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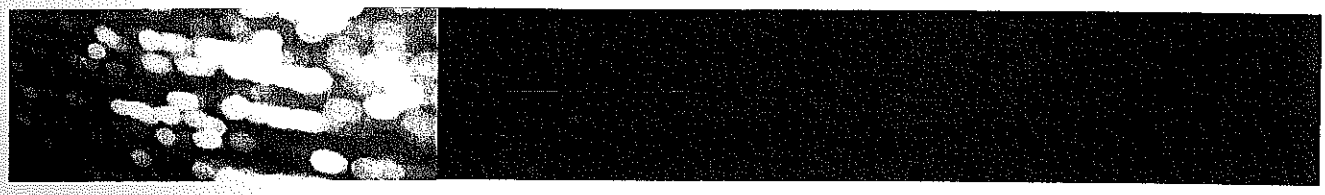
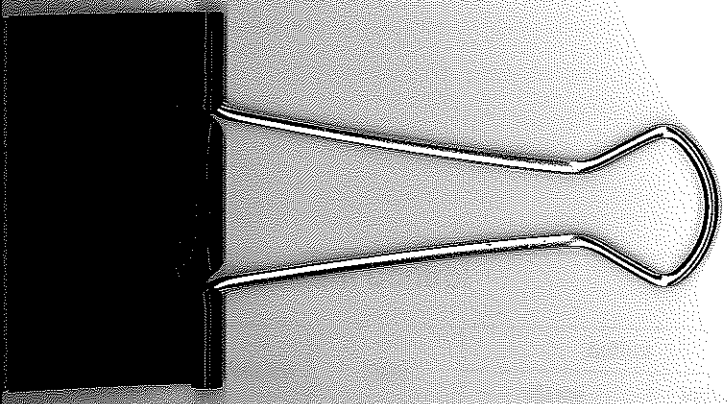


GOONDIWINDI ENVIRONS

FLOODING INVESTIGATION



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APPENDICES

1. INTRODUCTION

This study has been prepared for Waggamba Shire Council (WSC) by Cardno Lawson Treloar (CLT) to assess the extent of flooding in the Goondiwindi Environs and the associated levels of hazard resulting from flooding for existing and future residential development, and to assist in floodplain risk management planning for the future growth of the township of Goondiwindi.

The study forms part of a package of investigations being undertaken under the National Disaster Risk Management Studies Programme run by the Australian Government Department of Transport and Regional Services, with funding from the Australian and State Governments, and the local authorities of Waggamba Shire Council (WSC) and Goondiwindi Town Council.

The overall study comprises the undertaking of airborne laser survey, numerical flood modelling, flood mapping and flood mitigation assessment. The study area encompasses land within a 12 km radius of Goondiwindi, referred to as the Goondiwindi Environs.

The Airborne Laser Survey has been undertaken under a separate component of the study by AAM-Hatch, and the resultant survey has been a major input to this flood investigation study.

This flood report is one of the first steps in floodplain risk management planning and provides the necessary background information to identify the level of risk, possible mitigation options and possible evacuation routes. These outputs will help WSC to plan future development and form a basis for disaster and rescue plans for WSC, Goondiwindi Shire Council and the Department of Emergency Services.

2. EXISTING LEVEES AND FUTURE DEVELOPMENT

The Goondiwindi Environs cover the township of Goondiwindi and its near surroundings. It is situated in Queensland, adjacent to the New South Wales border, approximately 400 km south west of Brisbane. The Goondiwindi Environs is bounded by the Macintyre River to the south, Callandoon Creek to the west and Piggy Piggy Creek and the Weir River to the east and north.

The township is on the northern bank of the Macintyre River, which flows in a westerly direction past the township and drains a catchment of approximately 6,900 sq.km. The Macintyre River catchment is part of the "Border Rivers" drainage basin which also includes the Weir and the Dumaresq Rivers. This system eventually drains into the Barwon River before joining the Murray Darling System.

2.1 Levee System

The township has experienced flooding in the past, predominantly from the Macintyre River, and hence has had a levee protection system in place for some time. During the 1976 flood, the levee was overtopped by about 100mm at Kildonan Road and floodwaters were lapping the crest of the levee system at other localised sections. Subsequent to the 1976 flood the levee system was raised. Further levee raising and construction also occurred based on recommendations included in flooding investigations carried out by the Department of Local Government in 1985 and by Lawson and Treloar in 1998 and from information gathered following the 1996 flood.

Previous assessments have indicated that the township levee is currently at a sufficient height to exclude an AEP 1%, or 1 in 100 year flood (Lawson and Treloar, 1998). Levee banks have 500 mm freeboard to a 1976 size flood event, which is one of the largest floods on record at Goondiwindi.

2.2 Future Residential Development

There is currently considerable development pressure for urban land within the Goondiwindi Environs area. Waggamba Shire Council has provided a study area for possible future residential development, as shown on Figure 1.1. The study area comprises the direct northerly surroundings of the township of Goondiwindi. Some of these areas are outside the direct protection of the existing levee system or the natural banks. Hence, part of the study area could be potentially flood prone land.

3. PREVIOUS INVESTIGATIONS AND GUIDING PRINCIPLES

3.1 Previous Investigations

Waggamba Shire Council (WSC) has, for over 20 years, been actively involved in floodplain management in the Border Rivers, through powers vested under the Local Government Act. Council's aim has always been to support sustainable development in an equitable manner, without creating adverse impacts on other landholders and stakeholders in the floodplain, or on the environment.

WSC was the first local government authority in Queensland to initiate full floodplain management, which commenced in 1985 with identification of key floodways throughout the Shire using historical events and in particular, the 1984 floods. Sinclair Knight Merz, using broadbrush and qualitative techniques, undertook this analysis with the result contained in 'Border Rivers Flood Plain Management Study' (1987). The primary objective of this study was the determination of a set of development guidelines for the Border Rivers floodplain region contained within Waggamba Shire.

In early 1990 WSC took the initiative to apply one of the first fully scientifically based floodplain studies in Queensland. Connell Wagner was commissioned to carry out an Hydraulic Analysis of Proposed Levee Banks in the Callandoon Creek Area of the Border Rivers Floodplain. This study was conducted using state of the art RUBICON hydraulic modelling software.

The RUBICON model was used successfully for several years to manage floodplain development and to effectively preserve floodways, until in 1997, pressures for development beyond the Callandoon Creek area meant that the RUBICON model extent was insufficient and extension was required.

In 1997, WSC applied for and received funding under the National Land Care Program to extend the hydraulic model to cover the Border Rivers floodplain from upstream of Boggabilla to downstream of Mungindi. An extensive photogrammetric survey of the Borders Rivers floodplain was carried out over the hydraulic model extents.

This survey, along with supplementary main channel survey was used by Lawson and Treloar (L&T) to build a new, more detailed and more extensive flood model, based on the quasi two-dimensional MIKE 11 modelling system, from the Danish Hydraulic Institute (DHI). This hydraulic model, at the time, was at the leading edge of technology, in terms of size. The model was completed and adopted for development assessment in late 1998.

This model was also utilised to obtain floodplain flow distributions. However, with improvements in technology and because of the availability of a full floodplain terrain model (based on the photogrammetric survey) by early 1999 and property specific ground survey, all development application assessments were being carried out by Council using full two-dimensional local area models, as a sub-part of the full floodplain model. Flows for the local two dimensional sub-models were obtained from the full floodplain MIKE11 model (Danish Hydraulic Institute (DHI), 2001).

In addition the 1998 flood showed an unexpected high water level at the Goondiwindi Gauge. L&T was commissioned by WSC to investigate possible causes of the increased flood levels at the Goondiwindi Gauge as well as causes of erosion at the entrance of Callandoon Creek. For this investigation L&T build a full two dimensional MIKE 21 (Danish Hydraulic Institute (DHI), 2003) Macintyre River (Boggabilla to Dingo Creek) model.

The MIKE 21 model showed that the 1998 MIKE 11 model had over-estimated the amount of flow breaking out of the Macintyre River upstream of Goondiwindi and flowing north

around Goondiwindi. Subsequently, L&T updated the MIKE 11 model to make it more consistent with flows predicted by the more detailed MIKE 21 model investigation.

In 2002 a hydraulic impact assessment was undertaken by CLT on behalf of WSC and Goondiwindi Town Council for several town levee failure scenarios. The outcomes of this study were the basis for the Goondiwindi Township Disaster Risk Management report. This report considered the risk to the existing township and environs areas of a failure of the town levee bank system, but did not deal specifically with major river flooding constraints beyond the existing leveed portion of the town.

3.2 WSC Guidelines for Floodplain Management

Any new development or levee works needs to comply with Waggamba Shire council local law no. 26 (levee banks) 2002.

Performance Objectives described in the local law include:

P1 – Floodways possess adequate hydraulic capacity and continuity to enable the orderly passage of flood water through the floodplain.

P2 – Floodway systems conform as closely, as is reasonable, to the natural drainage pattern.

P3 – Flood peak levels and timing are not unduly affected by the proposal.

P4 – Velocities of flow will be minimised and will be of an order that will not cause erosion under various land uses including cultivation.

P5 – There will not be any detrimental impact on any individual landholder or community infrastructure as a result of the proposal.

P6 – The risk of a proposed Levee Bank failing and causing hazards to people or property must be acceptable to the community

Recommended Measures that are relevant for this study are as follows

M1 A continuous network of core floodways is to be retained, including all river, creek and waterway main channels.

M2.1 The exit of flood water from floodways should be at rates and depths similar to those which would have been experienced under natural conditions and should discharge as close as practicable to the location of natural floodways.

M3.1 Sufficient pondage will be retained on the floodplain so that the flood peak is not significantly accelerated (ie. no significant change in flow time from Boggabilla to Mungindi) to downstream areas or its height increased.

M4.1 Velocities of flood flow in floodways will not be greater than 1m/s within all land the subject of a Permit application.

M5.1 The increase in maximum peak water level measured at the property boundaries for the land the subject of a Permit application compared to existing and pre-floodplain development (no levees) peak water levels is to be an absolute maximum of 200mm under a range of floods.

3.3 Floodplain Risk Management Guiding Principles

In relation to risk management, urban communities in South East Queensland have specified a requirement for 100 year flood immunity and additional freeboard for habitable floor levels. This is also established by the Standing Committee in Agricultural and Resource Management Report No. 72, 2000, entitled 'Floodplain Management in Australia Best Practice Principles and Guidelines'. Risk management is also considered by Department of Emergency Services in their 'Disaster Risk Management' publication by Zamecka and Buchanan (1999). The New South Wales Government Floodplain Management Manual (2001) is also a useful reference, stating current best practice in relation to flood management.

In relation to emergency services, evacuation emergency planning under more severe events beyond the 100 year flood event needs to be considered. In New South Wales, it is a requirement that assessment be made of the 0.5% AEP flood event up to the probable maximum flood in this regard. Hence, a requirement of this study is to consider such severe and extreme events.

4. AIM OF THE STUDY

The primary study aim has been to prepare a detailed flood study, which in turns relies upon a detailed two-dimensional hydraulic model along the Macintyre River, encompassing the existing township and its protection levee system, and future potential growth areas within 12 kilometres of the town centre.

This model has been calibrated against historical flooding events of 1976 and 1996 and used to assess flood extents for a number of design events. The model results have been used to assess hazard levels for existing and future development associated with the flooding events. Subsequently, mitigation options have been investigated to reduce the hazards levels.

The desired key outcomes for this investigation are:

- Development of a new flood model of the entire Goondiwindi Environs, encompassing the existing township and its protection levee system, and future potential growth areas within 12 kilometres of the town centre;
- Assessment of flood inundation extents, depths and durations of key historic events (1976 and 1996) and an assessment of the appropriate event for determination of habitable floors;
- Provision of flood maps for selected design events;
- Identification of hazards and risks associated with the modelled floods;
- Consideration of two key mitigation options;
- Provision of a database of flood information including depths and risk, to assist Council in their planning activities for the future; and
- Assistance with emergency / evacuation planning.

5. STUDY APPROACH

CLT has carried out this investigation using a full two dimensional flow modelling analysis and the following general methodology:

- Interrogate existing models for flood inflow hydrograph and downstream tailwater conditions to provide boundary conditions for the new Goondiwindi Environs (GE) flood model.
- Establish a new flood model of the GE area using:
    - New Airborne Laser Survey undertaken by AAMHatch;
    - Updated 1999 Heilbronn photogrammetric survey of the Border Rivers Floodplain;
    - Ground survey of the Goondiwindi Town Levee (July 2006); and
    - Below water (bathymetric) sections of the river.
- Calibrate the GE model to the 1976 and 1996 historic events.
- Undertake a flood frequency analysis of Goondiwindi and Boggabilla gauge information.
- Simulate the following design events:
    - 'Half of 1976' floods (a currently used design floods);
    - AEP 5%, 2% and 1% design events using Boggabilla gauge data;
    - AEP 0.2% and 0.5% design event by extrapolating the Boggabilla gauge results; and
    - An approximate Probable Maximum Flood (PMF), assumed to be twice the magnitude of the 1976 flood.
- Prepare flood maps for three key design flood events over the GE Area.
- Assess mitigation requirements (e.g. levee extensions and raising) including impacts, of two selected mitigation options.
- Identify flood hazards.
- Review previous detailed Goondiwindi levee failure risk assessment carried out by CLT.
- Identify key evacuation routes, stage/times and appropriate refuge locations to assist in emergency planning and management.

6. HYDROLOGY

6.1 Historical Flood Data at Boggabilla and Goondiwindi Gauges

As part of this study historical flood information was sought to gain an understanding of previous flood history and flood patterns as well as for model calibration purposes.

The major flooding events in February 1976 and January 1996 were used for calibration of the model.

Flood level and flow information associated with the Boggabilla and the Goondiwindi stream gauges, with station numbers 416002 and 416201A respectively, had previously been obtained as part of the Border River Floodplain Hydraulic Analysis.

The locations of the Boggabilla and Goondiwindi gauges are shown on Figure 1.1. The Goondiwindi gauge is located at the bridge over the Macintyre River located at the junction of Macintyre Street and McLean Street.

The Boggabilla gauge is situated approximately one kilometre downstream of the township of Boggabilla. The Boggabilla gauge has been chosen as the upstream boundary of the 2D model. The historical flood data of the Boggabilla Gauge has therefore been critical in calibrating the model and assessing design flows. It should be noted that the Gauge at Boggabilla has undergone three significant changes since it was established in 1895. The first changes were in gauge zero in 1924 and 1937. The Boggabilla Weir, completed in 1991, rendered this gauge ineffective due to ponding behind the weir. Hence, a new gauge was established in October 1991 downstream of this weir.

6.2 Historic Events of 1976 and 1996

Flood flows associated with the 1976 and 1996 Macintyre River events have been obtained from the rated stream gauging station at Boggabilla (Station Number 416002).

The rated flows indicated the following:

- 1976 event – 3241m3/s
- 1996 event – 3308m3/s

As the rated flows did not relate to the recorded flood levels, a joint calibration using the 2D hydraulic model was undertaken to obtain a more accurate flow rating. This calibration provided the following peak flow at the stream gauge for the corresponding peak gauge levels.

Table 6-1 Boggabilla Peak Discharges – Historic Events

Flood	Recorded Water Level (mAHD)	Peak Discharge (m^3/s)
1976	221.27	2760
1996	220.99	2280

6.3 Design Events

The Boggabilla stream gauge has 101 years of height and rated flow records. A flood frequency analysis based on peak annual floods and using a Log Pearson III distribution was undertaken with the 1976 and 1996 flood events amended in accordance with the rating provided by the hydraulic model.

The distribution is shown in Appendix A and design event flows are presented below.

Table 6-2 Boggabilla Peak Discharges – Design Events

ARI (years)	AEP (%)	Peak Discharge (m^3/s)
2	50	576
5	20	1157
10	10	1582
20	5	1996
50	2	2526
100	1	2912
200	0.5	3284
500	0.2	3754

6.4 Probable Maximum Flood (PMF)

A PMF of 5520 m^3/s, twice the 1976 flood magnitude, has been assumed based on previous studies by the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR).

Note:
In assessing design floods detailed above, it is important to recognise the highly complex nature of flooding at Goondiwindi, which can be caused by flooding in four separate stream systems, each of which can independently cause flooding. Hence, all studies of flooding to date by both NSW and QLD authorities have recognised that it is impractical to consider all individual and combination events. For this reason the investigations have been limited to specific historic events and local gauge derived design events. Similarly, the application of a Probable Maximum Precipitation (PMP) approach is considered equally impractical; hence DIPNR's approach to the PMF.

7. HYDRAULIC MODELLING

7.1 Modelling Software

The hydraulic analysis was performed with the aid of the computer program SOBEK, version 2.09.004 SOBEK is a hydrodynamic package developed by Delft Hydraulics in the Netherlands.

The model can simulate steady and unsteady hydrodynamic flow in two directions on a rectilinear grid. It is based on a robust finite difference scheme able to compute both *subcritical and supercritical flow regimes.*

The SOBEK model is suited for simulation of dynamic hydraulic behaviour of overland flow over initially dry land. Based on this and its supercritical solving ability the SOBEK modelling system was considered the most appropriate investigative tool.

7.2 Model Construction

7.2.1 Model Topography

Three topographic maps have been used in the analysis. The first topographic map has been used for calibration of the 1976 event. It has the original Macintyre River alignment without the Boggabilla Weir (Refer Figure 2.1). The second map has been used for calibration of the 1996 flood event. It incorporates the Boggabilla Weir and the new associated river alignment (Refer Figure 2.2). The last map reflects the new aerial laser survey topography for Goondiwindi and its surroundings. This case has been used for the design events (Refer Figure 2.3).

The model topography has been discretised into 20m square grid elements.
The extent of the hydraulic model is shown on Figure 1.1.

7.2.2 Levee systems

In each of the topographic maps the following three levee systems were incorporated.

Goondiwindi Levee System
The height of the Goondiwindi Township Levee was incorporated into the model using the 2006 ground survey data.

New South Wales Levee systems
The location of levee systems in New South Wales are based on existing and approved levees as described in the Guidelines for Macintyre River and Whalan Creek Flood Plain Development Boggabilla to Mungundi (Water Resources Commision – NSW – 1981).

In the SOBEK model it is assumed that no overtopping of the levee systems in New South Wales occurs during extreme events up to the PMF event. However, in reality some of the levees in New South Wales may overtop during extreme events and minor overtopping may occur during the AEP1% event. More detailed ground survey of the top of the levee banks will be required to determine this.

With the NSW levee heights adopted in the SOBEK model as described above, a conservative approach has been applied for the extreme events. Even allowing for this assumption, for flood events up to the AEP 1% event the impact of the levee heights on peak water levels will be limited.

NSW Local Levee System opposite Goondiwindi Township
One particular area of interest is a local levee system located opposite Goondiwindi Township, on the New South Wales side of the Macintyre River, approximately in line with Marshall Street. This levee forms part of a local water distribution network and managed to block the 1976 and 1996 Macintyre River floods. In the SOBEK model the height of this local levee system is set at a conservative (high) level of RL 218.5mAHD. For a scenario where this local levee system is removed, it is estimated that peak water levels can be reduced by 0.03 to 0.05 metres for the PMF event. Such removal would have very little effect on flooding of the Goondiwindi Township and the proposed works.

7.2.3 Boundary Conditions

Inflow boundaries for the historic events of 1976 and 1996 were determined as described in Section 6.2. Design event discharges have been estimated using a flood frequency analysis (Refer to Table 6.2).

Tailwater conditions in the SOBEK model were controlled by a discharge/water level (Q/H) relationship at the downstream boundary of the model based on normal depth conditions.

Downstream model boundaries were set at a distance which will have a negligible influence on peak water levels in the areas of interest, such as the study area for possible future development and the existing levee system of the Goondiwindi Township.

7.2.4 Roughness

The spatial variation of roughness was incorporated into the model by assigning each grid element an individual Manning's 'n' roughness value.

Model roughness (Manning's n) values were chosen based on generally accepted roughness values for different landuses. The roughness values used are shown below in Table 7.1. A general Mannings 'n' value of 0.05 was adopted, mostly for the grassed / grazing floodplain areas.

Table 7-1 Typical Roughness Values Adopted

Land Use	Manning's 'n' Value
Flood Plain Trees	0.05 – 0.08
Flood Plain Cleared Land	0.05
Macintyre River	0.03
Creeks	0.04 - 0.08
Local Ponds	0.025
Built up area (buildings)	0.20
Roads	0.02

7.3 Model Calibration

Calibration was undertaken using 2 historic flood events, the major event in 1976 and 1996, as discussed in Section 6. Models have been calibrated to recorded peak flood levels.

Tables 7.2 and 7.3 compare available historic data and calibrated model results for the 1996 and 1976 events respectively. The 1996 and 1976 models have been calibrated to the recorded water levels at the Boggabilla and the Goondiwindi Gauges. Also two flood marks were found at the Millers residency for the 1996 event during the 2006 levee survey.

These flood marks are located on the downstream section of the model, along the Macintyre River (Refer to Figure 1.1 for the location of these additional flood marks).

Table 7-2 Calibration Summary 1996 event

Location	Gauge zero (m AHD)	Recorded Depth (m)	Recorded Level (m AHD)	Modelled Level (m AHD)	Difference (m)
Gauge Boggabilla	208.48	12.513	220.99	221.01	+ 0.02
Gauge Goondiwindi	207.56	10.615	218.18	218.19	+ 0.01
Millers Flood Mark			215.73 215.75	215.70	- 0.03 - 0.05

For the 1976 event additional information was found in the report "Investigation of Flooding at Goondiwindi" prepared by the Engineering & Technical Services Division for Goondiwindi Town Council in December 1985. A recorded water level at the most upstream location of the Goondiwindi Town Levee has been used specifically for the calibration of the 1976 model (refer Figure 1.1 for location of 1976 Flood Mark).

Table 7-3 Calibration Summary 1976 event

Location	Gauge zero (m AHD)	Recorded Depth (m)	Recorded Level (m AHD)	Modelled Level (m AHD)	Difference (m)
Gauge Boggabilla	208.48	12.8	221.27	221.27	+ 0.00
Gauge Goondiwindi	207.56	10.5	218.06	218.17	+ 0.11
Upstream of Goondiwindi Levee	--	--	219.88	219.88	+ 0.00

It should be noted that the hydraulic model incorporates current (as of 2006) topography including farming levees. Some of these levees, especially in the floodplain area south of Goondiwindi, may not have existed in 1976, impacting on flow distribution within the floodplain. It is therefore considered the 1976 calibration result is reasonable taking into account this uncertainty.

7.4 Design Events

Design event hydraulic modelling was run using the calibrated SOBEK model in conjunction with the calculated design discharges as discussed in section 6.3.

7.5 Model Results and Figures

For the historic events of 1996 and 1976 and for the design events the following model results are included in the Figure section at the end of this report:

- Peak water levels combined with flow patterns;
- Peak water depth combined with flow patterns;
- Hazard maps (as described in following Section 7.6)

Table 7.4 shows the flows and predicted water and gauge levels at the Goondiwindi and the Boggabilla gauge (1996 location) for the two historic events of 1976 and 1996 and for the design events.

Table 7-4 Predicted Water Levels and Flows in Sobek

Event	Boggabilla Gauge			Goondiwindi Gauge		
	Flows	Water Levels	Gauge Levels	Flows	Water Levels	Gauge Levels
AEP	(m^3/s)	(m. AHD)	(m. AHD)	(m^3/s)	(m. AHD)	(m. AHD)
5%	1996	220.91	12.43	1310	218.16	10.60
1996*	2280	221.02	12.54	1380	218.19	10.63
2%	2526	221.09	12.61	1430	218.21	10.65
1976**	2760	221.15 ***	12.67	1430	218.17	10.61
1%	2912	221.2	12.72	1500	218.24	10.68
0.5%	3284	221.3	12.82	1561	218.27	10.71
0.2%	3754	221.41	12.93	1636	218.30	10.74
PMF	5520	221.78	13.30	1857	218.41	10.85

* Based on 1996 Topography
** Based on 1976 Topography
*** Predicted water level at existing Boggabilla Gauge location.

7.6 Hazard maps

Provisional Hydraulic Hazard Categories – as defined in the Figure G2 (Appendix G) of NSW Floodplain Management Manual (2001), have been calculated through and around the township for the historic events of 1976 and 1996 and for each design event.

The Provisional Hazard Categories include definitions of:

- 'High' Hazard,
- 'Moderate' Hazard, and
- 'Low' Hazard.

Areas of high hazard indicate possible danger to personal safety as wading and evacuation by trucks becomes difficult. There will also be the potential for structural damage to buildings. Areas of low hazard indicate that able bodied adults should be able to wade without difficulty and evacuation by trucks should be possible. In areas defined as the transition zone the degree of hydraulic hazard is dependent on its landuse (NSW Floodplain Management Manual).

Definitions of these categories can also be found in the glossary in section 15.

It should be noted that these definitions are appropriate for able-bodied adults only. In the case where children, elderly or disabled persons are affected by floodwaters the hazard categorisation of 'Low' is likely to be upgraded to 'High'.

8. FLOOD RISKS TO BE MANAGED

In development of a floodplain risk management plan, three specific flood risks need to be addressed:

Existing Risk
The control of flood damage and personal danger to the existing community and properties at risk (Refer to section 8.1).

Future Risk
The control of flood damage and personal danger in areas yet to be developed (Refer to section 8.2).

Continuing Risk
The control of flood damage and personal danger associated with management measures being overwhelmed by a larger flood than the flood used to design management measures, and / or those areas outside the "protected" area.

To address the risks a floodplain management plan should aim to achieve an appropriate mix of measures. There are four groups of management measures:

- *Structural flood mitigation measures (refer to section 9);*
- Land use controls (property modification measures);
- Development and building controls (property modification measures);
- Flood emergency management measures (refer to section 10).

8.1 Existing Risk

The township is protected by a levee system. The results of this study show that no severe flooding of the existing township occurs for events up to a 0.2% AEP event, provided that (minor) overtopping of the levee system doesn't lead to erosion or a breach of this levee system.

Severe overtopping of the levee system does occur during a PMF event, in particular on the north eastern levee banks along Brigalow Creek and on the south eastern levee banks along the Macintyre River. Locations where overtopping occurs during the 1% and the 0.2% AEP Event are marked in Figure 1.3.

Areas of high risk within the township during this PMF event are:

- The area around Jabiru Drive/Jacaranda Drive/George Street, partially surrounded by Serpentine Lagoon.
- Koloma Home for the Aged.
- Between Albert and Moffatt Streets.

Refer to Figure 1.2 for these locations.

8.2 Future Risk

Figure 1.1 shows the study area for possible future development. The results of this flood study show that the northern and eastern side of the study area is inundated to depths of 1.0 to 2.0 metres in the floodplain, and locally up to 5.5 metres in Brigalow Creek.

Similarly, the majority of this part of the study area is in the high hazard category for all events.

Safe locations in the study area are located:

- East of the airport and south of Crooked Creek;
- Around Brennan Road.

Refer to Figure 1.3 for these safe future development areas.

9. IMPLEMENTATION OF STRUCTURAL MEASURES

In this investigation the following structural flood modification options were examined:

- Extension of the levee system around the airport, to allow for transport by air even during severe flooding, when access by roads may be blocked.
- Raising the levees to prevent the township from being flooded in a 1% AEP event; and
- Raising the levees to prevent the township from being flooded in a 0.2% AEP event.

9.1 Proposed New Levee Height

Figure 1.4 shows the proposed new levee height based on the 1% AEP Peak Flood Levels and a proposed freeboard of 300mm in relation to the existing levee heights, surveyed In July 2006. Figure 1.4 also shows the 0.2% AEP Peak Flood Level with no freeboard.

The 0.2% flood levels are in general lower than the new proposed levee height, except for some locations on the eastern banks along Brigalow Creek.

9.2 Impacts of Structural Measures

The purpose of the proposed measures is to provide a higher level of safety for the inhabitants within the levee protected area.

The proposed measures will still need to comply with WSC guidelines for floodplain management as described in section 3.2. As can be seen on Figure 14.4 the increase in peak water level in the floodplain is well within the stated 200 mm range for a 1% AEP event.

The highest increase in peak water levels for the 1% AEP event occurs near the proposed extension of the levee system around the airport, with peak water levels rising up to 140 mm on adjacent properties east of the Cunningham Highway.

Raising the levee system along Brigalow Creek results in impacts of up to 40 mm. Raising the levee system along the Macintyre River shows no adverse impacts for the 1% AEP event.

10. FLOOD PLANNING LEVELS

An important aspect of a floodplain risk management study is the selection by Council of flood planning levels (FPLs) to be used for risk management purposes in the floodplain risk management plan.

The flood planning levels used for planning control purposes is derived from a combination of the adopted flood level plus freeboard, as explained below.

Adopted Flood Level
Flood Planning Levels used to be based on the biggest recorded flood, which for the Goondiwindi Environs was the 1976 flooding event. The Flood Study indicates that this 1976 flood was an event with an AEP less than 1% (refer to Section 6).

At this time, the 1% AEP Flood has become the most common basis for FPL's used in Australia, particularly for residential development in urban areas. It is proposed to adopt the 1% AEP Flood as the new basis for future flood planning levels for the Goondiwindi Environs. The choice of the 1% AEP will result in a requirement for higher habitable floor and road levels, than for the 1976 flood.

Freeboard
The purpose of freeboard is to cater for uncertainties in the estimation of flood levels across the floodplain, localised hydraulic behaviour, impacts that are related to a specific event, embankment or levee settlement, and other effects such as climate change. In effect, freeboard acts as a factor of safety, however, it should never be relied on to provide protection against floods larger than the flood used to derive the FPL. Any added protection is a bonus, not a guarantee.

Local guidelines used by Councils in South East Queensland required a freeboard of 300 to 500 mm.

The Queensland Urban Drainage Manual (Neville and Jones, 1995) and Australian Rainfall and Runoff (the Institution of Engineers, 1998) recommend 300mm freeboard.

For the Goondiwindi Environs 300mm freeboard corresponds to a large amount of additional flow through the relatively large floodplain. Hence, it is considered appropriate from a hydraulic perspective to adopt a freeboard of 300mm.

10.1 Habitable Floor Levels Future Development

It is recommended that habitable floor levels for future development be set at the 1% AEP Flood Level with an additional freeboard of 300mm.

10.2 Habitable Floor Levels and Road Levels Brennan Road

To set future habitable floor and road levels for the Brennan Road area two flooding scenarios have been investigated using the *2D SOBEK model*.

External Flooding from Macintyre River
This scenario assumes that the Brennan Road area is inundated due to a failure / a breach of the levee system during a 1% AEP flood in the Macintyre River. Peak water levels over the main part of the Brennan Road area are at 214.86m AHD (Refer to figure 11.1).

Local Rainfall Flooding

Since the Brennan Road area has no natural point of discharge, there is potential for excessive pondage in the Brennan Road area during extreme rainfall events. This scenario has been tested with the SOBEK 2D model.

The size of the catchment area that contributes is assessed at approximately 180 ha. The extent of the catchment area is shown in Figure 12.1.

The probable maximum precipitation (PMP) has been determined for a range of storm durations. A 12 hour PMP storm has been found to be critical. This event has 0.66 m. of rainfall, enough to pond the Brennan Road area, which then starts draining in a northerly direction to a local tributary of Callandoon Creek.

Peak water levels over the main part of the flooded Brennan Road area are at 215.23m AHD (Refer to figure 12.1).

From the results detailed above, the extreme local rainfall burst produces higher peak flood levels. However, when freeboard considerations are taken into account, there is little difference between the required levels for extreme local rainfall bursts (with no freeboard) and for Macintyre River 1% AEP flooding events (with freeboard):

1% AEP External Flood + 300 mm. freeboard	= 215.16 m AHD
PMP peak flood level	= 215.23 m AHD

Hence, a minimum habitable floor level of RL 215.2m AHD is recommended for this area.

11. FLOOD EMERGENCY RESPONSE AND EVACUATION

Flood emergency management consists of:

- Flood warning;
- Mobilisation of emergency services, and
- Evacuation (if required).

This section describes flood emergency management strategies for severe flooding events with occurrence of:

- Overtopping of the levees, and
- Levee failures.

Levee Failure scenarios are based on the previously reported Levee Failure Study ("*Goondiwindi Township* Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar). All figures from this report can be found in the reference section of this report.

11.1 Flood Warning

The Bureau of Meteorology manage an ALERT flood warning system for the Border Rivers, including flooding at Goondiwindi.

Given the large catchment of the Macintyre River, warning times are generally more than a day; however, once water levels reach within a metre of overtopping levees, increased frequency of monitoring and review of evacuation requirements should occur.

11.1.1 1% AEP Event Warning Times in the Flood Plain

With the SOBEK 2D model it is assessed how long it takes for a 1% AEP design flood to fill the floodplain. Appendix B shows flow rates and water levels at the Boggabilla and *Goondiwindi* Gauges for this 1% AEP Flood Event.

Based on the rising limb of the 1976 flooding event, it is assumed that a 1% AEP Flood can rise from a relative small flow (25 m^3/s) to its peak discharge of 2912 m^3/s in a time of 48 hours. Within those 48 hours, the entire floodplain of the Goondiwindi Environs is flooded. Refer to Appendix B1 for the exact shape of this 1% AEP flood at the Boggabilla Gauge.

