Wimmera Catchment Management Authority

Waterways for Life.

Northern Grampians Shire Council

Glenorchy Flood Study

Report No. J140/R01G Draft B (Final)

April 2006

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

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The study team acknowledges the contributions made by these groups and individuals, in particular:

- The Project Reference Group for the study, consisting of:

  Clare Mintern - Wimmera CMA Floodplain Management Officer

  Don Barnes – formerly Wimmera CMA Floodplain Management Officer

  Melissa Morris - Wimmera CMA Local Government Liaison Officer

  Cr Kevin Erwin – Councillor Northern Grampians Shire Council

  Mark Goode - Northern Grampians Shire Council

  Michael File - Northern Grampians Shire Council

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1 INTRODUCTION

This report outlines the investigations undertaken for the flood study of Glenorchy and surrounds. This flood study aids the Wimmera Catchment Management Authority (Wimmera CMA) and Northern Grampians Shire Council (NGSC) in defining the existing flooding behaviour.

The Glenorchy Flood Study is the second stage in the floodplain management process for Glenorchy. The flood study follows the Glenorchy to Horsham Flood Scoping Flood Study (Water Technology 2003). The flood study was a key recommendation of the previous flood scoping study. The outcomes from this flood study will form the technical basis of the Glenorchy Floodplain Management Plan.

The flood study involved a hydrologic analysis of the Wimmera River and a hydraulic assessment of flood behaviour in the town and surrounding floodplain areas. The flood levels and inundation extents have been identified for a range of design floods up to the 1 in 200 year flood event. Figure 1-1 displays the study area for the Glenorchy flood study.

A study team lead by Water Technology was commissioned to undertake the flood study for the NGSC and Wimmera CMA. The study team carried out the investigations in accordance with instructions from Wimmera CMA. MPMedia were engaged to undertake the media and community consultation. Michael Cawood and Associates prepared the flood response aspects and assisted in the flood warning aspects.

The structure of this report is as follows:

- Section 2 Study background – provides study context and background.
- Section 3 Available data – outlines available previous flood related investigations, stream flow and topographic data employed in this study
- Section 4 Hydrologic analysis - discusses the methodology and output from the hydrologic analysis and design flood hydrograph determination.
- Section 5 Hydraulic analysis – details the development and calibration of the hydraulic model, and the determination of design flood levels..

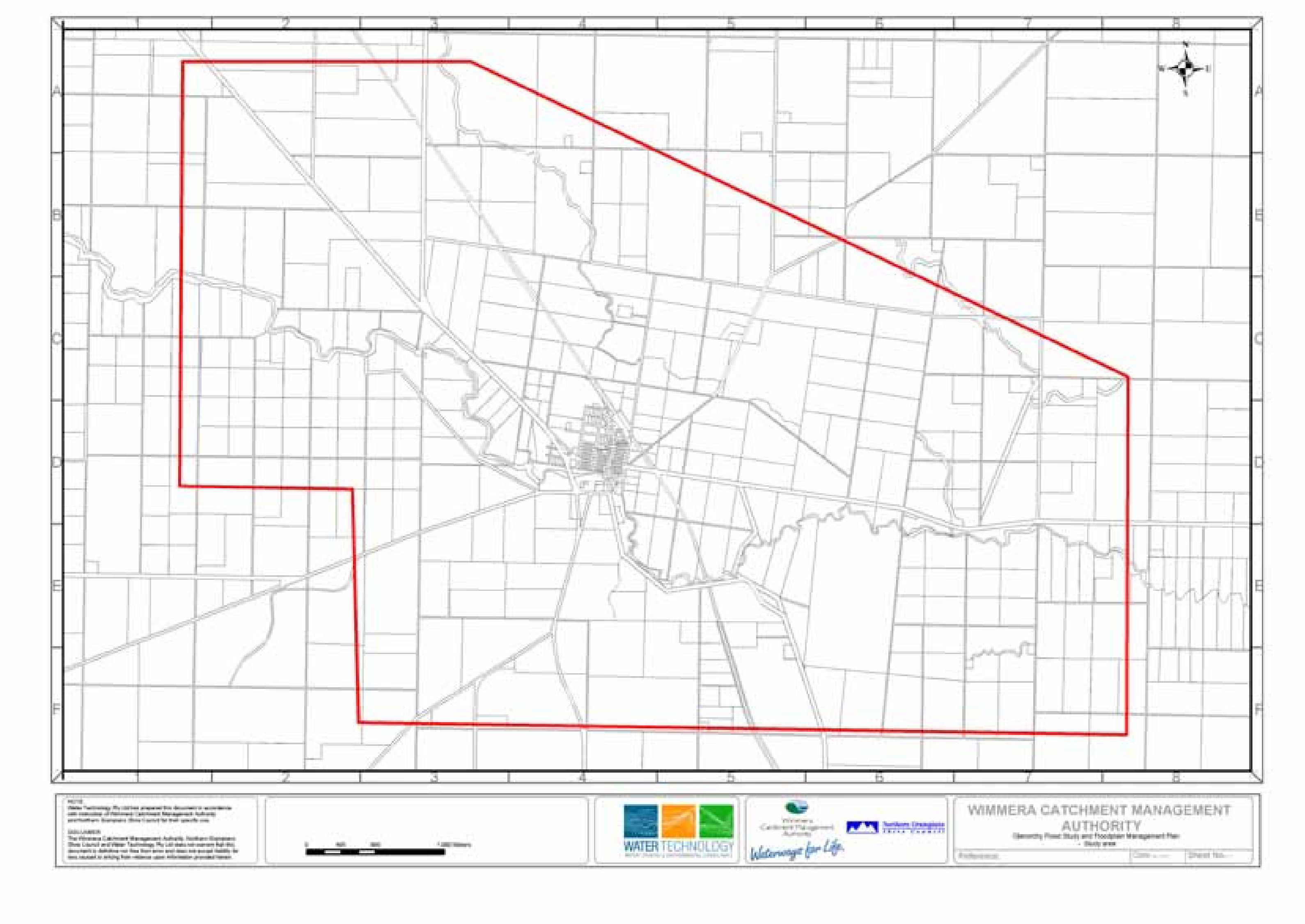

Figure 1-1 Glenorchy Floodplain Management Study area

2 STUDY BACKGROUND

Glenorchy, as with many rural centres in the Wimmera Region, is positioned in close proximity to a drainage line which, in turn, places the development. The Glenorchy township suffers significant inundation in moderate to major flood events and there is a significant amount of documentation of historic flood events through the area.

The 1909 flood event is the largest on record. Flood elevation contours for the 1909 event through the township have been presented as part of the FDT project (based on RWC, 1988), along with a substantial number of observed flood heights for subsequent events. These include events in 1956, 1973, 1981, 1983 and 1988.

Flooding through the Glenorchy township is a result of both direct inundation from the Wimmera River, and breakout flow from upstream areas flowing through the town. Between 2 and 3 km upstream of Glenorchy, Dunmunkle Creek and the Swedes Cut (a high level cut diverting water to Swedes Creek) divert floodwaters to the north. A substantial portion of these floodwaters flows through railway embankment bridges, returning to the Wimmera River through the Glenorchy township.

Figure 2-1 is an aerial photograph of the upstream portion of Glenorchy, taken during the 1988 event. Note that the 1988 event is estimated as having (at the Horsham gauge) an ARI of approximately 10 years (Water Technology, 2003).

