Australian Government

BIOREGIONAL ASSESSMENTS

PROVIDING SCIENTIFIC WATER RESOURCE INFORMATION ASSOCIATED WITH COAL SEAM GAS AND LARGE COAL MINES

Conceptual modelling for the Gippsland Basin bioregion

Product 2.3 from the Gippsland Basin Bioregional Assessment

2018

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The Bioregional Assessment Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated with coal seam gas and large coal mines. A bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential direct, indirect and cumulative impacts of coal seam gas and large coal mining development on water resources. This Programme draws on the best available scientific information and knowledge from many sources, including government, industry and regional communities, to produce bioregional assessments that are independent, scientifically robust, and relevant and meaningful at a regional scale.

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ISBN: 978-1-925315-90-5

Citation

DELWP (2017) Conceptual modelling for the Gippsland Basin bioregion.

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2.3 Conceptual modelling for the Gippsland Basin bioregion

This product summarises key system components, processes and interactions in this bioregion.

It also describes the coal resource development pathway (CRDP), which articulates the most likely combination of coal and coal seam gas (CSG) developments at a bioregion or bioregion scale, including the individual projects expected in future.

The conceptual model guides how the groundwater modelling (product 2.6.2) is conducted.

2.3.1 Methods

Summary

The *conceptual model of causal pathways* characterises the *causal pathway*, the chain of logic or activities – either intentional or unintentional – that link coal resource development and potential impacts on water and water-dependent assets. This section details the specific application to the Gippsland Basin bioregion.

Key concepts and terminology are also explained, and the overall steps are summarised:

a) Synthesising the key system components, processes and interactions for the geology, hydrogeology and surface water of the bioregion;

b) Defining the baseline coal resource development (baseline) and the coal resource development pathway (CRDP).

The approach taken in the Gippsland Basin bioregion has utilised existing state-based resources and knowledge of geological, surface water and groundwater conceptual models, particularly 'The Gippsland Groundwater model' (Beverly et. al., 2015) developed for the Victorian on-shore gas investigations undertaken in 2014–15.

2.3.1.1 Background and context

The approach taken in the Gippsland Basin bioregion has utilised existing state-based resources and knowledge of geological, surface water and groundwater conceptual models, particularly 'The Gippsland Groundwater model' (Beverly et. al., 2015) developed for the Victorian on-shore gas investigations undertaken in 2014–15. The application to the Gippsland Basin bioregion is described in the individual sections that follow.

Conceptual models are abstractions or simplifications of reality. A number of conceptual models are developed for a bioregional assessment (BA), including conceptual models for geology, groundwater and surface water, which underpin the numerical modelling.

Section 2.3.3 subsequently defines two potential futures (Figure 1), namely the:

- *Baseline coal resource development* (baseline), a future that includes all coal mines and CSG fields that are commercially producing as of December 2012
- *Coal resource development pathway* (CRDP), a future that includes all coal mines and CSG fields that are in the baseline as well as those that are expected to begin commercial production after December 2012.

The difference between CRDP and baseline (known as the *additional coal resource development* (ACRD) is the change that is primarily reported in a BA.

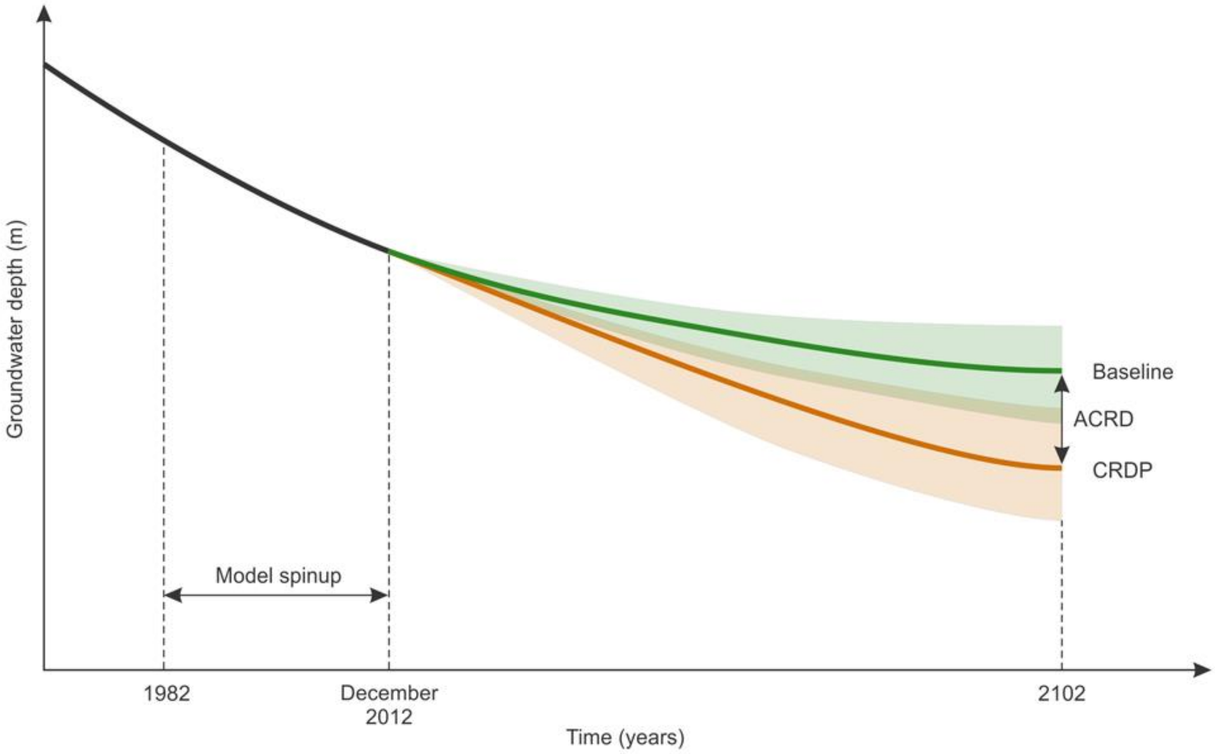

Figure 1 **Generic example of groundwater depth at a specific location over time for the baseline coal resource development (baseline), coal resource development pathway (CRDP) and additional coal resource development (ACRD)**

2.3.2 Summary of key system components, processes and interactions

Summary

The flow processes and interactions in the Gippsland bioregion are controlled by the layering of the aquifers and locations where there are high groundwater pumping rates.

In general, most groundwater recharge occurs at the margins and areas of outcropping older aquifers and either discharges in the low-lying areas on or off-shore. Under most natural conditions the streams and rivers in the Gippsland bioregion are gaining and area connected to the water table.

