TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

DATA COLLECTION REPORT

VOLUME 1 - REPORT

FINAL REPORT

JULY 2012

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FOREWORD

The State Government's Flood Policy is directed at providing solutions to existing flooding problems in developed areas and to ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

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

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

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

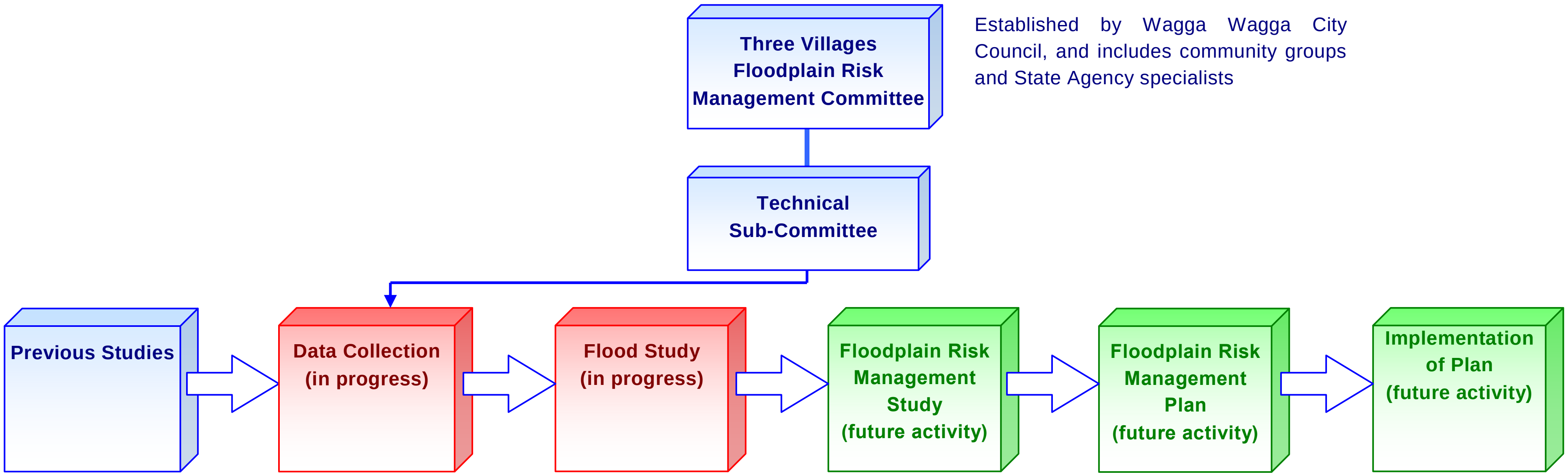
The Tarcutta, Ladysmith and Uranquinty Flood Studies are jointly funded by Wagga Wagga City Council and the NSW/Commonwealth Governments, via the Office of Environment and Heritage, Department of Premier and Cabinet. The Flood Studies constitute the first stage of the Floodplain Risk Management process for the villages and have been prepared for Wagga Wagga City Council to define flood behaviour under current conditions.

The Flood Studies have been prepared under the guidance of the Floodplain Management Committee comprising representatives from Wagga Wagga City Council, the Office of Environment and Heritage, Department of Premier and Cabinet and the Consultant, NSW State Emergency Service and Community Representatives from the three villages.

ACKNOWLEDGEMENT

Wagga Wagga City Council has prepared this document with financial assistance from the NSW and Commonwealth Governments through the Natural Disaster Resiliance Program. This document does not necessarily represent the opinions of the NSW or Commonwealth Governments.

FLOODPLAIN RISK MANAGEMENT PROCESS



The NSW State Emergency Service commissioned studies to capture flood intelligence following the October 2010 and March 2012 floods. Several studies were also undertaken during the planning and detail design of the Tarcutta Bypass (Hume Highway Upgrade).

Involves the compilation of existing data and the collection of additional data.

Involves detailed hydrologic and hydraulic modelling of the Tarcutta Creek, Kyeamba Creek and Sandy Creek catchments.

The Floodplain Risk Management Study will determine options which will seek to reduce the impact of flooding on the community in consideration of social, ecological and economic factors.

Preferred floodplain management options will be publicly exhibited and the responses from the community incorporated in the Plan. The Plan will then be formally approved by Council following the public exhibition period.

Implementation of the Plan will allow Council to reduce the impact of flooding on the community through flood, property, and response modification measures. The measures may include structural works, planning controls, flood warnings, flood readiness and response plans, ongoing data collection and monitoring.

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ANNEXURES

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ABBREVIATIONS

AEP	Annual Exceedance Probability (%)
AHD	Australian Height Datum
ARI	Average Recurrence Interval (years)
ARR	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
FDM	Floodplain Development Manual, 2005
NoW	NSW Office of Water
OEH	Office of Environment and Heritage, Department of Premier and Cabinet (formerly Department of Environment, Climate Change and Water [DECCW])
RMS	Roads and Maritime Services (formerly Roads and Traffic Authority)
SES	State Emergency Service
WWCC	Wagga Wagga City Council

S1 SUMMARY AND RECOMMENDATIONS

S1.1 Summary

The collection and review of flood related data were the formal starting points for the Flood Studies and are described in this report, the first of three reports comprising the *Tarcutta, Ladysmith and Uranquinty Flood Studies.* **Figure S1.1** shows the three catchments which comprise the study area. This Appendix covers the three villages in a single report, as the data collected is mainly "regionally based", particularly in the case of rainfalls recorded during recent flood events. However, each village will have its own Flood Study report.

The report firstly outlines the data available to the Consultants at the commencement of the study (e.g. hydrographic, survey and results of previous studies). It also contains a list of recommendations for further analysis of the existing hydrographic data (mainly at the gauging stations) and survey of features controlling flood levels and flow patterns in the villages. There is also a recommendation for constructing an independent hydraulic model for the Tarcutta floodplain, rather than the Flood Study adopting the existing model developed by others for flood investigations associated with the recently constructed Hume Highway Bypass.

The reader will note that the report contains sections of the recent study prepared for SES by Bewsher Consulting, 2011 which related to the collection of flood data in urban centres following the record October 2010 flood in the Murrumbidgee Valley. Some of this rather wordy material has been included as an *aide memoire* for the benefit of the Consultants during the model calibration phase (which is to be reported in a future working paper). Depending on those results some of the Bewsher, 2011 material may be edited from future versions.

The objective of the Flood Studies is to define flood behaviour at the three villages *under present day conditions* for floods ranging between 5 and 200 year average recurrence interval (ARI), as well as for the Probable Maximum Flood. For the purposes of the Flood Studies, hydrologic models of the study catchments will be used to generate flood flows and hydraulic models of the channels and floodplains at each village will be used to convert flows into flood levels, flow patterns and velocities. The hydrologic models will be based on the RAFTS rainfall-runoff software, while the hydraulic models will be based on the TUFLOW two-dimensional modelling system.

To assist with data collection and promotion of the study to the various communities, Wagga Wagga City Council (WWCC) has distributed Community Newsletters at each village inviting residents to provide information on historic flooding (ref. **Annexure A**).

There are stream flow and telemetered rainfall data available on both the Tarcutta Creek catchment and on the Kyeamba Creek system in the case of Ladysmith. Sandy Creek at Uranquinty is ungauged, with no telemetered rain gauges located in the catchment. These data were collected and analysed for several recent historic storms with a view to using the data to calibrate the hydrologic models for the Tarcutta Creek and Kyeamba Creek catchments. It was envisaged that the RAFTS model parameters found to apply for those two catchments could be transposed to the ungauged Sandy Creek catchment at Uranquinty.

The Bewsher Consulting, 2011 study also provided a great deal of useful information for this present study. In particular the Bewsher study identified flooding patterns, properties affected by flooding and depths of above-floor inundation and summarised responses to a Community Questionnaire distributed after the flood. The information contained in that study greatly assisted the site inspections carried out by the present Consultants and have allowed specifications for surveys to be prepared for the three villages (**Annexure B**).

S1.2 Recommendations

Recommendations for further analysis of the existing data, collection of additional data and adoption of ALS data for preparing TUFLOW models for the three floodplains are as follows:

Tarcutta

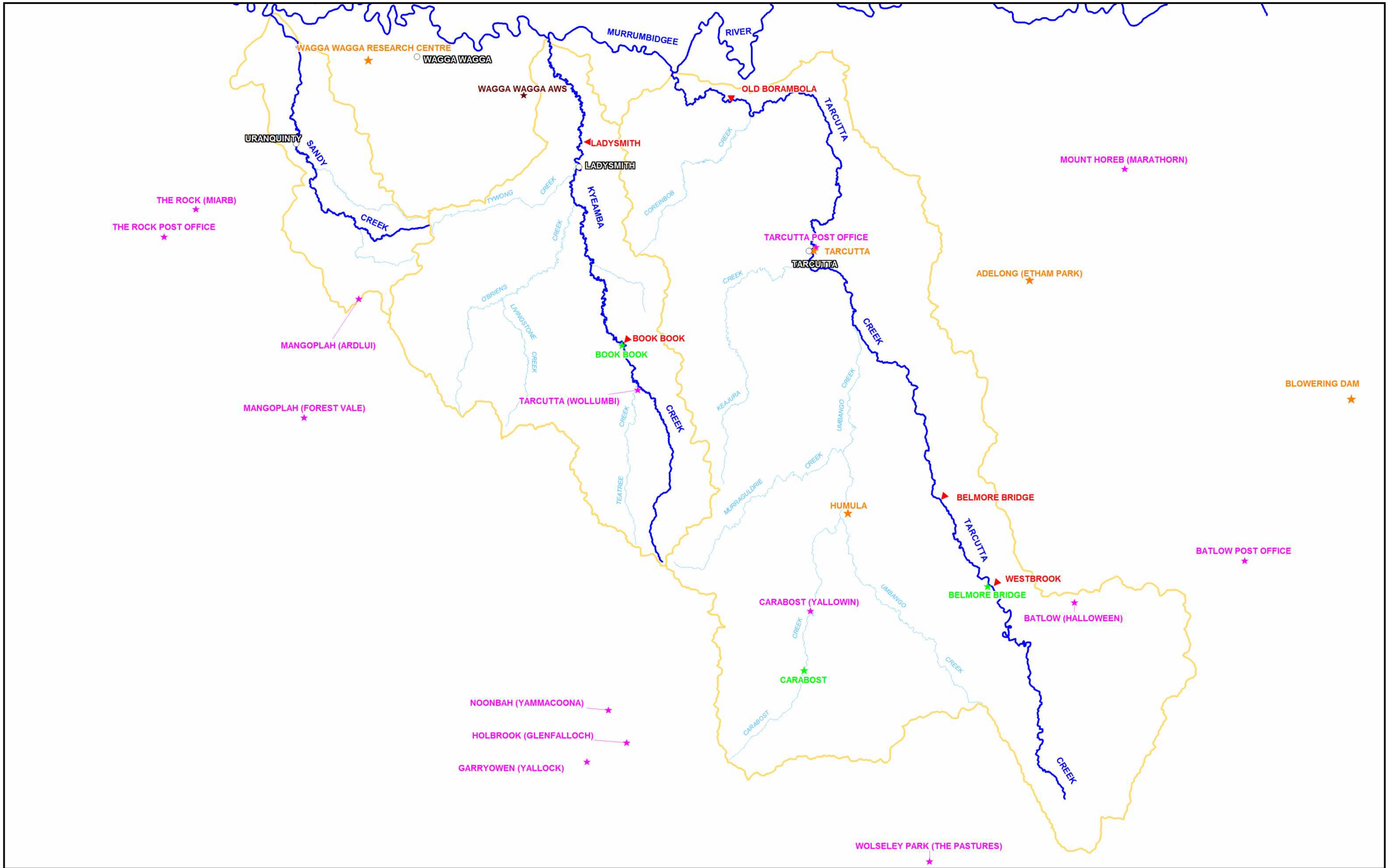
- From the review of the data and the results of preliminary hydraulic calculations reported later, it is considered that the rating curve at Old Borambola gauging station on Tarcutta Creek downstream of the village underestimates the peak discharge of major flood events. From discussions with New South Wales Office of Water (NoW), the high flow portion of the rating curve for the gauging station has been estimated by "eye" rather than by accepted hydraulic principles. The Consultants propose to revise the high flow portion of the rating curve at Old Borambola using hydraulic calculations based on one-dimensional modelling of the floodplain in the vicinity of the gauging station. In order to assess the potential attenuation of flows over the 16 km reach downstream of Tarcutta it is also proposed to extend the model upstream to the village and run the model in unsteady mode. This approach will yield a more accurate estimate of attenuation of flow than the alternative procedure of using the channel routing feature contained in the RAFTs model approach and at comparable cost (initial results are reported in **Section 1.9.3** of this report).
- An "independent" TUFLOW model of the Tarcutta Creek floodplain should be prepared using existing ALS data provided by WWCC, in lieu of the Flood Study adopting the existing TUFLOW model developed for investigation and design of the Hume Highway Bypass. For the preparation of that model, the Consultants propose to undertake some limited additional survey of the channel and floodplain of Tarcutta Creek downstream of the old Hume Highway to include possible amendments to the channel and floodplain subsequent to the recent flood events.
- Survey data of the creek and floodplain and collection of historic flood marks as summarised in **Annexure B**.

Ladysmith

- From discussions with personnel from NoW, the high flow portion of the rating curve for the gauging station on Kyeamba Creek at Ladysmith has also been "estimated by eye" rather than by accepted hydraulic principles. The Consultants propose to complete their initial revision of the high flow portion of the rating curve at Ladysmith using hydraulic calculations based on the one and two-dimensional modelling of the floodplain in the vicinity of the gauging station.
- The scope of the proposed survey of the creek and floodplain and the collection of historic flood marks are summarised in **Annexure A**.

Uranquinty

- The scope of the proposed survey of the creek and floodplain and collection of historic flood marks at the village are summarised in **Annexure B**. The work includes survey of drainage structures and floor levels in flood affected residences as identified by Bewsher, 2011.
- It is hoped that responses to the Community Newsletter will provide further information on the temporal pattern of rainfall recorded on the afternoon of 15 October 2010, which appears to be responsible for the local catchment overland flooding which surcharged the town levee.



N

3 0 3 6 9 km

Scale: 1:300,000

Lyall & Associates

LEGEND

▼ Stream Gauge	★ All Weather Station (AWS)
★ Daily Rain Gauge	★ BoM Flood Warning Network
★ Pluviograph Station	— Study Catchments

NOTE:
Note co-ordinates of Belmore Bridge rain gauge as per advice received from BoM.

TARCUTTA, URANQUINTY AND LADYSMITH FLOOD STUDIES

Figure S1.1

STUDY CATCHMENTS

1 TARCUTTA

1.1 Background

Tarcutta has a population of about 250 and is located on the Hume Highway 40 km south-east of Wagga Wagga. The village lies on the eastern bank of Tarcutta Creek, a tributary of the Murrumbidgee River. Tarcutta Creek has a catchment area of about 1,341 km^2 at Tarcutta.[1] Three principal sub-catchments make up the catchment at the village (see **Figure 1.1** which is taken from the Bewsher, 2011 report on data collection following the October 2010 flood in the Murrumbidgee Valley):

- Tarcutta Creek (also known as Oberne Creek) catchment which rises to the south near Tumbarumba and contributes runoff from 575 km^2 of catchment area.
- Umbango Creek (588 km^2), which joins Tarcutta Creek about 30 km upstream of the town.
- Keajura Creek (178 km^2) which joins Tarcutta Creek just upstream of the village.

The Tarcutta (Oberne) Creek catchment has gauging stations upstream of Tarcutta, at Westbrook and Belmore Bridge (station unrated and used for flood warning purposes). Tarcutta village has a manual gauge at the old Hume Highway Bridge. Old Borambola is an automatic gauge on Tarcutta Creek located downstream of the village. It gauges an additional 290 km^2 of catchment including the Coreinbob Creek catchment, giving a total gauged catchment area of 1,660 km^2, as advised by the Tumut office of NoW.

Parts of Tarcutta are protected by three levees – the Tarcutta levee, the Hambledon levee and the Old Tarcutta Inn levee (see **Figure 1.2,** also taken from Bewsher, 2011).

1.2 Previous Studies of Flooding at Tarcutta

A flood study was undertaken by Parsons Brinkerhoff (PB) as part of the Environmental Assessment for the Hume Highway Bypass of Tarcutta (PB, 2009). That study was based on a rainfall-runoff hydrologic model (WBNM) of the catchment and a two-dimensional hydraulic model (TUFLOW) employing a 10 m grid size, with natural surface elevations derived from an Airborne Laser Scanning (ALS) survey which was captured in 2009. The hydrologic model was calibrated to four historical events, all of which occurred prior to the record flood of October 2010 (ref. **Table 1.1**). The TUFLOW hydraulic model was calibrated to several flood marks applying to the September 2005 flood, which approximated a 5 year ARI flood in terms of peak discharge at Old Borambola.

A discharge-frequency curve for the flood record at Old Borambola gauge had been prepared by WMAwater for an investigation of the Bypass in 2007 which showed a large negative skew in the upper portion of the curve. The highest gauged discharge was an in-bank flow equivalent to the 5 year ARI peak. It was concluded by the previous investigators that the rating curve seriously underestimated the peak flows of major floods (such as occurred later in October 2010). As a consequence, PB, 2009 gave little weight to the discharge-frequency curve and based its estimation of design floods on the results of the WBNM catchment model. On this basis, PB, 2009 estimated the 100 year ARI peak discharge at Old Borambola at 905 m^3/s.

[1] This area was calculated from the RAFTS model developed for the present Flood Study.

TABLE 1.1
FLOODS AT OLD BORAMBOLA GAUGING STATION (GS 410047)

Date of Flood	Rank of Flood	Peak Stage (m)	Discharge (m^3/s)	Comments
October 1992	6	4.88	300	Analysed by PB,2009 for calibration of WBNM catchment model
October 1993	8	4.65	255	
September 2000	21	3.4	85	
September 2005	14	4.2	182	
March 2010	13	4.27	210	Recent floods which could potentially be used for calibration of RAFTS catchment model
September 2010	3	5.2	No data	
October 2010	1	5.42	450	
December 2010	5	4.9	330	
March 2012	7	4.84	No data	

The conclusion that high flows at Old Borambola are underestimated by the rating curve is supported by a comparison of peak flows at that gauge with corresponding flows at the Ladysmith gauge on Kyeamba Creek (ref. **Tables 1.1** versus **Table 2.1**). As noted later in **Section 2.3**, a similar situation of underestimation of flows by the rating curve may also occur at the Ladysmith gauge. The highest peak at Old Borambola where the catchment area amounts to 1,660 km^2 is 450 m^3/s (for the October 2010 flood), compared with 390 m^3/s at Ladysmith, where the catchment is only 530 km^2. The Tumut office of NoW advised that the usual procedure of using hydraulic calculations based on hydraulic conveyance capacity to extend the rating curve at Old Borambola (as well as at the Ladysmith gauge on Kyeamba Creek) has not been carried out and the high flow portions have been estimated by "eye". At Old Borambola, the October 2010 levels exceeded the maximum gauged levels and inundated the floodplain to a depth of over 1.0 m. In addition the gauging section did not extend onto the floodplain.

Subsequent to the PB, 2009 investigation, the Tarcutta Hume Alliance carried out flood modelling associated with the design of the Hume Highway Bypass (THA, 2010a); with additional studies being carried out following the occurrence of the October 2010 flood (THA, 2010b, 2010c). The Hume Highway Bypass of Tarcutta includes an elevated road embankment located within the floodplain downstream of the village. The route of the Bypass is shown on **Figure 1.2**. The waterway openings comprise a 330 m bridge across the Tarcutta Creek floodplain and a 60 m overbank floodway bridge.

None of these investigations involved improvements in the accuracy of the Old Borambola rating curve. The estimation of October 2010 flows by THA, 2010c was based on the PB, 2009 WBNM model and assessed the peak discharge as 900 m^3/s, equivalent to the 100 year ARI discharge (compared with a flow of 450 m^3/s for that event from the rating curve).

Consultants' Note
Further work is clearly needed to better define the high flow rating, otherwise it will not be possible to undertake model calibration for the Flood Study with any confidence. **Section 2.3** provides the Consultants' recommendation to refine the high flow rating curve by hydraulic analysis. The recommended work also includes unsteady flow hydraulic modelling of Tarcutta Creek between Tarcutta and the gauging station in order to assess whether or not there is an attenuation of peak flows which could potentially be responsible for a reduction in peak flow between those two locations.

1.3 Flood History

A history of floods in the Tarcutta Creek catchment is presented in **Table 13.1** of the Bewsher, 2011 study, based on gauge records (post-1938 for Old Borambola) and a newspaper search. Flood peaks for the Old Borambola gauge are reproduced herein as **Figure 1.3**.

The PB, 2009 study used pluviographic data recorded at sites outside the Tarcutta Creek catchment for model calibration. More recently, reporting rain gauges have been installed by BoM within the catchment, as part of its upgrading of its flood warning system. THA also had access to pluviographic data within the catchment at Tarcutta and Humula. Consequently, selection of the October 2010 and subsequent events for calibration purposes would be of advantage to the Flood Study, provided that the aforementioned problem with the rating curve at Old Borambola could be resolved.

Figures 1.4 to **1.6** show stage and discharge hydrographs for four recent flood events at Westbrook, Belmore Bridge and Old Borambola gauging stations, while **Figure 1.7** shows the extent to which these four floods, including the September 2010 event, inundated the floodplain at Old Borambola. As mentioned, the Belmore Bridge gauge is used by BoM for flood warning purposes and is not rated. **Figure 1.8** shows cumulative rainfalls at telemetered rain gauges for the four storms (ref. **Figure S.1.1** for gauge locations) and **Figures 1.9** to **1.14** relate the recorded storm rainfalls to design rainfall Intensity-Frequency-Duration (IFD) Curves.

1.4 October 2010 Flood

The October 2010 flood peak is the highest recorded flood at Tarcutta gauge (4.49 m), surpassing the next highest (in December 2010) by 0.64 m. At Old Borambola the peak height on the gauge was 5.42 m and the peak discharge 450 m^3/s (according to the rating curve). By inspection of the rainfall data on **Figure 1.8** rainfalls recorded at Carabost and Humula were most intense. These stations are located on the ungauged Umbango Creek, which was the main contributor to the flood event. For the 18 hour storm duration (which corresponds to the critical duration for the catchment at Tarcutta according to the previous studies) the recurrence intervals of rainfalls varied from 20 year ARI at Carabost to only 1 year ARI at Belmore Bridge located on Tarcutta (Oberne) Creek. These falls occurred on a wet catchment during the second burst of rainfall responsible for the flood peak of 15 October at Tarcutta. Given that losses would have been very small, the resulting flood peak would be expected to have a recurrence interval greater than 20 years ARI.

