Goulburn River Environmental Flows Hydraulics Study

Hydraulic model application and affected asset assessment

Environmental flow scenarios

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PROJECT DETAILS

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1. INTRODUCTION

The Goulburn Broken Catchment Management Authority (Goulburn Broken CMA) has commissioned the Goulburn River Environmental Flow Hydraulics Study. The study is required to undertake hydraulic and hydrologic modelling of the Goulburn River from Lake Eildon to the River Murray.

This report documents the application of the hydraulic models to simulate flow/flood behaviour over a range of environmental flow magnitudes. A further report discusses the application of the hydraulic model for the floodplain management purposes.

The study brief outlined the following project tasks:

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

This document reports on aspects of the fifth project tasks.

The structure of this report is as follows:

- Section 2: provides an overview of the considerations in the development of the flow scenario assessed.
- Section3: outlines the inundation and affected assets characteristics under the flow scenario considered
- Section 4: contains the conclusions and key outcomes

2. HYDRAULIC MODEL APPLICATION SCENARIOS SCOPING

2.1 Overview

The application of the hydraulic models can grouped as follows:

- Environmental flows: Flow scenarios to achieve inundation of key environmental asset
- Floodplain management flows: Design flood events for floodplain management

This report is confined to the environmental flows scenarios only. A further report discusses the application of the hydraulic model for the floodplain management purposes.

As discussed in the Hydraulic Model Construction and Calibration report (Water Technology 2009b), the study area was broken into eight model reaches, as follows (refer to Figure 2-1):

A. Eildon to Alexandra
B. Alexandra to Ghin Ghin
C. Ghin Ghin to Kerrisdale
D. Kerrisdale to Mitchellstown
E. Mitchellstown to Wahring
F. Wahring to Kialla
G. Kialla to Bunbartha
H. Bunbartha to the Murray River

Sections 2.2 discusses the development of the environmental flows flow scenarios assessed.

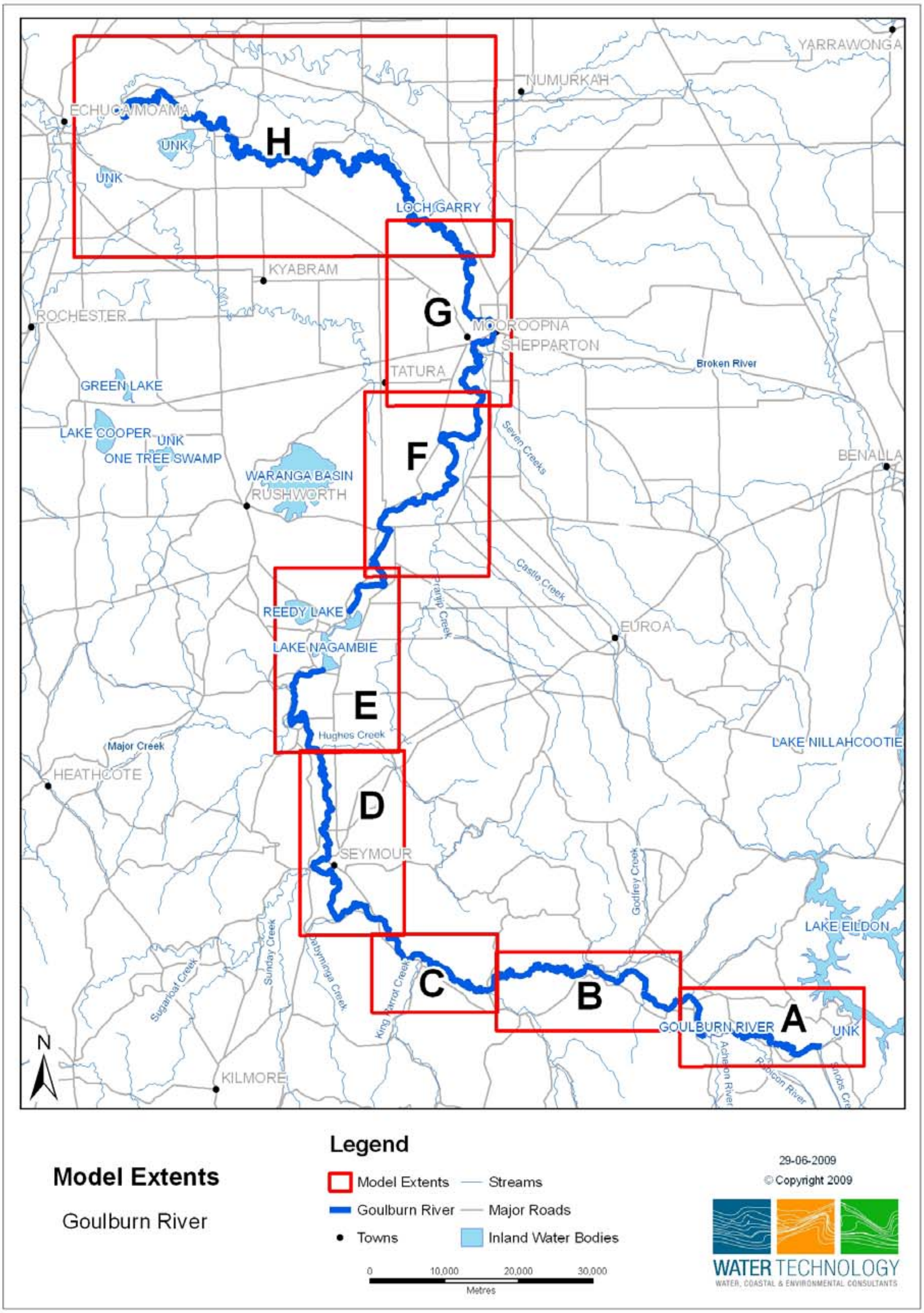

Figure 2-1 Study area – model reaches

2.2 Environmental flow scenarios

For environmental flows range, the purpose of the project was to provide preliminary understanding of the flood/flow characteristics of the Goulburn floodplain. Key questions were:

- How does water flow onto the Goulburn floodplain?
- What environmental and economic/social assets are inundated at different river flows (at different points along the river)?
- What is a 'safe' maximum flow rate for environmental flows being sent to the River Murray, and how does this vary along the river?
- What losses occur at different flow rates?
- What are the travel times for different flows along the Goulburn River?
- What attenuation occurs as water flows along the river?

This project provided an initial exploration of the above questions, and to inform future directions of investigations.

Cottingham et al. (2003) discussed a floodplain wetland inundation regime between 15,000 – 60,000 ML/d. This regime has informed the range of environmental flow events considered by this study.

For this initial exploration, a series of preliminary model application runs been have undertaken based on releases from Lake Eildon and no tributary flows. The peak flows considered included 20,000 ML/d, 30,000 ML/d, 40,000 ML/d, 50,000 ML/d and 60,000 ML/d. For each of these peak flows, the flow hydrograph was constructed to increase at the maximum rate of rise allowed, then held at the peak steady at the maximum flow to allow equilibrium flow conditions to be established along the model reach, and then decreased at the maximum rate of fall allowed back to minimum flow. The model continued to run to allow the floodplain to fully drain.

The study area was broken into eight hydraulic models, as discussed in the Hydraulic model construction and calibration (Water Technology 2010), and as shown in Figure 2-1.

For the environmental flow scenarios, each of the eight model reaches was modelled separately. The flow hydrographs were applied as a boundary inflow at the upstream limit of each model reach. Hence, these preliminary model application runs assess the travel time of the flow hydrograph along the model reach, but not flow transfer between reach models.

The duration of the flow hydrograph varied along the study reach as the time required to achieve equilibrium conditions was a function of reach length and floodplain storage. Model Areas A – G employed a 10 day hydrograph duration, and Model Area H used a 20 day duration.

Table 2-1 displays the flow hydrographs durations and volume.

As discussed above, steady state flow conditions (i.e. constant flow along the reach) were assessed in the hydraulic model. The attenuation of flow hydrographs within each reach, and along the entire study reach was not assessed.

The assessment of flow attenuation requires the hydraulic modelling of a range of flow hydrographs to reflect potential releases from Eildon. The flow hydrographs would encompass a range of peak flows, rates of rise and fall, and flood volumes. Each potential flow hydrograph would be applied as an inflow immediately downstream of Eildon. The modelled flow hydrograph at the downstream limit of each model reach would be then applied as the inflow for the next downstream model.

Table 2-1 Environmental flow scenario – Event durations and volume

Reach	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Vol (ML)	Vol (ML)	Vol (ML)	Vol (ML)	Vol (ML)
Eildon to Bunbartha (Model A-G)	128500	178500	223500	272900	315000
Bunbartha to the Murray River (Model H)	257000	357000	447000	545800	630000

Figure 2-2 and Figure 2-3 display the environmental flow hydrographs.

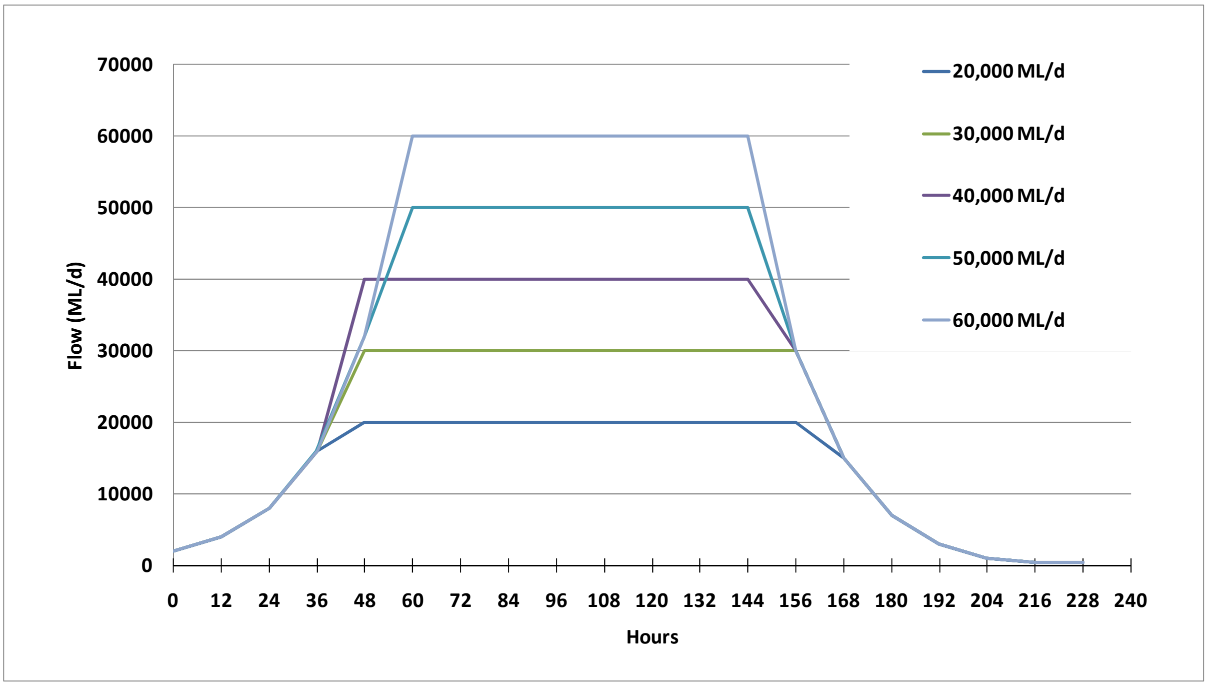

Figure 2-2 Environmental flow hydrographs – Model A-G – Eildon to Bunbartha

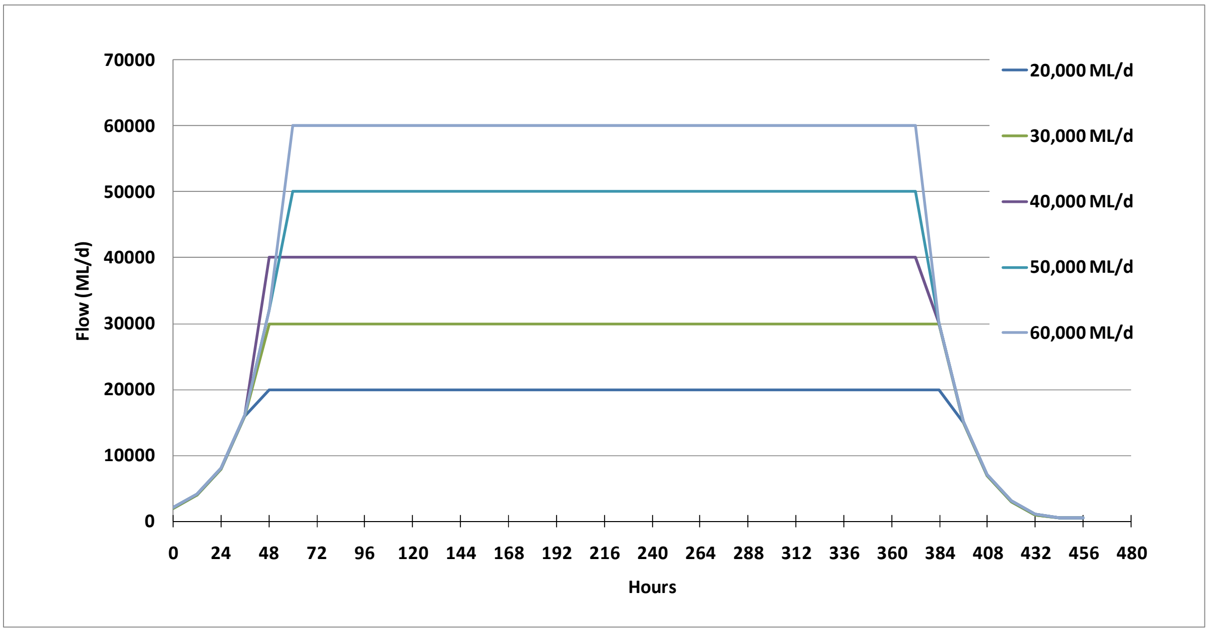

Figure 2-3 Environmental flow hydrographs – Model H

2.3 Hydraulic model capabilities and limitations

The Hydraulic Model Construction and Calibration report (Water Technology 2009b) discussed the calibration of the hydraulic modelling framework to available stage and flow data. The robustness of the model calibration needs to be considered when assessing the outcomes of the model application.

Key points from the model calibration to note are as follows:

- Upstream of Goulburn Weir
  - At Trawool, for flows from 15,000 to 28,000 ML/d, the modelled water levels were higher than the observed gaugings. Generally, the modelled water levels over this flow range were 200 – 400 mm above the gaugings. Over a flow range of 28,000 to 60,000 ML/d, the modelled and gauged water levels were found to be in good agreement (within 200 mm).
  - A similar pattern in modelled water levels was found at Seymour. For flows up to 32,000 ML/d, the modelled water levels were higher than gaugings by 200 – 400 mm. For higher flows up to 60,000 ML/d, the modelled and gauged water levels were in good agreement (within 200 mm).
- Downstream of Goulburn Weir
  - At Murchison, the modelled rating curve showed a considerable discrepancy from the gaugings. The observed gaugings at Murchison showed considerable scatter in the rating curve. The modelled water levels were found to be significantly lower than the observed gaugings for flows up to 60,000 ML/d.
  - At Shepparton, the observed gaugings shows a considerable scatter for flows from 10,000 ML/d to 40,000 ML/d. This scatter can be up to 1 m for a given flow. The modelled rating curve lies at the lower limit of the scatter of the observed gaugings. Above 40,000 ML/d, the modelled rating curve and observed gaugings were in good agreement.
  - At McCoy's Bridge, the modelled and observed rating curves were found to be in good agreement for flows up to 35,000 ML/d. For higher flows, significant flows occur in effluent streams such as Deep, Wakiti, Sheepwash and Skelton Creeks.

Similar to observed gaugings at Shepparton, there was considerable scatter in the gaugings at McCoy's Bridge.

Upstream of Goulburn Weir, the calibration results suggests a general trend, that the hydraulic model is likely to overestimate the flood levels and extents (inundated areas), and in turn overestimate the quantity of affected assets, for flows up to about 30,000 ML/d. Above this flow (30,000 ML/d), the calibration indicates the model's prediction of water levels for a given flow is reasonable. This overestimate in modelled and observed water levels translates to an underestimate of flow at a given water level. The calibration results suggest this underestimate of flow is about 2,000 – 3,000 ML/d. That is an observed flow of 25,000 ML/d is equivalent to a modelled flow of ~ 22,000 ML/d. -

In the reach upstream of Goulburn Weir, the quantity of affected assets assessed in the following sections is considered to reflect an upper limit for flows up to 30,000 ML/d.

Downstream of Goulburn Weir, the comparison of modelled and observed rating curves at Murchison and Shepparton revealed a general trend in model calibration performance to underestimate water levels. Particularly, at Murchison, calibration results suggest the model significantly underestimates water level (up to 1.2 m at 30,000 ML/d) for a given flow, and in turn underestimates the quantity of affected assets. A similar, slightly reduced (up to 0.8 m) difference is shown at Shepparton. However, at McCoy's Bridge, the model appears to overestimate water levels.

In the reach Murchison to Shepparton, the quantity of affected assets assessed in the following sections is considered to reflect a lower limit for flows up to 60,000 ML/d. With the reach adjacent to McCoy's bridge likely to reflect a upper limit to the quantity of affected assets.

The discussion above highlights the considerable uncertainty arising from the model calibration in the assessment of affected assets under the environment flow scenarios. Further, it is worthy to note, the observed flow gaugings show considerable scatter. This scatter reflects in the variation in the channel physical form and changes in vegetation over time. Future refinements in the model structure and calibration will be unable to resolve this natural variation. The management of flows along the reach will to need to consider these natural variations.

To assess the impact of model uncertainty on affected asset identification, a range of sensitivity analyses are recommended. Details are provided in Section 5.

3. HYDRAULIC MODEL APPLICATION OUTPUTS – ENVIRONMENTAL FLOW SCENARIOS

3.1 Overview

The eight linked 1D-2D hydraulic models, as discussed in the Hydraulic Model Construction and Calibration Report (Water Technology, 2009), were applied to the environmental flow scenarios.

