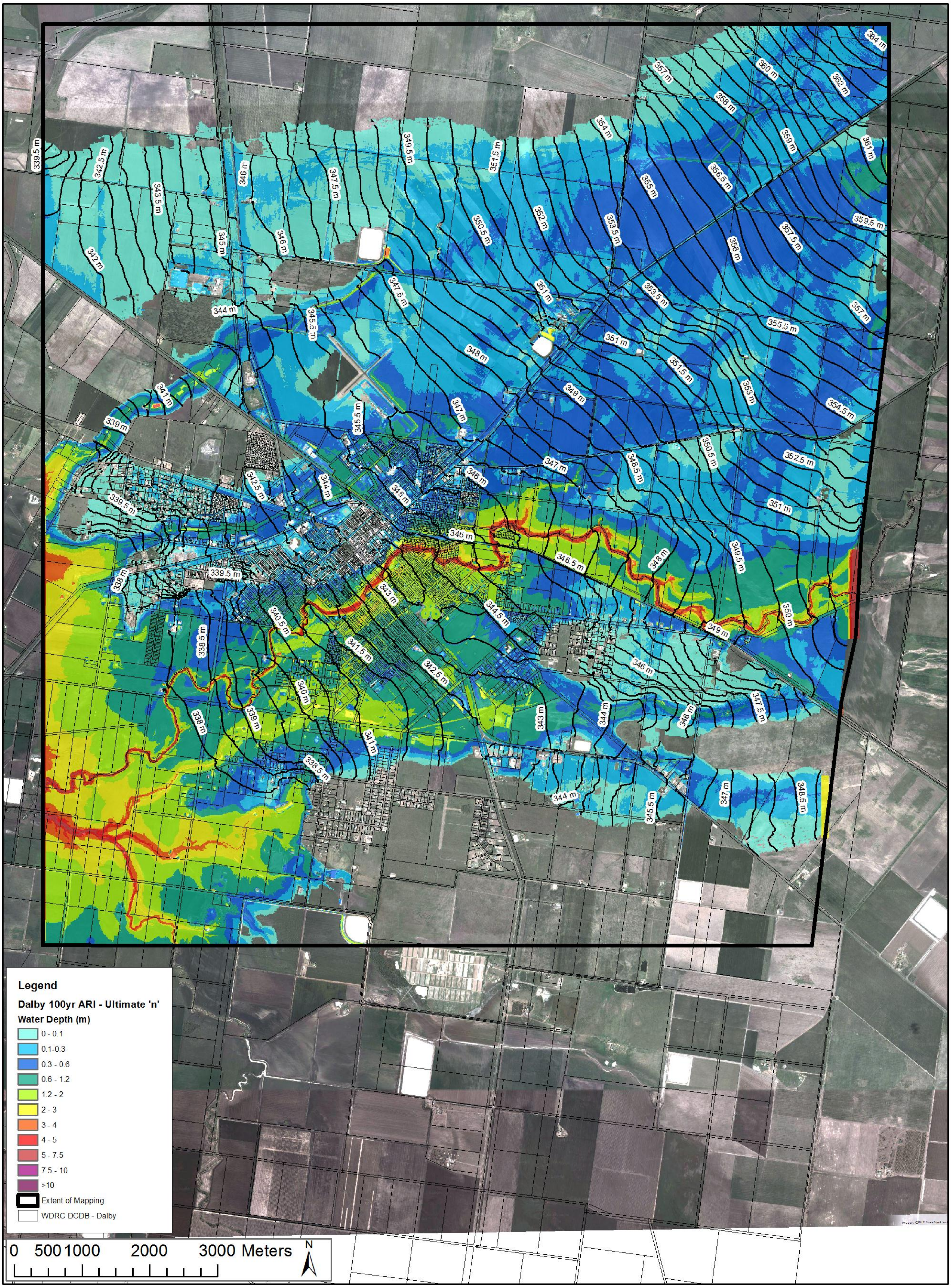


Figure E.3 **1 in 100 AEP Flood (Ultimate Level of Development)**

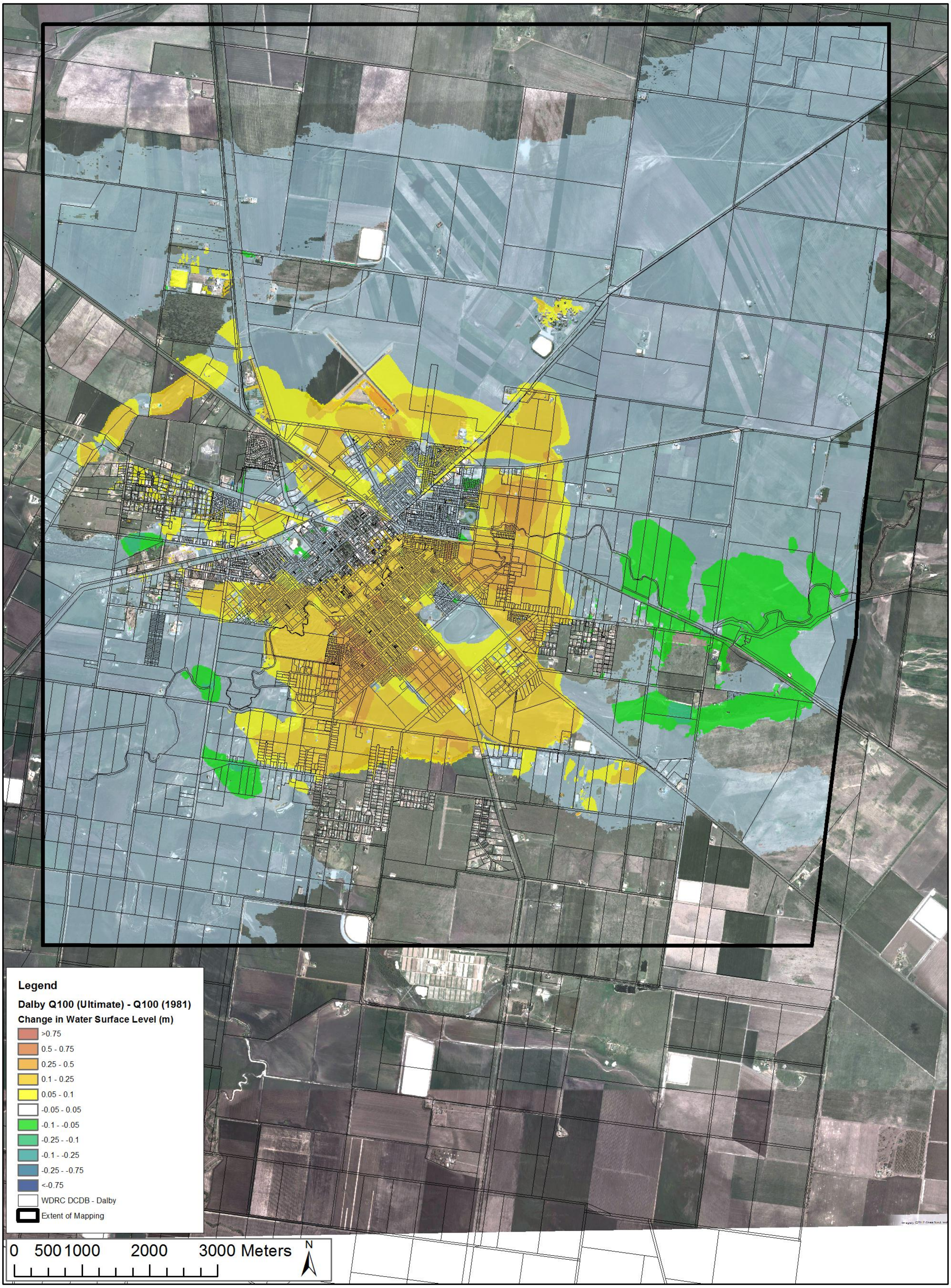


Figure E.4 Flood Level Difference – 1 in 100 Flood (1981 vs Ultimate Level of Development)

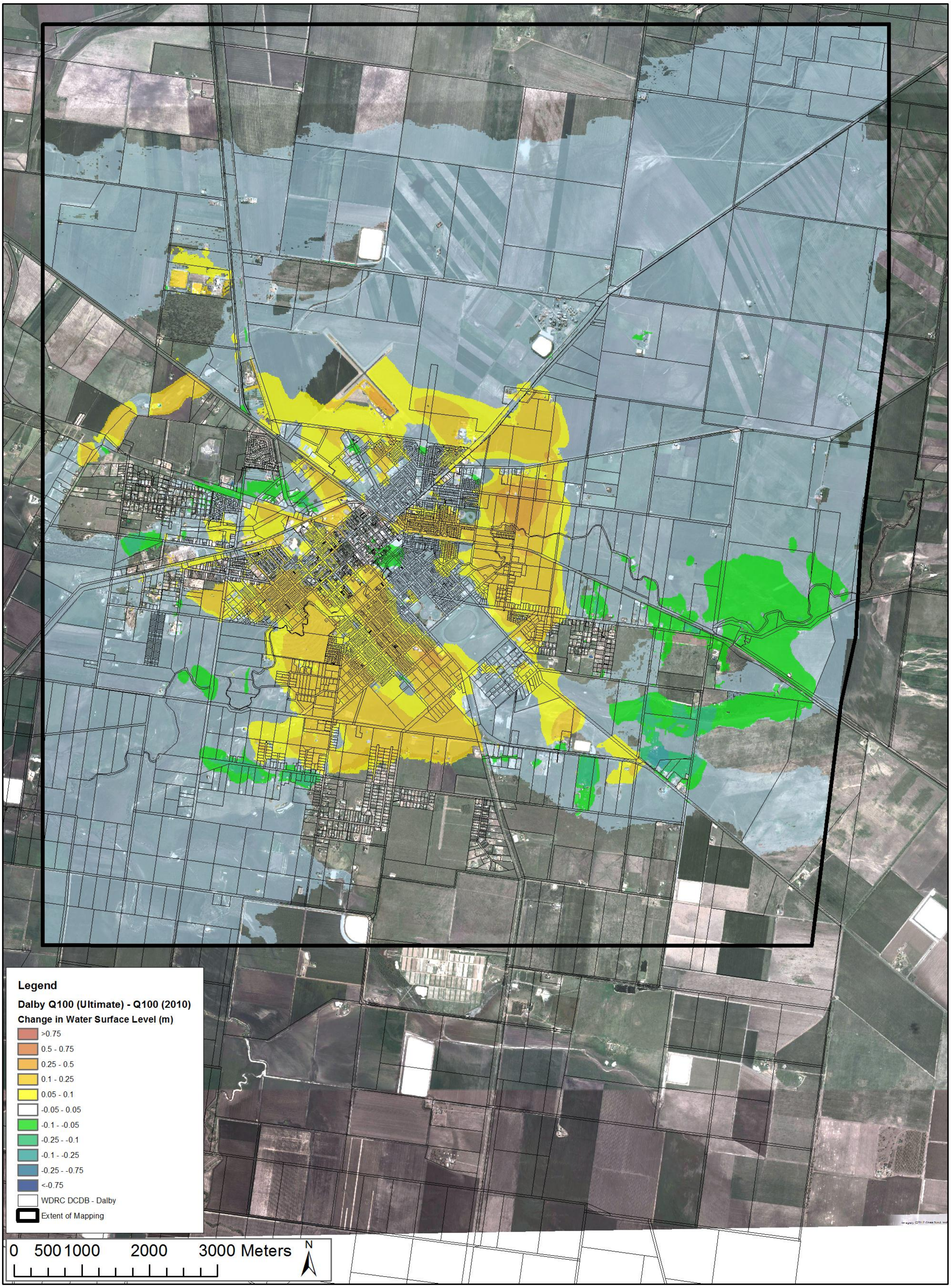


Figure E.5 Flood Level Difference – 1 in 100 Flood (2010 vs Ultimate Level of Development)

APPENDIX F COMPARISON OF THE DALBY 1981 AND 1 IN 100 AEP FLOODS WITH DIFFERENT LEVELS OF TOWN DEVELOPMENT (1981 AND ULTIMATE)

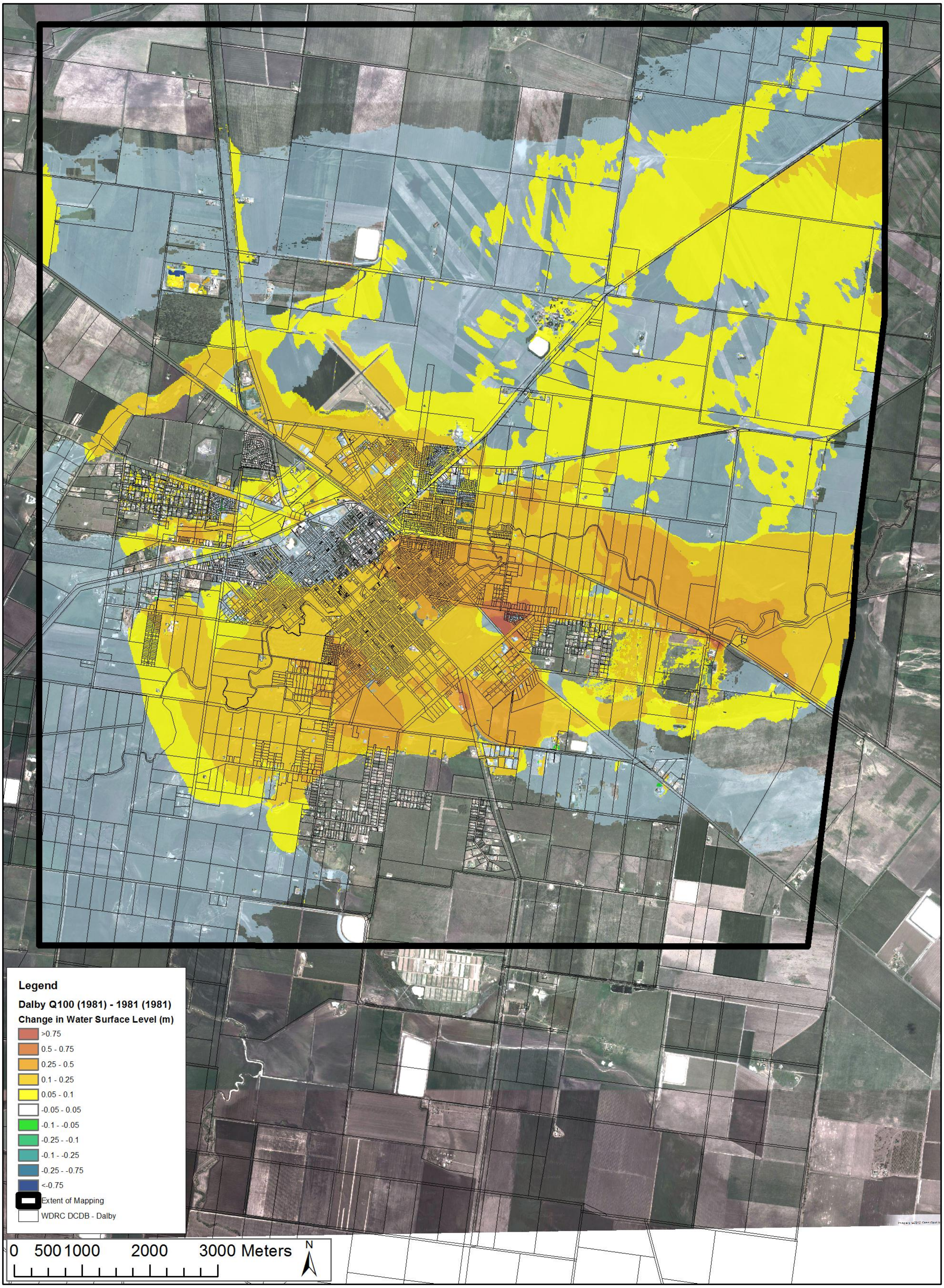


Figure F.1 1 in 100 (1981 land use) vs 1981 (1981 land use)