WWCC undertook a flood frequency analysis using flood heights at Old Borambola, which gave a 100 year ARI peak stage of about 5.5 m, which is similar to the observed 5.42 m on 16 October 2010. If as is likely some flood peaks were missed in the early years, the 100 year

ARI flood height may be somewhat higher than 5.5 m, rendering the October 2010 flood event somewhat more frequent.
The two flood peaks corresponding to the two rainfall bursts are clearly depicted for the Westbrook and Belmore Bridge gauges, but are more difficult to detect at Old Borambola gauge. Tarcutta (Oberne) Creek peaked at Westbrook at 18:30 hours on Friday 15 October and at Belmore Bridge at 21:45 hours (flood peak travel time 3.25 hours). There is some uncertainty about when Tarcutta Creek peaked at Tarcutta. The Rural Fire Service (RFS) log suggests that the flood peaked at about 19:40 hours (**Table 1.2**).

This is also consistent with information received from Council which shows a flood peak travel time from Belmore Bridge to Tarcutta of "-2" hours (i.e. Tarcutta peak at 19:45 hours, two hours before the peak at Belmore Bridge upstream). However, how regularly the manual gauge at Tarcutta was monitored during the event is not known (given the absence of any other readings, the difficult access as floodwater rises and the limited visibility at night, it appears not to have been monitored regularly). The RFS log shows later observations that imply higher floodwaters at 20:00 – 21:00 hours (see **Table 1.2**), and the RFS captain estimated the peak occurred at about 21:00 hours. A suggestion in THA (2010b) of a peak at midnight is considered too late for Tarcutta village. In the absence of further information, it is believed that the peak at Tarcutta occurred at about 20:00 – 21:00 hours.

TABLE 1.2
RURAL FIRE SERVICE LOG OF EVENTS AT TARCUTTA
15 OCTOBER 2010 FLOOD

Time (hours)	Intelligence
16:13	Predicted floodwaters to impact on Tarcutta early evening.
18:42	Tarcutta Creek now rising very quickly, about 1 hour for peak to reach Tarcutta.
19:41	Peak of floodwaters at Tarcutta.
20:13	Floodwaters at Tarcutta coming over levee banks as quick as sandbags put down. The local pub and Mobil service station are being impacted upon by water. Houses near the Police station [are] where the main effort to protect from water [is occurring]. Police closing Tarcutta off. Hume Hwy south of Tarcutta closed.
21:14	Tarcutta village: water now pouring over levee bank into village. People being evacuated by residents to RSL club at Tarcutta.

Based on interviews with the publican and the resident at 6 Centenary Drive, Bewsher, 2011 noted that water backed up on the upstream (eastern) side of the Bypass roadwork on Thursday 14 October. Floodwater was observed coming around the front of the pub and over the Hume Highway (from west to east) by 16:00 hours on Friday 15th (see **Figure 1.2**). At about 19:00 hours, water was ankle deep at 6 Centenary Drive, rising to waist deep shortly afterwards. Both the pub and the residence at 6 Centenary Drive were flooded *prior* to overtopping of the main Tarcutta levee, as floodwater backed up from the roadwork. According to the resident, when the main town levee overtopped (from about 20:00 hours) the floodwater at 6 Centenary Drive was no deeper but had a high flow velocity. The floodwaters receded somewhat overnight, allowing the Hume Highway to be re-opened on Saturday morning.

1.5 December 2010 Flood

The December 2010 flood peak is the highest recorded at Westbrook and Belmore Bridge gauges (both on Tarcutta (Oberne) Creek, upstream of the Umbango Creek junction) but not at Tarcutta, which according to Bewsher, 2011 may be attributed to reduced inflows from tributaries or to scour of the channel at Tarcutta during the October 2010 event.

The flood peaked at Westbrook at 03:30 hours on Thursday 9 December, at Belmore Bridge at 03:00 hours, at Tarcutta at 12:00 hours, and at Old Borambola at 20:00 hours where the peak discharge was about 330 m^3/s (according to the rating curve). The height at Tarcutta (3.85 m) was lower than in October 2010 (4.49 m), because of lesser contributions from the Umbango system.

The upstream heights prompted the SES to reinforce the main town levee with sandbags (about three high) from the Riverina Water Pump Station to the end of the levee near the Hume Highway Bridge. The levee was not overtopped, although there was little freeboard. Similarly the Hambledon levee was not overtopped, but the Old Tarcutta Inn residence was threatened (via the drain, not levee overtopping).

The rainfall responsible for this event occurred over the rain-day of 9 December and resulted in a single peaked hydrograph. For the 18 hour critical storm duration at Tarcutta, the recurrence intervals of rainfalls varied from slightly greater than 20 year ARI at Belmore Bridge on Tarcutta (Oberne) Creek, to around 1 year ARI at Carabost on the ungauged Umbango Creek.

The December 2010 flood would be a suitable event for calibration of the RAFTS model of Tarcutta Creek provided that the problems with the rating curve at Old Borambola could be resolved.

1.6 March 2010 Flood

The rainfalls responsible for this event occurred after the prolonged drought period. For the 18 hour critical storm duration at Tarcutta, the recurrence intervals of rainfalls varied from in excess of 20 year ARI at Carabost on Umbango Creek and at Wagga AWS less than 1 year ARI at Belmore Bridge. Contributions from the Tarcutta (Oberne) Creek catchment were quite small. At Old Borambola a double peaked hydrograph was recorded with the second peak achieving a discharge of about 210 m^3/s, slightly greater than the 5 year ARI (184 m^3/s).

Given the double peaked nature of the hydrograph this would be a difficult flood to successfully calibrate the RAFTS model and is not a particularly large event.

1.7 March 2012 Flood

Although rainfalls for this event were significant in terms of frequency, achieving about a 20 year ARI at Carabost and between 5 and 10 year ARI at Belmore Bridge, it is not possible to include this flood for model calibration as no gauge data are available at Old Borambola during the occurrence of the flood peak (ref **Figure 1.6**).

1.8 Summary Remarks

The October 2010 and December 2010 floods offer the best opportunity for model calibration. Model testing could be carried out for the March 2012 event provided NoW could supply information on the missing section of the stage hydrograph at Old Borambola. As mentioned, successful model calibration is dependent on achieving a more accurate representation of the high flow rating curve at Old Borambola. Model "calibration" undertaken using the existing rating curve will in our view result in misleading model parameters, which if adopted for design purposes, will lead to unreliable results for the Flood Study.

1.9 Recommendations for Further Data Collection and Analysis

1.9.1. Development of an Independent TUFLOW Model

At the Inception Meeting for the Flood Study in May 2012, the Consultants recommended preparing a TUFLOW model representing 2012 present day conditions based on the ALS survey data supplied by Council, with the existing Hume Highway road design (to be supplied by RMS) added to the model. This approach was an alternative to using the TUFLOW model which had been prepared by PB, 2009 and as amended by THA used in the design process of the Hume Highway Bypass of Tarcutta, including the pre- and post-road analyses of the October 2010 flood referred to in **Section 1.2**.

One of the reasons for recommending an "independent" model representing 2012 conditions for the Flood Study was to avoid the study (and possibly Council) being drawn into anticipated legal action by residents against RMS in regard to the possible impacts of the October 2010 road works on flooding at the village. It is often difficult for later users to correctly interpret all of the features which have been incorporated into hydraulic models developed by previous investigators. Although the present Consultants have undertaken a preliminary review of the structure of THA's TUFLOW model, we consider that it is not possible for us to assure ourselves that it contains all of the features which influence flooding at the village.

After the meeting the Consultants viewed the Tarcutta site and were approached by several residents. One resident was firmly of the view that there had been significant changes to the morphology of the channel and floodplain of Tarcutta Creek following the floods of the last few years. His view was that at least some of these changes had been caused by the works associated with the construction of the Hume Highway deviation, in particular a haul road which was in existence at the time of the October 2010 flood and which may not have been removed post-construction. The Consultants were not in a position to comment on the accuracy of the resident's claims. The relevance of the October 2010 flood to the Flood Study is for model calibration purposes only. Assessments of the effects of the Bypass on pre-project flood levels and flooding patterns are outside the scope of the Flood Study.

<u>Consultants' Recommendation T1</u>
For the above reasons, the Consultants recommend that an "independent" TUFLOW model of the Tarcutta Creek floodplain be prepared using existing ALS data provided by WWCC, in lieu of the study adopting the existing TUFLOW model developed for investigation and design of the Bypass.

1.9.2. Recommendation for Additional Survey at Tarcutta

Council's ALS survey (which would be used for constructing the independent TUFLOW model if the Consultants' recommendation is adopted by WWCC, as well as the ALS survey used by THA are dated 2008–2009 and therefore predate the four significant/major floods which have occurred over the past few years and which had the potential to affect the channel and floodplain (i.e. March 2010, October 2010, December 2010 and the recent March 2012 event).

Both Bewsher, 2011 and local residents noted that conditions in the channel and floodplain have not been stable across the historical period. The channel is influenced by erosion and siltation. The floodplain has also undergone significant changes, with the construction of two levees on the upstream side of the existing Hume Highway Bridge over Tarcutta Creek in 1969. This was part of a bridge upgrade and floodway bridge construction project, where the levees were intended to guide floodwaters under the bridges and to provide protection to floodplain structures (PB, 2009, p7). Following flooding in the 1980s and 1990s, the levees were raised (RTA, 1997). These features are included in existing ALS survey.

However, to defend possible claims by persons questioning the results that the Flood Study results are based on an obsolete ALS which does not represent 2012 conditions, it is proposed to undertake some limited additional survey of the channel and floodplain downstream of the old Hume Highway.

Bewsher, 2011 identified 11 buildings which experienced above floor inundation during the October 2010 flood. The depths of above floor inundation are shown on **Figure 7** in **Annexure B** which was taken from Figure 13.2 of Bewsher, 2011. It is proposed to survey the floor levels of these properties as part of the present flood studies. The peak flood level at each building will then be determined based on the depth of above floor inundation noted in the responses to SES's Flood Questionnaire. This approach to deriving historic flood marks is preferred as the capture of floor level data will assist in the preparation of the future *Floodplain Risk Management Study and Plan* for the village.

Several hydraulic structures were observed during the initial site inspection, information on which is not contained in the data provided by WWCC. In order to accurately model flooding and drainage patterns in the village it will be necessary for a surveyor to capture details of these structures.

Consultants' Recommendation T2

For the above reasons, the consultant recommends that several cross sections of the inbank of Tarcutta creek between the old and new Hume Highway bridges be surveyed. **Figure 4** in **Annexure B** shows the location of cross sections to be surveyed along the creek. The surveyed cross sections will be used by the Consultants as input to the one-dimensional elements of the independent TUFLOW model of the Tarcutta Creek floodplain.

The consultant also recommends that the floor levels of those buildings which experienced above floor inundation during the October 2010 flood be surveyed (refer **Figure 7** in **Annexure B**), as well as several hydraulic structures which influence flooding patterns.

1.9.3. Revision of the High Flow Rating Curves

As mentioned, successful model calibration is dependent on achieving a more accurate representation of the high flow rating curve at Old Borambola, as model calibration undertaken using the existing rating curve is likely to lead to misleading model parameters which, if adopted for design purposes are likely to lead to unreliable results for the Flood Study.

Revision of the high flow rating curve would normally require the development of a hydraulic model extending over a short reach of Tarcutta Creek downstream of Old Borambola. However, in order to assess whether there is significant attenuation of the flood wave between the village and the gauge site, it would be necessary to extend the hydraulic model upstream to Tarcutta and run it in unsteady flow mode.

Figure 1.15 shows the layout of a HEC-RAS model which was developed using ALS data supplied by WWCC for the purpose of the present flood studies. The cross sectional based hydraulic model extends from a location immediately downstream of the Hume Highway Bypass to a location 3.3 km downstream of Old Borambola, a total distance of 25 km by river.

Discharge hydrographs for the October 2010 flood, as generated by the Tarcutta Creek RAFTS model developed for the Flood Study were used as input to the hydraulic model, with rainfall loss values adopted from PB, 2009.[2,3]

Figure 1.16 shows the good correspondence was achieved between NoW's rating curve for Old Borambola and those generated by the hydraulic model for an inbank Manning's n value of 0.06. By comparison with **Figure 1.7**, the rating curve generated by the hydraulic model deviates significantly from NoW's rating curve at about top of bank level (i.e. at about 194.75 m AHD which corresponds to a level of 4.05 m on the gauge).

A Manning's n value of 0.08 on the overbank was required to generate a peak flood level which corresponds to the recorded gauge height of 5.42 m on the gauge. **Table 1.3** gives the peak flows generated by the Tarcutta Creek RAFTS model for the October 2010 flood.[4] Modelled and recorded peak flood levels at Old Borambola are also given.

Peak flows and flood levels for the 50 and 100 year ARI design storms of 18 hours duration (the critical storm duration) were also derived using the Tarcutta Creek RAFTS and HEC-RAS models. Design rainfall depths were adjusted by applying Aerial Reduction Factors (ARF's) derived from ARR, 1998 and Jordan et al, 2011. **Table 1.3** gives peak 50 and 100 year ARI flows at Tarcutta and Old Borambola for ARF's from these two references. The peak 50 and 100 year ARI flood levels generated by the hydraulic model at Old Borambola are also given in **Table 1.3**.

[2] For the purpose of the current assessment, rainfall recorded at the Carabost (GS 72012) and Belmore Bridge (GS 572010) rain gauges was considered to be representative the rain which fell on the Umbango Creek system, and upper Tarcutta (Oberne) Creek systems, respectively, while the rainfall which was recorded at the Book Book rain gauge (GS 572008) was considered representative of the rain which fell in the Tarcutta Creek catchment downstream of its confluence with Umbango Creek.

[3] Rainfall loss values adopted for the current assessment are given in Table 2 in Appendix A of PB, 2009 for a design storm with an ARI of 100 years.

[4] Peak flows given in **Table 1.3** at Old Borambola were derived by routing the Tarcutta Creek RAFTS model discharge hydrographs through the HEC-RAS model.

From the values given in **Table 1.3**, the October 2010 flood would appear to have been equivalent to between a 50 and 100 year ARI event. Adoption by WWCC of the Consultants' recommendation, will allow further refinement of the RAFTS and HEC RAS models to improve features such as the spatial and temporal distribution of the historic rainfall and the shape of the high flow rating curve at Old Borambola.

Consultants' Recommendation T3

The Consultants propose to revise the high flow portion of the rating curve at Old Borambola using hydraulic calculations based on one-dimensional modelling of the floodplain in the vicinity of the gauging station. In order to assess potential attenuation of flows over the 16 km reach downstream of Tarcutta it is proposed to extend the model upstream to the village and run the model in unsteady mode. This approach will yield a more accurate estimate of attenuation of flow than the alternative procedure of using the channel routing feature contained in the RAFTs model approach and at comparable cost. The availability of a hydraulic model which extends to Old Borambola will also assist in the model calibration process.

TABLE 1.3
SUMMARY OF PRELIMINARY RAFTS AND HEC-RAS MODELLING

Location	Gauge Height (m)						Peak Discharge (m^3/s)					
	October 2010 Flood		50 year ARI		100 year ARI		October 2010 Flood		50 year ARI		100 year ARI	
	Recorded	Modelled	[ARF= 0.81][(1)]	[ARF= 0.88][(2)]	[ARF= 0.81][(1)]	[ARF= 0.88][(2)]	Recorded	Modelled	[ARF= 0.81][(1)]	[ARF= 0.88][(2)]	[ARF= 0.81][(1)]	[ARF= 0.88][(2)]
Tarcutta Creek at Tarcutta[(3)]	-	-	-	-	-	-	-	680	570	700	730	875
Tarcutta Creek at Old Borambola[(4)]	5.42	5.48	4.98	5.40	5.48	5.68	450	900	630	895	945	1115

1. Jordan et al, 2011
2. ARR, 1998
3. Peak flows generated by the Tarcutta Creek RAFTS model.
4. Peak flows were derived by routing the Tarcutta Creek RAFTS model discharge hydrographs through the HEC-RAS model.
5. Modelled flows shown on this table were superseded by later analysis undertaken during the testing of the flood models developed for the design flood estimation.

