



Latrobe Valley Regional REHABILITATION STRATEGY

Latrobe System Water Availability Technical Report

May 2020

Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.



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EXECUTIVE SUMMARY

The Latrobe Valley Regional Water Study (LVRWS) is one of several technical studies providing input to the Latrobe Valley Regional Rehabilitation Strategy (LVRRS). As part of the LVRWS, this report documents the assumptions, tools and methods used to estimate current water availability in the Latrobe System. It also projects water availability for a range of potential future climate and water use scenarios.

The Latrobe System includes the Latrobe River, its tributaries such as the Morwell, Tanjil and Tyers Rivers, and the Latrobe River outflows to the Gippsland Lakes. It includes major water storages (e.g. Blue Rock Reservoir, Moondarra Reservoir and Lake Narracan) and associated water harvesting infrastructure to supply water to towns, industry, agriculture and the environment.

Current surface water availability: Current surface water availability in the Latrobe System under baseline (post-1975 until 2016-17) climate conditions is approximately 800 GL/yr. Annual water availability since 1975 has ranged from just over 300 GL/yr to just under 1,500 GL/yr, highlighting the potential for significant fluctuations in water availability in wet and dry years.

In the post-1997 period, which includes the Millennium Drought (1997-2009), water availability is considerably lower, at approximately 600 GL/yr. The extent to which the post-1997 period represents additional natural climate variability or permanent climate change is unknown, hence it is prudent to consider the possibility of this period representing a new climate baseline.

Water availability under climate change: Climate change projections for the region indicate a wide range of possible futures. Under climate change, by the year 2040 water availability in the Latrobe System could be 36% lower (under the high climate change projection) or up to 23% higher (under the low climate change projection), with a median projection of a 10% decrease in water availability. By the year 2065, this uncertainty expands to range from a 49% decrease to a 10% increase, with a median projection of an 18% decrease in water availability.

When these percentage declines are applied to current water availability, under the high (dry) climate change projection, water availability in the Latrobe System could decline significantly by 2060 to ~400 GL/yr. Year 2040 water availability projections range from 500-1,000 GL/yr, with a median projection of 700 GL/yr in 2040, declining to ~650 GL/yr in 2065.

Potential water availability for mine rehabilitation: This was assessed using an annual mass balance of projected water availability for a range of assumed supply from power generator bulk entitlements, independent of climate-related constraints on supply. After considering the results from the various water supply scenarios modelled, the likely range of fill durations was estimated for an assumed filling scenario. This was not the direct output of any single model assessment, but rather was the result of interpreting the full suite of model outputs and their assumptions. This analysis is preliminary in nature and may be refined if more detailed pit lake modelling is undertaken.

The assumed filling scenario involves the planned mine closure timeline, the maximum target water body capacity, groundwater supply of 15 GL/yr to Hazelwood and 15 GL/yr to Loy Yang, surface water supply from power company bulk entitlements of 25 GL/yr to Yallourn and 40 GL/yr to Loy Yang, and supply from other sources (similar in magnitude to historical supply from Gippsland Water to the power generators) of 20-25 GL/yr. These assumed supply volumes are consistent with historical water use during a drought year. Assuming no interruption to supply, it is concluded that the time frame for filling the mine voids would be approximately:

- 15-20 years for Hazelwood;
- 20-25 years for Yallourn; and
- 25-30 years for Loy Yang.

When evaporative losses are considered, these timeframes extend out by another five years. Large volumes of additional water (notionally 5-10 GL/yr extra per mine) would be required to materially hasten these filling rates. The volume that is assumed to be available from power generator bulk entitlements for mine rehabilitation is based on historical water use in a drought year. If this volume were based on average historical water use, the volume available would be lower and the fill times would be extended.

As noted previously, these timeframes could be significantly under-estimated because filling will need to be restricted or halted under dry conditions to prevent unacceptable impacts on other water users, cultural values and the environmental values of the Latrobe River, Lower Latrobe wetlands and Gippsland Lakes under the medium and high (dry) climate change scenarios or if the dry conditions since 1997 continue. Under both current conditions and drier climate change projections, there is likely to be a relatively large proportion of years in which filling could not be sustained. It may be

possible to continue filling the mine voids at a slower rate during dry conditions by using groundwater, but rehabilitation could still take many decades.

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1 INTRODUCTION

The Latrobe Valley Regional Rehabilitation Strategy (LVRRS) is part of the Victorian Government's response to the findings of the Hazelwood Mine Fire Inquiry. The inquiry found that there were significant uncertainties and gaps in knowledge surrounding the closure and rehabilitation of the Latrobe Valley's three brown coal mines (DPC, 2016). The LVRRS is designed to address some of these knowledge gaps (DJPR, 2019a). The Latrobe Valley Regional Water Study (LVRWS) is one of several technical studies providing input to the LVRRS. As part of the LVRWS, this summary report on Latrobe System Water Availability documents the assumptions, tools and methods used to estimate current water availability in the Latrobe River basin. It also projects water availability for a range of potential future climate and water use scenarios.

1.1 PURPOSE OF THIS REPORT

The Department of Environment, Land, Water and Planning (DELWP) has responsibility for delivering Action 195 (Regional Water Study) of the Victorian Government Implementation Plan, arising from the Hazelwood Mine Fire Enquiry (DPC, 2016). Under Action 195, the Regional Water Study is tasked with assessing the viability of filling options for the potential water bodies and impacts, including:

1. Potential water availability and use of regional water resources for mine rehabilitation
2. Analysis of potential alternative sources of water to those currently available to the Latrobe Valley Coal Mines
3. Potential water quality impacts in water bodies, groundwater and off-site surface waters
4. Potential impacts on aquatic ecosystems and downstream users
5. Scope of likely requirements for long-term regional groundwater monitoring

This technical report on Latrobe System water availability provides technical input to items 1 above. It is one of several background technical reports for the LVRWS that cover a range of other topics including environmental assessments, water quality assessments, groundwater modelling and more detailed integrated pit lake modelling.

Figure 1 illustrates the various thematic elements within the Regional Water Study. Elements G (water availability), H (water use scenarios) and L (water availability for mine rehabilitation) are those addressed by this summary report.

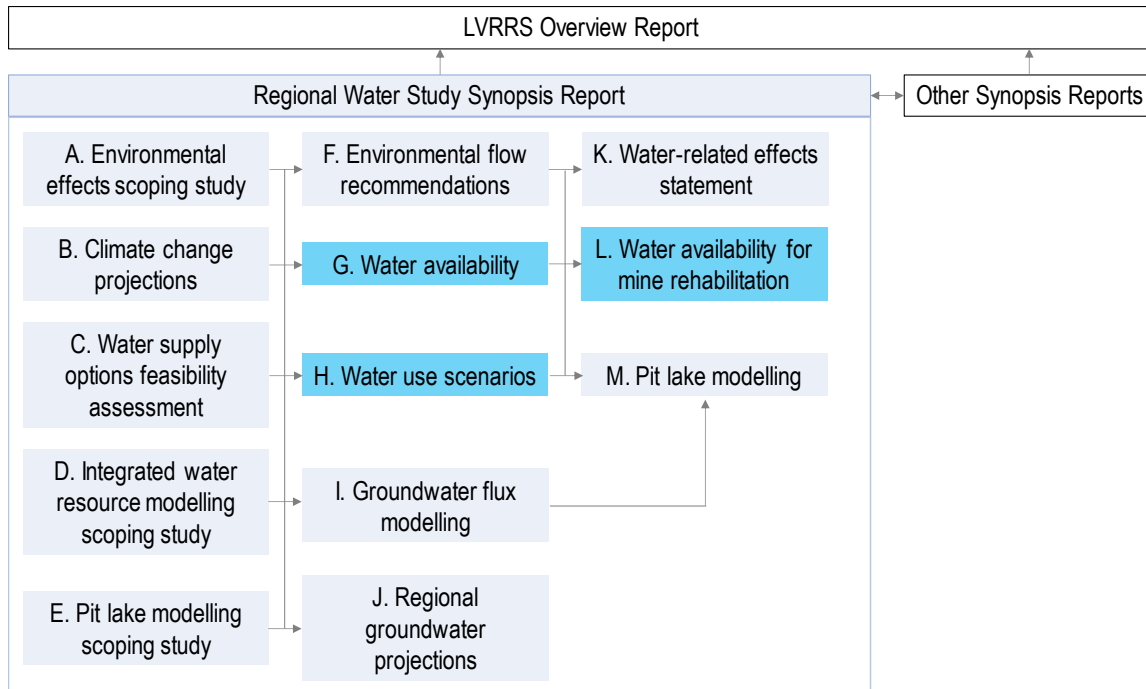


Figure 1 Thematic elements of the Latrobe System Water Availability Report (G, H, L) within the themes of the LVRWS

1.2 SCOPE AND STRUCTURE OF THIS REPORT

This technical report covers the Latrobe System for water management, which spans the Latrobe River basin. It includes the Latrobe River, its tributaries such as the Morwell, Tanjil and Tyers Rivers, and outflows to the Gippsland Lakes. It includes major water storages (e.g. Blue Rock Reservoir, Moondarra Reservoir and Lake Narracan) and associated water harvesting infrastructure to supply water to towns, industry, agriculture and the environment.

The scope of this report is to provide the following information:

- Surface water availability and use for existing water users, including the environment
- Potential surface water availability for mine rehabilitation
- Potential groundwater availability for mine rehabilitation
- Projected time frame(s) to fill mine voids under various scenarios
- Sensitivities to climate variability and climate change

The LVRRS objectives for water resources, as stated in the LVRRS Overview Report (DJPR, 2019a) highlight the need for supporting information to provide a long-term view, particularly in the context of climate change, and that it must take into account the water needs of both consumptive users (i.e. towns, agriculture, industry) and the environment. The scope of this report is informed by those objectives.

Estimates of time frame(s) to fill mine voids are preliminary estimates only and will need to be further refined as part of more detailed pit lake modelling if required for a Declared Mine Rehabilitation Plan.

This report therefore provides information on:

- Data sources (Section 2);
- An overview of current surface water sharing arrangements in the Latrobe System, and groundwater licensing in the region (Section 3);
- Current and projected Latrobe System water availability (Section 4);
- Current and projected Latrobe System water demand (Section 5); and
- Estimated water availability for mine rehabilitation, including filling rates of proposed water bodies and the sensitivities associated with those filling rates (Section 6).

1.3 ACKNOWLEDGEMENTS

DELWP (surface water) is the lead author of this report, however much of this work was collaborative in nature. It considered the assumptions and outcomes from parallel studies being undertaken for the LVRRS, and sought feedback at interim stages. The broader Regional Water Study for the LVRRS was undertaken by the Integrated Water Resource Modelling Group consisting of DELWP (surface water), GHD (local groundwater), DJPR (regional groundwater), RGS Environmental (pit lakes), CDM Smith (expert oversight and review), the Latrobe Valley Mine Rehabilitation Commissioner and Gippsland Water. Two workshops were held to present models and results, and to deliberate on coordination of the studies and agreements related to climate datasets, rehabilitation scenarios, evaporation calculations, and integration. The results and key decisions from the Regional Water Study, which included results from the assessments presented in this summary report, were tested with the mine operators. The authors of this report acknowledge the contributions to this report from Integrated Water Resource Modelling Group for the LVRRS, as well as feedback from the mine operators.

2 DATA SOURCES

The water availability assessment draws upon a range of observed data, registered licensing information, and other specialist technical studies. For transparency, information sources of relevance to the water availability assessment are listed in Table 1.