The 1% AEP flood shows the following flooding process:

- When water levels in the Macintyre River rise above RL 217.25m AHD at the Goondiwindi Gauge, a break out of the Macintyre to the floodplain south of Goondiwindi is likely to occur. Within 12 hours after a flood reaching this gauge height, this part of the floodplain could be completely inundated.
- When water levels in the Macintyre River rise above RL 220m AHD at the Boggabilla Gauge, a break out of the Macintyre River to the north is getting more likely to occur and evacuation of inhabitants within the flood plain east and north of Goondiwindi will be required. Within 24 hours after a flood reaching this gauge height, this part of the floodplain could be completely inundated.

Figure 8.4 shows the inundation of the floodplain in time steps of 4 to 8 hours from the moment the 1% AEP flood commences at Boggabilla. Priorities should be based on flooding times, as shown in Figure 8.4.

11.1.2 PMF Event Warning Times in the Township

Figure 5.4 shows what areas are inundated in the township in time steps of 6 to 12 hours during a PMF event after the first overtopping of the levees occurs. Most of the township is inundated within 12 to 18 hours after the first overtopping of the levee system occurs during the PMF flood.

11.1.3 Levee Failure Warning Times in the Township

In terms of warning times in the event of a levee bank failure, Figure 6 in the reference section of this report, shows broad indicative zones of 1, 3 and 6 hour times to flood.

11.2 Emergency Services Mobilisation

Mobilisation for assistance from the SES can occur through residents contacting the SES or through the Queensland Police activating the response where emergency services are mobilised in accordance with the findings of this Report.

In case of a levee failure, or overtopping of the levees during a severe flooding event (PMP), the following three services are surrounded with depths of around 0.5 metres:

- The Fire Brigade Station on the corner of Herbert and Bowen Streets;
- The Ambulance Station on the corner of Marshall and Frideswide Streets;
- The Police Station on the corner of Herbert and Brisbane Streets.

It is therefore important to ensure that all three emergency services receive priority notification to ensure vehicles can exit the site prior to inundation.

The police station is immediately adjacent to higher, flood-free land.

11.3 Evacuation

Details of evacuation are listed here in terms of:

- Priorities;
- Routes; and
- Centres.

The need to evacuate will be identified by the SES who issues evacuation warning messages. These messages will normally take the following form (SES, 1995):

- Time of issue and title of Authorising Officer,
- Description of the area to which the warning applies and the flood threat to that area, and
- Information on:

- Location of and route to evacuation centre,
- Time by which evacuation should occur, and
- Arrangements for those without their own transport.

SES volunteers should ensure that:

- Residents raise furniture above the likely flood level;
- Residents secure buildings and vehicles. It is advisable to remove all vehicles from properties unless secured against movement during floods;
- Where practical, floatable objects are suitably secured to prevent debris or environmental impacts;
- Where practical and safe, that electrical hazards are minimised by turning off and disconnecting all appliances and equipment;
- All evacuees register at the closest/most convenient evacuation centre, and
- No individuals remaining within properties are unaware of the need to evacuate and the method of evacuation.

11.3.1 Evacuation Priorities In The Floodplain

Areas that are not protected by the existing or the proposed extended levee system require habitable floor levels up to PMF peak water levels for all new development, rather than evacuation.

For existing properties Council will need to undertake extensive floor level survey, before the actual need for evacuation can be assessed. It is not practical to raise existing road levels in flood prone areas. Hence for safe evacuation it is required to start evacuation procedures at the early stages of flooding.

The Brennan Road area doesn't need direct evacuation, provided the levee banks don't breach or fail, since this area is not inundated during the PMP event

11.3.2 Evacuation Priorities In The Township

The cause of flooding influences the maximum available time to evacuate and is therefore of direct relevance to the priority order to evacuate.

When the levees of the township overtop during a PMF sized flood, the list of evacuation of residents should be based on Figure 5.4, with time zones indicating the priority of evacuation.

However, should a levee breach or fail, than the proposed order of evacuation priority is as follows.

- Residences within 50 metres of the levee breach — Priority 1
- Kaloma Home for the Aged — Priority 2
- Hospital* — Priority 3
- 1 Hour time to flood zone ** — Priority 4
- 3 Hour time to flood zone ** — Priority 5

- 6 Hour time to flood zone ** Priority 6

* If at Risk of Flooding, due to levee failure

** Refer to Figure 6 in the Reference Section of this report.

It should be noted that the pattern of levee failure may change the order in which flooding occurs. Clearly, any houses in the immediate vicinity of a levee breach must be evacuated, because of the potential for high hazard should flood height reach the breach height. Monitoring of river levels relative to breach height is critical.

The list of evacuation priorities is based on the age, health and likely number of people within a particular area, as well as the concentration of people within a small area (such as a school or retirement village).

Unless additional structural measures are put in place to protect the Kaloma Home for the Aged, because of its low level and proximity to the main drainage path from the township, evacuation immediately after a levee breach will need to be a priority.

11.3.3 Evacuation Routes

Figure 7 in the reference section shows critical evacuation routes, possible evacuation refuge centres and zones feeding each centre.

Local refuges are suggested at the Golf Club, the Community Centre and around River Gums Drive. As long as the levees don't breach or fail, these local refuges are safe (dry) locations. In case of (multiple) levee breach failures, the airport could potentially be the only sizable area actually free from flooding.

11.3.4 Evacuation Centres

Possible locations of evacuation centres have been identified as part of the Levee Failure Study ("Goondiwindi Township Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar) to assist with the identification process, and are shown in Figure 7 in the reference section of this report. This figure also shows feeder zones for each centre.

Some locations that would otherwise be suitable for evacuation actually lie within the floodplain. Likely areas of refuge within the floodplain or located where access may be compromised include:

- Goondiwindi Community Centre,
- Goondiwindi Golf Club, and
- High ground around River Gums Drive.

A review of the suitability of these facilities should be undertaken by the Disaster Management Committee.

11.4 Post Flood Recovery

Following a flood, a number of activities will ensue:

- Once flood waters recede, the SES are to advise residents when they may return to their properties.
- Council and other relevant authorities will need to arrange for restoration or clean up of public assets.

Following a flood it is important to collate as much data as possible close to the event. For example, data to be collected include:

- Photographs/video of flooding;
- Rainfall;
- Weather patterns;
- Flood levels;
- Flood velocities;
- Number of persons evacuated and location of evacuation;
- Insurance claims and damage cost estimates (separated into private residences, businesses and public utilities);
- Effectiveness of evacuation plan, and
- Effectiveness of flood warning systems.

12. CONCLUSIONS

This study has been prepared for Waggamba Shire Council (WSC) by Cardno Lawson Treloar (CLT) to assess the extent of flooding in the Goondiwindi Environs and the associated levels of hazard resulting from flooding for existing and future residential development, and to assist in floodplain risk management planning for the future growth of the township of Goondiwindi.

The overall study comprises the undertaking of airborne laser survey, numerical flood modelling, flood mapping and flood mitigation assessment. The study area encompasses land within a 12 km radius of Goondiwindi, referred to as the Goondiwindi Environs.

This flood report is one of the first steps in floodplain risk management planning and provides the necessary background information to identify the level of risk, possible mitigation options and possible evacuation routes. These outputs will help WSC to plan future development and form a basis for disaster and rescue plans for WSC, Goondiwindi Shire Council and the Department of Emergency Services.

The hydraulic model that was built for the hydraulic flooding investigation was based on accurate survey data and has been calibrated and validated against the recorded water levels for the historic flooding events of 1996 and 1976 recorded, in particular for the Boggabilla and the Goondiwindi Gauge.

The Flood Study indicates that the largest flood on record in the Goondiwindi Environs, the 1976 flood, was a flood event with an AEP less than 1%. As the flood model has been calibrated to this event and the smaller 1996 event, it is considered results for design events up to the 1% AEP are within acceptable confidence limits.

A flood frequency analysis was used to estimate design flooding events ranging from 5% to 0.2% AEP event, which have consequently been investigated with the new SOBEK 2D model.

The model results have been used to assess peak water levels, peak water depths and hazard levels for each design event. Mitigation scenarios have been investigated, consisting of raising levees and extending the existing levee system around the airport. The hydraulic impacts of these mitigation options have been assessed and comply with the allowable maximum 200mm raise of peak water levels for a 1% AEP event.

New levee heights and future flood planning levels are proposed based on the 1% AEP event flood levels and an additional recommended 300mm freeboard.

Safe future development areas in the study area are located east of the airport, south of Crooked Creek and around Brennan Road.

Flood emergency management strategies have been described based on the model results, and have been compared to the previously undertaken Levee Failure Study ("Goondiwindi Township Disaster Risk Management Report", J7803/R2, February 2003, Cardno Lawson Treloar).

Future studies and work by Council will utilise the findings of this investigation to refine future planning for growth in the Goondiwindi Environs, and to refine emergency flood management procedures for the town and surrounding area.

13. REFERENCES

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14. LIMITATIONS AND QUALIFICATIONS

This report has been prepared by CLT specifically for WSC and specifically to provide advice on the flooding characteristics of the Macintyre River at the Goondiwindi Environs.

Our analysis and overall approach has been specifically catered for the particular requirements of WSC, and may not be applicable beyond this scope. For this reason any other third parties are not authorised to utilise this report without further input and advice from CLT.

CLT has relied on the following studies and information prepared by others:

- 3D terrain information and survey provided by AAMHatch.
- 3D ground survey data of the existing levee system (July 2006) provided by SMK Consultants Pty Ltd.
- Limited historic flood levels and flows at the Department of Infrastructure, Planning & Natural Resources (DIPNR) Boggabilla stream gauge and at the Department of Natural Resources and Mines (DNRM) Goondiwindi stream gauge.
- Photogrammetry carried out for the Border Rivers Floodplain Hydraulic Analysis (BRFHA) Study.

The accuracy of the report is dependent on the accuracy of this information.

Future observed flood levels may vary from the predicted levels in this report depending on the characteristics of the catchments, rainfall, channels and floodplain.

In particular caution is required in use of events larger than the 1976 flood, since no historic data exists for such events. The nominal PMF event used in this study is based on the NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) approach. This approach has been applied to previous studies, but is not based on PMP analysis.

15. GLOSSARY OF TERMS*

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. e.g. some roads may be designed to be overtopped in the 1 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe area	The remaining area of flood-prone land after floodway and flood storage areas have been defined.

Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. The maximum extent of flood liable land. Floodplain Risk Management Plans encompass *all* flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning levels (FPL)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severity's. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodways	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.

Freeboard	A factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. It is usually expressed as the difference in height between the adopted flood planning level and the flood used to determine the flood planning level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the floodplain, such as wave action and localised hydraulic behaviour; impacts that are specific event related, such as levee and embankment settlement other effects such as "greenhouse" and climate change. Freeboard is included in the flood planning level.
High hazard	Possible danger to life and limb; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.

Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Moderate hazard	A transition zone between low and high hazard. The dregree of hazard is dependant on site conditions and the nature of the proposed development.
Peak discharge	The maximum discharge occurring during a flood event.
Probable Maximum Flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probable Maximum Precipitation (PMP)	The greatest depth of precipitation for a given duration meteorologically possible for a given size storm at a particular location at a particular time of year.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Annual Exceedence Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

* Many terms in this Glossary have been derived or adapted from the NSW Government *Floodplain Management Manual*, 2001.

FIGURES

Cardno Lawson Treloar

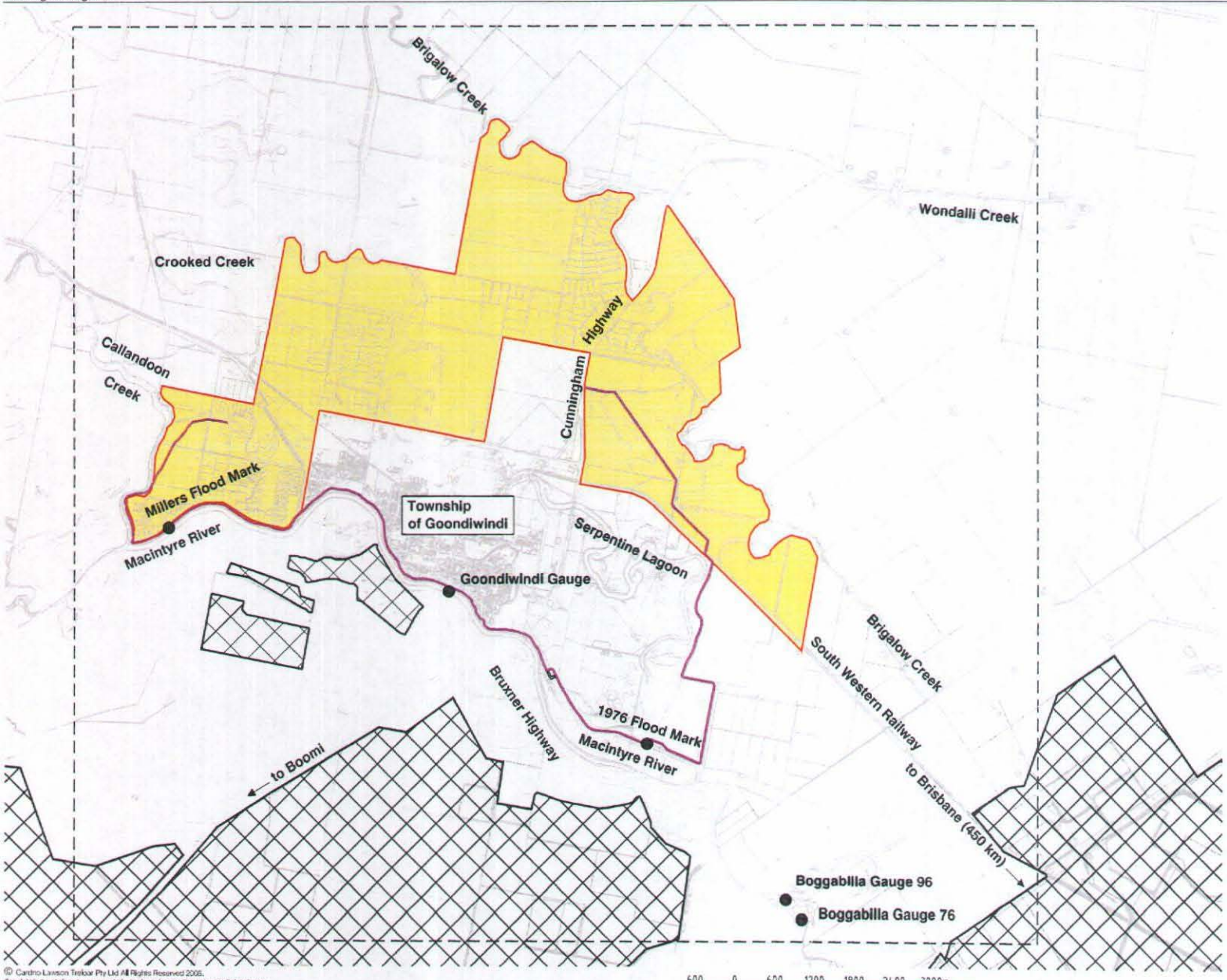

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FIGURE 1.1

STUDY AREA POTENTIAL FUTURE RESIDENTIAL DEVELOPMENT AND MODEL EXTENT

Rev: Orig. Date: September 2006

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: G:\Work\LAT\LJ865\1\Acad\R1\1-Figure 1.1 Study Area.dwg
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PRINT DATE: 22 March, 2007 - 4:10pm

Cardno Lawson Treloar

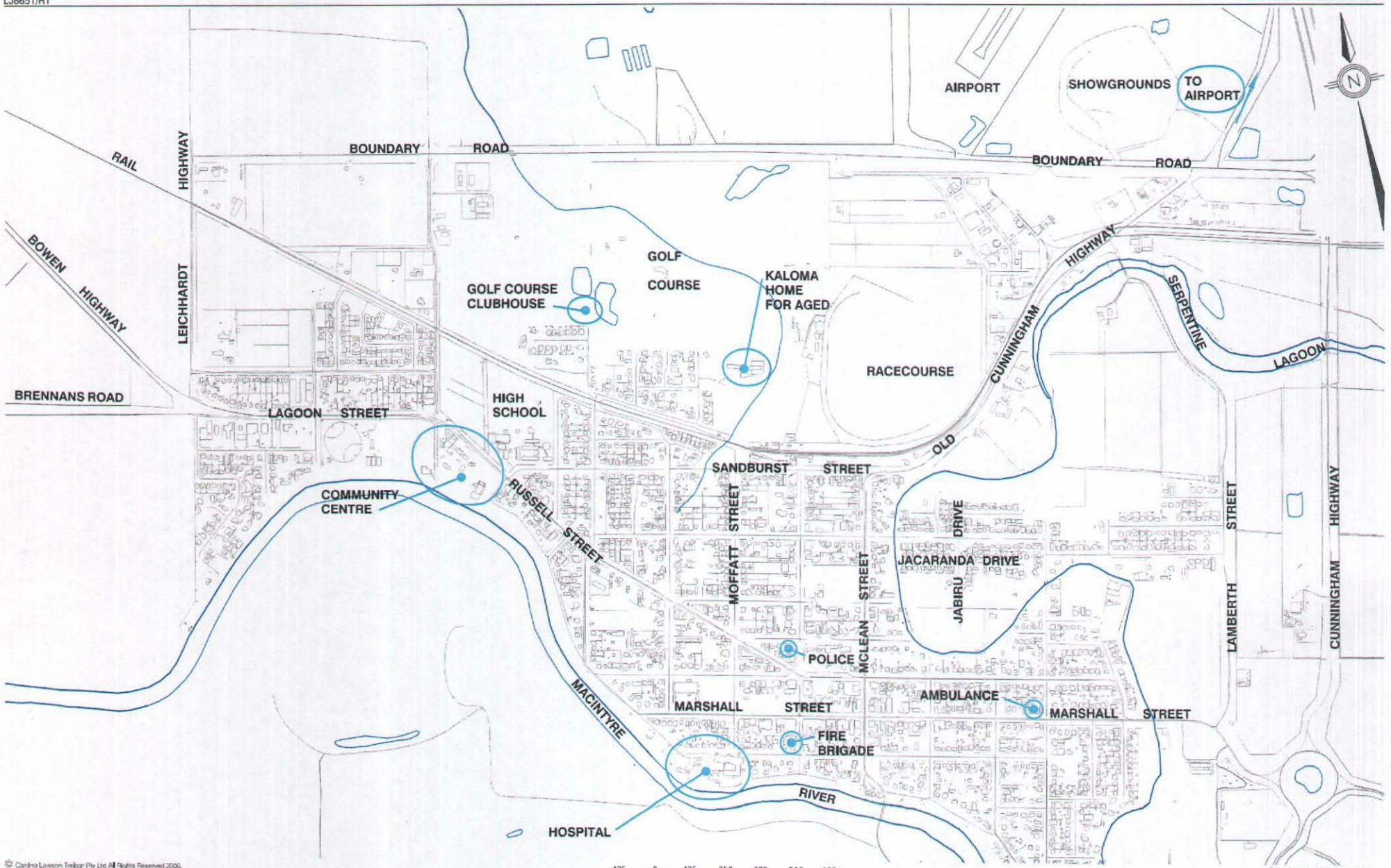

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FIGURE 1.2

RESIDENTIAL AREA AND REPORTING REFERENCE POINTS

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\Work\LJ651\Acad\R1v3\Figure 1.2 Locations.dwg
XREFs: SURVEY

Project No.: LJ8651

PRINT DATE: 23 March, 2007 - 6:10pm

Cardno Lawson Treloar

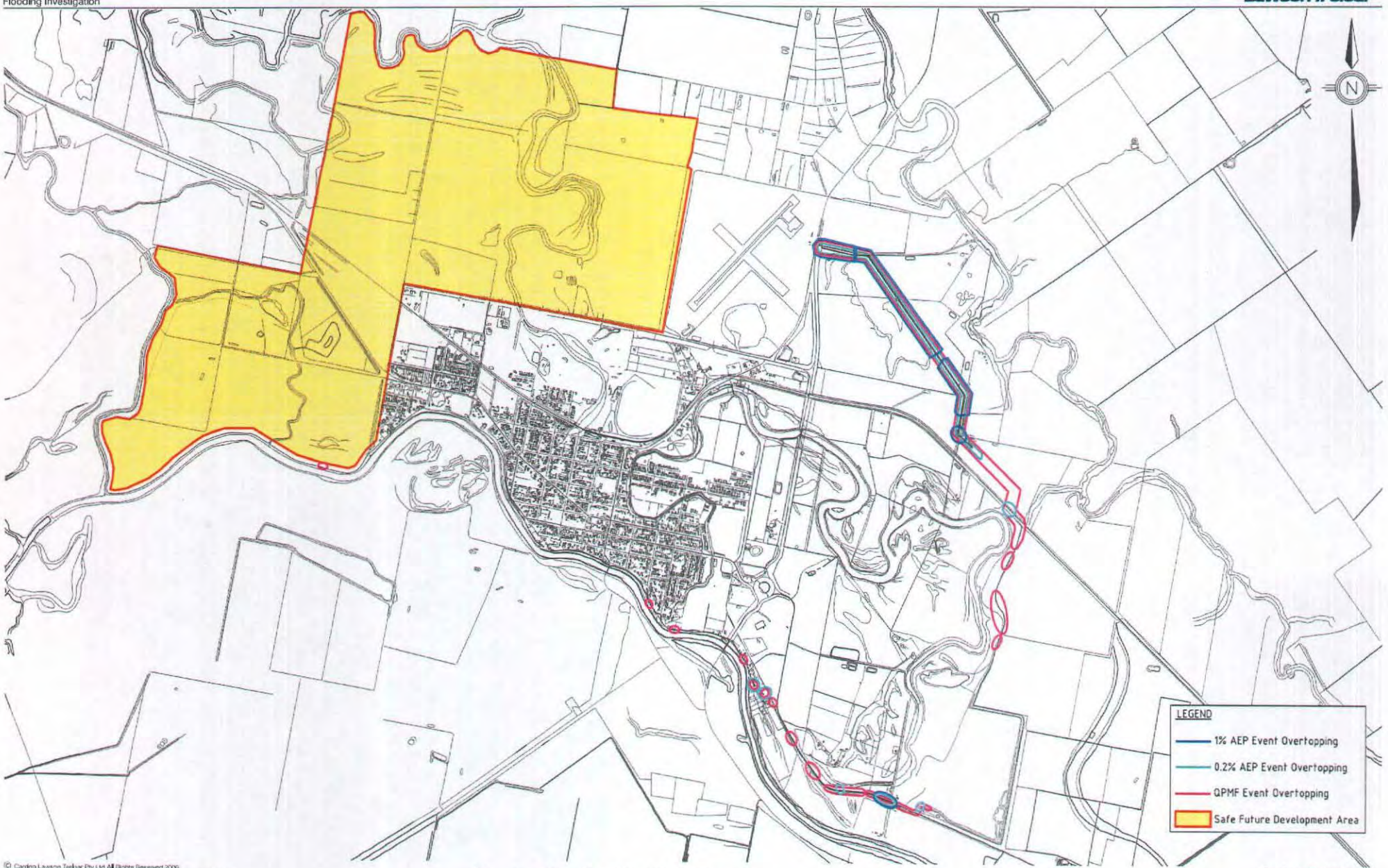

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FIGURE 1.3

OVERTOPPING OF LEVEE SYSTEM AND SAFE FUTURE DEVELOPMENT AREAS

Rev: Orig. Date: March 2007

Waggamba Shire Council

Project No.: J8651/R1

CAD FILE: O:\Work\AT\J8651\Acad\R1\J8651Figure 1.3 Overtopping.dwg
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Cardno Lawson Treloar

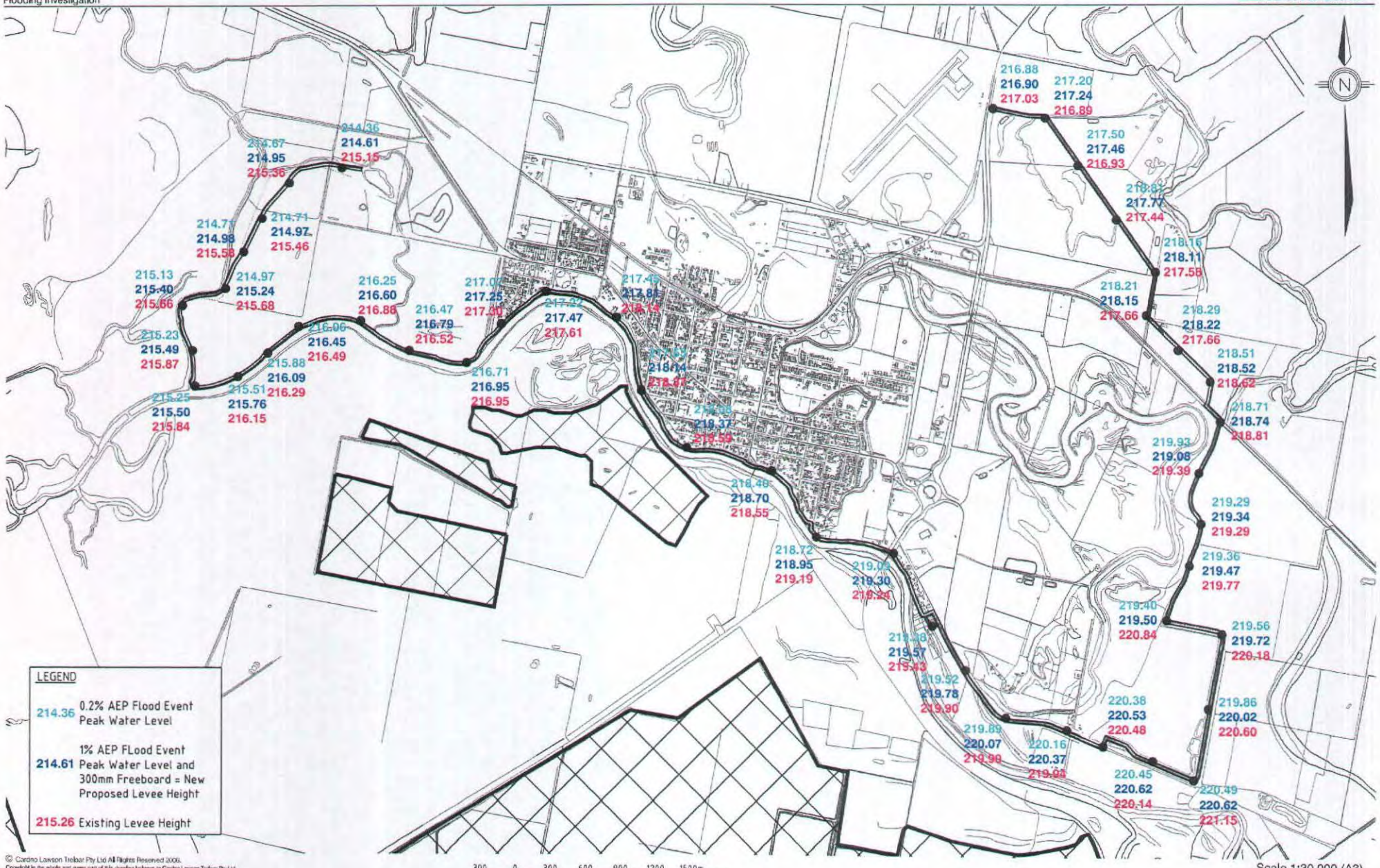

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FIGURE 1.4

0.2% AEP PEAK WATER LEVELS AND PROPOSED AND EXISTING LEVEE HEIGHTS

Rev: Orig. Date: March 2007

Waggamba Shire Council

Project No.: J8651/R1

CAD FILE: D:\Work\LAT\J865\Acad\R1\Figure 1.4 Levees.dwg
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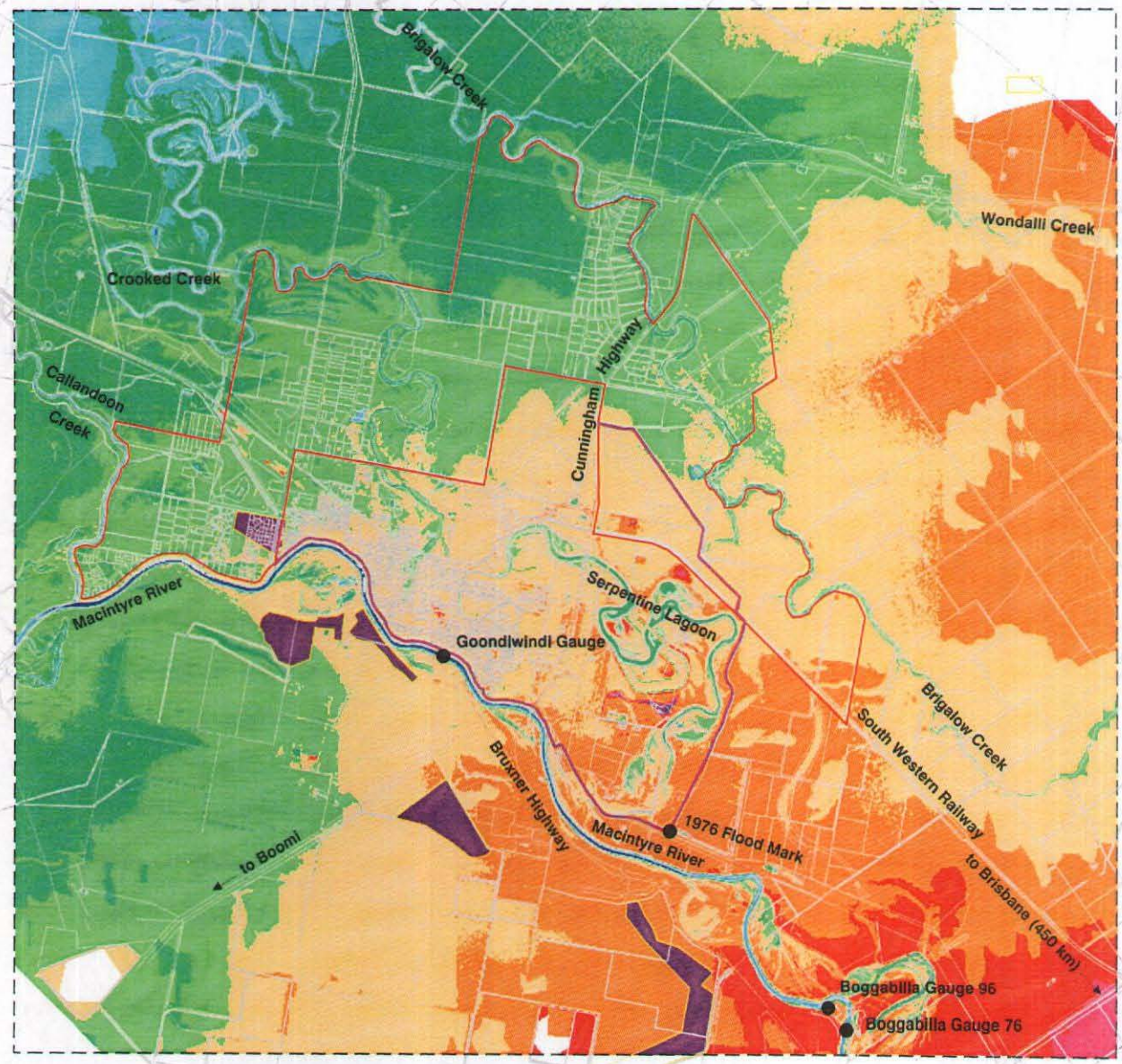
Cardno Lawson Treloar



LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Elevation (mAHD)

- Above 226.00
- 224.00 to 226.00
- 222.00 to 224.00
- 220.00 to 222.00
- 218.00 to 220.00
- 216.00 to 218.00
- 214.00 to 216.00
- 212.00 to 214.00
- 210.00 to 212.00
- 208.00 to 210.00
- 206.00 to 208.00
- 204.00 to 206.00

