Goulburn River Environmental Flows Hydraulics Study

Hydraulic model construction and calibration

One dimensional and Linked hydraulic models

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1. INTRODUCTION

This report documents the hydraulic model construction and calibration undertaken as part of the Goulburn River Environmental Hydraulics Study. This report details the hydraulic modelling framework, component hydraulic model construction and calibration. This report focuses on the hydraulic models (1D & linked models) employed for the environmental flows scenarios. A separate report (Water Technology 2010a) details the hydraulic models (2D models) employed for the floodplain management scenarios.

Goulburn Broken Catchment Management Authority (Goulburn Broken CMA) has commissioned the Goulburn River Environmental Flow Hydraulics Study. This study has undertaken hydrologic and hydraulic analysis of the Goulburn River from Lake Eildon to Murray River.

The study brief outlines the following key study tasks:

1. Data collation and review – Collation and review of the available topographic and streamflow data information.
2. Topographic data gap identification – Identify the gaps in the available topographic data, and suggest potential mediation options.
3. Asset mapping – Locate and map known public and private assets along the Goulburn River and adjacent surrounds.
4. Hydrologic analysis – Investigate relative contribution from downstream tributaries, and assess design flood hydrographs for the Goulburn River catchment.
5. Hydraulic analysis and flow behaviour – Assess flow behaviour of the Goulburn River over a range of potential environmental flows.
6. Socioeconomic assessment – Evaluate the social and economic costs of potential Goulburn River environmental flows.
7. Real time flow management – Review and scope real time flow management framework.
8. Management option assessment – Scope feasibility of management options for environmental flow releases.

This report addresses aspects of the fifth study tasks.

The structure of this report is as follows:

- Section 2: outlines the philosophy underpinning the hydraulic modelling framework
- Section 3: details the construction of the component hydraulic models
- Section 4: discusses the calibration of the component hydraulic models

2. HYDRAULIC MODELLING FRAMEWORK

2.1 Overview

This section discusses the philosophy underpinning the hydraulic modelling framework employed for this study.

The complexity of the flow and flood behaviour required a flexible hydraulic modelling framework. The adopted framework simulated the flow behaviour over a full range of flows (in-channel to overbank/floodplain inundation). The key hydraulic modelling elements are discussed in Section 2.2.

A comprehensive hydraulic modelling framework has been employed in this study. However, the outcomes of the hydraulic modelling must be viewed in the light of the hydraulic models' capabilities, limitations and uncertainties. These aspects are discussed in Section 2.3.

2.2 Hydraulic model elements

The framework was required to simulate the flow behaviour over a full range of flows (in-channel to floodplain) balancing against excessive model simulation times. The hydraulic modelling framework comprised the following component hydraulic models:

- One dimensional (1D) hydraulic models: Key waterways and anabranches for in-channel flows
- Two – dimensional (2D) hydraulic models: Broad scale floodplain features for large flood events (discussed in a separate report Water Technology 2010a)
- Linked one – two dimensional hydraulic (1D/2D) model: Combines the 1D model with the broad 2D floodplain models to assess adjacent floodplain wetlands engagement.

Hydraulic modelling suite, MIKE11, MIKE21 and MIKE FLOOD, developed by the Danish Hydraulic Institute (DHI) has been applied in this study. MIKE FLOOD is a state-of-the-art tool for floodplain modelling that combines the dynamic coupling of the one-dimensional MIKE 11 river model and MIKE 21 fully two-dimensional model systems. Further details on the capabilities of the MIKE FLOOD modelling system can be found at http://www.dhisoftware.com/mikeflood.

The hydraulic modelling framework was required to simulate flow behaviour for potential environmental flows events, and for major flood events. Cottingham et al. 2003 discussed a floodplain wetland inundation regime between 15,000 – 60,000 ML/d. This regime has informed the range of environmental flow events considered by this study.

Additionally, the study brief specified the consideration of the 20, 50 and 100 year flood events along the river from Eildon to the Murray River confluence. These flood events provided information for use in floodplain management. Table 2-1 outlines the design peak flow estimates for key locations along the Goulburn River, and sources for the estimates. Further discussion of the floodplain management scenarios is provided in a separate report (Water Technology 2010a).

Table 2-1 Goulburn River design flood estimates and sources

Location	Design Peak flow (ML/d)				Source
	10 year	20 year	50 year	100 year	
Downstream of Lake Eildon	32,000	43,200	64,800	90,700	SRWSC 1981
Trawool	58,000	74,000	101,000	128,000	Water Technology (2010b)
Seymour	60,820	87,610	128,300	162,000	WBM (2001)
Murchison	68,400	87,000	114,000	134,000	SKM (2002)
Shepparton	102,000	137,000	180,000	219,000	SKM (2002)

A comparison of the environmental flow range and design peak flow estimates showed that the upper limit of the environmental flow range (60,000 ML/d) corresponded to approximately a 45 year ARI event downstream of Eildon reduces to about a 10 year event at Trawool/Seymour, and a 8-9 year ARI event at Murchison. Further downstream at Shepparton, a 60,000 ML/d flows has ARI of 3-4 years. This variation in the ARI of a 60,000 ML/d flow highlighted the change in the hydraulic characteristics of the Goulburn River and floodplain throughout the study area. This change in hydraulic characteristics and the requirement to simulate the above flow regimes was reflected in the adopted hydraulic modelling framework. The following discussion outlines the reasoning underpinning the hydraulic modelling framework adopted by this project.

The Goulburn River below Lake Eildon was broken into two 1D models, Eildon to Goulburn Weir, and Goulburn Weir to the Murray River confluence. The 1D models consisted of river cross sections spaced at a nominal 500 m centres. The cross sections employed in the 1D models extend up to bank height. The cross sections were sourced from the available bathymetric and ALS topographic data. A full discussion of the available topographic sources was contained in the Topographic Data Review (Water Technology 2008). As the cross section only extended to bank height, the use of the 1D model was limited to flows up to bankfull. Details of the 1D model construction is provided in Section 3.2.

The calibration of the 1D model focused on the routing of in channel flows (up to 15,000 ML/d). The principal calibration was the comparison of modelled and observed stage-discharge curves. As outlined in Water Technology (2008), bathymetric data were not available upstream of Lake Nagambie. For this reach, the calibration aimed to assess appropriate combinations of hydraulic roughness (Manning's n) and invert lowering. Bathymetric data was available downstream of Goulburn Weir, and the calibration evaluated Manning's n. Details of the 1D model calibration is provided in Section 4.2. The 1D models were the key input to the linked 1D-2D models discussed below.

The 2D hydraulic model component consists of eight model domains covering the Goulburn River floodplain below Lake Eildon. The key input for the 2D model component was the topographic data obtained from the ALS data. For seven of 2D model areas, a 25 m grid size was adopted to represent the topographic features. The lower Goulburn model (Loch Garry to the Murray River) employed a 60 m grid. These grid sizes were considered suitable for the delineation of key topographic features, such as embankment and levees etc. Also, the grid sizes enabled reasonable model run times (say up to 12 hours). The representation of the hydraulic characteristics of the river channel was constrained by the grid size. As a consequence, the use of the 2D model was limited to significant overbank flooding events. For these significant overbank flooding events, the relative proportion of the flow in the river channel is less than the flow proportion across the floodplain. As such, the capacity of the river channel is less significant to the overall flood behaviour. Details of the 2D model construction are provided in Section 3.3. The 2D models were the key input to the linked 1D-2D models discussed below. The calibration of the 2D models is discussed in a separate report (Water Technology 2010a).

The linked 1D-2D hydraulic model combined the 1D river channel model with 2D floodplain model. This linking enabled the simulation of flows just exceeding bankfull capacity, but insufficient to cause extensive floodplain inundation. In particular, the linked 1D-2D models were applied to simulate flow behaviour for the environmental flow regimes considered. Details of the linked 1D-2D model construction are provided in Section 3.4.

The calibration of the linked 1D-2D models centred on historical flows within the environmental flow range (15,000 - 60,000 ML/d). As outlined in Table 2-1, the upper limit (60,000 ML/d) reflects a large flood event (> 20 year ARI) for reaches upstream of Trawool, a medium flood event (~ 10 year event) for Trawool to Murchison, and a small flood (< 5 year ARI event) Shepparton to the Murray River confluence. This variation in relative magnitudes has driven the linked 1D-2D model calibration. Upstream of Trawool, the linked 1D-2D model has been calibrated to flood events with observed flood levels. Downstream of Trawool, as the relative flood magnitude is less, the occurrence of a 60,000 ML/d event attracts limited community interest due to lower inconvenience / damages arising. Hence, there were few observed flood levels and the calibration was limited to the comparison of stage-discharge curves at gauges. Table 2-2 outlines the model elements, their purpose, calibration and application.

Table 2-2 Model elements: purpose, calibration and application

Model elements	Purpose	Calibration	Application
1D model	In channel flows (up to 15,000 ML/d) Manning's n assessment Invert lowering evaluation	Stage-discharge (rating) curve	Building block for linked 1D-2D model
2D model (discussed in a separate report)	Floodplain flow for large floods (> 20 year ARI)	Observed flood levels and extents from major flood events	Flood behaviour (flood levels and extents) for large events Flood mapping outputs from Trawool to Murray River confluence
Linked 1D-2D model	In-channel and floodplain flows (15,000 - 60,000 ML/d)	Observed flood levels and extents from major flood events upstream of Trawool Stage-discharge (rating) curve downstream of Trawool	Flood behaviour (flood levels and extents) for environmental flow events Flood mapping outputs from Eildon to Trawool

2.3 Hydraulic model capabilities and uncertainties

There are numerous contributing factors to the ultimate output uncertainty in a complex hydraulic modelling exercise such as that undertaken for this study. Some of the uncertainties relate to the data inputs, whilst others are dependent on the numerical modelling processes itself. Sources of output uncertainty related to the input data for the hydraulic modelling include:

- ALS data
- Bathymetry and cross section survey
- Definition of hydraulic controls/structures
- Observed flows for model input
- Observed flows and water levels for model calibration

Sources of uncertainty related to the hydraulic modelling process include:

- Model numerical and computational schemes – these relate to the ability of the model to replicate the physics of free-surface flow in channels and over land.
- Floating point accuracy of computing resources (truncation error)
- Model schematisation and set-up (location and spacing of cross-sections, grid resolution)
- Model parameters such as computational time-steps, surface-friction and other energy-loss parameters (expansion/contraction coefficients and eddy viscosity for example).

There is a wide variation in the magnitude of the impact associated with each source of uncertainty. In order to identify the most significant sources of uncertainty it is possible to consider items as either first or second order magnitude, where second order items are of a significantly smaller magnitude compared to first order items and can generally be ignored. A listing of the main sources of the modelling uncertainty and their approximate magnitudes is provided in Table 2-3.

Due to the complexity of the relationships between the input data and modelling outputs, there is no direct correlation between input and output data accuracy. Further, the error bounds on the data inputs are generally not cumulative. For example, inaccuracies in survey data inputs may be compensated for through adjustment of calibration parameters to achieve output hydraulic results that are nominally more accurate than the sum of the errors in the input data. Hence there are inferred relationships between model inputs and output accuracy that are typically developed through hydraulic modelling project experience.

The model development process can only address uncertainties arising from the following aspects:

- Definition of hydraulic controls/structures
- Model schematisation and set-up (location and spacing of cross-sections, grid resolution)
- Model parameters such as computational time-steps, surface-friction and other energy-loss parameters

Section 3 discusses the consideration of these three aspects in the model development.

The remaining aspects from Table 2-3 are constrained by the available data sources.

Table 2-3: Comparisons of Sources of Uncertainty

Scenario/Data/Process	Order of Accuracy	Approximate Impact on Results
ALS data and DEM	First	Change in floodplain levels/depths 0.1 m
Cross-section survey	First	Minimal direct impact, location and spacing of sections is more critical to model outputs
Definition of hydraulic controls/structures	First	Change in floodplain levels/depths 0.1 to 0.2 m
Observed flows for model input	First	Depends on available data, aim for observed/calibration accuracy +/- 10 % for flows
Observed flows and water levels for model calibration	First	Depends on available data, +/- 10 % for flows & +/- 0.15 m for observed flood levels.
Model numerical and computational schemes – these relate to the ability of the model to replicate the physics of free-surface flow in channels, wetlands and over land.	Second	N/A
Floating point accuracy of computing resources (truncation error)	Second	N/A
Model schematisation and set-up (location and spacing of cross-sections, grid resolution)	First	Difficult to quantify, aim for overall accuracy of +/- 0.1 m for levels and +/- 10 % for flows
Model parameters such as computational time-steps, surface-friction and other energy-loss parameters	First	Change in floodplain levels/depths +/- 0.1 m
Level/accuracy of model calibration	First	Depends on availability of calibration data, aim for +/- 0.1 m for levels and +/- 10 % for flows

3. HYDRAULIC MODEL CONSTRUCTION

3.1 Overview

This section details the construction of the hydraulic model components.

The hydraulic model construction for each element required understanding of the key influences on flow behaviour. The application of a particular modelling element to a given reach was driven by the key flow behaviour influences.

As discussed in Section 2.2, the hydraulic modelling framework comprises the following component hydraulic models:

- One dimensional (1D) hydraulic models: Key waterways and anabranches for in-channel flows
- Two – dimensional (2D) hydraulic models: Broad scale floodplain features for large flood events
- Linked one – two dimensional hydraulic (1D/2D) model: Combines the 1D model with the broad floodplain models to assess adjacent floodplain wetlands engagement.

The principal input to the model construction was the available topographic data. The representation of the significant topographic features underpinned a robust hydraulic model. The topographic data was required to define waterway form and floodplain features. The 1D hydraulic models required the waterway cross sections as the basic building block. The 2D hydraulic models required a regular grid of spot heights to define the floodplain terrain.

The hydraulic model construction also required the specification of boundary conditions, i.e. flows/water levels at the upstream and downstream limits of the hydraulic models. These boundary conditions can be sourced from observed data and/or estimated values from hydrologic models.

Channel form, riparian vegetation and floodplain land use influences the hydraulic roughness. The hydraulic roughness reflects the resistance against flow, due to friction, along a channel or over a floodplain. The evaluation of the hydraulic roughness required evaluation through model calibration, comparison of modelled and observed water levels and flows.

Section 3.2, 3.3 and 3.4 details the use of topographic data, model boundaries and hydraulic roughness, during the model component development, for the 1D, 2D and linked hydraulic models respectively.

3.2 One dimensional model components (Mike11 – Up to bankfull flows)

As discussed, the two 1D models (Eildon to Goulburn Weir and Goulburn Weir to the Murray River confluence) have been developed. The use of the 1D models was limited to flows up to bankfull. The 1D models consisted of the following elements.

