Final Report

Goulburn River Environmental Flows Hydraulics Study - Potential Flood Damage Assessment

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Prepared for

Goulburn Broken Catchment Management Authority

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Introduction

1.1 Background

This study is concerned with assessing the potential consequences of controlled releases from Lake Eildon to cause flooding along the Goulburn River in order to inundate environmental features on the floodplain to improve environmental outcomes.

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

The study brief outlines the following key study tasks:

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

This report addresses the sixth study task.

The assessment involves two main phases. The first, which being undertaken by Water Technology, is the development of hydrological models in order to simulate the flooding events that would be associated with different releases of water from Eildon Dam and determine the “footprint” of the resulting flood waters along different reaches of the Goulburn River. It is this footprint which determines the potential for the flood event to cause damage and impose costs. The identification of the potential types of damage and development of assessment measures for the costs involved forms the second phase and is the subject of this report prepared by URS Australia Pty Ltd. The reaches of the Goulburn River selected for evaluation by Water Technology are shown Figure 1-1 shown below.

1.2 General Approach

In undertaking the second phase, the approach used was to take the results from the first phase in terms of flood footprint and associated potential damage to property, infrastructure and livelihoods within that footprint. Estimates of potential costs involved were then determined using the Rapid Appraisal Methodology for Floodplain Management (the ‘Flood RAM’). This method was developed in 2000 and updated in 2008 and is based on two the key principles:

> *Optimal ignorance* – knowing what facts are worth knowing; and
>
> *Appropriate imprecision* – knowing that precise data are often unnecessary and, in the case of flood damage estimation, may not be possible to obtain.

The use of the RAM approach will help ensure that the information needed to assess flood damage costs is collected in a cost-effective way, and is available to inform decisions about the size of a flooding event which should be triggered. Information about the potential benefits from particular flooding events is also required to inform this decision. The estimation of potential benefits is discussed further in Section 4.

The term 'damage' in the context of this project refers to not only physical damage, but the economic costs incurred as a result of the flood.

The overall approach for the damage assessment is as follows:

1) Determine assets that would be inundated under each proposed release regime for the eight selected river reaches.
2) Group assets into appropriate categories.
3) Investigate the key drivers of damage for each asset category.
4) Develop 'unit loss' estimates for each category, quantitatively incorporating the key drivers where appropriate and data is available
5) Apply unit loss estimates to assets inundated for each proposed release regime
6) Sum asset damages to estimate total damage for each release regime most likely by river reach.

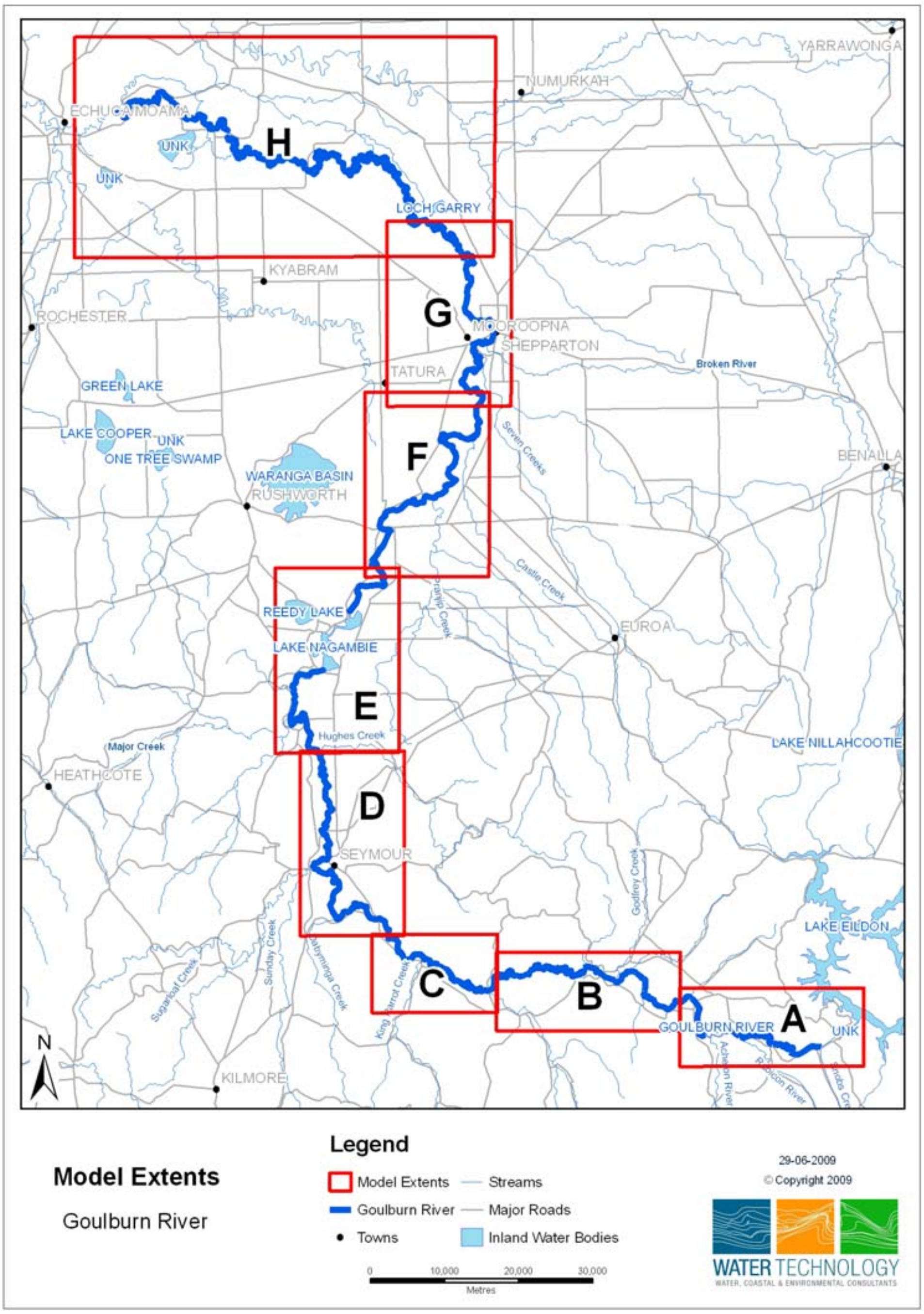
1.3 Selected River Reaches

The eight river reaches selected along the Goulburn River for assessment purposes are shown in Figure 1-1 and approximate:

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

1 Introduction

Figure 1-1 Selected reaches of the Goulburn River



Flood Damage Assessment Factors

2.1 Drivers of Flood Damage

URS has investigated a wide range of studies and information regarding damages caused by floods. Although there are many factors that contribute to the damage caused by individual flood events, the following drivers of flood damages are considered key:

- Physical characteristics of the asset
- Depth of inundation
- Velocity of inundation
- Duration of inundation
- Warning time and preparedness

These are briefly described in the following section.

Physical Characteristics of the Asset

The most important determinant of the damage to an inundated asset is the physical characteristics of the asset itself. The absorption of water by building materials can compromise structural integrity and strength. The contents of buildings are often highly susceptible to water damage when flooded. Flood waters also tend to weaken sub-grades of roads and pavements, increase potholing and cracking.

Biological systems are impacted by flood waters in both and positive and negative ways. Flood waters provide much needed hydration to ecological life in flood plains and riparian zones, and brief flooding of agricultural areas can provide some benefit to agricultural production. However, flooding of longer duration, or higher velocity, will damage crops and pastures, and drown stock.

Depth of Inundation

The depth of inundation is a key driver of damage for many asset types, particularly in buildings. The magnitude of damage rises considerably once flooding reaches floor level, where damage starts to contents as well as structural aspects such as plasterwork and joinery. Cars, caravans and other vehicles (including farm vehicles) are generally undamaged up until a critical depth of inundation, beyond which significant damage begins to occur.

The depth of inundation is a factor in the loss of stock during floods. Flooding generally does not directly affect stock until a critical depth is reached and losses to drowning occur. A relationship between depth and damage is less clear for cropping and pastures.

Duration of Inundation

Flood waters that recede quickly cause significantly less damage than floods that persist for longer periods. Studies have shown that buildings that are inundated for periods of greater than 12 hours suffer approximately twice the damage to structure and contents than with shorter floods. Similarly, damage to agricultural crops and pastures increase significantly with duration of inundation, particular if the duration is sufficient to kill the pasture/crop. Short periods of inundation, however, can provide some benefit to agricultural productivity.

Indirect economic and social impacts of flooding tend to increase with longer duration of flooding. Health impacts are more prevalent with longer duration floods, and activities by emergency and essential services can be precluded by persistent floodwaters. Floodwaters may also prevent access to businesses by customers and suppliers, and repair efforts can also be hindered.

2 Flood Damage Assessment Factors

Velocity of Floodwaters

Although velocity of floodwaters is recognised as an important driver of flood damage, very little data are available about the extent of damage. This is largely a consequence of little data being available about the velocity of the floodwaters. The literature on the influence of the velocity of flow on damage costs from dam failure is more extensive, however, the associated velocities would be considerably faster and more powerful flows than that for riverine flooding associated with controlled releases.

Warning Time and Preparedness

Prior warning of flooding allows preventative measures to be undertaken which reduces the amount of damage caused by flooding. Damage to assets that can be moved to higher ground, such as building contents, vehicles and livestock, is preventable with sufficient warning time. Other preventative measures such as sandbagging and levies can also be implemented to prevent damage with sufficient warning time. Experience of flooding and preparedness are also key factors in determining people's response to flooding and the level of consequential damage. Flood studies often consider this in terms of 'actual to potential damage ratios'. This is discussed further in Section 2.2.

"Artificial flooding" like that proposed for this project allows for preparation and planning well in advance. It is conceivable that, with sufficient warning, potential damage to movable objects could be virtually mitigated, while impacts on agricultural enterprises could be vastly reduced through altering agricultural practices and taking precautionary action, including limiting the duration to avoid loss of pasture and crops. There are costs involved in these actions that would need to be considered in assessing flood damage.

2.2 Actual Damage and Potential Damage

The unit values of damages estimated in this report represent the 'potential' level of damage that would occur if no remedial actions of any kind were undertaken, consistent with no ability or opportunity to reduce exposure to damages. However, in most instances many property owners have time to make some preparations aimed at reducing damages, for example, removing valuable items or cars from the property, sand bagging, or raising valuables to a height above the likely level of inundation. Consequently it may also be beneficial to estimate the likely 'actual' level of damages which would occur in each flood event. This can be expressed as a ratio of actual to potential damages.

The level of damages that could be avoided is a function of available flood warning time and the prior flood experience of those at risk. People are less likely to prevent damage if they are inexperienced, uninformed or have received no warning. Smith et al (1990) observed the ratios of actual to potential damages for major floods across Australia during the 1970s and 1980s. These observations are summarised in Table 2-1.

Table 2-1 Effect of warning time and experience on damages

Flood	Warning Time	Experience of Flooding	Ratio of actual to potential damages
Brisbane	30 hours	Rare flooding, potential hazard not recognised	0.90
Bairnsdale	20 hours	Frequent flooding, well prepared	0.45
Eugowra	7 hours	Frequent flooding, well prepared	0.35
Forbes	70 hours	Frequent flooding, well prepared	0.30
Inverall	10 hours	Rare flooding, potential hazard not recognised	0.70
Nyngan	5 hours	Rare flooding, potential hazard not recognised	0.85
Queenbeyan	6 hours	Rare flooding, potential hazard not recognised	0.81
Geelong	3 hours	Rare flooding, potential hazard not recognised	0.75
Lismore	12 hours	Frequent flooding, well prepared	0.40
Traralgon	6 hours	Frequent flooding, well prepared	0.60
Sydney	3 hours	Rare flooding, potential hazard not recognised	0.80

Based on these ratios, Read Sturgess & Associates (2000) adopted the ratios of actual to potential damages in Table 2-2, defining ‘experienced’ as having experience of floods within the last 5 years.

Table 2-2 Proposed ratios of actual to potential damages

Warning Time	Experienced Community	Inexperienced Community
Less than 2 hours	0.8	0.9
2 to 12 hours	Linear reduction from 0.8 at 2 hours to 0.4 at 12 hours	0.8
Greater than 12 hours	0.4	0.7

It is important to remember that in the context of flood damage estimation, the term ‘actual damages’ is really referring to *estimated* actual damages.

In the context of floods resulting from controlled releases, it is possible that warning times may be vastly greater than 12 hours and the ratio of actual to potential damages may be significantly smaller than those estimated in Table 2-2.

2.3 Replacement Value and Economic Costs

Many of the studies into flood damages draw on data collected by insurance companies. Insurance companies are generally interested in their own liability, which is usually the cost of repairing or replacing damaged goods. Most of the damages covered by insurance companies are assessed based on current market values, however some damages, such as building contents, are often covered under “new for old” type policies for which damaged goods are replaced with new ones rather than goods of similar value. Replacement values for these items therefore typically overstate the true economic damage to building contents, since the current market value (or 'remaining value') of goods prior to flood damage is typically less than the cost of new items. The economic value of these goods tends to depreciate as a result of the passing of time, and use.

To account for this fact, 'average remaining values' may be estimated as a percentage of new value. The difficulty with making such an estimation is that the ages of the contents in question, and the resulting depreciation in value, are unknown. If we assume that the average age of building contents is 50 percent of their depreciable life, and that depreciation is linear, then it is reasonable to estimate that the economic value of building contents is approximately 50 percent of replacement value. It is also assumed that damaged goods have zero residual ('scrap') value. Damages estimated from previous studies also need to be adjusted to present day values using an approximate CPI adjustment factor; a three percent per annum factor is proposed.

2.4 Direct and Indirect Damage

Indirect (tangible) damages comprise losses from disruption of normal economic and social activities that arise as a consequence of the physical impact of the flood; for example, costs associated with clean-up, emergency response, providing community support, as well as disruption to transport, utilities, employment and commerce.

The development of unit losses for the various different categories of indirect values has proved exceedingly difficult. The overriding factor has been the lack of available data, particularly Australian data, with which to formulate meaningful representative values of likely costs. As data becomes more accurate and more available it may become possible to determine these values with more confidence.

Instead of using unit losses for each category, we have chosen to represent indirect values as a proportion of direct values. There are a considerable number of studies that provide some basis and justification for using this approach.

Kates (1965) undertook a study in the United States in which he found that the magnitude of indirect damage costs was 15 per cent of direct damage costs for residential buildings, 37 per cent for commercial buildings, and 45 per cent for industrial buildings. Clean-up costs were included as direct damages. Smith et al (1979) made estimations of indirect costs as a proportion of direct costs for damages incurred during floods in Lismore in 1974. They found that indirect damages to residential buildings were about 39% of direct damage costs, about 27% for commercial buildings, about 52% for industrial buildings. Clean-up costs were included in indirect damage costs for this study. Read Sturgess and Associates (2000) estimated that indirect costs of the 1993 Benalla flood were 27 per cent of the direct damage costs and 35 per cent of the direct costs of 1998 East Gippsland Flood. These were not differentiated for property types.

Given the fact that indirect damages are a function of the timing, duration, intensity and location of flooding, uncertainties in the magnitude of indirect damages for a particular flood event are considerable. As a result, no value has been attributed to indirect damage in this analysis. It is noted, however, that such damages do exist and the damages calculated here should therefore be considered a lower bound of the total damages of flooding.

