wannonWATER

Improving Environmental Flows in the Gellibrand River:

Assessment of Water Supply Augmentation Options.

Dated: May 2016

Report Name:	Improving Environmental Flows in the Gellibrand River: Assessment of Water Supply Augmentation Options
Report Custodian:	Tim Harrold
Checked by:	Peter Wilson
Approved by:	
Date:	May 2016
Version No:	10

Document Control			
Revision No	**Date**	**Author(s)**	**Brief Description of Change**
0	January 2014	Tim Harrold	Original Document
2	June 2014	Tim Harrold	After review.
3	August 2014	Peter Wilson	Curdievale bore costs and minor updates
4	Sept 2014	Peter Wilson	Amended from Exec meeting
5	Sept 2014	Peter Wilson & Tim Harrold	Minor changes. Issued for DEPI, CCMA & SRW comment
6	October 2014	Tim Harrold	Incorporates DEPI, CCMA & SRW comments.
7	November 2014	Peter Wilson	Minor changes. Presented to Wannon Water Board
8	October 2015	Tim Harrold	Updated cost estimates for downstream treatment of water quality following Carlisle River bores five month trial at 6 ML/d; updated "next steps".
9	May 2016	Peter Wilson	Minor changes to numbers and text around the need to treat the water to manage Manganese levels. Replaced Tables 1 & 3.
10	September 2016	Tim Harrold	Table 2 and Fig 2 updated to match May 2016 spreadsheet (as tracked changes)

PO Box 1158
Warrnambool 3280

Dated: May 2016

Contents

Executive Summary

Wannon Water's Otway Supply System provides water from the Gellibrand catchment to Warrnambool and other towns in South-Western Victoria. Extractions have been decreasing since 2006 due to demand management but increasing population is expected to result in greater extractions into the future. The extractions have potential to affect summer low flows in the Gellibrand River. Provision of an alternative supply to reduce river extractions in low-flow periods (which occur mainly in February and March) will benefit the environment.

The Western Region Sustainable Water Strategy Action 7.3 contains the following actions:

1. *The Corangamite Catchment Management Authority, Wannon Water, The Department of Environment and Primary Industry and Southern Rural Water will assess a preferred water supply augmentation option and implementation process to improve critical flows in the Gellibrand River through the summer low flow period.*
2. *Wannon Water will undertake detailed assessments of the preferred augmentation options to better understand the supply security benefits, costs and risks of each option, and the change in demand for Gellibrand River water.*
3. *Corangamite CMA will quantify the environmental benefits of maintaining summer base flows to levels below the recommendations in the Assessment of Environmental Flow requirements for the Gellibrand River.*
4. *Resourcing of this Option will be investigated and documented in the regional strategy for healthy rivers and wetlands and water supply-demand strategies of the relevant agencies.*

This report addresses the second action which is to provide detailed assessments of the preferred augmentation options.

This report has been preceded by the September 2012 Alluvium Report "Assessment of the environmental benefits and risks of flows below the summer low flow recommendation in the lower Gellibrand River". This report was commissioned by the Corangamite CMA to address the third action, which concludes that:

> *"The assessment findings suggest that the minimum summer low flow requirements of the lower Gellibrand River are driven primarily by the estuary, which requires flows in the order of 100 ML/d to maintain mouth openings and limit the upstream extent of the salt wedge. Flow management in the lower Gellibrand River should therefore target the provision of at least 100 ML/d at Burrupa, throughout the low flow season. The analysis suggests that the low flow requirements in the freshwater reach are not as high, with flows between the lowest naturally recorded flow and the existing recommendation (i.e. 57 to 86.4 ML/d) providing similar levels of certainty of achieving the specific ecological objectives identified in the 2006 FLOWS study.*
>
> *The analysis of the relative impact of each water supply scenario on ecological objectives found that all water supply augmentation options result in a notable decrease in risk, compared to current conditions or the base case. Adoption of the base case option alone (i.e. 6 ML/d of augmentation at North Otway Pump Station) has considerable environmental benefit and should therefore be pursued as a starting point to improve environmental values in the system."*

This report identifies several possible options and option combinations and compares the costs and environmental benefits for these options. Net Present Costs are evaluated over a 25 year project life with a 6% discount rate. The primary metric chosen for evaluating environmental benefits is a "relative benefit to estuary" based on the Proportion of February/March days below 100 ML/d at Burrupa (cf. Alluvium 2012 Table 4). It so happens that options with high relative benefit to estuary at low cost also have high freshwater reach benefits.

The resulting shortlisted options are:

Option	Description	groundwater substitution capacity (ML/d)	Relative benefit to estuary	Capital Cost ($m)	Net Present Cost ($m)	NPV/ML installed capacity ($m/ML)
Current	No change from current conditions	0	0	0	0	0
N6	The existing Carlisle River borefield (located at North Otway) could be run at 6 ML/d during summer low flow periods without breaching existing licence conditions.	6	5	0.05	0.48	0.080
N12	The existing Carlisle River borefield could be run at 12 ML/d during summer low flow periods if existing licence conditions are amended.	12	9	0.10	0.75	0.063
N12 S6	In addition to N12, input up to 6 ML/d of groundwater to the South Otway pipeline during summer low flow periods.	18	10	1.60	2.81	0.156
N20	In addition to N12 construct two new bores at North Otway so up to an additional 8 ML/d is input during summer low flow periods. This will allow full groundwater substitution at North Otway.	20	11	1.49	2.54	0.127
N12 C10	In addition to N12, input up to 10 ML/d of groundwater to the South Otway pipeline at Curdievale during summer low flow periods.	22	12	4.95	4.25	0.193
N12 S12	In addition to N12 & S6, construct one more bore at South Otway so up to an additional 6ML/d is input during summer low flow periods.	24	13	2.40	3.96	0.173
N12 S18	In addition to N12 & S12, construct one extra bore at South Otway allowing an additional 6ML/d to be input to the South Otway pipeline during summer low flow periods. This will allow full groundwater substitution at South Otway.	30	15	3.20	5.11	0.170
N20 S18	In addition to N12 & S18, construct two more bores at North Otway. This will allow full groundwater substitution at both locations during summer low flow periods.	38	18	4.60	6.90	0.181

Note: * GHD2014 associates N6 with approximately 10% depletion of river flows. N12 is also subject to depletion of river flows. This is not accounted for in the Table as the percentage is an estimate.

The above shortlist provides information to assist the decision regarding which option to implement. Possible capital expenditure ranges from $0 to $4.6 million, with the benefit to the estuary increasing as expenditure increases. However the shortlist shows that significant environmental benefit can be obtained with options N6 and N12 at no capital cost (beyond the cost of a monitored trial and hydrogeological investigation associated with N12).

Alluvium (2012) recommended that 6 ML/d of augmentation at North Otway Pump Station should be pursued as a starting point to improve environmental values in the system. Alluvium was influenced by advice regarding the existing licence conditions. On review, the existing North Otway bores are capable of pumping 12 ML/d over the two driest months every year with no problems anticipated apart from possible interference with river flows. The above table shows environmental benefits that should justify the relaxation of the existing licence conditions that limit the discharge to 6 ML/d and provide a conservative "stop pumping" trigger.

Beyond implementation of Option N12, expenditure of $1.5m would allow construction and testing of a new bore at South Otway to substitute an additional 6 ML/d. Option S6 involves a new borefield in a location that has acknowledged groundwater potential. Establishment of new observation bores and investigative pump testing are substantial components of this option to ensure there is no detrimental impact on the river or groundwater dependant ecosystems. This phase of work is estimated to cost $0.25m. Using the knowledge gained from implementing S6, additional bores could be established increasing the substitution at the South Otway location to 18 ML/d resulting in a total substitution of 30 ML/d.

Analysis presented in this report shows that over the last five years, Otway storages have been operated at high levels over summer. Independent of the other options considered here, Wannon Water will review its minimum storage operating levels and aim to keep its storages closer to the target curve. This could make between 200 and 400ML available to the environment over summer and autumn (with this volume extracted over winter and spring instead). In a typical dry year, this may represent 3 - 4 ML/day additional river flow.

Note however that this is a short term option: as summer demands increase over time, the storages will be drawn down to target levels anyway. (Target storage levels are water needed in storage to cater for pipeline or pump failures and water contamination events that occur from time to time.)

Use of the Curdievale borefield does not present as a preferred option when operating imperatives are included in the costs. The existing 10ML/d bore (constructed in 2014) will cater for growth post 2030 and is an interim emergency water source for Warrnambool (designed to run with an existing diesel pump for short periods). Utilising this resource for groundwater substitution will require equipping the bore with an electric pump, balancing tank, pump station and SCADA controls. It will also require a cooling tower to reduce the temperature of the 42.5 degree groundwater. The resource will not be available for groundwater substitutions post 2030 unless a replacement bore is constructed, and the overall cost of this is high compared to South Otway options, thus removing this option from the short list.

The next step in this work will be a 2016 meeting of the partner agencies to discuss the implementation process.

1. Introduction

1.1 The Otway Supply System

Wannon Water's Otway Supply System provides water from the Gellibrand catchment to Allansford, Camperdown, Cobden, Koroit, Lismore/Derrinallum, Mortlake, Noorat/Glenormiston, Purnim, Simpson, Terang and Warrnambool in South-Western Victoria. This supply system serves 21,000 urban and 1,200 rural properties and supports a population of around 50,000 people. The system is shown in Figure 1.

Figure 1 The Otway Supply System

Water from the Gellibrand catchment is extracted from the Arkins Creeks, the North Otway pump station or the South Otway pump station. The Arkins Creeks can yield up to 14 ML/day over the winter months (with booster pumping 20ML/day) but during summer often reduces to 1 ML/day. It is during the summer months that the Otway System relies on extractions from the Gellibrand River. Extractions have been decreasing since 2006 due to demand management and substitution of other locally sourced water where available but increasing population is expected to place pressure on the system into the future.

Extractions at the North Otway pump station (NOPS) and the South Otway pump station (SOPS) impact flows in the Gellibrand River, particularly relevant over summer low-flow periods. Provision of an alternative supply to reduce river extractions in low-flow periods (which occur mainly in February and March) will benefit the environment. Available alternative sources are groundwater (at North Otway, South Otway or Curdievale) or winter flow harvesting (at North Otway, if an offstream storage is constructed).

1.2 Previous Studies

The GHD 2010 Report “Options for Enhancing Summer Flows in the Gellibrand River” presented results from REALM modelling of a number of supply substitution options designed to enhance summer flows in the Gellibrand River downstream of the North Otway and South Otway pump stations. The outputs from this report included initial costings for the options, time series for each flow regime and metrics which showed relative changes to the flow regime resulting from each option. The environmental benefits of these flow regimes were assessed by Alluvium in 2012.

The September 2012 Alluvium Report “Assessment of the environmental benefits and risks of flows below the summer low flow recommendation in the lower Gellibrand River” concludes that:

> *“The assessment findings suggest that the minimum summer low flow requirements of the lower Gellibrand River are driven primarily by the estuary, which requires flows in the order of 100 ML/d to maintain mouth openings and limit the upstream extent of the salt wedge. Flow management in the lower Gellibrand River should therefore target the provision of at least 100 ML/d at Burrupa, throughout the low flow season. The analysis suggests that the low flow requirements in the freshwater reach are not as high, with flows between the lowest naturally recorded flow and the existing recommendation (i.e. 57 to 86.4 ML/d) providing similar levels of certainty of achieving the specific ecological objectives identified in the 2006 FLOWS study.*
>
> *The analysis of the relative impact of each water supply scenario on ecological objectives found that all water supply augmentation options result in a notable decrease in risk, compared to current conditions or the base case. Adoption of the base case option alone (i.e. 6 ML/d of augmentation at North Otway Pump Station) has considerable environmental benefit and should therefore be pursued as a starting point to improve environmental values in the system.”*

The Alluvium Report presents results for two metrics that will be used here to compare the environmental benefits of the augmentation options. The most important metric is “% of days in February and March with flows below 100 ML/d at Burrupa”. The results for this were:

Modelled natural conditions[1]	26%
Modelled current conditions	83%
Base case (6ML/d augmentation)	78%
Full substitution at either NOPS or SOPS	73%
Full substitution at both NOPS and SOPS	65%

Note 1: without any farm dams or river extractions

The lower this figure is, the better it is for the environment. This metric (which in this report is used to give the “Estuary Benefit”) is important due to Alluvium’s conclusion that flow management should target the provision of at least 100 ML/d at Burrupa.

The second metric presented by Alluvium is the proportion of days in February and March which have moderate environmental risk in the freshwater reach. This is measured at Burrupa (and reported here as the “Lower freshwater reach benefit”. Assuming that the hydrology has no spatial variation, the metric can also be evaluated at NOPS, and is reported here as the “Upper freshwater reach benefit”, with the combined freshwater benefit calculated as the sum of upper and lower reach benefits).