- Branches:
    - Key waterways included:
        - Goulburn River
        - Downstream reaches of Broken River, Seven Creeks, Acheron River, Dabyminga Creek, Gardiner Creek, Major Creek, Home Creek, Sunday Creek Hughes Creek, King Parrot , Castle Creek and Pranjip Creek.
- Cross Sections:
    - ALS extracted cross sections: Nominal 500 m spacing. As discussed in Topographic Data Review (Water Technology 2008), the ALS data does not include the cross

section below the water level at the time of the ALS data capture. ALS extracted cross sections were revised to account for the “missing” area as follows:

- Goulburn River below Goulburn Weir: Bathymetric survey of the river inverts was available. The ALS cross sections were revised to include the available bathymetric survey as shown in Figure 3-1.
- Goulburn River at Lake Nagambie: Bathymetric survey of the river bed was available within the Lake Nagambie storage. The ALS cross sections were revised to include the available bathymetric survey
- Goulburn River above Lake Nagambie: No bathymetric survey of the river inverts was available. A range of invert lowerings, 1 m to 3 m, were trialled to yield suitable re-production of observed water levels and flows. The general approach of the invert lowerings is shown in Figure 3-2. The assessment of the invert lowering is further discussed in Section 4.2.2.
- Total ALS extracted cross-sections – 817

- Boundaries:
    - Upstream of Goulburn Weir:
        - Observed streamflows: Goulburn River at Eildon
        - Observed and Modelled streamflows: Rubicon River, Acheron River, Home Creek, Yea River, King Parrot Creek, Hughes Creek. Whiteheads Creek, Sunday Creek, Major Creek
    - Downstream of Goulburn Weir:
        - Observed streamflows: Goulburn River at Murchison, Broken River at Orrvale, Seven Creeks at Kialla West
        - Modelled streamflows: Castle Creek and Pranjip Creek
- Roughness
    - Hydraulic roughness within the 1D model was expressed as Manning’s n. This study assessed Manning’s n via comparison of modelled and observed water levels, flows and stage discharge (rating) curves at gauges. Further discussion of Manning’s n is provided in Section 4.2.2.

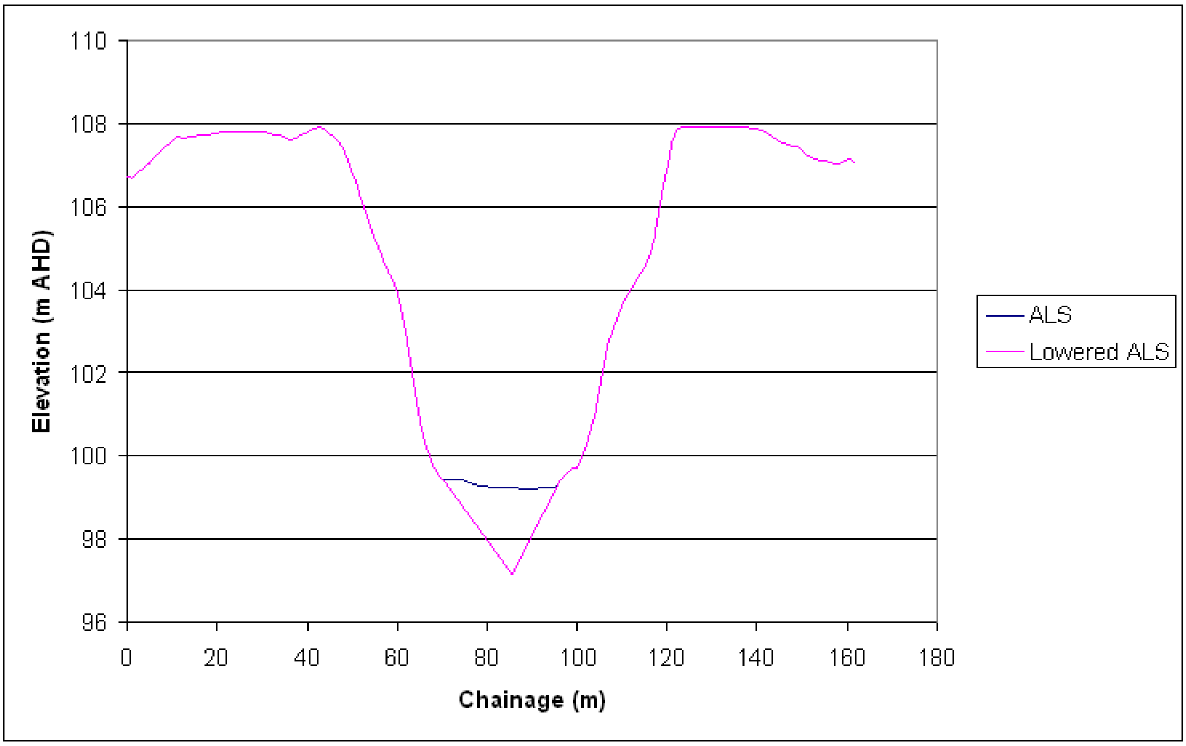

Figure 3-1 ALS extracted cross section modification – below Goulburn Weir

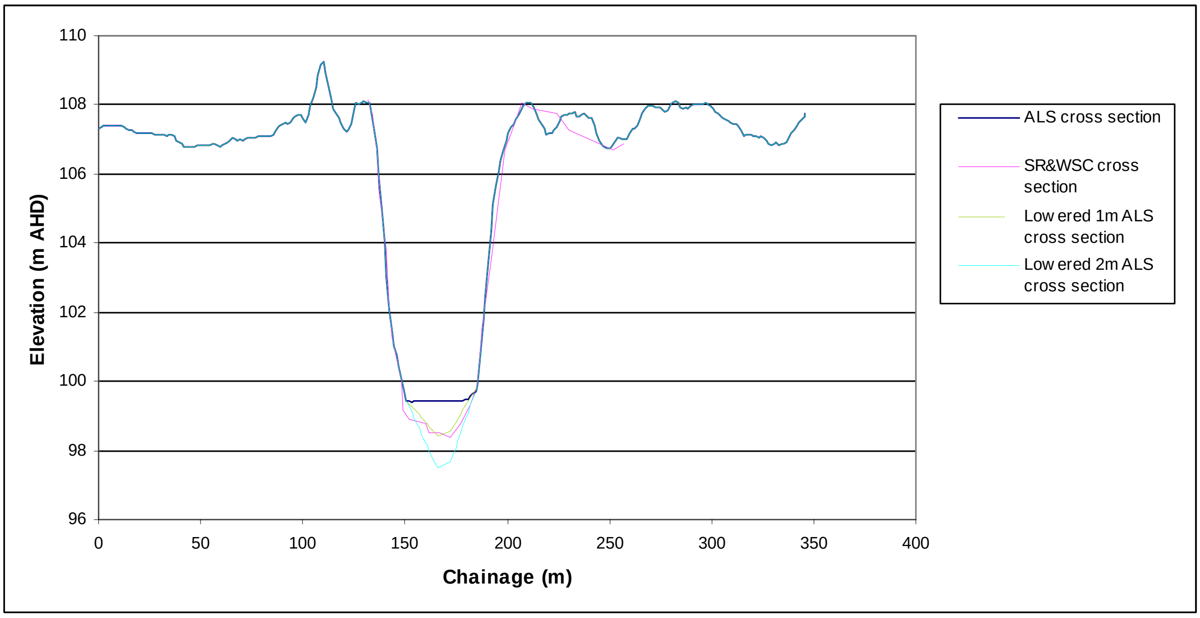

Figure 3-2 ALS extracted cross section modification – above Lake Nagambie

3.3 Two dimensional model components (MIKE 21)

As discussed, this study applied 2D models at the broad floodplain scale to simulate flow behaviour for events with extensive overbank (floodplain) flooding. The 2D models consisted of the following elements:

- Grid extent and resolution
    - The study area was segmented into eight broad scale 2D model areas:
        - Eildon to Alexandra
        - Alexandra to Ghin Ghin
        - Ghin Ghin to Kerrisdale
        - Kerrisdale to Mitchellstown
        - Mitchellstown to Wahring
        - Wahring to Kialla
        - Kialla to Bunbartha
        - Bunbartha to the Murray River

      For the first seven 2D broad scale model areas, the ALS data was interpolated into 25 m. For the lower Goulburn (Bunbartha to the Murray River), a 60 m grid was adopted as per Water Technology (2005). These grid resolutions represent a trade-off between adequately describing the fine topographic features within the study area and allowing the model simulations to be completed within a practical timeframe.

      Key topographic features, such as road and channel embankments, were stamped into the model grids. This stamping ensures these key features are reflected in the 2D model topography.

      Due to grid resolution, the hydraulic characteristics of the river channel may not be well resolved in the 2D model. As such, the use of the 2D models is limited to flows with extensive overbank flooding.

- Boundaries:
    - Upstream of Goulburn Weir:
        - Observed streamflows: Goulburn River at Eildon
        - Observed and Modelled streamflows: Rubicon River, Acheron River, Home Creek, Yea River, King Parrot Creek, Hughes Creek. Whiteheads Creek, Sunday Creek, Major Creek
    - Downstream of Goulburn Weir:
        - Observed streamflows: Goulburn River at Murchison, Broken River at Orrvale, Seven Creeks at Kialla West
        - Modelled streamflows: Castle Creek and Pranjip Creek
    - Inter-model boundaries: Modelled outflows from the upstream model provided the flow boundaries for the downstream models. A nominal downstream water level forms the downstream boundaries for each model area. Each model has an overlap of approximately 1 km. This overlap was used to ensure that the flow conditions in the adjoining models were the same for both the downstream end of one model and the upstream end of the next. The flows were extracted from each model just prior to the model outflow

- Roughness
  - Hydraulic roughness within the 2D model was expressed as Manning's n. For the estimation of the floodplain Manning's n, this study assessed land use and vegetation cover. The evaluation of Manning's n was undertaken through the calibration of the modelled and observed flood levels, and extents. The range of Manning's n values employed is discussed in a separate report (Water Technology 2010a).

3.4 Linked one-two dimensional model components (MIKE Flood)

The linked 1D-2D models coupled the two 1D models with the eight 2D models. As discussed, 1D models were limited to flows up to bankfull, and the 2D models were limited to flows where extensive floodplain inundation occurred. The linking of the 1D and 2D models enabled the simulation of flows from below bankfull up to minor floodplain inundation.

- Branches, cross sections and grids
  - Eight linked models were constructed based on the 2D model grid extents. The linked models used the 1D models' branches and cross sections.
  - The 2D models' grids were employed in linked models, with the river channel "infilled". This infilling removed the river channel from the 2D grid. This removal ensured no double counting of the river channel in the linked models, as the river channel was incorporated in the 1D model.
  - The links between the 1D and 2D models were spaced at the 2D grid resolution (i.e. 25 m above Loch Garry and 60 m in the lower Goulburn below Loch Garry).
- Boundaries:
  - The boundaries were taken as per the 1D and 2D model components
- Roughness
  - The component calibration of the 1D and 2D models provided the basis of the Manning's n values used in the linked models. Further refinement of the Manning's n values was undertaken for the linked models through the calibration of the modelled and observed water levels, and stage-discharge (rating) curves. The range of Manning's n values employed is discussed in Section 4.3.

4. HYDRAULIC MODEL CALIBRATION

4.1 Overview

This section discusses the refinement of the hydraulic models' parameters through calibration against observed water level and streamflow data.

The calibration process consisted of systematic comparison of observed flow/flood behaviour against the hydraulic modelling results. This process incorporated comparisons between gauged stream flow data, observed flood levels, observed stage-discharge (rating) curves, and areas of inundation. The models' parameters were adjusted to minimise the differences between the modelled and observed data.

A robust calibration required the comparison of modelled and observed flood behaviour across a range of flow magnitudes.

The following observed data was required for a historical event to be used in model calibration:

- Well defined inflows and outflows (boundary conditions).
- Flow and level measurements over time (temporal distribution) at discrete points of interest within and along the river such as effluent points and control structures.
- Flood extent and/or depth measurements (spatial distribution) at multiple times.
- Measures over a time period that exhibits the desired hydraulic responses in terms of flooding and drying of the system.

The historical flow/flood events used to calibrate the models were chosen on the basis of available flow information, and relevant flood level and extent information.

Each hydraulic model component required an individual calibration process, as the focus of each component varied. The 1D model calibration focused on the model's ability to re-produce flow behaviour up to bankfull flows (up to 15,000 ML/d), in particular in-channel storage and travel times. Further the 1D model calibration aimed to assess an appropriate definition of the channel invert upstream of Lake Nagambie through lowering of the ALS data. Details of the 1D model calibration are provided in Section 4.2.

The 2D model calibration is discussed in a separate report (Water technology 2010a).

The linked 1D-2D model calibration examined the likely environmental flow events, 15,000 to 60,000 ML/d. As discussed in Section 2.2, the relative magnitude of a 60,000 ML/d peak flow varied along the study area. Hence, the focus of the calibration shifted along the study area. Upstream of Trawool, where 60,000 ML/d has an ARI greater than 20 year event, the calibration considered large flood events and used the available flood level information. Downstream of Trawool, the focus of the calibration was stage-discharge curves, as other observed flood/water levels were not available. Details of the linked 1D-2D model calibration are provided in Section 4.3.

4.2 1D model calibration

4.2.1 Available calibration data and calibration event selection

The focus of 1D model calibration was the general flow behaviour up to bankfull flows. In particular, reasonable representation of in-channel storage and travel time along the reach. Hence, the selection of calibration events reflected a series of bankfull freshes with adequate available observed flow and water level data suitable for model calibration.

There are long term water level and streamflow data gauges at the following locations:

- Goulburn River at Eildon
- Goulburn River at Trawool
- Goulburn River at Seymour
- Goulburn River at Murchison
- Goulburn River at Shepparton
- Goulburn River at McCoy's Bridge

An initial calibration phase focused on flow episodes where Eildon releases were the dominant inflows (i.e. periods of low tributary inflows). This focus on Eildon release dominant periods reduced uncertainty in the inflows to the hydraulic model from ungauged tributary inflows. Any uncertainty /errors in the inflow to the hydraulic model influences the comparison of the modelled and observed water levels.

The initial calibration phase selected the Eildon release dominant periods, November to May, for the years 2005 to 2007. Figure 4-1 displays the streamflow time-series for the Goulburn River at Seymour and Murchison over the initial calibration phase.

Further discussions with the Study Steering Committee highlighted that the maximum flows within the initial calibration period were considerably less than the bankfull capacity. Two additional calibration periods were selected, September- October 1991 and August 1996. Figure 4-2 and Figure 4-3 displays the streamflow time-series for the Goulburn River at Seymour and Murchison over the periods September- October 1991 and August 1996 respectively.