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 2.1

1976 FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

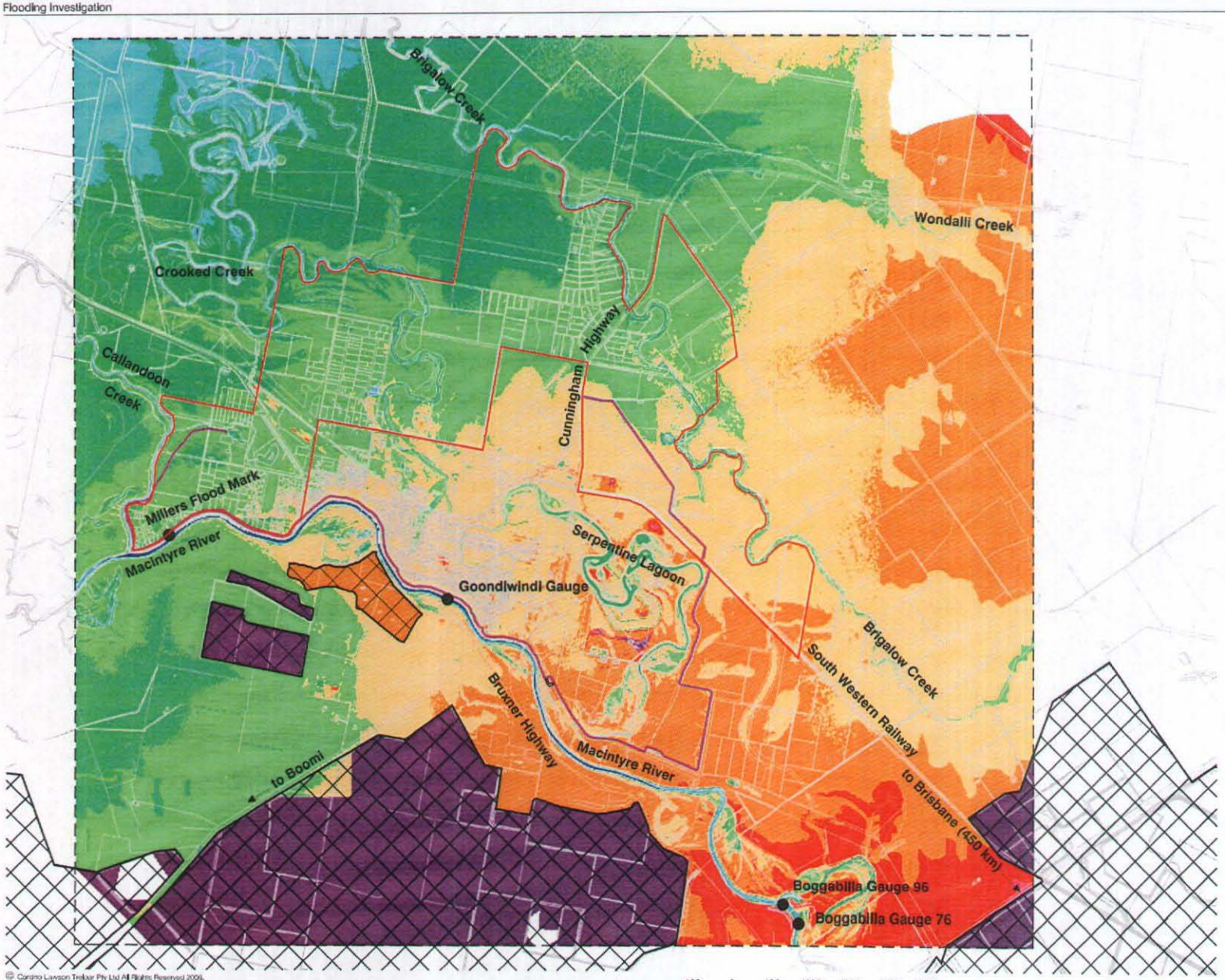
Rev: Orig. Date: March 2007

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: G:\Work\LAT\LJ8651\Acad\R1v3\Figure 2.1_3 1976.dwg
XREFs: J:\803\FigureBase_Levees 1996; Results; Waggamba_Shire_2005_HAZARD_R1_Text
PRINT DATE: 26 March, 2007 - 8:22am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Elevation (mAHD)

- Above 226.00
- 224.00 to 226.00
- 222.00 to 224.00
- 220.00 to 222.00
- 218.00 to 220.00
- 216.00 to 218.00
- 214.00 to 216.00
- 212.00 to 214.00
- 210.00 to 212.00
- 208.00 to 210.00
- 206.00 to 208.00
- 204.00 to 206.00

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: G:\Work\LAT1_LJ8651\Acad\R1\s3\Figure 2.2_A 1996.dwg
XREF's: J7603FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_test

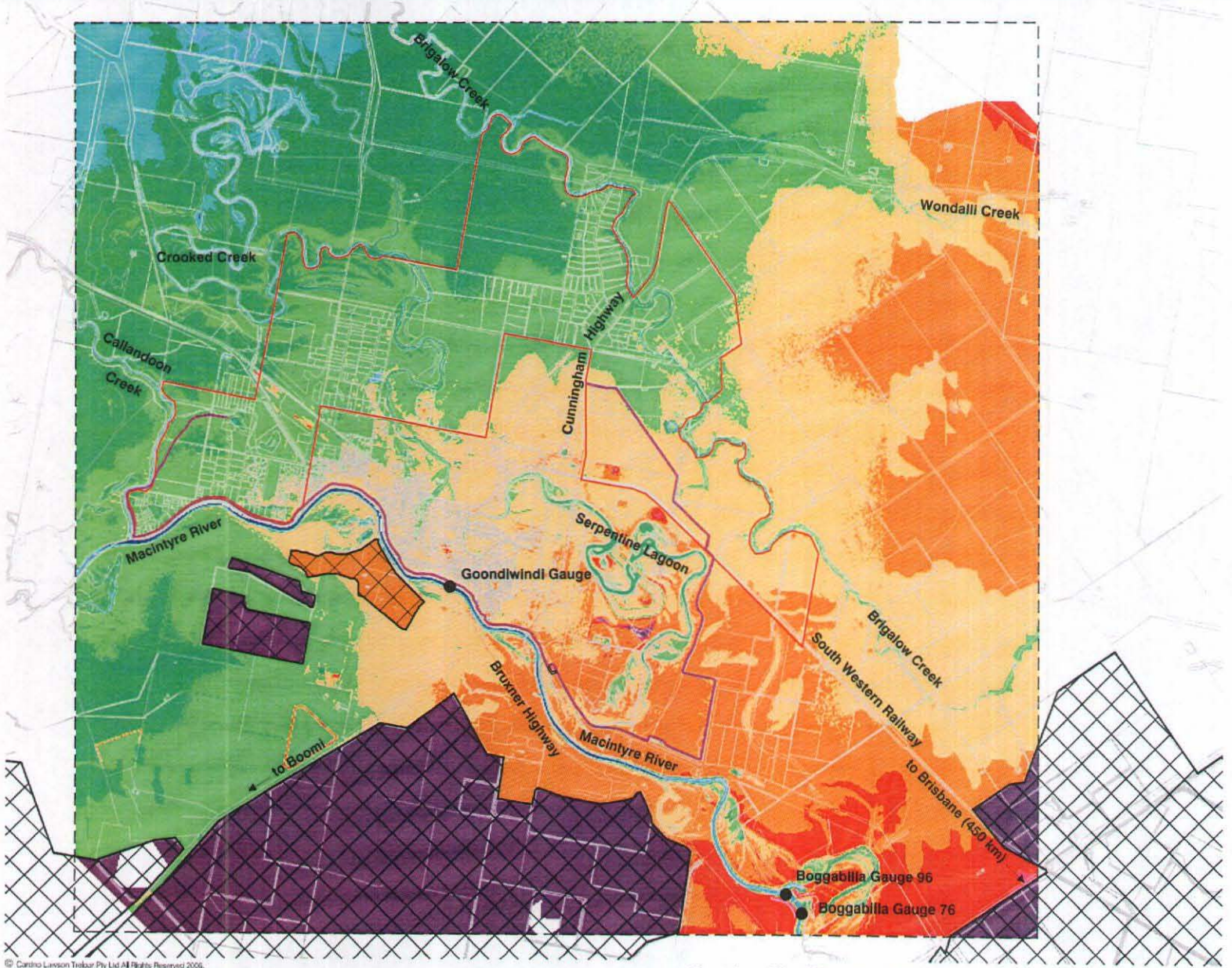
FIGURE 2.2

1996 FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:28am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Elevation (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 2.3

DESIGN FLOODING EVENT - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Rev: Orig. Date: March 2007

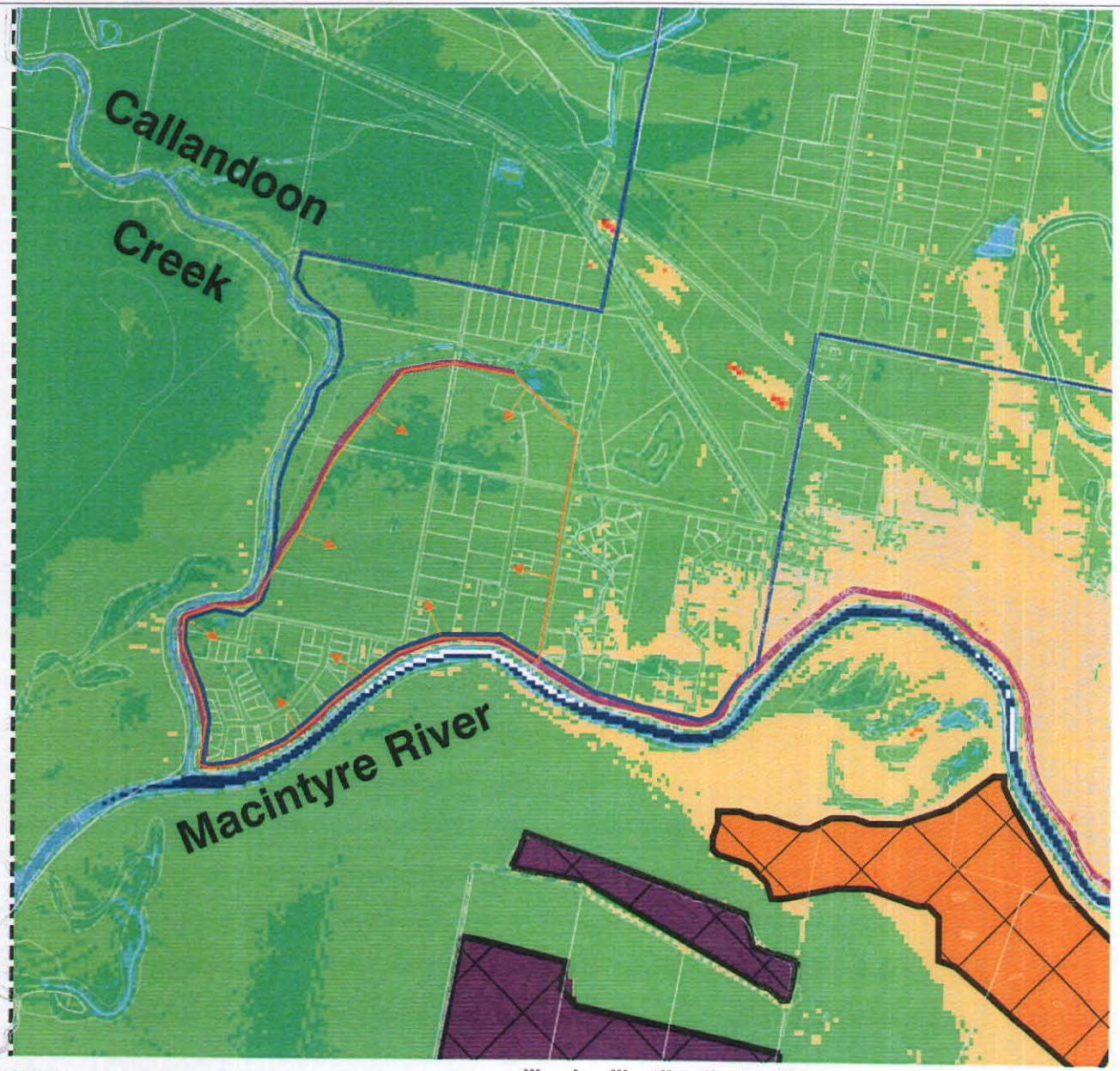
Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1s3\Figure 5 2006 PMF.dwg
XREF's: J7868\FigureBase_Levees 1996; Results; Waggamba_Shire_2025, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 9:57am

Cardno Lawson Treloar



LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Local Rainfall Catchment Brennans Road

Elevation (mAHD)

- Above 226.00
- 224.00 to 226.00
- 222.00 to 224.00
- 220.00 to 222.00
- 218.00 to 220.00
- 216.00 to 218.00
- 214.00 to 216.00
- 212.00 to 214.00
- 210.00 to 212.00
- 208.00 to 210.00
- 206.00 to 208.00
- 204.00 to 206.00

200 0 200 400 600 800 1000m
1:20,000

Scale 1:20,000 (A3)

FIGURE 2.4

LOCAL PMP FLOODING BRENNANS ROAD - TOPOGRAPHIC MAP AND LEVEE LOCATIONS

Rev: Orig. Date: March 2007

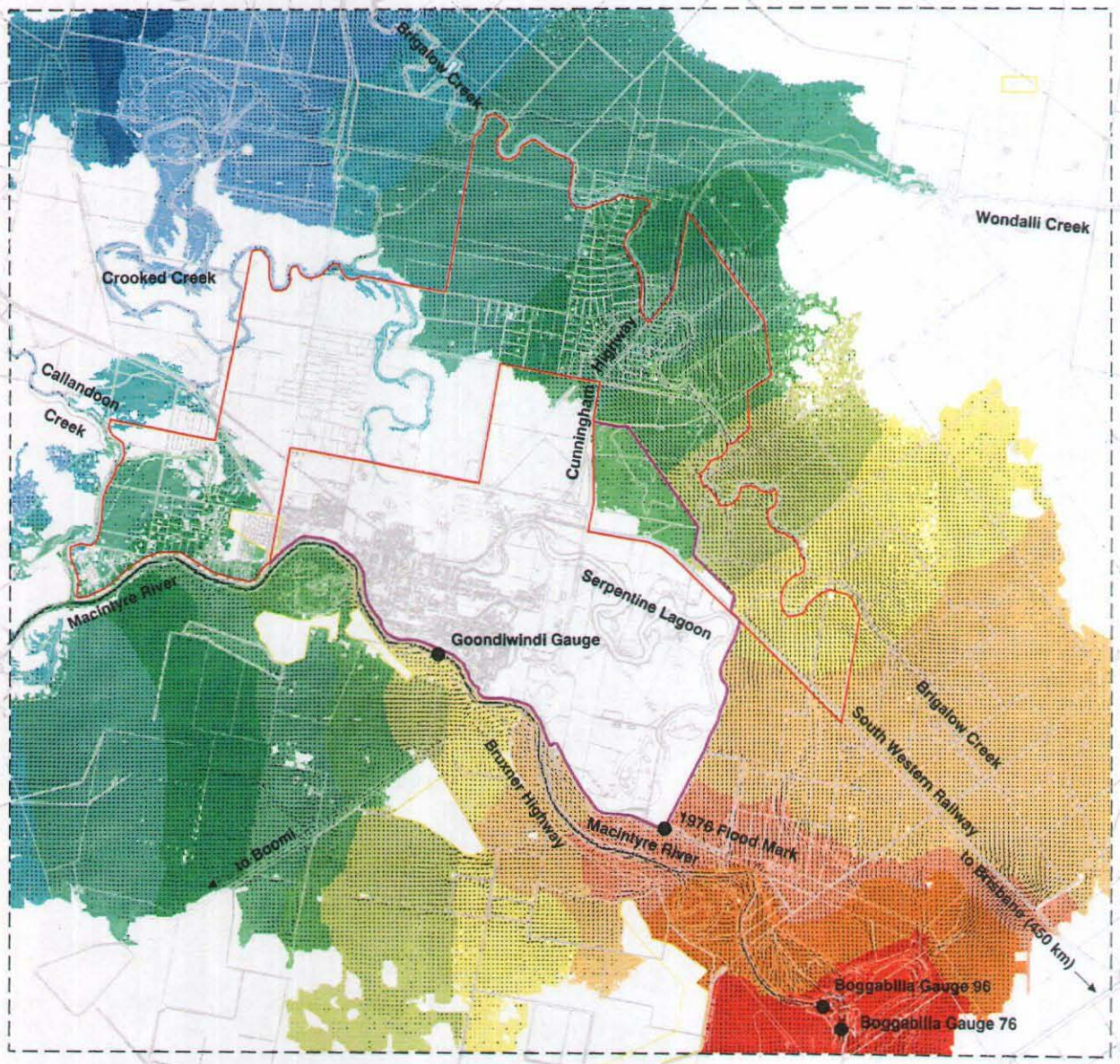
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1s3\Figure 2.4_12 2006 PMP BREN.dwg
XREF's: J7803\FigureBase, Levees 1996, Results_Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 11:28am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 3.1

1976 FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

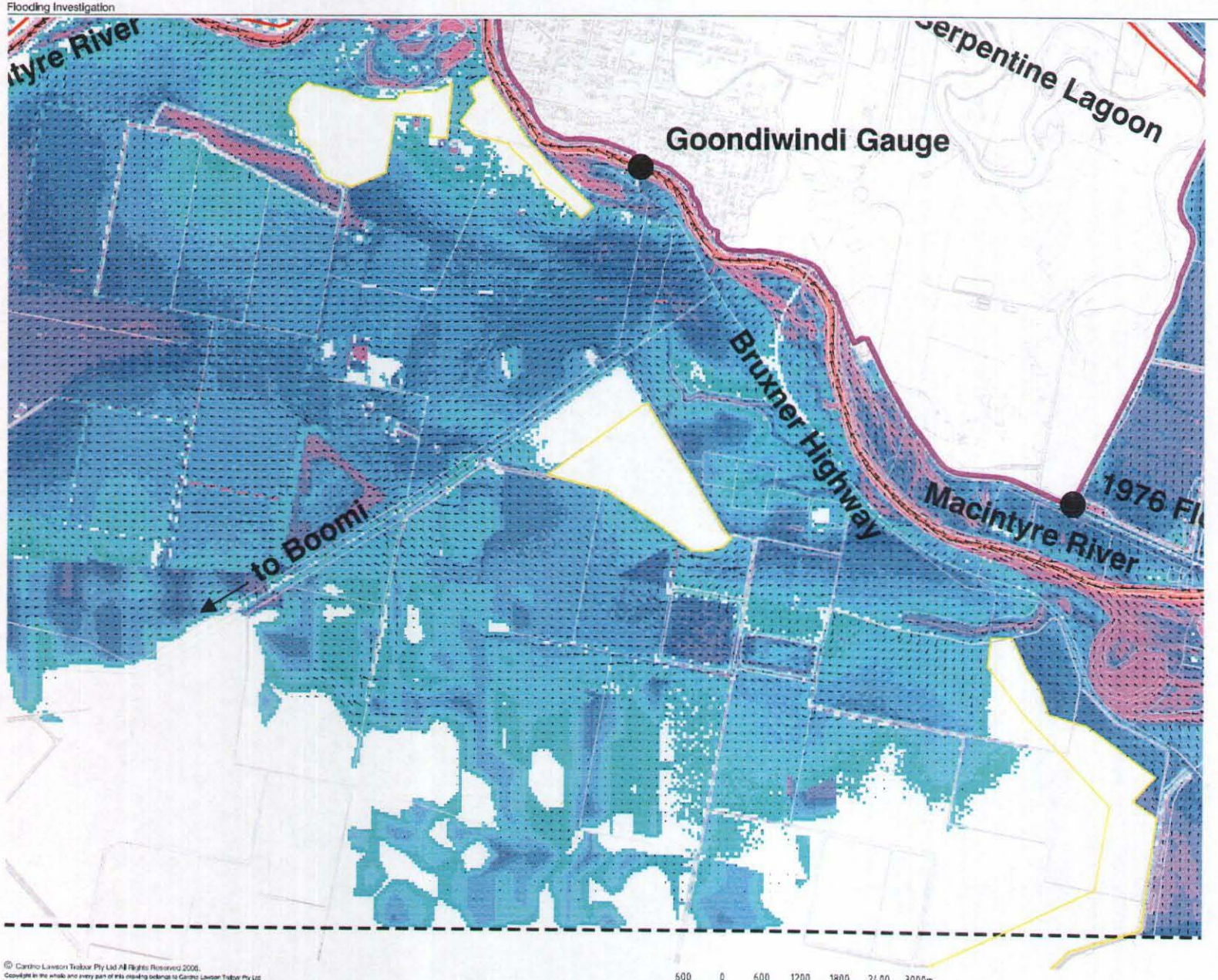
Waggamba Shire Council

CAD FILE: G:\Work\LAT\LJ8651\Acad\Rpt\Figure 2.1_3 1976.dwg
XREF's: J7603FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_Text

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:24 am

Cardno Lawson Treloar



LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Water Depth (m)

- Above 8.00
- 6.00 to 8.00
- 4.00 to 6.00
- 2.00 to 4.00
- 1.50 to 2.00
- 1.00 to 1.50
- 0.80 to 1.00
- 0.60 to 0.80
- 0.40 to 0.60
- 0.20 to 0.40
- 0.05 to 0.20

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 3.2

1976 FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

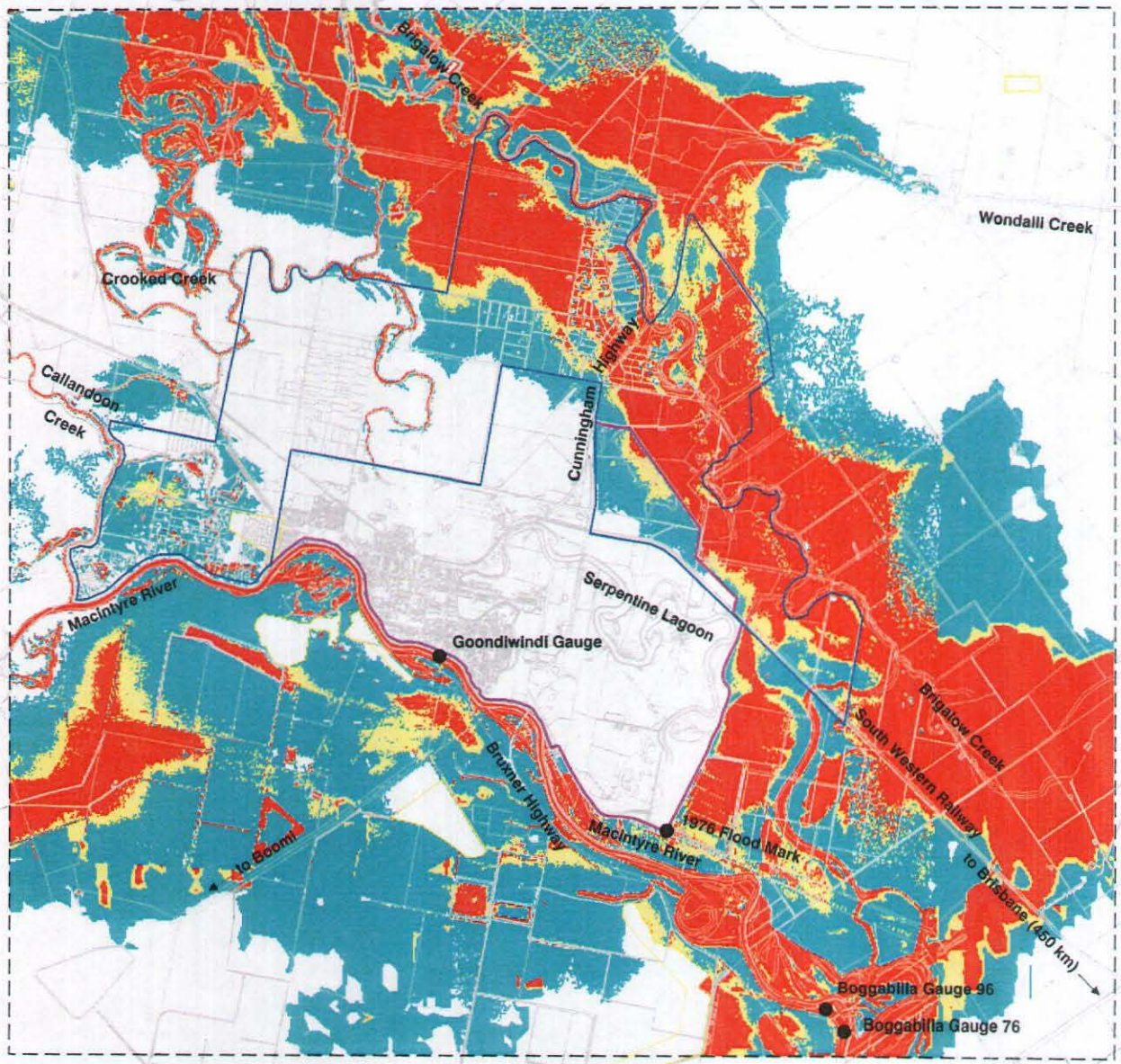
Waggamba Shire Council

CAD FILE: G:\Work\LA71_08651\Acad\Riv2\Figure 2.1_3 1976.dwg
XREFs: J7803Figure Base, Levees 1956, Results, Waggamba_Shire_2005, HAZARD, R1_test

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:26am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

600 0 600 1200 1800 2400 3000m
1:60,000

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\3\Figure 2.1_3 1976.dwg
XREFs: J7803\FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_levs

Scale 1:60,000 (A3)

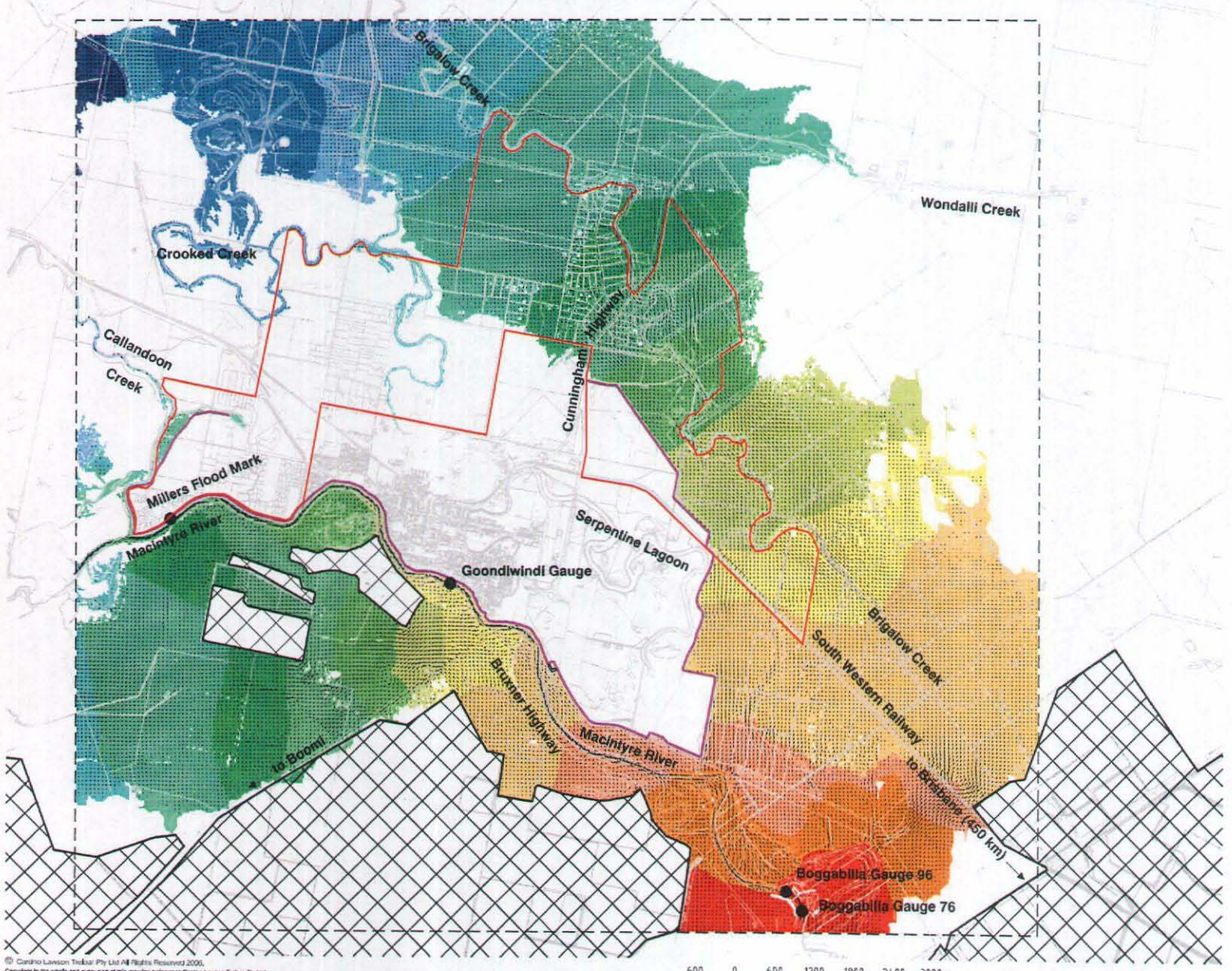
FIGURE 3.3

1976 FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:36am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

600 0 600 1200 1800 2400 3000m
1:60,000

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1v3\Figure 2.2_4 1996.dwg
XREFs: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Scale 1:60,000 (A3)

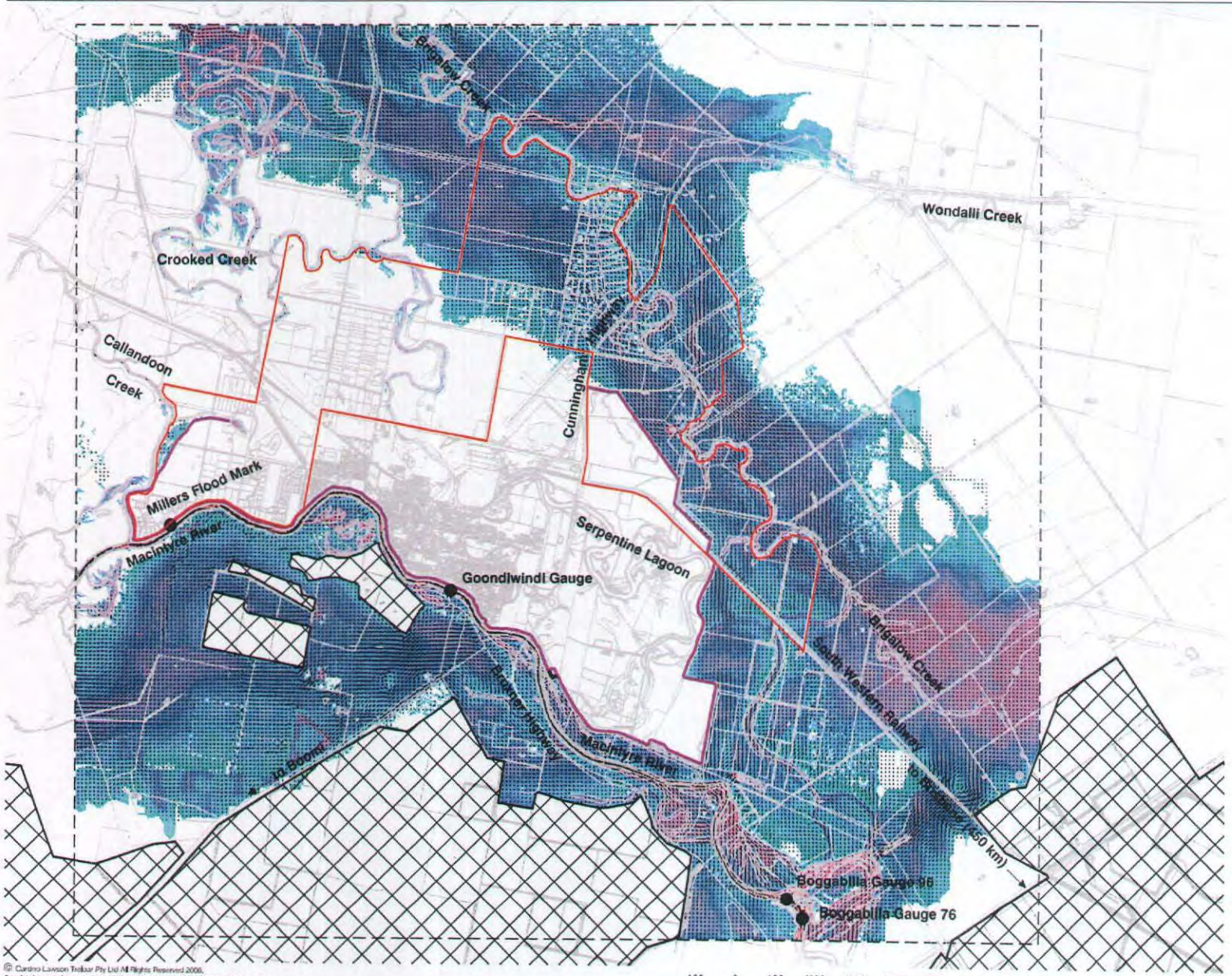
FIGURE 4.1

1996 FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:55am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 4.2

1996 FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

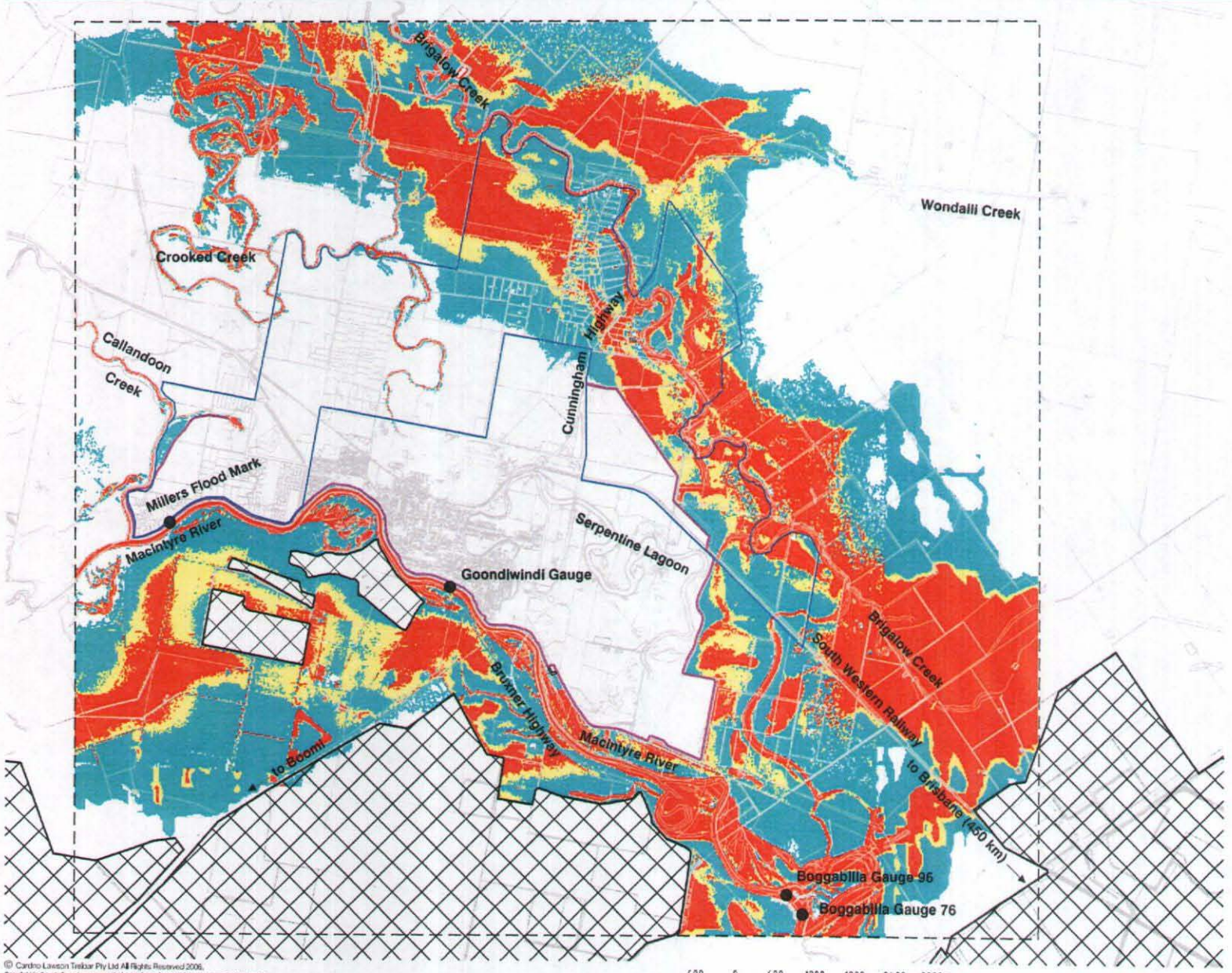
Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1x3\Figure 3.2_x 1996.dwg
XREF's: J7483FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_test