The existing Carlisle River borefield was established in 2000 and consists of two production bores and eight observation bores adjacent to the Gellibrand River. Licence conditions for the borefield require monitoring of the observation bores to ensure that groundwater levels are not drawn down to a trigger level that is set at 1m above the water level in the river. Each production bore has been pump tested at 6 ML/d. The GHD (2006) “Carlisle River Bores – Hydrogeological review” documents pump tests that confirm that the existing Carlisle River borefield can be run at 6 ML/d continuously for at least six months without reaching trigger levels in the observation bores. This is longer than the longest recorded low flow period in the river; the bores will be turned off over winter and aquifer water levels will recover. However, it is also possible to run the borefield at 12 ML/d and this was pump tested over eight days in 2009. The GHD (2009) "Report for Carlisle River Borefield – Pumping Test Results" predicts that the existing Carlisle River bores run at 12 ML/d continuously for 19 days will drawdown the water table to trigger levels in the observation bores. Such an event would require shutdown of the borefield under the current licence conditions (which also state a daily extraction limit of 6ML; this condition was waived for the 2009 pump test). Operation of the existing borefield at 12ML/d would require the licence conditions to be amended. The 2009 pumping test concluded that the bores could be run at 12ML/d over the driest two months every year without any issues apart from possible interference with river flows, and suggested that numerical modelling may be required to confirm this interference. Hydrogeological assessment undertaken as part of the installation of the bores by John Leonard in 2000 concluded that:

- *"No reduction in streamflow (indicative of induced streambed infiltration) was observed during either test"; and*
- *"Springs monitored within this zone did not demonstrate reductions in flow that could be attributed to the pumping tests."*

It should be noted that the Alluvium 2012 is based on REALM modelling that is reported in GHD 2010, "Options for Enhancing Summer Flows in the Gellibrand River". The modelling was calibrated in 2006 and 2009 against a range of flows, particularly for the timing of flood peaks and overall flow volumes over the entire year. The available model parameters should have been set to give a reasonable representation in the low flow range (<100 ML/d), but this has not been verified. Verification of modelled low flows against gauged flows in the 0-100 ML/d range over summer months is recommended if further modelling of the low flows is required.

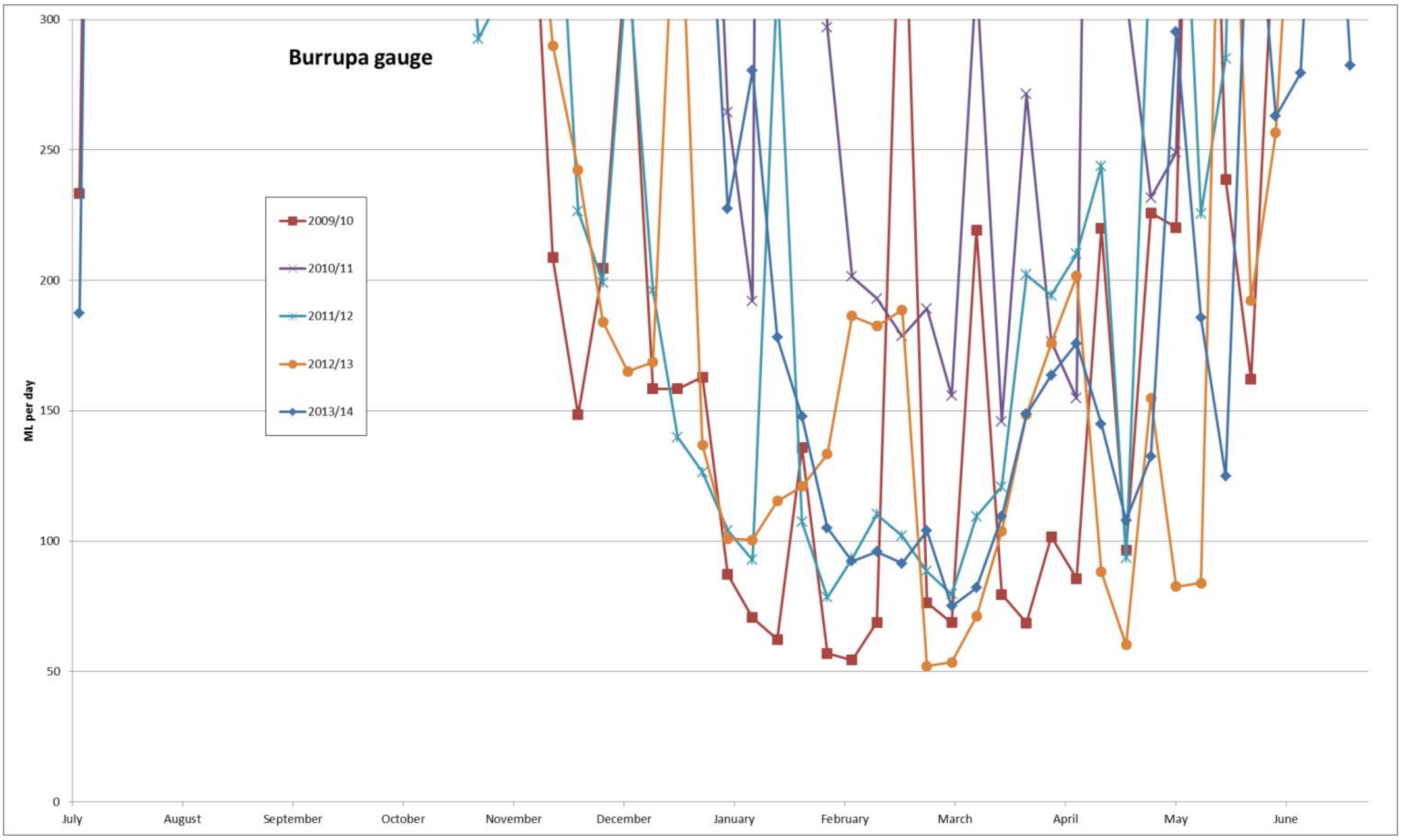
GHD 2014, "Carlisle River/Gellibrand Borefield 5 yearly review" includes review of river levels and groundwater levels in the two production bores and eight observation bores. This report shows recovery in aquifer levels after pumping stops and recovery in aquifer levels over winter and spring.

1.3 Gellibrand River Flow Records

Flow records are available for the last 45 years from the Burrupa Gauging station located in the lower Gellibrand as shown in Figure 1 above.

Figure 2 below shows low flows at the Burrupa gauge as measured over the last 5 years. These low flows occur in summer and autumn, and vary from year to year. For example, flows were above the 100ML/d threshold throughout the 2010/2011 year. Note also the volatility of the flow in some years presumably in response to rainfall events in the catchment.

Figure 2 Low Flows at the Burrupa Gauge



Analysis of the historic flows shows that:

1. On average, there are about 7 weeks of flow of less than100 ML/d at Burrupa every year, but this varies between zero and twenty weeks depending on the year.
2. 16 weeks of low flows occur in about 10% of years.
3. 13 years out of the 45 year record have 2 weeks or less flow of less than 100 ML/d being 29 % of years.

For the purposes of the following options analysis, it has been assumed that flow substitution will be required for 60 days per year but as detailed above it will vary from none to 112 days.

Refer to Appendix C for the full historic weekly flow record and further details.

2. Project Outline

The Western Region Sustainable Water Strategy Action 7.3 contains the following actions:

1. *The Corangamite Catchment Management Authority, Wannon Water, The Department of Environment and Primary Industry and Southern Rural Water will assess a preferred water supply augmentation option and implementation process to improve critical flows in the Gellibrand River through the summer low flow period.*
2. *Wannon Water will undertake detailed assessments of the preferred augmentation options to better understand the supply security benefits, costs and risks of each option, and the change in demand for Gellibrand River water.*
3. *Corangamite CMA will quantify the environmental benefits of maintaining summer base flows to levels below the recommendations in the Assessment of Environmental Flow requirements for the Gellibrand River.*
4. *Resourcing of this Option will be investigated and documented in the regional strategy for healthy rivers and wetlands and water supply-demand strategies of the relevant agencies.*

This report addresses the second action which is to provide detailed assessments of the preferred augmentation options.

2.1 Project Drivers

The key driver for this project is the improvement of summer low flows in the Gellibrand River.

2.2 Project Strategic Objectives

The strategic objective for this project is to meet the requirement of the Western Region Sustainable Water Strategy Action 7.3. It will also help fulfil *Wannon Water's Statement of Obligations*, which requires Wannon Water to seek to enhance ecological benefits where service standards to customers are not compromised.

The Action is also identified in Wannon Water's Water Supply Demand Strategy 2012-2060 being Action 2.1 "*Exploring options to improve environmental flows in the Gellibrand River"*.

2.3 Project Scope

The scope of this report is to review a range of options to improve summer flow in the Gellibrand, and to present a short list of preferred options, including a summary of costs and benefits for each option in the short list. The intent is to provide information to assist in making a future decision regarding which option(s) should be progressed and potentially implemented.

2.4 Consultation and Communication with Stakeholders

Statutory stakeholders for environmental flow management in the Gellibrand River include:

- The Corangamite Catchment Management Authority – responsible for waterway management and is the Environmental Water Holder for the Gellibrand River;
- The Department of Environment and Primary Industry – representative of the Victorian Government which sets the rules for access to water and provides funding for projects;
- Southern Rural Water – administers private diversion licences on the Gellibrand River and groundwater licences; and
- Wannon Water – the largest water user in the Gellibrand catchment and the implementing agency for augmentation options.

A working group from these four organisations oversaw the production of the Alluvium 2012 report (cf. Section 1.2) and will review this report. Implementation of any recommendations from this report that involve new capital works is likely to be dependent on government funding.

Community stakeholders with an interest in the Gellibrand Riverine environment include:

- Landowners, Landcare and other environmental community groups;
- Colac Otway Shire as the responsible planning authority and
- Wathaurung Aboriginal Corporation as Registered Aboriginal Party (RAP) for the area.

A Consultation Plan needs to be developed to ensure all the stakeholders are aware of the studies currently undertaken and the environmental benefits of further progressing some or a number of the options to improve summer flows in the Gellibrand River.

3. Options Analysis

3.1 Options Overview

The September 2012 Alluvium Report discusses a number of possible options for augmenting summer low flows in the Gellibrand River. These options are as follows with further detail provided in Appendix B (note that option labelling is changed for the purposes of this report):

Current

Current arrangements for accessing water from the Gellibrand, with no augmentation of summer low flows. The existing Carlisle River bores are there for contingency or to achieve required volumes if the Bulk Entitlement rules restrict river extractions during very low flow periods.

N6 – North Otway bores 6 ML/d

The existing Carlisle River bores (which are located at North Otway) could be run at 6 ML/d (the licenced volume) during summer low flow periods. This groundwater could be supplied into the North Otway pipeline in place of water extracted from the river.

N12 - North Otway bores 12 ML/d

Implement groundwater substitution of up to 12 ML/d at North Otway. Alluvium 2012 and GHD 2010 assume this will require a new borefield, however, the two existing Carlisle River bores can be run at 6ML/d each. (This will require amendment of the extraction licence to double the licenced extraction rate and remove the drawdown trigger level. Costing for this option includes a monitored trial and hydrogeological investigation associated with the licence amendment).

N20 - North Otway bores 20 ML/d

Construct an additional borefield at North Otway so that up to 20ML/d of groundwater is input during summer low flow periods. Note that this is the capacity of the North Otway pipeline. (The new borefield will supply 8 ML/d, and combine with option N12.)

N6 C18 - North Otway bores 6 ML/d + Curdievale bores 18 ML/d

Combine Option N6 with construction of a new borefield at Curdievale so that up to 18ML/d of groundwater is input to the South Otway pipeline and 6 ML/d into the North Otway pipeline during summer low flow periods. Note that the capacity of the South Otway pipeline is 18 ML/d.

N6 S18 - North Otway bores 6 ML/d + South Otway bores 18 ML/d

Combine Option N6 with construction of a new borefield at South Otway so that up to 18ML/d of groundwater is input to the South Otway pipeline and 6 ML/d into the North Otway pipeline during summer low flows.

NW - North Otway Offstream Storage to allow Winter Flow Harvesting up to 20 ML/d

Construct a new 1,000 ML offstream storage and offtake pipeline at North Otway. The best location for this storage is 2.5km from the river. This would allow winter flow harvesting to replace summer extractions at North Otway, representing up to a 20 ML/d augmentation of summer low flows.

NW C18 - Offstream Storage (up to 20 ML/d) and Curdievale 18ML/d

This is a combination of options NW and C18.

Alluvium 2012 gives modelled benefits for the above options that are reported in Table 2 below.

Additional to the options listed in Alluvium 2012, a new 10ML/d bore was constructed at Curdievale in 2014, to cater for future growth and as an interim emergency water source for Warrnambool (designed to run with an existing diesel pump for short periods). This leads to:

C10 - Curdievale bore 10 ML/d

Up to 10 ML/d of groundwater is input to the South Otway pipeline at Curdievale during summer low flow periods. This would require equipping of the existing emergency bore with an electric pump, balancing tank, pump station and SCADA controls. It would also require a cooling tower to reduce the temperature of the 42.5 degree groundwater and construction of a new bore in 2030, which is when the emergency bore is expected to be needed for system augmentation due to forecast growth in demand.

Other options considered in this current report are:

S6, S12, S18
Construction of between one and three bores adjacent to the South Otway pipeline at Valley View Road, with each bore expected to yield 6 ML/d.

N12 S6, N12 S12, N12 S18, N20 S18 – Combination of the above options
These new options were not assessed in the Alluvium report; however it is possible to interpolate the benefits based on the Alluvium 2012 results.

