Cardno
Shaping the Future

Appendix B

Wildlife Lake Weir Concept Design

Table of Contents

List of Tables

List of Figures

Appendices

1 Introduction

Cardno has been engaged by Penrith Lakes Development Corporation (PLDC) to undertake flood modelling and concept design of flood structures at Penrith Lakes. This report focuses on Hunts Gully, and the proposed weir to connect the Wildlife Lake to the existing creek which feeds into the Nepean River. The analysis includes velocities within the flowpath, peak water level impacts and preliminary costings and sketches of selected design options.

2 Background

As part of the analysis of Hunts Gully additional SOBEK models have been created. These include:

- A preliminary 1D model to undertake initial testing
- Base 2D case, terrain supplied PLDC (091030_Two Lakes V13d_triangles.dwg, received 30/10/09).
- Multiple weir options modelled in 2D to analyse the velocities across the weir and along the flowpath.

The above 2D models all utilise a 15m grid.

In addition to these models, a detailed 5m child grid was developed and nested within the above 2D model to provide greater resolution of flows and velocities through the pinch point in Hunts Gully and to test the effectiveness of the 15m grid in this area.

3 Concept Design

The Wildlife Lake Weir is located in the far north-west corner of the site, and lies very close to the site boundary. During flood events, this flow path experiences significant flow in both directions – initially from the River to the Lake system as levels in the river rise, and secondly from the Lakes to the river as the river levels start to fall and the Lakes begin to empty.

The analysis of the Wildlife Lake Weir had a number of aims. These included:

- Minimising weir width to reduce construction costs
- Minimising weir velocities to reduce protection works
- Ensuring that no impacts extend beyond the PLDC site boundary
- Ensuring that no construction or protection is required beyond the PLDC site boundary

4 Preliminary 1D Model

A 1D model was constructed to represent Hunts Gully and the associated weir. This model provided a coarse representation, but was suitable for undertaking initial tests on various alternatives.

The options identified from the 1D model testing were then analysed in the 2D models (refer following sections).

5 Detailed 2D Model

The 2D model was used to examine the operation of the Wildlife Lake Weir in detail. The following section details the investigation into various options for The Wildlife Lake Weir.

All of the models utilised a 15m grid, and have a weir crest of 30m based on the model resolution.

5.1 Preliminary Design Scenario – v13d option 4

The preliminary design scenario is the existing current design supplied by PLDC. In the preliminary design scenario the weir at Hunts Gully is located adjacent to the site boundary and is at an RL of 14mAHD (refer Figure 1).

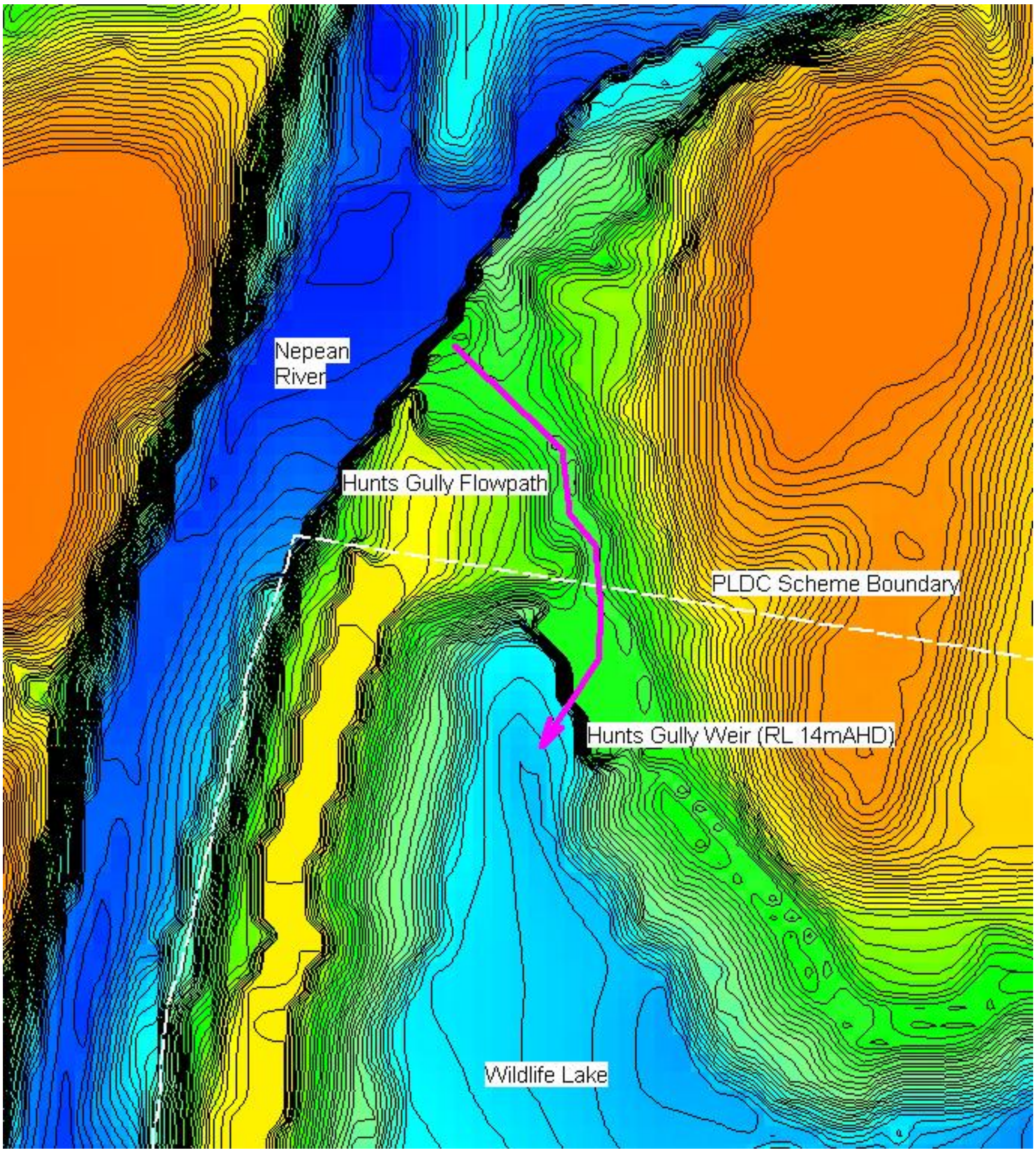


Figure 1. Preliminary Design Scenario Terrain Details

5.2 Version 1

The main control for water entering through Hunts Gully is the pinch point located near the boundary of the PLDC site. Based on initial testing in the 1D model, this pinch point was extended into the PLDC site by approximately 50 metres. The intention of this option was to attempt to move the higher velocities off Hunts property in the north and onto the PLDC site, where it can be managed by suitable protection measures.

In this option, there is effectively no weir crest. Instead, the pinch point forms the main control for the flow. The invert of the pinch point is approximately 13m AHD.

5.3 Version 2

Version 2 is based on the preliminary design scenario but raises the level of the weir crest from 14m AHD to 16m AHD.

5.4 Movement of Weir Crest

Following discussions with PLDC, the weir structure was moved 30m south, to ensure that all construction works were kept within the site boundary.

Versions 1 and 2 were run prior to this decision. They are included in the graphs and tables of this section for completeness, but are not considered to be feasible options.

When the weir was moved, it was also straightened out, so that it runs in a more east-west alignment, in order to ensure that flows are directed into the lake and not along the lake edge which would increase scour (refer **Figure 2**).