Sections 3.2 to 3.10 discuss the model application outputs for the environmental flows scenarios.

For each model area and flow scenario, a range of inundation characteristics were evaluated. Table 3-1 displays the inundation characteristics assessed and their use /purpose.

Table 3-1 Environmental flow scenarios – Inundation characteristics assessed

Inundation characteristics	Use / Purpose
Floodplain area - Maximum Extent - Drained area	Floodplain area inundated reflects the nature of the floodplain form within a reach. Change in floodplain areas with flow magnitude highlights floodplain terrain thresholds. Drained area reflects the depressions/wetlands filled and retaining water following a flow event
Floodplain storage - Maximum volume - Drained volume	Floodplain storage reflects the flow volume required to inundate the floodplain Drained volume indicates the flow volume retained on the floodplain, and unavailable to downstream reaches.
Buildings - Number affected - Flood depths at buildings	Buildings grouped as residential and other (out buildings, public buildings etc) Affected buildings are key driver in potential damages arising from a flow event. Guides potential management measures to limit potential building damage.
Roads and bridges	Roads grouped as national, regional, local, sealed/unsealed. Affected roads are key driver in potential damages arising from a flow event. Guides potential management measures to limit potential road and bridge damage.
Land use	Land use grouped on the basis of significant agricultural activities, Affected land use groups are key driver in potential damages arising from a flow event. Guides potential management measures to limit potential damage to agricultural activities.

Inundation characteristics	Use / Purpose
Wetlands	Wetlands defined as drained areas (see above) where the depth exceeds 0.5 m and the areas exceeds 2500 m^2. Used as a surrogate to identify areas which may benefit from periodic inundation. Formal assessment wetland condition/value is outside the scope of the current project. Guides potential management measures to enhance inundation if appropriate.
Terrestrial vegetation	Terrestrial vegetation defined as areas with "highly likely native vegetation – woody" (Asset Mapping – Data Collation and Review Report (Water Technology, 2009). Used as a surrogate to identify areas which may benefit from periodic inundation. Formal assessment vegetation condition/value is outside the scope of the current project. Guides potential management measures to enhance inundation if appropriate.
Other assets - Caravan parks - Aquaculture activities - Quarries	Other assets include infrequent land use groups. Other assets are key driver in potential damages arising from a flow event. Guides potential management measures to limit potential damage to agricultural activities.

3.2 Flood behaviour

This section outlines the key general flow behaviour characteristics within the eight study reaches. In particular, changes in flow behaviours across the range of flow magnitudes are outlined, as such commence to flow thresholds for significant breakouts and anabranches.

The discussion in this section provides a general overview of flow behaviour. Appendix A contains the flood inundated maps for the eight reaches under the five environmental scenarios. Further examination of the flood maps can provide insight at a local scale.

The travel time along the reaches was evaluated through the comparison of the flow hydrographs at the upper and lower limits of each reach. Appendix A contains the flow hydrographs at the upper and lower limits of each reach. The indicative travel times, for the peak flow to arrive at the downstream limit of the reach, were determined as follows:

Reach A Eildon to Alexandra: 40-48 hours

Reach B Alexandra to Ghin Ghin: 60-72 hours

Reach C Ghin Ghin to Kerrisdale : 24-32 hours

Reach D Kerrisdale to Mitchellstown: 48 to 56 hours

Reach E Mitchellstown to Wahring: 96 to 122 hours

Reach F Wahring to Kialla: 144to 172 hours

Reach G Kialla to Bunbartha:126 to 192 hours

Eildon to Alexandra	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel Overbank/floodplain inundation to south and east of Thornton along Rubicon River channel Overbank/floodplain inundation to south and west of Alexandra (~ 2km) along river flats
30,000 ML/d	Extensive overbank/floodplain inundation to south and east of Thornton along Rubicon River channel Flow along anabranch adjacent to "The Breakaway" (Hobans Road)
40,000 ML/d	Extensive overbank/floodplain inundation to south and east of Thornton along Rubicon River channel Flow along anabranch at foot of hills adjacent to Back Eildon Road Inundation of caravan park/ holiday cabins along Back Eildon Road (east of Thoms Lane)
50,000 ML/d	Extensive overbank/floodplain inundation to south and east of Thornton along Rubicon River channel Extensive overbank/floodplain inundation to adjacent to Acheron River confluence Overbank/floodplain inundation adjacent to McMartins Road
60,000 ML/d	Extensive overbank/floodplain inundation along entire reach Inundation of properties within Thornton township

Alexandra to Ghin Ghin	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel Areas of limited overbank/floodplain inundation and anabranch flow: - West of Alexandra (~ 7 km) (Whanregarwen) - North of Molesworth (immediately downstream of Goulburn Valley Highway Bridge)
30,000 ML/d	General overbank/floodplain inundation along reach, except for a short length (` 1 km) north of Killingworth
40,000 ML/d	Extensive overbank/floodplain inundation along reach Inundation of quarry operations north of Killingworth (adjacent to Switzerland Road)
50,000 ML/d	Extensive overbank/floodplain inundation along reach. Similar to 40,000 ML/d flow extent
60,000 ML/d	Extensive overbank/floodplain inundation along entire reach

Ghin Ghin to Kerrisdale	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel
30,000 ML/d	Areas of limited overbank/floodplain inundation and anabranch flow between Ghin Ghin Bridge and King Parrot Creek confluence Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Trawool
40,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow between Ghin Ghin Bridge and King Parrot Creek confluence Flow along anabranch at southern limit of floodplain adjacent to Homewood Road Inundation adjacent to quarry operations along Homewood Road
50,000 ML/d	Extensive overbank/floodplain inundation along reach. Similar to 40,000 ML/d flow extent
60,000 ML/d	Extensive overbank/floodplain inundation along entire reach

Kerrisdale to Mitchellstown (includes Seymour)	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel
30,000 ML/d	Areas of limited overbank/floodplain inundation and anabranch flow between Trawool and Ferris Creek (Tallarook)confluence Areas of limited overbank/floodplain inundation and anabranch flow between Whiteheads Creek confluence and Mitchellstown
40,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow between Trawool and Ferris Creek (Tallarook)confluence Areas of extensive overbank/floodplain inundation and anabranch flow between Whiteheads Creek confluence and Mitchellstown Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Seymour
50,000 ML/d	Extensive overbank/floodplain inundation along entire reach.
60,000 ML/d	Extensive overbank/floodplain inundation along entire reach

Mitchellstown to Wahring (include Goulburn Weir/Lake Nagambie)	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Mitchellstown
30,000 ML/d	Generally confined to river channel Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Mitchellstown
40,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow adjacent to Mitchellstown. Flow along anabranch to the south of Mitchellstown (adjacent to Mitchellstown Road and Major Creek confluence)
50,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow adjacent to Mitchellstown.
60,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow adjacent to Mitchellstown.

Wahring to Kialla	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel
30,000 ML/d	Areas of limited overbank/floodplain inundation and anabranch flow along entire reach Partial inundation of back swamp to the south-east of Toolamba
40,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow along entire reach Complete inundation of back swamp to the south-east of Toolamba
50,000 ML/d	Similar to 40,000 ML/d, areas of extensive overbank/floodplain inundation and anabranch flow along entire reach Complete inundation of back swamp to the south-east of Toolamba
60,000 ML/d	Areas of extensive overbank/floodplain inundation and anabranch flow along entire reach Complete inundation of back swamp to the south-east of Toolamba

Kialla to Bunbartha (including Shepparton – Mooroopna)	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Generally confined to river channel Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Shepparton (downstream of Midland Highway (Causeway))
30,000 ML/d	Areas of extensive overbank/floodplain inundation of adjacent riparian areas Complete inundation of Gemmills swamp
40,000 ML/d	Areas of extensive overbank/floodplain inundation of adjacent riparian areas Complete inundation of Gemmills swamp
50,000 ML/d	Areas of extensive overbank/floodplain inundation of adjacent riparian areas Complete inundation of Gemmills swamp
60,000 ML/d	Areas of extensive overbank/floodplain inundation of adjacent riparian areas Complete inundation of Gemmills swamp

Bunbartha to Murray River confluence	
Flow magnitude	**Key Flow behaviour characteristics**
20,000 ML/d	Areas of limited overbank/floodplain inundation and anabranch flow adjacent to Loch Garry (upstream ~ 8 km to downstream ~ 10 km) Limited outflow at the Deep Creek outlet to Bunbartha Creek and Deep Creek. Flow along creeks confined to channel
30,000 ML/d	Areas of extensive overbank/floodplain inundation within the levees Limited outflow at the Deep Creek outlet to Bunbartha Creek and Deep Creek. Flow along creeks confined to channel Limited outflow at the Wakiti Creek outlet structure to Wakiti Creek. Fills local water holes and the Wakiti Lagoons. Limited outflow at the Hancocks Creek Outlet structure to Hancocks Creek towards the Yambuna State Forest. Partial inundation of Madowla Lagoon
40,000 ML/d	Areas of extensive overbank/floodplain inundation within the levees Limited outflow at the Deep Creek outlet to Bunbartha Creek and Deep Creek. Flow along creeks confined to channel Limited outflow at the Wakiti Creek outlet structure to Wakiti Creek. Fills local water holes and the Wakiti Lagoons. Limited outflow at the Hancocks Creek Outlet structure to Hancocks Creek towards the Yambuna State Forest. Complete inundation of Madowla Lagoon
50,000 ML/d	Similar inundation pattern as for the 40,000 ML/d
60,000 ML/d	Similar inundation pattern as for the 40,000 ML/d

3.3 Floodplain area assessment

The maximum inundated floodplain area and “drained” areas were assessed for each model reach and environmental flow scenario.

The maximum inundated floodplain areas for each scenario reflects the changes in the floodplain extents as the flow increases. Significant changes in maximum inundated floodplain areas across the flow scenarios indicates the engagement of considerable additional floodplain areas between flow rates i.e. a threshold level in floodplain is crossed.

The “drained area” was assessed as the area inundated following a flow event. This drained area highlights depressions in the floodplain (anabranch, cut offs etc) where water is unable to flow back to the river, and is stored on the floodplain. This stored flow can be viewed as a part of the transmission loss for releases from Eildon. Section 3.4 discusses the floodplain volume characteristics.

The lower reach, Bunbartha to the Murray River confluence, is characterised by a number of large lagoons and back swamps. Further, this reach is considerably longer with a larger floodplain than other model reaches. Initial hydraulic model runs indicated to obtain a “drained condition” would

require a simulation period in excess of 40 days. Given the hydraulic model size, running the hydraulic model over this simulation period would be impractical, due to excessive model run times (12-14 days). As such, the drained area was not evaluated for the reach Bunbartha to the Murray River confluence. Further discussion is provided later in this section.

Table 3-2 displays the maximum flood plain area inundated for each scenario, after flows stabilised along the whole reach. Further, Table 3-2 shows the inundated area at the conclusion of the flow event, after water on the floodplain had been allowed to fully drain.

Table 3-2 Environmental flow scenario – maximum and "drained" flood plain area Inundated

Reach	**Flow scenario**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	Max Area (ha)	***Drained Area (ha)***	**Max Area (ha)**	***Drained Area (ha)***	**Max Area (ha)**	***Drained Area (ha)***	**Max Area (ha)**	***Drained Area (ha)***	**Max Area (ha)**	***Drained Area (ha)***
Eildon to Alexandra	752	98	1204	137	1740	205	2231	249	2739	289
Alexandra to Ghin Ghin	728	195	2080	475	3515	*731*	3545	793	4042	793
Ghin Ghin to Kerrisdale	333	189	836	232	1403	355	1821	409	2108	487
Kerrisdale to Mitchellstown	531	100	1448	458	2070	552	2754	669	3627	696
Mitchellstown to Wahring	485	190	936	380	1313	441	1614	492	1859	492
Wahring to Kialla	182	19	1751	336	3077	953	3886	1143	4209	1143
Kialla to Bunbartha	1185	278	4223	2154	5277	2839	5481	2963	5719	2963
Bunbartha to the Murray River	3775	*N.A*	12110	*N.A*	16404	*N.A*	18988	*N.A*	21472	*N.A*
Total	**7971**		**24588**		**34799**		**40320**		**45775**	

Figure 3-1 and Figure 3-2 display the maximum inundated area and drained areas for each reach and environmental flow scenarios.

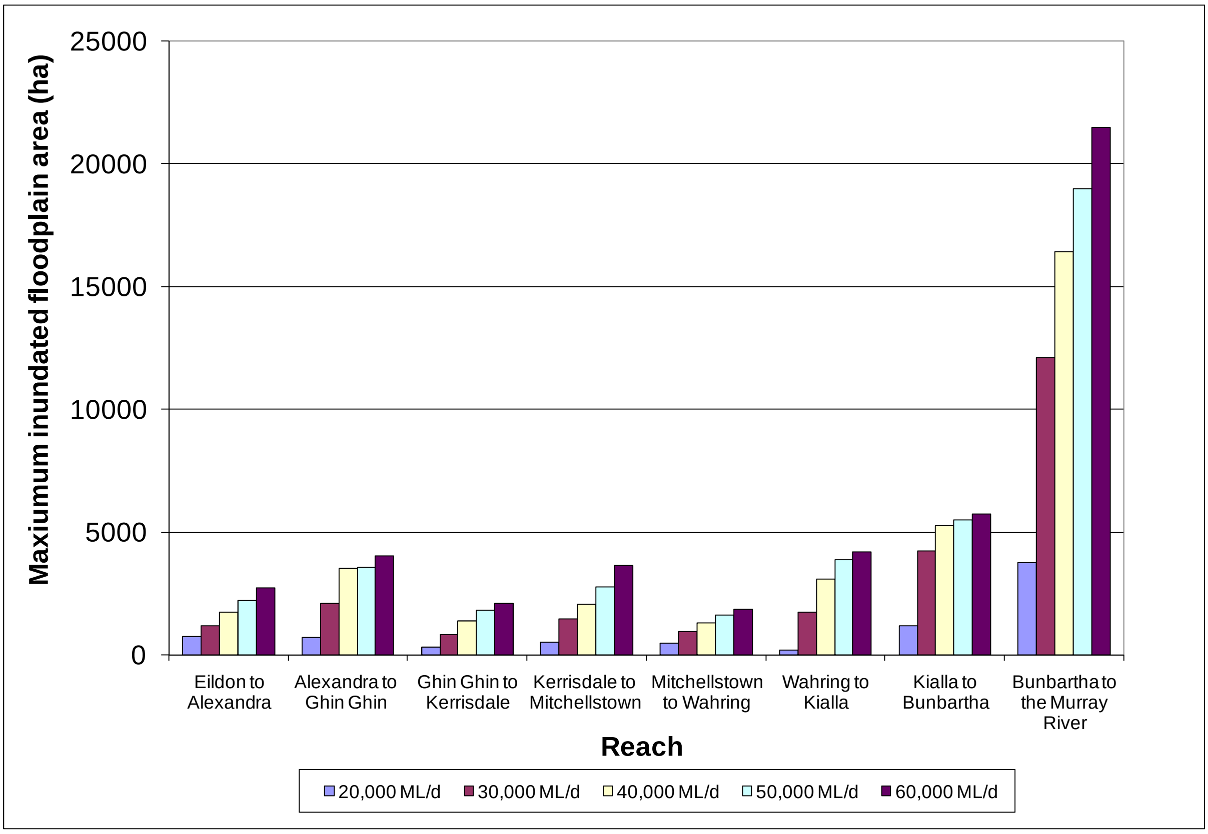

Figure 3-1 Environmental flow scenario – Maximum inundated floodplain area

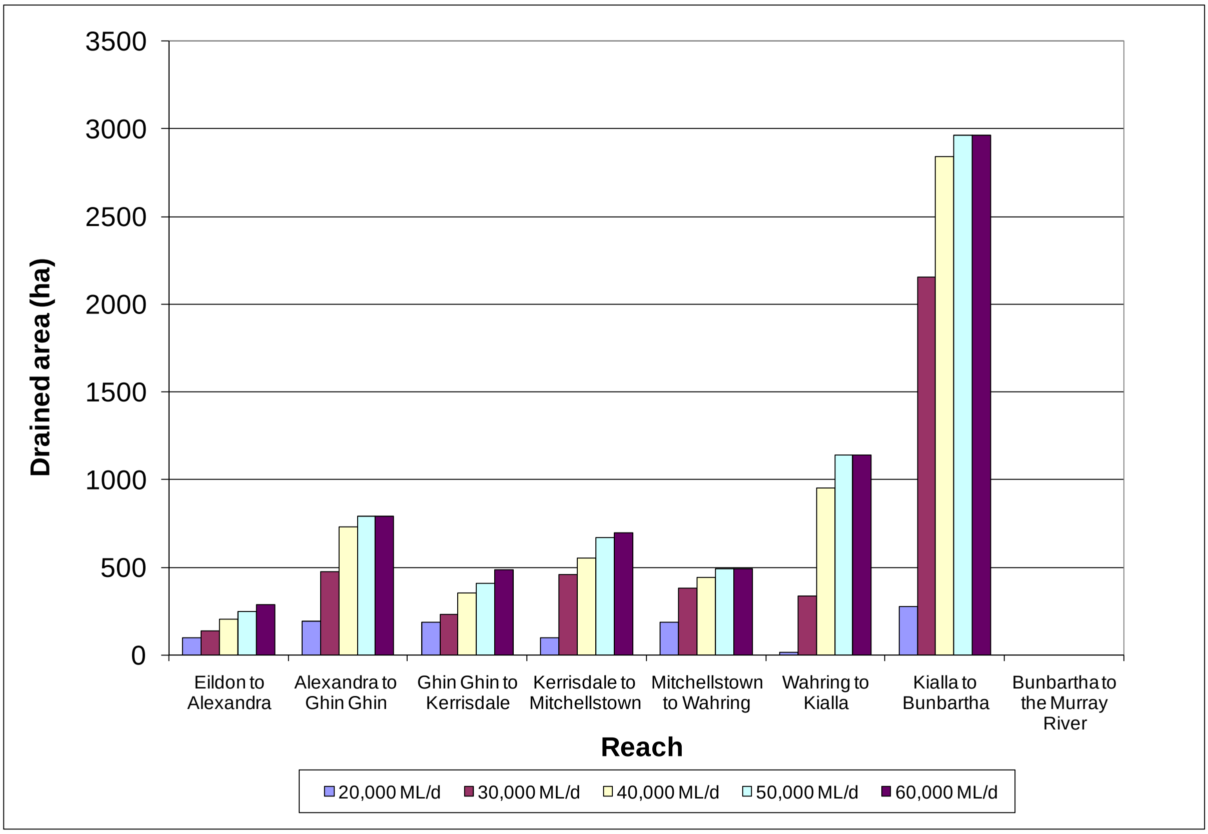

Figure 3-2 Environmental flow scenario – Drained floodplain area

The upper reach, Eildon to Alexandra, displays a relative uniform increase in floodplain area inundated with increasing flows. This reflects the absence of significant topographic thresholds on the floodplain. A similar pattern was seen for the drained areas.