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 8:36am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

600 0 600 1200 1800 2400 3000m
1:60,000

Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\J8Figure 2.2_4 1996.dwg
XREFs: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Scale 1:60,000 (A3)

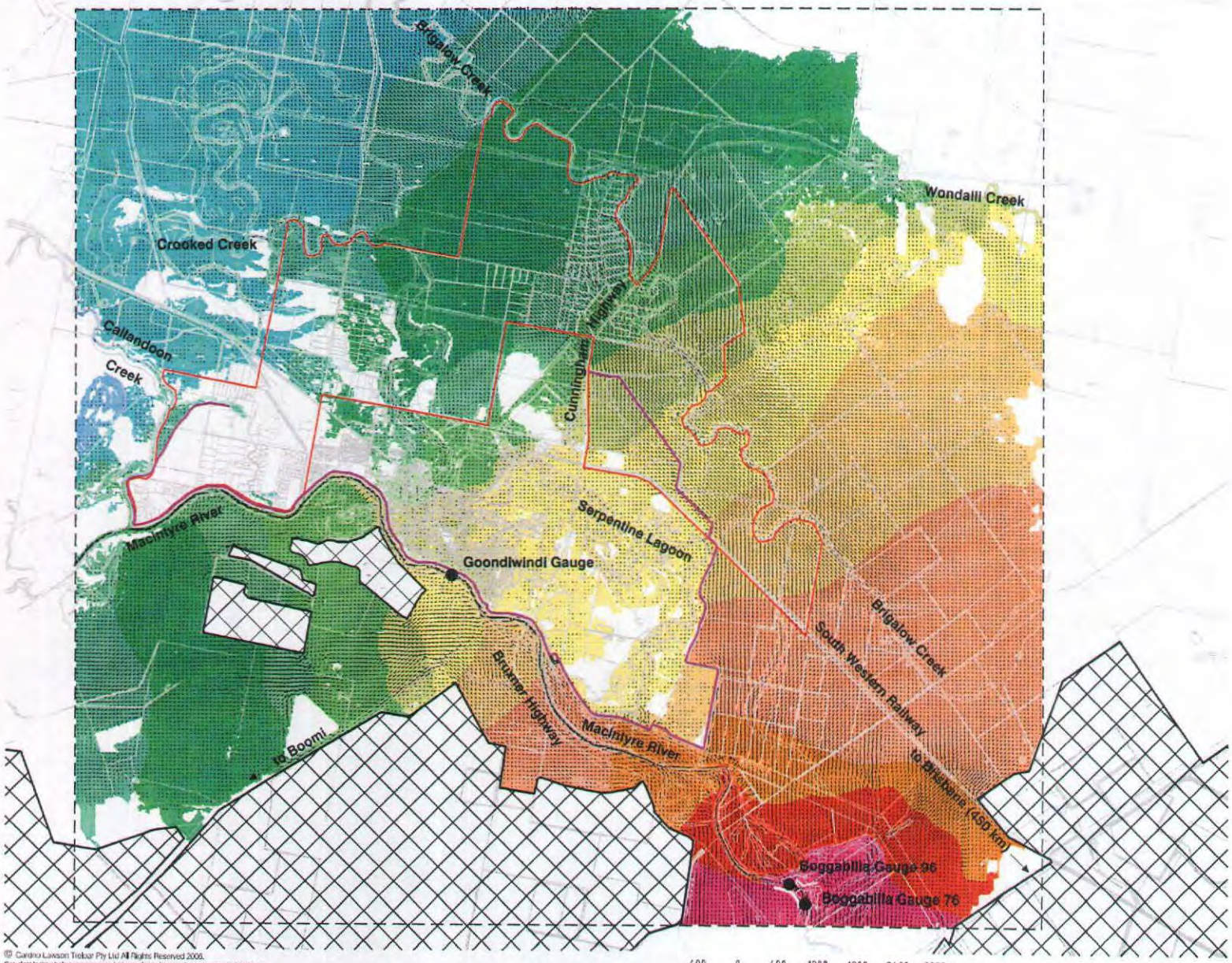
FIGURE 4.3

1996 FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 9:04am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 5.1

2*1976 FLOOD (ASSUMED PMF) FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

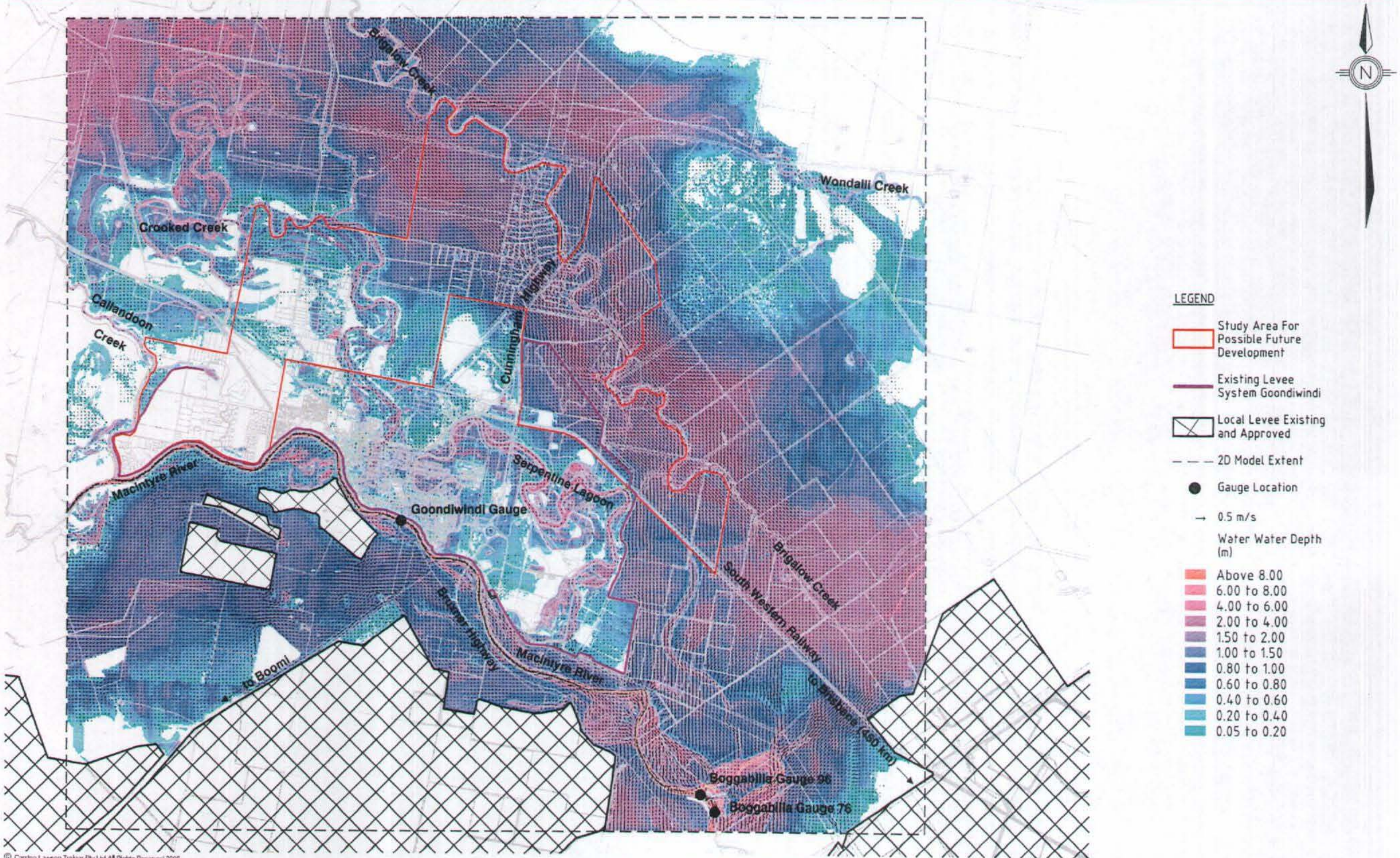
Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1\Figure 5 2006 PMF.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_3005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 9:56am

Cardno Lawson Treloar



Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 5 2006 PMF.dwg
XREF's: J7803FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_Text

Scale 1:60,000 (A3)

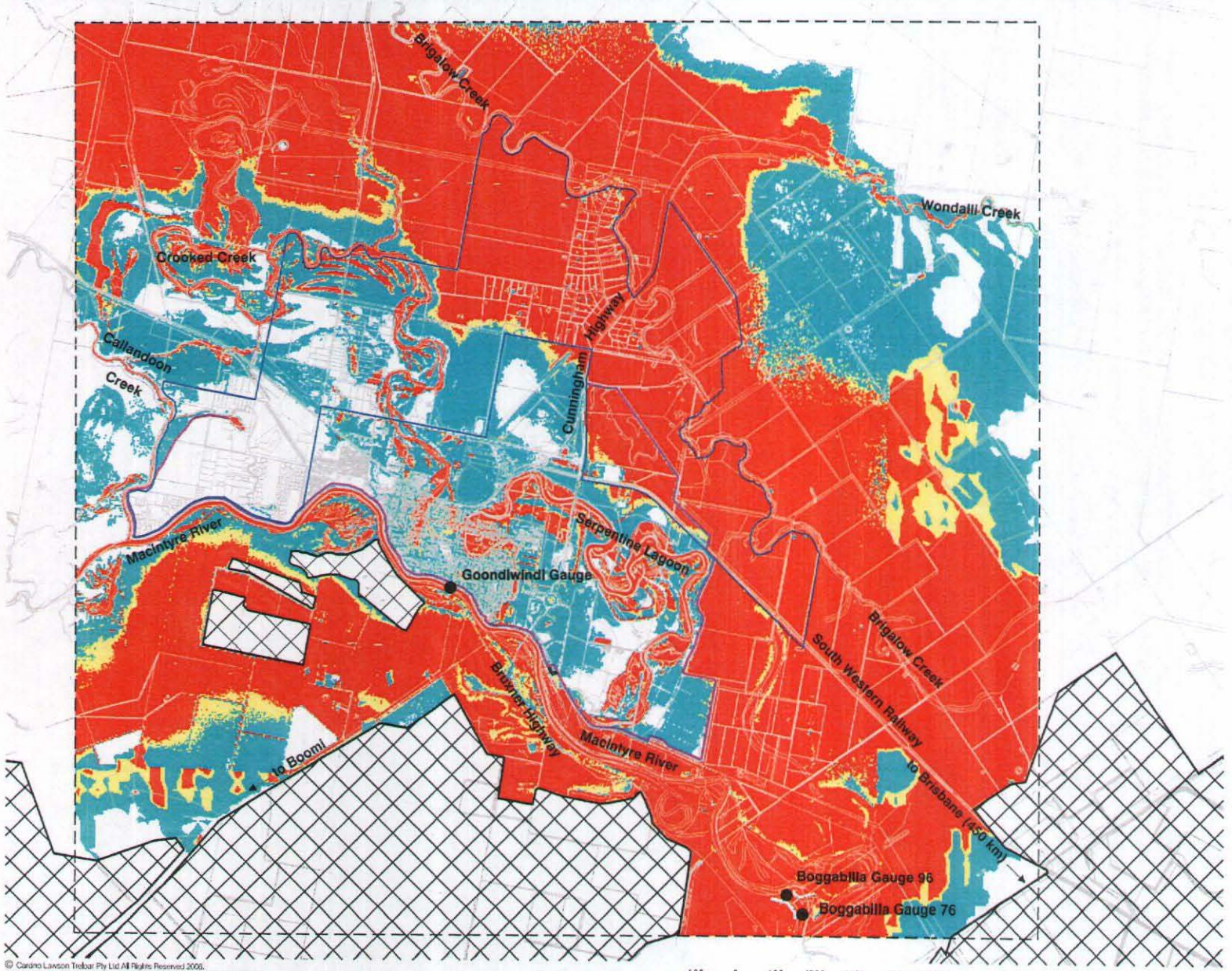
FIGURE 5.2

2*1976 FLOOD (ASSUMED PMF) FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 9:55am

Cardno Lawson Treloar



Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1v3\Figure 5 2006 PMF.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2025, HAZARD, R1_text

Scale 1:60,000 (A3)

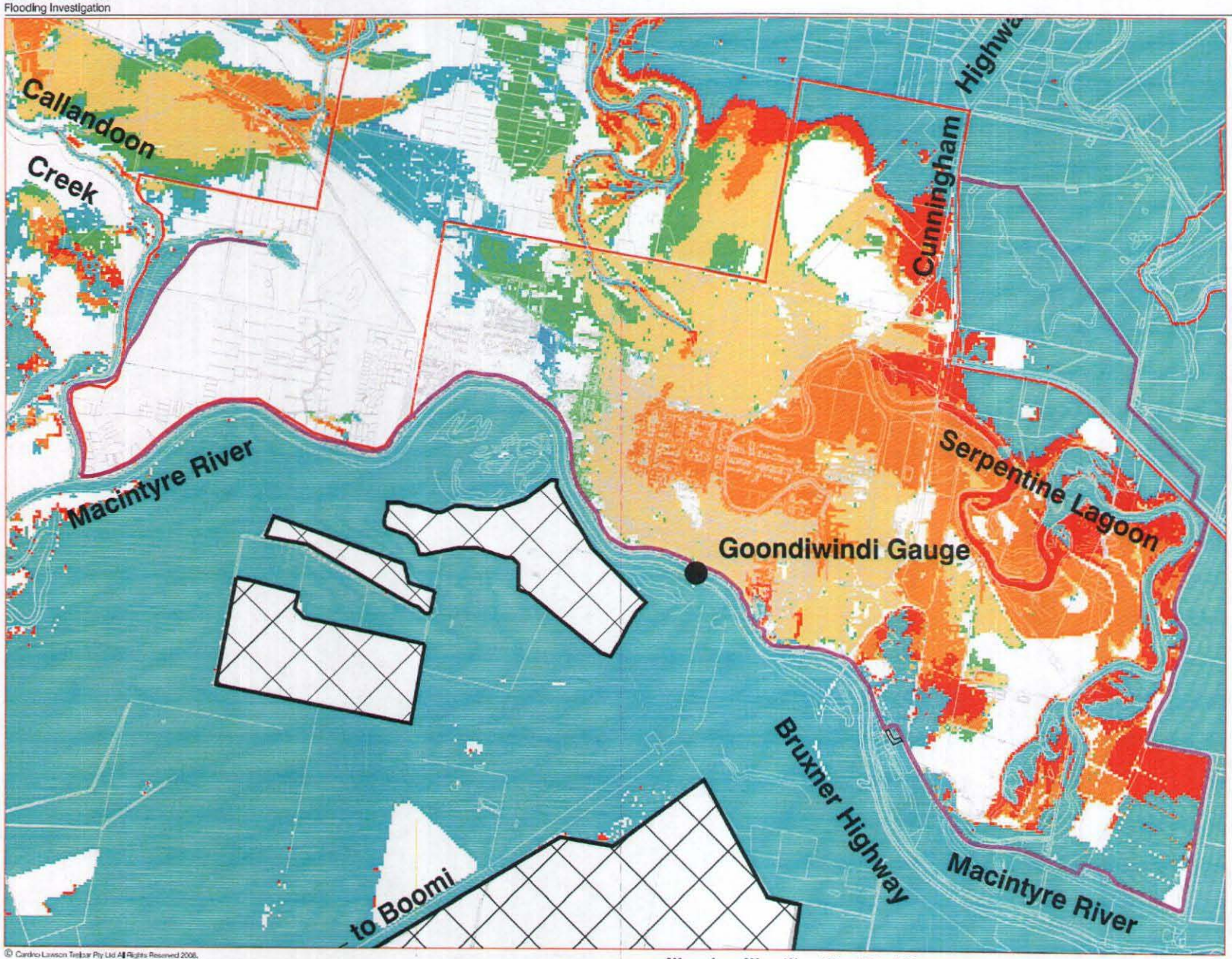
FIGURE 5.3

2*1976 FLOOD (ASSUMED PMF) FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 16 March, 2007 - 9:56am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Time to flood after first overtopping occurs

- 3 hours
- 6 hours
- 12 hours
- 18 hours
- 24 hours
- 36 hours
- 48 hours

300 0 300 600 900 1200 1500m
1:30,000

Scale 1:30,000 (A3)

FIGURE 5.4

PMF FLOODING EVENT - TIME TO FLOOD FROM START OF OVERTOPPING OF LEVEE BANKS

Rev: Orig. Date: September 2006

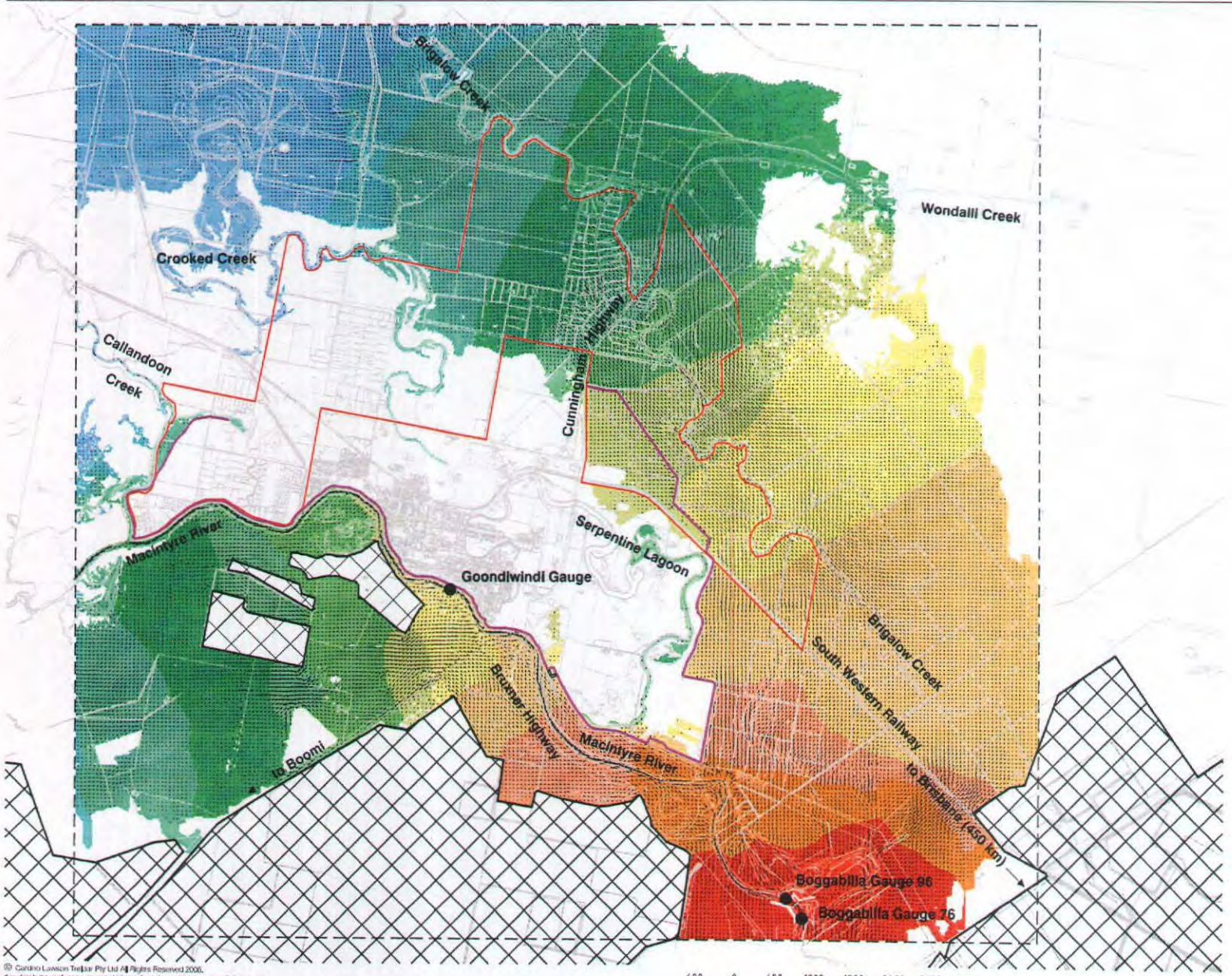
Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: O:\Work\LJ\8651\Acad\R1\2006 PMF Time To Flood.dwg
XREF's: J:\803\FigureBase, Levees 1996, Waggamba_Shire_2005, R1_text, Color_legend, Results3h, Results6h, Results12h, Results18h, Results24h, Results36, Results48

PRINT DATE: 27 September, 2006 - 1:33pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 6.1

0.2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

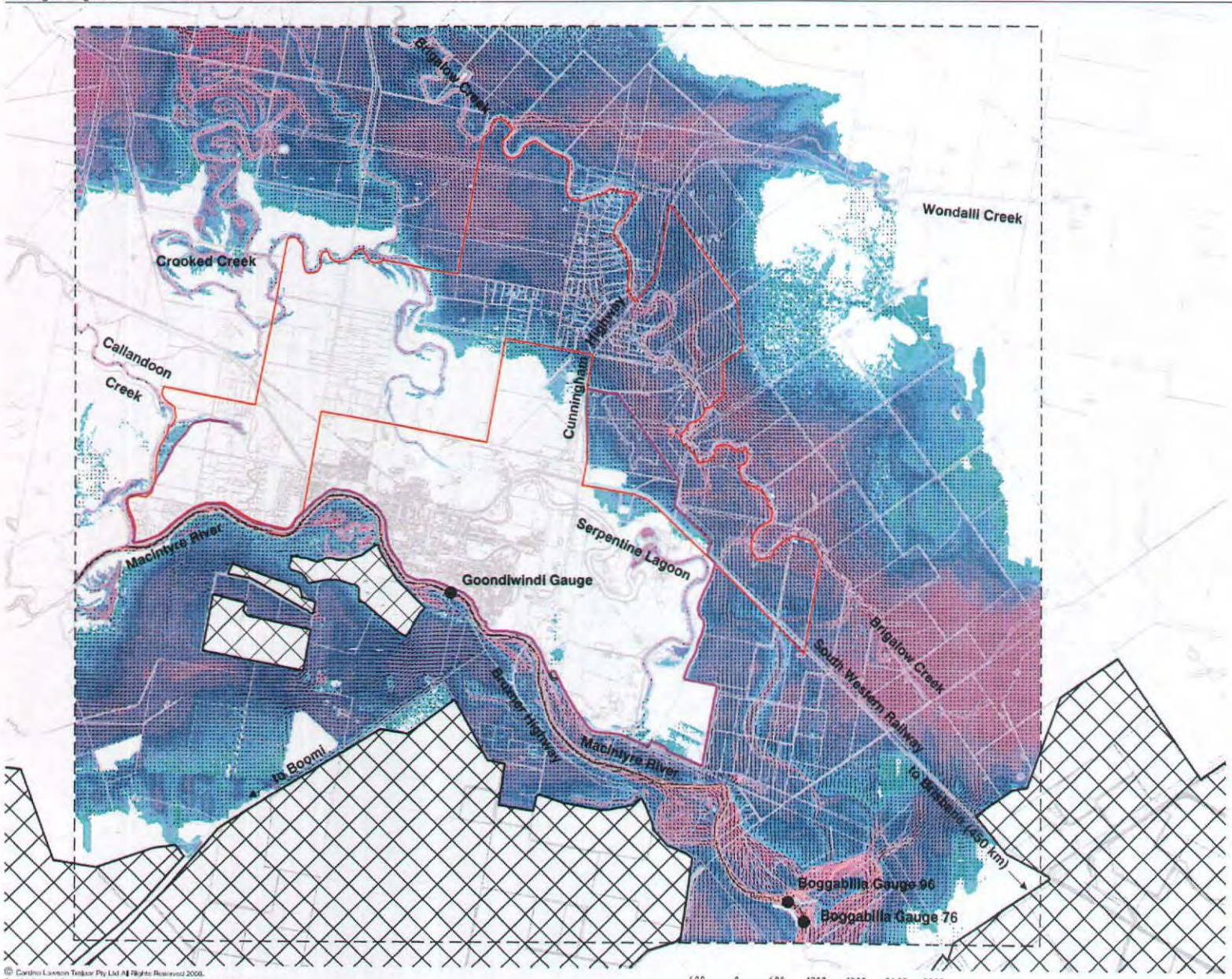
Waggamba Shire Council

CAD FILE: O:\Work\LAT\LJ8651\Acad\R1\2006 Q500.dwg
XREF's: J7683FigureBase, Levees 1996; Results, Waggamba_Shire_2005, HAZARD_R1_Text

Project No.: LJ8651/R1

PRINT DATE: 14 September, 2006 - 9:06pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Water Depth (m)

- Above 8.00
- 6.00 to 8.00
- 4.00 to 6.00
- 2.00 to 4.00
- 1.50 to 2.00
- 1.00 to 1.50
- 0.80 to 1.00
- 0.60 to 0.80
- 0.40 to 0.60
- 0.20 to 0.40
- 0.05 to 0.20

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 6.2

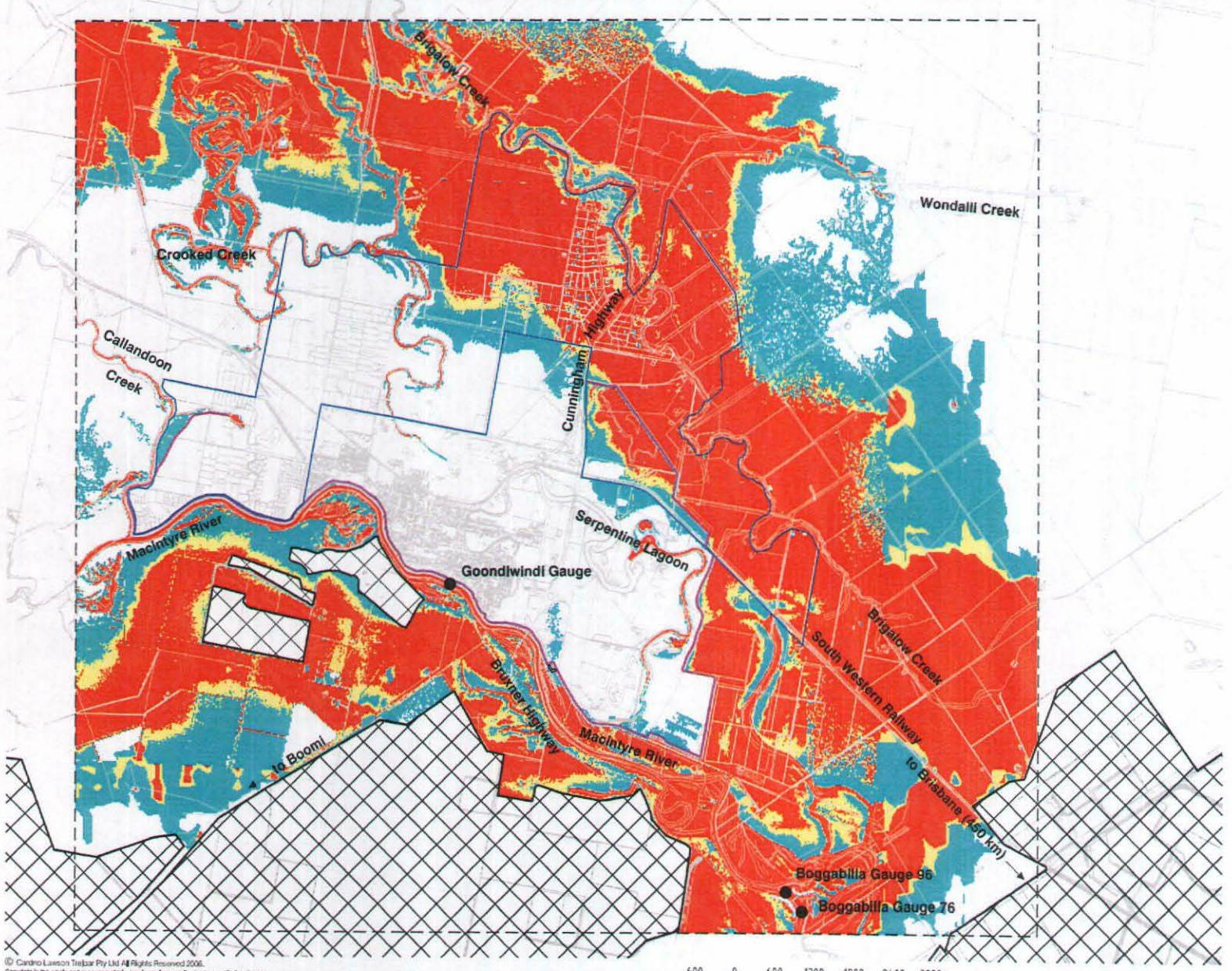
0.2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

Waggamba Shire Council
CAD FILE: G:\Work\LAT\J8651\Acad\R1\2006 0505.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1
PRINT DATE: 14 September, 2006 - 9:04pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 6.3

0.2% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: September 2006

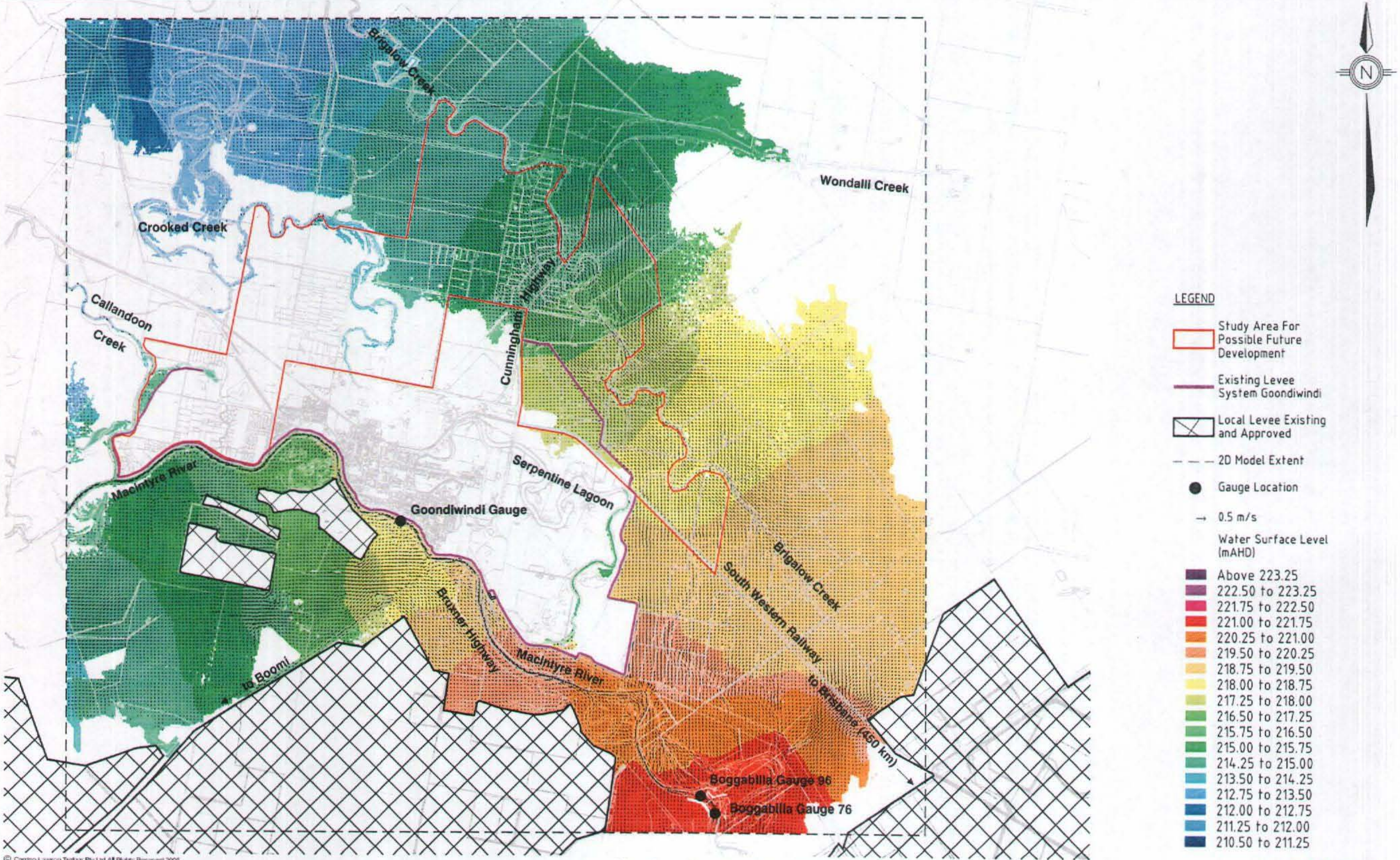
Waggamba Shire Council

CAD FILE: G:\Work\LAT\LJ8651\Acad\R1\2006 0508.dwg
XREF's: J1603FigureBase, Levees 1996, Results; Waggamba_Shire_2005, HAZARD, R1_test