Table 1 Information Sources for Latrobe Water Availability Summary Report

Information type	Information Source	How it was used in this water availability assessment
Observed climate	Bureau of Meteorology (http://bom.gov.au) SILO, State of Queensland (https://www.longpaddock.qld.gov.au/silo/)	Estimating water body evaporation and input to background water resource modelling
Observed streamflow	Victorian Water Management Information System (http://data.water.vic.gov.au/)	Input to background water resource modelling and environmental flow assessments
Water entitlements	Victorian Water Register (https://waterregister.vic.gov.au/)	Documenting water entitlements and licences
Water use	Metered data sourced from the Victorian Water Register (https://waterregister.vic.gov.au/) Estimated data sourced from GHD (2018) water resource model inputs Victorian Water Accounts (e.g. DELWP, 2018)	Estimating current water use
Minimum environmental water requirements	Draft environmental flows study by Alluvium (2019) based on the FLOWS method (DEPI, 2013) for Victorian rivers and the EEFAM method (DSE, 2012) for Victorian estuaries	Defining minimum environmental water requirements
Climate change projections	Jacobs et al. (2017) climate change projections study, which draws upon the projections in DELWP (2016) guidelines	Projected water availability under climate change

3 OVERVIEW OF CURRENT WATER SHARING ARRANGEMENTS

3.1 INTRODUCTION

This section includes an overview of the Latrobe System of surface water entitlements within the Latrobe River Basin (Section 3.2), the nature of those surface water entitlements (Section 3.3), and groundwater licences in the managed aquifers from which groundwater is currently drawn for mine void stability (Section 3.4).

3.2 LATROBE SYSTEM DESCRIPTION

The Latrobe River Basin (see **Error! Reference source not found.**) is located in Gippsland and lies between the Strzelecki Ranges and the Great Dividing Range, forming part of the catchment of the Gippsland Lakes. The Latrobe River originates on the Mount Baw Baw Plateau and flows east through the Basin where it joins the Thomson River, before flowing into Lake Wellington — the westernmost point of the Gippsland Lakes.

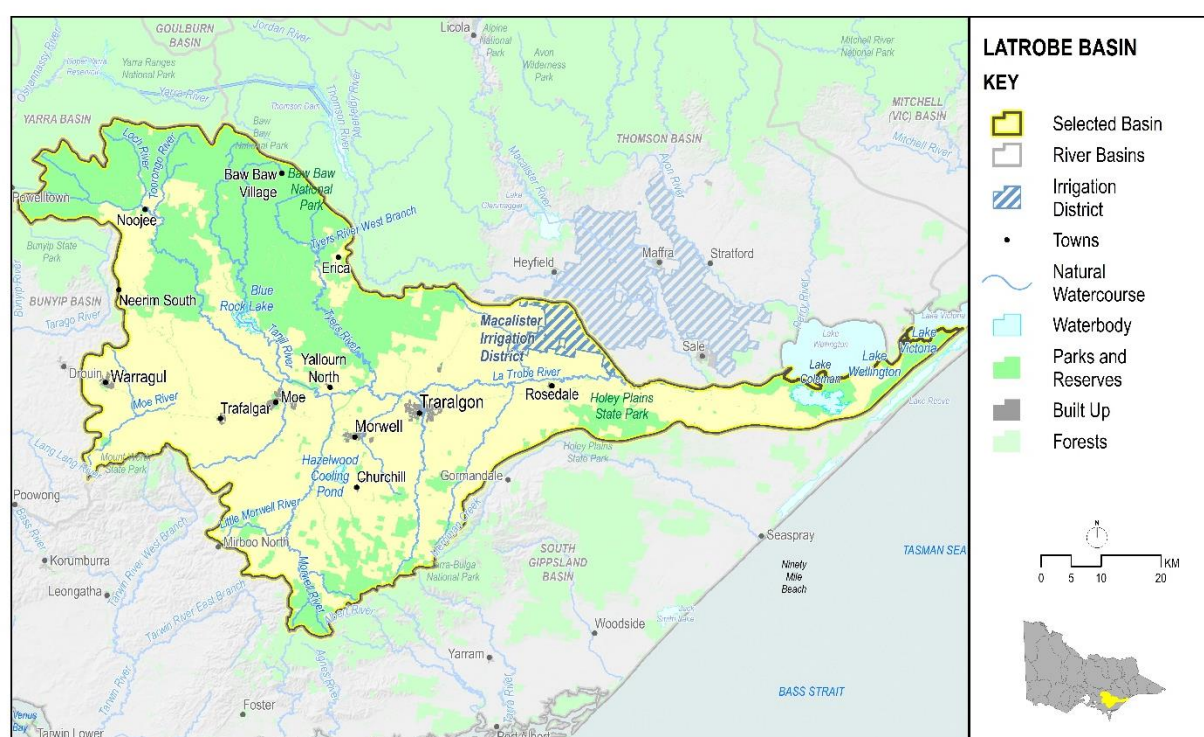


Figure 2 The Latrobe River Basin (DELWP, 2018)

Streamflows in the mid and lower reaches of the Latrobe Basin can be regulated by major storages, including Blue Rock Reservoir (on the Tanjil River), Moondarra Reservoir (on the Tyers River) and Lake Narracan (on the Latrobe River). The part of the Latrobe Basin where flows can be regulated, so as to deliver water to towns, industry and irrigators, is referred to as the “Latrobe System”. The extent of the Latrobe System is shown schematically in Figure 3.

Responsibility for the surface water resources management in the Latrobe Basin is shared between the following stakeholders:

- **Southern Rural Water:** Has the Resource Manager function for the Latrobe Basin. Southern Rural Water is also the Storage Manager for the Latrobe supply system, and operates this system which comprises of Blue Rock Reservoir and Lake Narracan for supply to Gippsland Water, the power generators, licensed diverters and the Victorian Environmental Water Holder.
- **Gippsland Water:** Gippsland Water is the Regional Urban Water Authority for the majority of the Latrobe Basin, providing water and wastewater services to the townships of Morwell, Traralgon and Rosedale from Moondarra Reservoir while Moe is supplied from the Tanjil River (released from Blue Rock Reservoir) and Narracan Creek. Provides high quality industrial supply from Moondarra Reservoir to Hazelwood power station (when it operated)

and other power generators and major industries, as well as supplying recycled water from the Gippsland Water Factory.

- **West Gippsland Catchment Management Authority:** Is the waterway manager for the Latrobe Basin.
- **Victorian Environmental Water Holder:** Holds and manages environmental entitlements in the basin.
- **East Gippsland Catchment Management Authority:** Is the site coordinator for the Gippsland Lakes Ramsar Site and are responsible for, amongst other things, overseeing the implementation of the Ramsar site management plan priorities.

Groundwater resources are managed separately from the surface water resources of the Latrobe Basin. Southern Rural Water is the licensing authority for groundwater resources in the region. Under the mine licences and groundwater licences held by the Latrobe Valley Coal mines there is a requirement for the mine operators to partner in delivering a regional monitoring program.



Figure 3 The Latrobe System prior to mine closures (adapted from GHD, 2013)

Blue Rock Reservoir and Lake Narracan are primarily used to supply Yallourn, Loy Yang A and Loy Yang B power stations. Lake Narracan harvests water from the Latrobe River from where it is pumped directly to the power stations from Yallourn Weir (just below Lake Narracan). Water is released from Blue Rock Reservoir to Lake Narracan when flows from the unregulated upper Latrobe River are not enough to meet demand. Moondarra Reservoir is used to supply Latrobe Valley towns and major industrial customers, including Australian Paper and (when it operated) Hazelwood power station. The capacity of these major storages is listed in Table 2. In addition to on-farm water sources, private diverters (e.g. for irrigation or stock and domestic water use) in the lower Latrobe River harvest unregulated flows from the river directly, but their supply can also be supplemented by water stored in Blue Rock Reservoir for those private diverters.

Table 2 Major water storages in the Latrobe supply system

Storage	Capacity (GL)	Location	Purpose
Blue Rock Reservoir	198.3	Tanjil River upstream of Latrobe River confluence	<ul style="list-style-type: none"> - Supply of water to electricity generators for cooling towers - Supply to Gippsland Water's Moondarra Reservoir via transfer pipeline* - Supply to Moe urban demand - Supply to irrigators and private diverters - Supply meet downstream environmental water requirement - Provision of drought reserve
Lake Narracan	7.2	Latrobe River, near Moe	<ul style="list-style-type: none"> - Supply of water to electricity generators for cooling towers - Operating rules accommodate recreational users and harvesting of unregulated flows
Moondarra Reservoir	29.9	Tyers River	<ul style="list-style-type: none"> - Gippsland Water supply to urban and industrial demands, including Hazelwood Power Station (when it operated) and major industries

* Gippsland Water transfers water from its share of Blue Rock Reservoir to Moondarra Reservoir based on its operating rules and requirements

3.3 SURFACE WATER ENTITLEMENTS

Most surface water entitlements in the Latrobe System are specified as a percentage share of the available streamflow and a share of reservoir capacity. This enables transparent water sharing during dry years, whilst an annual cap on diversions limits extraction in average to wet climate years. Some entitlements have their annual cap expressed as a rolling average over a 2-3 year period, which provides additional flexibility in managing for climate variability.

The surface water entitlements of the Latrobe System aim to provide a very high reliability of supply to the State's power generators, whilst also providing water for other major industries, surrounding towns, agriculture, recreation, and the environment. Some unique features of the surface water entitlements in the Latrobe System include:

- Different entitlement arrangements for each of the different power companies. Yallourn and Loy Yang A are supplied from dedicated bulk entitlements. Loy Yang B is supplied via a licence which is allocated water from a dedicated bulk entitlement held by Southern Rural Water. These three entitlements allow up to 96.5 GL/yr to be taken from waterways in the Latrobe System. Hazelwood is supplied by agreement from Gippsland Water's bulk entitlement, which is also used to supply towns and Australian Paper Manufacturers.
- The Latrobe Reserve bulk entitlement (also known as the drought reserve), which was created in 2013 to provide high water security for all entitlement holders in a drying climate. In accordance with the entitlement rules, the drought reserve holds water that can be purchased for temporary use by entitlement holders during drought. The total volume in the reserve cannot be sold at any one time, so as to always allow for future contingencies after its first access in a drought. A small portion (2.5%) of this entitlement is set aside for private diversion licence holders (i.e. irrigators) so that they do not have to compete financially against urban and industrial water users for access to the drought reserve.
- The Latrobe 3/4 Bench bulk entitlement, which is associated with a parcel of Crown Land adjacent to Loy Yang B, named the Loy Yang 3/4 Bench. It was set aside in 1996 when power generation was privatized and was intended to be the source of water for any future power development on the site. The potential future use of the entitlement is however not fully restrictive, with the entitlement stating that it can be used for "future electricity generation requirements, or other purposes" (Minister administering the Water Act, 1996). This entitlement has been allocated to the State Government but is not currently used.
- Ability to use return flows. The entitlements provide that return flows to the Latrobe River from power generation and paper production activities can be used by private diverters and the environment, with access shared 50/50. This arrangement provides clarity around access to this resource, maximises its productive value, and helps to conserve water held in storage upstream.

- A range of means for providing environmental flows, including an environmental entitlement to capture, store and release water from Blue Rock Reservoir, an environmental entitlement that allows water to be diverted into the Lower Latrobe Wetlands, and minimum passing flows specified on consumptive bulk entitlements. The Lower Latrobe Wetlands entitlement has no assigned volume, but rather has water level triggers for accessing water to inundate these wetlands, rather than passing all the water in the river directly through to Lake Wellington.
- A range of means for providing water to private diverters (e.g. for irrigation or for stock and domestic water use) in the lower Latrobe River, including access to a share of inflows and storage capacity in Blue Rock Reservoir, a share of unregulated inflows to Lake Narracan, a share of additional unregulated inflows to Lake Narracan if not being used by other bulk or environmental entitlement holders, and a share of return flows from power generation and paper production.
- Recognition of recreational values, with the entitlement rules for operating Lake Narracan designed to allow for up to three water skiing events to be held every year.
- Carryover of unused entitlement volumes from year to year indefinitely in each entitlement holder's storage capacity, subject to deductions for evaporation and reservoir spills.

The bulk and environmental entitlements in the Latrobe System are listed in Table 3, including their share of inflows and share of storage capacity in each major reservoir, and the maximum annual volume that can be harvested. The annual volume harvested cannot exceed the maximum annual volume stated in the entitlement. For Southern Rural Water's Latrobe entitlement, and Gippsland Water's entitlements in Moondarra Reservoir and Blue Rock Reservoir, the annual volume harvested is averaged over a two or three year period. This allows for higher harvest volumes in some individual years, as long as the two or three-year average annual harvest is less than the specified annual limit. The "rules-based" entitlements in Table 3 do not specify a maximum annual divertible volume, with annual use under these entitlements limited only by the availability of Latrobe System inflows, and/or storage capacity or access rules.