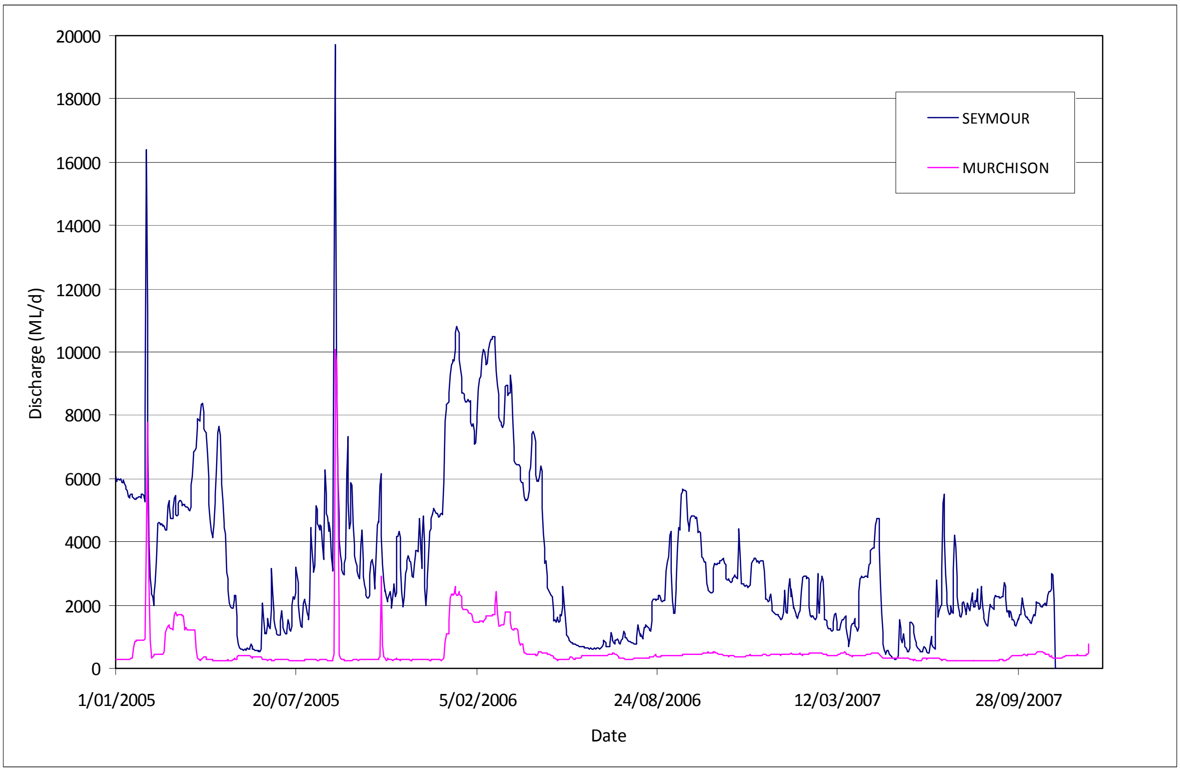

Figure 4-1 1D model initial calibration period January 2005 – December 2007 - Goulburn River at Seymour and Murchison - Observed streamflows

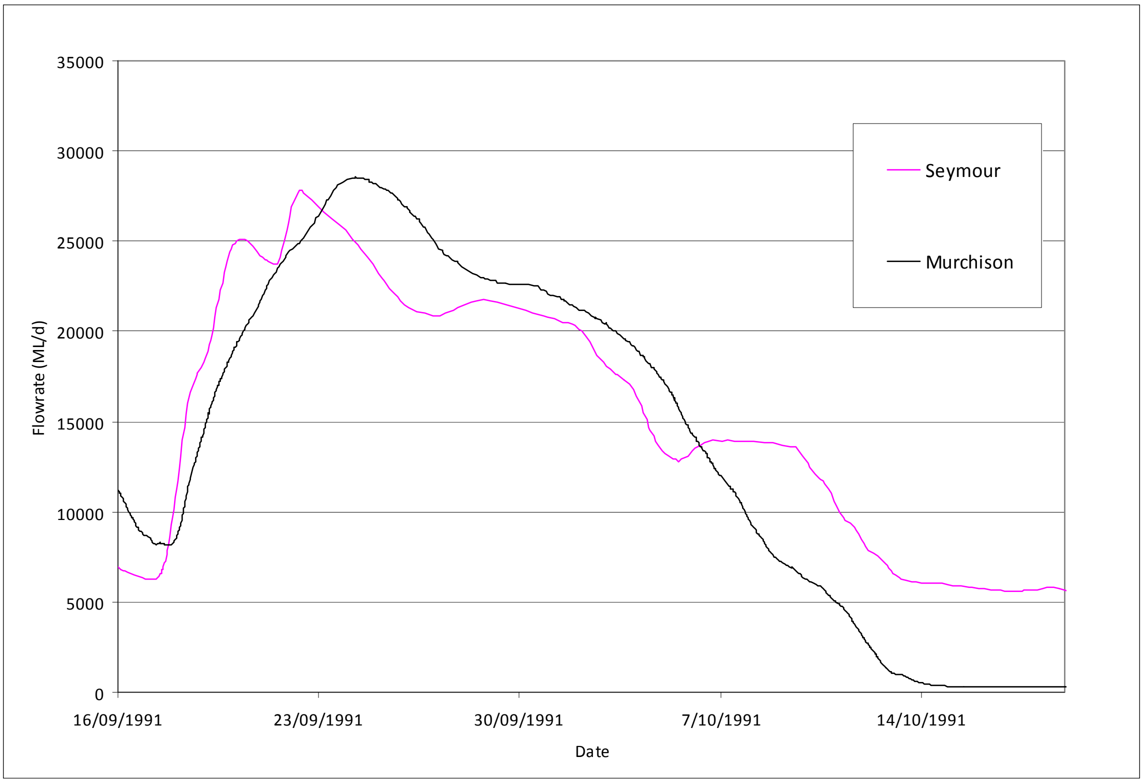

Figure 4-2 1D model calibration period September – October 1991 - Goulburn River at Seymour and Murchison - Observed streamflows

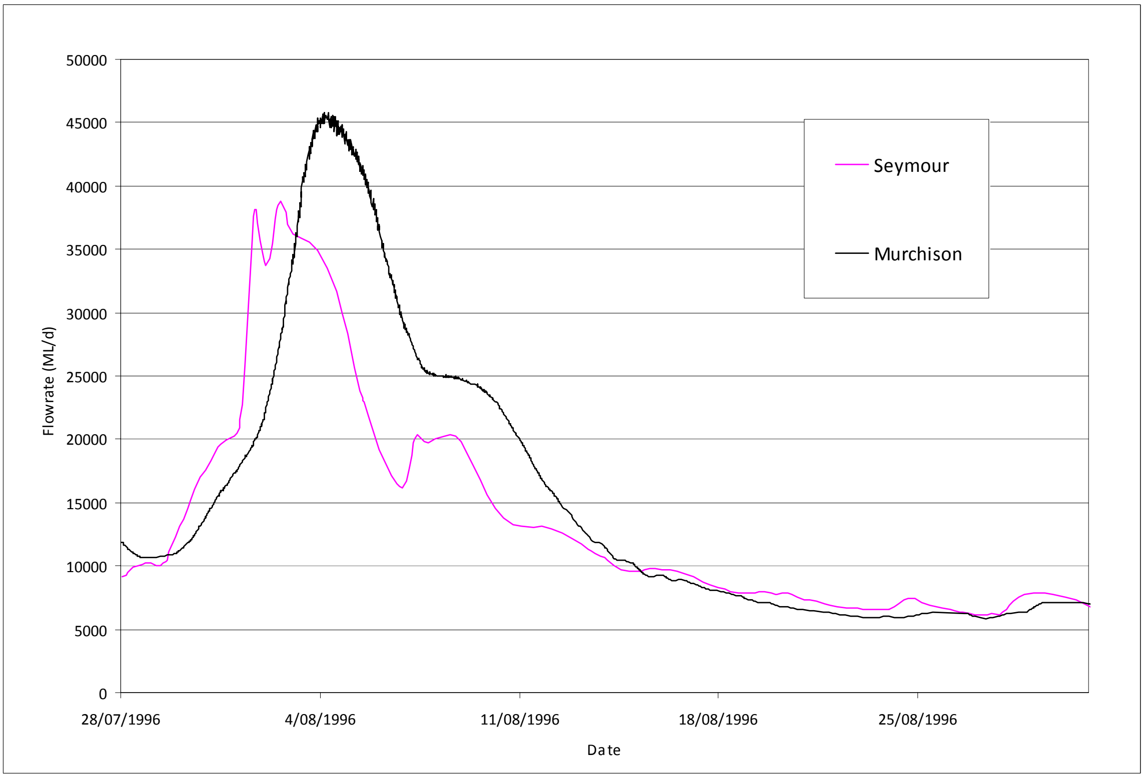

Figure 4-3 1D model calibration period August 1996 - Goulburn River at Seymour and Murchison - Observed streamflows

The peak flows during the additional calibration periods are approximately 38,000 ML/d at Seymour and 45,000 ML/d at Murchison. This compared to peak flows of 12,000 ML/d at Seymour and 4,000 ML/d at Murchison in the initial calibration period.

For the additional calibration periods, gauged tributary inflows as well as Eildon releases were applied as hydraulic model inflows. There is likely to be inflows from the ungauged portion of the catchments not accounted for in the model inflows. Further discussion of the impacts of ungauged inflow on the model calibration is provided in Section 4.2.3.

4.2.2 Approach

Upstream of Goulburn Weir

The 1D model calibration targeted the simulation of observed water levels, flows and travel times for flows up to bankfull.

As discussed in Section 3.2, upstream of Goulburn Weir, cross sections extracted from the ALS required revision to account for the waterway area beneath the water level at the time of the ALS data capture.

A range of uniform invert lowerings were applied to the ALS extracted cross sections. The range of invert lowerings considered included 1 m, 1.5 m, 2 m and 3 m. Due a lack of topographic data to assess the potential spatial variation of the invert lowerings, a uniform lowering was adopted.

The modelled water levels and flows were compared to the observed values at the streamflow gauges at Trawool and Seymour. As discussed in the Topographic Data Review (Water Technology 2008), agreement in modelled and observed water levels can be achieved by adjustments to hydraulic roughness (Manning's n) and lowering the channel invert. The use of unrealistic Manning's n was considered undesirable as the effort to compensate for the unaccounted waterway area was lumped into the roughness values. Further, the lower Manning's n increased the flood wave speed and affected the flood travel time along the river. In combination with a range of invert lowerings, a range of Manning's n values was trialled. A single manning's n value was adopted for the reach. Further discussion of this aspect is provided in Section 4.2.4.

Section 0 details the comparison of water levels and flows for the combinations of invert lowerings and Manning's n values assessed.

Downstream of Goulburn Weir

The 1D model calibration downstream of Goulburn Weir, similar to the upstream model, focused on the simulation of observed water levels, flows and travel times for flows up to bankfull.

Observed streamflow at Murchison was applied as the upstream inflows to this model. Also, observed streamflow for Seven Creeks at Kialla West and the Broken River at Orrvale were applied as model inflows. No other tributary inflows were considered in the model calibration.

As discussed in Section 3.2, downstream of Goulburn Weir, cross sections extracted from the ALS require revision to account for the waterway area beneath the water level at the time of the ALS data capture. The ALS cross extracted cross sections were revised to include the channel invert obtained for the available bathymetric survey (sourced from GBCMA).

The modelled water levels and flows were compared to observed values at the streamflow gauges at Murchison and Shepparton. As discussed in the Topographic Data Review (Water Technology 2008), agreement in modelled and observed water levels can be achieved via adjustment of the hydraulic roughness (Manning's n).

Section 4.2.3 details the comparison of water levels and flows for a range of Manning's n values assessed.

4.2.3 Calibration results

Upstream of Goulburn Weir

Initial calibration period (2005-2007)

A range of combined invert lowerings and Manning's n values were trialled for the initial calibration period (2005-2007). These early model runs revealed as the invert lowering increased, the Manning's n values increased to achieve a reasonable simulation of observed streamflow and water levels. This was seen by the variation in the set of Manning's n values trialled for a given invert lowering, refer to Table 4-1.

Table 4-1 Upstream of Goulburn Weir – Invert lowering and manning's n values

Invert lowering	Manning's n values
1 m	0.025, 0.03, 0.033 & 0.035
1.5 m	0.03, 0.033, 0.035 & 0.04
2 m	0.035, 0.04 & 0.045
3 m	0.04, 0.045 & 0.05

The aim of the calibration was to determine an optimal invert lowering and Manning's n value combination. This optimisation was undertaken using the initial calibration period (2005-07). The optimal combination was then trialled in the additional calibration periods (1991 & 1996).

The assessment of calibration was undertaken through comparison of observed time-series of both streamflows and water levels at Trawool and Seymour. Appendix A contains the full suite of time-series comparison plots at Trawool and Seymour.

The comparison revealed as Manning's n increased the modelled hydrograph rates of rise and fall decreased, and travel time increased. Visual examination of the time-series comparison plots revealed the optimal Manning's n values for each invert lowering, as outlined in Table 4-2.

Table 4-2 Upstream of Goulburn Weir – Optimal Manning's n values for each invert lowering

Location	Invert lowering	Optimal Manning's n
Trawool	1 m	~ 0.03
	1.5 m	~ 0.035
	2 m	~ 0.045
	3 m	> 0.05
Seymour	1 m	~ 0.03
	1.5 m	~ 0.035
	2 m	~ 0.040
	3 m	~ 0.045

As noted, ungauged inflows not accounted for in the model inflows, results in the modelled flows being less than the observed flows.

Examination of the time-series comparison plots and rating curve comparison indicated, the combination of invert lowering of 1.5 m and Manning's n 0.035, yields reasonable re-production of the observed flow behaviour. As discussed, the absence of tributary inflows limits direct comparison of the modelled and observed water levels. For periods, where the observed and modelled flows were similar, the observed and modelled water level were generally within 0.1 m.

Additional calibration period (1991 and 1996)

For the additional calibration period (August 1991 & October 1996), the preliminary optimal combination of invert lowering of 1.5 m and Manning's n 0.035 was trialled. Appendix A contains the full suite of time-series comparison plots at Trawool and Seymour.

Rating curve comparison

Due to the absence of tributary inflows, the modelled flows were generally less than the observed flows. This lower modelled flow influenced the comparison of modelled water levels. To overcome the lower modelled flows, modelled and observed stage-discharge relations were compared.

Figure 4-4 and Figure 4-5 shows the modelled (invert lowering 1.5 and Manning's n 0.035) and observed stage-discharge (rating) curve for the Goulburn River at Trawool and Seymour respectively.

Discussion of the calibration results is provided in Section 4.2.4

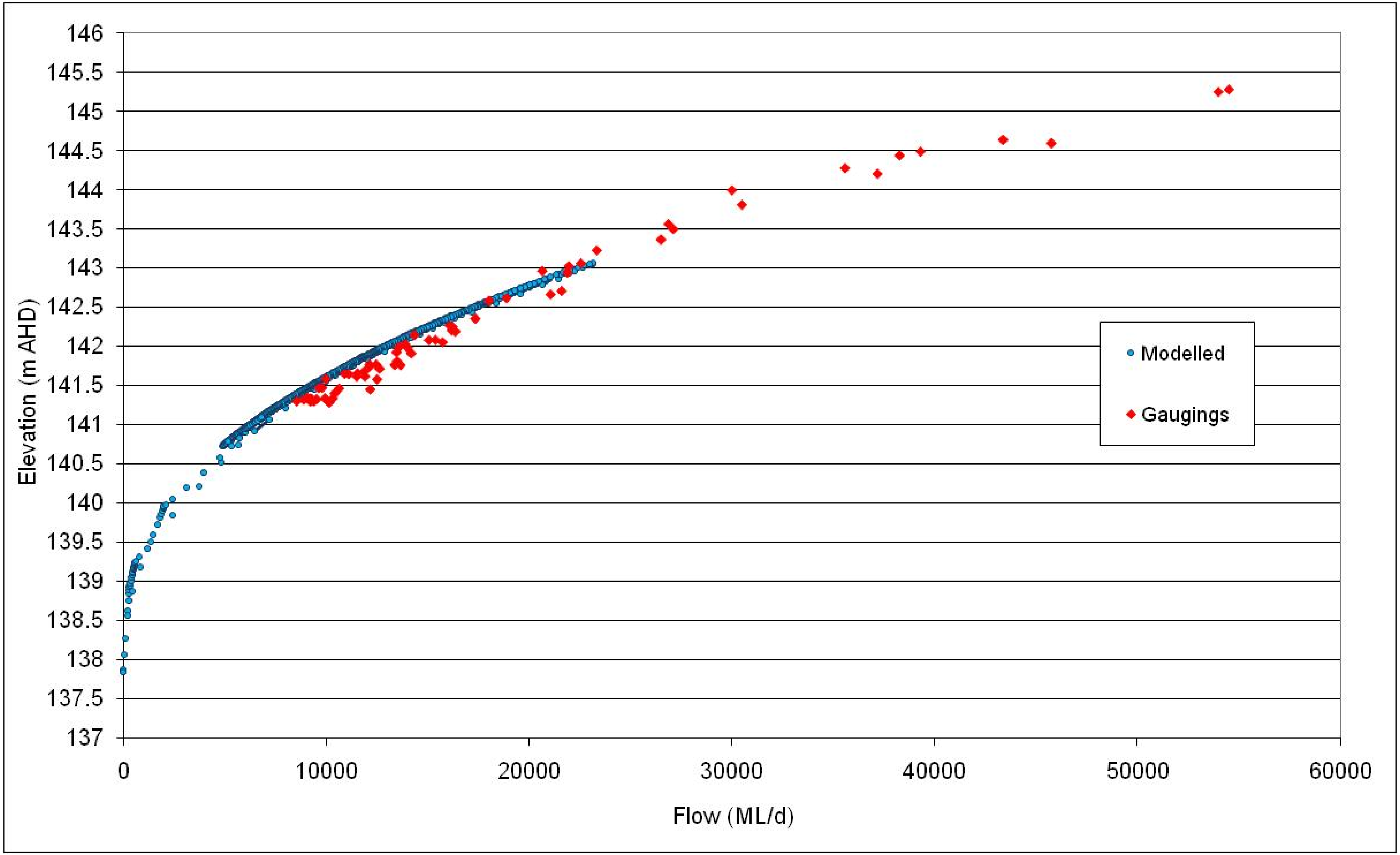

Figure 4-4 Upstream of Goulburn Weir – Goulburn River at Trawool – Modelled and observed stage-discharge relationship