Project No.: LJ8651/R1

PRINT DATE: 28 September, 2006 - 1:19pm

Cardno
Lawson Treloar

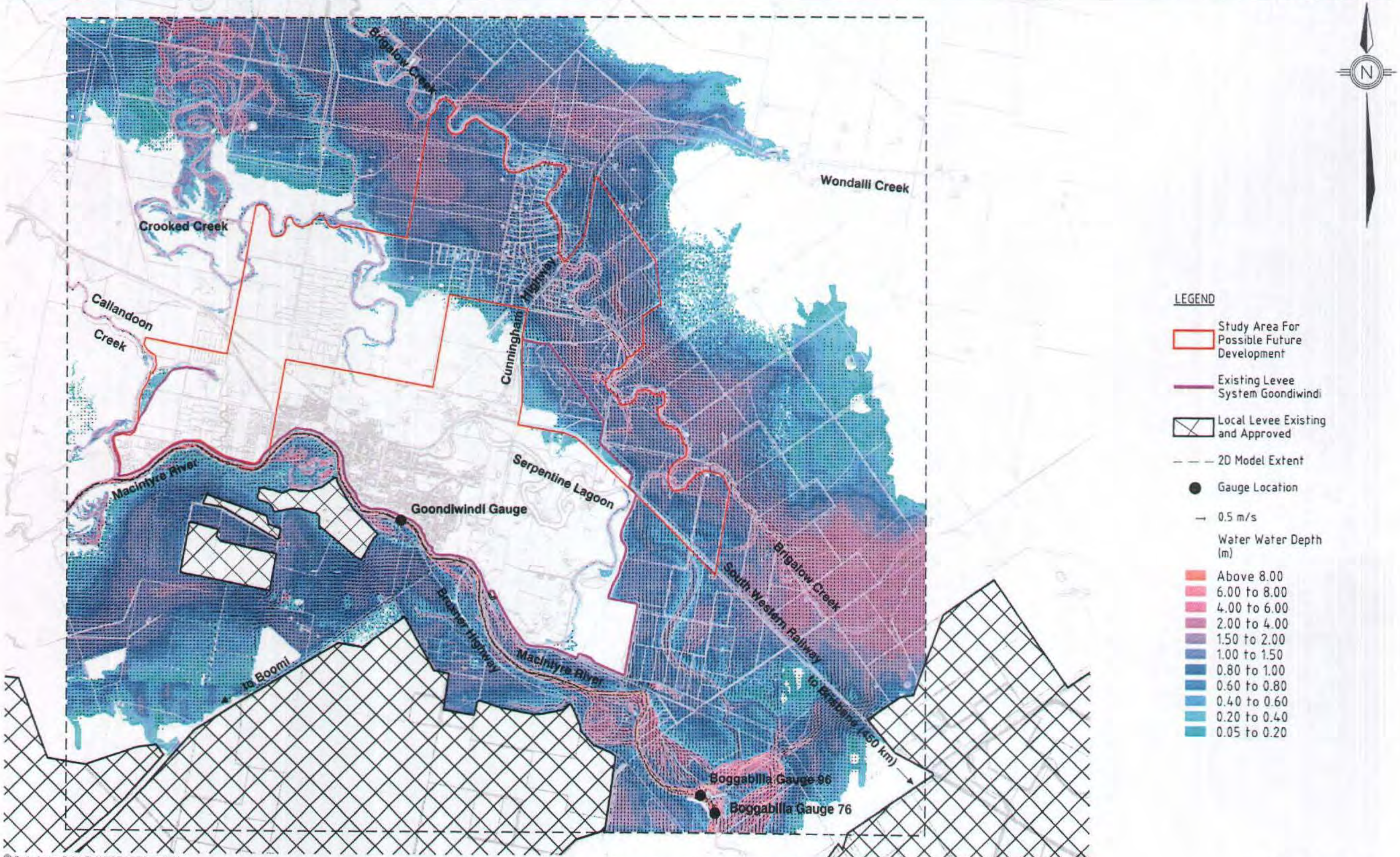

Brigalow Creek
Wondalli Creek
Crooked Creek
Callandoon
Creek
Cunningham Highway
Serpentine Lagoon
Macintyre River
Goondiwindi Gauge
Bruxner Highway
Brigalow Creek
South Western Railway
to Brisbane (450 km)
Macintyre River
to Boomi
Boggabilla Gauge 96
Boggabilla Gauge 76
N
LEGEND
Study Area For Possible Future Development
Existing Levee System Goondiwindi
Local Levee Existing and Approved
2D Model Extent
Gauge Location
0.5 m/s
Water Surface Level (mAHD)
Above 223.25
222.50 to 223.25
221.75 to 222.50
221.00 to 221.75
220.25 to 221.00
219.50 to 220.25
218.75 to 219.50
218.00 to 218.75
217.25 to 218.00
216.50 to 217.25
215.75 to 216.50
215.00 to 215.75
214.25 to 215.00
213.50 to 214.25
212.75 to 213.50
212.00 to 212.75
211.25 to 212.00
210.50 to 211.25
600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 7.1

0.5% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 7.2

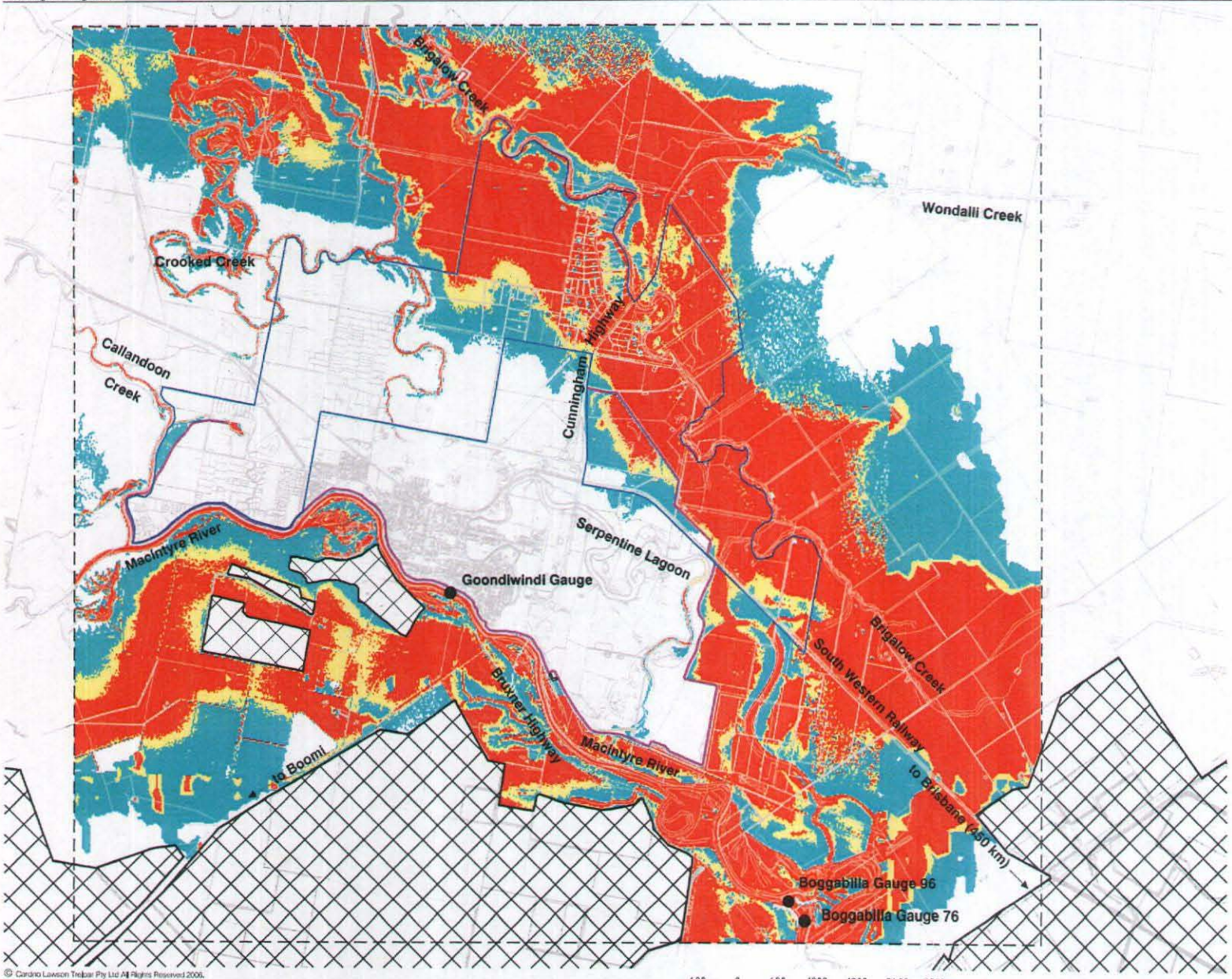
0.5% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

Waggamba Shire Council
CAD FILE: O:\Work\LAT\J8651\Acad\R1\2506 0200.dwg
XREF's: J8651FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1
PRINT DATE: 14 September, 2006 - 5:01pm

Cardno Lawson Treloar



Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 Q700.dwg
XREF's: J7603FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Scale 1:60,000 (A3)

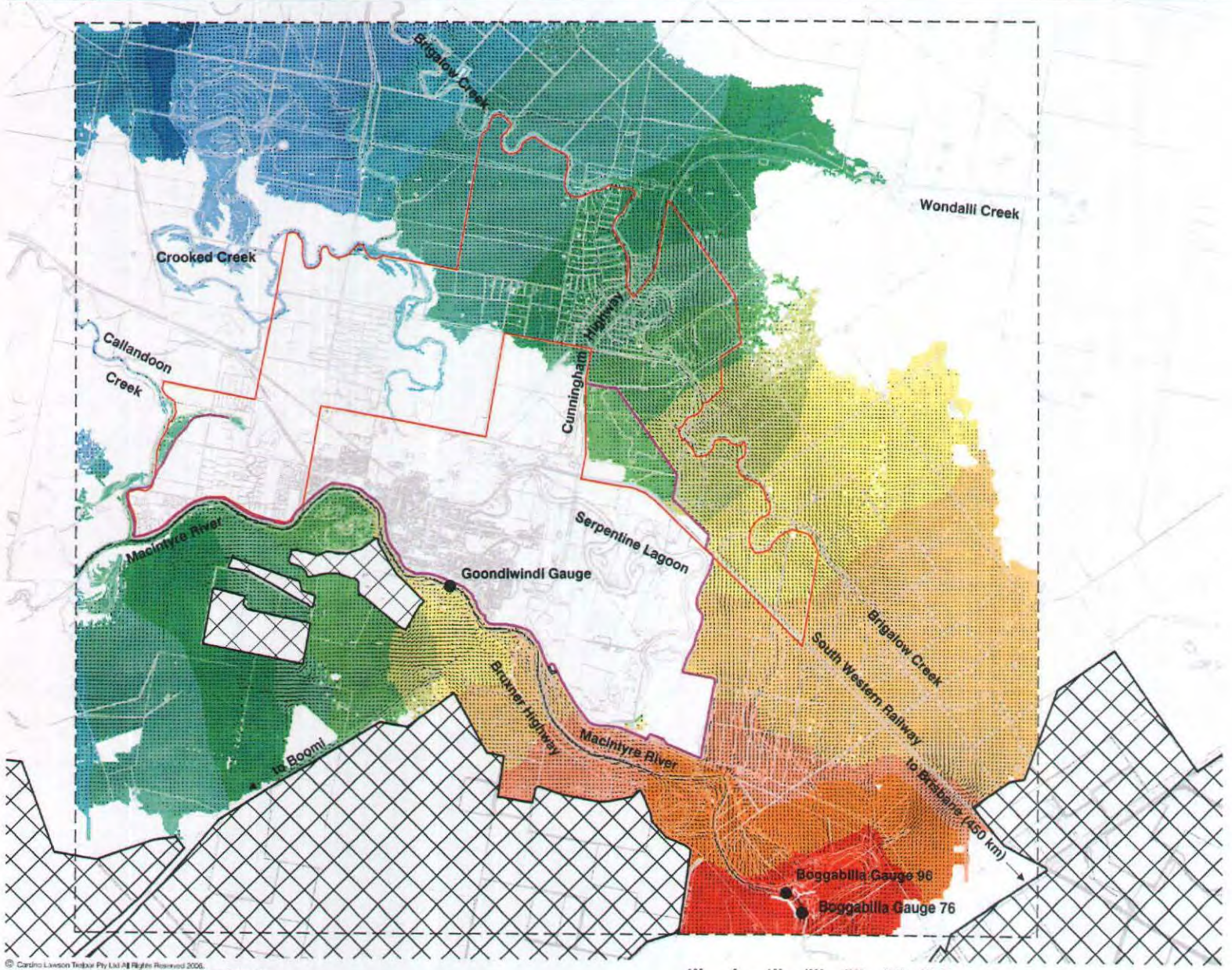
FIGURE 7.3

0.5% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 20 September, 2006 - 7:34pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 8.1

1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

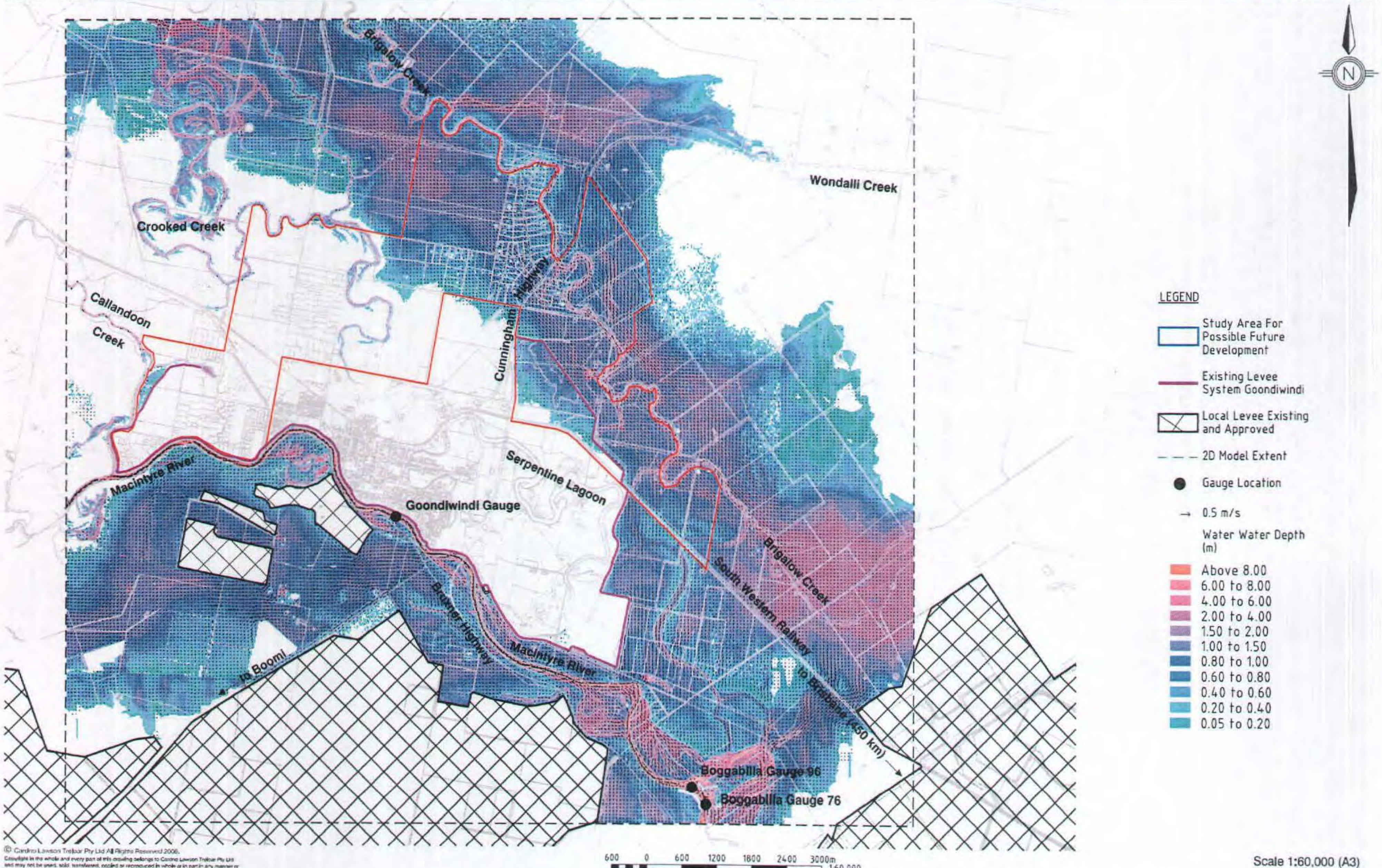
Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1\2006 Q100.dwg
XREFs: J7883FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 21 September, 2006 - 9:41am


Brigalow Creek
Wondalli Creek
Crooked Creek
Callandoon Creek
Cunningham Highway
Macintyre River
Serpentine Lagoon
Goondiwindi Gauge
Brigalow Creek
South Western Railway
to Brisbane (450 km)
Bruxner Highway
Macintyre River
to Boomi
Boggabilla Gauge 96
Boggabilla Gauge 76
LEGEND
Study Area For Possible Future Development
Existing Levee System Goondiwindi
Local Levee Existing and Approved
2D Model Extent
Gauge Location
0.5 m/s
Water Water Depth (m)
Above 8.00
6.00 to 8.00
4.00 to 6.00
2.00 to 4.00
1.50 to 2.00
1.00 to 1.50
0.80 to 1.00
0.60 to 0.80
0.40 to 0.60
0.20 to 0.40
0.05 to 0.20
N
600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

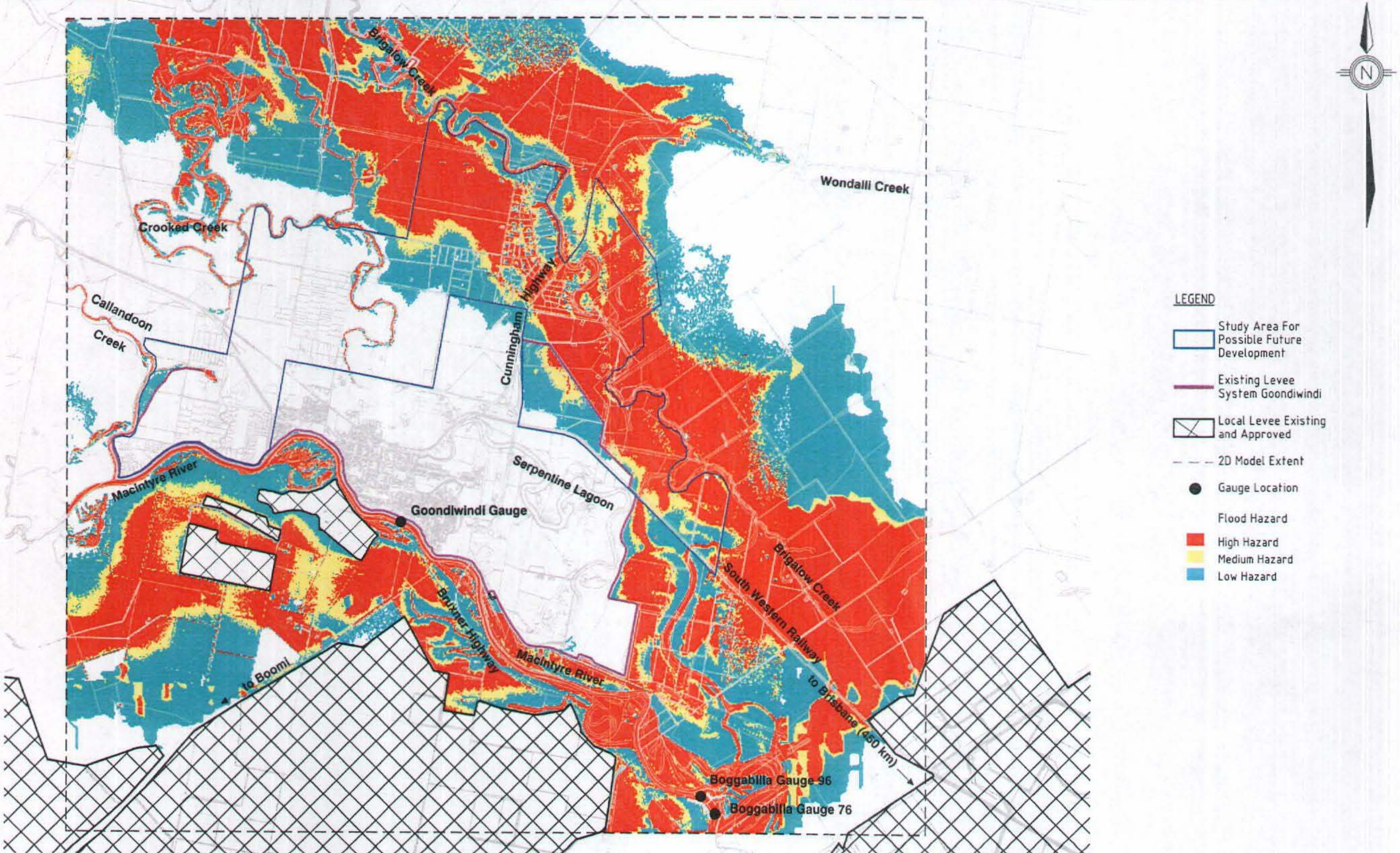
FIGURE 8.2

1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

Waggamba Shire Council
CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 0103.dwg
XREF's: J1883FigureBase; Levees 1996; Results; Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1
PRINT DATE: 14 September, 2006 - 9:42pm



Scale 1:60,000 (A3)

FIGURE 8.3

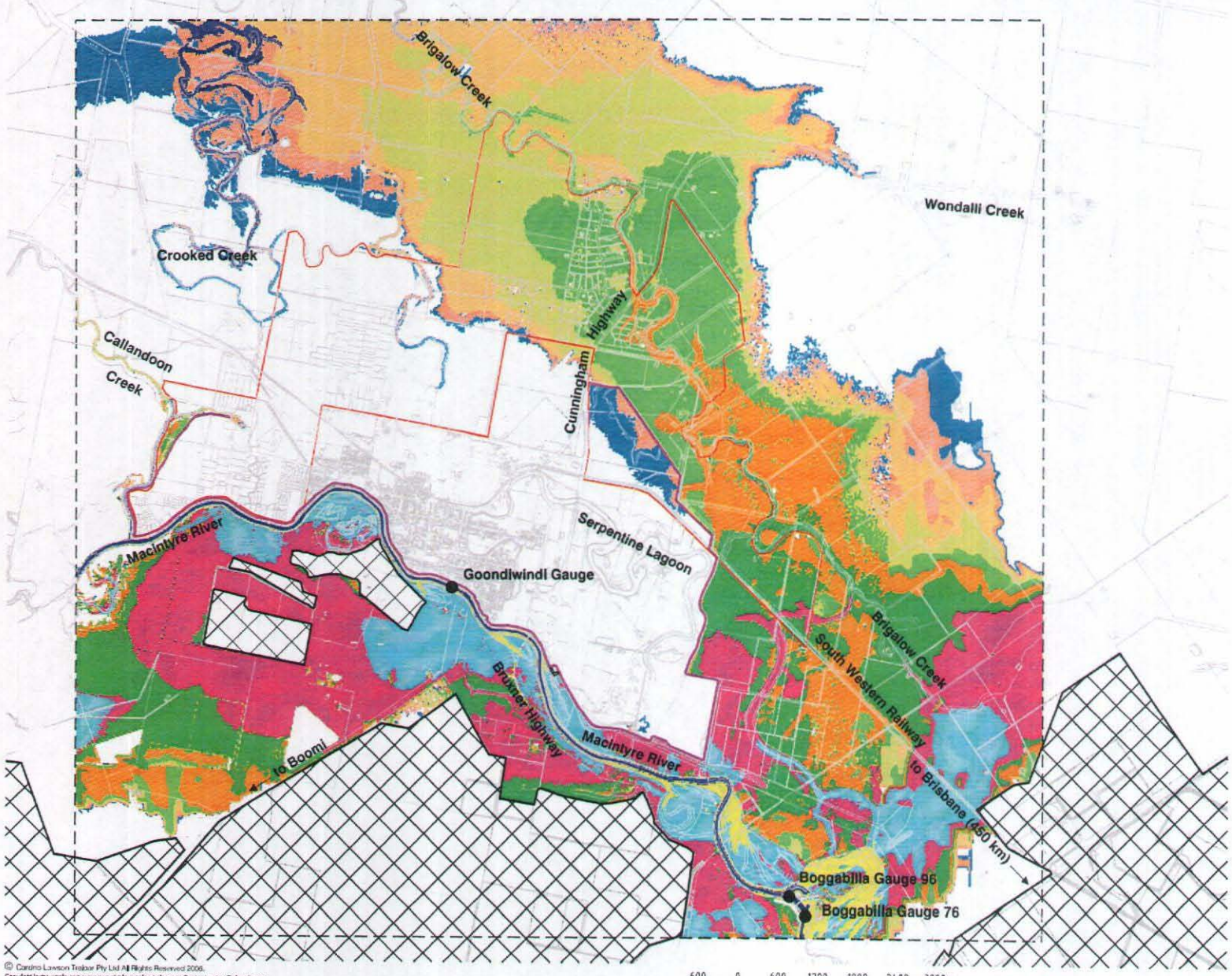
1% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: September 2006

Waggamba Shire Council
CAD FILE: O:\WorkLAT\J8651\Acad\R1\2006 0103.dwg
XREF's: J1803FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_text

Project No.: LJ8651/R1
PRINT DATE: 14 September, 2006 - 9:43pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 8.4

1% AEP FLOODING EVENT - TIME TO FLOOD FROM START OF 1% AEP FLOOD EVENT AT BOGGABILLA GAUGE

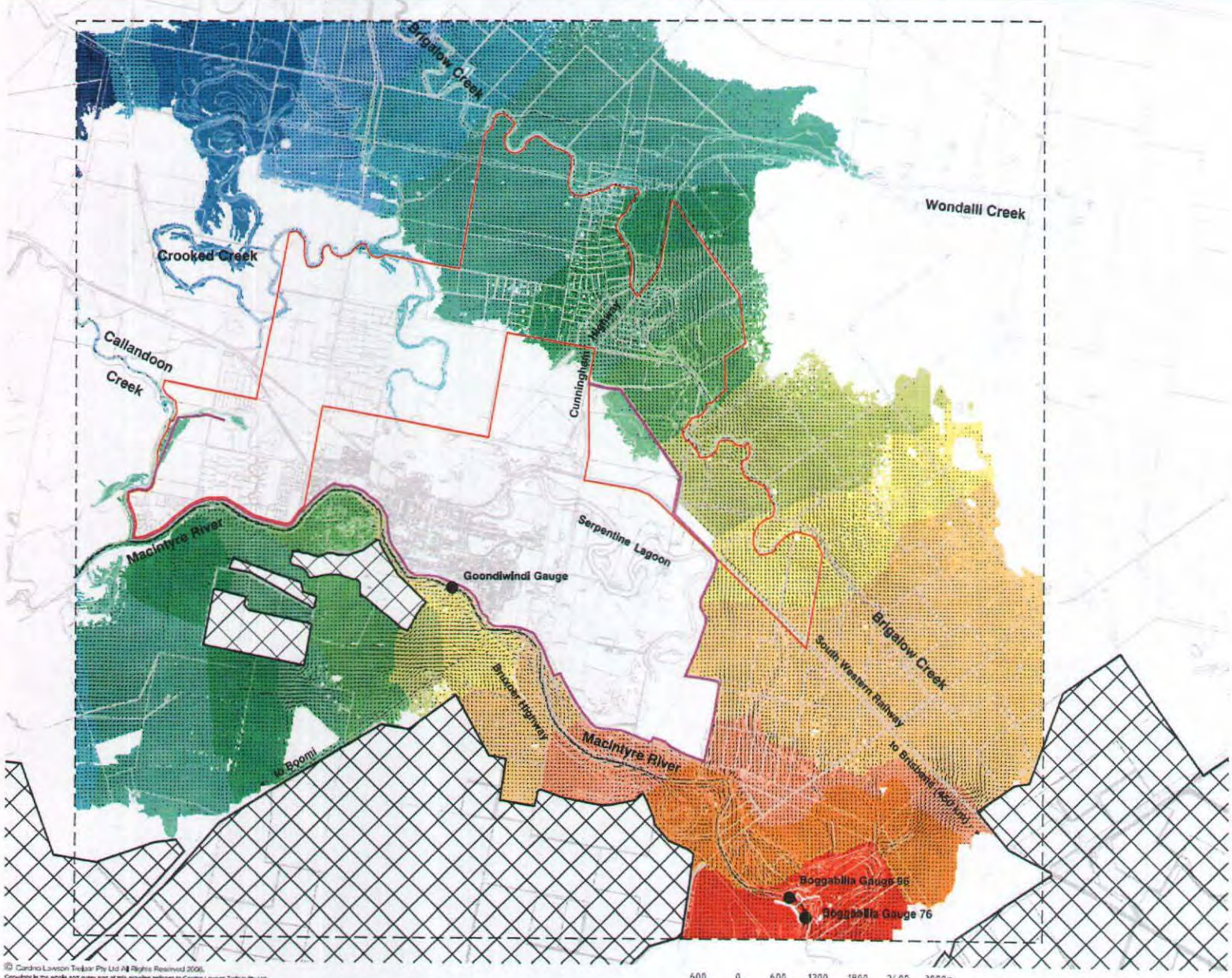
Rev: Orig. Date: September 2006

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: O:\Work\AT\J8651\Acad\R1\2006 Q100 Time To Flood.Dwg
XREF's: J7883FigureBase, Levees 1996, Waggamba_Shire_2005, R1_Text, Results4h, Results52h, Results8h, Results12h, Results16h, Results20h, Results24h, Results28h, Results32h, Results36h, Results40h, Results44h, Results48h, Color_legend
PRINT DATE: 27 September, 2006 - 1:36pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

Scale 1:60,000 (A3)

FIGURE 9.1

2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

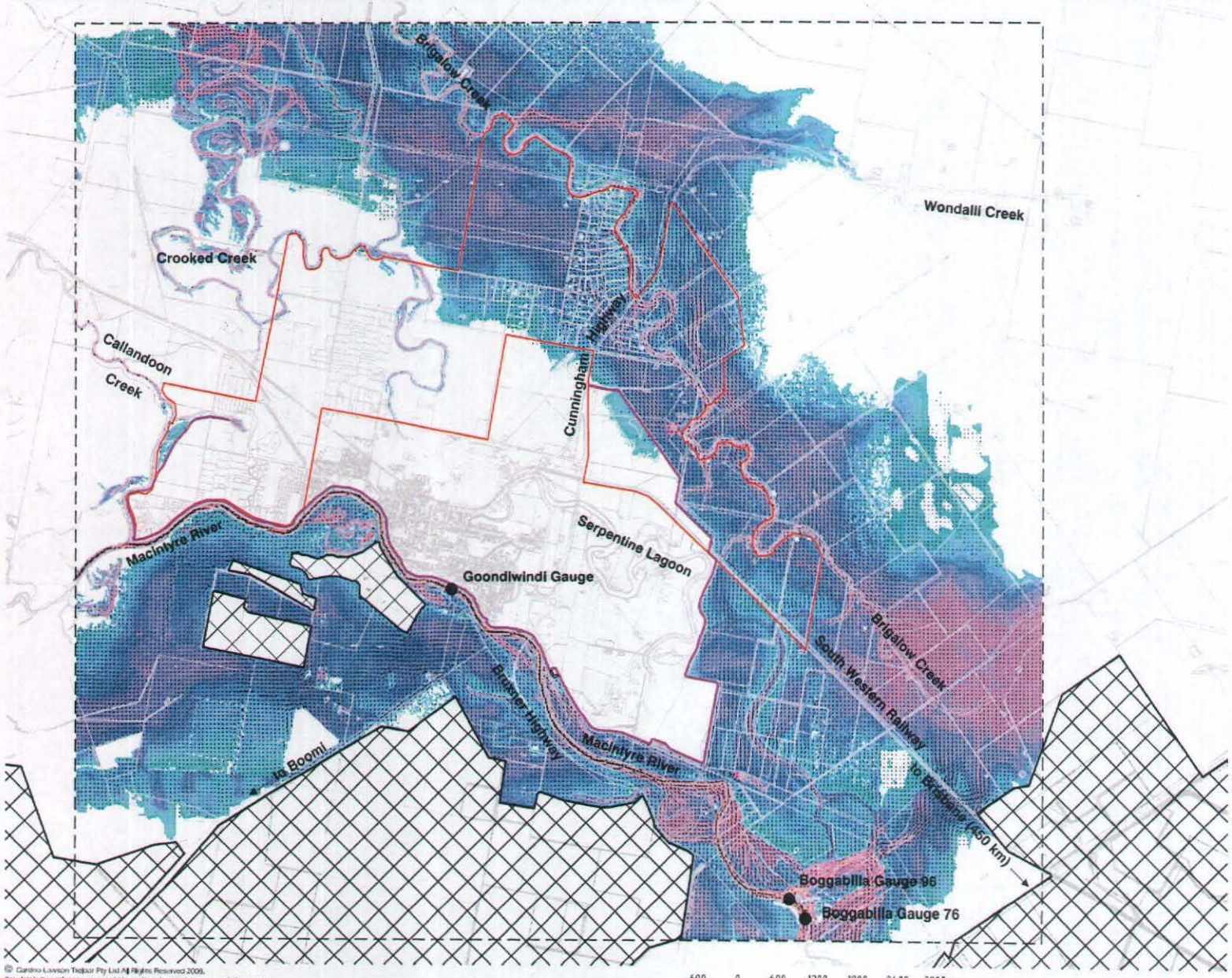
Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: D:\Work\LAT\J8651\Acad\R1\Base 2006 Q50 WLT.dwg
XREF's: J7883\FigureBase, Levees 1996, Results, Waggamba_Shire_2035, HAZARD