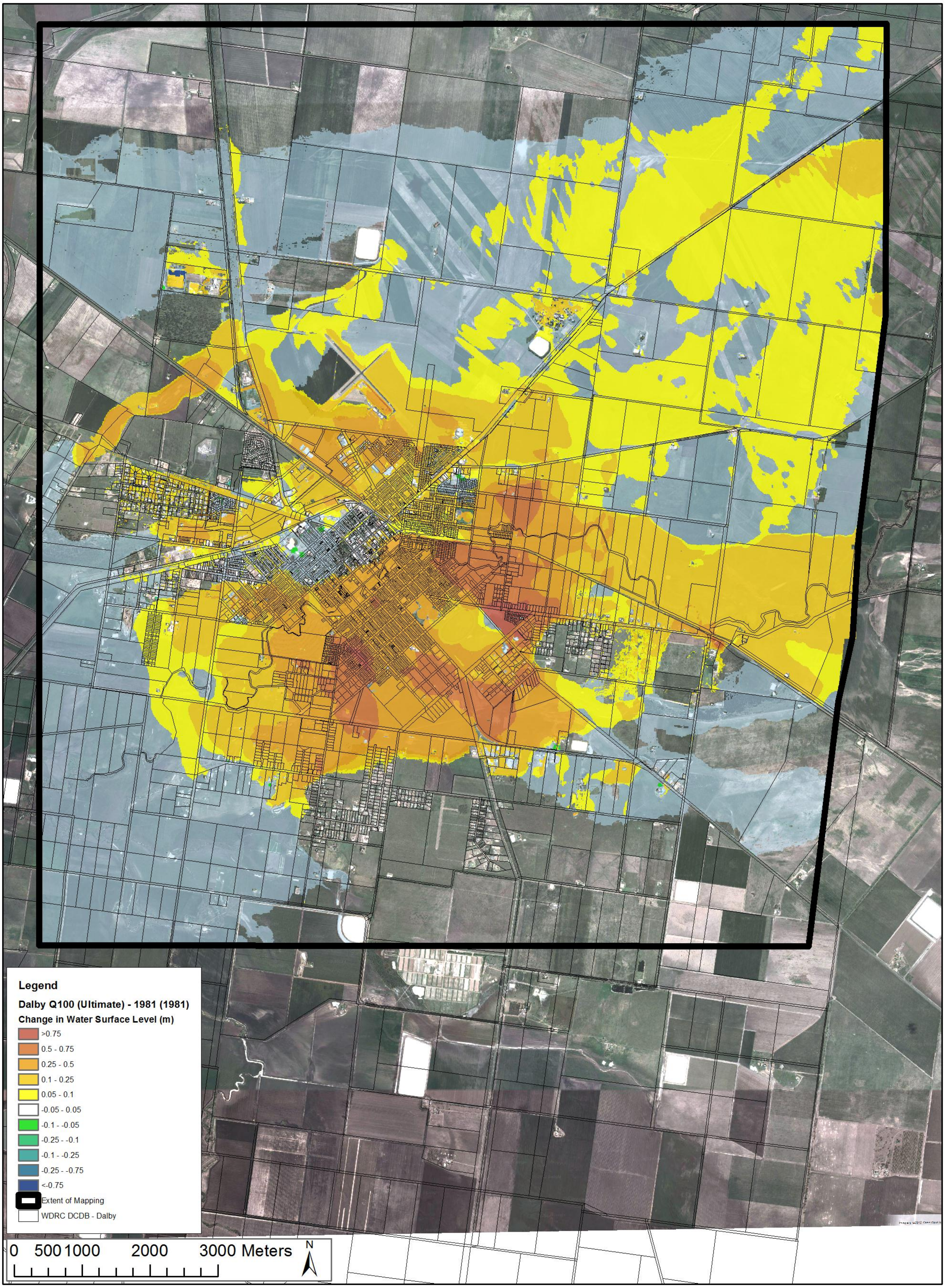


Figure F.2 **1 in 100 (Ultimate land use) vs 1981 (1981 land use)**

APPENDIX G JOINT CALIBRATION OF THE 1981 AND 2011 FLOODS - RESULTS

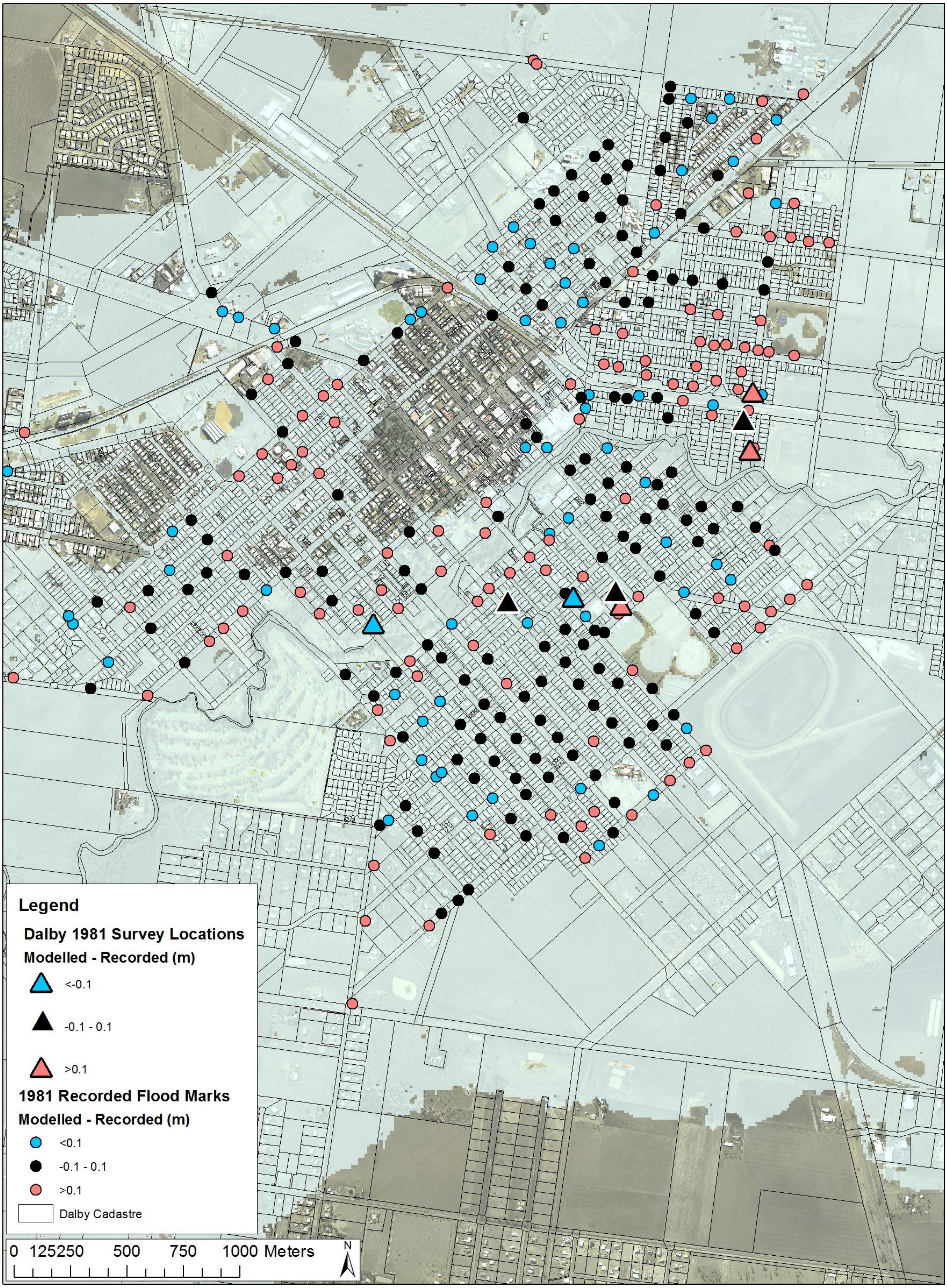


Figure G.1 **1981 Model Calibration Results – 3 Colours**

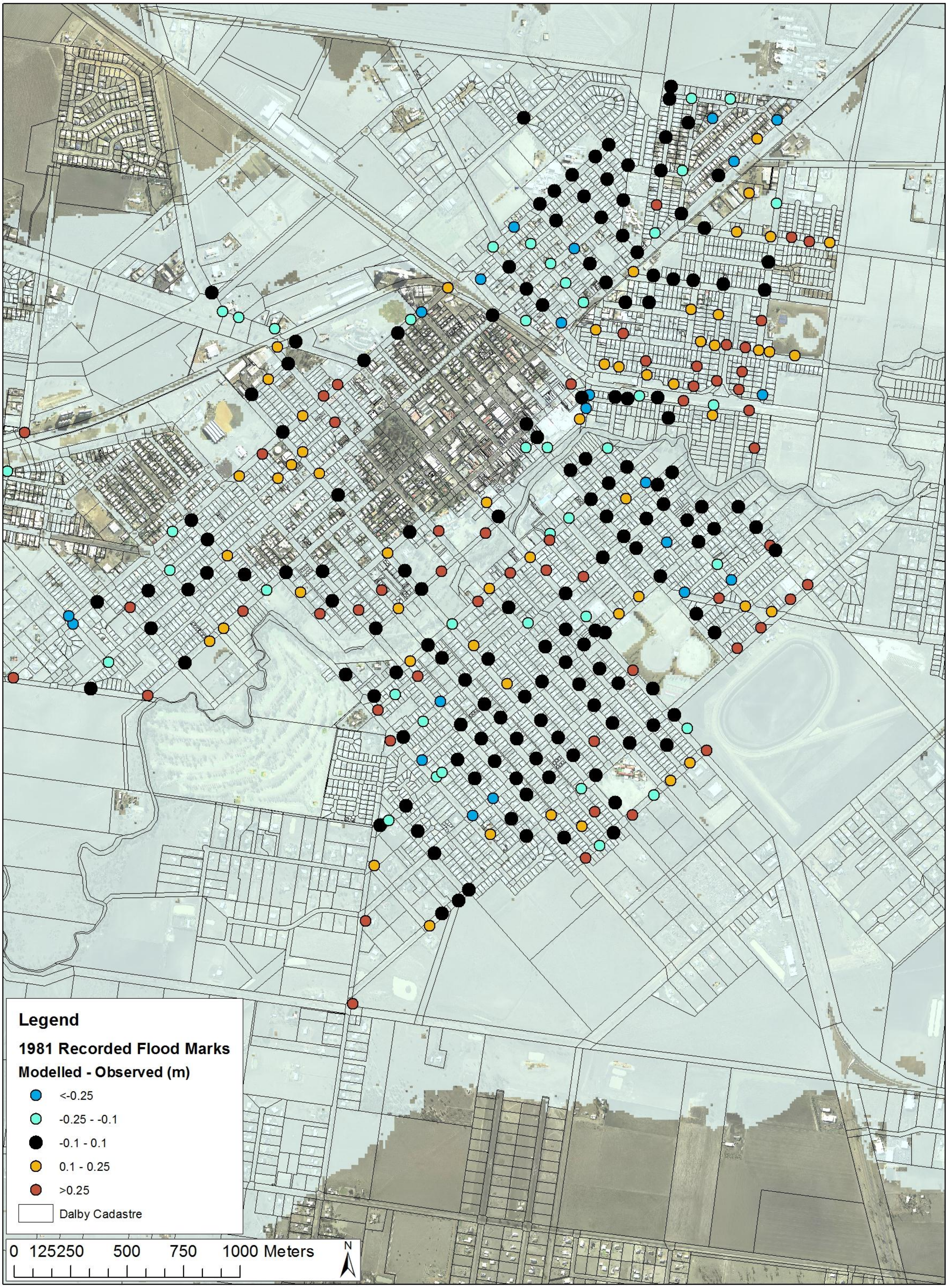


Figure G.2 1981 Model Calibration Results – 5 Colours

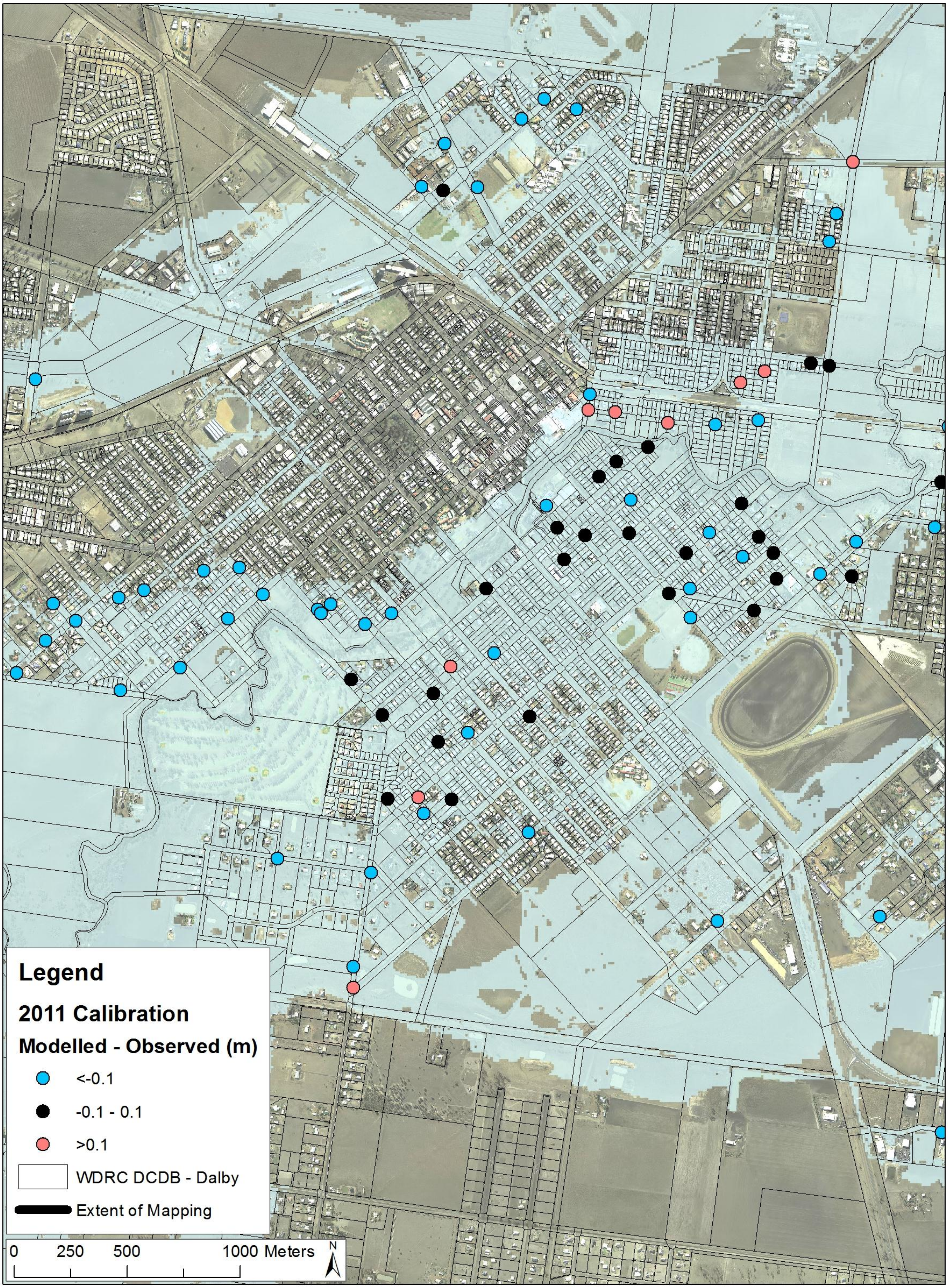


Figure G.3 **2011 Model Calibration Results – 3 Colours**

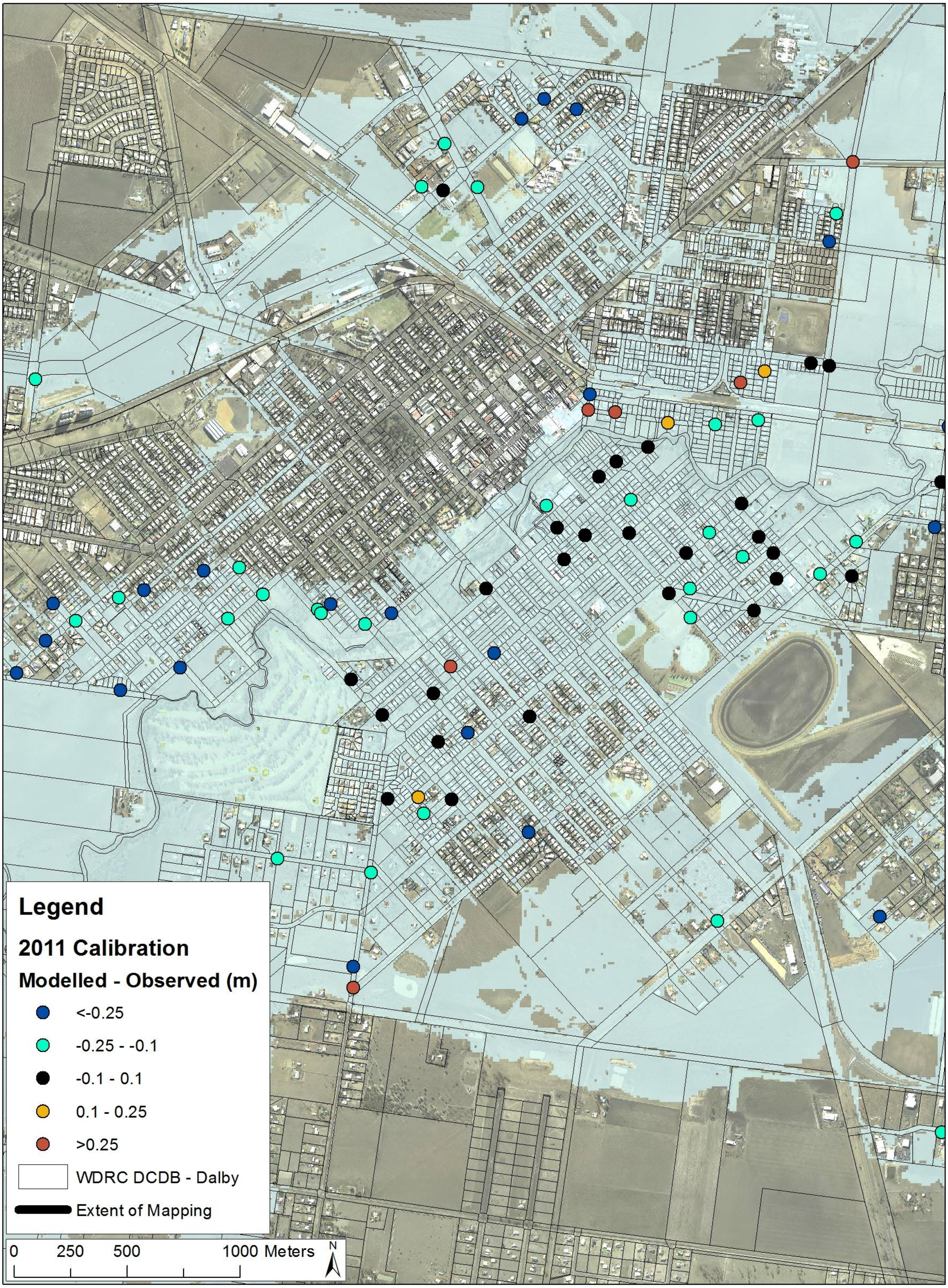


Figure G.4 2011 Model Calibration Results – 5 Colours

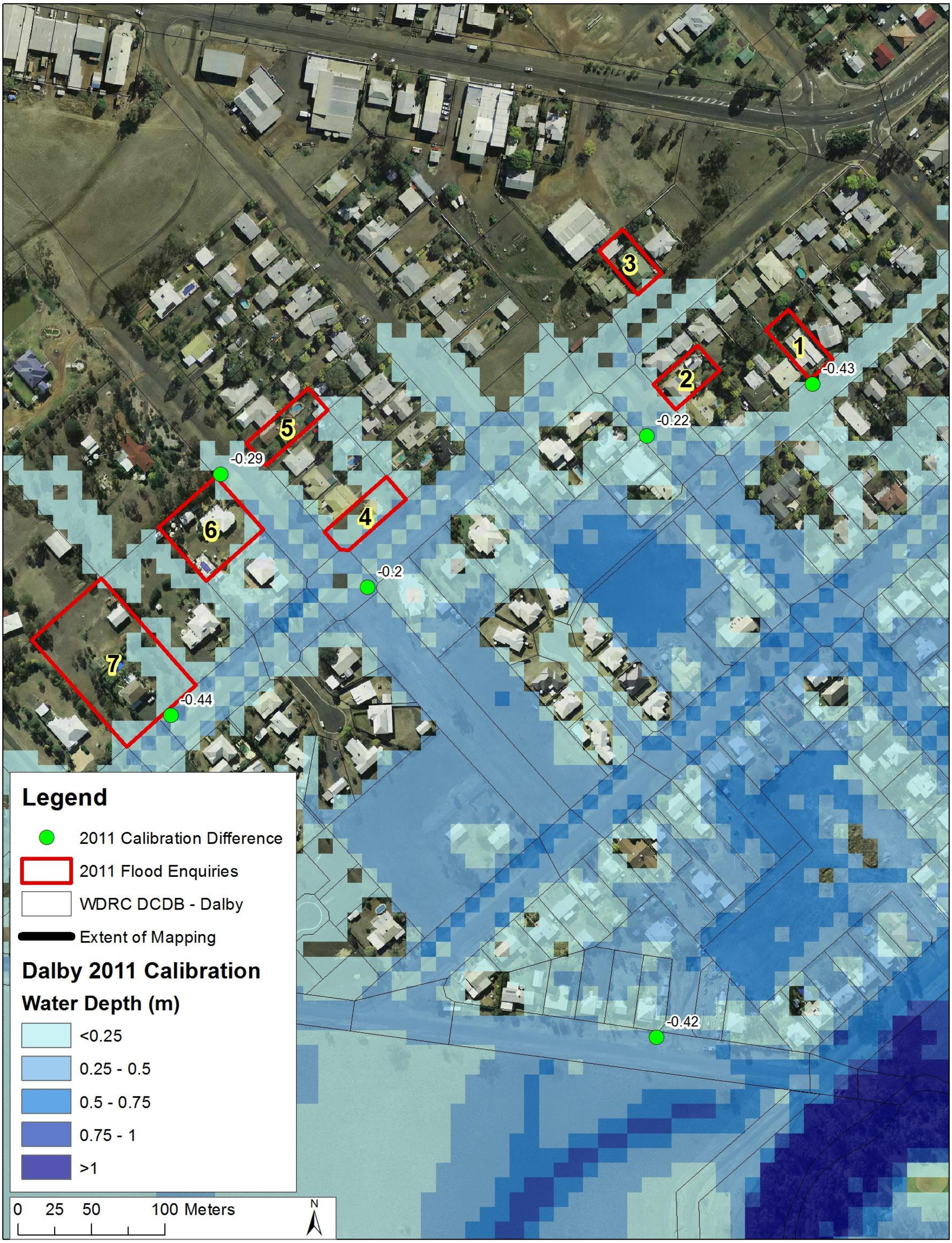


Figure G.5 Modelled Flood Extent in the Nicholson Street Area

APPENDIX H DALBY 1893 FLOOD MAGNITUDE ESTIMATION

H.1 Introduction

Substantial analysis was been undertaken to compare the 1893 and 1981 flood magnitudes. This information was essential to the study as the 1893 was a large flood, possibly the largest on record. As such, the uncertainty in its magnitude may have a substantial influence on the results of any flood frequency analysis (FFA) undertaken. The limited data available includes:

- Recorded Rainfall Data
- Historic newspaper articles regarding the water level at Dalby Station
- Historic newspaper articles regarding the water level at Queen's Hotel.
- Historic newspaper articles regarding the water level at Dalby Convent.

H.2 Recorded rainfall data

Daily rainfall records for Dalby and areas surrounding the catchment were sourced from the Bureau of Meteorology. These were used to give an indication of rainfall in the catchment during the 1893 flood event, and hence an indication of the flood magnitude. During February 1983 three cyclones caused widespread rainfall throughout the South East Queensland. The majority of rainfall occurred around the Myall Creek catchment between the 13th February and 19th February. Figure H.1 shows the available rainfall totals in the area for this period. As can be seen in the image, there is a large gradient in rainfall totals with large values being recorded to the east of the catchment and (significantly) smaller totals recorded to the west.

Unfortunately the limited rainfall data means there is significant uncertainty regarding the spatial rainfall distribution for the 1893 event across the Myall Creek catchment.

For comparison, the 1981 4 day rainfall totals are shown in
Figure H.2. The Myall Creek catchment is also indicated as a red line in both Figure 1 and Figure 2.