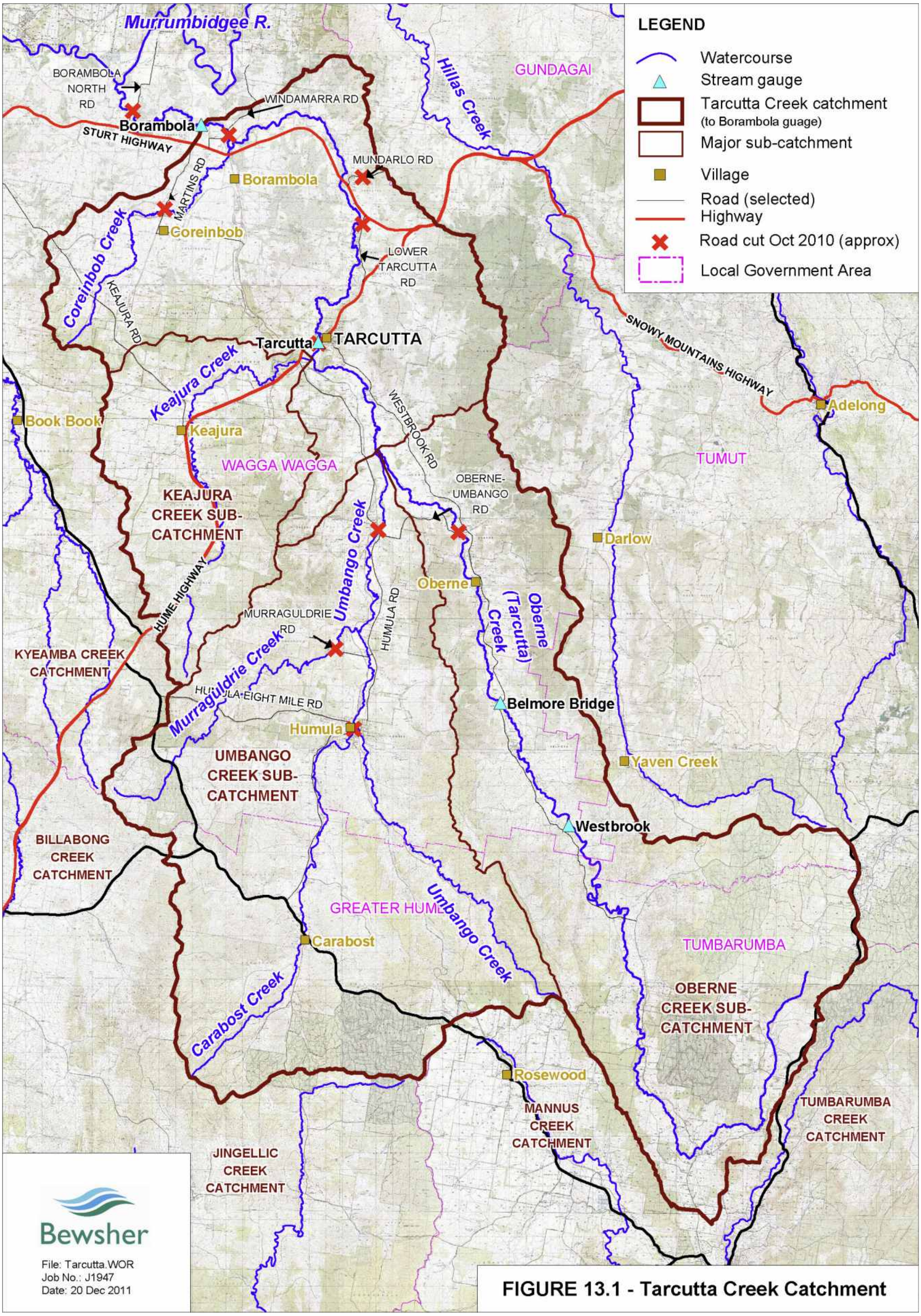


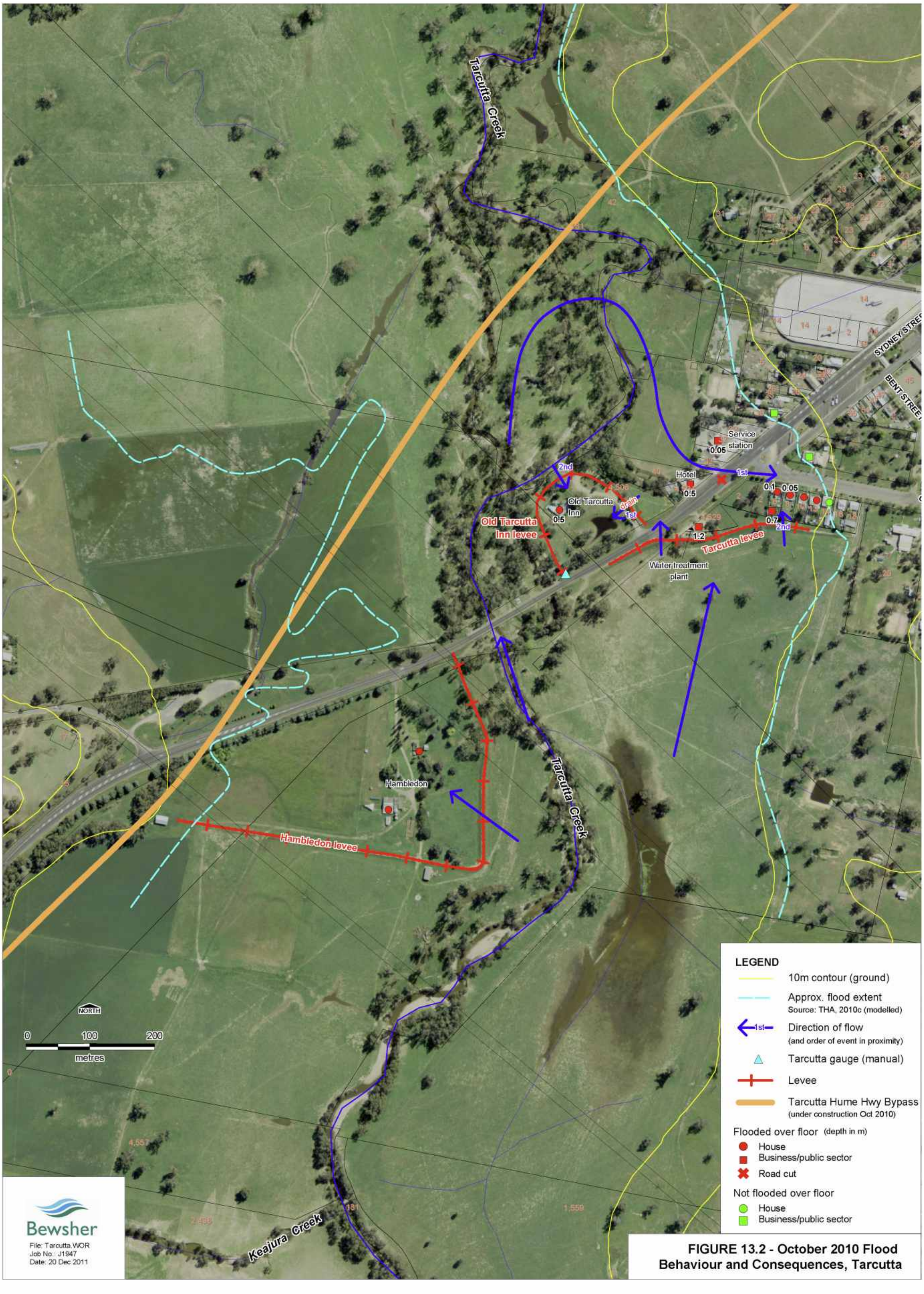
FIGURE 13.1 - Tarcutta Creek Catchment

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.1

Source: Bewsher, 2011

TARCUTTA CREEK CATCHMENT

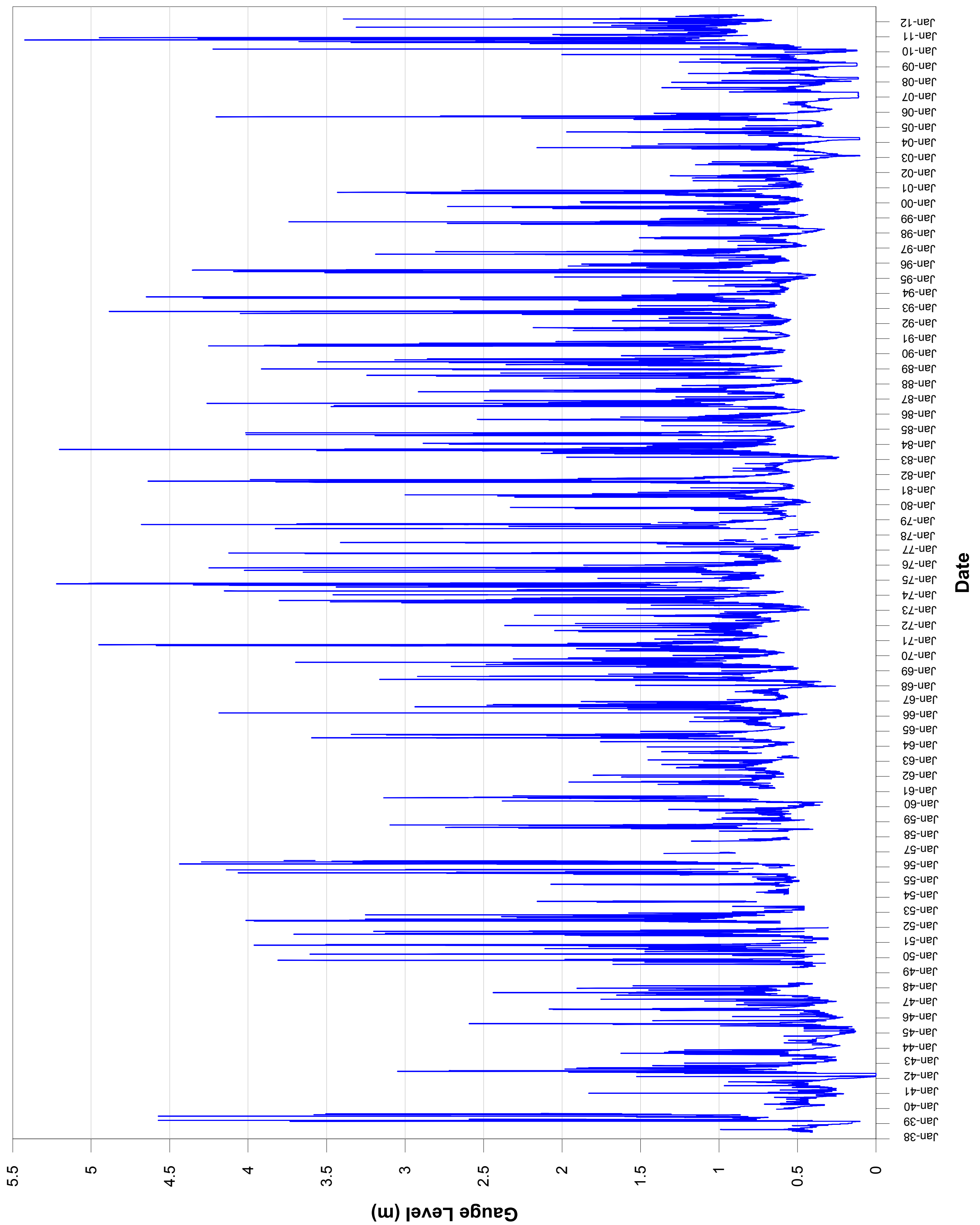


TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.2

OCTOBER 2010 FLOOD BEHAVIOUR AND CONSEQUENCES TARCUTTA

Source: Bewsher, 2011



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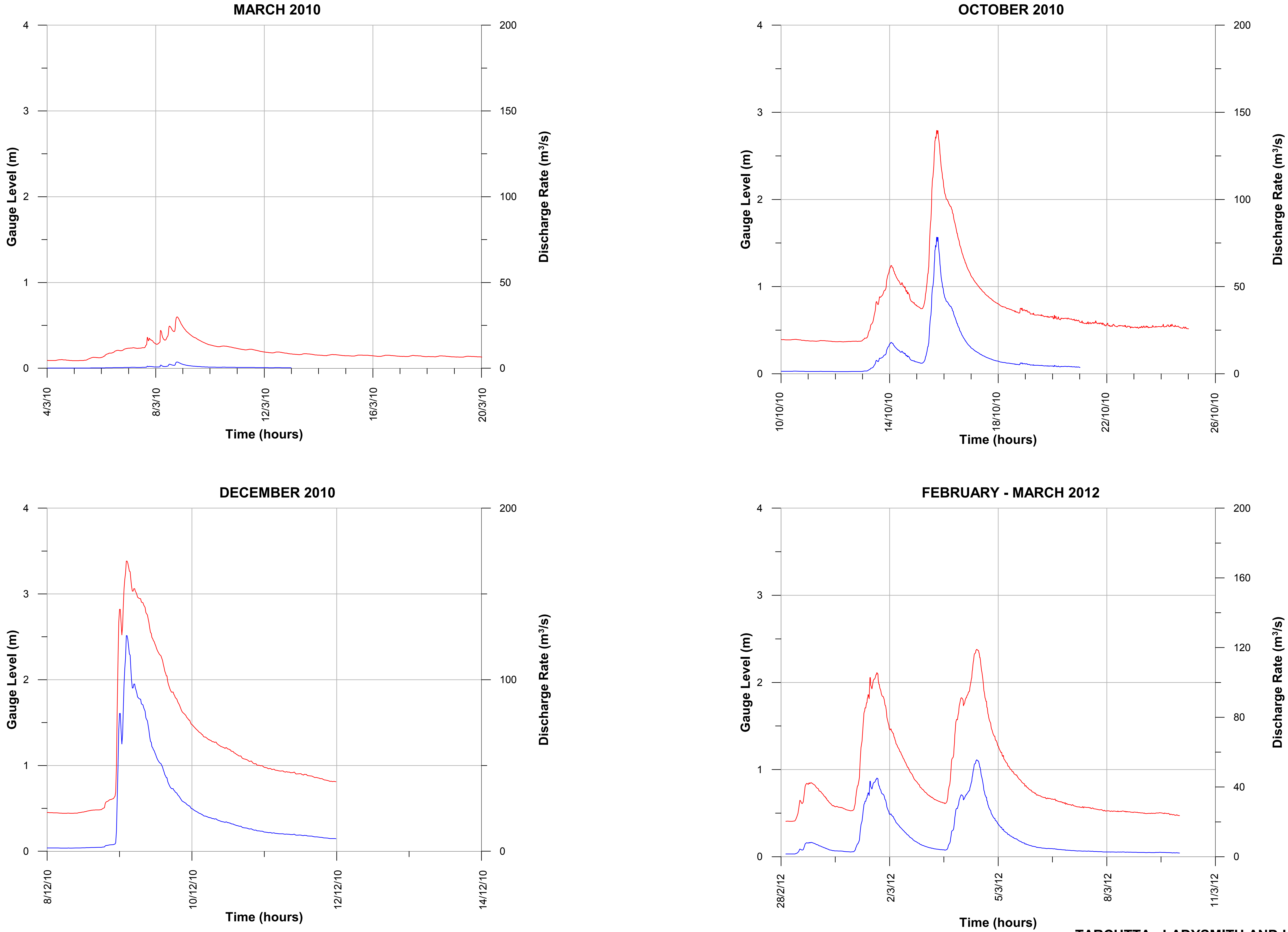
TARCUTTA LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.3

FLOOD PEAKS AT OLD BORAMBOLA GAUGE (GS 410047)



TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.4

STAGE AND DISCHARGE HYDROGRAPHS AT WESTBROOK GAUGE (GS 410058)

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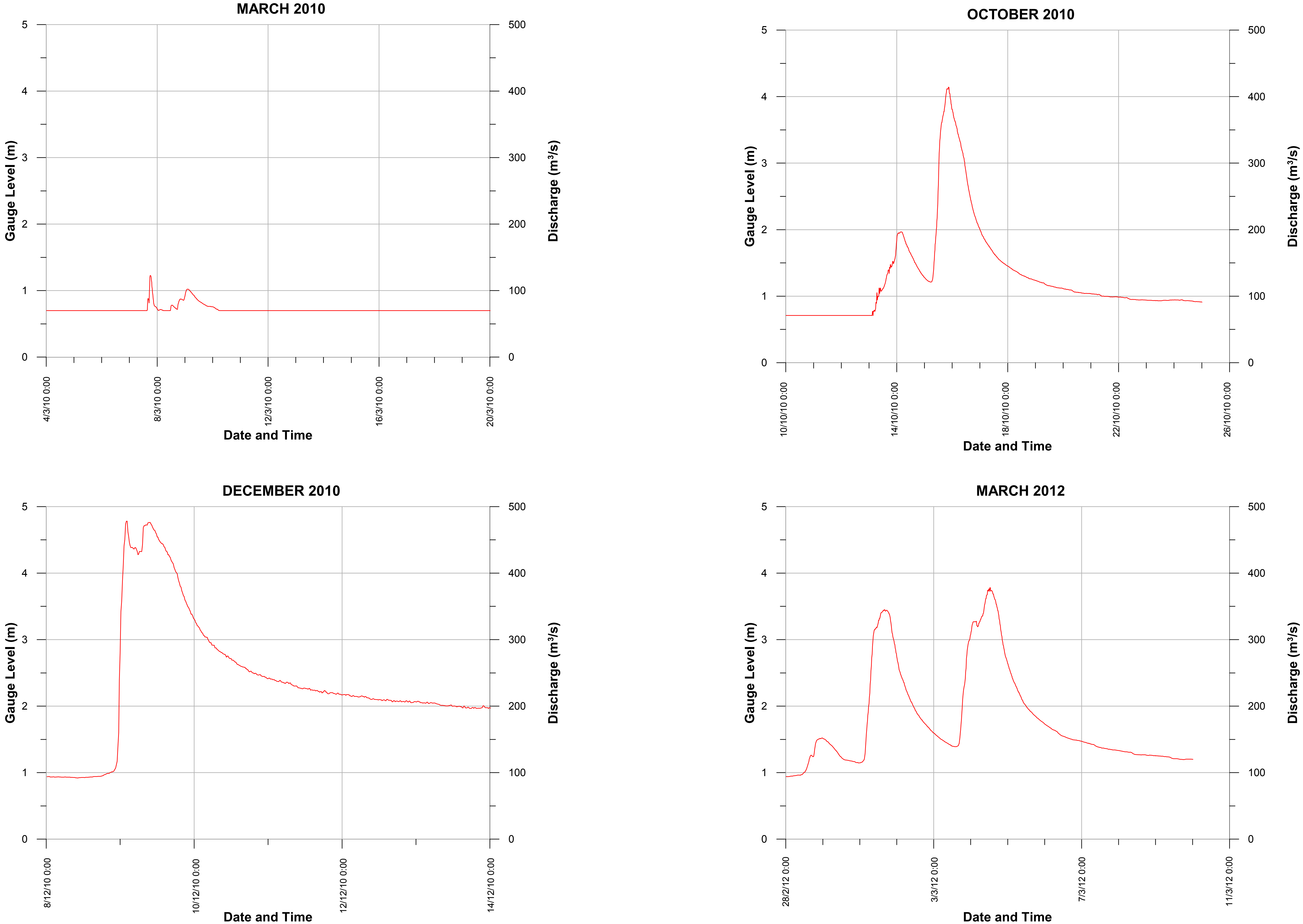
NOTE:

Catchment Area = 332 km²
Gauge Zero = 316.071 m AHD

LEGEND

Discharge Rate (m²/s)
Gauge Level (m)



Lyall & Associates

NOTE:

Station Not Rated
Gauge Zero: 284.367 m AHD

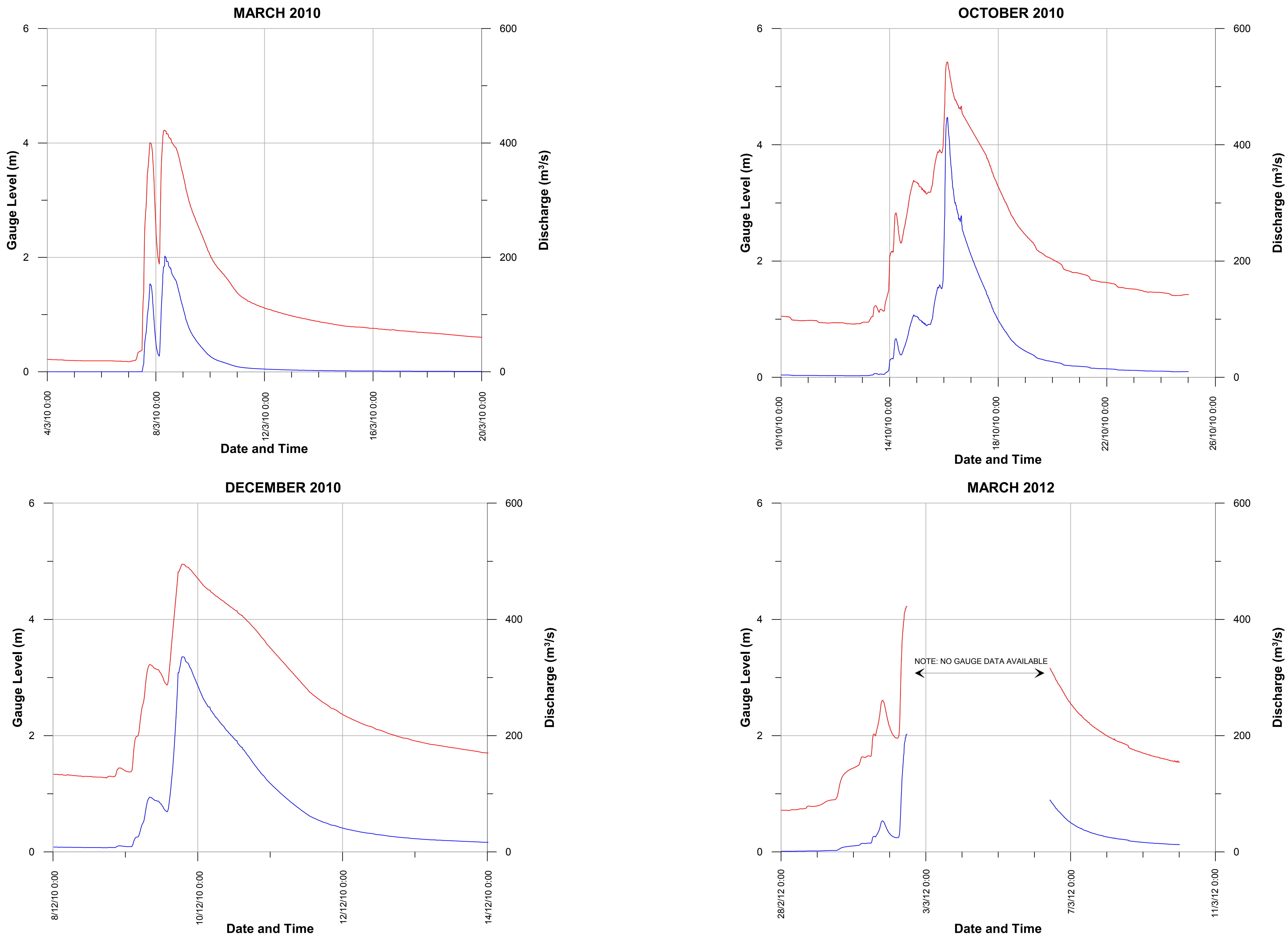
LEGEND

Gauge Level (m)

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.5

STAGE AND DISCHARGE HYDROGRAPHS
AT BELMORE BRIDGE GAUGE (GS 410155)



NOTE:

Catchment Area = 1,660 km²
Gauge Zero = 190.699 m AHD

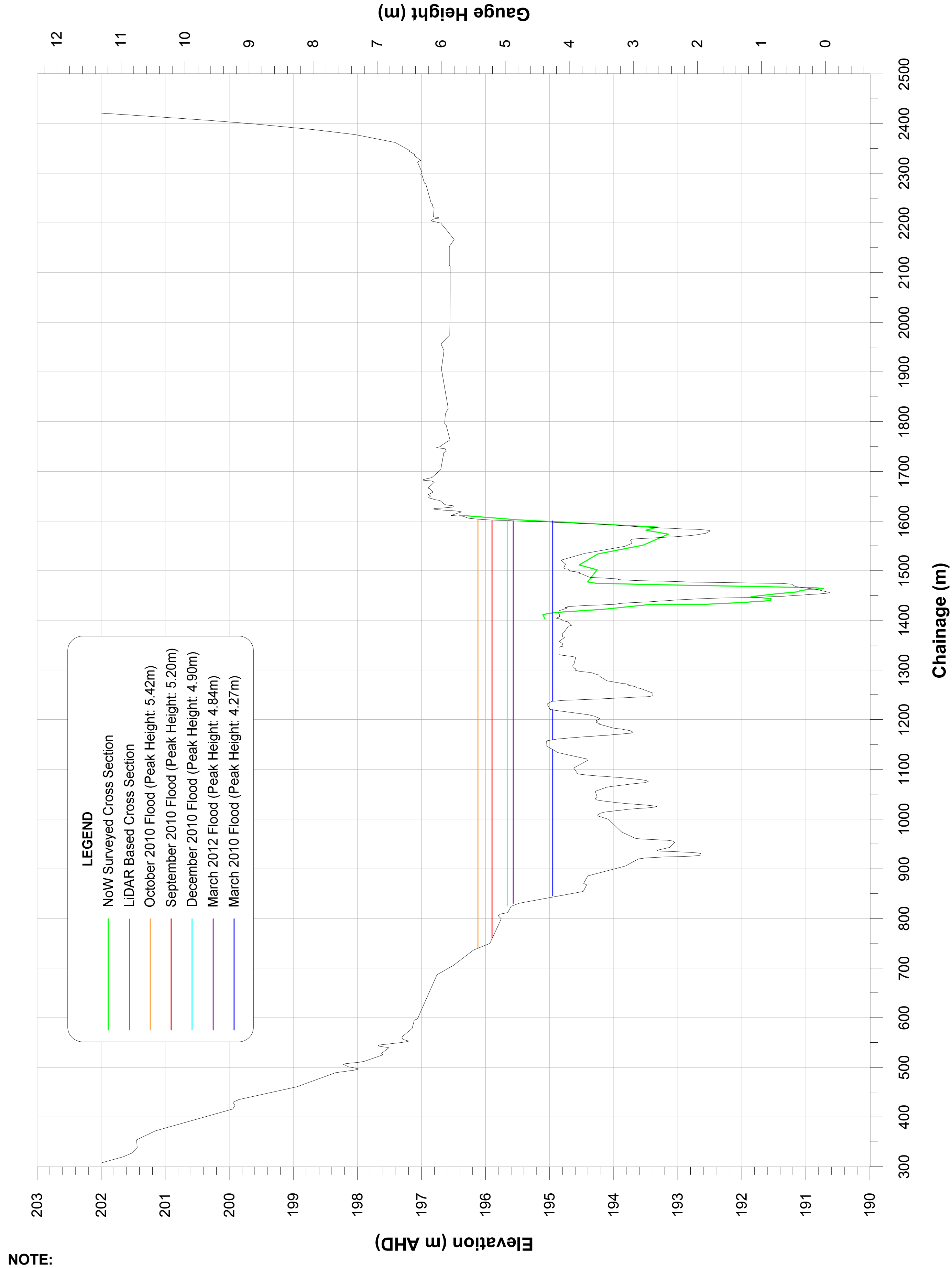
LEGEND

Discharge (m³/s)
Gauge Level (m)

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.6

STAGE AND DISCHARGE HYDROGRAPHS
AT OLD BORAMBOLA GAUGE (GS 410047)



NOTE:

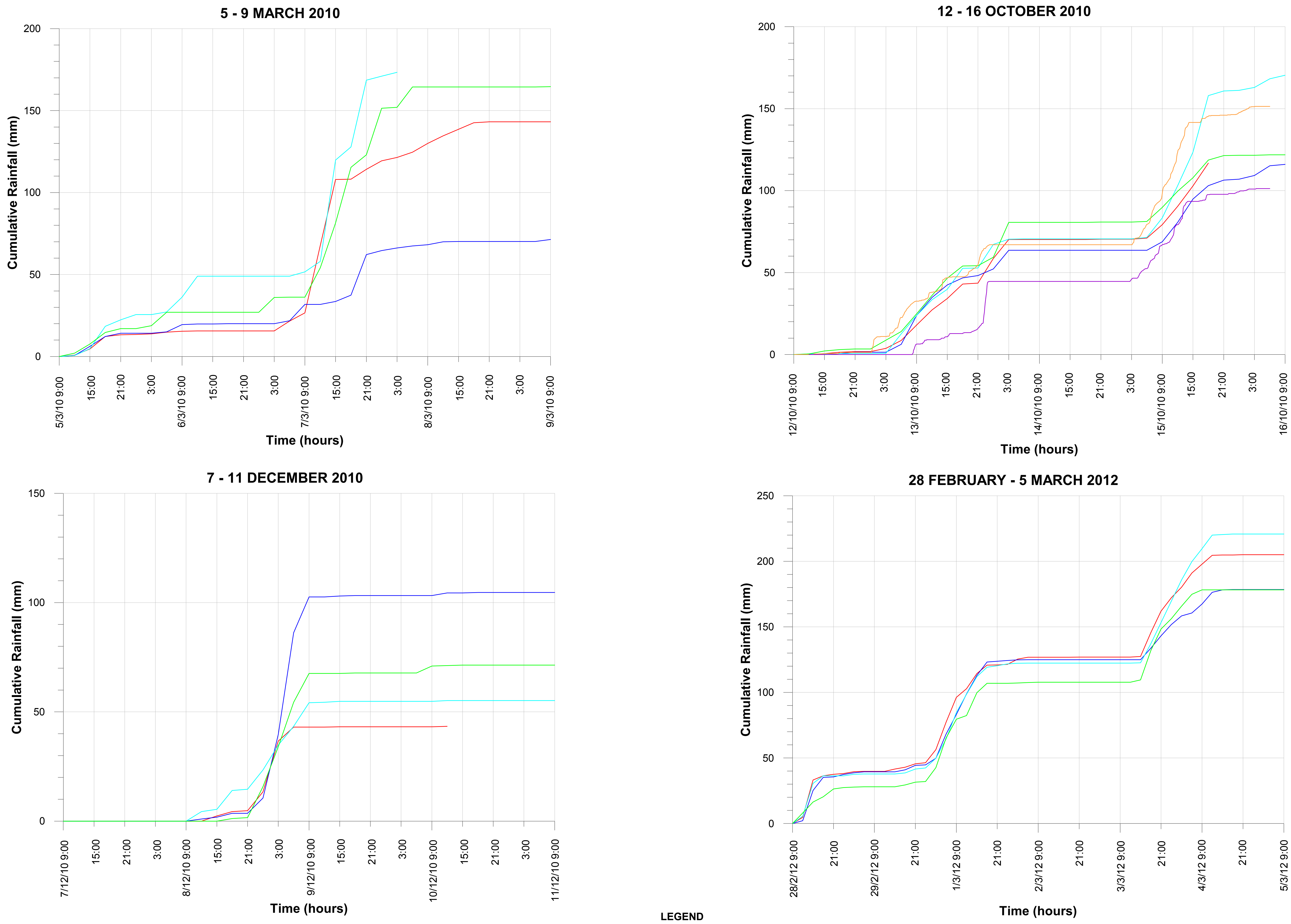
Gauge Zero = 190.699 m AHD
Refer Figure 1.15 for Location of Stream Gauge and LiDAR Based Cross Section.