Coal mining and off-shore oil and gas operations can induce changes in groundwater level at any depth in the geological column. The spatial and temporal influence of groundwater level changes is controlled by local hydraulic properties. A reduced groundwater level may cause a level drop in a groundwater pumping bore that makes it harder to extract water or cause the bore to dry out periodically. Another potential effect of reduced groundwater level is to induce flow away from the alluvial aquifer that would otherwise discharge as baseflow to a stream.

The section provides further context to the differing components of the hydrological cycle of the Gippsland Basin bioregion (see companion product 1.1 for the Gippsland Basin bioregion) and to describe the potential water impacts which may be affected by current and proposed coal and coal seam gas (CSG) development.

The extent of water flows and pathways are limited to the Gippsland Catchment which extends beyond the Gippsland Basin BA area.

Current and proposed coal mining operations are contained within the Latrobe Valley part of the Gippsland Basin. Traditional gas developments (e.g. gas entrapments) operate in the Gippsland Basin off-shore area. There are no operating or proposed CSG developments in the Gippsland Basin.

2.3.2.1 Geology

This section describes the dominant geological features and processes which may be affected by coal mining and CSG development in the Gippsland Basin bioregion.

A description of the geology of the Gippsland Basin bioregion is provided in companion product 1.1 for the Gippsland Basin bioregion. The Gippsland Basin extends throughout the entire Gippsland region, the Gippsland sedimentary basin includes all Tertiary and younger aged sediments. The Gippsland Catchment area covers approximately 3.6 million hectares.

The Gippsland sedimentary basin is composed of a variety of sedimentary sequences and is underlain by faulted and fractured Palaeozoic metasediments and Cainozoic metasediments (Strzelecki Group). Faulting within the Gippsland Basin since the Tertiary developed a number of local sedimentary depressions, where individual and distinct sedimentary facies have developed.

Simplified schematic cross sections of the broad geological groups showing the Baragwanath anticline and relative scale of each group is shown in Figure 18 and 19 of the Context Statement (see companion product 1.1 for the Gippsland Basin bioregion).

Palaeozoic metasediments outcrop along the northern and eastern on-shore margin, which also correspond with the surface water catchment extent. The Strzelecki Group geology outcrops throughout much of the south-western parts of Gippsland at topographic highs.

The oldest sedimentary sequence in the Gippsland Basin is the Golden Beach Group. The majority of the Golden Beach Group Formation exists off-shore with limited on-shore occurrence. Directly overlying the Golden Beach Group is the Latrobe Group. The Latrobe Group has extensive coverage off (approx. 80%) and on shore (approx. 20%) of the Gippsland Basin.

Schaeffer (2008) (and authors prior) linked the differing sedimentary sequences of the differing depressions into a hydrostratigraphic equivalence framework. Figure 2 shows the geology across the basin is highly variable. The brown coal geological units are distributed through much of the Latrobe Valley Depression and are interbedded with sandy facies units. Much of the coal which is mined in the Latrobe Valley is sourced from the Morwell and Yallourn Seams. The Traralgon coal seams (T0, T1 & T2) have been identified as prospective CSG sources (Goldie Divko, 2015).

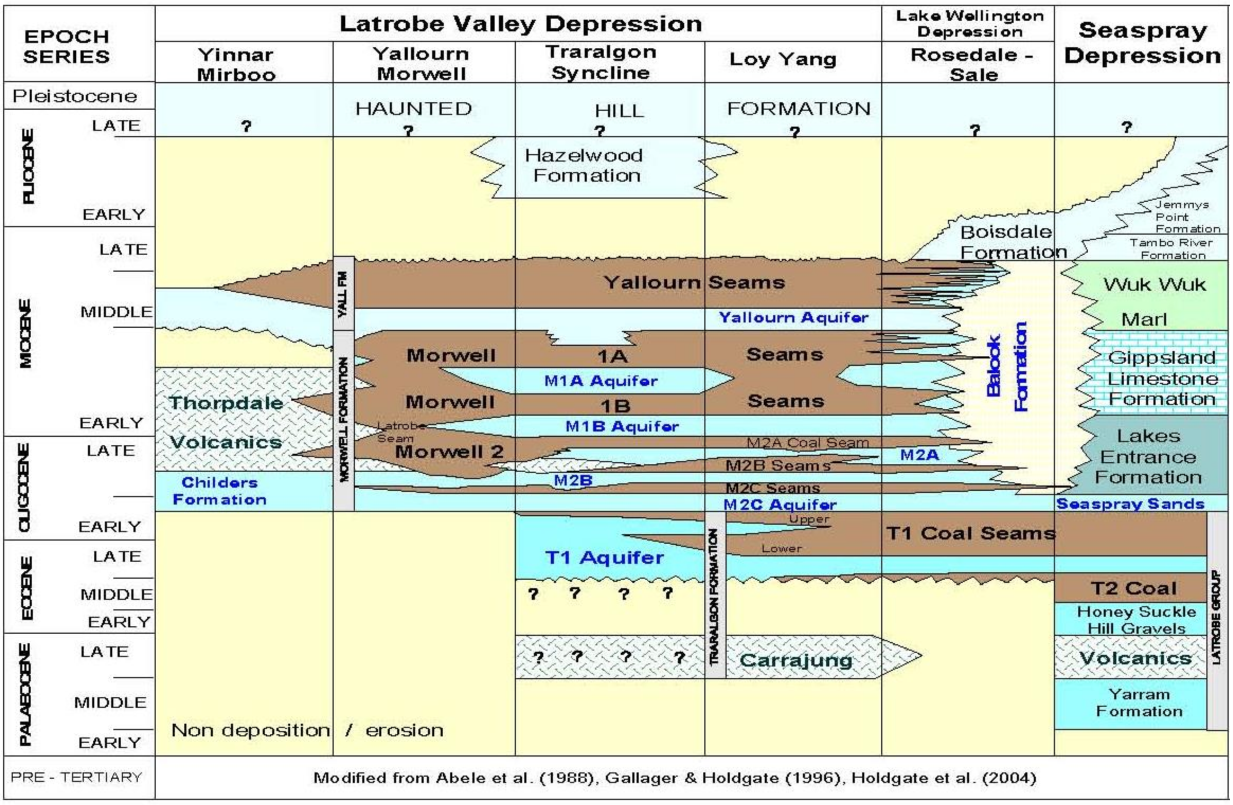

Figure 2 Gippsland sedimentary basin equivalent hydrostratigraphic framework

Source: Schaeffer (2008)

The Victorian Aquifer Framework (VAF) surface geology is presented in Figure 3 and show much of the Gippsland Basin bioregion is dominated by pre-Tertiary aged geology (sourced via GHD, 2012). Much of the sedimentary basin is overlain by Quaternary sediments which mask the complexity of the geological distribution and differing facies.