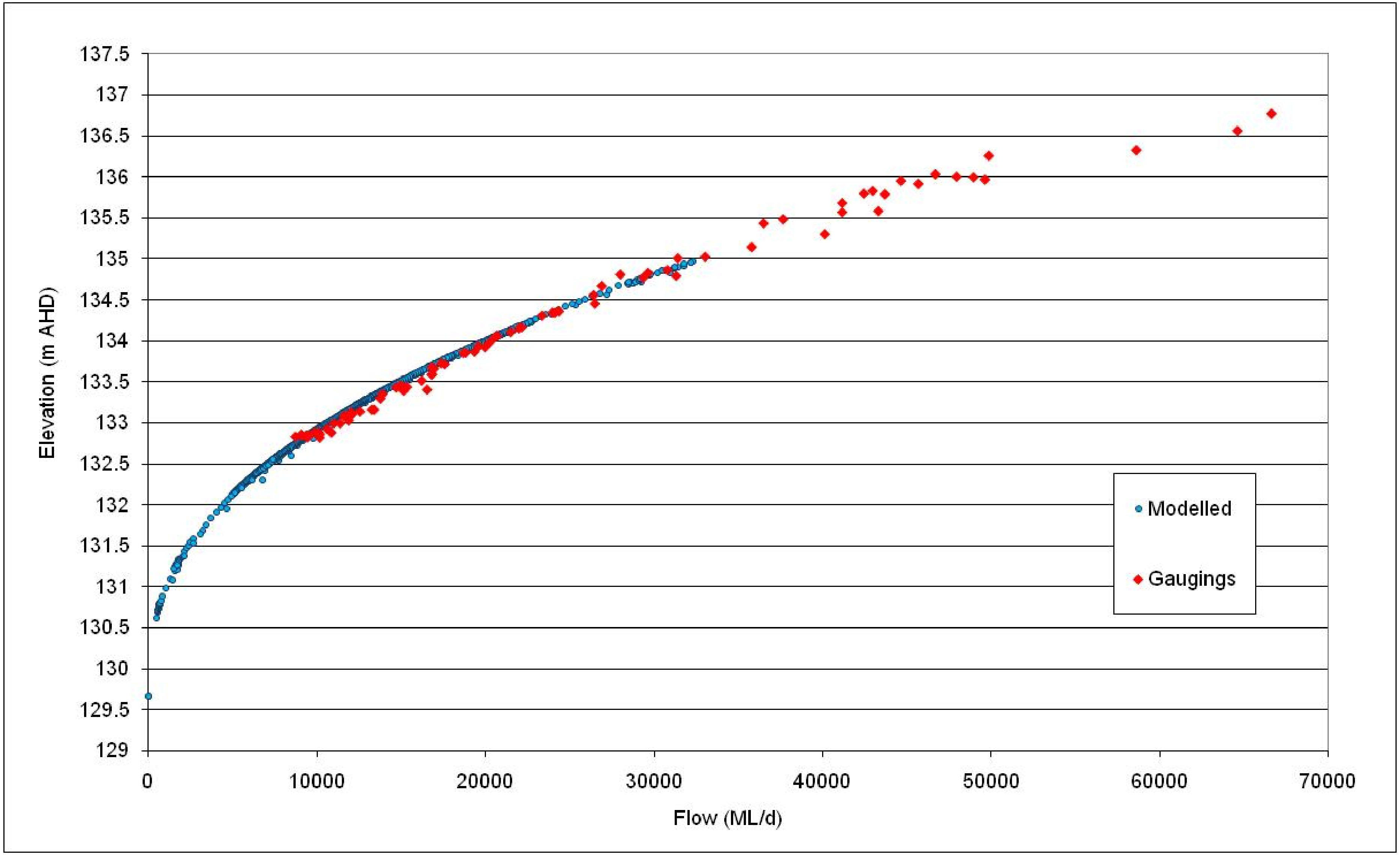

Figure 4-5 Upstream of Goulburn Weir – Goulburn River at Seymour – Modelled and observed stage-discharge relationship

Downstream of Goulburn Weir

Initial calibration period (2005- 2007)

As discussed, the bathymetric survey provided the waterway inverts for the reach downstream of Goulburn Weir. A range of Manning's n values were trialled. The aim of the calibration was to determine an optimal Manning's n value.

During the initial calibration period (2005-2007), due to diversions at Goulburn Weir, the flow at Shepparton was generally quite low.

The assessment of calibration was undertaken through comparison of observed time-series of both streamflows and water levels at Shepparton, Murchison and McCoy's Bridge. Appendix A contains the full suite of time-series comparison plots at Shepparton, Murchison and McCoy's Bridge.

The comparison revealed as Manning's n increased the modelled hydrograph rates of rise and fall decreased, and travel time increased. Visual examination of the time-series comparison plots suggest a Manning's n value of 0.05 yielded a reasonable re-production of observed water levels and flows at Shepparton. The travel time of observed peak flows was maintained with a Manning's n of 0.05.

Additional calibration period (1991 & 1996)

For the additional calibration period (August 1991 & October 1996), the preliminary optimal Manning's n 0.05 was trialled. Appendix A contains the full suite of time-series comparison plots at Shepparton and McCoy's Bridge.

Rating curve comparison

The modelled flows were generally less than the observed flows, due to ungauged inflows. This lower modelled flow influenced the comparison of modelled water levels. To overcome the lower modelled flows, modelled and observed stage-discharge relations were compared. Figure 4-6, Figure 4-7 and Figure 4-8 shows the modelled (n=0.05) and observed flows for the Goulburn River at Shepparton, Murchison and McCoy's Bridge respectively.

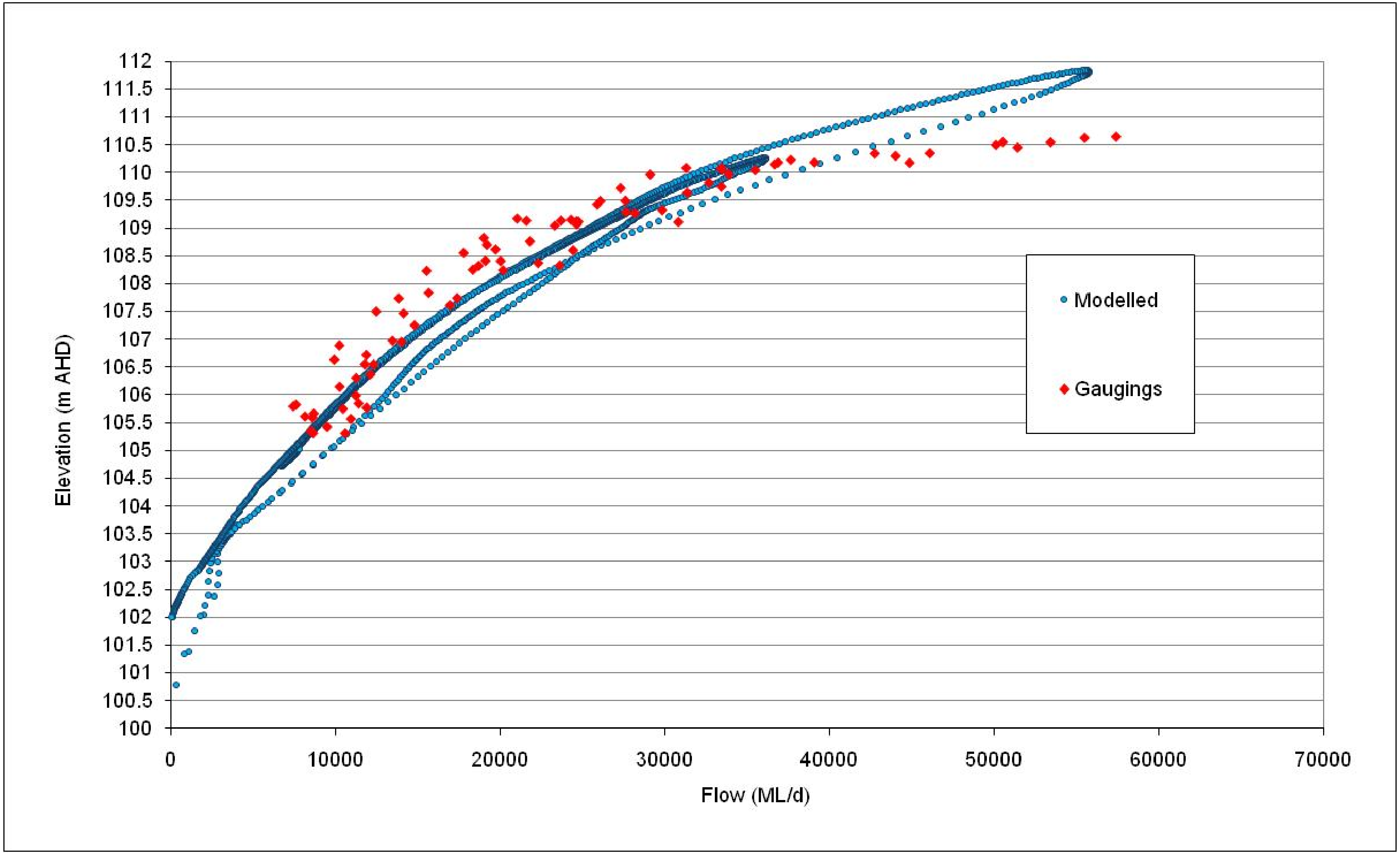

Figure 4-6 Downstream of Goulburn Weir – Goulburn River at Shepparton – Modelled and observed stage-discharge relationship

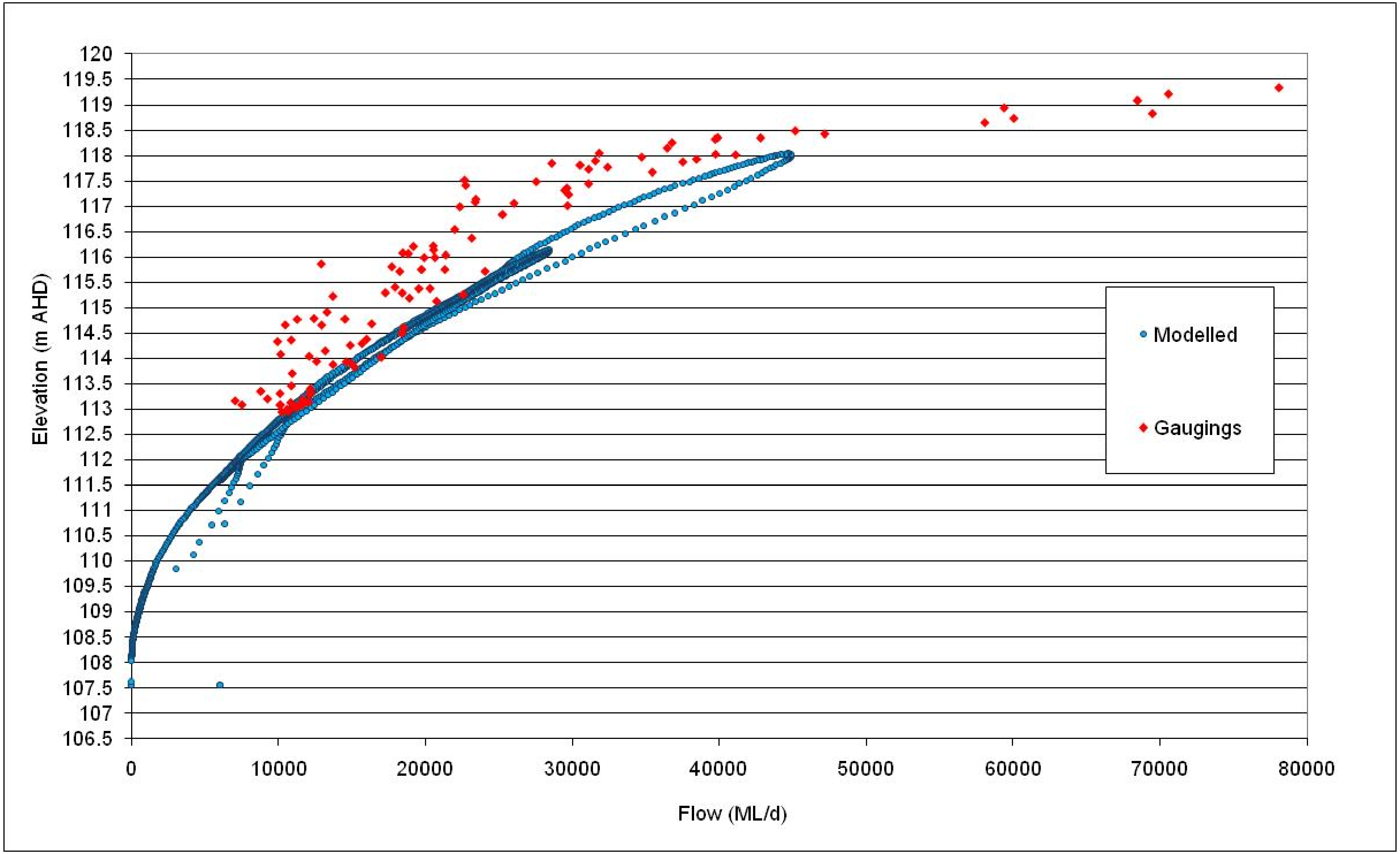

Figure 4-7 Downstream of Goulburn Weir – Goulburn River at Murchison – Modelled and observed stage-discharge relationship