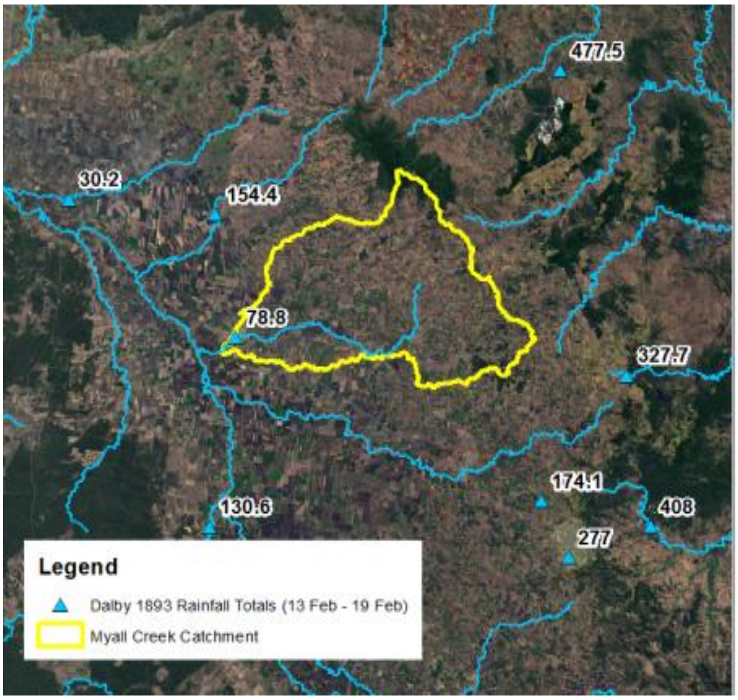


Figure H.1 1893 Rainfall Totals (13 Feb – 19 Feb)

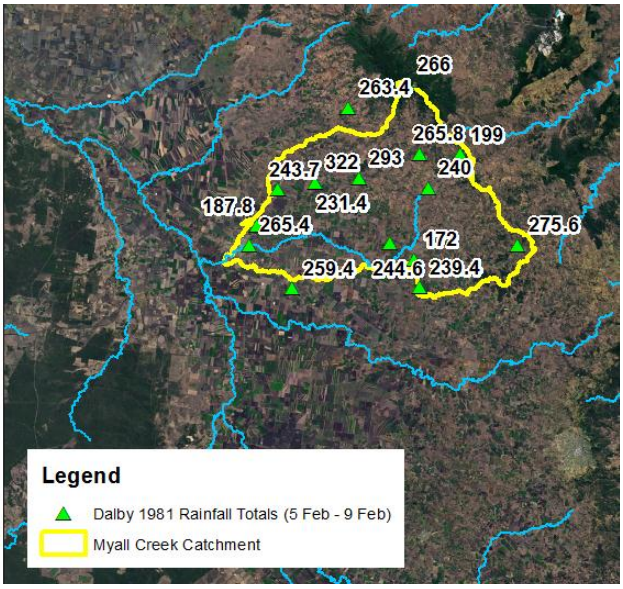
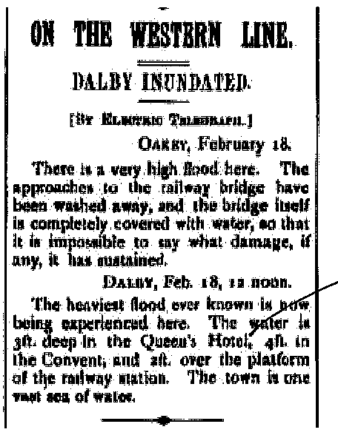


Figure H.2 1981 Rainfall Totals (5 Feb – 9 Feb)

H.3 Recorded water levels

A newspaper article from the Warwick Argus shown in Figure H.3, had three observed depth recordings in Dalby during the 1893 flood. These were at the Dalby railway station, Queen's Hotel and the Dalby Convent. An attempt was made to estimate Myall Creek discharges that for each of these levels at the given locations. The following sections review the data regarding the water level and present discharge estimates associated with each water level.



ON THE WESTERN LINE.

DALBY INUNDATED.

[By Electric Telegraph.]

Oakey, February 18.

There is a very high flood here. The approaches to the railway bridge have been washed away, and the bridge itself is completely covered with water, so that it is impossible to say what damage, if any, it has sustained.

Dalby, Feb. 18, 12 noon.

The heaviest flood ever known is now being experienced here. The water is 3ft. deep in the Queen's Hotel, 4ft. in the Convent, and 2ft. over the platform of the railway station. The town is one vast sea of water.

"The heaviest flood ever known is now being experienced here. The water is 3ft deep in the Queen's Hotel, 4ft in the Convent, and 2ft over the platform at the railway station. The town is one vast area of water.

Figure H.3 Article from the Warwick Argus, 21 February 1893.

H.4 Dalby station water level

Two newspaper reports state that the Dalby station platform was 2ft under water during the 1893 flood in Dalby. Hydraulic modelling suggests that a discharge (~8,000m3/s) significantly higher than all other recorded flood events would be required to attain this depth of water. For comparison, the discharge associated with the 1981 flood event (which is held by some as the largest on record) has been estimated to be ~1,430 m^3/s.

A discharge estimate corresponding to a depth of 2ft from railway track level was undertaken. Figure H.4 shows the modelled water surface levels at the station for a given discharge as well as the estimated ground levels. Using the reported depth of 2ft above the railway track level, a value for the 1893 discharge was estimated to be 1,440 m^3/s.

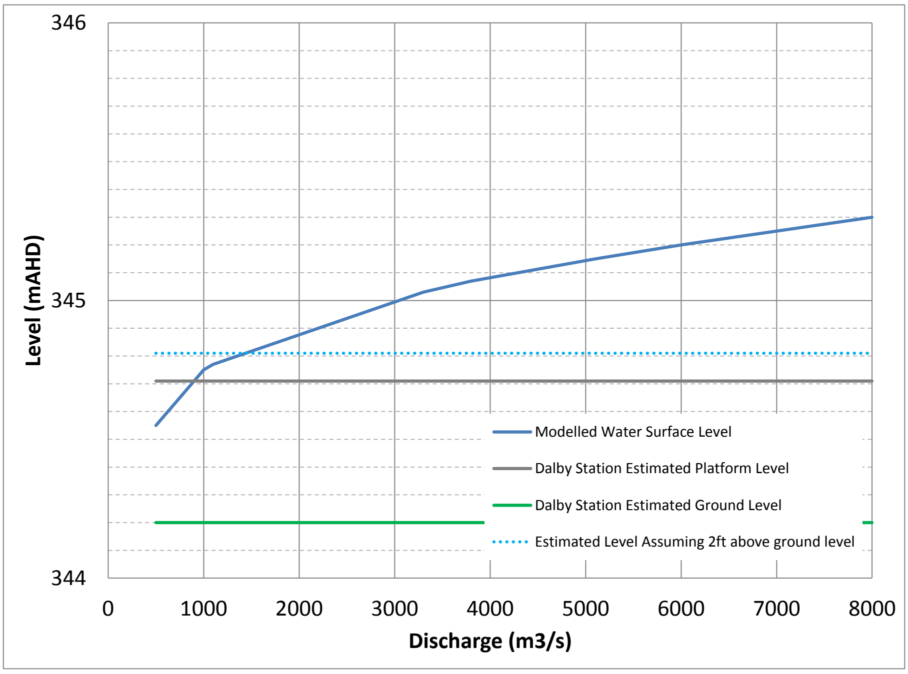


Figure H.4 Dalby Station 1893 estimated flood level

H.5 Queen's Hotel water level

An historic depth observation of 2ft within the Queen's hotel was used to assist in the estimate of the 1893 flood discharge. The hotel burned down some time in the last century and a labelled historic aerial photograph was used to find the location of the site. With the site being relatively flat, an approximate floor level was used to estimate the 1893 level and hence discharge. Figure H.5 shows the estimated floor and 1893 flood level, with hydraulic modelling suggesting a discharge of 1,770m^3/s.

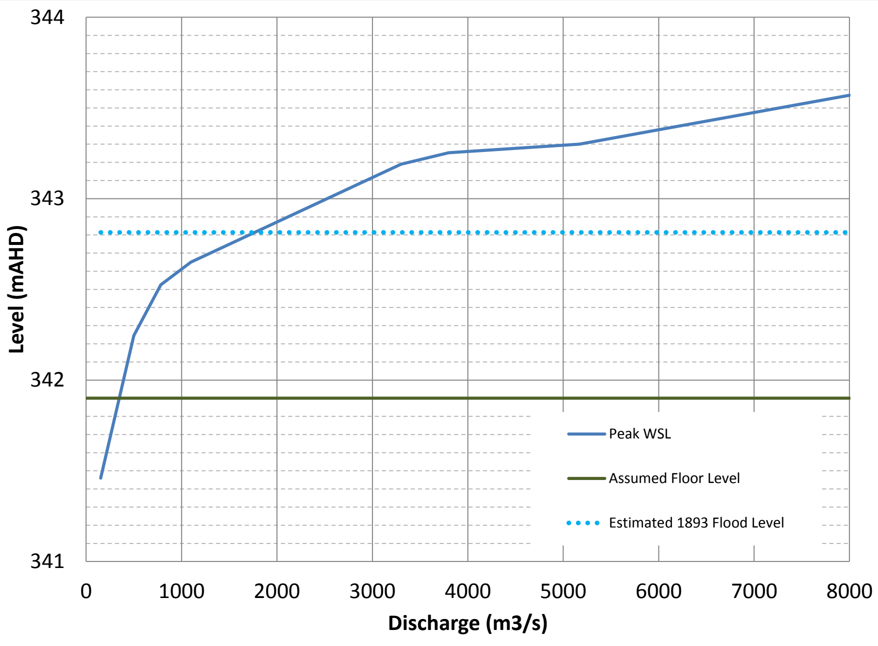


Figure H.5 Queen's Hotel Estimated 1893 Flood Level

H.6 Dalby Convent water level

An historic depth observation of 4ft within the Dalby Convent was also used to assist in the estimate of the 1893 flood discharge. The Dalby Convent is no longer standing and the land on which it stood has been considerable altered with fill. Historic photographs show the convent's floor matching the surrounding ground level, therefore a level was taken from the adjacent road (Myall St) on the basis that the road does not appear to have altered significantly in level. An approximate floor level (based on the topographic data) was used in conjunction with the historic newspaper article and hydraulic model results to estimate the 1893 discharge. Figure H.6 shows the estimated floor and 1893 flood level, with hydraulic modelling suggesting a discharge of 1,630 m^3/s.

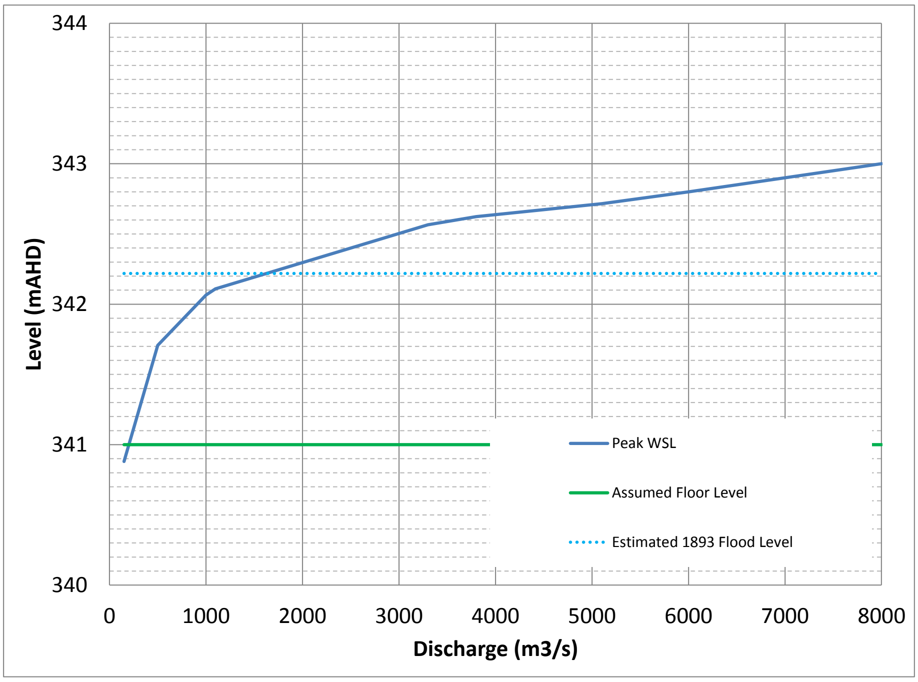


Figure H.6 Dalby Convent Estimated 1893 Flood Level

H.7 Results Summary

Table H.1 shows the results summarised along with sensitivity estimates. Figure H.8 shows the range of discharges possible using the available information, including the best estimate.

Table H.1 1893 Discharge Estimates based on recorded flood levels

Location	Level	Estimated Discharge (m^3/s)
Dalby Station	2ft above railway track level -100mm	900
	2ft above railway track level	1,436
	2ft above railway track level +100mm	2,283
	2ft above platform level	~8,000
Queens Hotel	2ft above Lowest point of flat portion of the SE site	570
	2ft above Mable St road level adjacent to the SE site (indicative of floor level of Queen's hotel)	1,768
	2 ft above Mable St road level adjacent to the NW site (indicative of floor level of Queen's hotel)	6,435
Dalby Convent	4ft above the lowest point on the site	796
	4ft above Myall St level (indicative of historic convent floor level)	1,628
	4ft above the highest point on the site	2,110

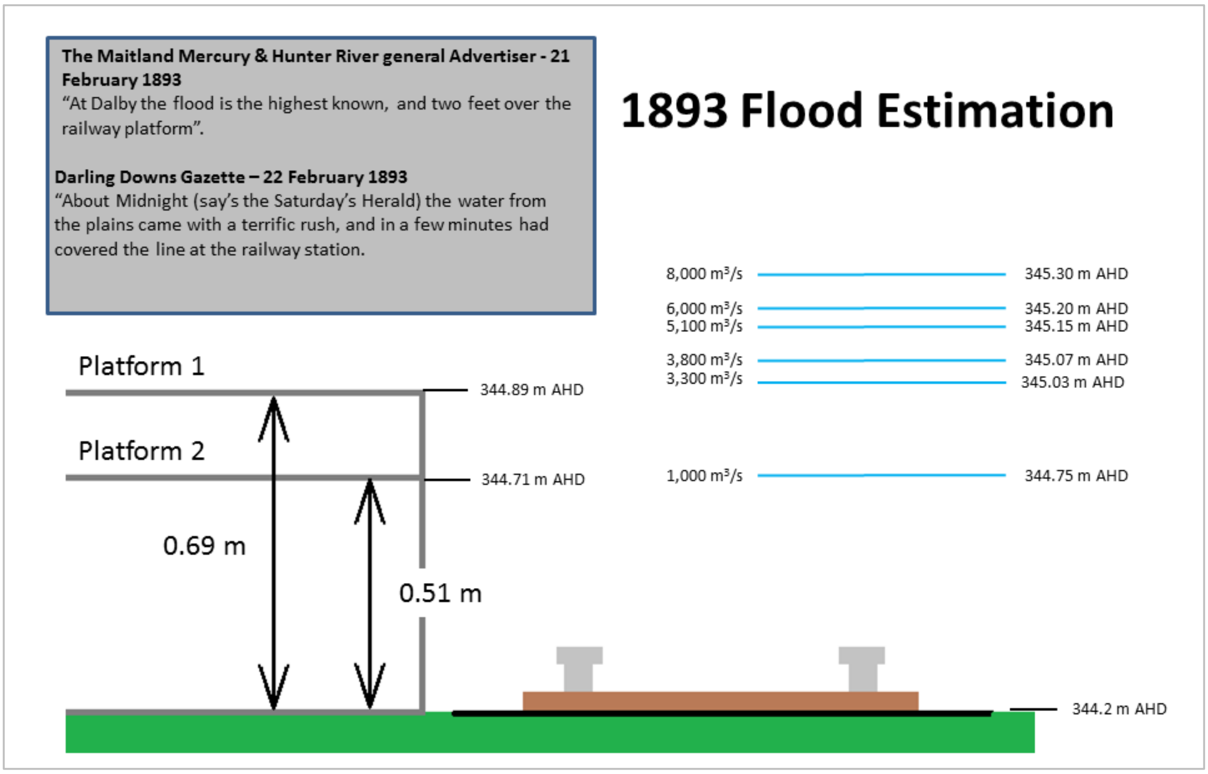


Figure H.7 1893 Flood Estimation

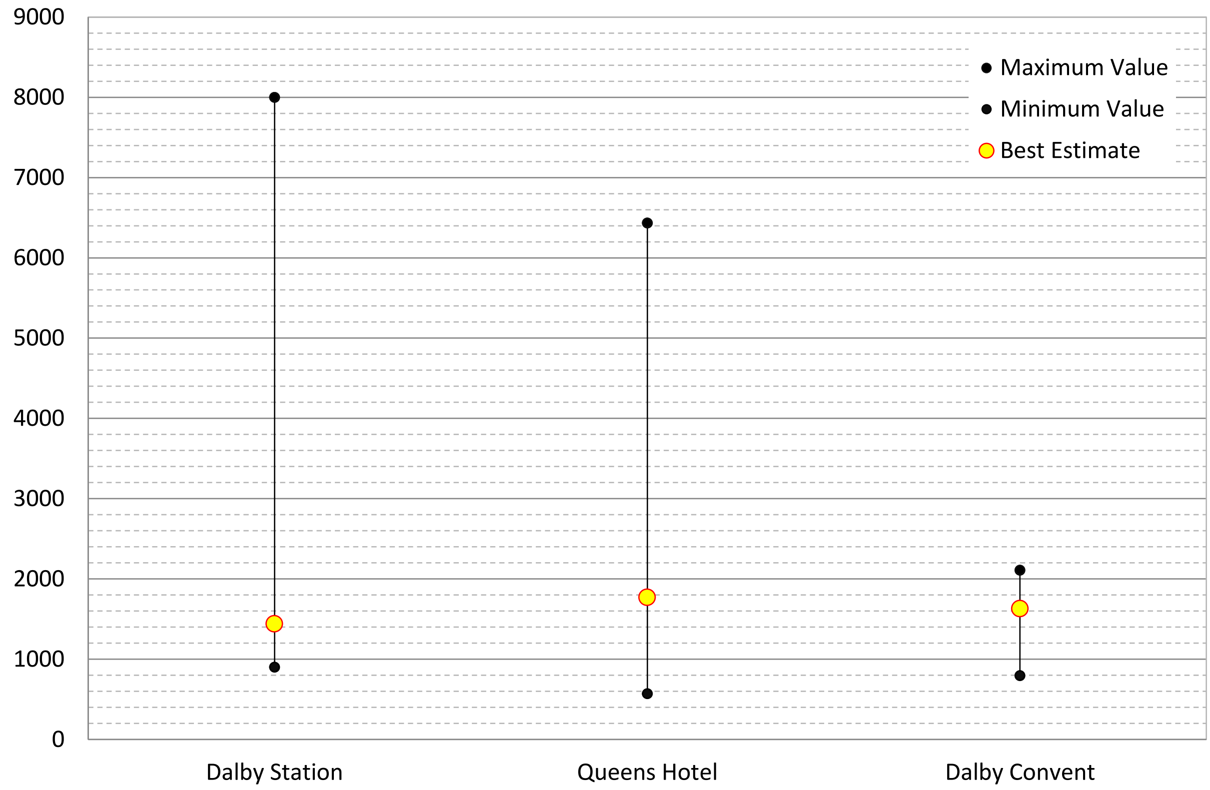


Figure H.8 Range of possible 1893 discharges

H.8 DISCUSSION

As can be seen in the sensitivity analysis within the results summary section, a difference in reference level of 100mm (which is less than the margin of error associated with flood debris marks) causes discernible difference in the estimated discharge. This is partly due to the nature of large floods in Dalby where a large change in discharge causes a relatively minor increase in water level.

While further investigations into the 1893 event have been conducted, there is still significant uncertainty regarding the discharge to be assigned to the 1893 event. If the best estimates of flow for each of the three data points (Dalby Station, Queens Hotel and Dalby Convent) are averaged, an estimate of 1,645 m^3/s results.

There are a number of uncertainties associated with the discharge estimates that have been presented. Along with the unknown catchment rainfall and sensitivity to reference levels for the recorded depths, the following is of note:

- The Dalby train station recorded level was presented as 2ft above the station platform. The modelling results suggested that the discharge magnitude required to attain this level was significantly larger than any previously recorded flood event. More specifically the flow corresponding to a level of 2ft above the station platform has been estimated to be approximately 8,000 m^3/s. This flow is approximately six times the flow of next largest flood event (of the order of 1,400m^3/s). Sensitivity testing was carried out by interpreting the level described as 2ft above the station platform as being 2ft above the rail tracks at that location.

