Appendix A

Previous Mountain Creek Flood Study and TUFLOW modelling

Hume Highway - Woomargama Bypass

Mountain Creek Flood Study

March 2008

Roads and Traffic Authority, NSW

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1. Introduction

1.1 Background

The NSW Roads and Traffic Authority (RTA) proposes to construct a bypass of the Hume Highway around the town of Woomargama, NSW. Woomargama is a small town located between Albury and Holbrook along the Hume Highway. Mountain Creek flows in a north-westerly direction along the northern edge of Woomargama. The Hume Highway currently crosses Mountain Creek via a bridge located on the eastern edge of Woomargama.

Three alignment options have been proposed for the Woomargama bypass, options A, B and C. Option A would bypass Woomargama to the north, paralleling the existing Hume Highway alignment and crosses Mountain Creek and its floodplain twice - immediately to the north and to the north-west of Woomargama. Option B and Option C would bypass Woomargama to the north-west and also include proposed crossings of Mountain Creek, as well as several other drainage lines.

1.2 Study Objectives

The objective of this study is to determine existing flood conditions along Mountain Creek in the vicinity of Woomargama. Results of this flood study will be used during assessment of the bypass options and will provide a base case for assessment of flood impacts resulting from the proposed Woomargama bypass. This study has been conducted in accordance with the NSW Government's Floodplain Development Manual (April 2005) and guidance in Australian Rainfall and Runoff (Engineers Australia, 2001).

1.3 Available Data

The following data were used in this flood study:

- Detailed survey of Mountain Creek in the vicinity of Woomargama (data provided by RTA based on surveys conducted by Phil Reid, Mat Swindle and Paul Ogden during the following periods: 29-08-07 to 31-08-07; 10-09-07 to 14-09-07 and 18-09-07 to 20-09-07). This survey included detailed survey of the both the Hume Highway and the Fairbairn Road bridges crossing Mountain Creek.
- 1:100,000 Holbrook topography map (Commonwealth of Australia, 1982).
- 1: 25,000 topography maps for Mountain Creek, Narra Narra and Home Flat (Land Information Centre NSW, 1978).
- Soil Survey of NSW, Soil Landscapes of the Holbrook-Tallangatta, 1:100 000 Sheet (Department of Land and Water Conservation, 2003).

2. Study Area

2.1 Location

Woomargama is located in south-western NSW approximately 70km north of Albury and approximately 15km south of Holbrook. Mountain Creek flows through Woomargama on the northern side of the town. The Hume Highway currently passes through Woomargama.

This flood study focuses on an approximately 8km reach of Mountain Creek in the vicinity of Woomargama. This reach extends from approximately 3.5km upstream of the Hume Highway bridge at Woomargama to just downstream of the Fairbairn Road bridge. This section of the creek contains the existing Hume Highway bridge and the proposed crossings required for all three of the bypass options.

2.2 Climate

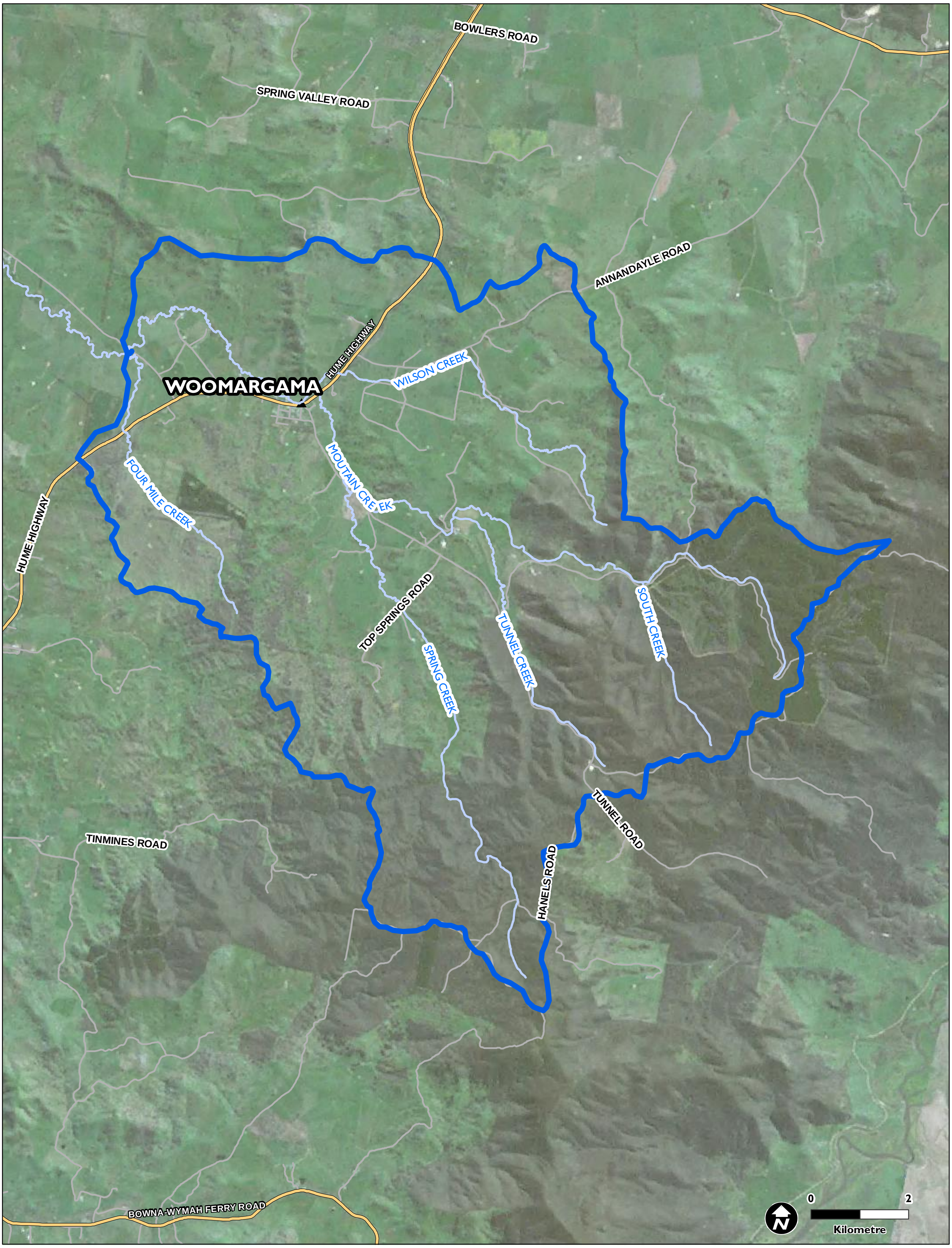
The average annual rainfall for Woomargama is about 740 mm/yr, which is based on 126 years of rainfall data recorded at the Bureau of Meteorological Station (BoM) No 072049, located approximately 4.5km south of Woomargama at Woomargama Estate. The climate is characterised by warm to hot summers and cool to cold winters, and rainfall is winter dominant. The average annual class “A” pan evaporation for Holbrook (located about 15km north of Woomargama) is 1,161mm/yr (Water Conservation and Irrigation Commission, 1975).

2.3 Catchment Description

Mountain Creek is a tributary of Billabong Creek which itself is a tributary of the Murray River, and therefore is within the Murray-Darling Basin. Mountain Creek joins Billabong Creek approximately 17km north west of Woomargama. In the vicinity of Woomargama, Mountain Creek is also known as Woomargama Creek.

Major tributaries of Mountain Creek within the study area include Spring Creek, Tunnel Creek, Wilson Creek and Four Mile Creek. Spring Creek and Tunnel Creek both join Mountain Creek upstream of Woomargama. Wilson Creek joins Mountain Creek at Woomargama, just downstream from the existing Hume Highway bridge and Four Mile Creek joins Mountain Creek just downstream of the Fairbairn Road bridge. An overview of the catchment is shown in Figure 2-1.

Upstream of the junction of Mountain Creek and Four Mile Creek, Mountain Creek has a catchment area of 129.5km^2. A field inspection of the catchment was undertaken on 19th February 2008. During this inspection it was noted that the catchment has gently undulating topography and is predominately cleared for rural use with scattered patches of native vegetation. The primary rural activities within the catchment are cattle and sheep grazing. The upper reaches of the catchment have steeper topography and are densely forested, containing areas of the Woomargama State Forest.



Classified road — Local Roads — Drainage — Catchment boundary

Figure 2-1 Mountain Creek Catchment Map

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2.4 Mountain Creek

Mountain Creek is an ephemeral system. The NSW Department of Water and Energy (DWE) advise that stream flow generally occurs only after catchment rainfall or when base flow from groundwater is sufficient. At other times, the river is reduced to a series of disconnected pools. Advice from DWE is that there is generally no flow during the summer months. A gauge station (410096) on Mountain Creek, approximately 10km downstream of Woomargama, existed until it was decommissioned in 1994.

A field inspection of the study area was conducted on the 19th February 2008. During this inspection, it was noted that Mountain Creek has an incised channel with primarily sandy banks and floor. The creek exhibits a high level of sinuosity, which was attributed to the low gradient of the creek and the soils present. The creek had ponded water in locations at the time of the inspection which was slowly flowing in some locations.

The floodplain is narrow near Woomargama and the Hume Highway bridge, being confined by a large hill on the right hand side of the creek and the Hume Highway on the left hand side (looking downstream). Further downstream, the floodplain widens, principally spreading out from the right hand side of the creek through the valley.

Vegetation in the main channel is sparse but large eucalypts and willows line the banks. There are also occasional large logs and snags across the channel. Floodplain vegetation consists primarily of long grass with scattered native trees.

2.5 Waterway Structures

There are two existing structures across Mountain Creek within the study area. One is the existing Hume Highway bridge and the other is the Fairbairn Road bridge. Details of these structures were obtained from survey data provided by the RTA and supplemented by aerial photo measurements. Table 2-1 summarizes the details.

Table 2-1: Mountain Creek - road crossing details

Location	Structure type	Channel Invert Level (mAHD)	Structure Soffit Level (mAHD)	Road Crest Level (mAHD)
Hume Highway Bridge	15m single span bridge	303.07	306.741	308.265
Fairbairn Road Bridge	10m single span bridge	282.17	287.26	288.26

Note: mAHD in metres Australian Hight Datum

3. Hydrologic Analysis

3.1 Overview

No previous studies or hydrologic models were available to determine flows within the Mountain Creek Catchment. A XP-RAFTS model of the Mountain Creek catchment upstream of Fairbairn Road was developed to assess flows in Mountain Creek during design storm events.

The hydrologic model was used to assess flows during the 20, 100 and 2000 year ARI (Average Recurrence Interval) and PMF (Probable Maximum Flood) design storm events. These storm events were adopted to ensure that adequate information is available for later stages of the Woomargama Hume Highway bypass project. The 20 year ARI event will be required for design of scour protection at proposed waterway crossings. The 100 year ARI event will be required to determine road levels and assess waterway opening requirements of proposed structures to ensure the highway is not inundated during this event. The 2000 year ARI event has been assessed because the ultimate limit state design of all bridge structures will be based on this event (as specified in the RTA Bridge Waterway Manual, 2000). The PMF event was modelled to provide a worst case assessment of flooding within each watercourse.

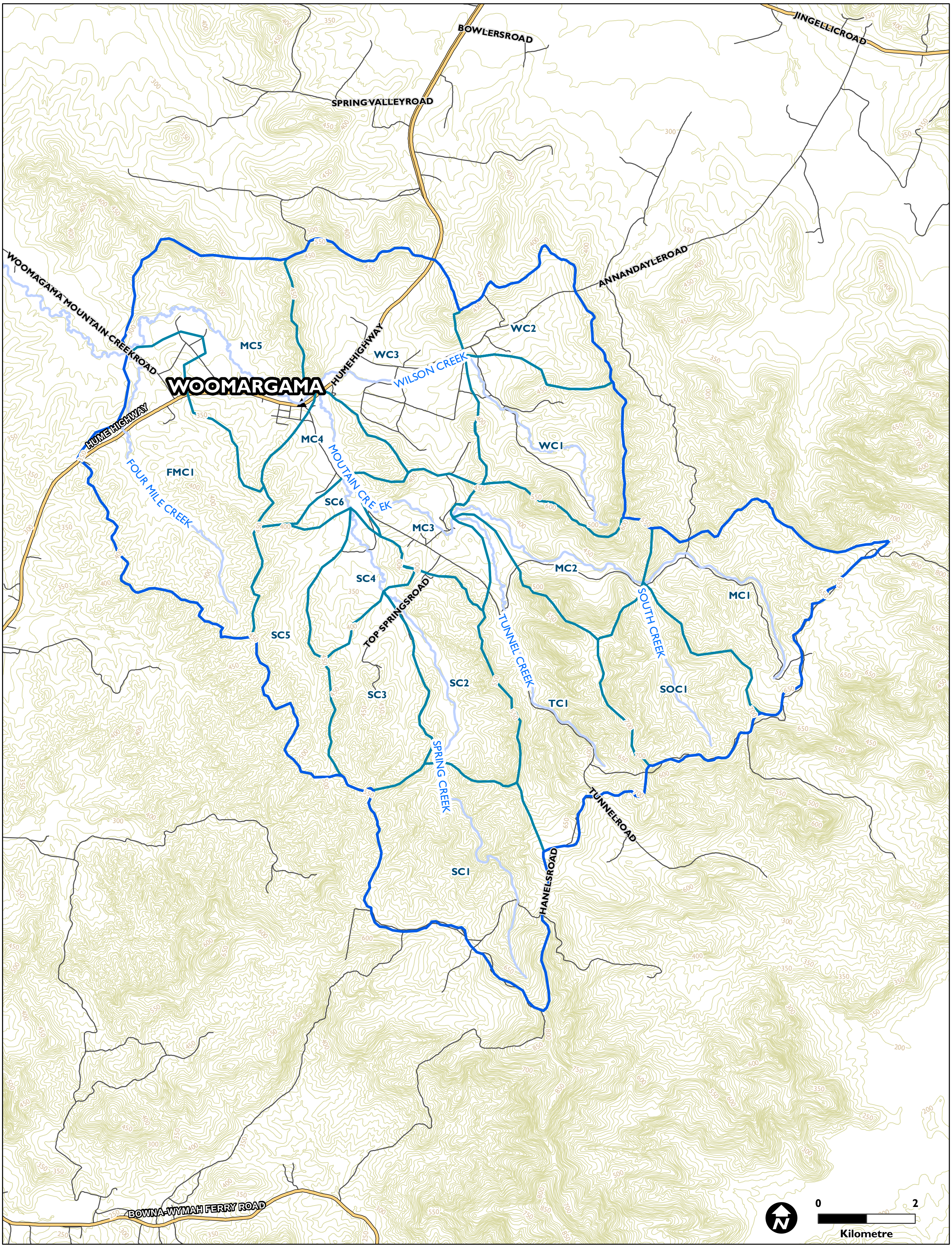
3.2 Hydrologic Model Setup

3.2.1 Catchment Parameters

The Mountain Creek catchment has a total area of 129.5km^2 upstream of the Fairbairn Road bridge. This catchment was subdivided into 17 sub-catchments to enable greater definition of catchment parameters within the XP-RAFTS model. Additional nodes were included in the model to represent key locations such as junctions of waterways and places where input into the hydraulic model was required. The breakdown and location of each of the sub-catchments is shown in Figure 3-1.