The Latrobe River provides an essential source of freshwater to the Ramsar-listed Gippsland Lakes, with the provision of water for the environment as noted above and in Table 3. The frequency, duration, timing and magnitude of freshwater inflows drive ecological functioning in the Gippsland Lakes. The lower Latrobe floodplain wetlands – Sale Common, Dowd Morass and Heart Morass – are important ecological assets that rely on freshwater inputs and provide habitat for many waterbirds, including migratory species protected under international agreements. Environmental entitlements held in the Thomson and Macalister Rivers also provide environmental flows to the Latrobe River downstream of the Thomson River confluence. These combined flows help with inundation of the lower Latrobe wetlands and also help to prevent the upstream movement of the salt wedge in the Latrobe estuary when flows are low.

Table 3 Bulk and Environmental Entitlements in the Latrobe System

Entitlement ¹	Holder	Purpose	Blue Rock Reservoir	Lake Narracan		Moondarra Reservoir	Maximum Annual Entitlement Volume (ML) ⁴
			Share of inflows and storage capacity (%)	Share of inflows (%)	Share of storage capacity (%)	Share of inflows and storage capacity (%)	
Gippsland Water – Blue Rock	Gippsland Water	Urban and industrial ³	17.08	0	0	0	20,000 (averaged over 3 years)
Gippsland Water – Moondarra Reservoir	Gippsland Water	Urban and industrial ³	0	0	0	100%	62,000 (averaged over 2 years)
Gippsland Water – Narracan Creek (Moe)	Gippsland Water	Urban	0	0	0	0	3,884
Yallourn	Energy Australia	Power Generation	15.72	22.41	29.94	0	36,500
Loy Yang A	AGL	Power generation	17.22	24.55	32.80	0	40,000
Loy Yang B	SRW	Power generation	8.61	12.28	16.40	0	20,000
Loy Yang 3/4 Bench	Environment Minister ²	Future power generation	10.95	15.61	20.86	0	25,000
Latrobe – Southern Rural	SRW	Irrigation	2.10	25.15	0	0	13,400 (averaged over 2 years)
Latrobe Reserve	SRW	Water security	18.87	0	0	0	Rules based, (limited by storage capacity)
Blue Rock Environmental Entitlement	VEWH	Environment	9.45	0	0	0	Rules based (limited by reservoir inflows and storage capacity)
Lower Latrobe Wetlands Environmental Entitlement	VEWH	Environment	0	0	0	0	Rules based, (limited by river levels)
Private diversion licences from unregulated rivers	Private diverters	Domestic, stock, irrigation, commercial	0	0	0	0	18,891

Notes to table

1. Excludes unused bulk entitlements for Boolarra, Thorpdale and Noojee, as well as minor volumes available under bulk entitlements for Erica-Rawson and Mirboo North. Private diversion licences from unregulated rivers are issued by Southern Rural Water, separately to private diversion licences supplied from Southern Rural Water's Latrobe System bulk entitlement.
2. This bulk entitlement is administered by the Department of Treasury and Finance.

3. Water from these Bulk Entitlements includes water that has historically provided for power generation at the Hazelwood Power Station, but also includes supply to other major industrial water users
4. The average historical use under each bulk entitlement is much lower than the maximum annual entitlement volume
5. In 2014, Gippsland Water was allocated a 3.87% inflow and storage share of the previously unallocated share of Blue Rock Reservoir. To correspond with this, its max take was increased from 15,150 ML/year to 20,000 ML/year over 3-year consecutive period.

Registered or licensed commercial and irrigation farm dams have an estimated total capacity of 16 GL, and farm dams for stock and domestic use have an estimated total capacity of 15 GL (DELWP, 2018). These dams have first access to local runoff, notwithstanding any upstream interception. The Latrobe Basin Local Management Plan outlines the local rules governing all private diversions from the Latrobe Basin (SRW, 2014a). The Plan states that the basin is fully allocated. The volume of private diversion licences supply from SRW's Latrobe System entitlement is approximately 20% lower than SRW's entitlement. The plan allows licence holders to take additional "off-quota water", up to 20% in excess of their licensed volume, during high flow conditions. Bans and rostering can occur during periods of water shortage.

3.4 GROUNDWATER LICENCES

Groundwater licences in the region are managed independently of the surface water management system. The main aquifers in the Latrobe Valley are the Haunted Hills, the Morwell and the Traralgon aquifer systems. Groundwater extracted by the Latrobe Valley coal mines is sourced from these aquifers which are in the Rosedale GMA and the Stratford GMA.

Total licensed groundwater volume held by for the three mine sites from the Stratford and Rosedale GMAs combined is 45,765 ML/yr. Groundwater extraction to reduce the aquifer pressure and maintain the stability of the mine voids has averaged around 30 GL/yr (DJPR, 2019a), with most of this volume sourced from the Stratford GMA (DELWP, 2018).

4 CURRENT AND PROJECTED LATROBE BASIN WATER AVAILABILITY

4.1 INTRODUCTION

This section documents the estimation of water availability in the Latrobe Basin. It includes the assumptions around the climate conditions under which water availability is assessed (Section 4.2), the methods and tools used (Section 4.3), the results from applying those methods and tools to estimate current water availability (Section 4.4), climate change projections (Section 4.5), and water availability under those climate change projections (Section 4.6).

4.2 BASELINE CLIMATE CONDITIONS

The baseline climate period for the LVRRS was selected after considering natural climate variability and observed historical climate change, taking into account the recommendations of the *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (the guidelines) (DELWP, 2016).

With respect to climate and streamflow variability, water availability in any river basin will be higher in wet years and lower in dry years. Utilising climate and streamflow information from a wide range of wet, dry and average years avoids bias that could be introduced if sampling climate and streamflow information from only wetter or only drier periods.

The observed climate and streamflow record is not stationary. It has been observed in the research outcomes from the Victorian Climate Initiative (Hope et al., 2017) that Victoria's climate has changed over recent decades, with strong evidence of drier conditions in the cooler months of the year (from April to October). This finding is supported by observed changes in the atmospheric drivers of Victoria's climate, such as the southward expansion of the tropics, that are consistent with climate change projected by global climate models under higher greenhouse gas concentrations (DELWP, 2019a). These recent decades also exhibit considerable natural climate variability that has contributed to the observed drying trends, notably due to the influence of the Millennium Drought event from 1997 to 2009.

4.2.1 POST-1975 CLIMATE AND STREAMFLOW BASELINE

To represent baseline climate and streamflow conditions that are more representative of current levels of greenhouse gas concentrations, the *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (the guidelines) (DELWP, 2016) recommend the use of the post-1975 climate period. This period was selected as a trade-off between being short enough to reasonably represent recent greenhouse gas conditions, but long-enough to capture a wide range of natural climate variability. As per the recommendations in the guidelines, the post-1975 period has been adopted for estimating baseline water availability for the Latrobe Basin in the Latrobe Valley Regional Water Study.

The post-1975 period relative to earlier available data is shown in Figure 4 at one streamflow gauge for which earlier data exists (Latrobe River at Willow Grove 226204). It can be seen from this figure that the post-1975 period includes the 1982/83 drought and the Millennium Drought (1997-2009). Importantly, it includes the driest year on record in 2006/07. The post-1975 period has however been characterized by the absence of high streamflow years, relative to the pre-1975 period. It can be seen, for example, that the wettest year in the post-1975 period is 45% lower than the wettest year on record in the Latrobe River at Willow Grove. This wet year (1996/97) is only the 23rd wettest year over the whole period of available data from 1930 to 2019. It is not known for certain to what extent the absence of any very high flow years in the Latrobe basin in the post-1975 period is due solely to climate change or due at least in part to random climate variability. However, it is clear that on average streamflows are much lower in the post-1975 period, and that those streamflows are consistently lower in the majority of years. The adoption of the post-1975 period does not preclude the possibility of very high flows in individual years in the future, however the observations since 1975, when coupled with the broader climate observations and climate modelling in DELWP (2016), suggest that their frequency in the future will be lower than observed prior to 1975. The volume of licensed diversions in the Upper Latrobe River (upstream of Lake Narracan) is approximately 1.2 GL/yr (SRW, 2014a), indicating that changes in private diversions in the Upper Latrobe River over time would only have had a very small to negligible influence on the observed changes in gauged streamflows, which are in the order of hundreds of gigalitres in Figure 4.

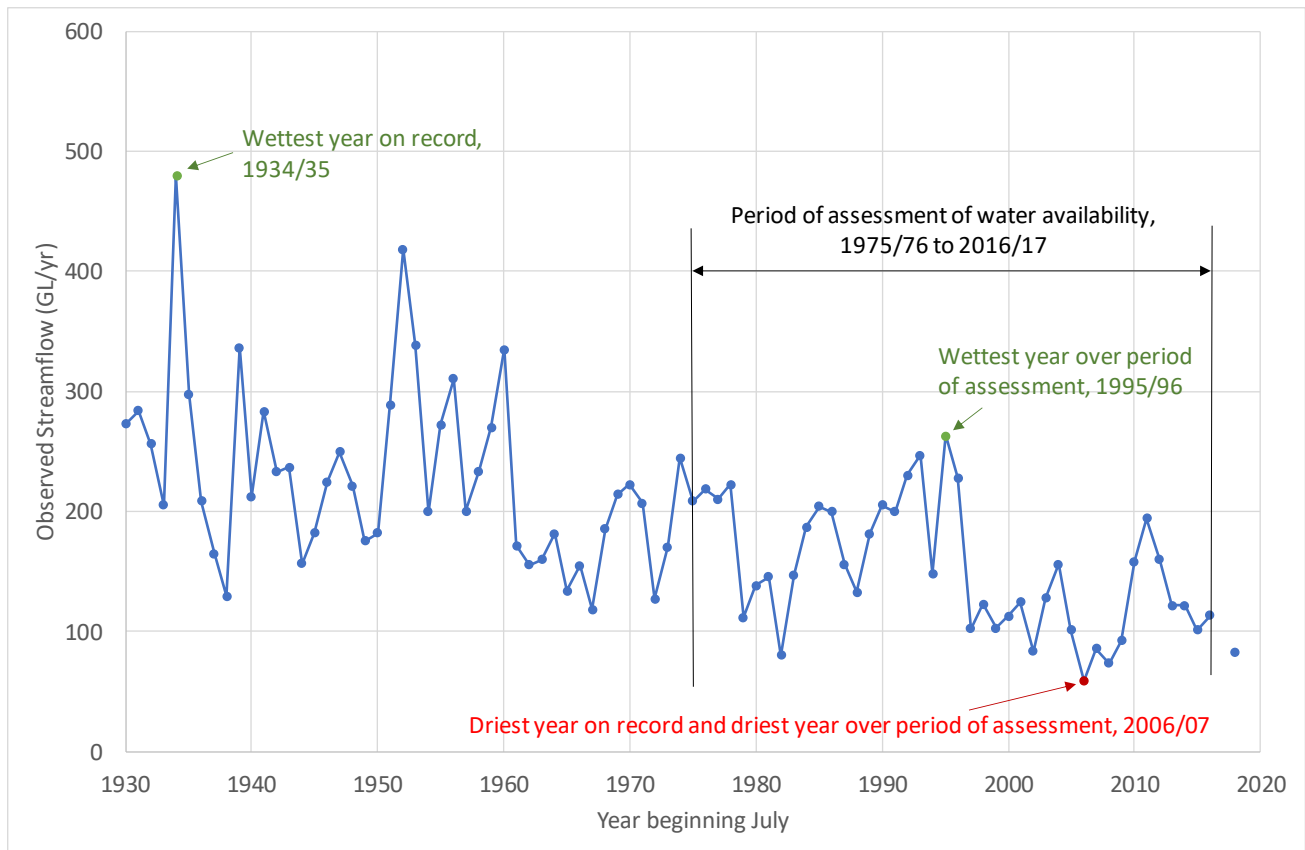


Figure 4 Observed historical streamflow in the Upper Latrobe River at Willow Grove (streamflow gauge 226204)

4.3 METHODS AND TOOLS FOR ESTIMATING WATER AVAILABILITY

The estimate of water availability presented in this report is based on information sourced from the water resource models of the Latrobe Basin. Water sharing arrangements in the Latrobe Basin have historically been modelled using REALM resource allocation models. These models have recently been used to estimate urban supply system yield in Gippsland Water's Urban Water Strategy (Gippsland Water, 2017) and to assess historical changes in water availability in Victoria's Long-Term Water Resources Assessment in southern Victoria (DELWP, 2020a). These REALM models operate on a weekly time step for the Upper Latrobe River, and on a monthly time step for the Latrobe System, over the period January 1957 to October 2017. The start of the modelling period is limited by the availability of long-term streamflow records at key streamflow gauging locations in the Latrobe River and its tributaries. Due to the level of effort in preparing all climate, streamflow and demand inputs to these models, the end of the modelling period is limited to available data at the time of the most recent update of the model inputs. Similar updates to extend the dataset are typically undertaken around every five years.