PRINT DATE: 14 September, 2006 - 10:15am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 9.2

2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

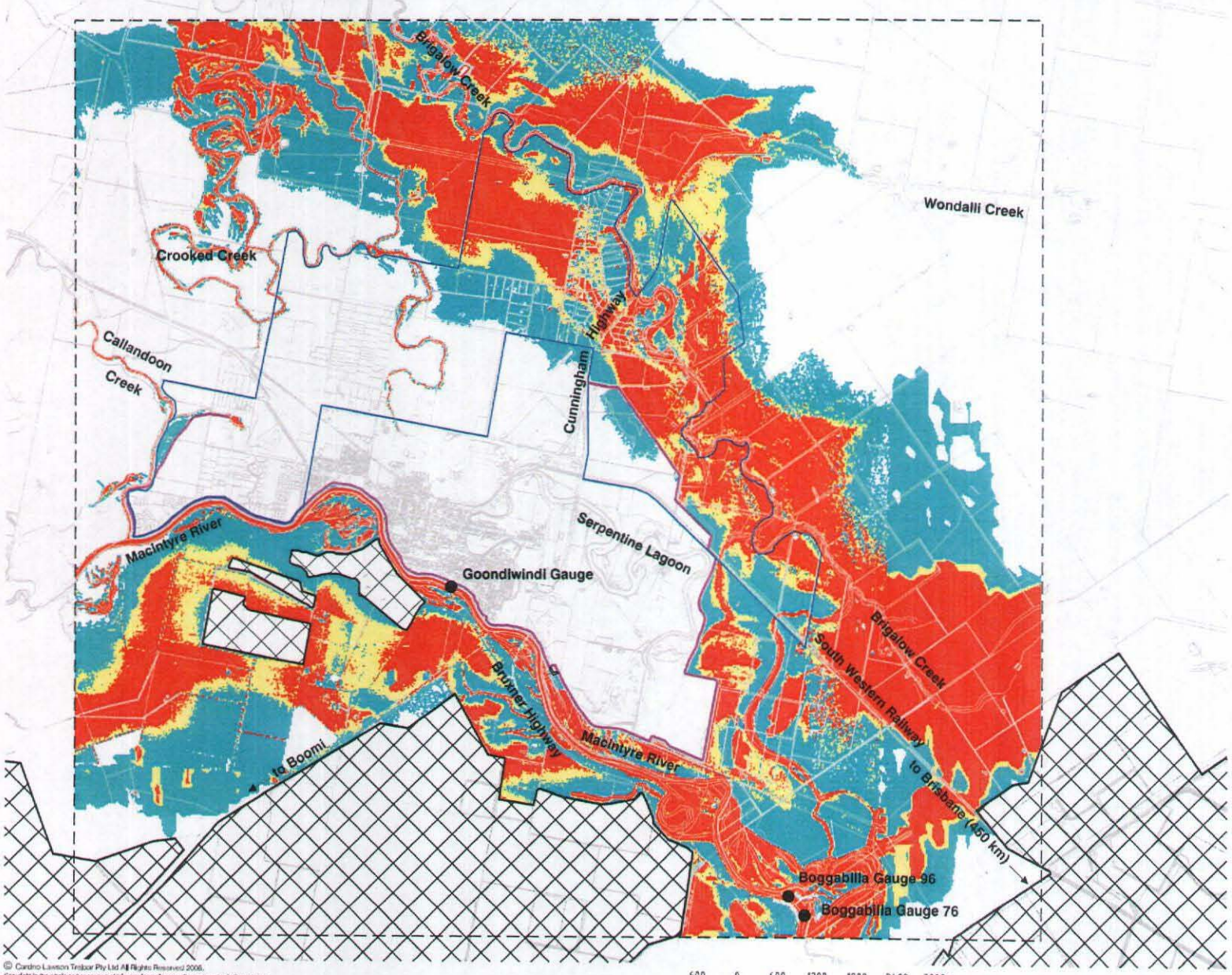
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 050.dwg
XREF's: J7803FigureBase; Levees 1996; Results; Waggamba_Shire_2005_HAZARD_R1_text

Project No.: LJ8651/R1

PRINT DATE: 14 September, 2006 - 9:45pm

Cardno Lawson Treloar



Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: O:\Work\LAT\LJ8651\Acad\R1\2006 050.dwg
XREF's: J1803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Scale 1:60,000 (A3)

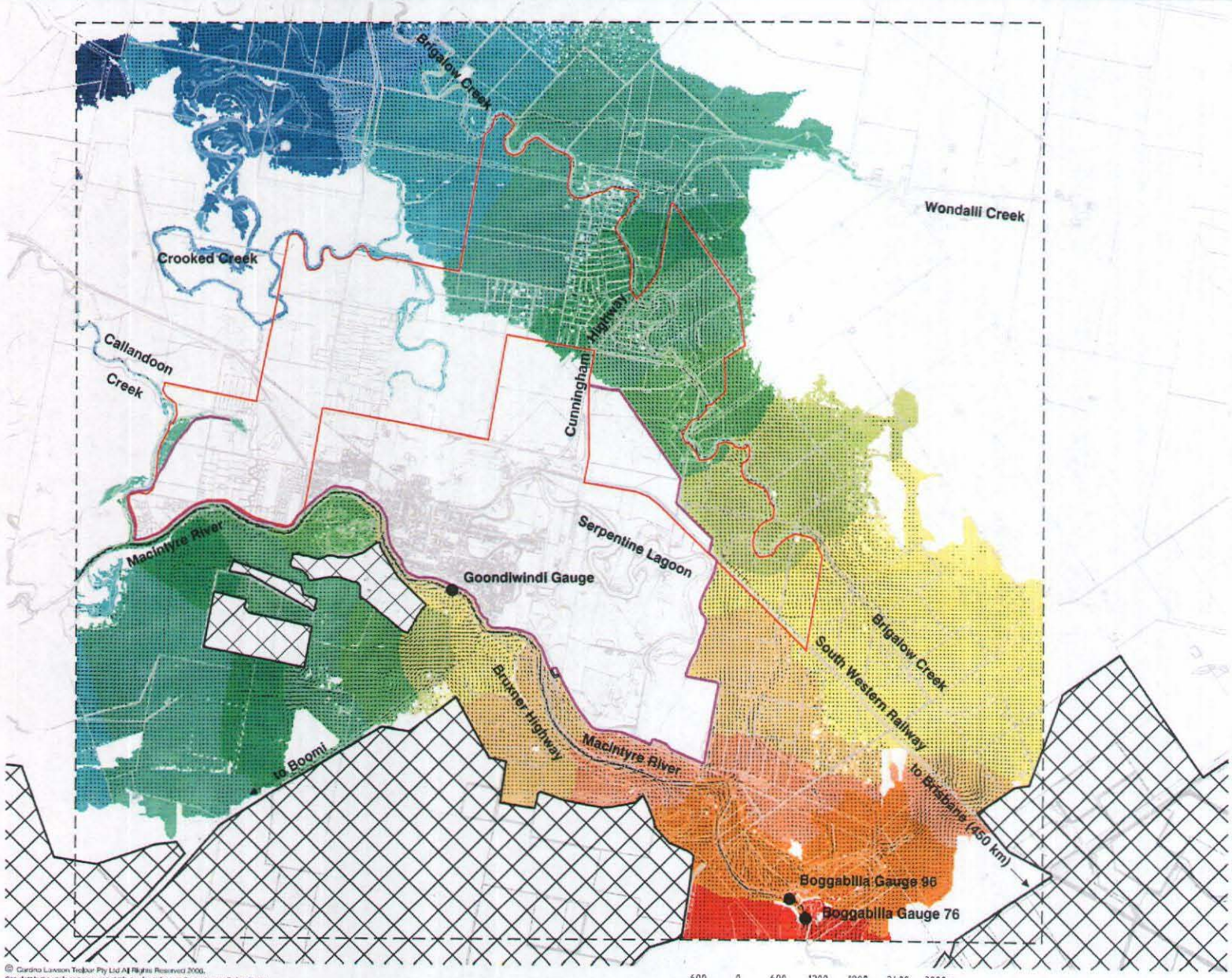
FIGURE 9.3

2% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 21 September, 2006 - 9:48am

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Surface Level (mAHD)

- Above 223.25
- 222.50 to 223.25
- 221.75 to 222.50
- 221.00 to 221.75
- 220.25 to 221.00
- 219.50 to 220.25
- 218.75 to 219.50
- 218.00 to 218.75
- 217.25 to 218.00
- 216.50 to 217.25
- 215.75 to 216.50
- 215.00 to 215.75
- 214.25 to 215.00
- 213.50 to 214.25
- 212.75 to 213.50
- 212.00 to 212.75
- 211.25 to 212.00
- 210.50 to 211.25

Scale 1:60,000 (A3)

FIGURE 10.1

5% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

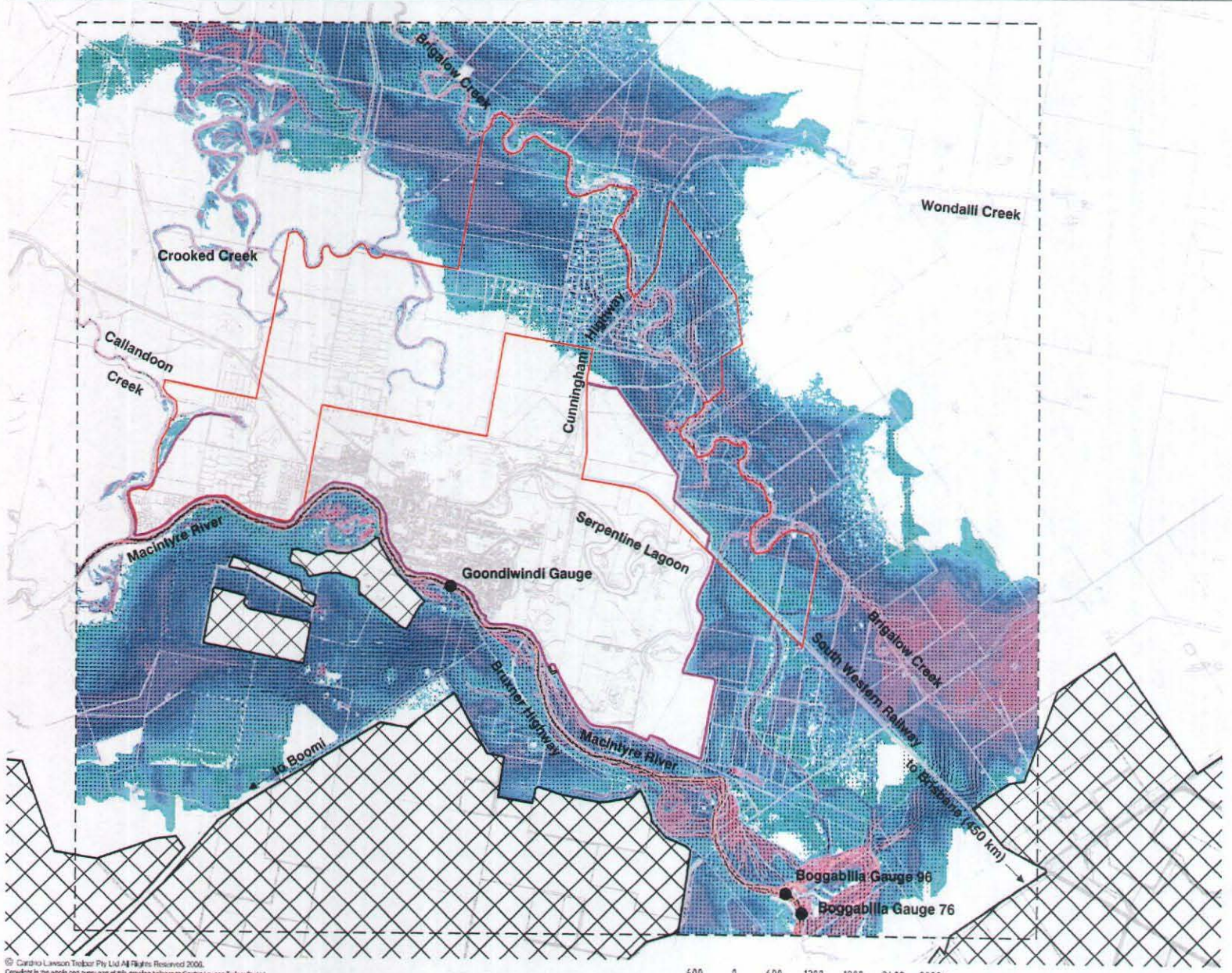
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 020.dwg
XREFs: J7863FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE 14 September, 2006 - 9:49pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Water Water Depth (m)

- Above 8.00
- 6.00 to 8.00
- 4.00 to 6.00
- 2.00 to 4.00
- 1.50 to 2.00
- 1.00 to 1.50
- 0.80 to 1.00
- 0.60 to 0.80
- 0.40 to 0.60
- 0.20 to 0.40
- 0.05 to 0.20

Scale 1:60,000 (A3)

FIGURE 10.2

5% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

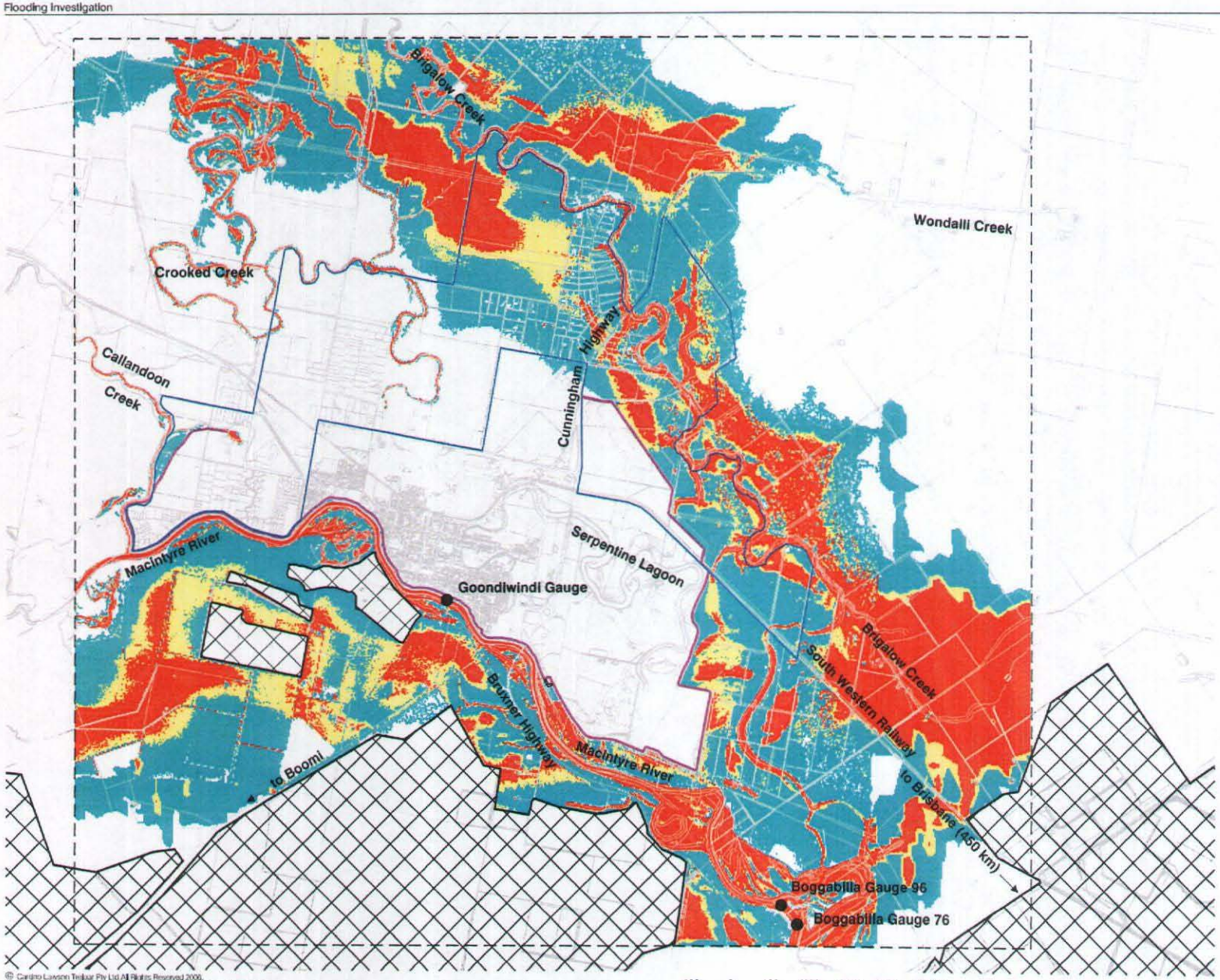
Waggamba Shire Council

CAD FILE: G:\Work_AT\LJ8651\Acad\R1\2006 G20.dwg
XREF's: J7883FigureBase; Levees 1996; Results; Waggamba_Shire_2005_HAZARD_R1_test

Project No.: LJ8651/R1

PRINT DATE: 14 September, 2006 - 9:50pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 10.3

5% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: September 2006

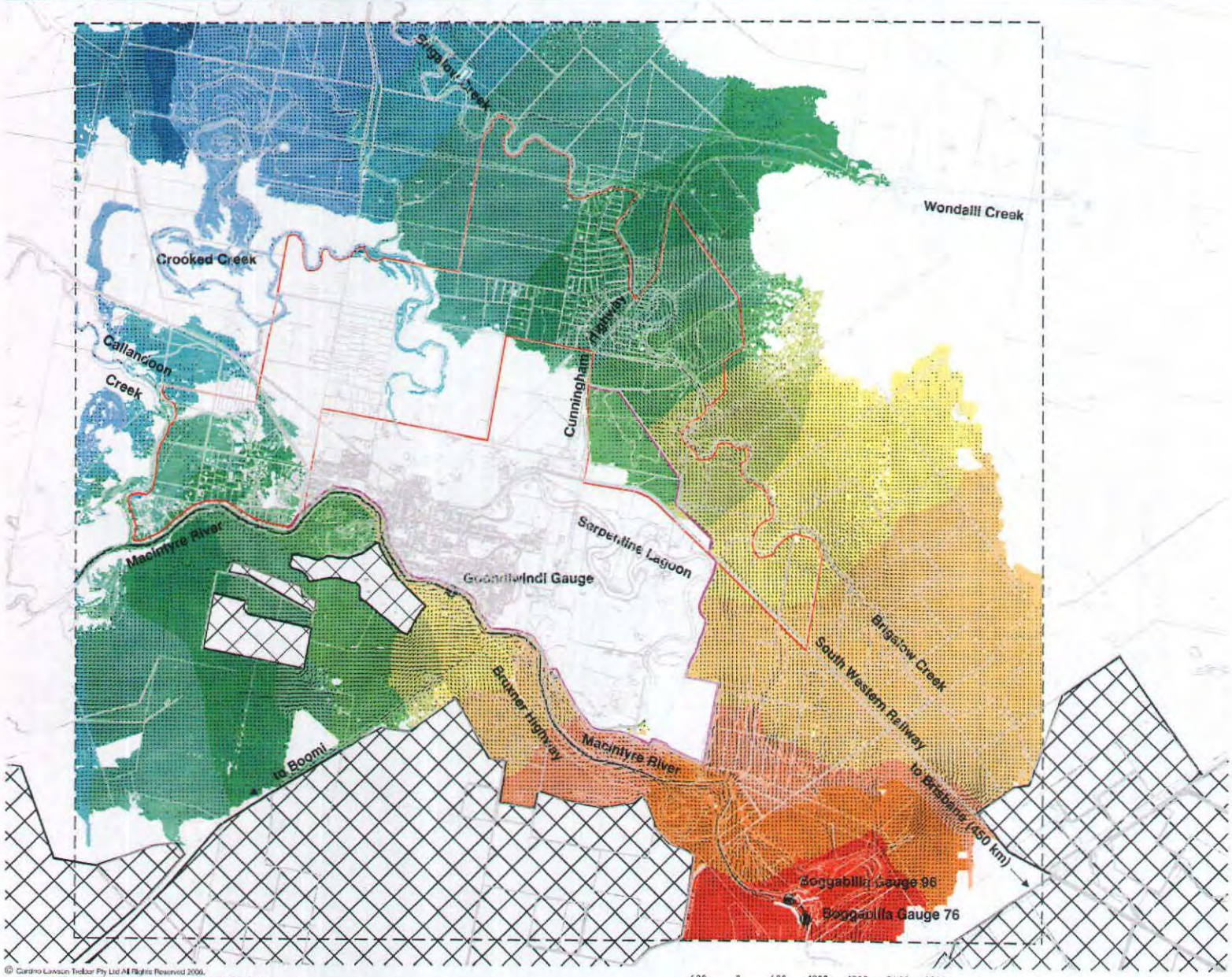
Project No.: LJ8651/R1

Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\AR1\2006 020.dwg
XREFs: J7883FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

PRINT DATE: 21 September, 2006 - 9:53am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 11.1

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

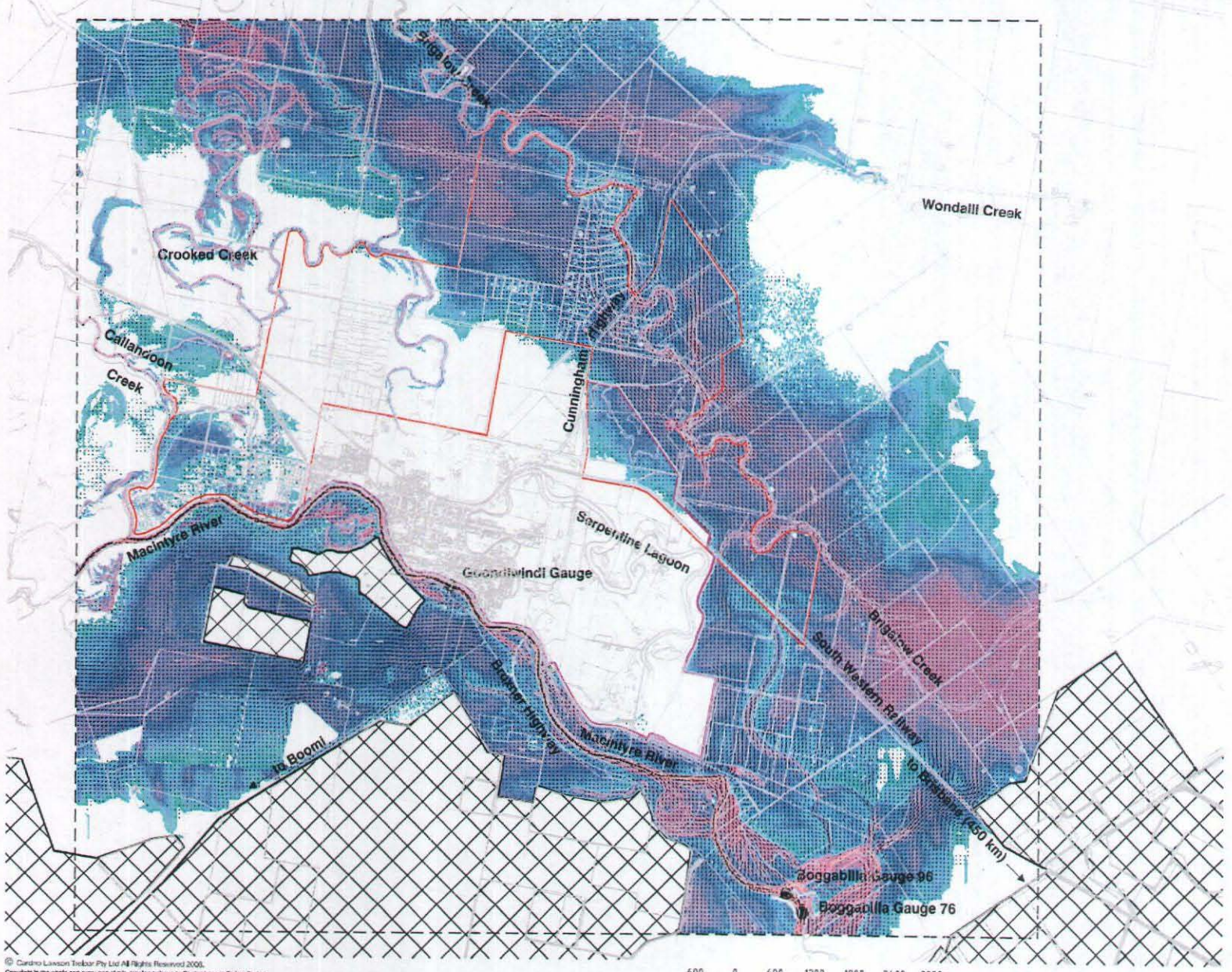
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1e3\Figure 11 2006 Q100 BRENdwg
XREFs: /J8651FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 11:22am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 11.2

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

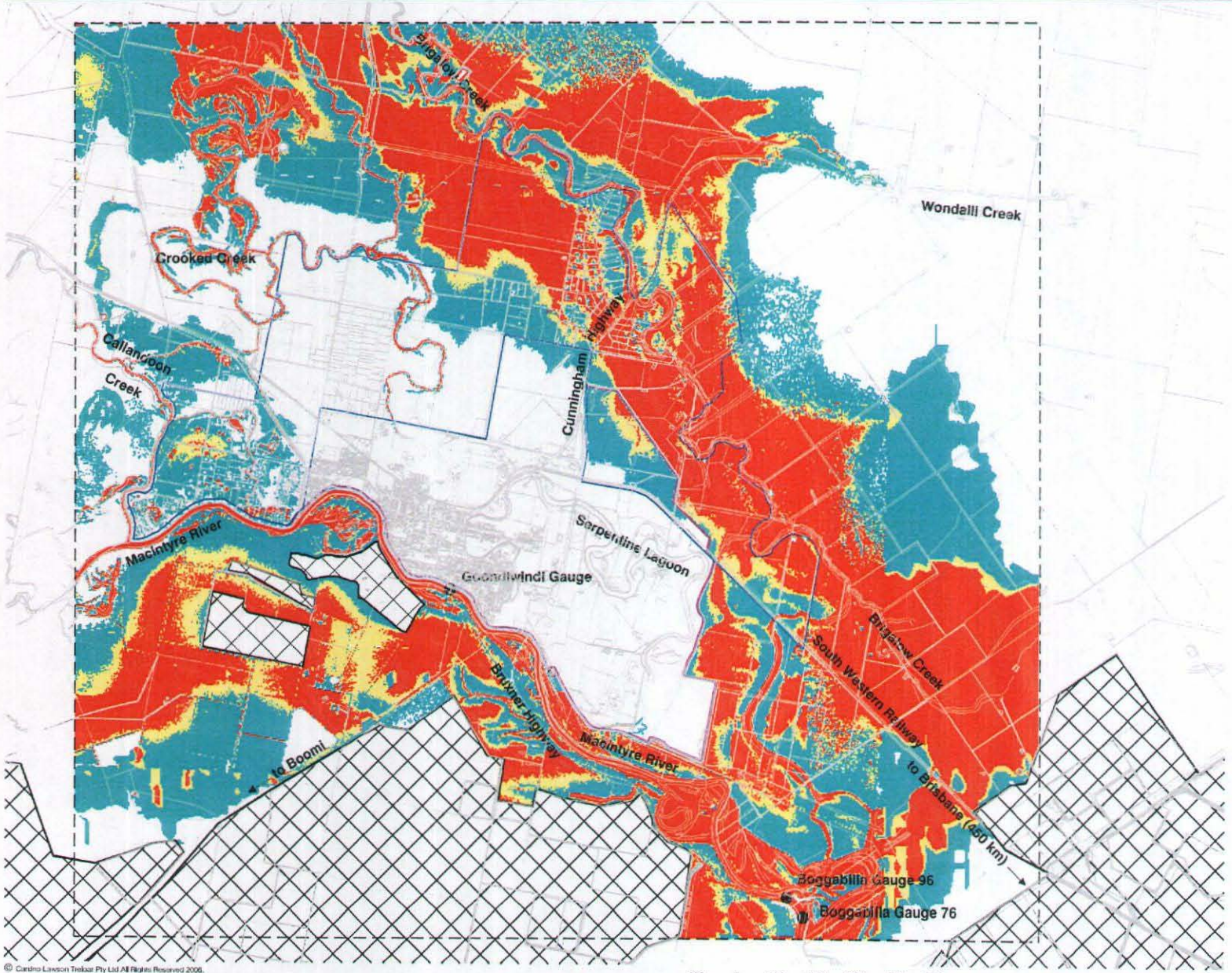
Rev: Orig. Date: March 2007

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: G:\Work\LAT\J8651\Acad\R1v3\Figure 11 2006 0100 BREN.dwg
XREF's: J7883FigureBase, Levees 1996, Results, Waggamba_Shire_2025, HAZARD, R1_text
PRINT DATE: 26 March, 2007 - 11:11am

Cardno Lawson Treloar



Rev: Orig. Date: March 2007

Waggamba Shire Council

CAD FILE: G:\Work\LAT\J8651\Acad\R1\Figure 11 2006 Q100 BREN.dwg
XREF's: J1803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_test

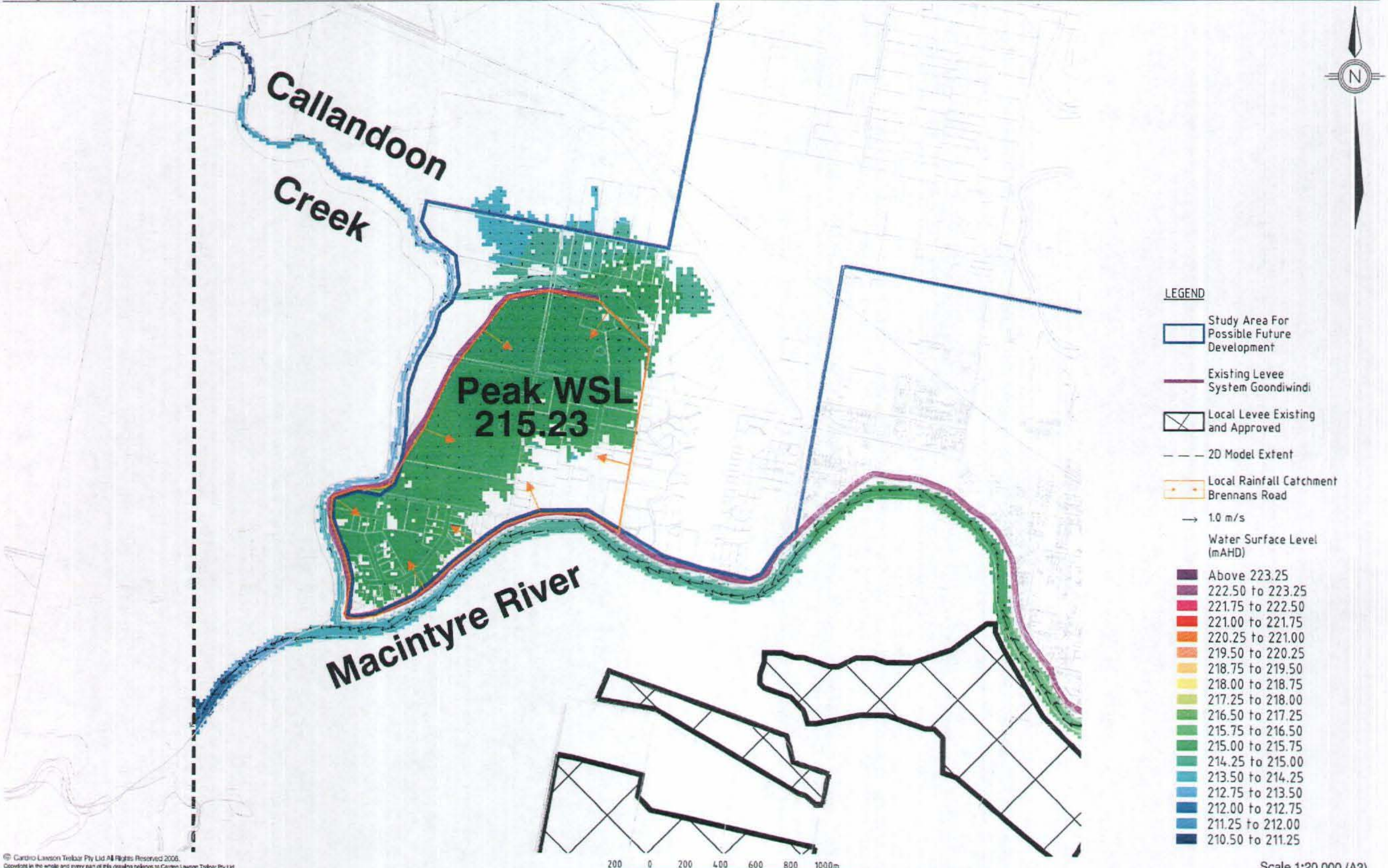
Scale 1:60,000 (A3)