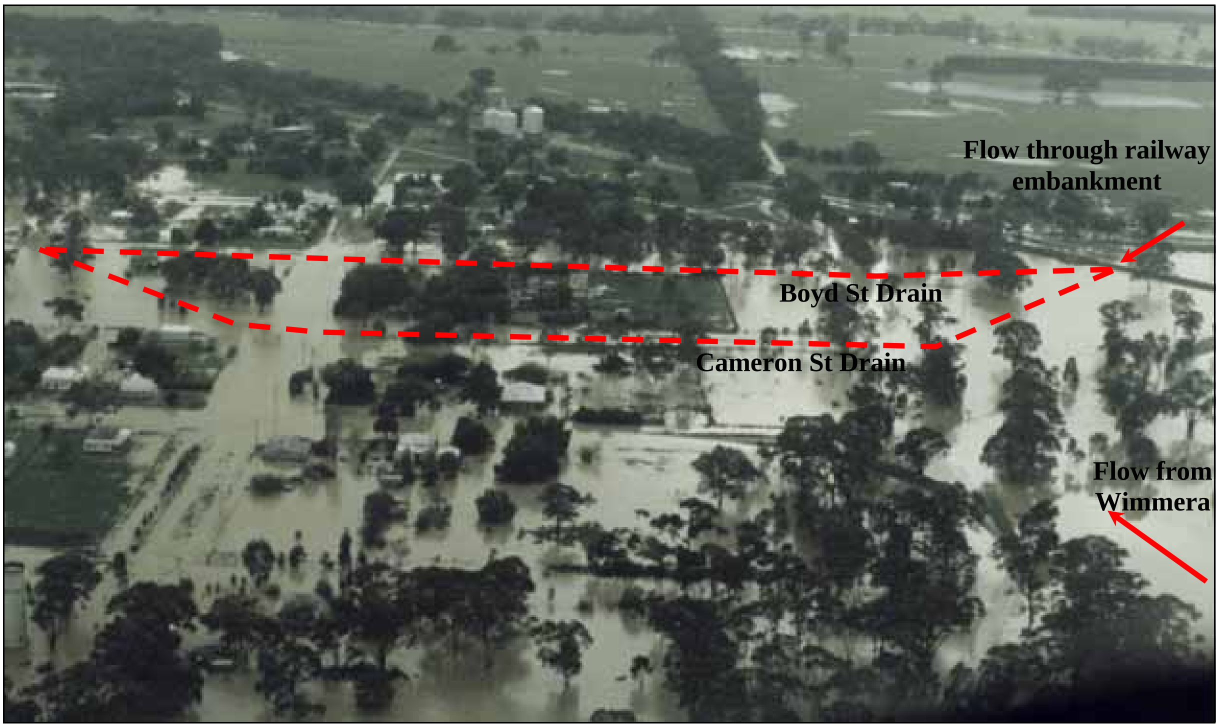

Figure 2-1 Aerial View of the 1988 Event through Glenorchy – Upstream Portion

The passage of flood flows through the township itself has been highly altered over time. The principal drainage works consist of two channels running along Boyd and Cameron Streets, joining downstream of the town. In addition, there have been numerous private bund/levee systems constructed over time by individual landowners in order to protect their residences. These are generally of poor construction quality.

Flooding through Glenorchy is also a result of direct inundation by the Wimmera River. The RWC (1988) report describes the natural narrowing of the floodplain. There are also significant embankments associated with roads in this area that have the potential to substantially modify flow patterns. The major crossing of the Wimmera River just downstream of the Glenorchy township is the Stawell – Warracknabeal Rd. Although this is a sizeable bridge crossing, there are significant embankments intruding onto the Wimmera River floodplain. The embankments associated with the previous bridge crossing are still during the 1988 flood event present upstream of the existing crossing. Figure 2-2 is an aerial photograph of this area.

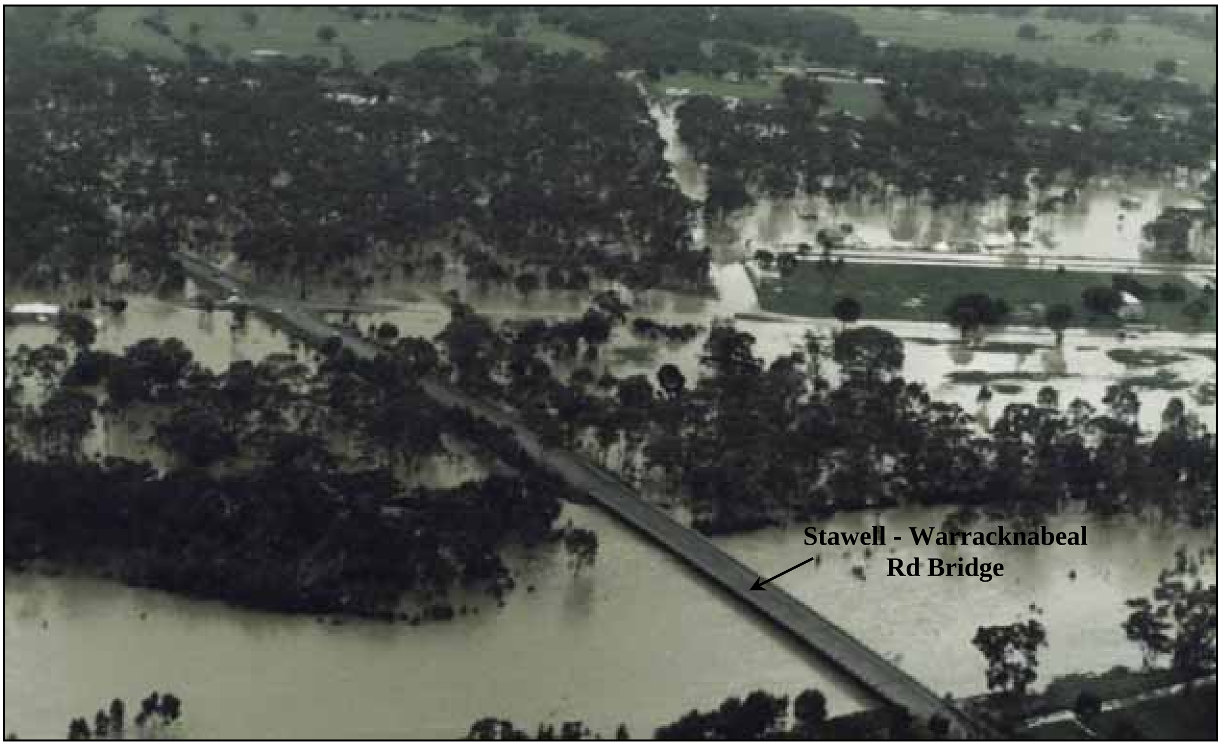

Figure 2-2 Aerial View of the 1988 Event through Glenorchy – Downstream Portion

3 AVAILABLE INFORMATION

3.1 Observed flood level and extent data

The Flood Data Transfer (FDT) project (Sinclair Knight Merz 2000) collated flood data throughout the Wimmera River Catchment. For Glenorchy the following observed flood data was collated:

- Observed flood levels for the August 1909, February 1973, August 1981, September 1983, September 1988 and October 1996.
- Aerial flood photography (showing flood extent) for the February 1973, August 1981, September 1988 and October 1996.