The reach, Alexandra to Ghin Ghin, displayed a step change in maximum floodplain area inundated between 30,000 ML/d to 40,000 ML/d. There was little change in maximum area between flow scenario 40,000 to 50,000 ML/d. A similar pattern was seen for the drained areas.

The mid reaches (Ghin Ghin to Kerrisdale, Kerrisdale to Mitchellstown, Mitchellstown to Wahring) displayed relative uniform increases in floodplain area inundated with increasing flows. This reflects the absence of significant topographic thresholds on the floodplain. The drained area for the reach Ghin Ghin to Kerrisdale displays a uniform increase with flow magnitude. For the other two mid reaches, a step change in drained areas occurred between 20,000 ML/d and 30,000 ML/d. Further, for these two reaches, there was a little change in drained area between 50,000 ML/d and 60,000 ML/d.

A significant step change in floodplain area inundated occurs for the lower reaches, Wahring to Kialla and Kialla to Bunbartha, between flows 20,000 ML/d to 30,000 ML/d. Between 50,000 ML/d and 60,000 ML/d there was little change in floodplain area. A similar pattern was seen for the drained areas.

The reach Bunbartha to Murray River has a significant larger flood plain area than the other reaches. In part, this is due to the longer reach length. However, this does reflect the extensive floodplain area in this reach. A step change in floodplain area occurred between 20,000 ML/d and 30,000 ML/d.

The reaches, Ghin Ghin to Kerrisdale and Mitchellstown to Wahring, have relatively smaller maximum floodplain area than other reaches. This in part reflects the confined nature of the floodplain and these reaches. Further, it should be noted that the Ghin Ghin to Kerrisdale reach is the shortest model reach.

As discussed, practical limitations prevented the assessment of drained areas in the reach Bunbartha to the Murray confluence. To overcome these limitations, requires the re-construction of the hydraulic model for this reach. The single hydraulic model could be split into at least two separate models. Careful consideration would be needed to ensure the correct transfer of flow between new model areas. The smaller models could then run concurrently to asses drained areas in a practicable model run time.

3.4 Floodplain volume and storage assessment

The maximum floodplain volume and “drained” volume were assessed for each model reach and environmental flow scenario.

The maximum floodplain volume indicates the volume of water required to be stored in the river and on the floodplain in the reach to achieve maximum inundation. Most of this water will be released from the river/floodplain during the draining phase.

The drained volume, as discussed in Section 3.3, assesses the volume captured in depressions following a flow event. This stored flow can be viewed as a part of the transmission loss for releases from Eildon. As such, this stored volume is unavailable to downstream reaches.

For the lower reach, Bunbartha to the Murray River confluence, as discussed impractical model run times limited the assessment of drained areas, and in turn the drained volumes were not assessed.

Table 3-3 displays the maximum volume of water stored on the flood plain for each scenario. Further, Table 3-3 shows the volume stored on the flood plain after water has fully drained from the flood plain.

Table 3-3 Environmental flow scenario – maximum and "drained" flood plain volume

Reach	Flow scenario									
	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Max Vol (ML))	*Drained Vol (ML)*	Max Vol (ML))	*Drained Vol (ML)*	Max Vol (ML))	*Drained Vol (ML)*	Max Vol (ML))	*Drained Vol (ML)*	Max Vol (ML))	*Drained Vol (ML)*
Eildon to Alexandra	6104	*2333*	10694	*3101*	15926	*4267*	21248	*5150*	26911	*5966*
Alexandra to Ghin Ghin	6551	*4523*	20232	*10948*	39506	*13774*	39697	*15319*	47461	*16282*
Ghin Ghin to Kerrisdale	6439	*4429*	10768	*3997*	17373	*7372*	23661	*8424*	29729	*10141*
Kerrisdale to Mitchellstown	5848	*4284*	17053	*10665*	26281	*13019*	36641	*16037*	46937	*18314*
Mitchellstown to Wahring	5186	*2406*	13905	*6188*	21972	*7475*	30251	*8486*	39295	*9147*
Wahring to Kialla	3515	*1186*	22910	*8718*	43755	*18422*	66021	*22074*	81755	*25449*
Kialla to Bunbartha	11824	*7326*	48705	*36070*	74498	*49200*	86381	*52180*	96089	*54001*
Bunbartha to the Murray River	48104	*N.A*	138627	*N.A*	193537	*N.A*	232307	*N.A*	262807	*N.A*
Total	**93571**	***9357126487***	**282894**	***79687***	**432848**	***113529***	**536207**	***127670***	**630984**	***139300***

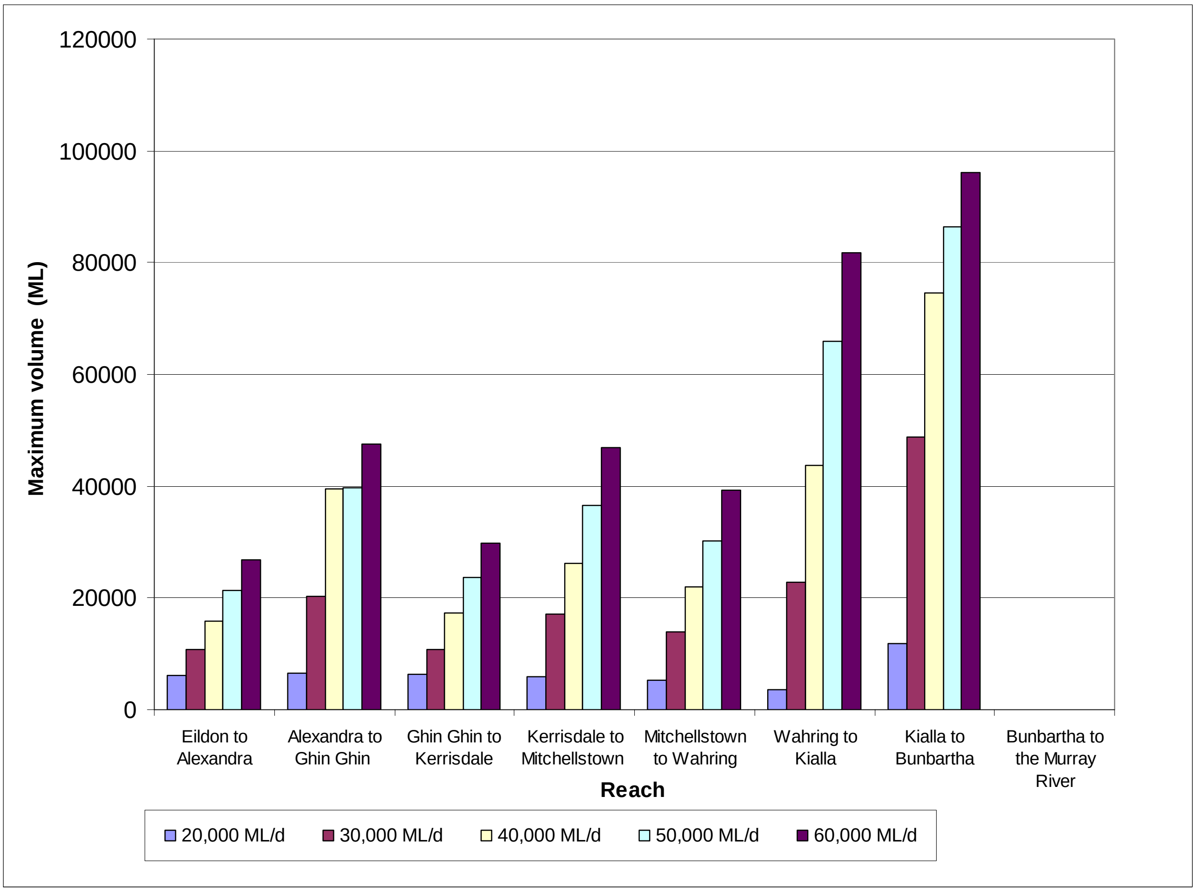

Figure 3-3 Environmental flow scenario – Maximum volumes

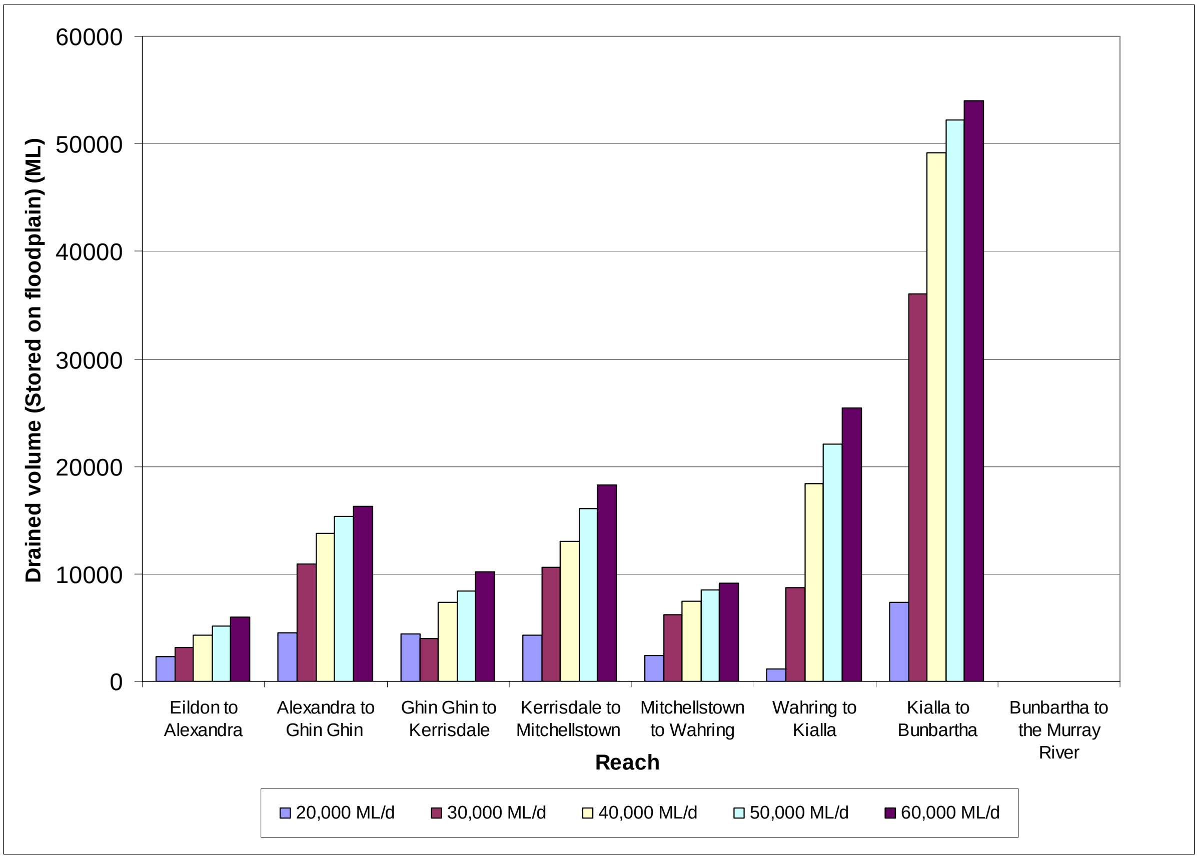

Figure 3-4 Environmental flow scenario – Drained volumes (stored on floodplain)

Table 3-4 displays the drained volume (stored volume) as percentage of the total flow volume

Table 3-4 Environmental flow scenario – "drained" flood plain volume (as a percentage of total flow volume)

Reach	Flow scenario "Drained" flood plain volume (as a percentage of total flow volume)				
	20,000 ML/d	**30,000 ML/d**	**40,000 ML/d**	**50,000 ML/d**	**60,000 ML/d**
Eildon to Alexandra	*2%*	*2%*	*2%*	*2%*	*2%*
Alexandra to Ghin Ghin	*4%*	*6%*	*6%*	*6%*	*5%*
Ghin Ghin to Kerrisdale	*3%*	*2%*	*3%*	*3%*	*3%*
Kerrisdale to Mitchellstown	*3%*	*6%*	*6%*	*6%*	*6%*
Mitchellstown to Wahring	*2%*	*3%*	*3%*	*3%*	*3%*
Wahring to Kialla	*1%*	*5%*	*8%*	*8%*	*8%*
Kialla to Bunbartha	*6%*	*20%*	*22%*	*19%*	*17%*
Bunbartha to the Murray River	N.A	N.A	*N.A*	N.A	*N.A*

The maximum volume and drained volumes exhibit similar trends as seen for the maximum and drained area inundated.

The upper reach, Eildon to Alexandra, displays a relative uniform increase in both maximum floodplain storage and drained volume with increasing flows. This reflects the absence of significant topographic thresholds on the floodplain. The drained volume as expressed as a percentage of the total volume remains constant at 2% across the flow scenarios.

The reach, Alexandra to Ghin Ghin, displays a step change in maximum floodplain volume inundated between 30,000 ML/d to 40,000 ML/d. There is a little change in maximum floodplain volume between flow scenario 40,000 to 50,000 ML/d. However, the drained volume shows a relatively uniform increase with flow. This suggests a small additional volume is stored on the floodplain at the end of the flow event in the 50,000 ML/d event, in comparison to the 40,000 ML/d. The drained volume as expressed as a percentage of the total volume varied marginally from 4% to 6% across the flow scenarios.

The mid reaches (Ghin Ghin to Kerrisdale, Kerrisdale to Mitchellstown, Mitchellstown to Wahring) display relative uniform increases in maximum floodplain volume and drained volume with increasing flows. This reflects the absence of significant topographic thresholds on the floodplain. The drained volume as expressed as a percentage of the total volume varied marginally from 3% to 6% across the flow scenarios.

A significant step change in maximum floodplain volume and drained volume occurs for the lower reaches, Wahring to Kialla and Kialla to Bunbartha, between flows 20,000 ML/d to 30,000 ML/d. In line with the maximum areas and drained areas, this suggests a topographic threshold in the floodplain is crossed between 20,000 ML/d and 30,000 ML/d. The drain volume percentage increased from 1% to 8% for the reach Wahring to Kialla.

The reach Kialla to Bunbartha shows a step change in drain volume percentage from 6% to 20% between the 20,000 ML/d and 30,000 ML/d. This indicates that significant wetlands volumes are being filled at the water level inundated by the 30,000 ML/d flow.

Further, the reach Kialla to Bunbartha displays a higher drained volume percentage, 17%-22%, than the other reaches. This reflects the presence of a number of lagoons and back swamps in this reach.

3.5 Buildings

As discussed, inundation of buildings is a principal component in the potential damages arising from a flow event.

The Asset Mapping – Data Collation and Review Report (Water Technology 2009) identified buildings using the CFA building layers, reconciled against the aerial photography. The buildings were grouped into the following two categories:

- Residential
- Other (out buildings, hay shed, machinery shed etc)

Inundation of buildings is likely to cause significant inconvenience and possible economic loss (damage) to affected landholders. This preliminary identification of affected buildings provides a board overview of the absolute and relative number of buildings affected for the range of environmental flow scenarios.

In some instances, buildings may have local flood protection works (i.e. levees). At the spatial scale of the hydraulic models (25 m & 60 m grids), these local protection works are unlikely to be captured. Further, the available topographic data (ALS data) may not capture these local protection works. Any local works will need to assess on a case by case basis.

Table 3-5 shows the number of buildings inundated within each reach for each environmental flow scenario.

