Appendix B Hydrology and Flood Study

Western Rail Coal Unloader
Mt Piper Power Station

FLOOD STUDY

- March 2007

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Sinclair Knight Merz
ABN 37 001 024 095
100 Christie Street
PO Box 164
St Leonards NSW
Australia 1590
Tel: +61 2 9928 2100
Fax: +61 2 9928 2500
Web: www.skmconsulting.com

Contents

1. Introduction

Delta Electricity is proposing to build a rail balloon loop and coal unloading facility to service the needs of Mount Piper Power Station in future years. The proposed rail loop, coal unloader and conveyor system would be built on land owned by Delta in the area known as Pipers Flat, located between Portland and Wallerawang townships. The Western Rail Coal Unloader project would involve the construction and operation of:

- A rail loop comprising a branch rail line off the Wallerawang – Mudgee Main Line;
- A coal unloader building which would allow coal to be delivered into a hopper located below the rail line;
- A conveyor system which would carry the coal to the existing coal handling facility at the Mt Piper Power Station.

The proposed rail loop for the Western Coal Unloader is located in the floodplains of Pipers Flat Creek and its tributaries Thompsons Creek and Irondale Creek. The proposed loop crosses Pipers Flat Creek twice, once on the northern side and once on the eastern sides of the loop. In addition, the proposed loop will run along the existing railway embankment, which crosses both Thompsons and Irondale Creeks. Construction of the new loop will require extension of the waterway crossings underneath the existing railway embankment.

The loop embankment has the potential to cause an increase in peak flood levels upstream, depending on the magnitude of the peak flood flows and the size of waterway structures through the embankments. Such potential restrictions may affect adjacent property or infrastructure, alter the morphology of the creek watercourses and floodplains, and determine the ability of the proposed rail loop to survive a large flood intact. This report investigates potential flood impacts of the proposed design for the loop, relative to existing flood behaviour in the Pipers Creek floodplain.

1.1 Purpose of this Study

This study has been carried out as described in*'Proposal for a Flood Study for Western Rail Coal Unloader, Wallerawang', 30 November 2006.*

The objectives identified were to:

- satisfy the flood study requirements of the Department of Planning;
- assess the existing extent of flooding due to Pipers Flat Creek and Thompsons Creek in the vicinity of the project site for selected flood events up to and including the 100 year Average Recurrence Interval (ARI) event, and the Probable Maximum Flood (PMF) event;

- assess the impact of the project on flood levels and flows in the vicinity of the project site for the specified flood events;
- identify and describe the size and shape of required waterway openings and flood relief structures to be incorporated into the project; and
- assess the effectiveness and reliability of these measures, and the extent of any residual impacts in the vicinity of the site.

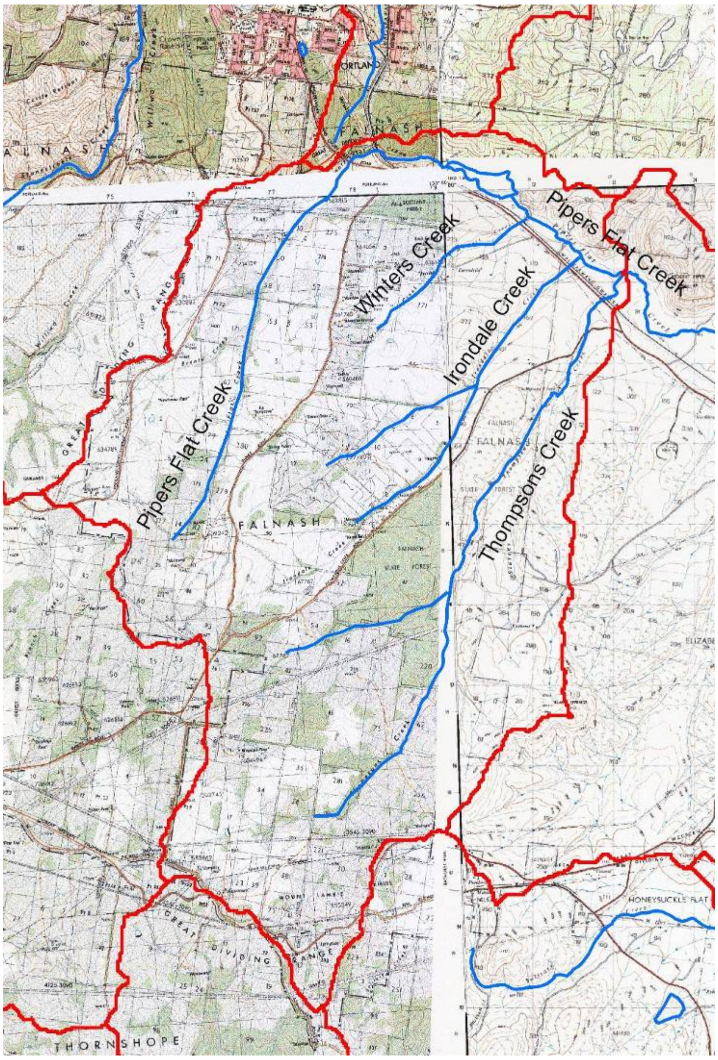
Modifications to the original methodology outlined in the proposal include:

- Hydrological modelling has been carried out using RORB instead of XP-RAFTS. RORB has been used extensively throughout Australia on a range of catchments, and is directly applicable to this type of situation.
- Hydraulic modelling has been carried out with MIKE21 instead of TUFLOW. MIKE21 is an industry standard two-dimensional modelling package, used extensively throughout Australia and the worldwide. MIKE 21 Flow Model is a modelling system for 2D free-surface flows. MIKE 21 Flow Model is applicable to the simulation of hydraulic and environmental phenomena.

2. Background

2.1 Catchment Topography

The Pipers Flat Creek catchment is situated along the eastern edge of the Great Dividing Range, with a north-easterly aspect. The catchment (shown in Figure 2-1) is drained by several parallel creek gullies running from the Great Dividing Range towards the north-east. The northern edge of the catchment is bounded by Mount Piper, and at the foot of the mountain the creek gullies merge into an open floodplain at Pipers Flat, the site of the proposed rail loop.



- **Figure 2-1: Pipers Flat Creek Catchment and Major Tributary Creeks**

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The four main creeks which run down these gullies are separate until they merge at Pipers Flat within a length of approximately 2 kilometres.

2.2 Existing Creek Floodplain

At the site of the proposed loop, Pipers Flat Creek runs from north west to south east across a generally flat floodplain approximately 150 metres wide, bounded by steep soil and rock slopes on the northern side, and gentle hills and tributary gullies on the southern side (see Plate 2-1).

When not in flood, Pipers Flat Creek is confined to a shallow channel varying between two and three metres across, and typically one to two metres deep from the top of the stream bank edge (see Plate 2-2). The capacity of the creek channel is relatively low, and in most flood events flows will leave the creek channel, and spread out relatively evenly across the flat floodplain. As water spills out of the channel, the predominant flow direction will change from following the line of the creek, to following the slope of the wider floodplain. Consequently, the whole floodplain is important in conveying floodwater downstream.

▪ **Plate 2-1: Typical Floodplain View at Pipers Flat**

- **Plate 2-2: Typical Stream Channel at Pipers Flat**

2.3 Existing Floodplain Infrastructure

The proposed rail loop is being constructed adjacent to an existing railway line, and parallel to an existing road. This existing railway line and road cross both Thompsons and Irondale Creek. The embankments and structures associated with these crossings already affect the propagation of floods into Pipers Flat Creek, and water levels in the upstream creek floodplains. The location of these structures is shown in Figure 2-2, and a typical view of the embankments is shown in Plate 2-3.

The characteristics, dimensions and plan surveys of the waterway crossings are included in Appendix A. As a summary, the key existing structures of interest in this study are:

- The low bridge Portland to Wallerawang road crossing of Thompsons Creek
- The high bridge railway crossing of Thompsons Creek
- The semi-circular corrugated culvert road crossing of Irondale Creek
- The brick elliptical culvert railway crossing of Irondale Creek

Other structures which potentially affect flood flows but which are outside of the extent of the study include:

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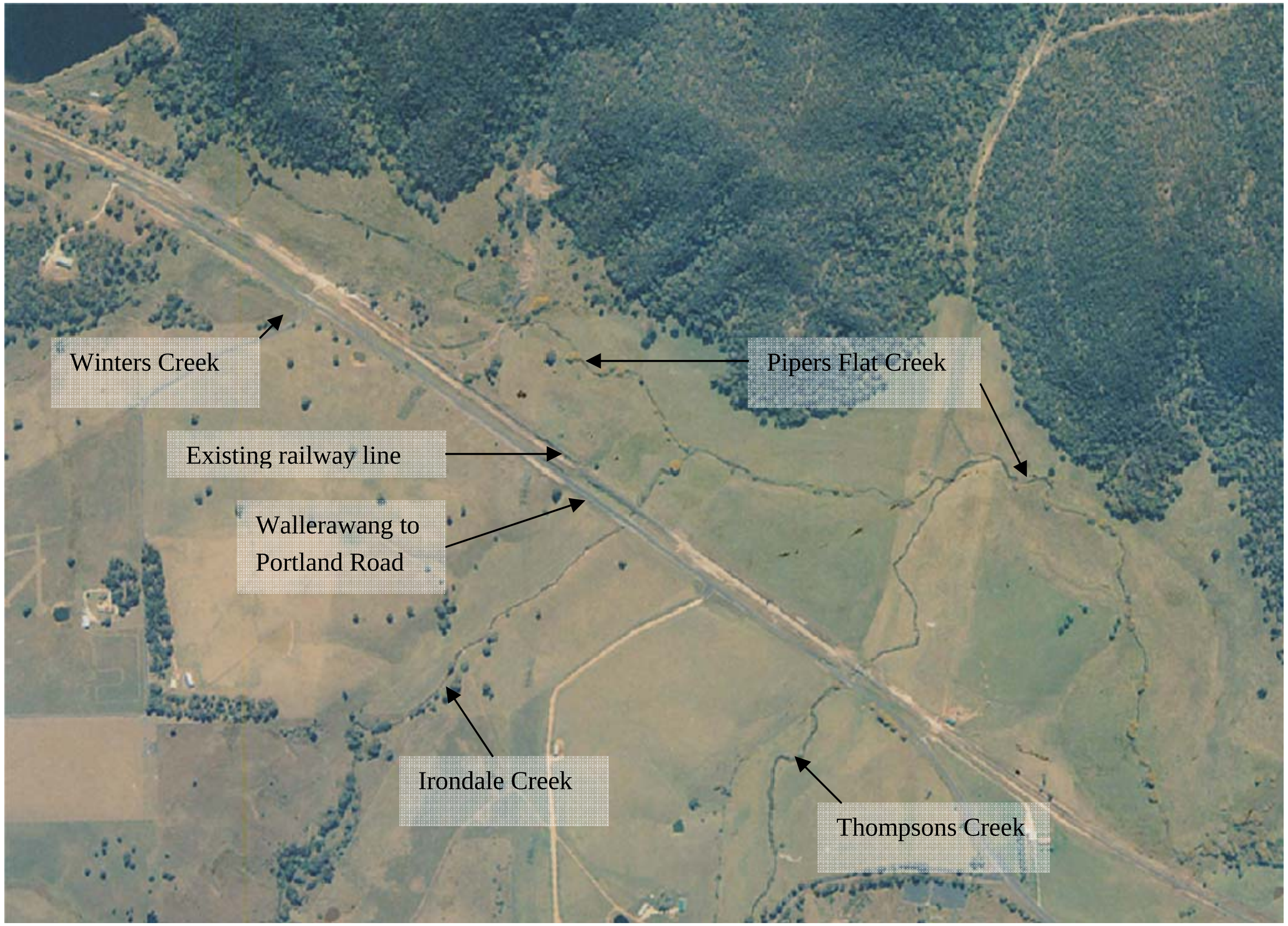
- Road and railway crossings of Winters Creek: This creek joins Pipers Flat Creek just upstream of the rail loop site
- A water supply reservoir on Pipers Flat Creek approximately 700 m upstream of the rail loop site: Given its function as a water supply reservoir, it would normally kept close to full, and is unlikely to attenuate larger flood flows.
- Pipers Flat Railway line crossing approximately 2.3 km upstream of the rail loop site: This is small bridge with low waterway capacity, however the rail embankment sits relatively low on the floodplain, and is likely to overtop in a major flood.
- Pipers Flat Creek Road crossing approximately 2.9 km upstream of the rail loop site: Two box culverts through a large road embankment, each 2.8 m by 2.3 m. These are likely to be highly surcharged in a large flood event, and there may be some attenuation of peak flood flows due to storage in the upstream floodplain. However, for the purposes of this study this has been ignored.

- **Plate 2-3: View of Road and Rail Embankments at the Irondale Creek Crossings**



- **Figure 2-2: Existing Infrastructure and waterway crossings at Pipers Flat**

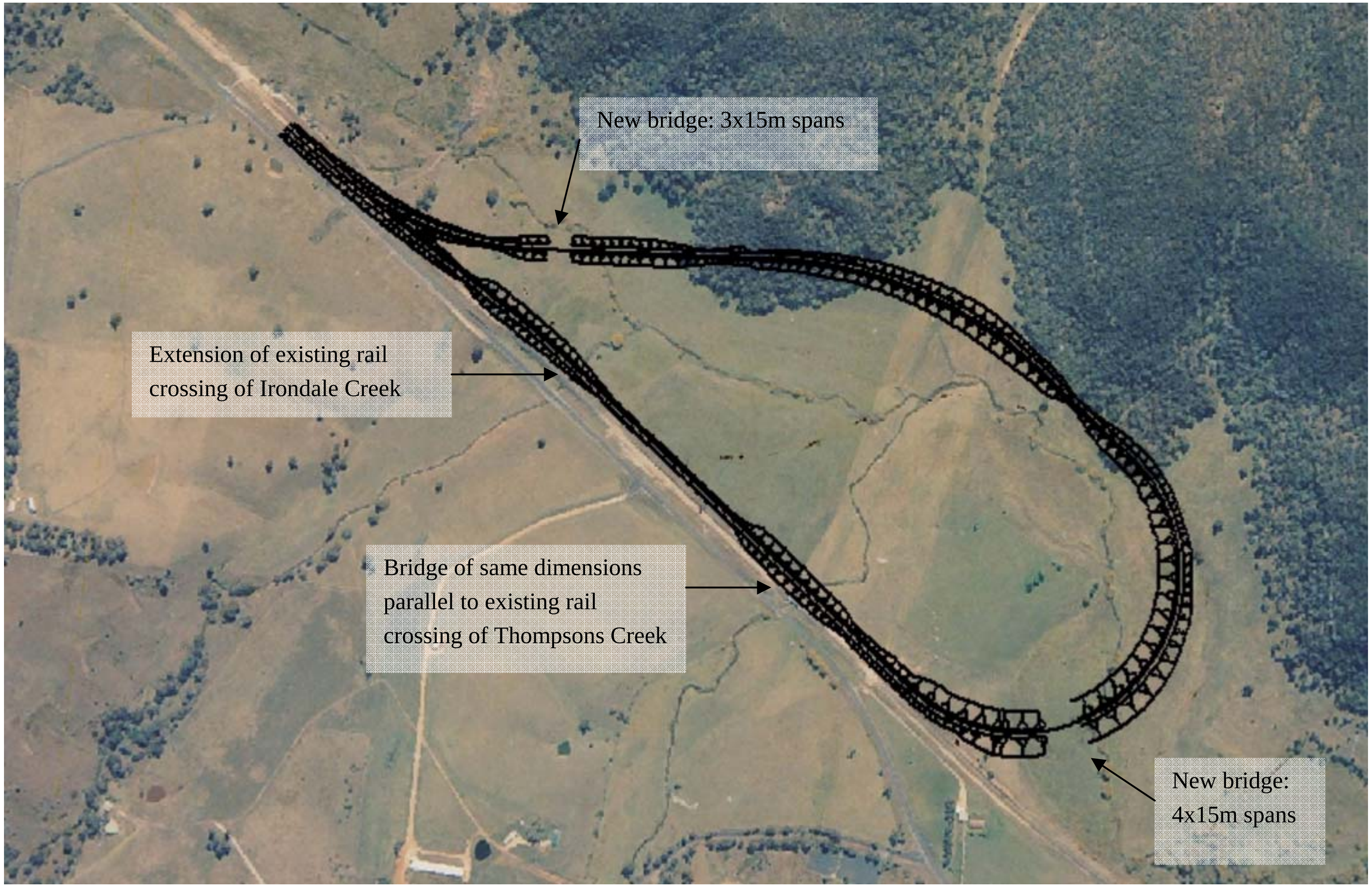
2.4 Proposed Rail Loop Development

The proposed rail loop will cross the Pipers Creek Floodplain at two locations, as well as Thompsons Creek and Irondale Creek (see Figure 2-3). Based on the current design of the loop and the existing railway crossings, the parameters of the additional crossings analysed in this report are:

- **Pipers Flat Creek – upstream embankment**: Bridge structure with three spans, each of 15 metres opening
- **Pipers Flat Creek – downstream embankment**: Bridge structure with four spans, each of 15 metres opening
- **Irondale Creek**: Three concrete culverts of 2.1 m diameter
- **Thompsons Creek**: Construction of a bridge structure with 2 spans, each of 15 metres opening.

