Improving Knowledge of Water-Dependent Assets and Receptors in the Gippsland Basin

DEPARTMENT OF ENVIRONMENT, LAND, WATER AND PLANNING

Groundwater Dependent Ecosystem Conceptual Modelling

Final V2

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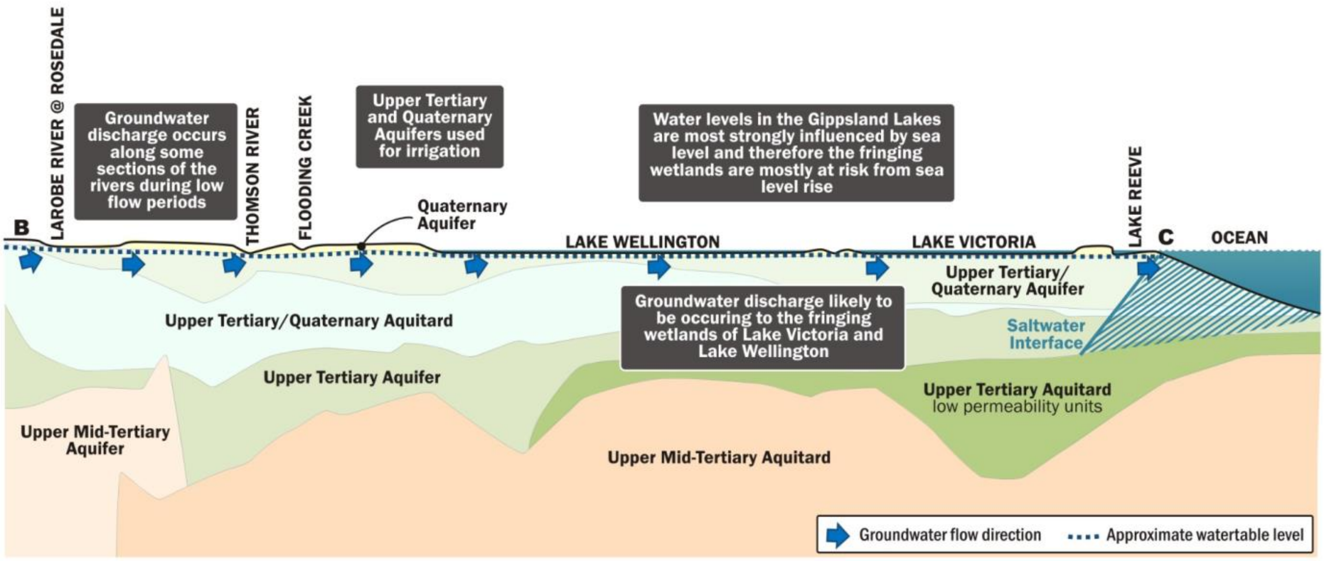

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Draft A	6/3/2015	Draft report for client comments	SH	ST	ST
Final A	1/5/2015	Final Report to client	SH	ST	ST
Final B	20/5/2015	Final Report to client (updates to conceptual model booklets)	SH	ST	ST

Contents

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to present our approach to developing conceptual models for five Groundwater Dependent Ecosystems (GDEs) in the Gippsland Basin and to provide the technical information used in the development of the conceptual models in accordance with the scope of services set out in the contract between Jacobs and the Client. That scope of services, as described in this report, was developed with the Client.

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1. Introduction

1.1 Project background

In response to community concerns regarding large scale coal and coal seam gas (CSG) activities, the federal government established the Independent Expert Scientific Committee (IESC) on Coal Seam Gas and Coal Mining in 2012. The Committee provides independent expert advice to Governments to ensure that future decisions about the potential water-related impacts of coal and CSG developments are better informed. The Bioregional Assessments are one of the key mechanisms to assist the IESC in developing this advice to ensure it is based on the best available science and independent expert knowledge. Six priority areas across Australia have been identified for bioregional assessment and the Gippsland Basin is one of these.