TARCUTTA LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.7

CROSS SECTION AT OLD BORAMBOLA GAUGE (GS 410047)

Lyall & Associates



LEGEND

- Book Book (GS 572008)
- Belmore Bridge (GS 572010)
- Carabost (GS 72012)
- Wagga Wagga AWS (GS 72150)
- Humula
- Tarcutta

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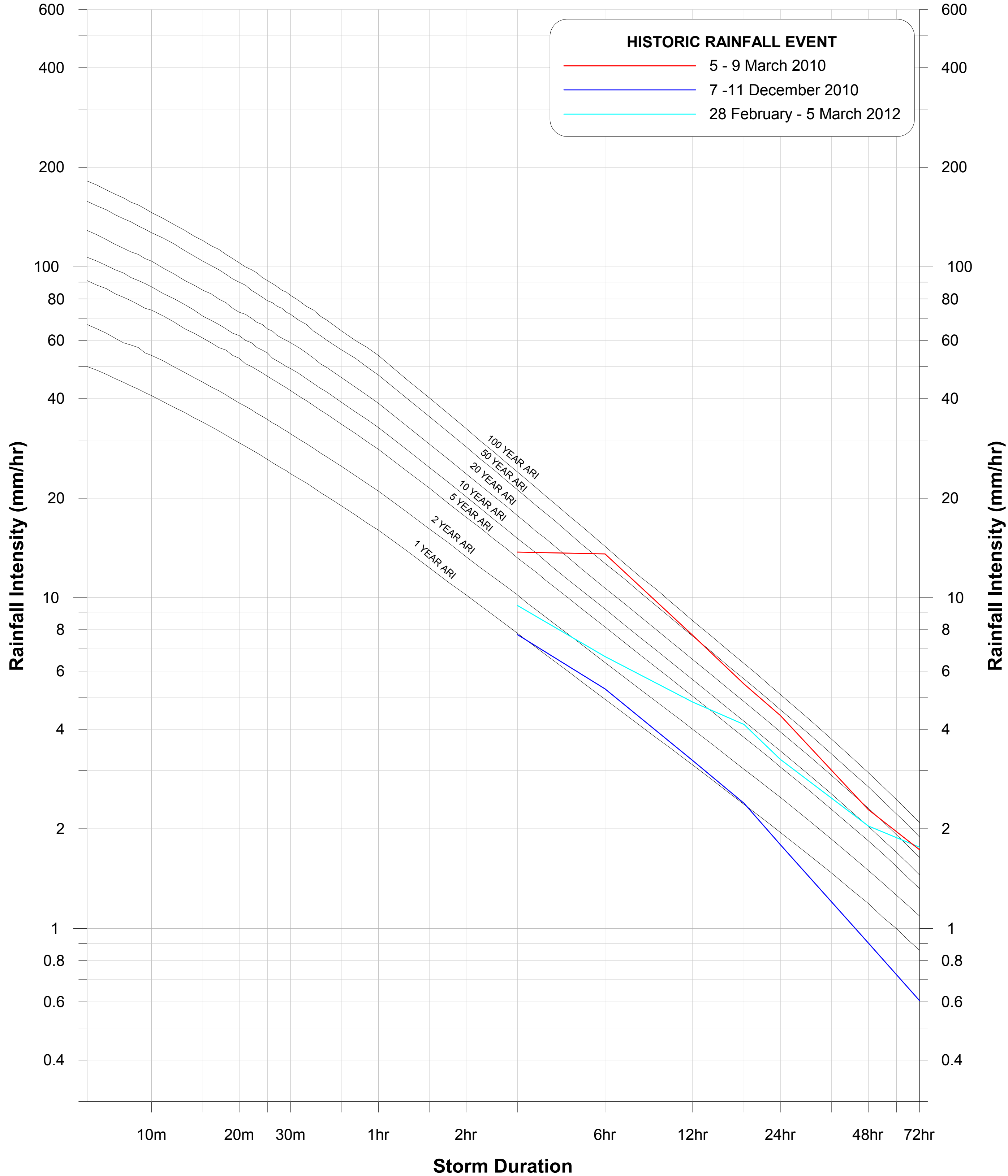
TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.8

HISTORIC STORM RAINFALLS



TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.9

INTENSITY-FREQUENCY-DURATION CURVES AND HISTORIC STORM RAINFALLS BOOK BOOK (GS 572008)

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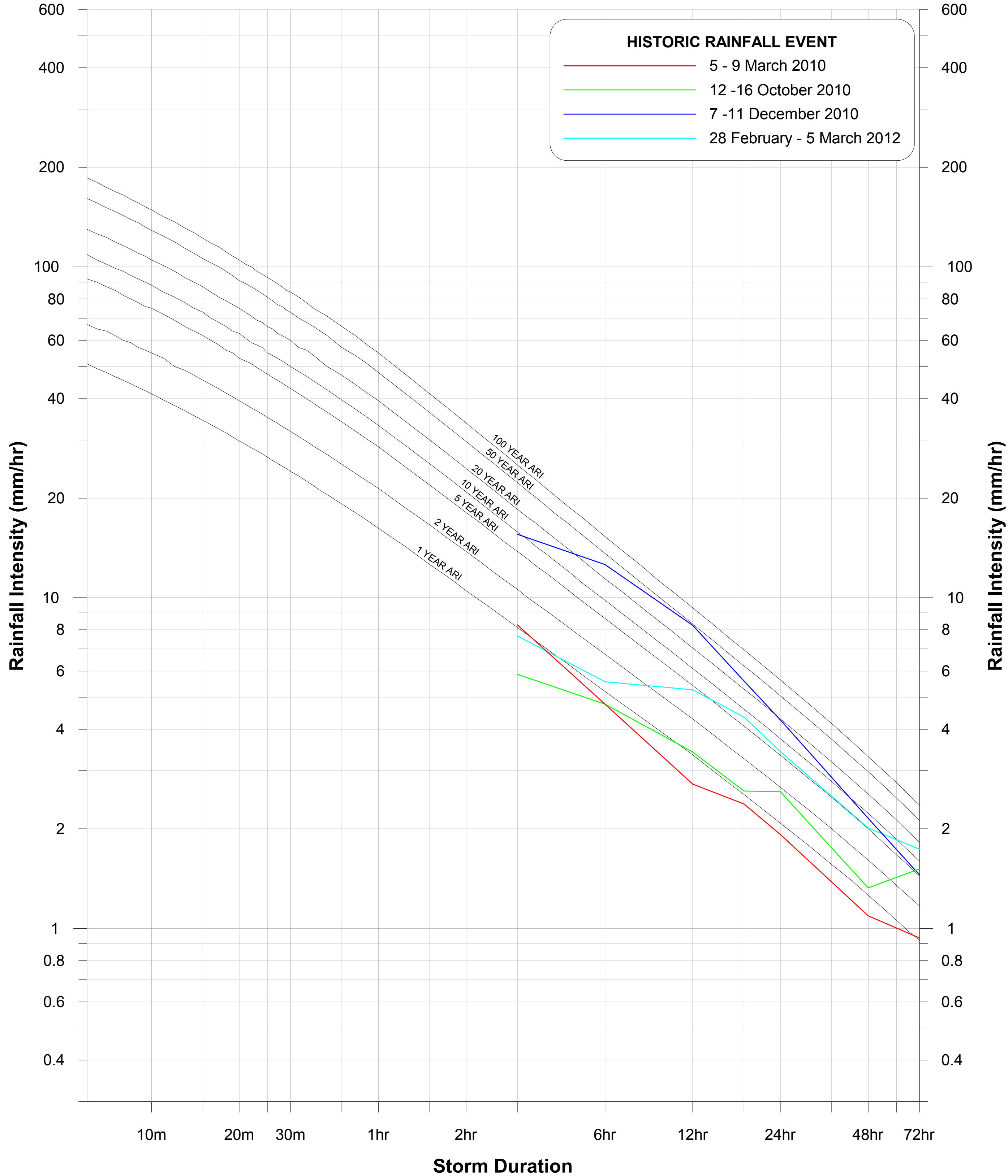

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.10

INTENSITY-FREQUENCY-DURATION CURVES AND HISTORIC STORM RAINFALLS BELMORE BRIDGE (GS 572010)

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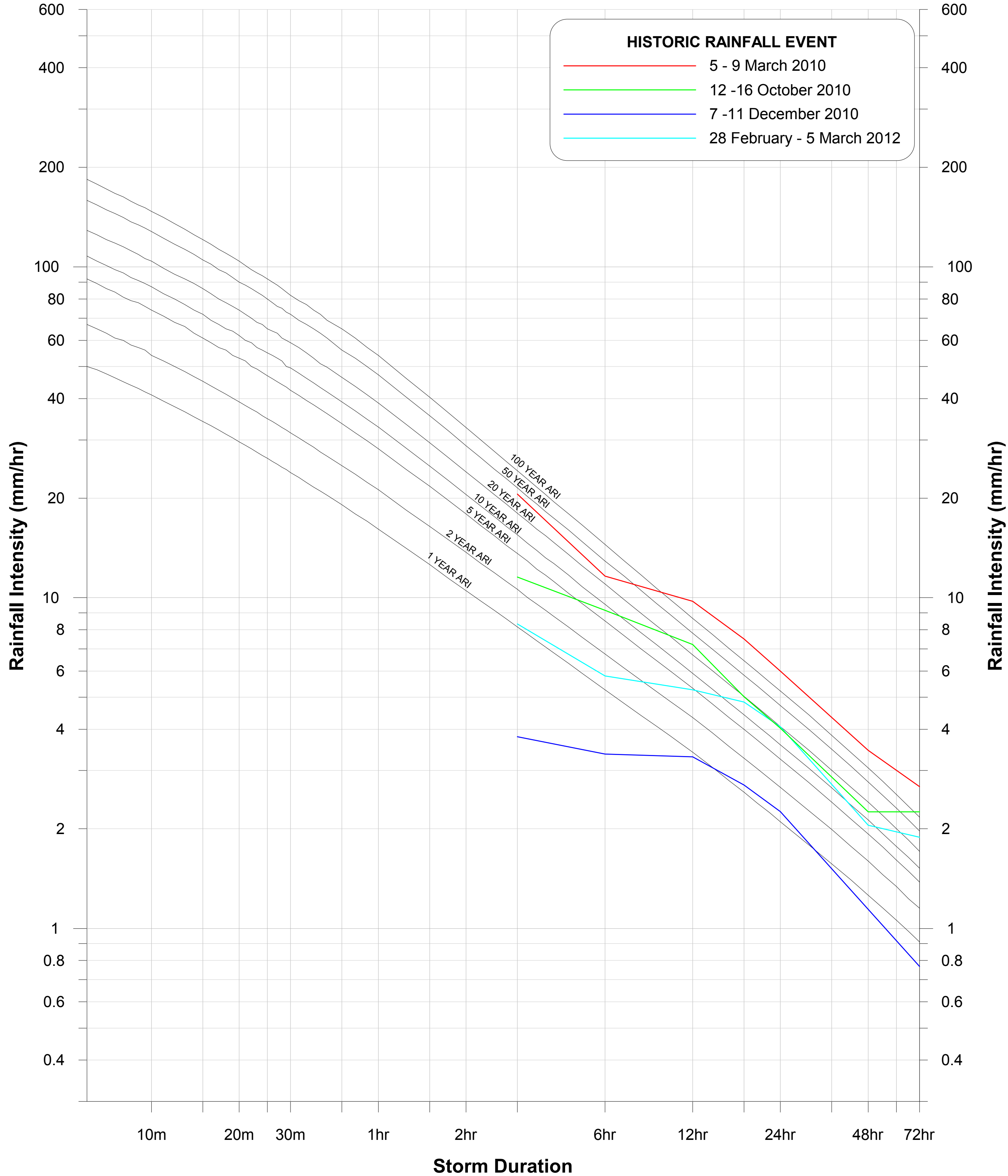

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.11

INTENSITY-FREQUENCY-DURATION CURVES AND HISTORIC STORM RAINFALLS CARABOST (GS 72012)

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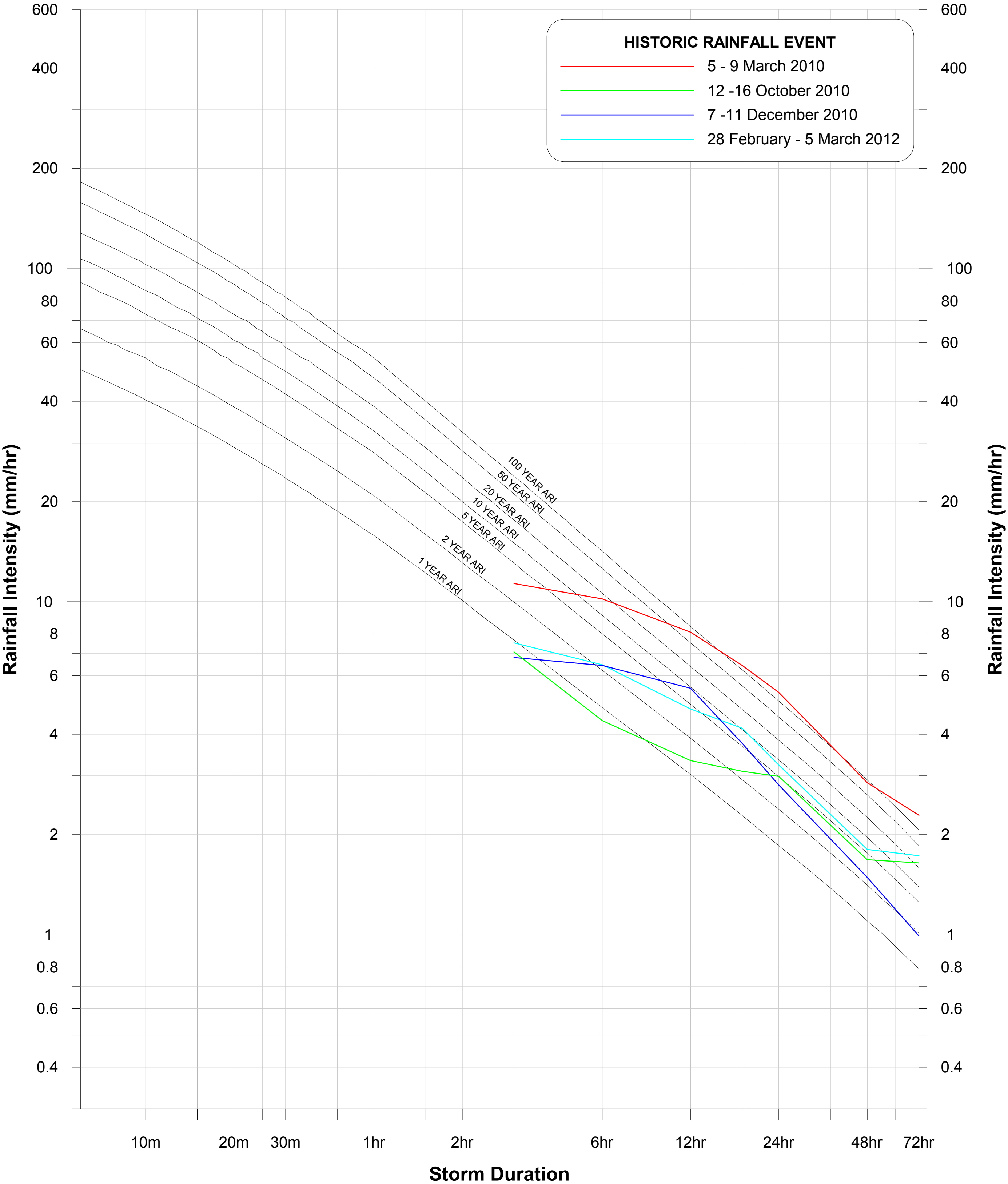

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.12

INTENSITY-FREQUENCY-DURATION CURVES
AND HISTORIC STORM RAINFALLS
WAGGA WAGGA AWS (GS 72150)

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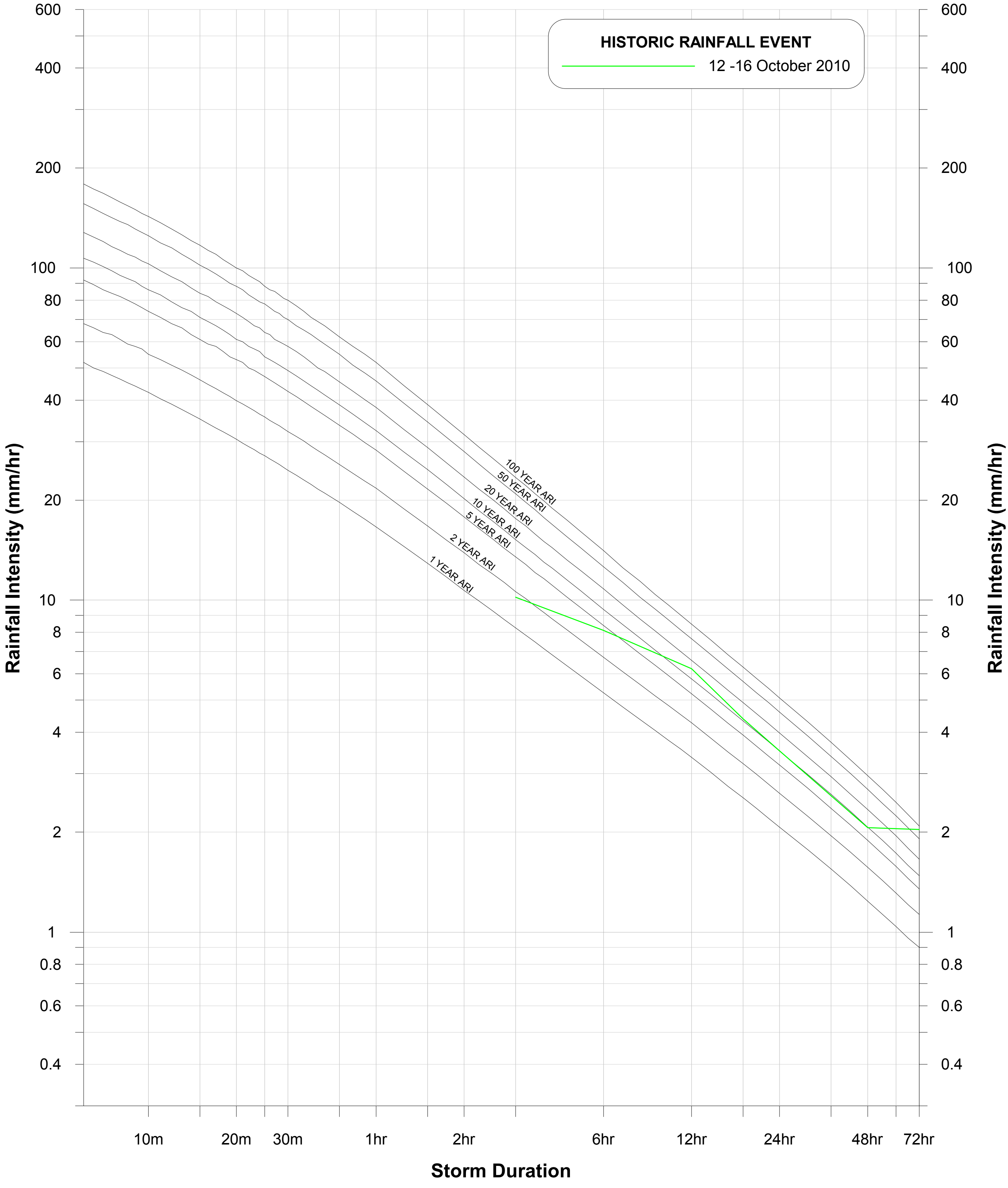

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.13

INTENSITY-FREQUENCY-DURATION CURVES AND HISTORIC STORM RAINFALLS HUMULA

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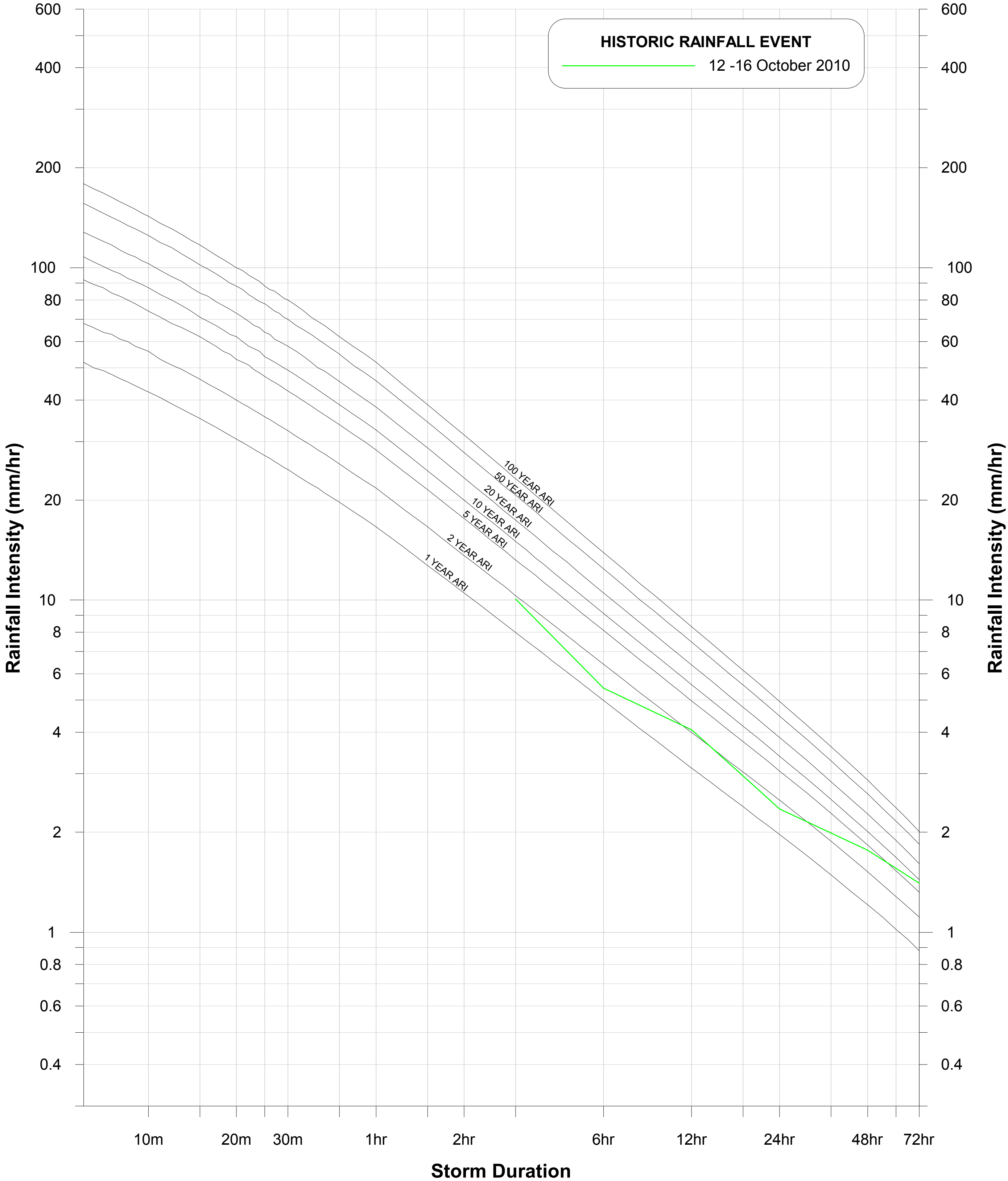