Table 3-5 Environmental flow scenario – Number of Inundated buildings

Reach	**Flow scenario**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	Res.	***Other***	**Res.**	***Other***	**Res.**	***Other***	**Res.**	***Other***	**Res.**	***Other***
Eildon to Alexandra	9	*15*	9	*23*	12	*43*	17	*80*	52	*94*
Alexandra to Ghin Ghin	0	*3*	4	*15*	13	*37*	13	*37*	22	*50*
Ghin Ghin to Kerrisdale	0	*2*	0	*2*	0	*3*	1	*3*	1	*5*
Kerrisdale to Mitchellstown	0	*0*	0	*5*	0	*11*	1	*17*	40	*81*

Reach	**Flow scenario**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	Res.	***Other***	**Res.**	***Other***	**Res.**	***Other***	**Res.**	***Other***	**Res.**	***Other***
Mitchellstown to Wahring	0	*1*	1	*3*	2	*4*	4	*12*	8	*15*
Wahring to Kialla	0	*0*	0	*2*	1	*3*	7	*10*	11	*15*
Kialla to Bunbartha	0	*1*	0	*2*	1	*3*	7	*10*	11	*15*
Bunbartha to the Murray River	2	*9*	13	*79*	14	*96*	18	*129*	20	*148*
Total	**11**	***31***	**27**	***131***	**43**	***200***	**68**	***298***	**165**	***423***

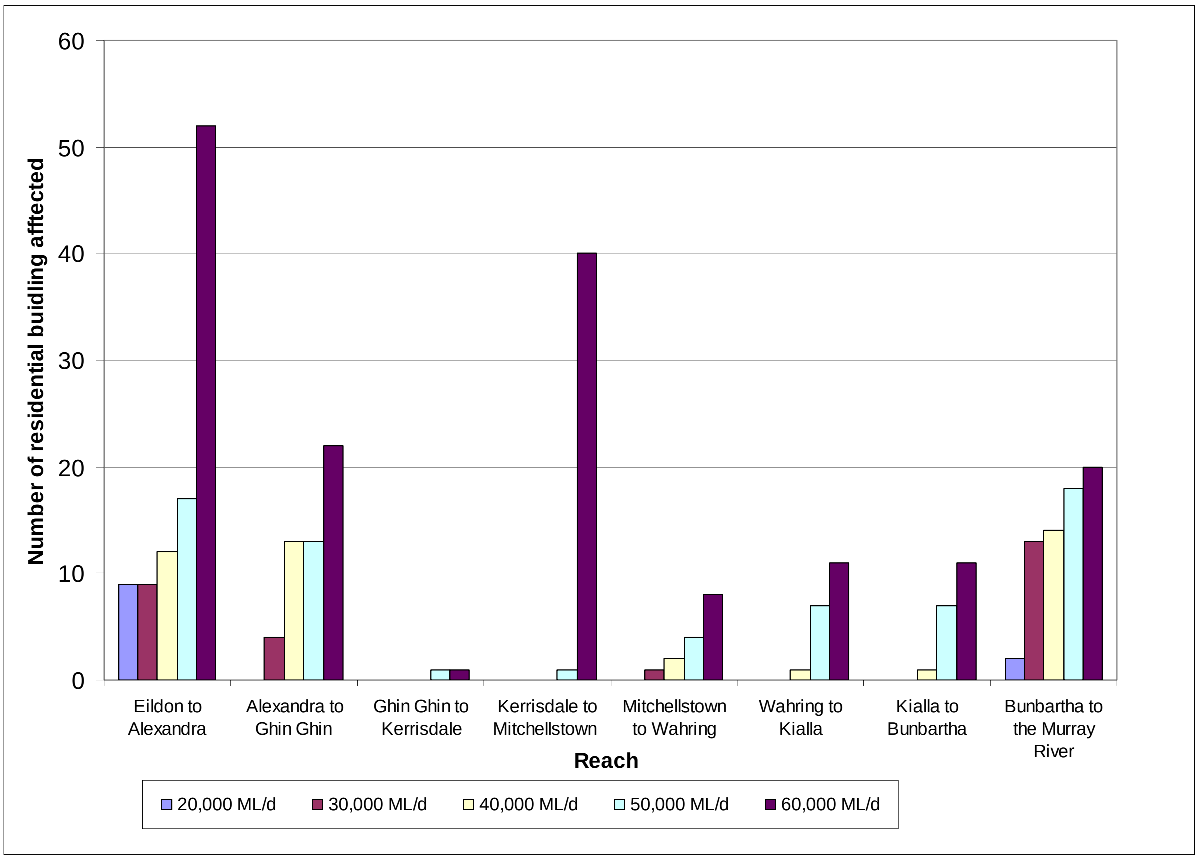

Figure 3-5 Environmental flow scenario –Residential buildings affected

For upper reach, Eildon to Alexandra, nine residential buildings were affected for the 20,000 and 30,000 ML/d scenarios. The affected residential buildings increased to 17 for the 50,000 ML/d event. There is a step increase to 52 affected residential buildings for the 60,000 ML/d scenario. This step increase reflects the flood affected residential buildings in Thornton.

No residential buildings are affected for the 20,000 ML/d scenario in the reach, Alexandra to Ghin. Four residential buildings affected for the 30,000 ML/d scenario, and increasing to 22 residential buildings in the 60,000 ML/d scenario. Affected residential buildings are isolated rural residential buildings outside Alexandra.

In reach Ghin Ghin to Kerrisdale, no residential buildings are affected for the 20,000 ML/d to 40,000 ML/d scenarios. A single residential building is affected for the 50,000 and 60,000 ML/d scenarios.

A step change in the affected residential buildings occurred in the reach Kerrisdale to Mitchellstown, for the 60,000 ML/d event. This reflects the inundation of residential buildings on fringe areas of Seymour.

The reaches, Mitchellstown to Wahring, Wahring to Kialla, Kialla to Bunbartha, have no residential buildings affected for the 20,000 ML/d event. A steady increase from one to eight affected residential buildings occurred for the reach Mitchellstown to Wahring. The reaches, Wahring to Kialla and Kialla to Bunbartha, show a step increase between the 40,000 ML/d and 50,000 ML/d flow events.

For the lower reach, Bunbartha to the Murray River confluence, there is a step increase from two residential buildings to 13 residential buildings between the 20,000 and 30,000 ML/d events. This was then followed by a steady increase to 20 affected residential buildings for the 60,000 ML/d.

The locations of affected residential buildings are shown on the inundation maps provided in Appendix A.

Above assessment only considered buildings located within the inundation extents. The economic damages for buildings affected by flooding can escalate rapidly if the flooding occurs above the building floor level. Available building floor level data in the study area was limited to Seymour and Shepparton- Mooroopna. This floor level data were collected as part of the respective flood studies.

As there was limited available floor level data, an assessment of the distribution of flood depths at building locations was undertaken to assess the likelihood of above floor flooding. Threshold flood depths of 0.3 and 0.6 m were selected to assess the distribution of flood depths at buildings. Table 3-6 displays the percentage of the total affected residential buildings number of residential buildings where the flood depth is greater than 0.3 and 0.6m

Table 3-6 Environmental flow scenario – Percentage of the total number of affected residential buildings with flood depths greater than 0.3 and 0.6 m

Reach	**Flow scenario and flood depth at residential building**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	> 0.3 m	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***
Eildon to Alexandra	89%	33%	100%	89%	92%	75%	94%	59%	44%	29%
Alexandra to Ghin Ghin	-	-	100%	50%	100%	62%	100%	62%	68%	50%
Ghin Ghin to Kerrisdale	-	-	-	-	-	-	100%	-	100%	100%
Kerrisdale to	-	-	-	-	-	-	100%	100%	13%	5%

Reach	Flow scenario and flood depth at residential building									
	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	> 0.3 m	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***	**> 0.3 m**	***> 0.6 m***
Mitchellstown										
Mitchellstown to Wahring	-	-	100%	100%	50%	50%	50%	50%	100%	88%
Wahring to Kialla	-	-	-	-	100%	100%	71%	57%	91%	73%
Kialla to Bunbartha	-	-	-	-	100%	100%	100%	100%	100%	55%
Bunbartha to the Murray River	100%	100%	77%	46%	71%	57%	56%	44%	70%	40%

For upper reach, Eildon to Alexandra, the 20,000 – 50,000 ML/d flow events shows that about 90% of affected residential buildings have a flood depth greater 0.3. There is a greater variation in the proportion of affected residential buildings where the flood depth exceeds 0.6 m. For the 60,000 ML/d event, the percentage of residential buildings where the flood depths exceeds 0.3 m falls to 44%. This reflects the shallow inundation of affected residential buildings in Thornton.

The reach, Alexandra to Ghin, displays a similar trend with the the percentage of affected residential buildings where the flood depths exceeds 0.3 m falls to 68% in the 60,000 ML/d from 100 % in the smaller flow events.

Four residential buildings affected for the 30,000 ML/d scenario, and increasing to 22 residential buildings in the60,000 ML/d scenario. Affected residential buildings are isolated rural residential buildings outside Alexandra.

As noted above, the reach Ghin Ghin to Kerrisdale, has only a single residential building affected for the 50,000 and 60,000 ML/d scenarios.

A step change in the percentage of residential buildings affected with a flood depths exceeding 0.3 m and 0.6 m occurred in the reach Kerrisdale to Mitchellstown, for the 60,000 ML/d event. This reflects the shallow inundation of residential buildings on fringe areas of Seymour.

The reaches, Mitchellstown to Wahring, Wahring to Kialla, Kialla to Bunbartha, have a relative small number of residential properties. As such, the percentage of affected residential buildings varies considerably.

For the lower reach, Bunbartha to the Murray River confluence, the percentage of affected residential buildings with flood depths exceeding 0.3 m varies from 100 % to56%. Similarly the percentage with flood depths exceeding 0.6 m varied from 100%to 40%.

The general pattern across the reaches is that the influence of flood depth is limited, expect at high flows (40,000 Ml/d and greater) in the upper reaches (above Ghin Ghin).

3.6 Road and bridges

As discussed, inundation of roads and bridges is a principal component in the potential damages arising from a flow event.

The Asset Mapping – Data Collation and Review Report (Water Technology 2009) identified roads and bridges using the VICMAP (TR_ROAD) layers. For the purposes of the damage assessment, the roads were grouped into the following two categories:

- Highway/Freeway (sealed)
- Arterial (sealed)
- Sub-arterial (sealed)
- Local (sealed and unsealed)

Table 3-7 shows the length of road, grouped as sealed or unsealed, within each reach over the environmental flow scenarios. Further details on the inundated roads is provided in Appendix B.

Table 3-7 Environmental flow scenario - Inundated roads

Reach	**Flow scenario**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	Seal (km)	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***
Eildon to Alexandra	1.2	*5.5*	1.9	*11.6*	4.8	*17.0*	7.7	*23.0*	10.4	*29.0*
Alexandra to Ghin Ghin	0.1	*4.3*	1.0	*14.6*	3.0	*27.7*	3.0	*28.0*	4.4	*33.7*
Ghin Ghin to Kerrisdale	0.0	*0.8*	0.0	*5.5*	0.2	*11.7*	0.5	*17.4*	0.8	*22.3*
Kerrisdale to Mitchellstown	0.5	*2.3*	1.0	*9.0*	1.4	*13.3*	1.9	*17.7*	3.5	*21.3*
Mitchellstown to Wahring	0.0	*1.2*	0.0	*3.6*	0.1	*8.6*	0.5	*12.5*	0.8	*15.4*
Wahring to Kialla	0.0	*1.9*	0.0	*13.3*	0.1	*38.7*	0.2	*56.5*	0.7	*64.1*
Kialla to Bunbartha	0.7	*24.0*	2.4	*124*	4.2	*179*	5.0	*193*	5.6	*200*
Bunbartha to the Murray River	0.8	*66.5*	4.0	*197*	4.5	*270*	6.5	*307*	9.1	*338*
Total	**3.3**	***106.5***	**10.3**	***378.6***	**18.3**	***566***	**25.3**	***655.1***	**35.3**	***723.8***

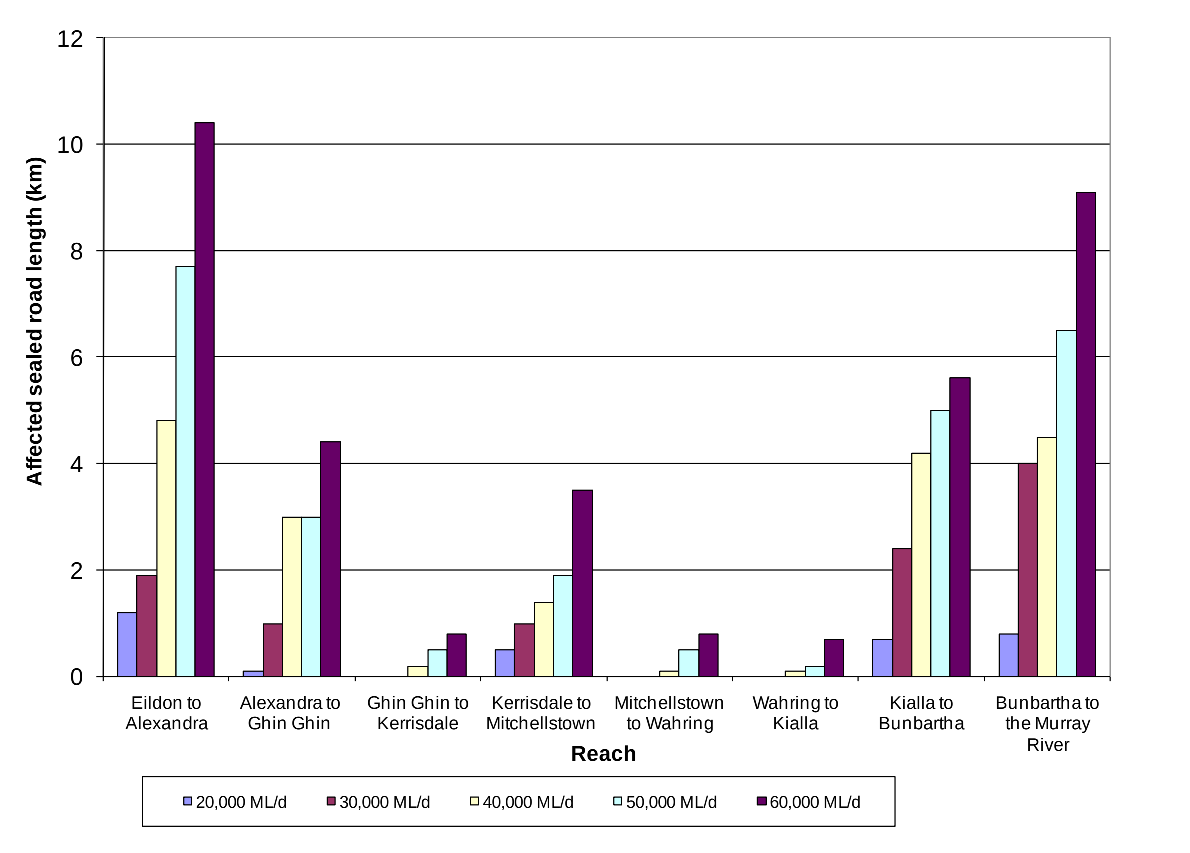

Figure 3-6 Environmental flow scenario – Affected sealed road lengths

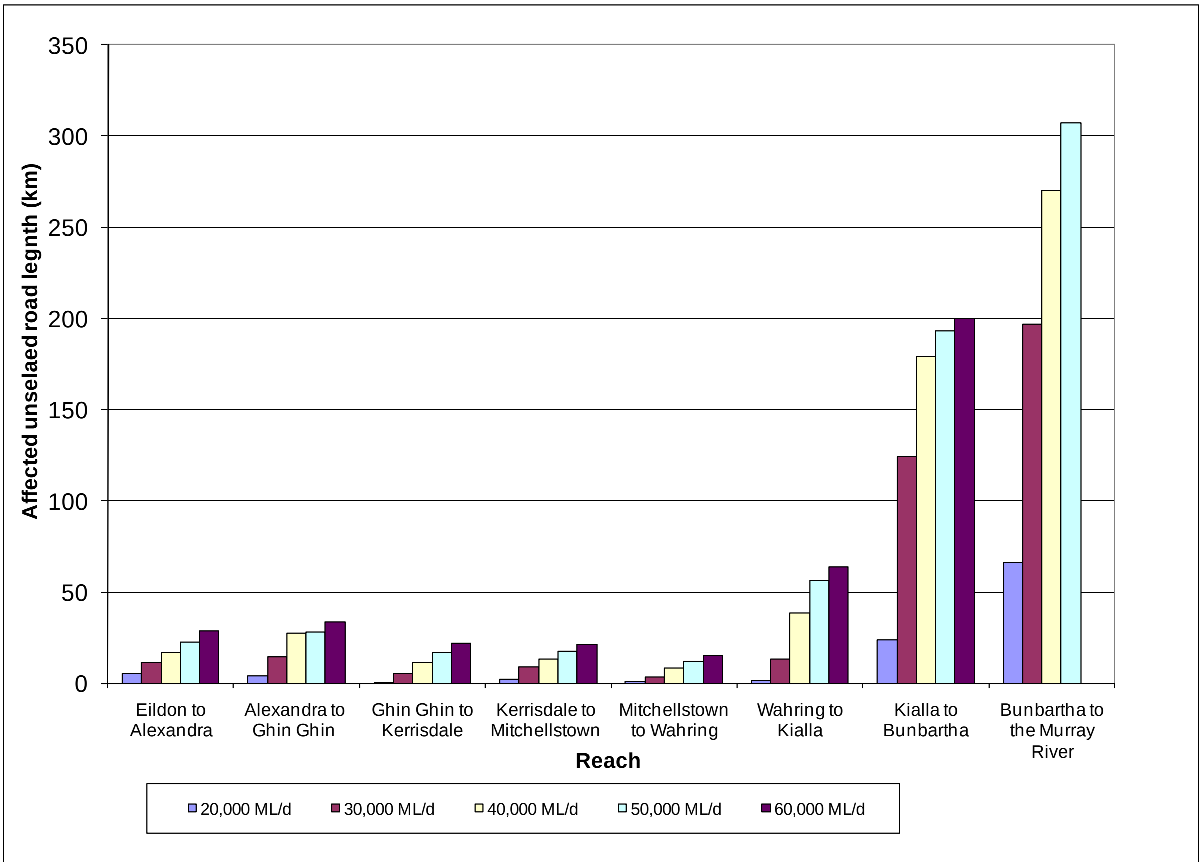

Figure 3-7 Environmental flow scenario – Affected unsealed road lengths

The length of sealed road affected for each flow scenario was considerably less than the unsealed road lengths. In case of the 20,000 ML/d event, the total affected sealed road length is 3.3 km compared to an unsealed road length of 106.5 km, and similarly for the 60,000 ML/d event where the affected sealed road length was 35.3 km compared with an unsealed road length of 723.8 km.

The upper reach, Eildon to Alexandra, displays a relatively higher affected length of sealed road in comparison to the upper - middle reaches (Alexandra to Kialla). The affected length of sealed roads for the upper reach, Eildon to Alexandra, is similar to the lower reaches, Kialla to the Murray River confluence.

The upper and middle reaches (Eildon to Wahring) display a lower length of affected road length (up to 30 km). However, there is a marked increased in the affected unsealed road length in the lower reaches (Wahring to the Murray River confluence). In particular, there is a significant increase for the reaches Kialla to Bunbartha and Bunbartha to the Murray River confluence. For these two lower reaches, there is a step change in the affected unsealed road length between the 20,000 and 30,000 ML/d events.

Table 3-8 shows the inundated bridges, grouped as sealed or unsealed, within each reach over the environmental flow scenarios. The grouping into sealed and unsealed reflects the relative importance of the bridge in a local and regional context.