In addition, for the purposes of this study we have assumed:

- The proposed railway embankment will be at approximately the same level as the existing embankment at the Thompsons Creek and Irondale Creek crossings
- The existing Winters Creek rail crossing is not affected by the proposed rail loop, and no extension of the existing culvert underneath the railway line at this point is required



- **Figure 2-3: Proposed design of loop and additional waterway crossings at Pipers Flat**

3. Hydrologic Modelling

3.1 Hydrologic Background

In order to determine the design inflows into the hydraulic model, a RORB hydrologic model of the catchment was built. RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. The model is areally distributed, nonlinear, and applicable to both urban and rural catchments. It makes provision for temporal and areal variation of rainfall and losses and can model flows at any number of gauging stations. In addition to normal channel storage, specific modelling can be provided for retarding basins, storage reservoirs, lakes or large flood plain storages. Base flow and other channel inflow and outflow processes, both concentrated and distributed, can be modelled.

RORB has the capacity to use a Monte-Carlo approach to produce design flood estimates that incorporate the joint probability of several flood causing factors for extreme floods. The layout of the RORB model is shown in **Figure 3-1**.

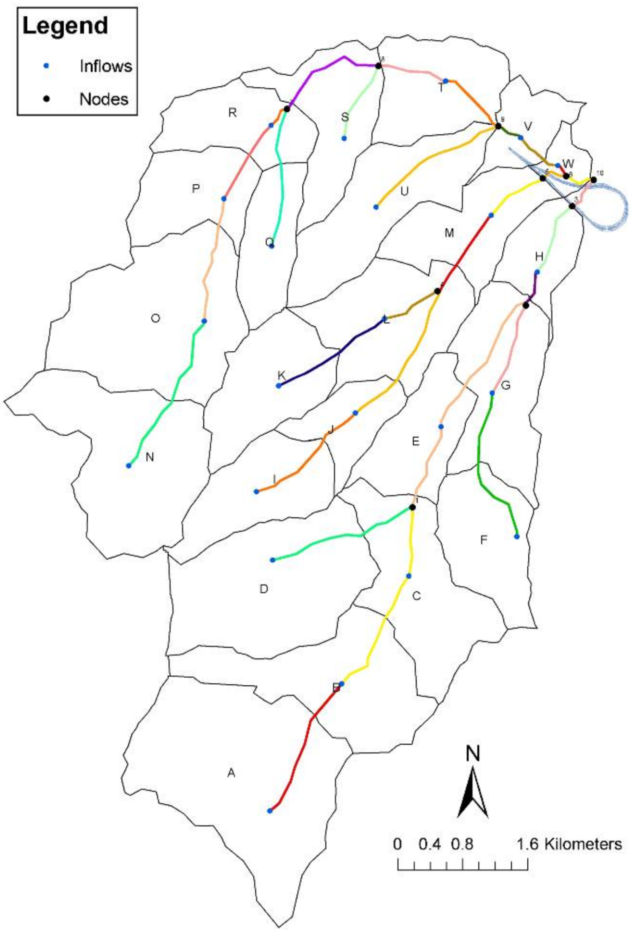


Figure 3-1: RORB model layout.

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3.2 Model Parameters

The catchment is ungauged so the RORB model parameters were determined by consulting Australian Rainfall & Runoff (AR&R) (1998) and recent technical papers. The k_c value was determined by comparing the value recommended by AR&R (1998) (using Kleemola (1987)) and those derived from Pearse et al. (2002). These are shown in **Figure 3-2** and **Figure 3-3**.

$$k_c = c \times d_{av}$$

d_{av}	5.62

	Victorian	Yu	CRCCH
c (Expected)	1.25	0.96	1.14
c (High)	2.07	1.94	2.13
c (Low)	0.75	0.47	0.61

	Victorian	Yu	CRCCH
k_c (Expected)	7.03	5.40	6.41
k_c (High)	11.63	10.90	11.97
k_c (Low)	4.22	2.64	3.43

▪ **Figure 3-2: Estimates of k_c from Pearse et al. (2002).**

$$k_c = 1.22A^{0.46}$$

A	46.4	km²

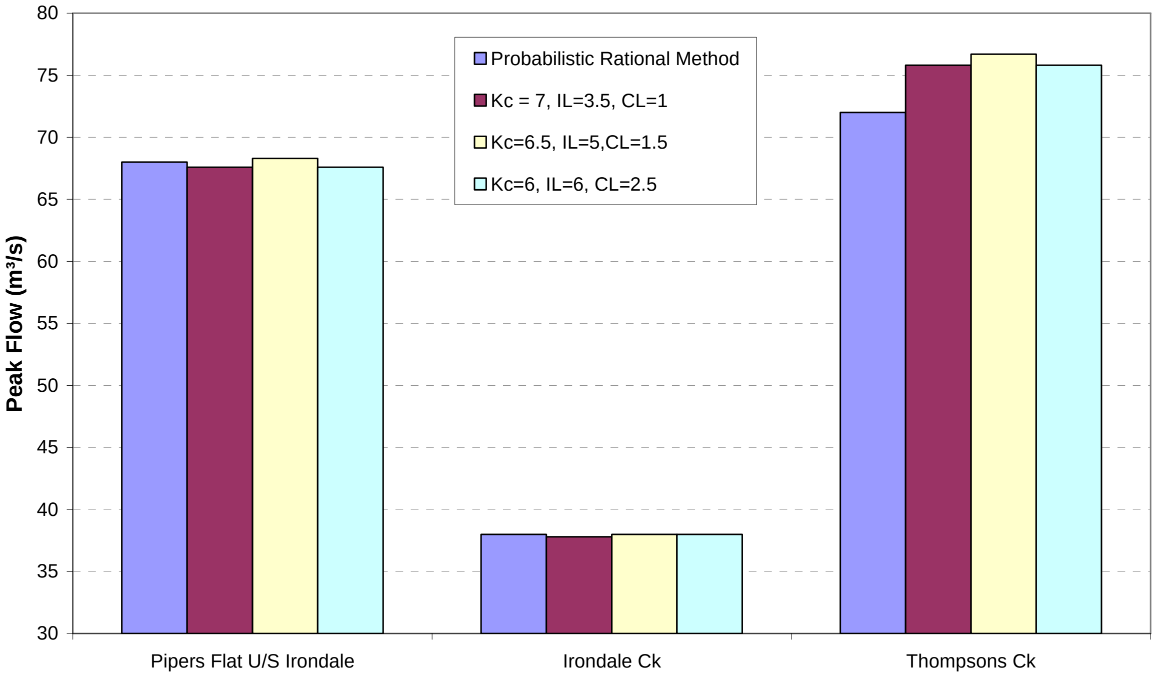
k_c (Kleemola 1987)	7.13

▪ **Figure 3-3: Estimates of k_c from AR&R (1998).**

Although the estimates of k_c from both of these sources are quite similar, a range of values were run in RORB with different losses in order to match the peak flows from the Probabilistic Rational Method (PRM) for an ARI of 100 years. These are shown in **Table 3-1** and **Figure 3-4**.

▪ **Table 3-1: Comparison of peak flows for 100 year ARI storm event at different locations from PRM and RORB with different k_c and losses.**

	PRM (Sydney)		Kc = 7, IL=3.5, CL=1		Kc=6.5, IL=5,CL=1.5		Kc=6.0, IL=6.0, CL=2.5	
	Peak Flow (m³/s)	Tcrit (hrs)	Peak Flow (m³/s)	Tcrit (hrs)	Peak Flow (m³/s)	Tcrit (hrs)	Peak Flow (m³/s)	Tcrit (hrs)
Pipers Flat U/S Irondale	68	2.29	67.6	6h	68.3	6h	67.6	4.5h
Irondale Ck	38	1.71	37.8	6h	38	4.5h	38	3h
Thompsons Ck	72	2.37	75.8	6h	76.7	6h	75.8	4.5h



- **Figure 3-4: Comparison of RORB estimates with those from PRM for 100 year ARI storm event.**

Based on the match with the PRM estimates, it was decided that a k_c of 6.0, and the corresponding losses of IL = 6.0 and CL = 2.5 were the most appropriate for the following reasons:

- Best fit to probabilistic method estimates in terms of magnitude;
- Best fit to probabilistic method estimates in terms of duration of the storm causing the peak flow; and,
- This k_c yielded the most sensible losses.

3.2.1 Model Sensitivity To k_c

In order to quantify how sensitive the peak outflow estimates are to k_c, the model was run with the losses from the model parameters. From Table 3-1 and Figure 3-1 it can be seen that altering the k_c parameter by 0.5 can cause a change in the peak flow by around 7% when losses are kept constant.

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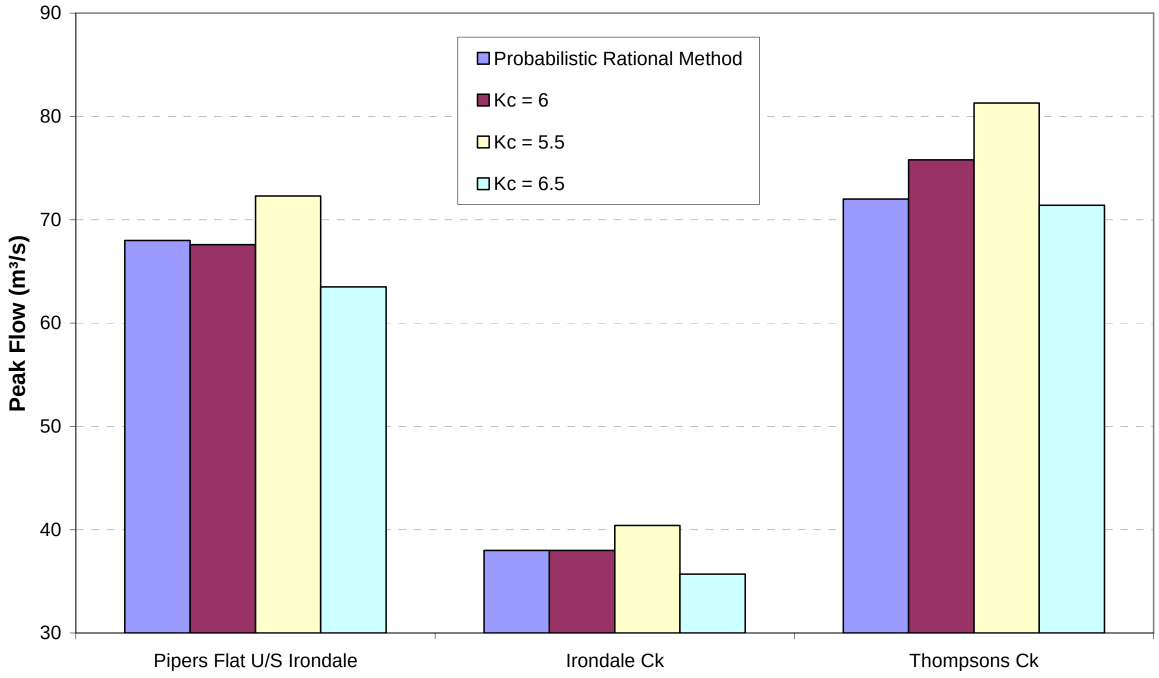
▪ **Table 3-1: Test of sensitivity of peak flow estimates to k_c with IL=6.0 and CL=2.5.**

	Kc = 6		Kc = 5.5		Kc = 6.5	
	Peak Flow (m³/s)	Tcrit (hrs)	Peak Flow (m³/s)	Tcrit (hrs)	Peak Flow (m³/s)	Tcrit (hrs)
Pipers Flat U/S Irondale	67.6	4.5h	72.3	6h	63.5	6h
Irondale Ck	38	3h	40.4	3h	35.7	3h
Thompsons Ck	75.8	4.5h	81.3	6h	71.4	6h



▪ **Figure 3-1: Test of sensitivity of peak flow estimates to k_c with IL=6.0 and CL=2.5.**

3.3 Design Rainfall Estimates

3.3.1 Intensity-Frequency-Duration analysis for events up to 1 in 50 AEP

The design rainfall depths were estimated from an IFD analysis using the procedure in *Book II* of *Australian Rainfall and Runoff* (I.E.Aust. 1987). Design rainfall depths were estimated for burst durations between 1 and 6 hours for a representative point near the centroid of the overall catchment of each dam. Factors for estimating rainfall intensities were extracted from Volume 2 of Australian Rainfall and Runoff (I.E.Aust. 1987) and are listed in **Table 3-2**.

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▪ **Table 3-2 IFD factors determined from *Australian Rainfall and Runoff Volume 2* (I.E. Aust., 1987)**

Factor	Value
i2y1h	23.0
i2y12h	5.0
i2y72h	1.6
i50y1h	44.0
i50y12h	9.0
i50y72h	2.7
F2	4.31
F50	15.73
Skew	0.16

3.3.2 Areal Reduction Factors

Point rainfall estimates were converted to catchment average values using the areal reduction factors developed for Victoria by the CRC for Catchment Hydrology (Siriwardena and Weinmann, 1996). The new areal reduction factors, based on daily rainfall data from across Victoria, represent a significant improvement over the values presented in the 1987 edition of *Australian Rainfall and Runoff* which were based upon a limited US study.