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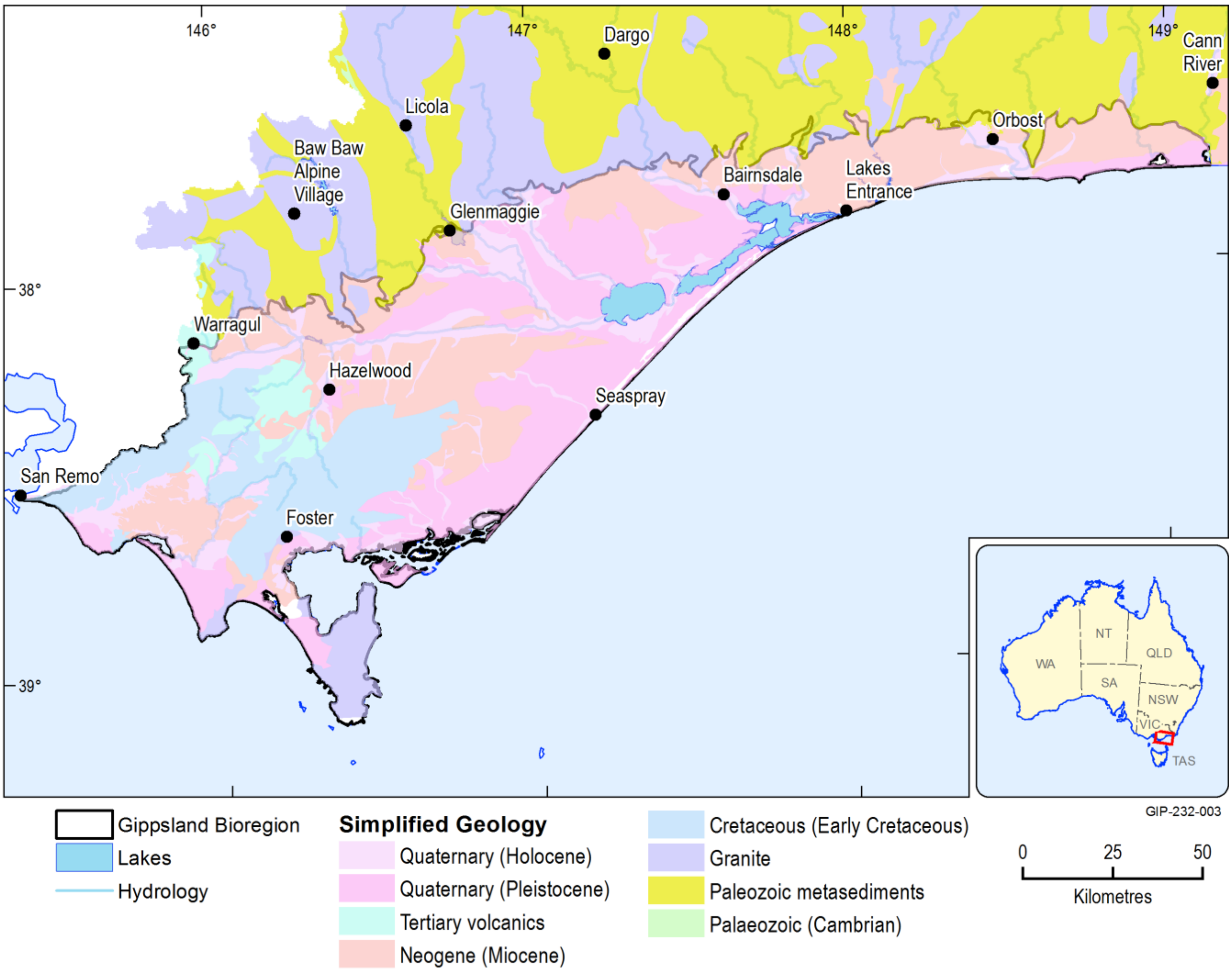

Figure 3 Surface geology map of Gippsland Basin bioregion

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2.3.2.2 Hydrogeology

This section describes the dominant hydrogeological features and processes which may be affected by coal mining and CSG development in the Gippsland Basin bioregion. A detailed description of the key aquifer systems is in Section 1.1.4 of companion product 1.1 for the Gippsland Basin bioregion.

The major aquifers of the Gippsland Basin bioregion have been defined using the National Aquifer Framework classification approach (BOM 2012). In Victoria, the Victorian Aquifer Framework (VAF) has been used to describe a group of simular geological units as a singular hydrostratigraphic unit for the purposes of reducing complexity but retaining hydrogeological integrity. In Gippsland, VAF units have been defined by GHD (2012). Beverly et al. (2015) utilised the VAF to develop a multilayer groundwater model throughout the Gippsland Basin bioregion Beverly et. at., (2012).

The model delineated individual coal seams and perspective formations which may contain gas (such as the Strezlecki Group) in the Gippsland area. The resultant grouping and splitting of particular geological and VAF units is presented in Table 1. The delineation of the coal and prospective gas formations as individual hydrostratigraphic units provides greater opportunity to consider the movement of groundwater throughout the landscape in comparison to the standard VAF data set (Beverly et al., 2015).

Table 1 Victorian Aquifer Framework name and descriptions

VAF layer no. and name	Coal name (if present)	Generalised aquifer or formation/model layer description
Na	na	Marine water thickness
101 – Upper Tertiary /Quaternary Basalts (UTB)		Quaternary
102 – Upper Tertiary / Quaternary Aquifer (UTQA)		Haunted Hill Formation
103 – Upper Tertiary / Quaternary Aquitard (UTQD)		Nuntin clay
105 – Upper Tertiary Aquifer (Fluvial) (UTAF)		Boisdale Formation
106 – Upper Tertiary Aquitard (UTA)	na	Jemmy's Point Formation and upper Hazelwood Formation
	Yallourn Coal Seam	Y, Y1a, Y1b, Y2, Y1; Y_all
	Yallourn Aquifer & interseam	Hazelwood Formation; Y_all floor & M1a_all top
107 – Upper Mid Tertiary Aquifer	Lower M2 interseam,	Balook Formation Tambo River, Wuk Wuk Marl, Gippsland Limestone
	M1A coal	Yarragon Formation, M10, M1a, M1b2, ML, M12; M1a_all
	Morwell 1A interseam/aquifer	M1a_all_floor and M1b_top
	Morwell 1B coal	M1b, M1b1, M1b2, ML, M12
	Morwell 1B interseam	Floor M1b_all & M2_all top
	Morwell 2	M2, M2A, M2B coal; M2_all
108 – Upper Mid Tertiary Aquitard (UMTD)		Lakes Entrance Formation
109 – Lower Mid Tertiary Aquifer (LMTA)		M2c aquifer/Seaspray sands
112 – Lower Tertiary Basalts (LTB)		Thorpdale volcanics
111 – Lower Tertiary Aquifer (LTA)	na	Upper Latrobe Group
	T1 coal	TP, T1, TRU, TRM, TRL
	T1 interseam	Floor T1_all & Top T2_all
	T2 coal	na
	T2 interseam	Lower Latrobe Group; T2_all floor