Potential Flood Damages from Proposed Environmental Releases

3.1 Introduction

The assessment of flood damages covers eight main areas along the Goulburn River, downstream of Eildon (see Figure 1-1 in Section 1.2). These eight areas are approximately:

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

The extent of flooding in each of these areas has been modeled by Water Technology for five different flow rates through each modeled reach:

- 20,000 megalitres;
- 30,000 megaitres;
- 40,000 megalitres;
- 50,000 megalitres; and
- 60,000 megalitres.

The spatial extent of the modeled floods has formed the basis for determining the types and number of assets inundated. The flood damage assessment undertaken here utilises derived unit values (see Appendix A) to assess the expected damage to these assets in each flood event modeled.

3.2 Data Availability

A considerable amount of data and information has been sought to derive the unit damages described in Appendix A. In addition to this, a range of GIS overlays were used to identify the location and size of assets that exist within the footprint of the modelled flood events. The main information used to determine potentially flooded assets include:

- Hydraulic modelling undertaken by Water Technology;
- Land-use overlays covering the Goulburn Broken Catchment;
- Vicmap layer entitled 'IN_BUILDING_POINT' to derive building locations, with further manual checks against aerial photography; and
- Vicmap layer entitled 'TR_ROADS' for roads and bridges.

See Water Technology (2009) Report for further information regarding asset mapping for this project.

3.3 Unit Values and Assumptions

The derivation of unit values including assumptions is presented in Appendix A. Some additional assumptions have also been necessary to apply these values given the specific information available for identified assets.

The duration of flooding is not presently known but is expected to be greater than seven days. This is assumed to be the case in the analysis presented here, however, the sensitivity of results to this assumption is tested in Section 0 by calculating the damages for less than seven days of flooding.

3 Potential Flood Damages from Proposed Environmental Releases

Although velocity of flood waters is recognised as being a factor in flood damages, insufficient data relating velocity to damage is available to quantify this relationship. Velocity is therefore assumed to be constant in the analysis of damages.

A general assumption of the assessment is that sufficient warning of flooding will be provided to asset owners such that mobile objects including vehicles, contents of buildings, and farm stock will be moved to higher ground or off-site.

Assumptions that are specific to asset types are presented below.

3.3.1 Buildings

Unit values were derived for residential, commercial and industrial buildings based on a derived relationship between depth of flooding above floor level and damage to building structures and contents (see Appendix A). Although some information about absolute flood height is available from the hydraulic modelling, there is no information available about the respective floor heights of each building. As a result, it has not been possible to determine flood levels above floor. Making assumptions about floor heights is difficult, as buildings that exist in lower-lying areas, and are consequently more susceptible to flooding, are often built with higher floor levels.

The analysis presented here has assumed that, on average, all buildings within the flood extents are flooded to a depth of 10cm above floor. This uncertainty has been tested in Section 0 using lower and higher flood depths to provide an indication of the range of building damages that can be expected.

In addition, it has been assumed that significant warning will allow non-fixed building contents to be moved out of the way of the flood hazard. It is recognised however that some items can not be moved. It is therefore assumed that given ample warning and preparation time, actual contents damage is 30 percent of potential damage (in line with the findings from Forbes in Table 2-1).

Contents damage has therefore assumed to be 30 percent of those proposed in Appendix A This assumption has also been tested in Section 0 by applying higher actual to potential damage ratios that correspond with shorter warning times.

A summary of the unit value used for buildings and contents using an overfloor flood depth of 10cm is outlined in Table 3-1.

Table 3-1 Building unit damages

Damage component	Residential ($ per structure)	Commercial/Industrial ($ per structure)
Structural	15,260	18,000
Contents	8,120	12,000
External damage & clean-up	9,000	12,000
TOTAL	32,380	42,000

It is not possible from the data available to differentiate residential buildings from commercial and industrial, however it is understood that the vast majority of inundated buildings are likely to be residential. We have assumed that 90 percent of inundated buildings are residential.

In addition to the above building categories, a number of sheds exist within the indicated flood extents. URS (2007) investigated the impacts of damages arising from dam failure. Damages to rural sheds were found to range between $5,000 and $50,000 per shed. However, given the fact that dam failures would be expected to cause much greater amount of damages than the flooding being investigated here, relevant damages for this study are likely to be in the low end of this range. A unit value for shed damage of $5,000 per shed has therefore been assumed for this analysis.

3.3.2 Roads and Bridges

Unit values for roads and bridges have been derived as described in Appendix A. These categories have been matched to the road categories supplied as GIS outputs, as presented in Table 3-2

Table 3-2 Road categories

GIS category	Unit value category (sealed roads)	Unit value category (unsealed roads)
Highway	Major Highway	-
Arterial	Major sealed road	Unsealed Road
Sub-Arterial	Major sealed road	Unsealed Road
Collector	Minor sealed road	Unsealed Road
Local	Minor sealed road	Unsealed Road

No differentiation has been made between major and minor bridges in the GIS outputs. It is therefore assumed that all bridges are minor bridges, as described in Appendix A. Releases of 20,000 ML, 30,000 ML, and 40,000 ML have been considered as causing 'minor flooding' in this analysis, while larger releases of 50,000 and 60,000 ML have been considered 'major flooding'. This assumption is tested in the sensitivity analysis in Section 3.5.8.

A summary of the unit values applied in this analysis are presented Table 3-3

Table 3-3 Damage to roads and bridges ($ per km)

	Major Flood			Minor Flood		
Road Type	Initial Road Repair	Subsequent Accelerated Deterioration of Roads	TOTAL COST	Initial Road Repair	Subsequent Accelerated Deterioration of Roads	TOTAL COST
Major highway (4 lane)	$220,000	$110,000	$330,000	$110,000	$55,000	$165,000
Major sealed road	$55,000	$27,500	$82,500	$27,500	$13,750	$41,250
Minor sealed road	$30,000	$15,000	$45,000	$15,000	$7,500	$22,500
Unsealed road	$9,000	$4,500	$13,500	$4,500	$2,250	$6,750
Minor Bridge	Not estimated separately	Not estimated separately	$133,000	Not estimated separately	Not estimated separately	$33,000

3.3.3 Agriculture

As stated previously, it is assumed that animals and farm equipment can be moved to higher ground or off-site to avoid flood impacts. Some adjustment may be required in some circumstances, however this should be short-tem and costs have therefore been assumed insignificant.

Flood damage to agriculture is therefore primarily concerned with impacts on crops (including horticulture) and pastures. Standard values for different categories of agriculture have been derived in Appendix A. These have been matched to land-use data as presented in Table 3-4 . Damages are based on releases of water in September, however damages at later months has been investigated in Section 0. As discussed, it is assumed that the period of inundation is greater than seven days. The sensitivity of this assumption is also tested in Section 0.

Note that the vast amount of forestry affected by inundated waters is natural red-gums in the lower reaches of the Goulburn. A small area of hardwood plantation is likely to be inundated in Area A also. Impacts of these flood waters is likely to be benign at worst, and would likely result in improved health and growth rates of these forests (pers. com. Andrew Morton, URS Forestry). These benefits have not been assessed here, and flood damage has been assumed to be zero for forestry.

Pigs and intensive agriculture rely considerably on off-farm feedstock as opposed to pastures. Therefore no additional costs have been assumed for these land-uses.

Table 3-4 Agriculture unit damage values

Land Use Description	Unit Value Damage Category	Unit value ($ per ha)
2.1.0 Livestock grazing	Other Fruit	90
2.1.0 Grazing natural vegetation	Dryland Pasture	90
2.2.0 Production forestry	Forestry	0
3.1.1 Hardwood plantation	Forestry	0
3.2.0 Grazing modified pastures	Dryland Pasture	90
3.3.0 Grazing modified pastures	Dryland Pasture	90
3.3.0 Cropping	Dryland Broadacre Crops	135
3.3.1 Cereals	Dryland Broadacre Crops	135
3.3.4 Oil seeds	Dryland Broadacre Crops	135
3.3.5 Sown grasses	Dryland Pasture	90
3.4.3 Hay & silage	Dryland Pasture	90
3.5.1 Tree fruits	Other Fruit	3,885
3.5.2 Oleaginous fruits	Other Fruit	3,885
3.5.4 Vine fruits	Grapes	1,907
3.5.7 Vegetables & herbs	Vegetables	7,970
4.2.0 Irrigated modified pastures	Irrigated Pasture	450
4.3.0 Irrigated cropping	Irrigated Broadacre Crops	372
4.3.2 Irrigated pasture legumes	Irrigated Pasture	450
4.3.3 Irrigated hay & silage	Irrigated Pasture	450
4.3.4 Irrigated sown grasses	Irrigated Pasture	450
4.4.1 Irrigated tree fruits	Other Fruit	3,885
4.4.3 Irrigated hay & silage	Irrigated Pasture	450
4.4.4 Irrigated vine fruits	Grapes	1,907
4.4.7 Irrigated vegetables & herbs	Vegetables	7,970
4.4.8 Irrigated Legumes	Irrigated Pasture	450
5.2.0 Intensive animal production	Intensive ag.	0
5.2.5 Pigs	Intensive ag.	0

3.3.4 Other Assets

Fish Farms (aquaculture)

Four trout farms exist along the upper Goulburn that could potentially be affected by releases of large volumes of released water. One of these is situated within Area A, the remaining three are within Area B. The information presented here was obtained through conversations with Ed Meggitt, a partner in Goulburn River Trout. All farms require a constant flow-through of fresh water. The first three fish farms down the river are situated fairly high above the river surface and are therefore protected from smaller releases. These farms pump water into and out of the river. This pumping infrastructure is susceptible to damage, along with stocks of trout, if levees are breached. Ed estimated that releases of approximately 40,000 ML or more would breach the levees with potential damages of $3-4 million including stock losses. The last fish farm along the river sits at roughly the same height as the river surface and water flows through via gravity. This farm is therefore more susceptible to impacts from smaller releases. Ed estimated that a release of 20,000 ML would mean that they would need to pump water out of the farm and could not feed fish in this time. His estimated costs in lost growth, pumping and labour costs would be approximately $10,000 per day of flooding. Larger releases would threaten infrastructure and existing stock, with potential losses of approximately $1-2 million. Ed suggested that if water is to be released, his preference would be for it to occur closer to early summer when they are already preparing their operations for higher waters as a result of releases for irrigation delivery.

The information provided is not suitable for a unit value approach to damage estimation. As the potential losses are potentially quite large, a site-specific risk assessment is warranted to more accurately assess how vulnerable these operations are to flood impacts, and what the specific impacts on these businesses are.

Quarries

It has been difficult to obtain useful information on the economic impacts of riverine flooding on quarries. One quarry along the Goulburn that may potentially be impacted by environmental releases is Yea Sand & Gravel. The manager of the quarry suggested that flooding of the quarry would shut down operations and a large pump would need to be brought in to remove the water. He could not provide any indication of lost revenues or associated costs. Consultants at Bell Cochrane and Associates, who designed levees for this quarry, indicated that the quarry is quite well protected with a levee system that diverts any on-site water to a creek. They also reaffirmed that any flooding of the quarry itself would shut down operations, as the particular rock being quarried requires a dry operation.

As was the case with fish farms, the size and scope of these operation warrants further dedicated, case-by-case risk assessments rather than a unit value approach. This will need to involve detailed site-specific hydrological assessments in addition to detailed studies of the impacts of flooding on each business.

3.4 Identified Assets within Flood Paths

The number (or area as appropriate) of each asset class inundated by each volume of release across all areas is presented in Table 3-5. A breakdown for each area is presented in Appendix B**.**

3 Potential Flood Damages from Proposed Environmental Releases

Table 3-5 Inundated assets for each release volume (all areas)

Asset	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Buildings (number)					
Residential	11	28	45	68	122
Commercial/Industrial	1	4	6	7	13
Sheds	32	135	215	291	396
Roads (km)					
Major sealed road	1.6	3.3	7.0	10.8	15.2
Minor sealed road	0.6	3.9	4.9	5.7	7.0
Unsealed road	6.6	26.5	45.9	58.3	76.2
Bridges					
Minor	1.6	3.3	4.2	4.7	5.4
Agriculture (ha)					
2.1.0 Livestock grazing	102	265	402	451	498
2.2.0 Production forestry	2,405	7,854	8,760	9,116	9,210
3.1.1 Hardwood plantation	12	22	27	35	44
3.2.0 Grazing modified pastures	411	2,080	2,585	2,947	3,356
3.3.0 Grazing modified pastures	662	1,836	3,568	4,218	5,157
3.3.0 Cropping	175	773	987	1,213	1,368
3.3.1 Cereals	8	23	23	23	23
3.3.4 Oil seeds	45	61	61	61	61
3.3.5 Sown grasses	1	13	22	22	25
3.4.3 Hay & silage	0	8	17	17	20
3.5.1 Tree fruits	0	0	0	3	7
3.5.2 Oleaginous fruits	0	1	1	1	1
3.5.4 Vine fruits	0	2	2	2	2
3.5.7 Vegetables & herbs	3	7	9	13	16
4.2.0 Irrigated modified pastures	33	169	247	304	345
4.3.0 Irrigated cropping	23	265	324	393	445
4.3.2 Irrigated pasture legumes	0	5	11	16	23
4.3.3 Irrigated hay & silage	1	2	9	37	54
4.3.4 Irrigated sown grasses	118	181	249	298	355
4.4.1 Irrigated tree fruits	0	6	7	9	13
4.4.3 Irrigated hay & silage	0	0	0	1	3
4.4.4 Irrigated vine fruits	16	86	201	267	315
4.4.7 Irrigated vegetables &	0	0	0	1	1
4.4.8 Irrigated Legumes	7	14	37	81	188
5.2.0 Intensive animal production	0	29	29	29	29
5.2.5 Pigs	0	16	16	16	16

3.5 Flood Damage Assessments

Presented in this section are the flood damage assessments for each release volume. Within each release volume, damages have been broken up by broad asset category (ie buildings, roads etc.) for each of the study areas along the Goulburn River. A more detailed breakdown of damages within asset categories is provided in Appendix B.

As discussed in Section 3.3.4, it has not been possible to assess economic damages involved with aquaculture enterprises and quarries. However the impacts on these businesses could be considerable and warrant a separate detailed study to supplement the results below.

3.5.1 Damage Assessment - 20,000 ML release

Estimates of expected flood damage for a 20,000 ML release are presented Table 3-6.

Table 3-6 Flood Damage - 20,000 ML Release

Flooded Area	Value of Asset Damage				
	Buildings	Roads	Bridges	Agriculture	TOTAL
Area A	$ 366,425	$ 103,585	$ 14,049	$ 97,412	**$ 581,472**
Area B	$ 15,000	$ 27,070	$ 5,431	$ 44,330	**$ 91,831**
Area C	$ 10,000	$ 255	$ 2,347	$ 7,842	**$ 20,443**
Area D	$ -	$ 32,234	$ 1,189	$ 13,571	**$ 46,994**
Area E	$ 5,000	$ 5,158	$ 8,629	$ 30,440	**$ 49,226**
Area F	$ 5,000	$ 2,267	$ 678	$ 9,780	**$ 17,725**
Area G	$ 5,000	$ 67,475	$ 14,818	$ 8,428	**$ 95,720**
Area H	$ 151,761	$ 80,655	$ 5,612	$ 55,063	**$ 293,091**
ALL AREAS	**$ 558,187**	**$ 318,698**	**$ 52,753**	**$ 266,866**	**$ 1,196,503**

3.5.2 Damage Assessment - 30,000 ML release

Estimates of expected flood damage for a 30,000 ML release are presented in Table 3-7.