3.3.3 Growth curves for estimating depths between 1 in 50 and 1 in 2000 AEP

A regional approach for estimating design rainfall depths was adopted for durations between 1 and 12 hours and AEPs between 1 in 50 and 1 in 2000 developed by Jordan *et al*. (2004). Rainfall records were obtained from the Bureau of Meteorology for twelve continuously recording rain gauges that were located around Australia. These records were analysed using an approach similar to the CRC-FORGE method to estimate regional growth factors for rainfall depths between 1 in 50 and 1 in 2000 AEP and durations up to 12 hours.

3.3.4 Interpolation of design depths between 1 in 2000 AEP and the PMP

The interpolation procedure as recommended in *Book VI of Australian Rainfall and Runoff* (Nathan and Weinmann, 2000) was used to interpolate between the 1:2000 and PMP design rainfall depths.

3.3.5 PMP Depths (and beyond)

PMP estimates for durations 6 hours or less were obtained by applying the Generalised Short Duration Method (GSDM) as outlined in Bureau of Meteorology (2003). In order to obtain accurate estimates of the PMPDF from the Monte-Carlo sample, it was necessary to extrapolate these depths one order of magnitude outside the PMPDF using a linear interpolation in the log-normal domain.

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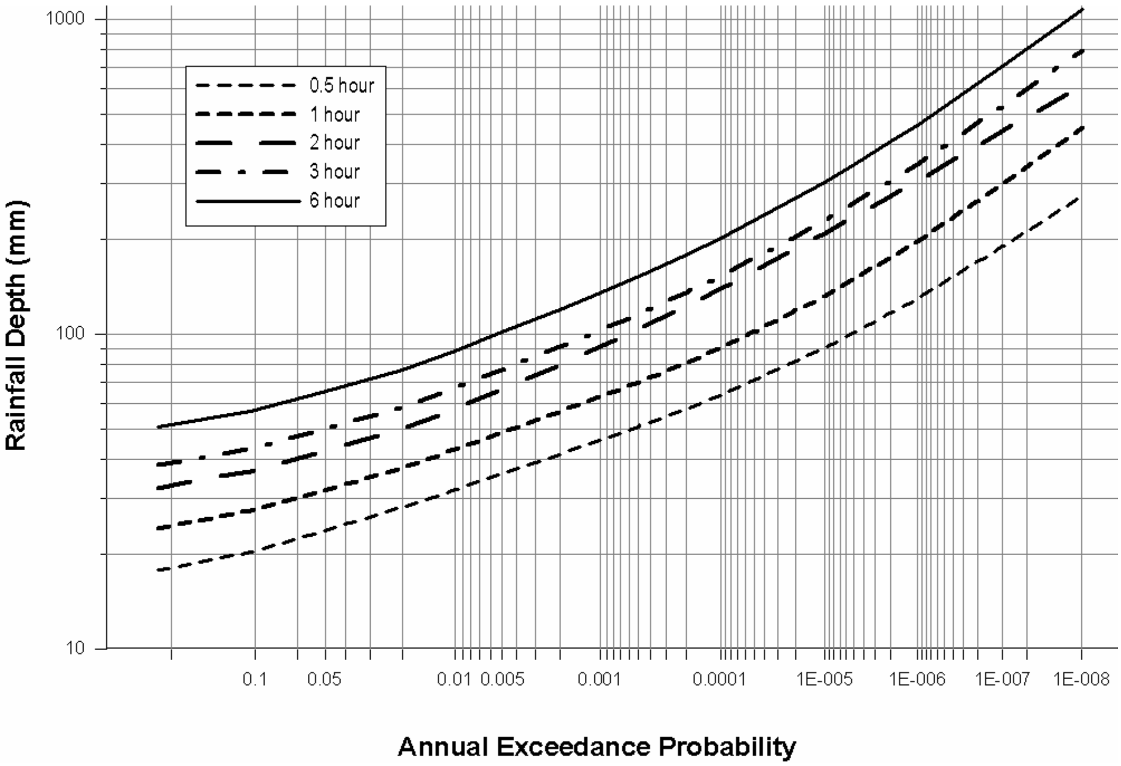
The adopted rainfall depths are shown in **Figure 3-5**.



- **Figure 3-5: Design rainfall depths.**

3.4 1 in 5 to 1 in 500 year ARI Flood Estimates

The RORB model was run with the losses model parameters outlined above. The temporal patterns from AR&R (1986) were applied after filtering them for imbedded bursts. A uniform spatial pattern was also used.

The peak flows for each inflow point into the rail loop are shown in **Table 3-3**. The hydrographs for each of these inflow points are shown in **Appendix B**.

- **Table 3-3: Peak flows for different ARIs at different locations.**

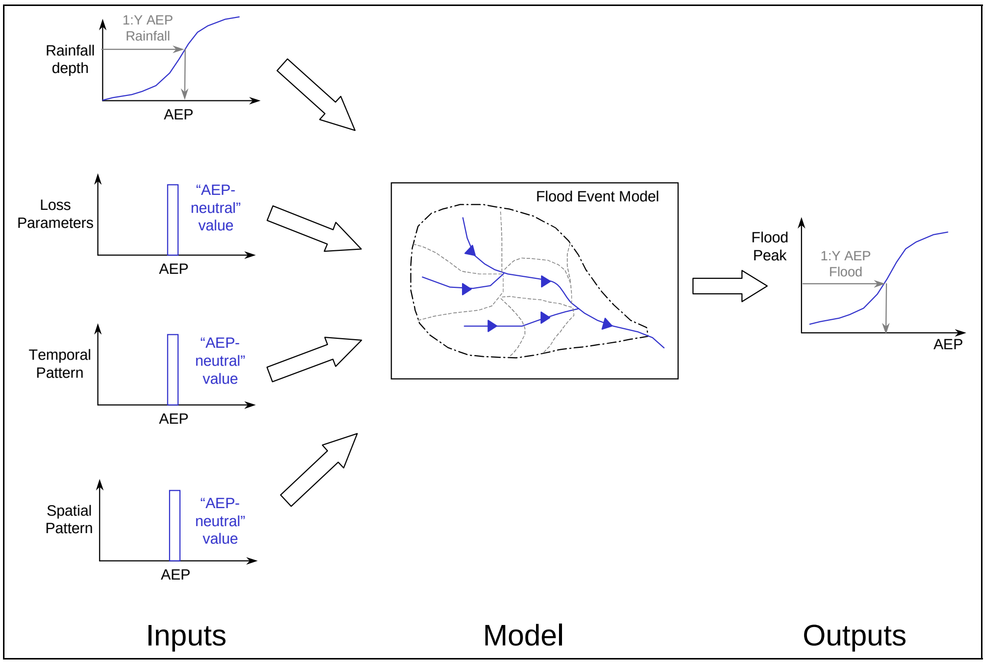
ARI (years)	Pipers Flat U/S Irondale Ck	Irondale Ck	Thompsons Ck
5	30.3	17.6	34.1
10	36.9	21.2	41.5
20	45.9	26.1	51.6
50	58.4	32.9	65.7
100	67.6	38.0	75.8
200	77.9	43.6	87.5
500	92.3	51.6	103.6

3.5 PMPDF Estimate

The PMP Design Flood (PMPDF) is defined as the flood with the same annual exceedance probability as the Probable Maximum Precipitation (PMP). In the case of the catchment being investigated, this is an AEP of 1 in 10^7.

3.5.1 Event-based and Monte-Carlo Approaches

Current practice for estimation of design floods is typically based on the “design event” approach (as applied to the more frequent events in **Section 3.3**), in which all parameters other than rainfall are input as fixed, single values. This concept is illustrated in **Figure 3-6** for the case where a distribution of design rainfalls is combined with fixed values of losses, rainfall temporal patterns and spatial patterns. Considerable effort is made to ensure that the single values of the adopted parameters are “AEP-neutral”, that is, they are selected with the objective of ensuring that the resulting flood has the same annual exceedance probability as its causative rainfall.



- **Figure 3-6 Schematic illustration of the design event approach**

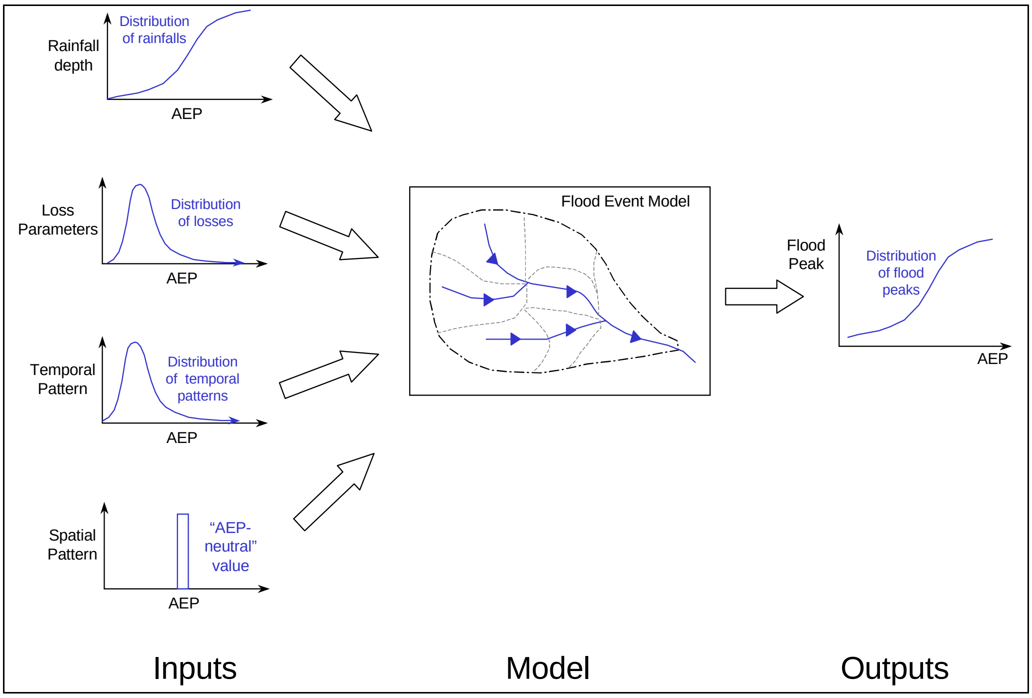
While this approach represents current “best practice” in Australia (and overseas), it does suffer from the limitations that:

- the AEP-neutrality of some inputs can only be tested on frequent events for which independent estimates are available;

- for more extreme events, the adopted values of AEP-neutral inputs must be conditioned by physical and theoretical reasoning; and,
- the treatment of more complex interactions (such as the seasonal variation of inputs) becomes rapidly more complex and less easy to defend.

Joint probability techniques offer an alternative to the design event method. These techniques recognise that any design flood characteristics (e.g. peak flow) could result from a variety of combinations of flood producing factors, rather than from a single combination. For example, the same peak flood could result from a moderate storm on a saturated basin, or a large storm on a dry basin; in probabilistic terms, a 1 in 100 AEP flood could be the result of a 1 in 50 AEP rainfall on a very wet catchment, or a 1 in 200 AEP rainfall on a dry catchment. Joint probability approaches attempt to mimic "mother nature" in that the influence of all probability distributed inputs are explicitly considered, thereby providing a more realistic representation of the flood generation processes.

The method is easily adapted to focus on only those aspects that are most relevant to the problem. For example as illustrated in **Figure 3-7** it is possible to adopt single "AEP-neutral" values for some inputs (in this case the manner in which rainfalls are spatially distributed over the catchment), and full distributions for other more important inputs, such as losses and temporal patterns.

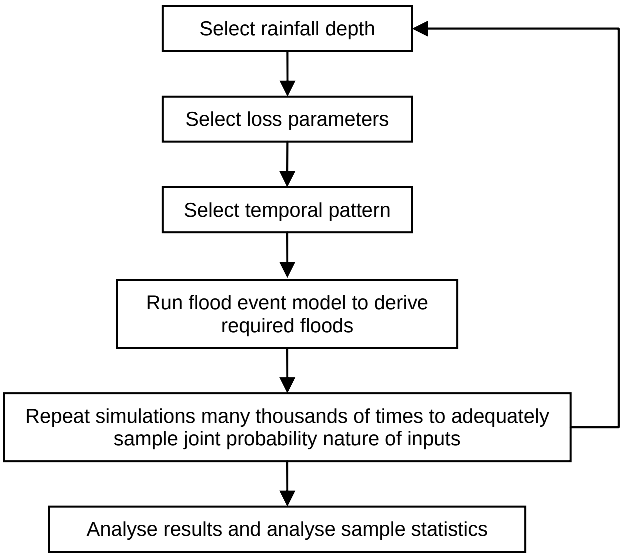


- **Figure 3-7 Schematic illustration of the joint probability approach**

The following sections outline the overall framework adopted, and the nature of the evidence used to characterise the distribution of the inputs.

3.5.2 Overview of adopted joint probability framework

An overview of the joint probability framework adopted is illustrated in **Figure 3-8**. In essence the approach involves the undertaking of numerous model simulations where the model inputs are varied in accordance with that observed in nature. The inputs are sampled from non-parametric distributions that are either based on readily available design information or else on the results of recent research.



- **Figure 3-8: Overview of adopted joint probability framework**

In developing the joint probability framework particular attention was given to ensuring that the nature of the inputs and the manner in which they are incorporated are consistent with the philosophy detailed in the current "Australian Rainfall and Runoff" Book VI (Nathan and Weinmann, 2000) guidelines. The following briefly describes the main elements of the approach, and the manner in which they relate to established design information.

Select rainfall depth. Rainfall depths are stochastically sampled from the cumulative distribution of rainfall depths. The relationship between burst depth and annual exceedance probabilities is based directly on the Book VI guidelines, though additional information is obtained from ARR procedures to derive rainfalls down to AEPs as frequent as the 1 in 2 AEP event. In addition, approximate values for rainfalls more extreme than the Probable Maximum Precipitation (PMP) are derived by simple linear extrapolation in the logarithmic – Normal probability domain. These extrapolation rainfalls represent burst depths down to AEPs approximately one order of magnitude less frequent than that of the PMP, though these contribute little to the final results.

Select storm losses: Storm initial and continuing losses are stochastically sampled from a non-parametric distribution that was determined from the analysis of a large number of Victorian catchments (Hill et al., 1997).

Select Temporal Pattern. Temporal patterns are randomly selected from a sample of temporal patterns. The temporal patterns are derived from large historic storms that have been observed in the region, and are from the same database used to construct the design patterns used in the current design event approach.

Monte-Carlo simulation. Simulations are undertaken using a stratified sampling approach in which the sampling procedure focuses selectively on the probabilistic range of interest. Thus, rather than undertake many millions of simulations in order to estimate an event with, say, a 1 in 10^6 probability of exceedance, a reduced number of simulations are undertaken over a specified number of probability intervals. The rainfall frequency curve was divided into 50 intervals uniformly spaced over the standardised normal probability domain, and 200 simulations were taken within each division. Thus, a total of 10,000 simulations were undertaken to derive the frequency curve corresponding to each storm duration considered.

3.5.3 Model Inputs

Since the catchment is so small (46.2 km^2), it has been assumed that the critical duration will be short (less than 6 hours) and so the GSDM procedure for deriving rainfall depths and spatial patterns has been used.

Rainfall Depths

The rainfall depths used are shown in **Figure 3-5**.

Pre-burst Rainfall

The temporal pattern of rainfall antecedent to the main rainfall burst (pre-burst pattern) was adopted from Jordan et al. (2003).