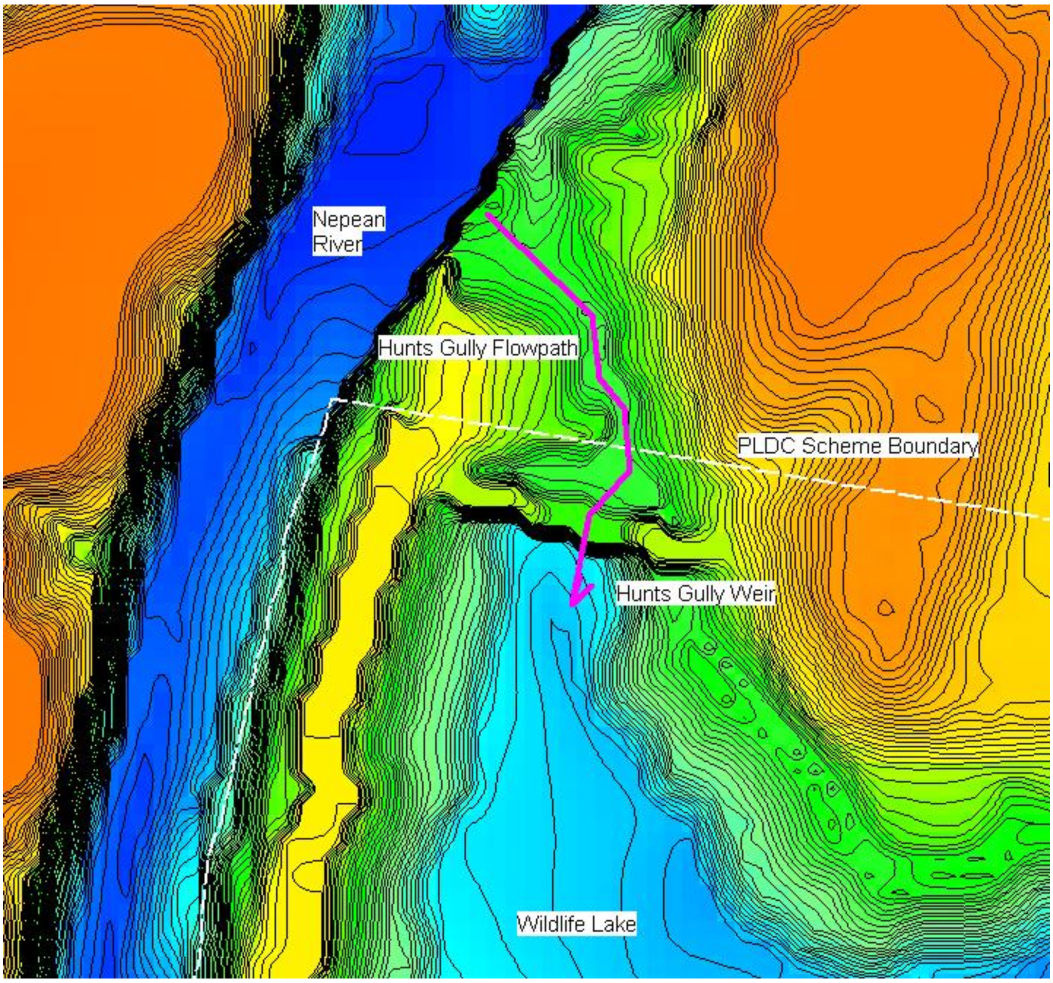


Figure 2. Proposed Location of Wildlife Lake Weir

5.5 Version 3

The first configuration of the relocated weir consists of a weir crest at 16m which runs for a width of 65m. At each end of the weir crest, the level ramps up to 18.5mAHD at a grade of 1 in 6. This 18.5mAHD level then extends until it intersects with the 18.5 contour of the design preliminary design scenario (refer **Figure 3**).

The central section at 16mAHD is designed to carry the initial high velocity flows in order to minimise the protection works required. The additional area added at 18.5mAHD represents an elevation at which point the differences in the water levels between the Wildlife Lake and Hunts Gully is relatively small, resulting in lower velocities across this area.

5.6 Version 4

In order to investigate the impact of changing the weir crest level, version 4 was constructed with the weir crest lowered from 16mAHD to 15.2mAHD. In all other respects it is identical to version 3.

5.7 Versions 5 and 6

Two additional models were created to analyse the effect of altering the weir width. In version 5, the weir width was reduced to 40m, and in version 6 it was increased to 100m. In all other respects they are identical to version 3.

Typical sections of these options are shown in **Figure 3**.

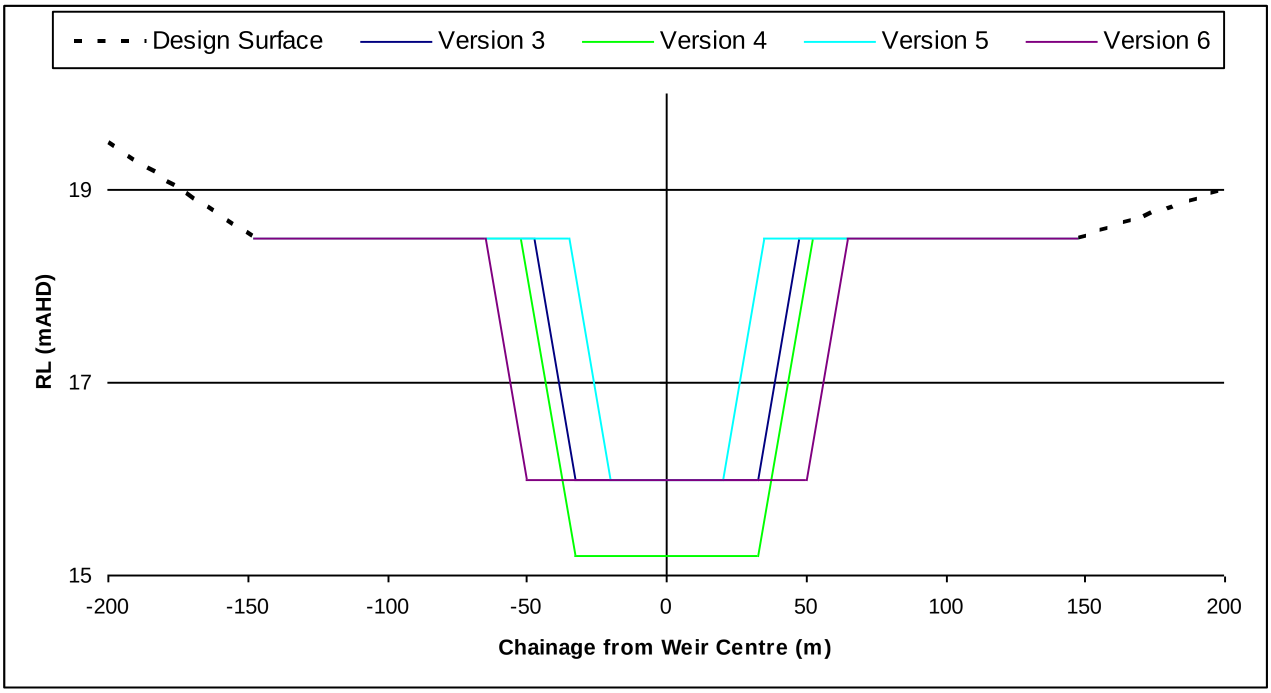


Figure 3. Typical Weir Sections

6 2D Model Results

Each of the previously detailed versions were tested in the 2D SOBEK model. The results are discussed below.

6.1 100 year ARI Velocity

The base design case showed significant velocities at the PLDC property boundary. These velocities were above 3m/s and as such would require protection works within Hunts property. Version 1, with an extension of the pinch point onto the PLDC property, did not result in a significant change in the velocities.

Raising the weir and moving the weir location within the PLDC site served to reduce velocities at the boundary and within the creek to more manageable levels, generally in the order of 2 – 2.5m/s. In the existing case (base case) the velocities in the creek are approximately 1m/s.