Possible Purchase of Private Diverter Licences
There is approximately 2,130ML of private diverter licences in the Gellibrand drinking water catchment. GHD(2010 “Report on Options for Enhancing Summer Flows in the Gellibrand River” made an assessment of the possible purchase of these licences and discounted this option as it is expected to have very little impact on river flows. GHD estimated that these licences extract a total of around 6ML/d in summer, with only 30% of the licenced volume being diverted in 2008/2009. Not all licence holders would be willing to sell, and those that would sell are likely to be those who make relatively little use of their licenced volume. GHD identified a high risk that licence purchases would not be realised as improved streamflows, and proposed a risk control measure of converting annual licences to winter fill licences in order to protect summer flows. This “purchase of licences” option has not been assessed and is not included in Table 2.

Note that even if Wannon Water and private licence holders ceased all diversions, farm dams (and Olangolah Weir and the West Gellibrand reservoir, which are Barwon Water storages and provide passing flows of up to 1ML/d and 5ML/d respectively) have substantially modified the river system from natural conditions. Under natural conditions, 26% of modelled flows on February and March days are less than 100 ML/day at Burrupa. This increases to 65% without Wannon Water extracting any water under otherwise “current conditions” and 83% if Wannon Water does extract water. The increase in low-flow days from 26% to 65% is largely attributable to the impact of farm dams. It is suggested that controls on the number, size or operation of farm dams in the catchment should be introduced.

Airspace – Use of air space in existing system storages
GHD (2010) considered an Airspace Option – “Modify the operating rules for existing system storages to increase extractions from the Gellibrand River during wetter months (winter and spring), with less extraction in the drier months”. This option is considered in Appendix B4. (GHD 2010 noted that this option is independent of the other options.)

In practice, the system storages are always close to 100% full on 1 December. This option will involve drawing the storages down more over summer, to a “target storage level” which is maintained for system security purposes. That is, water is needed in storages to cater for pipeline or pump failures and water contamination events that occur from time to time. The storages will be filled over winter and spring. Wannon Water is taking steps to implement this option. Compared to the last five years, this option is expected to reduce summer extractions by up to 4 ML/d. Note however that this is a short term option: as summer demands increase over time, the storages will be drawn down to target levels anyway.

3.2 Licensing Considerations

Option NW (offstream storage and winter harvesting) will require the Otway System Bulk Entitlement to be amended to increase the daily extraction limit at North Otway.

Options N6 and C10 will not require any changes to the existing groundwater licences.

Option N12 will not require an increase in the licensed volume of the existing groundwater licence. However, the licence will need to be amended to a daily extraction limit of 12 ML/d instead of 6 ML/d, and amended to remove 'cease-to pump' trigger levels in OB6 and OB8 that are currently set at 1metre above the river level.

Option N18 will require an increase in licensed volume, and Options S6, S12, and S18 will require a new groundwater licence. N18, S6, S12 and S18 will require sign off by the Minister as a change to the Permissible Consumptive Volume (PCV) will be required.

3.3 Costs for each Option

Costs for each option (including selected combined options) are given in Table 1. This draws on information for each option that is given in the appendices to this report. Common costs (as per "current conditions") are not included in the table. Full Net Present Cost calculations are given in Appendix D.

Table 1 Costs for each Option

Values below are in $thousands															
Option Number	**N6**	**N12**	**N20**	**NW**	**C10**	**C18**	**S6**	**S12**	**S18**	**combined**	**combined**	**combined**	**combined**	**combined**	**combined**
Description	**North Otway existing bores 6ML/d**	**North Otway existing bores 12ML/d**	**North Otway 2 bores 20ML/d**	**North Otway Offstream Storage 20 ML/d**	**Curdievale bores 10ML/d**	**Curdievale bores 18ML/d**	**South Otway 1 bore 6ML/d**	**South Otway 2 bores 12ML/d**	**South Otway 3 bores 18ML/d**	**N12 S6 18 ML/d**	**N12 C10 22 ML/d**	**N12 S12 24 ML/d**	**N12 S18 30 ML/d**	**N20 S12 32 ML/d**	**N20 S18 38 ML/d**
new production bores			2x150	-	-	2,000	400	2x400	3x400	400	-	800	1,200	1,100	1,500
new observation bores			2x22.5	-	-	-	6x60	6x60	6x60	360	-	360	360	405	405
Land purchase			-	40	-	50	-	-	-	-	-	-	-	-	-
Easements, site establishment			4x5	-	-	5	7x5	8x5	9x5	35	-	40	45	60	65
Submersible pump, rising main, cables			2x60	-	100	2x100	60	2x60	3x60	60	100	120	180	240	300
Site civil works			80	-	-	63	40	2x40	3x40	40	-	80	120	160	200
Transfer pipelines			300	1,500	-	10	10	2x10	3x10	10	-	20	30	320	330
Pumps & Cooling tower			-	800	575	2x575	-	-	-	-	575	-	-	-	-
Power supply			2x50	200	100	2x100	50	2x50	3x50	50	100	100	150	200	250
Switchboard and SCADA			2x100	400	140	2x140	100	2x100	3x100	100	140	200	300	400	500
Hydro assessment / Pump testing		35	35	-	-	-	100	100	100	135	35	135	135	135	135
1000 ML storage/extra works 2030		-	-	8,000	3,033	3,033	-	-	-	-	3,033	-	-	-	-
Calgon Treatment at downstream WTP's	45	45	45	-	100	100	100	100	100	145	145	145	145	145	145
Total Capital Cost (inc. 20% contingency, ex. GST)	**54**	**96**	**1,494**	**13,128**	**4,858**	**8,509**	**1,506**	**2,304**	**3,102**	**1,602**	**4,954**	**2,400**	**3,198**	**3,798**	**4,596**
Annual Operating costs															
Chlorination for Manganese	10.0	15.0	20.0				0.0	0.0	0.0	15.0	15.0	15.0	15.0	20.0	20.0
Calgon Dosing for manganese	20.0	30.0	40.0		60.0	80.0	40.0	60.0	80.0	70.0	90.0	90.0	110.0	100.0	120.0
Pumping (marginal cost above cost of pumping from river)	3.6	7.2	10.8		9.6	25.6	3.6	7.2	10.8	10.8	16.8	14.4	18.0	18.0	21.6
Personnel costs		0.0	5.0	10.0	2.5	5.0	2.5	5.0	7.5	2.5	2.5	5.0	7.5	10.0	12.5
4% pump & electric, 1 % pipeline	-	0.0	16.6	63.0	32.6	65.9	6.9	13.8	20.7	6.9	32.6	13.8	20.7	30.4	37.3
Total Annual Operating Cost	**33.6**	**52.2**	**92.4**	**73.0**	**104.7**	**176.6**	**53.0**	**86.0**	**119.0**	**105.2**	**156.9**	**138.2**	**171.2**	**178.4**	**211.4**
Values below are in $millions															
Net Present Cost	0.48	0.75	2.54	11.77	3.70	7.43	2.05	3.20	4.35	2.81	4.25	3.96	5.11	5.75	6.90
NPC per ML of installed diversion capacity	**0.080**	**0.063**	**0.127**	**0.588**	**0.370**	**0.413**	**0.342**	**0.267**	**0.242**	**0.156**	**0.193**	**0.165**	**0.170**	**0.180**	**0.181**

Notes on Table 1

N6-annual pumping	(Pumping head to deliver to the balancing tank is 60 m for the bores and 40m for the river. This leads to electricity costs of an extra $10 per ML pumped from the bores (based on 2001 estimates for the Carlisle River borefield). Assume gw substitution = 6ML/d*60 days.
N12-hydrogeological investigation	estimate from GHD, March 2014
N12-annual pumping	As per N6. Assume gw substitution = 12ML/d*60 days.
N20-new production bores	Actual 2001 cost was 100K. 150m deep bores, 300mm diameter.
N20-new observation bores	actual 2001 cost was $15K each. 150m deep bores, 100mm diameter.
N20-pump, riser, cables	actual 2001 cost was $40K each
N20-transfer pipelines	300m of DN225 and 600m of DN300 including crossing the Gellibrand; 300*200 +600*220 = 200K + 100K for river crossing
N20-power supply	both new bores are near a powerline
N20-annual pumping	As per N6. Assume gw substitution = 18ML/d*60 days.
N20-personnel costs	allow 2 hours a week at $50/hour to check on the four new bores
NW-switchboard	high lift @ 20ML/d
NW-offstream storage	GHD2010 estimate
NW-transfer pipeline and pumps	3km of DN450 @ $500/m Large pumpsets at two locations
NW-personnel costs	allow 4 hours a week at $50/hour to check on the new storage
C10-new production bore	New bore in 15 years to provide for demand growth and 10 ML reduced extraction from the River.
C10-site civil works	Assumed completed (part of emergency bore set up)
C10-power supply & switchboard	source=GHD2012
C10-pumps and cooling tower	New pump station required to deliver water into pipeline with some flow from Gellibrand River. Cooling required to bring temperature down to around 20 deg.
C10-annual pumping	Pumping costs determined using headloss calculations to determine heads and current power costs
C10-personnel costs	allow 1 hour a week at $50/hour to check on SCADA etc., and additional $10,000/yr for cooling tower
C10-pump, riser, cables	source=GHD2012
C18-new production bores	New bore now and another in15 years time to provide for demand growth and 18 ML reduced extraction
C18-site civil works	source=GHD2012
C18-pumps and cooling tower	New pump station required to deliver water into pipeline with some flow from Gellibrand River. Cooling required to bring temperature down to around 20 deg.
C18-transfer pipelines	source=GHD2012; assumes new Curdie Vale bore is adjacent to South pipeline and injects straight into it
C18-annual pumping	Pumping costs determined using headloss calculations to determine heads and current power costs
C18-personnel costs	allow 2 hours a week at $50/hour to check on SCADA etc., and additional $20,000/yr for cooling tower
S6, S12, S18-new production bor	500m deep bores; 200mm diameter
S6, S12, S18-new observation bo	300-500m deep bores; 100mm diameter
S6, S12, S18-transfer pipelines	240m of DN225; 480m of DN300; 240*200 +480*220 = 150K
S6, S12, S18-power supply	the new bores are all near the powerline
S6, S12, S18-annual pumping	Extra $10 per ML pumped from the bores cf. river (based on 2001 estimates for the Carlisle River borefield). Assume gw substitution = (6,12,18)ML/d*60 days.
S6, S12, S18-personnel costs	Allow (1,2,3) hours a week at $50/hour to look after the new bores

3.4 Selection of Combined Options

The costings in Table 1 show:

- Options N6 and N12 (which use the existing bores) have low capital cost and should therefore be implemented before other options are considered. N12 has the lowest NPC per ML.
- Option N20 has lower capital cost than other options with similar diversion capacity (i.e. NW, C18, S18). N12 or N20 therefore form a part of all combined options that are further considered.
- Option C10 (10 ML using existing Curdievale bore and constructing another bore in 15 years to meet demand growth requirements) has a lower NPC per ML than S6 (one South Otway bore) but significantly higher capital cost. S12 and S18 are both lower in NPC per ML with greater benefits and this is reflected in the combined options that are further considered.
- The costs of Options N12 and S6 combined are significantly lower capital cost than either C18 (additional Curdievale bore) or S18 (three South Otway bores) with similar benefits. N12 and S6 also has an NPC per ML similar to N20 (0.168 compared to 0.127) and should be further considered.
- Options N12 and S12 combined provide slightly greater benefit in flows at a similar NPC per ML (0.180 compared to 0.176) than N12 and C10 combined. Thus N12 and S12 could be progressed before N12 and C10.
- Options N12 and S18 combined provide similar benefit in flows at a lower NPC per ML (0.180 compared to 0.186) than N20 and S12 combined. Thus N12 S18 could be progressed before N20 and S12.

Table 2 summarises the benefits of each option, with reference to the Alluvium 2012 results. The “estuary benefit” in Table 2 is based on the percentage of modelled flows on February and March days that are below 100 ML/d at Burrupa (Alluvium 2012 Table 4), reported as improvement over current conditions. The “freshwater reach benefit” in Table 2 is based on the percentage of modelled flows on February and March days that have moderate environmental risk (Alluvium 2012 Table 11), reported as improvement over current conditions. Wannon Water has two pumping stations on the Gellibrand River; changes in extractions at the north pumping station will affect the upper and lower freshwater reaches and the estuary, while changes at the south pumping station will only affect the lower freshwater reach and the estuary. Table 2 gives a “combined benefit metric” which combines the estuary benefit (a whole number between 0 and 57) with the freshwater benefit (a decimal to two significant figures between 0.00 and 0.16). The intention of this combined metric is to allow both estuary and freshwater benefit to be seen at a glance. The whole number portion is the estuary benefit and the fraction is the freshwater benefit.