The Bioregional Assessment program for Gippsland Basin is being managed by the Commonwealth Department for Environment (DoE) and the Victorian Department of Environment, Land, Water and Planning (DELWP), in partnership with the two Catchment Management Authorities (CMAs) in the Gippsland Basin; the East Gippsland and West Gippsland CMAs.

A key part of the Bioregional Assessment program is developing a good understanding of water assets, including those dependent on groundwater (for this project termed Groundwater Dependent Ecosystems - GDEs), which have the potential to be impacted by activities associated with large coal mining and CSG activities. In addition, a recent report prepared for the East and West Gippsland CMAs recommended improve conceptual understanding of all high value GDEs (SKM, 2014).

This project aims to collate data on five representative GDEs in the Gippsland Basin and use this information to develop conceptual models that help visualise and communicate the potential relationships between large coal mining and CSG extraction activities and groundwater and surface water in the connected environments, and to indicate how changes in groundwater and surface water levels and flows could impact on ecosystems dependent on the groundwater for all or some of their water needs.

Recent experience across Australia and overseas has stressed the criticality of stakeholder engagement and understanding of onshore gas developments. Providing readily-understood information products that accurately describe the situation and risks in a way the community and resource managers understand helps promoting clearer discussion about water resources, potential uses and risks to those resources and the ecosystems they support.

Although focused on coal mining and CSG extraction activities in the Gippsland Basin, the conceptual models developed in this project outline broad surface water and groundwater interactions, and so include impacts associated with other threats posing risk to the ecological functions of GDEs (e.g. climate change, extraction for irrigation).

1.2 Conceptual models

Conceptual models are a powerful tool for describing and visualising complex interactions, and hence very useful communication tools. They can synthesise complex ecological, geological, hydrological and hydrogeological data into a clear overview that can focus consideration on to key features or processes. They are also valuable for helping to understand the nature of and confidence in relationships between groundwater dependent ecosystems, the regional landscape setting, land uses, and localised processes affecting water movement. They can highlight critical groundwater services (including ecosystems) and threats to those services, and help to identify knowledge gaps and inform future investigations. As such, conceptual models are iterative tools that can be updated over time as new knowledge becomes available.

The National GDE Tool Box's Groundwater Modelling Guidelines[1] and the IESC's Methodology for Bioregional Assessments[2] provided a basis for conceptualising GDEs. The National GDE Toolbox suggests that conceptual models model provides the following functions:

- Clarifies the problem, and ensures that the critically important components and ecological interactions between them have been identified, ensuring that system managers have an understanding on how the system is structured and functions;
- Identifies the 'known' and the 'unknowns' and therefore the critical knowledge gaps to identify where research investments should be focused;
- Allows predictions to be made in regards to the likely impacts of different management interventions and therefore identifies those interventions that may not be effective; and
- Assists with the design of monitoring program and selection of appropriate indicators.

Conceptual models vary in complexity and can take several forms depending on the purpose for preparing them. In ecological and natural resource investigations they are often represented as an aerial view of the landscape or landform or as a combination of graphical representations combined with process diagrams. Alternatively conceptualisation formats can also include written narratives, tables, mathematic formulations and schematic diagrams such as box-and-arrow models.

There is no single, best, all-purpose conceptual model, however for GDE assessments; a good conceptual model will describe the ecosystem's hydrology and hydrogeology, and biotic components and processes. Both the National GDE Tool Box's Groundwater Modelling Guidelines and the IESC's Methodology for Bioregional Assessments identify the following specific processes that should be considered when building a conceptual model:

- ***Hydrogeological processes*** such as the hydrogeologic layers, features and characteristics, inflows and outflows associated with surface water and groundwater, aquifer-to-aquifer interactions and surface water-to-groundwater interactions;
- ***Abiotic components*** such as catchment boundaries (including groundwater divides), recharge and discharge zones, storage process, groundwater flow and anthropogenic factors affecting surface water and groundwater. It is important to understand the temporal patterns of groundwater levels (seasonal and interannual);
- ***Biotic components*** such as the distribution of flora and fauna that form part of the ecosystem potentially reliant on groundwater for habitat, water source, food supply or other service and therefore may be sensitive to changes in flow, groundwater levels and/ or poor water quality; and
- ***Water regime*** that supports the GDE and the links between the abiotic and biotic components to highlight any critical groundwater services.