In Version 2 (16m AHD crest), Version 3 (16m AHD crest, 30 metres within property) and Version 5 (16m AHD crest at 40 metres wide), the velocities on Hunts property are of a similar magnitude, at approximately 2m/s. By comparison, increasing the weir width to 100 metres or lowering the weir crest to 15.2m AHD result in velocities on Hunt's property of 2.5m/s.

Lowering the weir to 15.2mAHD has little effect on the peak velocity over the weir, or the velocities entering the lake.

Shortening the weir significantly increased velocities over the weir and into the lake. The 100m weir had much lower velocities over the weir, but increased velocities within the creek.

A plot of velocity longsections are shown in **Figure 4**. The section starts at the Nepean River, runs through Hunts Gully, and extends approximately 100m into the lake. The PLDC property boundary is marked on the graph. A set of peak velocity plots in plan form for each option are included in **Appendix C**.

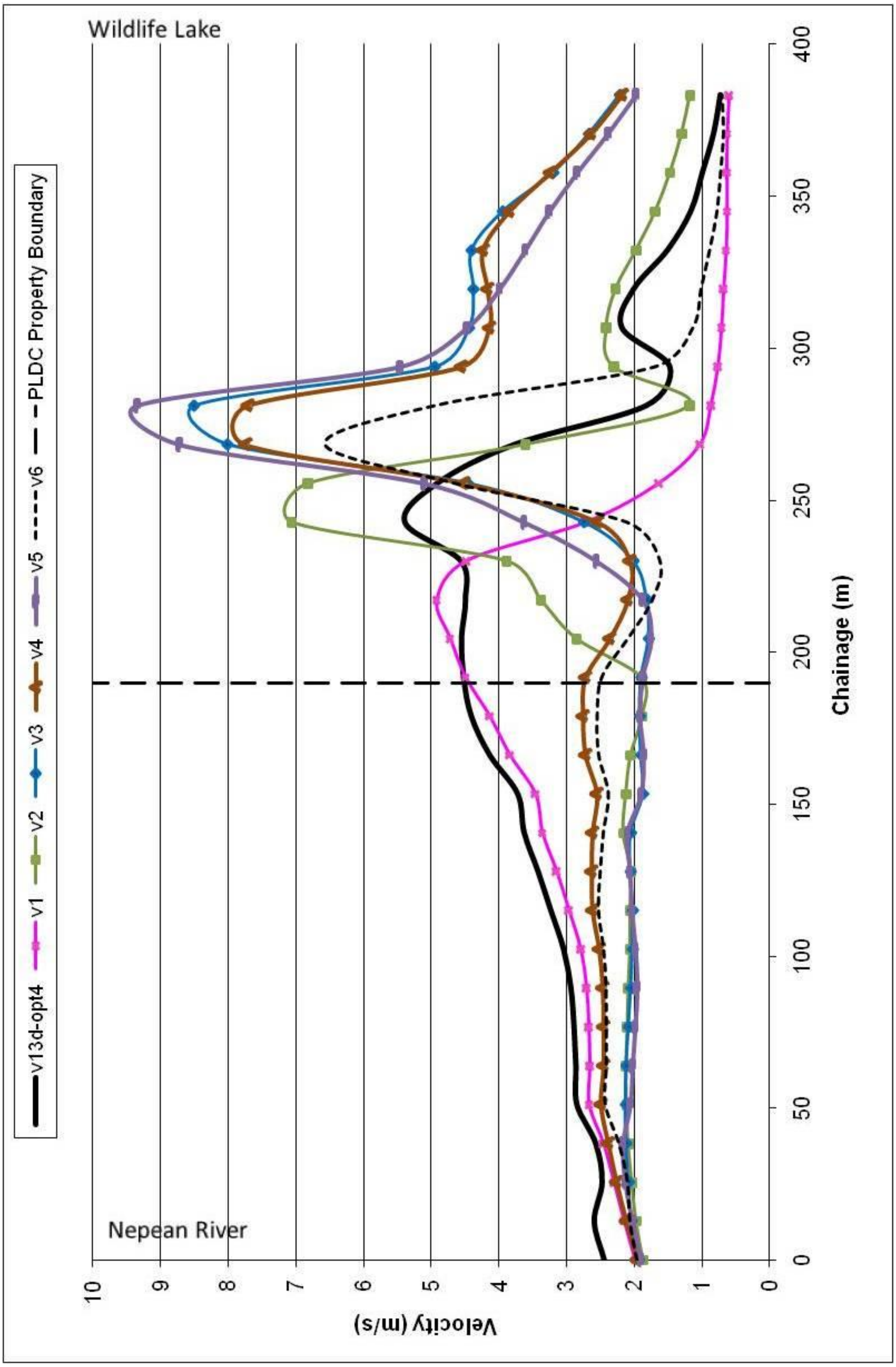


Figure 4. Peak Velocity Long Sections

6.2 Comparison of 100 year and 200 year ARI Velocities

A comparison was undertaken between the 100 year ARI and 200 year ARI velocities, for both the Version 3 and Version 4 scenarios (refer **Figure 5**). In both cases, the differences in velocities are relatively minor, and therefore the concept design has been prepared on the basis of the 100 year ARI results.