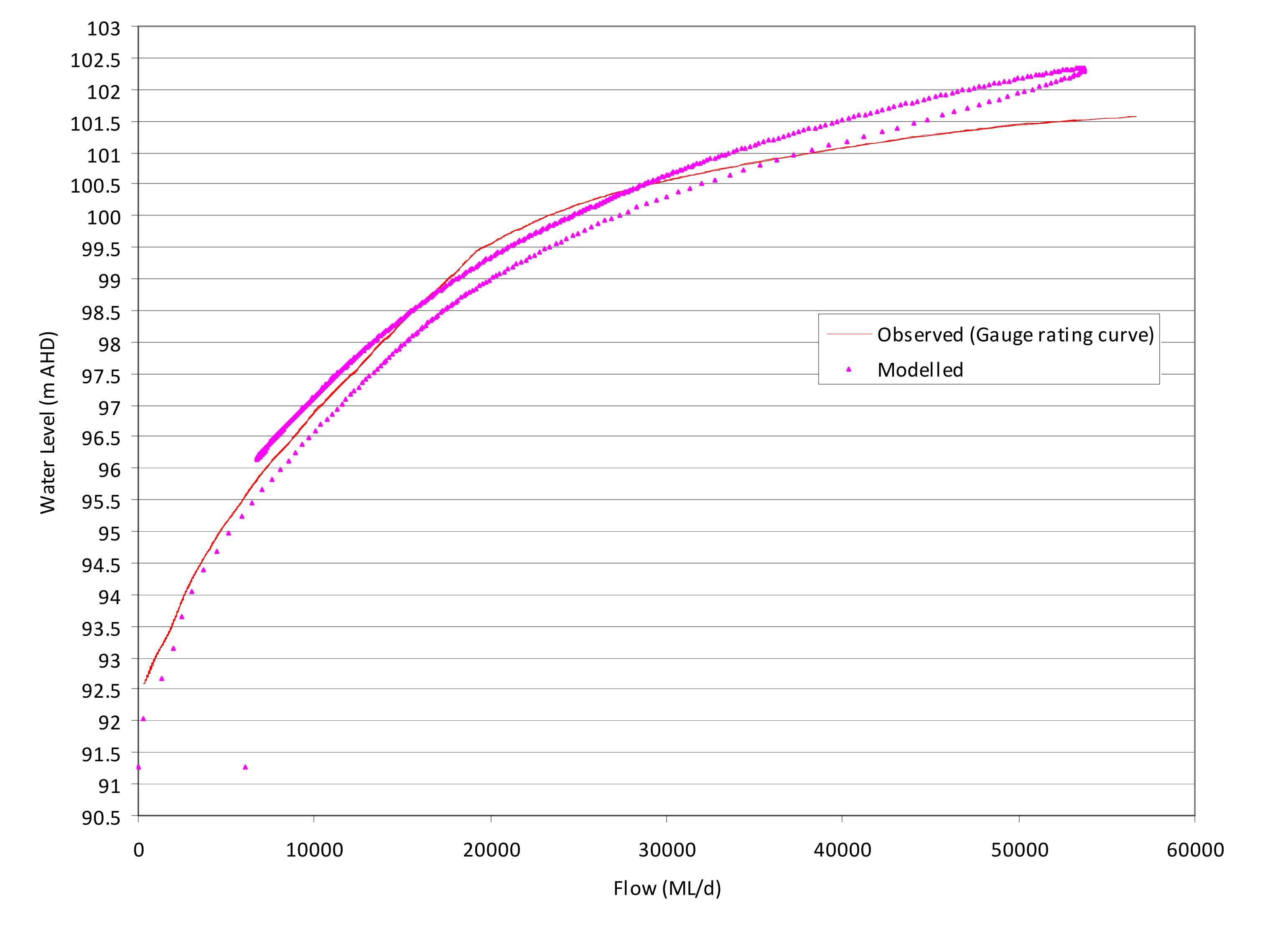

Figure 4-8 Downstream of Goulburn Weir – Goulburn River at McCoy's Bridge – Modelled and observed stage-discharge relationship

4.2.4 Discussion

Two separate model calibrations were undertaken for the reaches, upstream and downstream of Goulburn Weir.

As discussed, errors in the modelled and gauged flows arise due to the model inflows not accounting for ungauged flows. Hence the direct comparison of modelled and observed water levels in the time-series plots was constrained.

Upstream of Goulburn Weir, the calibration assessed various combinations of invert lowerings and Manning's n. The invert lowering was required given the absence of waterway geometry below the water level at the time of the ALS data capture. Uniform invert lowerings and Manning's n were applied along the entire reach (Eildon to Goulburn Weir).

The application of uniform invert lowering was considered an appropriate approach. The Topographic Data Review (Water Technology 2008) suggested that there can be considerable variation in flow depth. This variation arises from the presence of bar, riffles and pools. However, no bathymetric data was available to inform this spatial variation in depth. Thus, making the variation in the invert difficult to assess. A single uniform alternation was simple, and removes the need for further assumptions regarding the spatial variation.

Longitudinal variations in Manning's n can arise from changes in channel form, substrate and riparian vegetation. Further, these same elements can influence lateral variation in Manning's n across a cross section. This study has adopted a single Manning's n for the entire reach and within each cross section, i.e. no lateral or longitudinal variation. This assumption was premised on the absence of calibration data (observed flows and water levels) to validate any spatial variation.

From the time series plots, the general rate of rise and fall of the observed water levels and flows were reasonably re-produced by the hydraulic model. The travel time along the Goulburn River from Eildon to Seymour was well simulated.

Examination of the time-series comparison plots and rating curve comparison indicated, that the combination of invert lowering of 1.5 m and Manning's n 0.035, yielded reasonable re-production of the observed flow behaviour. As discussed, the absence of tributary inflows limited direct comparison of the modelled and observed water levels.

At Seymour, for periods where the observed and modelled flows were similar, the observed and modelled water levels were generally within 0.1 m.

At Trawool, the comparison of the modelled and observed rating curves suggested that the observed water levels were overestimated for flows up to about 15,000 ML/d. This may reflect the assumed waterway cross section with the invert lowering and/or change in roughness at these lower flows. However, at the flows of interest, i.e. approaching bankfull, the hydraulic model re-produced the observed rating curve well.

Downstream of Goulburn Weir, the calibration assessed a range of Manning's n values. The bathymetric data (Theiss 2008) informed the channel invert levels. A Manning's n value of 0.05 appeared to yield a reasonable re-production of observed flow behaviour at Shepparton and McCoy's Bridge.

At Shepparton, for flow up to 12,000 ML/d, modelled and observed water levels within 0.1 m. Through the flow range 15,000 ML/d – 25,000 ML/d, the modelled water levels underestimated the observed water level by up to 0.4 m. Above 25,000 ML/d up to bankfull (~40,000 ML/d), the modelled and observed water levels within 0.2 m.

At McCoy's Bridge, the modelled water levels overestimated observed water levels for low flow up to 5000 ML/d. Between 8000 ML/d and 30,000 ML/d, modelled and observed water levels were generally within 0.2 m.

For Murchison, the modelled rating curve showed a considerable discrepancy from the gaugings at Murchison. The observed gaugings at Murchison showed considerable scatter in the rating curve. The modelled water levels were found to be significantly lower than the observed gaugings for flows up to 60,000 ML/d. Further discussion of the linked 1D-2D model calibration at Murchison is provided in Section 4.3.4.

From the time series plots, shown in Appendix A, the general rate of rise and fall of the observed water levels and flows were reasonably re-produced by the hydraulic model. Further the travel time along the Goulburn River from Murchison to McCoy's Bridge was well simulated.

Further refinements to Manning's n values were made during the calibration phase of the linked models. Details of the linked models calibrations are provided in Section 4.3. For the reach upstream of Goulburn Weir, the 1.5 m lowering was adopted for use in the linked models.

The reliability of hydraulic model water levels and flows were unable to be established at locations away from the gauges. The reasonable preservation of the rise and fall, and travel time supported the model's ability in routing flows along the reach, and reflected reasonable accounting for storage along the reach.

Recommendation: To improve the assessment of the models' performance at locations other then at the streamflow gauges, it is recommended a series of water levels gauges are established along the Goulburn River and on key anabranches in the upper reaches. These water levels gauges could monitored manually during medium to high flow events.

4.3 Linked 1D-2D hydraulic model calibration

4.3.1 Available calibration data and calibration event selection

The focus of the linked 1D-2D model was the general flow/flood behaviour for flows up to 60,000 ML/d. As discussed, the relative frequency of this flow range decreases downstream along the Goulburn River. That is a 60,000 ML/d at Trawool is approximately a 10 year ARI event and at Shepparton approximately a 3-4 year ARI event.

As a consequence, a 60,000 ML/d above Trawool can be considered a significant flood event with inundation of adjacent properties/infrastructure, and impacts on the local community. For such an event, community interest is raised and observed flood levels are generally noted by the community.

Downstream of Trawool, a 60,000 ML/d flow is generally limited to the riparian corridor with less impact on the community. As the impacts are less, the community interest is limited, and generally few observed flood levels are noted.

Upstream of Trawool, the October 1993 event a peak flow at Eildon of 46,600 ML/d. This event resulted in considerable floodplain inundation. A number of observed flood levels were collected. Given the availability of observed flood levels and the peak flow in the range of interest, the October 1993 event was the primary linked 1D-2D model calibration upstream of Trawool.

Downstream of Trawool, there was an absence of observed flood/water levels for events with flows up to 60,000 ML/d. Similar to the 1D model calibration, the linked 1D-2D model calibration focused on comparison of observed and modelled rating curves for the gauges at Trawool, Seymour, Murchison, Shepparton and McCoy's Bridge.

4.3.2 Approach

The calibration of the linked 1D - 2D models was centred on the refinement of Manning's n values for the channel from the 1D model calibration. This refinement aimed to achieve a reasonable agreement between observed and modelled flood levels, and observed and modelled rating curves. No refinements were made to the floodplain Manning's n values from the 2D model calibration. It should be noted upstream of Lake Nagambie, the adopted 1.5 m invert lowering was applied, as per the 1D model calibration.

Upstream of Trawool, the linked model inflows were taken as observed flood hydrographs, where available, and/or modelled flood hydrographs, as follows:

- October 1993
    - Observed: Goulburn River at Eildon
    - Modelled: Acheron River at the Goulburn River confluence, Rubicon River at the Goulburn River confluence, Yea River at the Goulburn River confluence, Home Creek at the Goulburn River confluence

The modelled flood hydrographs were sourced from the URBS runoff routing model developed by BoM (2005). As discussed in Section 2.3, uncertainties in the model inflows can influence the calibration fit achieved. A number of linked model inflows were modelled URBS inflows. The URBS models (BoM 2005) were calibrated, and can be considered suitable for the estimation of inflows to the linked model in absence of observed flows. It was considered likely to be significant uncertainty surrounding these modelled hydrographs. Further, it should be noted that considerable uncertainty also surrounded the observed flow, due to extrapolation of the rating curves.

Downstream of Trawool, the linked model calibration compared modelled and observed rating curves for flows up to 60,000 ML/d.

4.3.3 Calibration results

Upstream of Goulburn Weir

As discussed, the linked 1D-2D model calibration focused on the refinement of the channel's Manning's n value from the 1D model calibration. Through comparison against observed flood levels and rating curves, a Manning's n value of 0.042 were adopted. This adopted values differed from the 0.035 value assessed in the 1D model calibration. Further discussion of the difference in Manning's n values is provided in Section 4.3.4. As per the 1D model calibration, this adopted Manning's n values was applied uniformly along the reach, and remained with flow depth. The assessment of variation in Manning's n with flow depth is provided in Section 4.3.4.

Figure 4-9, Figure 4-10 and Figure 4-11 displays the modelled October 1993 flood extents, and flood level differences for Goulburn River upstream of Trawool. The colours of dots reflect the differences in the modelled and observed flood levels. The dark and light green dots indicates observed flood levels were under-estimated, the orange dots indicate the modelled and observed flood levels are within 0.1 m and the red and purple dots indicates observed flood levels were over-estimated.

Table 4-3 displays the comparison of observed and modelled flood levels upstream of Trawool for the October 1993 event.

Table 4-3 Linked 1D-2D model calibration – upstream of Trawool – flood level comparison

Reach	Total observed flood levels	Number of modelled flood level within 100 mm	Number of modelled flood level within 200 mm
Eildon to Alexander	10	5 (50%)	8 (80%)
Alexander to Ghin Ghin	15	4 (27%)	10 (67%)
Ghin Ghin to Trawool	5	2 (40%)	4 (80%)
Entire reach: Eildon to Trawool	30	11 (37%)	22 (73%)

Across the reach upstream of Trawool, 22 of 30 modelled flood levels lied within +/- 200 mm of the observed flood levels. Given the uncertainty in model inflows from the tributary, this calibration outcome was considered reasonable.

As noted, from Trawool to Goulburn Weir, there were no observed flood levels for flows up to 60,000 ML/d, apart from at the Trawool and Seymour gauges. Figure 4-12 and Figure 4-13 display the modelled rating curves and observed gaugings at Trawool and Seymour.

At Trawool, for flows from 15,000 to 28,000 ML/d, the modelled water levels were higher than the observed gaugings. Generally, the modelled water levels over this flow range were 200 – 400 mm above the gaugings. Over a flow range of 28,000 to 60,000 ML/d, the modelled and gauged water levels were found to be in good agreement (within 200 mm).

A similar pattern in modelled water levels was found at Seymour. For flows up to 32,000 ML/d, the modelled water levels were higher than gaugings by 200 – 400 mm. For higher flows up to 60,000 ML/d, the modelled and gauged water levels were in good agreement (within 200 mm).

Further discussion of the linked 1D-2D model calibration is provided in Section 4.3.4.

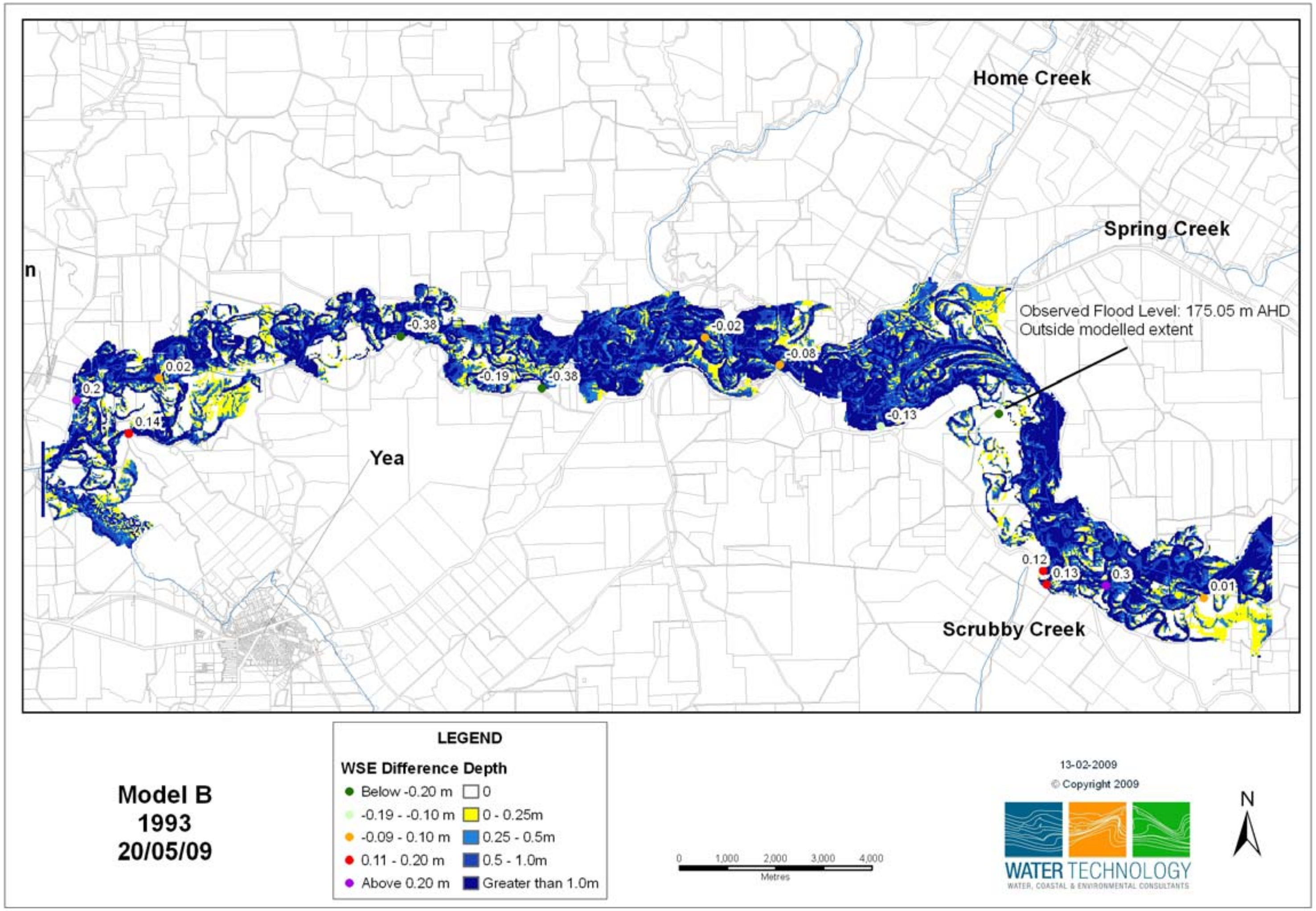

Figure 4-9 October 1993 – Eildon to Alexandra – Linked 1D - 2D model Calibration Results