As part of the Glenorchy to Horsham Flood Scoping Flood Study (Water Technology 2003), the community questionnaire identified a number of observed flood levels. These identified flood levels was subsequently surveyed. Also numerous flood photos were obtained. In total, some 84 flood marks have been located, levelled and documented.

The observed flood level and extent data was employed in the hydraulic analysis for the calibration of the hydraulic model as discussed in Section 5.3.

3.2 Streamflow data

The hydrologic analysis, as detailed in Section 4, required streamflow data for the Wimmera River adjacent to Glenorchy. The details of the available streamflow data are shown in Table 3-1.

Table 3-1 Wimmera River at Glenorchy (4152010): Nature of available streamflow data

Station Name and number	Period of record	Type of streamflow record obtained
Wimmera River at Glenorchy (415201)	21 March 1950 to 14 May 1975	Mean daily flow
Wimmera River at Glenorchy (415201)	15 May 1975 to 26 July 2005	Daily instantaneous peak flow

3.3 Topographic and floor level data

There have been two major sources of topographic information gathered during the course of the investigation, these being:

- Airborne laser scanning
- Field survey

Following the collection and processing of the topographic information, a detailed Digital Terrain Model (DTM) was developed as the basis for the establishment of a hydraulic model of the study area. The sources of the topographic information are discussed in more detail below.

3.3.1 Airborne laser scanning

Airborne laser scanning (ALS) was undertaken by AAM Hatch on 24 August 2004. The average ALS data point separation was 1.4 m. The gathered ALS data was filtered to remove non-ground strikes. Figure 3-1 illustrates the extent of the ALS data collected.

A sample of 134 test points indicated the standard error was 0.06 m on clear open ground. The deduced vertical accuracy was 0.15 m with a horizontal accuracy of 0.55 m.

3.3.2 Field Survey

Field survey was conducted by LICS (now Sinclair Knight Merz) to provide aerial photo control, waterway cross-sections, culvert/bridge structure details and road/rail embankments. The extent location and extent of the field survey is also illustrated in Figure 3-2.

3.3.3 Floor level data

As part of the field survey, floor level data was collected for 64 buildings/dwellings in Glenorchy. This floor data was employed in the flood damage assessment. Details of the flood damage assessment are provided in the Glenorchy Floodplain Management Plan – Study Report (Water Technology 2006).