Table 2 Benefits for Selected Options

	Modelled Natural Conditions	Current Conditions	N6	N12	N20	N12 S6	N12 S12	N12 S18	N20 S18
Comment	All onstream storages, farm dams and extractions removed				Full substitution/ no low-flow extractions at NOPS		Full substitution/ no low-flow extractions at SOPS		Full substitution/ No low-flow extractions at NOPS and SOPS
Project Benefits									
Proportion of Feb/Mar days below 100 ML/d at Burrupa (Alluvium 2012 Table 4)	26%	83%	78%	74%	73%	73%	70%	68%	65%
Improvement over current ("**Estuary Benefit**")	**57**	**0**	**5**	**9**	**10**	**10**	**13**	**15**	**18**
Proportion of Feb/Mar days of moderate environmental risk (SOPS to Burrupa) (Alluvium 2012 Table 11) ("Lower freshwater reach risk")	0%	8%	3.9%	1.7%	0%	0%	0%	0%	0%
Improvement over current **(Lower freshwater reach benefit)**	**0.08**	**0.00**	**0.04**	**0.06**	**0.08**	**0.08**	**0.08**	**0.08**	**0.08**
Proportion of Feb/Mar days of moderate environmental risk (NOPS to SOPS) ("Upper freshwater reach risk")[1]	0%	8%	3.9%	1.7%	0%	1.7%	1.7%	1.7%	0%
Improvement over current **(Upper freshwater reach benefit)**	**0.08**	**0.00**	**0.04**	**0.06**	**0.08**	**0.06**	**0.06**	**0.06**	**0.08**
Combined benefit metric[2]	**57.16**	**0.00**	**5.08**	**9.13**	**10.16**	**10.14**	**13.14**	**15.14**	**18.16**
Net Present Cost (from Table 1)			**$0.48m**	**$0.75m**	**$2.54m**	**$2.81m**	**$3.96m**	**$5.11m**	**$6.9m**

Notes: The "Proportion of Feb/Mar days below 100ML/d" is given in Alluvium 2012 Table 4 for modelled natural, current, N6, N12, N20, and N20 S18 conditions. The "Lower freshwater reach risk" is given in Alluvium 2012 Table 11 for modelled natural, current, N6, N12, N20, and N20 S18 conditions. Values for the modelled conditions for N12 S6, N12 S12, and N12 S18 are interpolated.

2. The values for "upper freshwater reach risk" assume that the Table 11 risks as calculated at Burrupa apply equally to the upper reach.

3. The combined benefit metric is calculated as: Estuary benefit + lower freshwater reach benefit + upper freshwater reach benefit.

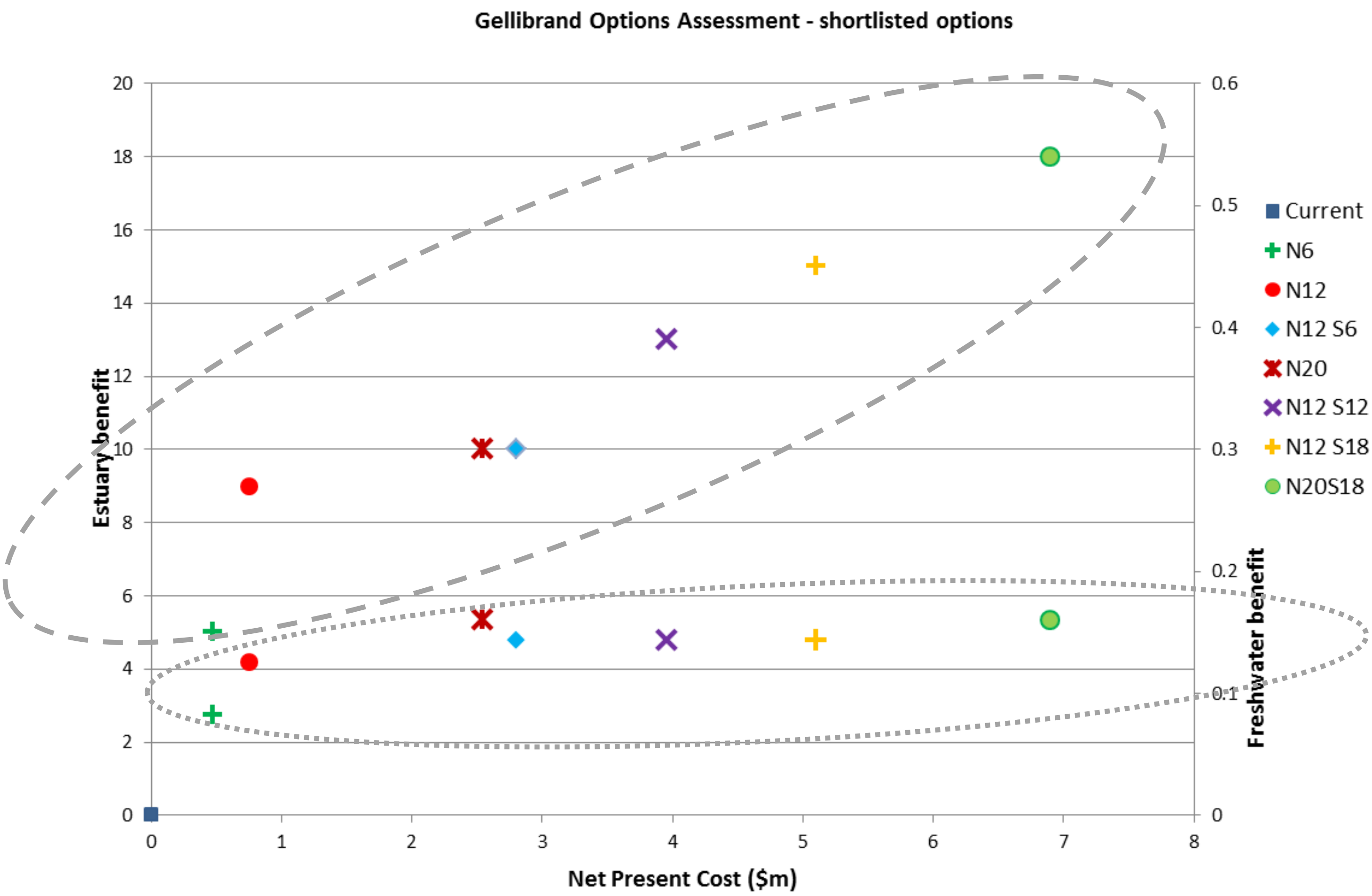
4. GHD2014 associates N6 with approximately 10% depletion of river flows. N12 is also subject to depletion of river flows. This is not accounted for in the above table as the percentage is an estimate.

3.5 Benefit vs. Cost Analysis

A benefit vs cost analysis for selected options is shown in Figure 2. Two sets of benefits are plotted on the figure – estuary benefits are circled by a dashed line; freshwater benefits are circled by a dotted line. It can be seen from the figure that estuary benefit increases as option cost increases; however the marginal freshwater benefit for expenditure beyond $1 million is low because (as reported in Alluvium 2012) risks to the freshwater environment occur infrequently in the existing flow regime. The flow regime is expected to change in the future due to climate change impacts.

Under current conditions, the risks to the freshwater environment can be virtually eliminated if groundwater substitution of 6-12 ML/d occurs at the North Otway pump station (cf. options N6 and N12, as shown in the Figure). Note that N6 and N12 are also associated with substantial estuary benefit at relatively low cost.

Figure 2 Shortlisted Options: Benefit vs Cost.



The shortlisted options are summarised in Table 3.

Table 3 Shortlisted Options

Option	Description	groundwater substitution capacity (ML/d)	Relative benefit to estuary	Capital Cost ($m)	Net Present Cost ($m)	NPV/ML installed capacity ($m/ML)
Current	No change from current conditions	0	0	0	0	0
N6	The existing Carlisle River borefield (located at North Otway) could be run at 6 ML/d during summer low flow periods without breaching existing licence conditions.	6	5	0.05	0.48	0.080
N12	The existing Carlisle River borefield could be run at 12 ML/d during summer low flow periods if existing licence conditions are amended.	12	9	0.10	0.75	0.063
N12 S6	In addition to N12, input up to 6 ML/d of groundwater to the South Otway pipeline during summer low flow periods.	18	10	1.60	2.81	0.156
N20	In addition to N12 construct two new bores at North Otway so up to an additional 8 ML/d is input during summer low flow periods. This will allow full groundwater substitution at North Otway.	20	11	1.49	2.54	0.127
N12 C10	In addition to N12, input up to 10 ML/d of groundwater to the South Otway pipeline at Curdievale during summer low flow periods.	22	12	4.95	4.25	0.193
N12 S12	In addition to N12 & S6, construct one more bore at South Otway so up to an additional 6ML/d is input during summer low flow periods.	24	13	2.40	3.96	0.173
N12 S18	In addition to N12 & S12, construct one extra bore at South Otway allowing an additional 6ML/d to be input to the South Otway pipeline during summer low flow periods. This will allow full groundwater substitution at South Otway.	30	15	3.20	5.11	0.170
N20 S18	In addition to N12 & S18, construct two more bores at North Otway. This will allow full groundwater substitution at both locations during summer low flow periods.	38	18	4.60	6.90	0.181

Note: * GHD2014 associates N6 with approximately 10% depletion of river flows. N12 and N20 are also subject to depletion of river flows. This is not accounted for in the Table as the percentage is an estimate.

The relative benefit to estuary shown in Table 3 is modelled for 2012 conditions. As summer demand, and hence extractions increase into the future, the relative benefit of greater installed capacity to substitute groundwater will increase.

Full capacity of the Otway System includes use of the existing Carlisle River bores at up to 6 ML/d to supplement (rather than substitute for) river extractions. This occurs when extractions are restricted to less than 15ML/d due to low flow in the river. This was allowed for in Alluvium 2012.

The capital cost of Option C10 does not include the cost of the recently constructed10ML/d bore at Curdievale but does include the cost of equipping the bore for production, cooling and injecting into the south Otway pipeline. Allowance has been made in the costs for the installation of an additional bore and associated works in 2030 to cater for increasing demands while providing for the substitution of river water during summer low flow periods.

It should be noted that groundwater substitution utilising bores at Curdievale of more than 10ML/d post-2030 would require Southern Rural Water to increase the Permissible Consumptive Volume for this aquifer system, prior to the construction of a second Curdievale bore.

The Benefit/Cost analysis concludes that using the existing bores at North Otway to substitute up to 12 ML/d during the low flow period is the most cost effective option resulting in significant improvement to both the upper and lower reaches and the estuary of the Gellibrand River.

3.6 Option Risks

There is a risk for all options that the water gains in the Gellibrand River are simply extracted by other users (irrigation) under existing extraction licences and flow sharing rules. Thus, implementation of any of these options would need to include an adjusted flow management regime with associated education and monitoring.

The options to increase the volume of water substituted are essentially around whether the water comes from the North or South Otway areas or Curdievale. This section examines the relative risks associated with these three locations.

North Otway

GHD (2006) identifies that the aquifer is relatively shallow in this location and interconnection with the River is likely. The groundwater flow through the aquifer is in a southerly direction to the ocean with an estimated 7,400 ML/year through flow at the North Otway location. Wannon Water’s experience is that the river gains approximately 20 ML/d flow between the North and South Otway offtakes during summer months supporting the fact that recharge of the river from groundwater occurs between these two locations.

Although development of another 8 ML/d is very small compared to the through flow and the proposed bore locations are around 500 m from the river, there is a risk that the groundwater recharge of the river may be impacted by this extraction. The risk of causing localised impact on springs and groundwater dependent ecosystems is also greater here than where the aquifer is deeper (South Otway).

Other risks at this location such as loss of power, fire damage and flooding are similar to the South Otway location but greater than Curdievale.

South Otway

GHD (2006) identifies that the aquifer is deeper at this location than at North Otway and has an overlying aquitard – refer appendix E for cross section of this aquifer that shows the aquitard. Thus, it is less likely to be as significant a recharge source for the river compared to the North Otway location. Thus, the extraction of water from this aquifer has a lower risk of impacting river flows than the North Otway location.

For the same reasons, the risk of impacting on springs and groundwater dependent ecosystems is lower.

The South Otway location is not proven and these options include preliminary investigations to better understand the characteristics of the aquifer and water quality. There is a risk that the aquifer characteristics are not as expected with lower yields and/or poor quality water resulting in these options not being viable.

Other risks at this location such as loss of power, fire damage and flooding are similar to the North Otway location but greater than Curdievale.

Curdievale

Curdievale bore accesses the lower tertiary aquifer at a depth of around 800 m which has a groundwater flow generally to the south and is thought to discharge to the ocean well offshore. For these reasons the risk of impacting any rivers or groundwater dependent ecosystems is far lower than either of the Otway locations.

The water temperature of around 42º C presents a risk of algal blooms and increased slime growth. This is addressed in part by including a cooling tower in the capital works but there is still an underlying higher risk of algal blooms in the downstream storages where this water is stored before treatment. The inclusion of more pumps and cooling towers presents a greater risk of mechanical breakdown compared to the North and South Otway locations.

The water has a higher salinity level compared to the North and South Otway location options but still below the 500 mg/l aesthetic limit for potable use. There are implications for industrial uses with increased salinity that would need to be explored as part of introducing this water source. Until the new bore is "pump tested" there is still a risk that some water quality parameters may present operational problems.

The risk of power loss and fire damage is still present at this site but lower than at the Otway sites. There is no flooding risk at this site.

3.7 Conclusions from Option Analysis

The shortlist in Table 3 provides information to assist the decision regarding which option to implement. Possible capital expenditure ranges from $0 to $4.6M, with the benefit to the estuary increasing as expenditure increases.