DELWP is in the process of transitioning its water resource modelling platform used across Victoria from REALM to Source. Source operates in a similar way to REALM, but offers the opportunity of improved performance on a daily time step, and is being implemented as part of a national strategy to standardise water resource modelling approaches across Australia. As part of this transition, DELWP recently derived daily time step climate, streamflow and demand inputs to the Upper Latrobe and Latrobe System REALM models for use in a Latrobe Source model that is currently under development (GHD, 2018). These inputs, aggregated to monthly and annual time steps, have been adopted for the LVRWS. REALM model performance using these updated and extended inputs was verified against previous versions of the Latrobe System REALM model in GHD (2018). Individual inputs to the REALM model based on estimated data (e.g. to infill periods of missing streamflow data) were calibrated against observed data in GHD (2018).

For the LVRWS, estimates of water availability are based on “unimpacted” streamflows throughout the basin. Unimpacted streamflows represent the flow in the river in the absence of historical water use, reservoirs and associated flow regulation. These unimpacted streamflows were derived in GHD (2018) for individual tributaries of the Latrobe River as per Equation 1.

$$\text{Unimpacted streamflow} = \text{Gauged streamflow} + \text{Upstream historical water use}$$

Equation 1

The unimpacted streamflows in each individual tributary were aggregated to generate the estimate of water availability for the Latrobe Basin as a whole. This estimate of Latrobe Basin water availability is for all creeks and rivers in the Latrobe Basin upstream of the Thomson River. When interpreting these estimates of water availability, it is noted that in practice:

- Average annual water availability to bulk entitlement holders will be slightly lower than that indicated by the unimpacted flow estimate, due to upstream harvesting of water by private diverters and farm dams. In the Latrobe Basin, average annual water use and evaporative losses from unlicensed (stock and domestic) farm dams was estimated to be approximately 5 GL/yr in 2017/18, whilst that from licensed (commercial) farm dams was estimated to be approximately 5 GL/yr (DELWP, 2018). Compared to other water users, unlicensed water use is relatively invariable from year to year. These volumes represent around 1% of total water availability in the Latrobe Basin in an average climate year, and around 3% in a drought year;
- Water availability to individual water users will also be limited by local water availability. For example, the Yallourn power station, which sources its water from Lake Narracan, does not have access to water available from the Morwell River, Tyers River, Traralgon Creek and other local creeks downstream of Lake Narracan;
- Net evaporative losses from major storages will reduce water availability. Evaporative losses ranged from 4-12 GL/yr from 2016/17 to 2017/18, whilst direct rainfall on storages ranged from 3-10 GL/yr over this same period (DELWP, 2018);
- Return flows will provide additional water over and above the estimate of unimpacted streamflows, for as long as the power companies and the paper mill continue to discharge this water to the river. From 2006/07 to 2017/18, return flows ranged from 33-52 GL/yr, but have generally been below 40 GL/yr over the last five years (e.g. DELWP, 2018).

The Latrobe REALM models take into account the influence of stock and domestic water use, local water availability, evaporative losses from storages and return flows when allocating water for consumptive use. These models have been utilized in this study to assess the sensitivity of results to the combined effect of these factors.

4.4 POST-1975 AND POST-1997 BASELINE WATER AVAILABILITY

Post-1975 baseline water availability for the Latrobe Basin is shown in Figure 5 for each year from 1975/76 to 2016/17, which highlights the variability in available streamflows from year to year. This figure also includes annual water availability in the post-1997 period. Summary statistics for various periods within the post-1975 climate baseline, the post-1997 climate baseline and the full period of available historic data are shown in Table 4. In this table the 5th percentile value corresponds to a 1 in 20-year dry streamflow, whilst the 95th percentile value corresponds to a 1 in 20-year wet streamflow.

From this table, long-term median water availability under post-1975 climate conditions is approximately 800 GL/yr. This represents the volume which would be available to the Latrobe Basin as a whole in 50% of years, on average over the long-term. In 50% of years, water availability would be less than this volume.

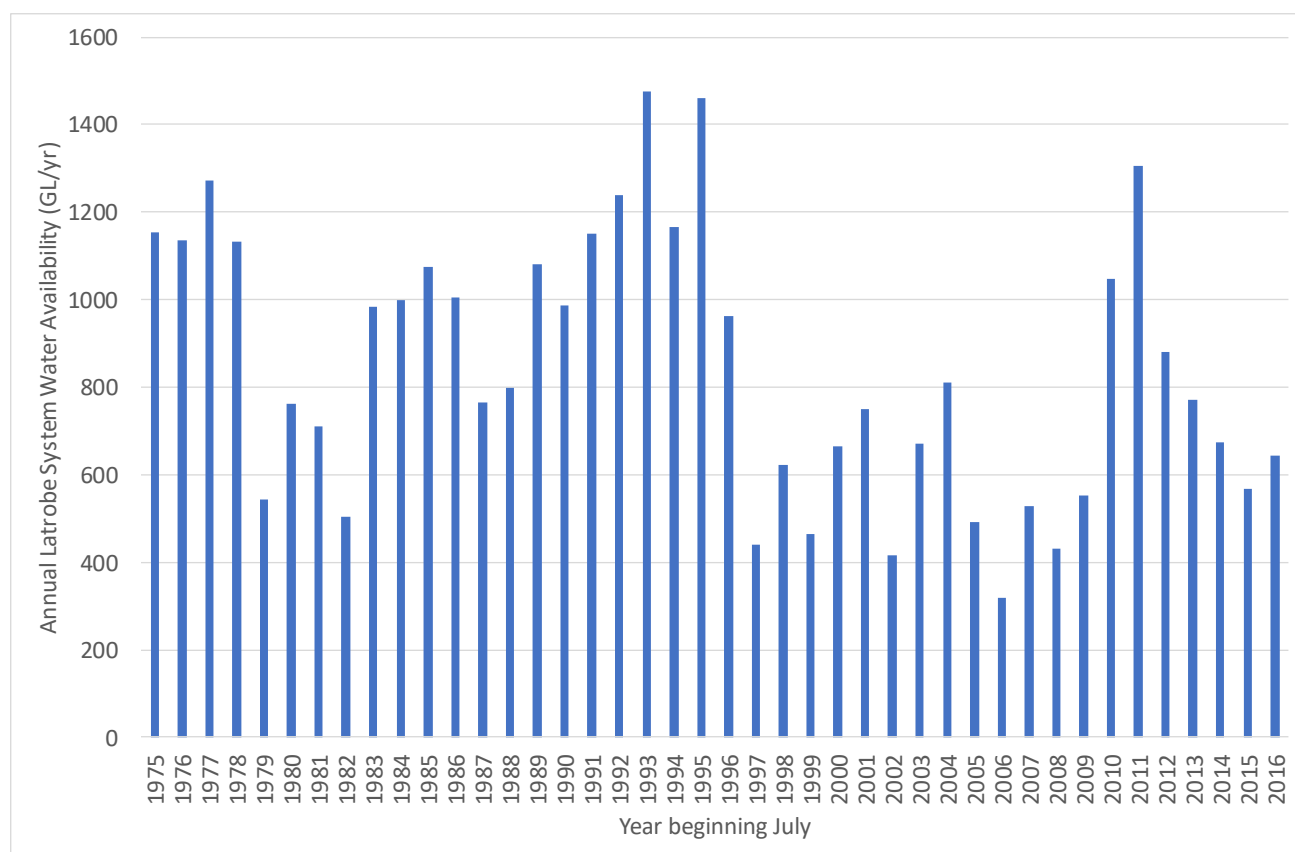


Figure 5 Annual Time Series of Latrobe Basin Water Availability, 1975/76 to 2016/17

Table 4 Annual water availability summary statistics over different periods (GL/yr)

Period	Average	Median	Minimum	Maximum	5 th percentile	95 th percentile
1975/76-2014/15	855	805	318	1,477	432	1,314
1997/98-2016/17	653	633	318	1,306	412	1,061
1957/58-2016/17	860	807	318	1,477	440	1,274

Within the post-1975 climate baseline, climate conditions since 1997 have been particularly dry. This period includes the Millennium Drought (1997-2009), which is the most severe and prolonged drought in the historical record in Victoria. It also includes lower than average cool season (April to October) rainfall during and in the decade after the end of the Millennium Drought. This change in cool season rainfall in Victoria has been linked to anthropogenic climate change (DELWP, 2019a).

The *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (DELWP, 2016) recognise the possibility that rainfall conditions experienced since the start of the Millennium Drought could represent a permanent shift in rainfall for Victoria, at least in the near-term. To this end, the guidelines recommend consideration of a post-1997 climate baseline for near-term planning applications, which assumes that the drier conditions experienced since 1997

could continue in the near-term. This is regarded in the guidelines as a precautionary scenario for water planning purposes.

A post-1997 climate baseline could have different interpretations, depending on the extent to which these recent conditions are attributable to climate change versus climate variability. The extent to which rainfall and streamflow conditions experienced in Victoria since 1997 are attributable to anthropogenic climate change or natural climate variability is unclear. DELWP (2019a) notes that cool season rainfall since the late 1990s has been tracking along the high (dry) climate change projection from global climate models, assuming no influence from natural climate variability on the observed rainfall declines.

For the Latrobe Basin, within the post-1975 climate baseline period, observed streamflows have been on average 36% lower in the post-1997 period relative to the pre-1997 period, as shown in Table 5. When compared against the post-1975 baseline as a whole, post-1997 streamflows have been 23% lower. When compared against the global climate model projections in Table 6, it can be seen that this is drier than the medium climate change projection for the year 2040, but not as dry as the high (dry) climate change projection for 2040.

Table 5 Change in runoff under post-1997 climate conditions

Post-1975 average annual unimpacted streamflow (GL/yr)	Pre-1997 average annual unimpacted streamflow within post- 1975 baseline period (GL/yr)	Post-1997 average annual unimpacted streamflow (GL/yr)	Post- 1997 runoff relative to Pre- 1997 baseline runoff (%)	Post- 1997 runoff relative to Post- 1975 runoff (%)
843	1,016	653	-36%	-23%

4.5 CLIMATE CHANGE PROJECTIONS

Climate change projections for the LVRWS were prepared by Jacobs et al. (2017). These were provided for a high greenhouse gas emissions scenario (the RCP8.5 scenario in IPCC (2015)), which according to DELWP (2016) is suitably precautionary for water supply planning applications. A high (dry), medium and low (wet) global climate model projection was provided, representing uncertainty in global climate model behaviour for the given emissions scenario. These three projections are sampled from the 42 available global climate models that were used in the Intergovernmental Panel on Climate Change's most recent global assessment report (IPCC, 2015). The high (dry) projection is sourced from the model that generates the 10th percentile driest projection (i.e. only 10% of models produce results that are drier than this projection), whilst the low (wet) projection is sourced from the model that generates the 10th percentile wettest projection. As such, the projections represent indicative upper and lower bound estimates, with only a small number of global climate model results lying outside of this range.

Projections for the years 2040 and 2065 in Jacobs et al. (2017) were informed by the *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (the guidelines) (DELWP, 2016). This included adopting the same emissions trajectory and selecting a 10th, 50th and 90th percentile result from the global climate models. However, the project area for the LVRWS covers multiple river basins flowing into the Gippsland Lakes so Jacobs et al. (2017) spatially averaged the climate change projections over the Gippsland region to utilise the same global climate model across the Latrobe, Thomson, Mitchell and Tambo River basins, for each individual (high, medium or low) projection. Meanwhile, the DELWP (2016) guidelines utilised projections applicable to each river basin individually, without requiring the same global climate model to necessarily be sampled from in adjacent river basins. The differences in runoff projection from the two methods are illustrated in Table 6, which highlight the uncertainty in these projections associated with different (but equally valid) post-processing of global climate model outputs.