Design Temporal Patterns

A sample of 10 Monte-Carlo temporal patterns were used for the design storms (Jordan et al. 2003). These temporal patterns have been derived from analysis of the temporal patterns of convective thunderstorm events from rainfall stations around Australia. Pre-burst rainfall temporal patterns were also derived using this data set. This sample of temporal patterns was applied to rainfall event durations between 0.5 and 6 hours.

Design Spatial Patterns

The adopted design spatial pattern was adopted from the GSDM guidelines (BOM, 2003). The design spatial patterns vary with burst rainfall duration so that they are consistent with the approach used to derive the PMP rainfall depth.

Design Losses

The adopted design storm losses were derived from verification of the RORB model to estimates obtained from the rational method (see **Section 3.1**). The initial and continuing losses were then stochastically sampled from a non-parametric distribution that was determined from the analysis of a large number of Victorian catchments (Hill et al., 1997).

3.5.4 PMPDF Estimate

Estimates of the PMPDF at different locations in the catchment are shown in **Table 3-4** and the design hydrographs are shown in **Appendix C**.

- **Table 3-2: PMPDF estimates for each location.**

Location	Peak Flow (m^3/s)	Duration (hrs)
Pipers Flat Upstream of Irondale Creek	840	3
Irondale Creek	510	2
Thompsons Creek	900	3

4. Hydraulic Model – Development

4.1 Overview

The MIKE21 model of the Western Rail Loop is based on the following data:

- 1m contours based on topographic survey of the Pipers Creek floodplain over the length of the proposed site.
- Survey of the existing Irondale Creek and Thompsons Creek waterway structures underneath the existing railway line and Wallerawang to Portland Road
- 5 metre contour maps
- Digital Elevation Model (DEM) of the proposed embankment in the form of z attributed polylines.

Development of the model involved the following steps:

- Formation of a two dimensional ground elevation grid to represent both the existing ground profile, as well as the proposed rail loop embankment design;
- Development of suitable boundary conditions, to specify behaviour of flood flows coming into and leaving the site;
- Representation of the existing and proposed waterway openings through embankments; and
- Estimation of parameters controlling floodplain hydraulics, such as surface roughness.

4.2 Model Grid Development

The model grid was developed using detailed topographic survey of the site, and the 5 metre contour topographic dataset. The detailed topographic survey covers the extent of the proposed project, however it does not include areas south west of the existing railway line, including the Wallaerwang to Portland Road and the Thompsons and Irondale Creek channel and floodplains to the south. In order to represent these areas, the 5 metre contour dataset was spliced into the detailed topographic model dataset. The coarseness of this data represents a significant limitation in terms of hydraulic representation of flows as they approach the proposed rail loop.

The resulting topographic model of the Thompsons Creek and Irondale Creek channel and floodplain is coarse, and this should be considered when reviewing the results of this study. However, as this is incorporated into both the existing and proposed models, the modelling in this study still has value in assessing the relative increase in flood levels caused by the proposed loop. While detailed survey south of the Wallerawang to Portland Road would have provided a more accurate assessment of peak water levels upstream of the road embankment, the current model does assess the impact of the additional waterway crossing length at Thompsons and Irondale Creeks.

4.3 Boundary Conditions

The boundary conditions for this hydraulic model include:

- Flood flows in Pipers Creek downstream of the confluence with Winters Creek
- Flood flows in Irondale Creek upstream of the Wallerawang to Portland Road embankment
- Flood flows in Thompsons Creek upstream of the Wallerawang to Portland Road embankment
- Water level in the floodplain downstream of the proposed rail loop

Flood-flow hydrographs have been calculated as described in Section 3 of this report, and have been inserted directly into the hydraulic model.

A fixed water level has been used as the downstream boundary of the hydraulic model. Model results may depend on the water level assumed at this boundary in some floods. However examination of the flood behaviour in the existing situation indicates that flood depths in the floodplain are typically close to uniform flow. This implies that if the downstream boundary is far enough away from the area of interest, it will not be overly sensitive to the assumed downstream water level at the boundary.

4.4 Waterway Opening Representation

Waterway openings have been represented within the two-dimensional grid in the MIKE21 model. In order to correctly model the head loss through each of the waterway openings, each opening was modelled in HEC-RAS. The 1 in 100 year flood event was used to adjust the roughness in the MIKE21 model to reflect the losses from the HEC-RAS model.

4.5 Model Parameters

A detailed assessment of the roughness of the floodplain has not been undertaken, and no data exists to confirm the selection of model roughness through verification of model results. For the existing conditions, a Mannings n of 0.050 has been assumed across the floodplain. This is considered to be somewhat conservative given the current use of the floodplain area as sheep and cattle grazing with minimal vegetation on the floodplain apart from short grass.

For the proposed conditions, the river beds and adjacent 30m width of flood plain were modelled with a roughness of 0.06 as it is expected that these areas will be vegetated after the rail has been constructed.

4.6 Model Calibration

No recorded data about past flooding is available for the study area. This includes anecdotal information about the frequency of floodplain inundation.

The hydraulic model for this study is therefore uncalibrated. While a calibrated model would have been preferred, it is considered that the uncalibrated model will provide a reliable relative assessment of the effect of the rail loop on flood levels and velocities.

4.7 HEC-RAS Modelling

The limitations of the MIKE-21 software mean that the MIKE-21 model of the proposed rail loop does not adequately simulate the head loss through the culverts. To supplement the MIKE-21 model, HEC-RAS models were developed of the Thompson and Irondale Creek openings. These models were used to determine whether the design for the proposed openings are adequate to carry the 1 in 100 year flood such that they do not lead to an increase in flood levels upstream of the proposed railway.

4.7.1 Thompson and Irondale Creeks

Results from the existing and proposed conditions models for the Thompsons creek structures are shown in Figure 4-1 and Figure 4-2 respectively. From these it can be seen that the existing road is being overtopped under existing conditions during the 100 year flood event. The results indicate that this structure is the hydraulic control for upstream water levels. The water level upstream of the proposed railway does not change due to the introduction of the proposed opening.

Existing and proposed conditions models for the Irondale creek structures are shown in Figure 4-3 and Figure 4-4 respectively. In this case, the existing road and railway are being overtopped under both existing and proposed conditions. The culvert through the proposed railway is not affecting the upstream water level.

These results indicate that the proposed openings for Thompsons and Irondale Creek will not lead to an increase in upstream water level during a 100 year flood event. The existing infrastructure is controlling the flood levels upstream of the proposed railway. The results from the HEC-RAS model were also used to alter the roughness in the MIKE-21 model to gain a similar downstream water level within the rail loop to improve the MIKE 21 simulation of flooding downstream of the proposed openings.

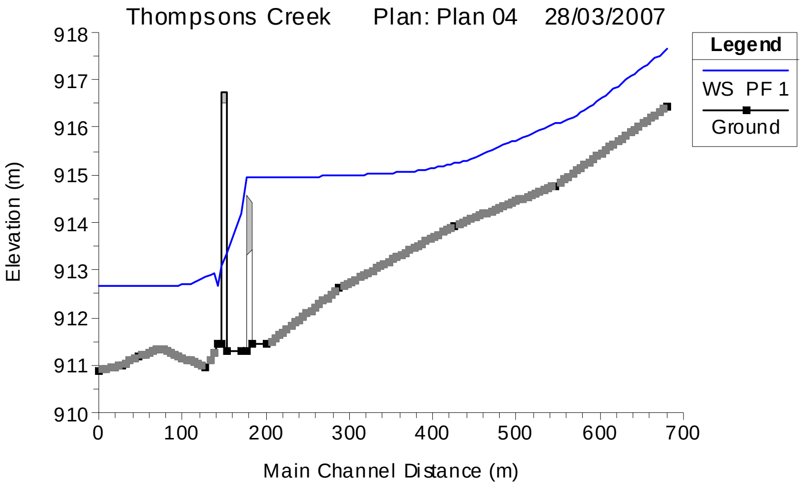


Figure 4-1: Thompsons Creek inlet for existing conditions.

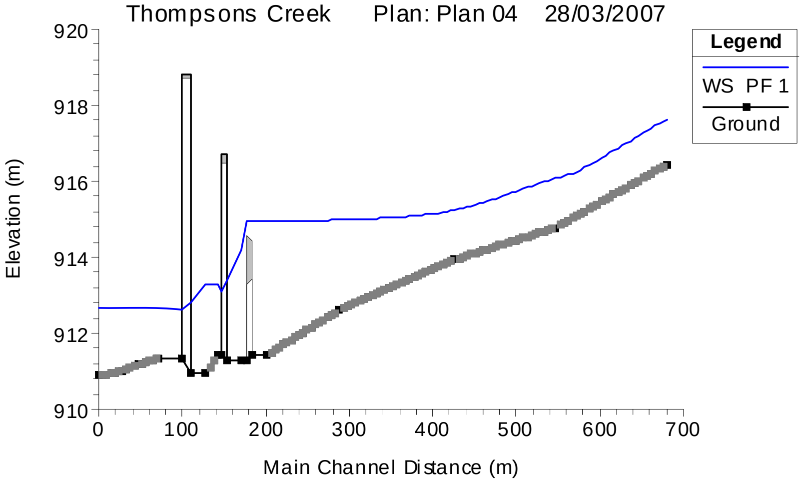
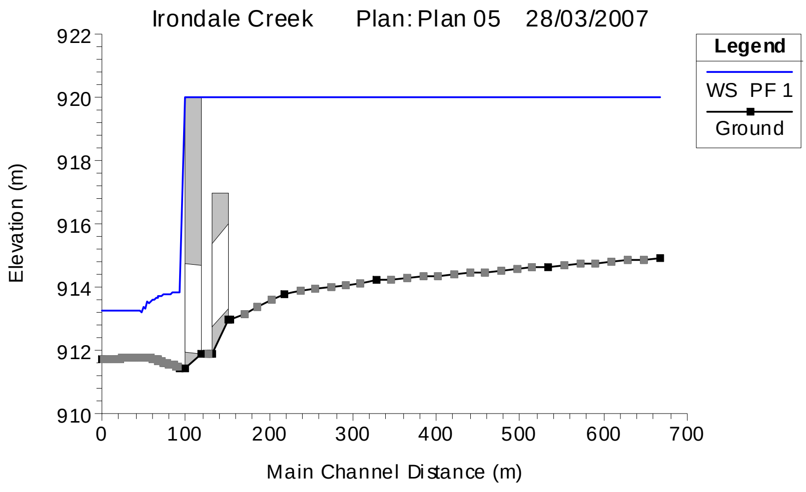
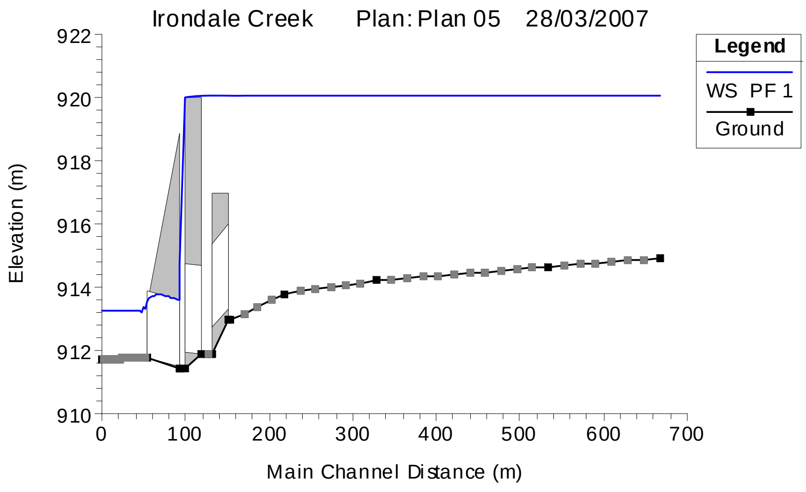


Figure 4-2: Thompsons Creek inlet for proposed conditions.



▪ **Figure 4-3: Irondale Creek inlet for exsiting conditions.**



▪ **Figure 4-4: Irondale Creek inlet for proposed conditions.**

4.7.2 Pipers Creek

The results for the pipers creek inlet into the rail loop are shown in Figure 4-5 and Figure 4-6 for existing and proposed conditions respectively. Similary, the HECRAS results for the pipers creek outlet from the rail loop are shown in Figure 4-7 and Figure 4-8. For both of these cases, it can be seen that the rail bridge is causing a change in the upstream water level. These results have been used to alter the roughness in the MIKE-21 model in order to adequately model their influence.

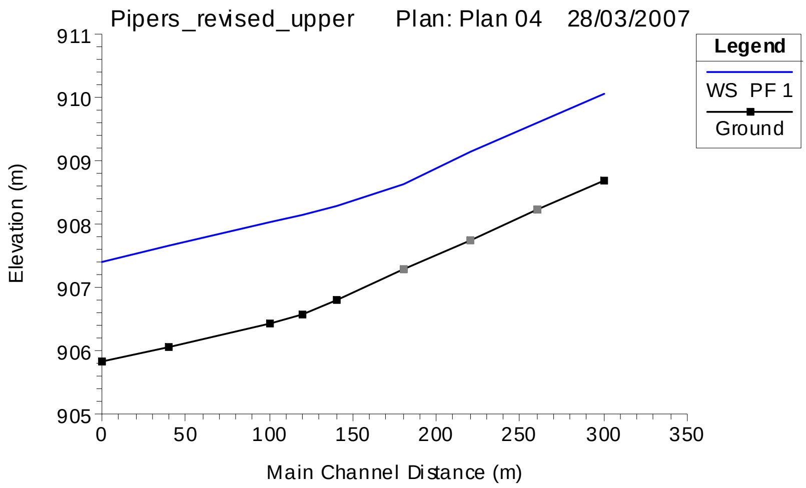


Figure 4-5: Pipers Creek inlet for existing conditions.