113 – Cretaceous and Permian Sediments (CPS)		Strzelecki top 500m
		Strzelecki 500-1000m
		Strzelecki 1km-2km
		Strzelecki 2km-3km
		Strzelecki 3km-4km
		Strzelecki 4km-6km
		Strzelecki >6km
114 – Mesozoic and Palaeozoic Bedrock (BSE)		Palaeozoic basement

2.3.2.3 Regional groundwater flow system conceptualisation

The regional groundwater flow conceptualisation considers the Tertiary aquifers in the Gippsland Basin as behaving as three distinct flow systems incorporated into the Central Gippsland, East Gippsland and Seaspray groundwater catchments, with the Tarwin (southern terraces) and Moe sub-basin considered to be separate to these flow systems (see Figure 21 in Section 1.1.3.4 of the Context State for the Gippsland Basin bioregion). All are underlain by the regional basement aquifer which includes the Strzelecki Group and Palaeozoic basement.

The dominant aquifers in the Gippsland region are summarised as (see Table 1 for VAF layers):

- Quaternary deposits – The quaternary aquifers primarily consist of coarse sand and gravel along the river valleys and flood plains of the major rivers and dune deposits in coastal areas. They are generally unconfined. Permeability ranges from low to high.
- Upper Cenozoic aquifer – This aquifer is primarily comprised of various fluvial deposits (Wurruk Sand) in the Boisdale Formation and some unnamed Tertiary sands. It occurs in many parts of the flood plain in West Gippsland. It is generally greater than 50 m thick with highly variable permeability. It is generally semi-confined or unconfined depending on permeability of overlying materials.
- Upper Mid-Cenozoic aquifer – This aquifer primarily consists of sands and gravel in the Balook Formation, Morwell Formation and Alberton Formation. Relatively permeable members of Hazelwood Formation, Gippsland Limestone and Lakes Entrance Formation also form parts of this aquifer. The aquifer is buried up to 1000 m and is dominantly semi-confined to confined.
- Lower Mid-Cenozoic aquifer – Seaspray Sand forms the main part of this aquifer. It mainly occurs around the Morwell area in West Gippsland and is generally confined with moderate permeability.
- Lower Cenozoic aquifer – This aquifer primarily consist of the Childers Formation, M2, Traralgon Formation and Burong formations. These formations mainly occur around the Latrobe Valley. The aquifer is mainly semi-confined to confined with moderate permeability.

- Tertiary Basalts – They include Thorpdale Volcanics, Carrajung Volcanics and Older Volcanics. They occur around the Warragul, Thorpdale and Leongatha areas. Their permeability ranges from low to moderate depending on the density of fracturing. This aquifer is generally confined with little outcrop.
- Palaeozoic metasediments and Strzelecki Group – Fractured rock aquifers in fresh rock with variable permeability depending on the density of fracturing.

Additionally, there are a number of well-defined aquitards in the region, specifically:

- Nuntin Clay in the Boisdale Formation occurs beneath the Quaternary deposits and covers the majority of the flood plains
- Clay/coal seams form aquitards that occur in various formations (e.g. Yallourn, Yarragon, Morwell, Traralgon and Burong formations) in the north-west of the Gippsland Basin
- Upper Gippsland Limestone located in the east and centre of the Gippsland Basin.

Recharge to aquifer(s) occurs both directly where geology outcrops (in the elevated parts of the region) plus on broad alluvial plains and indirectly when the water subsequently passes vertically into the respective aquifer(s). Groundwater flow direction is generally toward the coast (or locally low areas). Most recharge to aquifers in the Gippsland Basin occurs via direct rainfall recharge or from flood recharge events.

Tertiary aquifers generally contain good quality water for many kilometres offshore indicating the groundwater is sourced from on-shore sources.

Groundwater flow direction in the Northern Terrace and Seaspray Depression aquifers (Central Gippsland and Seaspray groundwater catchments) is dominantly west to east with limited lateral interconnectivity due to regional aquifer pinching out at the Baragwanath anticline. Local discontinuous faults are not considered to be frequent and therefore are not considered to influence regional groundwater flow direction.

Figure 4 shows a schematic cross section of the region and shows that the Latrobe Group and younger aquifers all extend out to sea. The older and deeper Strzelecki Group and Palaeozoic Basement receive recharge from the elevated parts of the Gippsland Catchment and discharge locally into waterways and in some areas, off-shore.