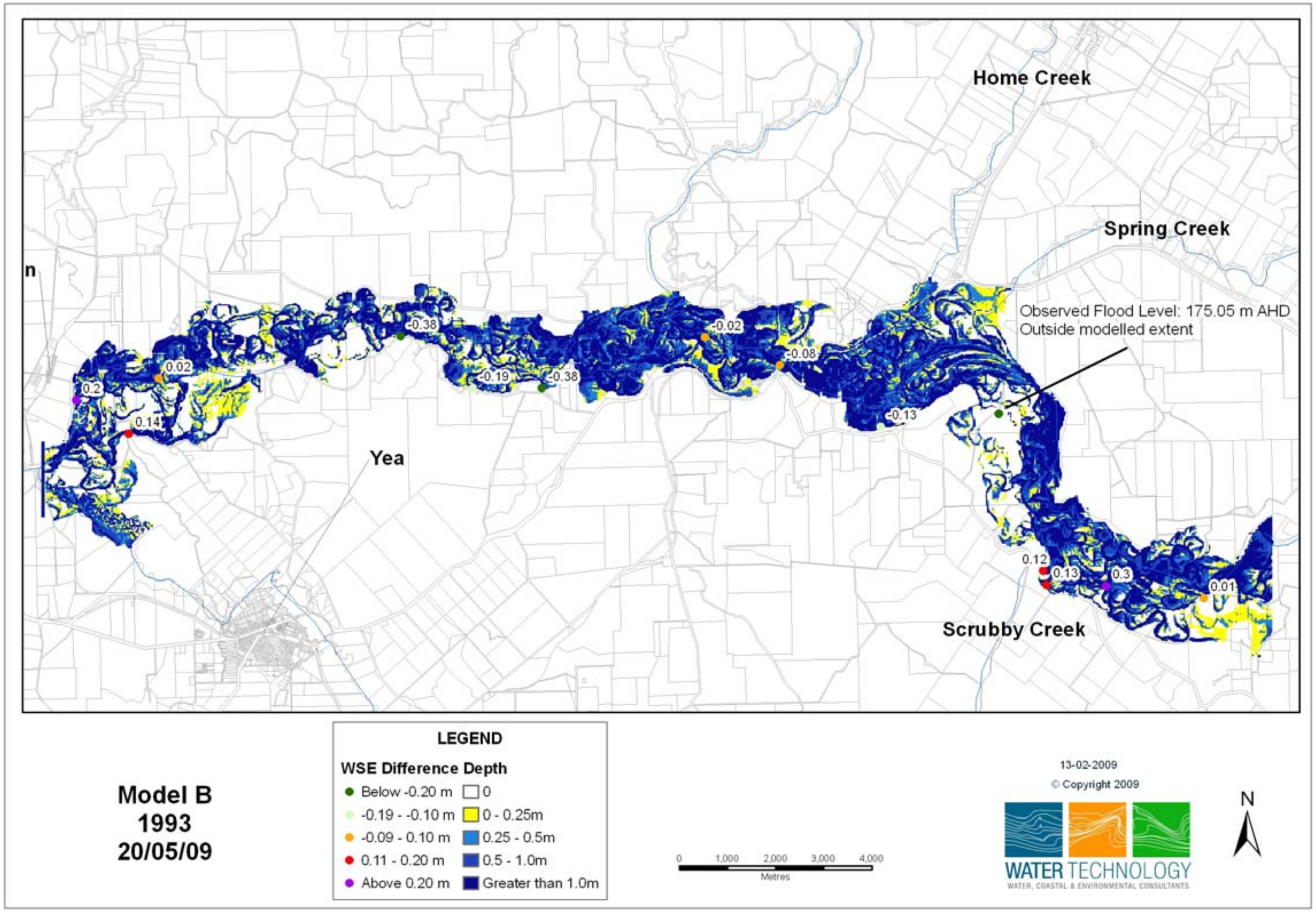

Figure 4-10 October 1993 – Alexandra to Ghin Ghin– Linked 1D - 2D model Calibration Results

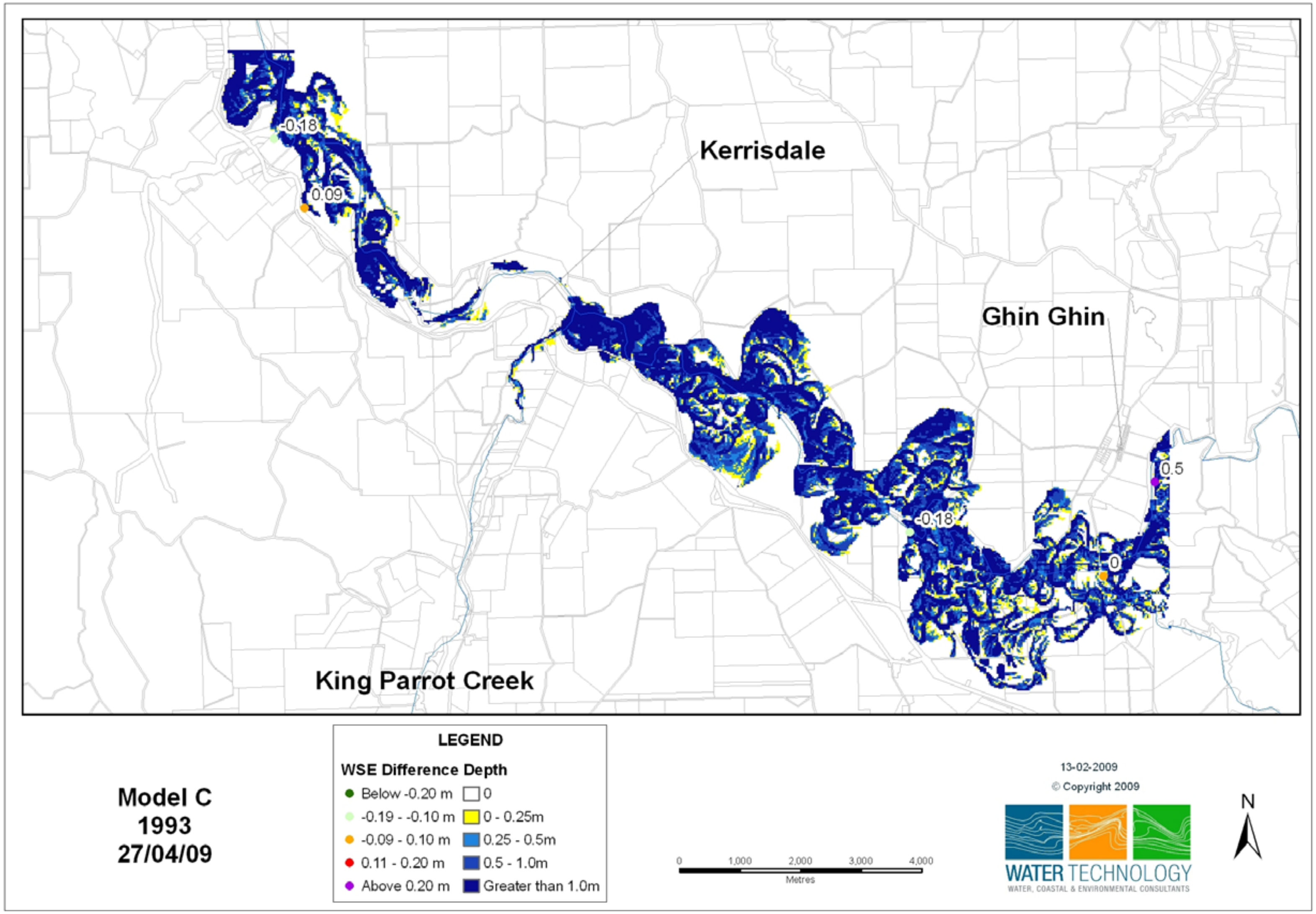

Figure 4-11 October 1993 –Ghin Ghin to Trawool – Linked 1D - 2D model Calibration Results

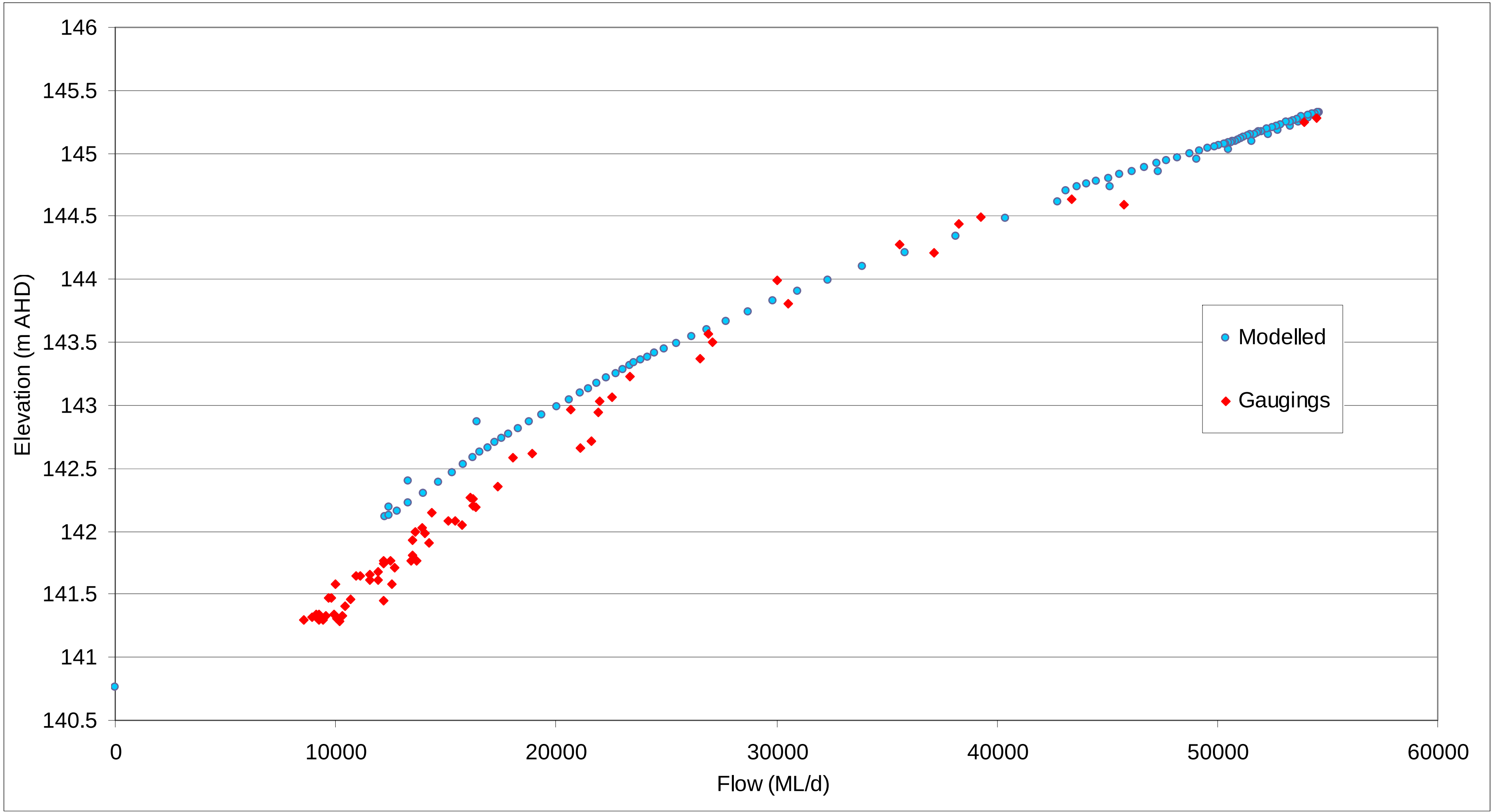

Figure 4-12 Linked 1D-2D model calibration - Upstream of Goulburn Weir – Goulburn River at Trawool – Modelled and observed stage-discharge relationship

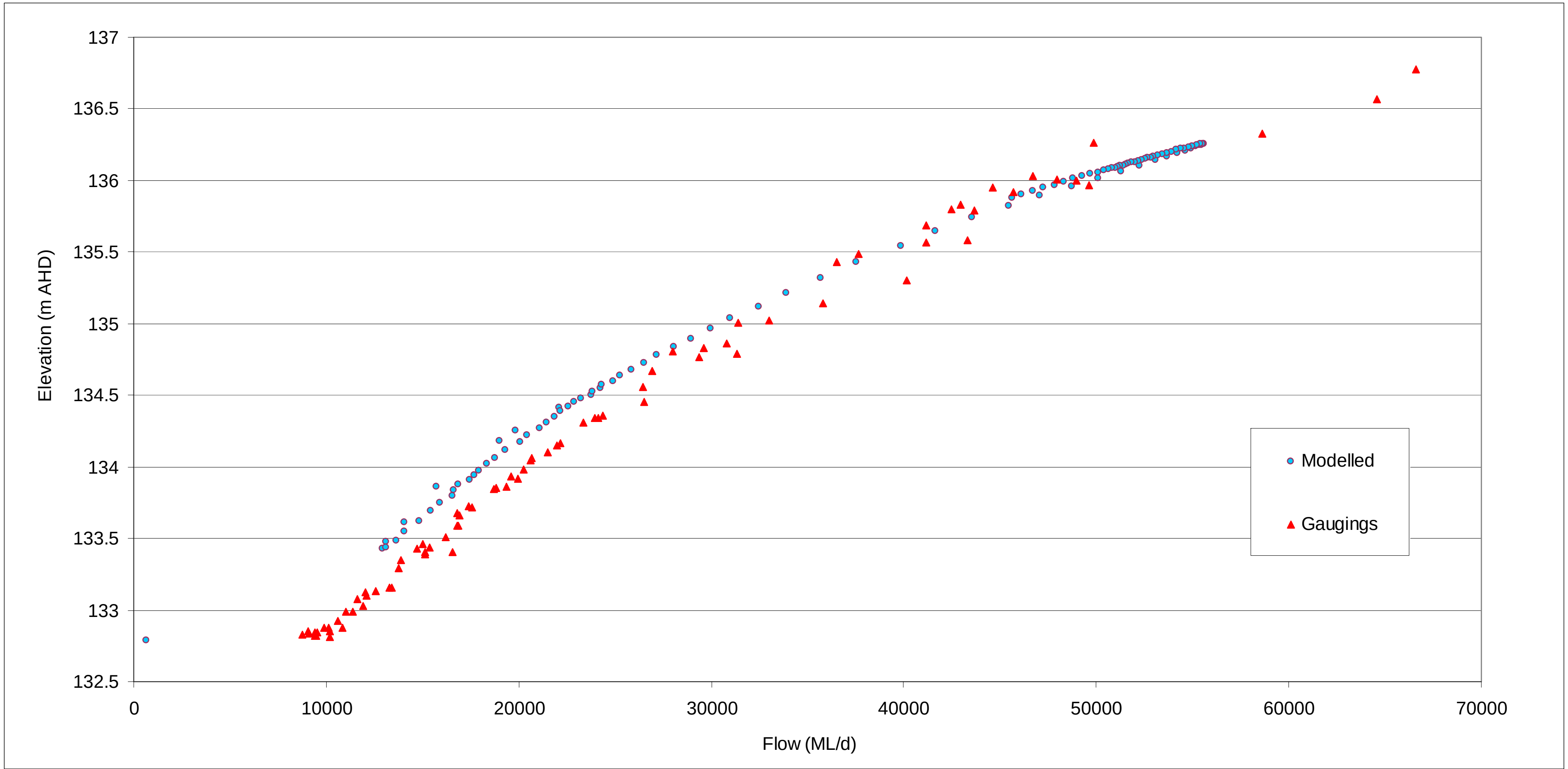

Figure 4-13 Linked 1D-2D model calibration - Upstream of Goulburn Weir – Goulburn River at Seymour – Modelled and observed stage-discharge relationship

Downstream of Goulburn Weir

As discussed, the linked 1D-2D model calibration focused on the refinement of the channel's Manning's n value from the 1D model calibration. Through comparison against observed gaugings, a Manning's n value of 0.07 were adopted. This adopted value differed from the 0.05 value assessed in the 1D model calibration. Further discussion of the difference in Manning's n values is provided in Section 4.3.4. As per the 1D model calibration, this adopted Manning's n values was applied uniformly along the reach, and remained constant with flow depth.