Table 3-8 Environmental flow scenario - Inundated bridges

Reach	**Flow scenario**									
	20,000 ML/d		**30,000 ML/d**		**40,000 ML/d**		**50,000 ML/d**		**60,000 ML/d**	
	Seal (km)	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***	**Seal (km)**	***Un-Sealed (km)***
Eildon to Alexandra	0.3	*0.1*	0.3	*0.1*	0.4	*0.2*	0.6	*0.2*	0.7	*0.2*
Alexandra to Ghin Ghin	0.1	*0.0*	0.4	*0.1*	0.4	*0.2*	0.4	*0.2*	0.4	*0.2*
Ghin Ghin to Kerrisdale	0.0	*0.1*	0.0	*0.1*	0.0	*0.1*	0.1	*0.1*	0.1	*0.1*
Kerrisdale to Mitchellstown	0.0	*0.0*	0.2	*0.0*	0.2	*0.1*	0.4	*0.1*	0.8	*0.1*
Mitchellstown to Wahring	0.0	*0.3*	0.0	*0.3*	0.0	*0.3*	0.1	*0.3*	0.1	*0.3*
Wahring to Kialla	0.0	*0.0*	0.0	*0.1*	0.0	*0.1*	0.1	*0.2*	0.2	*0.2*
Kialla to Bunbartha	0.4	*0.1*	0.7	*0.2*	0.8	*0.3*	0.9	*0.3*	0.9	*0.3*
Bunbartha to the Murray River	0.1	*0.2*	0.5	*0.4*	0.5	*0.6*	0.5	*0.6*	0.6	*0.7*
Total	**0.9**	***0.8***	**2.1**	***1.3***	**2.3**	***1.9***	**3.1**	***2***	**3.8**	***2.1***

Across the entire study reach, the length of affected sealed bridges varied from 0.9 km for the 20,000 ML/d flow to 3.8 km for the 60,000 ML/d flow. A similar trend was displayed in the affected unsealed bridge length, with a variation between 0.8 km to 2.1 km over the flow range 20,000 ML/d to 60,000 ML/d.

The reach Kialla to Bunbartha displayed the largest length of affected bridges. This reflects the three bridge crossings in this reach. Similarly, the higher affected bridge lengths in the reaches, Eildon to Alexandra and Kerrisdale to Mitchellstown, are due to the four bridge crossings in each reach.

3.7 Land use

A variety of agricultural activities are undertaken on the floodplain of Goulburn River along the study reach. The Asset Mapping – Data Collation and Review Report (Water Technology 2009) identified a number of land use classes using the DPI land use data. For the purposes of the damage assessment, URS (2009) grouped the DPI land use classes into the following eight categories:

- Dryland Pasture
- Dryland Broadacre Crops
- Irrigated pasture
- Other Fruit
- Forestry
- Grapes
- Vegetables
- Intensive agriculture

Table 3-9 and Figure 3-8shows total affected areas for the above land use categories under the environmental flow scenarios along the entire study reach (Eildon to the Murray River confluence).

Table 3-9 Environmental flow scenario – Eildon to Murray confluence - Affected land use areas

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	1624	5503	8866	11067	13567
Dryland Broadacre Crops	229	877	1467	2133	2780
Irrigated pasture	182	637	1031	1466	2003
Other Fruit	17	93	209	285	352
Forestry	2417	7875	9313	9910	10219
Grapes	0	2	2	2	2
Vegetables	3	7	9	14	17
Intensive agriculture	0	55	68	74	106

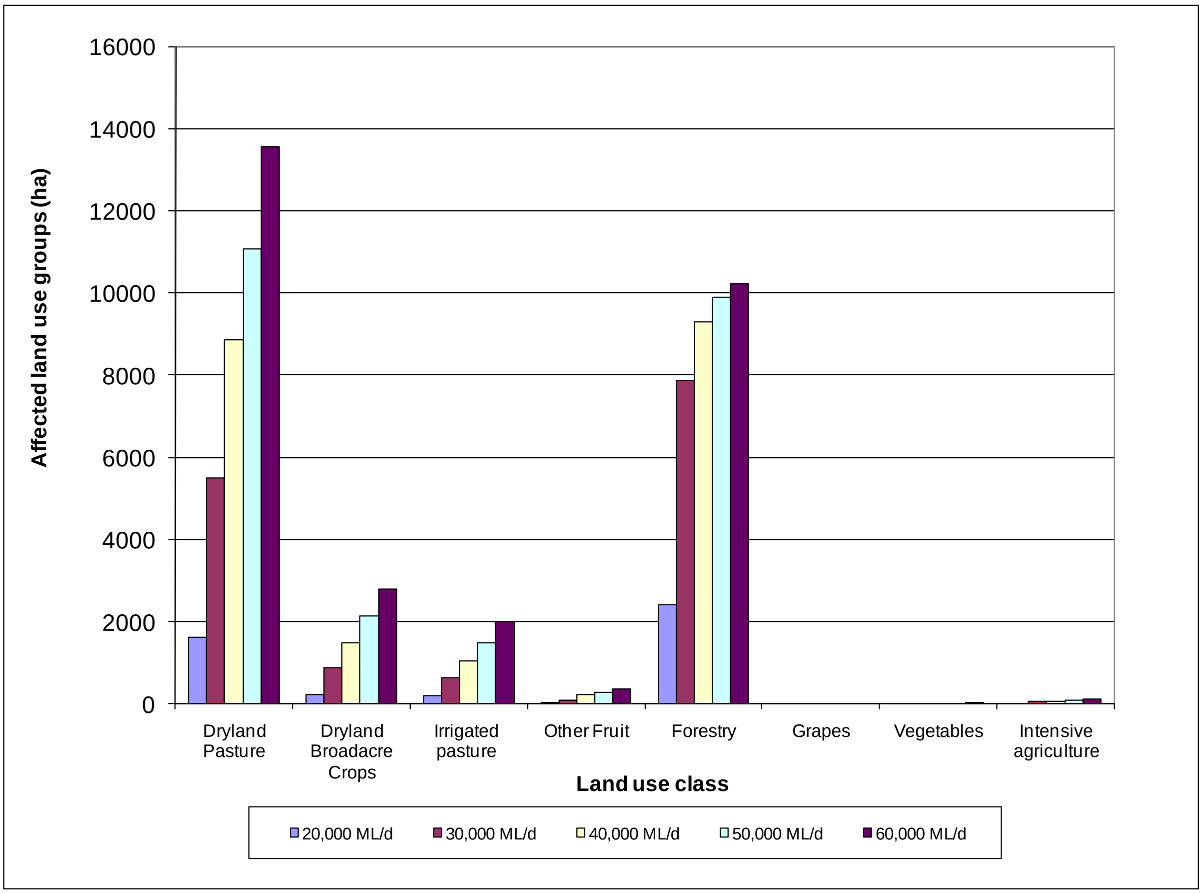

Figure 3-8 Environmental flow scenario – Affected land use areas

As seen in Table 3-9 and Figure 3-8, the land use groupings, dryland pasture and forestry have the significant largest areas affected than the other groupings. Dryland broad acre cropping and irrigated pasture have similar total affected areas. The remaining land use groupings, other fruit, grapes, vegetables and intensive agriculture have relative small affected areas. However, these activities have a higher unit values.

The values of the potential damages for each land use grouping are detailed in URS (2009).

All land use groupings, except for forestry, display a relative uniform increase in affected area with flow magnitude. For forestry, there is a step change in affected areas between 20,000 ML/d and 30,000 ML/d.

Appendix C contains the inundated land use characteristics for each river reach and environmental flow scenario.

3.8 Wetlands areas

The periodic inundation of floodplain wetlands was identified by Cottingham et al. (2003) as an important issue to address in the environmental flow recommendation.

The definition of wetlands area was discussed in the Asset Mapping – Data Collation and Review Report (Water Technology 2009). The general definition of wetland identification adopted by this study considered the drained area. The drained areas were defined as the areas retaining water following the recession of a 60,000 ML/d flow event. The wetland areas discussed in this section was based on this definition. It should be noted that neither field verification of the identified wetland areas nor assessment of wetland conditions/values were undertaken in this study. These aspects were outside of the scope of this study.

For the lower reach, Bunbartha to the Murray River confluence, as discussed impractical model run times limited the assessment of drained areas, and in turn the wetland areas were not assessed. However, it should be noted that the native terrestrial vegetation, as discussed in Section 3.9, provides guidance to the likely wetland area inundation trends for the various flow regimes. Also, the inundation maps provided in Appendix A display the inundated floodplain areas across the environmental flow scenarios.

Table 3-10 displays the area and percentage of wetlands inundated for the environmental flow scenarios. Figure 3-9 shows the percentage of wetland area inundated in each reach as a proportion of those inundated at 60,000 ML/day.

Table 3-10 Environmental flow scenario - Inundated wetland areas

Reach	Flow scenario									
	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Area (ha)	*% of Total*	Area (ha)	*% of Total*	Area (ha)	*% of Total*	Area (ha)	*% of Total*	Area (ha)	*% of Total*
Eildon to Alexandra	69.4	*37*	91.7	*48*	148	*78*	167	*88*	189	*100*
Alexandra to Ghin Ghin	191	*31*	188	*30*	579	*93*	589	*94*	624	*100*
Ghin Ghin to Kerrisdale	98.0	*24*	227	*57*	336	*84*	374	*93*	401	*100*
Kerrisdale to Mitchellstown	99.7	*23*	273	*63*	273	*63*	404	*92*	437	*100*
Mitchellstown to Wahring	170	*55*	255	*83*	285	*92*	298	*97*	309	*100*
Wahring to Kialla	19.1	*3*	428	*62*	627	*91*	666	*97*	690	*100*
Kialla to Bunbartha	390	*28*	1349	*97*	1382	*100*	1383	*100*	1385	*100*
Bunbartha to the Murray River	N.A	*N.A*	N.A	*N.A*	N.A	*N.A*	N.A	*N.A*	N.A	*N.A*
Total (excluding Bunbartha to the Murray River confluence)	**1037.2**	***26%***	**2811.7**	***70%***	**3630**	***90%***	**3881**	***96%***	**4035**	***100%***

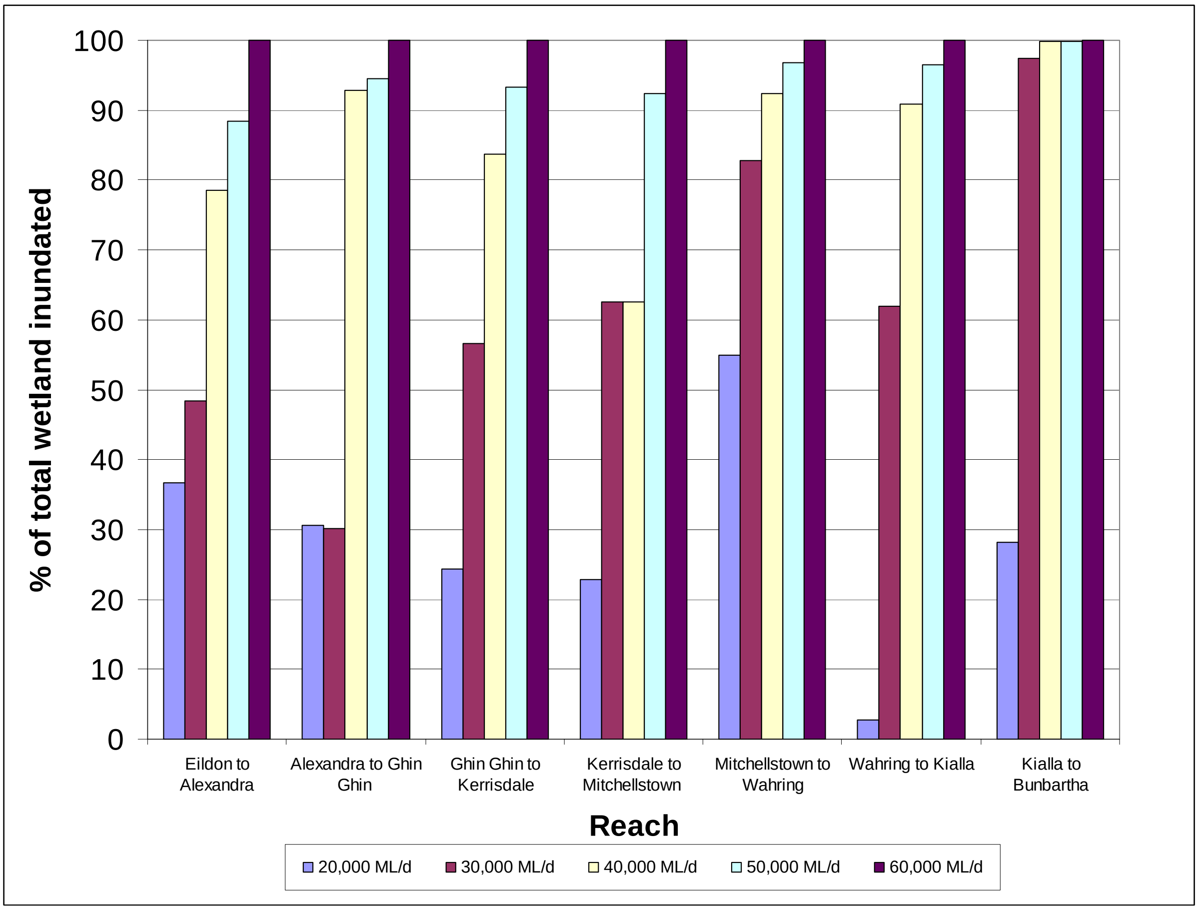

Figure 3-9 Environmental flow scenario - Inundated wetland areas percentage

Across the study reach, the 20,000 ML/d event affects about 26% of the identified wetland areas. There is a step increase to 70 % for the 30,000 ML/d flow event, then to 90 % and 96% for the event 40,000 and 50,000 ML/d flow events respectively.

The upper reaches, Eildon to Alexandra and Alexandra to Ghin Ghin, display a step change in the percentage of the inundated wetland areas between 30,000 and 40,000 ML/d. However, for the reach Ghin Ghin to Kerrisdale, the step change occurs between 20,000 ML/d and 30,000 Ml/d.

Over 50% of the wetland areas was inundated for the 20,000 ML/d flow in the reach Mitchellstown to Wahring. This contrasts with only 3% of the wetland areas inundated for the 20,000 ML/d flow in the reach Wahring to Kialla. There was a step increase to 62% for the 30,000 ML/d in the reach Wahring to Kialla.

For the lower reach, Kialla to Bunbartha, 28% of wetland area was inundated for a flow of 20,000 ML/d, with a marked step increase to 97 % for the 30,000 ML/d. This reflects the partial inundation of the adjacent riparian corridor under a flow of 30,000 ML/d, compared to limited inundation for the 20,000 ML/d flow.

3.9 Terrestrial native vegetation

Generally stands of terrestrial native vegetation mirrors the location of wetland areas. Terrestrial vegetation is trees and understorey plants which depend on or are used to inundation. The definition of terrestrial vegetation was taken as “highly likely native vegetation – woody”, as discussed in the Asset Mapping – Data Collation and Review Report (Water Technology 2009b). Table 3-11 displays the area and percentage of terrestrial vegetation inundated for the environmental flow scenarios. Figure 3-10 shows the percentage of terrestrial vegetation area inundated in each reach.

Table 3-11 Environmental flow scenario - Inundated terrestrial native vegetation

Reach	Flow scenario									
	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Area (Ha.)	*% of Total*	Area (Ha.)	*% of Total*	Area (Ha.)	*% of Total*	Area (Ha.)	*% of Total*	Area (Ha.)	*% of Total*
Eildon to Alexandra	395	*49*	458	*57*	603	*75*	702	*88*	801	*100*
Alexandra to Ghin Ghin	552	*33*	1133	*68*	1568	*94*	1575	*94*	1672	*100*
Ghin Ghin to Kerrisdale	260	*25*	573	*55*	804	*77*	957	*92*	1038	*100*
Kerrisdale to Mitchellstown	335	*23*	880	*60*	1156	*79*	1384	*94*	1467	*100*
Mitchellstown to Wahring	311	*31*	575	*57*	740	*73*	891	*88*	1006	*100*
Wahring to Kialla	161	*5*	1568	*47*	2625	*80*	3160	*96*	3302	*100*
Kialla to Bunbartha	1076	*21*	3993	*77*	4931	*95*	5096	*98*	5210	*100*
Bunbartha to the Murray River	3461	*26*	10010	*75*	11705	*88*	12606	*95*	13299	*100*
Total	**6551**	***24***	**19190**	***69***	**24132**	***87***	**26371**	***95***	**27795**	***100***

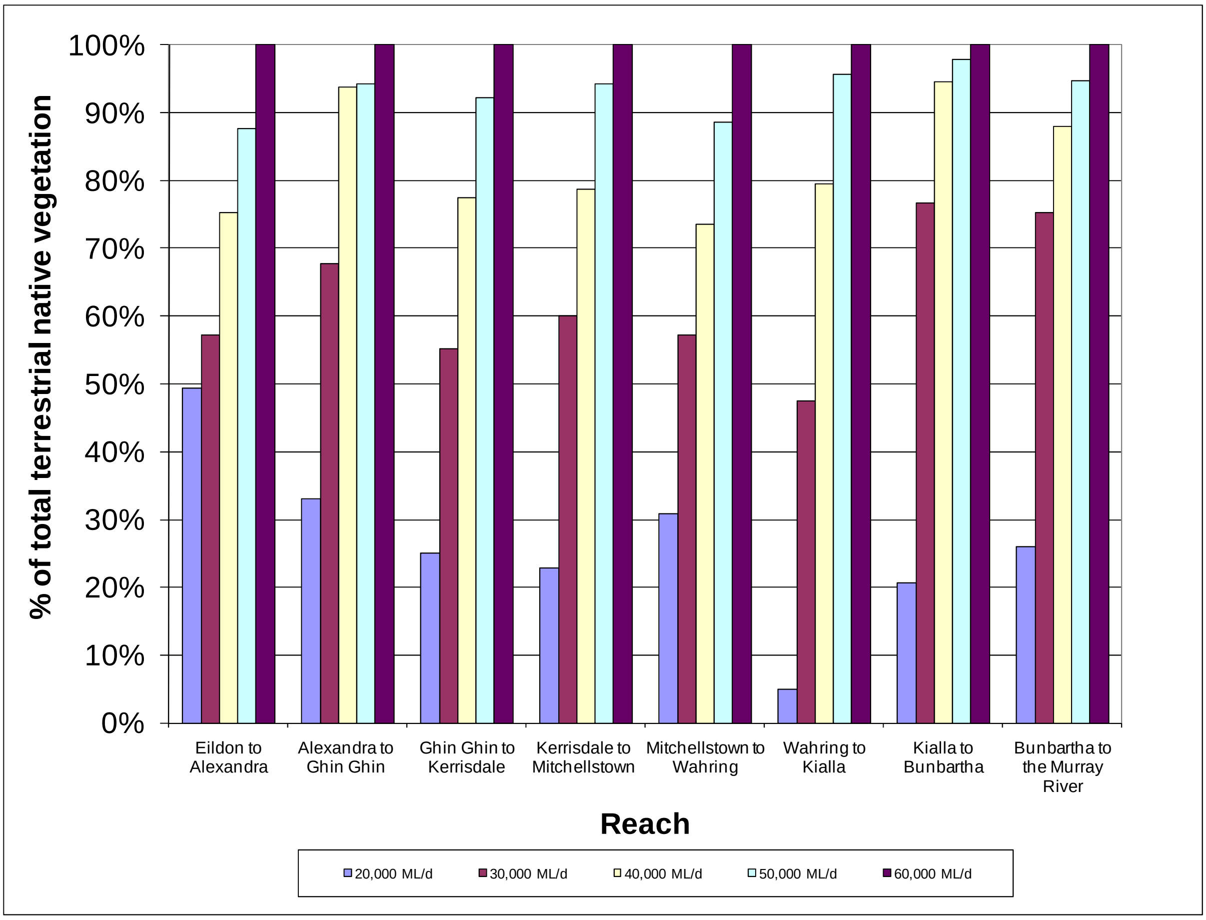

Figure 3-10 Environmental flow scenario - Inundated native vegetation percentage

Similar trends were observed for the inundated terrestrial native vegetation as for the wetland areas. Across the study reach, the 20,000 ML/d event affects about 24% of the identified terrestrial native vegetation. There is a step increase to 69 % for the 30,000 ML/d flow event, then to 87 % and 95% for the event 40,000 and 50,000 ML/d flow events respectively.