Table 6 Projected change in runoff for the Latrobe Basin under climate change

Year	Projection type	Jacobs et al. (2017) projected change from post-1975 baseline	DELWP (2016) projected change from post-1975 baseline
2040	High (dry)	-35.5%	-31.3%
	Medium	-10.0%	-10.7%
	Low (wet)	+22.6%	+8.7%
2065	High (dry)	-49.2%	-41.5%
	Medium	-17.9%	-16.3%
	Low (wet)	+10.3%	+0.1%

Projected changes in net evaporation are shown in Table 7. Again, there are small differences between the projections in Jacobs et al. (2017) for the LVRWS and the DELWP (2016) guidelines, due to the selection of common global climate models across all river basins of the Gippsland Lakes in Jacobs et al. (2017).

Table 7 Projected change in rainfall and potential evaporation for the Latrobe Basin under climate change

Year	Projection type	Jacobs et al. (2017) projected rainfall change from post-1975 baseline	DELWP (2016) projected rainfall change from post-1975 baseline	Jacobs et al. (2017) projected potential evaporation change from post-1975 baseline	DELWP (2016) projected potential evaporation change from post-1975 baseline
2040	High (dry)	-14.2%	-11.4%	+5.8%	n/a
	Medium	-4.2%	-4.0%	+4.5%	+4.5%
	Low (wet)	-3.7%	+3.3%	+2.5%	n/a
2065	High (dry)	-20.9%	-16.7%	+11.5%	n/a
	Medium	-4.5%	-4.5%	+7.6%	+7.6%
	Low (wet)	-2.3%	+2.2%	+4.7%	n/a

n/a indicates that these values were not provided in DELWP (2016)

The RCP8.5 greenhouse gas emissions trajectory was adopted in Jacobs et al. (2017), consistent with the advice in the State Government guidance (DELWP, 2016). All emissions scenarios produce similar global temperature outcomes up to 2030, with only small differences by the year 2040 (IPCC, 2015). If a lower emissions trajectory were to eventuate, the above projections for the Latrobe Basin could be both less dry (for the dry projection) or less wet (for the wet projection) than shown in Table 6, particularly beyond the year 2040.

The next round of global climate modelling from the Intergovernmental Panel on Climate Change is due to be released from mid-2021 to mid-2022. The projections in Table 6 are likely to change when those new global climate model results are released.

4.6 WATER AVAILABILITY UNDER PROJECTED CLIMATE CHANGE

The climate change projections presented in Section 4.5 were applied to the current water availability estimates to project water availability under climate change in the year 2040 and 2065. DELWP (2016) notes that climate change will manifest in practice as a series of steps and trends (including non-linear trends), but the timing and magnitude of those steps and trends in any given year is not precisely known. In the absence of this knowledge, water availability between these years was linearly interpolated (DELWP 2016). Prior to 2040, climate change projections were linearly interpolated from zero in the year 1995, which is the mid-point of the reference climate period used in DELWP (2016) and Jacobs et al. (2017) to derive the climate change projections. Beyond 2065, Jacobs et al. (2017) assumed a linear extrapolation using the same annual rate of change as that projected to occur from 2040 to 2065.

Projected changes to long-term average water availability are presented in Figure 6. In this figure, the post-1975 long-term average and the post-1997 long-term average are represented by median historical values.

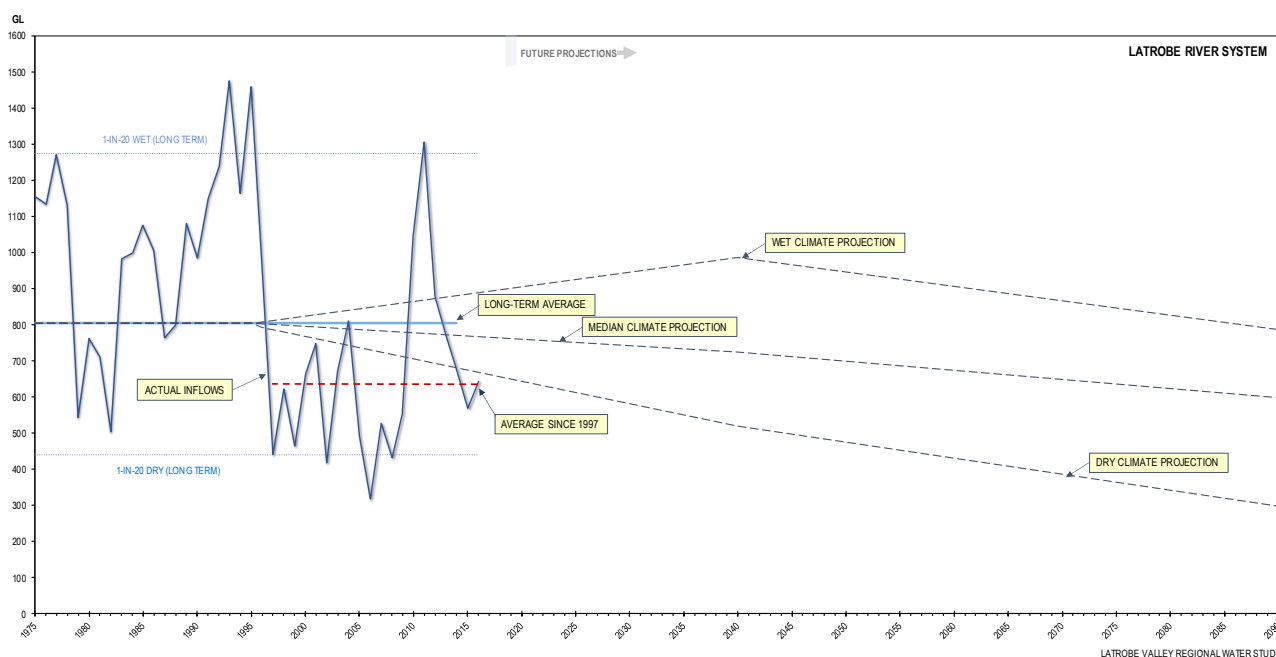


Figure 6 Climate change projections of water availability for the Latrobe Basin

Under the high (dry) climate change projection, flows in the Latrobe Basin could decline significantly by 2060 to ~400 GL/yr. Year 2040 water availability projections range from 500-1,000 GL/yr, with a median projection of 700 GL/yr in 2040, declining to ~650 GL/yr in 2065. These values are shown in Table 8. If the drying conditions currently being experienced in Gippsland continue into the future along the high (dry) climate change projection, by 2048, when Loy Yang is scheduled to close, inflows in the Latrobe River Basin may be approximately half of their historic average.

The *Guidelines for Assessing the Impact of Climate Change on Water Supplies in Victoria* (DELWP, 2016) do not present a preferred reference point from which to interpolate the global climate model projections prior to 2040. As stated above, a 1995 reference point has been adopted, consistent with the manner in which the global climate model scaling factors were derived in DELWP (2016) and Jacobs et al. (2017). If the alternative interpretation of the 2016 guidelines were adopted, and interpolation proceeds from the current year of 2020, then projected water availability under climate change prior to 2040 would be slightly higher than shown in Figure 6 for the medium and high (dry) climate change projection, and

slightly lower for the low (wet) climate change projection. The difference caused by the uncertainty in this assumption is greatest in 2021 and reduces to zero in 2040.

Table 8 Climate change projections of water availability for the Latrobe Basin

Year	Water availability (GL/yr)		
	Low (wet) projection	Medium projection	High (dry) projection
2030	950	740	580
2035	970	730	550
2040	990	730	520
2045	970	710	500
2050	950	700	480
2055	930	690	450
2060	910	670	430
2065	890	660	410
2070	870	650	390

5 CURRENT AND PROJECTED LATROBE SYSTEM WATER DEMAND

5.1 INTRODUCTION

This section documents the estimation of water demands in the Latrobe System. It includes consumptive water demands from both surface water and groundwater, historical water use at the mine sites for power generation, environmental water demands, and estimated rates of evaporation from open water bodies.

5.2 CONSUMPTIVE WATER DEMAND

5.2.1 SURFACE WATER DEMAND

Current surface water use by bulk entitlement is tabulated in Table 9 for a drought year (2006/07) and as an average annual volume from 2006/07 to date (2018/19). Drought year volumes are presented as an indicative upper bound on historical water use.

Water was used from the Latrobe Reserve entitlement for the first time during dry conditions in 2018-19. SRW offered 2085 ML of water to irrigators in three auctions held in February, April and May 2019, with 1950 ML purchased.

The measured water use in the drought year (2006/07) in Table 9 by individual water users includes use of the 14.6 GL of allocation transferred (traded) from the Loy Yang 3/4 Bench entitlement to the power generators, section 51 licence holders and Gippsland Water (to supply power generators) in that year to offset the impacts of very low water availability (DELWP 2018). This occurred prior to the creation of the Latrobe Reserve entitlement, which would perform this function under current conditions, rather than drawing from the Loy Yang 3/4 Bench entitlement.

Table 9 Average annual surface water use by consumptive water users (source: Victorian Water Accounts, e.g. DELWP, 2018)

Entitlement ⁽¹⁾	Maximum Annual Entitlement Volume (ML)	Average annual volume (ML/yr) 2006/07 to 2018/19			Drought Year (2006/07) volume (ML/yr)		
		Diversions	Return Flows	Net Diversions	Diversions	Return Flows	Net Diversions
Gippsland Water –Blue Rock ⁽²⁾	20,000 (averaged over 3 years) ⁽⁵⁾	51,396	24,246	27,150	50,450	21,405	29,045
Gippsland Water – Moondarra Reservoir ⁽²⁾	62,000 (averaged over 2 years)						
Gippsland Water – Narracan Creek (Moe)	3,884	1,901	0	1,901	2,695	0	2,695
Yallourn	36,500	27,447	13,142	14,305	30,580	12,293	18,287
Loy Yang A	40,000	21,790	4,576	32,020	24,942	4,040	39,554
Loy Yang B	20,000	14,806			18,652		
Loy Yang 3/4 Bench	25,000	0	0	0	0 ⁽⁴⁾	0 ⁽⁴⁾	0 ⁽⁴⁾
Latrobe – Southern Rural	13,400 (averaged over 2 years)	6,646	0	6,646 ⁽³⁾	7,399	0	7,399 ⁽³⁾
Private diversion licences from unregulated rivers	18,891	7,734	0	7,734	14,000	0	14,000
Total	239,675	131,720	41,964	83,110	148,718	37,738	103,581

Notes to table

1. Excludes unused bulk entitlements for Boolarra, Thorpdale and Noojee, as well as minor volumes available under bulk entitlements for Erica-Rawson and Mirboo North. Excludes diversions from stock and domestic farm dams, which do not require a licence.
2. Water from these Bulk Entitlements includes water that has historically provided for power generation at the Hazelwood Power Station, but also includes supply to other major industrial water users
3. Includes diversions from the return flows from power generators and industry
4. Usage from the Loy Yang 3/4 Bench entitlement that was made available in 2006/07 to other entitlement holders is accounted for in the water use of those other entitlement holders.
5. In 2014, Gippsland Water was allocated a 3.87% inflow and storage share of the previously unallocated share of Blue Rock Reservoir. To correspond with this, its max take was increased from 15,150 ML/year to 20,000 ML/year over 3-year consecutive period.

Unlicensed stock and domestic water use from farm dams within the Latrobe River basin is additional to the values in Table 9. The total water use from these dams (i.e. usage plus net evaporation) was estimated to be approximately 5 GL/yr in 2017/18 (DELWP, 2018).

Surface water use at the mine sites for power generation is presented in Table 10. This table indicates that since 2006-07, the Latrobe Valley power stations have used, on average, around 78 GL/year of surface water from the Latrobe River system for power generation and around 21 GL/year has been returned to the Latrobe River system. Water use in the 2006/07 drought year is indicative of maximum historical water use for power generation. As above, the water use in 2006/07 year was supplemented by the transfer of allocations from the Loy Yang 3/4 Bench entitlement in a similar manner to the way the Latrobe Reserve would currently operate. Supply to Energy Brix prior to its closure was approximately 6 GL/yr on average (Gippsland Water, 2017), with return flows from Energy Brix approximately 2 GL/yr on average and 4.3 GL/yr in the 2006/07 drought year (e.g. DELWP, 2018).