Alluvium (2012) recommended that 6 ML/d of augmentation at North Otway Pump Station should be pursued as a starting point to improve environmental values in the system. Alluvium was influenced by advice regarding the existing licence conditions. On review, the existing North Otway bores are capable of pumping 12 ML/d over the two driest months every year with no problems anticipated apart from possible minor interference with river inflow from groundwater (as documented in GHD 2009) and the lowering of groundwater levels below the existing "turn off" trigger. To implement this option, the extraction licence would need to be amended and the level condition relaxed. Figure 2 and Table 3 show environmental benefits that result from amendment of existing licence conditions. It should be noted that when the condition was put in place, it was a safeguard against impacting the river flows from groundwater extraction as a precautionary approach. This option substitutes extraction from the river with groundwater meaning that the river will be better off even if there is some reduction in natural flow from groundwater to river. This report therefore recommends that 12 ML/d of augmentation at the North Otway pump station (achieved by simultaneous operation of both existing bores during summer low-flow periods) be pursued as a starting point to improve environmental values in the system. The only cost for option N12 is for the monitoring and hydrogeological investigation to confirm that localised environmental impacts are small and the installation of chemical dosing at a number of Wannon Water treatment plants to manage the impact of the higher manganese level in the bore water.

Beyond implementation of Option N12, expenditure of approximately $1.5M would allow construction and testing of a new bore at South Otway to substitute an estimated 6 ML/d. Option S6 involves a new borefield in a location that has acknowledged groundwater potential and, as discussed above, has lower risks of river interference than the North Otway option N20. Establishment of new observation bores and investigative pump testing are substantial components of this option to ensure there is no detrimental impact on the river or groundwater dependant ecosystems as the first step estimated to cost $0.25M.

Although utilising the Curdievale bore could be done at a cost of $1.2M, its long term use would require an additional $3.6M in 2030 making it a long term less attractive option than the other combined options shown in Table 1. It should be noted that this bore was installed to provide security of supply to the region in the event of an Otway fire or other emergency that renders the Gellibrand River water unusable and to meet system growth demands beyond 2030. Sourcing additional water from the South Otway area preserves the benefits of the Curdievale bore investment.

Analysis presented in Appendix B4 shows that over the last five years, Otway storages have been operated at high levels over summer. Independent of the other options considered here, Wannon Water will aim to keep its storages closer to the target curve. In a dry year, this may represent an additional 3 – 4 ML/day less extracted from the Gellibrand River over summer and autumn (with this volume extracted over winter and spring instead).

Note however that this is a short term option: as summer demands increase over time, the storages will be drawn down to target levels anyway. (Target storage levels are water needed in storage to cater for pipeline or pump failures and water contamination events that occur from time to time.)

The next step in this work will be a 2016 meeting of the partner agencies to discuss the implementation process.

4. References

Alluvium 2012. "Assessment of the environmental benefits and risks of flows below the summer low flow recommendation in the lower Gellibrand River". Report prepared for Corangamite Catchment Authority.

GHD 2006. Report for Newlingrook GMA Review of Groundwater Resources. Report prepared for the Department of Sustainability and Environment.

GHD 2006. Carlisle River Bores - Hydrogeological Review. Report prepared for Wannon Water.

GHD May 2009. Carlisle River Borefield Part B – Pumping Test Results. Report prepared for the Corangamite Catchment Management Authority. GHD April 2010. Options for Enhancing Summer Flows in the Gellibrand River. Report prepared for the Corangamite Catchment Management Authority.

GHD 2012. Report for Curdievale Borefield Business Case. October 2012. Report prepared for Wannon Water.

GHD 2014, "Carlisle River/Gellibrand Borefield 5 yearly review". Report prepared for Wannon Water.

SKM March 2007. Task 1 – Review of Plumatella Control and Disinfection at Gellibrand Main Pump Station. Final Report. Report prepared for Wannon Water.

SKM April 2007. Newlingrook and Gellibrand GMA Groundwater Investigation Scoping: Final Report. Report prepared for Barwon Water.

SKM 2008a, Newlingrook Groundwater Investigation: Bore Completion Report. Report prepared for Barwon Water.

SKM 2008b. Newlingrook and Gellibrand Groundwater Investigation: South Newlingrook Observation Bore Assessment. Final Report September 2008. Report prepared for Barwon Water.

SKM 2012. Newlingrook Groundwater Investigation: Gellibrand River Streambed and Baseflow Assessment. December 2012. Report prepared for Barwon Water.

SMEC 2003. The Development and Evaluation of Augmentation Options for the Otway Water Supply. Report prepared for Wannon Water.

Wannon Water 2015. Carlisle River Bores – Report on 6ML/d Five Month Trial.

Appendix A Notes regarding treatment of source water

Raw water from Arkins Creek (which runs over approximately four months of the year) is currently not treated before it enters Wannon Water pipelines. Up to 2013, raw water from the Gellibrand River at NOPS was chlorinated to maintain a free chlorine residual concentration of 2.5 mg/L at the pump station discharge over the balance of the year (approximately 8 months per year). This strategy was effective in limiting biofilm build-up (plumatella) in the North Otway pipeline (SKM March 2007). As of 2014, dosing for Plumatella control occurs on an intermittent basis at 1.5mg/L one week on, three weeks off. (This change was made to improve operating efficiency).

The Arkins Creek section of the North Otway Pipeline has historically been swabbed from the weirs to the 16 Mile valve where a swab removal facility is located. The section from Tank Hill to Warrnambool Storage has also been swabbed but other sections have not been swabbed regularly since 1990.
Raw water at SOPS is not treated. Biofouling in the South Otway Pipeline has historically been managed by swabbing the pipeline every year. Swabbing of the pipeline has not occurred over the last 6 years due to concerns regarding the disposal of swab water. Reintroduction of regular swabbing for both pipelines is being investigated.

A five month trial of the Carlisle River borefield occurred in Summer/Autumn 2015 (Wannon Water 2015). The severe iron slime issues that occurred in the balancing tank during borefield operation in 2002 and 2003 did not reoccur during the trial. It is thought that these previous issues may have been due to iron bacteria that are no longer affecting the site. The higher iron levels in the North Otway Pipeline that resulted from the trial are above aesthetic limits but are considered to be tolerable. However towards the end of the trial period, staining and fouling occurred at Camperdown, Simpson and Terang Water Treatment Plants. Staining was also noticed by some supply by agreement customers on the pipeline. The staining is affected by the water quality in the mix of source waters, which varies from year to year and by location, but it is clear that the staining is related to high soluble manganese levels in the Carlisle River bores.

The following actions are recommended to reduce the staining and fouling issues associated with potential future operation of the Carlisle River borefield (Wannon Water 2015):

- Limiting groundwater substitution to periods when flows at Burrupa are less than 100ML/d;
- Continuous dosing of chlorine into the North Otway Pipeline during borefield operation (at an operational cost of $10 000 - $20 000 per year);
- Introduction of calgon dosing at Simpson, Camperdown and Terang (at a capital cost of $45 000 and an operational cost of $20 000 - $40 000 per year).
- Introduction of calgon dosing at Warrnambool (at a capital cost of $100 000 and an operational cost of $40 000 - $80 000 per year).
- If iron slime in the balancing tank reoccurs (which is considered unlikely), annual “Clear Bore” treatment of the bores to kill the bacteria may be enough to manage the iron fouling problem. (This cost has been removed from the calculations in this report as of September 2015).

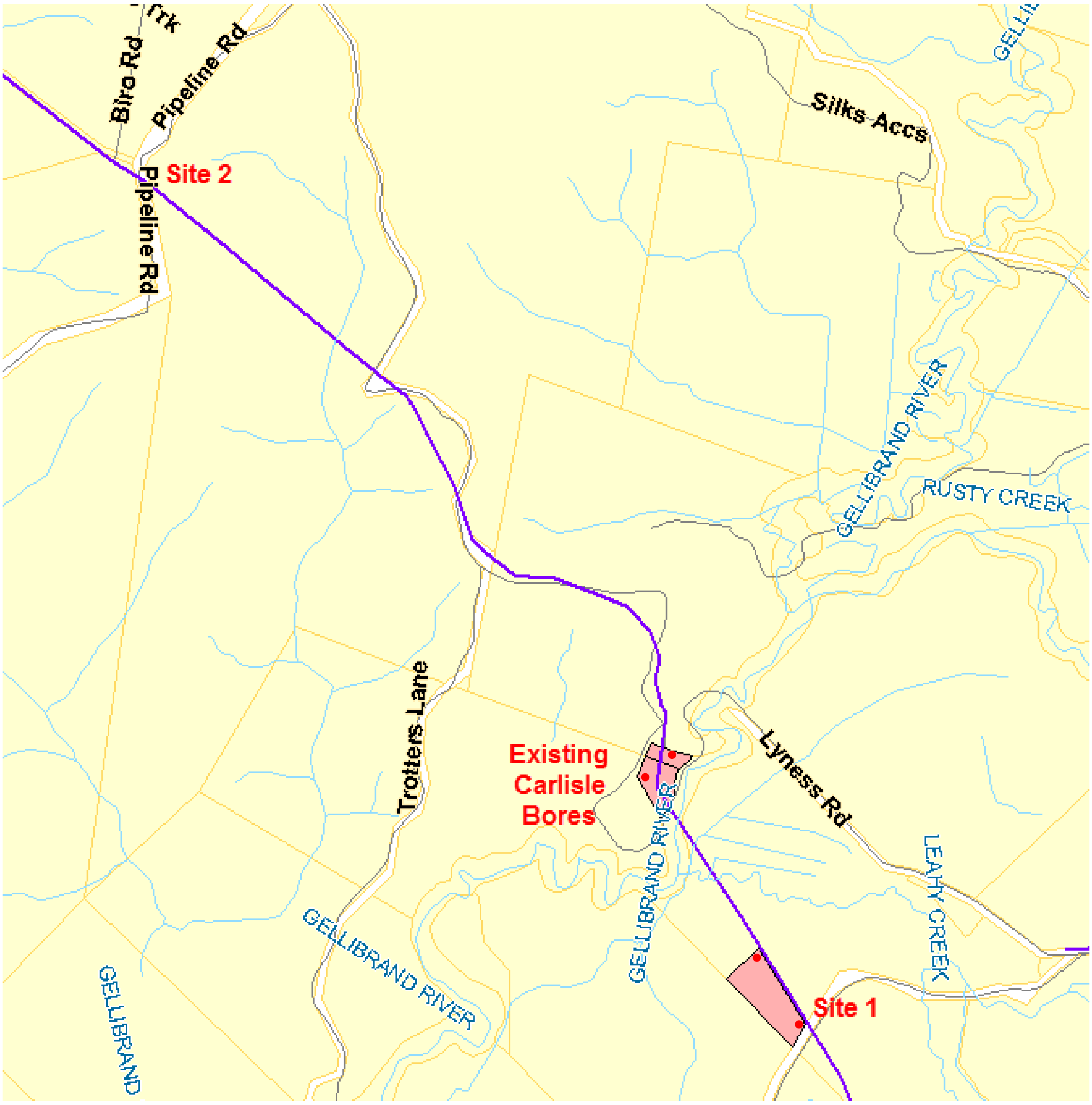
There is no information available regarding the quality of groundwater at South Otway. There is a risk that it may be high in salinity or some other parameter. The only way to confirm this is via the investigation program associated with the S6 option. However, beyond the costs of these investigations, the options evaluation assumes that the quality of this source water will be similar to that of the North Otway bores and acceptable for potable supply.

The other raw water source considered in this report is deep groundwater at Curdievale. The temperature of this water has been measured at 42.5º C and the water quality has been assessed as meeting Australian Drinking water Guidelines. There is a significant risk of algal blooms in the Warrnambool storages receiving this water due to temperature increases. Accordingly, this option includes cooling the water to around 20º C. before it is pumped to the Dales Road Storage, where it will

mix with other source water before being treated in the Warrnambool Water Treatment Plant.
It is noted that low-volume sampling of Curdievale bore in March 2013 showed soluble Manganese of 0.02 mg/L, which is higher than river water and may lead to staining problems. An allowance for calgon dosing at Warrnambool (at a capital cost of $100 000 and an operational cost of $60 000 - $80 000 per year) is costed in to the Curdievale options.

Appendix B Augmentation Options: Location Maps and Option Details

B1. Options N12 and N20. North Otway bores 12 ML/d or 20 ML/d



Option N12 (North Otway bores 12 ML/d) involves use of the two existing Carlisle bores at 6ML/d each.

Option N20 (North Otway bores 20 ML/d) involves use of the existing Carlisle bores at 12ML/d, plus two bores at site 1 (one at the Gellibrand River Road; the second 280m to the north, as shown in the above figure).

The two existing Carlisle bores are located at the North Otway Pump Station and are 75 metres and 125 metres from the river. Based on 10m contours, the bores are at RL 55m and the river here is at RL 25m. These bores can each run at 6ML/d. Currently only one bore is run at a time to meet the existing licence condition and to avoid drawdown to the trigger level in the nearby observation bores. Note that the existing bores are about 135 metres deep with 300 mm diameter pump casing to 80 metres and 219mm diameter production strings.

Site 1 is at the Carlisle River Residence on the Gellibrand River Road. The road is at RL45m and the site is 400m from Leahy Creek and 900m southeast of the existing bores.

Option N12 assumptions:

Pumping head to deliver to the balancing tank is 60 m for the bores and 40m for the river. This leads to electricity costs of an extra $10 per ML pumped from the bores (based on 2001 estimates for the Carlisle River borefield).

- A monitored trial and hydrogeological investigation (costed by GHD at $42 000 including 20% contingency) will be carried out to confirm that localised environmental impacts of the increased pumping rate are small.