Sub-catchments MC1, SoC1, TC1 and SC1 represent the upper reaches of the catchment and are characterised by steep topography and forested land. Sub-catchments MC2, MC3, MC4, SC2, SC3, SC4 and SC5 represent the other reaches of the Mountain Creek catchment upstream of the Hume Highway Bridge at Woomargama. These sub-catchments have flatter gradients and are characterised by rural land use. Sub-catchments WC1, WC2 and WC3 represent the Wilson Creek catchment. This catchment is characterised by undulating topography and rural land use. Wilson Creek joins Mountain Creek just downstream of the Hume Highway Bridge. Sub-catchment MC5 represents the catchment area between the Hume Highway bridge and Fairbairn Road bridge. Sub-catchment FMC1 represents the Four Mile Creek catchment, which joins Mountain Creek just downstream of Fairbairn Road.

Catchment parameters, such as slopes, flow path lengths and sub-catchment areas, were defined using 1:25000 topographic maps. Notes and photographs taken during the field investigations and aerial photographs were used to determine other catchment parameters, including percentage impervious and catchment roughness values (see Appendix A).



Classified road — Local roads — Cadastre — Drainage — 10m Contours — Catchment boundary — Subcatchment data

Figure 3-1 Hydrologic Model Subcatchments

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Loss parameters were adopted based on recommendations in Australian Rainfall and Runoff (2001) and the XP-RAFTS manual. Details of XP-RAFTS model input parameters adopted are detailed in Table 3-1.

Channel routing was incorporated into the model using the Muskingham-Cunge method. Channel cross sections were defined for the larger tributaries and XP-RAFTS was used to calculate the parameters used in the routing calculations. Cross sections were defined based on survey data where it was available, and 1:25 000 topographic maps in other areas.

Table 3-1: Mountain Creek catchment parameters

Sub-catchment	Area (ha)	Slope (%)	n	% Impervious	Land Use	Soil Type	Initial Loss (mm)	Continuing Loss (mm/hr)
MC1	996.66	5	0.1	0	forest	sandy silty clay	20	5
SoC1	737.99	8	0.1	0	forest	sandy silty clay	20	5
JnctMC_SoC	Additional Node – junction of Mountain Creek and South Creek							
MC2	633.35	6	0.05	0	rural	clayey sand	10	3
TC1	1093.1	13	0.1	0	forest	sandy silty clay	20	5
Jnct MC_TC	Additional Node – junction of Mountain Creek and Tunnel Creek							
SC1	1216.4	10	0.1	0	forest	sandy silty clay	20	5
SC2	678.93	4	0.05	0	rural	sandy silty clay	10	3
SC3	620.54	6	0.05	0	rural	sandy silty clay	10	3
Jnct SC	Additional Node – junction of upper tributaries of Spring Creek							
SC4	323.96	3	0.05	0	rural	sandy silty clay	10	3
SC5	610.45	4	0.05	0	rural	sandy silty clay	10	3
Jnct SC2	Additional Node – junction of mid-tributaries of Spring Creek							
SC6	78.02	1	0.05	0	rural	sandy silty clay	10	3
MC3	433.79	4	0.05	0	rural	sandy silty clay	10	3
Jnct MC_SC	Additional Node – junction of Mountain Creek and Spring Creek							
MC4	405.26	5	0.05	0	rural	sandy silty clay	10	3
u/s bridge	Additional Node – junction contributing catchments upstream of Hume Highway bridge							
WC2	519.28	4	0.05	0	rural	sandy clay	10	3
WC1	820.69	4	0.05	0	rural	sandy clay	10	3
WC	Additional Node – junction of upper tributaries of Wilson Creek							
WC3	1326.6	3	0.05	0	rural	clayey sand	10	3
d/s bridge	Additional Node – junction Wilson Creek and Mountain Creek							
MC5	1085.8	5	0.05	0	rural	sandy silty clay	10	3
FMC1	1371.6	3	0.05	0	rural	sandy silty clay	10	3
MC6	Additional Node – junction Four Mile Creek and Mountain Creek							

3.2.2 Rainfall Intensity Frequency Duration Parameters

Rainfall Intensity Frequency Duration (IFD) parameters were obtained from Australian Rainfall and Runoff, Volume 2 (Engineers Australia 1987, 2001). These parameters were input into the XP-RAFTS model developed for the Mountain Creek catchment. IFD parameters for Woomargama are shown in Table 3-2.

Table 3-2: Woomargama IFD Parameters

Variable	Symbol	AR&R reference	Value
Rainfall intensity (mm/hr) (2 year ARI; 1 hour storm duration)	${}^{2}I_{1}$	Map1.7	20.65
Rainfall intensity (mm/hr) (2 year ARI; 12 hour storm duration)	${}^{2}I_{12}$	Map2.7	3.98
Rainfall intensity (mm/hr) (2 year ARI; 72 hour storm duration)	${}^{2}I_{72}$	Map3.7	1.14
Rainfall intensity (mm/hr) (50 year ARI; 1 hour storm duration)	${}^{50}I_{1}$	Map4.7	43.43
Rainfall intensity (mm/hr) (50 year ARI; 12 hour storm duration)	${}^{50}I_{12}$	Map5.7	7.11
Rainfall intensity (mm/hr) (50 year ARI; 72 hour storm duration)	${}^{50}I_{72}$	Map6.7	1.84
Average coefficient of skewness	G	Map7	0.21
Geographical factor (2 year ARI)	F2	Map8	4.32
Geographical factor (50 year ARI)	F50	Map9	15.2

3.2.3 PMP Calculation

Probable Maximum Precipitation (PMP) intensities were calculated using the procedures outlined in *The Estimation of Probable Maximum Precipitation in Australia: generalised short duration method* (Bureau of Meteorology, 2003). These were used to determine the 2000 year ARI and PMP temporal rainfall patterns which were input into the XP-RAFTS model to determine the peak flows during the 2000 year ARI and PMP design storm events. It was assumed that the catchment was already wet (initial loss was set to be the same as continuing loss) when modeling the 2000 year ARI and PMP storm events.

Parameters used in the PMP calculations are detailed in Table 3-3 below. The moisture adjustment factor (MAF) was determined from Figure 3 in *the estimation of probable maximum precipitation in Australia: generalised short duration method* (Bureau of Meteorology, 2003). The elevation adjustment factor (EAF) was adopted as 1 because the elevation of the catchment is below 1500mAHD. The roughness parameter used in PMP calculations is a measure of how steep the catchment is. Topographic maps were used to determine this parameter.

Table 3-3: Mountain Creek PMP calculation parameters

Parameter	Value
Moisture adjustment factor	0.62
Elevation adjustment factor	1
Percentage defined as 'Rough' (meaning steep topography)	0%

3.3 Hydrologic Model Results

3.3.1 Critical Durations

The Mountain Creek XP-RAFTS model was run for a range of durations for each of the design events being assessed. The duration resulting in the maximum peak discharge for each event was adopted as the critical duration. Table 3-4 details the critical durations determined for each design storm event assessed.

Table 3-4: Mountain Creek critical durations for design storm events

Annual Recurrence Interval	Duration
20 year	2hr
100 year	2hr
2000 year	2hr
PMF	2hr

3.3.2 Peak Flows

Flow hydrographs were produced from the XP-RAFTS model for each of the critical duration, design storm events. These hydrographs were used as inputs to the hydraulic model (see Section4.1.4 below). Key points of interest in the RAFTS model were flow from nodes Jnct MC_SC (upstream point of hydraulic model), MC4 (additional flows generated upstream of the Hume Highway bridge), WC (input from Wilson Creek, just downstream of the Hume Highway bridge), MC5 (additional flows generated upstream of Fairbairn Road bridge), and FMC (flows from the Four Mile Creek catchment). Digital copies of the XP-RAFTS model are provided on a CD located in Appendix C.

Peak flows from the hydrographs applied to the hydraulic model are shown in Table 3-5.

Table 3-5: Mountain Creek Catchment Peak Flows

Sub-catchment	Peak flows (m^3/s)			
	20 Year ARI	100 Year ARI	2000 Year ARI	PMF
Jnct MC_SC (Total catchment upstream)	130	243	727	2455
MC4	15	26	63	188

(local sub-catchment flows)				
WC (Total flows Wilson Creek catchment)	64	113	305	1019
MC5 (local sub-catchment flows)	31	55	144	461
FMC (Total flows Four Mile Creek catchment)	27	49	139	478

3.4 Hydrologic Model Sensitivity Analysis

A stream gauging station (410096), located approximately 10km downstream of Woomargama, existed until being decommissioned in 1994. Due to the distance downstream of the study area and the length of time since it ceased operation, data from this gauge was not considered to be appropriate for use in calibration of the XP-RAFTS model.

Model parameters were selected based on values recommended within Australian Rainfall and Runoff (Engineers Australia, 2001). Due to lack of suitable data being available for calibration, a sensitivity analysis was undertaken in order to establish the levels of confidence for the model. Results of this analysis are presented in Table 3-6.

Table 3-6: Hydrologic Model Sensitivity Analysis

Location	Manning's n		Initial Loss		Continuing Loss	
	+20%	-20%	+20%	-20%	+20%	-20%
Upstream of Hume Highway Bridge	Decrease in flows by 12% to 20%	Increase in flows by 13% to 31%	Decrease in flows by 5% to 16%	Increase in flows by 4% to 15%	Decrease in flows by 2% to 6%	Increase in flows by 2% to 6%
Wilson Creek Catchment	Decrease in flows by 14% to 16%	Increase in flows by 18% to 21%	Decrease in flows by 5% to 6%	Increase in flows by 4% to 5%	Decrease in flows by 2% to 3%	Increase in flows by 2% to 3%
Between Hume Highway and Fairbairn Road	Decrease in flows by 12% to 16%	Increase in flows by 14% to 21%	Decrease in flows by 5% to 7%	Increase in flows by 5% to 7%	Decrease in flows by 2% to 3%	Increase in flows by 2% to 3%

The results of the sensitivity analysis suggest that the XP-RAFTS model is relatively robust and not greatly susceptible to changes in assigned catchment characteristics. While the change in flow resulting from changes to Manning's n values are high, this indicates that the model is behaving as expected.

4. Hydraulic Analysis

The Danish Hydraulics Institute (DHI's) MIKE11 computer hydraulic modelling program was used to analyse the existing flooding conditions of Mountain Creek. Unsteady flow models were developed for each of the critical durations storms, the 20-year, 2 hour, the 100-year, 2 hour, the 2000-year, 2hr and the PMF. The study reach extends from approximately 3,350 metres upstream of the Hume Highway crossing to approximately 260 metres downstream of Fairbain Road. Cross-sections were also placed at the proposed bypass locations. Option A alignment crosses Mountain Creek at chainage 4862 and Options B and C cross at chainage 5940.

4.1 Hydraulic Model Setup

4.1.1 Cross-sections

Cross-section data provided by the RTA were input into the cross-section geometry file. Cross-sections are labelled according to chainage along the Mountain Creek thalweg, beginning with Chainage 0 at the upstream end of the study reach and ending at Chainage 11,148 at the downstream end. Figure 4-1 shows the cross-section locations. Surveyed cross-section data provided by the RTA are located in Appendix B. Elevation data in the overbank areas were taken from 10-metre topographic maps for cross-sections that required extension beyond the survey data.

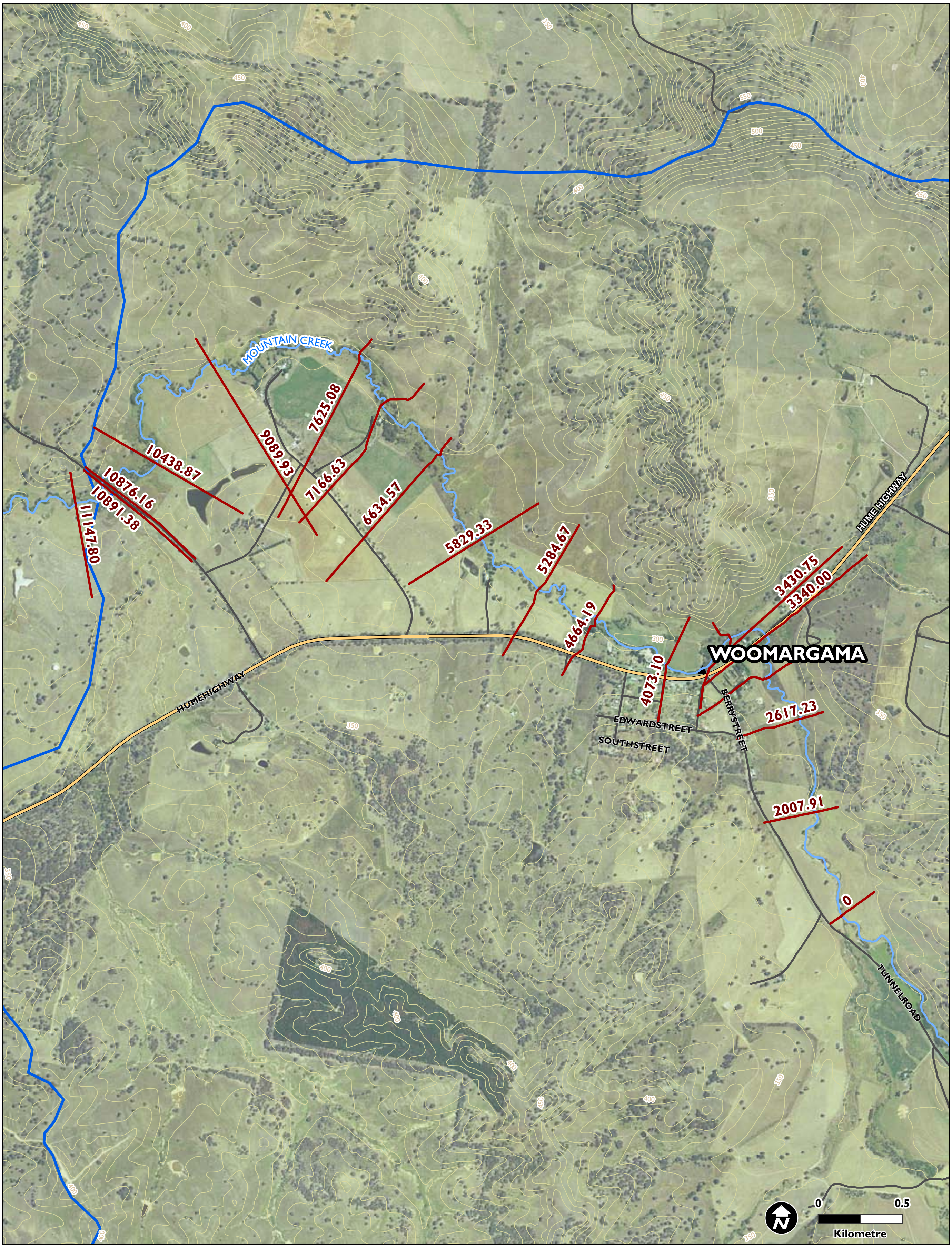
4.1.2 Manning's n-values

Manning's n-values were selected based on field observations and aerial photography. Values input into MIKE11 range from 0.045 in the low flow channel to 0.040 in the overbank areas. Appendix A contains photos and notes taken during the field investigation showing typical main channel and overbank areas.

4.1.3 Bridge Analyses

Bridge data for the Hume Highway and Fairbain Road crossings of Mountain Creek were obtained from the RTA and input into the MIKE11 network file. Channel data for the upstream cross-section of the Hume Highway bridge were not provided. Therefore, the upstream cross-section geometry was derived by copying the downstream channel data and adjusting the elevations based on channel slope. Surveyed bridge data provided by the RTA are located in Appendix B.

The bridges were modelled using the United States Federal Highway Administration (FHWA) Water Surface Profile method. Default values were used for the submergence, overtopping and pier loss coefficients.