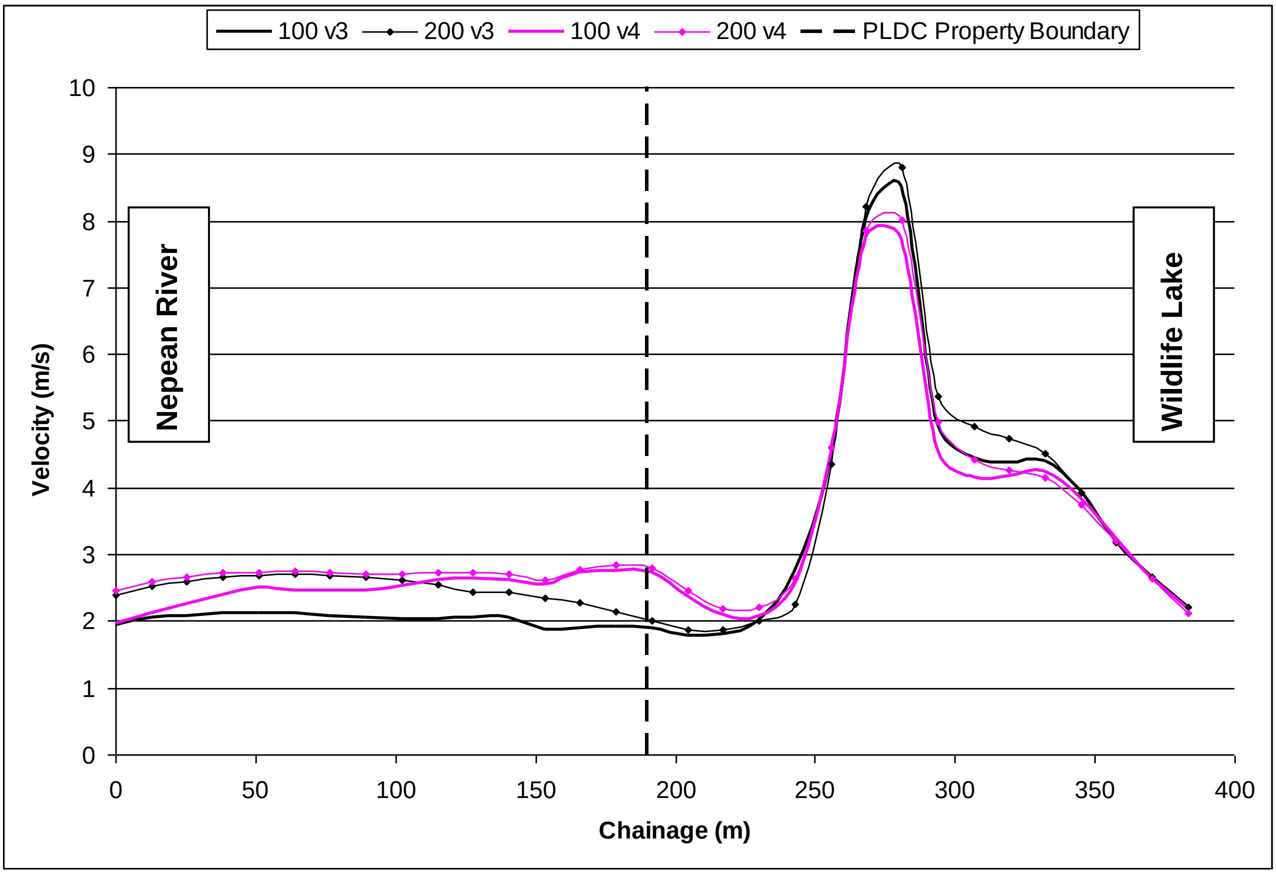


Figure 5. Comparison of 100 year ARI and 200 year ARI Velocities

6.3 Hunts Gully Pinch Point Analysis

Close to the PLDC property boundary, there is a constriction to the creek flow path (refer **Figure 5**). The width of this constriction is 10-15m. As the 2D model utilises a grid of 15m, there is the possibility that the velocities and flows in this area may not be representative.

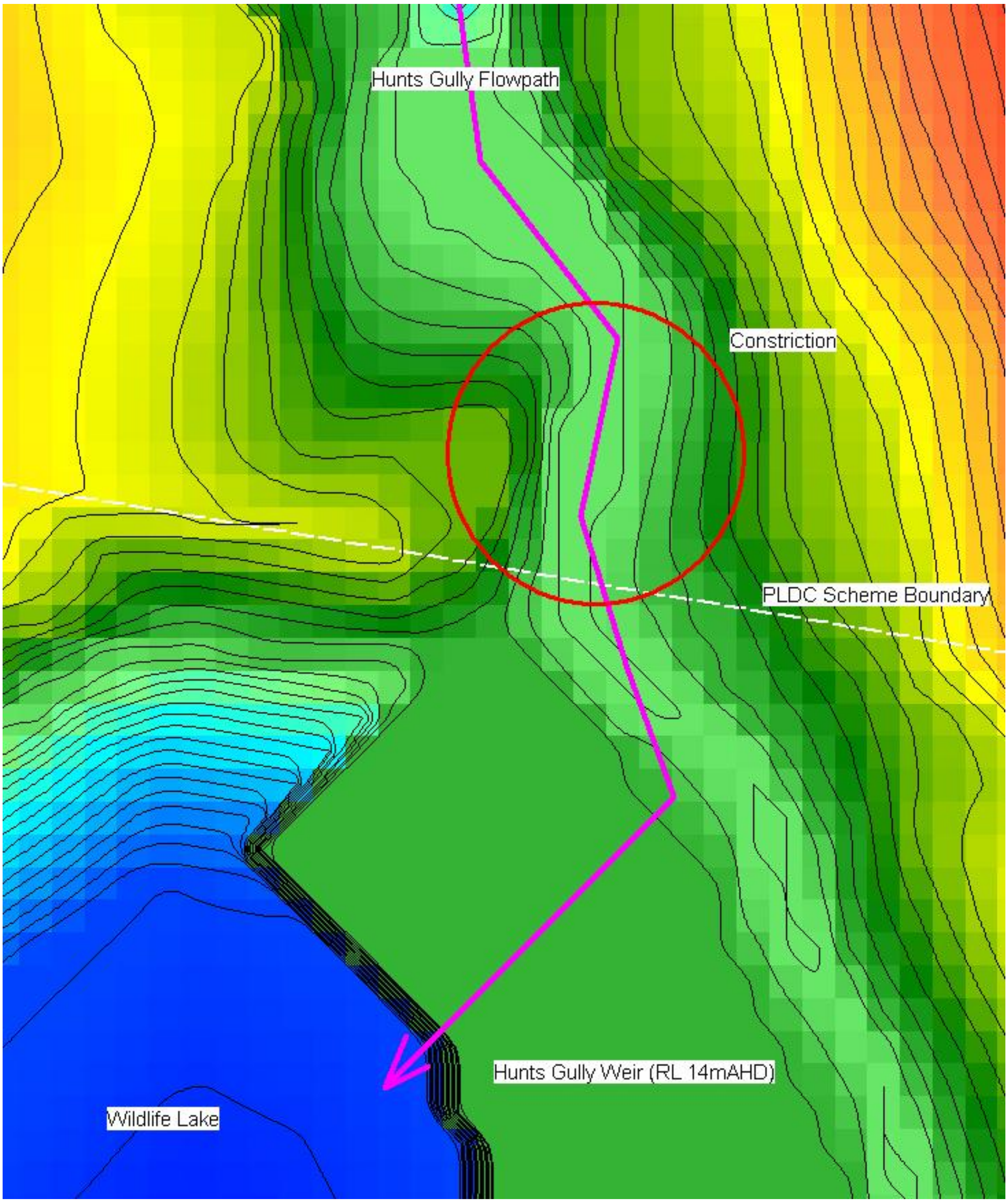


Figure 6: Hunts Gully Pinch Point

In order to investigate the effectiveness of the 15m grid in defining this area, a 5m child grid was created to cover the Hunts Gully area.

The results suggest that the 2D 15 metre grid model is generally accurate in predicting velocities through Hunts Gully. The velocities approaching the constriction and the velocities downstream of the weir are comparable.

The child grid model suggests slightly reduced velocities over the weir – approximately 10% lower than the 2D model.

The greatest difference between the models was in the area between the mid-point of the constriction, and the weir crest. In this area, the child grid model suggested velocities approximately 12% high than the 15m 2D model. In the 5m child model, these velocities remained high until the weir, were they dropped off sharply. In the 15m model however, the velocities remained relatively within the creek, before climbing and dropping sharply before and after the weir structure. The results are shown in **Figure 7** below.

Notwithstanding the results of this analysis, it would be recommended to undertake a detailed analysis of the preferred option utilising a child grid, to ensure that the velocities in this area are representative.