Across the entire study reach, the lower reaches, Wahring to the Murray River confluence contained considerably larger areas of inundated terrestrial native vegetation than the other reaches. In part, this reflects the presence of sizable riparian vegetation corridors in these reaches.

3.10 Other assets

Several other assets were identified as having a high potential damages due to inundation. These assets include:

- Caravan parks and holiday villages
- Quarries
- Aquaculture

The following section outlines the nature and location of the identified other assets, and the flood related impacts arising from the environmental flow scenarios.

In some instances, the above assets may have local flood protection works (i.e. levees). At the spatial scale of the hydraulic models (25 m & 60 m grids), these local protection works are unlikely to be captured. Further, the available topographic data (ALS data) may not capture these local protection works. Any local works will need to assess on a case by case basis.

Caravan Park /Holiday cabins		
Caravan park/holiday village location	**Indicative nature of assets**	**Key flow behaviour characteristics**
Reach: Eildon to Alexandra 1. Back Eildon Road near Nicholas Lane	~50 buildings/ vans plus office	Limited inundation for flows to up 60,000 ML/d. Generally only 1 % of total park area affected
Reach: Eildon to Alexandra 2. Back Eildon Road near Thoms Lane	~50 buildings/ vans plus office	20,000 ML/d: No inundation 30,000 ML/d: Considerable inundation about 21 % of area 40,000 ML/d: Considerable inundation about 29 % of area 50,000 ML/d: Significant inundation about 44 % of area 60,000 ML/d: Significant inundation about 63 % of area
Reach: Eildon to Alexandra 3. Breakaway Road	~30 buildings/ vans plus office	20:000 ML/d: Limited inundation about 12 % of area 30,000 ML/d: Significant inundation about 38% of area 40,000 ML/d: Significant inundation about 53 % of area 50,000 ML/d: Significant inundation about 88 % of area 60,000 ML/d: Significant inundation about 99 % of area
Reach: Alexandra to Ghin Ghin 4. Recreation Reserve Road Molesworth	~25 buildings/ vans plus office	20:000 ML/d: Limited inundation about 12 % of area 30,000 ML/d: Significant inundation about 73% of area 40,000 ML/d: Significant inundation about 93 % of area 50,000 ML/d: Significant inundation about 93 % of area 60,000 ML/d: Significant inundation about 99 % of area
Reach: Kerrisdale to Mitchellstown 5. Adjacent to Progress Street Seymour	~15 buildings/ vans plus office	20:000 ML/d: No inundation 30,000 ML/d: Significant inundation about 51% of area 40,000 ML/d: Significant inundation about 52 % of area 50,000 ML/d: Significant inundation about 82 % of area 60,000 ML/d: Significant inundation about 92 % of area

Caravan Park /Holiday cabins

Caravan park/holiday village location	Indicative nature of assets	Key flow behaviour characteristics
Reach: Wahring to Kialla 6. High Road Murchison	~15 buildings/ vans plus office	20:000 ML/d: No inundation 30,000 ML/d: Limited inundation about 15% of area 40,000 ML/d: Considerable inundation about 32 % of area 50,000 ML/d: Significant inundation about 75 % of area 60,000 ML/d: Significant inundation about 84 % of area
Reach: Wahring to Kialla 7. River Road Murchison	~25 buildings/ vans plus office	Limited inundation for flows to up 60,000 ML/d. Generally only 1 % of total park area affected

Quarry locations	Indicative nature of assets	Key Flow behaviour characteristics
Reach: Alexandra to Ghin Ghin Switzerland Road Killingworth	Quarry area ~ 14 ha	20:000 ML/d: No inundation 30,000 ML/d: No inundation 40,000 ML/d: Southern pit affected. Affected area ~ 4ha 29 % of area 50,000 ML/d: Southern pit affected. Affected area ~ 4ha 29 % of area. No increase in affected areas from the 40,000 ML/d event. 60,000 ML/d: Southern pit affected. Affected area ~ 4ha 29 % of area. No increase in affected areas from the 40,000 ML/d event.
Reach: Ghin Ghin to Kerrisdale Homewood Ghin Ghin Road Homewood	Quarry area ~ 25 ha	20:000 ML/d: No inundation 30,000 ML/d: Northern pit affected. Affected area ~ 11ha. 44 % of area. 40,000 ML/d: Northern pit affected. Affected area ~ 11ha. 44 % of area. Inundation adjacent to southern pit 50,000 ML/d: Northern and southern pits affected. Affected area ~ 19ha. 76 % of area. 60,000 ML/d: Northern and southern pits affected. Affected area ~ 19ha. 76 % of area. No increase in affected areas from the 50,000 ML/d event.
Reach Kerrisdale to Mitchellstown Gordon Crescent	Quarry area ~ 25 ha – north of	20:000 ML/d: No inundation 30,000 ML/d: No inundation

Seymour	Goulburn River ~ 6 ha – south of Goulburn River	40,000 ML/d: North of Goulburn River. Western pit affected. Affected area ~ 5 ha. 16 % of area. 50,000 ML/d: North of Goulburn River. Western pit affected. Affected area ~ 5 ha. 16 % of area. No increase in affected areas from the 40,000 ML/d event. 60,000 ML/d: North of Goulburn River. Western pit affected. Affected area ~ 5 ha. 16 % of area. South of Goulburn River. Pit affected. Affected area ~ 6 ha. 19 % of area.

Aquaculture location	**Indicative nature of assets**	**Key Flow behaviour characteristics**
Reach: Eildon to Alexandra Clarks Road – Goulburn Valley Highway	~5 ha ~ 38 ponds Diversion from Goulburn River	20:000 ML/d: No inundation 30,000 ML/d: No inundation 40,000 ML/d: No inundation 50,000 ML/d: No inundation 60,000 ML/d: No inundation
Reach: Eildon to Alexandra McMartins Road	~5 ha ~ 23 ponds Diversion from Goulburn River	20:000 ML/d: No inundation 30,000 ML/d: Limited inundation 40,000 ML/d: Significant inundation Affected area ~3 ha. 60 % of area. Access to office buildings affected. 50,000 ML/d: Significant inundation Affected area ~3 ha. 60 % of area. Access to office buildings affected. No increase in affected areas from the 40,000 ML/d event. 60,000 ML/d: Significant inundation Affected area ~4 ha. 60 % of area. Access to office buildings affected.

4. CONCLUSIONS

Flood behaviour, inundated areas and floodplain volume

Generally, the reaches Alexandra to Ghin Ghin, Kerrisdale to Mitchellstown, Mitchellstown to Kialla and Kialla to Bunbartha show significant increases in inundated area for increasing flows up to 40,000 ML/d. For higher flows, changes in inundated area were limited. For the other reaches, the inundated areas increase uniformly with increasing flow.

A similar pattern was found for the floodplain volume, except for the reach Wahring to Kialla. In this reach, there appears to be a step change in floodplain volume for a small increase in inundated area from 40,000 to 60,000 ML/d.

Buildings

In the upper reaches, Eildon to Alexandra and Alexandra to Ghin Ghin, the number of affected buildings is relatively higher than the other reaches. This reflects the higher relative magnitudes of the environmental flow scenario flows. A 60,000 ML/d flow in the upper reaches a has an indicative ARI of 45 years, compared to about 10 years at Seymour.

A step change in the affected residential buildings occurred in the reach Kerrisdale to Mitchellstown, for the 60,000 ML/d event. This reflects the inundation of residential buildings on fringe areas of Seymour.

In some instances, the presence of local flood protection works (i.e. levees) will affect local flood behaviour around buildings and other assets. At the spatial scale of the hydraulic models (25 m & 60 m grids), these local protection works are unlikely to be captured. Further, the available topographic data (ALS data) may not capture these local protection works. Any local works will need to assess on a case by case basis.

Roads and Bridges

The length of affected roads and the number of affected bridges generally display a uniform increase with flow. Further assessment is required to determine the relative local importance and potential social impacts if a road is impassable. For example, is the road the only access, and inundation will result in landholder isolation.

Land use

The predominant land use classes affected, by area, are the dryland pasture and forestry.

For the reaches, Alexandra to Ghin Ghin, Wahring to Kialla, and Bunbartha to the Murray confluence, a step change increase in affected land use area occurred at 30,000 ML/d. The other reaches displayed a uniform increase in affected area with increasing flow.

Wetlands and terrestrial native vegetation

Similar inundation patterns were found for the wetlands and terrestrial native vegetation areas. This reflects the high spatial correlation of the two groups.

Across the study reach, the 20,000 ML/d event affects about 26% of the identified wetland areas. There is a step increase to 70 % for the 30,000 ML/d flow event, then to 90 % and 96% for the event 40,000 and 50,000 ML/d flow events respectively.

Similar trends were observed for the inundated terrestrial native vegetation as for the wetland areas. Across the study reach, the 20,000 ML/d event affects about 24% of the identified terrestrial native vegetation. There is a step increase to 69 % for the 30,000 ML/d flow event, then to 87 % and 95% for the event 40,000 and 50,000 ML/d flow events respectively.

Across the entire study reach, the lower reaches, Wahring to the Murray River confluence contained considerably larger areas of inundated terrestrial native vegetation than the other reaches. In part, this reflects the presence of sizable riparian vegetation corridors in these reaches.

Other assets – Caravan park, quarries and fish farms

There are seven caravan parks located along the study reach. For two of seven caravan parks, inundation commenced at 20,000 ML/d. For a further three caravan parks, inundation commenced at a flow of 30,000 ML/d. The remaining two caravan parks have limited inundation for a flow of 60,000 ML/d.

There are three operating quarries located along the study reach. For one quarry, inundation commenced at 30,000 ML/d. The remaining two quarries are affected for flows 40,000 ML/d and above.

There are two operating fish farms located along the study reach. For one farm, inundation commenced at 30,000 ML/d. The remaining farm is unaffected for flows up to 60,000 ML/d.

In some instances, the presence of local flood protection works (i.e. levees) will affect local flood behaviour around these assets. At the spatial scale of the hydraulic models (25 m & 60 m grids), these local protection works are unlikely to be captured. Further, the available topographic data (ALS data) may not capture these local protection works. Any local works will need to assess on a case by case basis.

Modelling uncertainty

The Hydraulic Model Construction and Calibration report (Water Technology 2009b) discussed the calibration of the hydraulic modelling framework to available stage and flow data. The robustness of the model calibration needs to be considered when assessing the outcomes of the model application. Key considerations from the model calibration:

- In the reach upstream of Goulburn Weir, the quantity of affected assets assessed in the following sections is considered to reflect an upper limit for flows up to 30,000 ML/d.
- In the reach Murchison to Shepparton, the quantity of affected assets assessed in the following sections is considered to reflect a lower limit for flows up to 60,000 ML/d.
- In the reach adjacent to McCoy's bridge likely to reflect a upper limit to the quantity of affected assets.

There is considerable uncertainty arising from the model calibration in the assessment of affected assets under the environment flow scenarios. Further, it is worthy to note, the observed flow gaugings show considerable scatter. This scatter reflects in the variation in the channel physical form and changes in vegetation over time. Future refinements in the model structure and calibration will be unable to resolve this natural variation. The management of flows along the reach will need to consider these natural variations.

To assess the impact of model uncertainty on affected asset identification, a range of sensitivity analyses are recommended. Details are provided in Section 5.

5. FURTHER WORK

This section outlines requirements for further work in the refinement and application of the hydraulic modelling framework for the environmental flow scenarios.

Flow attenuation

As discussed above, steady state flow conditions (i.e. constant flow along the reach) were assessed in the hydraulic model. The attenuation of flow hydrographs within each reach, and along the entire study reach was not assessed.

The assessment of flow attenuation requires the hydraulic modelling of a range of flow hydrographs to reflect potential releases from Eildon. The flow hydrographs would encompass a range of peak flows, rates of rise and fall, and flood volumes. Each potential flow hydrograph would be applied as an inflow immediately downstream of Eildon. The modelled flow hydrograph at the downstream limit of each model reach would be then applied as the inflow for the next downstream model.

Drained area in the lower Goulburn

As discussed, practical limitations prevented the assessment of drained areas in the reach Bunbartha to the Murray confluence. To overcome these limitations, requires the re-construction of the hydraulic model for this reach. The single hydraulic model could be split into at least two separate models. Careful consideration would be needed to ensure the correct transfer of flow between new model areas. The smaller models could then be run concurrently to assess drained areas within a practicable model run time.

Local flood protection works

In some instances, the presence of local flood protection works (i.e. levees) will affect local flood behaviour around buildings and other assets. At the spatial scale of the hydraulic models (25 m & 60 m grids), these local protection works are unlikely to be captured. Further, the available topographic data (ALS data) may not capture these local protection works. Any local works will need to assess on a case by case basis.

Local road importance

This assessment has identified affected road lengths over the environmental flow range. The lengths of affected roads were totalled for each reach. This approach yielded total affected road lengths for a various road classes across the study reach.

Further assessment of the local importance of specific affected roads is required to quantify potential social impacts, e.g. landholders being isolated by road, access to local services disrupted.

Quantification of mode uncertainty on affected asset assessment

As noted, the outputs (water levels/extents) from the hydraulic modelling framework are surrounding by uncertainty. To quantify the sensitivity of the affected asset identification to the hydraulic model uncertainty, the following approach is recommended as part of future work:

- Review patterns in affected asset for each reach, to identify whether particular assets are sensitive to changes in flows within a certain flow range
- For the identified asset, reach and flow, run hydraulic modelling framework over a range of flows
- Assess the quantity of affected assets using the hydraulic modelling outputs.

6. REFERENCES

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

Water Technology. (2009). *Goulburn River Environmental Hydraulics Project - Asset Mapping - Data Collation and Review Report.* Melbourne: Goulburn Borken CMA.

Water Technology. (2010). *Goulburn River Environmental Hydraulics Study - Hydraulic Model Construction and Calibration.* Melbourne: Goulburn Broken CMA.