They should also identify spatial and temporal variation and key assumptions and uncertainties about the processes.

[1] SKM (2011). Australian groundwater-dependent ecosystem toolbox part 2: assessment tools. Waterlines report, National Water Commission. Canberra.

[2] IESC (2013). Methodology for bioregional assessment of the impacts of coal seam gas and coal mining development on water resources. Canberra.

2. Project overview

2.1 Water – dependent assets in the Gippsland Basin

The IESC on Coal Seam Gas and Large Coal Mining Development defines a water asset as "*an entity contained in a bioregion where the specific characteristic can be ascribed a defined value and which can be clearly linked, either directly or indirectly, to a dependency on groundwater or surface water quantity or quality*[3]*"*.

Depending on the purpose of the project, the application of this definition can include both natural and artificial assets. A full suite of asset types that have been variably considered as water-dependent throughout the Bioregional Assessment program in Victoria is summarised in Table 1.

Table 1 Water asset definitions from Victorian Bioregional Assessment projects

Natural water assets	Artificial water assets
• Groundwater aquifers • Springs • Wetlands • Rivers • Lakes • Creeks • Estuaries • Large marine intertidal zones • Groundwater dependent ecosystems • Floodplains	• Bores • Irrigation districts • Irrigation channels (e.g. small local irrigation channels) • Drains (e.g. small local) • Irrigation channels (large named channels only e.g. those that are regionally significant) • Rural and urban water storages (e.g. dams, waste water ponds) • Drains (large only e.g. those constructed to re-route streams and rivers) • Artificial wetlands

2.2 Site selection

The first step in this project was to select five suitable GDE sites across the Gippsland Basin for the development of conceptual models. When selecting the suitable GDE sites, the following was considered:

- ***GDE setting / typology*** – This includes surface and subsurface expressions of groundwater including estuarine, palustrine (e.g. swamps bogs, marshes), riverine and floodplain GDE types. It should be noted that palustrine GDEs are being captured in a concurrent project "*Assessing Groundwater Contribution to Wetlands and the Environmental Risk of Licenses Water Extractions"* being undertaken by Jacobs for DELWP and therefore were not considered in this project. The first step of this wetland assessment is a conceptualisation process.

- ***Data availability*** – Information must be available to enable a conceptualisation of the critical hydrogeological, hydrological and ecological processes of the GDE (e.g. value, condition, evaporation, f, surface water flow, quality and regulation, groundwater movement, levels, recharge, discharge and quality).

- ***Threats*** – This includes exposure to threats such as current and/or future coal mining and future CSG activities and/or other groundwater and surface water extraction activities.

- ***Value*** – This involves identification of high value GDEs which have water dependency. These were easily identified in the database developed in a recent project undertaken (by Jacobs) for East and

[3] IESC (2013). Methodology for bioregional assessment of the impacts of coal seam gas and coal mining development on water resources. Canberra

West Gippsland CMA to identify and prioritise high value and at-risk groundwater dependent water assets[4]

Sites with adequate available data, of high value and of importance to both the community and resource managers in the Gippsland Basin were short-listed. The other two criteria were used to select a range of circumstances to test the development of conceptual models.

A site selection workshop was undertaken with the key stakeholders (DELWP and the East Gippsland and West Gippsland CMAs) to identify and confirm the five suitable sites across the Gippsland Basin based on the above considerations. This workshop also identified the key messages that each conceptual model would focus on and these are provided in more detail in Section 3.

Participants at the workshop decided to include a basin scale model (Basin overview and Gippsland Lakes) to provide broader context for the other four models and to test the applicability of the approach at different scales.