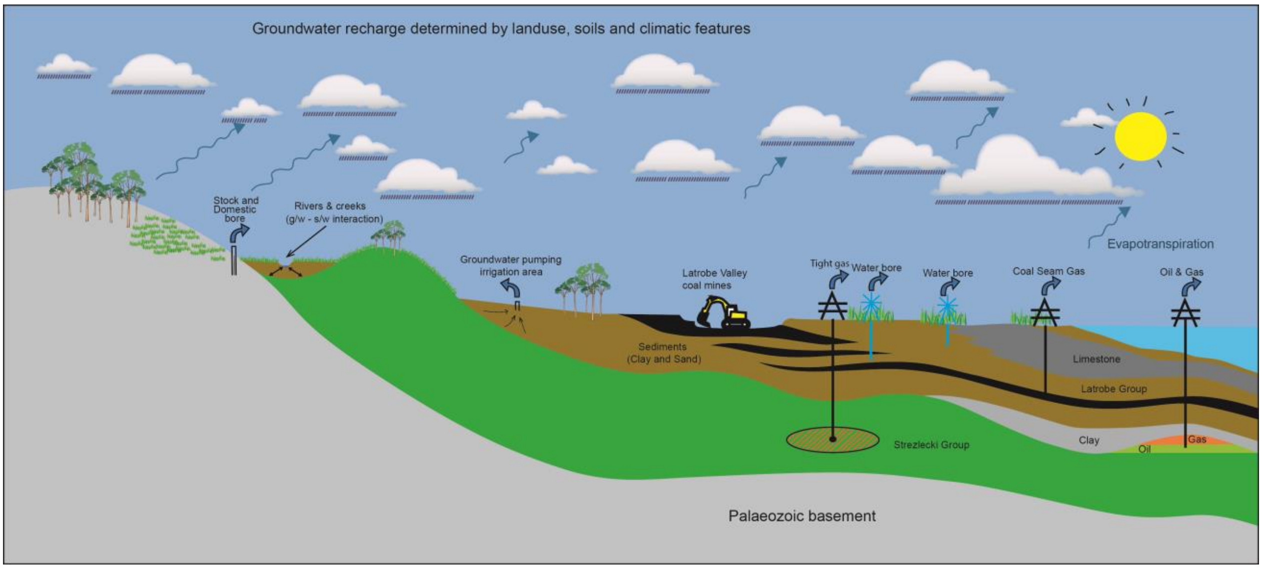

Figure 4 Simplified regional cross-section for the Gippsland Basin; only major stratigraphic units are shown (source: Beverly et al., 2015)

2.3.2.4 Surface water

A summary of the surface water hydrology is presented below, with additional information provided in the companion product 1.1.5 (Context statement – surface water hydrology and water quality).

The Gippsland region includes the South Gippsland, Latrobe, Thomson, Macalister, Avon, Mitchell, Tambo and Nicholson, Snowy and East Gippsland river basins, as shown in Figure 5. The Latrobe, Thomson-Macalister, Avon, Tambo, Nicholson and Mitchell rivers flow into the Gippsland Lakes, while the Tarwin, Snowy and Cann rivers flow into small estuaries or to the sea. The Tarwin, Agnes and Tarra rivers flow steeply from the southern face of the Strzelecki Ranges to the coast. The Gippsland Lakes form the largest estuarine lake system in Australia. Along with Ninety Mile Beach they are major features of the region. Dunes and wetlands are common around the lakes and along the coast. There are also some large dams such as Blue Rock, Thompson Dam and Glenmaggie Dam, and extensive channel and drain networks in the Macalister Irrigation District.

Latrobe River

The Latrobe Basin includes the Latrobe, Tanjil, Tyers, Moe, Morwell and Traralgon river systems. The Latrobe River rises at an elevation of approximately 750 m due west of Noojee. Its headwaters, together with the Ada, Loch and Toorongo rivers, drain the eastern and southern slopes of the Yarra Ranges, which form a southern extension of the Great Dividing Range. Approximately 70 km from its source, the Latrobe River emerges from the foothills onto its floodplain. The river flows through the Latrobe Valley and discharges into Lake Wellington, at the western end of the Gippsland Lakes. The Latrobe River is the highest contributor of freshwater inflows to the Gippsland Lakes, contributing 44% of mean annual inflow. The Latrobe River system has been most affected by regulation and extraction, with a 33% reduction of inflows to Lake Wellington (Tilleard et al., 2009).

The Latrobe Valley houses two major water storages, Blue Rock Lake (capacity 208 GL) and Moondarra Reservoir (capacity 30 GL). Another much smaller storage, Lake Narracan, is situated on the main stem of the Latrobe River at Yallourn near Moe. Blue Rock and Lake Narracan are primarily used to supply Yallourn, Loy Yang A and Loy Yang B power stations.

The environmental condition of the Latrobe River varies from excellent in the headwaters to moderate and poor condition in the mid – lower reaches below the storages. Freshwater flows from the Latrobe Basin are critical for sustaining the health of the Ramsar-listed Gippsland Lakes, which underpin the region's tourism industry.

Mitchell River

The Mitchell River has been identified as a heritage river and as one of two iconic rivers in Victoria. This is largely because of its size, being the largest unregulated river in Victoria, and it supports a wide range of environmental and social values. Land use in the upper catchment includes sections of the Alpine National Park and the Mitchell River National Park.

The Mitchell River system originates on the southern slopes of the Great Dividing Range, with the Wonnangatta and Dargo rivers being the two major rivers in this area, and forming the Mitchell River downstream at their confluence. The Mitchell River discharges to Lake King within the Gippsland Lakes. Other surface water systems include the Humfray, Dargo, Wongungarra and Wonnangatta rivers, Wentworth Creek and the Gippsland Lakes.

The river system is highly valued by the community for urban and rural water supply, recreation and its contribution to the Gippsland Lakes. The Mitchell River provides about one third of the total flow to the Lakes system on average.

Around 70% of the catchment consists of fractured rock outcrop of Palaeozoic-aged metasediments and intrusive rocks. Small areas of contained alluvial valley sequences occur in the highland valleys together with layered systems within Tertiary-aged volcanics. The southern third of the catchment contains the regional aquifer systems of the Gippsland Basin sequence (SKM 2012a).

Thomson and Macalister rivers

The Thomson River flows from the Dividing Range and joins the Latrobe River to the south of Sale. The Macalister River flows from the Alpine National Park in the Snowy Ranges and joins the Thomson River between Maffra and Sale. The Thomson and Macalister rivers then continue towards and contribute flows to the Ramsar-listed Gippsland Lakes. The Thomson River above Cowwarr Weir is listed as a Heritage River.

There are two major storages within the Thomson-Macalister system, namely Lake Glenmaggie situated on the Macalister River and the Thomson Reservoir on the upper reaches of the Thomson River. Lake Glenmaggie is the main source of supply for the Macalister Irrigation District, the largest irrigation area south of the Great Dividing Range. The Thomson Dam provides some of Melbourne's water supply system and the Macalister Irrigation District.

However, both the Thomson and Macalister rivers are amongst the most stressed rivers in Victoria due to the altered flow regimes through regulation and over allocation of water for irrigation and consumptive use. As such river management is considered to have the greater impact on mitigating river stress than groundwater/baseflow management. The Thomson and Macalister rivers directly below the Thomson Dam and Lake Glenmaggie respectively have reduced annual flows and reversed seasonality as a result of the reservoirs, with high flows in January and February and low flows during the winter months. This altered flow regime has significant impacts on the breeding and migration cues for fish. The dams and weirs are also a barrier to fish movement. Poor water quality in the rivers is affecting water supplies for consumptive use and recreation, as well as the Gippsland Lakes.

Avon River

The Avon River rises on the slopes of Mount Wellington in the eastern highlands and flows south to Lake Wellington. A significant portion of the upper catchment is protected in the Avon Wilderness Area (295 km^2). The upper catchment is steep, heavily forested and largely inaccessible. The channel is stable and confined by bedrock. The upper reaches of the Avon River including Turton and Dolodrook rivers and Ben Cruachan Creek have been listed as Natural Catchment Areas.