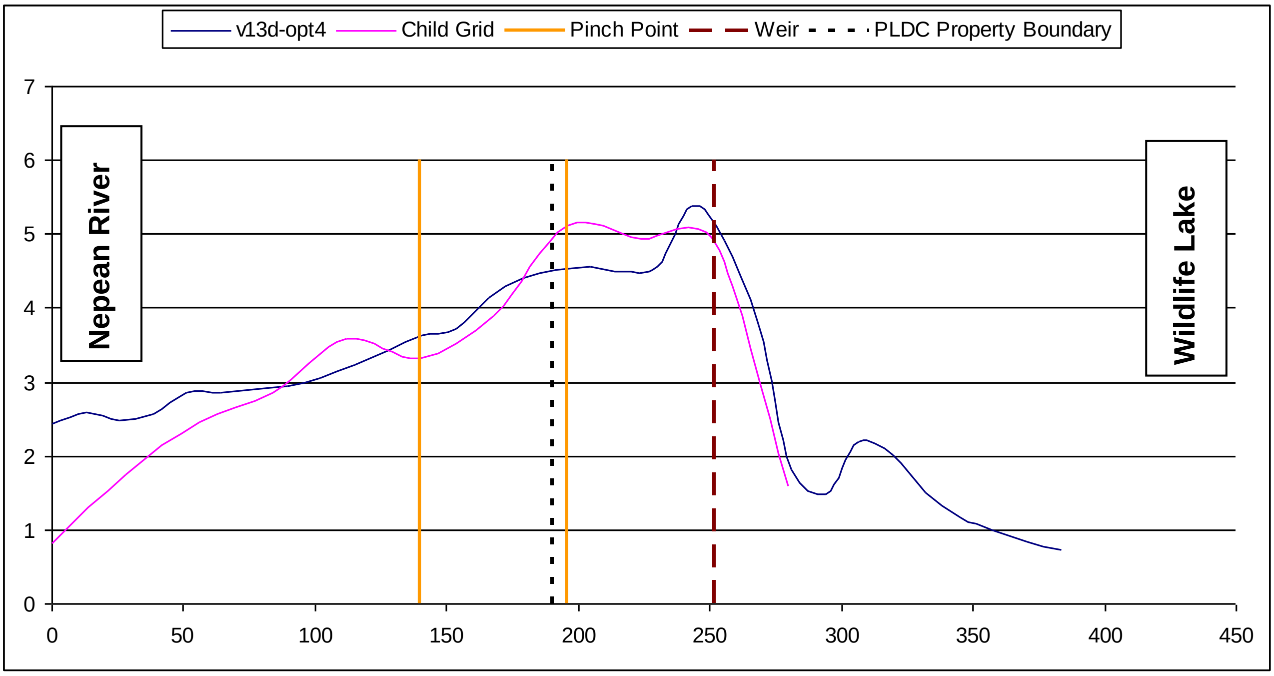


Figure 7. Velocity Long Section of 5m and 15m models in Hunts Gully

6.4 Protection Works

The results of the above analysis suggest that Version 3, 5 and 6 are the most viable options for Hunts Gully. Versions 1 and 2 are too close to the property boundary, and therefore have insufficient room for construction. 13d opt 4 results in high velocities on Hunt's property, and would therefore require protection works on Hunt's property.

These 3 options were then analysed further to determine the extent of protection works required. The critical velocities were adapted from scour velocity plots in CIRIA Report 116 (CIRIA, 1987). This plot is included in **Attachment C**. The critical velocities were adopted for selected durations of inundation and are shown in **Table 1**. These points are marked on the graph in **Attachment C**. For the 2hr peak comparison the peak velocity from the model was used, assuming conservatively that the peak velocity occurred over a 2hr period. For the average comparisons, velocities were averaged over 5, 10 and 30 hour periods. These durations were chosen to provide a reasonable range for concept design. It is recommended that these velocities be reviewed in detailed design, with input from appropriate manufactures.

Table 1: Limiting Velocities for Protection Measures

	RCC, if greater than... (m/s)	Reinforced Grass, if greater than... (m/s)	Good Grass, if greater than... (m/s)
2hr Peak	6.0	5.0	4.0
5hr Average	4.5	3.5	2.0
10hr Average	4.0	3.0	1.5
30hr Average	3.0	2.5	1.0

Summarised in **Tables 2** and **3** are the peak and average velocities for versions 3, and the associated protection works. Chainage increases from the Nepean River to Wildlife Lake, with Ch0 occurring at the beginning of the weir crest.

Table 2: Version 3 Critical Velocities (m/s)

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Peak	1.75	3.00	3.75	9.00	4.75	1.25
5hr Mean	1.50	1.75	3.50	7.75	2.50	1.00
10hr Mean	1.50	1.75	2.75	5.50	1.50	0.50
30hr Mean	1.00	1.25	1.50	2.00	0.50	0.25

Table 3: Version 3 Protection Measures

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Mean				**RCC**	Good Grass	
5hr Mean			**Reinforced Grass**	**RCC**	Good Grass	
10hr Mean			Good Grass	**RCC**		
30hr Mean				Good Grass		

Note: Blank squares assume poor grass cover

Summarised in **Tables 4** and **5** are the peak and average velocities for versions 5, and the associated protection works. Chainage increases from the Nepean River to Wildlife Lake, with Ch0 occurring at the beginning of the weir crest.

Table 4: Version 5 Critical Velocities (m/s)

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Peak	1.25	1.75	3.75	9.00	7.50	1.50
5hr Mean	1.00	1.50	2.25	8.50	7.00	1.00
10hr Mean	1.00	1.50	2.00	7.25	5.50	0.75
30hr Mean	0.75	1.00	1.50	3.00	2.25	0.50

Table 5: Version 5 Protection Measures

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Mean				**RCC**	**RCC**	
5hr Mean			Good Grass	**RCC**	**RCC**	
10hr Mean			Good Grass	**RCC**	**RCC**	
30hr Mean				Good Grass	Good Grass	

Note: Blank squares assume poor grass cover

Summarised in **Tables 6** and **7** are the peak and average velocities for versions 5, and the associated protection works. Chainage increases from the Nepean River to Wildlife Lake, with Ch0 occurring at the beginning of the weir crest.

Table 6: Version 6 Critical Velocities (m/s)

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Peak	2.25	2.00	2.50	7.75	5.00	1.50
5hr Mean	2.00	1.75	1.75	7.00	4.50	1.25
10hr Mean	1.50	1.25	1.50	4.75	2.75	1.00
30hr Mean	1.00	1.00	1.00	2.00	1.25	0.50

Table 7: Version 6 Protection Measures

Chainage	**-45**	**-30**	**-15**	**0**	**15**	**30**
2hr Mean				**RCC**	**Reinforced Grass**	
5hr Mean	Good Grass			**RCC**	**Reinforced Grass**	
10hr Mean				**RCC**	Good Grass	
30hr Mean				Good Grass		

Note: Blank squares assume poor grass cover

The above protection works are indicative only, as they are based on a 15m grid. They have been used to inform the concept design of the weir.

Both sides of the weir structure would require protection as significant flows occur both into and out of the Wildlife Lake. The proposed concept weir structure consists of a 3m high RCC structure at a 1 in 1 grade on the north face, a 10m long reinforced concrete slab along the weir top, and a 7m high RCC structure at a 1 in 1 grade on the south face of the weir. For the purposes of costings, it has been assumed that the RCC extends 1 metre below the operating level. It is also assumed that a concrete slab would extend approximately 10m underwater at 1m below operating level to prevent scour, assist in energy dissipation and prevent scour should the lake level fall below operating levels. A sketch of this option is included in **Appendix A**.

6.5 Cost Considerations

On a cost-per-metre basis, it is likely that the cost of each option will be similar. As such, the 40m weir will be the cheapest to construct, the 100m weir the most expensive. The 65m weir will lie roughly in the middle of these costs.

6.6 WL and Impacts

Alterations to the Wildlife Lake Weir affect water levels in the Wildlife Lake. It should be noted that any water level changes are confined to the Wildlife Lake and the northern area near Smith Street. There are no changes to water levels in any other lakes or the Nepean River due to changes at Hunts Gully.

The peak levels in the Wildlife Lake for the base case, preliminary design scenario and the design options are shown in **Table 8**. Also shown are the differences compared to the base case scenario and the preliminary design scenario levels.

Table 8: Water Level Changes between Wildlife Lake Weir Options

Version	Details	100yr Level (mAHD)	Level Difference to Base Case (m)	Level Difference To Prelim. Design (m)
Base Case	Base case conditions	20.67	-	-
Prelim. Des.	120m Weir, RL14, at boundary	20.84	+0.17	-
1	170m Weir, RL 14, at boundary	20.86	+0.19	+0.02
2	120m Weir, RL 16, at boundary	20.91	+0.24	+0.07
3	65m Weir, RL 16, shifted south	20.90	+0.23	+0.06
4	65m Weir, RL 15.2, shifted south	20.89	+0.22	+0.05
5	40m Weir, RL 16, shifted south	20.93	+0.26	+0.09
6	100m weir, RL 16, shifted south	20.88	+0.21	+0.04

Although the changes are relatively small, and do not affect the peak levels or filling rates of the other lakes, any increases will serve to further increase the impacts on the properties north of Smith Street, north east of the site. The impacts on the properties in this area are in the order of 0.18 metres, and therefore any increase will only further exacerbate this issue.