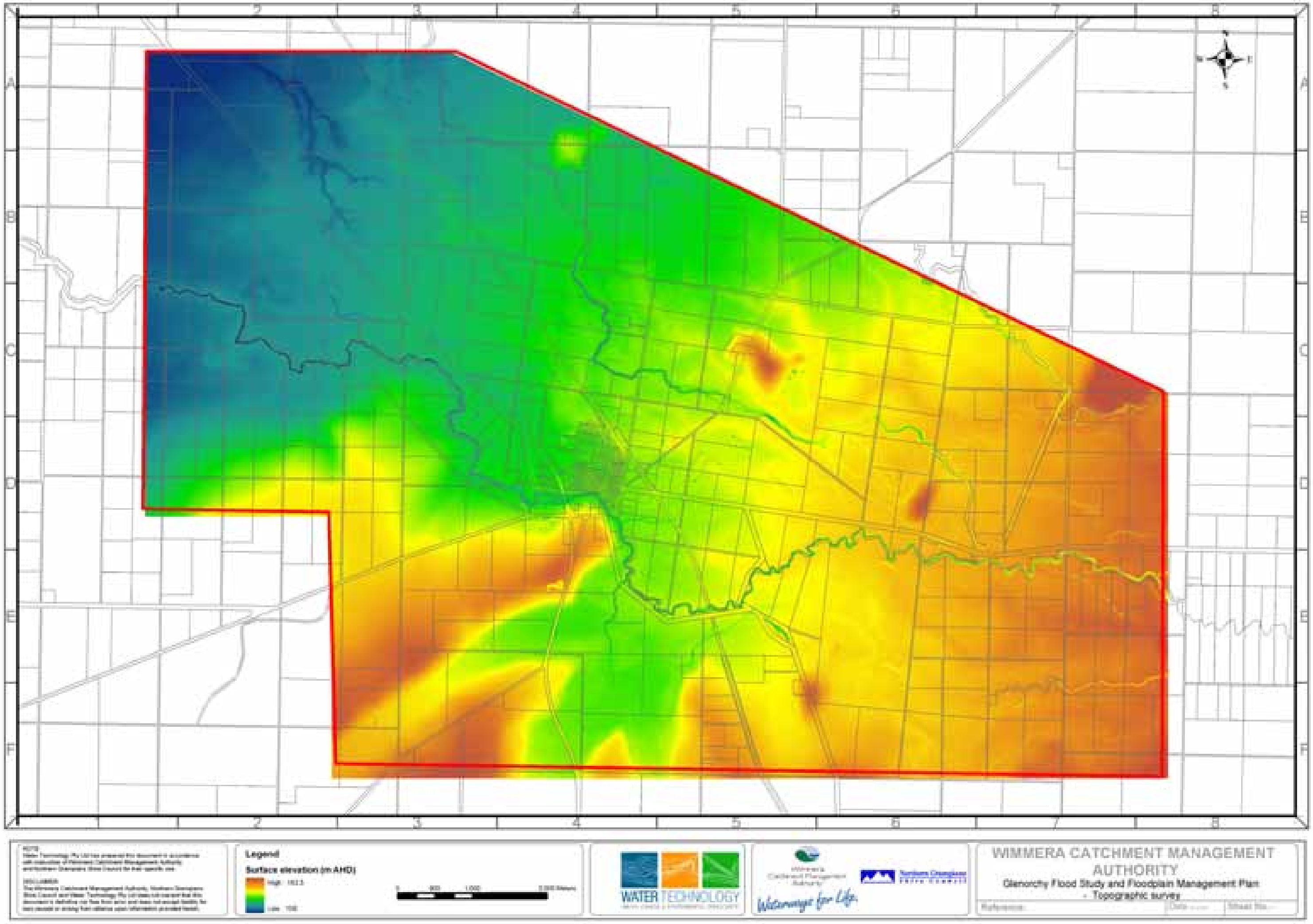

Figure 3-1 ALS Survey Extent

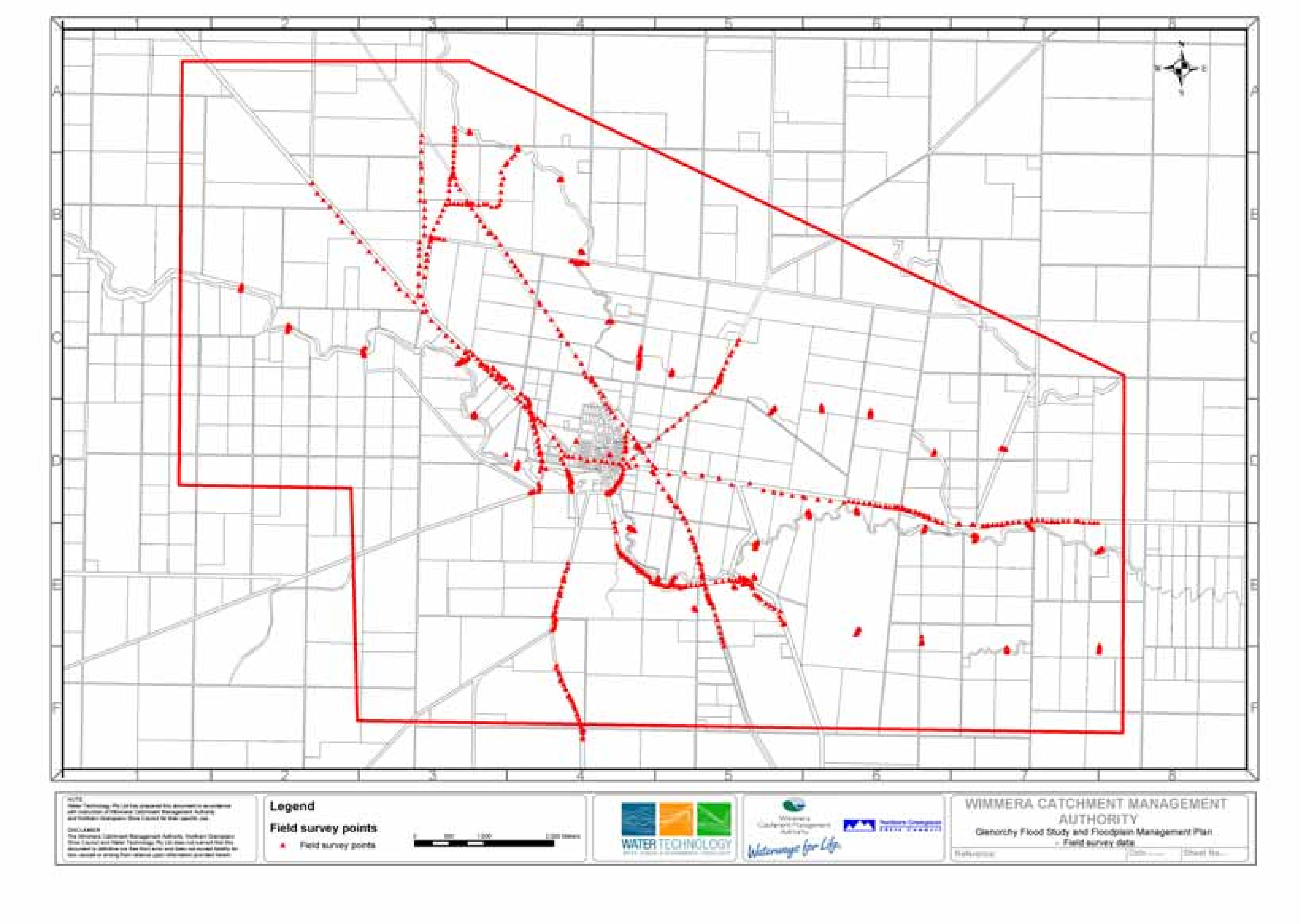

Figure 3-2 Field survey extent

4 HYDROLOGIC ANALYSIS

4.1 Overview

Design flood hydrographs were required for the 5, 10, 20, 50, 100 and 200 year ARI floods at Glenorchy. As discussed in Section 3.2, streamflow data at Glenorchy is available from 1950 to date (55 year of streamflow data).

Given the available streamflow data at Glenorchy, the study team employed at site flood frequency analysis to determine design peak flows at Glenorchy. The design flood hydrographs were then determined by scaling the observing hydrographs by the ratio of the design peak flow to the observed peak flow.

This section details the input data, methodology and outputs for the hydrologic analysis.

4.2 Available data

For this study, streamflow data was obtained from Thiess - Hydrographic Services for the period 1950 to date at Glenorchy Weir (Tail water gauge) (gauge number 415201) as outlined in Section 3.2.

For the peak flow frequency analysis, as outlined in Section 4.3, it was necessary to estimate the daily instantaneous peak flows for the entire period 21 March 1950 to 14 May 1975. A relationship was developed between the maximum mean daily flow and the daily instantaneous peak flow for each month over the period of concurrent data (15 May 1975 to 26 July 2005). Figure 4-1 displays this relationship between the monthly maximum mean daily flow and instantaneous peak flow.

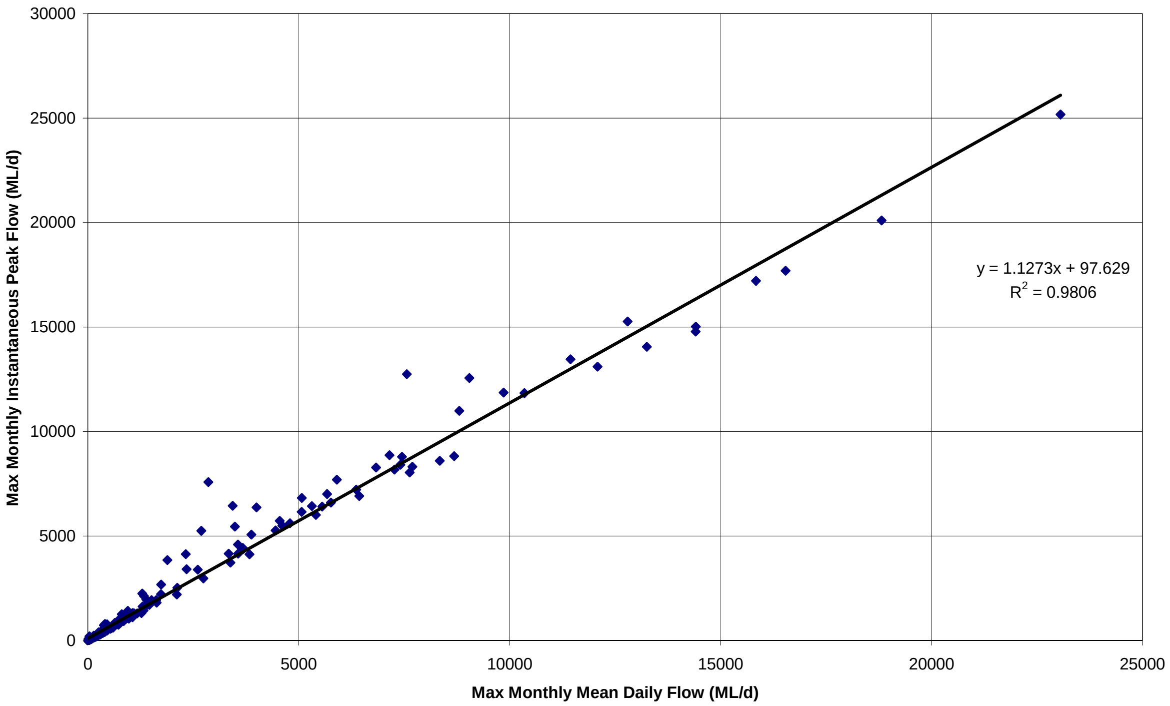

Figure 4-1 Wimmera River at Glenorchy: Mean daily flows and peak instantaneous flows

Daily peak flows were estimated using the mean daily flow and the above relationship for the period 21 March 1950 to 14 May 1975. The estimated daily peak flows were combined with the recorded daily peak flows to form a complete series of daily maximum instantaneous flows over the entire period for analysis.