Table 10 Average annual surface water use by mine site for power generation (source: Victorian Water Accounts, e.g. DELWP, 2018)

Mine site	Maximum Annual Entitlement Volume (ML)	Average annual volume (ML/yr) 2006/07 to 2018/19			Drought Year (2006/07) volume (ML/yr)		
		Diversions	Return Flows	Net Diversions	Diversions	Return Flows	Net Diversions
Hazelwood	Supply by agreement contract amounts	14,000	3,668	10,332	14,000	1,277	12,723
Yallourn	36,500	27,447	13,142	14,305	30,580	12,293	18,287
Loy Yang	60,000	36,596	4,576	32,020	43,594	4,040	39,554
Total	96,500 plus supply by agreement contract amounts for Hazelwood	78,043	21,386	56,657	88,174	17,610	70,564

5.2.2 GROUNDWATER EXTRACTIONS

Average groundwater extractions from 2005/06 to 2018/19 for the three mines combined is 28 GL/yr, which is significantly less than the aggregated licensed volume of 45 GL/yr. Over the period 2012/13 to 2017/18 for which published groundwater use information is available for the mine sites, groundwater use at the mine sites has ranged from 23 GL/yr up to full use of the licensed volume of 45 GL/yr (e.g. DELWP, 2018).

5.3 MINIMUM ENVIRONMENTAL WATER DEMAND

Minimum environmental flows in the Latrobe River and downstream wetlands were recommended in the environmental flow study for the river (Alluvium, 2019). These represent the minimum requirements to achieve environmental objectives and maintain ecosystem values. Flows above these minimum requirements would provide additional environmental benefits for the river, downstream wetlands and the broader Gippsland Lakes, closer to what that ecosystem would have experienced naturally.

These minimum environmental flows include the passing flows specified on consumptive bulk entitlements. However, due to our improved knowledge of minimum environmental water requirements through application of the FLOWS method (Alluvium, 2019), these minimum environmental flows are typically higher than the passing flows that were specified in bulk entitlements.

Minimum environmental flows are recommended for eleven individual river reaches within the Latrobe Basin, including several on tributaries of the Latrobe River (Alluvium 2019). These eleven reaches include locations with minimum passing flows on water diversions in consumptive bulk entitlements. For the LVRWS water availability assessment, the river reach with the greatest environmental water demand within the Latrobe System was Reach 4 on the Latrobe River from Scarnes Bridge to Kilmany South, with measurements at a streamflow gauge at Rosedale. This reach is upstream of the Thomson River, but downstream of the major tributaries of the Latrobe River and the major diversion locations for consumptive users. The minimum environmental flow recommendations for this reach, including their magnitude, duration, frequency and seasonal timing, are specified in Table 11. This table recommends, for example, a minimum flow in summer/autumn of 380 ML/d or natural, and 3-6 freshes of 1,400 ML/d of 5-7 day duration, depending on the prevailing climate conditions in any given year.

Table 11 Minimum environmental water requirements for the Latrobe River for the reach from Scarnes Bridge to Kilmany South (Reach 4) (Alluvium, 2019)

Flow component	Magnitude (ML/day)	Frequency (No/period)		Duration (days)	
Summer / Autumn Baseflow	380 or natural	DROUGHT	Cont	DROUGHT	Cont
		DRY		DRY	
		AVG		AVG	
		WET		WET	
Summer / Autumn Fresh	1,400 ML/day	DROUGHT	3	DROUGHT	5 days
		DRY	6	DRY	6 days
		AVG	6	AVG	6 days
		WET	6	WET	7 days
Winter / Spring Baseflow	1,800 or natural	DROUGHT	Cont	DROUGHT	Cont
		DRY		DRY	
		AVG		AVG	
		WET		WET	
Winter / Spring Fresh	3,000 ML/day	DROUGHT	3	DROUGHT	2 days
		DRY	5	DRY	4 days
		AVG	6	AVG	6 days
		WET	6	WET	7 days
Bankfull	8,000 ML/day	DRT / DRY	-	DRT / DRY	-
		AVG	1/year	AVG	2 days
		WET		WET	
		Overall: Max duration between events: 2 years			
Overbank	> 10,000 ML/day	DRT / DRY	-	DRT / DRY	-
		AVG / WET	1/ 2 years	AVG / WET	2 day
		Overall: Max duration between events: 2 years			

The recommendations for Reach 4 were converted into an annual minimum environmental water demand for the system for each type of climate year. For baseflows, the minimum environmental water demand was the recommended daily volume multiplied by the number of days in each season to which it applied. For freshes, the volume per event was estimated on a daily time step using the rates of streamflow rise and fall recommended in Alluvium (2019). From this analysis, the volume of water required in each type of climate year was as shown in Table 12. Fresh volumes are over and above baseflow volumes being provided in the same season. These fresh events are assumed to occur independently, and that a higher magnitude flow event (e.g. an overbank event) does not count as a lower magnitude flow event (e.g. a summer/autumn or winter/spring fresh).

Table 12 Annual minimum environmental water demand by type of climate year for the Latrobe River for the reach from Scarnes Bridge to Kilmany South (Reach 4).

Flow component	Annual Minimum Environmental Water Demand (GL/yr)			
	Wet Year	Average Year	Dry Year	Drought Year
Summer/autumn baseflow	15	15	15	15
Summer/autumn fresh	56	50	50	22
Winter/spring baseflow	275	275	275	275
Winter/spring fresh	55	48	28	9
Bankfull	29	29	0	0
Overbank	36	36	0	0
Sub-total excluding passing flows	465	452	367	320
Passing flows (with a daily requirement of 300 ML/d at Thoms Bridge)	110	110	110	110
Total minimum environmental flow	575	561	476	430

In combination with flows from the Thomson River, these Latrobe River flow recommendations also contribute to the environmental water demands in the Lower Latrobe Wetlands and Lake Wellington.

When undertaking time series analysis of environmental water demands, each year of data was categorised as being wet, average, dry or drought. The definition of each of these types of climate year are shown in Table 13, which also indicates the historical likelihood of those conditions occurring.

Table 13 Climate condition definitions (Alluvium, 2019)

Climate condition	Definition	Years this climate condition occurred historically from 1957 to 2017 in inflows to Blue Rock Reservoir and Lake Narracan	
		Number of years	% of years
Drought	50% of average annual flow	3	~ 5%
Dry	50-75% of average annual flow	10	~ 17%
Average	75-125% of average annual flow	34	~ 57%
Wet	>125% of average annual flow	13	~ 22%

Historical volumes of water delivered for the environment from the Latrobe System environmental entitlements varies from year to year, depending on climate conditions. Excluding volumes delivered to the Lower Latrobe wetlands (which are not measured nor need to be accounted for under the environmental entitlement), the historical volume of water delivered in each year was as shown in Table 14. These volumes are significantly lower than the minimum environmental water demand previously presented in Table 12. This is because the role of the environmental entitlement is to supplement streamflows to better meet the minimum environmental water demand and reduce the likelihood of environmental water demand shortfalls. Water held in storage under the environmental entitlement can also be carried over from year to year, either to accumulate water to deliver larger, less frequent environmental flow events and/or as a safeguard against drying conditions.

Table 14 Historical water delivered from environmental entitlements and volume of outflow to the Gippsland Lakes (source: Victorian Water Accounts, e.g. DELWP, 2018)

Year	Volume of water delivered from environmental entitlements (excluding diversions to the Lower Latrobe wetlands) (ML/yr)	Volume of outflow to the Gippsland Lakes (excluding Thomson River) (ML/yr)
2013/14	3,748	687,487
2014/15	3,984	586,940
2015/16	3,750	473,132
2016/17	3,713	525,405
2017/18	11,224	401,559
2018/19	5,502	
Average 2013/14 to 2017/18	5,320	534,901

Indicative environmental water demand shortfalls at current levels of consumptive use have been estimated under average, dry and drought years from 1975 to date. After classifying each climate year since 1975 as per Table 13, and assuming a long-term average annual water use for consumptive users, environmental water demand shortfalls are shown in Figure 7. Minimum environmental water demands in the Latrobe River are not met in years of low water availability. Shortfalls in minimum environmental water demands are estimated to occur in 15 years out of the 21 years since 1997, compared with only 3 years out of 22 years between 1975 and 1996. River flows significantly exceeded minimum flow requirements in three of the 21 years in the post-1997 period.

These shortfalls are indicative only because (i) the calculations are undertaken an annual time step, which could underestimate shortfalls on individual days of low flow and high environmental water demand and (ii) consumptive water use is assumed to be an average annual value, when in practice it would vary on individual days and from year to year.

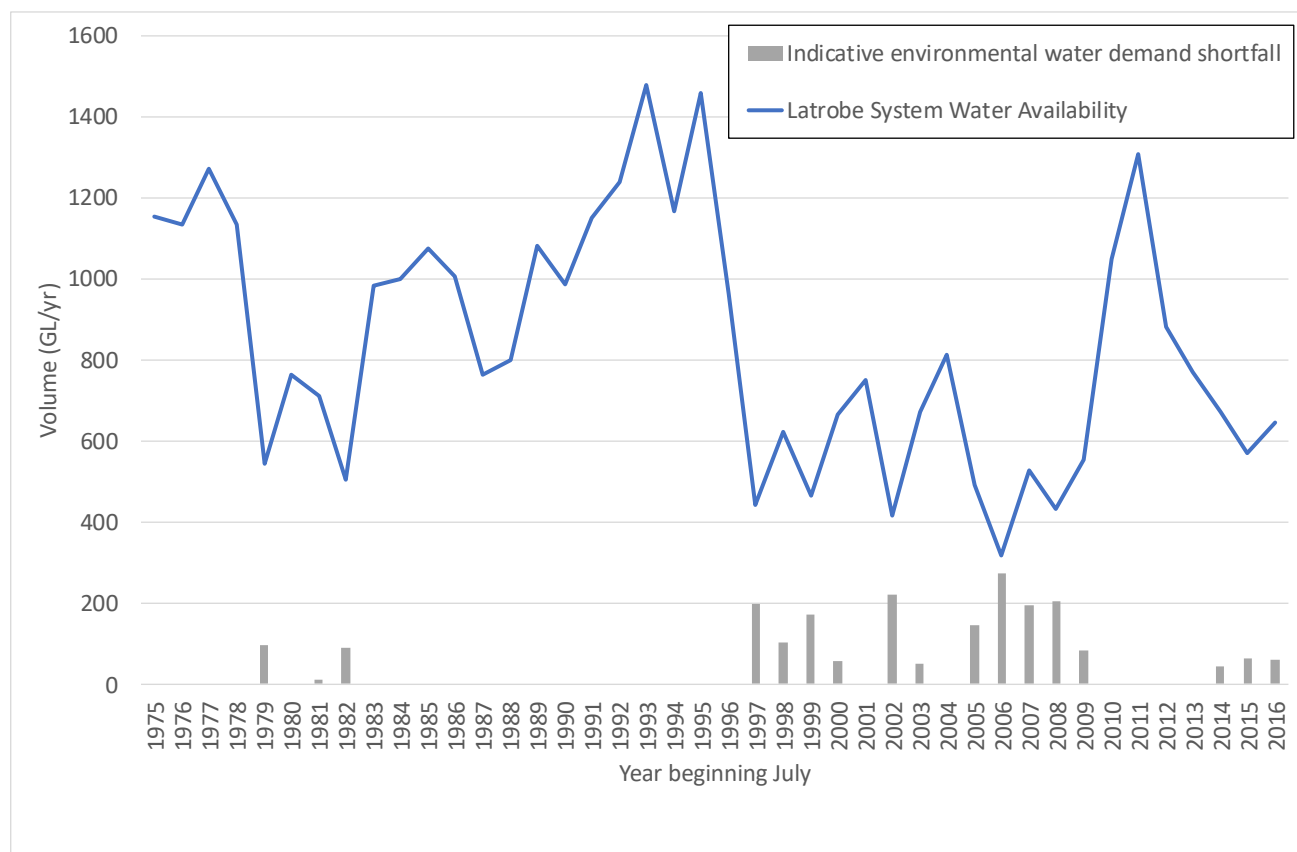


Figure 7 Annual environmental water demand shortfall in the Latrobe River system under post-1975 climate conditions

5.4 EVAPORATIVE WATER DEMAND

Evaporative water demand from the mine water bodies was estimated using the bathymetry (size and shape) of the potential water bodies and rates of potential evaporation.