Table 3-7 Flood Damage - 30,000 ML Release

Flooded Area	Value of Asset Damage				
	Buildings	Roads	Bridges	Agriculture	TOTAL
Area A	$ 406,425	$ 137,720	$ 16,947	$ 173,124	**$ 734,217**
Area B	$ 204,522	$ 111,947	$ 14,991	$ 128,590	**$ 460,051**
Area C	$ 10,000	$ 789	$ 2,583	$ 35,308	**$ 48,680**
Area D	$ 25,000	$ 90,492	$ 6,045	$ 62,180	**$ 183,716**
Area E	$ 89,381	$ 12,426	$ 10,135	$ 107,064	**$ 219,006**
Area F	$ 10,000	$ 5,559	$ 4,267	$ 95,125	**$ 114,950**
Area G	$ 136,761	$ 180,948	$ 31,148	$ 57,191	**$ 406,048**
Area H	$ 867,567	$ 400,033	$ 25,379	$ 314,765	**$ 1,607,744**
ALL AREAS	**$ 1,749,657**	**$ 939,915**	**$ 111,495**	**$ 973,346**	**$ 3,774,413**

3.5.3 Damage Assessment - 40,000 ML release

Estimates of expected flood damage for a 40,000 ML release are presented in Table 3-8.

Table 3-8 Flood Damage - 40,000 ML Release

Flooded Area	Value of Asset Damage				
	Buildings	Roads	Bridges	Agriculture	TOTAL
Area A	$ 613,187	$ 382,060	$ 19,661	$ 250,224	**$ 1,265,132**
Area B	$ 615,567	$ 362,846	$ 19,513	$ 234,881	**$ 1,232,807**
Area C	$ 15,000	$ 11,927	$ 4,984	$ 75,147	**$ 107,057**
Area D	$ 55,000	$ 134,684	$ 10,606	$ 115,621	**$ 315,911**
Area E	$ 126,761	$ 22,040	$ 10,824	$ 264,691	**$ 424,317**
Area F	$ 47,381	$ 12,663	$ 5,244	$ 207,930	**$ 273,217**
Area G	$ 326,284	$ 336,269	$ 35,257	$ 87,293	**$ 785,104**
Area H	$ 984,948	$ 525,898	$ 31,937	$ 470,074	**$ 2,012,856**
ALL AREAS	**$ 2,784,127**	**$ 1,788,387**	**$ 138,026**	**$ 1,705,861**	**$ 6,416,401**

3.5.4 Damage Assessment - 50,000 ML release

Estimates of expected flood damage for a 50,000 ML release are presented in Table 3-9.

Table 3-9 Flood Damage - 50,000 ML Release

Flooded Area	Value of Asset Damage				
	Buildings	Roads	Bridges	Agriculture	TOTAL
Area A	$ 860,090	$ 1,262,347	$ 105,219	$ 363,432	**$ 2,591,087**
Area B	$ 610,567	$ 725,692	$ 78,644	$ 237,258	**$ 1,652,161**
Area C	$ 47,381	$ 49,594	$ 28,565	$ 104,040	**$ 229,579**
Area D	$ 117,381	$ 389,410	$ 63,649	$ 171,694	**$ 742,133**
Area E	$ 231,522	$ 87,731	$ 50,859	$ 371,984	**$ 742,096**
Area F	$ 276,664	$ 62,245	$ 38,821	$ 298,146	**$ 675,876**
Area G	$ 527,806	$ 849,400	$ 151,032	$ 97,910	**$ 1,626,148**
Area H	$ 1,279,470	$ 1,553,127	$ 152,634	$ 684,292	**$ 3,669,523**
ALL AREAS	**$ 3,950,881**	**$ 4,979,544**	**$ 669,422**	**$ 2,328,757**	**$ 11,928,603**

3.5.5 Damage Assessment - 60,000 ML release

Estimates of expected flood damage for a 60,000 ML release are presented in Table 3-10.

Table 3-10 Flood Damage - 60,000 ML Release

Flooded Area	Value of Asset Damage				
	Buildings	Roads	Bridges	Agriculture	TOTAL
Area A	$ 2,201,888	$ 1,668,925	$ 112,515	$ 479,680	**$ 4,463,008**
Area B	$ 976,612	$ 1,046,868	$ 82,038	$ 294,707	**$ 2,400,225**
Area C	$ 57,381	$ 72,108	$ 28,439	$ 125,557	**$ 283,485**
Area D	$ 301,903	$ 646,640	$ 113,417	$ 213,890	**$ 1,275,850**
Area E	$ 376,045	$ 112,499	$ 51,013	$ 436,516	**$ 976,073**
Area F	$ 440,806	$ 113,773	$ 46,924	$ 393,410	**$ 994,913**
Area G	$ 714,948	$ 963,903	$ 160,858	$ 115,866	**$ 1,955,575**
Area H	$ 1,406,851	$ 2,302,579	$ 164,775	$ 946,790	**$ 4,820,995**
ALL AREAS	**$ 6,476,433**	**$ 6,927,295**	**$ 759,979**	**$ 3,006,418**	**$ 17,170,125**

3.5.6 Summary of Results

Presented in Table 3-11 is a summary of the results of the total flood damage for each area and for each release volume. Unsurprisingly, damages increase in all areas as the volume of water released. The largest largest flood damages occur in Area A, followed closely by Area H. The total magnitude of flood damages ranges from approximately $1.2 million for a 20,000ML release, to $16.5 million for a 60,000 ML release.

3 Potential Flood Damages from Proposed Environmental Releases

Table 3-11 Summary of flood damages by area

Flooded Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 581,472	$ 734,217	$ 1,265,132	$ 2,591,087	$ 4,463,008
Area B	$ 91,831	$ 460,051	$ 1,232,807	$ 1,652,161	$ 2,400,225
Area C	$ 20,443	$ 48,680	$ 107,057	$ 229,579	$ 283,485
Area D	$ 46,994	$ 183,716	$ 315,911	$ 742,133	$ 1,275,850
Area E	$ 49,226	$ 219,006	$ 424,317	$ 742,096	$ 976,073
Area F	$ 17,725	$ 114,950	$ 273,217	$ 675,876	$ 994,913
Area G	$ 95,720	$ 406,048	$ 785,104	$ 1,626,148	$ 1,955,575
Area H	$ 293,091	$ 1,607,744	$ 2,012,856	$ 3,669,523	$ 4,820,995
Total All Areas	**$ 1,196,503**	**$ 3,774,413**	**$ 6,416,401**	**$ 11,928,603**	**$ 17,170,125**

A summary of damages by asset type for each release volume is presented in Table 3-12. Damage to buildings make up the majority of total damages in the smaller release volume, while roads and bridges tend to make up a greater portion for the larger release volumes.

Table 3-12 Summary of flood damages by asset type

ASSET TYPE	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Buildings	$ 558,187	$1,749,657	$ 2,784,127	$ 3,950,881	$ 6,476,433
Roads	$ 318,698	$ 939,915	$ 1,788,387	$ 4,979,544	$ 6,927,295
Bridges	$ 52,753	$ 111,495	$ 138,026	$ 669,422	$ 759,979
Agriculture	$ 266,866	$ 973,346	$ 1,705,861	$ 2,328,757	$ 3,006,418
TOTAL	$1,196,503	$3,774,413	$ 6,416,401	$11,928,603	$ 17,170,125

3.5.7 Key Drivers of Damage within Asset Classes

A breakdown of damage to individual assets types within each asset class is provided in Appendix B. A summary of the key drivers within each asset class in presented below.

Buildings

The largest magnitude of building damage occurs in Areas A and H, under all release volumes. Damage to residential buildings (including contents and clean-up) is the major contributor to building damages under all release volumes. Damage to sheds makes up a considerable proportion of building damages also.

Roads and Bridges

Area H incurs the greatest flood damage to roads across all flood releases, followed by Area A. The major component of these damages is flooding of major highways. Relative to the other areas, Area H also has a significant length of unsealed roads inundated in releases above 30,000ML which contributes considerable damage to the total road damage (typically about one-third of total road damage). Area C incurs the least amount of road damage of any of the areas.

Damage to bridges contributes the least to total damages of all the damage categories, in each release volume. Damage to bridges increases markedly at the 50,000 ML release, primarily due to the assumption that floods inflict 'major' damage at these volumes. This assumption has been analysed in the sensitivity analysis in Section 3.5.8.

Agriculture

The majority of damage to agricultural enterprises is through flooding of pastures, particularly modified pastures.

Irrigated horticulture (excluding vineyards) is significantly affected in Area A, and contributes about a quarter of total damages for smaller releases in Area A, rising to about one-third as the release volumes become larger. Considerable damage to vineyards occurs in Areas D, E and F for all release volumes (except Area D in a 20,000 ML release). Damage to vineyards makes up about 80 percent of all agricultural damages in Area E.

Irrigated cropping is impacted reasonably heavily in Area H by releases greater than 30,000 ML, making up about one-third of agricultural damages on average.

3.5.8 Sensitivity Analysis

The results presented in the previous section have been calculated with the involvement of a number of necessary assumptions. The sensitivity of these results to changes in some of these assumptions is investigated here, including:

- Duration of flooding;
- Flood heights;
- Timing of floods; and
- Flood warning time.

3 Potential Flood Damages from Proposed Environmental Releases

Duration of Flooding

As discussed in Appendix A, it was found that damage to agriculture is dependant on the duration of the flood. It has been assumed so far in this assessment that the duration of flooding is greater than seven days. The impacts on agricultural damages and total damages of assuming that duration is *less* than seven days is presented in Table 3-13.

Agricultural damages are reduced by between 58 and 70 percent as a result of changing this assumption, producing a reduction in total damages of between 8 and 16 percent.

Table 3-13 Sensitivity analysis - decreased duration of flooding

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 33,676	$ 68,163	$ 90,327	$ 144,618	$ 195,141
Area B	$ 2,626	$ 11,544	$ 13,100	$ 13,100	$ 17,621
Area C	$ -	$ -	$ -	$ -	$ -
Area D	$ -	$ 21,671	$ 50,910	$ 77,143	$ 86,665
Area E	$ 22,547	$ 86,863	$ 226,419	$ 316,074	$ 367,375
Area F	$ 9,009	$ 63,357	$ 129,780	$ 168,645	$ 233,008
Area G	$ 2,514	$ 29,975	$ 37,681	$ 41,597	$ 44,331
Area H	$ 10,264	$ 55,763	$ 87,216	$ 135,265	$ 207,997
Total Ag. Damage - All Areas	**$ 80,635**	**$ 337,336**	**$ 635,434**	**$ 896,441**	**$ 1,152,139**
Change in Ag. Damages	-70%	-65%	-63%	-62%	-62%
Total Asset damage - All Areas	$ 1,010,272	$ 3,138,403	$ 5,345,974	$ 10,496,287	$ 15,315,846
Change in total damages	-16%	-17%	-17%	-12%	-11%

Flood Heights

In the calculation of damages to buildings (including contents), it was assumed in this assessment that flood heights were 10cm above floor height. To test the sensitivity of this assumption, we have used a lower bound assumption for flood height of below floor height (ie external flooding only – no structural or contents damage) and an upper bound assumption of 0.5m above floor level.

The impacts on building damages of these lower and upper bound assumptions are presented in Table 3-14 and Table 3-15, respectively. The lower bound assumption reduces building damages by between 31 and 39 percent. Total damages are reduced by between 12 and 17 percent.

3 Potential Flood Damages from Proposed Environmental Releases

Table 3-14 Sensitivity analysis - decreased flood height assumption

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 291,425	$ 291,425	$ 398,187	$ 560,090	$ 1,731,888
Area B	$ -	$ 129,522	$ 430,567	$ 430,567	$ 731,612
Area C	$ -	$ -	$ -	$ 32,381	$ 32,381
Area D	$ -	$ -	$ -	$ 32,381	$ 161,903
Area E	$ -	$ 74,381	$ 106,761	$ 171,522	$ 301,045
Area F	$ -	$ -	$ 32,381	$ 226,664	$ 365,806
Area G	$ -	$ 106,761	$ 236,284	$ 407,806	$ 504,948
Area H	$ 106,761	$ 472,567	$ 504,948	$ 634,470	$ 666,851
Total Building Damage - All Areas	**$ 398,187**	**$ 1,074,657**	**$ 1,709,127**	**$ 2,495,881**	**$ 4,496,433**
Change in Building Damages	-29%	-39%	-39%	-37%	-31%
Total Asset damage - All Areas	**$ 1,036,503**	**$ 3,099,413**	**$ 5,341,401**	**$ 10,473,603**	**$ 15,190,125**
Change in total damages	-13%	-18%	-17%	-12%	-12%

The upper bound assumption increases building damages by between 8 and 10 percent. Total damages are increased by between 3 and 5 percent.

Table 3-15 Sensitivity analysis - increased flood height assumption

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 412,599	$ 452,599	$ 669,621	$ 942,176	$ 2,443,017
Area B	$ 15,000	$ 225,044	$ 677,132	$ 672,132	$ 1,079,220
Area C	$ 10,000	$ 10,000	$ 15,000	$ 52,511	$ 62,511
Area D	$ -	$ 25,000	$ 55,000	$ 122,511	$ 327,555
Area E	$ 5,000	$ 94,511	$ 137,022	$ 252,044	$ 417,088
Area F	$ 5,000	$ 10,000	$ 52,511	$ 312,577	$ 492,110
Area G	$ 5,000	$ 147,022	$ 357,066	$ 579,110	$ 781,643
Area H	$ 162,022	$ 929,132	$ 1,051,643	$ 1,366,687	$ 1,499,198
Total Building Damage - All Areas	**$ 614,621**	**$ 1,893,308**	**$ 3,014,995**	**$ 4,299,748**	**$ 7,102,342**
Change in Building Damages	10%	8%	8%	9%	10%
Total Asset damage - All Areas	**$ 1,252,938**	**$ 3,918,064**	**$ 6,647,269**	**$12,277,470**	**$ 17,796,034**
Change in total damages	5%	4%	4%	3%	4%

3 Potential Flood Damages from Proposed Environmental Releases

Timing of Floods

It was assumed that environmental releases would occur in September to match normal spring flows. The impacts on agriculture of releasing water later in the season, in both October and December have been assessed here. The results of this assessment are presented in Table 3-16 and Table 3-17, respectively.

A release in October results in an increase in damage to agriculture of between 26 percent and 64 percent. Total damages increase by between 6 and 14 percent.

Table 3-16 Sensitivity analysis - October release

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 97,412	$ 173,124	$ 250,224	$ 403,947	$ 571,391
Area B	$ 44,330	$ 150,274	$ 256,809	$ 259,186	$ 316,670
Area C	$ 7,842	$ 35,308	$ 75,147	$ 104,040	$ 125,557
Area D	$ 13,571	$ 104,219	$ 215,660	$ 323,407	$ 382,050
Area E	$ 75,459	$ 279,903	$ 711,454	$ 987,202	$ 1,151,181
Area F	$ 27,519	$ 208,507	$ 433,023	$ 583,556	$ 802,785
Area G	$ 9,789	$ 131,405	$ 170,250	$ 189,734	$ 210,757
Area H	$ 60,668	$ 330,649	$ 330,649	$ 330,649	$ 330,649
Total Ag. Damage - All Areas	**$ 336,590**	**$ 1,413,389**	**$ 2,443,216**	**$ 3,181,720**	**$ 3,891,040**
Change in Ag. Damages	26%	45%	43%	37%	29%
Total Asset damage - All Areas	**$ 1,266,227**	**$ 4,214,456**	**$ 7,318,143**	**$ 13,196,389**	**$ 18,788,378**
Change in total damages	6%	12%	14%	11%	9%

A release in December results in an increase in damage to agriculture of 32 percent and 76 percent. Total damages increase by between 7 and 17 percent.