Option N20 assumptions: as for Option N12 except:

- A bore drilled on the Gellibrand River Road in this vicinity will sustainably yield 4ML/d (45 L/s).
- Allow for two new observation bores near the production bores. Note that the existing Carlisle River Observation bores (especially Obs 8) will also serve this site.
- Bore depth 150m, bore diameter 300mm for production; 100mm for observation.
- Water from the two new production bores is piped into the balancing tank adjacent to the existing Carlisle bores. (300m of DN225 pipeline; and 600m of DN300 pipeline, including a crossing of the Gellibrand River).

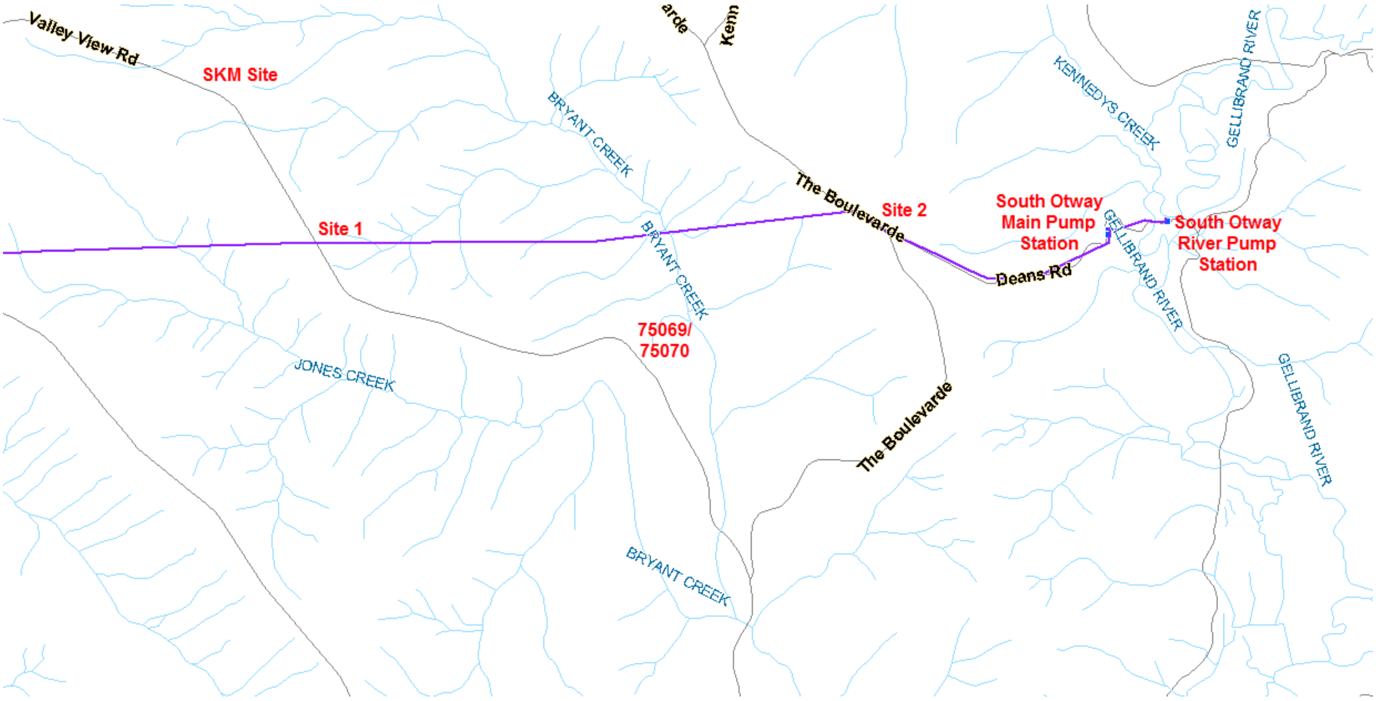
Note that the two proposed new North Otway bore sites are close to power lines. This will minimise the cost of providing site power.

SKM2007 discusses a “river site” near the existing Carlisle River bores and maps the Princetown syncline though Carlisle River. Site 1 is near the syncline so yields are likely to be high but the river site has connectivity with the river, which may lead to limitations on the licence similar to those for the existing Carlisle River bores. There is a risk that Option N20 may (after sustained pumping, say 20 days or more) draw groundwater levels down below the level of the river. However this situation would be temporary and the aquifer would be fully replenished every winter.

Site 2 is at Pipeline Road. The site is RL240m and 2.8 km northwest of the existing bores. Note that this is the high point on the North Otway Pipeline (except for Arkins Creek, which is at RL 340m).

Note that SKM2007, 2008a investigated the “anticline site”. This site corresponds with site 2 and has low hydraulic connectivity to the river, which is the key advantage of the site. However SKM2008a gives bore completion reports and gamma logs for three observation bores at this site (constructed 2008) which indicate that there is very little water bearing strata. At obs 1, the sands at about 40 metres depth do not produce any water. Bedrock is at 55 metres. The standing water level of 93 metres below ground level is down too far for airlift. Based on the SKM2008a results, it is very unlikely that the target yields of 5.5 ML/d per bore can be achieved at site 2.

B2. Options S6, S12 and S18. South Otway bores 6, 12 or 18 ML/d



The South Otway River Pump Station and Main Pump Station are on Deans Road near the Gellibrand River Road. This is close to the Gellibrand River/Kennedys Creek confluence. Based on 10m contours, the river here is at RL 15m. The South Otway Pipeline runs east-west as shown in the above figure, past Valley View Road and the Boulevarde.

Note that this region has been the subject of desktop studies (GHD 2006, SKM2007). The potential bore yields are unknown but are estimated for the purposes of this assessment as 6ML/d (70 L/s) per bore. This estimate is expected to be refined after test drilling and test pumping.

SKM2007 recommends a site for construction of a 500m deep, 200mm diameter production bore that is shown as the “SKM site” in the above figure. This site is RL95m, 5.5km from the South Otway Main Pump Station. The SKM site was chosen as the location most likely to yield high groundwater volumes while minimising interactions with the Gellibrand River. The aquifer at this location is deeper than the NOPL location and anticipated to be less connected to the river.

Option S6, S12 and S18 (South Otway bores 6, 12 or 18 ML/d) involves the construction of one to three production bores at or near site 1. Site 1 is located where the pipeline crosses Valley View Road. This site is at RL100m and is 1km south of the “SKM site”, 4.7km from the main pump station and 4.9km from the Gellibrand River. This site was chosen to be close to the SKM site while minimising to length of transmission pipelines.

Site 2 is located where the pipeline crosses the Boulevarde. The site is at RL 110m and is 1.4 km from the main pump station and 1.6km from the Gellibrand River.

The high point on the South Otway pipeline is further to the west at Plantation Road, at RL120m.

Assumptions:

- Each bore drilled in the South Otway vicinity will sustainably yield 6ML/d (70 L/s).

- Any iron fouling issues can be dealt with by annual treatment with clearbore at a cost of $5 000 per year per bore.
- Water extracted at the new bores can be injected directly into the South Otway pipeline at a static head of (120 -100 =) 20m.
- Pumping head is 20m greater for pumping from the bores compared to pumping from the river. This leads to electricity costs of an extra $10 per ML pumped from the bores (based on 2001 estimates for the Carlisle River borefield).
- Allow for six new observation bores.
- Bore depth 500m, bore diameter 200mm for production; 100mm for observation.

Note that Site 1 is close to 7kV power lines (and site 2 is close to 22kV power lines). This will minimise the cost of providing site power.

There is a risk that groundwater may be high in salinity. Water quality testing should be done at all stages of the pilot bore investigation program. Until this testing occurs, for the purposes of options evaluation, it is assumed that salinity will be acceptable for potable supply.

There is an existing nested state observation bore site consisting of bores 75069 and 75070 that is 4km southwest of the South Otway Main Pump Station. 75069/75070 is at RL 70m, with constructed depth/diameter of 300m/100mm and 47m/unknown. SKM 2008b conducted a pump test at 75069 and found:

- 75069 screens the Pebble Point Formation (this is the target aquifer for the proposed production bore). Water levels show seasonal fluctuations generally less than 20cm. A slight decline (20cm) in water levels has occurred between 1999 and 2008.
- 75069 had to be pumped at very low rates (0.5 L/s) which is likely to be due to a combination of short screened intervals (only 3m of screen), narrow bore diameter, and fine-grained aquifer lithology. The rapid recovery observed after pumping shows that the bore is in good hydraulic connection with the aquifer and is giving accurate water level measurements. However, the casing integrity is dubious, because: i) the pump could not be lowered any further than 100m due to an obstruction in the bore, and ii) became caught when trying to lift the pump from this depth.

B3. Options C10 and C18. Curdievale bores 10ML/d or 18 ML/d

Curdievale is located about halfway between the Gellibrand River/Kennedys Creek confluence and Warrnambool. The South Otway pipeline passes through this location. Curdievale groundwater has been identified as the preferred option for a future major augmentation of Warrnambool's supply. Wannon Water constructed one bore at Curdievale yielding 10ML/d in 2014, to be available for emergency supply to Warrnambool. Option C10 would involve utilising this bore in preference to river extractions during summer months and constructing an additional bore in 2030 to allow for increased demand to be met while achieving the substitution objective of 10 ML/day – thus preserving the purpose of the existing bore. Option C18 would involve construction of two additional bores resulting in a total of 18 ML/d substitution capacity. These options also include the cost of equipping the bores and cooling the water to around 20º C and balance tanks and pump stations to inject into the South Otway pipeline. This is because the existing plan is to use the new bore in emergencies utilising an existing diesel pump, not as a fully equipped bore. As an emergency facility it would only be pumping into the pipeline without water being supplied from Plantation Road requiring smaller pumps than if it was running in combination with Gellibrand River water.

GHD 2012 Appendix C gives a cost estimate of $2m for construction of a bore yielding 10ML/d at Curdievale. This estimate covers construction costs for the bore and does not include equipping the bore or construction of pipework or other infrastructure.

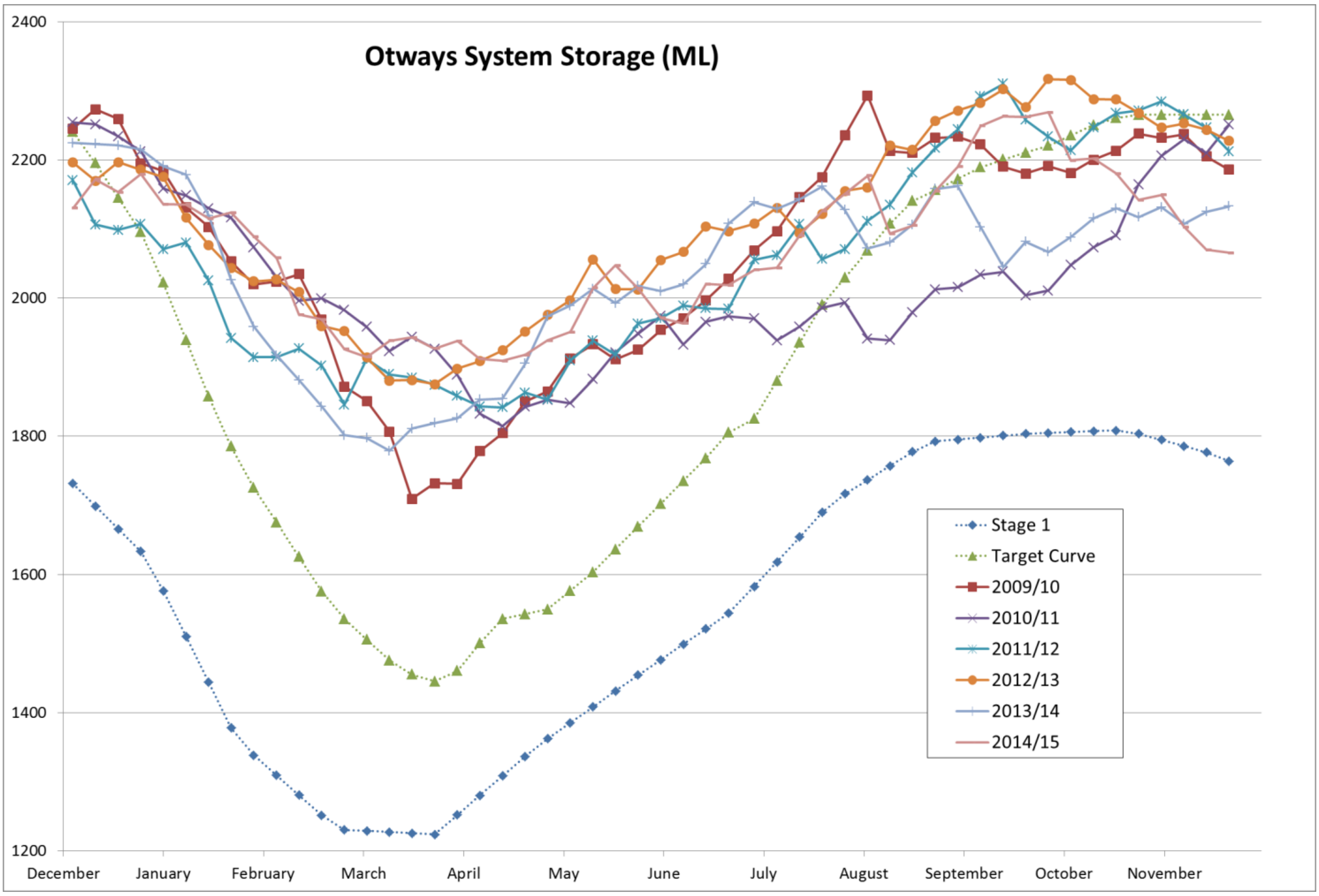
For supply of 10ML/d from Curdievale to Warrnambool, GHD2012 give the following information:
Curdievale NSL = RL 37m; Warrnambool storage FSL =RL 35.5m.
Bore pump operating head = 80m lift in the bore + 30m losses in local pipework + 30m losses in SOPL.
Pump duty = 115L/s (10ML/d) @ 140m head.
Selected submersible bore hole pump: Grundfos SP360-5D G, budget price $63 000.