- The Queens hotel's location is uncertain. Historic maps show the hotel on the north-western side of Marble Street in Dalby while historic aerial photographs label a building on the south-eastern side of Marble Street as the location. As the ground level rises as distance from Myall Creek increases, if the depth at the Queen's hotel is interpreted as occurring at the south-eastern location, this depth is smaller, leading to a decreased estimate for the 1893 discharge when compared to the discharge obtained if the north western location is used. Attachments 3 and 4 show the differing reported location of the Queen's hotel.
- Historic photographs suggest that the Queen's hotel underwent significant structural changes between 1865 and 1930. The original layout of the Queen's hotel is a single storey slab structure with the floor level most likely at ground level. A photograph from 1930 shows the Queen's hotel as a 2-storey structure with the floor level raised approximately 2-3 feet above the ground level. Attachment 2 shows the Queen's Hotel in 1865 and 1930.
- Newspaper reports from 1942 and 1975 suggest that tail water level of the Myall Creek in 1893 was higher than in other flood events, possibly increasing levels. Modelling undertaken during this investigation suggests that the amount of influence from the Condamine River is minimal within the town of Dalby. However, there remains the possibility that extreme levels within the Condamine River may have had an impact.
- Newspaper reports from 1922 and 1942 suggest that the 1893 event was the greatest experienced up until this time, being greater than the 1908 event which was approximately 1,100 m^3/s.

The Plough Inn

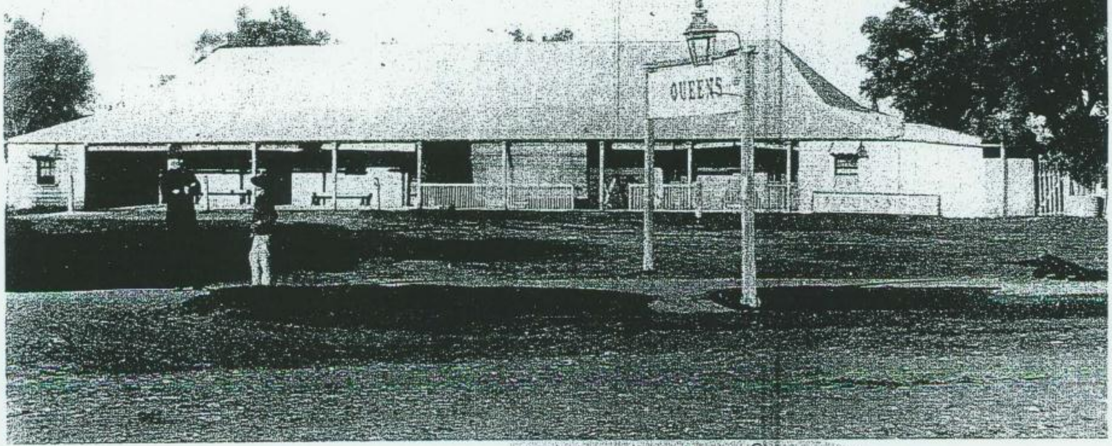
In 1846, a slab dwelling was erected by Mr Henry Stuart Russell of Cecil Plains Station for a former loyal employee, Mr Samuel Stewart. The hut was built at the junction of the Greenbank, St Ruth and Jimbour runs and stood on what later became the west corner of Myall and Bunya Streets. Here Stewart operated Stewart's Public House. In 1863 a two story structure was built and named The Plough Inn. The building was destined to become Saint Columba's, the first catholic school and residence for the Sisters of Mercy when they came to Dalby 8 August 1877 under Mother Mary Rose.

Dalby Family History Society

Figure H.9 Dalby Convent (The Plough Inn)

Queen's Hotel

The Queen's hotel began life as a slab hut with a shingle roof in the 1840s. It became the Queen's Arms in 1865 when a licence was issued to Charles and Sue King.



The Queen's Hotel.

Queen's Hotel about 1930.
The Council Chambers are on the left of the picture.

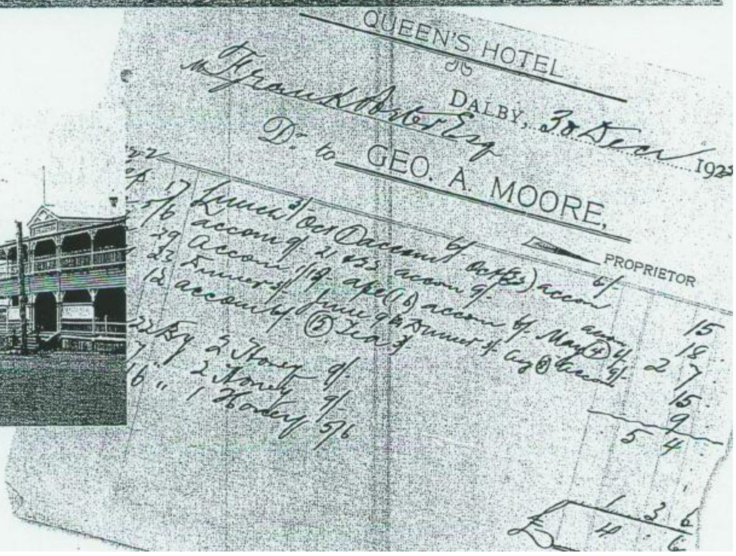


Figure H.10 Queens Hotel

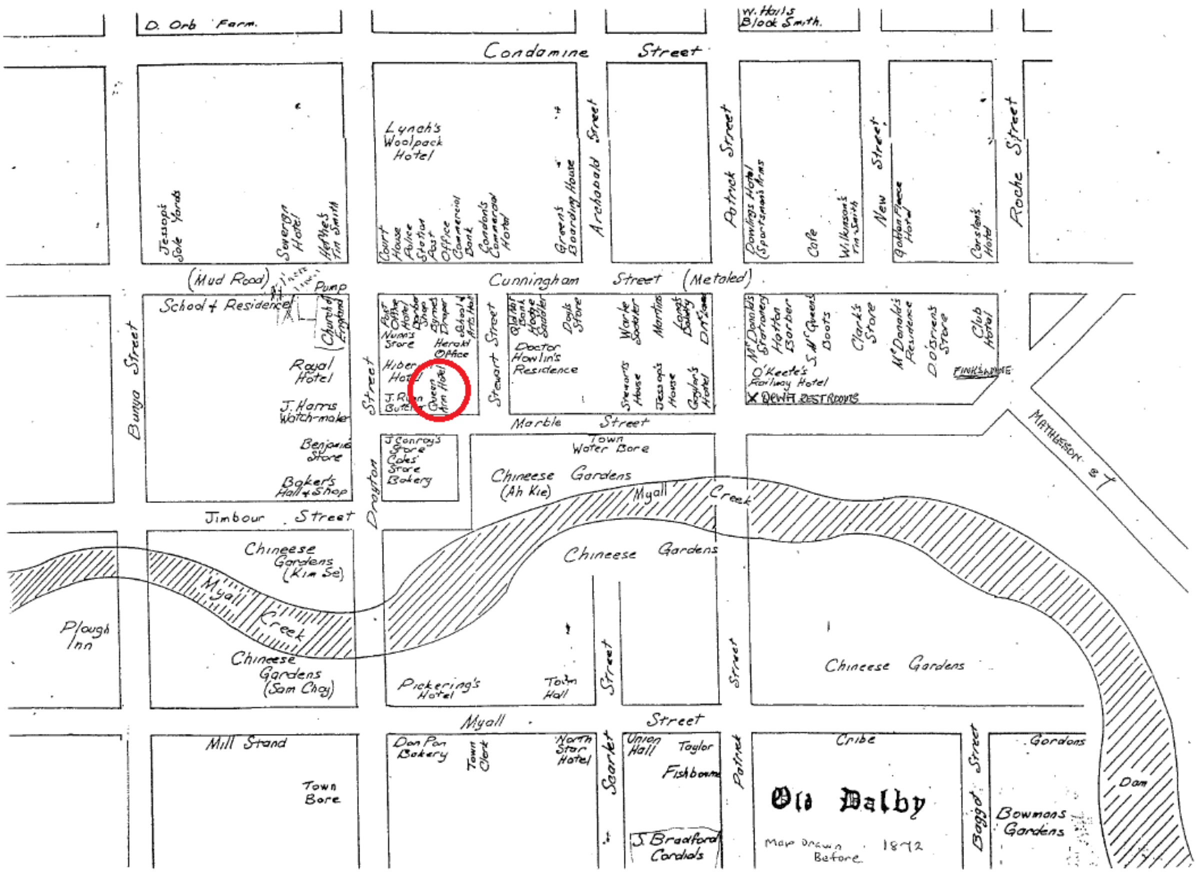


Figure H.11 Dalby pre-1872 Hand drawn map showing the location of the Queen's (Arm) Hotel

Page 12 — Dalby Herald, Friday, June 12, 1987

An Aerial view of Dalby in 1929

• *This aerial picture of Dalby was taken by F.W. Thiel and Aircraft Photo for "The Queenslander" in 1929 was found on the Chinchilla Rubbish dump by Mr. M.P. (Con) Allan and presented to Mr. Boyd Weir, Swan St, Dalby.*

It was one of a number of early photographs and other memorabilia which was retrieved by Mr. Allan.

The photo appeared in the Queenslander on November 31, 1929. (Incidently there are only 30 days in November!)

Some of the noted landmarks in the picture are listed below.

1. Russell Hotel
2. Finks Plumbing Works
3. Dalby Herald
4. Now Knox Building
5. Union Bank (now Carrick Ashmead & Co.)
6. Ogdens
7. Australian Cafe (now Big Rooster)
8. Albion Hotel
9. Queens Hotel
10. [illegible] (now S.W.Q.E.B.)
11. Arcadia Hotel (now Country Club)
12. School of Arts
13. Bore Baths
14. Contin Boarding House
15. St. Johns Church of England
16. Dalby State School
17. St. Columba's Convent
18. Convent School
19. St. Joseph's Catholic Church
20. St. Joseph's Hall
21. Residence — Mr. J. Shaw Thompson
22. Mrs. Ritzman's Corner Store
23. Post Office
24. Commercial Hotel
25. Q.N. Bank (now Suncorp)
26. Residence — Mr. Punch
27. Residence — Dr. H.L. Hawthorne
28. Residence — Mr. Skerman
29. Residence — Mr. E. Geisel
30. Residence — Mr. J. Knox
31. Windsor Hotel
32. Ewings Building
33. Salvation Army Hall
34. Salvation Army Residence
35. Oddfellows Hall
36. Golden Fleece Hotel with stables at back
37. Thomas Jack & Co.
38. Residence — Mr. T. Jack
39. Imperial Hotel
40. Residence — Mrs. Woolgar
41. Residence — Mr. V. Buckley
42. Grand Hotel (rebuilt as Hotel Motel)
43. Bell Park
44. Station Masters Residence
45. Mulhollands Boarding House (now St. Marks Lutheran Church)
46. Brooks Blacksmithy
47. Chemist Shop (Mr. Connolly) (now Nearhos Chemist)
48. Bank of N.S.W. (now Westpac)
49. Commonwealth Bank
50. Sister Devers Nursing Home
51. Methodist Church
52. Residence — Miss Higgins
53. Original Star Theatre

Figure H.12 Aerial photograph of Dalby in 1929 showing the location of the Queen's Hotel.

H.9 1893 Historic Data

An assessment of the 1893 flood magnitude based upon historical depth records for Dalby was conducted. As the structures that the flood was measured against were no longer standing or the flood estimate based upon the data appeared to be unreasonable (i.e. it was difficult to calculate an estimate within reasonable error bounds). The conclusion was that, due to large uncertainty, a definitive discharge estimate could not be established. Notwithstanding this, the evidence suggests that 1893 was a very large flood. Figure H.13 shows the estimate range that was calculated during the previous investigation. The figure shows a wide range of possible values with the possible range for two of the three values in excess of 600%.

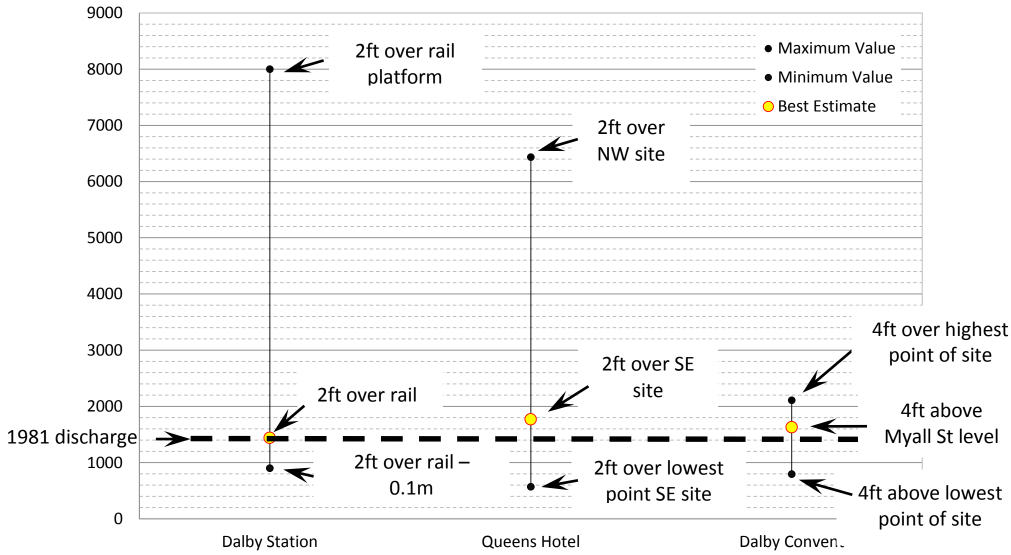


Figure H.13 Dalby 1893 Flood Estimates

H.10 Historic climate data

H.10.1 Catchment Rainfall

Recorded rainfall around the Myall Creek catchment for the 1893 event is shown in Figure H.1. As can be seen in the figures, there was only one rainfall station within the Dalby catchment in 1893. However, totals recorded to the west of the catchment varied greatly compared to the totals recorded to the east of the catchment. The rainfall in Dalby leading up to the flooding around the 20th Feb was due to a tropical cyclone, this was the third cyclone to hit south-east Queensland in February 1893.

H.10.2 Regional Flooding

In February 1893 widespread flooding occurred over much of south-east QLD; associated with three tropical cyclones. Rain gauges to the east of catchment (which were closer to parts of the catchment than Dalby) received record high rainfall totals in excess of 450mm. Record rainfalls were observed up and down the coast with Brisbane experiencing its largest flood on record. The BOM southern oscillation index for Jan and Feb 1893 (11.3 and 7.7 respectively) were highly positive which generally leads to above average rainfall in south east QLD.

Note that this was the third cyclone to hit south east Queensland in February 1893; antecedent soil conditions would have been saturated. Figure H.14 to Figure H.16 show articles relating to flooding in South-East QLD through February 1893.

Note that large floods were reported in towns either side of Dalby (Oakey, Jondarian, and Chinchilla)

> In 1893, of course, the entire eastern seaboard of Australia was inundated by floodwaters caused by cyclonic weather conditions. The Brisbane River was in flood and the Victoria Bridge was seriously damaged. Inland areas were also seriously affected. Floodwaters washed rapidly into Chinchilla.

Figure H.14 Excerpt from "Footsteps Through Time – A History of Chinchilla Shire

> The Railway Commissioners on Monday receive from the district traffic manager at Toowoomb the following message:—" Lines considerab further damaged, especially on the main rang Piles and girders of Murphy's Creek Brid damaged. Embankment near Peachey, Crow Nest line, subsided two chains. Heavy floods Oakey, Jondarian, Dalby and Chinchilla."

Figure H.15 Excerpt from Freemans Journal – Sydney 1893

Looking back in time -The Great Flood 1893

The **1893 Brisbane flood**, occasionally referred to as the **Great Flood of 1893** or the **Black February flood**, occurred when the Brisbane River burst its banks on three occasions in February 1893. These three major floods was named "Black February", with a fourth flood event also experience in June.

The Brisbane river runs through the centre of Brisbane,with much of the population living in areas beside the river. The first flood on the 4th February was due to a deluge associated with a tropical cyclone, called "Buninyong", with record breaking falls in the Stanley River headwaters. A second cyclone struck on the 11th February causing relatively minor flooding compared to the first flood. When the third cyclone hit on 19th February, it was almost as devastating as the first, and it left up to one third of Brisbane's residents homeless. This time however the flood in the Brisbane River was largely from waters from the upper reaches of Brisbane River, rather than the Stanley River.

Indooroopilly Railway Bridge

The total damage caused by the flooding has been estimated at $4 million (1893 figures), although no official figures exist.

During the first flood, Crohamhurst recorded 914.4 mm of rain that fell in a 24 hour period. In the four days leading up to this flood, a total of 3092 mm (6.5 feet) or rain fell on the Crohamhurst property. The water surge was recorded on the Port Office gauge (now the City gauge) as being 8.35 m (27 feet, 5 inches) above the low tide level. The February 1893 floods were the second and third highest water levels ever recorded at the City gauge, the highest being the January 1841 flood at 8.43 m (27 feet, 8 inches). Some aboriginal history however suggests a flood level of nearly 12 m prior to European settlement.

Construction of Somerset Dam

The southern regions of the city were most affected by the flood. Both bridges that crossed the river, the Victoria Bridge and the Railway bridge at Indooroopilly were destroyed.

Of historical interest, the rainfall recorded for the month of February 1893 at Kilcoy Post Office was 1422.4 mm. The heaviest downfall being 373.4mm on 2 February and 307.3mm on 16 February. Esk Post office recorded 199.9mm on the same date and 252.7mm on 17 February, bringing the monthly total at Esk to 1036.4mm.

Figure H.16 SEQ Catchments article on 1893 Flooding

H.11 Linksview flood history

H.11.1 Introduction

As part of the community consultation process and also provided separately by the Technical Review Panel (TRP), an email was received from Craig Hartley (dated 25 Oct. 2013) that detailed information regarding flooding at the 'Linksview' property, between Condamine Street and Myall Creek. This letter contains anecdotal flood information including observations of 1893. The following figures provide additional detail (based on hydraulic modelling results) relevant to observations contained in this email at 'Linksview':

- Figure H.20 1981 Modelled Flood Depth – 'Linksview'
- Figure H.21 1893 (3,300 m^3/s) Modelled Flood Depth – 'Linksview'
- Figure H.22 1893 (2,000 m^3/s) Modelled Flood Depth – 'Linksview'

H.11.2 Flooding in 1981

The 'Linksview' document states the following regarding the 1981 flood level at the house.

"The 1981 flood came to within 1 inch of entering the 1881 house." (pg 2, 6th paragraph)

Table H.2 shows modelled 1981 flood levels at the property. There are three identifiable buildings at this location. It is not clear which building is being referred by the 1881 house, so all buildings have been reported on in Table 1 below. The results indicate a modelled depth between 0.1m and 0.16m below the floor. Given the uncertainty in the anecdotal evidence, this is considered a good match to the 1" below floor estimate.

Table H.2 1981 modelled flood levels at 'Linksview' property

Building ID	1981 Modelled Level (m AHD)	Ground Level (Estimated from LiDAR) (m AHD)	Floor Level (Ground Level + 300mm) (m AHD)	Flood Depth above floor level (m)
1	340.82	340.62	340.92	-0.10
2	340.76	340.61	340.91	-0.15
3	340.64	340.50	340.80	-0.16

H.11.3 Pre 1900's Flooding

Mr. Hartley states that the house was built in 1881 after the largest flood on record at the time in 1879. He notes:

"The important story the Brennan's told Pete Healy is that their old home had never had water through it since it was built in 1881…" (pg 2, paragraph 1)

Table H.3 and Table H.4 show the results of modelling for 1893 flood using different discharges. The 2,000 m^3/s modelled water level is at or below the 1981 level while the 3,300 m^3/s modelled water level is at or below the floor level (and above the 1981 level).

Table H.3 1893 (3,300 m^3/s) Flood Level Estimate at 'Linksview'

Building ID	3,300 m^3/s 1893 Modelled Level (m AHD)	Ground Level (Estimated from LiDAR) (m AHD)	Floor Level (Ground Level + 300mm) (m AHD)	Flood Depth above floor level (m)
1	Not Present in 1893			
2	340.86	340.61	340.91	-0.05
3	340.80	340.50	340.80	0.00

Table H.4 1893 (2,000 m^3/s) Flood Level Estimate at 'Linksview'

Building ID	2,000 m^3/s 1893 Modelled Level (m AHD)	Ground Level (Estimated from LiDAR) (m AHD)	Floor Level (Ground Level + 300mm) (m AHD)	Flood Depth above floor level (m)
1	Not Present in 1893			
2	340.76	340.61	340.91	-0.15
3	340.63	340.50	340.80	-0.17

Based on the comparisons above:

- The calibrated hydraulic model predicts flood levels for the 1981 event consistent with the observation that *"The 1981 flood came to within 1 inch of entering the 1881 house."*
- With floodplain conditions as they were in 1893, modelling indicates that a flow of approximately 2,000m^3/s or above would have been necessary to reach the corresponding levels as observed in 1981.
- A discharge of up to 3,300 m^3/s for the 1893 event is consistent with the observation that the "*old home had never had water through it since it was built in 1881*".