4.3 Peak flow frequency analysis at Glenorchy

A frequency analysis was undertaken for the period 1950 to 2005 using the annual peak instantaneous flows. A log Pearson 3 distribution was fitted to the annual peak flows series using the techniques outlined in IEAust (1987). Peak flows less than 1,000 ML/d were excluded from the analysis in accordance with IEAust (1987).

Results from the frequency analysis are presented in Table 4-1 and Figure 4-2. The fit of distribution to the observed peak flows is considered reasonable.

Table 4-1 Wimmera River at Glenorchy: Peak flow frequency analysis

Average recurrence interval (years)	Design peak flow (ML/d)	Design peak flow (m^3/s)
5	14,100	163
10	19,000	220
20	23,500	272
50	29,000	336
100	32,800	380
200	36,400	421

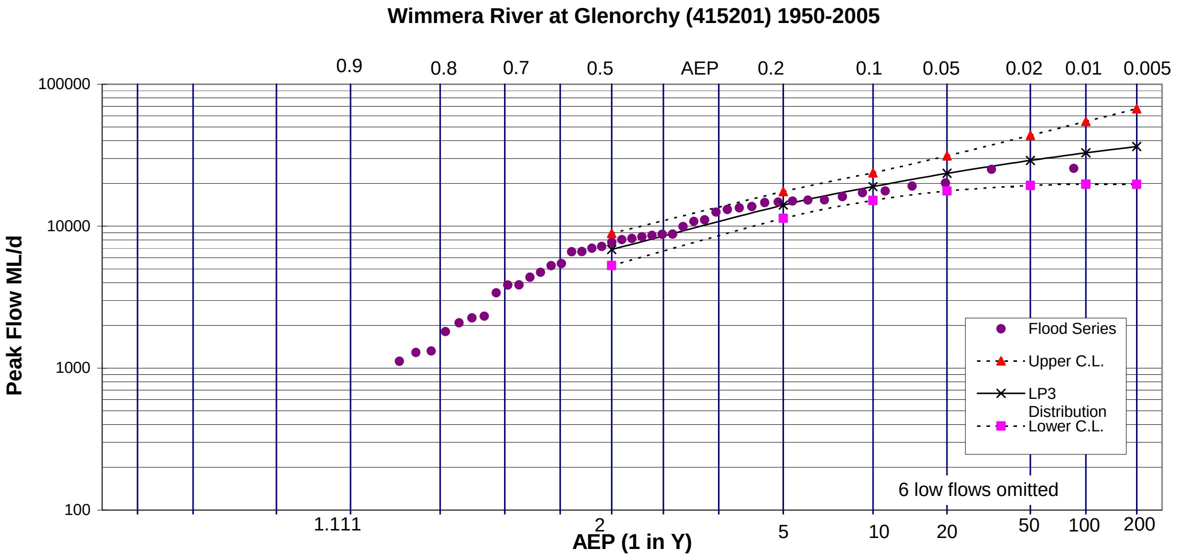

Figure 4-2 Wimmera River at Glenorchy: Peak flow frequency analysis

4.4 Design flood hydrograph estimation

To simulate the storage behaviour of the floodplain adjacent to Glenorchy, design flood hydrographs are required as input to the hydraulic analysis. The peak flow frequency analysis, discussed in Section 4.3, provides only design peak flows at Glenorchy with no information provided on the shape of the design flood hydrograph.

For the purposes of this study, the design flood hydrographs were estimated by scaling observed flood hydrographs using the ratio of the design and observed peak flows. Prior to May 1975, observed streamflow data consisted of daily mean flows (as detailed in Table 3-1). As a result, the observed flood hydrographs from the available streamflow data at Glenorchy from May 1975 were considered for their suitability in design flood hydrograph estimation.

The September 1988 flood is the largest flood event since May 1975 with an observed peak flow of 25,167 ML/d and an estimated ARI of 1 in 30 years. The study team considered as September 1988 was the largest available flood hydrograph, the September 1988 observed flood hydrograph was suitable for use in the design flood hydrograph estimation.

The design flood hydrographs was estimated by scaling the September 1988 using ratio of required design peak flows (from Table 4-1) by the observed peak flow (25,167 ML/d). Figure 4-3 shows the September 1988 observed flood hydrograph and the estimated design flood hydrographs.

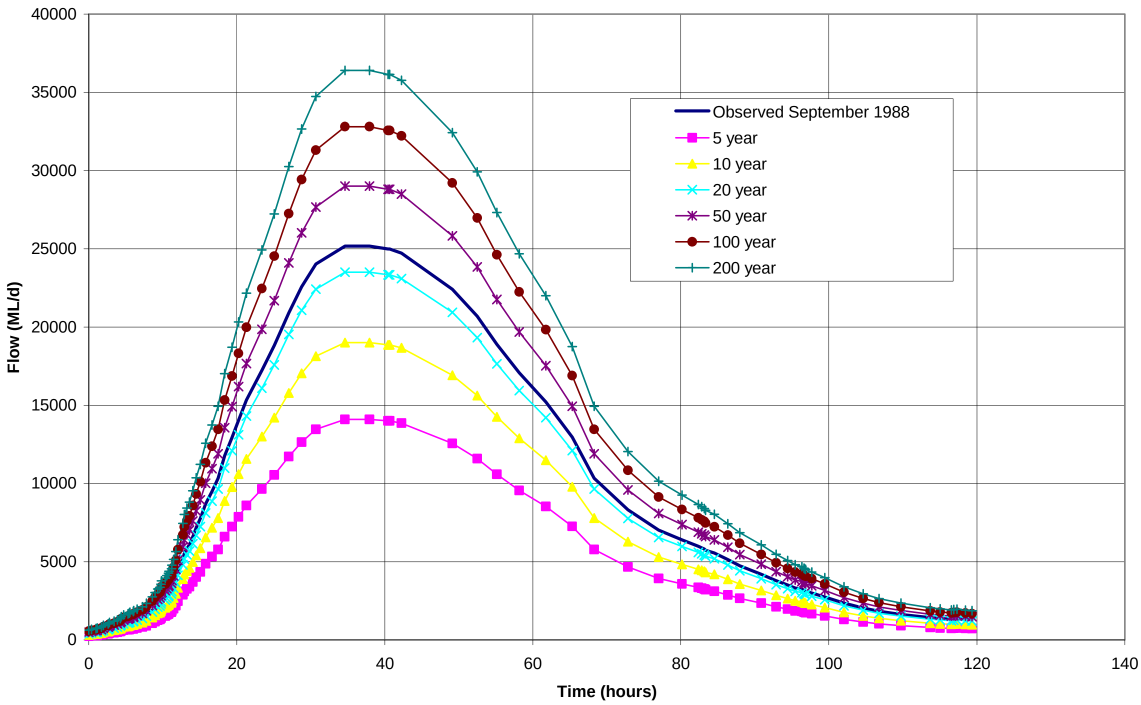

Figure 4-3 Wimmera River at Glenorchy: Design flood hygrographs and September 1988 flood hydrograph

5 HYDRAULIC ANALYSIS

5.1 Overview

The design flood levels and extents were required for the 5, 10, 20, 50, 100 and 200 year ARI design flood events across the study area. A hydraulic analysis was undertaken to determine the required design flood levels and velocities.