Classified road — Local roads — Drainage — 10m Contours — Catchment boundary — Cross section locations

Figure 4-1 Cross - Section Locations

4.1.4 Boundary Conditions

Hydrographs derived from the XP-RAFTS hydrologic model were input into the MIKE11 boundary file at appropriate points along the study reach as listed below in Table 4-1:

Table 4-1: Input Hydrograph Locations

RAFTS Node	MIKE11 Chainage in River metres	Location
Jnct MC_SC	0	Approximately 3,350m upstream of Hume Highway
MC4	3,340	Upstream of Hume Highway
WC3	3,583	Confluence of Wilson Creek
MC5	10,876	Upstream of Fairbain Road
FMC1	10,891	Confluence of Four Mile Creek

The downstream boundary condition at Chainage 11,148 was determined by setting the boundary type to Q-h in the MIKE11 boundary file. MIKE11 calculates normal depth using the flow rate and the processed hydraulic parameters data for the cross-section.

Initial conditions were determined using a hotstart result file to stabilise the unsteady model. The hotstart result file consists of the steady state solution for the modelled reach.

4.2 Hydraulic Model Results

The following summarises the baseline results for the existing conditions at the locations where the bypass options would cross Mountain Creek. Baseline results will be used in the following phases for design recommendations for the bypass bridge structure.

Table 4-2: Baseline Results

Option A – Chainage 4861	**Options B & C – Chainage 5940**
100-year FL = 299.59 mAHD	100-year FL = 295.96 mAHD
Flow Width = 383 m	Flow Width = 251 m
20-year Velocity = 0.99 m/sec	20-year Velocity = 0.52 m/sec
PMF Velocity = 2.14 m/sec	PMF Velocity = 1.51 m/sec

Note: FL is peak flood level

A digital copy of the MIKE11 project is provided on CD in Appendix C.

4.3 Hydraulic Model Sensitivity Analyses and Validation

No observed water levels or gauge data are available for the study reach. Therefore, calibration of the hydraulic model to real data was not possible. Model parameters were selected based on values recommended in Australian Rainfall and Runoff (Engineers Australia, 2001). Due to no suitable data being available for calibration, a sensitivity analysis was undertaken in order to establish the levels of confidence for the model. Results of this analysis are presented in Table 4-3.

Table 4-3: Hydraulic Model Sensitivity Analysis

Location	**Manning's n**	
	+20%	**-20%**
Study Reach	Mean increases in peak flood level = 0.10 m	Mean decreases in peak flood level 0.08 m

The results of the sensitivity analyses suggest that the MIKE11 model is behaving as expected, with increases and decreases to flood level with adjustment of Manning's n-values.

In addition to the sensitivity analysis, the bridge analyses were validated by running the Mike11 model using the Energy method to analyse the bridges. The FHWA method results were compared to the Energy method results and found to be very similar, with a mean decrease in flood level of 0.01m.

5. Conclusions

This flood study presents the existing condition hydrologic and hydraulic analyses results for Mountain Creek in the vicinity of Woomargama. The results will be used to aid with the selection of the bypass option and the detailed design phase for the Woomargama Bypass of the Hume Highway.

Appendix A

Field Investigation Notes and Photos

MEMORANDUM

Date:	22/2/08	
To:	Tami Norton	
Copy :		
From:	Kate Stephens	
Job no:	2116784D	
Re:	Site Visit to Woomargama – 19th February 2008	

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Site Visit Overview

On Tuesday 19th February 2008, Tami Norton and Kate Stephens visited Woomargama to assess the 8km reach of Mountain Creek that is the subject of the Flood Study being conducted on behalf of the RTA for the proposed Woomargama bypass. The upstream catchment was also assessed during this site visit.

The majority of the reach of Mountain Creek that is within the bounds of the flood study was visited to establish the existing condition of the waterways. Features of the waterways and infrastructure (such as roadway bridges and culverts) were noted and survey data provided by the RTA compared to identified site features. A drive through the upstream catchments was also undertaken to gain an understanding of broader catchment conditions. Photographs were taken during the site visit to assist with determining hydraulic roughness parameters for use in development of both the hydrologic and hydraulic models.

Site Description

- Mountain Creek, in vicinity of bypass Option B and C crossings

(Photograph reference: photo 001 – 021)

In the vicinity of this location the creek has an incised channel and wide floodplain, which primarily extends on the right hand side of the creek. The creek has a sandy bottom and contained ponded water that was very slowly flowing at the time of the site visit. The creek exhibits a high level of sinuosity (probably a result of the flat gradient and sandy soils).

Vegetation in the main channel was sparse but large eucalypts and willows line the banks. There were also occasional large logs and snags across the channel. Floodplain vegetation consists primarily of long (~1m high) grass.

Visual estimate of Manning's n values: channel 0.045, right overbank 0.04, left overbank 0.05.

Property owner comment: last major flood ~ 5 years ago, floodwaters are contained within the floodplain (below the top of the embankment on the left hand side of the creek). Floodwaters spread across the wide floodplain.

- Mountain Creek, in vicinity of bypass Option A crossing

(Photograph reference: photo 025 – 061)

In the vicinity of this location the creek has an incised channel and wide floodplain, which primarily extends on both the right and left hand side of the creek. The creek has a sandy bottom and contained ponded water that was very slowly flowing at the time of the site visit. The creek exhibits a high level of sinuosity (probably a result of the flat gradient and sandy soils).

Vegetation in the main channel was sparse but large eucalypts and willows line the banks. There were also occasional large logs and snags across the channel. Floodplain vegetation consists primarily of long (~1m high) grass.

Visual estimate of Manning’s n values: channel 0.045, right overbank 0.04, left overbank 0.05.

A pump was set up to draw water from the creek at for use in a house just downstream of where bypass Option A crosses the creek.

Property owner comment: flood flow is shallower on the right hand side floodplain and deeper on the left hand side.

- Mountain Creek, at Woomargama

(Photograph reference: photo 062 – 064)

Characteristics of the creek were similar to locations above, however the vegetation along the banks of the channel was slightly denser. The left overbank area is vegetated with grass. The area slopes up to meet the Hume Highway and the grass had recently been mowed.

The floodplain narrows in this location with a hill located on the right hand side of the channel.

- Mountain Creek, at existing Hume Highway Bridge

(Photograph reference: photo 065 – 069)

Again, the creek in this location presented similar characteristics (meandering channel, sandy bottom, similar vegetation). The floodplain is again not as wide in this location with a hill located on the right hand side of the channel.

Photographs of the underside of the bridge were taken.

- Mountain Creek, at Fairbairn Road Bridge

(Photograph reference: photo 070 – 076)

Upstream of the Fairbairn Road bridge, Mountain Creek is less sinuous then at the locations described above. The creek was only observed from the bridge so the substrate of the bottom of the channel was not noted. The floodplain is wide with grass and eucalypts growing on the right overbank area, and primarily grass on the left overbank area.

On the right of the channel, a levee has been constructed upstream from the bridge (see photo 76). Due to access restrictions it is unclear how far upstream from the road this levee extends. The purpose of this levee was also unclear, but it is thought that it may have been constructed to assist in directing flows from the wide floodplain under the road bridge and prevent damage to the road embankment on the right hand side of the channel.

Downstream of the Fairbairn Road bridge, the channel has steep eroded banks, particularly on the right hand side, but also on the left hand side of the channel. The creek again is less sinuous then it was further upstream. Vegetation in the channel is thick grass/ reeds, with the overbank areas vegetated with grass.

Four Mile Creek joins Mountain Creek just downstream of the Fairbairn Road bridge. Just upstream of the junction, Four Mile Creek has heavily eroded banks (photos 71 & 72).

- Mountain Creek, further along Fairbairn Road

(Photograph reference: photo 077 – 080)

Fairbairn Road was driven along until the point where Mountain Creek flows close to the road. At this point the creek again is less sinuous then it was further upstream. Vegetation on the banks of the channel consists of willows and eucalypts with the overbank areas vegetated primarily with short grass and some scattered trees. Access to the creek at this location was limited (the creek was viewed from Fairbairn Road). The substrate of the channel was therefore not able to be assessed.

- Mountain Creek Catchment upstream of Woomargama

The upper reaches of the catchment were assessed via a drive along both Tunnel Road and Annandale Road. Tunnel Road follows Mountain Creek to the point where Tunnel Creek joins Mountain Creek. Tunnel Road then follows Tunnel Creek to the upper reaches of the catchment. Annandale Road follows Wilson Creek to the upper reaches of the Wilson Creek catchment.

The reaches of Mountain Creek and Tunnel Creek in the vicinity of the town of Woomargama consist of gently undulating topography and general rural land use (primarily grazing cattle and

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some sheep). Higher up in the catchment the land becomes steeper and is densely forested, containing areas of the Woomargama State Forest.

The Wilson Creek catchment is very similar to the reaches of Mountain Creek and Tunnel Creek catchments in the vicinity of Woomargama (gently undulating and characterised by rural land use). Wilson Creek joins Mountain Creek just downstream of the Hume Highway bridge.

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Mountain Creek – Typical floodplain overbank

Mountain Creek – Typical main channel section

Mountain Creek – Existing Hume Highway Bridge crossing, looking upstream

Fairbain Road – Bridge crossing of Mountain Creek, looking west

Mountain Creek at Fairbain Road Bridge – Looking upstream at levee

Mountain Creek at Fairbain Road Bridge – Looking downstream

Appendix B

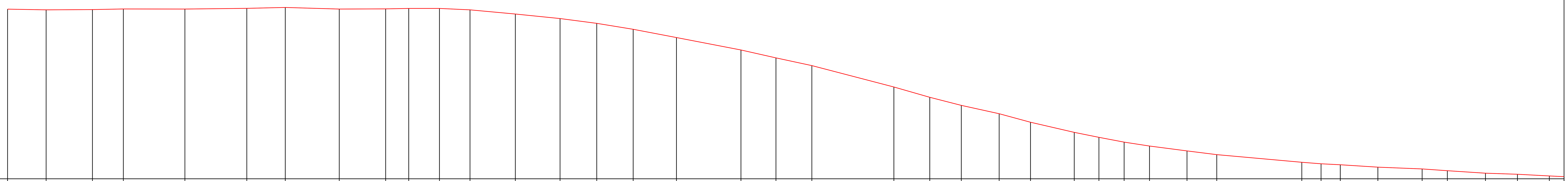
RTA Survey Data

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 1 of 6

Horizontal Scale = 1:1000, Vertical Scale = 1:100



MCL1 LEVELS	Chainage
316.070	759.372
316.083	781.433
316.112	796.118
316.107	825.440
316.143	854.890
316.183	873.246
316.108	898.914
316.116	920.997
316.136	932.016
316.136	946.607
316.071	961.180
315.872	982.746
315.656	1004.047
315.427	1021.525
315.142	1038.838
314.749	1059.474
314.154	1090.145
313.774	1106.803
313.407	1123.921
312.385	1162.968
311.892	1180.036
311.509	1195.056
311.109	1213.076
310.702	1227.999
310.218	1248.816
309.980	1260.594
309.750	1272.578
309.567	1284.656
309.333	1302.532
309.155	1316.694
308.788	1357.157
308.717	1366.313
308.671	1375.497
308.556	1393.365
308.471	1414.439
308.388	1426.464
308.269	1444.599
308.219	1459.809
308.136	1475.006

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 2 of 6

Horizontal Scale = 1:1000, Vertical Scale = 1:100

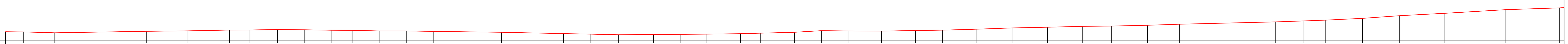
HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 3 of 6

Horizontal Scale = 1:1000,Vertical Scale = 1:100

Level Datum =306.000



MCL1 LEVELS	Chainage
306.427	2231.509
306.386	2246.487
306.457	2289.981
306.478	2309.805
306.517	2329.528
306.521	2339.304
306.541	2352.346
306.531	2365.347
306.509	2378.216
306.503	2387.836
306.473	2400.702
306.475	2413.564
306.454	2426.358
306.413	2458.922
306.349	2488.320
306.321	2501.348
306.292	2514.582
306.300	2531.114
306.314	2543.792
306.322	2556.505
306.344	2572.461
306.367	2582.105
306.411	2598.143
306.489	2610.909
306.474	2623.580
306.468	2639.523
306.498	2655.714
306.513	2668.569
306.558	2684.858
306.619	2701.576
306.651	2718.375
306.697	2735.184
306.710	2748.761
306.745	2765.898
306.797	2781.307
306.908	2826.683
306.953	2840.378
306.993	2850.763
307.075	2868.218
307.203	2885.903
307.319	2907.372
307.493	2936.362
307.579	2961.743

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 4 of 6

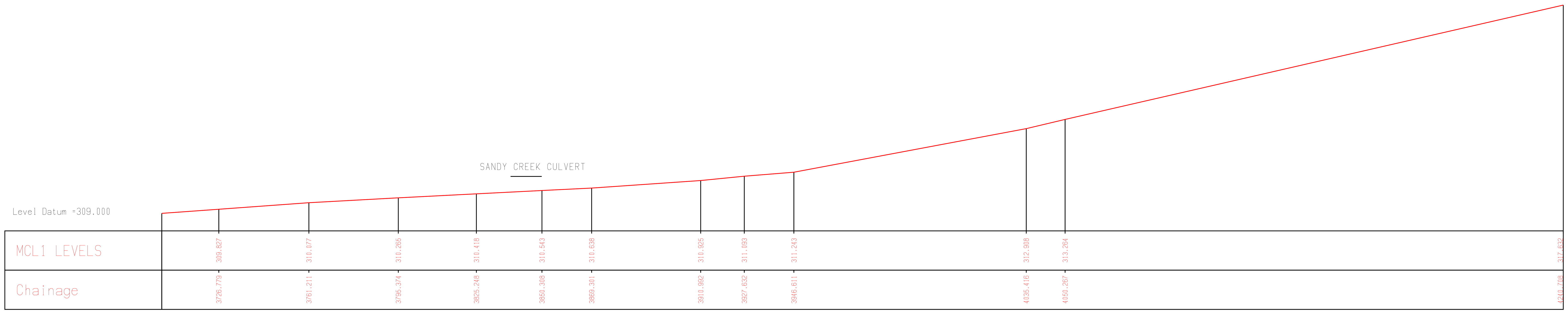
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 5 of 6

Horizontal Scale = 1:1000,Vertical Scale = 1:100

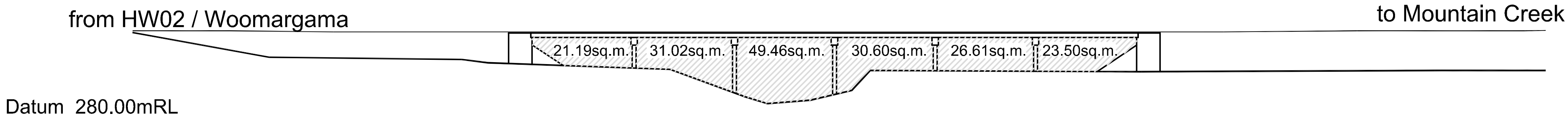


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

EXISTING HIGHWAY PROFILE
Looking Downstream 6 of 6

Horizontal Scale = 1:1000, Vertical Scale = 1:100



Total area under bridge: 182.38 sq.m.