GHD 2012 Appendix F gives the following cost estimates for equipping a 10ML/d production bore (not including 20% contingency):

Submersible pump, rising main, cables	$100 000
Site civil works	$ 63 000
Transfer pipelines	$ 10 000
Power supply	$100 000
Switchboard and SCADA	$140 000
Cooling tower, tanks and pumps (added by Wannon Water)	$ 575000.

B4. Airspace Option

GHD 2010 noted an Airspace Option – to Modify the operating rules for existing system storages to increase extractions from the Gellibrand River during wetter months (winter and spring), with less extraction in the drier months. This option is considered here.



The above Figure shows that for the last six years:

- Otway system storages have been full on 1 December;
- System storage levels over summer have been well above the revised target curve.

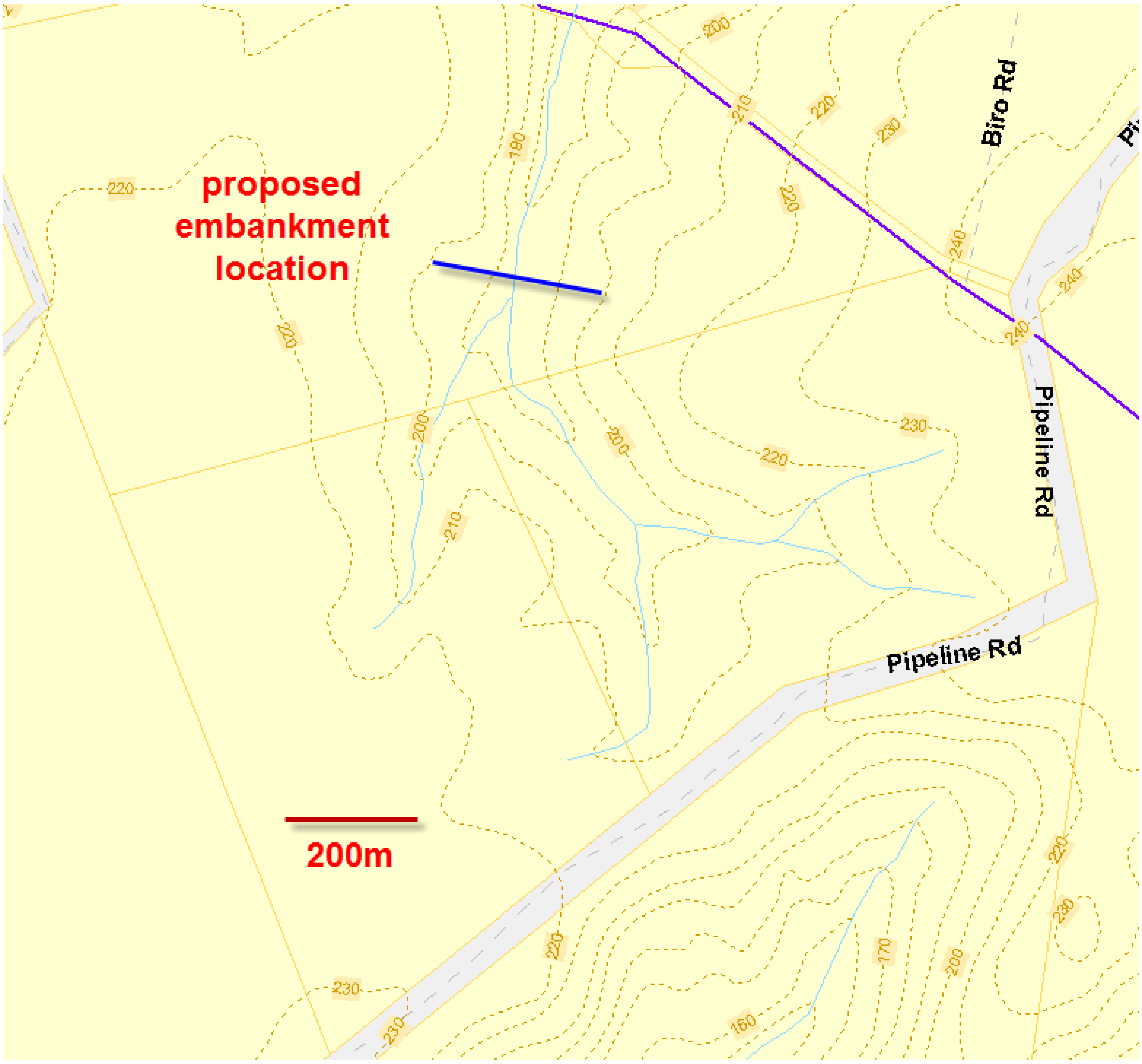
If the storages were operated at the target curve, an additional 200-400ML of drawdown would occur over summer months for these years. This represents up to 4ML/d of reduced summer extractions.

The target curve is a "target storage level" which is maintained for system security purposes. That is, water is kept in storages to cater for pipeline or pump failures and water contamination events that occur from time to time. The storages are filled over winter and spring.

Wannon Water is taking steps to further investigate this option to determine which individual storage has scope to be allowed to decline closer to their target curve. Compared to the last five years, this option is expected to reduce summer extractions by up to 4 ML/d. Note however that this is a short term option: as summer demands increase over time, the storages will be drawn down to target levels anyway.

B5. Option NW. North Otway offstream storage and winter harvesting
GHD 2010 costs a 1000 ML winterfill storage constructed about 2.5km from the Gellibrand River on the North Otway Pipeline at $8m (not including transfer pipelines and winter harvesting pumps). The $8m estimate of GHD 2010 is adopted here.

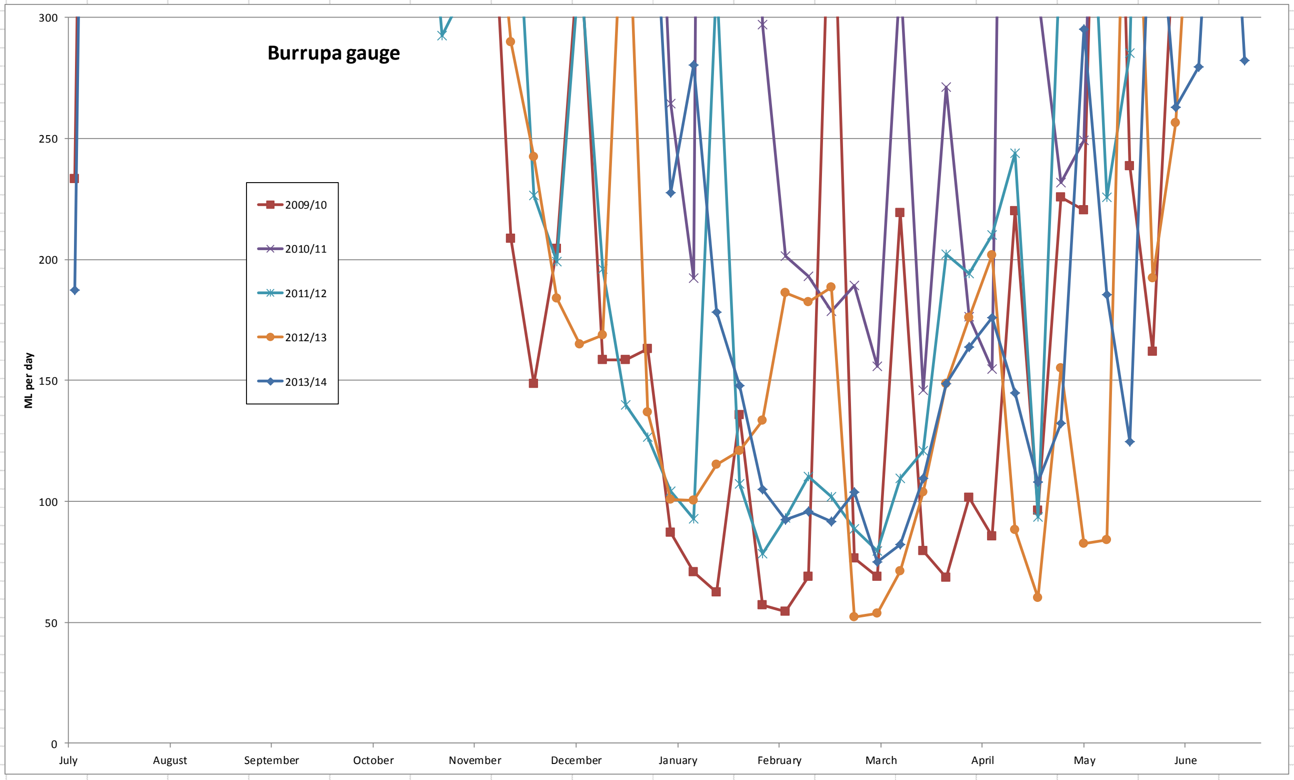
This location is shown below, along with a proposed embankment location. Note that the local catchment is cleared, but the areas northeast of the pipeline and southeast of Pipeline Road are forested. Note that the high point on the pipeline is RL240m and the FSL of the proposed 1GL storage is RL 205m, with an embankment length of 300m, embankment volume of 10 000m3 and a maximum storage depth of 20m.



Appendix C Historic Gellibrand River Flow Trends

FLOW RECORDS AT BURRUPA OVER LAST 5 YEARS

		Gellibrand @Burrupa gauge (235224)				
week	date	2009/10	2010/11	2011/12	2012/13	2013/14
1	July	233	454	908	1413	188
2	July	898	499	3451	1493	884
3	July	1555	449	2660	1138	754
4	July	503	679	1616	1021	918
5	July	620	357	1412	1944	425
6	August	1300	2777	842	942	2159
7	August	685	20147	1062	1758	3688
8	August	1268	3463	1497	1943	2245
9	August	2271	2816	638	2029	5688
10	September	3235	2632	470	2339	1106
11	September	1819	3832	556	1552	643
12	September	716	1235	465	777	698
13	September	751	806	442	658	3417
14	October	1358	808	1058	1759	1568
15	October	569	563	532	612	1362
16	October	786	725	404	1751	636
17	October	745	716	293	589	512
18	October	379	380	311	420	1565
19	November	391	1070	487	391	551
20	November	209	413	396	290	600
21	November	148	387	227	242	686
22	November	205	466	199	184	1585
23	December	333	322	323	165	459
24	December	158	1244	196	169	399
25	December	158	516	140	379	396
26	December	163	484	126	137	401
27	January	87	265	104	101	227
28	January	71	192	93	100	280
29	January	62	1591	316	115	178
30	January	136	697	107	121	148
31	January	57	297	78	133	105
32	February	54	201	93	186	92
33	February	69	193	110	182	96
34	February	383	179	102	189	92
35	February	76	189	88	52	104
36	March	69	156	80	54	75
37	March	219	318	109	71	82
38	March	80	146	121	104	109
39	March	69	271	202	149	149
40	April	102	176	194	176	164
41	April	86	155	210	202	176
42	April	220	841	244	88	145
43	April	96	310	94	60	108
44	April	226	232	335	155	132
45	May	220	249	424	83	295
46	May	581	595	226	84	186
47	May	239	497	285	460	125
48	May	162	1040	667	192	377
49	June	349	496	341	257	263
50	June	329	1606	2956	419	279
51	June	330	549	493	854	444
52	June	597	3928	1533	238	282



The above Figure shows flows at Burrupa, with flows < 100 ML/d highlighted. These low flows occur in summer and autumn, and vary from year to year. For example, flows were above the 100ML/d threshold throughout the 2010/2011 year.