H.12 Historic Newspaper Reports

H.12.1 1893 Compared to 1908 at Queen's Hotel

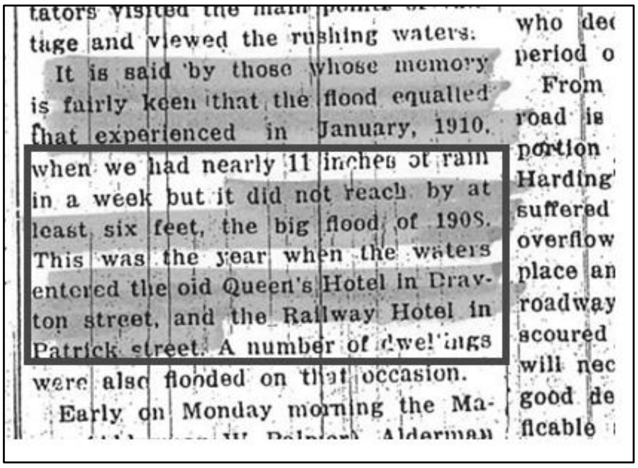
The modelled flood level in 1908 for the Queens hotel was used to assist in the estimate of the 1893 discharge. The following is of note:

- The 1908 flood had a recorded level at Patrick Street. This was used to estimate the discharge at 1,100 m^3/s from the rating curve developed from modelling.
- In 1908 the water entered into the Queen's hotel. This was reported in a newspaper article in the Dalby Herald in 1922, shown in Figure H.17. The report suggests that the flood levels only just reached the floor level.
- The Warwick Argus in 1893 reported that the Queen's Hotel was inundated to 3 feet above the floor level (Figure H.18).
- If the level of the Queens Hotel floor is taken as approximately the 1908 flood level, the 3,300 m^3/s 1893 model produces results that are 0.6m (~2 ft) higher.

Table H.5 shows the modelled water level for the scenarios discussed above.

Table H.5 Modelled Water levels at assumed Queen's Hotel Site

Event	Discharge (m^3/s)	Water Surface Level (m AHD)
1893	3,300	343.20
1908	1,100	342.66
1981	1,430	342.96



tage and viewed the rushing waters.
It is said by those whose memory is fairly keen that the flood equalled that experienced in January, 1910, when we had nearly 11 inches of rain in a week but it did not reach by at least six feet, the big flood of 1908. This was the year when the waters entered the old Queen's Hotel in Drayton street, and the Railway Hotel in Patrick street. A number of dwellings were also flooded on that occasion.
Early on Monday morning the Ma-

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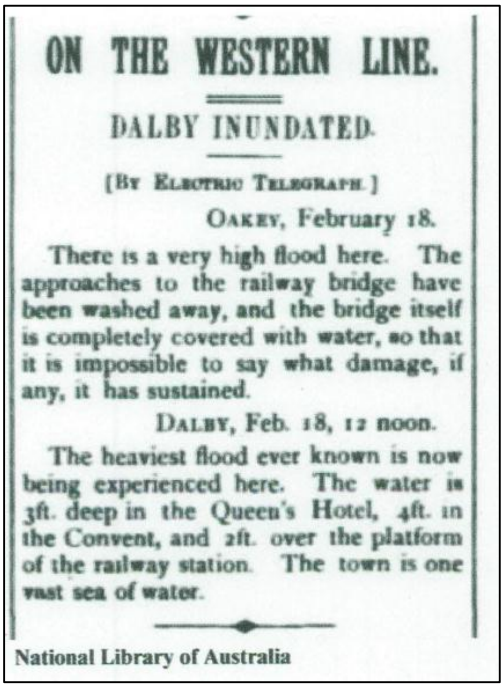
Figure H.17 Newspaper article in Dalby Herald from 1922



ON THE WESTERN LINE.

DALBY INUNDATED.

[By Electric Telegraph.]

Oakey, February 18.

There is a very high flood here. The approaches to the railway bridge have been washed away, and the bridge itself is completely covered with water, so that it is impossible to say what damage, if any, it has sustained.

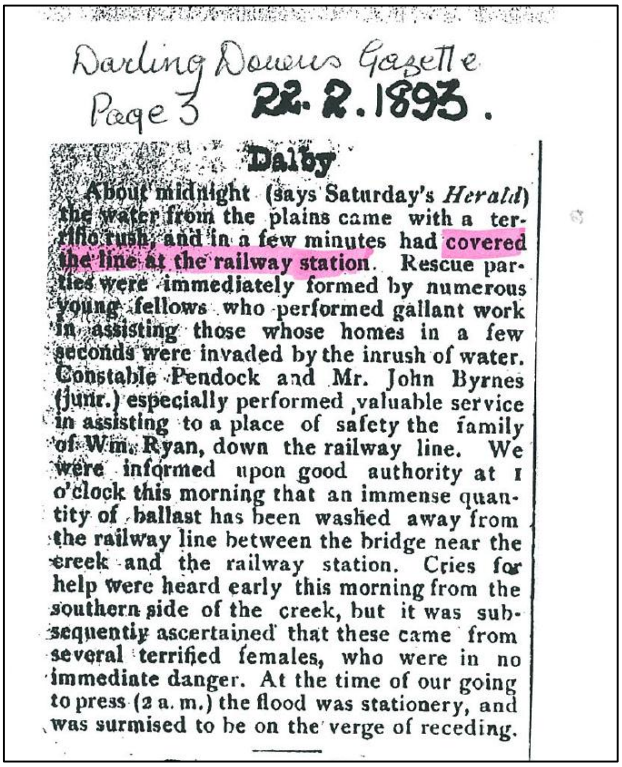
Dalby, Feb. 18, 12 noon.

The heaviest flood ever known is now being experienced here. The water is 3ft. deep in the Queen's Hotel, 4ft. in the Convent, and 2ft. over the platform of the railway station. The town is one vast sea of water.

National Library of Australia

Figure H.18 Newspaper article from Warwick Argus from 1893

The following newspaper article came from the Darling Downs Gazette ion 22 Feb 1893.



Darling Downs Gazette
Page 3 22. 2. 1893.

Dalby

About midnight (says Saturday's *Herald*) the water from the plains came with a terrific rush, and in a few minutes had covered the line at the railway station. Rescue parties were immediately formed by numerous young fellows who performed gallant work in assisting those whose homes in a few seconds were invaded by the inrush of water. Constable Pendock and Mr. John Byrnes (junr.) especially performed valuable service in assisting to a place of safety the family of Wm. Ryan, down the railway line. We were informed upon good authority at 1 o'clock this morning that an immense quantity of ballast has been washed away from the railway line between the bridge near the creek and the railway station. Cries for help were heard early this morning from the southern side of the creek, but it was subsequently ascertained that these came from several terrified females, who were in no immediate danger. At the time of our going to press (2 a. m.) the flood was stationery, and was surmised to be on the verge of receding.

Figure H.19 Article from Darling Downs Gazette 1893

These observations indicate that the 1893 flood was greater than the 1,100 m^3/s in 1908 and likely to be larger than the 1,430 m^3/s in 1981. This estimate is based on the interpretation of the article presented in Figure 5 that that 1908 only entered the Queens Hotel at floor level whereas the article presented in Figure 6 indicates that the flooding in 1893 in the Queens Hotel was approximately 3ft deep.

H.13 Dalby development change

Note that adjustments to the hydraulic model were made to represent differing historic floodplain configurations, based chiefly on available historic aerial photography. It is worth noting that with development progress in the town of Dalby (corresponding to gradually increasing overall "roughness" of floodplain) the discharge in 1893 would have to be greater than that of 1981 to attain the same flood level (due to the considerably different amounts of development).

H.14 Conclusion

The available data indicates that the 1893 flood had a higher discharge than the 1981 flood.

It is possible that the 1893 flood was substantially larger; however there is considerable uncertainty regarding how much larger and to date it has not been possible to reduce this uncertainty.

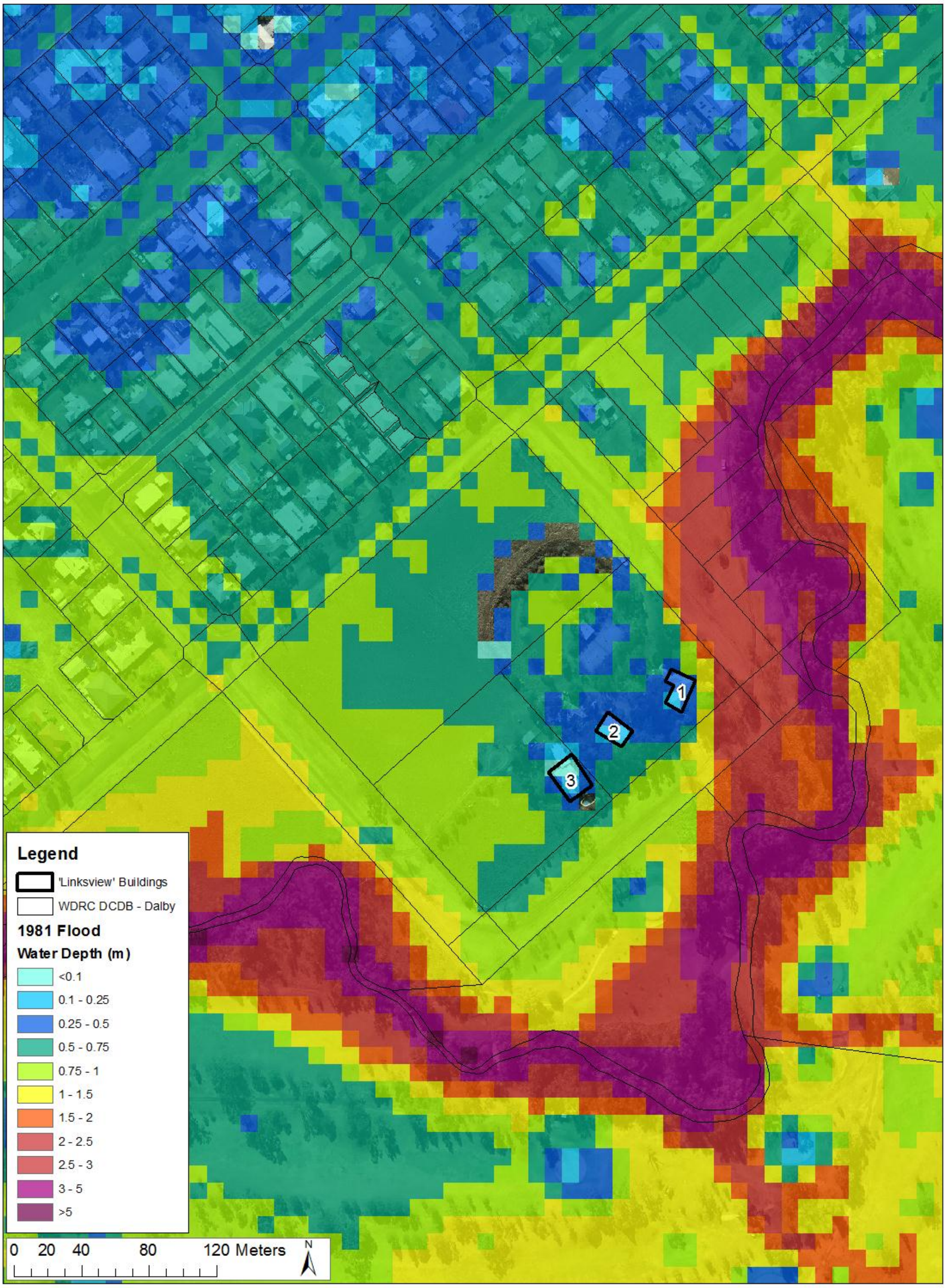


Figure H.20 1981 Modelled Flood Depth – 'Linksview'

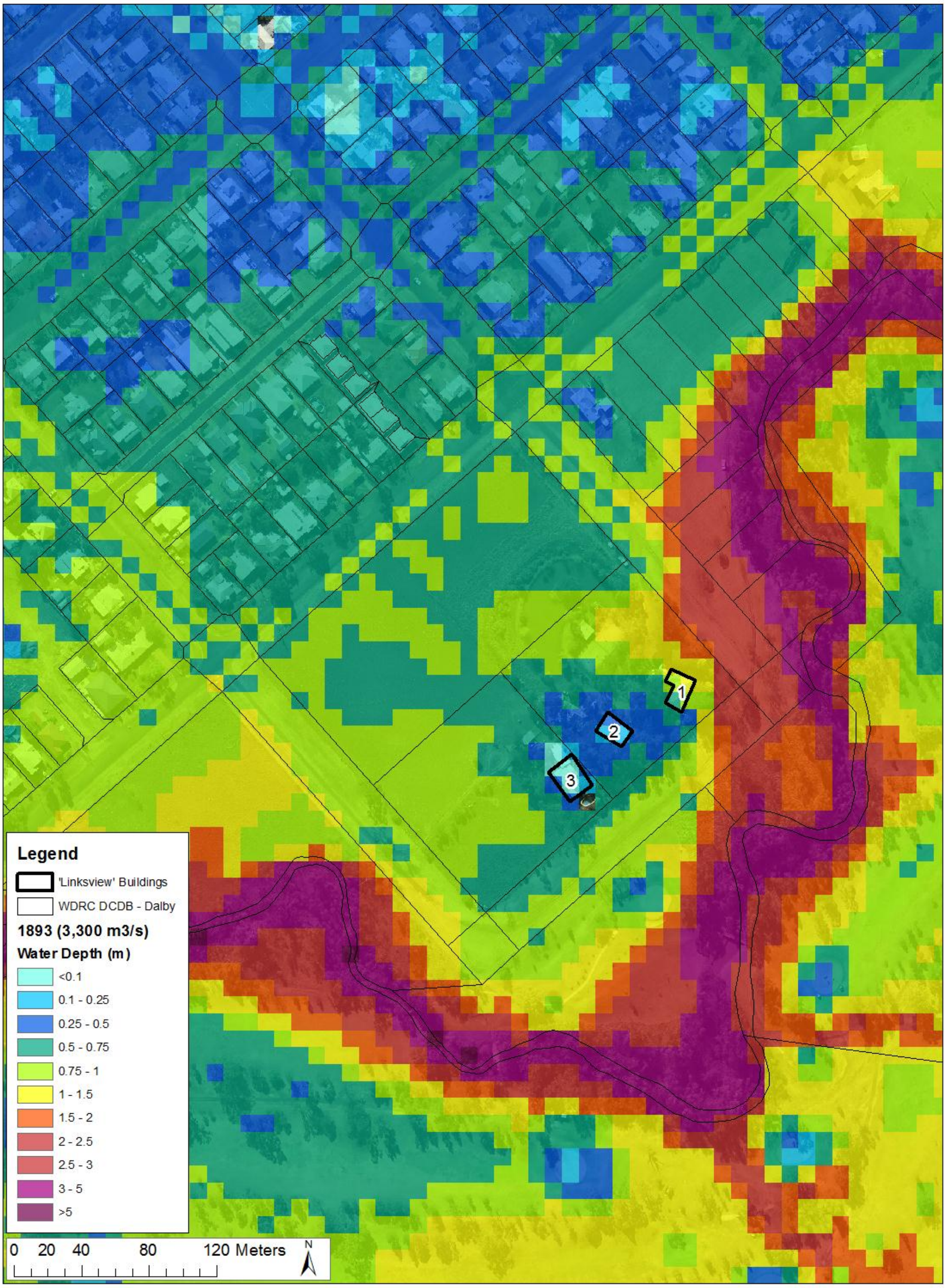


Figure H.21 1893 (3,300 m^3/s) Modelled Flood Depth – 'Linksview'