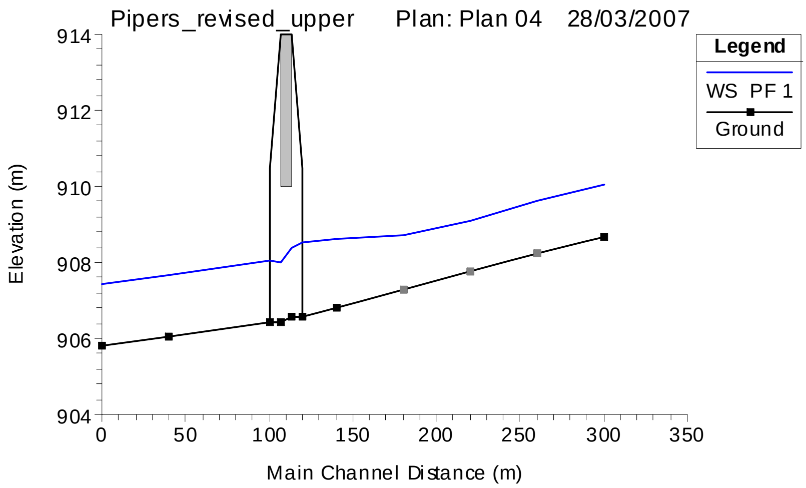
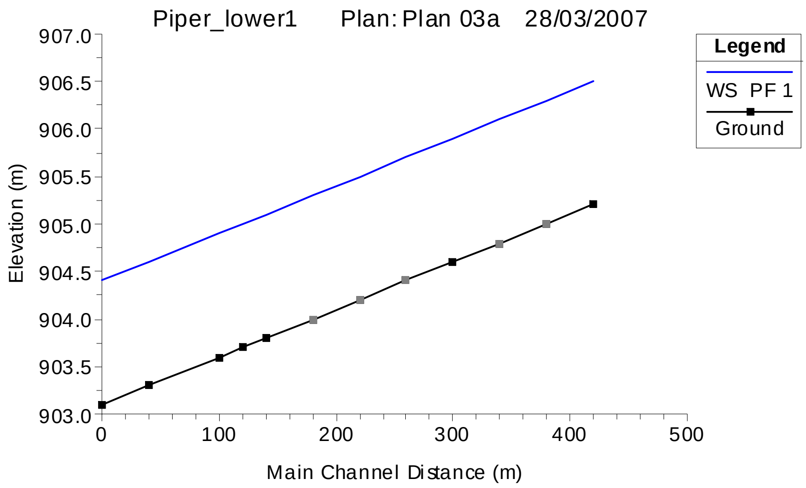
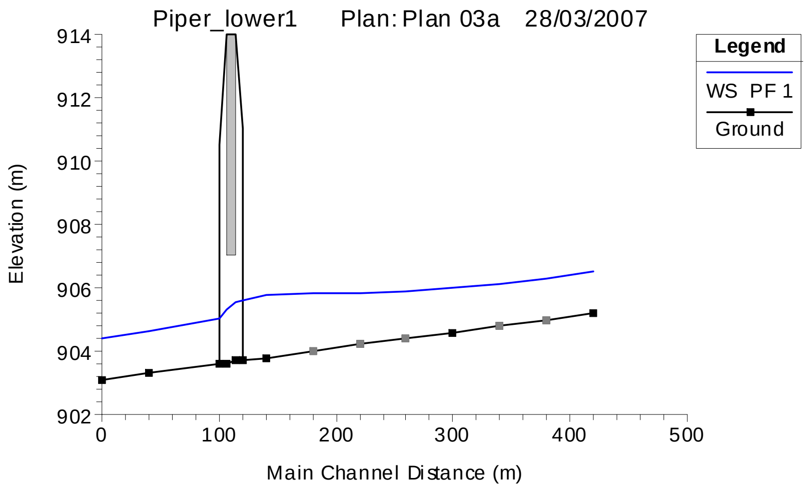


Figure 4-6: Pipers Creek outlet for proposed conditions.



- **Figure 4-7: Pipers Creek outlet for existing conditions.**



- **Figure 4-8: Pipers creek outlet for proposed conditions.**

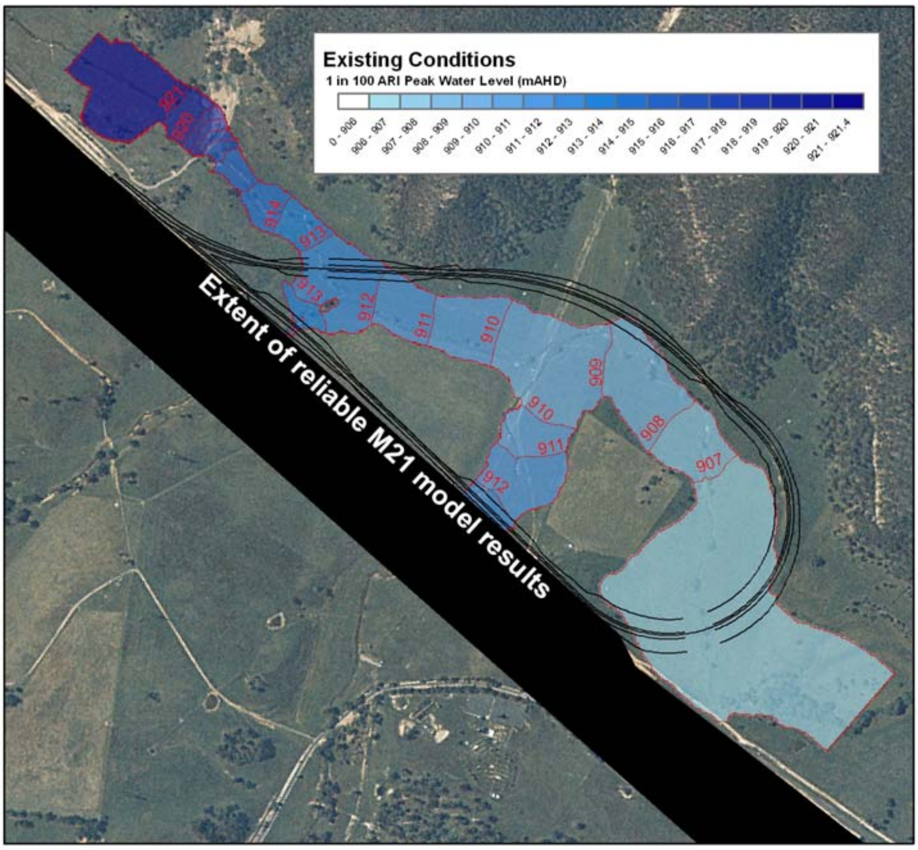
5. Hydraulic Modelling – Results and Analysis

The hydraulic models representing existing (EC) and proposed (PC) conditions as described in Section 4 were used to simulate the 100 year design flood. Details on the derivation of this flood event are described in Section 3. The models produce a time series of grid based water level, flood depth, velocity and discharge. To reflect the impacts of the proposed conditions on the nature of flooding in the study area figures showing the peak water elevation and peak flow velocity estimated using the two models have been prepared.

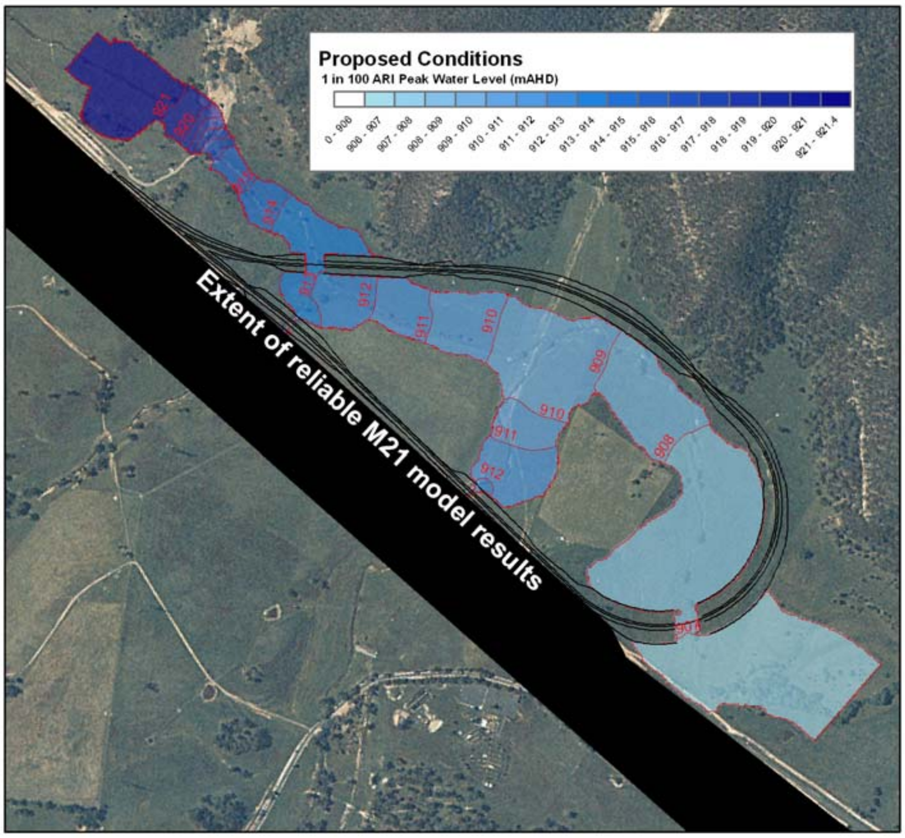
Figure 5-1and Figure 5-2 show the peak water elevation for the EC model and PC model respectively. Figure 5-3 shows the peak flow speed for the PC model.

To further illustrate the impacts, the difference between the EC and PC peak elevation results was calculated. This calculation is shown in Figure 5-4.

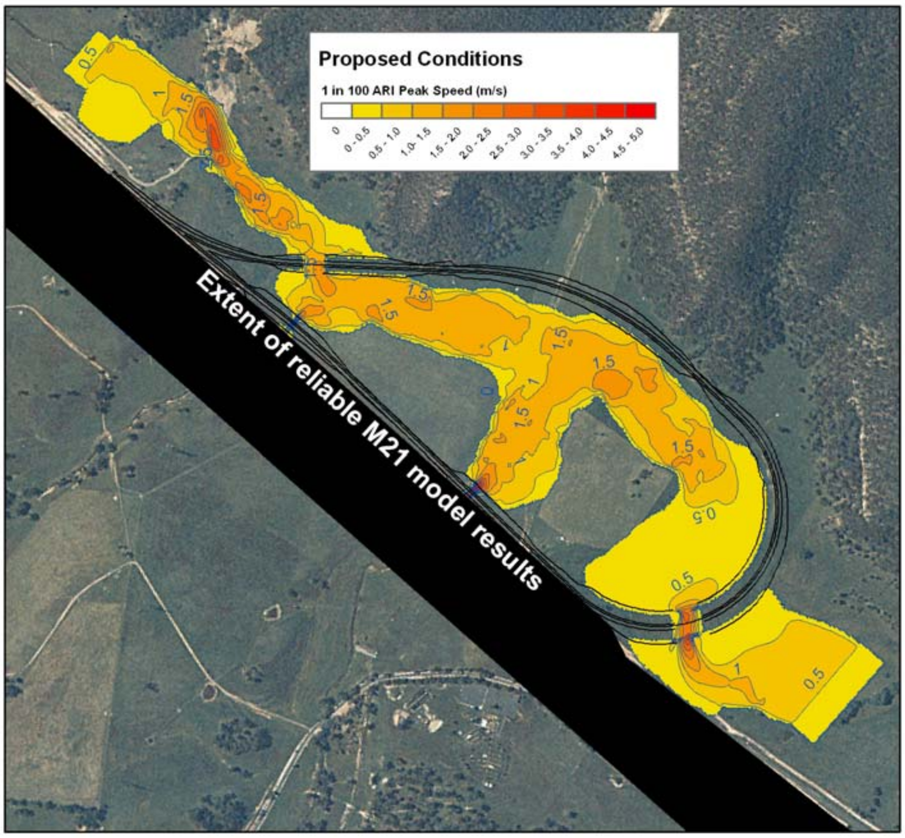
The peak water level, speed and change in water level results for EC and PC under PMPDF conditions and for the one in five and one in twenty year flood events are shown in Appendix D and Appendix E respectively.



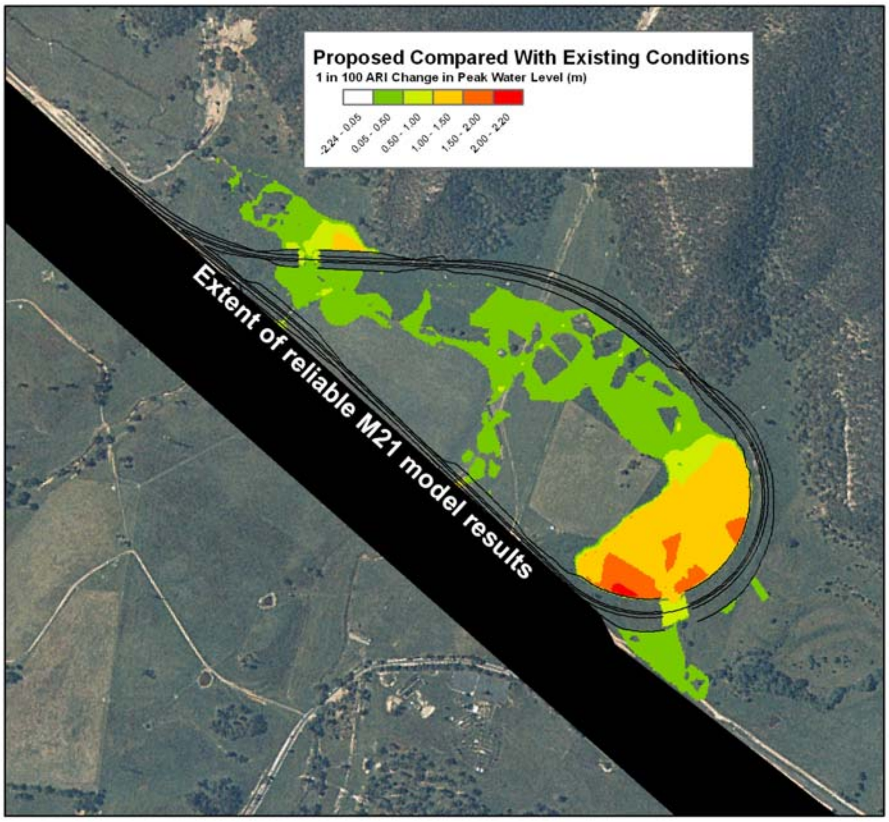
■ **Figure 5-1: Existing conditions 100 year design flood peak water elevation.**



- **Figure 5-2: Proposed conditions 100 year design flood peak water elevation.**



- **Figure 5-3: Proposed conditions 100 year design flood peak flow speed.**



- **Figure 5-4: Impact of proposed conditions relative to existing conditions 100 year design flood peak water elevation.**

6. Conclusions

6.1 100 year flood events

Peak Water Level

The model results show an increase in 100 year flood levels at several locations, namely;

1) upstream of the proposed embankment where Pipers Flat Creek enters the proposed rail loop;
2) upstream of the existing rail embankment at the Thompsons and Irondale Creek crossings; and
3) upstream of the proposed embankment where Pipers Flat Creek exits from the proposed rail loop.

At locations 1) and 2) consideration may be given to enlargement of the existing opening sizes to counteract this effect.

Location 3) exhibits the worst impacts (up to 2.2 m) with regard to flood level. This suggests there may be a need to consider additional flood capacity through the embankment. This may be achieved either through the use of additional flood relief culverts, or through enlargement of the main opening.

Although there is considerable increase in flood levels, the embankment height of the proposed rail line is more than 15 metres above the peak water elevation for the 100 year design flood.

Peak Flow Speed

Peak flood velocity provides an indication of the likelihood of scour occurring. The largest speed is found through the Thompsons Creek crossing of the proposed embankment where it reaches 4.9 m/s. Through the Irondale Creek crossing of the proposed embankment, the speed reaches 3.7 m/s. Upstream of the rail loop along Pipers Creek, the peak speed reaches 3.3 m/s and as Pipers Creek exits the rail loop, the speed reaches 3.7 m/s. These results indicate that scour is an issue of concern that may require more consideration.

6.2 PMPDF Results

As shown in Appendix D, in the PMPDF event the proposed rail line embankment is overtopped at the Thompsons Creek crossing. The embankments at Irondale Creek and at the Pipers Flat Creek crossings are not overtopped in the PMPDF (Figure D-2 of Appendix D). However, the presence of the loop embankment does increase peak flood levels by 3.0 to 5.0 metres upstream of both of the Pipers Flat Creek crossings (Figure D-4 of Appendix D).