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.14

INTENSITY-FREQUENCY-DURATION CURVES AND HISTORIC STORM RAINFALLS TARCUTTA

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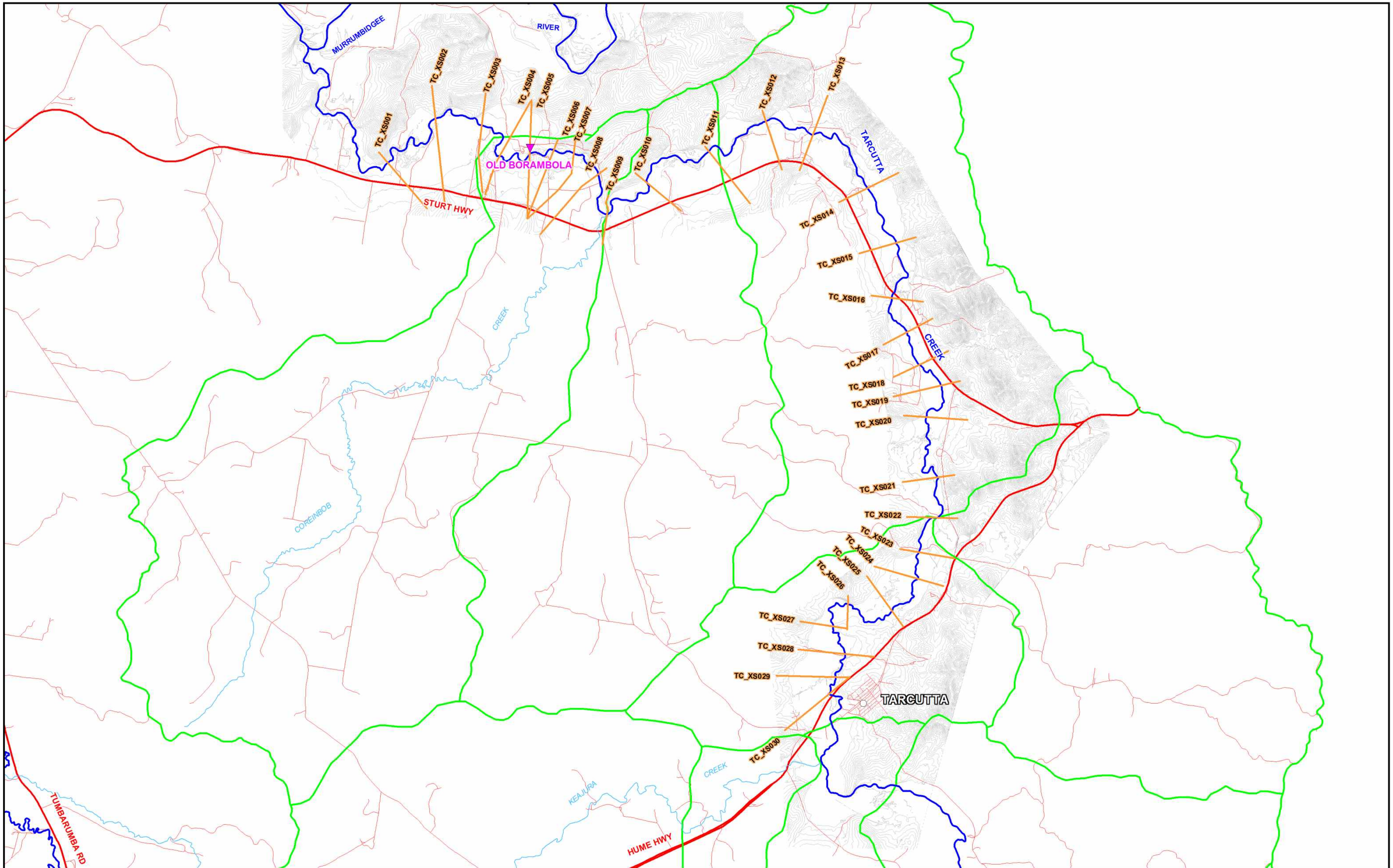

N

1 0 1 2 3 km

Scale 1:80,000

LEGEND

Major Road	TC_XS01 HEC-RAS Cross Section and Identifier
Minor Road	
Sub-catchment Boundary	

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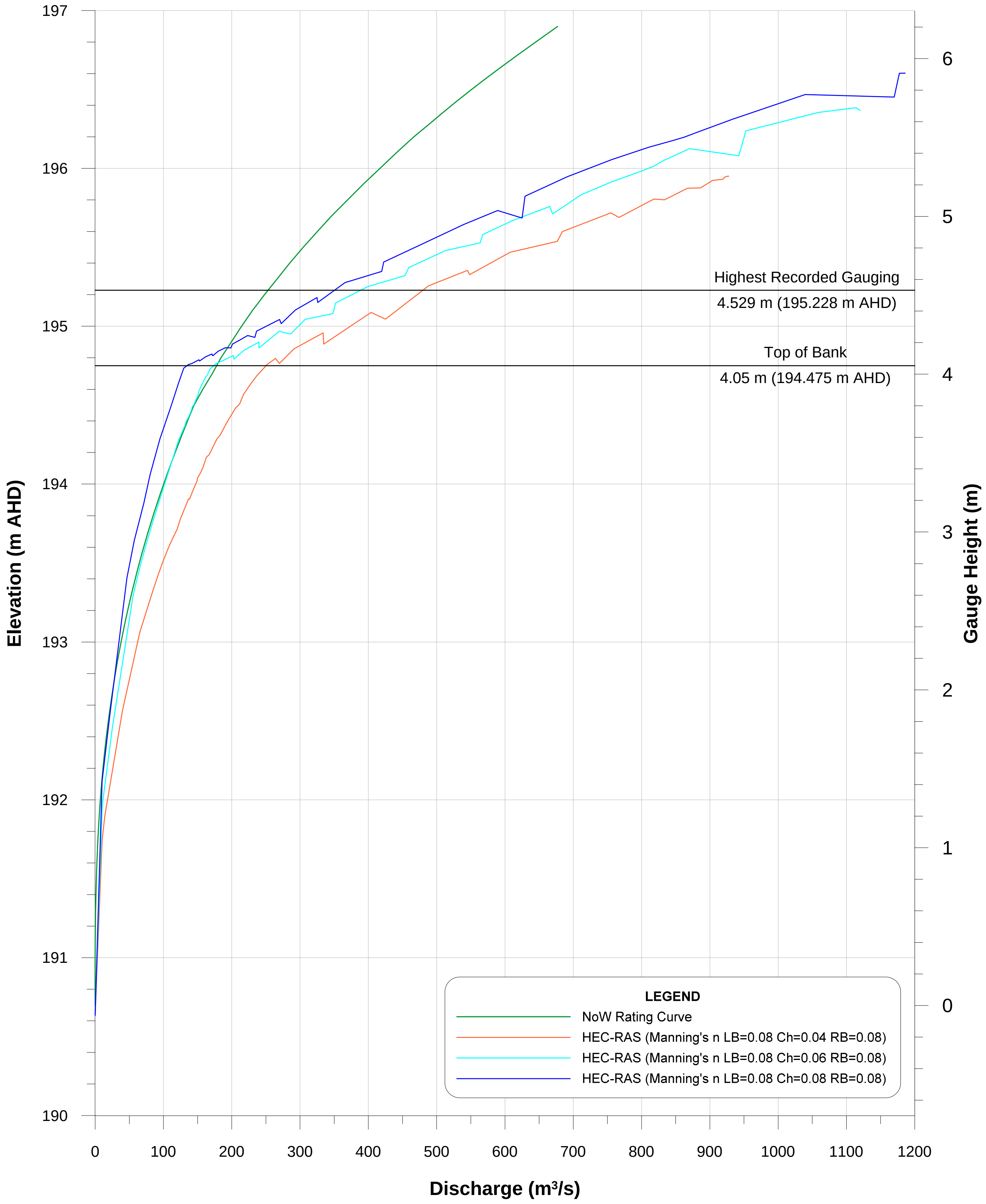
TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.15

HEC-RAS MODEL LAYOUT



Note:
Gauge Zero = 190.699 m AHD

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TARCUTTA LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 1.16

COMPARISON OF RATING CURVES
AT OLD BORAMBOLA GAUGE (GS 410047)

2 LADYSMITH

2.1 Background

Ladysmith has a population of about 200 and is located on Kyeamba Creek about 17 km (by river) upstream of its confluence with the Murrumbidgee River and 22 km from Wagga Wagga. Kyeamba Creek drains a catchment of 530 km^2 at the Ladysmith stream gauging station, flowing north from the Kyeamba Range at an elevation of 702 m at Mount Burngoogee to Ladysmith (elevation about 205 m). The catchment is elongated, with significant tributaries – O'Briens Creek and Tywong Creek – joining just upstream of Ladysmith (see **Figure 2.1,** taken from Figure 14.1 of Bewsher, 2011). There is also a stream gauge (unrated) and telemetered rain gauge in the upper reaches of Kyeamba Creek at Book Book which is used for flood warning purposes.

2.2 Previous Studies

No formal flood studies have been undertaken at Ladysmith or in the Kyeamba Creek catchment. The Water Resources Commission prepared an inundation map of the August 1983 flood for Ladysmith. No buildings were reported affected by that event, which reached 5.75 m (200.94 m AHD) on the Ladysmith gauge. Serious flooding was also reported in 1939 and 1974, but the gauge records for those years are discontinuous.

2.3 Historic Flooding

Kyeamba Creek has flooded many times since European settlement. **Figure 2.3** plots maximum stages since 1938 at the Ladysmith gauge, which is located just upstream of the disused Wagga Wagga to Tumbarumba railway line bridge (about 1 km downstream of Ladysmith). Although the gauge record is not continuous, the two highest floods on record are the March 2010 (5.85 m) and October 2010 (6.67 m) floods. **Table 2.1** over presents a ranking of floods at the Ladysmith. The Tumut office of NoW advised that the maximum gauging at the Ladysmith gauge occurred at a height of 5.5 m for a discharge of 194 m^3/s and that, as for Old Borambola, the high flow rating curve has been estimated by "eye". The rating curve is probably adequate for floods up to 6 m but there is considerable uncertainty in accepting it for calibrating the October 2010 flood which at 6.67 m is around 1.2 m higher than the maximum gauged height.

2.4 October 2010 flood

Respondents to the Bewsher, 2011 Questionnaire reported that the October 2010 flood was a record event in the Kyeamba Creek catchment. **Figure 2.2** shows flooding patterns in the vicinity of Ladysmith and is taken from **Figure 14.7** of Bewsher, 2011.

Hydrographs for the Kyeamba Creek gauges at Book Book and Ladysmith for the October 2010 flood are shown in **Figures 2.4** and **2.5** and show that the flood was double peaked. Only incomplete rainfall data are available at the Book Book telemetered rain gauge and therefore it is not possible to assess the return period of rainfalls. Depths are available at several daily gauges. The first rain event produced a fall of 96 mm at Wollumbi, and led to a peak of 2.75 m at 02:30 hours on Thursday 14 October at Book Book and a peak of 5.22 m at 12:30 hours at Ladysmith. The second rain event produced a fall of 135 mm at Kyeamba Downs, and with the preceding rain having saturated the catchment and the creek levels still high, produced higher flood peaks of 4.56 m at 16:00 hours on Friday 15 October at Book Book and 6.67 m at 21:00 hours at Ladysmith. Flood levels exceeded 5.0 m at Ladysmith for almost three days.

TABLE 2.1
FLOODS AT LADYSMITH GAUGING STATION (GS 410048)[1]

Date of Flood	Rank of Flood	Peak Stage (m)	Discharge (m^3/s)
September 2005	6	5.05	114
March 2010	3	5.85	250
September 2010	4	5.19	136
October 2010	1	6.67	390
December 2010	5	5.10	125
March 2012	2	6.02	290

1. Note that only those floods for which recently recorded rainfall data are available are presented in **Table 2.1**. Data for the period 1938-1987 show that peak stage did not exceed 5.5 m on the gauge over this period.

According to Bewsher, 2011, flooding at the Ladysmith gauge is strongly influenced by its location just upstream of the disused Wagga Wagga to Tumbarumba railway line, which has an embankment several metres above the floodplain and acts as a major control. It is understood that the railway line embankment was overtopped in October 2010. Flow from a flood runner also eroded a portion of the railway embankment just west of the bridge provided for that flood runner, leaving the railway tracks hanging in mid-air.

Reported flow velocities were generally slow for inundation of the floodplain. Information about the direction of flows (especially overland flows) in the vicinity of Ladysmith village is shown on **Figure 2.3**. Insufficient data were available to Bewsher, 2011 to prepare a complete flood extent.

2.5 March 2010 Flood

Hydrographs for the March 2010 Kyeamba Creek flood are shown in **Figure 2.4** and **2.5**. The peak level at Ladysmith was 5.85 m equivalent to a discharge of 250 m^3/s (as only a small extension of the rating curve above the maximum gauged level of 5.5 m was required, the discharge estimate for this event is probably sufficiently accurate for model calibration purposes). At the Book Book rain gauge, rainfall intensities were around the 50 year ARI level for durations exceeding about 4 hours. This may be somewhat inconsistent compared with the (incomplete) record of Book Book rainfalls for the considerably larger (in terms of peak discharge) October 2010 flood.

The flood peak travel time between the Book Book and Ladysmith gauges was almost 9 hours in the March event. A house located 300 metres downstream of the railway line – 'Trevella' – was reportedly flooded to a depth in the October event only 0.2 m greater than in the March event, which may also point to the influence of the railway line as a hydraulic control.

2.6 December 2010 Flood

The December 2010 flood was only a minor event on the Kyeamba Creek catchment with rainfalls at Book Book around 1 year ARI in intensity over a broad range of durations (**Figure 1.8**).

2.7 March 2012 Flood

The March 2012 flood was a double peaked flood with peak level and discharge of 6.02 m and 290 m^3/s at Ladysmith. Rainfall intensities at the Book Book gauge were only around the 2 to 10 year ARI level for the range of durations likely to be critical on this catchment. These intensities are inconsistent with the much greater intensities experienced during the smaller (in discharge terms) March 2010 event. Further research on rainfalls experienced in the catchment would be required to achieve a successful calibration of the RAFTS model for this flood.

2.8 Summary Remarks

The October 2010 flood offers the best opportunity for model calibration, provided the rainfall record at the Book Book rain gauge could be completed (by further discussions with BOM). Calibration of the March 2010 flood would not be as dependent on the accuracy of the rating curve as it is a smaller, single peaked event which a peak closer to the highest gauged flow. However, there is a concern that the rainfall recorded at Book Book may overestimate average falls in the catchment. The converse applies for the larger March 2012 event, successful calibration of which would require a greater accuracy in the rating curve.

2.9 Recommendations for Further Data Collection and Analysis

2.9.1. Recommendation for Additional Survey at Ladysmith

As discussed at the Inception Meeting, cross sections of the inbank area of Kyeamba Creek at Ladysmith will be derived from the available ALS survey data, rather than from field survey means. Field survey will therefore be limited to capturing details of critical hydraulic structures and the floor levels of the two residences identified in Bewsher, 2011 as having experienced above floor inundation during the October 2010 flood.[5] A cross section will also be taken along the disused Wagga Wagga Tumbarumba railway line where it crosses the floodplain of Kyeamba Creek (refer **Section 2.9.2** for further discussion).

Consultants' Recommendation L1

The Consultants recommend that field survey at Ladysmith be limited to the capture of information on critical hydraulic structures and the floor levels of the two residences which are reported to have experienced above floor inundation during the October 2010 flood. The Consultants also recommend that a cross section be taken along the disused Wagga Wagga Tumbarumba railway line at the location of the Ladysmith stream gauge. **Figures 3** and **6** in **Annexure B** show the extent of the proposed survey at Ladysmith.

[5] Note: Peak flood levels recorded at the two residences will be determined based on the depth of above floor inundation noted in the responses to SES's Flood Questionnaire. The approach to deriving historic flood marks is preferred as the capture of floor level data will assist in the preparation of the future *Floodplain Risk Management Study and Plan* for the village.

2.9.2. Revision of the High Flow Rating

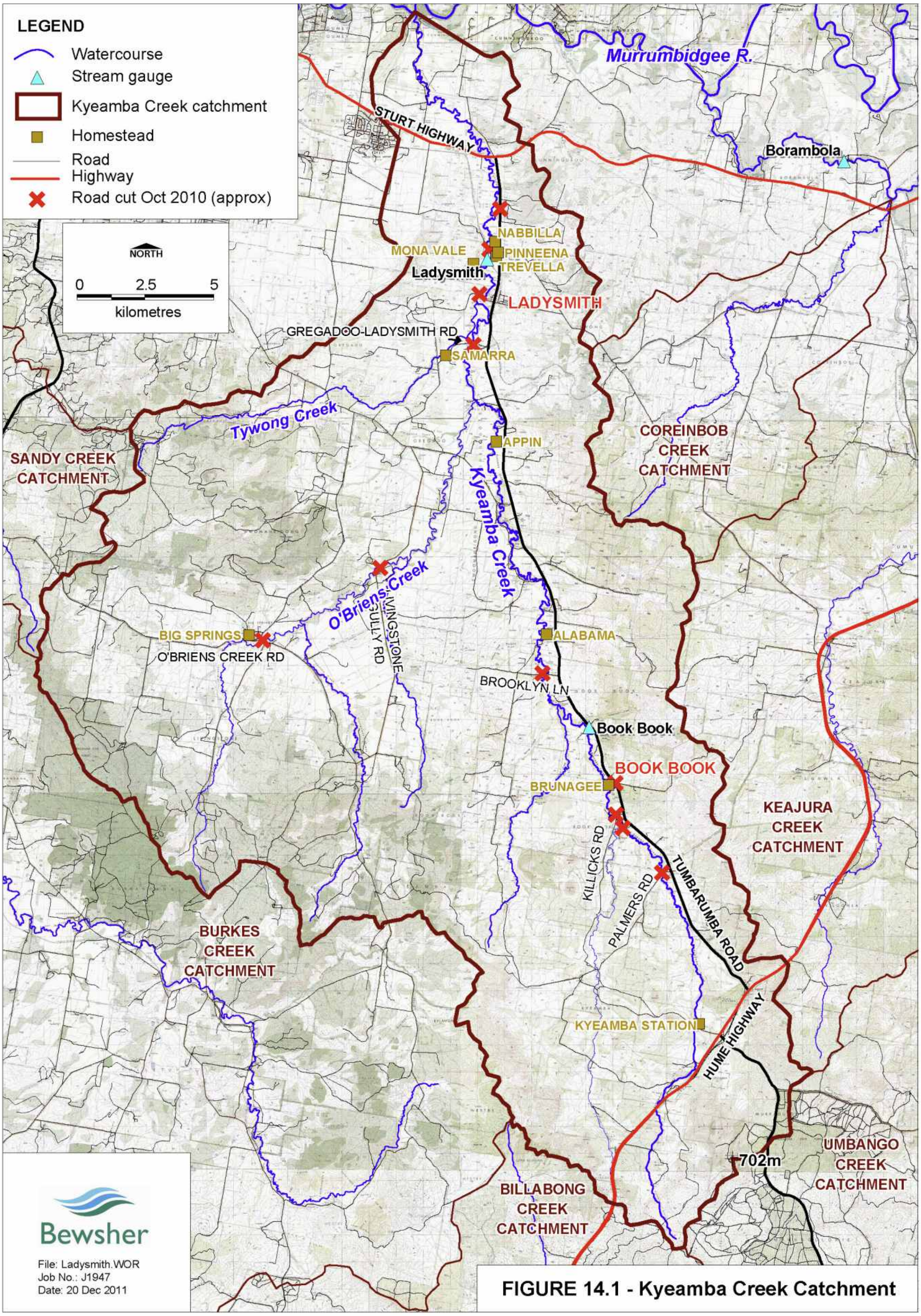
Successful model calibration for the larger events is dependent on achieving a more accurate representation of the high flow rating curve at Ladysmith. Model calibration undertaken using the existing rating curve is likely to lead to misleading model parameters, which if adopted for design purposes are likely to lead to unreliable results for the Flood Study. Accordingly, the Consultants propose to revise the high flow portion of the rating curve at Ladysmith using hydraulic calculations based on TUFLOW modelling of the floodplain in the vicinity of the gauging station.

Figure 2.6 shows a comparison between natural surface levels derived from the ALS survey data and a cross section which was surveyed by NoW in 1996 along the railway line. Peak water levels reached by the six floods listed in **Table 2.1** are also shown. From **Figure 2.6**, it can be seen that only the October 2010 flood overtopped the railway embankment. It is also noted that the surveyed cross section does not encompass the full width of flow.

By inspection of NoW's rating curve (reproduced as **Figure 2.7**), the high flow portion of the curve (i.e. that portion of the curve which lies above the level of the railway embankment), does not increase as rapidly as the stage versus discharge relationship derived based on a broad crested weir relationship and is more an extension of the combined conveyance capacity of the two waterway openings in the railway embankment.

Consultants' Recommendation L2

The Consultants propose to revise the high flow portion of the rating curve at Ladysmith using hydraulic calculations based on TUFLOW modelling of the floodplain in the vicinity of the gauging station. The Consultants also recommend that a cross section be surveyed at the location of the gauge, since the last creek survey was undertaken in 1996 and scour of the openings in the railway embankment may have occurred in the recent floods.



TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.1

KYEAMBA CREEK CATCHMENT

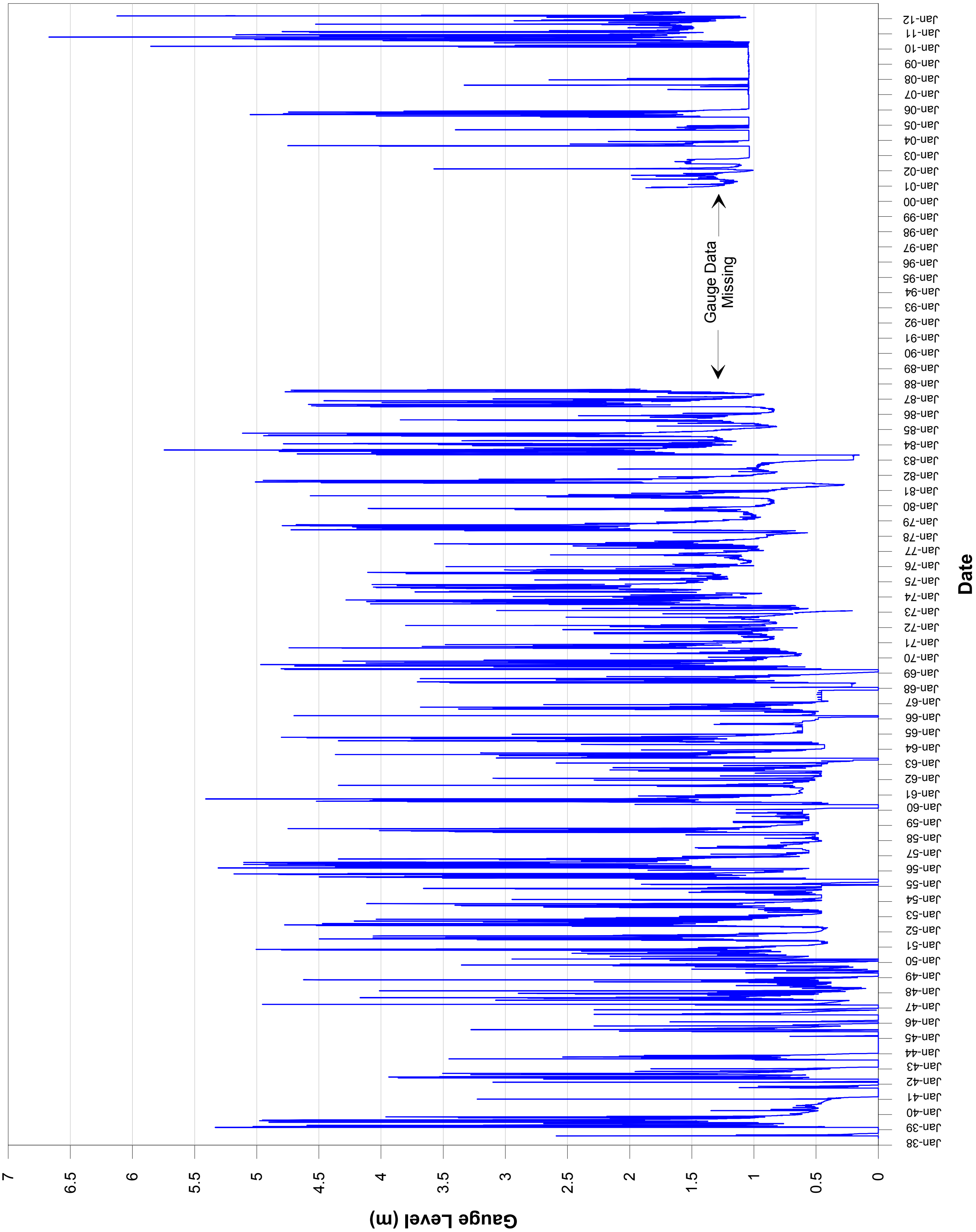
Source: Bewsher, 2011

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.2

OCTOBER 2010 FLOOD BEHAVIOUR AND CONSEQUENCES LADYSMITH

Source: Bewsher, 2011



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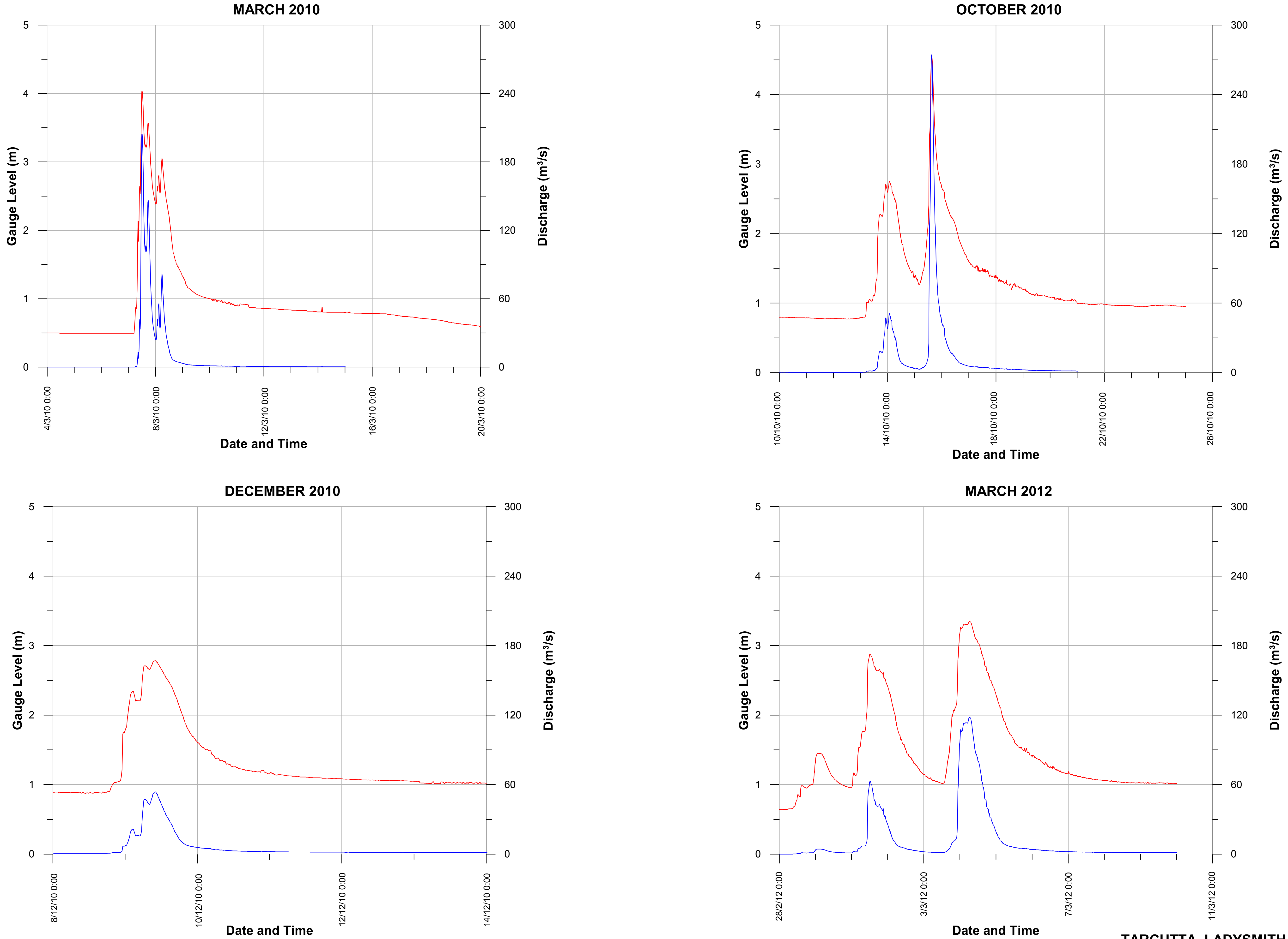
TARCUTTA LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.3

FLOOD PEAKS AT LADYSMITH GAUGE (GS 410048)



NOTE:

Catchment Area = 145 km²
Gauge Zero = 244.113 m AHD

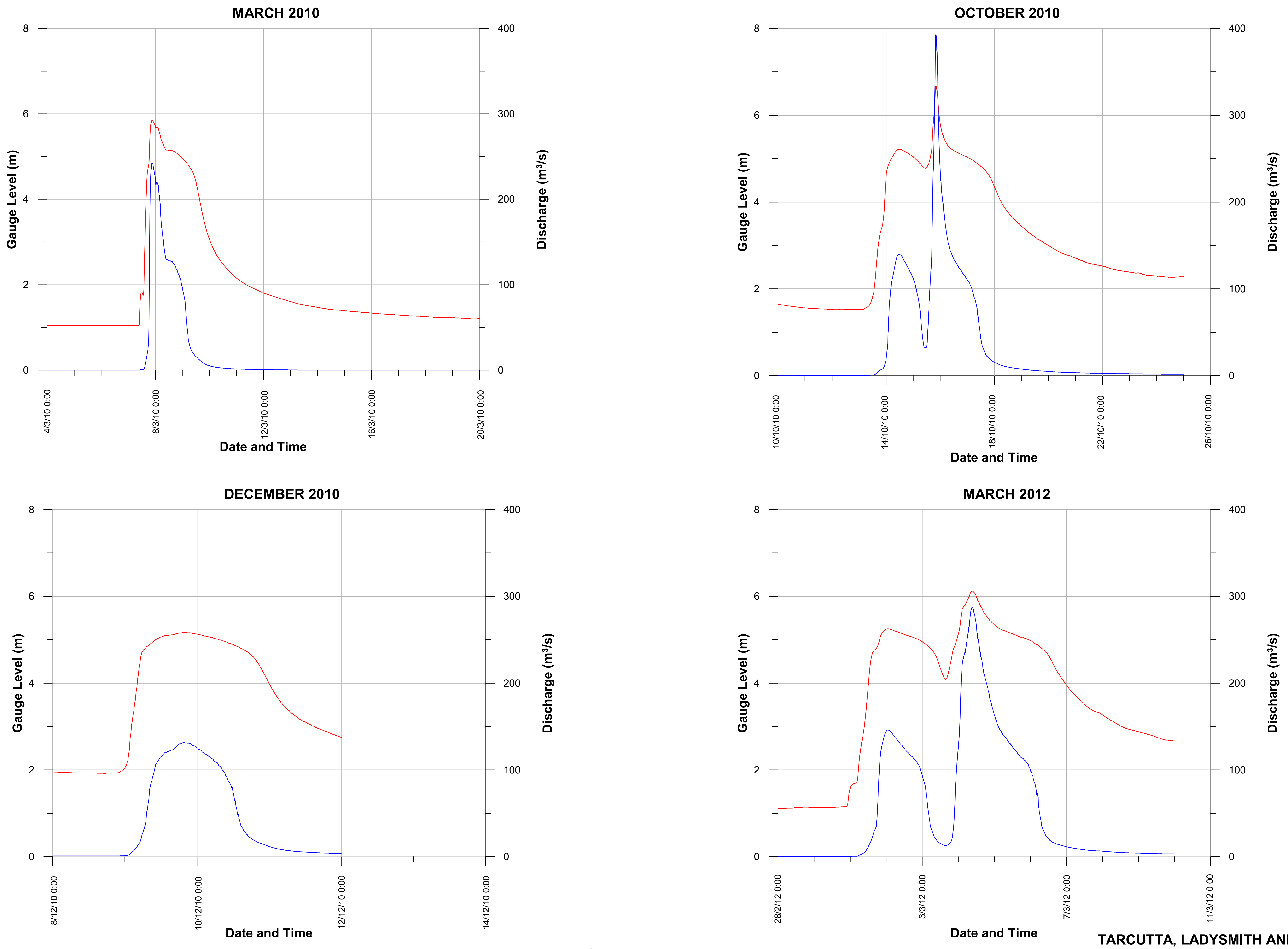
LEGEND

Discharge (m³/s)
Gauge Level (m)

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.4

STAGE AND DISCHARGE HYDROGRAPHS AT BOOK BOOK GAUGE (GS 410156)



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NOTE:

Catchment Area = 530 km²
Gauge Zero = 195.224 m AHD

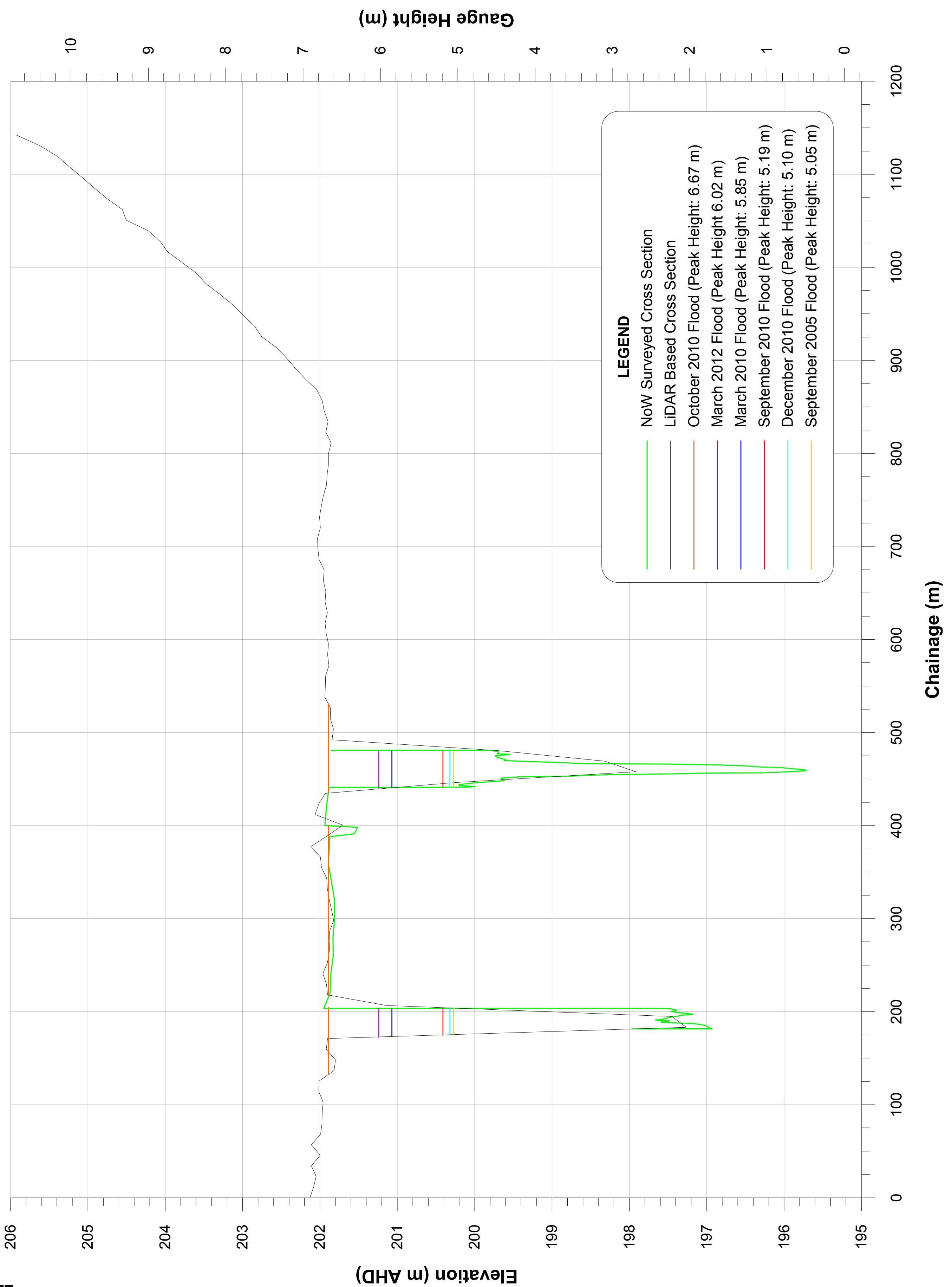
LEGEND

Discharge (m³/s)
Gauge Level (m)

TARCUTTA, LADYSMITH AND URANQUNITY FLOOD STUDIES

Figure 2.5

STAGE AND DISCHARGE HYDROGRAPHS AT LADYSMITH GAUGE (GS 410048)



NOTE:

Gauge Zero = 195.224 m AHD
LiDAR based cross section located along disused Wagga Wagga - Tumbarumba railway line west of Tumburumba Road.

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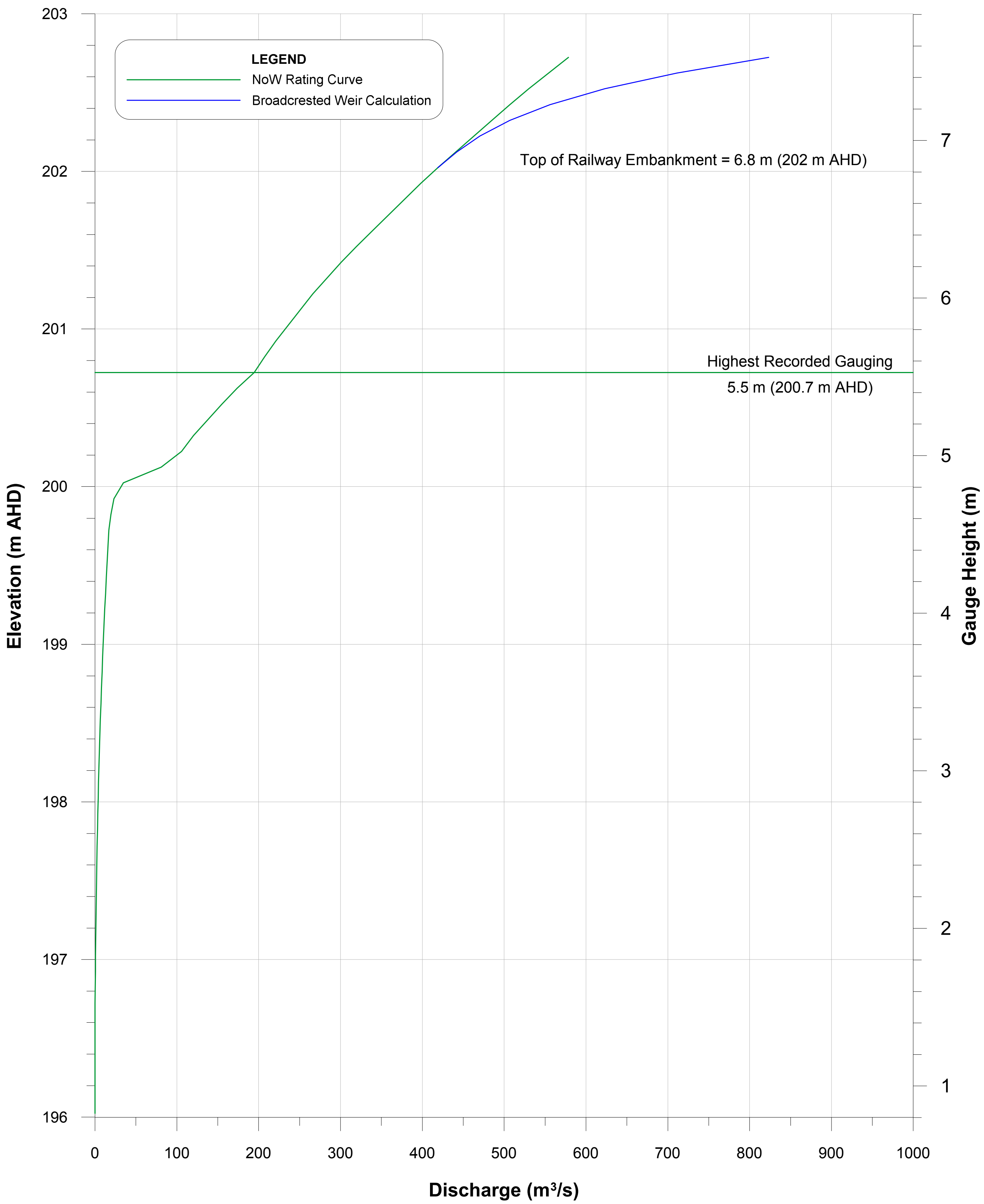
TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.6

CROSS SECTION AT LADYSMITH GAUGE (GS 410048)



Note:
Gauge Zero = 195.224 m AHD

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TARCUTTA LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 2.7

COMPARISON OF RATING CURVES
AT LADYSMITH GAUGE (GS 410048)

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Version: 1, Version Date: 09/09/2015

3 URANQUINTY

3.1 Background

Uranquinty is a village of about 700 people, located on the Olympic Way and the Melbourne-Sydney railway line, about 15 km south-west of Wagga Wagga. Sandy Creek passes through the town and drains an area of 128 km^2 above the village[6]. The highest elevation on the catchment boundary is 473 m, falling to 200 m at Uranquinty. The creek flows about 27 km in a generally NNW direction to the town, and continues to the Murrumbidgee River (see **Figure 3.1,** taken from Figure 15.1 of Bewsher, 2011).

3.2 Previous Studies

The *Murrumbidgee Valley* report of the *NSW Inland Rivers Floodplain Management Studies, Sinclair Knight and Partners, 1987* identified two different sources of flooding in Uranquinty:

1) Local flooding from a small catchment to the north of the main stream – this water either runs through the town or banks up behind the railway line and road and eventually escapes through small culverts;

2) Sandy Creek, which breaks its banks upstream of the town – floodwaters inundate the low lying southern edges of the village before returning to the creek downstream of the road and railway bridges.

The study recommended stream “improvement” and levee works. Subsequently Council prepared plans for the Uranquinty Levee Scheme, which provided a design protection level of 50 year ARI against flooding from Sandy Creek (insufficient funds were available for 100 year ARI level of protection). The works were staged, with the western side of the railway addressed first. This involved construction of an earth embankment levee from the railway to Baker Street (average height 1.6 m) (see **Figure 3.2** taken from Figure 15.3 of Bewsher, 2011) and an overflow path (10 m wide, average depth 0.9 m). East of the railway, the works involved construction of an earth embankment levee from Deane Street to the railway (average height 1.6 m).

Although Deane Street was raised as far north as Connorton Street, constraints meant that the 200 mm freeboard built into the rest of the levee was not included, so that it represents a low point in this eastern levee system. In order to address the threat of overland flows, various other earth embankments have been built, including one on the northern side of town intended to divert flows from the north to the west[7], and one on the eastern side of Connorton Street to divert flows from the northeast around the southeastern corner of the town (only about 200 mm high). These levees or embankments are marked on **Figure 3.2**.

Following the October 2010 event severe inundation problems occurred when water was trapped behind the main levee east of the railway.

[6] Catchment area estimated for this study, based on a catchment boundary drawn from the 30 m SRTM data.

[7] The capacity of the railway culverts is not sufficient to allow diversion of larger flows from east of the railway to west of the railway. This was exacerbated by the rail maintenance authority reducing the capacity of such culverts by instigating a program in the 1980s of replacing timber bridge type culverts with Armco pipe culverts – most noticeably at a previously major culvert just north of the Uranquinty level crossing and reducing capacity by up to 50-70%. *[Source: Bewsher, 2011]*.

3.3 Hydrologic Data

3.4 Historic Flooding

A history of inundation problems at Uranquinty is presented in the Bewsher, 2011 study based on previous reports, a search of historical newspapers, and input from the community via the Questionnaires. It is understood that the main Sandy Creek levee has not been overtopped since it was constructed in the 1980s. The mechanism of flooding in January 1995 was the same as that described for the October 2010 flood, with water being trapped behind the high levee. Reports from two residents indicate that the level reached in the recent flood was about 40 cm higher than in the 1995 event.