The water body bathymetry is shown in Table 15. The estimated capacity of the mine water bodies when full is assumed to be 638 GL for Hazelwood, 725 GL for Yallourn and 1,418 GL for Loy Yang.

Table 15 Water body bathymetry

Water body						
Water level	Hazelwood		Yallourn		Loy Yang	
	Surface Area (km ²)	Volume (GL)	Surface Area (km ²)	Volume (GL)	Surface Area (km ²)	Volume (GL)
Full	11.2	640	20.3	725	15.9	1,420

There are various methods available to estimate rates of evaporation from large water bodies. Considering the strengths and limitations of each of the approaches, McMahon et al. (2013) identified Morton's (1986) shallow lake method to be preferred for estimating evaporation from open water bodies, as the evaporation estimates had been widely and independently tested. There is no difference in magnitude between Morton's deep and shallow lake evaporation for annual evaporation estimates (McMahon et al. 2013). Morton's shallow lake evaporation also has the advantage that infilled datasets of this parameter are available for all of Australia from SILO (Scientific Information for Land Owners) datasets, produced by the Queensland State Government (State of Queensland, 2020).

Rainfall and evaporation vary across time and mine sites. Average annual rainfall, evaporation and net evaporation (i.e. evaporation minus rainfall) are shown in Table 16, together with the estimate of the average annual volume of net evaporation when the mine water bodies are full, using the surface areas presented in Table 15.

Table 16 Average annual net evaporation from mine water bodies when full, 1/7/1975 to 30/6/2017

Water body	Evaporation (mm/yr)	Rainfall (mm/yr)	Net evaporation (mm/yr)	Net evaporation when mine water body is full (GL/yr)
Hazelwood	704	1,061	356	4.0
Yallourn	753	1,068	315	6.4
Loy Yang	730	1,065	335	5.3
Total				15.7

6 POTENTIAL WATER AVAILABILITY FOR MINE REHABILITATION

6.1 INTRODUCTION

This section of the report outlines the process to estimate the time to fill each of the mine voids with water under a range of scenarios. It includes an explanation of the modelling approach and assumptions and a presentation of results. It should be noted that these are broad, preliminary estimates for the LVRWS and may be superseded by more detailed pit lake modelling.

Around 1,600 GL would be needed to partly fill the mine voids to counter weight balance while up to 2,800 GL of water could be needed to completely fill all mine voids to their crests—a volume equivalent to the size of five Sydney Harbours or three Thomson Dams. Whilst this volume is much larger than the average annual historic water use and entitlement volumes (Figure 8), mine rehabilitation will be undertaken progressively over many decades as individual mines close. As such, the filling rate if required for mine rehabilitation would be limited to the power stations' current annual net usage and filling would be restricted or halted under dry conditions to prevent unacceptable impacts on water security, other water users and values including river function and the Lower Latrobe wetlands and Gippsland Lakes.

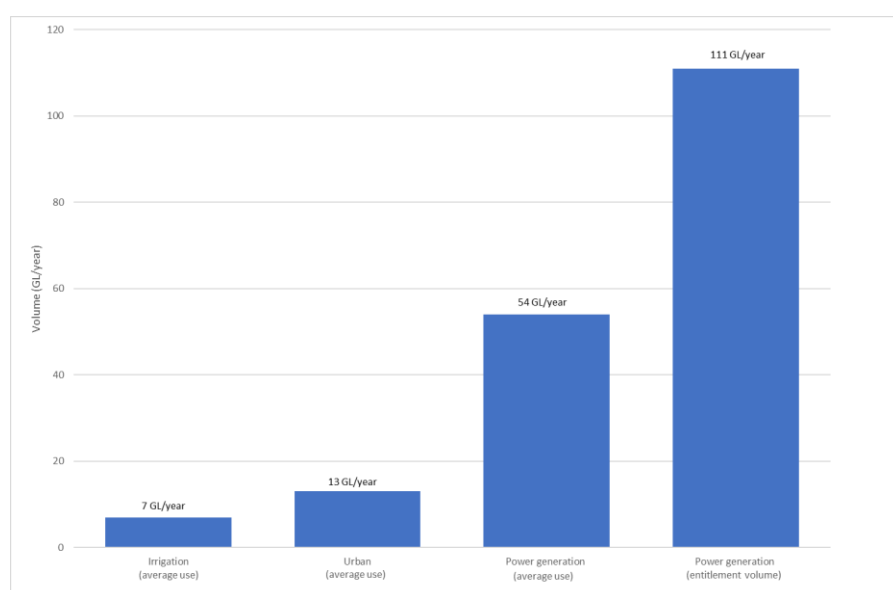


Figure 8 Average annual water use and entitlement volumes

6.2 ANNUAL MASS BALANCE OF PROJECTED WATER AVAILABILITY

6.2.1 MODELLING APPROACH

The modelling approach for estimating the time to fill each mine void with water is a simple average annual mass balance, carried out in Microsoft Excel. Equation 2 estimates the volume in the potential water body in any given year (t) and Equation 3 defines the volume of water assumed to be supplied to the potential water body on each time step.

$$\text{Volume in water body (t)} = \text{Volume in water body (t-1)} + \text{Annual supply to water body (t)}$$

Equation 2

IF Volume in water body (t) < Target THEN

Annual supply to water body (t) = Annual water availability (t); and

IF Volume in water body (t) = Target THEN

Annual supply to water body (t) = Annual maintenance volume

Equation 3

Each mine void is assessed independently in order of planned mine site decommissioning, but with the ability to use the same supply source to fill the water bodies sequentially. Given the level of uncertainty in water availability the modelling

approach is high level and preliminary in nature. It provides an indication of the likely range of filling durations. A key limitation to the modelling is that it assumes no interruption to the annual water availability, for example due to dry conditions. Further assumptions are listed below.

6.2.2 SCENARIO DESCRIPTIONS AND ASSUMPTIONS

A range of filling scenarios were investigated as part of the LVRWS. These are listed in Table 17 and include:

- A supply of surface water, such as that supplied in the past by Gippsland Water for power generation, could be made available, subject to the Minister for Water's (or delegates) approval of an application for water for this purpose, to all mine operators in a sequential manner over time and could be in the order of 20 GL/yr or 22 GL/yr. This volume is indicative of the historical volumes supplied to Hazelwood and Energy Brix, previously reported in Section 5.2
- A range of assumed supply from Blue Rock Reservoir and the Latrobe River, including full entitlement use (36.5 GL/yr Yallourn, 60 GL/yr Loy Yang), historical use in a drought year (18 GL/yr Yallourn, 37 GL/yr Loy Yang), and various other increments of assumed supply to Yallourn and Loy Yang from zero to 20 GL/yr.
- A range of assumed supply from groundwater, including use of the full licensed volume (22.484 GL/yr Hazelwood, 3.285 GL/yr Yallourn, 19.996 GL/yr Loy Yang) and historical use (13 GL/yr Hazelwood, 0 GL/yr Yallourn, 15 GL/yr Loy Yang).

This assessment is preliminary in nature, as part of range finding of the sensitivity of filling times to different assumptions. Due to the nature of these assumptions the filling duration is more likely to be under-estimated than over-estimated. In addition to the assumptions about supply volumes, various other assumptions include:

- Filling commences according to the planned mine site closure timeline. The planned mine site closure timeline involves closure of Hazelwood in 2022, Yallourn in 2032 and Loy Yang in 2048. Hazelwood mine closed in 2017, earlier than planned.
- Filling is assessed on an annual time step, with no allowance for seasonal or daily variance in water availability. If supply on wet days is limited by the ability to transfer water to the proposed water bodies, this assumption could result in an over-estimation of water availability, and therefore an under-estimation of the duration of the filling period.
- Filling assumes the same supply volumes from any given supply source in each year over the fill period. This does not allow for inter-annual variability in water availability. Supply in dry years could be constrained by water availability. This assumption could therefore result in an over-estimation of water availability in dry years, and therefore an under-estimation of the duration of the filling period.
- No access to flood flows or river diversions, outside of existing use from bulk entitlements supplying the mine sites.
- A supply of surface water, such as that supplied in the past by Gippsland Water for power generation, could be made available to all mine sites in a sequential manner over time. The use of this supply volume is sequential, with initial use at Hazelwood, then transfer to Loy Yang after Hazelwood has reached its target volume, then transfer to Yallourn after Loy Yang has reached its target volume. One potential source of this supply is from Gippsland Water. However, Gippsland Water's Urban Water Strategy (Gippsland Water, 2017) indicates that supply from Blue Rock Reservoir via Moondarra Reservoir could become a constraint in the future if demand in the Latrobe urban supply system were to increase significantly due to a new industry, in addition to the mine rehabilitation supply.
- No allowance for projected climate change. Under the medium and high (dry) climate change projections, this could result in an over-estimation of water availability, and therefore an under-estimation of the duration of the filling period.
- Maintenance volumes are assumed to be equal to the average annual net evaporation from each water body at the maximum target fill volume, under post-1975 climate conditions, and do not include seepage. No evaporative or seepage loss is assumed during the fill period. When evaporative losses are considered, these timeframes extend out by another five years. No allowance has been made for the projected impact of climate change on evaporative losses. As noted in previously in Table 7, evaporation is projected to increase over time.
- No restrictions on supply from groundwater. Based on the information in the Catchment Statement for Central Gippsland and Moe Groundwater Catchments (SRW, 2014b), this is a reasonable assumption unless rates of groundwater level decline were to change in the future, but would be subject to specific groundwater license conditions.
- No other supply from other water sources. If additional water sources were identified, this would result in an under-estimation of water availability and therefore an under-estimation of the duration of the filling period.

- No consideration of the fluctuations in the quality of water supply to the mine voids. Any constraints on the water quality of source water could potentially lengthen the duration of the filling period.

Table 17 Scenario descriptions and assumed supply volumes from surface water and groundwater.

Scenario number (and notes)	Supply of surface water outside of bulk entitlements for power generation (GL/yr)	Blue Rock Reservoir / Latrobe River supply (GL/yr)		Groundwater supply (GL/yr)		
		Yallourn	Loy Yang	Hazelwood	Yallourn	Loy Yang
01 – Sensitivity to different assumed supply volumes	20	18	37	13	0	15
02 – Groundwater and surface water supply at licence and entitlement volumes	22	36.5	60	22	3.3	20
03 – Sensitivity to different assumed supply volumes	22	20	20	13	0	15
04 – Sensitivity to different assumed supply volumes	22	15	15	13	0	15
05 – Sensitivity to different assumed supply volumes	22	10	10	13	0	15
06 – No supply from power generator bulk entitlements	22	0	0	13	0	15
07 – Groundwater supply 15 GL/yr to Loy Yang only, none to other mine sites	22	10	10	0	15	0

6.2.3 RESULTS

For each scenario, the duration of the period of filling is as shown in Table 18. For example, for Scenario 01, which assumes the water available for mine site rehabilitation is similar to drought year historic water use, it is estimated that Hazelwood would take ~20 years to fill, Yallourn ~24 years and Loy Yang ~22 years to fill. Hazelwood is estimated to be full in the early 2040s, Yallourn by around the mid 2050s, and Loy Yang at around 2070. All fill durations and estimated end dates for filling are indicative only, and are subject to the various assumptions and uncertainties previously outlined in Section 6.2.2. Due to the nature of these assumptions the filling duration is more likely to be under-estimated than over-estimated.

Some observations can be made about the range of outcomes possible under the different modelling assumptions. These include that:

- If full entitlement volumes were supplied to the mine voids (Scenario 02), rather than volumes indicative of drought year historical use (Scenario 01), the duration to fill each mine void would be shortened by around 5 years at Hazelwood, ~10 years at Yallourn and ~8 years at Loy Yang. However, under this scenario there would be unacceptable impacts on the reliability of supply to other existing water users and the environment.
- Lower volumes of water sourced from outside of the power generator bulk entitlements (Scenarios 03 to 06) or from groundwater (Scenario 07) would substantially lengthen fill durations, relative to assuming ~20 GL/yr from this supply source (Scenario 01). Under the lowest assumed water availability (Scenario 06), Loy Yang is estimated to not reach its target fill volume until the early 22nd century.