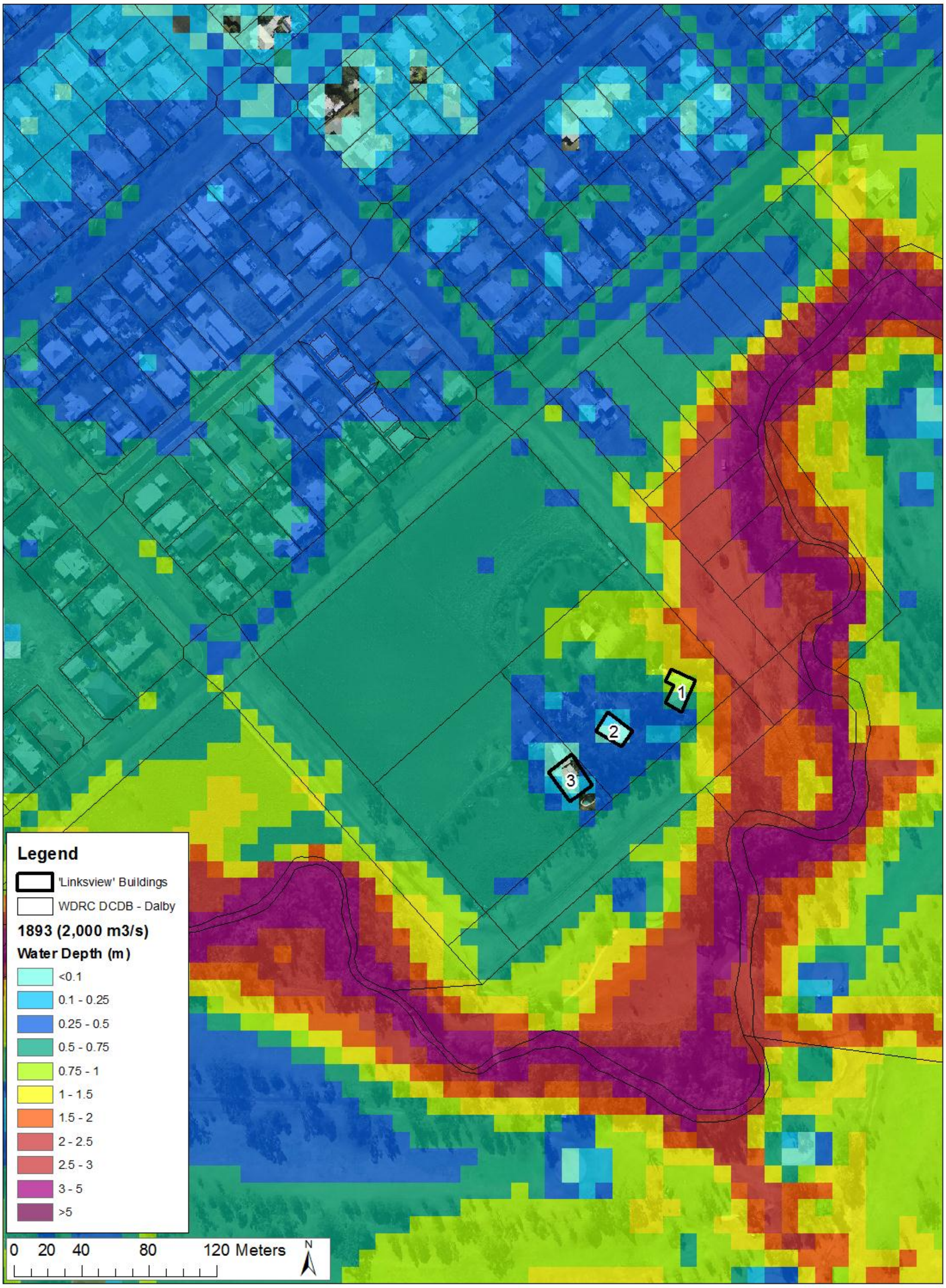


Figure H.22 **1893 (2,000 m^3/s) Modelled Flood Depth – 'Linksview'**

APPENDIX I MOCATTA'S CORNER FLOW MODELLING RESULTS

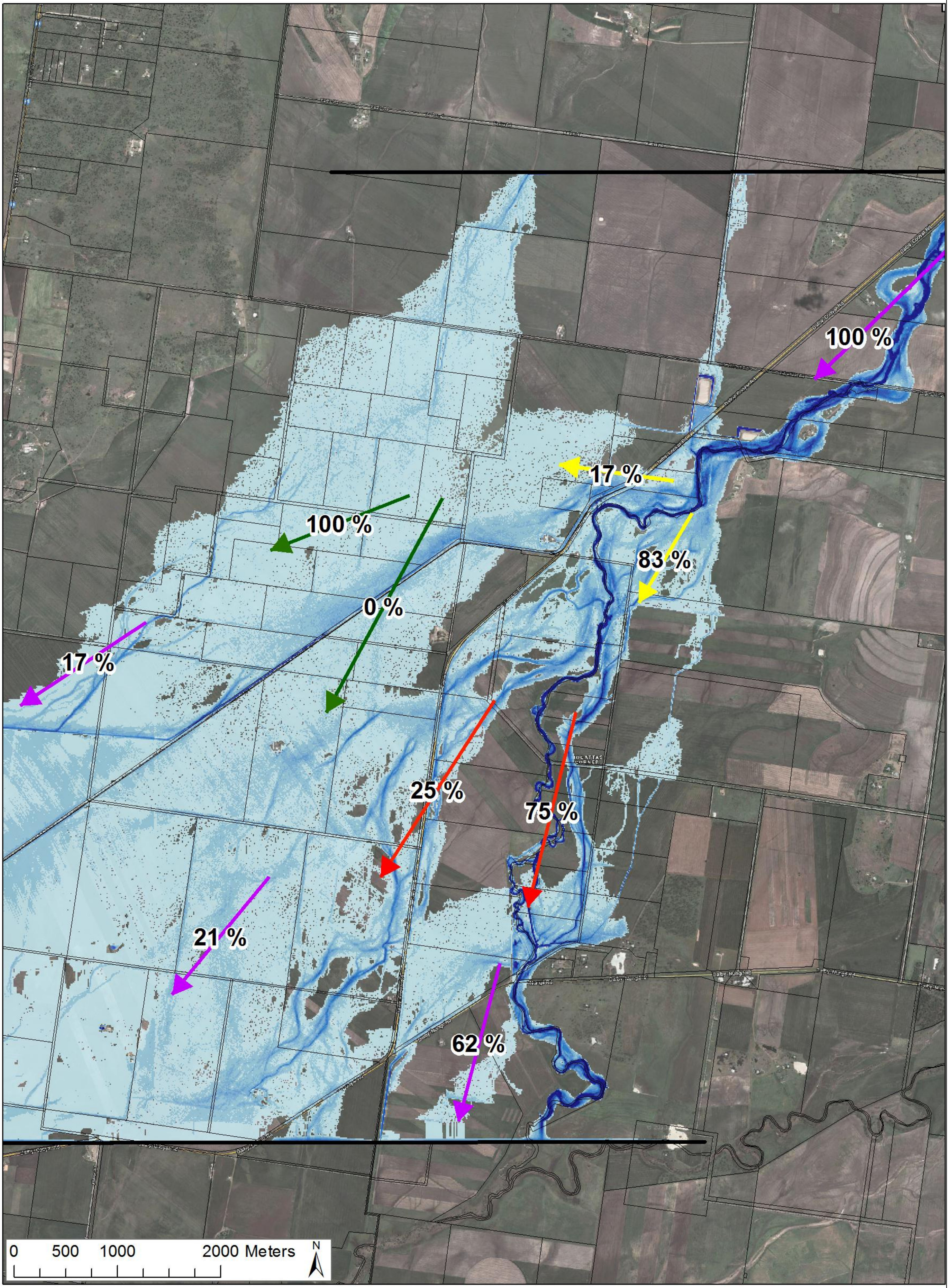


Figure I.1 Dalby 1 in 10 AEP – Mocatta's Corner Flow Splits

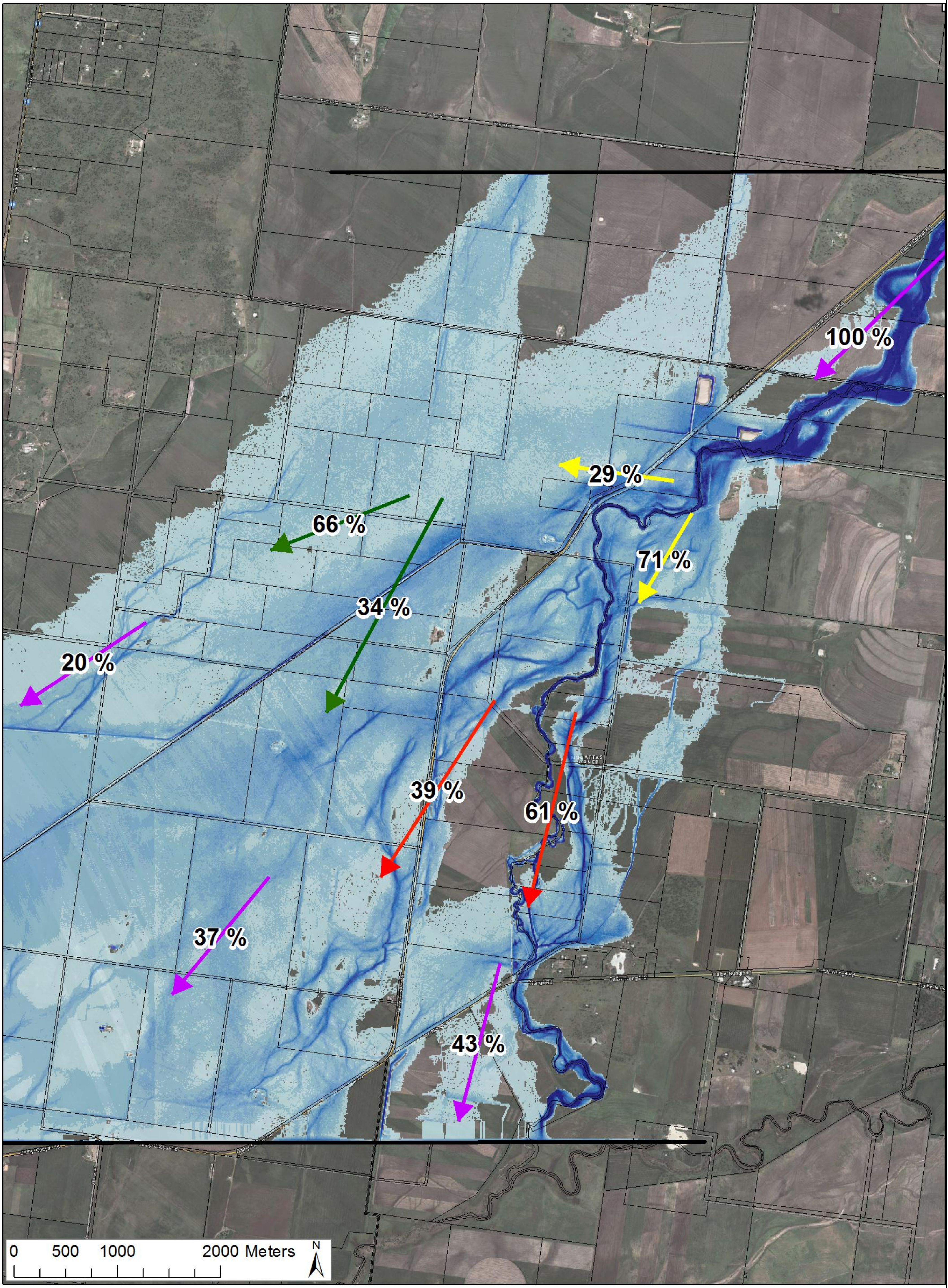


Figure I.2 Dalby 1 in 20 AEP – Mocatta's Corner Flow Splits

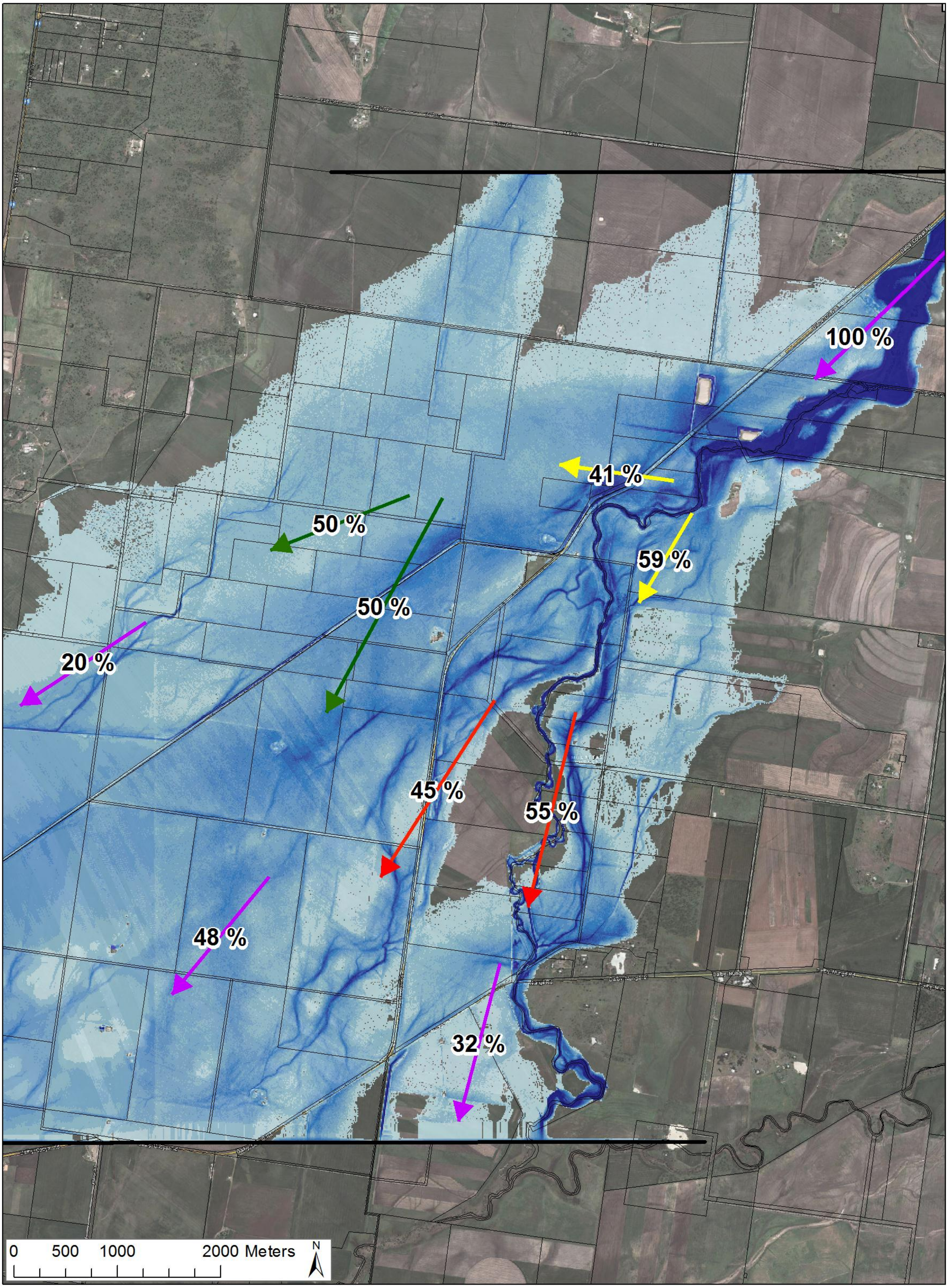


Figure I.3 Dalby 1 in 50 AEP – Mocatta's Corner Flow Splits

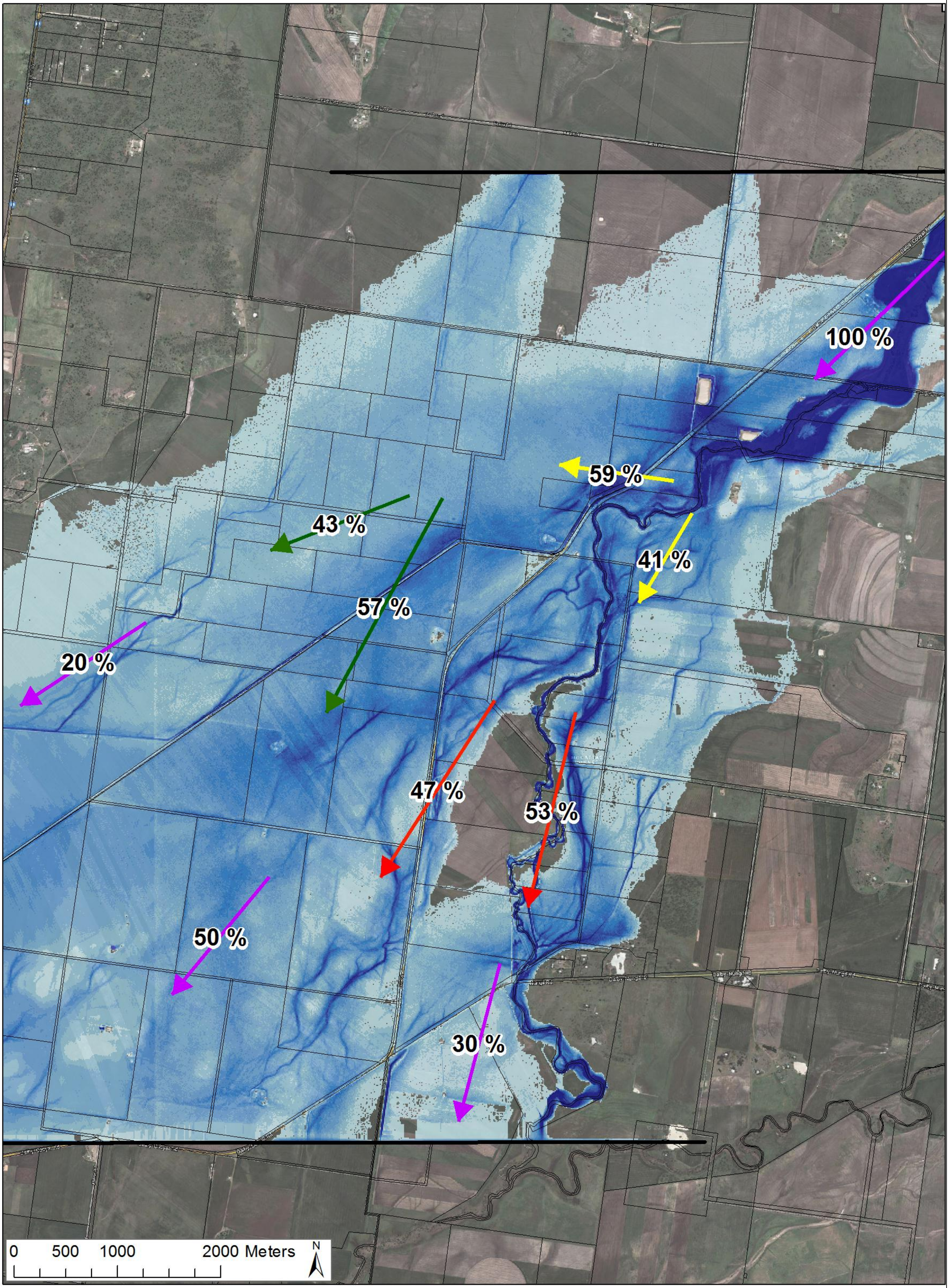


Figure I.4 Dalby 1 in 100 AEP – Mocatta's Corner Flow Splits

APPENDIX J STORMWATER MODELLING – DALBY

J.1 Overview

The aim of this component of the study was to define stormwater flowpaths through Dalby. For clarity, in this report, for the purpose of stormwater management, the term “stormwater flowpath” is adopted to cover both overland and stormwater flowpaths. Management of stormwater flowpaths in Dalby has historically been very difficult primarily because Dalby has very flat topography with many stormwater flowpaths difficult to identify (from maps and/or site inspection) due to their broad, shallow cross sections. Further, a number of large flowpaths run through Dalby that are both stormwater flowpaths and Myall Creek anabranches. As such, traditional stormwater management techniques are difficult to apply in Dalby. The aim of this current study was to provide a map of Dalby stormwater flowpaths and a simple and consistent methodology to estimate stormwater catchment areas and discharges.

The following methodology was adopted:

- Streamlines and catchment areas were defined using CatchmentSIM software (CSS, v2.5).
- A Flow Width vs Discharge Relationship was defined:
- A number of stormwater flowpath cross sections were selected within the Dalby area which were considered to represent flowpath locations draining a range of different catchment areas.
- The 1 in 100 AEP peak discharge and flow width at each cross section was determined using the Rational Method and Manning’s Equation, respectively.
- A regression equation was fitted to the flow width vs catchment area data (the flow width regression model).
- The flow width regression model was applied to all streamlines in Dalby.
- The model results were checked in selected locations against site specific flow width calculations.

It was found that there was considerable variation in the accuracy of the regression equation (with the equation both under and over predicting flow widths. However, a sensitivity analysis of different regression equations failed to provide a better solution, due to the inherent flowpath variability in Dalby. The adopted stormwater flowpath model was selected in consultation with WDRC. The chosen solution was to:

- Adopt the regression model, as it provided a clear and accurate representation of stormwater flowpaths.
- Use the WDRC Planning Scheme to overcome the inherent inaccuracy of the flowpath mapping by defining performance criteria and acceptable solutions so that development areas adjacent to the flowpaths (but not necessarily overlain by them) would be identified as sites that may be impacted by a stormwater flowpath.

J.2 Stormwater and Overland Flowpath Definition

The aim of this component of the study was to define stormwater flowpaths through Dalby. For the purpose of this report, these are defined as follows:

- Stormwater is local runoff that is (generally) a result of a short duration rainfall (e.g. a summer thunderstorm) over a limited area (e.g. the area of Dalby Township or less).
- Stormwater flooding is differentiated from riverine flooding as the latter is (generally) a result of long duration rainfall (e.g. 12 hrs or greater) over a wide area (e.g. all or a large portion of the Myall Creek catchment).
- In Dalby, Riverine flooding occurs in the main branch of Myall Creek and a number of anabranches.

- Stormwater flowpaths are the routes taken by stormwater as it concentrates and flows towards a creek. In Dalby, stormwater (generally) flows towards Myall Creek or one of its anabranches:
- This report does not consider the impact of ponded stormwater on Dalby (or the impact of development on ponded stormwater). This report only considers the stormwater once it has concentrated in an overland flowpath.
- The terms overland flowpath and stormwater flowpath relate to flowpaths in undeveloped (e.g. natural, rural) and developed (i.e. a built environment), respectively. The two definitions can generally be considered as terms of convenience and can generally be used interchangeably.

For clarity, in this report, for the purpose of stormwater management:

- The term “stormwater flowpath” is adopted to cover both overland and stormwater flowpaths.
- The terms stormwater and stormwater flowpath are used interchangeably.

J.3 Background

Management of stormwater flowpaths in Dalby has historically been very difficult for the following reasons:

- Dalby has very flat topography and many stormwater flowpaths are difficult to identify from maps or a site inspection; due to their broad, shallow cross sections.
- Once flow paths are identified, it is difficult to accurately define the catchment draining to the flowpath; once again due to the flat topography.
- The flat topography means that there is considerable catchment storage during storms. That is, over much of Dalby, stormwater does not flow monotonically from smaller to larger flow paths (in a textbook manner); extensive stormwater ponding occurs. Further, once again due to the flat topography, minor flow barriers (e.g. roads, footpaths, garden beds) will tend to inhibit the longitudinal connectivity of the stormwater flow and increase ponding.
- This stormwater behaviour is confirmed by visual observation by WDRC officers.
- Given the catchment storage of stormwater, the use of the Rational Method to estimate stormwater discharge will most probably result in an overestimate of discharge. This is because the Rational Method does not take into account the flow attenuation of catchment storage.
- A number of large flowpaths run through Dalby that are both stormwater flowpaths and Myall Creek anabranches. These flowpaths and flooding from these flowpaths have the following characteristics:
- The catchments are very large, with areas considerably larger than the area of Dalby Township.
- Low intensity, long duration regional rainfall (of a sufficient intensity and duration) over the majority of the catchments will produce riverine flooding of Dalby (as defined in Section J.2).
- High intensity, short duration local rainfall (of a sufficient intensity and duration) over the lower section of the catchment (i.e. near Dalby) will produce “stormwater” flooding in Dalby.
- On a local level (i.e. sub-areas within Dalby Township) stormwater flooding from these large flowpaths has very similar characteristics to those of riverine flooding in the same flowpaths (e.g. generally low velocities, flood extents well beyond the top-of-bank of the flowpaths). The main difference between the two types of flooding is the flood extent; a riverine flood affects all of Dalby.
- The reason for the unusual catchment behaviour (where the flowpaths convey both local and regional floods) is that the flowpaths have limited channel capacity which is not correlated

with catchment area. That is, in steeper landscapes (i.e. not floodplains), the channel capacity increases with catchment area so that (generally speaking) the increasing discharge (with area) is accommodated in a larger channel. The floodplain geomorphology around Dalby is such that the channels have (more or less) an upper capacity (independent of catchment area) and discharge in excess of channel capacity simply flows laterally to an adjacent channel (i.e. it is a braided system).

- Therefore, the traditional method of using catchment area as a parameter to estimate discharge does not work as (once the catchment gets large) the entire catchment does not contribute to flow in a channel.
- This also explains why these large anabranches convey “stormwater” floods; because a local storm over a small (lower) portion of the total catchment produces considerably more runoff than can be contained within the channel.