The floodwater speeds through the proposed Irondale and Thompsons Creek rail crossings are approximately 9 and 10 m/s respectively. In Pipers Flat Creek at the outlet of the loop, the peak floodwater speed reaches 7 m/s.

6.3 One in Five and one in Twenty Flood Events

The results are shown in **Appendix E**. The plots show that flood heights and velocities are consistent with the results from the 1 in 100 year event in that for smaller events the flood heights are lower and the velocities less. Afflux outside the Delta property boundary is zero and there would be no flood impacts on other properties.

7. References

Bureau of Meteorology (2003) *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method*, Hydrometeorology Advisory Services, June 2003.

Hill, P., Mein, R.G. and Weinmann, E. 1997, *Development and Testing of New Design Losses for South-Eastern Australia*, Hydrology and Water Resources Symposium, Auckland, p 71-76.

Institution of Engineers. 1998, *Australian Rainfall and Runoff – A Guide to Flood Estimation*, Volume 2, Institution of Engineers, Australia, Canberra.

Jordan, P., Nathan, R., Mittiga, L., Pearse, M. and Taylor, B. 2003, Evaluation and *Development of Extreme Rainfall Temporal Patterns for Dams Located on Small Catchments*, Proc. ANCOLD Conference, Hobart, 2003.

Kleemola, S. (1987) *Estimation of a runoff routing parameter from catchment characteristics for Eastern New South Wales*. Thesis (M.Eng.Sc.), Univ. Of New South Wales.

Nathan, R.J, Weinmann, P.E. 2000, Book VI, 'Estimation of Large to Extreme Floods', in National ommittee of Water Engineering (Ed.). *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Institution of Engineers, Australia, Canberra.

Appendix A Existing Floodplain Structures

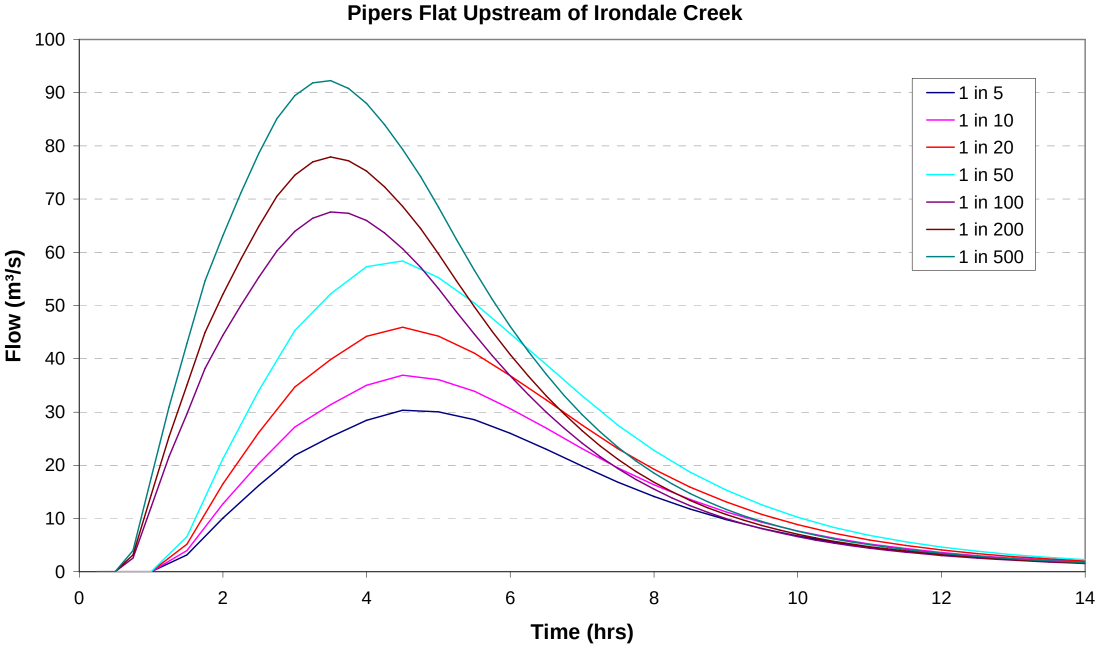
- **Table A-1: Existing floodplain structures**

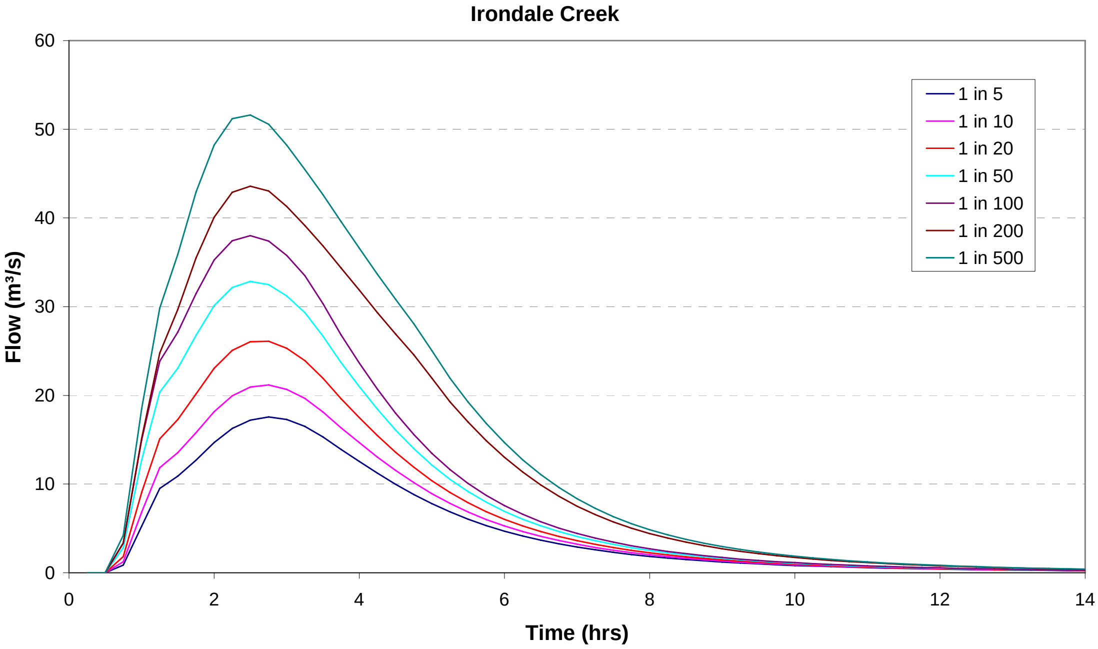
Structure location	Description	Photograph
Pipers Flat Creek Road Crossing	Twin box culverts each 2.8m wide and 2.3 m high	None available
Pipers Flat Creek Rail Crossing	Bridge with one large central opening, and two smaller side openings total bridge width ~23m central span ~9m central channel bed to bridge beam ~2.5m smaller side opening ground to bridge beam ~1.5m	
Winters Creek Road Crossing	3 x 1.5 m diameter circular culverts	
Winters Creek Rail Crossing	Corrugated flattened ellipse culvert, with base width 6.0 m and internal height 3.2 m	

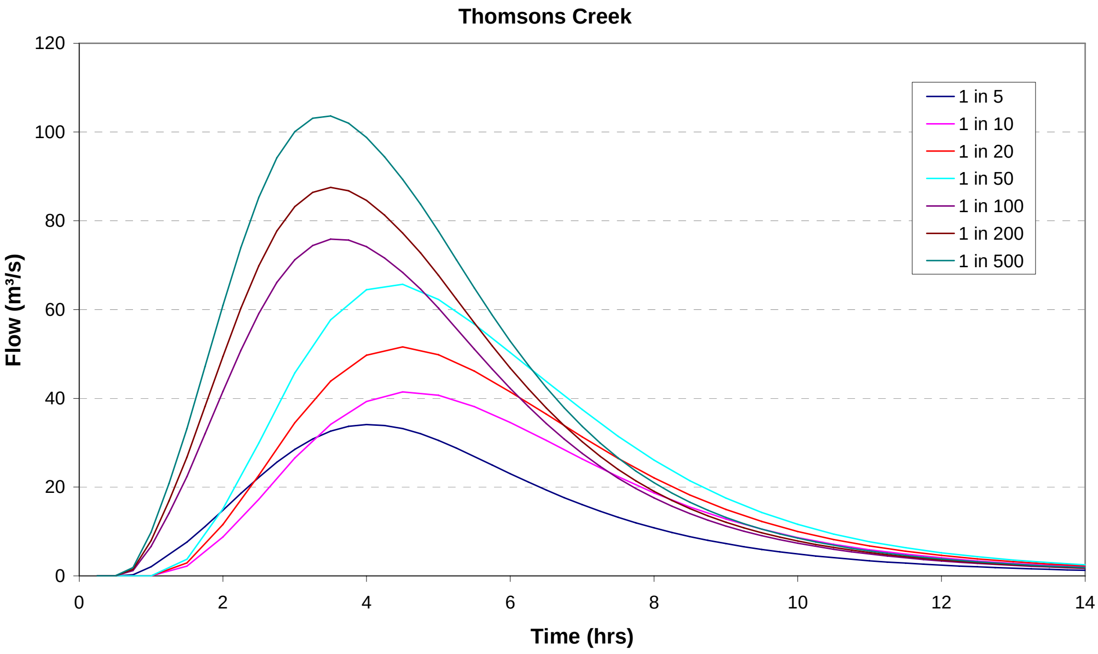
Structure location	Description	Photograph
Irondale Creek Road Crossing	Semi-circular corrugated culvert, base width 6.1 m, internal height 2.4m	
Irondale Creek Rail Crossing	Brick elliptical culvert, width (at widest point of ellipse - mid height, not ground level) 3.05m Height 3.2 m	
Thompsons Creek Road Crossing	Clear bridge span, with ~7m from one side to the other	

Structure location	Description	Photograph
Thompsons Creek Rail Crossing	Bridge with three openings Same width for all three of 5.4m Two outer openings ground level to bridge beam ~3.6m height Inner opening (includes stream channel) channel bed to bridge beam ~4.6m height	

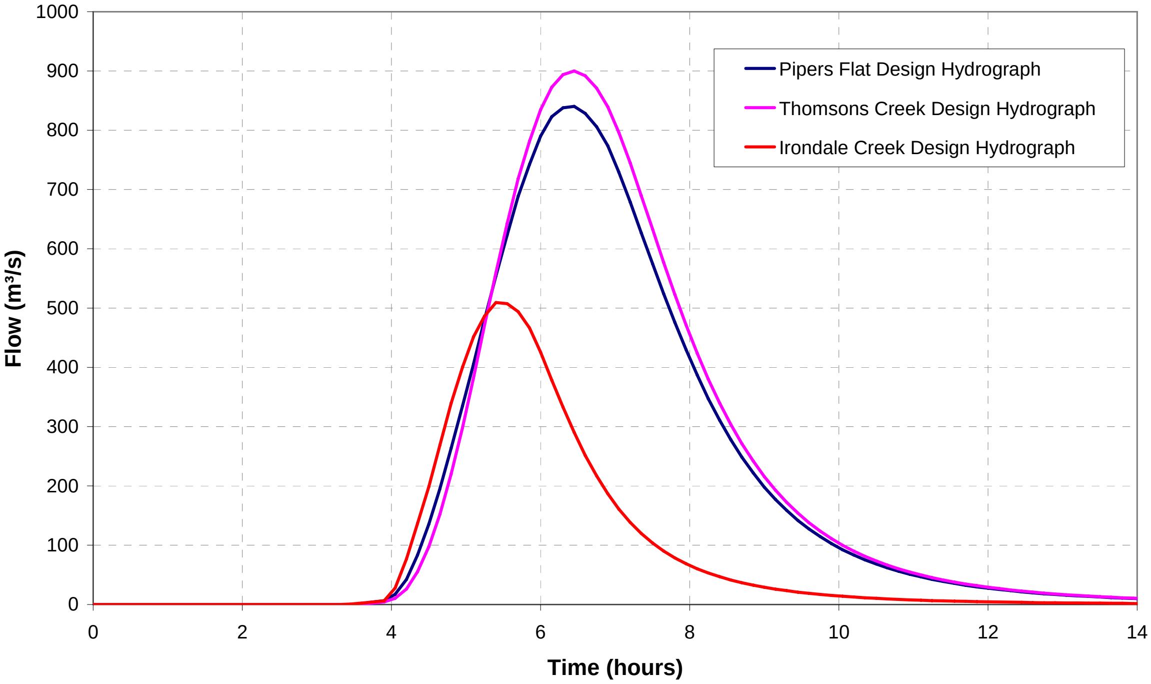
Appendix B Hydrographs for 1 in 5 to 1 in 500 ARI Events



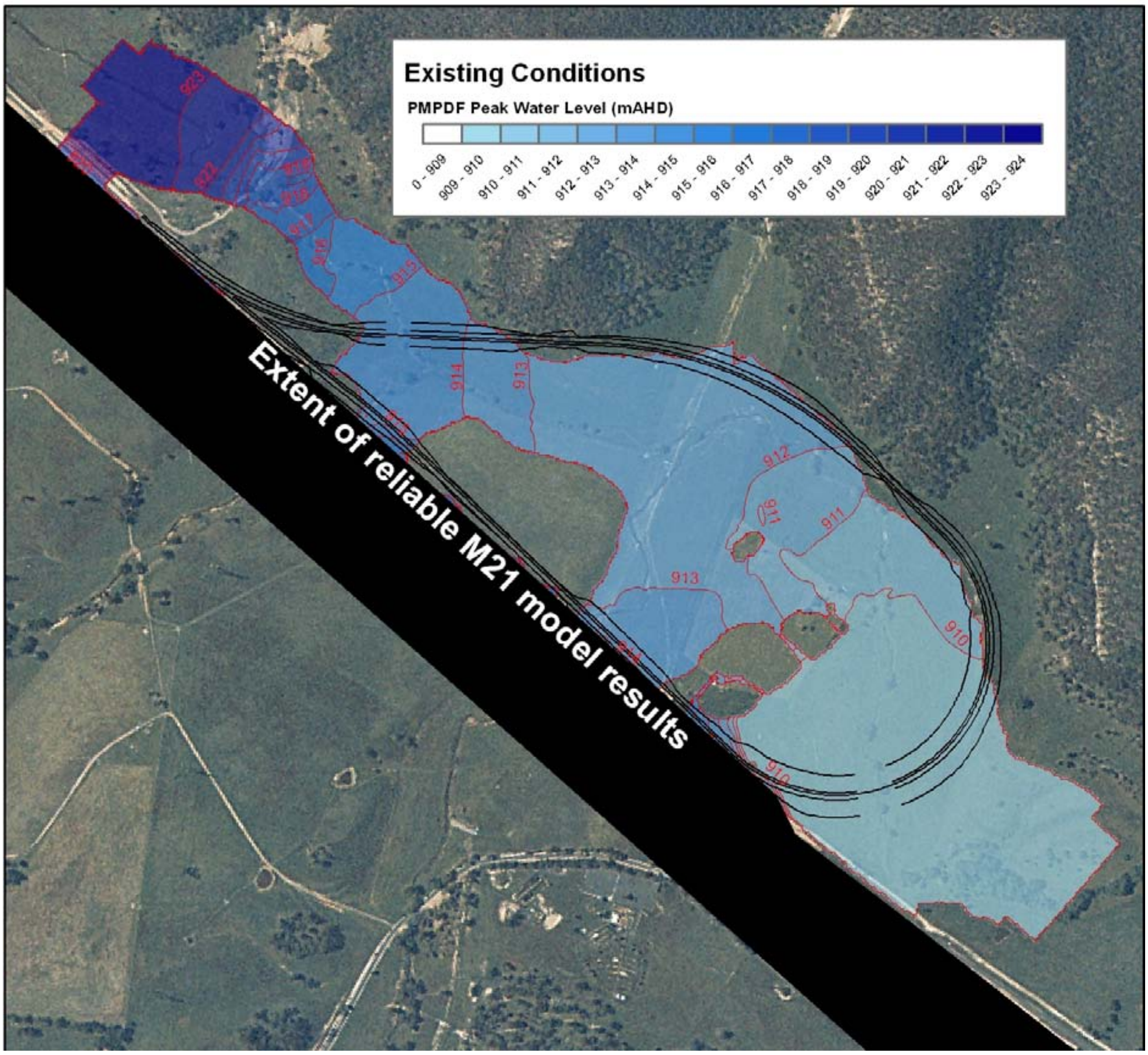



Thomsons Creek
Flow (m³/s)
Time (hrs)
0
20
40
60
80
100
120
0
2
4
6
8
10
12
14
1 in 5
1 in 10
1 in 20
1 in 50
1 in 100
1 in 200
1 in 500