The two-dimensional unsteady hydraulic model MIKE Flood was the principal tool for the hydraulic analysis. MIKE Flood is a state of the art tool for floodplain modelling that has been formed by the dynamic coupling of DHI's well proven MIKE 11 river modelling and MIKE 21 fully two-dimensional modelling systems.

The topographic data (discussed in Section 3.3) and the design flood hydrographs (discussed in Section 4.4) were inputs to the hydraulic analysis.

This section details the input data, methodology and outputs for the hydraulic analysis. The structure of the section is as follows:

- MIKE Flood model development – details the development of and input data to the MIKE Flood model (Section 5.2).
- MIKE Flood model calibration – details the selection of calibration events and calibration of model paramters (Section 5.3).
- Design flood levels and extents – summaries the estimation of design flood levels and extents with the calibrated MIKE Flood model for the exisiting floodplain conditions (Section 5.4).
- Discussion – provides comments on the the relaibility of hydraulic model's results and key hydraulic characterisitics (Section 5.5)

5.2 MIKE Flood hydraulic model development

5.2.1 Description of MIKE Flood model

Hydraulic modelling of the study area has been undertaken utilising the Danish Hydraulic Institute's (DHI) MIKE Flood modelling software. MIKE Flood is a state of the art tool for floodplain modelling that has been formed by the dynamic coupling of DHI's well proven MIKE 11 river modelling and MIKE 21 fully two-dimensional modelling systems. Through this coupling it is possible to extend the capability of the 2D MIKE 21 model to include:

- A comprehensive range of hydraulic structure (including weirs, culverts, bridges, etc);
- ability to accurately model sub-grid scale channels;
- ability to accurately model dam-break or levee failures.

For the present study, a two-dimensional (2D) MIKE 21 model has been set up to model the overall floodplain flows. A coupled one dimensional (1D) MIKE 11 model has also been utilised to explicitly model the Dunmunkle Creek offtake.

5.2.2 Model structure

The basis of the two dimensional model is the topographic grid which is based on the ALS and field survey. A 5m model grid has been employed for this study.

The Dunmunkle Creek offtake was modelled as MIKE 11 structures and dynamically coupled with the two dimensional model. Head loss through the offtake was be modelled explicitly within the model.

The culverts under the railway and the old bridge were incorporated into as one- dimensional elements linked to the two dimensional grid. The new bridge along the Stawell – Warracknabeal Road has little impact of the flood behaviour due to the high elevation of the underside of the bridge. As such the new bridge was not incorporated into the hydraulic model. However, the embankments either of the new bridge do influence flood behaviour and have been included in the hydraulic model.

The variation in hydraulic roughness within the study area has been schematised as a hydraulic roughness grid, representing various hydraulic roughness's eg open grassland, roads, thick vegetation. The hydraulic roughness grid was based principally on the aerial photograph (Wimmera CMA, 2005). Table 5-1 outlines the initial estimates of the hydraulic roughness parameters.

Table 5-1 Intial hydraulic roughness parameters

Floodplain Element	Manning's M	Manning's n (n = 1/M)
General Floodplain roughness (open space, lightly vegetated, agricultural land)	25	0.04
Vegetated areas (backyards)	28.5	0.035
Urban areas (buildings)	5	0.20
Clear, paved areas (streets)	50	0.02

The above Manning's M (and n) in Table 5-1 were adjusted, where required, as part of the hydraulic model calibration (refer to Section 5.3). Figure 5-1 show the spatial distribution of the initial hydraulic model roughness.

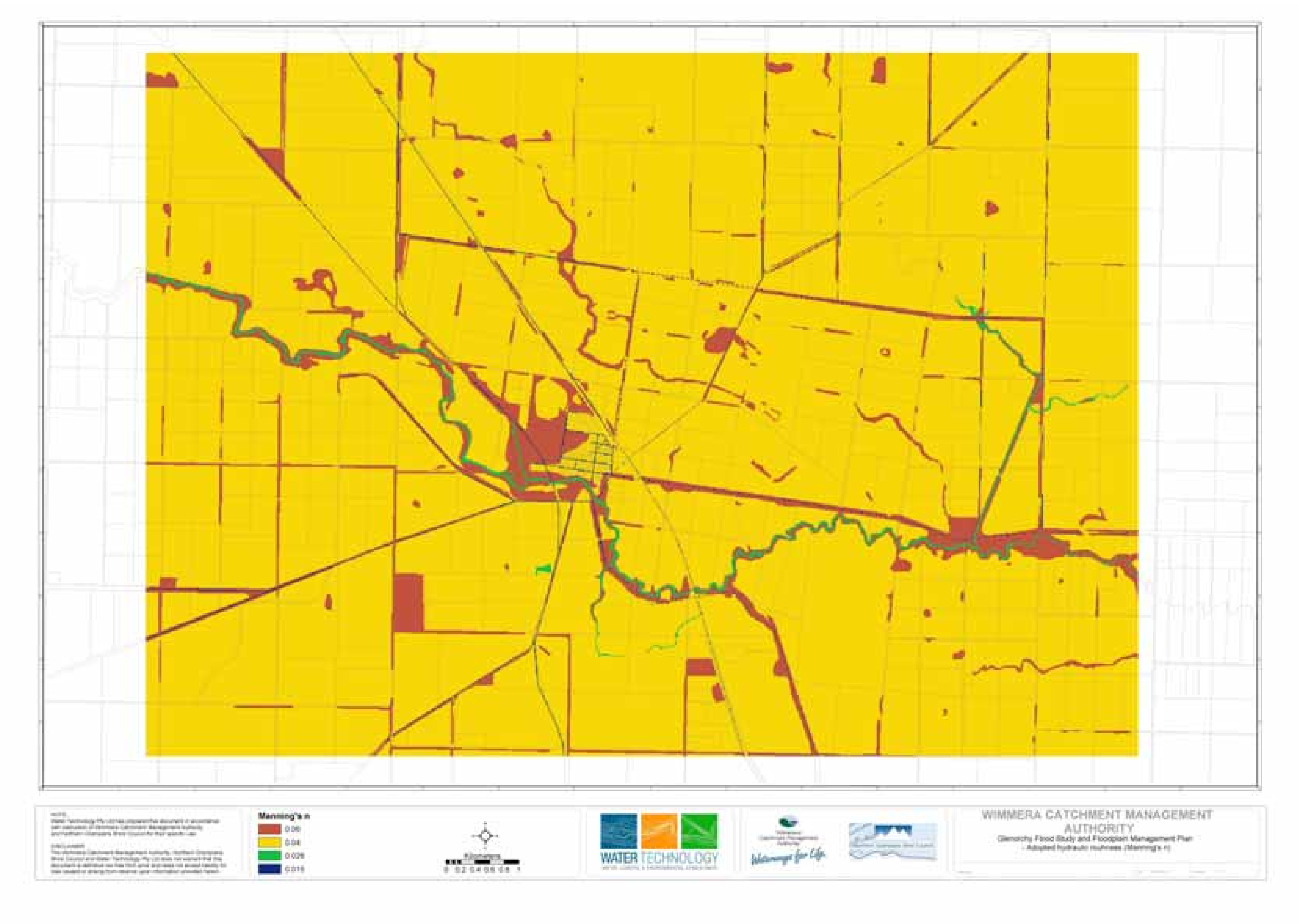

Figure 5-1 Initial Hydraulic Model Roughness

5.3 MIKE Flood hydraulic model calibration

5.3.1 Overview

The calibration process requires systematically comparing the hydraulic model's representation of flooding in the study area with observed flooding behaviour. This process may incorporate comparisons between gauged stream flows, observed maximum flood levels, areas of inundation as shown in aerial photography and eyewitness recounts of flooding behaviour. Where the model does not adequately represent what was observed, the reason for the discrepancy is identified and inputs into the model are adjusted as required.