Table 2 Sites selected for conceptual model development

Site Name	GDE Setting/ Typology	Data Availability	Threat	Value
Basin overview and Gippsland Lakes	• Surface expression of groundwater • Riverine • Coastal wetlands and lakes	• Adequate	• Current coal mining footprint • Potential CSG footprint • Irrigation	High*
Latrobe River	• Surface expression of groundwater • Riverine • Floodplain	• Adequate	• Current coal mining footprint • Potential CSG footprint	High*
Mitchell River	• Surface expression of groundwater • Riverine/ floodplain	• Adequate	• Groundwater extraction • Irrigation	High*
Gippsland Red Gum Plain and Seasonal Herbaceous Wetlands	• Surface and sub-surface expression of groundwater • Terrestrial Vegetation	• Adequate	• Currently not well understood	High*
Corner Inlet	• Estuarine	• Adequate	• Groundwater extraction • Current off shore oil and gas extraction • Potential CSG footprint	High*

* Defined in Jacobs (2014) *Identification of Groundwater Dependent Water Assets in the Gippsland Basin*. Report Prepared for the East and West Gippsland CMAs.

2.3 Data collation and templates

The conceptual models were developed by collating data, reviewing available literature regarding the groundwater and ecological processes, supplemented by a field inspection of the chosen sites which was undertaken with representatives from DELWP and the East Gippsland and West Gippsland CMAs.

[4] Jacobs (2014). Identification of groundwater dependent water assets in the Gippsland Basin. Report prepared for the East and West Gippsland CMAs

A template was developed to ensure a consistent approach and structure for explaining the critical hydrogeological and ecological processes across all five sites and to enable a subjective approach to identifying threats and values. The template lists key themes and questions relating to the specific processes listed in Section 1.2 that require attention when collating and reviewing the data. A summary of the themes and questions are provided in Table 3 and the completed templates are provided in the Appendices (Appendix B to Appendix E). It should be noted that a data template was not compiled for one of the sites (Gippsland Basin and Lakes Overview) because information used to develop the conceptual model was drawn from the information collected for the remaining four sites.

Table 3 GDE data templates

Reference	Theme	Questions
1	**Ecosystem type**	What are the characteristics of the GDE, including: • Type • Location • Site history • Value • Condition • Geomorphic description?
2	**Climate**	What climate is the GDE located in in (e.g. rainfall)?
3	**Hydrology**	What is the general hydrology of the GDE, including: • Catchment • Water source • Water regime • Naturalness • Flow regulation • Flow volume, timing and quality?
4	**Hydrogeology**	What is the hydrogeological setting of the GDE, including: • Aquifer • Geology • Soils • Groundwater level, movement and flow • Recharge/ discharge characteristics • Water quality?
5	**Groundwater connection**	What is the nature of groundwater connection at the site? • Aquifer and location of interaction • Direction of connection (gaining, losing, variable) • Temporal characteristics
6	**Groundwater service**	How does groundwater support the values of the GDE, including: • Critical groundwater processes • Environmental water requirements of species

7	**Key Threats**	**What are the key threats to the GDE, including:** • **Coal seam gas and extraction** • **Coal mining** • **Other water extraction and development** • **Climate change?**
8	**Site resilience/ sensitivity**	What would happen to the GDE if groundwater was taken away (i.e. how resilient/ sensitive is the GDE to a change in groundwater)?
9	**Knowledge gaps**	What are the key knowledge gaps?

2.4 Conceptual models

The schematics of the conceptual models were developed by drawing out the key information collated in the templates. The output of the conceptual model is a communication tool that uses the combination of graphics, text, maps and photographs to communicate the major processes associated with the GDEs, the potential threats to the GDEs and key knowledge gaps.

Conceptual models can be developed for a range of audiences from detailed technical models through to high level models targeted at capacity building among the general public. As such, the communication tool applied in the conceptual model development is dependent on the audience targeted. The conceptual model communication tools for the five selected sites are intended to improve understanding of the systems by the community and resource managers. They were initially developed in an A3 poster format with more complex descriptions of the GDEs processes and threats. However, review of the draft conceptual models (which included review by the project's Technical Working Group, the East Gippsland and West Gippsland CMAs and their Community Advisory Groups (CAG) and the DELWP Resource Assessment and Planning Team) indicated that the draft conceptual models were too complex for the intended audience, and the models were simplified and converted into a 4-page A4 booklet format (provided in Appendix A to Appendix E).