FIGURE 11.3

LEVEE FAILURE BRENNANS ROAD - 1% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 11:18am


Callandoon
Creek
Peak WSL
215.23
Macintyre River
N
LEGEND
Study Area For Possible Future Development
Existing Levee System Goondiwindi
Local Levee Existing and Approved
2D Model Extent
Local Rainfall Catchment Brennans Road
1.0 m/s
Water Surface Level (mAHD)
Above 223.25
222.50 to 223.25
221.75 to 222.50
221.00 to 221.75
220.25 to 221.00
219.50 to 220.25
218.75 to 219.50
218.00 to 218.75
217.25 to 218.00
216.50 to 217.25
215.75 to 216.50
215.00 to 215.75
214.25 to 215.00
213.50 to 214.25
212.75 to 213.50
212.00 to 212.75
211.25 to 212.00
210.50 to 211.25
200 0 200 400 600 800 1000m
1:20,000

Scale 1:20,000 (A3)

FIGURE 12.1

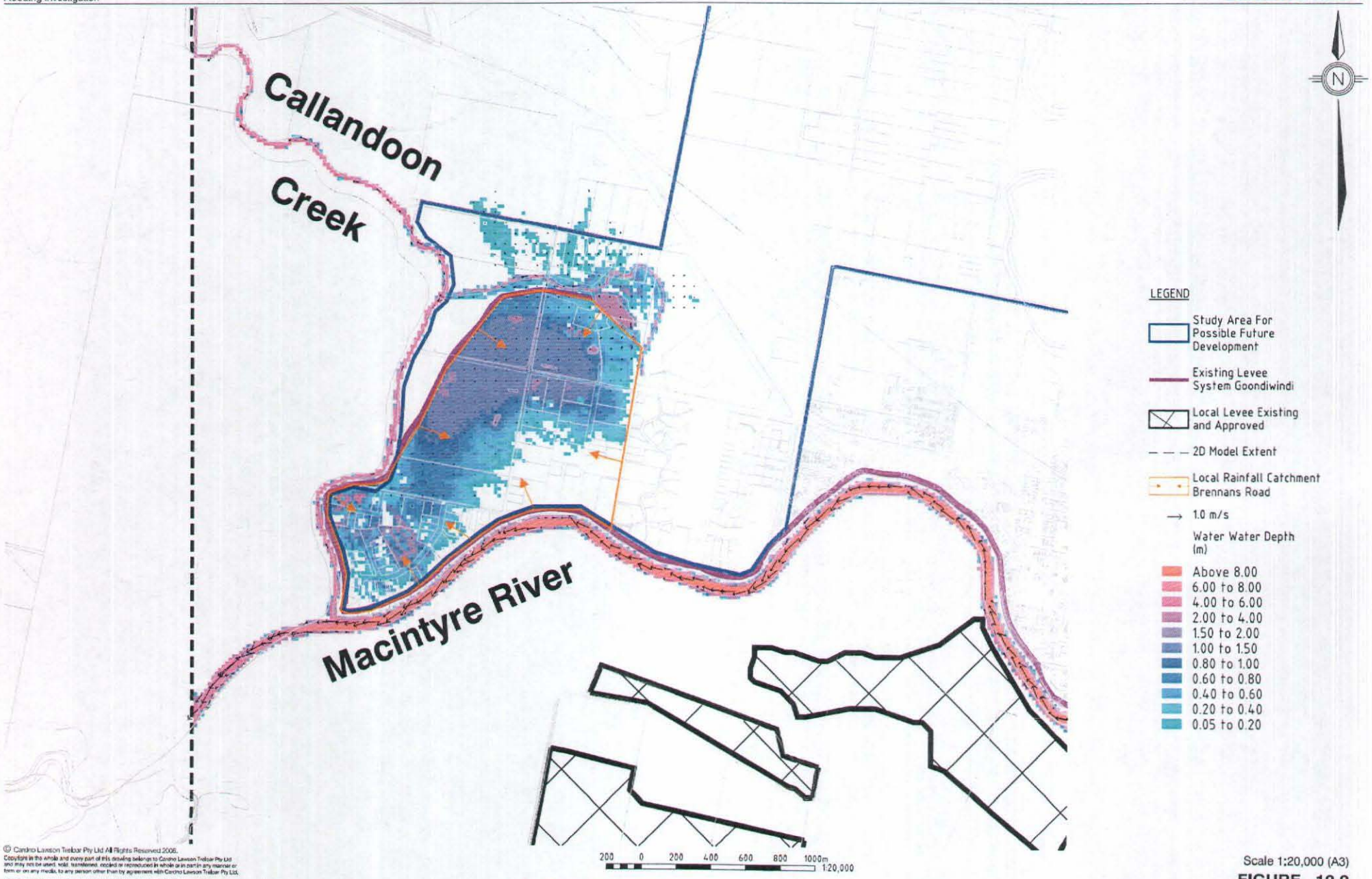
LOCAL PMP FLOODING BRENNANS ROAD - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: March 2007

Waggamba Shire Council
CAD FILE: O:\WorkLAT\J8651\Acad\R1v3\Figure 2.4_12 2006 PMP BREN.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

Cardno Lawson Treloar



Scale 1:20,000 (A3)

FIGURE 12.2

LOCAL PMP FLOODING BRENNANS ROAD - PEAK WATER DEPTHS AND FLOW PATTERNS

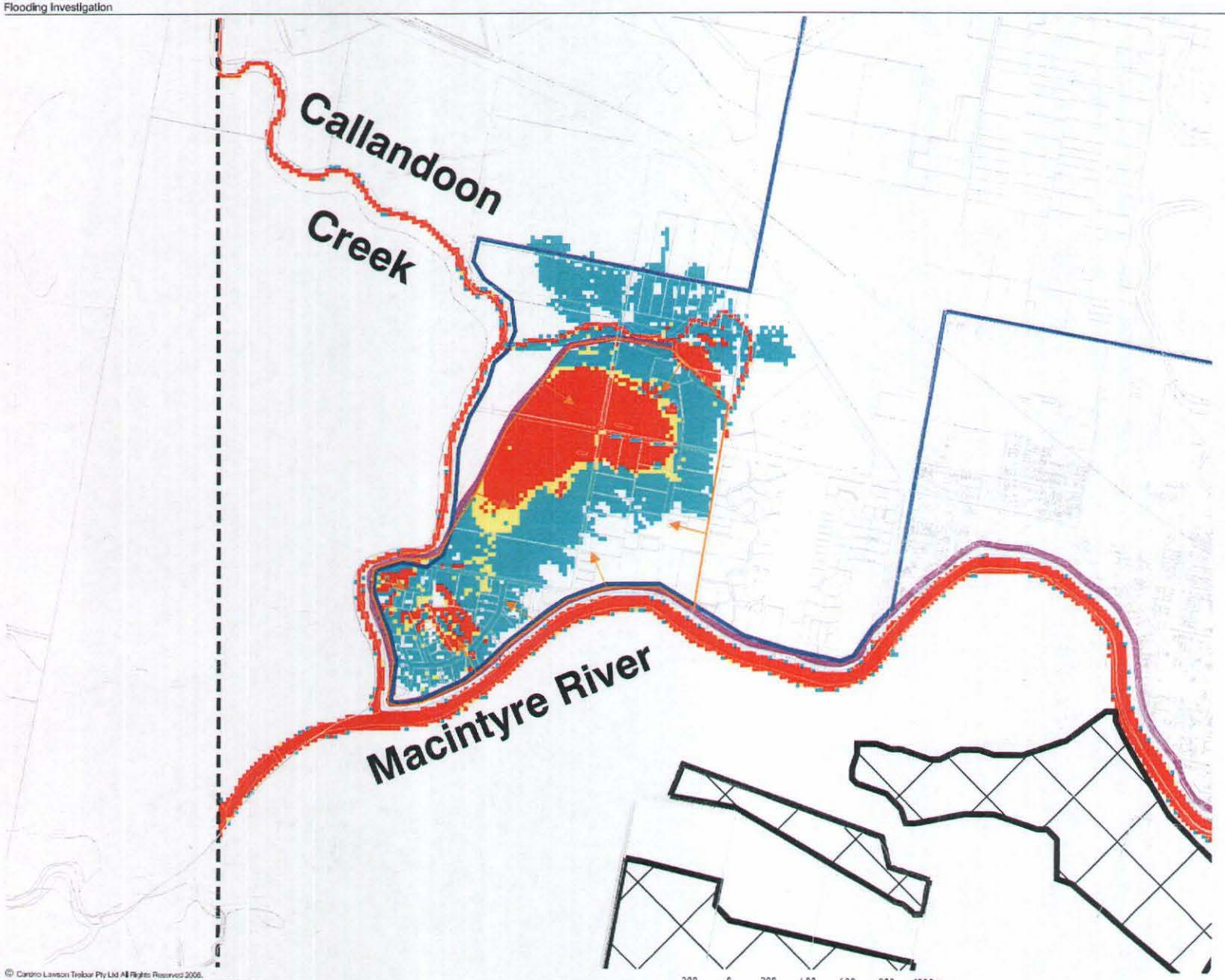
Rev: Orig. Date: March 2007

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: O:\Works_AT\J8651\Acad\R1x3\Figure 2.4_12 2006 PMP BREN.dwg
XREF's: J7883\FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_Text
PRINT DATE: 26 March, 2007 - 10:29am

Cardno Lawson Treloar



Scale 1:20,000 (A3)

FIGURE 12.3

LOCAL PMP FLOODING BRENNANS ROAD - FLOOD HAZARD

Rev: Orig. Date: March 2007

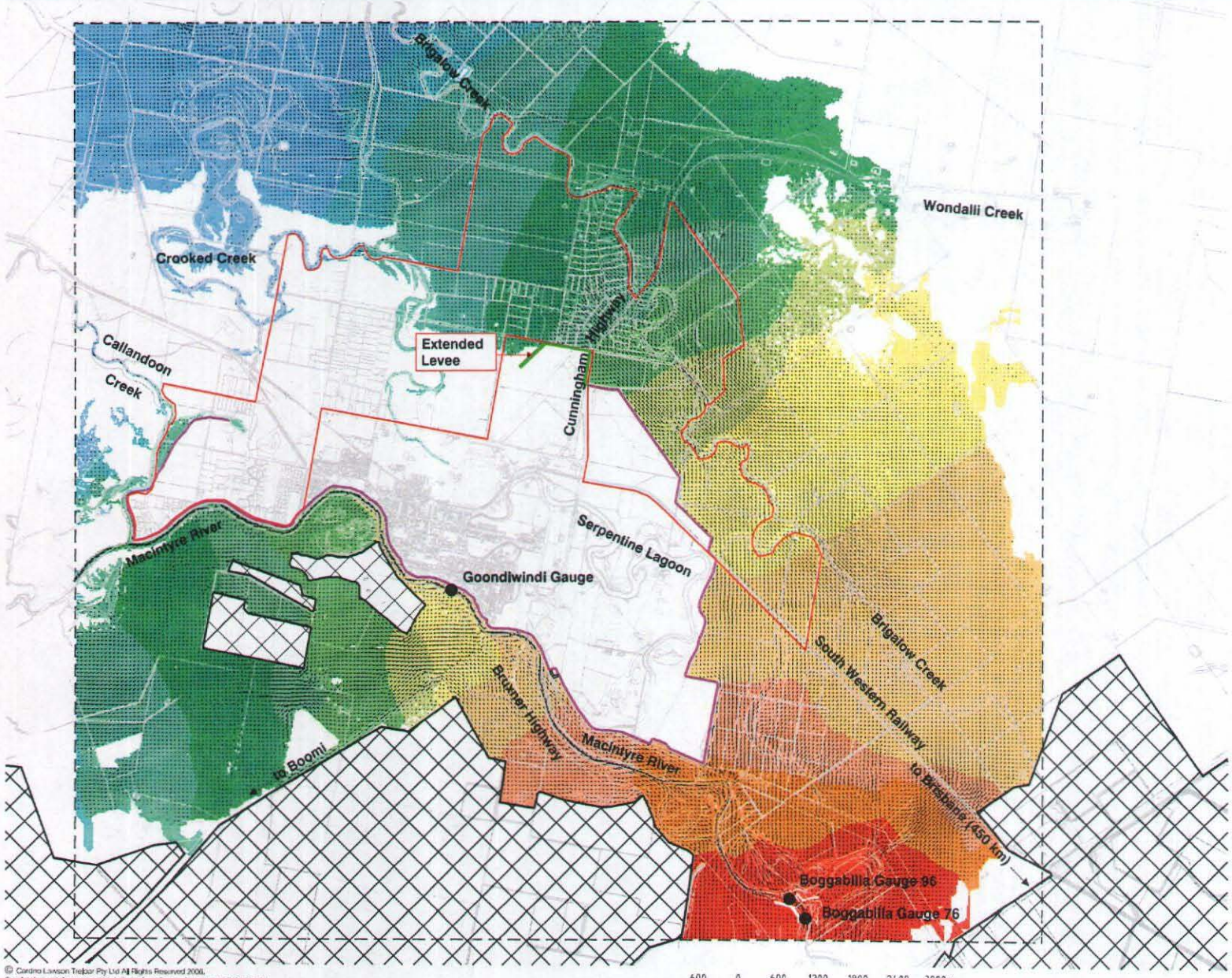
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1v3\Figure 2.4_12 2006 PMP BREN.dwg
XREFs: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_fasc

Project No.: LJ8651/R1

PRINT DATE: 26 March, 2007 - 11:33am

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 13.1

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 0500 M06A.dwg
XREFs: J7613FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_text

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 1:42pm

Cardno Lawson Treloar

Scale 1:60,000 (A3)

FIGURE 13.2

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

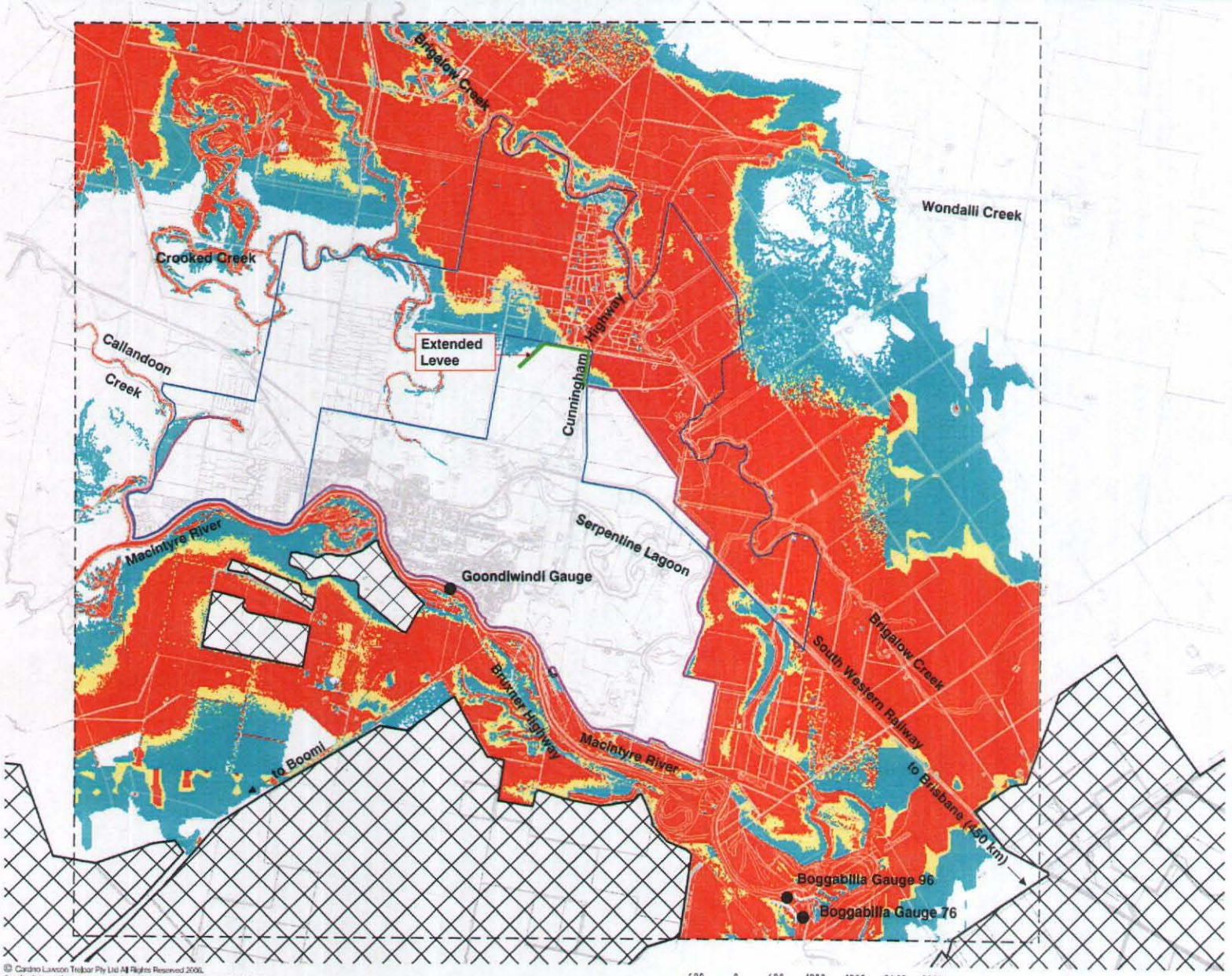
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 0508 M06A.dwg
XREFs: J7603FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 1:46pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

600 0 600 1200 1800 2400 3000m
1:60,000

Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 0500 H08A.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_Text

Scale 1:60,000 (A3)

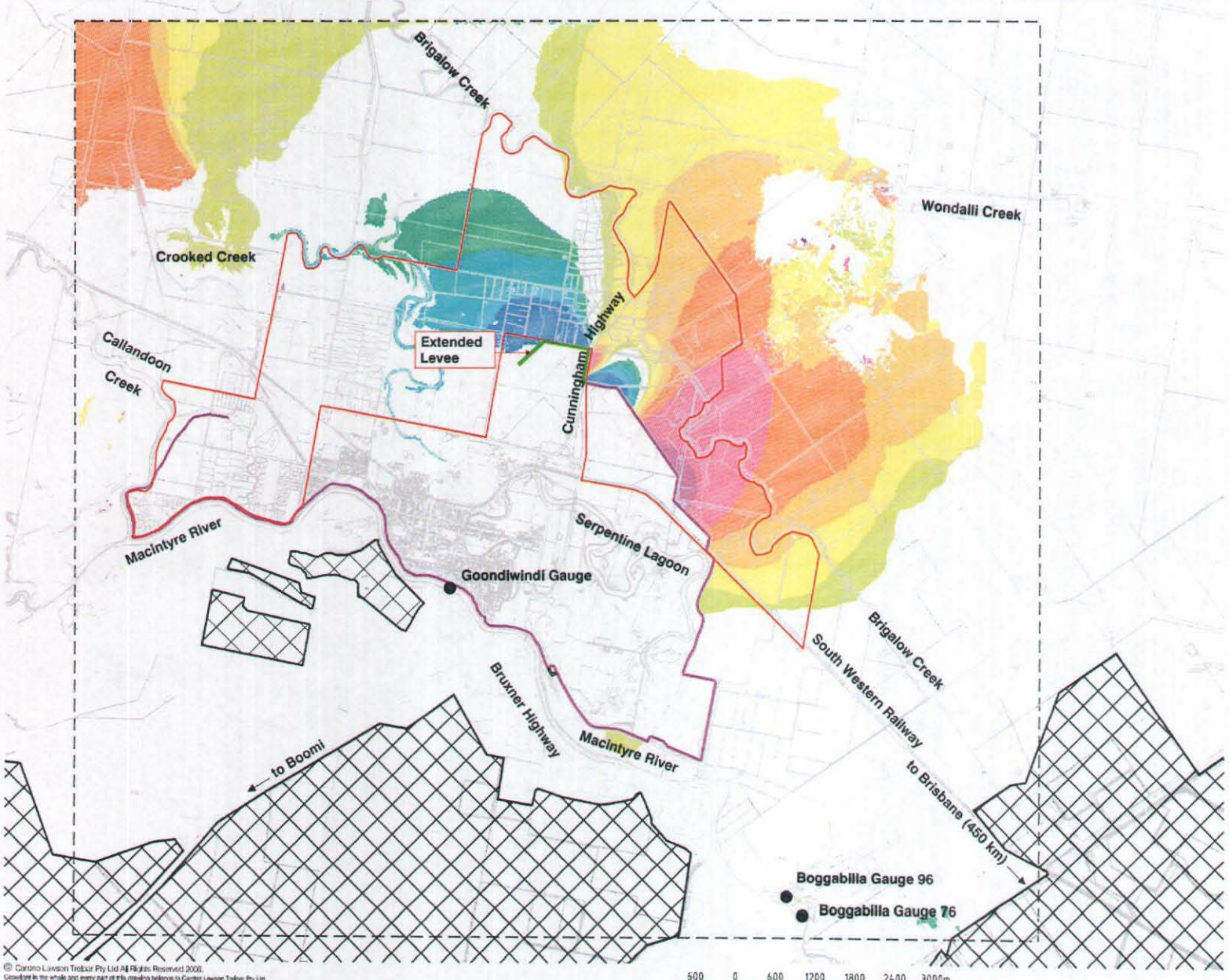
FIGURE 13.3

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - FLOOD HAZARD

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 1:45pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 13.4

RAISED AND EXTENDED LEVEES - 0.2% AEP FLOODING EVENT - PEAK WATER LEVEL IMPACTS

Rev: Orig. Date: September 2006

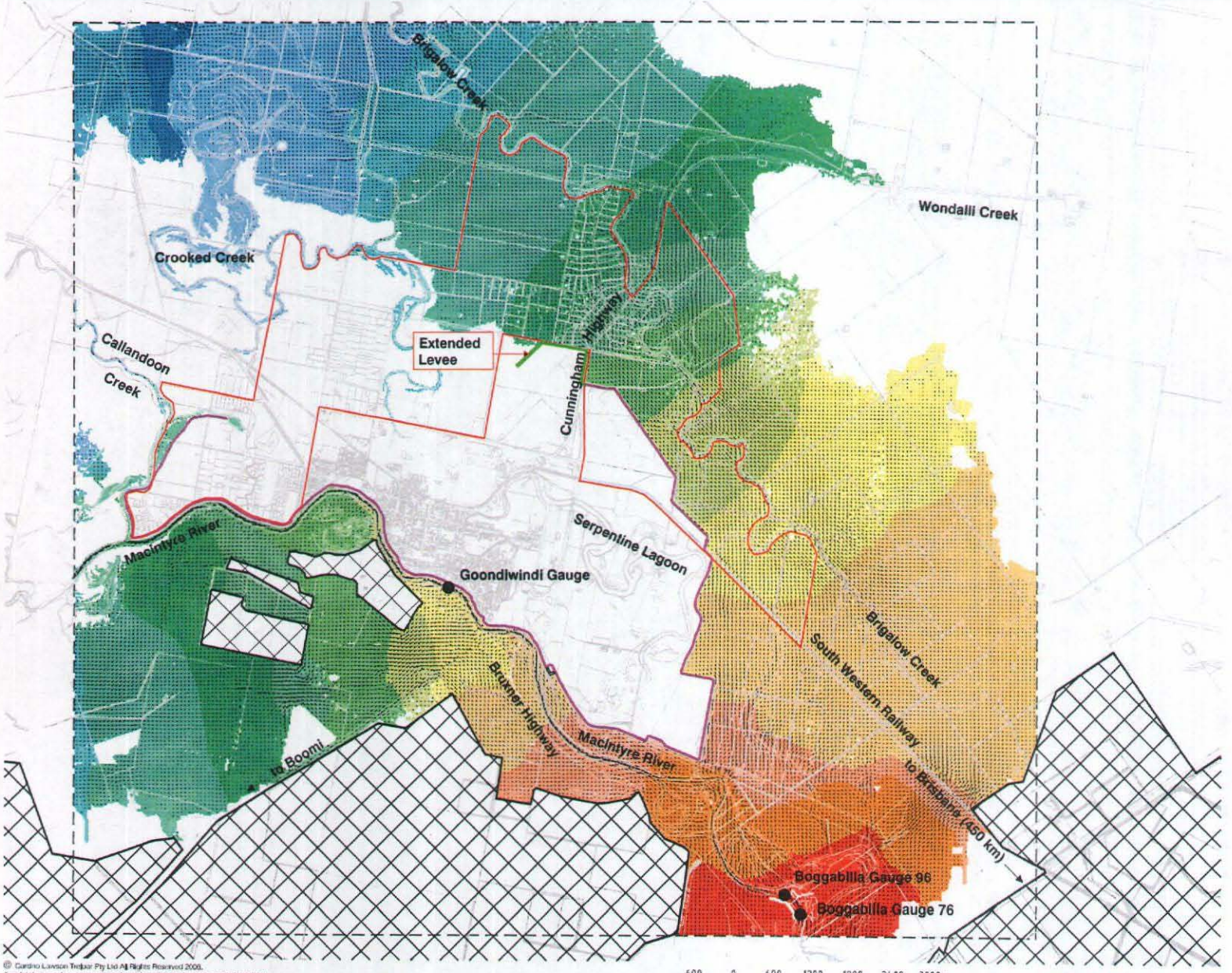
Waggamba Shire Council

CAD FILE: O:\Work\LAT\LJ8651\Acad\R1\2006 0505 MIKE4.dwg
XREF's: ./7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_levs

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 1:43pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 14.1

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER LEVELS AND FLOW PATTERNS

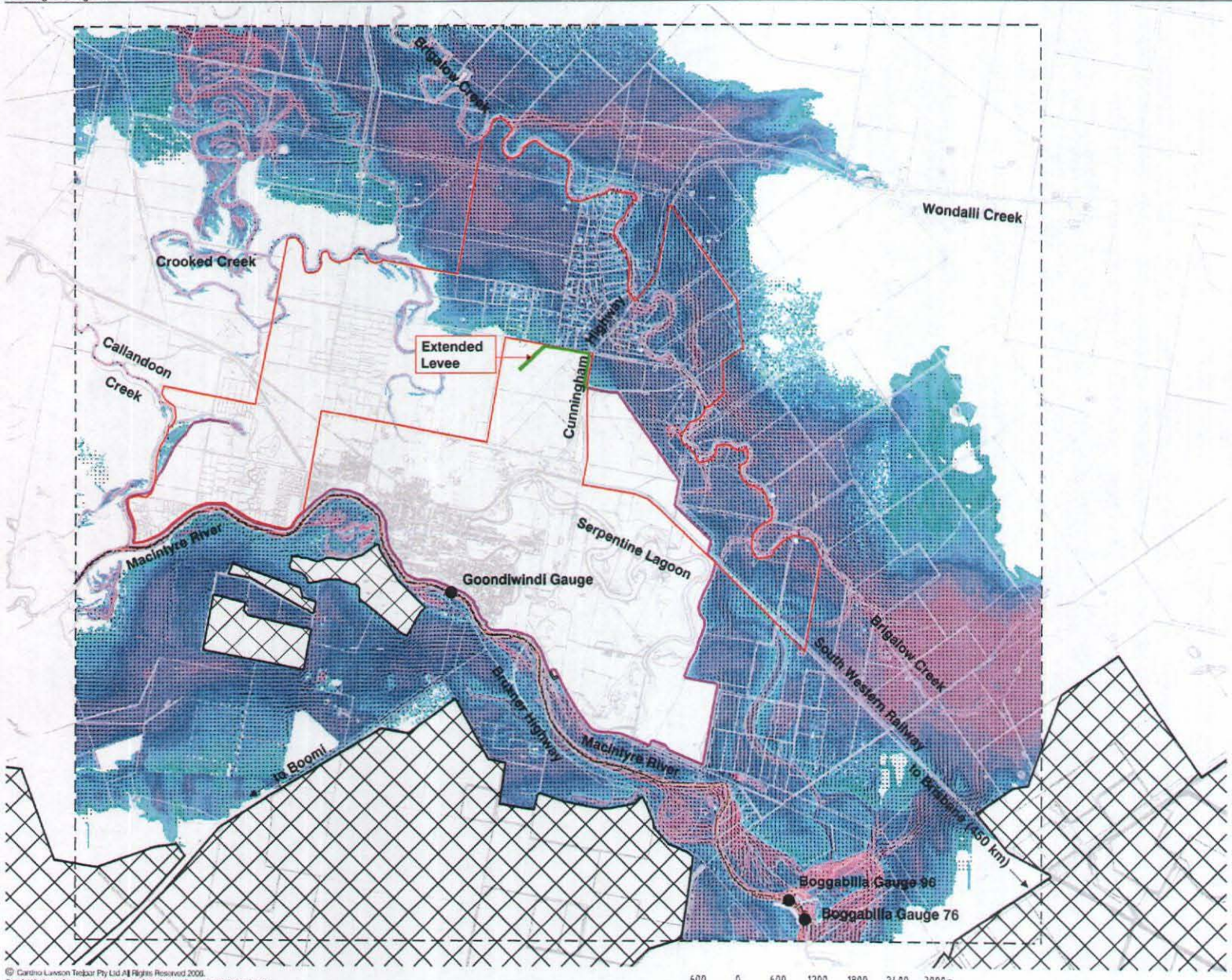
Rev: Orig. Date: September 2006

Waggamba Shire Council

Project No.: LJ8651/R1

CAD FILE: D:\Work\LAT\J8651\Acad\R1\2006 Q100 H06A.dwg
XREFs: J7663FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_text
PRINT DATE: 25 September, 2006 - 12:36pm

Cardno Lawson Treloar



Scale 1:60,000 (A3)

FIGURE 14.2

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER DEPTHS AND FLOW PATTERNS

Rev: Orig. Date: September 2006

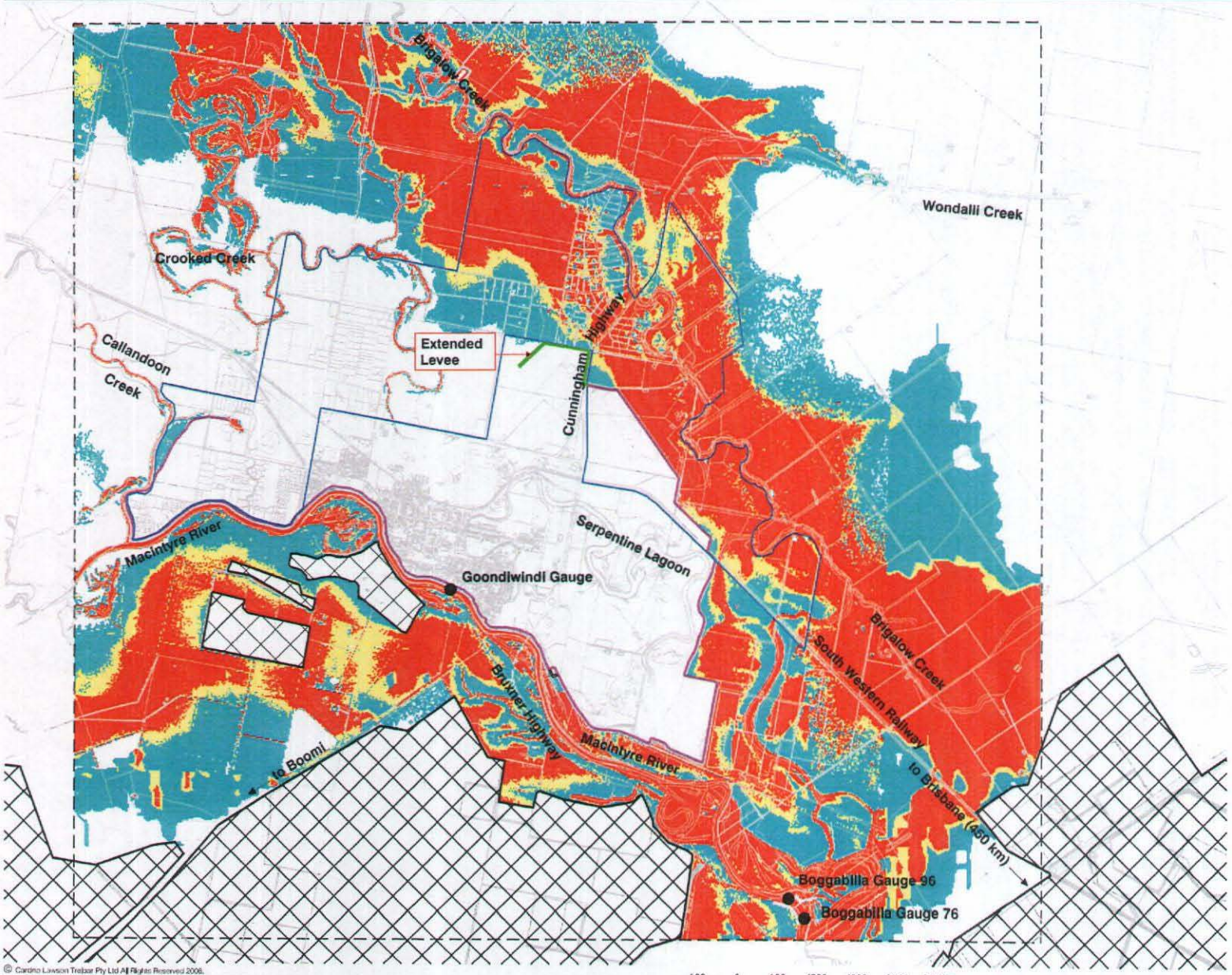
Waggamba Shire Council

CAD FILE: O:\Work\LAT\J8651\Acad\R1\2006 0108 H664.dwg
XREF's: J7403FigureBase; Levees 1996; Results; Waggamba_Shire_2005; HAZARD; R1_Text