7 Wildlife Lake Weir Recommendations

Based on the above analysis the recommended option for the Wildlife Lake Weir is Option 3.

Option 3 has a 65m central weir crest at 16.0mAHD, utilising an RCC weir structure at 1 in 1 grades on both upstream and downstream faces. At both the northern and southern ends of the RCC face a concrete pad and dissipater structure is proposed to reduce flow energy.

Embankments at each end of the weir are proposed at a level of 18.5mAHD. These embankments would extend until they meet with the natural surface. The purpose of the embankment is to provide a greater flow area once the weir has been drowned out and the need for erosion protection is minimised. A slope of 1 in 6 is proposed for the embankment and no protection is required if good grass cover is maintained. This would require irrigation. If irrigation cannot be provided or steeper slopes are required, then reinforced grass or a suitable alternative would be required.

The 65m weir represents the best combination of performance and cost effectiveness – being of a sufficiently small length to reduce costs, and yet still being able to convey the required flows at low velocities in Hunts Gully. It also maintains the filling rate of Wildlife Lake which is important for the successful operation of Weir 6.

8 Qualifications

The following qualifications apply to this report:

- The attached sketches are concept designs only, and would require detailed design at a later stage.
- No geotechnical analysis has been consulted in the preparation of this report. Only a broad appreciation of the soil types has been considered.
- The design of the Weir has been based on the 100 year and 200 year ARI design events. No other design events have been modelled. No sensitivity analysis has been undertaken but it is recommended that this be undertaken prior to the detailed design phase.
- The results presented in this report are based on the current design for the Penrith Lakes Development. Any changes to this design may result in different flow behaviour across the Wildlife Lake Weir and therefore may require different options for energy dissipation and scour protection.

9 References

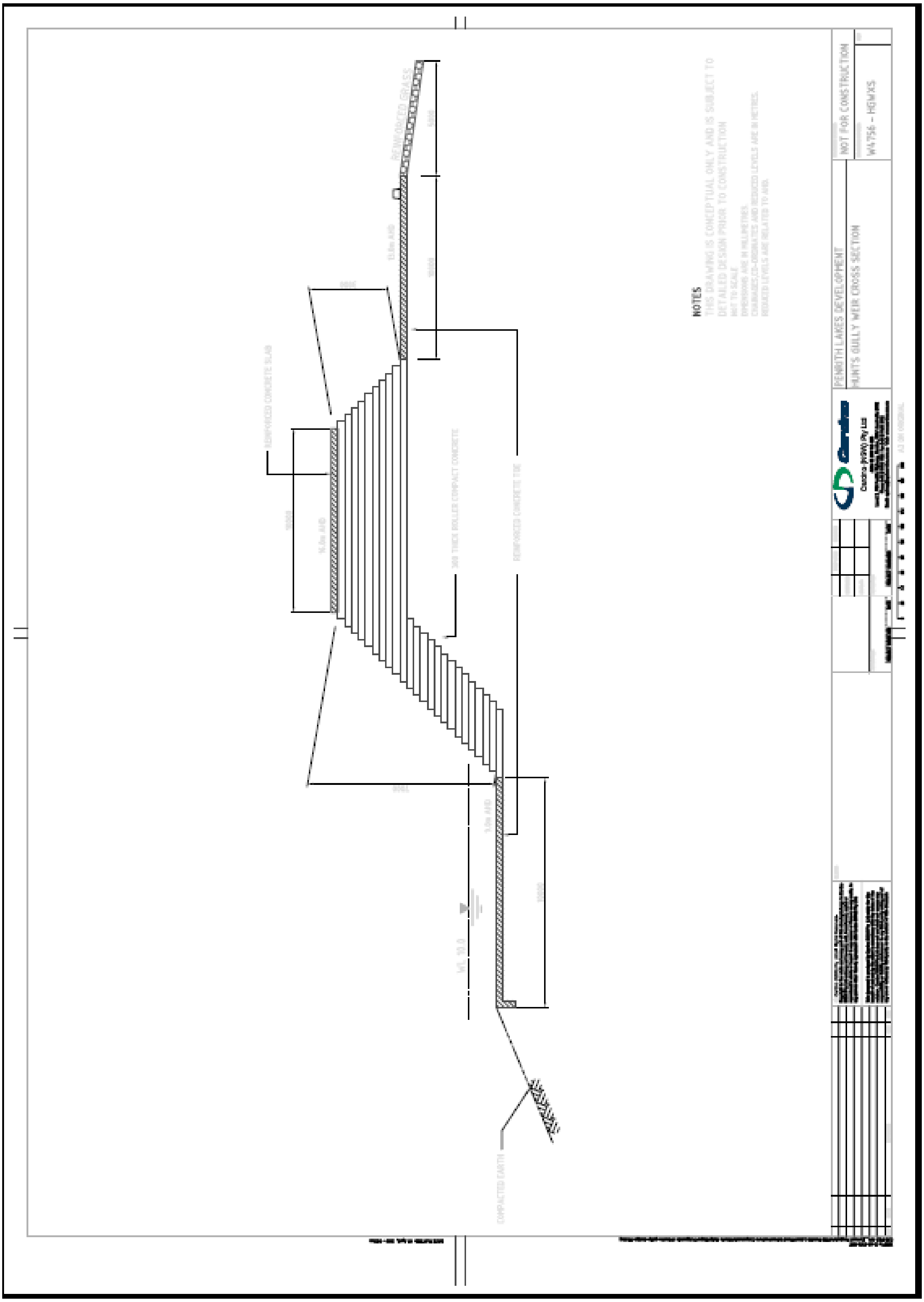
Cardno Lawson Treloar (2009). *Penrith Lakes Flood Modelling: Model Calibration and Verification*, December, prepared for Penrith Lakes Development Corporation, Final.

Cardno Lawson Treloar (2009). *Concept Design of Weir 6 (Letter)*, April, prepared for Penrith Lakes Development Corporation.

Construction Industry Research and Information Association [CIRIA] (1985). *Reinforcement of Steep Grassed Waterways: Review and Preliminary Design Recommendations*, Technical Note 120, London.

Attachment A

Concept Sketches


REINFORCED GRASS
NOTES
THIS DRAWING IS CONCEPTUAL ONLY AND IS SUBJECT TO DETAILED DESIGN PRIOR TO CONSTRUCTION
NOT FOR CONSTRUCTION
W4756 – HGW XS
PENRITH LAKES DEVELOPMENT
HUNTS GULLY WEIR CROSS SECTION
Cardno (NSW) Pty Ltd