The process of completing the templates discussed in Section 2.3 means that although the A4 conceptual model booklets are simplified high level versions, the templates still provide the technical detail used to inform the development of the models and therefore can be referred back to for more detailed information if required. The completed templates can also be updated with new information and used to adapt or refine the schematics of each conceptual model.

3. Site Conceptualisations

As discussed in Section 2.4, five GDE sites in the Gippsland Basin were selected for the development of a conceptual model:

- Gippsland Basin and Gippsland Lakes Overview
- Mitchell River and Floodplain – Gleneladale to upper estuary limit
- Gippsland Red Gum Woodlands and Seasonal Herbaceous Wetlands – Stratford to Bairnsdale
- Latrobe River – Morwell to downstream of Rosedale (not including the estuary)
- Corner Inlet and Nooramunga

The following sections provide further details on each of the sites, specifically an overview of the site, the purpose of the model and the key messages that each conceptual model will focus on as identified in the site selection workshop. The completed data template and A4 conceptual model booklet for each site are provided in the Appendices.

3.1 Gippsland Basin and Gippsland Lakes Overview

Overview

The Gippsland Basin is a complex hydrogeological basin that supports a number of significant environmental values, including rivers, wetlands and coastal lakes. It is also significant for agriculture, forestry, recreational and commercial fishing and coal mining. Onshore, unconventional gas development (CSG) is an emerging issue within the basin that has the potential to impact on water resources and is causing concern within the local community. Of particular concern is the potential impact to Gippsland Lakes and their associated fringing wetlands and estuaries.

Purpose of the model

To provide an introduction to the Gippsland Basin and its hydrogeology, and CSG reserves in the Basin and the potential for their development to affect water-dependent assets. The model will assess the role of groundwater in the Gippsland Lakes and outline if it is a critical component of the water regime for the lakes, the fringing wetlands and river estuaries. It will also assess the current and future risks to groundwater resources and the potential consequences for ecosystem values.

Key messages/ issues

The key messages/ issues considered in the model include:

- The Gippsland Basin supports a wide range of ecological, economic, recreational and cultural values.
- The hydrogeology of the basin is complex.
- Groundwater is an important water source for a range of consumptive uses as well as rivers, wetlands and some vegetation communities.
- There has already been an impact on groundwater levels in the deeper Lower Tertiary Aquifer due to off-shore oil and gas development.
- Activities that lower the groundwater levels, such as onshore groundwater extraction (e.g. irrigation), potential coal seam gas development and coal mine dewatering, have the potential to adversely affect GDEs in some areas.

The completed A4 conceptual model booklet for the Gippsland Basin and Lakes Overview is provided in Appendix A. A data template was not compiled for the Gippsland Basin and Lakes Overview because information used to develop the conceptual model was drawn from the information collected for the remaining four sites (provided in Appendix B to Appendix E). In addition, the Baseline Monitoring Program for the Gippsland Basin being under taken by Jacobs for DELWP[5] was used for specific details about CSG reserves in the Gippsland Basin.

3.2 Mitchell River and Floodplain

Overview

The Mitchell River is a significant floodplain river system with high value water dependent assets in the river and on the floodplain. There is also intensive horticultural development on the floodplain, including significant surface water and groundwater extraction to support the horticulture industry. This has impacted on the flow regime of the river and also (with flood mitigation works and agricultural development) directly affected wetland habitats on the floodplain. Further water resource development proposals (new storages, groundwater extraction, Managed Aquifer Recharge etc) represent future incremental risks to the system.

Purpose of the model

To tell the story of water resource development on the Mitchell River floodplain, the implications of this (and future) development on groundwater/surface water interactions, and the consequence for instream and floodplain water dependent assets.

There is an increasing focus on the values and management of this system, so conceptualisation will support this process, including helping to identify risks that could become the focus for future management.

Key messages/ issues

The key messages/ issues considered in the model include:

- Groundwater flow systems, flow paths and recharge and discharge zones.
- Connectivity and expression (surface and sub-surface).
- Seasonal and climate driven changes (Summer/winter and wet/dry climate cycles)
- Complexity of water issues and threats to groundwater
- Description of values and role of groundwater in contributing to the water regime requirements of instream and floodplain values

The completed data template and A4 conceptual model booklet for the Mitchell River and Floodplain is provided in Appendix B.