Whilst not directly assessed, it is inferred from the examination of the scenario modelling results that changes to the mine closure timetable could affect fill durations, particularly if filling periods were to overlap, the ~20-22 GL/yr volume assumed to be made available from other sources may not be available for successive filling of mine voids until the filling of the preceding mine void has finished.

If target fill volumes were lower than assumed, the fill duration would be shorter than shown.

Table 18 Estimated fill duration and end date for filling based on planned closure dates

Scenario number (and notes)	Hazelwood		Yallourn		Loy Yang	
	Fill duration (years)	End date for filling	Fill duration (years)	End date for filling	Fill duration (years)	End date for filling
01 – Sensitivity to different assumed supply volumes	20	2041	24	2056	22	2070
02 – Groundwater and surface water supply at licence and entitlement volumes rather than historic use	15	2036	14	2046	14	2062
03 – Sensitivity to different assumed supply volumes	19	2040	22	2054	28	2076
04 – Sensitivity to different assumed supply volumes	19	2040	25	2057	32	2080
05 – Sensitivity to different assumed supply volumes	19	2040	29	2061	37	2085
06 – No supply from power generator bulk entitlements	25	2046	34	2080	70	2118
07 –Groundwater supply 15 GL/yr to Loy Yang only, none to other mine sites	29	2050	35	2067	58	2106

Figure 9 illustrates the do-nothing scenario, whereby surface water use for power generation declines over time as each mine site is closed. Environmental water demand and water use from other existing consumptive users is assumed to remain constant into the future in this figure. This can be contrasted with Figure 10, which shows a mine rehabilitation scenario that uses an annual volume of water that is representative of water usage under historical power generation in a drought year. Figure 10 is based on Scenario 01.

Figure 9 and Figure 10 illustrate that:

- Water historically provided to the mine sites for power generation can be re-purposed for filling the mine voids under post-1975 baseline climate conditions.
- Under post-1997 baseline climate conditions, water availability in the Latrobe Basin would be substantially lower than under post-1975 baseline climate conditions, such that the duration to fill the mine voids could be substantially lengthened or would no longer be possible without compromising values associated with environmental or other consumptive uses of water.
- Under the low (wet) climate change projection, water availability within the Latrobe Basin is projected to increase and there would be water surplus to the minimum environmental water requirements and existing use (including power generation).
- Conversely, under the medium climate change projection, demand for water would be greater than average annual water availability from ~2035 onwards. In this case less water might be available to harvest in some years, and the Yallourn and Loy Yang mine voids would take longer to fill. When considered on an average annual time step, and notwithstanding current shortfalls in supply to consumptive users and the environment in dry years, filling would be unlikely to significantly affect river function or water security until ~2035.
- Under the dry climate change projection, water availability in the Latrobe Basin would drop substantially over the coming decades, and the duration to fill the mine voids could be substantially lengthened or would no longer be possible without compromising values associated with environmental or other consumptive uses of water.

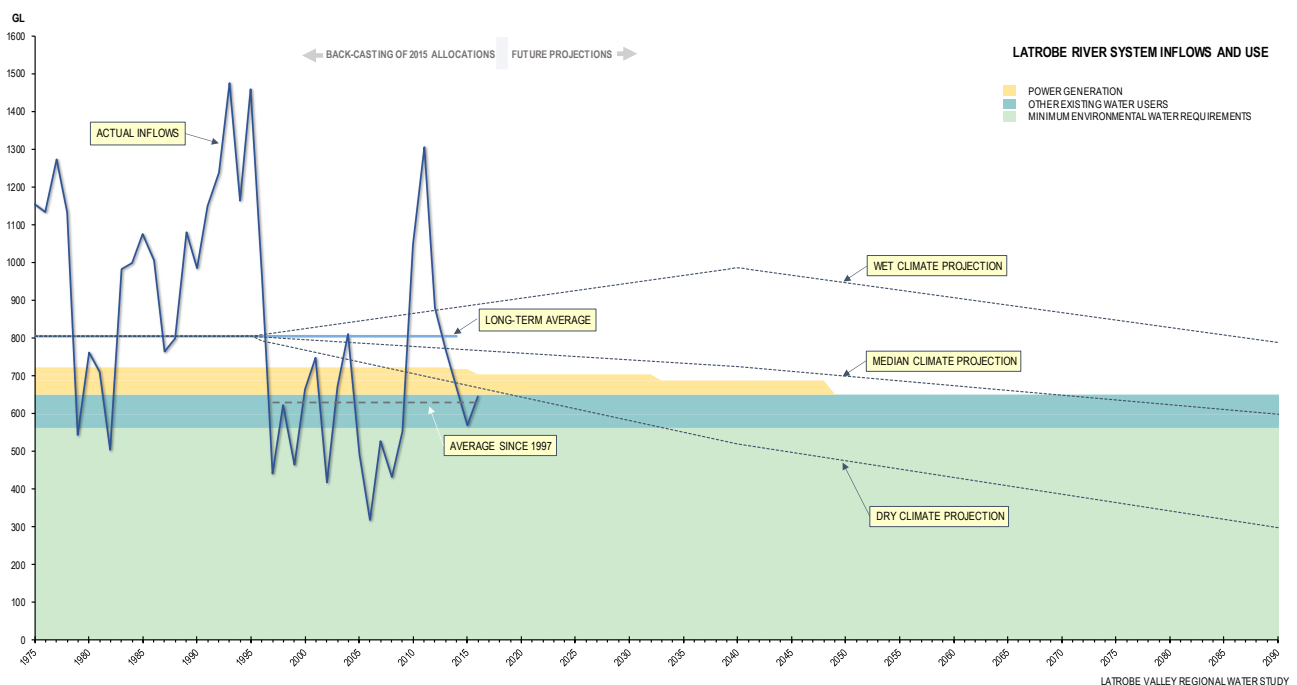


Figure 9 Historical inflows, projected average annual inflows and surface water use under planned mine closure without the filling of mine voids with water from the Latrobe System

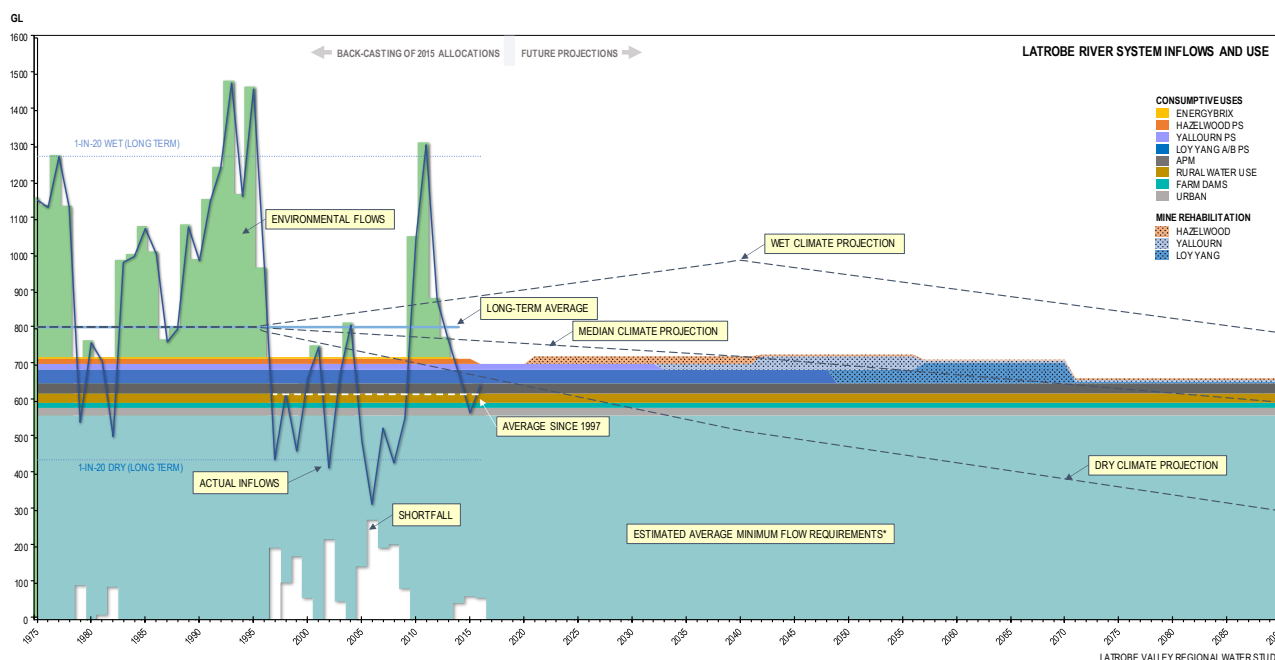


Figure 10 Historical inflows, projected average annual inflows and surface water use under planned mine closure and filling of mine voids with water from the Latrobe System (Scenario 01 – max fill, planned closure)

6.3 CONSOLIDATED ESTIMATE OF DURATION OF FILLING PERIODS

After considering the results from the various scenarios modelled using the annual mass balance approach and its various assumptions, the likely range of fill durations was estimated for an assumed filling scenario. This was not the direct output of any single model assessment, but rather was the result of interpreting the full suite of model outputs and their assumptions.

The assumed filling scenario involves the planned mine closure timeline, the maximum target water body capacity, groundwater supply of 15 GL/yr to Hazelwood and 15 GL/yr to Loy Yang, surface water supply from power company bulk entitlements of 25 GL/yr to Yallourn and 40 GL/yr to Loy Yang, and supply from other sources (similar in magnitude to historical supply from Gippsland Water to the power generators) of 20-25 GL/yr. These volumes are consistent with the historical water use figures during a drought year, previously presented in Section 5.2. Assuming no interruption to supply, it is concluded that the time frame for filling the mine voids are estimated to be:

- 15-20 years for Hazelwood;
- 20-25 years for Yallourn; and
- 25-30 years for Loy Yang.

When evaporative losses are considered, these timeframes extend out by another five years.

Large volumes of additional water (notionally 5-10 GL/yr extra per mine) would be required to materially hasten these filling rates. The volume that is assumed to be available from power generator bulk entitlements for mine rehabilitation is based on historical water use in a drought year. If this volume were based on average historical water use, the volume available would be lower and the fill times would be extended.

As noted previously, these estimates could be significantly under-estimated because filling will need to be restricted or halted under dry conditions to prevent unacceptable impacts on other water users and the environmental values of the Latrobe River, Lower Latrobe wetlands and Gippsland Lakes under the medium and high (dry) climate change scenarios, and under a post-1997 climate baseline. Under both current conditions and drier climate change projection, there is likely to be a relatively large proportion of years in which filling could not be sustained. It may be possible to continue filling the mine voids at a slower rate during dry conditions by using groundwater, but rehabilitation could still take many decades.

6.4 PIT LAKE MODELLING

Estimates of time frame(s) to fill mine voids are preliminary estimates only and will need to be further refined as part of more detailed pit lake modelling if required for Declared Mine Rehabilitation Plan. The pit lake modelling is expected to be more complex in nature, but would have the advantage of explicitly modelling the mine voids, rather than simply

representing them as a demand node (as was done in this study). It is expected that the results from the mine-specific pit lake modelling, that should be completed by mine licensees as part of their preparation of their Declared Mine Rehabilitation Plans, will supersede the projected rates to fill prepared in this study.

6.5 SOURCE MODELLING

The monthly time step REALM water resource model of the Latrobe is currently transitioning to a Source model that performs the same functions as REALM, but can more readily operate on a daily time step. It is anticipated that once this Source model has been suitably validated, it will replace the existing REALM model used in this study

7 LIST OF ACRONYMS

APM	Australian Paper Manufacturers
DELWP	Victorian Department of Environment, Land, Water and Planning
DJPR	Victorian Department of Jobs, Precincts and Regions
GL	Gigalitre
LVRRS	Latrobe Valley Regional Rehabilitation Strategy
LVRWS	Latrobe Valley Regional Water Study
ML	Megalitre
REALM	Resource Allocation Model, which is water resource modelling software used by DELWP to model long-term water allocation and use for supply systems.
SRW	Southern Rural Water
VicCI	Victorian Climate Initiative
yr	year

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