HISTORIC FLOW RECORD AT BURRUPA GAUGE – 45 YEARS

fy ending:	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
July	279	1573	4125	916	908	411	564	695	10675	518	951	12107	629	377	1526	218	907	1551	2413	649	473	2369
July	894	1952	1262	2299	525	1539	1187	478	1066	3033	625	5948	2226	407	2046	1092	427	3139	686	460	859	6011
July	855	1872	1153	1346	540	1027	1607	348	1395	2688	422	1455	1161	316	1191	587	568	2241	990	593	745	1391
July	477	3057	1123	2022	1520	7435	1216	320	986	2310	455	1636	780	336	1456	895	3556	1296	2484	475	880	1416
July	1061	1467	1423	1154	630	4155	755	265	6166	2033	563	1166	1744	313	1164	1565	1137	4137	818	2086	466	2040
August	1002	3625	1259	664	1529	2151	1603	1291	3142	798	1438	2146	761	567	850	757	1282	1437	828	935	1448	1237
August	944	1357	1374	1985	2248	3848	1294	1513	987	7212	2957	1453	2778	268	1859	603	3180	697	1045	1212	1788	4016
August	875	4548	975	778	1076	5576	1037	842	719	3505	1457	2854	3505	237	1589	1009	1682	1921	584	961	703	2372
August	438	1473	2794	614	698	1255	3543	1098	1206	1348	1035	1846	3613	186	1024	2803	2067	857	2244	945	2736	3636
September	840	4890	2255	563	2401	3138	3251	584	488	899	1228	2482	2540	164	712	1571	1711	1424	1143	703	5514	1486
September	2355	1997	1397	748	3190	2760	2033	1448	1171	691	2813	1767	966	523	2999	1092	727	2144	1836	478	813	1553
September	3964	2519	1369	497	1603	6995	1746	928	833	1752	4309	1908	606	238	3736	959	525	1721	1292	882	1648	750
September		2465	1022	441	927	3979	1809	3774	757	970	805	3407	492	214	1661	5954	383	1572	647	424	1238	832
October		1768	2518	299	561	2574	752	712	663	722	2396	907	718	408	922	2550	483	632	603	378	696	688
October		799	4875	330	375	1191	958	1832	640	450	2174	2360	1024	193	555	959	332	1978	671	368	801	557
October	365	678	1613	1027	488	803	3122	1129	322	465	6326	2517	428	166	543	550	269	987	417	559	3144	2795
October	266	492	1236	307	1001	792	2329	3034	847	434	921	686	729	749	1084	618	335	2293	1519	723	2965	1959
October	798	398	1411	222	1891	608	4658	723	314	2050	684	749	368	271	509	376	798	3551	442	414	2973	725
November	561	336	2288	198	758	563	3391	604	219	363	365	1229	249	165	602	340	354	888	293	275	1149	471
November	318	303	1419	349	517	550	2066	394	501	539	1241	751	570	142	828	272	487	572	225	200	577	740
November	466	5059	1412	205	412	407	707	379	196	921	583	436	374	142	1914	231	445	431	157	274	722	307
November	360	492	795	166	296	269	1115	286	158	443	308	288	191	88	490	393	290	306	212	1814	313	307
December	464	313	390	129	349	266	420	372	527	333	256	326	145	73	366	192	420	221	1047	635	304	208
December	381	306	653	119	223	205	316	255	194	347	202	188	139	1150	245	192	1329	482	302	516	186	196
December	306	371	348	104	187	248	268	316	143	2204	270	258	144	176	163	622	846	839	172	285	171	161
December	241	254	548	89	437	225	198	263	135	623	199	144	104	73	104	281	841	447	119	188	109	197
December	188	398	379	103	235	289	136	237	189	341	262	115	78	58	68	194	424	265	107	195	174	123
January	1725	715	262	98	142	141	104	146	133	197	97	88	88	56	68	157	322	2228	126	413	63	761
January	606	275	682	159	125	329	108	191	73	165	823	102	96	159	47	108	300	399	79	268	63	118
January	318	115	226	89	115	141	83	284	66	725	189	72	63	50	105	73	218	253	77	132	54	78
January	201	165	161	58	80	111	131	149	91	139	193	103	102	37	81	63	155	200	114	65	45	670
February	154	2136	134	76	126	95	93	143	125	110	142	97	66	38	55	46	98	150	60	51	5628	256
February	123	731	125	143	112	84	120	90	177	83	131	126	44	31	46	55	82	86	70	75	1452	166
February	158	317	462	69	125	84	96	130	204	76	84	72	31	28	46	54	58	77	60	69	422	228
February	139	225	309	112	144	85	94	125	77	77	92	78	41	28	43	55	90	175	50	43	213	101
March	97	172	638	151	166	90	179	104	89	94	79	75	31	31	66	91	76	111	51	32	161	78
March	181	140	237	97	112	97	101	92	60	154	94	82	56	37	41	93	67	136	99	162	148	134
March	142	211	193	147	119	261	74	146	94	571	88	114	45	36	160	135	48	102	119	88	121	127
March	657	142	176	160	100	152	113	158	95	125	75	104	68	1770	86	106	53	137	55	72	102	249
April	275	119	155	360	158	163	131	267	148	122	91	108	135	164	328	83	57	366	49	69	192	178
April	243	122	151	145	264	344	186	185	143	222	92	90	54	199	112	714	82	182	44	117	108	259
April	176	105	227	166	457	122	102	236	316	164	73	86	47	251	74	243	102	183	42	161	214	130
April	377	491	162	1286	132	122	110	159	118	192	550	106	70	155	141	1044	292	173	45	164	164	173
April	1563	1301	656	835	300	134	164	192	202	196	784	91	280	218	220	306	736	150	103	109	759	190
May	1259	1608	236	2520	446	142	247	185	137	316	307	89	166	856	150	204	215	352	126	176	309	206
May	676	2309	196	697	277	308	151	215	220	432	421	306	384	385	154	238	601	318	170	444	260	156
May	1215	695	430	1598	568	1553	241	171	223	250	526	156	188	413	157	376	1208	745	168	165	368	226
May	827	409	324	1239	368	714	631	340	363	241	662	152	370	225	214	254	733	1382	171	272	314	218
June	496	6943	228	1028	231	501	293	2311	653	436	323	306	537	484	186	300	461	1051	208	454	485	246
June	356	2079	195	1849	192	695	808	734	1151	369	302	189	213	1137	230	501	564	523	1028	423	452	1772
June	1294	1031	196	2199	244	518	564	837	450	456	362	486	316	1501	262	645	560	758	871	719	528	1009
June	774	3852	235	1397	812	525	358	1563	457	307	512	349	977	563	243	856	3264	2081	750	936	766	1474
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
no. of weeks <100	1	0	0	7	2	6	5	2	8	4	10	11	15	14	12	9	10	2	13	9	4	2

fy ending:	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
July	2853	728	416	985	1360	2068	373	571	288	346	348	2021	378	1740	245	210	474	480	233	454	908	1413	188
July	2362	1601	1291	421	2496	1696	270	582	218	340	278	3075	281	2068	275	462	1757	433	898	499	3451	1493	884
July	1136	1955	915	357	2825	1670	328	735	177	232	405	823	280	1836	247	477	977	726	1555	449	2660	1138	754
July	892	2072	696	646	4518	2961	465	388	539	1078	857	1748	336	3536	381	1394	898	726	503	679	1616	1021	918
July	1980	1197	553	723	1819	1502	308	557	290	1894	383	939	1933	2381	1180	374	517	781	620	357	1412	1944	425
August	2510	2273	976	3495	3996	4569	296	1068	291	403	516	898	985	1146	1078	609	1514	842	1300	2777	842	942	2159
August	5095	2097	1015	2309	3696	4757	602	494	442	730	1564	1071	819	1976	1325	367	1290	2028	685	20147	1062	1758	3688
August	4736	2315	2375	2006	858	2512	699	384	768	1625	1798	1050	1099	3597	768	356	1060	1709	1268	3463	1497	1943	2245
August	4940	3098	824	1534	640	1846	1359	606	371	1088	4662	511	2826	841	868	496	488	1204	2271	2816	638	2029	5688
September	2064	4527	2261	588	631	1226	1541	246	277	1622	825	687	2364	1150	1189	250	348	950	3235	2632	470	2339	1106
September	1135	1381	1594	496	989	1461	1966	284	374	2939	1112	938	743	1031	431	710	239	446	1819	3832	556	1552	643
September	1193	2531	1040	927	646	6205	1794	1738	259	2601	514	523	2257	3090	2050	299	712	425	716	1235	465	777	698
September	6579	3470	4010	2035	817	2541	526	1992	207	727	349	849	1104	923	1062	347	472	681	751	806	442	658	3417
October	1596	3356	742	2216	425	1800	355	622	142	755	482	2100	1486	599	1154	233	1477	367	1358	808	1058	1759	1568
October	777	1226	1042	2783	491	1528	281	871	93	1259	593	619	874	452	599	193	2115	365	569	563	532	612	1362
October	545	3273	521	1262	867	898	281	1924	229	1430	1464	1484	667	372	1120	121	657	235	786	725	404	1751	636
October	458	1823	1156	555	358	673	316	963	184	910	1104	605	737	257	516	158	335	165	745	716	293	589	512
October	445	622	837	416	381	490	171	996	168	2167	1364	742	703	971	565	115	251	142	379	380	311	420	1565
November	1249	1638	2775	560	312	412	351	347	110	1696	880	524	2677	382	360	105	2047	170	391	1070	487	391	551
November	787	946	782	2303	2970	365	197	271	229	508	821	342	520	452	457	159	692	165	209	413	396	290	600
November	358	780	435	462	474	579	215	471	133	418	1887	267	316	564	280	319	294	91	148	387	227	242	686
November	273	1519	315	388	334	339	125	239	472	201	1354	250	272	263	189	85	246	284	205	466	199	184	1585
December	227	576	236	286	267	415	134	215	124	125	922	216	187	254	187	67	149	224	333	322	323	165	459
December	189	990	192	188	262	609	117	164	99	78	693	343	136	363	150	54	140	263	158	1244	196	169	399
December	1429	441	384	126	228	274	112	114	125	55	428	207	137	177	144	51	94	1448	158	516	140	379	396
December	570	773	324	251	330	233	106	113	93	134	315	137	510	111	115	47	1250	242	163	484	126	137	401
December	289	466	1154	125	188	163	65	180	209	167	359	140	69	106	110	51	183	184	87	265	104	101	227
January	387	328	457	112	175	123	50	65	213	40	374	122	56	296	95	43	88	134	71	192	93	100	280
January	406	281	404	69	125	91	62	67	72	21	256	83	81	117	79	43	83	99	62	1591	316	115	178
January	222	251	270	68	102	93	62	49	69	15	176	86	52	110	47	125	84	85	136	697	107	121	148
January	175	398	176	119	203	223	81	60	98	24	142	64	66	113	66	119	69	102	57	297	78	133	105
February	135	192	135	75	212	112	61	67	60	5	116	135	105	1911	103	71	69	111	54	201	93	186	92
February	149	128	156	72	969	104	81	76	47	23	660	87	96	598	114	58	117	121	69	193	110	182	96
February	137	115	153	129	292	73	73	89	48	64	174	93	84	240	90	76	109	141	383	179	102	189	92
February	109	241	113	36	146	95	62	78	52	9	175	150	68	173	94	58	178	152	76	189	88	52	104
March	114	371	168	19	180	113	63	145	54	32	134	205	47	128	98	79	178	177	69	156	80	54	75
March	113	182	111	236	104	105	61	63	57	38	82	97	67	166	118	84	188	212	219	318	109	71	82
March	116	135	114	118	309	111	60	76	56	87	84	89	83	131	154	102	194	287	80	146	121	104	109
March	90	161	83	212	189	136	56	74	55	318	96	177	106	99	24	145	247	94	69	271	202	149	149
April	121	157	68	316	191	146	91	74	55	71	86	120	375	90	29	83	150	81	102	176	194	176	164
April	748	158	152	532	217	235	114	77	52	54	65	109	71	105	160	62	193	84	86	155	210	202	176
April	185	137	234	289	339	157	245	76	49	99	81	202	52	105	175	50	141	83	220	841	244	88	145
April	190	125	234	358	708	144	214	95	56	228	69	146	95	136	469	57	93	122	96	310	94	60	108
April	187	112	170	251	390	121	149	110	38	1314	193	116	168	107	102	60	145	491	226	232	335	155	132
May	246	143	220	401	266	652	96	81	121	185	90	125	329	124	381	141	279	131	220	249	424	83	295
May	454	160	326	289	238	421	131	126	201	126	85	105	157	111	578	52	208	116	581	595	226	84	186
May	389	147	847	376	194	231	93	324	319	254	328	133	156	105	264	105	347	428	239	497	285	460	125
May	301	213	577	361	298	222	512	198	344	190	229	220	208	130	206	162	166	197	162	1040	667	192	377
June	374	202	660	357	263	321	231	513	1098	238	168	156	264	161	161	366	149	157	349	496	341	257	263
June	1226	328	287	1726	845	231	543	184	830	311	370	495	266	195	138	159	106	1209	329	1606	2956	419	279
June	1507	472	591	1562	403	510	590	1127	323	750	833	845	1218	310	208	237	261	439	330	549	493	854	444
June	769	787	588	713	390	264	985	540	233	773	658	306	2222	822	256	515	324	236	597	3928	1533	238	282
	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
no. of weeks <100	1	0	2	6	0	4	16	16	19	16	9	7	14	2	9	20	7	7	12	0	6	7	5

The above Table shows flows at Burrupa, with flows < 100 ML/d highlighted. These low flows occur in summer and autumn, and vary from year to year. For example, flows were above the 100ML/d threshold throughout the 2010/2011 year. On average, there are about 7 weeks of flow <100 at Burrupa every year, but this varies between zero and twenty weeks depending on the year. 16 weeks (four months) of low flows occur in about 10% of years. 13 years out of the 45 year record have 2 weeks or less flow < 100 ML/d being 29 % of years.

Appendix D NPV Analysis

Insert printouts from spreadsheets.

Appendix E Newlingrook Aquifer Cross Section

Figure 35 from SKM 2010, LTA GRA

Bore 75069 is approximate location of South Otway Pipeline and Bore 85790 is approximate location of North Otway Pipeline