The hydraulic model developed by this study is based on current topographic data and flooding behaviour is therefore influenced by the current topography. As such, the ability of the hydraulic model to simulate observed historical flood behaviour is affected by changes to the topography subsequent to the flood event being modelled.

5.3.2 September 1988 hydraulic model calibration

As discussed in Section 4.4, the September 1988 flood event was the largest flood with observed available data of the flood hydrograph. A number of observed flood levels within Glenorchy and observed flood extent from aerial photography, as outlined in Section 3.1, are available for the September 1988. This observed flood level and extent data is required for use in the hydraulic model calibration.

Given the magnitude and available data for the September 1988, the study team selected the September 1988 as the principal hydraulic model calibration event.

The September 1988 observed flood hydrograph, as in Figure 4-3, was input into the hydraulic model. The Manning's M values, as shown in Figure 5-1, were employed for the initial hydraulic model calibration run.

Figure 5-2 shows a comparison the modelled and observed flood levels, and flood extent for the September 1988 event from the initial hydraulic model calibration run. The differences between the modelled and observed flood levels are generally less than 30 mm. The modelled flood extent closely follows the observed flood extent.

The study team considered the good agreement seen between the modelled and observed flood characteristics provides good confidence in the hydraulic model reliability. Given this good agreement, the Manning's M values shown in Figure 5-1 were adopted for use in the design flood levels and extents estimation. Details of the design flood levels and extents estimation are provided in Section 5.4.

Community feedback on the modelled September 1988 flood extent was positive with a general agreement that the modelled flood extent reflected the observed flood extent.

Further discussion of the hydraulic model calibration and modelled flood characteristics is provided in Section 5.5.

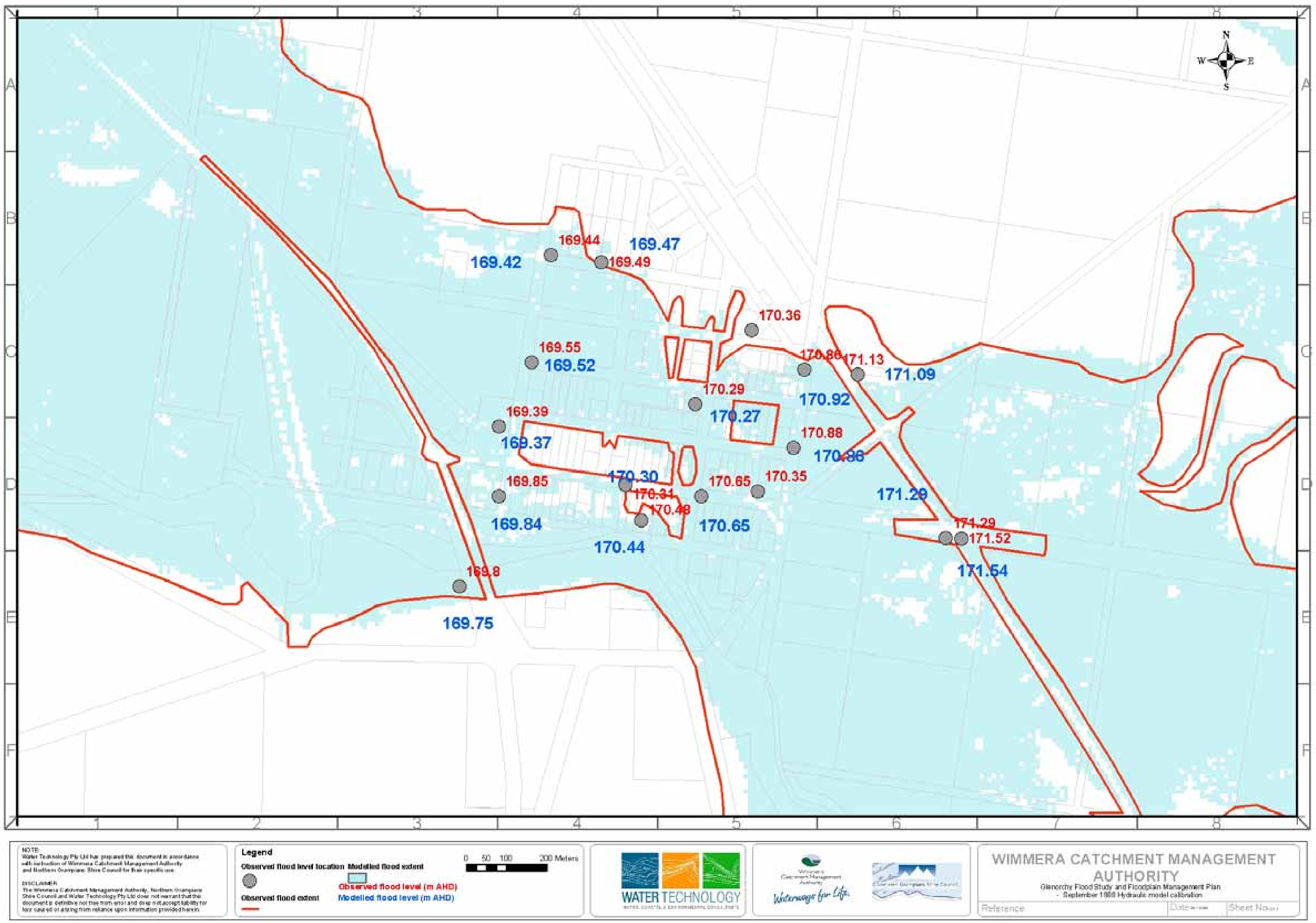

Figure 5-2 September 1988 flood event hydraulic model calibration

5.4 Existing conditions design flood levels and extents

Design flood levels and extents were determined via the calibrated MIKE Flood model for the 5, 10, 20, 50, 100 and 200 year ARI floods under the existing floodplain conditions. The existing flood plain conditions are defined as the ground levels determined by the topographic survey (August 2004).

The design flood hydrographs shown in Figure 4-3 were input into the MIKE Flood model to determine the corresponding ARI design flood levels and extents.

Figure 5-3 shows the 100 year ARI flood levels and extent for the existing conditions. The flood levels are provided as contours with elevations to m AHD and a contour interval of 200 mm. The shades of blue shown in Figure 5-3 indicate the flood depth above ground level.

The accompanying flood inundation map atlas contains the suite of flood inundation maps for the 10, 20, 50, 100 and 200 year ARI floods.

5.5 Discussion

5.5.1 Flooding behaviour overview and critical flood levels

The hydraulic analysis revealed a small range in flood levels across the design events at the Glenorchy stream flow gauge. The flood levels at the gauge ranged from 168.65 m AHD at the 10 year flood event to 168.80 m AHD for the 200 year flood event. This is relatively small increase in flood level and reflects the wide floodplain available for the storage and conveyance of flood flows.