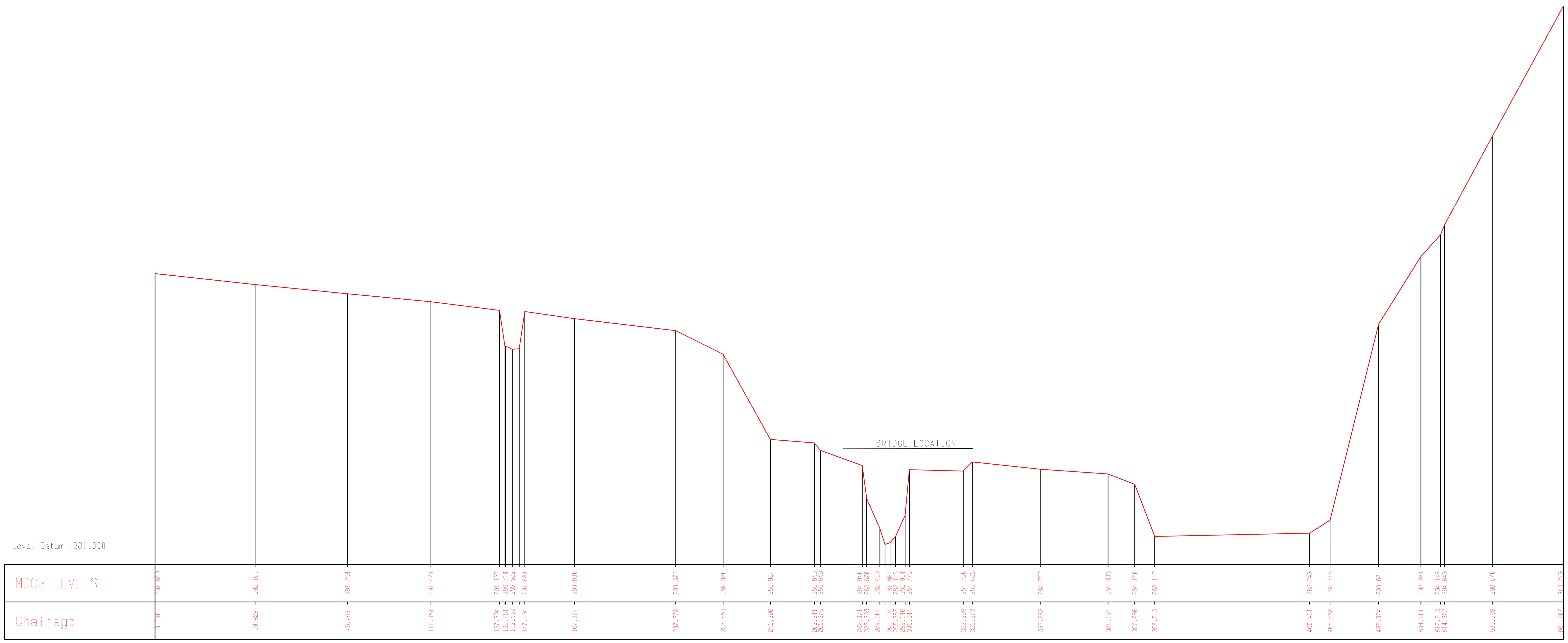
Fairbain Road, Woomargama - Bridge over Woomargama Creek

Looking Downstream

Natural Scale.

SURVEY SKETCH PURPOSE: FAIRBAIN BRIDGE	PROJECT: HW02 HUME HIGHWAY WOOMARGAMA BYPASS SURVEYS FOR FLOOD STUDY	SURVEY REF No: DATE: Oct. 2007 DRAWN BY: Paul Ogden DRAWING FILE No:	RTA

PLOT REF: SURVEY SKETCH A4L.DWG



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

FAIRBAIN RD DOWNSTREAM PROFILE
Looking Downstream 1 of 1

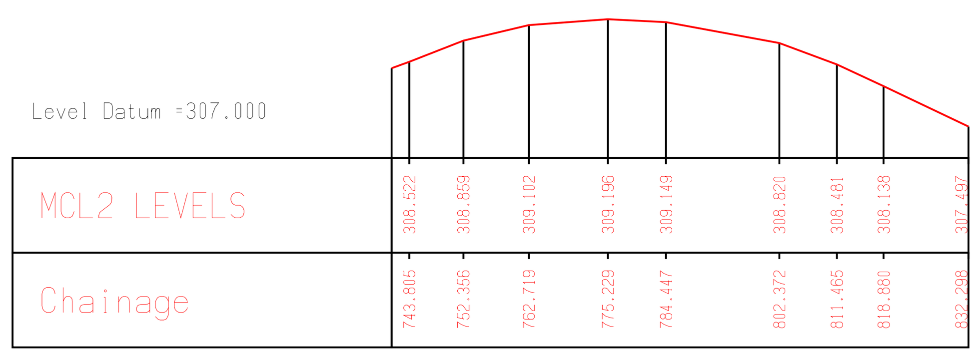
Horizontal Scale = 1:1000,Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

FAIRBAIN ROAD PROFILE
Looking Downstream 1 of 2

Horizontal Scale = 1:1000, Vertical Scale = 1:100

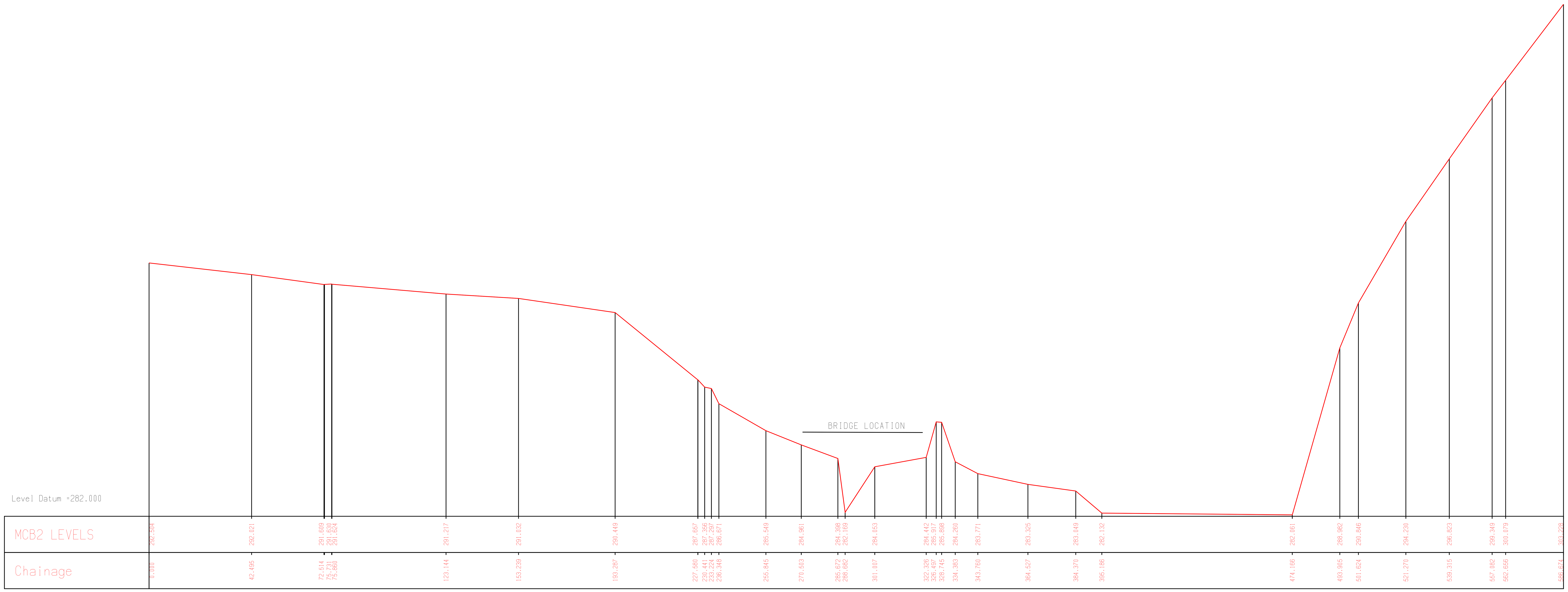


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

FAIRBAIN ROAD PROFILE
Looking Downstream   2 of 2

Horizontal Scale = 1:1000,Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

FAIRBAIN RD UPSTREAM PROFILE
Looking Downstream 1 of 1

Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'A' PROFILE
Looking Downstream 1 of 4

Horizontal Scale = 1:1000,Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'A' PROFILE
Looking Downstream 2 of 4

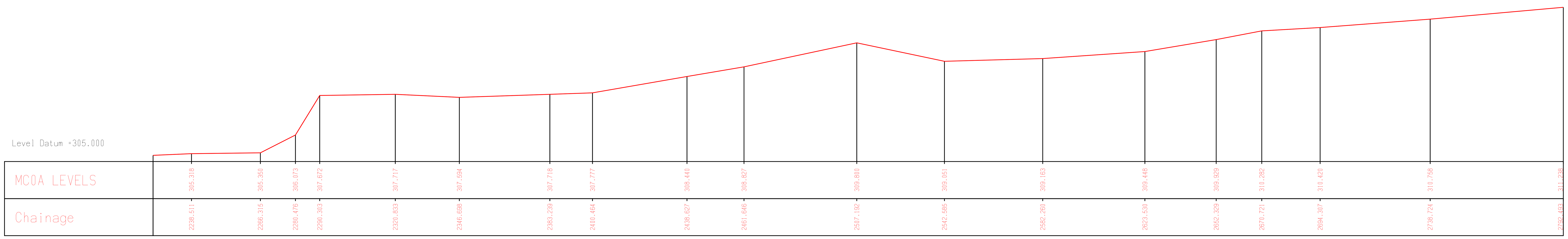
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION "A" PROFILE
Looking Downstream 3 of 4

Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'A' PROFILE
Looking Downstream 4 of 4

Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'B' PROFILE
Looking Downstream 1 of 3

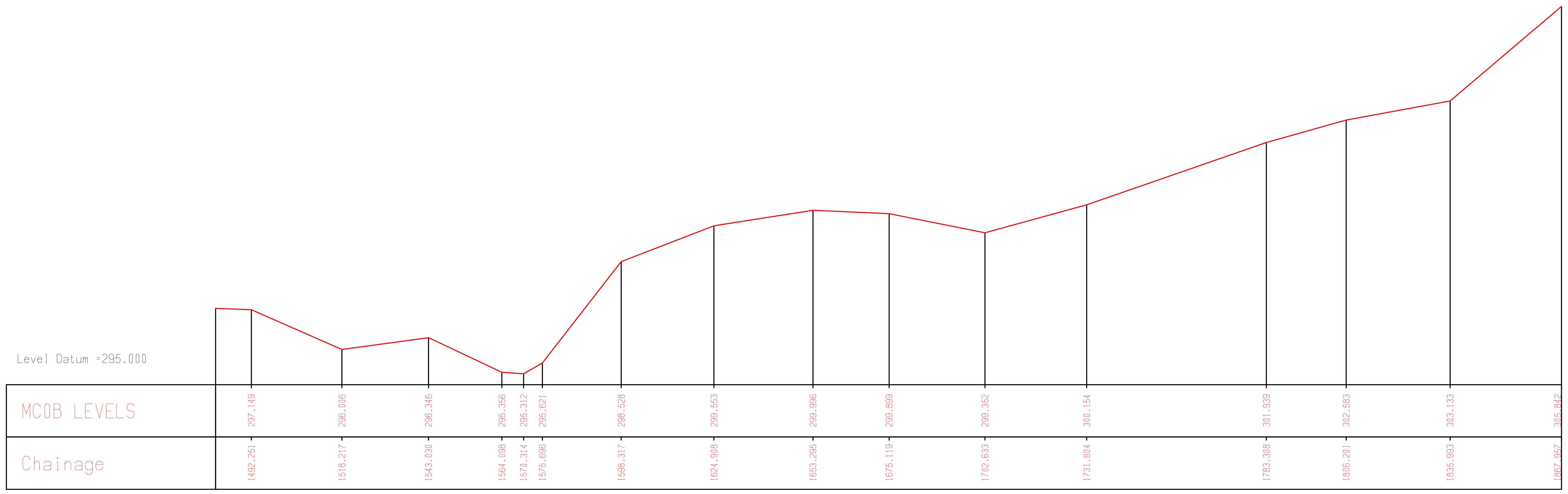
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'B' PROFILE
Looking Downstream 2 of 3

Horizontal Scale = 1:1000, Vertical Scale = 1:100

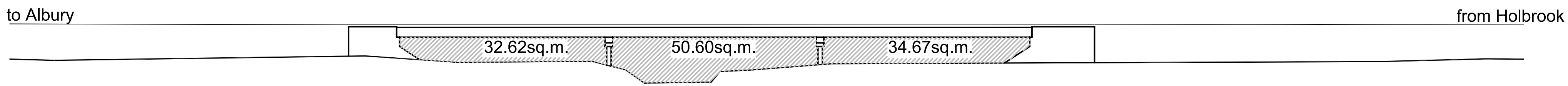


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

OPTION 'B' PROFILE
Looking Downstream 3 of 3

Horizontal Scale = 1:1000,Vertical Scale = 1:100



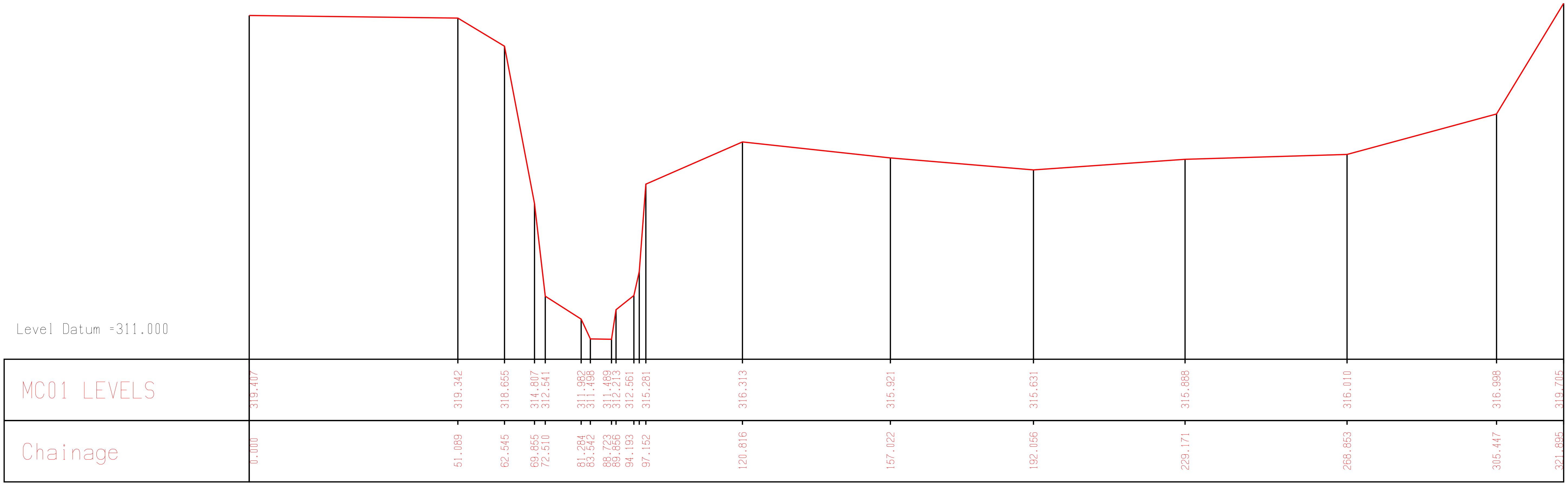
Datum 300.00RL

Total area under bridge: 117.89 sq.m.

HW02 Hume Highway - Bridge over Woomargama Creek
Looking Downstream
Natural Scale.