Table 3-17 Sensitivity analysis - December release

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 97,412	$ 173,124	$ 250,224	$ 404,059	$ 571,587
Area B	$ 44,330	$ 151,620	$ 258,140	$ 260,518	$ 318,004
Area C	$ 7,842	$ 35,308	$ 75,147	$ 104,040	$ 125,557
Area D	$ 13,571	$ 112,974	$ 236,481	$ 354,957	$ 417,284
Area E	$ 84,770	$ 315,699	$ 804,716	$ 1,117,221	$ 1,302,136
Area F	$ 31,184	$ 232,902	$ 481,983	$ 641,940	$ 878,356
Area G	$ 10,467	$ 134,126	$ 174,291	$ 194,099	$ 215,539
Area H	$ 64,009	$ 351,195	$ 351,195	$ 351,195	$ 351,195
Total Ag. Damage - All Areas	**$ 353,586**	**$ 1,506,949**	**$ 2,632,177**	**$ 3,428,029**	**$ 4,179,658**
Change in Ag. Damages	32%	55%	54%	47%	39%
Total Asset damage - All Areas	**$ 1,283,224**	**$ 4,308,016**	**$ 7,519,787**	**$ 13,473,833**	**$ 19,136,840**
Change in total damages	7%	14%	17%	13%	11%

3 Potential Flood Damages from Proposed Environmental Releases

Warning Time

It was assumed that adequate warning time would be available meaning that significant potential damages could be avoided by movement of objects and preparation. A ratio of actual to potential damages of 0.3 was assumed on this basis. The results of a reduction in warning time, such that the ratio of actual to potential damages increases to a higher level of 0.9, have been assessed here. The results of this assessment are presented in Table 3-18.

Increasing the actual to potential damage ratio to 0.9 increases total damages by between 12 percent and 18 percent.

Table 3-18 Sensitivity analysis - decreased warning time

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 727,596	$ 880,341	$ 1,477,328	$ 2,884,463	$ 5,394,100
Area B	$ 91,831	$ 524,995	$ 1,461,239	$ 1,880,593	$ 2,792,145
Area C	$ 20,443	$ 48,680	$ 107,057	$ 245,815	$ 299,721
Area D	$ 46,994	$ 183,716	$ 315,911	$ 758,369	$ 1,357,030
Area E	$ 49,226	$ 268,842	$ 490,389	$ 840,640	$ 1,139,561
Area F	$ 17,725	$ 114,950	$ 289,453	$ 789,528	$ 1,190,873
Area G	$ 95,720	$ 472,120	$ 916,120	$ 1,855,708	$ 2,233,843
Area H	$ 359,163	$ 1,869,776	$ 2,291,124	$ 4,012,735	$ 5,180,443
Total All Areas	**$ 1,408,699**	**$ 4,363,421**	**$ 7,348,621**	**$ 13,267,851**	**$ 19,587,717**
Change in total damages	18%	16%	15%	11%	14%

Assumption of Major Damage to Roads and Buildings in Larger Floods

In the analysis undertaken so far it has been assumed that 'major flooding' to roads and bridges occurs at releases equal to or greater than 50,000 ML. The difference in damages between 'minor' and 'major' flood damage is considerable for roads and bridges. To test the sensitivity of results to this assumption, results have been calculated assuming that only minor damage occurs to roads and bridges under all releases. These results are presented in Table 3-19.

Under the 50,000 ML and 60,000 ML releases, the damage to roads and bridges decreases by about half from changing this assumption. Total damages are reduced by about one quarter.

3 Potential Flood Damages from Proposed Environmental Releases

Table 3-19 Sensitivity analysis - change to assumptions for roads and bridges

Area	Volume of Environmental Release				
	20,000 ML	30,000 ML	40,000 ML	50,000 ML	60,000 ML
Area A	$ 581,472	$ 734,217	$ 1,265,132	$ 1,880,802	$ 3,543,948
Area B	$ 91,831	$ 460,051	$ 1,232,807	$ 1,230,185	$ 1,815,108
Area C	$ 20,443	$ 48,680	$ 107,057	$ 183,304	$ 226,048
Area D	$ 46,994	$ 183,716	$ 315,911	$ 499,572	$ 867,254
Area E	$ 49,226	$ 219,006	$ 424,317	$ 659,991	$ 881,468
Area F	$ 17,725	$ 114,950	$ 273,217	$ 615,565	$ 902,745
Area G	$ 95,720	$ 406,048	$ 785,104	$ 1,087,890	$ 1,352,677
Area H	$ 293,091	$ 1,607,744	$ 2,012,856	$ 2,778,197	$ 3,545,815
Total All Areas	**$ 1,196,503**	**$ 3,774,413**	**$ 6,416,401**	**$ 8,935,506**	**$ 13,135,065**
Change in damages to roads and bridges	**0%**	**0%**	**0%**	**-53%**	**-52%**
Change in total damages	**0%**	**0%**	**0%**	**-25%**	**-24%**

Findings and Next Steps

The assessment has shown that the environmental releases will potentially result in significant damages to a range of asset types. The total estimated value of these damages range from $1.2 million for a 20,000 ML release, to $17.2 million for a 60,000 ML release. Approximately half of these damages occur in Area A (Eildon to Alexander) and Area H (Bunbartha to the Murray River). Area C (Ghin Ghin to Kerrsidale) suffers the least damage, comprising only about 1 percent of total damages. Buildings tend to be the largest source of damage in most areas, however damage to roads and bridges becomes more significant under larger flooding events (50,000 ML and 60,000 ML releases). Sensitivity analyses of assumptions have shown the results to be reasonably robust, with alterations of assumptions resulting in changes in total damages of less than 20 percent in almost all cases. It was not possible to attain adequate information about potential impacts of floods on quarries and aquaculture, which would require a more detailed study of individual businesses. Preliminary findings indicate that these impacts could be significant and would justify such a study.

The focus of this report for phase 2 of the Goulburn River Environmental Flows Hydraulics study is on the potential flood damage costs for the eight selected river reaches associated with different water release regimes from Eildon Dam. An understanding of these costs is an important aspect in determining which release regime should be selected. Also important is that the damage cost estimates are robust and have been validated through on-the-ground assessment of potential costs that could be incurred under the different regimes. In this regard, some of the damage cost estimates provided in this report should be regarded as preliminary and will require further validation and sensitivity analysis.

Even if validated, the potential flood damage costs would not be sufficient to determine the optimal release regime. This regime will also be influenced by two other main considerations, namely:

- the value forgone from using the water released for a different purpose, such as being spread so as to not cause flooding for irrigation — the value of irrigation production forgone represents the opportunity cost of water to achieve a given flood event;
- the value of the environmental improvements gained through a flooding event, or series of events.

A third consideration, which is likely to be difficult to quantify, is the potential improvement in soil fertility/productivity for agricultural purposes as a result of the flooding of river flats. Given the inherent fertility of these flats which have been created over centuries, the ability to determine changes in that fertility as a consequence of any single controlled flood event, or a series of controlled events, is unlikely to occur.

Estimating the Opportunity Costs of Controlled Released Flood Water

The main opportunity cost from the use of water for a controlled flood event is likely to be associated with the water no longer being available for irrigated agriculture and horticulture production. Given the volume of water involved, and the potential area of different crops that could be irrigated with that volume, an estimate of the value of production forgone could be derived.

Another potential opportunity cost of the water that could arise is the lost potential to generate electricity at the hydro-generation plant at Eildon. This cost would only be incurred if, because of the selected timing of the controlled release, the operator of the generation plant could not use the water, or needed to use the water at the time of release when the price received for the generation of the electricity was lower than it used at another time.

Accordingly, these opportunity costs would need to be assessed individually for each controlled event.

4 Findings and Next Steps

Value of Environmental Improvements

Estimating the value of the environmental improvements from potential release regimes will involve a number of steps. The first, and perhaps most important step, is to understand the current state of the natural environment for each of the selected river reaches, particularly to identify any natural flora and associated fauna which may be threatened due to the absence of required flooding events that are essential for the health of such flora and fauna.

The next step is to articulate the change in the natural environments that would need to occur in order to achieve the required health and then estimate the volume of water required, and the timing of when that water should be released. These considerations would largely be informed by the expert opinions of, for example, biologists and ecologists. This is required because markets do not exist within which to establish a "price" for such changes in the value of the natural environment.

Once the required environmental outcomes have been articulated, and the associated flood control regimes established, there are a number of non-market techniques which can be used to estimate the value that people place on environmental improvements. Choice modelling is one technique. This technique was applied by URS for the Victorian Environmental Assessment Council to estimate the willingness of people from various communities in Victoria to pay for improved environmental outcomes (namely improved habitat and associated diversity and resilience of natural flora and fauna). Given the similarities in the natural environments, mainly the dominance of river red gums, the results of this study may help inform, through the use of a technique known as benefit transfer, the potential value of environmental improvements.

Maximising Net Benefits

The last stage in determining the optimal release regime is to assess the value of environmental improvements associated with different controlled release regimes with the damage and opportunity costs that would be incurred. Ideally, the optimal release regime would be the situation where the marginal increase in the value of environment improvement, from increasing the volume of water released (or adjusting the timing), just equalled the costs that would be incurred with that marginal increase. It is expected that site specific information, within the different river reaches, will be required to determine such marginal costs and benefits.

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6 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Goulburn Broken Catchment Management Authority and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated December 2007.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between August 2008 and December 2009 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix A Development of Unit Loss Values

Appendix A

A.1 Introduction

This section describes the process involved in determining values that could be used as the basis for estimating flood damages in different situations.

Due to the large area of land and number of assets that will be inundated by the environmental flow regimes proposed, our approach is to use a 'unit loss' approach to the estimation of flood damage for each specified river reach. That is, the approach is to employ standard, average, or site-specific survey data relating to losses. This approach to flood damage assessment was successfully used by Read Sturgess & Associates (now URS) in the development of the Rapid Appraisal Method for Floodplain Management (generally known as the 'Flood RAM') in 2000. The approach here is largely an update, extension, and refinement of the unit values developed in the Flood RAM.

Key asset categories were first identified before a thorough literatures search was conducted. Unit losses have been developed based on combinations of previous flood studies, insurance information, and various sources of data relating to asset value and replacement costs.

In Sections A.2 to A.6, the key asset categories that are typically affected by floods are described, the availability of data and key findings for each is outlined, and unit values have been proposed. These asset categories are:

- residential buildings;
- commercial and industrial buildings;
- roads and bridges;
- vehicles; and
- agriculture.

A.2 Residential Buildings

A.2.1 Description

Residential buildings come in a wide array of structures and styles, with varying types of contents and amenities, all of which affect the amount of damage caused by a given flood. The damages covered in this section refer not only to structural and internal contents damage, but also external damages to pools, spas, gardens, sheds and shed contents.

The degree of damage caused by floods to residential properties depends on a number of factors including[1]:

- Over-floor water depth – generally considered to be the most important factor in estimating losses
- Velocity – often regarded as the second most important factor; higher velocities create a greater chance of foundation or building collapse and more forceful destruction of contents
- Duration of inundation – generally regarded as an important contributory factor for damage to contents; may be the most significant factor in the destruction of the building structure as continued saturation causes wood to warp and rot, tiles to buckle, and metal objects and mechanical equipment to rust
- Sediment – particularly damaging to workings of mechanical equipment; adds to contents losses and clean-up problems; may include sewage

[1] Russel Blong, "Estimating Residential Flood Damage", 2001

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- Building materials – steel frame and brick buildings tend to be more durable in withstanding inundation and less susceptible to collapse than other materials. Interior construction of drywall and plaster will crumble under prolonged inundation though waterproof plaster performs better
- Building age – can indicate types of materials and condition of building
- Content location – small differences in elevation may make large differences in damage
- Warning time – increased warning times can reduce contents losses.

In the context of this study, building damage refers to damage that occurs to a dwelling as it is normally sold. It therefore includes a number of components including:

- foundations;
- external walls or external building (such as garages, sheds, outhouses etc.)
- interior linings or plasterwork
- floors;
- built-ins or joinery;
- doors and windows;
- internal decorations; and
- plumbing and electrical.

Building contents refers to items within the house, garage or shed, with exception of cars which are assessed separately.

A.2.2 Data Availability

ANUFLOOD (CRES 1992) is a commercially available interactive computer package that utilises stage-damage curves consisting of three building size categories and five contents value categories for residential buildings.

FloodAUS is a model developed by Risk Frontiers, a group within the Natural Hazards Research Centre at Macquarie University. FloodAUS follows the rationale that flood inundation risk needs to be assessed on a street address basis and therefore requires a great deal of information and involvement from the user. It uses stage-damage curves that were developed in a 2001 paper by Russel Blong of the NHRC which were adapted from UK data and tested against data from the 1986 floods of the Georges River.

Risk Frontiers has since developed improved stage-damage relationships based on larger data sets.

Water Studies (1996) conducted a flood damage survey of representative residential, industrial and commercial properties in Geelong, Batesford and Traralgon which produced dollar damages for a number of flood damage types.

Several studies have been done on the floods that affected the town of Katherine in the Northern Territory in 1998 and 2006. Emergency Management Australia (EMA) maintains a database of all natural disaster events in Australia, including description and value of damages if available. The 2006 flood in Katherine was categorised as moderate, and damaged approximately 300 homes as well as businesses in the central business district.

A.2.3 Key Findings

Damage to Buildings

Blong (2001) found that until flooding reaches the overfloor level most damage is to the external building. Damage to floors becomes important as soon as the water is overfloor, then the contributions from damage to plasterwork and joinery increase. Once inundation reaches 30-60 cm over floor there is little change in the proportions of total damage contributed by each building component.

The EMA information for the 2006 Katherine flood shows insurance claims for home buildings totalled $3.32 million for 122 claims, or approx. $27,200 per house (2008: $28,800).

Damage to Contents

Overfloor flooding results in home contents being damaged or destroyed. From the results of three Australian studies of flood damages, Blong (2001) has found that most damage to contents occurs in bedrooms (44-60%), followed by lounge/dining areas (27-31%) and then kitchens (9-20%). The remaining rooms accounted for less than 6%. His analysis also indicates that about 25 percent of potential household contents damage occurs with a depth of inundation of 0.25m, 50 percent occurs with a 0.5m depth, and 80 percent with a 1.0m depth. Almost all damage occurs within a depth of 1.2m.

The EMA information for the 2006 Katherine flood shows insurance claims for home contents totalled $1.87 million for 124 claims, or approx. $15,100 per house (2008: $15,500). The warning time varied, but can be assumed to be greater than 12 hours on average, as a counter disaster meeting was held the day prior to the Katherine River breaking its banks and flooding the CBD.

Clean-up Costs

Clean-up costs are those costs incurred to clean a building and its contents after a flood. Some examples of clean-up activities include removing mud and debris, drying and cleaning contents, and washing down walls. Strictly speaking, clean-up costs are not considered direct damages, however, they have been described in this section for the convenience of grouping them with other residential damages, as well as recognising they would not have been incurred in the absence of a flood.