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 12:34pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location

Flood Hazard

- High Hazard
- Medium Hazard
- Low Hazard

600 0 600 1200 1800 2400 3000m
1:60,000

Scale 1:60,000 (A3)

FIGURE 14.3

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - FLOOD HAZARD

Rev: Orig. Date: September 2006

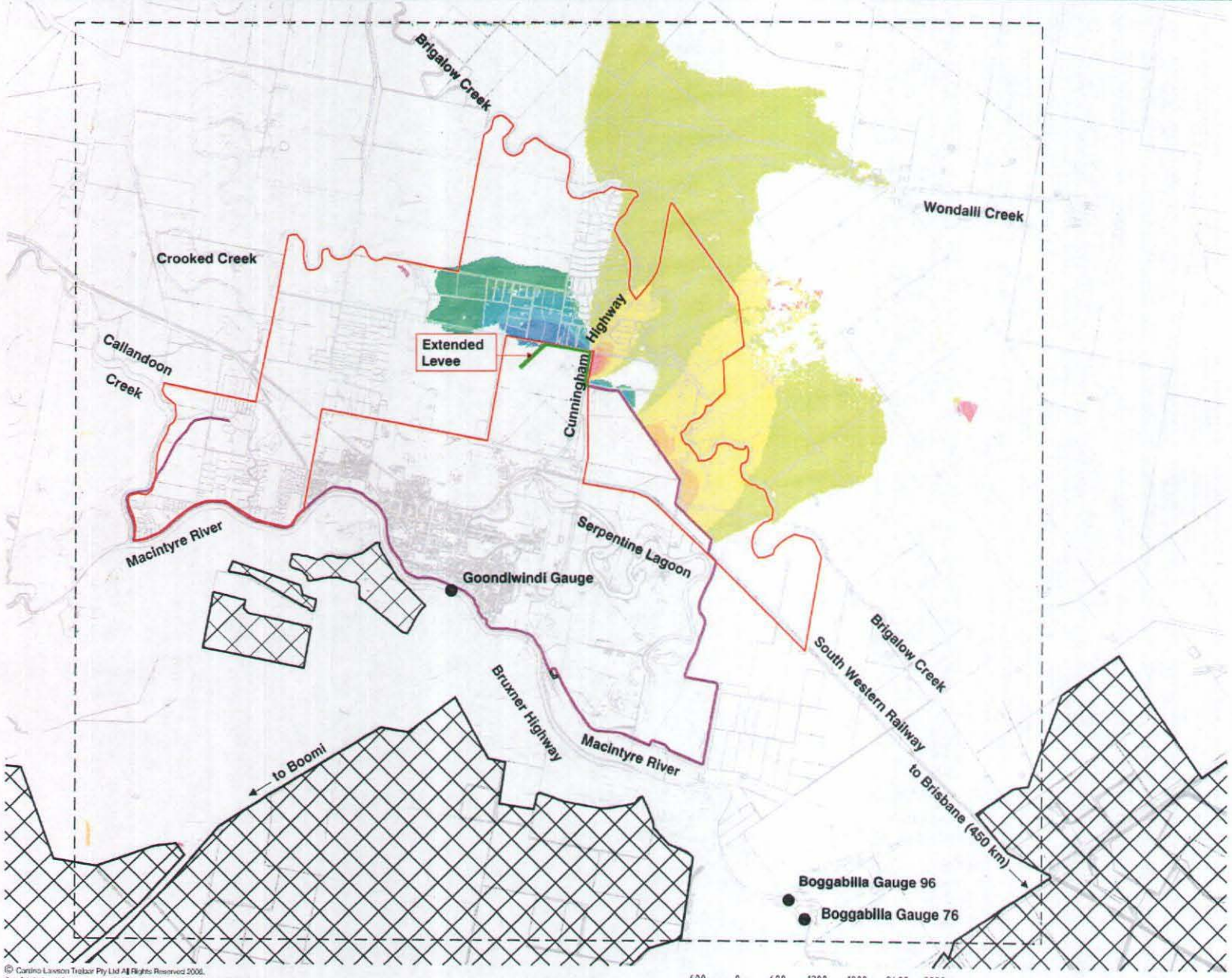
Waggamba Shire Council

CAD FILE: O:\Work\LAT\LJ8651\Acad\R1\2006 Q100 H06A.dwg
XREF's: /1863FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_test

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 12:35pm

Cardno Lawson Treloar



N

LEGEND

- Study Area For Possible Future Development
- Existing Levee System Goondiwindi
- Local Levee Existing and Approved
- 2D Model Extent
- Gauge Location
- 0.5 m/s

Peak Water Level Impacts (mm)

- Above 200
- 150 to 200
- 100 to 150
- 50 to 100
- 30 to 50
- 20 to 30
- 10 to 20
- 5 to 10
- -10 to -5
- -20 to -10
- -30 to -20
- Below -30

Scale 1:60,000 (A3)

FIGURE 14.4

RAISED AND EXTENDED LEVEES - 1% AEP FLOODING EVENT - PEAK WATER LEVEL IMPACTS

Rev: Orig. Date: September 2006

Waggamba Shire Council

CAD FILE: G:\Work\AT\J8651\Acad\R1\2006 0100 M06A.dwg
XREF's: J7803FigureBase, Levees 1996, Results, Waggamba_Shire_2005, HAZARD, R1_text

Project No.: LJ8651/R1

PRINT DATE: 25 September, 2006 - 12:38pm

REFERENCE DRAWINGS

J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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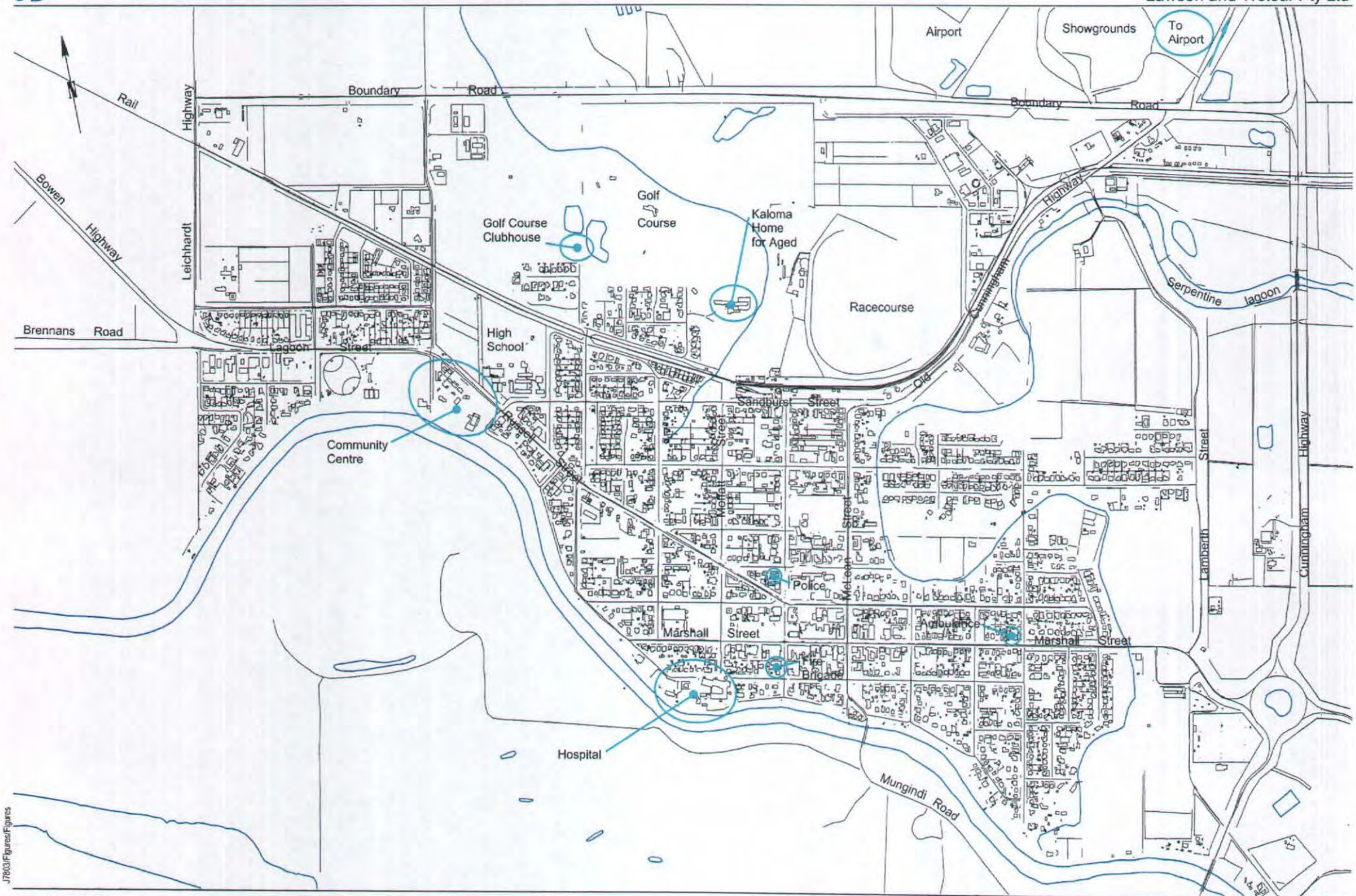
Goondiwindi Flood Disaster - Risk Management Report

Figure 1 - Goondiwindi Township



J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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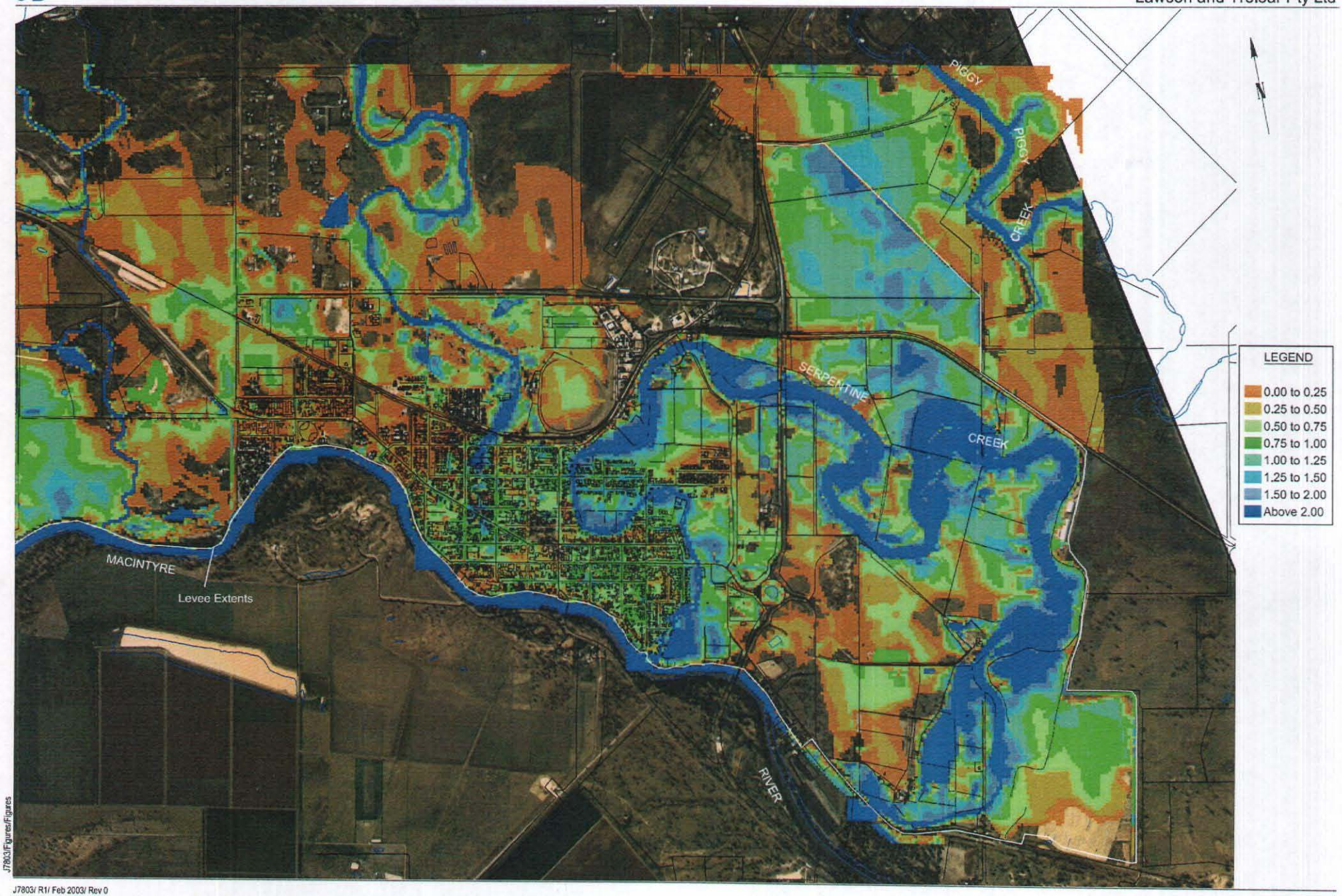
Goondiwindi Flood Disaster - Risk Management Report

Figure 2 - Residential Area and Reporting Reference Points



J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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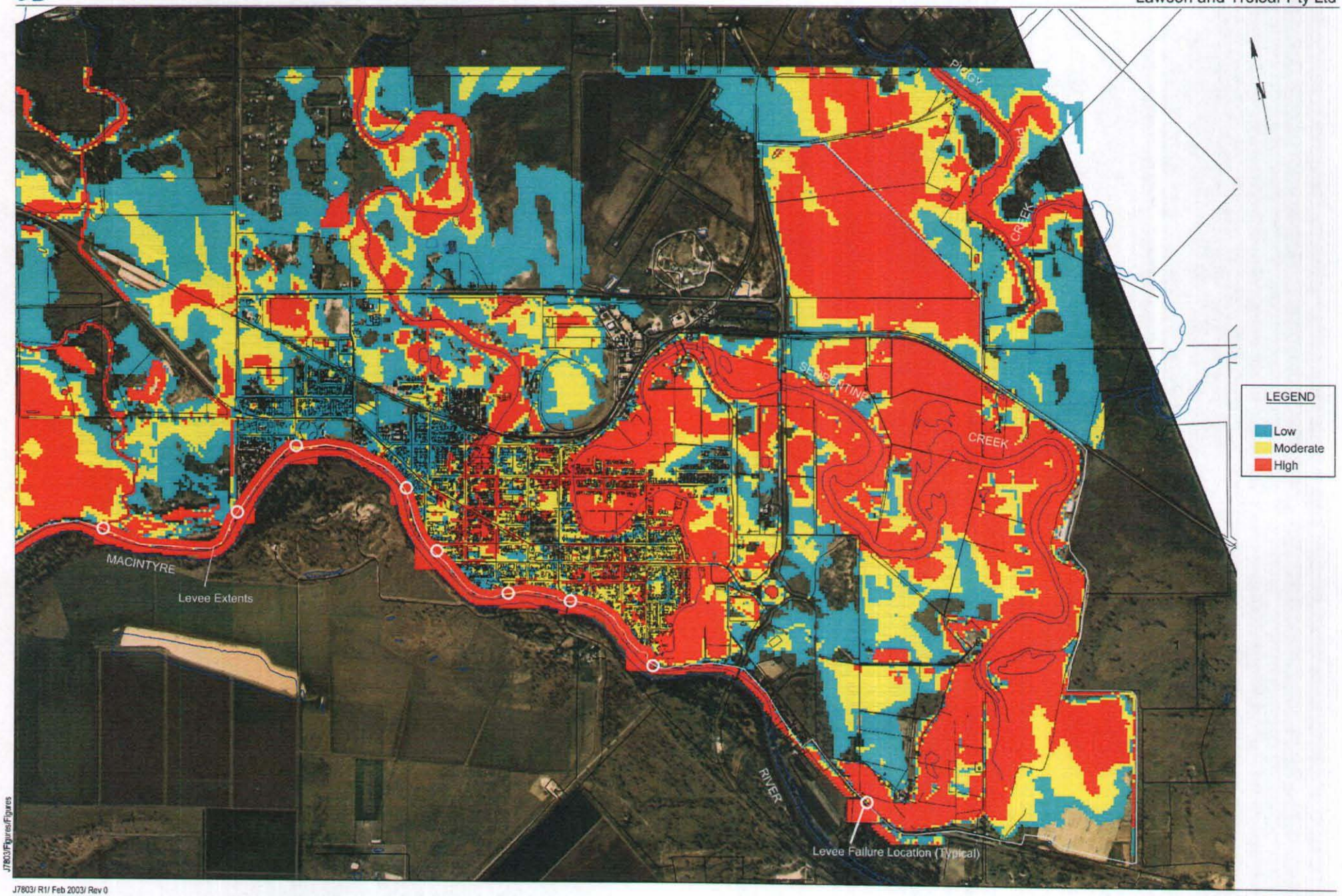
Figure 3 - Envelope of Depth from Multiple Levee Peak Failures - 500 Year (Twice 1976) Flood



J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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Figure 4 - Envelope of Hazard from Multiple Levee Peak Failures - 500 Year (Twice 1976) Flood

J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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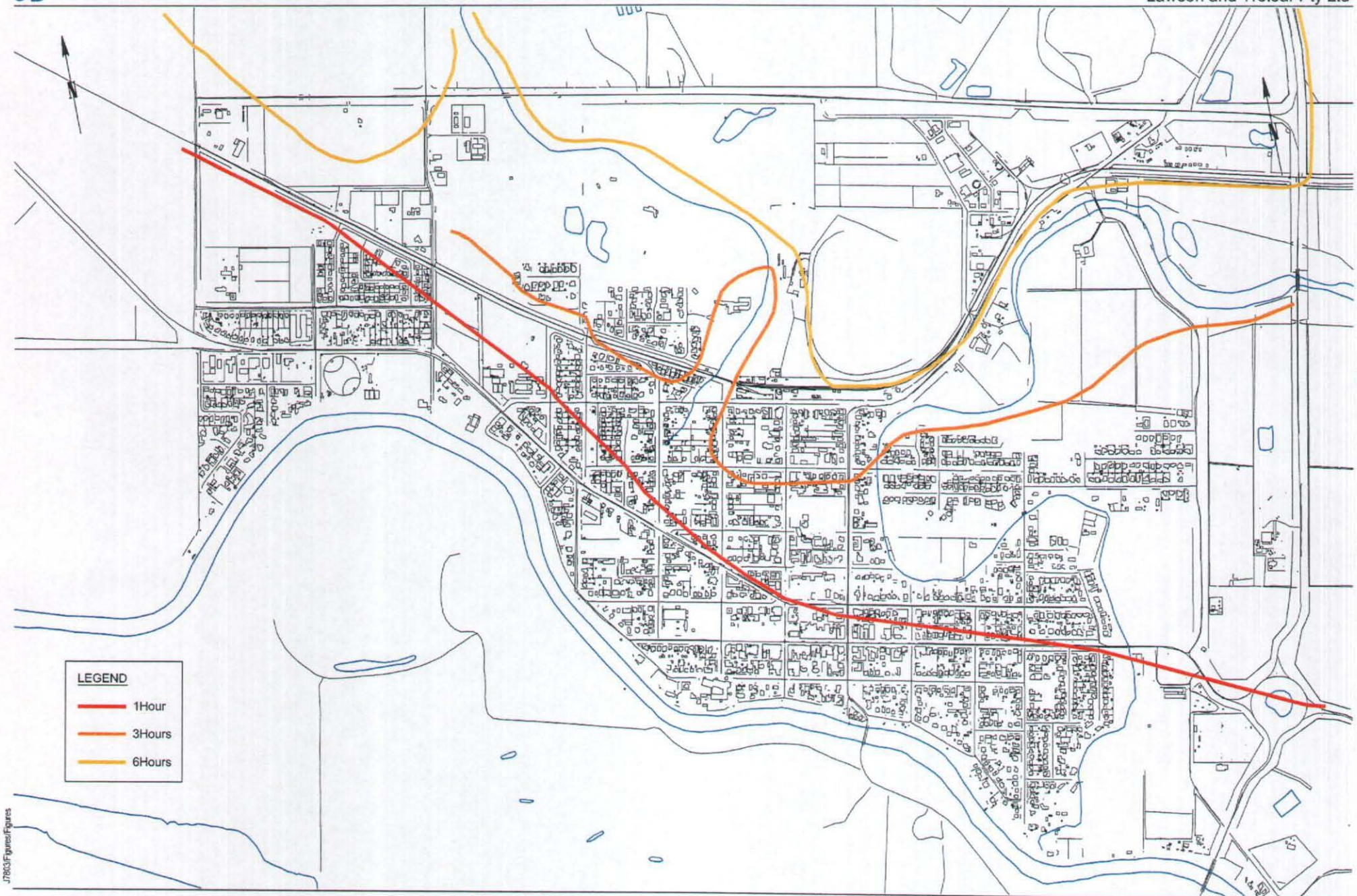
Goondiwindi Flood Disaster - Risk Management Report

Figure 5 - Treatment Options



J7803/Figures/Figures

J7803/ R1/ Feb 2003/ Rev 0

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Figure 6 - Time to Flood From Levee Breaching

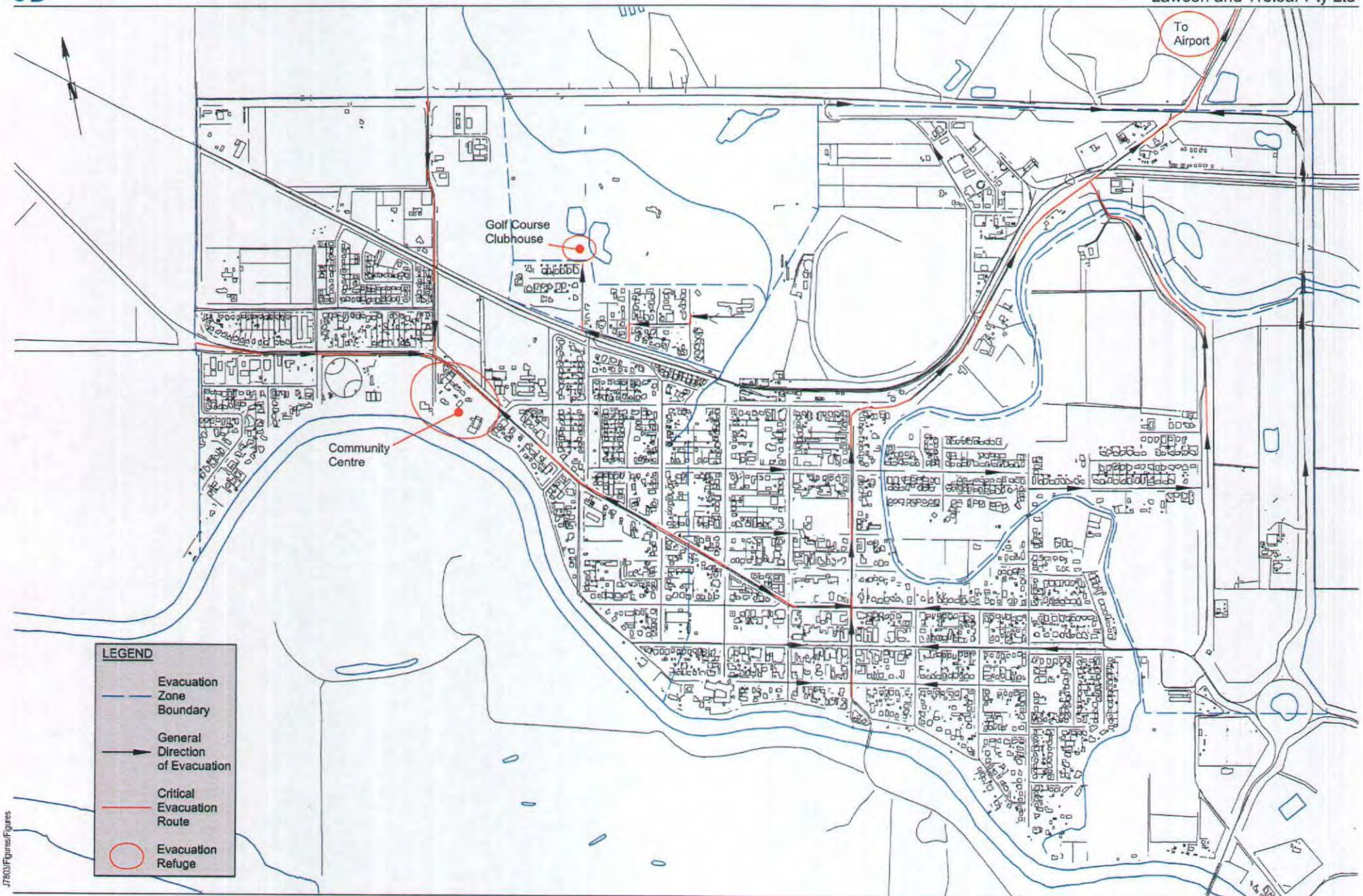

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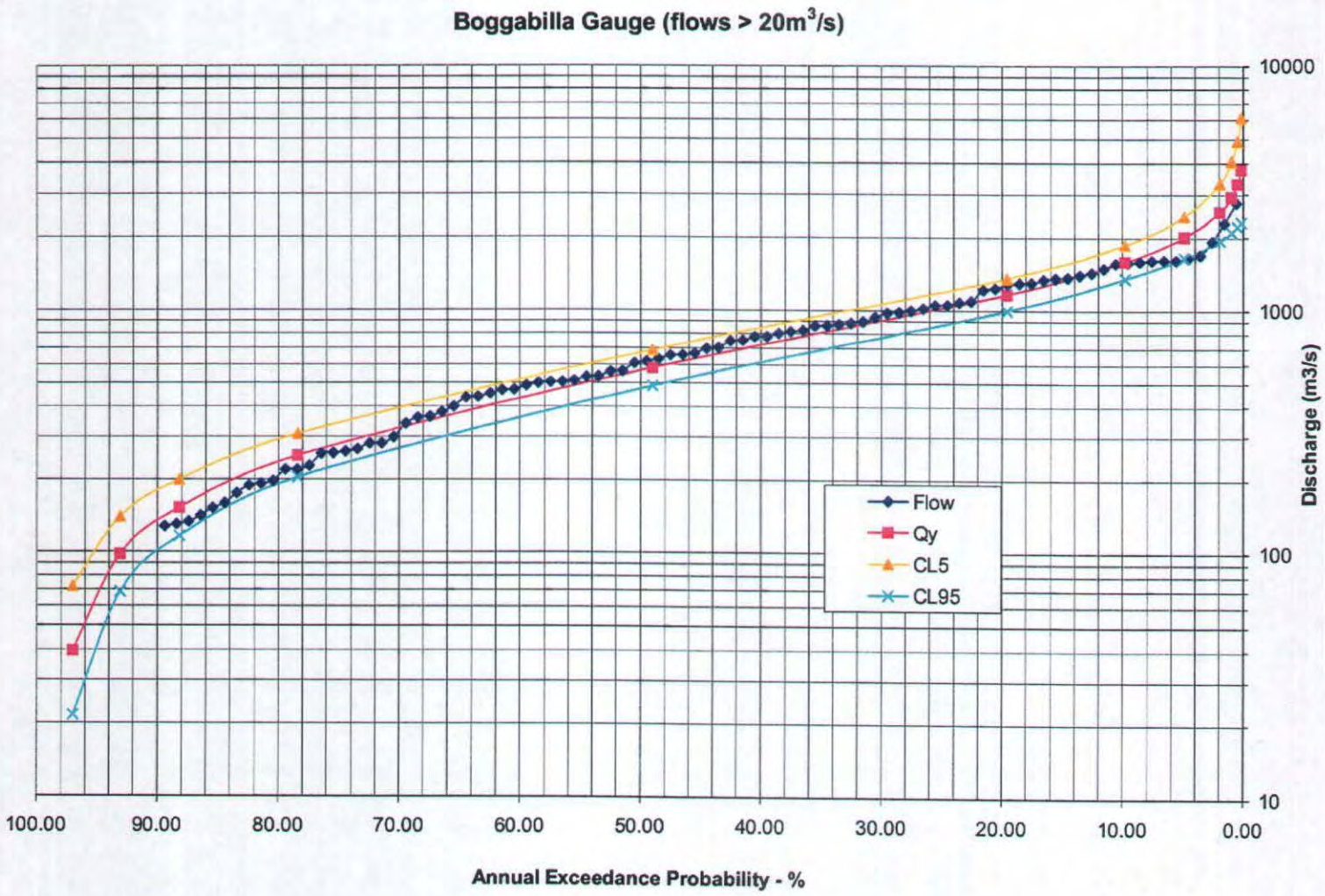
Figure 7 - Refuge Areas and Evaluation Routes

APPENDIX A

Boggabilla Flood Frequency Analysis

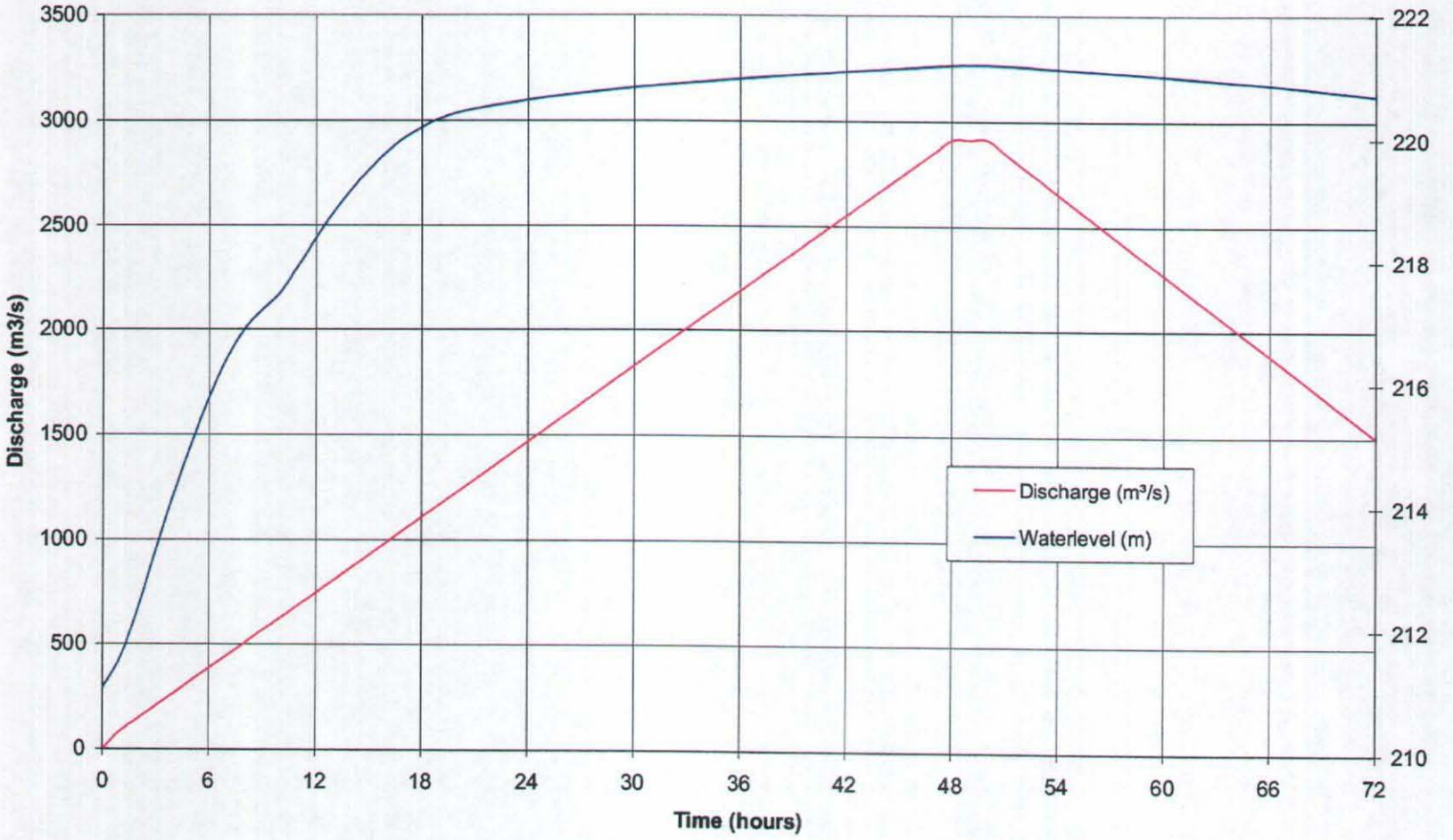
Appendix A


Boggabilla Gauge (flows > 20m3/s)
10000
1000
100
10
Discharge (m3/s)
Flow
Qy
CL5
CL95
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Annual Exceedance Probability - %

APPENDIX B

Flood Characteristics at Boggabilla Gauge and Flood Characteristics at Goondiwindi Gauge

Appendix B1 - Flood Characteristics at Boggabilla Gauge



Appendix B2 - Flood Characteristics at Goondiwindi Gauge