SURVEY SKETCH PURPOSE: WOOMARGAMA BRIDGE	PROJECT: HW02 HUME HIGHWAY WOOMARGAMA BYPASS SURVEYS FOR FLOOD STUDY	SURVEY REF No: DATE: Oct.2007 DRAWN BY: Paul Ogden DRAWING FILE No:	RTA

PLOT REF: SURVEY SKETCH A4L.DWG

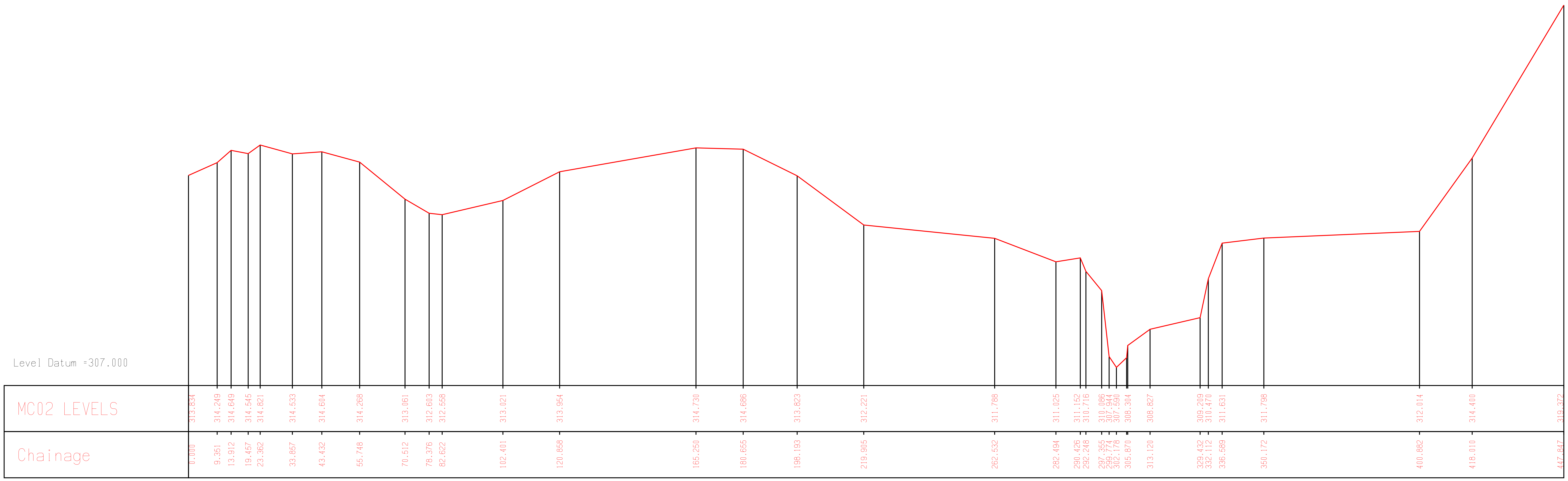


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S01
Looking Downstream

Horizontal Scale = 1:1000, Vertical Scale = 1:100 at A3

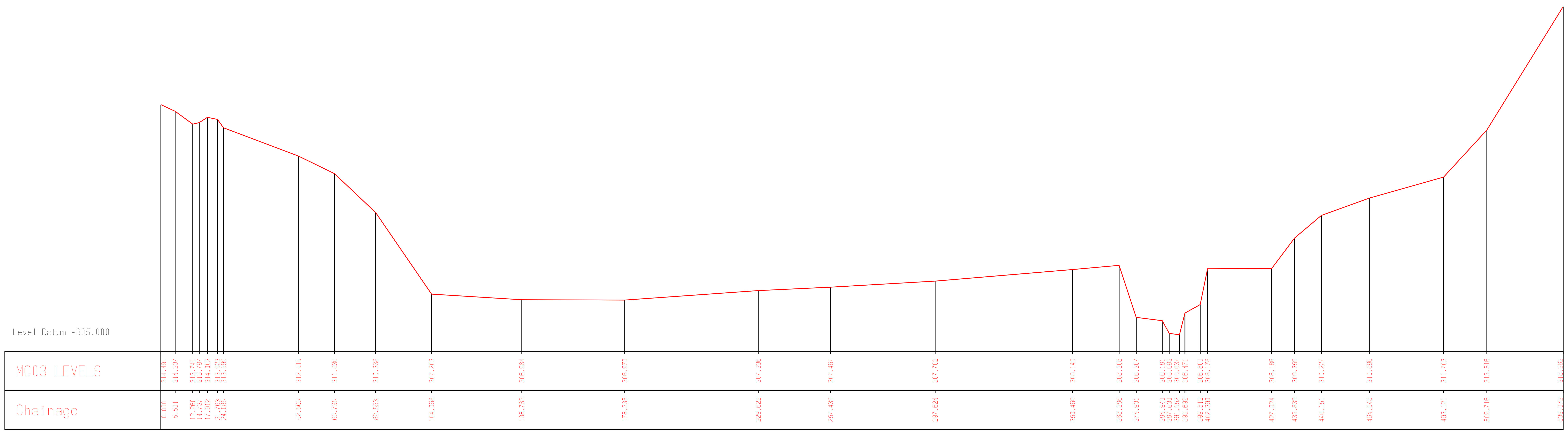


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S02
Looking Downstream
----

at A2
Horizontal Scale = 1:1000, Vertical Scale = 1:100

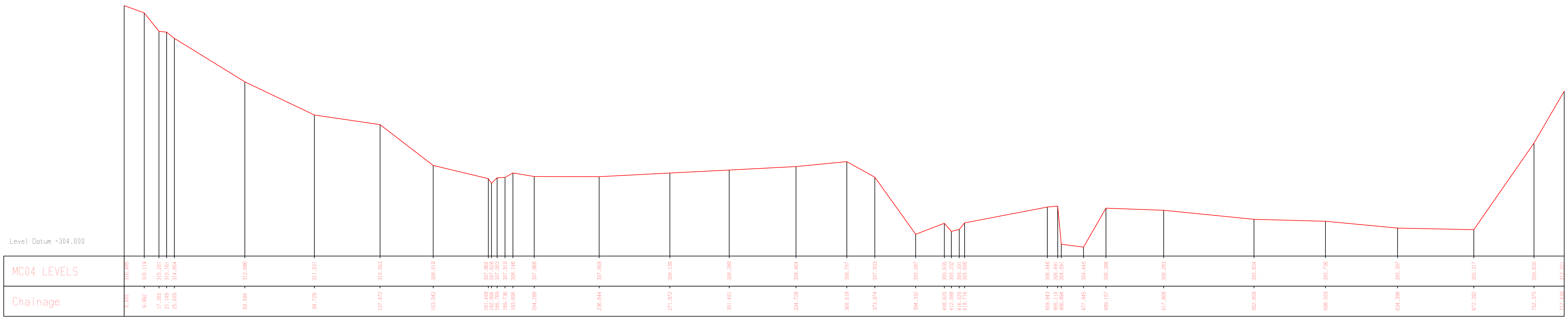


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S03
Looking Downstream

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100



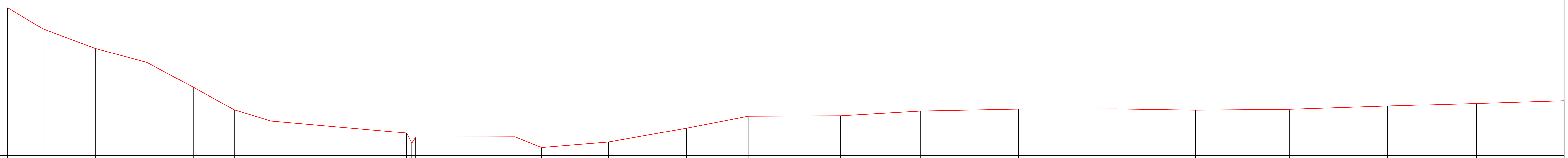
HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S04
Looking Downstream
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

Level Datum +306.000



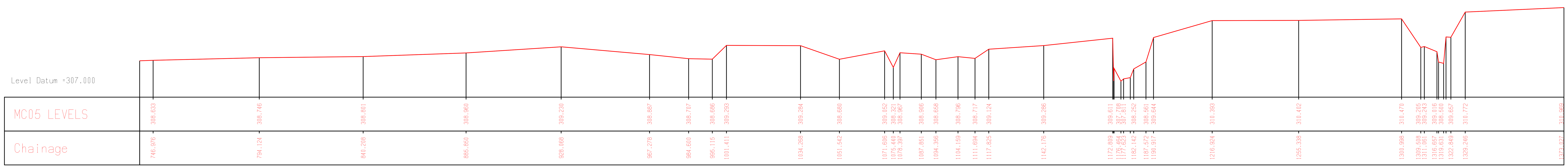
MC05 LEVELS	313.056	312.039	311.109	310.441	309.264	308.177	307.643	307.069	306.873	306.889	306.380	306.640	307.305	307.873	307.893	308.119	308.212	308.218	308.161	308.202	308.358	308.480
Chainage	0.000	16.904	41.745	66.361	88.390	107.942	125.445	189.962	194.283	241.604	254.202	286.089	323.290	352.612	396.675	434.510	481.186	527.717	565.573	610.386	656.863	699.422

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S05
Looking Downstream 1 of 2
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S05
Looking Downstream 2 of 2

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

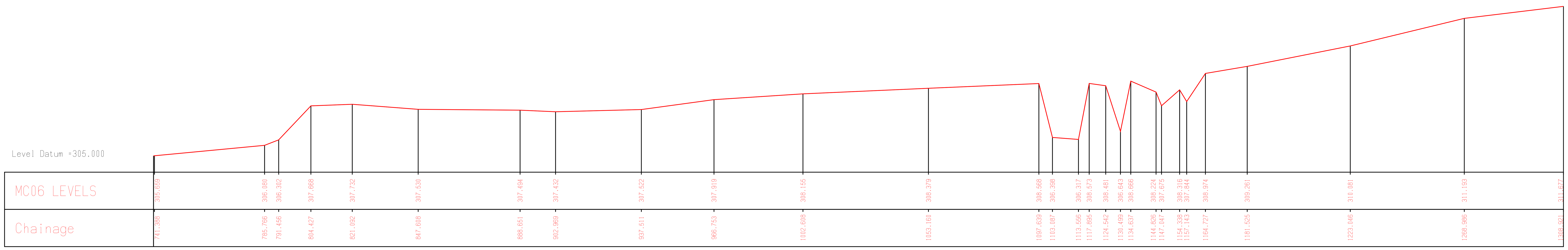
HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S06
Looking Downstream 1 of 2

----

at A1
Horizontal Scale = 1:1000,Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

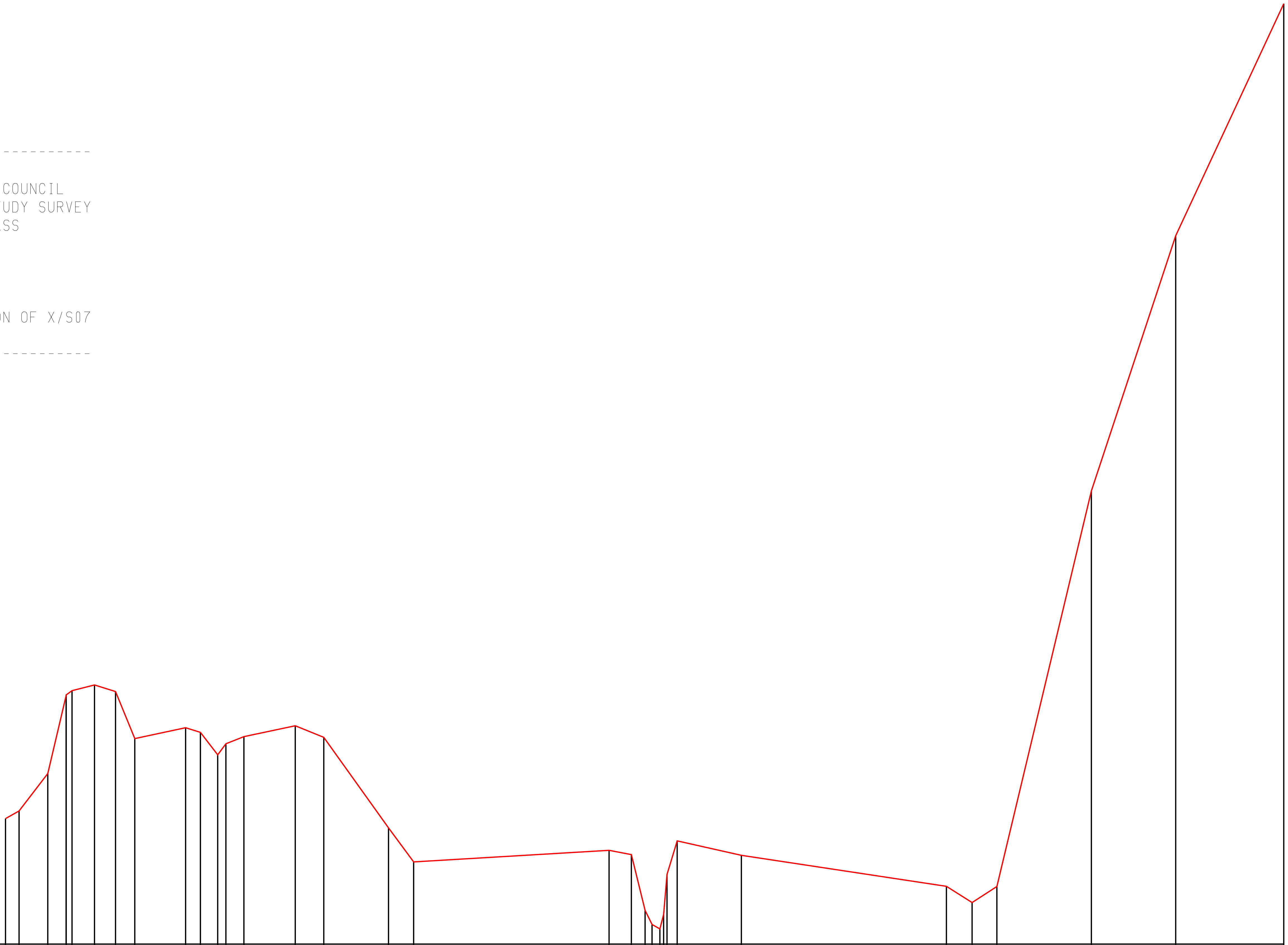
LONGITUDINAL SECTION OF X/S06
Looking Downstream 2 of 2
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S07
Looking Downstream



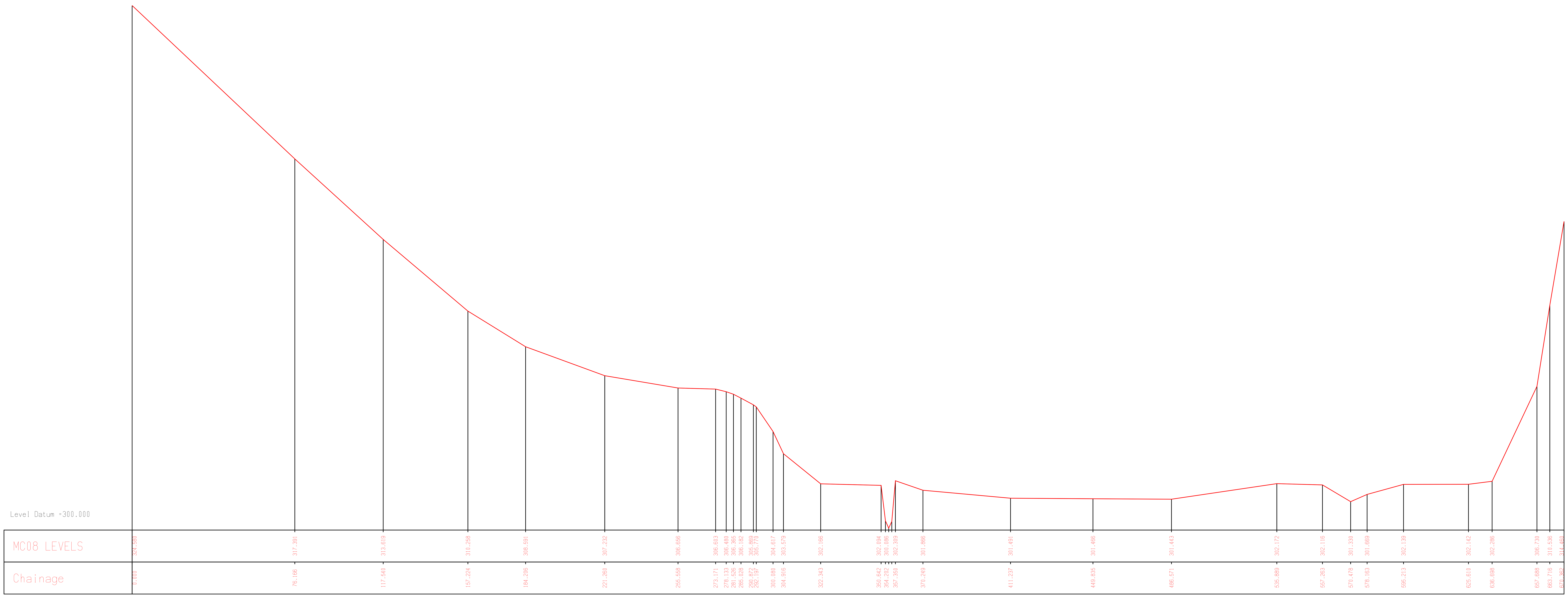
Level Datum =302.000

MC07 LEVELS	305.173	306.063	307.923	308.039	308.174	308.018	306.898	307.157	307.044	306.512
Chainage	3.236	10.056	14.424	15.841	21.210	26.185	30.802	42.893	46.416	50.525