Similar to the reach, Trawool to Goulburn Weir, there were no available observed water levels for flow up to 60,000 ML/d for the reach Goulburn Weir to the Murray River confluence. The assessment of the linked 1D-2D model calibration downstream of Goulburn Weir was centred on the comparison of modelled rating curve and observed gaugings at Murchison, Shepparton and McCoy's Bridge. Figure 4-14, Figure 4-15 and Figure 4-16 displayed modelled rating curves and observed gaugings for the Goulburn River at Murchison, Shepparton and McCoy's Bridge respectively.

Similar to the 1D model calibration (refer to Section4.2), the modelled rating curve showed a considerable discrepancy from the gaugings at Murchison. The observed gaugings at Murchison showed considerable scatter in the rating curve. The modelled water levels were found to be significantly lower than the observed gaugings for flows up to 60,000 ML/d. Further discussion of the linked 1D-2D model calibration at Murchison is provided in Section 4.3.4.

At Shepparton, the observed gaugings shows a considerable scatter for flows from 10,000 ML/d to 40,000 ML/d. This scatter can be up to 1 m for a given flow. The modelled rating curve lies at the lower limit of the scatter of the observed gaugings. Above 40,000 ML/d, the modelled rating curve and observed gaugings were in good agreement.

At McCoy's Bridge, the modelled and observed rating curves were found to be in good agreement for flows up to 35,000 ML/d. For higher flows, significant flows occur in effluent streams such as Deep, Wakiti, Sheepwash and Skelton Creeks. Similar to observed gaugings at Shepparton, there was considerable scatter in the gaugings at McCoy's Bridge.

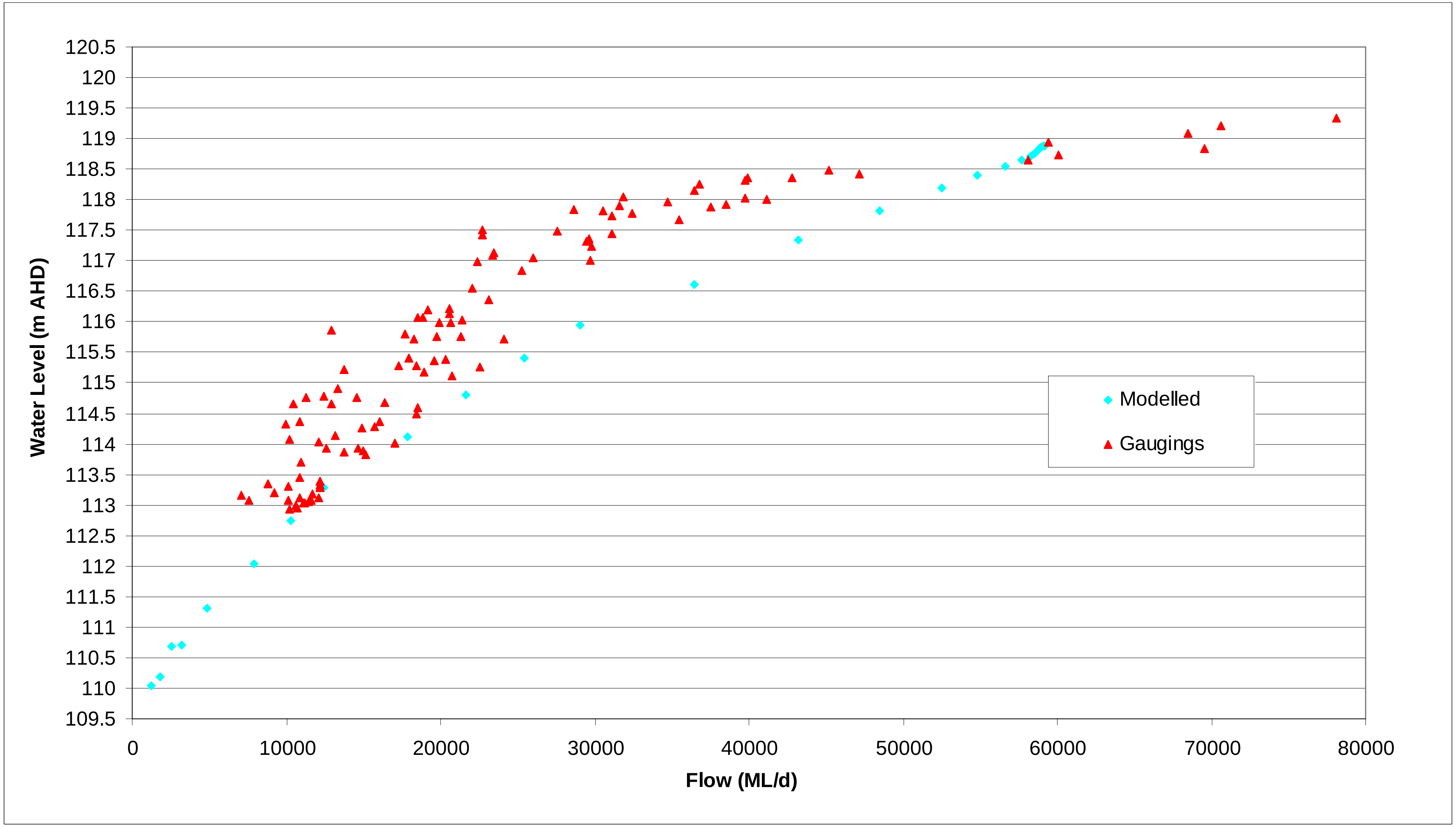

Figure 4-14 Linked 1D-2D model calibration - Downstream of Goulburn Weir – Goulburn River at Murchison – Modelled and observed stage-discharge relationship

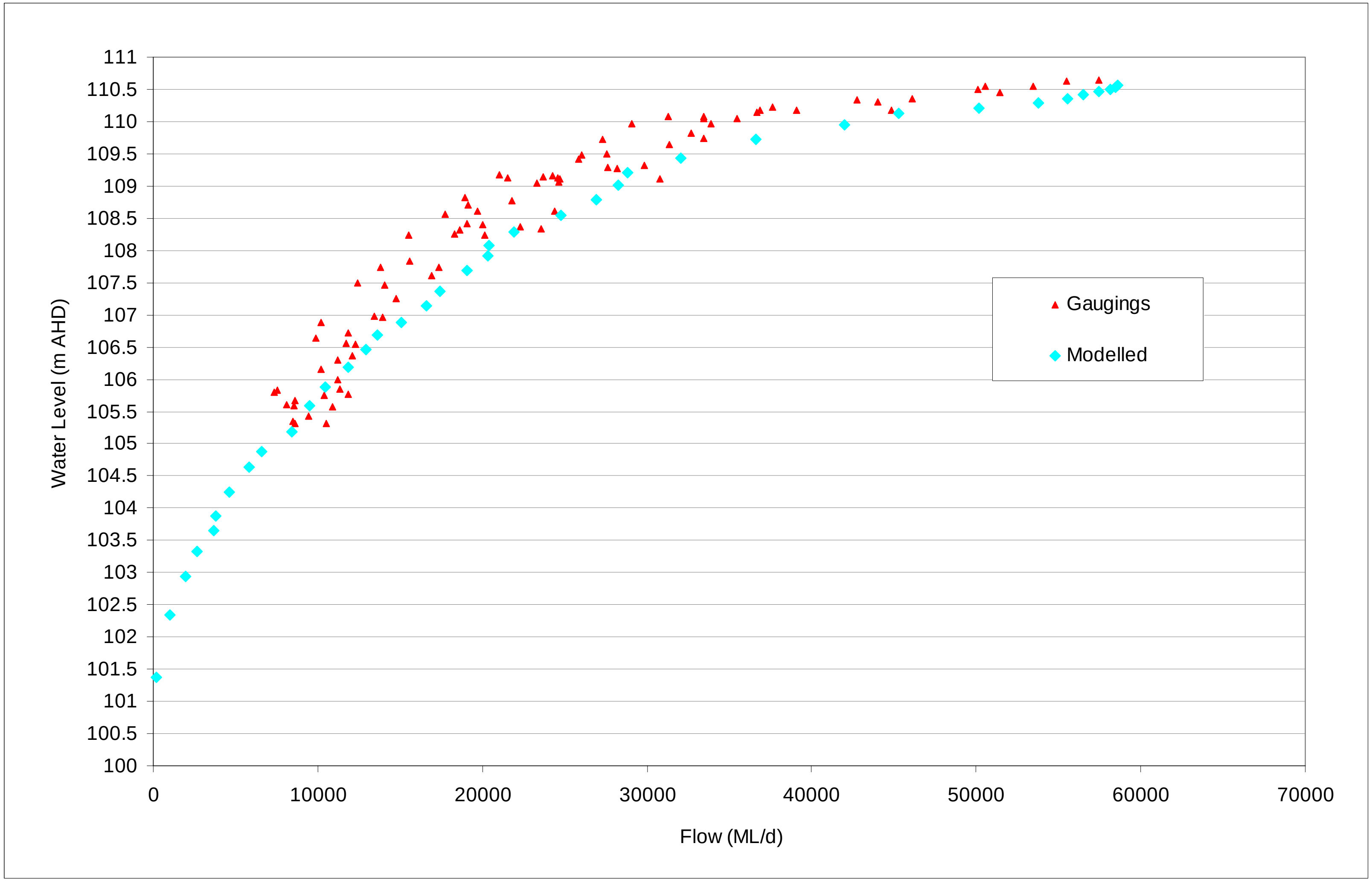

Figure 4-15 Linked 1D-2D model calibration – Downstream of Goulburn Weir – Goulburn River at Shepparton – Modelled and observed stage-discharge relationship

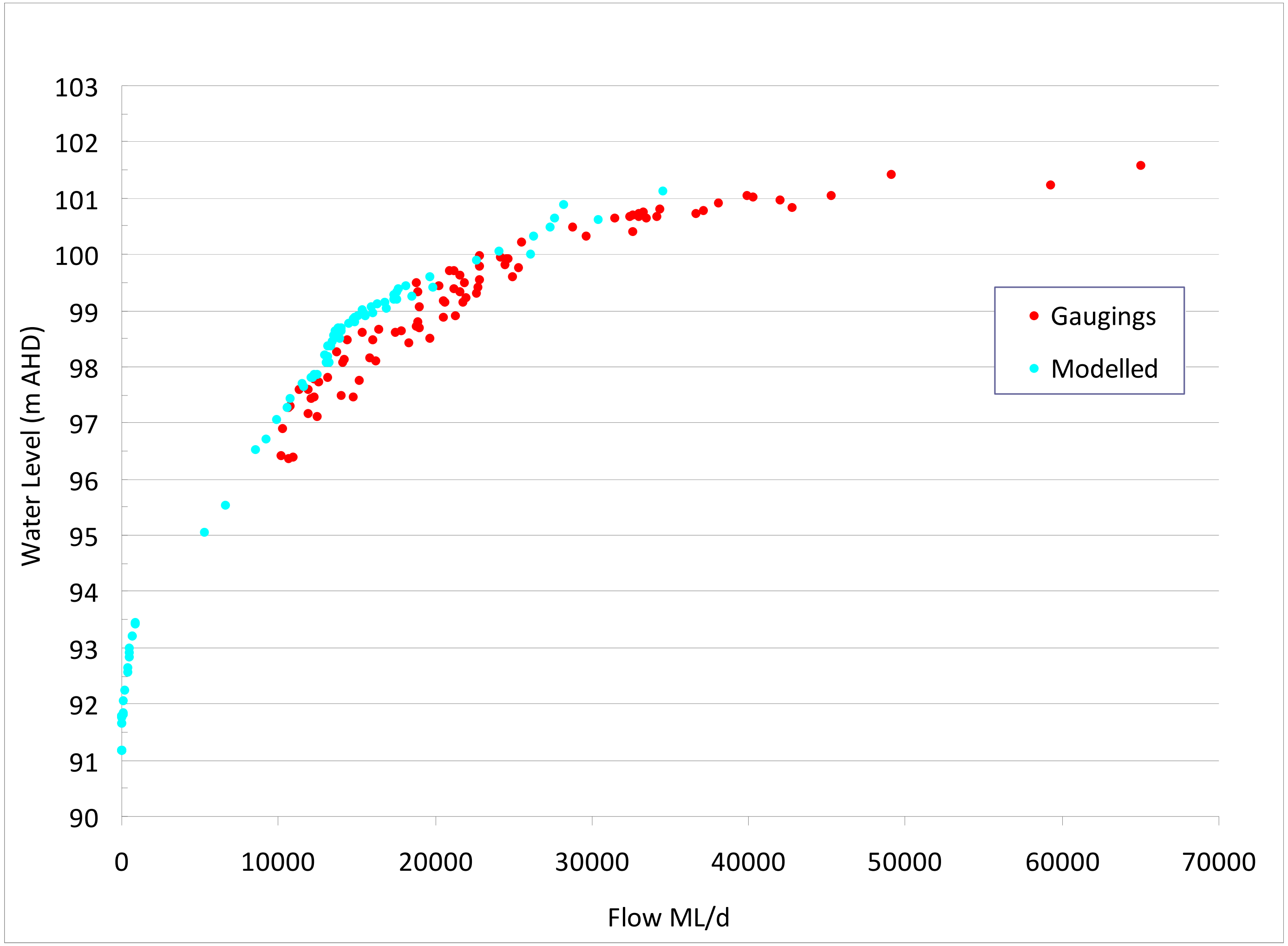

Figure 4-16 Linked 1D-2D model calibration – Downstream of Goulburn Weir – Goulburn River at McCoy's Bridge – Modelled and observed stage-discharge relationship

4.3.4 Discussion

For Trawool and Seymour, the modelled rating curves overestimate water levels for flows up to about 30,000 ML/d (refer to Figure 4-12 and Figure 4-13). In an effort to correct this over-estimation of water levels, variation in Manning's n with water levels were trialled in the 1D model. This approach conceptises the increase in Manning's n from the bed to banks, due to bank vegetation. For this trial, Manning's n was varied within flow in the 1D channel. The following two cases were assessed:

- Run 1:Manning's n set to 0.04 for flow up to 40,000 ML/d, and set to 0.05 for flows above 40,000 ML/d.
- Run 2: Manning's n set to 0.038 for flows up to 40,000 ML/d. then set to 0.04 from 40,000 ML/d to 60,000 ML/d, and set to 0.042 for flows above 60,000 ML/d

Figure 4-17 and Figure 4-18 display the modelled and observed rating curve for the Goulburn River at Trawool and Seymour.