This difficulty in identifying stormwater flowpaths and estimating discharges has resulted in the following problems for stormwater management in Dalby:

- It has been difficult to estimate stormwater flowpaths (to ensure they are not blocked by development).
- Once/if flowpaths are identified it has been difficult to determine the peak design discharge for the flowpath.
- There was considerable inconsistency and variation in catchment delineation and discharge estimation between different developments/studies.

J.3.1 Aim

The aim of this current study is to provide the following:

- A map of Dalby stormwater flowpaths to be used:
- In conjunction with the WDRC Planning Scheme as a trigger for stormwater assessment of developments.
- By WDRC for stormwater infrastructure planning.
- A simple and consistent methodology to estimate stormwater catchment areas and discharges.

J.4 Methodology

J.4.1 Streamline Definition

The CatchmentSIM software (CSS, v2.5) was used to identify stormwater flowpaths, stream lengths and catchment areas. The key aspects of the flowpath delineation were:

- The LIDAR and aerial photography used for the riverine floods study was adopted.
- A 3m digital terrain model (DTM) grid size was used.
- The minimum catchment area was 2ha. That is, the upstream end of each flowpath drained a catchment of 2ha.
- This minimum area was adopted in consultation with WDRC after assessment of flowpaths derived from a range of different minimum catchment areas. That is, a smaller minimum area (say 1ha) produces many more small flowpaths whereas a larger minimum area (say 5ha) produces fewer flowpaths.
- This represented the start of mapping.

J.4.2 Global Flow Width vs Discharge Relationship Definition

A number of stormwater flowpath cross sections were selected within the Dalby area which were considered to represent flowpath locations draining a range of different catchment areas. The following is of note:

- Most of the flowpaths tended to be in or near rural areas as most of the flowpaths within the developed areas were either constructed channels or streets.
- It was difficult to identify flowpaths with defined cross-sections due to the flat topography of Dalby. That is, many of the flowpaths were broad and wide with vague channel features such as top of bank.

Figure J.1 shows the location of the cross sections used to develop the global flow width vs discharge relationship.

The 1 in 100 AEP peak discharge and flow width at each cross section was determined using the Rational Method and Manning's Equation, respectively. Table J.1 shows the adopted Rational Method and Manning's Equation parameters. Note that, for simplicity, all parameters (except stream length and catchment area) were assumed to be constant for all cross sections.

Figure J.2 shows the relationship between flow width and catchment area for the selected cross sections. Figure J.2 also shows the regression relationship adopted for all Dalby stormwater flowpaths. The following is of note:

- A number of different relationships were tested. The relationship shown is that which provided results that WDRC considered most appropriate for the purpose of this study.
- Cross Sections 7 and 12 were not included in the regression as they were large and did not follow the general trend of the other cross sections.
- Cross Section 3 was omitted because the flow was out of bank therefore the calculated flow width was incorrect.

Table J.1 Adopted Rational Method and Manning's Equation Parameters for the Derivation of the Stormwater Flow Width vs Catchment Area Relationship

Parmeter	Value	Comments
Standard Inlet Time	15 mins	From QUDM (NRW, 2007) for a catchment with slope up to 3%
Runoff Coefficient (C_{10})	0.7	adopting a uniform catchment land use of township zone
Stream Velocity	0.6 m/s	• Estimated from riverine flooding hydraulic modelling results. • Used to estimate travel time.
Catchment area	Varied	From the CatchmentSIM flowpath delineation
Stream Length	varied	From the CatchmentSIM flowpath delineation
Manning's n	0.05	Considered a suitable value to represent the range of overall flow path roughness (e.g. from natural to constructed channels)
Slope	0.01 m/m	Estimated from the Dalby LIDAR

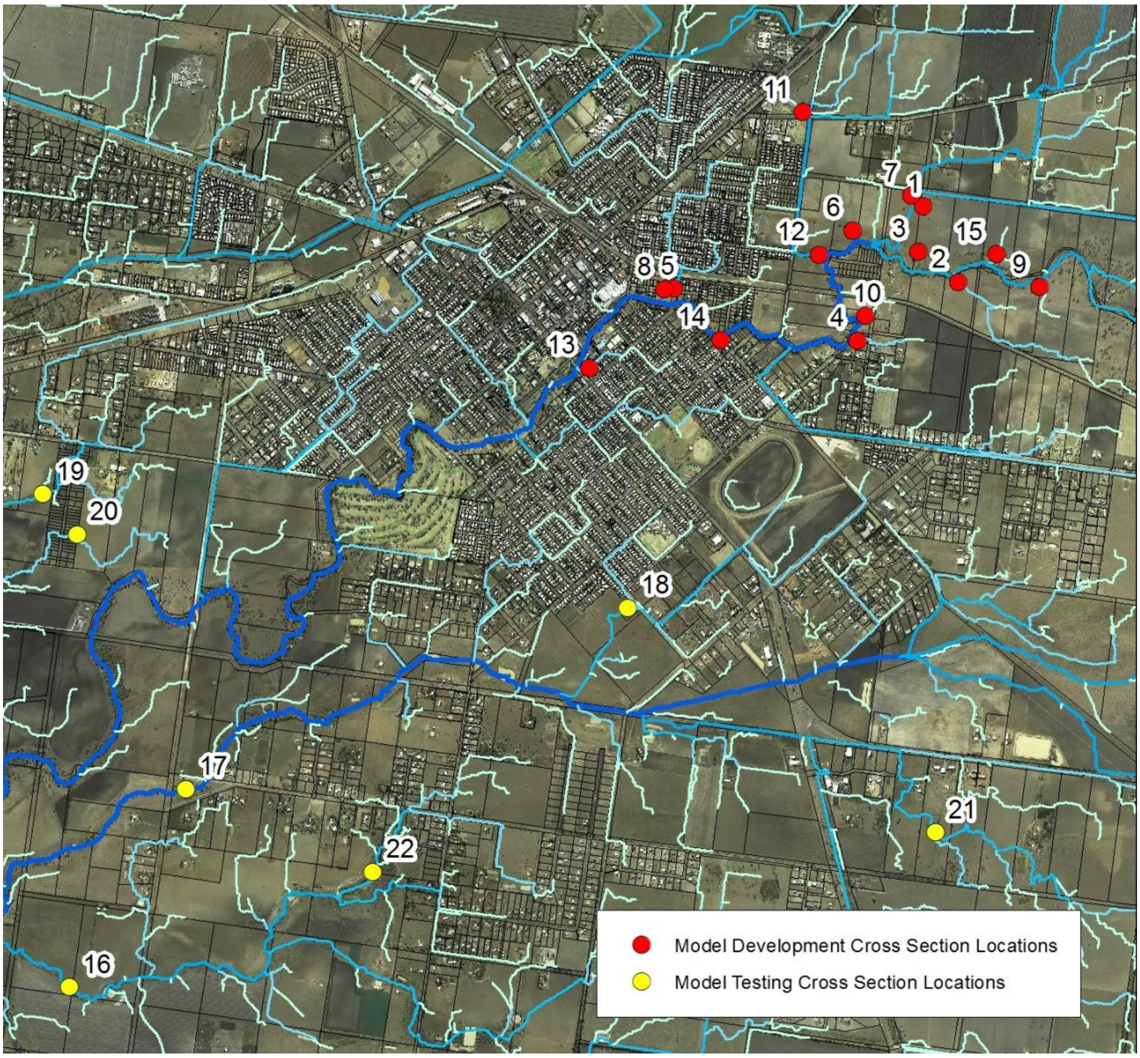


Figure J.1 Location of Channel Cross-Sections used to develop the Flow Width Regression Model

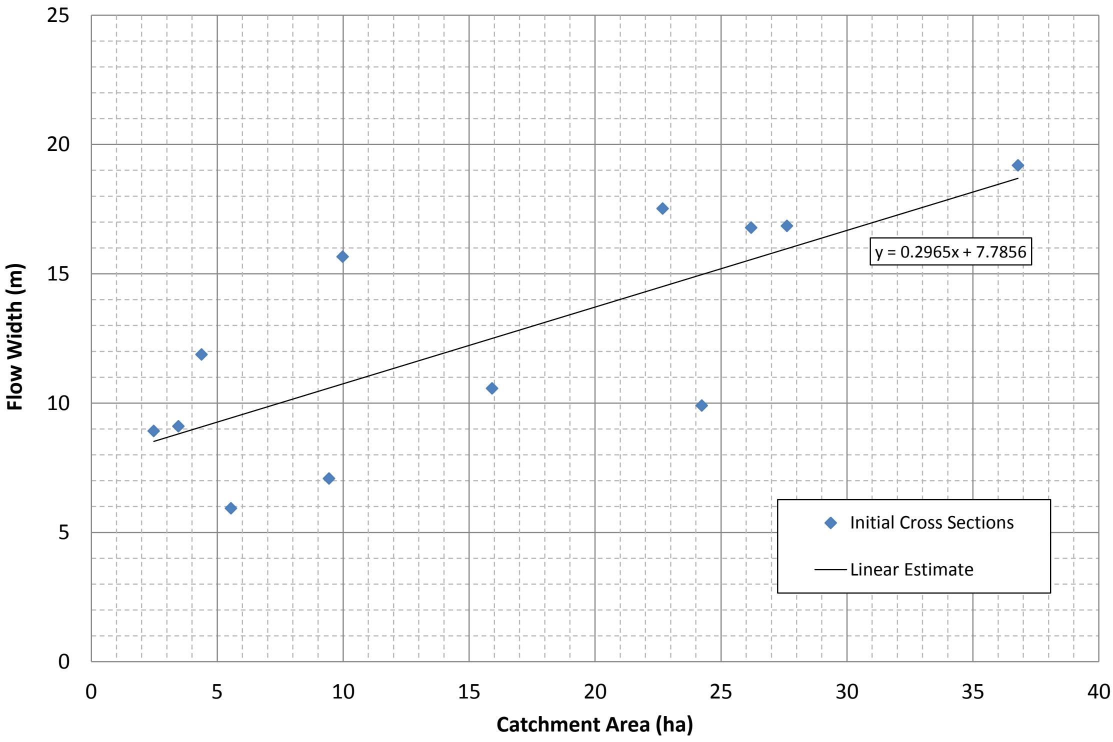


Figure J.2 Adopted Flow Width vs Discharge Relationship

J.4.3 Model Result Checks

The adopted flow width regression model was applied to all stormwater flowpaths in Dalby to create a map of stormwater flow widths. Figure J.3 shows the resultant stormwater flow widths. The results were checked by comparing the regression model flow width with the site specific flow width at a number of locations. The site specific flow width was estimated using the same Rational Method and Manning's Equation methodology described in Section (J.4.2). Figure J.1 shows the location of the cross sections used for the model check. Table J.2 shows the comparison between the flow width estimates using the regression equation and the site specific calculations. The following is of note:

- Table J.3 shows that Dalby flowpaths are characterised by the following:
- The majority of the flow paths are narrow with small catchment areas; the flowpaths drain to Myall Creek and its large anabranches.
- There are a small number of very wide flowpaths; which are also Myall Creek anabranches.
- There is a non-uniform flowpath size distribution with very few flowpaths in-between the small and large sizes.
- Table J.2 shows that there is considerable variation in the accuracy of the flow width regression model estimates.

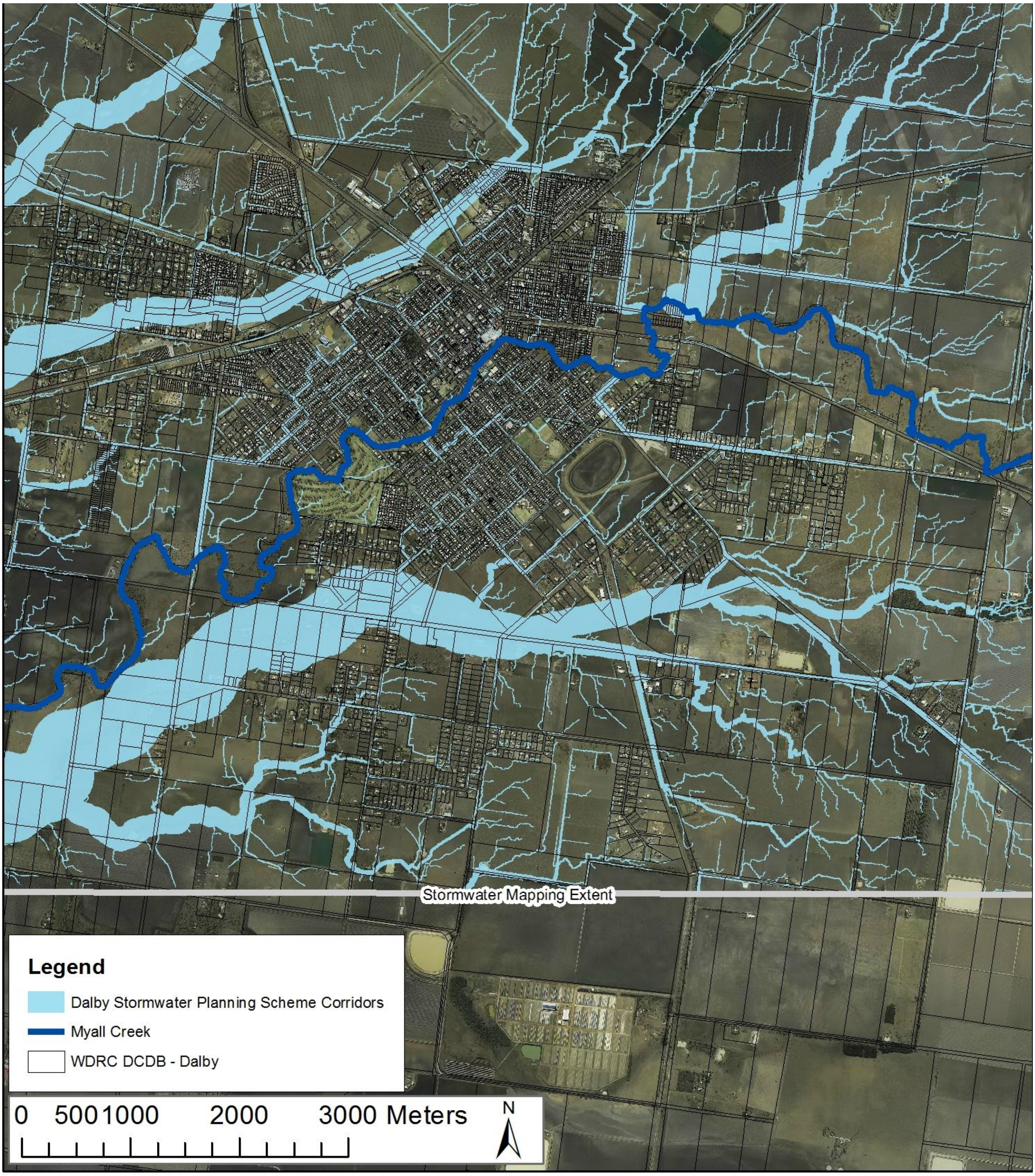


Figure J.3 Modelled Stormwater Flow Widths using the Adopted Flow Width Regression Relationship

Table J.2 Comparison of Flow Width Regression Model and Site Specific Flow Width Estimates

Cross Section	Flow Width (m)		Difference [1]	
	Flow Width Regression Model	Site Specific Calculation	(m)	(%)
16	216	106	-110	-103
17	586	171	-415	-242
18	49	358	309	86
19	57	140	83	59
20	17	180	163	91
21	51	345	294	85
22	48	186	138	74

1) Difference = site specific estimate - global estimate

Following the initial model checking (and the results shown in Table J.2 in particular) the flow width regression model was reviewed to determine if a more representative regression estimate was possible through the inclusion of the additional cross sections (i.e. those used for model checking) in the regression equation. Figure J.4 and Figure J.5 show the flow width vs catchment area relationships for the cross sections used in both model development and checking; the estimates for the largest catchments are omitted from Figure J.5. The following is of note:

- The figures show considerable scatter about the regression lines.
- It is considered that the estimates for the large stormwater catchments are incorrect because they assume that runoff from the entire catchment will remain within channel. As discussed in Section J.3 this is not the case; with channels having a limited capacity with excess water flowing laterally to adjacent channels. These data points for the largest catchments in Figure J.4 will have an undue and unrepresentative influence on the regression equation.
- Figure J.5 (with the estimates for the largest catchments omitted) shows reduced, but still considerable, scatter.

As an example of the variation between the regression model and site-specific estimates, Figure J.6 shows an enlarged view of the location of cross sections 19 and 20. The following is of note:

- For cross section 19, the regression model underestimates the site-specific flow width by some 83 m (Table J.2). The maximum depth of flow is approximately 0.20 m.
- For cross section 20, the regression model underestimates the site-specific flow width by some 163 m (Table J.2). The maximum depth of flow is approximately 0.17 m.

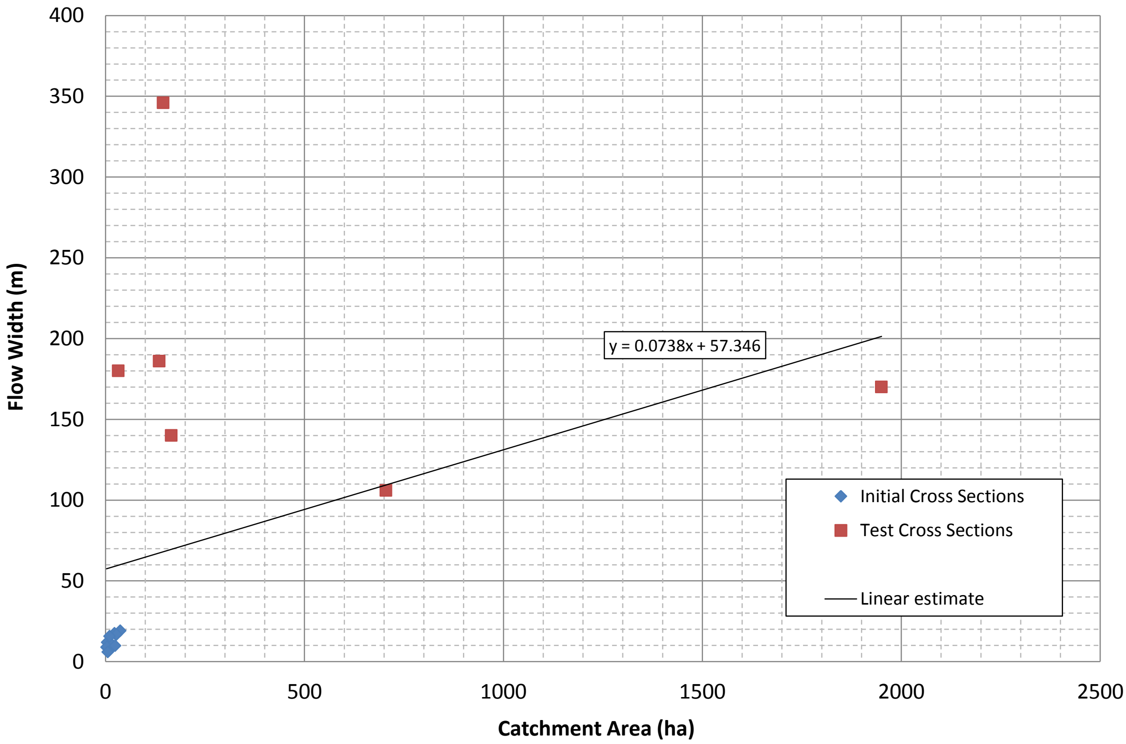


Figure J.4 Flow Width vs Discharge Relationship for All Cross Sections (Model Development and Checking)

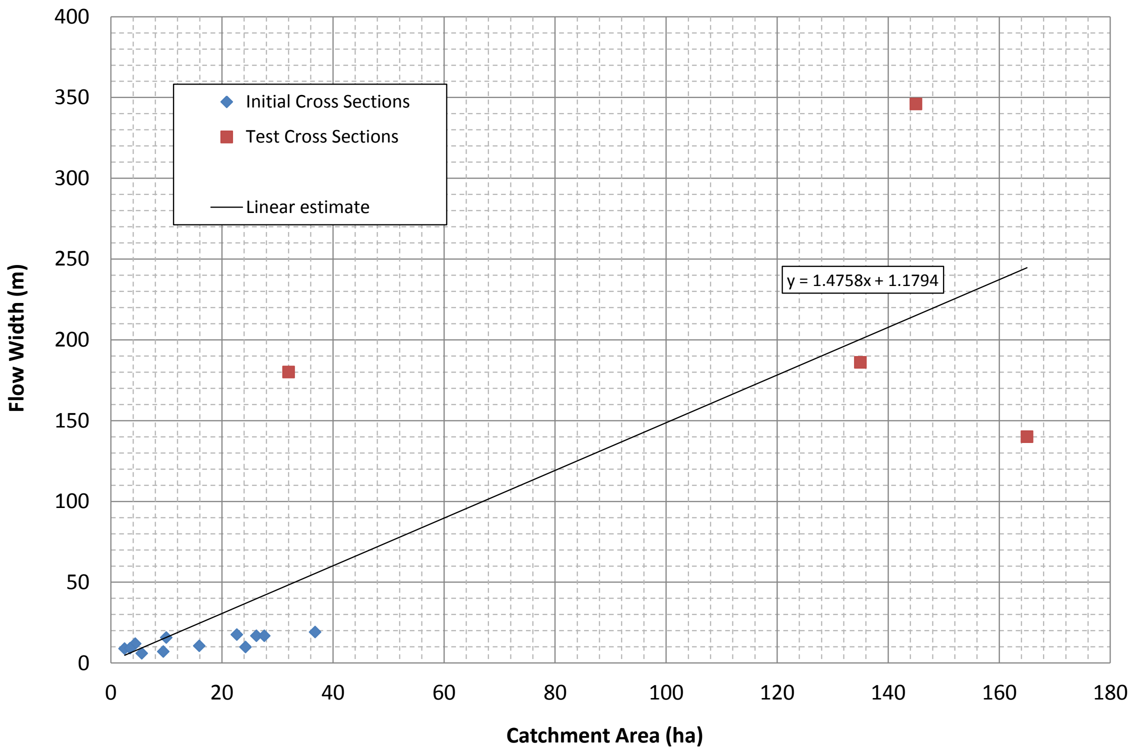


Figure J.5 Flow Width vs Discharge Relationship for Cross Sections (Model Development and Checking) – Excluding Largest Catchments

A number of different regression equations were tested, however, the results were all considered unsatisfactory due to the high scatter of the observed data about any chosen regression line. For example, considering Figure J.5, the regression line in the figure appears to provide a good fit to the data regression. However, consider point (32, 180) (cross section 20) the error in estimating the width of cross section is some 120 m; or 260% error. Therefore, the choice was between:

- The regression model underestimating the flow width in many locations (the initial model):
- The limitation of this option was that, when used as a stormwater overlay, there would be many sites with potential stormwater flowpath impacts that would not be identified.
- The regression model overestimating the flow width in many locations. The limitations with this option were:
- Testing showed that the flowpaths were so wide that they tended to merge into each other. The maps therefore lost the flowpath definition clarity.
- If used as an overlay, a very large percentage of Dalby would be falsely identified as being impacted by stormwater which would lead to many false triggers for proposed developments. This would place an unnecessary cost and time burden on both Council and the development proponent.