Appendix C Hydrographs for PMPDF



Appendix D Model Results for PMPDF



- **Figure D-1: Existing conditions PMP design flood peak water elevation.**

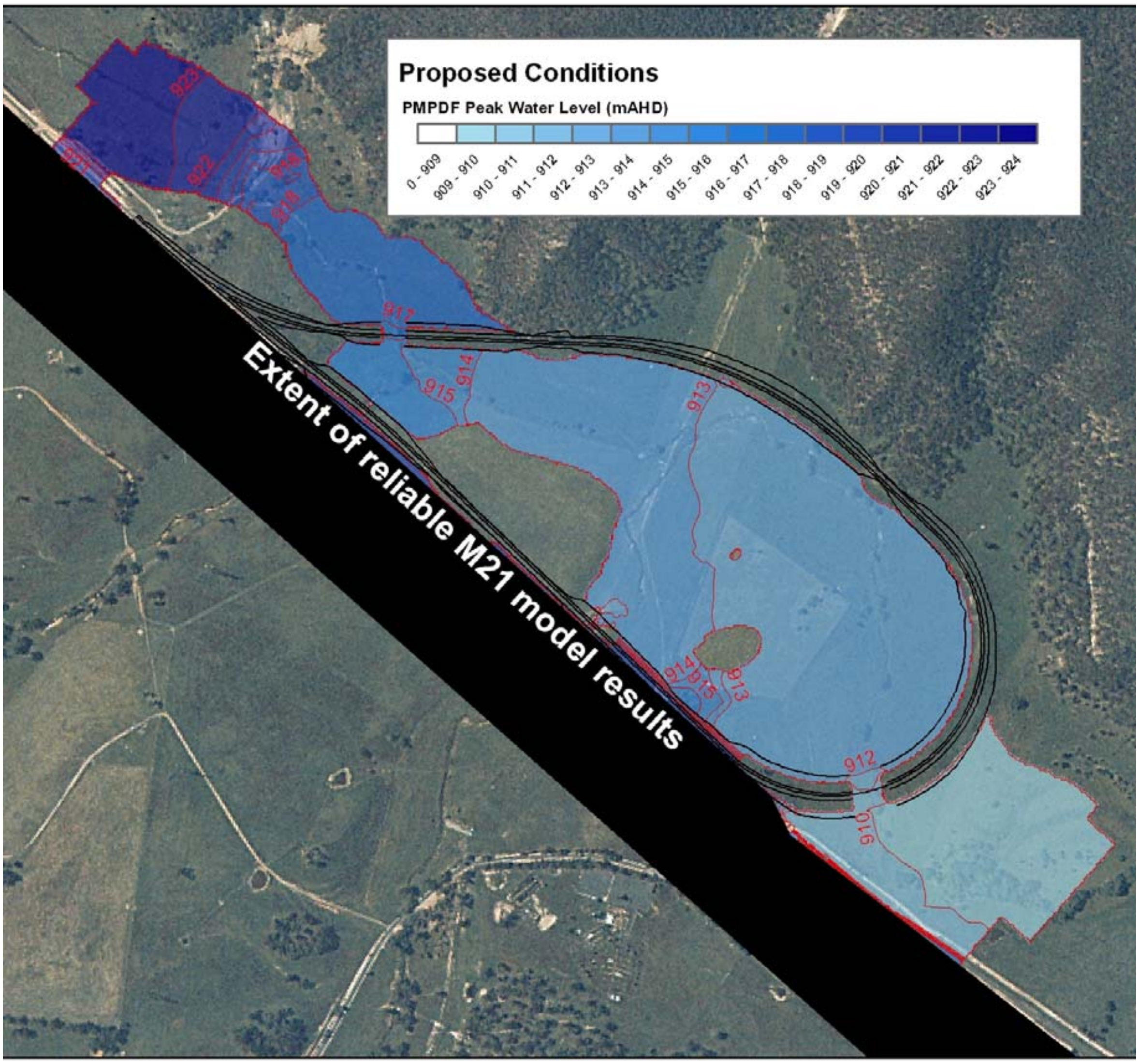


Figure D-2: Proposed conditions PMP design flood peak water elevation.

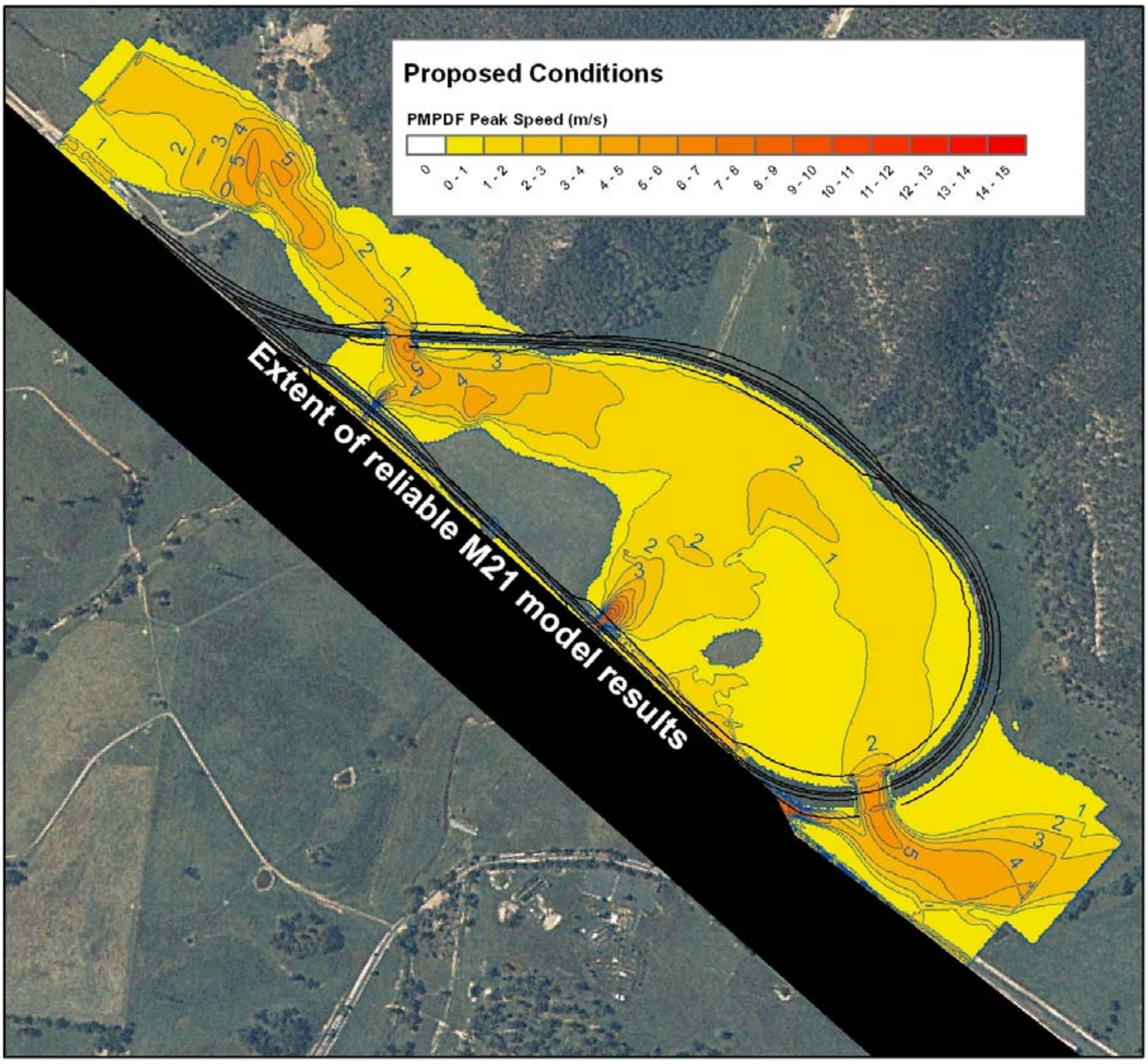


Figure D-3: Proposed conditions PMP design flood peak speed.

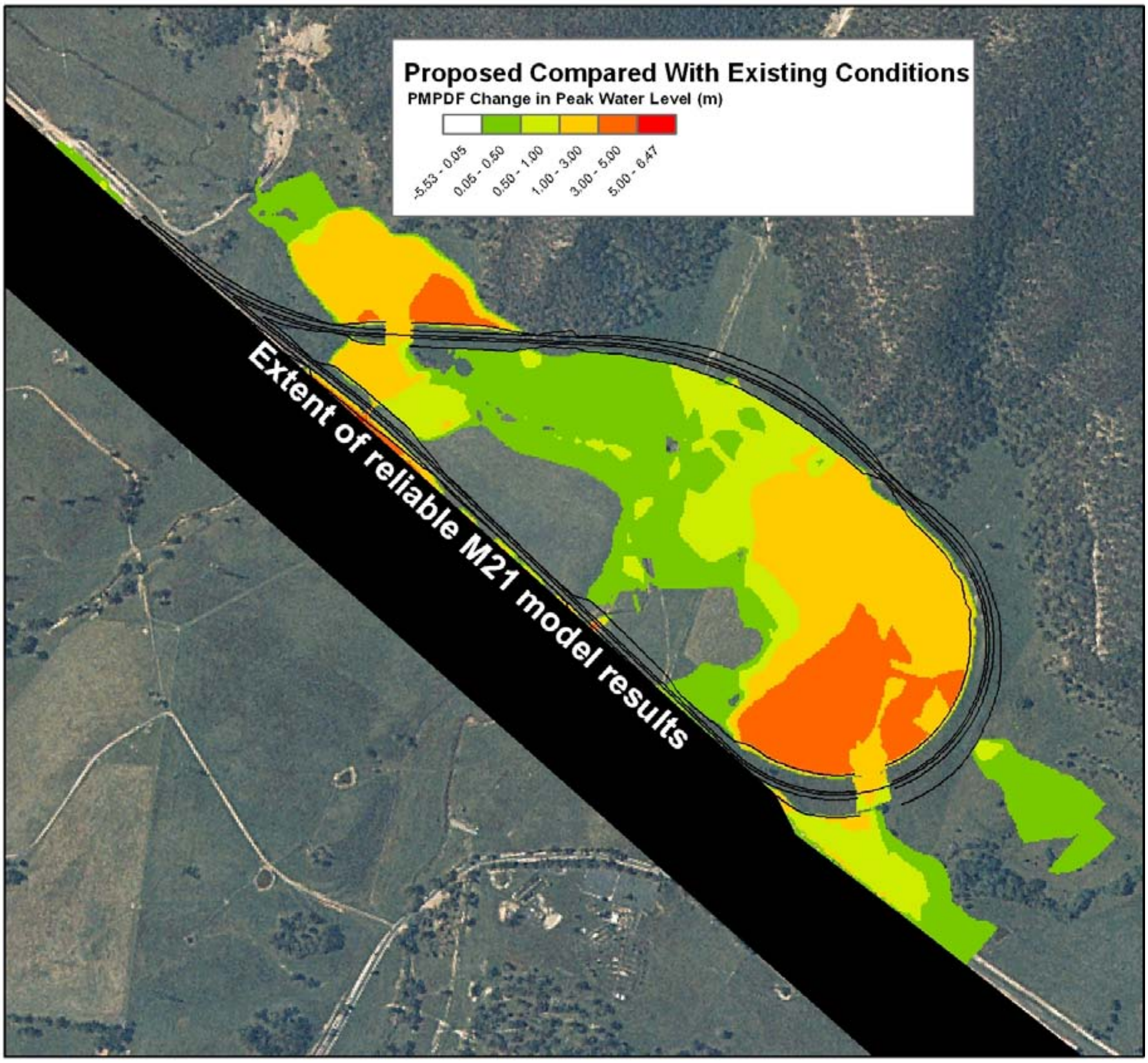
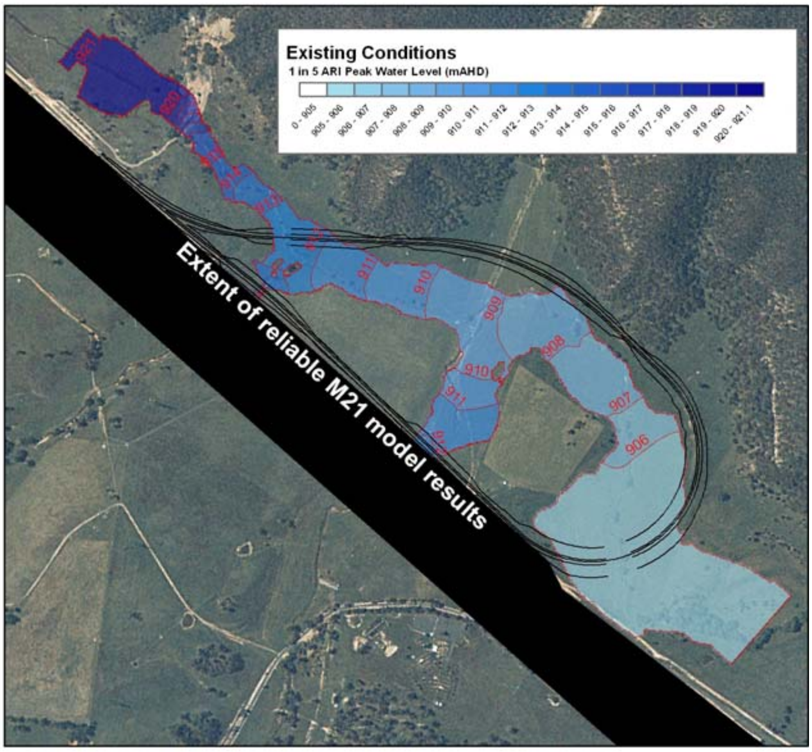
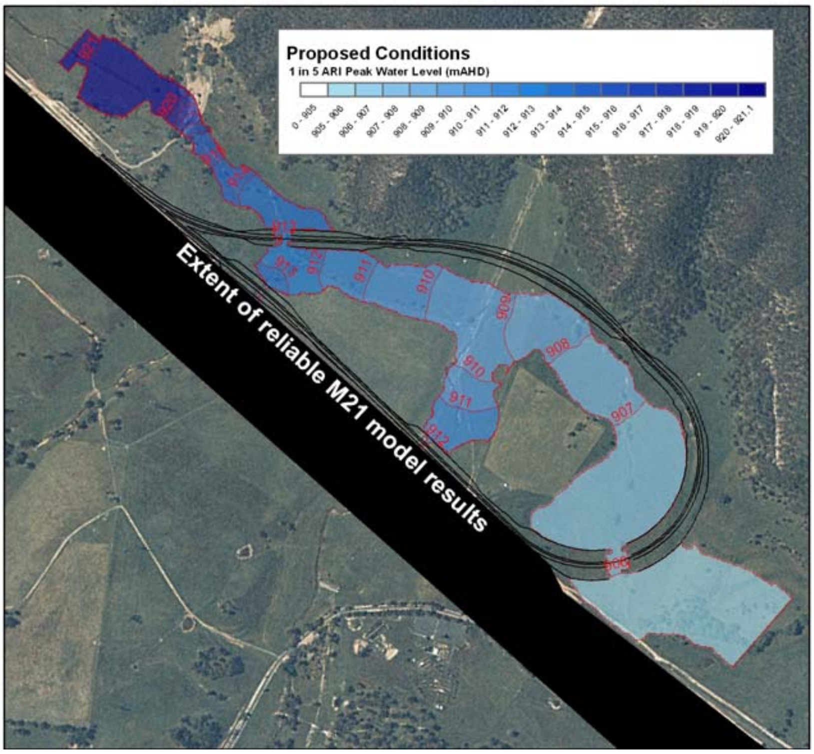
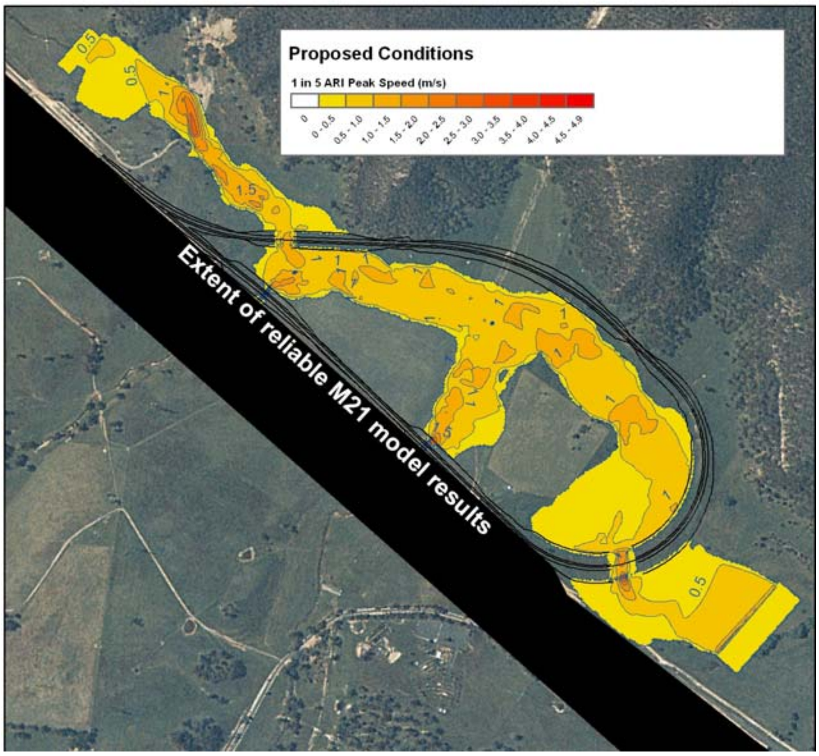