MC07 LEVELS	306.775	306.942	307.204	306.927	304.769	303.958	304.235	304.132	302.467	302.709
Chainage	52.509	56.797	68.999	75.828	91.242	97.205	143.758	149.068	154.011	156.751

MC07 LEVELS	304.459	304.115	303.374	302.991	303.372	312.799	318.881	324.413
Chainage	159.983	175.259	224.119	230.218	236.144	258.634	278.750	304.457

at A3
Horizontal Scale = 1:1000,Vertical Scale = 1:100



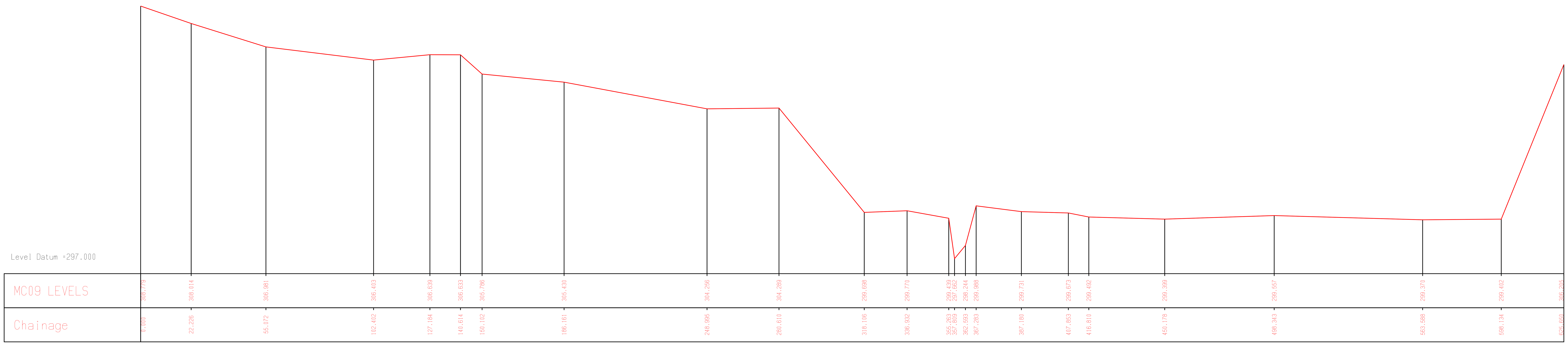
HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S08
Looking Downstream

---

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S09
Looking Downstream
----

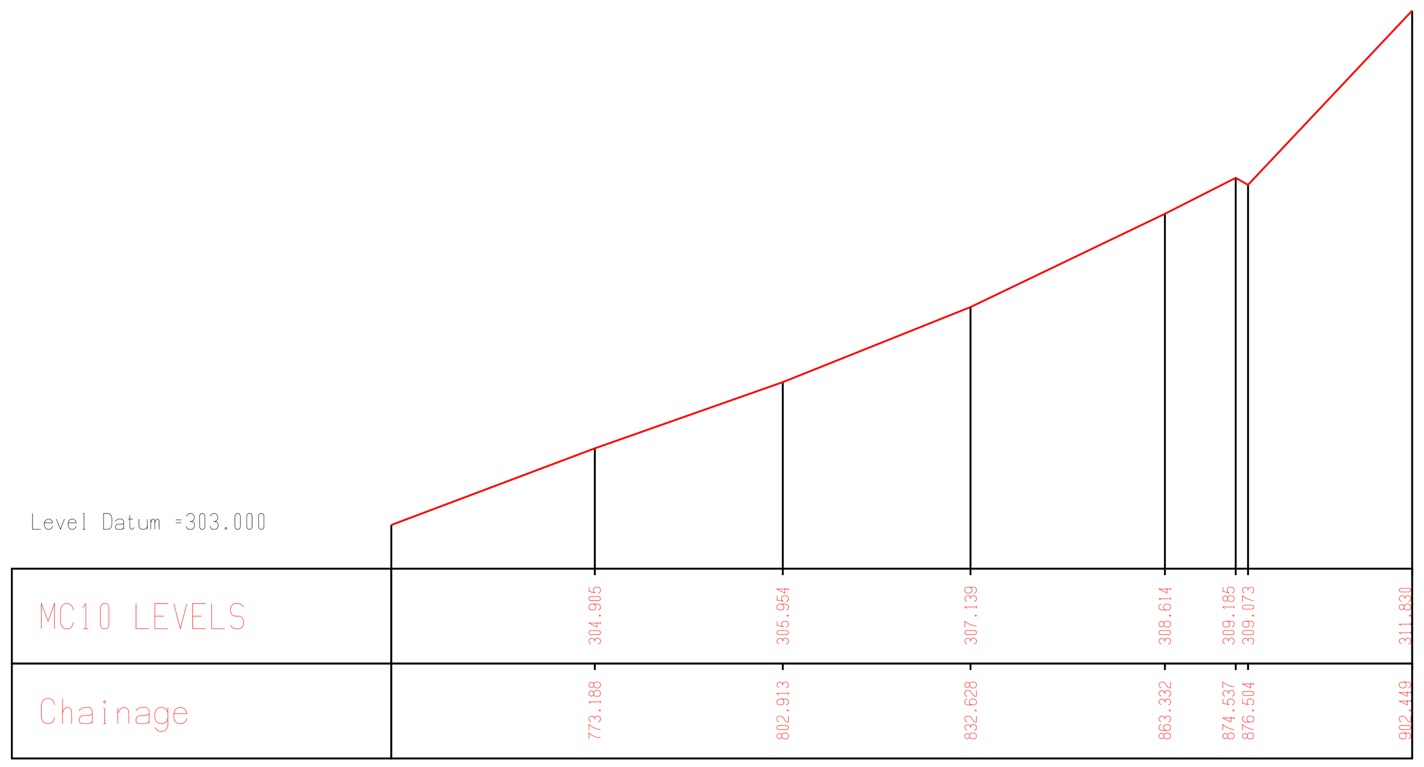
at A1
Horizontal Scale = 1:1000,Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S10
Looking Downstream 1 of 2
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

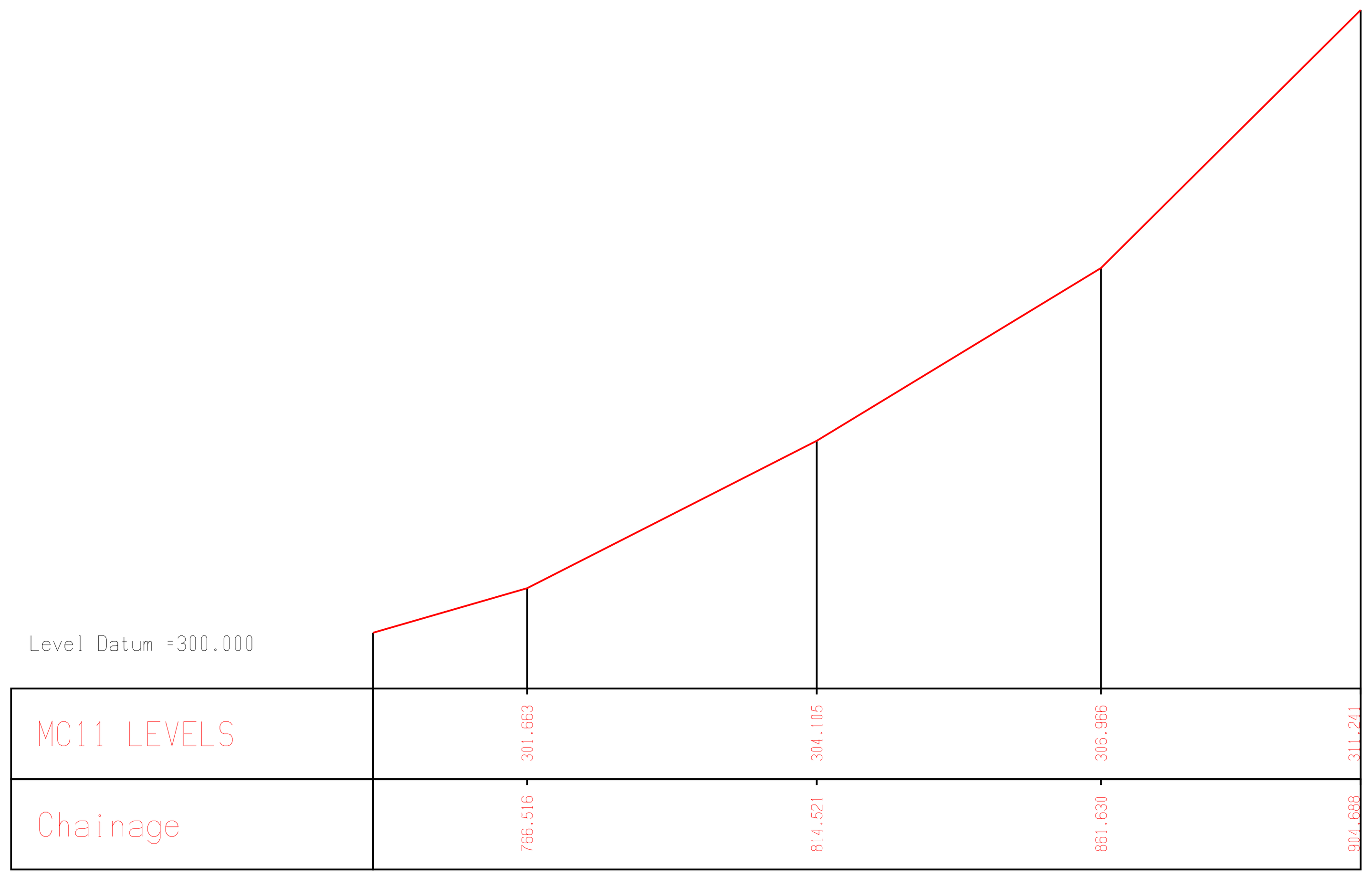


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S10
Looking Downstream 2 of 2

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S11
Looking Downstream 2 of 2
----

at A1
Horizontal Scale = 1:1000,Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S11
Looking Downstream 1 of 2

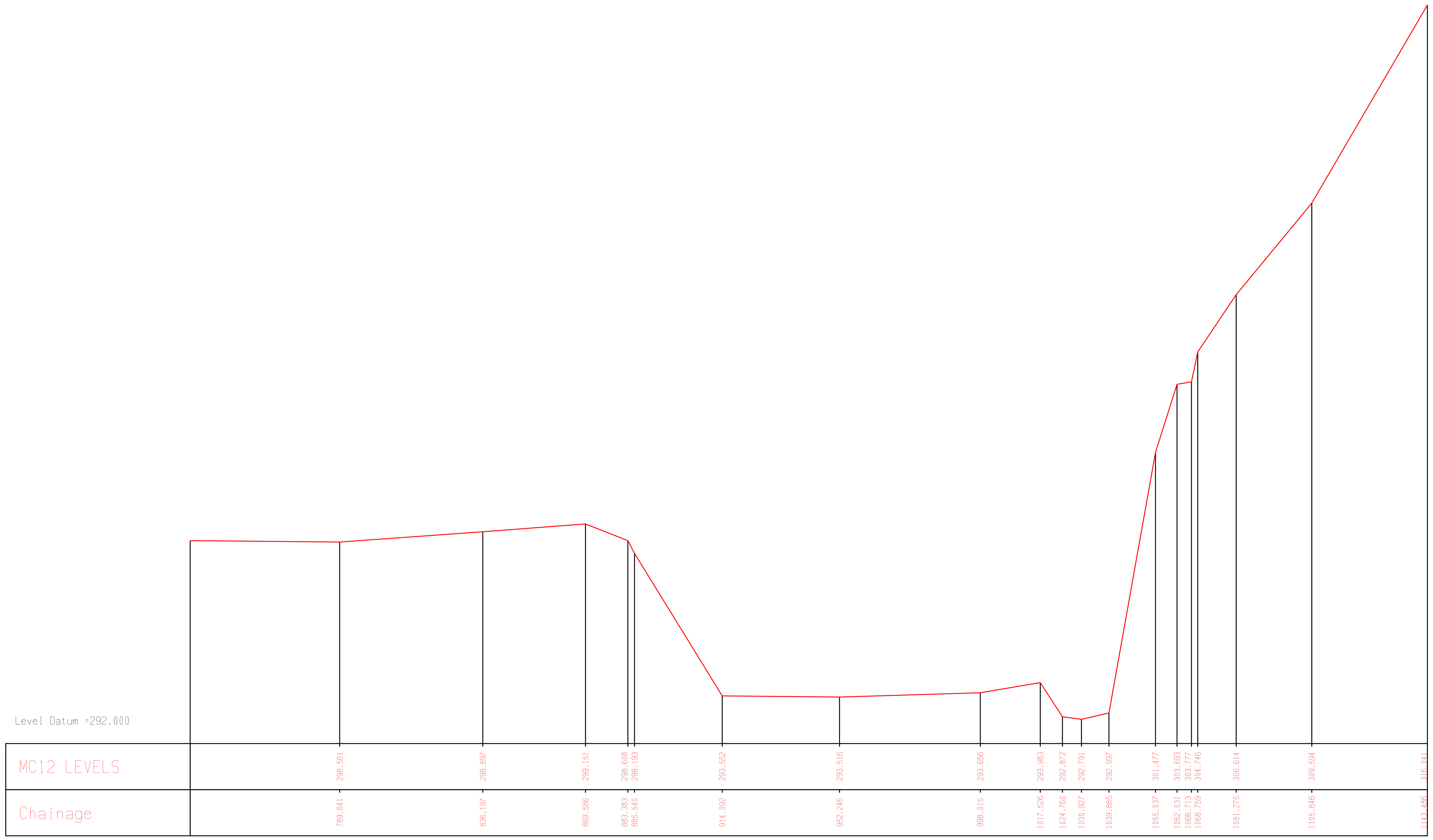
at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S12
Looking Downstream 1 of 2
----

at A1
Horizontal Scale = 1:1000,Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S12
Looking Downstream   2 of 2
----