Water Studies (1995) used data from a number of floods to estimate internal clean-up costs for overfloor flooding, finding an average figure of $3,200 (2008:$4,300) per household. Other studies by BTE (2001) found the average internal clean-up cost for an overfloor flood of a residential house in Katherine to be approximately $3,600 (2008: $4,400). Estimates using information from Smith et al. (1990) for internal clean-up costs total approximately $2,800 (2008: $4,300) per dwelling.

In a study of floods in Traralgon (DNRE 1996), it was found that external clean-up costs made up about 25 percent of the total clean-up costs of flooded residential housing.

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External Damages

External damages comprise damage to aspects of a residential property that are external to the building structure, but not including items such as lawnmowers, tools, etc., which have been defined as contents. External damages include damage to fences, pools, spas and landscaping. Almost 60 percent of total external damage is contributed by pools and spas, with damage to fencing making up 24 percent. The remainder is landscaping and other items. As a result, the size of external damages produced by a given flood is highly variable between residences, mostly depending on whether or not they contain pools and spas. Note that motor vehicle damage is treated as a separate item (i.e. it is not included as external damages, nor is it considered in damages to contents).

A.2.4 Unit loss values for residential buildings

Unit losses have been developed for damage to residential property including:

- buildings;
- building contents;
- clean-up costs; and
- external damages.

Building and Content Damages

The best approach for assessing damages to residential buildings and contents is to apply the stage-damage relationships developed by Risk Frontiers. These are derived from a large data set and correlate level of inundation directly with dollar damages to a significant degree of confidence. These relationships have been formulated for damage to both buildings and contents, for single storey, high set, and two-storey residential dwellings. The degree of confidence and accuracy inherent in these relationships is greater than was available when the Flood RAM was developed in 2000.

The relationships, presented in Table A-1 and Table A-2, represent a simple method for the estimation of residential flood damages. The only factor influencing the dollar damage estimate in these functions is the depth in metres of floodwaters above floor level. Note that a high-set building is defined here as a building with a floor level that is at least 1.5 metres above ground level.

Table A-1 Residential Building Damages

Building Type	2001 Damages ($)	2008 Damages* ($)
Single-Storey Residential Buildings	Y = 11967 + 4428 x	Y = 14,718 + 5,446 x
High Set Residential Buildings	Y = 15078 + 6776 x	Y = 18,544 + 8,334 x
Two-Storey Residential Buildings	Y = 8377 + 3040 x	Y = 10,303 + 3,739 x

Where: Y = estimated damage, x = overfloor depth in metres (positive values of x only)
*2001 damages adjusted to 2008 damages using a CPI inflator of three percent per annum.

The damage to residential contents developed by Risk Frontiers, presented in Table A-2 are based on replacement values of building contents. As discussed in Section 2.3, replacement values overstate the true economic cost of damages as damaged items are likely to have depreciated prior to flood events. It is therefore recommended that these damages be reduced by 50 percent, for reasons discussed in Section 2.3.

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Table A-2 Residential Contents Damages

Building Type	Overfloor Depth Range (x metres)	2001 Damages ($)	2008 Damages* ($)
Losses to contents - Single-Storey Dwellings	x ≤ 0	Y = 0	Y = 0
	0 ≤ x ≤ 2.0m	Y = 20000 + 20000 x	Y = 24,600 + 24,600 x
	x ≥ 2.0m	Y = 60000	Y = 73,800
Losses to contents - High Set Dwellings	x ≤ 0	Y = 0	Y = 0
	0 ≤ x ≤ 2.0m	Y = 20000 + 20000 x	Y = 24,600 + 24,600 x
	x ≥ 2.0m	Y = 60000	Y = 73,800
Losses to contents - Two Storey Dwellings	x ≤ 0	Y = 0	Y = 0
	0 ≤ x ≤ 2.0m	Y = 14000 + 14000 x	Y = 17,200 + 17,200 x
	x ≥ 2.0m	Y = 42000	Y = 51,700

*2001 damages adjusted to 2008 damages using a CPI inflator of three percent per annum.

For a rapid assessment where flood depths for individual buildings and building types are not readily available, we suggest an estimate be made of the number of buildings that are likely to be flooded overfloor and assume an average flood depth for all these buildings based on the severity of the flood. If it is not possible to estimate an average depth, we recommend using an average figure of $27,000 per property. Note that this corresponds to a flood depth of approximately ten centimetres over floor and is reasonably consistent with the findings from the Katherine Flood ($28,800, see Section A.2.3) as well as the Flood RAM ($26,000 after adjustment for inflation).

Clean-up Costs

As discussed in the previous section, there is significant variation in estimates of clean-up costs. Given the age of some of these estimates, we believe that it would be prudent to use a value of $4,000 per household for internal clean-up costs of overfloor floods, being at the upper end of these values. Underfloor floods have been assumed to incur no internal clean-up costs. Being a small component of damage estimates, it is unlikely that this variation will have any significant impact on the final assessment of damages.

On the basis of data obtained from the Traralgon floods, where external clean-up costs represented approximately 25% of building clean-up costs, we have estimated external clean-up costs to be approximately $1000 per household. Underfloor flooding generally involves the flooding of external areas, so these costs are assumed.

If a property is flooded over floor-level, clean-up costs of $4,000 for internal flooding and $1,000 for external flooding, a total of $5,000 per household, would provide a realistic estimate.

External Damages

Our best estimate based on information supplied by Risk Frontiers for external damages is $5,000 per residence. As discussed previously, this is a highly variable figure. A recent Risk Frontiers study concluded that $6,700 was appropriate, based on Sydney data. However, this figure could be too high for Melbourne and rural Victoria, due to fewer expensive external property improvements such as pools and spas. Note that this figure does not include damage to motor vehicles, which are assessed separately.

Appendix A

A.3 Commercial and Industrial Buildings

A.3.1 Description

Despite the fact that the commercial sector is universally recognised as an important part of any economy, investigations into flood damage typically neglect commercial damages in favour of residential damages, even though greater potential damage exists within the commercial sector (Smith, 1998). Accurate estimation of costs incurred by commercial and industrial properties is particularly difficulty, given the huge variability in size of buildings, value of plant and equipment, size of stock kept on hand, and the ability of occupiers of such buildings to respond efficiently to flood warnings. In contrast, damage to building structure is less variable for both commercial and industrial buildings. Since both commercial and industrial buildings share these attributes in relation to building and contents damages, it is convenient to group them together.

A.3.2 Data Availability

A number of studies have been reviewed that investigated the impacts of floods on commercial businesses. The Bureau of Transport Economics (2001) undertook a study of flood damage in Tamworth, and in particular the industrial area of Taminda, resulting from floods in November 2000. A number of direct and indirect damages were assessed as part of this study. Water Studies (1996) undertook a similar study of floods that occurred in Geelong and Traralgon in 1995.

A particularly useful study for the purposes of developing flood damage estimates for commercial and industrial buildings was undertaken by Gissing at Risk Frontiers. The study was focussed the Kempsey flood in 2001, and directly addressed commercial flood damage. An analysis was conducted to determine stage-damage relationships, which were determined to exist with a large degree of variability. This variability became the focus of further study by Gissing and Blong in 2004.

A rapid appraisal approach was used in studies undertaken by Read Sturgess and Associates in their Rapid Appraisal Method for Floodplain Management in 2000, and was similarly used by URS in a study of economic benefits of land use planning in flood management in 2002. Both these studies used unit losses to estimate damages, which is the same approach used in the current project.

The EMA information collected following the 2006 Katherine floods included total insurance claims of $2.86 million for 26 commercial properties, however it is not clear what categories of damage are included in the damage estimates.

A.3.3 Key Findings

Building Damages

From their studies of floods in Geelong and Traralgon, Water Studies (1996) found that, in general, industrial and commercial buildings suffered little structural damage. Typically, floors were concrete slab on ground and walls were steel sheet, concrete, brick or concrete block. Even permanent buildings and tourist vans and cabins of the caravan park, which had been flooded to depths of 0.3m to 2.0m above floor level, did not exhibit signs of structural damage when inspected.

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Data collected from the 2001 Kempsey flood suggested that damage to commercial building structure constitutes 15 per cent of total direct damages (Blong and Gissing, 2004). These results were from flooding that ranged in depth from several centimetres to three metres, with an average inundation level of 0.75m. Studies by Wright and Smith (1999) and Water Studies (1996) support the fact that building losses are commonly lower than contents losses, at least for relatively low velocity, shallow overfloor flood inundation of relatively short duration.

The Kempsey flood also produced data that revealed a relationship, albeit a weak one, between inundation level and building damages (Gissing 2001). This is further explored in the Section A.3.4.

Contents Damages

The size of damage to the contents of commercial and industrial buildings for a given level of inundation depends on many factors, including:

- value of items;
- type of item;
- quantity of items;
- height above ground that items are stored; and
- flood preparation, including warning time.

This variability is highlighted in Table A-3 which shows the average direct damages suffered by various businesses during the Kempsey floods in 2001. Although this data pertains to total damage, the majority of the variability results from the different contents of each business.

Table A-3 Damage Suffered by Different Business Types

Business Type	Average Direct Damage (A$/sq. m)
Service Stations	106
Women's hairdressing	96
Miscellaneous hardware dealers	95
Car repairs	71
Takeaway food stores	57
Sport & toy retailers	31
Clothing retailers	30
Tyre & Battery retailers	30
Car Dealers	19

Source: Gissing and Blong (2001)

The last flood in Kempsey prior to 2001 was in 1963, so flood readiness was low, however a flood warning system meant that 75% of businesses received 17 hours notice or more of the need to prepare their business.

This study found that the items most vulnerable to flood damage are perishables, electrical or stock containing paper-based packaging. Actual direct damage was 44 percent of potential direct damage, illustrating the effectiveness of early warning and associated loss reduction methods in reducing commercial sector losses.

Appendix A

Clean-up Costs

Clean-up costs include both material and labour costs incurred by a business as a result of clean-up efforts. Clean-up costs are highly variable, ranging from 6 percent to 86 percent of total direct damages, but typically comprising about 10 percent of total damages (Water Studies, 1996). Other data suggests clean-up costs comprise 39% (BTE 2000) and 56% (Gissing 2001) of total damages.

From its 2000 study of flood damage in Tamworth, the Bureau of Transport Economics found that clean-up costs averaged $1.20 (2008: $1.50) per square metre.

Preparation Costs

Commercial businesses avoid damages, mostly to contents, by preparing for floods. This may involve lifting flood-prone stock above the expected floor height, or transport of stock to a flood-free location. In undertaking these activities, costs are incurred.

Data on preparation costs is, for the most part, not readily available. BTE undertook a study of the amount of labour that businesses invested in preparing for floods in Tamworth. They found that the average person-hours per establishment were about 20 and equivalent to an average cost of 40 cents per square metre.

Loss of Business

The economic effect of lost trade resulting from floods depends heavily on where the boundaries of the analysis are drawn. From a highly localised perspective, an economic loss is suffered by flood affected businesses that are forced to close or are cut off from customers as a result of floods. Generally speaking, these customers seek alternative places for their purchases or use of services, or delay these activities. As a result, from a broader perspective, an economic transfer occurs rather than an economic loss. McMahon (1994) surveyed businesses whose premises were inundated by the 1990 flood in Charleville and concluded that there were substantial losses for businesses within the town, but that much of the trade lost would be been either diverted to competitors not affected by the flood, or recovered by catch-up trade after the flood.

In addition to this, certain businesses experience an increase in trade as a result of floods. Gissing (2001) found that, while the majority of retailers experienced losses in trade during and after the Kempsey floods, 21 percent experienced gains. Among these were businesses such as builders, painters, electricians, electrical appliance retailers and repairers, and motels.

A.3.4 Unit loss values for commercial and industrial buildings

Damage to Buildings and Contents

Although the relationship derived is not strong, we believe that the stage-damage data estimated by Gissing (2001) represents the most useful information for the development of this model. Damages were assessed by surveying business owners following the flood rather than being based on insurance claims. Contents are included in these damage estimates. This relationship has been used by URS (2002). It is based on information collected following flooding in the Kempsey district in 2001, and hence represents actual damages. Gissing also found that, on average, actual damages were about 44 per cent of potential damages. Therefore, an approximation of potential damages can be made by dividing actual damages by 0.44. This approximation has also been displayed in Table A-4.

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Table A-4 Commercial Stage-Damage Relationship

Depth of Overfloor Inundation (m)	Actual Damage per sq. m.	Potential Damage per sq. m
-0.3	$0	$0
0.0	$18	$40
0.05	$32	$72
0.1	$45	$101
0.2	$59	$135
0.3	$67	$153
0.5	$89	$201
0.6	$94	$215
0.9	$112	$255
1.0	$118	$268
1.2	$142	$322
1.5	$177	$402
1.8	$189	$430
2.1	$236	$537
2.4	$236	$537
2.7	$236	$537
3.0	$236	$537

Source: Gissing (2001) – Figures have been adjusted by CPI to 2008 values

Since these figures are based on average damages for commercial buildings, for use in this model we have made the assumption that they are representative of those buildings with medium value contents. We have also assumed that buildings with high value contents would incur damages that are fifty per cent greater, and those with low value contents would incur costs that are fifty per cent less (See Table A-5).

Appendix A

Table A-5 Commercial Stage-Damage Relationship for Different Contents Values

Depth of Overfloor Inundation (m)	Potential Damage per sq. m.		
	Low Value Contents	**Medium Value Contents**	**High Value Contents**
-0.3	$0	$0	$0
0.0	$20	$40	$60
0.05	$38	$72	$110
0.1	$51	$101	$152
0.2	$67	$135	$202
0.3	$77	$153	$230
0.5	$100	$201	$301
0.6	$107	$215	$322
0.9	$127	$255	$382
1.0	$135	$268	$402
1.2	$162	$322	$484
1.5	$202	$402	$604
1.8	$215	$430	$644
2.1	$269	$537	$794
2.4	$269	$537	$794
2.7	$269	$537	$794

Source: Gissing (2001) – figures have been adjusted by CPI to 2008 values

Where inundation depths are not readily available, we suggest estimating an average inundation for all commercial buildings flooded overfloor and applying the appropriate values from Table A-4 and Table A-5. A medium value of contents may be assumed in the absence of better information.

We believe that the use of unit losses as described here should be limited to buildings of area not greater than 1000 square metres. Beyond this limit the potential magnitude of the error inherent in the unit loss estimate becomes too large. Damage estimates for buildings larger than 1000 square metres should be evaluated on a case-by-case basis.

Clean-up Costs

Given that available data suggests that clean-up costs can be anywhere between 6 percent and 86 percent of the magnitude of direct damages, we believe that an average figure of 40 percent of direct damages is a reasonable estimate for clean-up costs.

A.4 Roads and Bridges

A.4.1 Description

Flooding can cause significant damages to roads and bridges, both by being washed away during the flooding event itself, and over time as a result of inundation damage from floodwaters. The intrusion of water under pavement has long been recognised as affecting pavement life and durability (NAASRA 1972).

A.4.2 Key Findings

Bridges and sections of roads can be washed away during flood events and most published estimates of flood damages to roads are dominated by these items. However, some damages to road pavement and bridge foundation do not become evident until considerably after the flood event. Excessive moisture in road pavements leads to deterioration in the durability of roads, and causes effects similar to a large increase in heavy vehicle traffic. In the severest cases, pavement life may be reduced by three-quarters (Bugden, 1997). General maintenance issues with the failure of roads caused by flooding are:

- weakening of pavement as subgrade wets up;
- rapid potholing and seal loss following seal cracking; and
- accelerated aging of bitumen.