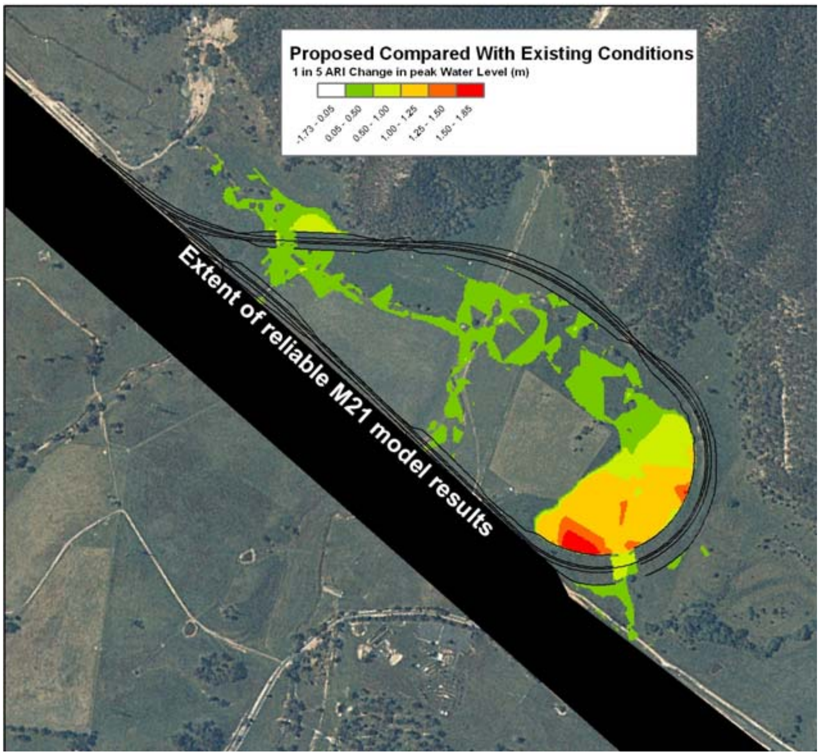
Figure D-4: Impact of proposed conditions relative to existing conditions PMP design flood peak water elevation.

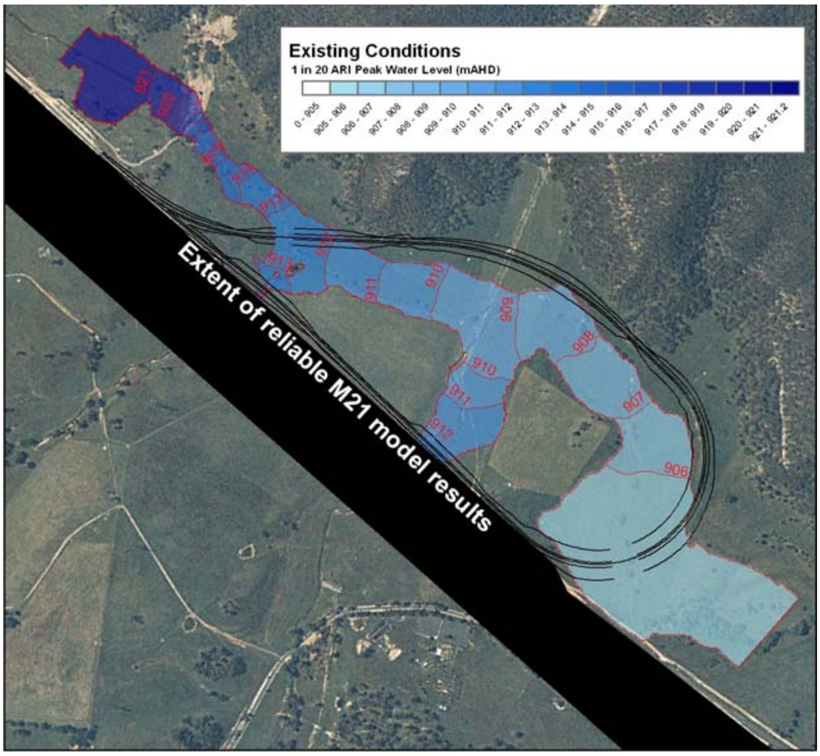
Appendix E Model Results from Other Flood Events

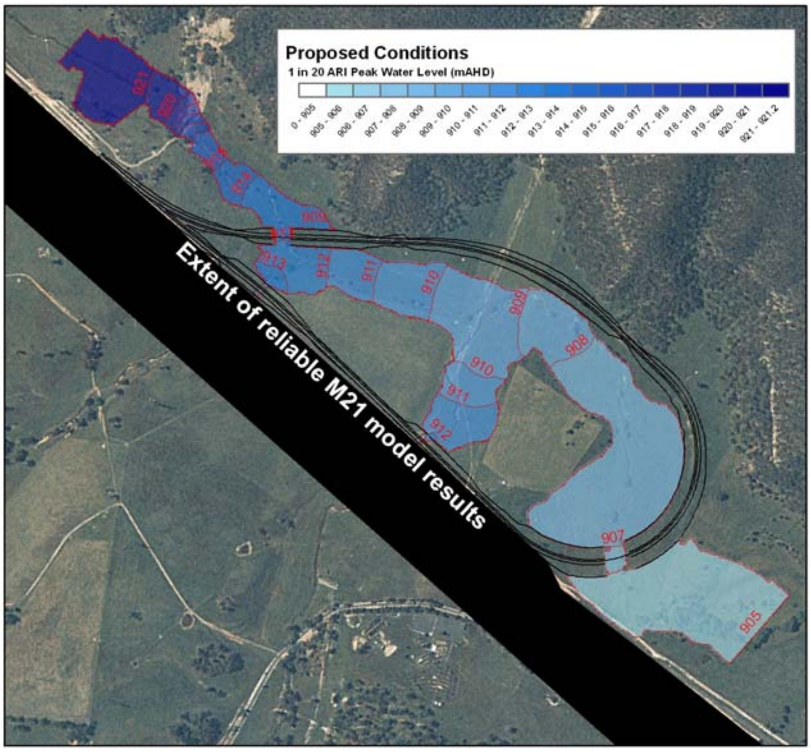

Existing Conditions
1 in 5 ARI Peak Water Level (mAHD)
0 - 905
905 - 906
906 - 907
907 - 908
908 - 909
909 - 910
910 - 911
911 - 912
912 - 913
913 - 914
914 - 915
915 - 916
916 - 917
917 - 918
918 - 919
919 - 920
920 - 921.1
Extent of reliable M21 model results
911
910
909
908
910
911
907
906

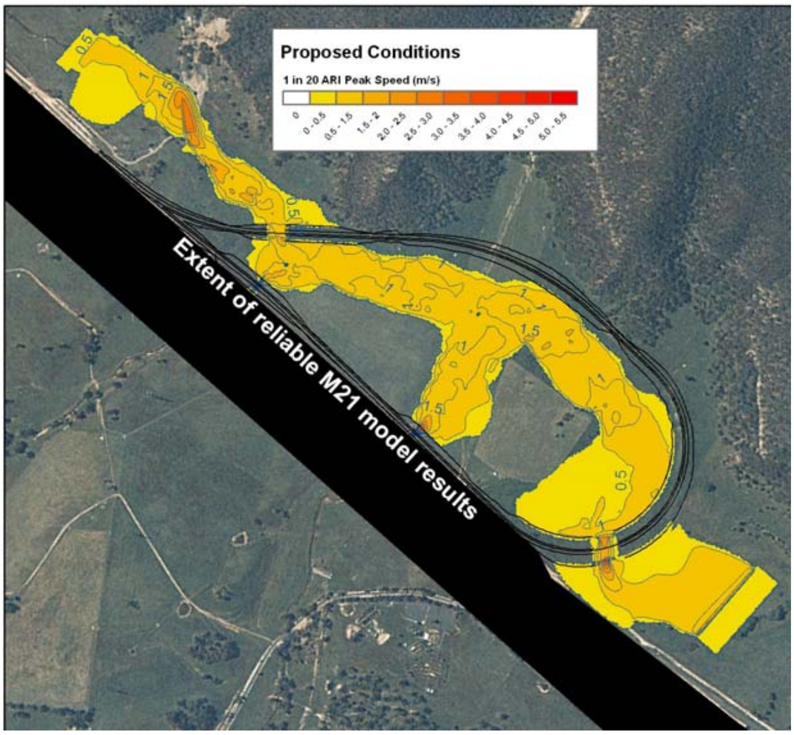

Proposed Conditions
1 in 5 ARI Peak Water Level (mAHD)
0 - 905
905 - 906
906 - 907
907 - 908
908 - 909
909 - 910
910 - 911
911 - 912
912 - 913
913 - 914
914 - 915
915 - 916
916 - 917
917 - 918
918 - 919
919 - 920
920 - 921.1
Extent of reliable M21 model results
911
910
908
910
911
912
907

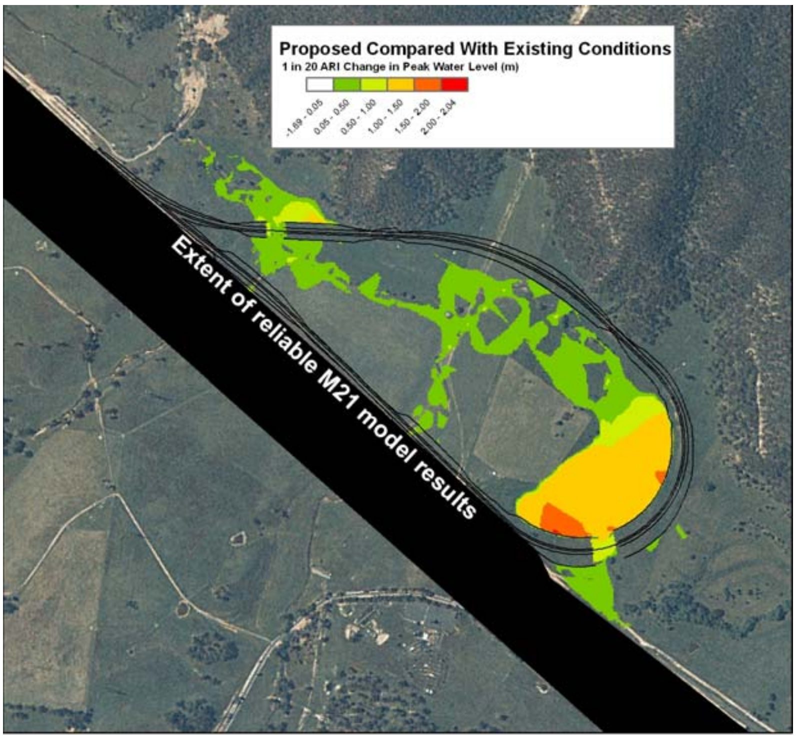

Proposed Conditions
1 in 5 ARI Peak Speed (m/s)
Extent of reliable M21 model results


Proposed Compared With Existing Conditions
1 in 5 ARI Change in peak Water Level (m)
Extent of reliable M21 model results


Existing Conditions
1 in 20 ARI Peak Water Level (mAHD)
Extent of reliable M21 model results


Proposed Conditions
1 in 20 ARI Peak Water Level (mAHD)
Extent of reliable M21 model results


Proposed Conditions
1 in 20 ARI Peak Speed (m/s)
0
0 - 0.5
0.5 - 1.5
1.5 - 2
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
3.5 - 4.0
4.0 - 4.5
4.5 - 5.0
5.0 - 5.5
Extent of reliable M21 model results


Proposed Compared With Existing Conditions
1 in 20 ARI Change in Peak Water Level (m)
-1.69 - 0.05
0.05 - 0.50
0.50 - 1.00
1.00 - 1.50
1.50 - 2.00
2.00 - 2.04
Extent of reliable M21 model results