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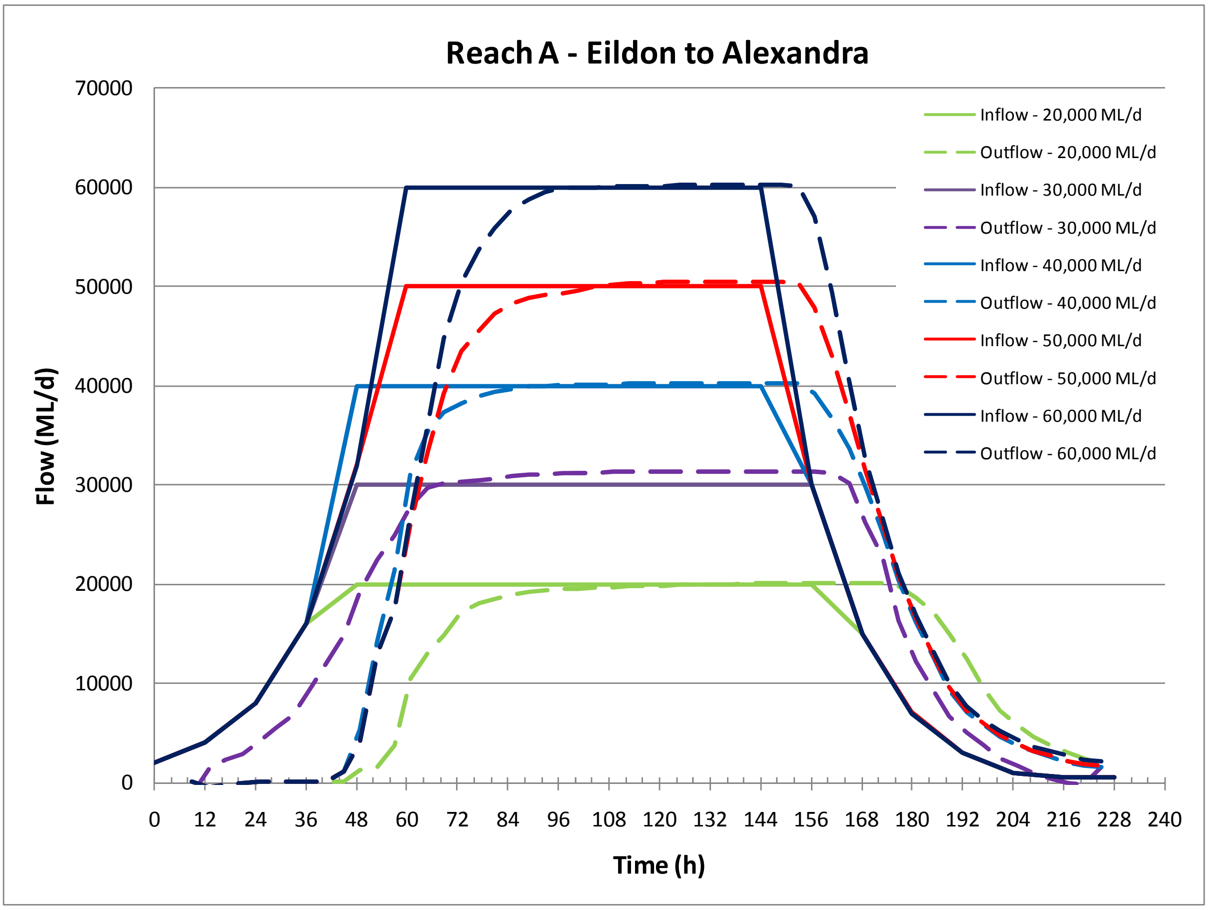
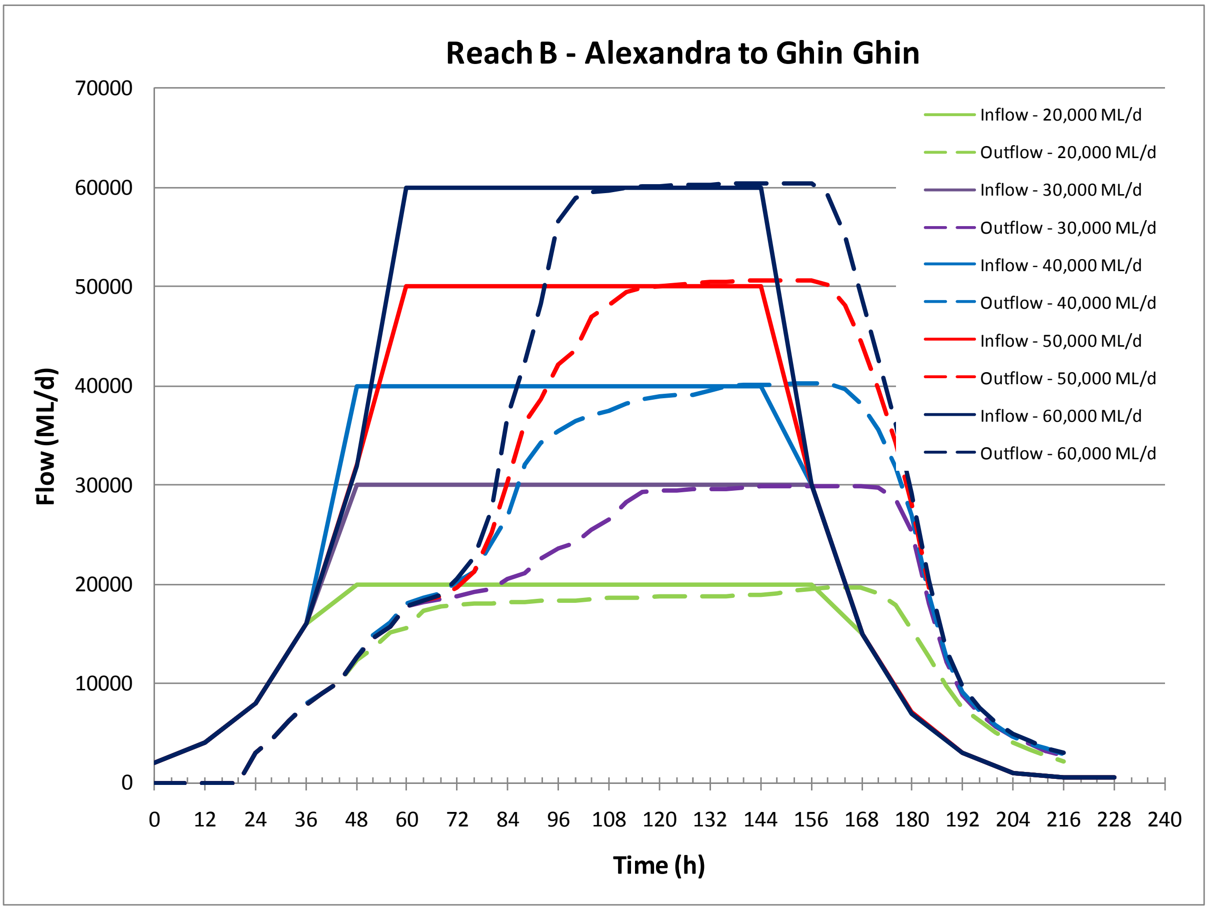
APPENDIX A FLOW HYDROGRAPHS


Reach A - Eildon to Alexandra
Flow (ML/d)
Time (h)
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d


Reach B - Alexandra to Ghin Ghin
Flow (ML/d)
Time (h)
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
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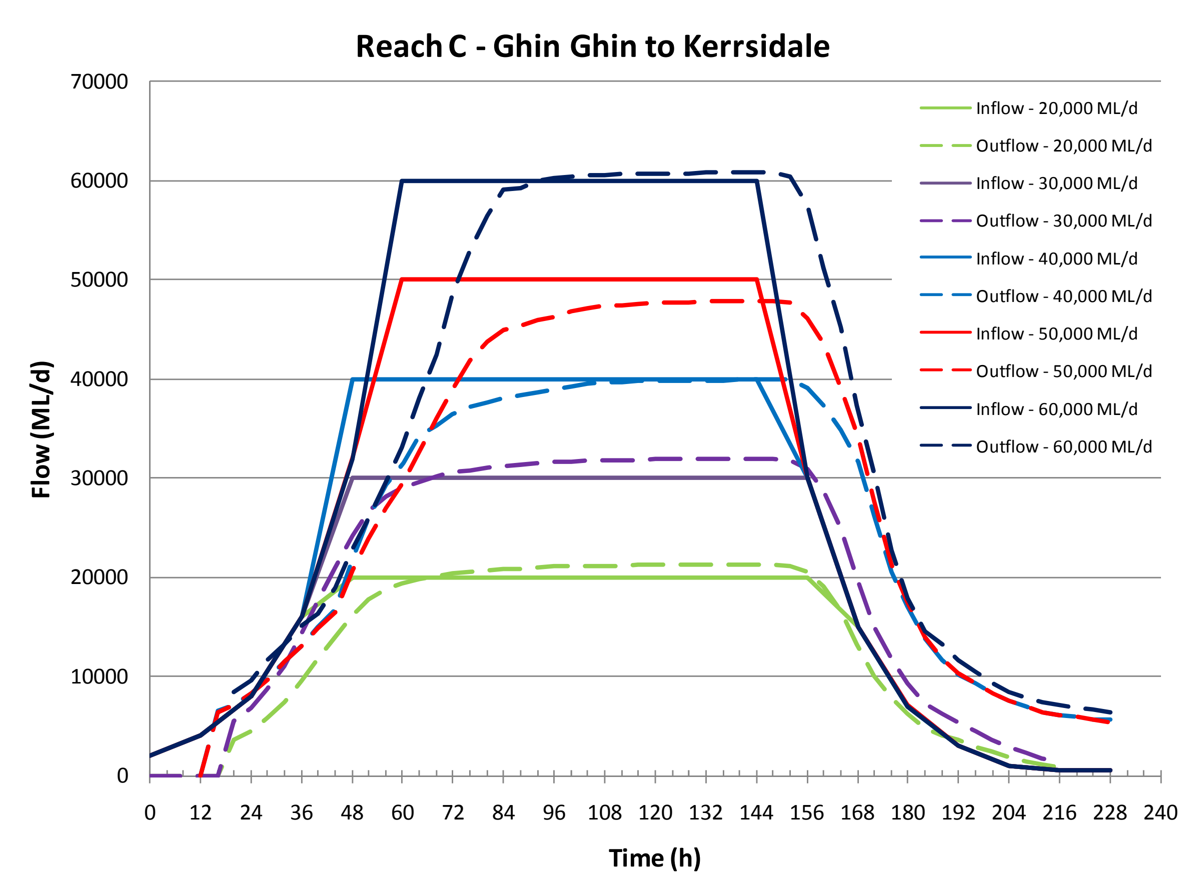
Outflow - 60,000 ML/d


Reach C - Ghin Ghin to Kerrsidale
Flow (ML/d)
Time (h)
0
10000
20000
30000
40000
50000
60000
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
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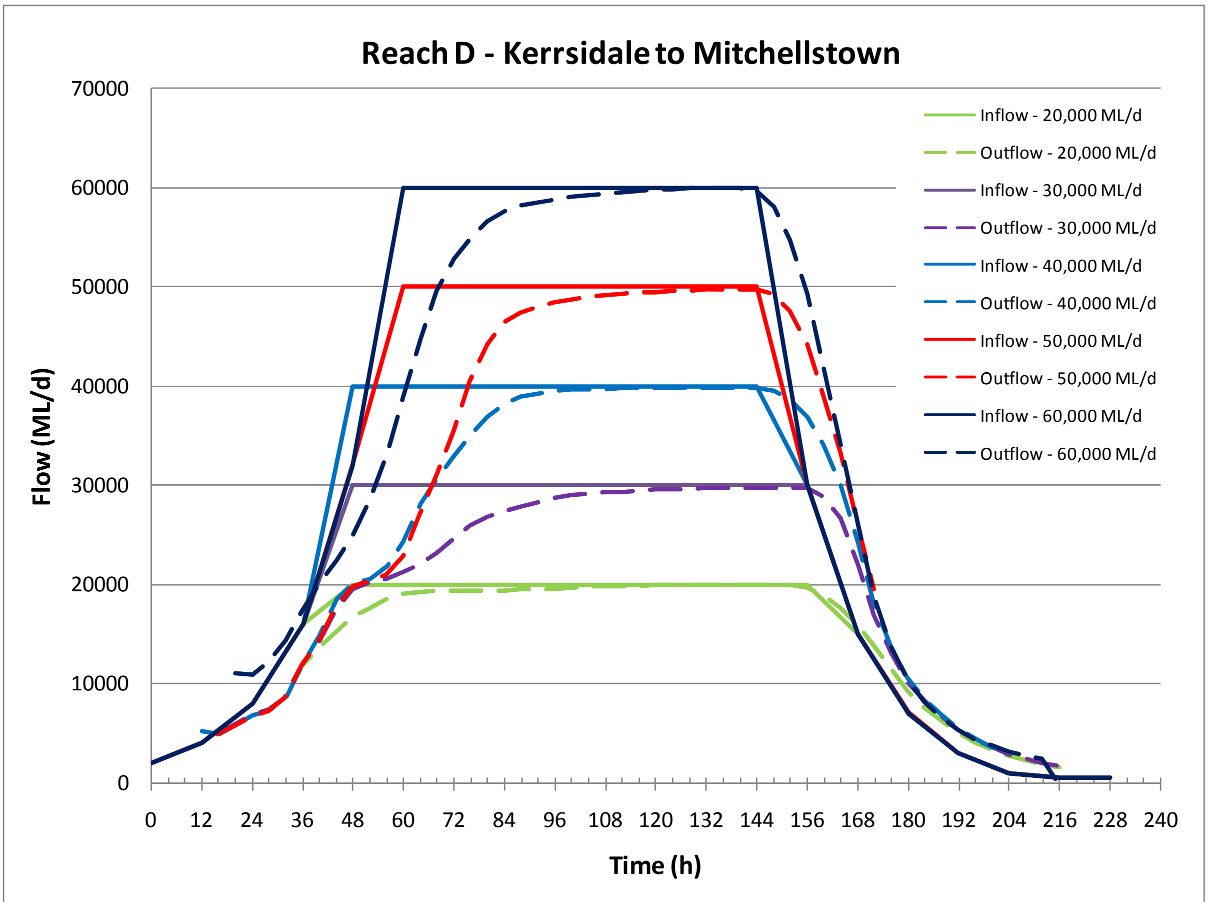
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d


Reach D - Kerrsidale to Mitchellstown
Flow (ML/d)
Time (h)
0
10000
20000
30000
40000
50000
60000
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
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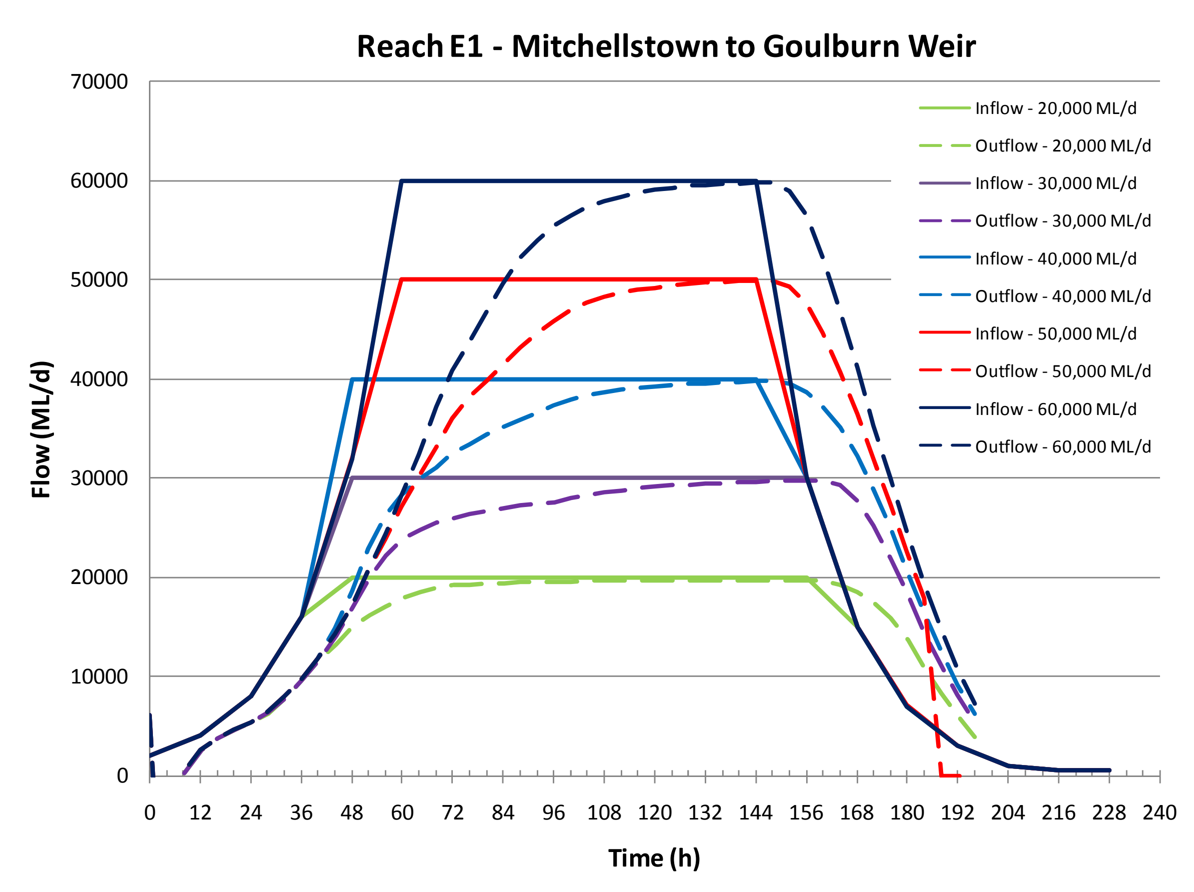
Outflow - 60,000 ML/d