Hydro Tasmania (2003) determined a number of unit losses for estimating damages to roads, highways and bridges within the Adelaide region. For urban roads, a damage cost of $10,000/km was assumed where inundation was minor, while a replacement cost of $25,000/km was assumed where greater inundation required the road to be replaced. For a major (4-lane) highway, a cost of $100,000/km was assumed, allowing for some pavement rehabilitation as well as clean-up damage. Costs were also allocated for bridges, $100,000/bridge where damage was expected to be sustained, $500,000/bridge where it was expected replacement would be required.

The 2007 floods in East Gippsland resulted in an estimated $5.5 million in damages to 189 different roads (Buchan, 2007). The total length of roads inundated is not known. A large number of bridges (39) were also significantly damaged. The total damage to bridges was estimated to be approximately $3 million, an average of approximately $77,000 per bridge.

Construction costs for new roads in Melbourne are presented in Table A-6. Note that flood damages would only be a fraction of the full costs of road/bridge construction.

Appendix A

Table A-6 Unit Road and Bridge Construction Costs (source: Rawlinsons, 2008)

Road Type	Cost
Basecourse only (grading, rolling/compaction, 100 mm crushed rock)	$8,900 per km
6.0m wide suburban road	$300,000 per km
Two-lane country highway	$550,000 per km
Duplicate two-lane city highway	$2.2 million per km
Bridge – two lane (11 m wide)	$10,500 per m
Bridge – four lane (20 m wide)	$30,000 per m

A.4.3 Unit Loss Values for Roads and Bridges

The severity of flooding, which incorporates duration of inundation and velocity of flooding, will determine the extent of flood damage to roads and bridges. For this reason, damage estimates have been provided for major and minor floods. Major and minor floods have been assumed to result in repair costs equivalent to ten and five percent of construction costs, respectively. The exceptions to this are unsealed roads which are likely to require repairs that are closer to their initial construction costs. Major floods have been assumed to cause damages roughly equivalent to initial construction costs of unsealed roads; minor floods have been assumed to be approximately half this value. Additional costs arising from increases in maintenance costs as a result of flooding have been assumed to be half the cost of initial repairs, which is consistent with the findings described in the Flood RAM.

Unit damages for roads are outlined in Table A-7.

Table A-7 Unit Damages for Roads (per km of road inundated)

	Major Flood			Minor Flood		
Road Type	**Initial Road Repair**	**Subsequent Accelerated Deterioration of Roads**	**TOTAL COST**	**Initial Road Repair**	**Subsequent Accelerated Deterioration of Roads**	**TOTAL COST**
Major highway (4 lane)	$220,000	$110,000	$330,000	$110,000	$55,000	$165,000
Major sealed road	$55,000	$27,500	$82,500	$27,500	$13,750	$41,250
Minor sealed road	$30,000	$15,000	$45,000	$15,000	$7,500	$22,500
Unsealed road	$9,000	$4,500	$13,500	$4,500	$2,250	$6,750

It is difficult to give an accurate estimate of damage to bridges due to the variety of bridge sizes and how these are impacted by floods of varying severity. Based on construction costs and the findings of Hydro Tasmania, it is reasonable to assume damages as presented in Table A-8. Increased maintenance costs resulting from flood damage are incorporated in these estimates.

Table A-8 Unit Damages for Bridges

Bridge Type	Major Flood	Minor Flood
Major (4-lane) bridge	$500,000	$100,000
Minor (2-lane) bridge	$133,000	$33,000

A.5 Vehicles

A.5.1 Description

Motor vehicles include damages to cars and trucks, motorcycles, and caravans. Damage to motor vehicles resulting from floods consists of things like:

- water-related mechanical damages;
- damage to electrical components;
- rusting and corrosion of various parts;
- damage to carpets and trimmings; and
- physical damage when cars are physically transported by water flows.

A.5.2 Available Data

Generally speaking, most studies of flood damages consider motor vehicles a part of external costs, and do not disaggregate these damages from the rest of external damages. Some assessments of motor vehicle damage were made in an environmental impact statement of a flood mitigation dam in Warragamba (ERM Mitchell McCotter 1995). Water Studies (1996) also included some information on damage to motor vehicles incurred during floods in Geelong and Traralgon in 1995, as did a study by the Centre for Resource and Environmental Studies into the flood that occurred in Sydney in 1986.

Risk Frontiers also have some useful information of motor vehicle damages collected from floods in Katherine, Wollongon and Nyngan.

A.5.3 Key Findings

The investigation by Water Studies into floods in Geelong and Traralgon in 1995 contains examples of businesses and homes, including damage to motor vehicles and where they were situated. Implicit is the very strong relationship between Flood Warning time, and ability to move cars to higher ground, which creates a shift between Actual and Potential damages. Motor vehicles are typically the largest component of external damage to residential dwellings. An average of $1,600 of actual motor vehicle damage was recorded in Traralgon for the 13 residential properties surveyed, which comprised 60% of total average potential damage. A total of 80 private caravans were flooded, 72 of which were flooded between above floor level to depths of between 0.3 and 2.0 metres. The direct damage to these caravans was estimated to be $165,000, or approximately $2,060 per caravan. It is not clear if contents of caravans is included in these estimates.

The CRES study of the Sydney flood that occurred in 1986 produced a number of interesting findings. The study found that caravan parks are often located on flood plains. These are often occupied by short-term residents without local flood knowledge or experience. Vans tend to float when water levels reach 2m making them especially susceptible to high damages, as well as a threat to nearby structures. This study incorporated vehicle damages into residential direct damages at a rate of

$2,000 per household if flooding levels exceeded 0.6 metres. Many vehicles suffered no damage as they were away from residences when flooding occurred, or had been deliberately relocated. However, respondents also reported that traffic on a major highway was so blocked that they could not move their cars from their premises to a flood-free location.

The study of the Warragamba Flood Mitigation Dam found depth of flooding is a critical component of vehicle damages, with a critical depth being approximately 0.9m. The study found that below this depth very little damage occurs, although one would expect this critical height to be lower than this. Above about 0.5 metres mechanical and electrical components of the car begin to become submerged, and the car interior becomes inundated, soaking carpets and trimmings.
Average insurance claims for motor vehicle damage resulting from a number of floods was obtained from Risk Frontiers and sourced from insurance data, and is displayed in Table A-9. Insurance for cars is generally based on repair value or replacement at market value, so adjustments to assessed damages for 'new for old' policies are not required. It is not clear why these estimates are significantly higher than the findings in Sydney and Traralgon, however large variability is to be expected as a result of differences in flood heights and durations, warning times, and ability to move flooded vehicles.

Table A-9 Average Motor Vehicle Damages

Flood	Average Damage	Average Damages ($ 2008)*
Katherine 1998	$12,451	$16,235
Wollongong 1998	$11,395	$14,860
Nyngan1990	$4,250	$6,505

*Adjusted for CPI

A.5.4 Unit loss values for vehicles

Since very little damage to motor vehicle occurs below a flood height of about 0.5m above ground level, damage at lower depths was ignored.

For flood depths above 0.5 m, and until more data is available, we believe it is reasonable to assume an approximate figure for motor vehicle damage from the information collected by Risk Frontiers of $10,000 per car.

Some assumptions will need to be made as to the number of cars parked at an average residence (we would expect this to be between one and two) and commercial sites. Since cars are mobile it is expected that damage to cars would decrease as warning times increased.

Based on the 1995 Water Studies findings, it is reasonable to assume a damage estimate of approximately $2,000 per caravan flooded above floor height. It is assumed that damages are minimal for below-floor flooding. Adjusting for CPI to 2008 values, the damage estimates for caravans is approximately $3,000 per caravan flooded over floor-level.

A.6 Agriculture

A.6.1 Description

The cost of flooding on agricultural enterprises will vary considerably depending on the duration of the flood. For many pastures and crops, inundation of less than five to seven days will not result in plant death, and many crops will recover. Periods of flooding greater than one week result in increased likelihood of plant death and disease. The following discussion highlights some of the key costs faced by farmers following a flood event.

A.6.2 Data Availability

Data of the same quality as used in the Flood RAM are not available as this was obtained through consultation with agronomists, which was beyond the scope of this study. The majority of studies focus on costs to homes and businesses. The economic impact assessment of the East Gippsland floods in 2007 prepared by Buchan Consulting was a useful source of information, as it addressed not only the cost to homes and businesses, but agricultural losses as well.

Additional information was obtained from the Victorian Department of Primary Industries (DPI) on livestock, pastures and the expected returns of various crops.

A.6.3 Unit loss value for agriculture

Irrigated Pastures

The findings of the Flood RAM were that inundations periods of less than 5 to 7 days resulted in negligible levels of plant death, with damages being restricted to alternative feeding of livestock while floods recede, paddocks dry, and necessary repairs are made. This was assumed to be a period of approximately one month.

Inundation periods of greater than seven days were assumed to result in significant levels of pasture death, requiring re-establishment of one third of the inundated area, over-sowing a third, with the remaining third not requiring treatment. Alternative feeding would be required for approximately three months.

These assumptions have been adopted here also.

Cost of Providing Alternative Livestock Feed

The cost of providing alternative livestock feed, based on a stocking rate of 15 dry sheep equivalents (DSE) per hectare, has not changed significantly since the last estimate was made in 2000. Key assumptions are noted below.

The cost of providing hay as an alternative food to pastures ranges between approximately $5.40 and $6.75 per DSE per month, with an average of approximately $6 per DSE per month. [2]

Assuming feed is being supplied as an alternative to pastures with a carrying capacity of 15 DSE per hectare, the cost of alternative feed is approximately $90 per hectare per month.

[2] Assumptions are based on DPI livestock feeding information available on their website, and Victorian hay prices available from the Australian Fodder Industry Association for March 2008.

Appendix A

Cost of Re-sowing/Over-sowing Irrigated Pasture

Cost of re-establishing irrigated perennial pasture are based on the 2004 DPI information paper, *Renovating Irrigated Perennial Pastures*, and adjusted for inflation. Oversowing involves topping and seeding with rye grass, while reestablishment costs include herbicide and spraying, cultivation, and sowing ryegrass and white clover. These costs are outlined in Table A-10.

Table A-10 Pasture Renovation Costs

Action	Cost Range per ha	Average Cost per ha ($)
Over-sowing	$90- $245	170
Re-sowing	$310 - $425	370

Unit Values for Irrigated Pasture

Based on the assumptions and costs outlined above, the unit losses for costs per area inundated are outlined in Table A-11.

Table A-11 Unit losses for Irrigated Pastures

Inundation Period	Cost per Hectare
Less than seven days	90
Greater than seven days	450

Dryland Pastures

The Flood RAM identified four options available to farmers with dryland pastures affected by flooding. The most expensive of these options is to cultivate, or use a knockdown herbicide, and then plant the area with improved pasture species such as phalaris. The cost of this option is estimated to be $150 per hectare (Dellwo et al., 2004 – adjusted for inflation).

For periods of inundation of less than five to seven days, damage to dryland pastures will generally be minimal and can be ignored. For periods greater than seven days, an estimate of the cost to repair pastures damaged by flooding has been based on a mix of annual and perennial pastures. For the purposes of this study it is assumed that annual pastures incur no cost to repair, perennial pastures incur costs of $150 per hectare as outlined above, and that there is a 60:40 split between annual and perennial pastures. This resulting unit value to be applied is therefore $90 per hectare of land inundated.

Livestock Losses

During a flood event, there is a risk of livestock death through drowning, and this cost needs to be considered. Replacement costs for livestock are outlined in Table A-12. Beef and sheep prices were derived from the DPI's South West Farm Monitor project 05-06, and adjusted for inflation. Dairy livestock values are based on the average price quoted by Wellard Group livestock exporters for heifers.

Appendix A

Table A-12 Suggested Livestock Values

Livestock Type	Cost per Head ($)
Dairy	988
Beef	687
Sheep for wool production	36
Sheep for lamb production	58

Cost of Livestock Disposal

Discussions with DPI suggest that the majority of farmers would dispose of dead animals by having them collected by a knackery. The cost of this is likely to be minimal, as many knackeries will take dead stock at no charge.

If this option is unavailable, burial is the most likely alternative. It is considered that the costs provided by the Flood RAM are still applicable, with an adjustment for inflation. It is therefore suggested that burial costs are likely to be in the vicinity of $8 to $13 per sheep, and $50 - $100 per head of cattle.

Crops

The costs to cropping enterprises will vary according to the type of crop, length of inundation and the timing of flood. Crops that are destroyed close to harvest date will avoid subsequent harvesting, marketing and selling costs, however costs incurred throughout the growing season will still impact on profits. Damage that occurs early in the season may allow enough time for replanting and subsequent revenue in the growing year.

Unfortunately, the models and data used in the Flood RAM to estimate agricultural damages for floods occurring at different times are not available. As a guide to current damages in the absence of better information, an estimate has be made by inflating the damages estimated in the Flood RAM by the rate that revenues per hectare have increased (or declined) for each of the crop categories since the Flood RAM was developed (see URS 2008). Although a correlation exists between crop damages and revenues, it may be stronger at certain times of the year. This approach is therefore an approximation only, and a more detailed study of the impacts of flood damages on farm profitability would greatly improve these estimates. Additionally, information for some crop types that were covered in the Flood RAM was not readily available (tobacco, hops, and flood sensitive orchards). The variable nature of agricultural returns means that we have no reasonable basis for altering the estimates used in the Flood RAM for these crop types and suggest that these continue to be used until better information is available.

The distribution of floods over the year has been taken from the Flood RAM and is assumed to still be valid. The estimated agricultural damages for inundation periods of less than seven days and greater than seven days are outlined in Table A-13 and Table A-14, respectively.

Appendix A

Table A-13 Agricultural Damages ($ per ha) - Inundation of Less than Seven Days

Month	Distribution of Floods	Dryland Broadacre Crops	Irrigated Broadacre Crops	Vegetables	Grapes	Other Fruit
Jan	0%	0	0	7970	1905	3885
Feb	0%	0	0	7970	1905	3885
Mar	0%	0	0	7970	1905	3885
Apr	0%	0	0	7970	1905	3885
May	0%	80	185	7970	1905	3885
Jun	8%	80	185	7970	1905	3885
Jul	8%	80	185	7970	1905	3885
Aug	23%	80	185	7970	1905	3885
Sep	31%	80	185	7970	1905	3885
Oct	23%	80	185	7970	1905	3885
Nov	0%	80	185	7970	1905	3885
Dec	8%	80	185	7970	1905	3885
YEAR	**100%**	**80**	**185**	**7970**	**1905**	**3885**

Table A-14 Agricultural Damages ($ per ha) - Inundation of Greater than Seven Days

Month	Distribution of Floods	Dryland Broadacre Crops	Irrigated Broadacre Crops	Vegetables	Grapes	Other Fruit
Jan	0%	0	0	7970	6903	17482
Feb	0%	0	0	7970	7297	17482
Mar	0%	0	0	7970	7691	17482
Apr	0%	0	0	7970	8085	17482
May	0%	50	215	7970	1907	3885
Jun	8%	71	254	7970	1907	3885
Jul	8%	92	294	7970	1907	3885
Aug	23%	113	333	7970	1907	3885
Sep	31%	135	372	7970	1907	3885
Oct	23%	156	412	7970	5721	17482
Nov	0%	177	452	7970	6115	17482
Dec	8%	198	491	7970	6509	17482
YEAR	**100%**	**132**	**366**	**7970**	**3141**	**8069**

Appendix A

Clean-up Costs

A lack of available data meant that it was not possible to more accurately adjust the broad figures per hectare quoted in the original Flood RAM for clean up costs. These are presented in Table A-15, and have been adjusted for inflation only.