The original adopted stormwater flowpath model was selected in consultation with WDRC (Figure J.2). The chosen solution was to:

- Adopt the initial regression model, as it provided a clear and accurate representation of stormwater flowpaths.
- Use the WDRC Planning Scheme to define performance criteria and acceptable solutions so that development areas adjacent to the flowpaths (but not necessarily overlain by them) would be identified as sites that may be impacted by a stormwater flowpath.

The adopted model is described further in Section J.4.4.

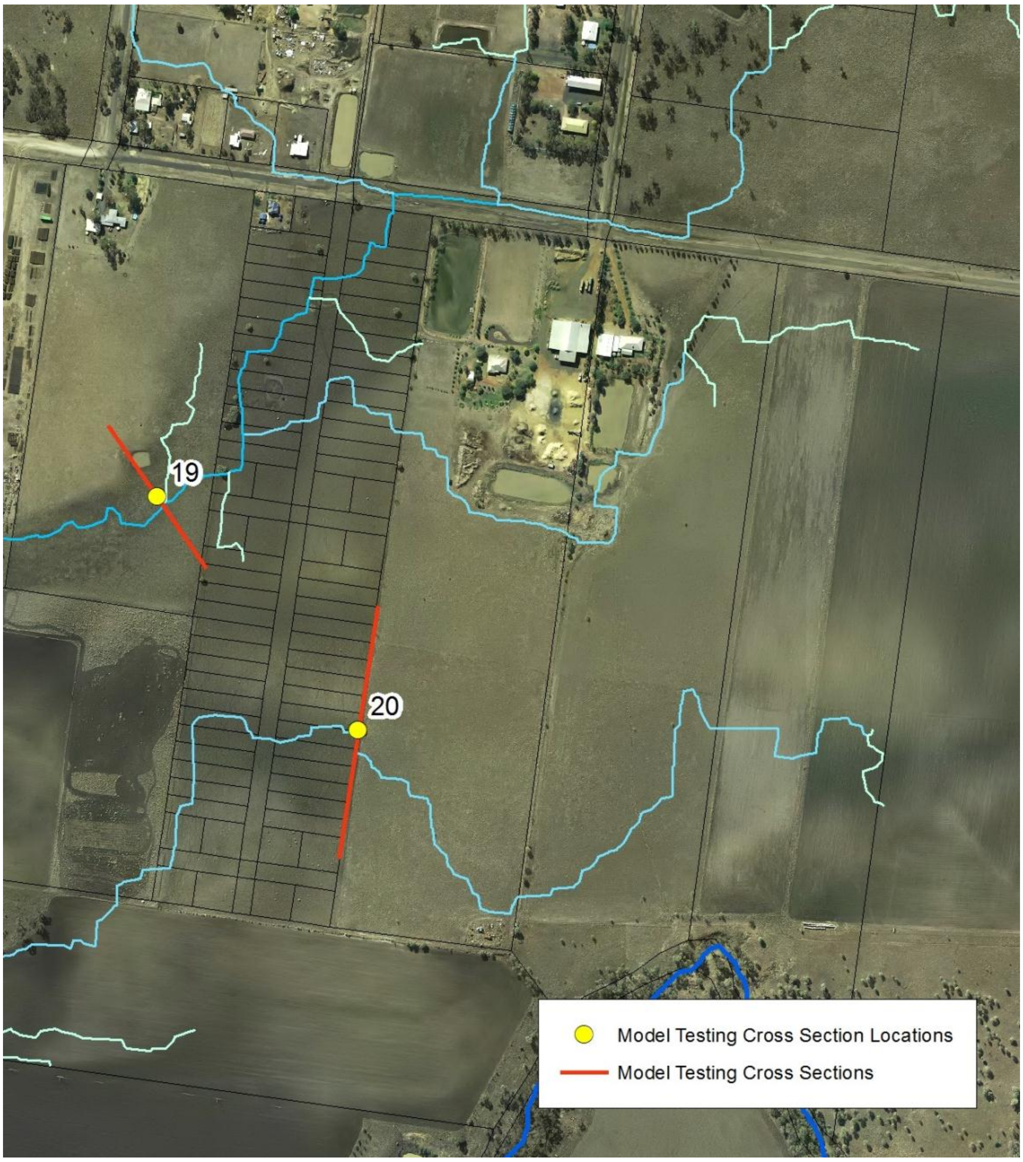


Figure J.6 Enlarged View of the Location of Cross Sections 19 and 20

J.4.4 Adopted Results

The adopted method of mapping for the Dalby stormwater flowpaths for use in the WDRC Planning Scheme was to:

- Adopt the initial flow width regression model, as it provided a clear and accurate representation of stormwater flowpaths.
- Use the WDRC Planning Scheme to define performance criteria and acceptable solutions so that development areas adjacent to the flowpaths (but not necessarily overlain by them) would be identified as sites that may be impacted by a stormwater flowpath.

The stormwater flowpaths were separated into minor and major categories:

- Minor flowpaths are those with modelled flow widths <= 50m. This equates to a catchment area <= 142 ha.
- Major flowpaths are those with modelled flow widths > 50m. This equates to a catchment area > 142 ha.

The two categories were requested by WDRC to enable different treatment within the WDRC planning scheme.

Appendix L shows the adopted stormwater overlay map with and without the riverine flood DFE hazard map as a background.

J.4.5 How Results will be implemented

This section describes how the stormwater flowpath overlay maps and other catchment parameters adopted by this study will be used for development assessment in Dalby. Note that the ultimate adoption and method of use of the maps and parameters will be dependent upon the following:

- Council's adopted planning scheme.
- Changes, from time to time, in the accepted best practice for calculating stormwater discharges [e.g. updates to QUDM (NRW, 2007)].

At the time of writing, it is considered that the Dalby stormwater modelling results will be used in the following manner:

- The planning scheme (or a document referenced by the planning scheme) will contain the stormwater flowpath overlay:
- The overlay will show the major and minor stormwater categories.
- The WDRC Planning Scheme will define performance criteria and acceptable solutions so that development areas adjacent to and/or intersected by the flowpaths will be identified as areas that may be impacted by a stormwater flowpath.
- If a proposed development triggers a stormwater flowpath assessment the proponent will have to undertake additional studies to better define the flow width of the identified flowpath(s) that the development may be impacting upon.
- Note that the stormwater flowpath overlay is only an approximate width for all streams with similar catchment area/stream length characteristics; not the exact flow width for that stream.
- The initial assessment is to be based upon the Rational Method and Manning's Equation:
- From the Council GIS, the proponent can obtain:
- Catchment area.
- Stream length.

- The impervious percentage and runoff coefficient defined in Section J.4.5.1 will be adopted.
- The proponent can apply the Rational Method with these values (with other data) to calculate the site specific discharge.
- The proponent can then use Manning's Equation to estimate the flow width.
- This will be a conservatively wide width (as the Rational Method does not account for catchment storage (see Section J.3).
- If Rational Method/Manning's Equation calculations show that the development does not impact upon the flowpath then no additional assessment is required.
- If the Rational Method/Manning's Equation calculations show that the proposed development impacts upon the flowpath then the proponent has the option of undertaking more detailed modelling to refine the flow width estimate.
- Additional modelling will need to include 2D unsteady state hydraulic modelling at an appropriate scale and resolution. It is considered this is the only appropriate method to properly assess the complex stormwater flowpath storage behaviour in Dalby.

Note that adoption of the catchment stream lengths and areas together with runoff coefficients defined for this report will ensure consistency and transparency in development and assessment.

J.4.5.1 Runoff Coefficients

An impervious percentage was assigned to each land use category in the revised planning scheme based upon recommendations in NRW (2007) and discussions with WDRC. Each impervious percentage was converted to a C10 runoff coefficient for use with the Rational Method. The same impervious percentage – land use category relationships were adopted for all towns within the WDRC area. Table J.3 shows the adopted impervious percentages and runoff coefficients for Dalby for each land use category.

J.5 Comment on Alternate Modelling Approaches

J.5.1 Rain-on-Grid

The use of the rain-on-grid approach for flood assessment is still under development as it is generally accepted that there is some doubt as to the accuracy of the model output. Notwithstanding this, Dalby was modelled using the rain-on-grid approach at the commencement of the study as part of the initial investigations into possible modelling techniques. It was found that the approach provided very poor streamline definition. That is, due to the flat topography, the water tended to pond across much of Dalby without concentrating into flowpaths.

After the initial assessment, the rain-on-grid approach was not used further in the study.

J.5.2 Detailed Unsteady State Modelling of All Flowpaths

It may appear that the adopted assessment approach combining the Rational Method/Manning's Equation (possibly) followed by detailed 2D unsteady state modelling is cumbersome and that it may have been better to undertake a 2D study of the entire stormwater network for inclusion in the planning scheme. Modelling all flowpaths with a 2D unsteady state model would be a formidable task (note that the rain-on-grid approach was shown to be inappropriate for Dalby). Further, detailed analysis is not required for all stormwater flowpaths, only those where development is proposed within the flowpath. Therefore, the adopted technique provides an accurate and very cost effective approach to stormwater management for Dalby.

Table J.3 Adopted Rational Method C10 Runoff Coefficients - Dalby

Land Use	Impervious Percentage (%)	C10	Comments
Rural Zone	0	0.39	Negligible impervious area
Township Zone	60	0.7	Residential – Lot size >750m2
Recreation Zone	0	0.39	Open Space (eg Parks)
Community Purpose Zone	Vary according to proposal	Mixed	Open Space/Township
Rural Residential Zone	15	0.47	Rural – 2-5 dwelling per ha
Residential Living Zone	60	0.7	Residential – Lot size >750m2
Local Centre Zone	90	0.85	Commercial or Industrial
Emerging Communities Zone	60	0.7	Residential – Lot size >750m2
Major Centre Zone	100	0.85	Commercial or Industrial
Residential Choice Zone	60	0.7	Residential – Lot size >750m2
Medium Impact Industry Zone	90	0.85	Commercial or Industrial
Low Impact Industry Zone	90	0.85	Commercial or Industrial
Specialist Centre Zone	90	0.85	Commercial or Industrial
District Centre Zone	100	0.9	Central Business

APPENDIX K DALBY STORMWATER FLOWPATH MAPS

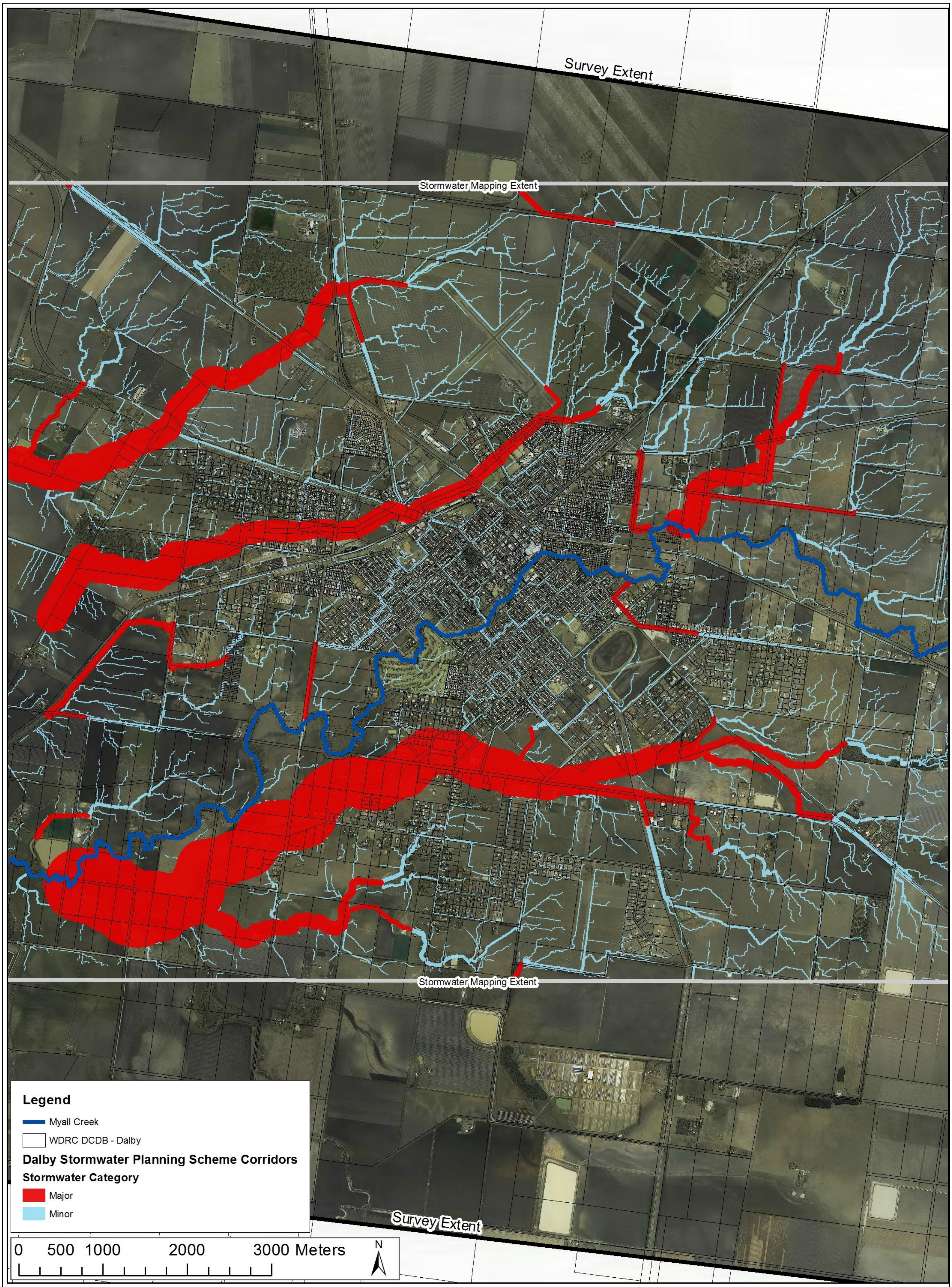


Figure K.1 **Dalby Stormwater Overlay**

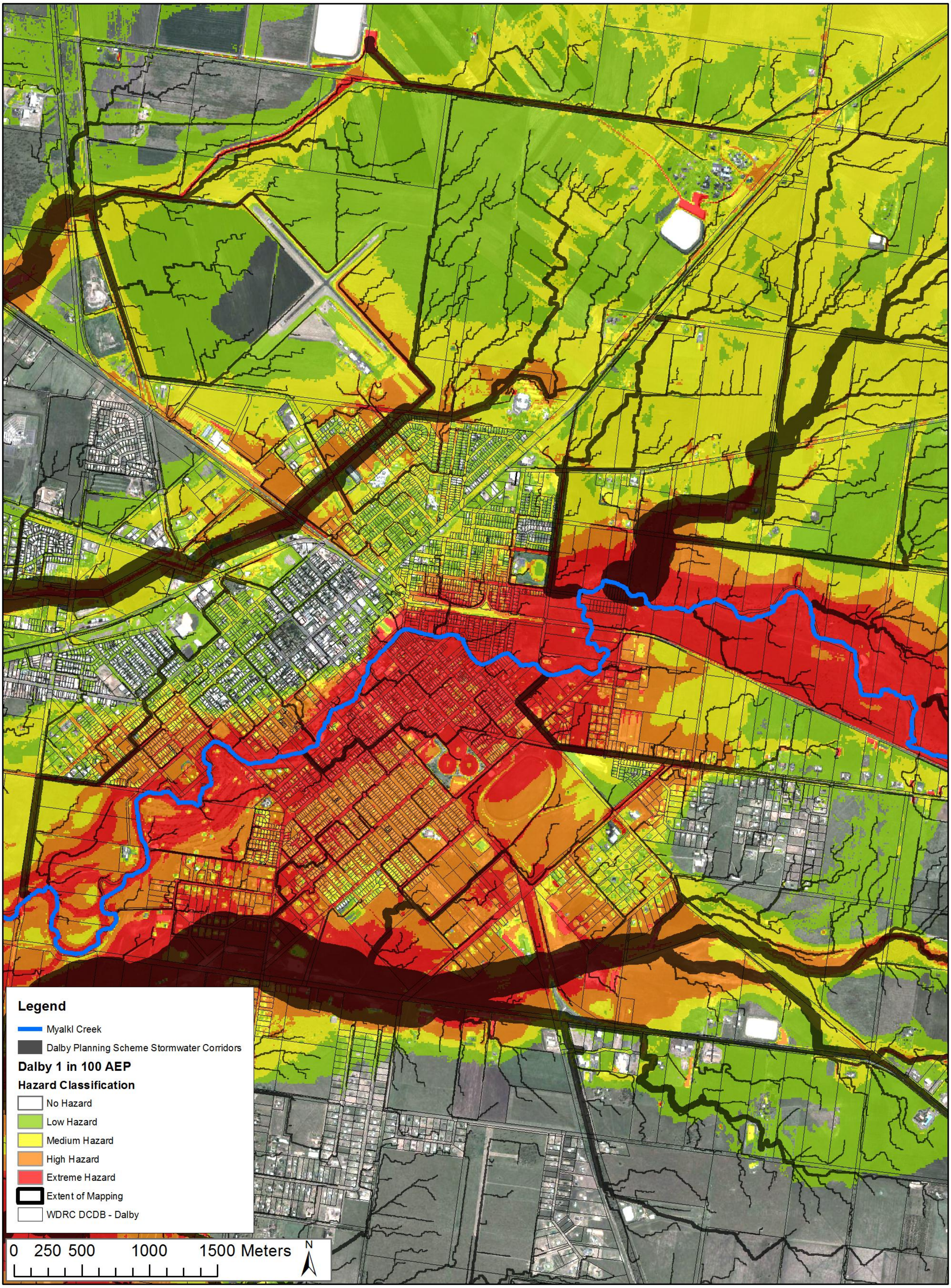


Figure K.2 Dalby Stormwater Flowpath Overlay and Riverine 1 in 100 AEP Flood Hazard