3.3 Gippsland Red Gum Woodlands and Seasonal Herbaceous Wetlands

Overview

The Red Gum Plains are a region of significant value supporting important vegetation communities including Red Gum Woodland and Seasonal Herbaceous Wetlands (which are listed as a threatened ecological community under the Commonwealth *Environment Protection and Biodiversity Conservation Act*). The area has been affected by significant land clearing and is the focus of potential land use change from grazing to forestry and irrigated agriculture. The vegetation has suffered dieback at various locations, but the cause is not well documented. The overall water regime is not well understood, particularly the role of groundwater.

Purpose of the model

[5] Jacobs, 2015. *Victorian Water Studies – Baseline Monitoring Program for the Gippsland Basin.* Prepared for DELWP.

To investigate the role of groundwater in the water regime of the vegetation and wetland communities, and to identify knowledge gaps that may need to be filled to better understand past, present and future impacts.

Key messages/ issues considered

The key messages/ issues considered in the model include:

- Gippsland Red Gum Woodland and Seasonal Herbaceous Wetland communities are fragmented from extensive land clearing
- Drainage lines (and pools) are directly dependent on shallow groundwater
- Red gums are dependent on groundwater in dry periods
- There are risks from lowered groundwater levels particularly in the north
- Risks from potential gas extraction on surface aquifers is likely to be limited by impermeable geology.

The completed data template and A4 conceptual model booklet for the Gippsland Red Gum Woodland and Seasonal Herbaceous Wetlands is provided in Appendix C.

3.4 Latrobe River (Morwell to downstream of Rosedale)

Overview

Current coal mining around Yallourn and Morwell has affected groundwater levels through dewatering and has affected river flows (e.g. reduced groundwater discharge to the causing a reduction in baseflow) in the Morwell and Latrobe River. Future groundwater extraction in the area through activities such as increased irrigation, changes to coal mining and potential CSG extraction activities may further affect groundwater processes in the River. The consequences of altered flow also extend to reaches downstream of where the groundwater extraction takes place. These current and future impacts on groundwater process are potentially buffered by regulated flow releases from the storages along the Latrobe River.

Purpose of the model

To tell the story of how current and future coal mining and potential CSG activities have and may affectriver flows

Key messages/ issues

The key messages/ issues considered in the model include:

- The Latrobe River supports high ecological, agricultural and economic values.
- The shallow aquifer is likely to have some degree of connection to the river.
- River regulation, realignment of sections of the river, and dewatering of coal mines has changed the interactions between river flows and shallow groundwater
- Further investigation is needed to determine risk from potential coal seam gas developments and large coal mine developments.

The completed data template and A4 conceptual model booklet for the Latrobe River is provided in Appendix D.

3.5 Corner Inlet and Nooramunga

Overview

Corner Inlet is a high value coastal wetland comprising river estuaries, coastal wetlands (especially saltmarsh and mangroves), sand bars and barrier islands. The area is internationally important due to significant vegetation and bird values. A groundwater study has been completed, however, There is currently limited understanding of the role groundwater plays in the water regime for the wetland areas.

Purpose of the model

To assess the role of groundwater in the system and determine if it is a critical component of the water regime for coastal zone areas and if so, what are the current and future risks to groundwater and consequence ecosystem values.

Key messages/ issues

The key messages/ issues considered in the model include:

- Corner Inlet supports significant ecological values.
- Groundwater is an important source of water for coastal wetlands and helps moderate salinity effects from the marine environment.
- There has already been an impact on groundwater levels in the deeper Lower Tertiary Aquifer due to off-shore oil and gas development.
- Further investigation is needed to determine the risks to GDEs from potential coal seam gas developments.

The completed data template and A4 conceptual model booklet for the Corner Inlet and Nooramunga is provided in Appendix E.