Table A-15 Clean-up Costs

Category	Cost of Clean Up ($ per ha)
Pasture and broadacre crops in floodway areas	31
Pasture and broadacre crops for low velocity flood events (typically across floodplain beyond the defined floodway)	12
Horticultural enterprises	431

More accurate figures were available for some specific components of the clean up cost, and these have been included in the sections below.

Alternative to Unit loss values

Under some circumstance it may be more useful to estimate damages using unit rates for individual components of flood damage. Some useful unit rates are included in this section.

Labour

There have been some changes to expected number of labour hours required to complete clean-up tasks. Any change or correction is noted in the sections below.

The cost of labour has not changed significantly, and is estimated at $18 per hour. The estimate is based on the cost per hour for casual labour, as used by the DPI in their *Loddon Mallee Horticulture Gross Margins 05-06*.

Fencing

The cost of repairs to farm fencing is significant, with over $9.8 million estimated to replace fencing lost in the East Gippsland floods in 2007. The costs outlined in Table A-16, are based on information collected from these floods (East Gipland Shire Council, 2007).

Table A-16 Costs of Fencing Repairs

Fence Type	Materials Cost per km ($)	Labour Hours per km	Labour Cost per km ($)	Total Cost per km ($)
Crown Boundary fencing	8,500	125	2,250	10,750
Boundary fencing	7,000	125	2,250	9,250
Internal fencing	7,000	125	2,250	9,250

Appendix A

Trellising

The cost of trellising are presented in Table A-17 and are based on the cost of preparing tomato trellising, as quoted by the DPI in their *Loddon Mallee Horticulture Gross Margins 05-06*, adjusted for inflation.

Table A-17 Costs of Trellising

	Materials Cost per ha ($)	Labour Hours per ha	Labour Cost per ha	Total Cost per ha ($)
Trellising	5,811	20	360	6,171

Trickle Irrigation Systems

The cost of replacing trickle irrigation are presented in Table A-18 and have been extrapolated from the cost of applying trickle irrigation to tomato plants, from the DPI *Loddon Mallee Horticulture Gross Margins 05-06*, adjusted for inflation.

Table A-18 Costs of Trickle Irrigation Systems

	Materials Cost per ha ($)	Labour Hours per ha	Labour Cost per ha ($)	Total Cost per ha ($)
Trickle irrigation system	900	3	54 (plus $27 for tractor use)	981

Vine Replacement

Prolonged flooding resulting in vine death will require vines to be replaced. The materials cost is based on using grafted disease resistant vines at a cost of $8,000 per hectare (Demediuk 2003) and inflated by the CPI to 2008 values. The time input has not been altered form the Flood RAM, however labour costs have been updated.

Table A-19 Costs of Vine Replacement

	Materials Cost per ha ($)	Labour Hours per ha	Labour Cost per ha ($)	Total Cost per ha ($)
Vine replacement	8,906	75	1,350	10,256

Soil Renovation and Erosion Repair

Floods of sufficient velocity, depth and period of inundation can transport valuable erode and transport topsoil, which requires subsequent repair. In the 2007 East Gippsland floods, some farms had up to six feet of erosion to pastures. The costs outlined in Table A-16 are based on information collected from these floods (East Gippland Shire Council, 2007).

Table A-20 Costs of Soil Renovation

	Cost per ha ($)
Soil renovation and erosion repair	130

Appendix B Flood Damage Breakdown

Appendix B

Table B-1 Damage breakdown – 20,000 ML release

Asset	Area A		Area B		Area C		Area D		Area E		Area F		Area G		Area H	
Buildings	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**
Residential - structural	9	137,363	0	0	0	0	0	0	0	0	0	0	0	0	2	30,525
Residential - contents	9	73,062	0	0	0	0	0	0	0	0	0	0	0	0	2	16,236
Residential - external & clean-up	9	81,000	0	0	0	0	0	0	0	0	0	0	0	0	2	18,000
Commercial - structural	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	18,000
Commercial - contents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12,000
Commercial - external & clean-up	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	12,000
Sheds	15	75,000	3	15,000	2	10,000	0	0	1	5,000	1	5,000	1	5,000	9	45,000
TOTAL BUILDINGS		**366,425**		**15,000**		**10,000**		**0**		**5,000**		**5,000**		**5,000**		**151,761**
Roads	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**
Major Highway	0.4	70,928	0.1	23,212	0.0	-	0.2	24,978	0.0	-	0.0	-	0.4	58,166	0.1	16,312
Major sealed road	0.8	32,230	0.0	480	0.0	-	0.0	-	0.0	-	0.0	945	0.0	-	0.8	32,394
Minor sealed road	0.0	-	0.0	-	0.0	-	0.3	7,195	0.0	-	0.0	-	0.3	7,156	0.0	-
Unsealed road	0.1	426	0.5	3,378	0.0	255	0.0	62	0.8	5,158	0.2	1,322	0.3	2,152	4.7	31,949
TOTAL ROADS		**103,585**		**27,070**		**255**		**32,234**		**5,158**		**2,267**		**67,475**		**80,655**
Bridges	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**
Major	0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0
Minor	0.4	$14,049	0.2	$5,431	0.1	$2,347	0.0	$1,189	0.3	$8,629	0.0	$678	0.4	$14,818	0.2	$5,612
TOTAL BRIDGES		**14,049**		**5,431**		**2,347**		**1,189**		**8,629**		**678**		**14,818**		**5,612**
Agriculture	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**
2.1.0 Livestock grazing	26.1	2,353	56.7	5,107	18.3	1,648	0.5	49	0.0	-	0.0	-	0.0	-	0	$ -
2.2.0 Production forestry	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	39.0	-	619.1	-	1,747	$ -
3.1.1 Hardwood plantation	11.8	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.2.0 Grazing modified pastures	0.0	-	0.0	-	0.0	-	123.8	11,144	67.3	6,061	1.0	88	17.7	1,595	202	$ 18,144
3.3.0 Grazing modified pastures	298.9	26,901	288.9	26,001	68.8	6,194	5.5	494	0.0	-	0.0	-	0.0	-	0	$ -
3.3.0 Cropping	0.0	-	0.0	-	0.0	-	20.9	1,885	18.1	1,630	0.9	80	1.9	174	133	$ 11,937
3.3.1 Cereals	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	8	$ 1,122
3.3.4 Oil seeds	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	45	$ 6,061
3.3.5 Sown grasses	0.0	-	1.0	91	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.4.3 Hay & silage	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.5.1 Tree fruits	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.5.2 Oleaginous fruits	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.5.4 Vine fruits	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
3.5.7 Vegetables & herbs	3.1	25,055	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
4.2.0 Irrigated modified pastures	0.0	-	0.0	-	0.0	-	0.0	-	0.4	191	1.5	685	6.0	2,695	25	$ 11,464
4.3.0 Irrigated cropping	0.0	-	0.0	-	0.0	-	0.0	-	0.1	51	0.0	0	8.6	3,195	14	$ 5,213
4.3.2 Irrigated pasture legumes	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
4.3.3 Irrigated hay & silage	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.1	58	1.1	477	0	$ -
4.3.4 Irrigated sown grasses	89.2	40,143	29.2	13,131	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
4.4.1 Irrigated tree fruits	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.1	291	0	$ 1,122
4.4.3 Irrigated hay & silage	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
4.4.4 Irrigated vine fruits	0.0	-	0.0	-	0.0	-	0.0	-	11.8	22,507	4.7	8,869	0.0	-	0	$ -
4.4.7 Irrigated vegetables & herbs	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
4.4.8 Irrigated Legumes	6.6	2,960	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
5.2.0 Intensive animal production	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
5.2.5 Pigs	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0.0	-	0	$ -
TOTAL AGRICULTURE	**436**	**97,412**	**376**	**44,330**	**87**	**7,842**	**151**	**13,571**	**98**	**30,440**	**47**	**9,780**	**655**	**8,428**	**2175**	**55,063**

Appendix B

Table B-2 Damage breakdown – 30,000 ML release

Asset	Area A		Area B		Area C		Area D		Area E		Area F		Area G		Area H	
Buildings	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)
Residential - structural	9	137,363	4	61,050	0	0	0	0	1	15,263	0	0	2	30,525	12	183,151
Residential - contents	9	73,062	4	32,472	0	0	0	0	1	8,118	0	0	2	16,236	12	97,416
Residential - external & clean-up	9	81,000	4	36,000	0	0	0	0	1	9,000	0	0	2	18,000	12	108,000
Commercial - structural	0	0	0	0	0	0	0	0	1	18,000	0	0	1	18,000	2	36,000
Commercial - contents	0	0	0	0	0	0	0	0	1	12,000	0	0	1	12,000	2	24,000
Commercial - external & clean-up	0	0	0	0	0	0	0	0	1	12,000	0	0	1	12,000	2	24,000
Sheds	23	115,000	15	75,000	2	10,000	5	25,000	3	15,000	2	10,000	6	30,000	79	395,000
TOTAL BUILDINGS		**406,425**		**204,522**		**10,000**		**25,000**		**89,381**		**10,000**		**136,761**		**867,567**
Roads	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)
Major Highway	0.5	78,865	0.5	89,394	0.0	-	0.4	71,248	0.0	-	0.0	-	0.7	118,227	1.1	179,712
Major sealed road	1.4	57,765	0.4	17,584	0.0	521	0.0	-	0.0	2,052	0.1	2,625	0.1	3,219	1.3	51,903
Minor sealed road	0.0	-	0.0	-	0.0	-	0.6	13,837	0.0	-	0.0	-	1.6	36,989	1.7	37,192
Unsealed road	0.2	1,090	0.7	4,969	0.0	268	0.8	5,407	1.5	10,374	0.4	2,934	3.3	22,513	19.4	131,226
TOTAL ROADS		**137,720**		**111,947**		**789**		**90,492**		**12,426**		**5,559**		**180,948**		**400,033**
Bridges	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)
Major	0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0
Minor	0.5	$16,947	0.5	$14,991	0.1	$2,583	0.2	$6,045	0.3	$10,135	0.1	$4,267	0.9	$31,148	0.8	$25,379
TOTAL BRIDGES		**16,947**		**14,991**		**2,583**		**6,045**		**10,135**		**4,267**		**31,148**		**25,379**
Agriculture	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)
2.1.0 Livestock grazing	35.3	$ 3,174	147.5	$ 13,271	70.7	$ 6,363	11.7	$ 1,056	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2.2.0 Production forestry	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	626.9	$ -	2009.8	$ -	5,217	$ -
3.1.1 Hardwood plantation	21.6	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.2.0 Grazing modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	321.2	$ 28,904	152.5	$ 13,723	117.2	$ 10,547	93.4	$ 8,408	1,396	$ 125,626
3.3.0 Grazing modified pastures	514.1	$ 46,268	956.4	$ 86,074	321.6	$ 28,945	44.3	$ 3,991	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.3.0 Cropping	0.0	$ -	0.0	$ -	0.0	$ -	47.8	$ 4,306	53.6	$ 4,826	14.8	$ 1,336	13.3	$ 1,198	643	$ 57,889
3.3.1 Cereals	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	23	$ 3,075
3.3.4 Oil seeds	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	61	$ 8,208
3.3.5 Sown grasses	0.0	$ -	12.6	$ 1,138	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.4.3 Hay & silage	0.0	$ -	8.2	$ 736	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.1 Tree fruits	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.2 Oleaginous fruits	0.0	$ -	1.1	$ 4,334	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.4 Vine fruits	0.0	$ -	1.7	$ 3,257	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.7 Vegetables & herbs	6.8	$ 54,283	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.2.0 Irrigated modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	2.9	$ 1,326	3.7	$ 1,666	46.9	$ 21,119	29.9	$ 13,433	85	$ 38,367
4.3.0 Irrigated cropping	0.0	$ -	0.0	$ -	0.0	$ -	1.0	$ 366	1.2	$ 453	13.7	$ 5,098	34.4	$ 12,813	215	$ 79,962
4.3.2 Irrigated pasture legumes	5.2	$ 2,357	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.3.3 Irrigated hay & silage	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	1.0	$ 459	1.2	$ 528	0	$ -
4.3.4 Irrigated sown grasses	137.7	$ 61,949	43.8	$ 19,712	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.1 Irrigated tree fruits	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	5.4	$ 20,811	0	$ 1,504
4.4.3 Irrigated hay & silage	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.4 Irrigated vine fruits	0.0	$ -	0.0	$ -	0.0	$ -	11.0	$ 21,000	45.3	$ 86,395	29.6	$ 56,417	0.0	$ -	0	$ 133
4.4.7 Irrigated vegetables & herbs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ 147	0.0	$ -	0	$ -
4.4.8 Irrigated Legumes	11.3	$ 5,093	0.2	$ 68	0.0	$ -	2.7	$ 1,231	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
5.2.0 Intensive animal production	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	29	$ -
5.2.5 Pigs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	16	$ -
TOTAL AGRICULTURE	**732**	**173,124**	**1171**	**128,590**	**392**	**35,308**	**443**	**62,180**	**256**	**107,064**	**850**	**95,125**	**2187**	**57,191**	**7685**	**314,765**