Attachment B

Velocity Plots for Wildlife Lake Weir Options

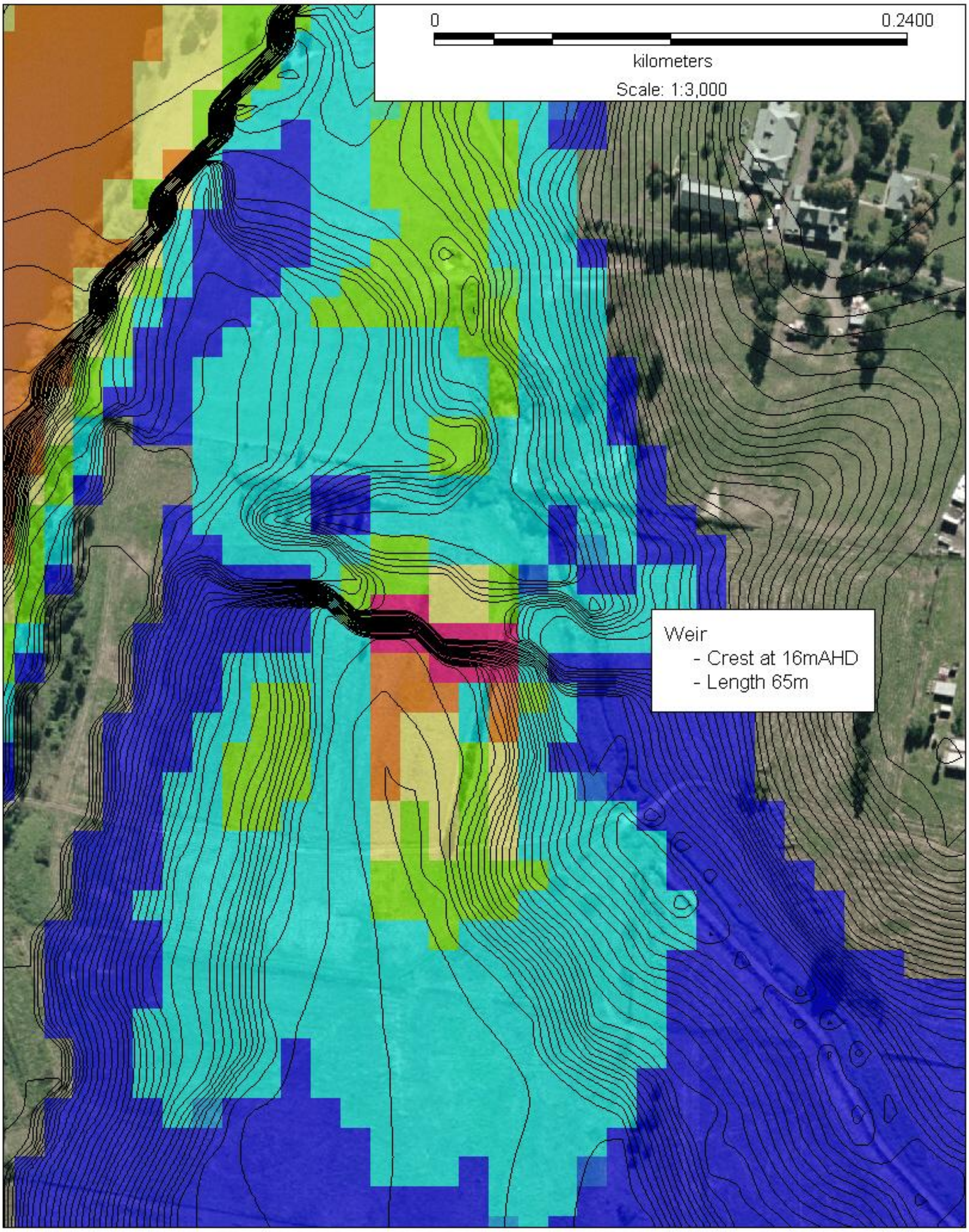
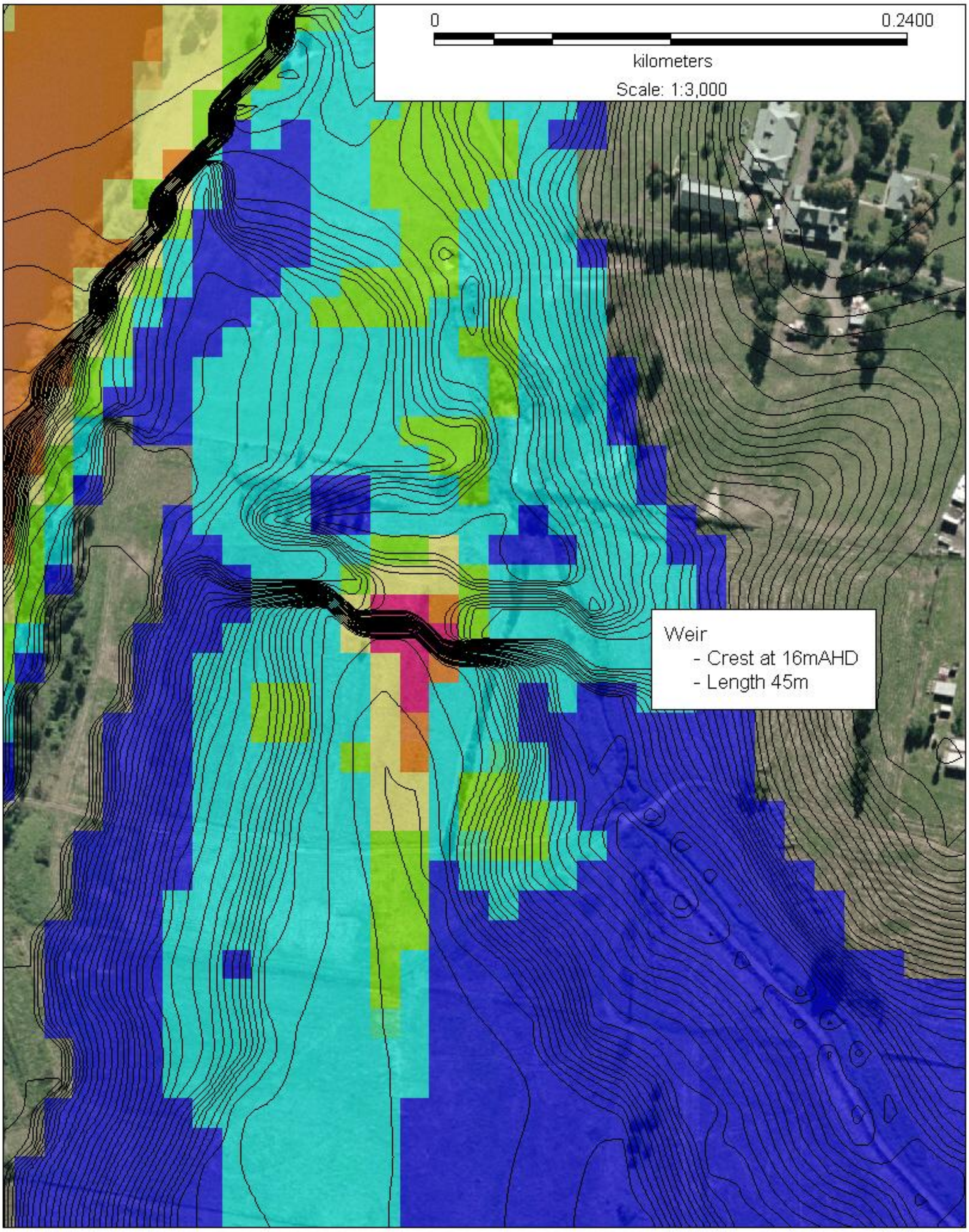


FIGURE
100yr Maximum Velocity
Hunts Gully - Version 3

PLDC
Hunts Gully Investigation

W4756
5 January 2010

w:_Current Projects\4756 Penrith Lakes\Results_Figures\Figure - Hunts Velocity Version 3



Cardno

FIGURE
100yr Maximum Velocity
Hunts Gully - Version 5

PLDC
Hunts Gully Investigation

W4756
5 January 2010

w:_Current Projects\4756 Penrith Lakes\Results_Figures\Figure - Hunts Velocity Version 5