Reach E1 - Mitchellstown to Goulburn Weir
Flow (ML/d)
Time (h)
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d
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30000
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50000
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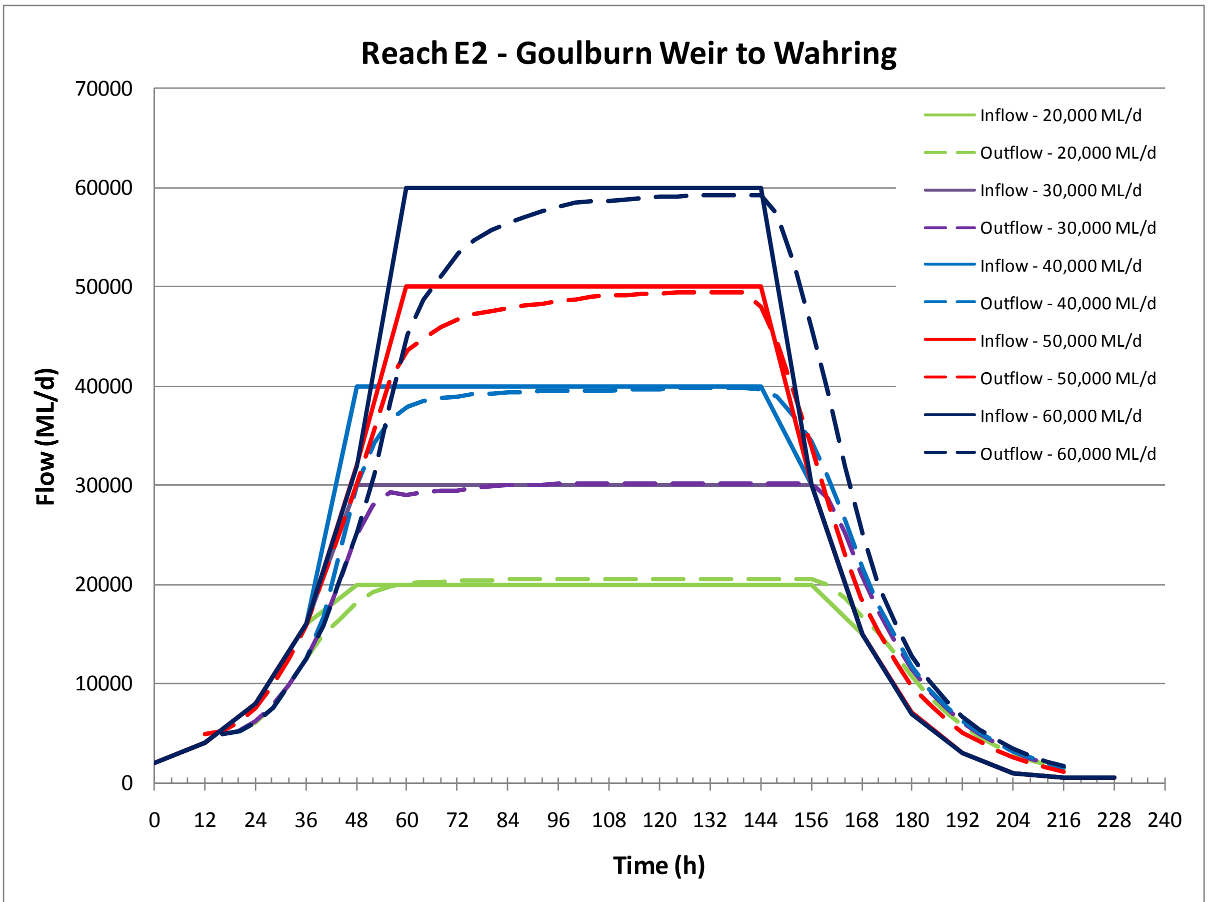
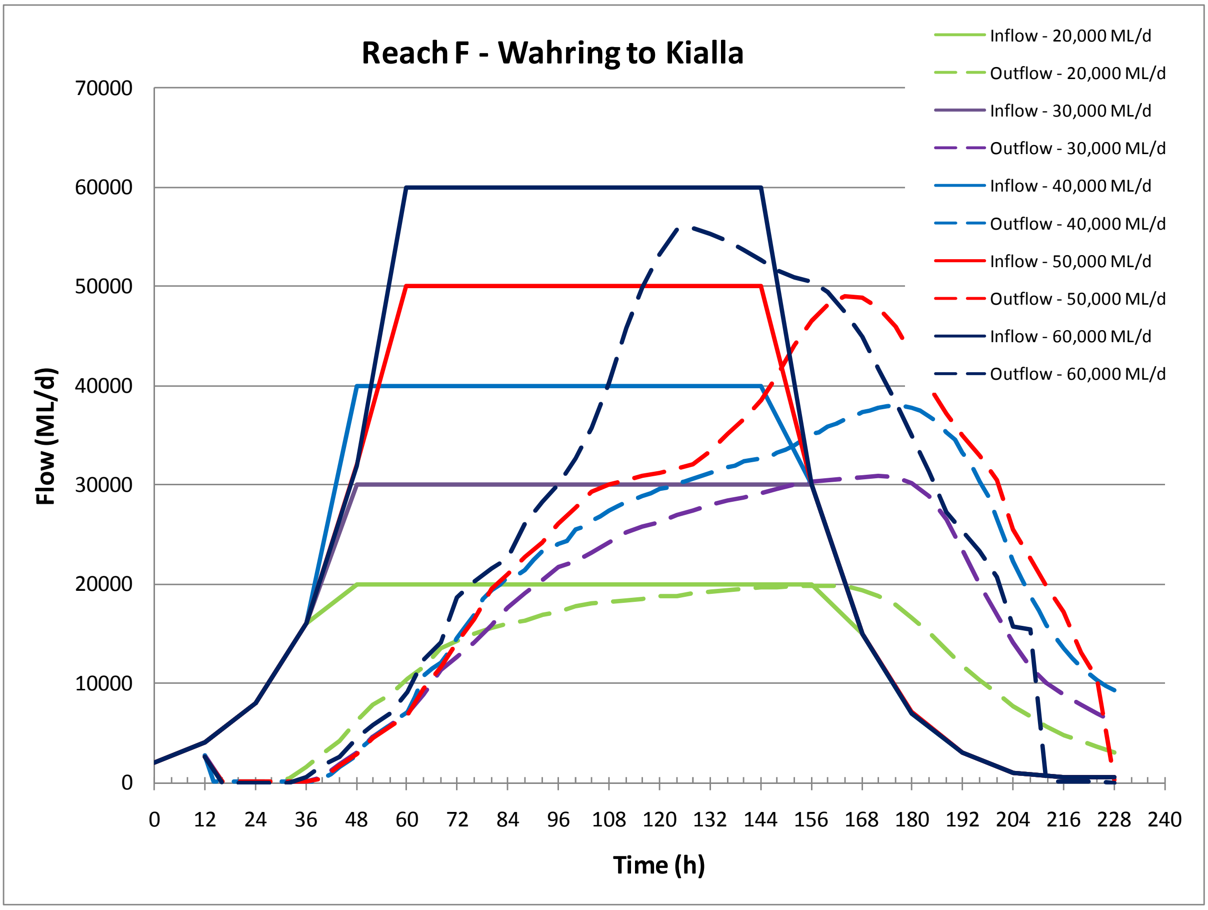
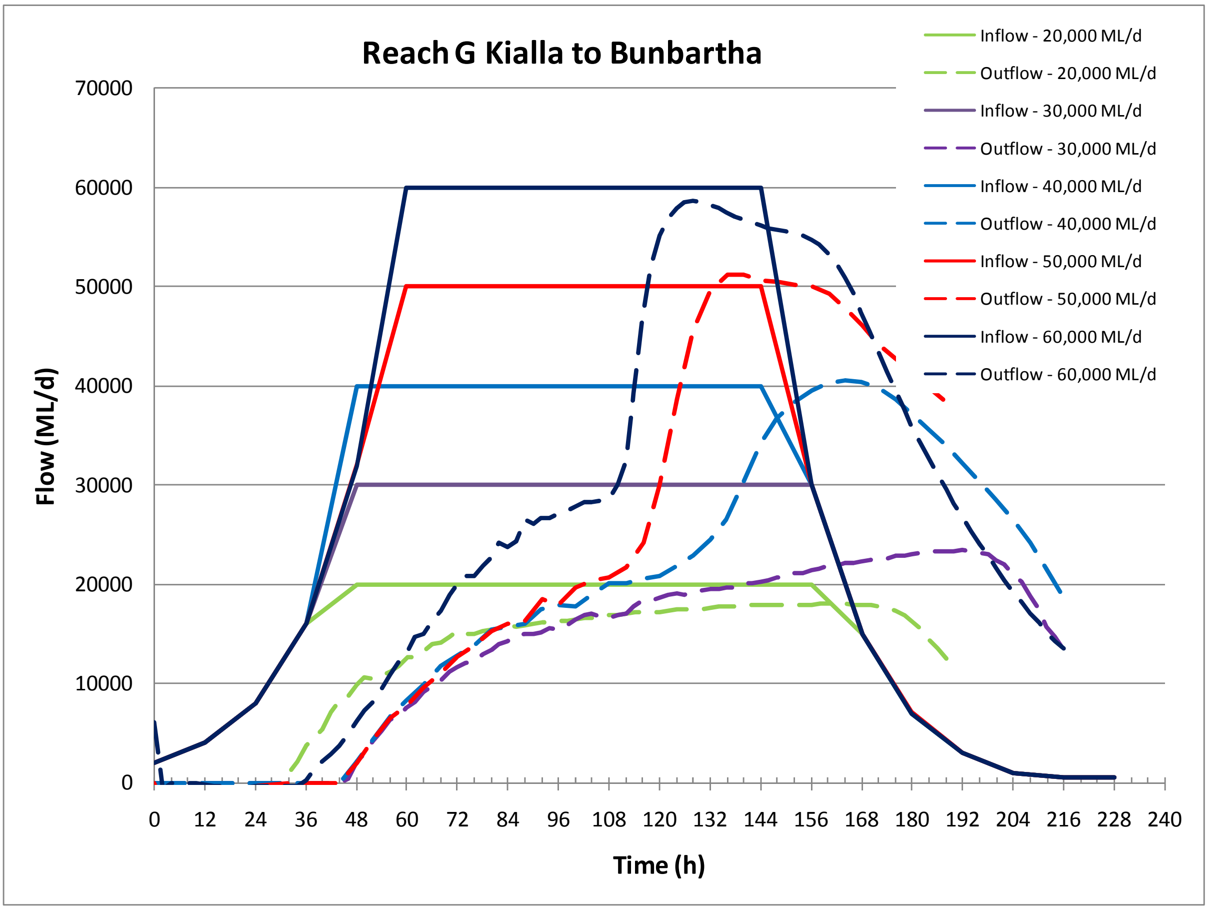
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240


Reach E2 - Goulburn Weir to Wahring
Flow (ML/d)
Time (h)
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d
0
10000
20000
30000
40000
50000
60000
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240


Reach F - Wahring to Kialla
Flow (ML/d)
Time (h)
0
10000
20000
30000
40000
50000
60000
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d


Reach G Kialla to Bunbartha
Flow (ML/d)
Time (h)
0
10000
20000
30000
40000
50000
60000
70000
0 12 24 36 48 60 72 84 96 108 120 132 144 156 168 180 192 204 216 228 240
Inflow - 20,000 ML/d
Outflow - 20,000 ML/d
Inflow - 30,000 ML/d
Outflow - 30,000 ML/d
Inflow - 40,000 ML/d
Outflow - 40,000 ML/d
Inflow - 50,000 ML/d
Outflow - 50,000 ML/d
Inflow - 60,000 ML/d
Outflow - 60,000 ML/d

APPENDIX B AFFECTED ROADS AND BRIDGES

Table B-1 Environmental flow scenario – Roads - Eildon to Alexandra

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.4	0.0	0.5	0.0	1.4	0.0	2.5	0.0	3.2	0.0
Arterial	0.2	0.0	0.4	0.0	0.7	0.0	0.8	0.0	1.0	0.0
Sub-Arterial	0.6	0.0	1.0	0.0	2.6	0.0	4.3	0.0	6.0	0.0
Local	0.0	0.1	0.0	0.2	0.0	1.0	0.1	1.2	0.2	2.1
2wd	0.0	5.4	0.0	11.5	0.0	16.0	0.0	21.7	0.0	27.0
Total	**1.2**	**5.5**	**1.9**	**11.7**	**4.7**	**17**	**7.7**	**22.9**	**10.4**	**29.1**

Table B-2 Environmental flow scenario – Roads - Alexandra to Ghin Ghin

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.1	0.0	0.5	0.0	1.8	0.0	1.8	0.0	2.6	0.0
Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Arterial	0.0	0.0	0.4	0.0	1.2	0.0	1.2	0.0	1.9	0.0
Local	0.0	0.5	0.0	0.7	0.0	1.8	0.0	1.8	0.0	2.3
2wd	0.0	3.8	0.0	13.8	0.0	26.0	0.0	26.3	0.0	31.5
Total	0.1	4.3	0.9	14.5	3	27.8	3	28.1	4.5	33.8

Table B-3 Environmental flow scenario - Roads - Ghin Ghin to Kerrisdale

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Arterial	0.0	0.0	0.0	0.0	0.2	0.0	0.5	0.0	0.8	0.0
Local	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.4	0.0	0.5
2wd	0.0	0.8	0.0	5.5	0.0	11.4	0.0	17.0	0.0	21.7
Total	0.0	0.8	0.0	5.5	0.2	11.7	0.5	17.4	0.8	22.2

Table B-4 Environmental flow scenario -Roads - Kerrisdale to Mitchellstown

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un--sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.0	0.0	0.1	0.0	0.1	0.0	0.4	0.0	1.0	0.0
Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Arterial	0.0	0.0	0.0	0.0	0.1	0.0	0.3	0.0	0.6	0.0
Local	0.3	0.0	0.6	0.8	0.6	1.2	0.8	1.5	1.2	1.8
2wd	0.0	2.3	0.0	8.2	0.0	12.2	0.0	16.3	0.0	19.6
Total	0.3	2.3	0.7	9	0.8	13.4	1.5	17.8	2.8	21.4

Table B-5 Environmental flow scenario - Roads - Mitchellstown to Wahring

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Arterial	0.0	0.0	0.0	0.0	0.2	0.0	0.6	0.0	0.8	0.0
Local	0.0	0.8	0.0	1.5	0.0	2.3	0.0	2.8	0.0	3.4
2wd	0.0	0.5	0.0	2.1	0.0	6.4	0.0	9.7	0.0	12.0
Total	0.0	1.3	0.0	3.6	0.2	8.7	0.6	12.5	0.8	15.4

Table B-7 Environmental flow scenario - Roads - Wahring to Kialla

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arterial	0.0	0.0	0.1	0.0	0.1	0.0	0.3	0.0	0.5	0.0
Sub-Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Local	0.0	0.2	0.0	0.4	0.0	1.2	0.0	2.6	0.2	4.7
2wd	0.0	1.8	0.0	12.9	0.0	37.5	0.0	53.9	0.0	59.4
Total	0.0	2	0.1	13.3	0.1	38.7	0.3	56.5	0.7	64.1

Table B-7 Environmental flow scenario – Roads - Kialla to Bunbartha

Type	20,000 ML/d		30,000 ML/d		40,000 ML/d		50,000 ML/d		60,000 ML/d	
	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)	Sealed (km)	Un-sealed (km)
Highway	0.4	0.0	0.7	0.0	1.4	0.0	1.8	0.0	2.0	0.0
Arterial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-Arterial	0.0	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2	0.0
Local	0.3	0.3	1.6	3.3	2.5	6.3	2.8	7.8	3.1	9.2
2wd	0.0	23.8	0.0	121.1	0.0	173.3	0.0	185.2	0.0	190.3
Total	0.7	24.1	2.4	124.4	4	179.6	4.8	193	5.3	199.5

APPENDIX C AFFECTED LAND USE

Table C-1 Environmental flow scenario - Inundated land use - Eildon to Alexandra

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	325	549	846	1116	1387
Dryland Broadacre Crops	0	0	0	0	0
Irrigated pasture	96	154	233	329	444
Other Fruit	0	0	0	3	7
Forestry	12	22	27	35	44
Grapes	0	0	0	0	0
Vegetables	3	7	9	13	16
Intensive agriculture	0	0	0	0	0
Total	**436**	**732**	**1115**	**1496**	**1898**

Table C-2 Environmental flow scenario - Inundated land use - Alexandra to Ghin Ghin

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	346	1104	2183	2209	2591
Dryland Broadacre Crops	1	21	39	39	45
Irrigated pasture	29	44	57	57	111
Other Fruit	0	1	1	1	1
Forestry	0	0	0	0	0
Grapes	0	2	2	2	2
Vegetables	0	0	0	0	0
Intensive agriculture	0	10	14	14	17
Total	**376**	**1182**	**2296**	**2322**	**2767**

Table C-3 Environmental flow scenario - Inundated land use - Ghin Ghin to Kerrisdale

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	87	392	835	1156	1395
Dryland Broadacre Crops	0	0	0	0	0
Irrigated pasture	0	0	0	0	0
Other Fruit	0	0	0	0	0
Forestry	0	0	0	0	0
Grapes	0	0	0	0	0
Vegetables	0	0	0	0	0
Intensive agriculture	0	0	0	0	0
Total	**87**	**392**	**835**	**1156**	**1395**

TableC-4 Environmental flow scenario - Inundated land use - Kerrisdale to Mitchellstown

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	139	435	655	909	1167
Dryland Broadacre Crops	21	48	105	181	256
Irrigated pasture	0	7	9	13	24
Other Fruit	0	11	26	40	44
Forestry	0	0	0	0	0
Grapes	0	0	0	0	0
Vegetables	0	0	0	0	0
Intensive agriculture	0	0	0	0	0
Total	**160**	**501**	**795**	**1143**	**1491**

Table C-4 Environmental flow scenario - Inundated land use - Mitchellstown to Wahring

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	71	160	236	312	413
Dryland Broadacre Crops	18	54	122	153	169
Irrigated pasture	1	5	25	63	77
Other Fruit	12	45	117	161	187
Forestry	0	0	0	0	0
Grapes	0	0	0	0	0
Vegetables	0	0	0	0	0
Intensive agriculture	0	0	0	0	0
Total	**102**	**264**	**500**	**689**	**846**

Table C-5 Environmental flow scenario - Inundated land use - Wahring to Kialla

Land use	Flow scenario				
	20,000 ML/d	30,000 ML/d	40,000 ML/d	50,000 ML/d	60,000 ML/d
	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)	Affected area (ha)
Dryland Pasture	86	621	861	914	1028
Dryland Broadacre Crops	2	13	33	42	72
Irrigated pasture	16	65	108	119	135
Other Fruit	0	5	6	7	7
Forestry	619	2010	2361	2407	2428
Grapes	0	0	0	0	0
Vegetables	0	0	0	0	0
Intensive agriculture	0	0	0	0	0
Total	**723**	**2714**	**3369**	**3489**	**3670**

Table C-6 Environmental flow scenario - Inundated land use - Kialla to Bunbartha

Land use	Flow scenario				
	20,000 ML/d	**30,000 ML/d**	**40,000 ML/d**	**50,000 ML/d**	**60,000 ML/d**
	Affected area (ha)	**Affected area (ha)**	**Affected area (ha)**	**Affected area (ha)**	**Affected area (ha)**
Dryland Pasture	563	1942	2642	3677	4725
Dryland Broadacre Crops	186	727	1084	1524	2010
Irrigated pasture	39	300	455	636	892
Other Fruit	0	0	1	5	16
Forestry	1747	5217	5743	5975	6182
Grapes	0	0	0	0	0
Vegetables	0	0	0	0	0
Intensive agriculture	0	45	53	60	89
Total	**2535**	**8231**	**9978**	**11877**	**13914**