The Lower Avon catchment below the Valencia Creek confluence flows through a topographically flat area which has been predominantly cleared for agriculture. The Avon River above Stratford and Freestone Creek have experienced dramatic widening since European settlement and now flow through wide mobile gravel beds. The Perry River joins the Avon approximately 1 km upstream from where the Avon discharges into Lake Wellington.

In the lower part of the Avon catchment, both surface water and groundwater are utilised for irrigation. The river has experienced low flows over the past decade and as a consequence, frequent irrigation restrictions have been imposed (Jones et al., 2009).

Snowy River

The Snowy River originates on the slopes of Mount Kosciuszko, draining the eastern slopes of the Snowy Mountains in New South Wales, before flowing through the Alpine National Park and the Snowy River National Park in Victoria and emptying into Bass Strait. The river flow was drastically reduced in the mid-20th century after the construction of four large dams (Guthega, Island Bend, Eucumbene, and Jindabyne) and many smaller diversion structures in its headwaters in New South Wales, as part of the Snowy Mountains Scheme.

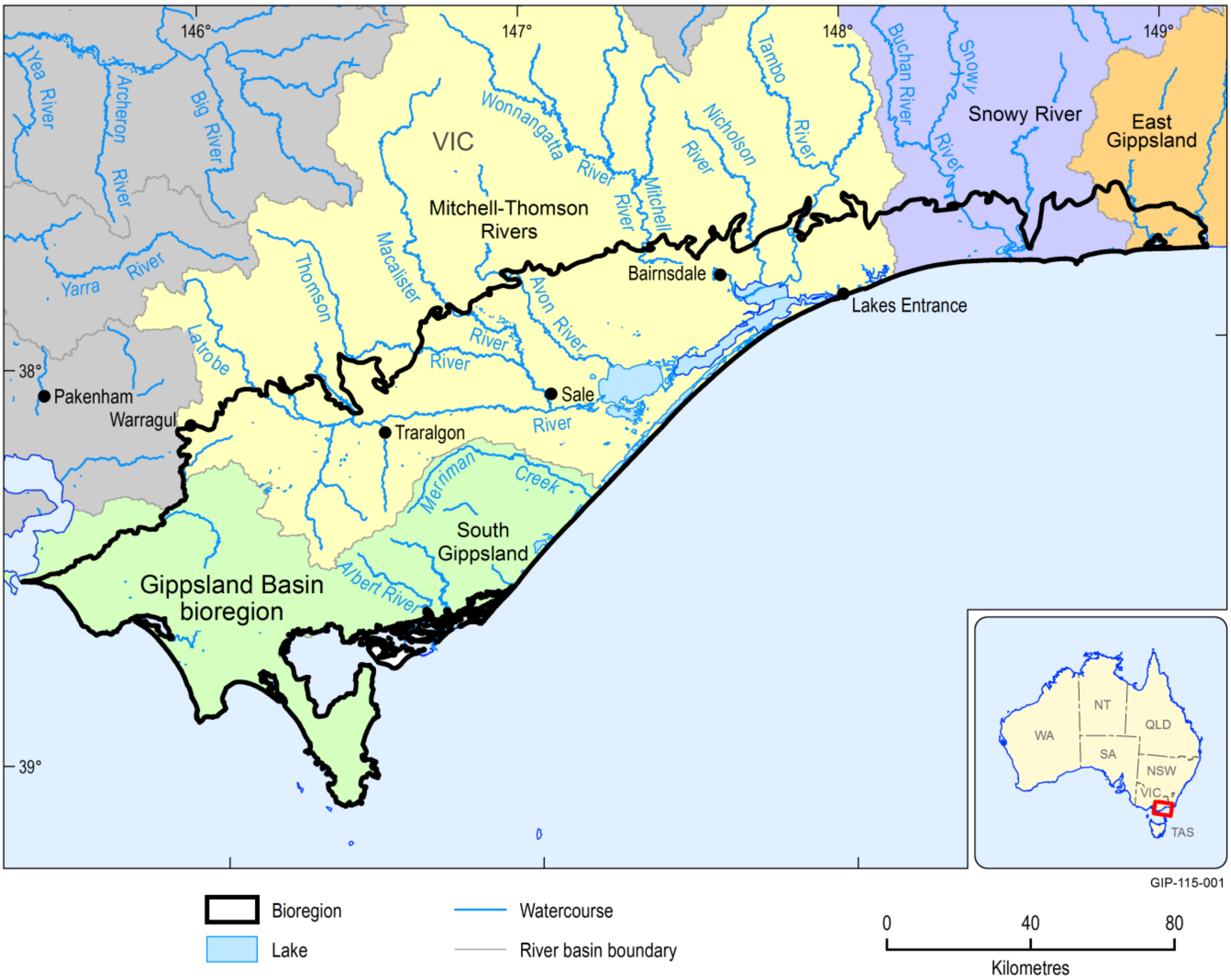

Figure 5 Location of the major watercourses and river basins of the Gippsland sub-region

2.3.2.5 Water balance

The water balance of the Gippsland Basin consists of one input (rainfall) and three mechanisms by which water may export (evapotranspiration, groundwater and surface water outflow to sea). The Gippsland Basin is contained within the surface catchment region known as the Gippsland Catchment. Broadly speaking, the water balance can be defined as the annual rainfall minus evapotranspiration and streamflow to sea.

Mean annual rainfall for the Gippsland Catchment is 940 mm/year (34,209 GL/year). Estimates of groundwater recharge generally range between 12 to 450 mm/year with a mean of 72.3 mm/year (2,631 GL/year) (Beverly et al., 2015). Groundwater outflow along the Gippsland Coast has been estimated to be 120.6 GL/year (50 GL/year East Gippsland (GHD, 2010a) and 70.6 GL/year West Gippsland (GHD, 2010b)).

Significant volumes of groundwater pumping occurs within the Gippsland Basin and the total catchment. Licensed groundwater use has been classified as three broad groups of users and typical volumes for the differing uses: stock and domestic use (10 GL/year); Irrigation (80,000 ML/year); and coal mine dewatering (25 GL/year) (Beverly et al., 2015). Groundwater evaporation has been estimated by Beverly et al. (2015) at 1,460 GL/year. Surface water base flow index in the upper parts of the Gippsland Catchment ranges in the order of 0.3 – 0.8. Surface water flow export to the sea has been estimated to be 6,922 GL/year via the major gauged rivers (DSE 2010a & b).