Appendix B

Table B-3 Damage breakdown – 40,000 ML release

	Area A		Area B		Area C		Area D		Area E		Area F		Area G		Area H	
Buildings	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)
Residential - structural	11	167,889	12	183,151	0	0	0	0	2	30,525	1	15,263	6	91,576	13	198,414
Residential - contents	11	89,298	12	97,416	0	0	0	0	2	16,236	1	8,118	6	48,708	13	105,534
Residential - external & clean-up	11	99,000	12	108,000	0	0	0	0	2	18,000	1	9,000	6	54,000	13	117,000
Commercial - structural	1	18,000	1	18,000	0	0	0	0	1	18,000	0	0	1	18,000	2	36,000
Commercial - contents	1	12,000	1	12,000	0	0	0	0	1	12,000	0	0	1	12,000	2	24,000
Commercial - external & clean-up	1	12,000	1	12,000	0	0	0	0	1	12,000	0	0	1	12,000	2	24,000
Sheds	43	215,000	37	185,000	3	15,000	11	55,000	4	20,000	3	15,000	18	90,000	96	480,000
TOTAL BUILDINGS		**613,187**		**615,567**		**15,000**		**55,000**		**126,761**		**47,381**		**326,284**		**984,948**
Roads	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)
Major Highway	1.4	236,621	1.8	302,075	0.0	2,230	0.6	106,799	0.0	-	0.0	-	1.4	227,382	1.2	203,127
Major sealed road	3.4	138,854	1.2	48,836	0.2	7,636	0.1	6,006	0.2	6,375	0.1	4,545	0.1	5,361	1.7	71,631
Minor sealed road	0.0	-	0.0	-	0.0	-	0.6	13,907	0.0	-	0.0	-	2.7	61,280	1.6	36,186
Unsealed road	1.0	6,585	1.8	11,936	0.3	2,061	1.2	7,971	2.3	15,666	1.2	8,117	6.3	42,247	31.8	214,954
TOTAL ROADS		**382,060**		**362,846**		**11,927**		**134,684**		**22,040**		**12,663**		**336,269**		**525,898**
Bridges	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)
Major	0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0
Minor	0.6	$19,661	0.6	$19,513	0.2	$4,984	0.3	$10,606	0.3	$10,824	0.2	$5,244	1.1	$35,257	1.0	$31,937
TOTAL BRIDGES		**19,661**		**19,513**		**4,984**		**10,606**		**10,824**		**5,244**		**35,257**		**31,937**
Agriculture	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)
2.1.0 Livestock grazing	54.1	$ 4,870	208.5	$ 18,764	119.8	$ 10,785	19.9	$ 1,788	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2.2.0 Production forestry	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	1181.3	$ -	2361.4	$ -	5,743	$ -
3.1.1 Hardwood plantation	27.4	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.2.0 Grazing modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	476.0	$ 42,843	226.5	$ 20,383	301.1	$ 27,095	185.5	$ 16,695	2,064	$ 185,787
3.3.0 Grazing modified pastures	791.5	$ 71,237	1974.3	$ 177,687	715.1	$ 64,362	87.4	$ 7,867	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.3.0 Cropping	0.0	$ -	0.0	$ -	0.0	$ -	104.5	$ 9,406	121.9	$ 10,970	84.7	$ 7,625	32.8	$ 2,948	951	$ 85,551
3.3.1 Cereals	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	37	$ 4,979
3.3.4 Oil seeds	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	97	$ 13,059
3.3.5 Sown grasses	0.0	$ -	21.7	$ 1,953	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.4.3 Hay & silage	0.0	$ -	17.2	$ 1,545	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.1 Tree fruits	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.2 Oleaginous fruits	0.0	$ -	1.1	$ 4,424	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.4 Vine fruits	0.0	$ -	1.7	$ 3,222	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.7 Vegetables & herbs	8.7	$ 69,380	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.2.0 Irrigated modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	3.1	$ 1,392	11.5	$ 5,193	91.2	$ 41,057	55.4	$ 24,938	110	$ 49,438
4.3.0 Irrigated cropping	0.0	$ -	0.0	$ -	0.0	$ -	2.2	$ 802	13.5	$ 5,033	41.8	$ 15,560	51.1	$ 19,025	346	$ 128,551
4.3.2 Irrigated pasture legumes	11.2	$ 5,033	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.3.3 Irrigated hay & silage	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	7.4	$ 3,308	1.3	$ 569	0	$ -
4.3.4 Irrigated sown grasses	191.7	$ 86,258	56.8	$ 25,578	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.1 Irrigated tree fruits	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.2	$ 697	6.0	$ 23,118	0	$ 1,942
4.4.3 Irrigated hay & silage	0.0	$ 3	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.4 Irrigated vine fruits	0.0	$ -	0.0	$ -	0.0	$ -	26.2	$ 49,976	117.0	$ 223,111	57.9	$ 110,490	0.0	$ -	0	$ 768
4.4.7 Irrigated vegetables & herbs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.3	$ 2,097	0.0	$ -	0	$ -
4.4.8 Irrigated Legumes	29.9	$ 13,444	3.8	$ 1,707	0.0	$ -	3.4	$ 1,547	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
5.2.0 Intensive animal production	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	35	$ -
5.2.5 Pigs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	18	$ -
TOTAL AGRICULTURE	**1114**	**250,224**	**2285**	**234,881**	**835**	**75,147**	**723**	**115,621**	**490**	**264,691**	**1766**	**207,930**	**2693**	**87,293**	**9401**	**470,074**

Appendix B

Table B-4 Damage breakdown – 50,000 ML release

	Area A		Area B		Area C		Area D		Area E		Area F		Area G		Area H	
Buildings	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)	Number	Value of damage ($)
Residential - structural	16	244,202	12	183,151	1	15,263	1	15,263	4	61,050	7	106,838	10	152,626	17	259,464
Residential - contents	16	129,888	12	97,416	1	8,118	1	8,118	4	32,472	7	56,826	10	81,180	17	138,006
Residential - external & clean-up	16	144,000	12	108,000	1	9,000	1	9,000	4	36,000	7	63,000	10	90,000	17	153,000
Commercial - structural	1	18,000	1	18,000	0	0	0	0	1	18,000	0	0	2	36,000	2	36,000
Commercial - contents	1	12,000	1	12,000	0	0	0	0	1	12,000	0	0	2	24,000	2	24,000
Commercial - external & clean-up	1	12,000	1	12,000	0	0	0	0	1	12,000	0	0	2	24,000	2	24,000
Sheds	60	300,000	36	180,000	3	15,000	17	85,000	12	60,000	10	50,000	24	120,000	129	645,000
TOTAL BUILDINGS		**860,090**		**610,567**		**47,381**		**117,381**		**231,522**		**276,664**		**527,806**		**1,279,470**
Roads	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)	Length of road (km)	Value of damage ($)
Major Highway	2.5	821,509	1.8	604,149	0.0	920	0.9	312,790	0.0	-	0.0	-	1.8	593,069	2.2	715,612
Major sealed road	5.1	419,219	1.2	97,672	0.5	42,913	0.3	22,619	0.6	49,453	0.3	27,470	0.2	12,802	2.6	217,551
Minor sealed road	0.1	4,765	0.0	-	0.0	-	0.8	33,903	0.0	-	0.0	-	3.1	137,849	1.7	78,168
Unsealed road	1.2	16,853	1.8	23,871	0.4	5,760	1.5	20,097	2.8	38,278	2.6	34,775	7.8	105,679	40.1	541,796
TOTAL ROADS		**1,262,347**		**725,692**		**49,594**		**389,410**		**87,731**		**62,245**		**849,400**		**1,553,127**
Bridges	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)	Length (km)	Value of damage ($)
Major	0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0
Minor	0.8	$105,219	0.6	$78,644	0.2	$28,565	0.5	$63,649	0.4	$50,859	0.3	$38,821	1.1	$151,032	1.1	$152,634
TOTAL BRIDGES		**105,219**		**78,644**		**28,565**		**63,649**		**50,859**		**38,821**		**151,032**		**152,634**
Agriculture	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)	Area (ha)	Value of damage ($)
2.1.0 Livestock grazing	67.8	$ 6,106	208.6	$ 18,776	147.3	$ 13,254	26.9	$ 2,422	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
2.2.0 Production forestry	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	1492.0	$ -	2407.2	$ -	5,975	$ -
3.1.1 Hardwood plantation	35.4	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.2.0 Grazing modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	635.6	$ 57,203	290.7	$ 26,167	412.4	$ 37,116	212.4	$ 19,118	3,090	$ 278,088
3.3.0 Grazing modified pastures	1048.2	$ 94,338	2000.5	$ 180,042	1008.7	$ 90,786	160.8	$ 14,473	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.3.0 Cropping	0.0	$ -	0.0	$ -	0.0	$ -	180.9	$ 16,280	152.7	$ 13,740	194.2	$ 17,480	42.0	$ 3,781	1,322	$ 119,010
3.3.1 Cereals	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	49	$ 6,553
3.3.4 Oil seeds	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	153	$ 20,684
3.3.5 Sown grasses	0.0	$ -	21.8	$ 1,965	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.4.3 Hay & silage	0.0	$ -	17.2	$ 1,545	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.1 Tree fruits	2.9	$ 11,421	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.2 Oleaginous fruits	0.0	$ -	1.1	$ 4,424	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.4 Vine fruits	0.1	$ 272	1.7	$ 3,222	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
3.5.7 Vegetables & herbs	13.0	$ 103,332	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.2.0 Irrigated modified pastures	0.0	$ -	0.0	$ -	0.0	$ -	3.0	$ 1,371	22.2	$ 9,983	130.7	$ 58,835	62.8	$ 28,240	127	$ 57,075
4.3.0 Irrigated cropping	0.0	$ -	0.0	$ -	0.0	$ -	2.9	$ 1,079	41.2	$ 15,309	79.0	$ 29,384	55.3	$ 20,554	509	$ 189,313
4.3.2 Irrigated pasture legumes	15.8	$ 7,106	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.3.3 Irrigated hay & silage	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	35.9	$ 16,168	1.4	$ 612	0	$ -
4.3.4 Irrigated sown grasses	241.6	$ 108,715	56.8	$ 25,578	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.1 Irrigated tree fruits	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	2.2	$ 8,533	6.6	$ 25,605	2	$ 6,300
4.4.3 Irrigated hay & silage	0.6	$ 248	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
4.4.4 Irrigated vine fruits	0.0	$ -	0.0	$ -	0.0	$ -	39.7	$ 75,798	160.9	$ 306,786	66.2	$ 126,192	0.0	$ -	4	$ 7,270
4.4.7 Irrigated vegetables & herbs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.6	$ 4,438	0.0	$ -	0	$ -
4.4.8 Irrigated Legumes	70.9	$ 31,895	3.8	$ 1,707	0.0	$ -	6.8	$ 3,068	0.0	$ -	0.0	$ -	0.0	$ -	0	$ -
5.2.0 Intensive animal production	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	40	$ -
5.2.5 Pigs	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	0.0	$ -	20	$ -
TOTAL AGRICULTURE	**1496**	**363,432**	**2312**	**237,258**	**1156**	**104,040**	**1057**	**171,694**	**668**	**371,984**	**2413**	**298,146**	**2788**	**97,910**	**11290**	**684,292**

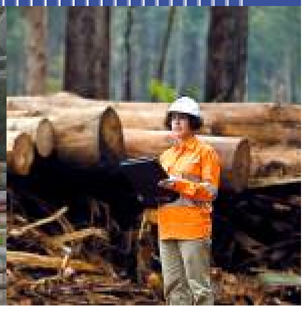
Appendix B

Table B-5 Damage breakdown – 60,000 ML release

	Area A		Area B		Area C		Area D		Area E		Area F		Area G		Area H	
Buildings	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**	**Number**	**Value of damage ($)**
Residential - structural	47	717,342	20	305,252	1	15,263	5	76,313	8	122,101	10	152,626	13	198,414	18	274,727
Residential - contents	47	381,546	20	162,360	1	8,118	5	40,590	8	64,944	10	81,180	13	105,534	18	146,124
Residential - external & clean-up	47	423,000	20	180,000	1	9,000	5	45,000	8	72,000	10	90,000	13	117,000	18	162,000
Commercial - structural	5	90,000	2	36,000	0	0	0	0	1	18,000	1	18,000	2	36,000	2	36,000
Commercial - contents	5	60,000	2	24,000	0	0	0	0	1	12,000	1	12,000	2	24,000	2	24,000
Commercial - external & clean-up	5	60,000	2	24,000	0	0	0	0	1	12,000	1	12,000	2	24,000	2	24,000
Sheds	94	470,000	49	245,000	5	25,000	28	140,000	15	75,000	15	75,000	42	210,000	148	740,000
TOTAL BUILDINGS		**2,201,888**		**976,612**		**57,381**		**301,903**		**376,045**		**440,806**		**714,948**		**1,406,851**
Roads	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**	**Length of road (km)**	**Value of damage ($)**
Major Highway	3.2	1,051,407	2.6	862,364	0.0	553	1.6	518,328	0.0	-	0.0	-	2.0	672,410	3.7	1,222,937
Major sealed road	7.1	581,881	1.9	153,845	0.8	65,079	0.6	50,487	0.8	66,393	0.5	39,854	0.2	13,661	3.4	283,194
Minor sealed road	0.2	7,492	0.0	-	0.0	-	1.2	53,114	0.0	-	0.2	10,675	3.4	152,986	2.0	91,320
Unsealed road	2.1	28,146	2.3	30,659	0.5	6,476	1.8	24,711	3.4	46,106	4.7	63,244	9.2	124,846	52.2	705,129
TOTAL ROADS		**1,668,925**		**1,046,868**		**72,108**		**646,640**		**112,499**		**113,773**		**963,903**		**2,302,579**
Bridges	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**	**Length (km)**	**Value of damage ($)**
Major	0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0	0.0	$0
Minor	0.8	$112,515	0.6	$82,038	0.2	$28,439	0.9	$113,417	0.4	$51,013	0.4	$46,924	1.2	$160,858	1.2	$164,775
TOTAL BRIDGES		**112,515**		**82,038**		**28,439**		**113,417**		**51,013**		**46,924**		**160,858**		**164,775**
Agriculture	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**	**Area (ha)**	**Value of damage ($)**
2.1.0 Livestock grazing	77.0	6926.6	223.2	20084.0	159.7	14370.6	38.0	3417.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
2.2.0 Production forestry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1564.4	0.0	2428.4	0.0	6,182	$ -
3.1.1 Hardwood plantation	44.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.2.0 Grazing modified pastures	0.0	0.0	0.0	0.0	0.0	0.0	791.7	71257.1	377.8	34001.7	491.3	44216.9	299.0	26912.7	4,112	$ 370,081
3.3.0 Grazing modified pastures	1309.7	117869.7	2367.4	213061.6	1235.4	111186.7	244.3	21985.5	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.3.0 Cropping	0.0	0.0	0.0	0.0	0.0	0.0	256.4	23072.4	168.5	15169.1	228.4	20556.7	71.7	6449.4	1,692	$ 152,284
3.3.1 Cereals	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90	$ 12,109
3.3.4 Oil seeds	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	228	$ 30,784
3.3.5 Sown grasses	0.0	0.0	25.3	2279.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.4.3 Hay & silage	0.0	0.0	19.9	1794.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.5.1 Tree fruits	6.7	25933.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.5.2 Oleaginous fruits	0.0	0.0	1.1	4430.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.5.4 Vine fruits	0.2	473.7	1.7	3228.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
3.5.7 Vegetables & herbs	16.2	128799.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
4.2.0 Irrigated modified pastures	0.0	0.0	0.0	0.0	0.0	0.0	3.3	1464.8	30.2	13590.6	152.9	68791.8	73.2	32949.7	186	$ 83,690
4.3.0 Irrigated cropping	0.0	0.0	0.0	0.0	0.0	0.0	6.9	2585.1	46.7	17355.8	115.5	42982.1	60.5	22514.4	706	$ 262,534
4.3.2 Irrigated pasture legumes	22.9	10301.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
4.3.3 Irrigated hay & silage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.3	23525.4	1.4	618.8	0	$ -
4.3.4 Irrigated sown grasses	289.5	130291.4	65.0	29253.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
4.4.1 Irrigated tree fruits	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.1	23761.6	6.8	26421.1	2	$ 7,981
4.4.3 Irrigated hay & silage	3.0	1335.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
4.4.4 Irrigated vine fruits	0.0	0.0	0.0	0.0	0.0	0.0	44.0	83940.7	186.9	356399.1	84.3	160795.3	0.0	0.0	14	$ 27,328
4.4.7 Irrigated vegetables & herbs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	8780.6	0.0	0.0	0	$ -
4.4.8 Irrigated Legumes	128.3	57749.5	45.7	20575.7	0.0	0.0	13.7	6167.7	0.0	0.0	0.0	0.0	0.0	0.0	0	$ -
5.2.0 Intensive animal production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68	$ -
5.2.5 Pigs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	$ -
TOTAL AGRICULTURE	**1898**	**479,680**	**2749**	**294,707**	**1395**	**125,557**	**1398**	**213,890**	**810**	**436,516**	**2696**	**393,410**	**2941**	**115,866**	**13301**	**946,790**







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