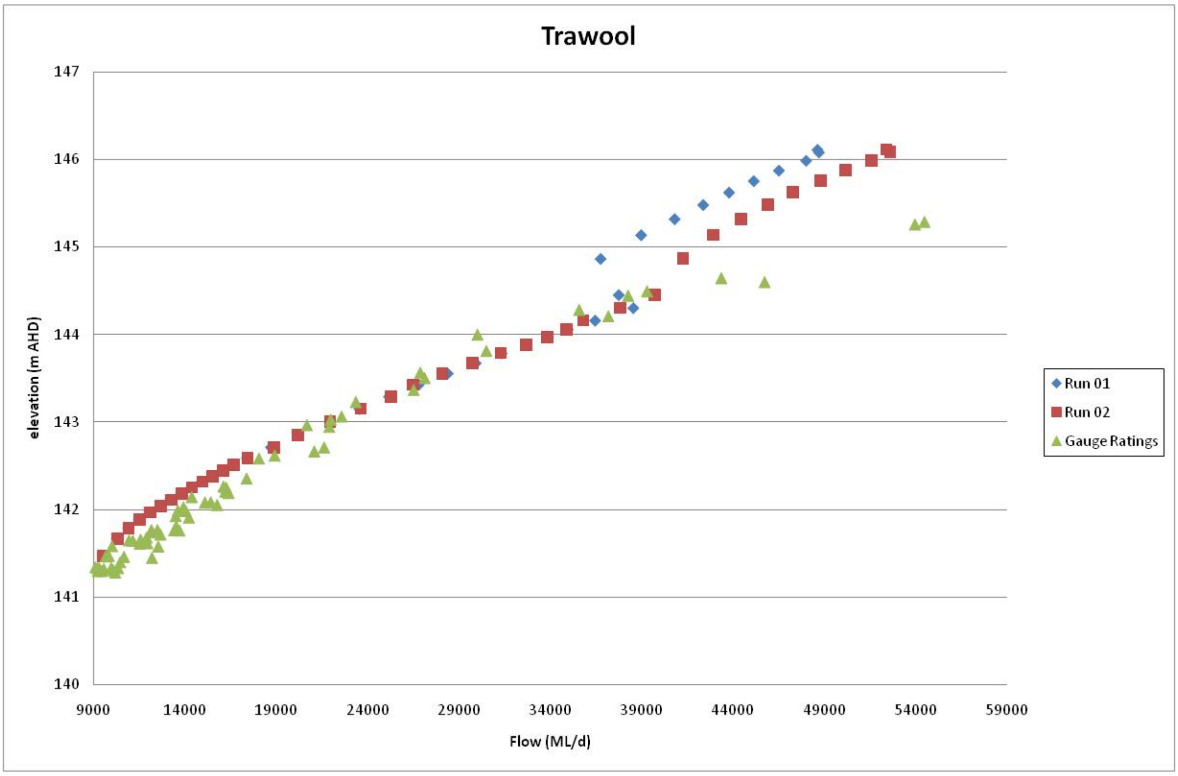

Figure 4-17 Linked 1D-2D model calibration – Upstream of Goulburn Weir – Goulburn River at Trawool – Variation in Manning's n- Modelled and observed stage-discharge relationship

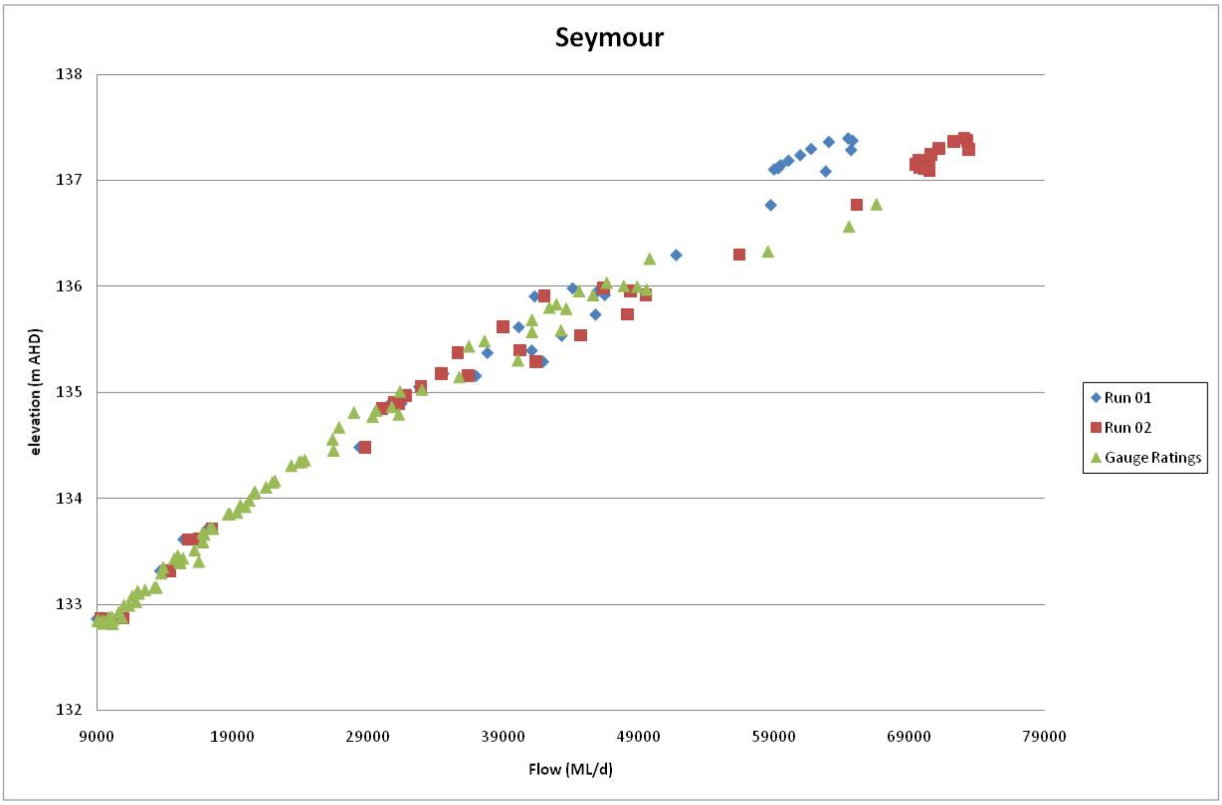

Figure 4-18 Linked 1D-2D model calibration – Upstream of Goulburn Weir – Goulburn River at Seymour – Variation in Manning's n- Modelled and observed stage-discharge relationship

The use of the varied Manning's n improved the comparison of modelled and observed rating curve at Seymour for Run 2. However, the results at Trawool show a considerable overestimated of water levels for flows above 40,000 ML/d. Given the mixed findings, it was considerable the use of single uniform Manning's n provided the best agreement at both locations.

As noted in Section 4.3.3, the comparison of modelled and observed rating curves at Murchison showed considerable discrepancies. During the community reference group discussions, the local landholders from Toolamba noted that the modelled flood levels appeared to overestimate flood extents for events up to 60,000 ML/d. This observation is consistent with the discrepancy found in the modelled rating curve at Murchison.

5. CONCLUSIONS AND RECOMMENDATIONS

Hydraulic model framework

A comparison of the environmental flow range and design peak flow estimates showed that the upper limit of the environmental flow range (60,000 ML/d) corresponded to approximately a 45 year ARI event downstream of Eildon reduces to about a 10 year event at Trawool/Seymour, and a 8-9 year ARI event at Murchison. Further downstream at Shepparton, a 60,000 ML/d flows has ARI of 3-4 years. This variation in the ARI of a 60,000 ML/d flow highlighted the change in the hydraulic characteristics of the Goulburn River and floodplain throughout the study area. This change in hydraulic characteristics and the requirement to simulate the above flow regimes was reflected in the adopted hydraulic modelling framework.

The framework was required to simulate the flow behaviour over a full range of flows (in-channel to floodplain) is displayed in Table 5-1.

Table 5-1 Model elements: purpose, calibration and application

Model elements	Purpose	Calibration	Application
1D model	In channel flows (up to 15,000 ML/d) Manning's n assessment Invert lowering evaluation	Stage-discharge (rating) curve	Building block for linked 1D-2D model
2D model (discussed in a separate report)	Floodplain flow for large floods (> 20 year ARI)	Observed flood levels and extents from major flood events	Flood behaviour (flood levels and extents) for large events Flood mapping outputs from Trawool to Murray River confluence
Linked 1D-2D model	In-channel and floodplain flows (15,000 - 60,000 ML/d)	Observed flood levels and extents from major flood events upstream of Trawool Stage-discharge (rating) curve downstream of Trawool	Flood behaviour (flood levels and extents) for environmental flow events Flood mapping outputs from Eildon to Trawool

Hydraulic model calibration

1D model

The 1D model calibration considered appropriate Manning's n values for the in channel flows. Due to the absence of bathymetric survey upstream of the Lake Nagambie, the 1D model calibration also assessed a range of uniform invert lowerings. The calibration showed that a 1.5 m lowering provided a reasonable agreement between observed and modelled water levels at the streamflow gauges, Trawool and Seymour.

The reliability of hydraulic model water levels and flows were unable to be established at locations away from the gauges. The reasonable preservation of the rise and fall, and travel time supported the model's ability in routing flows along the reach, and reflected reasonable accounting for storage along the reach.

Recommendation: To improve the assessment of the models' performance at locations other then at the streamflow gauges, the following actions are recommended:

- **GBCMA establish a series of water levels gauges along the Goulburn River and on key anabranches in the upper reaches. These water levels gauges could monitored manually during medium to high flow events.**

- **GBCMA consult with other agencies with an interest in flow quantity and quality of the Goulburn River, to co-ordinate monitoring activities.**

Linked 1D-2D model

The linked 1D-2D models were calibrated to the October 1993 event, for the reach Eildon to Trawool, and to observed flow gaugings at Trawool, Seymour, Murchison, Shepparton and McCoy's Bridge.

Across the reach upstream of Trawool, 22 of 30 modelled flood levels lied within +/- 200 mm of the observed October 1993 flood levels. Given the uncertainty in model inflows from the tributary, this calibration outcome was considered reasonable.

At Trawool, for flows from 15,000 to 28,000 ML/d, the modelled water levels were higher than the observed gaugings. Generally, the modelled water levels over this flow range were 200 – 400 mm above the gaugings. Over a flow range of 28,000 to 60,000 ML/d, the modelled and gauged water levels were found to be in good agreement (within 200 mm).

A similar pattern in modelled water levels was found at Seymour. For flows up to 32,000 ML/d, the modelled water levels were higher than gaugings by 200 – 400 mm. For higher flows up to 60,000 ML/d, the modelled and gauged water levels were in good agreement (within 200 mm).

A Manning's n value of 0.042 was adopted for in-channel flows across the reach Eildon to Goulburn Weir.

The overestimation of water levels for flows up to ~30,000 ML/d may be in part due to the absence of bathymetric survey upstream of Lake Nagambie. As discussed, the waterway geometry below the water surface at the time of the ALS capture, was approximated by lowering the mid point of ALS data by a uniform 1.5 m. The comparison of the modelled and observed flow gaugings suggest that this approach has underestimated the waterway area, and lead to an overestimation of water levels for this range flow range.

The capture of bathymetric data for the reach upstream of Lake Nagambie may aid in the improvement of the linked models' performance for flows up to ~ 35,000 ML/d.

Recommendation: To assess the need whether bathymetric data is required for the reach the upstream of Lake Nagambie, the following actions are recommended:

- **GBCMA to assess the importance of assets, both natural and built, affected for flows up to 35,000 ML/d.**

- **GBCMA to scope the costs and deliverables from bathymetric survey the reach upstream of Lake Nagambie.**

- **GBCMA to liaise with other relevant agencies to assess the potential uses of the bathymetric data in other project and activities.**

Similar to the 1D model calibration, the modelled rating curve showed a considerable discrepancy from the gaugings at Murchison. The observed gaugings at Murchison showed considerable scatter in the rating curve. The modelled water levels were found to be significantly lower than the observed gaugings for flows up to 60,000 ML/d.

Recommendation: To improve the linked 1D-2D model's performance for the reach adjacent to Murchison, it is recommended that the GBCMA to consider further hydraulic analysis of the reach to assess, in detail, the influences of flow behaviour

At Shepparton, the observed gaugings shows a considerable scatter for flows from 10,000 ML/d to 40,000 ML/d. This scatter can be up to 1 m for a given flow. The modelled rating curve lies at the lower limit of the scatter of the observed gaugings. Above 40,000 ML/d, the modelled rating curve and observed gaugings were in good agreement.

At McCoy's Bridge, the modelled and observed rating curves were found to be in good agreement for flows up to 35,000 ML/d. For higher flows, significant flows occur in effluent streams such as Deep, Wakiti, Sheepwash and Skelton Creeks. Similar to observed gaugings at Shepparton, there was considerable scatter in the gaugings at McCoy's Bridge.

A Manning's n value of 0.07 was adopted for in-channel flows across the reach Eildon to Goulburn Weir. This adopted value differed from the 0.05 value assessed in the 1D model calibration.

The reliability of the linked 1D-2D hydraulic models' water levels and flows were unable to be established at locations where no or limited observed flood level data was available.

Recommendation: To verify the linked 1D-2D models' performance at locations with no ready available historical flood level data, it is recommended that the GBCMA undertake consultation with relevant local landholders, if required.

6. REFERENCES

Cottingham, P., Stewardson, M., Crook, D., Hillman, T., Roberts, J., & Rutherfurd, I. (2003). *Environmental flow recommendations for the Goulburn river below Lake Eildon.* Canberra: CRC Freshwater Ecology and CRC Catchment Hydrology.

SKM (2002). *Sheppareton Mooroopna Flood Study and Floodplain Management Plan.* Melbourne: Goulburn Borken CMA and Greater SMitchell Shire .

SRWSC, 1981 - *Seymour – A report on Flooding from the Goulburn River, Appendix F: Lake Eildon Effect on Flood Frequencies at Eildon*, State Rivers and Water Supply Commission, Victoria.

Water Technology. (2008). *Goulburn River Environmental Hydraulics Project – Topographic data review.* July 2008. Melbourne: Goulburn Broken CMA.

Water Technology. (2010a). *Goulburn River Environmental Hydraulics Project – Hydaulic model construction and calibration –floodplain managment scenarios – two dimensional hydraulic models* April 2010. Melbourne: Goulburn Broken CMA.

Water Technology. (2010b). *Goulburn River Environmental Hydraulics Project - Hydrologic analysis - Streamflow data assessment and Tributary inflow analysis.* April 2010. Melbourne: Goulburn Broken CMA.

Water Technology and Sinclair Knight Merz. (2005). Lower *Goulburn River Floodplain Rehabilitation Scheme – hydraulic modelling report.* Melbourne: Goulburn Broken CMA.

WBM. (2001). *Seymour Flood Study Report.* Melbourne: Goulburn Broken CMA and Mitchell Shire .