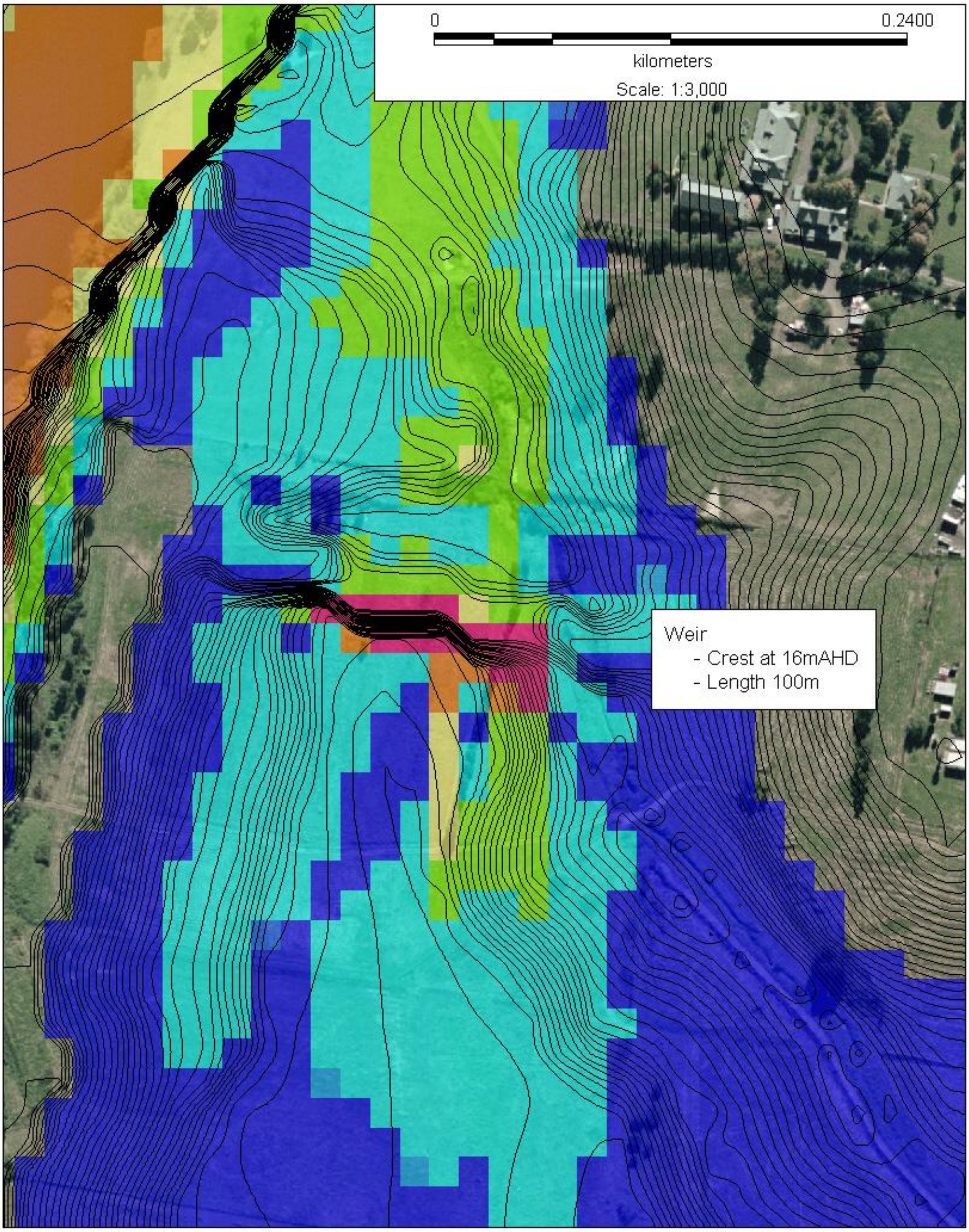


FIGURE
100yr Maximum Velocity
Hunts Gully - Version 6

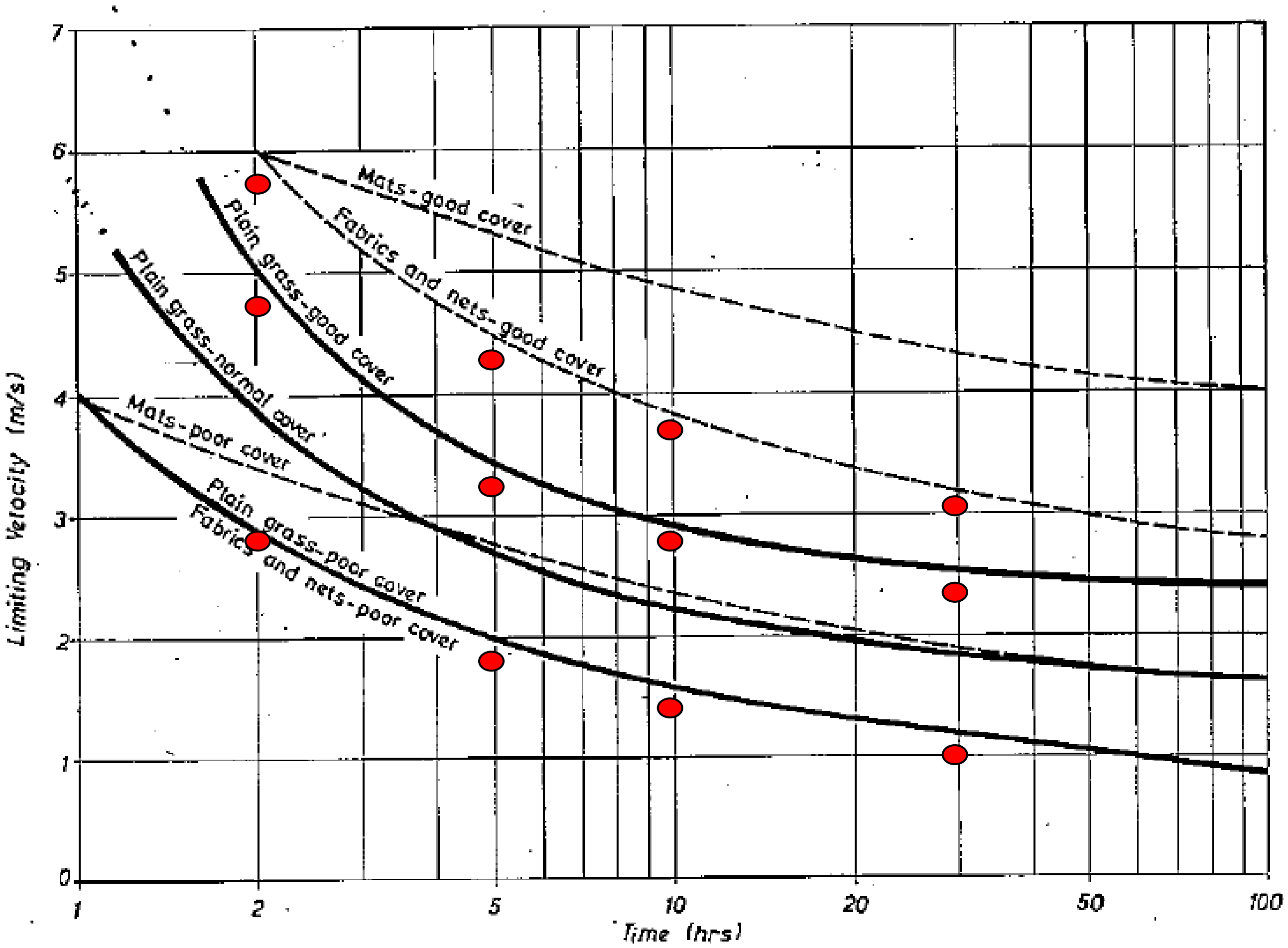
PLDC
Hunts Gully Investigation

W4756
5 January 2010

w:_Current Projects\4756 Penrith Lakes\Results_Figures\Figure - Hunts Velocity Version 6

Attachment C

CIRIA Velocity Plot (with critical values)



Critical velocity points for protection works