This difference in flood levels over the design flood events is relatively consistent for the township. Increases in flood magnitude results in minor increases in flood depths and extents.

The flood slope along the floodplain is relatively steep. The 100 year flood levels along Cameron Street varies from ~ 171 m AHD (at Marl Street) to 169.7 m AHD (at Arapiles Street). This represents a drop in flood levels of ~ 1.3 m over a distance of ~ 700 metres or a slope of 1 in 540.

The reach of the Wimmera River channel through the study area has a limited bankfull capacity. The bankfull capacity is relatively constant along the reach at ~120 m^3/s (10,360 ML/d). As a result flow across the floodplain occurs for relatively small flood events (less than 5 year flood events).

Breakouts occur upstream of the township with overland flow crossing the Glenorchy-Campbell Bridge Road and continuing through the culverts under the railway line. This overland flows then continues into the township along the Cameron and Boyd Street drains.

Downstream of the township, the Stawell – Warracknabeal Road embankment on the north side of the Wimmera River obstructs the overland flow. As a results a local increase in flood level occurs upstream of the embankment. However, due to the relative steep flood slope, the impact of the embankment is constrained to approximately ~ 100 metres upstream.

Flows into Dunmunkle Creek are controlled by the regulator and the Glenorchy-Campbell Bridge Road. For this study, the regulator was assumed to be closed. The flows along Dunmunkle Creek varied from 17 m^3/s (1,470 ML/d) for the 10 year Wimmera River event to 32 m^3/s (2,750 ML/d) for the 200 year Wimmera River flood event.

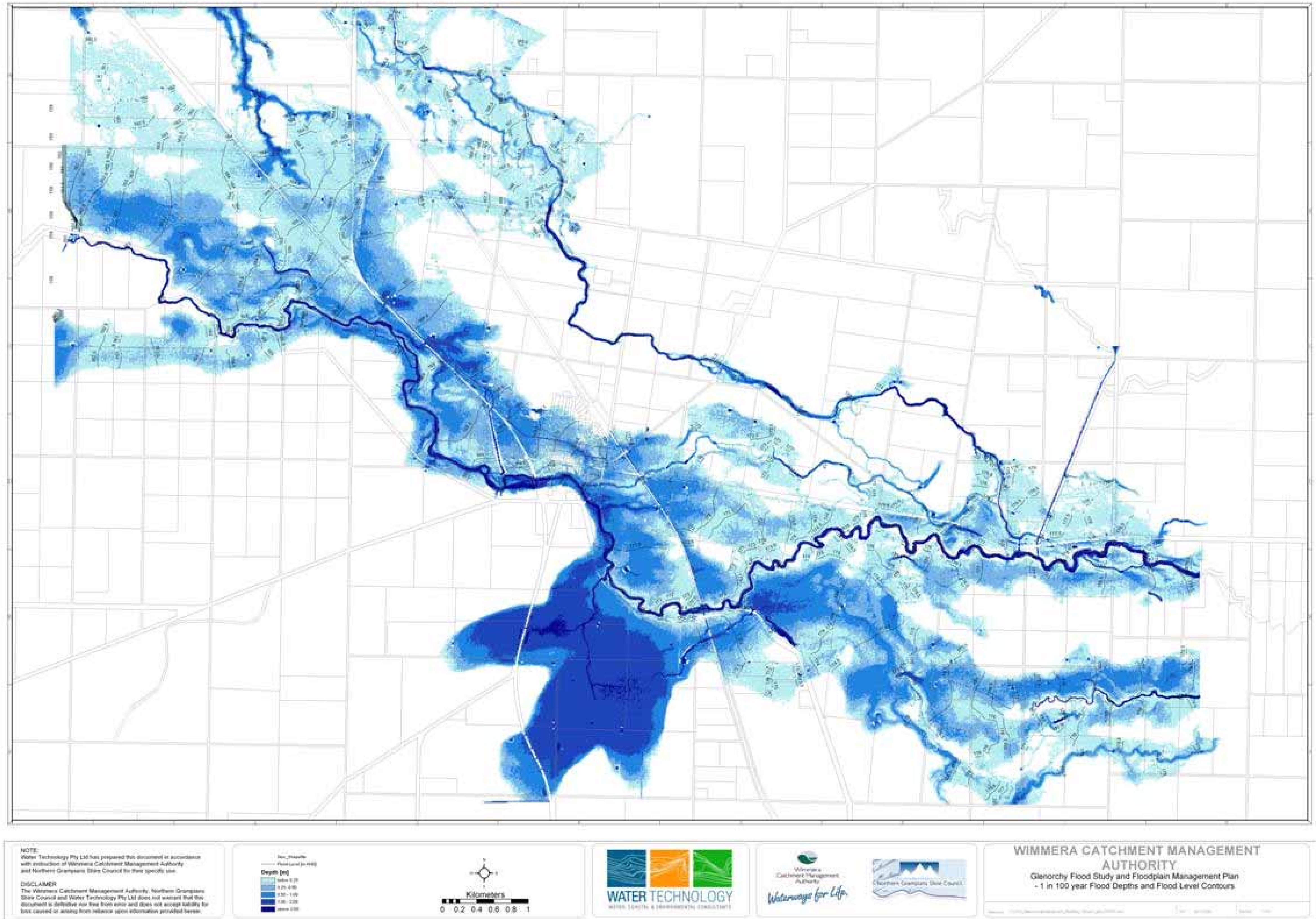

Figure 5-3 100 year ARI design flood levels and extent

5.5.2 Reliability of design flood levels

The study team considers the methodology employed as part of the hydrologic and hydraulic analyses provides for robust and rigorous estimates of design flood hydrographs and flood levels.

As discussed in Section 4, the design flood hydrographs were developed using peak flow estimates from an at-site flood frequency analysis. The reliability of the design peak flow estimates derived from a flood frequency analysis is based on the length of the streamflow record employed. For this study, 55 years of streamflow data was employed in the flood frequency analysis. The study team considers the approach employed and available data utilised which provides reliable design peak flow estimates. However, the reliability of the peak flow estimates is reduced for the 1 in 200 year ARI flood event.

Setting aside the reliability of the design flood hydrographs, the reliability of the design flood levels produced by the hydraulic model rests upon the quality of the model calibration. As discussed in Section 5.3, a comparison of modelled and observed flood levels for the September 1988 event show the modelled flood levels are generally within 30 mm of the observed. Furthermore there appears to be no systematic tendency to under or over-predict observed flood levels for the September 1988 event.

Given the above discussion, the study team considers the design flood levels are reliable with an indicative accuracy of the 50 mm. Further the study team considers the design flood level suitable for the purposes of this study.

6 REFERENCES

Sinclair Knight Merz (2000): *River Basin Report, Wimmera River, Lower Sub Catchment – Flood Data Transfer Project*. Consulting report prepared for the Department of Natural Resources and Environment, June 2000.

Water Technology (2003): *Glenorchy to Horsham Flood Scoping Study*. Consulting report prepared for the Wimmera CMA. February 2003.

GLOSSARY

Annual Exceedance 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. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years.
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.
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 frequency analysis	A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
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.

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.
Ortho-photography	Aerial photography which has been adjusted to account for topography. Distance measures on the ortho-photography are true distances on the ground.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
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.
Topography	A surface which defines the ground level of a chosen area.