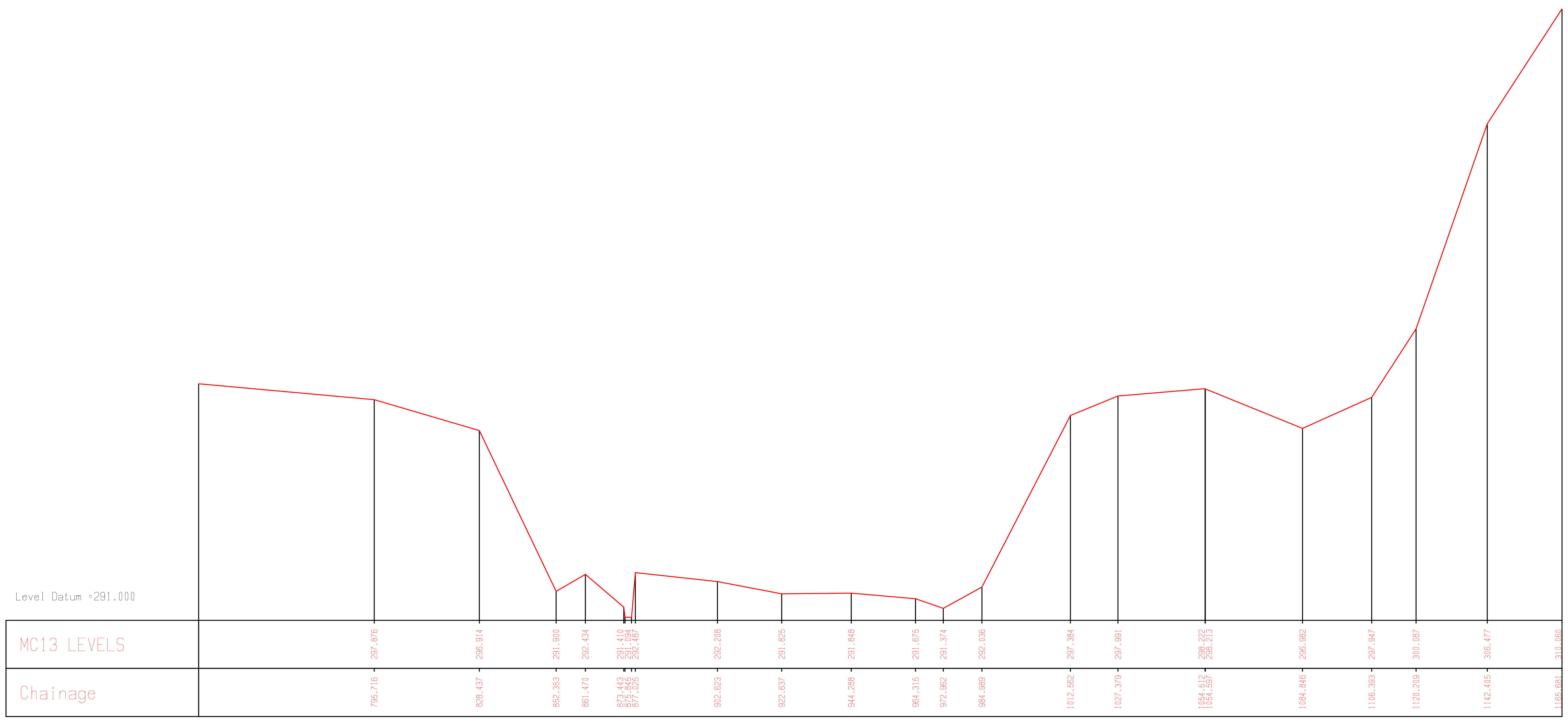
at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S13
Looking Downstream 1 of 2
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S13
Looking Downstream 2 of 2
----

at A1
Horizontal Scale = 1:1000, Vertical Scale = 1:100

Level Datum =293.000

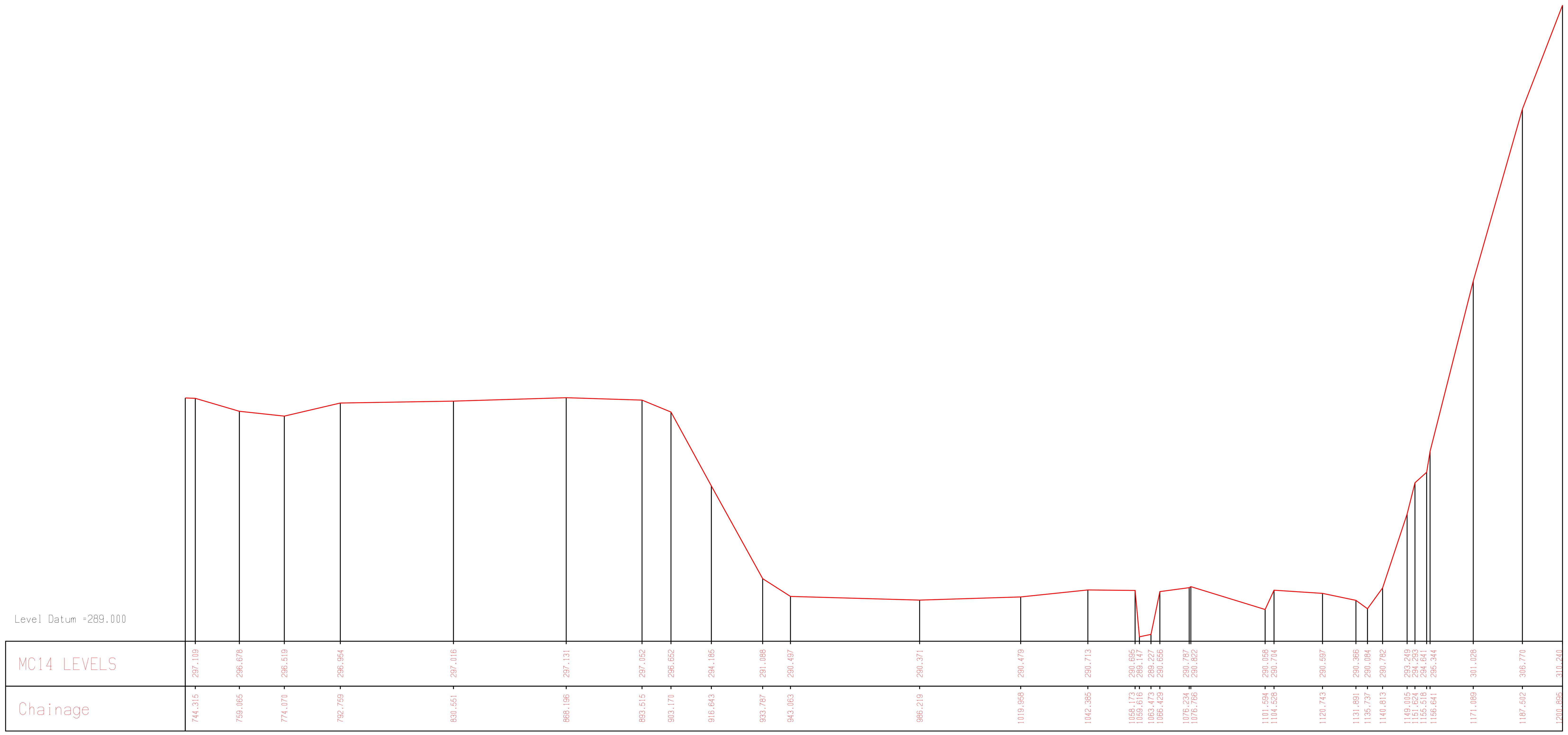
Chainage	MC14 LEVELS
0.000	310.656
46.027	307.221
94.767	303.575
143.917	300.777
192.518	298.720
239.907	297.023
280.178	296.045
312.897	295.132
318.252	294.561
321.719	294.555
323.093	294.725
329.279	295.070
336.862	295.104
339.907	295.383
342.832	295.149
346.524	295.721
354.925	295.894
360.164	295.783
362.967	296.022
381.547	296.113
415.980	295.593
435.645	294.585
447.253	293.775
452.921	293.618
460.654	294.276
482.893	296.156
503.538	296.756
537.321	297.052
558.602	296.870
608.489	296.584
656.950	297.091
705.737	297.273

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S14
Looking Downstream 1 of 2

Horizontal Scale = 1:1000, Vertical Scale = 1:100

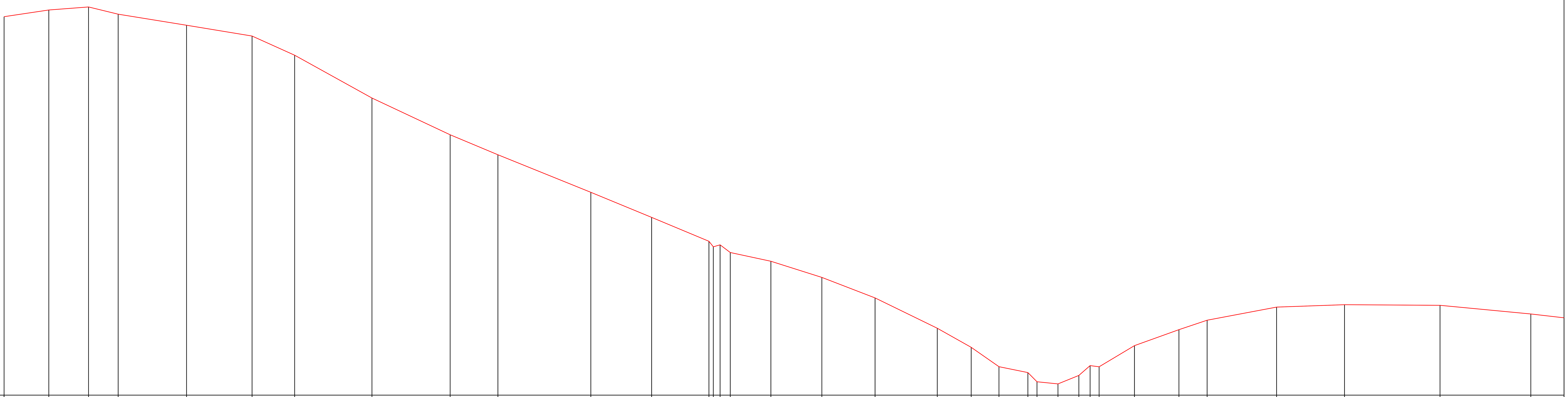


HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S14
Looking Downstream 2 of 2

Horizontal Scale = 1:1000, Vertical Scale = 1:100



Level Datum =291.000

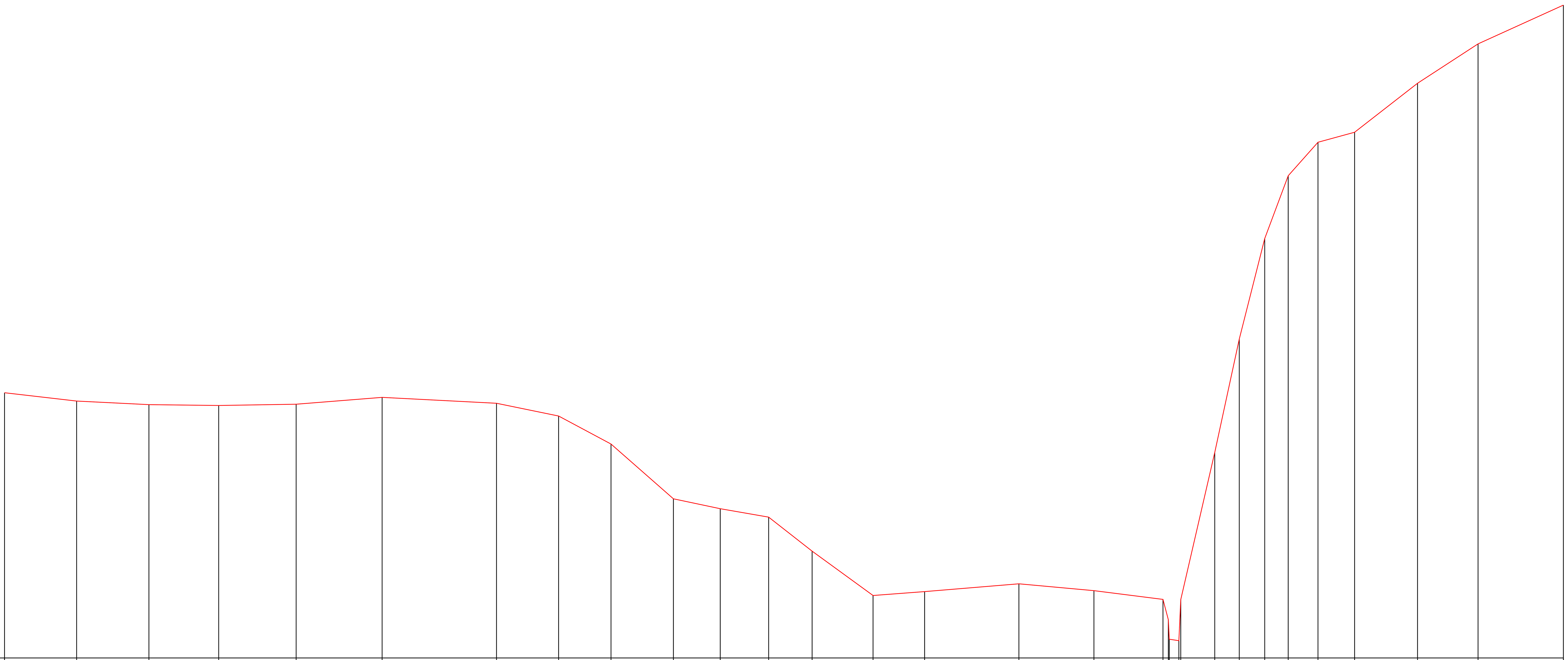
Chainage	MC15 LEVELS
0.000	308.994
21.264	309.313
40.138	309.455
54.186	309.111
86.684	308.585
117.822	308.071
138.020	307.163
174.773	305.125
211.896	303.379
234.574	302.429
278.721	300.644
307.612	299.452
334.833	298.318
336.897	298.053
340.131	298.148
344.945	297.782
364.262	297.368
388.451	296.599
413.724	295.625
443.312	294.182
459.416	293.275
472.592	292.353
486.341	292.073
490.670	291.638
500.602	291.537
510.564	291.940
515.868	292.405
520.161	292.348
536.965	293.356
558.063	294.115
571.479	294.565
604.453	295.188
636.745	295.301
682.117	295.272
725.224	294.859

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S15
Looking Downstream   1 of 2

Horizontal Scale = 1:1000,Vertical Scale = 1:100



Level Datum =284.000

Chainage	MC15 LEVELS
770.041	294.345
799.195	294.199
827.280	294.165
858.501	294.215
893.158	294.490
939.224	294.253
964.250	293.741
985.356	292.614
1010.537	290.408
1029.394	290.010
1048.892	289.672
1066.387	288.299
1090.970	286.515
1111.724	286.671
1149.727	286.984
1179.974	286.712
1207.772	286.357
1210.339	284.756
1214.168	284.696
1214.937	286.351
1228.619	292.274
1238.519	296.837
1248.774	300.885
1258.223	303.413
1270.230	304.760
1285.010	305.164
1310.341	307.137
1334.739	308.721
1369.103	310.281

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S15
Looking Downstream 2 of 2