TABLE 3.1
FLOOD HISTORY, URANQUINTY
(POST-LEVEE CONSTRUCTION)

Date	Consequences	Source
1995 January	10 cm inside 7 Ben Street (40 cm lower than October 2010); to top steps of 10 Morgan Street (43 cm lower than October 2010)	Questionnaires: interviews
2010 March	Ponding of stormwater behind levee	Questionnaires
2010 October	"Water where never seen before".	

3.5 October 2010 flood

Bewsher, 2011 received 30 completed questionnaires which provided a good understanding of the October 2010 flood event.

A total of 79 mm of rain was recorded at one site (location not specified) in the Sandy Creek catchment for the first rain episode on 13 and 14 October, 66 mm was recorded at the Caltex Service Station in town and 53 mm at the Power Station some 3 km west of the town for the same period. Falls of these magnitudes would have saturated the catchment. A reading of 73 mm was recorded at the Power Station for the second rain event. About 65 mm was recorded at 'Weemont' homestead about 2 km north of Urnaquinty during the two hours noon to 2 pm 15 October. The total storm rainfall was 126 mm at the Power Station, 134 mm at 'Rosebrook' and 167 mm at a residence in Taber Street in Uranquinty.

The very heavy rain from 12:00 hours to 14:00 hours on 15 October caused flash flooding from about 12:30 hours to 14:30 hours, with several requests for assistance being received at that time. This also tallies with reports of the time of peak at a few sites (see **Table 15.2**). Northeast of Uranquinty, runoff was reportedly crossing Olympic Way from the Aero Club towards town, because the dams and gutter on the southeast side of the road were overflowing. The gravel road base along Rodhams Road north of town was washed away at this time.

Flow paths described by residents are plotted on **Figure 3.2**. Overland flow paths were travelling towards Uranquinty from the northeast and east. An early peak (13:30 hours) was reported at a house on Connorton Street which was just flooded above floor level when flows from the east overtopped the modest (200 mm high) Connorton Street levee between the Neighbourhood Centre and Ryan Street. Shallow inundation was reported in some properties in Spaul Street (houses unaffected). Inundation to a depth of 300 mm was reported at the junction of Morgan and Yarragundry Streets in this early afternoon storm event.

In the area west of the railway, overland flows crossed Taber Street and reached depths of 300 mm at the Uranquinty Public School Covered Outdoor Learning Area (COLA) and 200 mm at the entrance to the school's internal "rain road". This overland flooding was reportedly exacerbated by blocked street gutters in the vicinity of Pearson Street. Some homes were affected by overflows from the small sewer pump station at the end of King Street when stormwater caused the capacity of the pump station to be exceeded.

The inundation associated with the heavy rain was of short duration, ceasing at about 14:30 hours. The later inundation occurred when overhead weather conditions were clear.

Beginning at about 15:30 hours, water overtopped the levee along Deane Street. The source of this inundation is uncertain, but in addition to overland flows from the northeast, the observation of a Key Street resident and the volume of flow observed over Deane Street suggest that perhaps a substantial portion of this flow was floodwater escaping Sandy Creek further upstream.

Photographs suggest that the depth of flow over Deane Street was up to about 200 mm (Bewsher, 2011). The water running down Ben Street was described as being "like rapids". However, the water entering the town at Deane Street was then tapped against the levee at the southern end of Morgan Street, and backed up within the levee to beyond the Urnaquinty Hotel on Morgan Street. The high level of Sandy Creek – though not enough to overtop the levee – prevented water trapped between the levee and the railway from escaping through the gated pipes into the creek. Respondents to the Bewsher, 2011 Questionnaire reported this phenomenon as "blockage" contributing to the flooding of Uranquinty.

Surveyed flood levels behind the levee show an almost flat flood surface (**Figure 3.2**). A flood extent is also shown based on flood marks surveyed by Council at Morgan Street, Ryan Street, O'Connor Street and Connorton Street, with estimates from residents in between. Most respondents reported that the flood peaked at about 19:00–20:00 hours.[8] The median reported duration of inundation associated with this type of flooding was 10-12 hours.

Problems caused by water backing up behind the levee west of the railway were not reported. This is attributed to the lesser volume of stormwater west of the railway mainly because of the effectiveness of the raised railway acting as a levee and the under-capacity of the culvert north of the levee crossing.

3.6 Recommendations for Further Data Collection and Analysis

3.6.1. Survey

<u>Consultants' Recommendation U1</u>

As for Ladysmith, the Consultants recommend that field survey at Uranquinty be limited to the capture of information on critical hydraulic structures and the floor levels of the residences which are reported to have experienced above floor inundation during the October 2010 flood. It is also recommended that two inbank cross sections be surveyed along the drainage line which runs from the intersection of Best and Ryan streets to the hydraulic structure beneath the levee. **Figures 2** and **5** in **Annexure B** show the extent of the proposed survey at Ladysmith.

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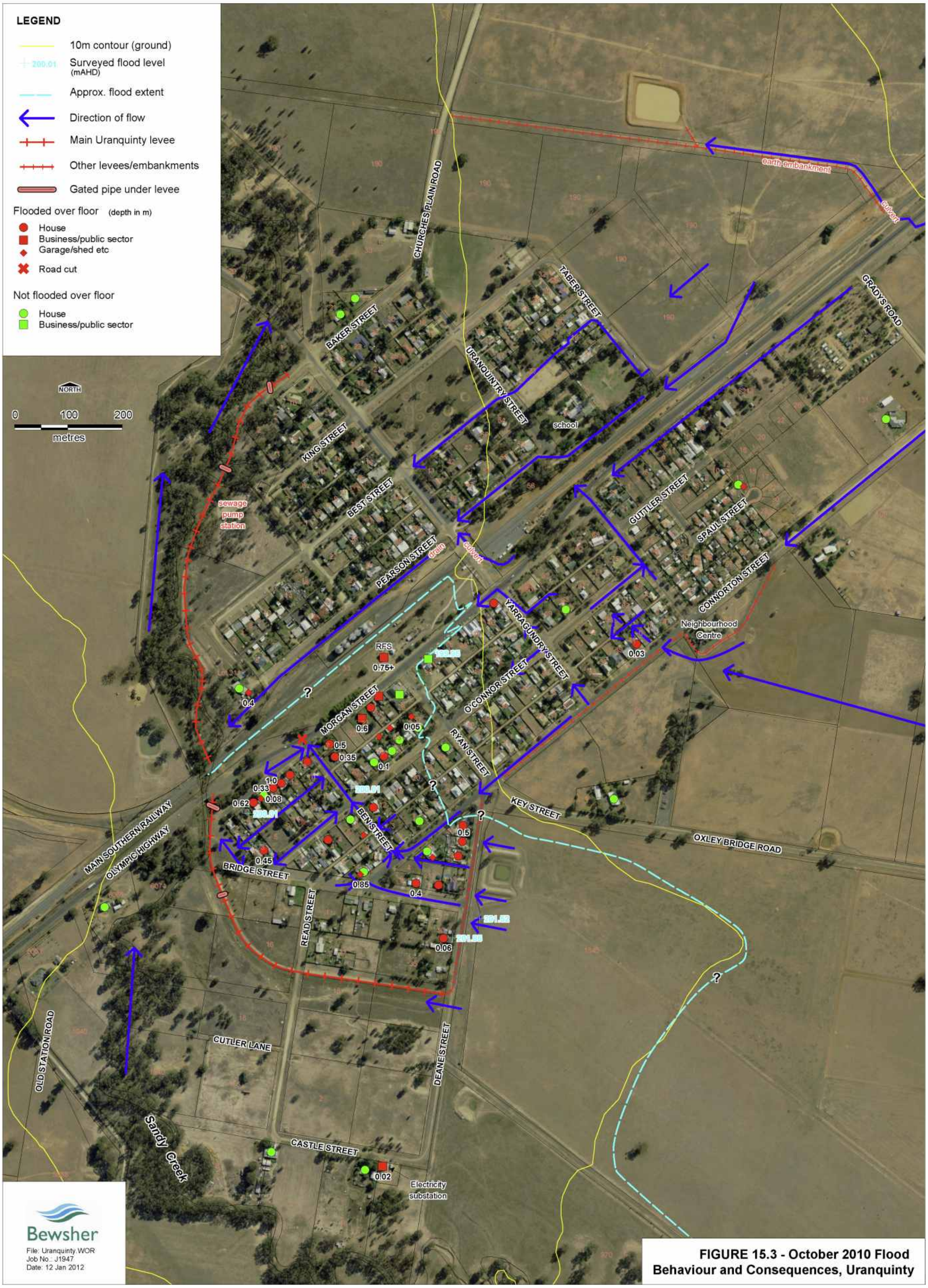
8 Also, the RFS log records "floodwaters steady" at 19:53 hrs and "falling on east side" at 21:03 hrs

TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 3.1

SANDY CREEK CATCHMENT TO URANQUINTY

Source: Bewsher, 2011



TARCUTTA, LADYSMITH AND URANQUINTY FLOOD STUDIES

Figure 3.2

OCTOBER 2010 FLOOD BEHAVIOUR AND CONSEQUENCES URANQUINTY

Source: Bewsher, 2011

4 REFERENCES

IEAUST (Institution of Engineers Australia), 1998 *"Australian Rainfall and Runoff – A Guide to Flood Estimation"*

Bewsher (Bewsher Consulting), 2011. *"Flood Intelligence, Collection and Review for Towns and Villages in the Murray and Murrumbidgee Regions following the October 2010 Flood".*

Jordan et al, 2011. *"Aerial Reduction Factors for Estimation of Design Rainfall Intensities for New South Wales and the Australian Capital Territory*". Paper presented at joint conference of the 34th IAHR World Congress – Balance and Uncertainty, 33rd Hydrology & Water Resources Symposium and 10th Hydraulics Conference, 26 June – 1 July 2011, Brisbane, Australia.

(Parsons Brinkerhoff), 2009. *"Hume Highway Upgrade Tarcutta Bypass Environmental Assessment Appendix A Flood Study"*.

(Sinclair Knight and Partners), 1987. *"Murrumbidgee Valley, NSW Inland Rivers Flood Plain Management Series, Water resources Commission".*

THA (Tarcutta Hume Alliance), 2010a. *"Design Report Flood Assessment, Doc No: THA-R-30-DR065A-FD-03".*

THA (Tarcutta Hume Alliance), 2010b. *"15 October 2010 Flood Event Summary Tarcutta Creek Catchment"*. Report prepared for RTA.

THA (Tarcutta Hume Alliance), 2010c. *"Preliminary Flood Assessment Tarcutta Creek Floodplain – 15 October 2010 Event"*. Report prepared for RTA.

ANNEXURE A
COMMUNITY NEWSLETTERS

Tarcutta FLOOD STUDY

To Residents of Tarcutta:

To assist the Tarcutta community prepare for future floods and to inform development controls, Wagga Wagga City Council is preparing a *Flood Study* for the village. Please see the back of this page for the approximate area of the study.

The *Flood Study* will define flooding patterns, flood levels in the creeks and overland flow paths in and around the village under present day conditions.

Council has engaged the services of Lyall and Associates Consulting Water Engineers to:

- Survey the creek in the vicinity of the village and collect historic flooding data.
- Develop computer based hydrological models of the catchments to determine flows for both historic storms and hypothetical design floods.
- Develop computer based hydraulic models of the creek and floodplain to determine flooding patterns, flood levels and velocities of flow.

Following the October 2010 flood the State Emergency Service (SES) distributed questionnaires to residents. The SES received over 100 responses from residents in the Tarcutta, Ladysmith and Uranquinty areas.

The SES's consultant is planning to contact a select number of residents who responded to the post-October 2010 questionnaire to discuss flooding behaviour which was observed in the village during the recent March 2012 event. Both sets of data will be used in the preparation of the *Flood Study*.

In addition to the SES surveys, Council would like any information from community members about how the floods impacted upon their properties and surrounds, including photos or videos of the flood events.

Please contact Council using the contact details below.

Please note that all information received will remain confidential.

Community Information

Wagga Wagga City Council

Contact: **Brad Jeffrey - Infrastructure Capacity Coordinator**

Phone: **1300 292 442**

Email: **jeffrey.brad@wagga.nsw.gov.au**

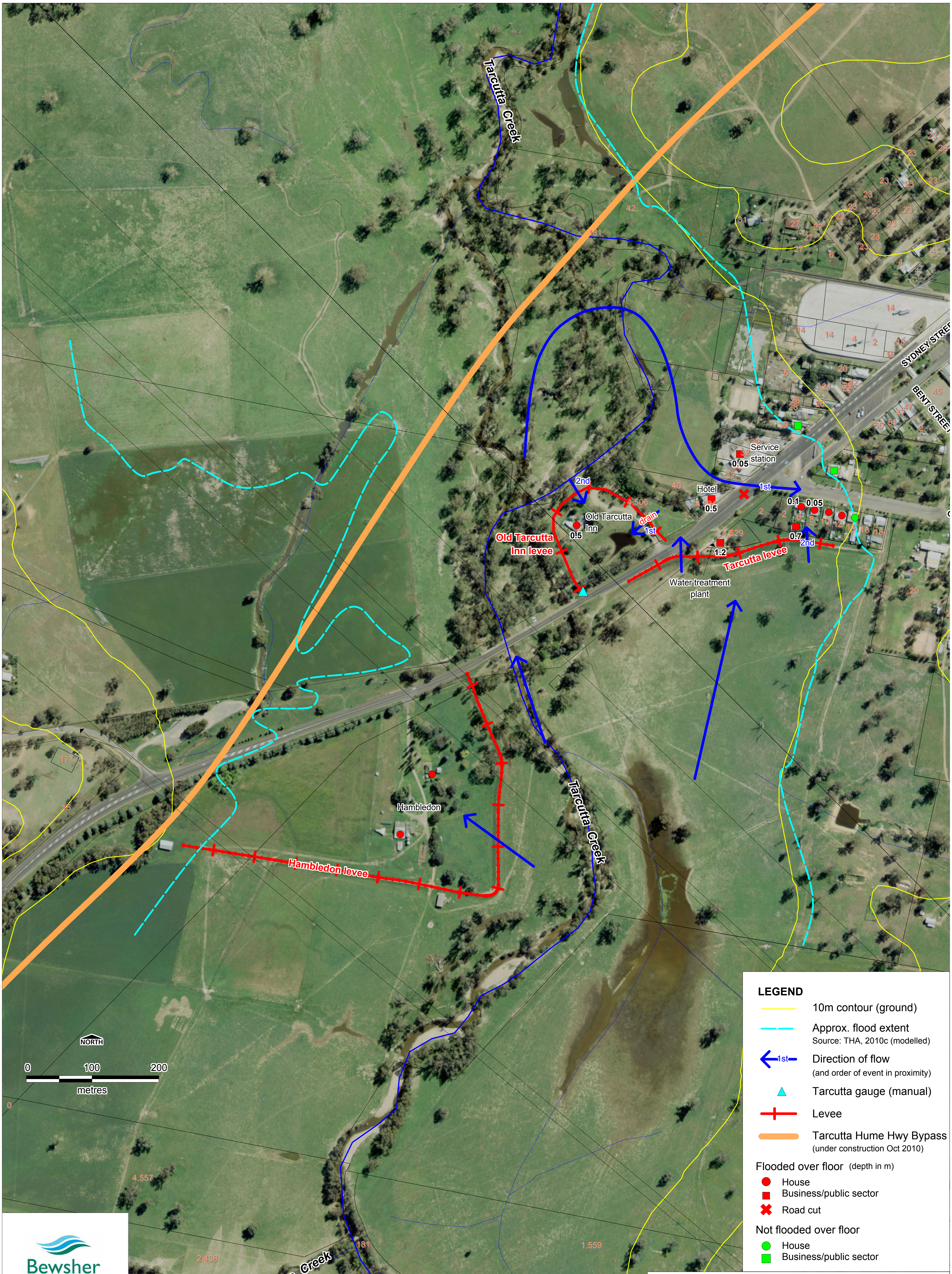


FIGURE 13.2 - October 2010 Flood Behaviour and Consequences, Tarcutta

Ladysmith
FLOOD STUDY

To Residents of Ladysmith:

To assist the Ladysmith community prepare for future floods and to inform development controls, Wagga Wagga City Council is preparing a *Flood Study* for the village. Please see the back of this page for the approximate area of the study.

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FIGURE 14.7 - October 2010 Flood Behaviour and Consequences, Ladysmith

Uranquinty
FLOOD STUDY

To Residents of Uranquinty:

To assist the Uranquinty community prepare for future floods and to inform development controls, Wagga Wagga City Council is preparing a *Flood Study* for the village. Please see the back of this page for the approximate area of the study.

The *Flood Study* will define flooding patterns, flood levels in the creeks and overland flow paths in and around the village under present day conditions.

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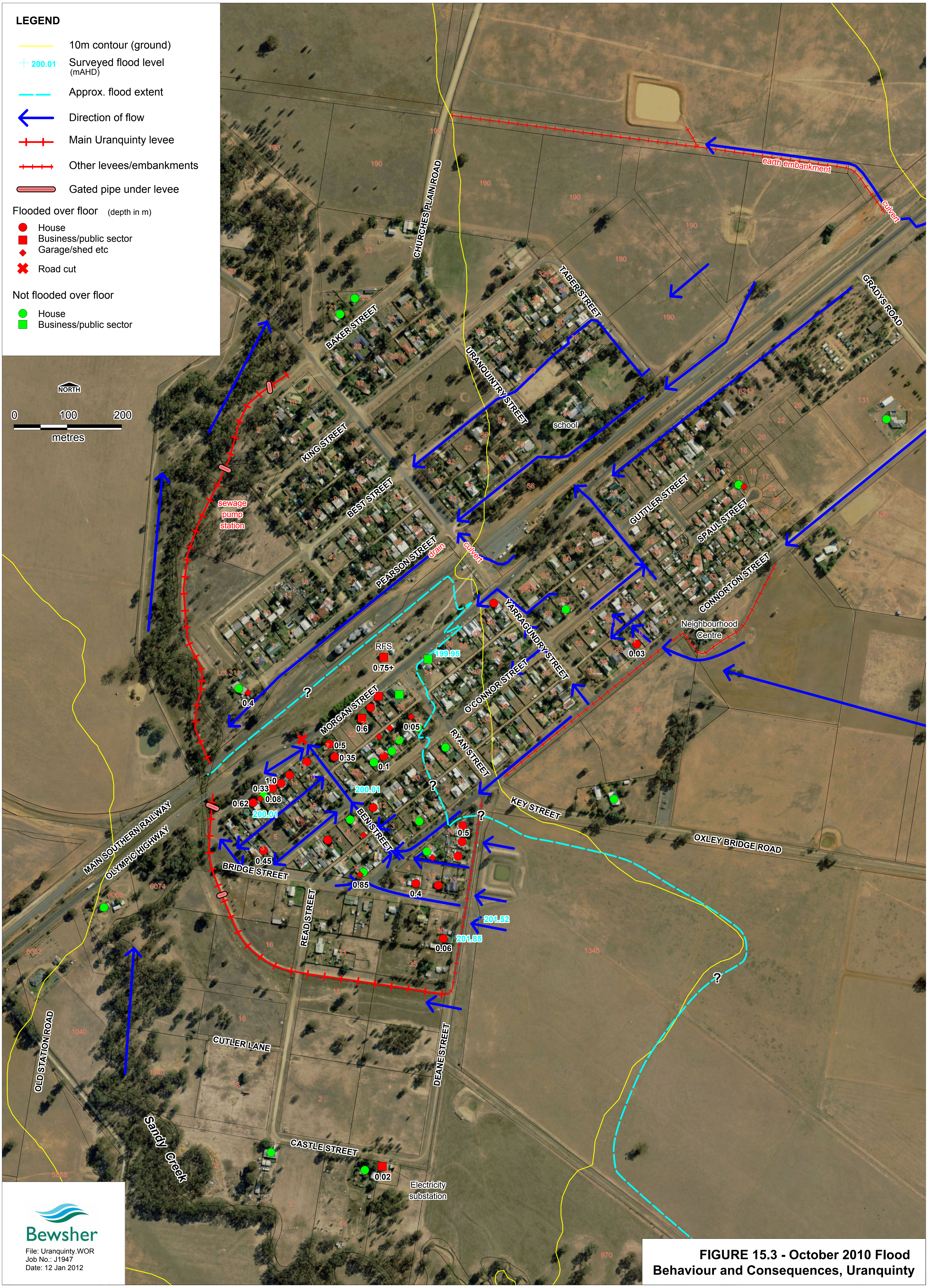

FIGURE 15.3 - October 2010 Flood Behaviour and Consequences, Uranquinty

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ANNEXURE B
SURVEY REQUIREMENTS

SURVEY BRIEF

Figure 1 shows the location of the three villages in relation to Wagga Wagga. **Figures 2** to **4** show requirements for survey of hydraulic structures and cross sections in each village, whilst **Figures 5** to **7** are extracts from Bewsher, 2011 showing those properties which experienced above floor inundation in the October 2010 flood (refer both the red and green dots/squares).

Data required for culvert crossings:

- Upstream and downstream invert
- Culvert size
- Number of barrels
- Photo of upstream and downstream headwall.