4. References

1. GHD, 2014. *Water Asset Identification Project State Report*. Report prepared for the Victorian Department of Environment and Primary Industries.

2. IESC, 2013. *Methodology for bioregional assessment of the impacts of coal seam gas and coal mining development on water resources*. Canberra.

3. Jacobs, 2015. Victorian Water Studies - Baseline Monitoring Program for the Gippsland Basin. Prepared for Department of Environment, Land, Water and Planning.

4. Richardson S, et al, 2011. *Australian groundwater-dependent ecosystem toolbox part 1: assessment framework*, Waterlines report, National Water Commission, Canberra

5. SKM, 2012. *Conceptualisation of Key Groundwater Dependent Ecosystems in Melbourne Water Catchments: Phase 1 Proof of Concept*. Report for Melbourne Water.

6. SKM, 2011. *Australian groundwater-dependent ecosystem toolbox part 2: assessment tools*. Waterlines report, National Water Commission. Canberra.

7. SKM, 2014. *Identification of Groundwater Dependent Water Assets in the Gippsland Basin*. Report Prepared for the East and West Gippsland CMAs.

Appendix A. Gippsland Basin and Gippsland Lakes Overview

Appendix B. Mitchell River Floodplain

Ref	Theme	Data Components, Information Sources	Description
1	**Ecosystem type**	• History of Lindenow • Gippsland Times 16/3/1944 • Alluvium, 2010	**Ecosystem type** • Mitchell River baseflow and permanent pools. • Floodplain billabongs, wetlands and flood runners. **Location** The Mitchell River extends from the Alpine area of the Great Dividing Range to the Gippsland Lakes at Bairnsdale. This conceptualisation will specifically focus on the section of River downstream of Glenaladale to the upper estuary limit. Downstream of Glenaladale the Mitchell River is a meandering system with numerous natural and artificial cut-offs. This section of the River is dominated by pool and riffle sequences which are greatest in length further upstream. **Site history** • 1840 - Gippsland first explored and described by Europeans (Angus McMillan and Pawel Strzelecki). McMillan describes area between Bairnsdale and Stratford, including the Mitchell River floodplain, as gently undulating forest very suitable for grazing. McMillan crosses area now known as Providence Ponds and describes them as a "chain of ponds". Strzelecki describes Mitchell valley and River Red Gum plains as luxurious pasture and open forest and grasslands. • 1843 - Gippsland proclaimed a squatters district. • 1850 - Exceptional heat and drought results in withered pasture, dry creeks and waterholes. "Black Thursday" bushfires decimate newly established farms along the northern edges of the plains. During dry periods the Red Gums "used all the soil moisture". • 1860 - Acts passed to open land to closer settlement. • 1886 - Extensive land clearing occurring. According to Alfred Howitt, large scale death of Red Gums occurred due to defoliation from insects which formed plague proportions in the 1880s due to a lack of bushfires. • Late 1880s - Government approves irrigation scheme in Mitchell valley. • 1891 - Stone Dam constructed on Mitchell River upstream of Glenaladale, but flooded in 1893 and irrigation attempts abandoned. Maize was a common crop planted on the cleared land. • Early-mid 1890s – Flood mitigation and erosion works along Mitchell River (levees, timber and rock structures) • 1920-29 - Lake Glenmaggie constructed on the Macalister River • 1920s - Irrigation channels built and widespread irrigation commenced in the Macalister district • 1930s - Irrigation drainage systems installed • 1944 - First broad scale spray irrigation of pasture along Mitchell River installed • Early 1950s - Irrigation induced salinity becomes a significant problem • 1955/56 - Deep surface drains, free flowing bores and pumps installed to increase drainage and remove saline groundwater