2.3.2.6 Gaps

The large area and complexity of groundwater processes within the Gippsland Basin bioregion provides many areas of information gaps. To increase the understanding of groundwater processes in the region the following issues are recommended for further work (in no particular order):

- increase the resolution and detail of hydrogeological raster data sets (e.g. extent, elevation and hydraulic properties) applied to areas of high interest, such as around the Latrobe Valley Coal mines
- review and adjust (where required) estimates of rainfall derived groundwater recharge rate
- consider the time lag between rainfall and groundwater recharge events
- ensure correct aquifer assignment to both time-series water level and pumping data
- better represent spatial and temporal groundwater baseflow information.

2.3.3 Baseline and coal resource development pathway

Summary

There are no baseline coal seam gas developments and three baseline coal mines in operation as of December 2012 for the Gippsland Basin bioregion. As of December 2012 there were also three future coal mine developments proposed under the coal resource development pathway (CRDP) for the Gippsland Basin bioregion. There is enough available information to include these three developments in the in the numerical modelling of the coal resource development pathway for the Gippsland Basin bioregion.

The three developments being modelled are the extensions of the existing open cut coal mines at Yallourn, Hazelwood and Loy Yang.

On 3 November 2016 the owner of the Hazelwood Power Station (ENGIE) announced that it would close the Hazelwood Power Station, with the closure occurring March 2017. The extension to the Hazelwood mine continued to be modelled under the Gippsland assessment as the announcement occurred after the finalisation of the CRDP in November 2015.

2.3.3.1 Developing the coal resource development pathway

This coal resource development pathway (CRDP) is based on information available in November 2015. Companion product 1.2 for the Gippsland Basin bioregion contains information on coal resources and lists potential future coal developments.

For the Bioregional Assessments Programme coal developments in operation as of the last quarter of 2012 are considered to form the baseline situation. There are no baseline coal seam gas (CSG) developments in the Gippsland Basin bioregion.

The Gippsland Basin bioregion CRDP consists of three proposed developments as shown in Data: Department of Economic Development, Jobs, Transport and Resources, GeoVic 3, Current Mining Licences and Leases, June 2015

These are made up of the continued expansion of the three open-cut coal mines: Yallourn, Hazelwood and Loy Yang. The locations of the three mines are shown in Figure 6.

The three coal mines are considered by the assessment team to have sufficient information available to be included in the Gippsland Basin bioregion numerical model. There are no CSG projects with sufficient information available to be modelled. The mines being modelled are Yallourn, Hazelwood and Loy Yang. The mine life and production rates for the mines to be modelled are shown in Table 4 and the planned development of these mines is described in Section 1.2.3 of companion product 1.2 for the Gippsland Basin bioregion.

Not all the potential coal developments identified in companion product 1.2 for the Gippsland Basin bioregion have been included in the Gippsland Basin bioregion CRDP. This is mainly because there was not enough known about the resource or the proposed development lacks detail. Further information on the reasons each development was included or not included in the CRDP is presented in Table 2. This table also provides the reasons why developments in the CRDP could not be included in the numerical modelling.

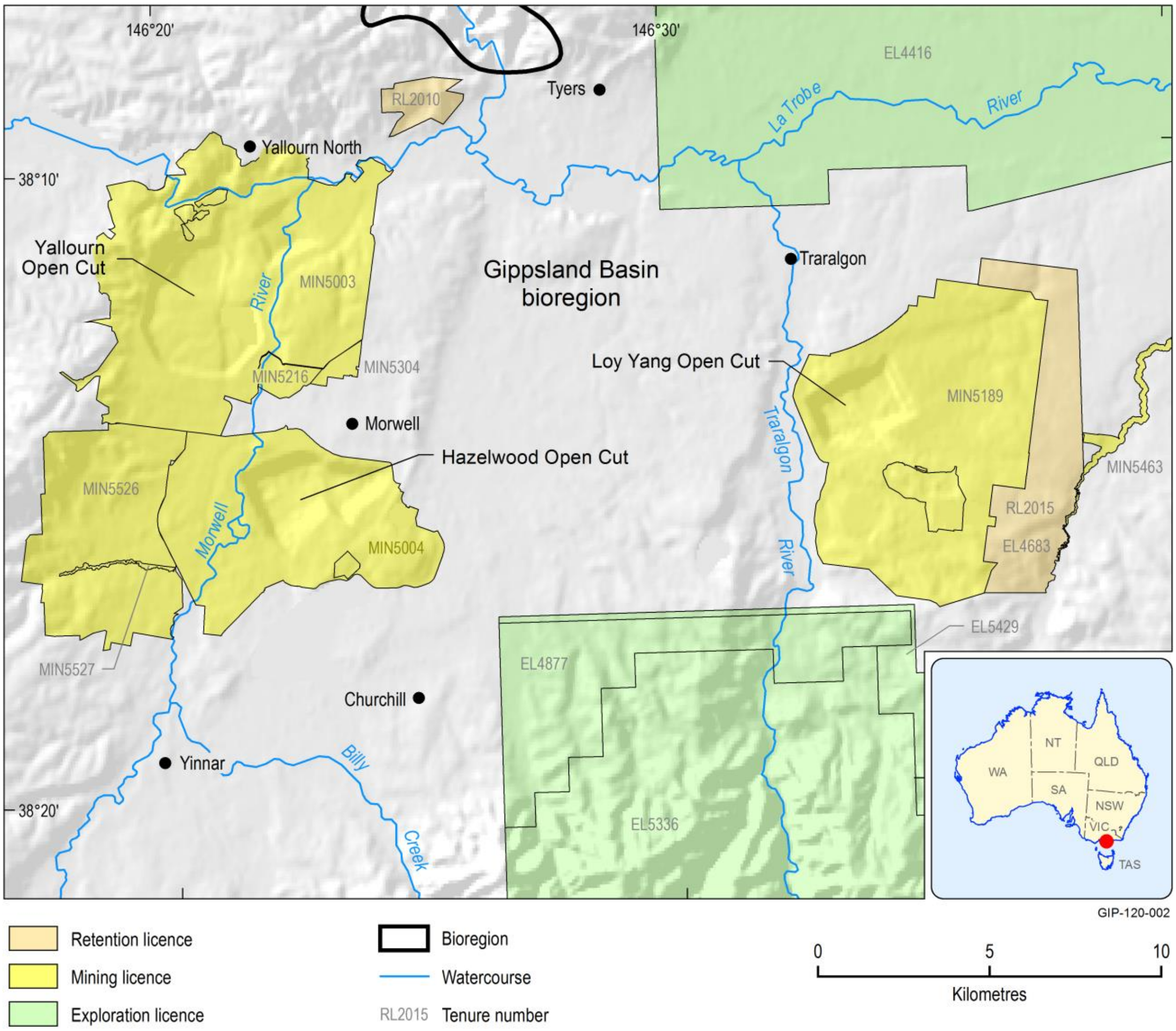

Figure 6 Coal developments in the Gippsland Basin bioregion coal resource development pathway (CRDP)

Data: Department of Economic Development, Jobs, Transport and Resources, GeoVic 3, Current Mining Licences and Leases, June 2015

Table 2 Summary table for existing operations and proposed developments to define the baseline and coal resource development pathway

The core activity in bioregional assessments is the comparison of two potential futures: (i) *baseline*, in which only the baseline development (as of December 2012) continues into the future; and (ii) *coal resource development pathway*, in which both the baseline development plus additional development continues into the future. However, as some mine plans may not yet be finalised and/or information is not yet made publically available, not all developments identified in the *coal resource development pathway* can be modelled, for some only commentary is possible. The CRDP was finalised for use in the assessment in November 2015.