Data required for bridge crossings:

- Hand drawn sketch of the bridge opening showing key details such as:
    - Width and number of piers
    - Level of underside of bridge deck
    - Thickness of bridge deck
- Photo of bridge opening looking in the downstream direction

Data required for Cross Sections:

- Excel spreadsheet of chainage versus elevation. Note: cross section to be surveyed looking in the downstream direction with chainage 0 located on the left bank
- AutoCAD drawing showing location and orientation of cross sections
- Photo of cross section looking in the downstream direction

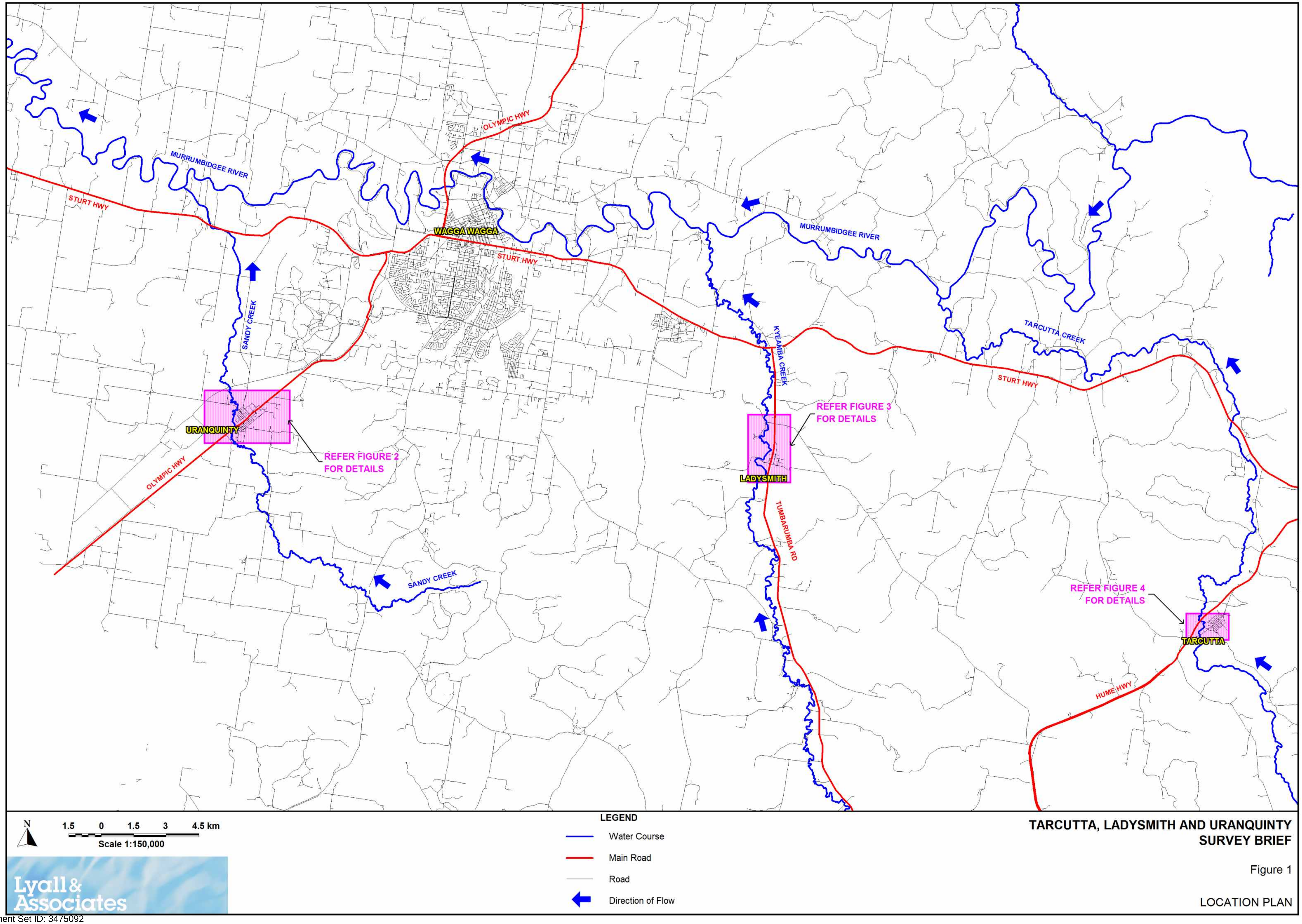
Data required for Households:

- Floor Level
- Adjacent Ground Level
- Address

Please Note:

- All levels to be m AHD.
- All cross section are to be drawn from left to right looking in a downstream direction.
- All points to be set out in Map Grid of Australia (MGA) Zone 55.

Note that the contours shown on **Figure 4** are from LiDAR data captured in 2008. Since this time the alignment of the creek between Sydney Street and Tarcutta Hume Highway Bypass may have changed. In this area we require in-bank survey of all creeks and channels at a spacing of approximately 100 m. Therefore, the number of cross sections required to accurately capture 2012 creek conditions may differ slightly from those shown on **Figure 4**.



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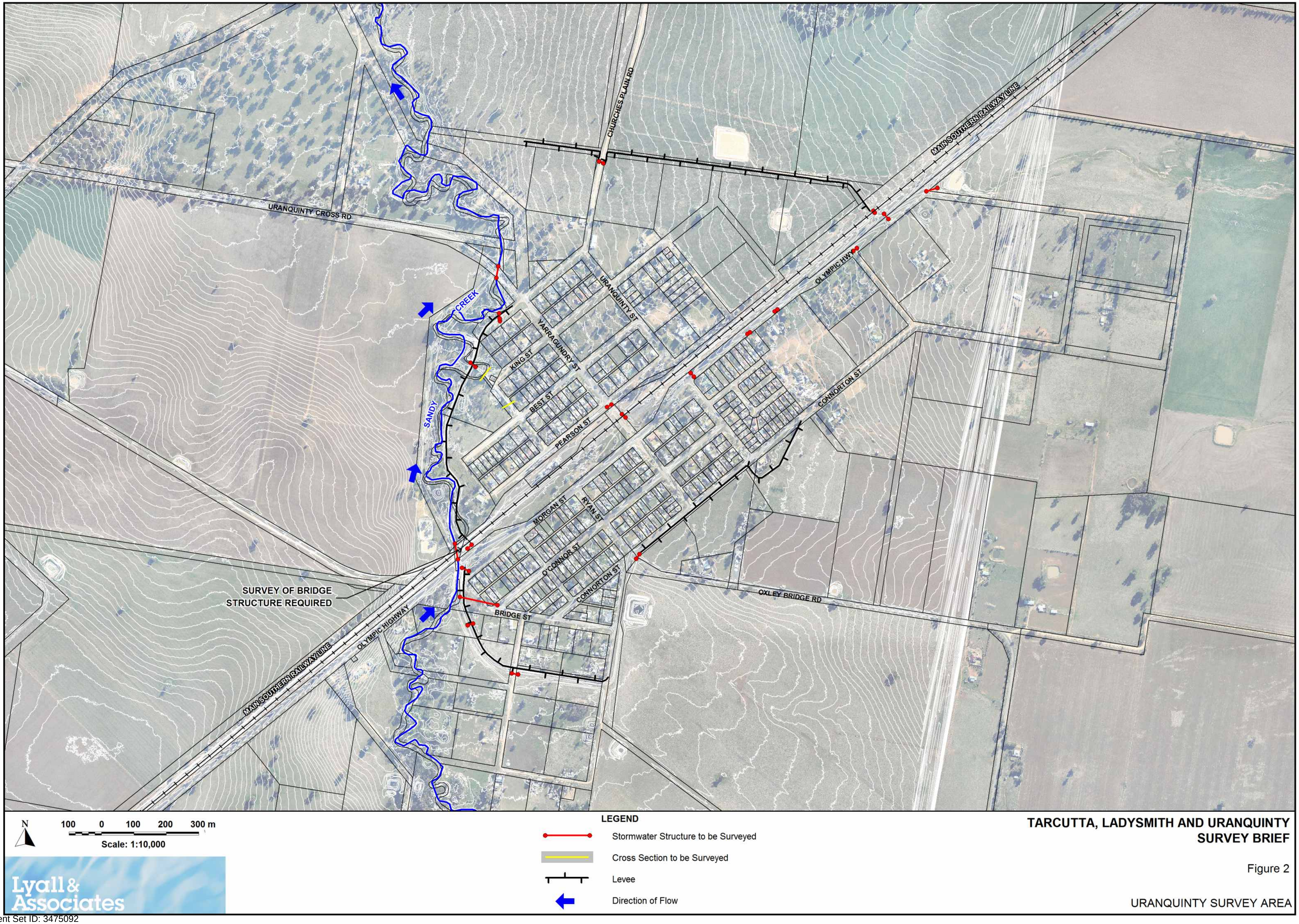
TARCUTTA, LADYSMITH AND URANQUINTY SURVEY BRIEF

Figure 1

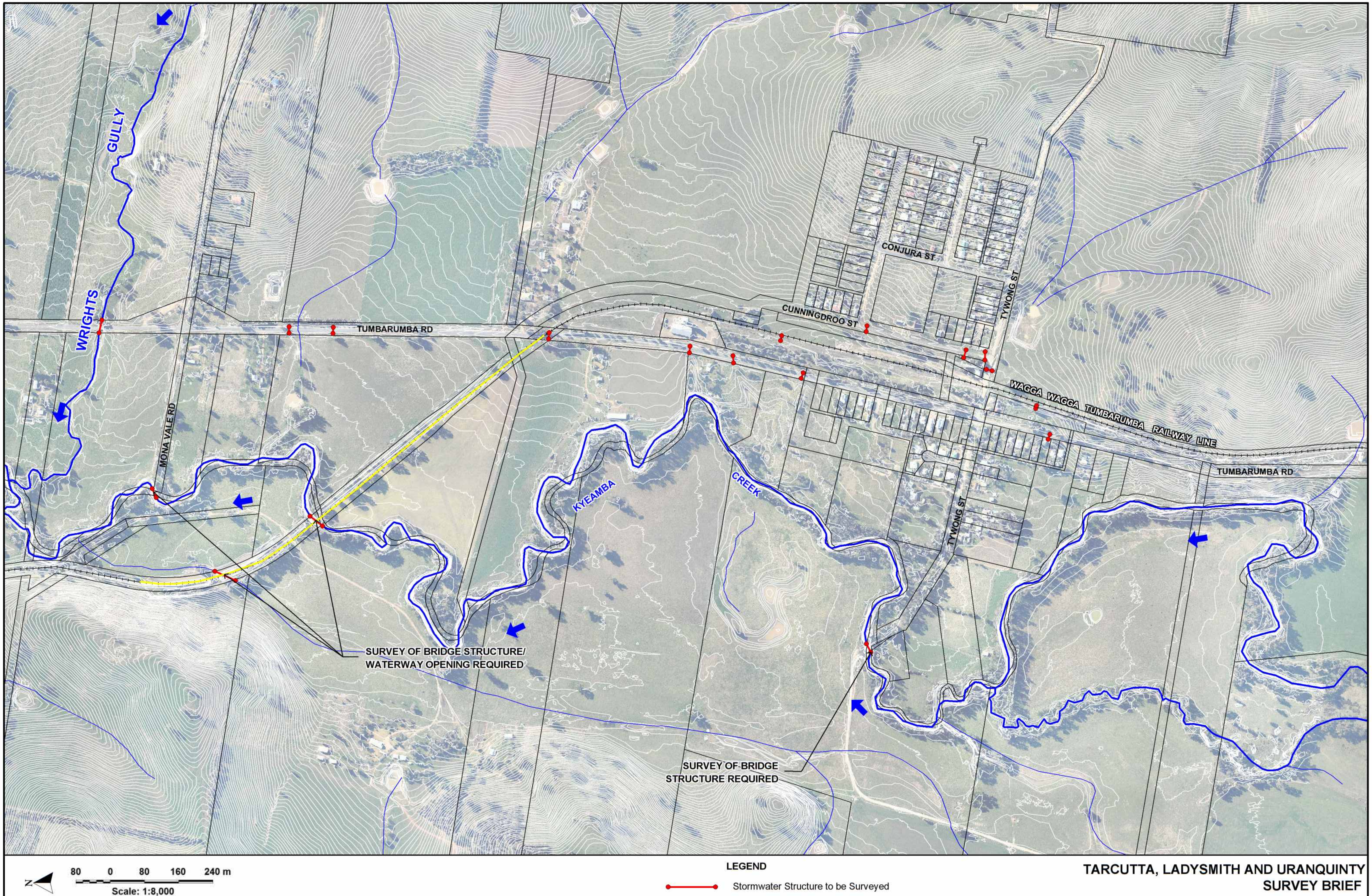
LOCATION PLAN



TARCUTTA, LADYSMITH AND URANQUINTY SURVEY BRIEF

Figure 2

URANQUINTY SURVEY AREA



LEGEND

- Stormwater Structure to be Surveyed
- Waterway
- Cross Section to be Surveyed
- Direction of Flow

TARCUTTA, LADYSMITH AND URANQUINTY SURVEY BRIEF

Figure 3

LADYSMITH SURVEY AREA

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N

50 0 50 100 150 m

Scale: 1:5,000

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LEGEND

- Stormwater Structure to be Surveyed
- Cross Sections to be Surveyed
- Waterway
- Levee
- Direction of Flow

TARCUTTA, LADYSMITH AND URANQUINTY SURVEY BRIEF

Figure 4

TARCUTTA SURVEY BRIEF

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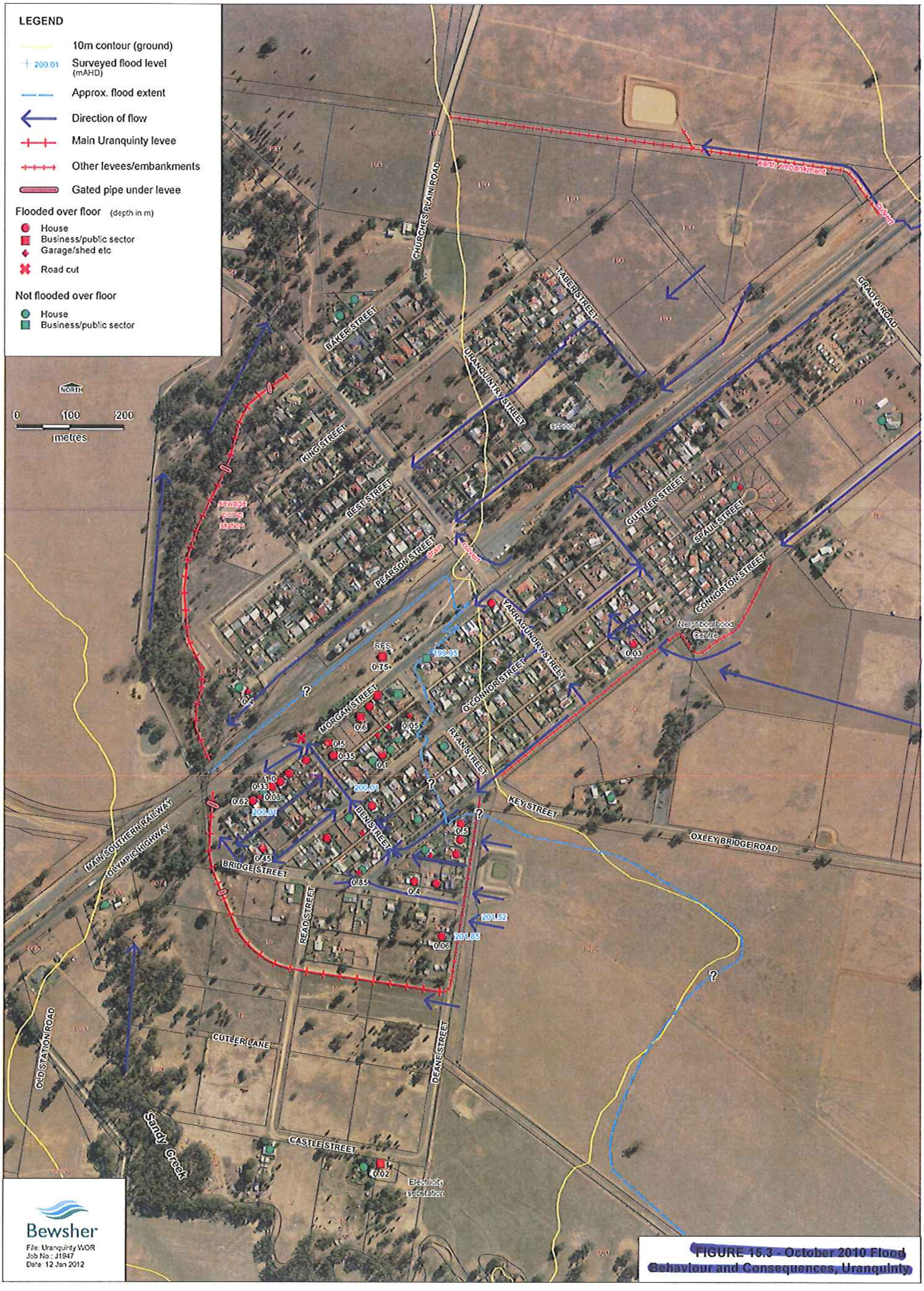

FIGURE 15.3 - October 2010 Flood Behaviour and Consequences, Uranquinty

Figure 5

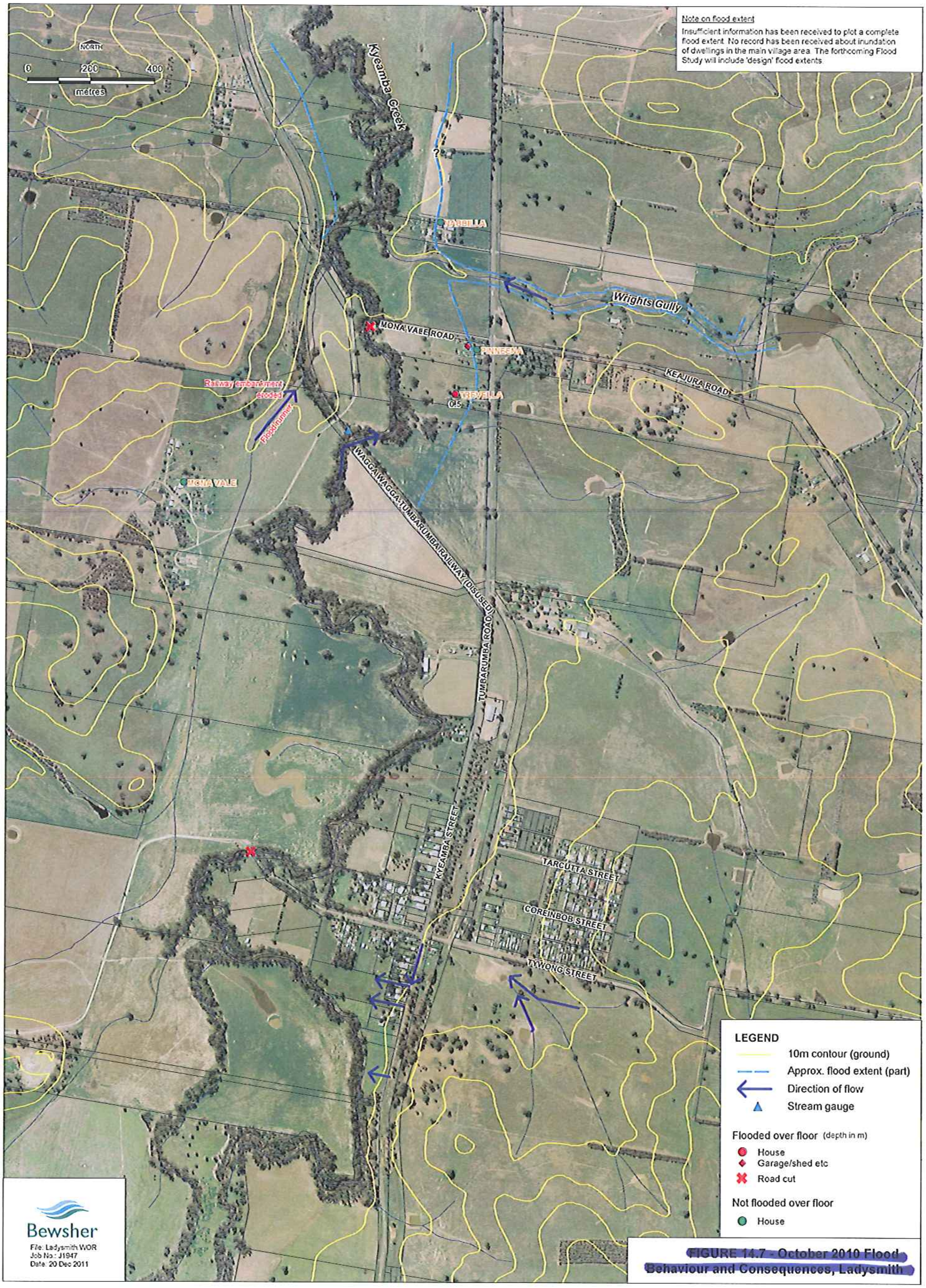

FIGURE 14.7 - October 2010 Flood Behaviour and Consequences, Ladysmith

Figure 6

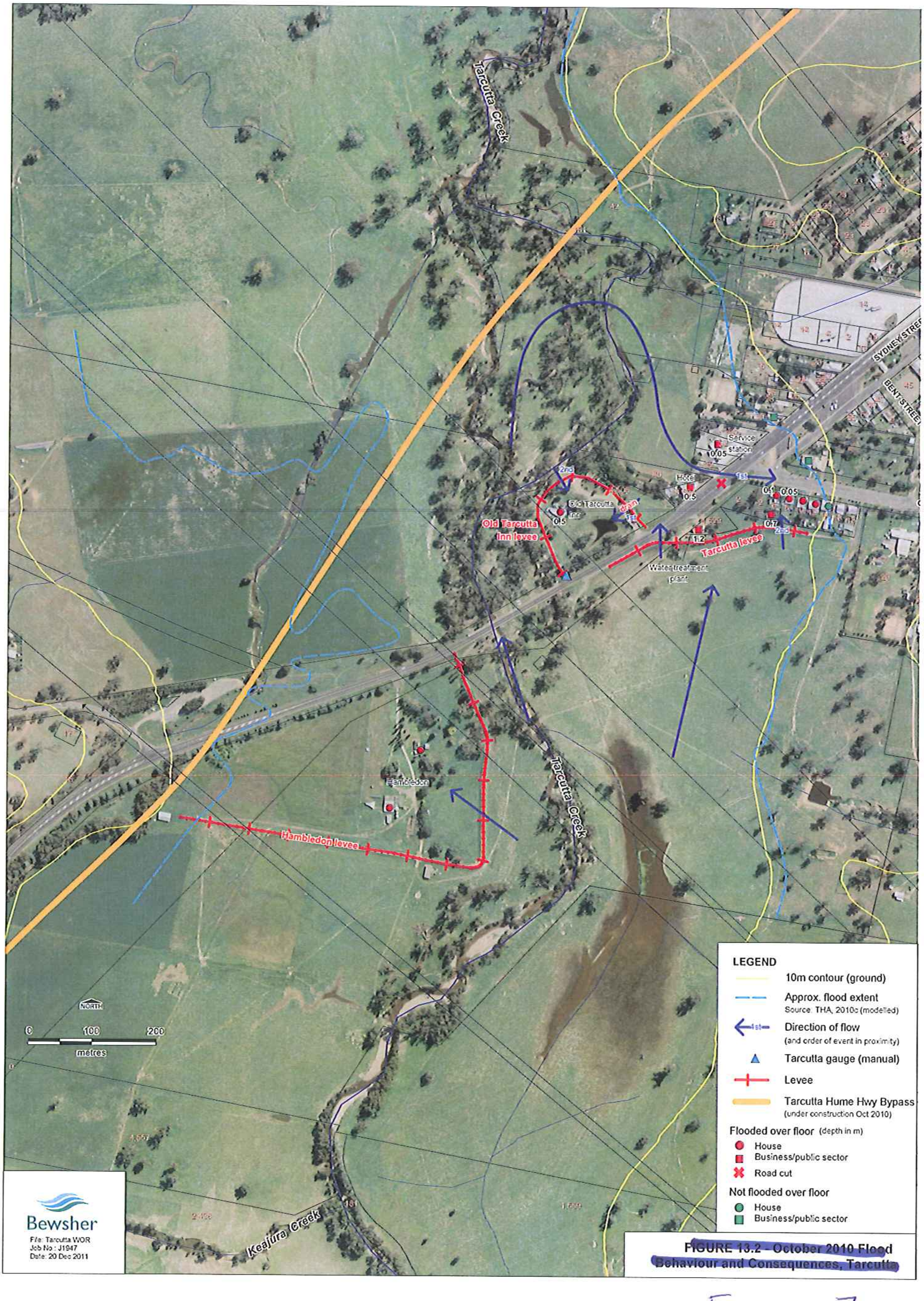

FIGURE 13.2 - October 2010 Flood Behaviour and Consequences, Tarcutta

Figure 7