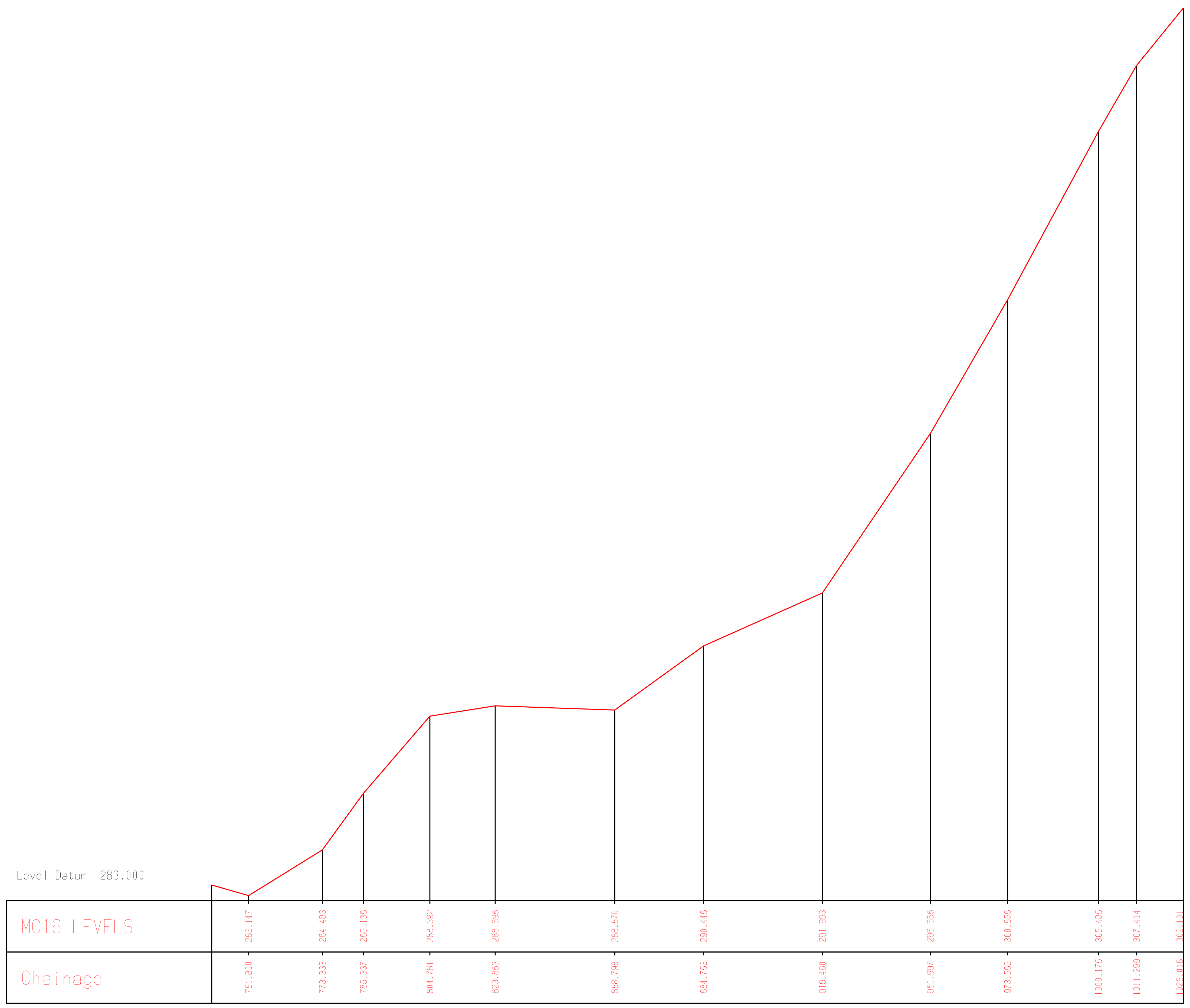
Horizontal Scale = 1:1000, Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S16
Looking Downstream 1 of 2

Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S16
Looking Downstream   2 of 2

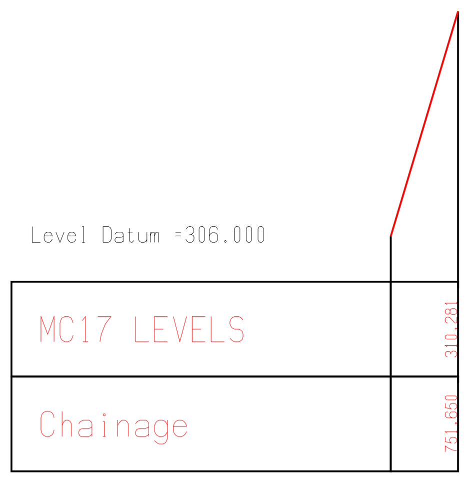
Horizontal Scale = 1:1000,Vertical Scale = 1:100

HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S17
Looking Downstream 1 of 2

Horizontal Scale = 1:1000, Vertical Scale = 1:100



HW02 HUME HIGHWAY
GREATER HUME SHIRE COUNCIL
WOOMARGAMA FLOOD STUDY SURVEY
FOR WOOMARGAMA BYPASS

Client: Ray Tester

LONGITUDINAL SECTION OF X/S17
Looking Downstream 2 of 2

Horizontal Scale = 1:1000,Vertical Scale = 1:100

Appendix C

Digital Copies of Models

MEMORANDUM

Date:	19 June 2008
To:	RTA, Ray Tester
Copy :	Mary Diab
From:	Tami Norton
Job no:	2116784D/MO_4324
Re:	Woomargama Bypass, HW02 Hume Highway – Proposed Bridge modeling for Options A & B Summary Results – TUFLOW Modelling

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Introduction

The RTA requested that PB perform detailed 2-Dimensional analysis of the Hume Highway, Bypass Options A2 creek crossings of Wilson Creek and Mountain Creek and the Option B crossing of Mountain Creek in the vicinity of Woomargama. The modelling is necessary for the cost analysis for this option and structures are a crucial component of the costing.

Background

PB was originally contracted to perform Mountain Creek Flood Study that analysed the existing conditions flooding of Mountain Creek using surveyed cross-sections provided by the RTA (August through September 2007). An XP-RAFTS hydrologic model was developed to provide inflows for the Mountain Creek MIKE11 hydraulic model. PB prepared an existing conditions Flood Study report that included the water levels at the cross-section locations and provided existing flows and velocities at the proposed Options A, B and C locations.

PB was subsequently asked by the RTA to provide estimated bridge opening lengths for two of the proposed bypass Options A and B (Option C has been eliminated as an option). PB provided estimated bridge opening lengths based on non-detailed analyses methods, i.e. top widths estimated from the existing conditions MIKE11 model. These estimated bridge openings were then analysed in MIKE11 by including an approximate bridge cross-section in the model at the proposed bypass crossing of Mountain Creek. An estimate of 150m for the bridge opening was reported to the RTA at the confluence of Wilson and Mountain Creeks and the Mountain Creek crossings for both Options A and B.

PB was then asked to provide a more detailed analysis to more accurately estimate the Option A bridge openings as it has become essential to the cost estimate for the Option. Additionally, PB was to incorporate a second bridge opening to address the natural springs located along the Option A alignment. It was agreed that with the limited survey data a HEC-RAS model would be a better tool for modelling the proposed bridge scenarios than MIKE11. PB then developed a HEC-RAS model as described in the previous memo, *Woomargama Bypass, HW02 Hume Highway – Proposed Bridge modelling for Option A Summary Results*.

The findings from these initial investigations were limited by the amount of survey data available to define Mountain Creek and Wilson Creek. The 1-dimensional models were therefore not able to adequately simulate flood behaviour in the Mountain Creek floodplain. It was identified that a 2-dimensional model would provide a better representation of the floodplain behaviour during critical design flood events.

Adopted Approach

To better define the behaviour of flooding a TUFLOW model for the exiting and proposed scenarios for the Mountain/Wilson Creek floodplain was developed. The proposed scenarios included Options A and B, with the Hume Highway crossing of both Mountain and Wilson Creeks. The objectives of this modelling are:

- Establish existing conditions water levels and flooding extends to use as base conditions to compare with the proposed conditions.
- Identify structures and properties that may be impacted by flooding.
- Determine the minimum bridge length openings required to meet the design criteria regarding afflux and scour.

It is important to note that the TUFLOW modelling performed for this project was developed based on limited DTM and survey data. Break line inverts were interpolated from known data points, but due to the distance between the points, the accuracy of the interpolated portions of the DTM is not suitable for use for any other purposes other than for estimating required bridge lengths for the RTA's costing analysis. This model is not intended for use for detailed or final design.

Design Criteria

The design criteria outlined in a memo distributed by SKM on 13/05/2008 are as follows:

The project works must be designed to take into account of the hydraulic performance so that inundation levels upstream and downstream of the project boundary are not increased in the 100 year ARI event by any more than the following:

- *Rural land without buildings or sensitive structures - 0.25m.*
- *Rural land where buildings or sensitive structures are already below the 100 year ARI flood level - 0.05m.*
- *Any land where buildings or sensitive structures previously not inundated in the 100 year ARI event would be at increased risk of inundation (including allowance for afflux) - 0.00m.*

Watercourses must have impacts assessed for a 50 year and 100 year Average Recurrence Intervals (ARI) and the Probable Maximum Flood (PMF). The following minimum Average Recurrence Intervals are to be applied to the transverse (cross) drainage design:

- *Culverts where surcharge is allowable - 50 years*
- *Culverts where surcharge is undesirable - 100 years*
- *Major storm event check for no property damage - 100 years*
- *Major storm event check for no structure damage - 2000 years.*

Scour protection shall be designed for all areas susceptible to scouring or erosion including batters and bridge abutments. Scour protection must be designed for a minimum maintenance free life of 50 years.

Revised XP-RAFTS Model

The existing conditions XP-RAFTS model developed as part of the Mountain Creek Flood Study did not include a node at the upstream end of the existing Hume Highway crossing of Wilson Creek. To provide a correct inflow at this point in the TUFLOW model, the XP-RAFTS model was updated to include a node at this location. Inflows input into the TUFLOW model are listed below in Table 1.

Table 1 TUFLOW Inflows

Node	Description	100-yr ARI Q (m^3/s)
u/s bridge (Mountain Creek)	Contributing u/s existing Hume Hwy bridge, Mountain Creek	254
u/s culvert (Wilson Creek)	Contributing u/s existing Hume Hwy culvert, Wilson Creek	112
WC3A (Wilson Creek)	Lateral inflow for contribution	21

	area between the Wilson/Mountain Creek confluence and d/s of Hume Hwy crossing of Wilson Creek	
MC5 (Mountain Creek)	Lateral inflow for contributing area between just d/s of Option B alignment crossing of Mountain Creek and the Wilson/Mountain Creek confluence	55

Hydraulic Modelling

The existing conditions and several scenarios for Options A and B were modelled as described in the following sections. All scenarios were run for the 100-yr ARI storm event.

DTM Data

SKM provided PB with a 2m x 2m grid to use for the TUFLOW modelling. Upon inspection of the grid data, it was discovered that the grid was inadequate for the purposes of the modelling. PB requested the raw DTM data from SKM and determined that the data did not include break lines or detail to define the top of bank or other floodplain features within the Mountain Creek floodplain. PB incorporated the existing RTA survey points and created break lines to define the flow paths within the floodplain based on aerial photo inspection and limited contour data. Given the level of accuracy of the DTM data and to save on computational time, a 5m x 5m grid was developed for TUFLOW modelling.

TUFLOW modelling

Model Extents

The TUFLOW modelling encompasses the area shown in Figure 1. Houses (or other buildings) located in the vicinity of the Mountain and Wilson Creek floodplains have also been identified from inspection of the aerial photography.

Figure 1 TUFLOW Model Extent showing Option A and B Alignments & Structures (model extent shown in orange)

Existing Conditions

The existing conditions model includes the existing Mountain Creek bridge and the existing culvert crossing of Wilson Creek. The Mountain Creek bridge is modelled as a flow constriction. The Wilson creek culvert is defined as a 1-D structure link to the 2D- network.

Proposed Bridge Scenarios

Option A

In addition to the existing Hume Highway bridge crossing, Option A consists of several proposed bridges that are modelled as flow constrictions:

- Wilson Creek crossing – existing 1-D culvert removed and replaced by flow constrictions
- Confluence of Wilson and Mountain Creeks
- Natural Spring crossing
- Mountain Creek crossing.

SKM's MX design file (received 13/05/08) was used to locate the Option A alignment. The z-point elevations were adjusted along the alignment for each scenario to represent the proposed roadway embankment.

Four (4) bridge opening scenarios were modelled for Option A. Scenario 1 models one long bridge that spans Mountain Creek and the natural spring. Scenarios 2 through 4 consist of varying bridge openings for the Mountain Creek and Natural spring crossings. The bridge widths for the confluence of Wilson and Mountain Creeks and the Wilson Creek crossing were set at the widths shown in SKM's MX design file for all four scenarios. Table 2 summarises the opening sizes used for each scenario:

Table 2 Option A – Modelled Bridge Lengths (NB= northbound, SB=south bound)

Scenario	Mountain Creek	Natural Spring	Confluence of Wilson and Mountain Creek	Wilson Creek	Total Bridge Length
1	SB - 670 m	SB - 200 m	SB - 220 m	SB - 65 m	2,015 m
	NB - 740 m	NB - 200 m	NB - 240 m	NB - 80 m	
2	SB - 240 m	SB - 250 m	SB - 220 m	SB - 65 m	1,605 m
	NB - 260 m	NB - 250 m	NB - 240 m	NB - 80 m	
3	SB - 200 m	SB - 200 m	SB - 220 m	SB - 65 m	1,420 m
	NB - 215 m	NB - 200 m	NB - 240 m	NB - 80 m	
4	SB - 230 m	SB - 200 m	SB - 220 m	SB - 65 m	1,495 m
	NB - 260 m	NB - 200 m	NB - 240 m	NB - 80 m	

Option B

Option B consists of the existing Hume Highway bridge crossing of Mountain Creek, the existing culvert crossing of Wilson Creek, and the proposed bridge crossing of Mountain Creek. The proposed bridge crossing of Mountain Creek is modelled as a flow constriction. SKM's MX design file (received 26/05/08) was used to locate the Option B alignment. The z-point elevations were adjusted along the alignment for each scenario to represent the proposed roadway embankment. Two (2) bridge opening scenarios were modelled for Option B. Table 3 summarises the opening sizes used for each scenario:

Table 3 Option B – Modelled Bridge Lengths

Scenario	Mountain Creek	Total Bridge Length
1	185 m	370 m
2	360 m	720 m

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TUFLOW Results

Existing Baseline Conditions

Figure 2 shows the resulting 100-yr water-depths and flood plain extents. Only three (3) of the houses (as shown in green on Figure 1) are shown to be 'wet' during the 100-yr ARI event. Table 4 summarises the resulting water levels at these houses.

Table 4 Water levels at 'wet' houses for Existing Conditions

Structure Number	100- yr Water Level (m)
"House 18"	307.9
"House 19"	307.8
"House 20"	307.8

Option A

Figures 3 through 6 show the resulting afflux impacts for each of the four bridge scenarios modelled, and are based on the 100-year ARI storm event. No structures are shown to be 'wet' for any of the scenarios. The three structures that are 'wet' for the existing conditions are located within the Option A proposed alignment footprint and are presumed to be properties that would be purchased should Option A be selected as the preferred option. Table 5 summarises the average afflux upstream of the Option A alignment for each scenario.

Table 5 Option A Scenarios – Average Afflux

Afflux (m)			
Scenario			
1	2	3	4
0.00	0.28	0.58	0.57

Option B

Figures 7 and 8 show the resulting average afflux impacts for the two bridge scenarios modelled, and are based on the 100 year ARI storm event. Only the three structures are shown to be 'wet' during the existing 100-yr ARI event are shown as 'wet' for the two proposed scenarios. However, there is no change in water levels at these structures. Table 6 summarises the average afflux for the two scenarios.

Table 6 Option B Scenarios – Average Afflux

Afflux (m)	
Scenario	
1	2
0.12	0

Conclusions

Option A - Scenario 1 meets the RTA design criteria while scenarios 2, 3 and 4 all exceed the criteria. However, scenarios 2 and 4 indicate only localised accedence of the criteria just upstream of the Option A alignment and may still be viable if the community determines that the impacts are acceptable.

Option B - Scenarios 1 and 2 were both meet the RTA criteria.

TUFLOW Figures

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