Name	Development type	Company	Baseline (Y/N)?	Coal resource development pathway (Y/N)? (modelled or commentary)	Year production did/will start	Expected duration of commercial operations	Total defined coal or coal seam gas resource	Comments
Yallourn Coal Field Development Project (supersedes Maryvale Extension Project)	Open-cut coalmine.	Energy Australia – Yallourn	Y	Y – modelled	2005 (Maryvale coal field)	29 Years (2032)	347.5 Mt[d] (as at 2001)	Able to be modelled.
West Field Project	Open-cut coalmine.	Hazelwood Power Corporation Pty Ltd	Y	Y – modelled	2011	20 years (2031)	470 Mt	Able to be modelled.
Future mining blocks within current MIN	Open-cut coalmine.	AGL - Loy Yang Power	Y	Y – modelled	1997	51 years (2048)	1.78 Bt	Able to be modelled.
Gelliondale	Open-cut coalmine.	Ignite Energy Resources Limited	N	N	na	na	6.2 Bt	Not enough information to be included in modelling
Gippsland Gas	CSG	Ignite Energy Resources	N	N	na	na	3.7 Tcf (Trillion cubic feet)	Not enough information to be included in modelling

Table 3 Coal development projects in the coal resource development pathway

Development project	Company	Included in CRDP (Y/N)?	Reasons for including/not including in CRDP
Yallourn Coal Field Development Project (supersedes Maryvale Extension Project)	Energy Australia – Yallourn	Y – modelled	There is a good understanding of the coal resources at Yallourn and its continued development is considered very likely to proceed. In June 2010, the Minister for planning at that time, Justin Madden, approved the *Yallourn Coal Field Re-alignment Project Environment Report*. In June 2011, a Work Plan variation as a result of the mine batter failure and the Maryvale Mine footprint redesign was approved. The forecast annual coal production at Yallourn Mine is 17.5 to 18.5 Mt per annum. The economic life of the Yallourn W Power Station is projected to terminate in 2032. In order to provide sufficient coal reserves to meet the projected demand for the Power Station life, additional coal reserves to those available in East Field Extension are required within TRUenergy's mining licence area. The coal within the revised Maryvale Field boundaries is sufficient to meet this demand (TRUenergy, 2011). There is enough information within this approved work plan on coal quality, quantity and scale to allow for this development to be included in the numerical modelling.
West Field Project	Hazelwood Power Corporation Pty Ltd	Y – modelled	There is a good understanding of the coal resources at Hazelwood and its continued development is considered very likely to proceed. The Hazelwood Power Station was fuelled by coal from the Hazelwood mine. Development of the mine is in a westerly direction in two phases. Phase 1 began in 2001 under project approvals existing at the time. Phase 2 of 'West Field' development of Hazelwood was proposed in 2004; expanding the mining area across the Morwell River to secure a coal supply until 2031 (DSDBI 2014). The 2004 *Hazelwood Environmental Effects Statement* contains enough information on coal quantity and the sequence of mining to allow for this development to be included in the numerical modelling.
Future mining blocks within current MIN	AGL - Loy Yang Power	Y – modelled	There is a good understanding of the coal resources at Loy Yang and its continued development is considered very likely to proceed. Loy Yang Power (1997) outlined a 40-year plan for Loy Yang A Power Station (until 2037) and a 30-year plan for Loy Yang B Power Station. The 1997 work plan contains enough information on coal quantity and the sequence of mining to allow for this development to be included in the numerical modelling.
Gelliondale	Ignite Energy Resources Limited	N	Ignite plans to exploit the relatively shallow brown coal at Gelliondale using conventional brown coal mining and upgrade with its Catalytic Hydrothermal Reactor (Cat-HTR) technology. There are no further details or approved development plans available so there needs to be considerable further work to improve geological understanding and determine potential for economic development.
Gippsland Gas	Ignite Energy Resources	N	Ignite Energy Resources have planned an exploration program to test the deeper lignite seams of the Traralgon Formation within EL 4416 for biogenic natural gas via drilling (Ignite Energy Resources 2015). The Gippsland Gas Project is at the preliminary appraisal stage. At the time of writing, there are no clear development plans available for progressing the Gippsland Gas Project into a coal seam gas production operation. Considerable further work to improve geological understanding and determine potential for economic development.

Table 4 Production rates for mines being modelled in Gippsland Basin bioregion CRDP

Mine name	Production rate product coal (Mt/yr)	Start date	Mining depth	Expected mine life
Yallourn Coal Field Development Project (supersedes Maryvale Extension Project)	12.9	2012[1]	125 m (base Yallourn Seam)	2032
Hazelwood - West Field Project	17.1	2011[2]	120-140 m (base M1)	2031
Loy Yang - Future mining blocks within current MIN	28.9	1997[3]	140 m (in the east)-215 m (in the west)(Base M2A)	2048

1. 2011 approved Work Plan, 2. 2004 approved Work Plan variation, 3. 1997 approved Work Plan

Bores are estimated to extract 14,255 ML per annum for coal mine dewatering from 116 bores (see companion product 1.5.1 for the Gippsland Basin bioregion). The Latrobe Valley mines dewatering volumes are accounted for in the Stratford and Rosedale GMAs in the Victorian Water Accounts. Each mine extracts from different formations and these GMAs underly the Latrobe Valley coal mines.

For details of mine developments refer to Section 2.3.3 of companion product 1.2 for the Gippsland Basin bioregion.

2.3.3.2 Gaps

The coal resource development pathway has been based on data available at the time. Any changes to the project closure plans and/or mine plans since 2015 are not included in the Gippsland Basin Bioregional Assessment. Production rates will vary over time depending on demand and will also depend on continued operation of the mines.

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