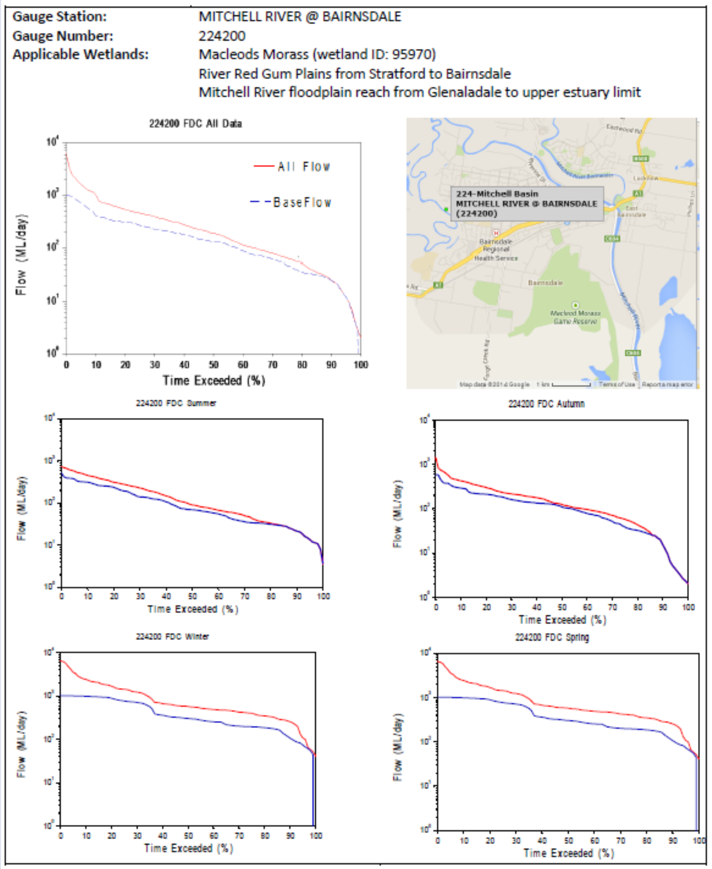
			from shallow aquifers • 1957 - Mitchell River Improvement Trust established and charged with protection of river banks and prevention of flooding of cleared land • 1960s - Dairy farming was common along Mitchell Valley • 1970s/ 80s - Intensive horticulture commenced, particularly in the Lindenow flats area. • 2003, 2006/07 – Majority of upper catchment burn during wildfires. Impact on river included change in sediment regime and change in hydrology. **Value** • One of the largest undammed rivers in Victoria, and is listed as a Heritage River. • Native fish community - particularly threatened Australian Grayling and other species that migrate between marine and freshwater environments to complete various life history stages. • Provides habitat for platypus. • Supports diverse macroinvertebrate, and aquatic and riparian plant communities. • Important source of freshwater inflow to the Gippsland Lakes. **Condition** The 2004 ISC assessment identified the reaches of the Mitchell River downstream of Glenaladale to the upper estuary limit as being in significantly worse condition than the rest of the catchment, reflecting the higher level of development of the lowland reaches. The hydrologic condition of these reaches also scored the poorest in the entire basin. Water resource development for domestic and agricultural uses, as well as flood mitigation activities, have altered the natural flow regime in this zone, increasing periods of low flow and causing summer stress. Levees are likely to have floodplain inundation patterns, with consequences for floodplain health. **Geomorphic description** The Mitchell River catchment can be divided into two physiographic regions; the Highlands (i.e. upper catchment above Glenaladale) and the Gippsland Plains (i.e. lower catchment below Glenaladale). The Gippsland Plains consist of rolling hills and terraces, through which the Mitchell River has formed a broad alluvial valley. The lower catchment is of low relief and drainage density. Between Glenaladale and Bairnsdale the catchment is dominated by a wide alluvial (Quaternary sediments) floodplain, set within Pleistocene terraces.
2	**Climate**	• Hofmann, H. & Cartwright, I., 2011. • BoM	**General climatic conditions** • The climate of the Bairnsdale area is classified as warm and temperate. • Average temperature high of 20.6°C throughout the year, with annual average low of 9.1°C. In January, Bairnsdale averages maximums of 25.8°C and lows of 15°C. During July, Bairnsdale averages a maximum of 13.7°C and a low of 3.8°C. • Rainshadows caused by the ranges occur in the Mitchell River catchment. The high country has an average rainfall of 1080 mm per annum, whereas the township of Bairnsdale has an average rainfall of approximately 716 mm per annum. .

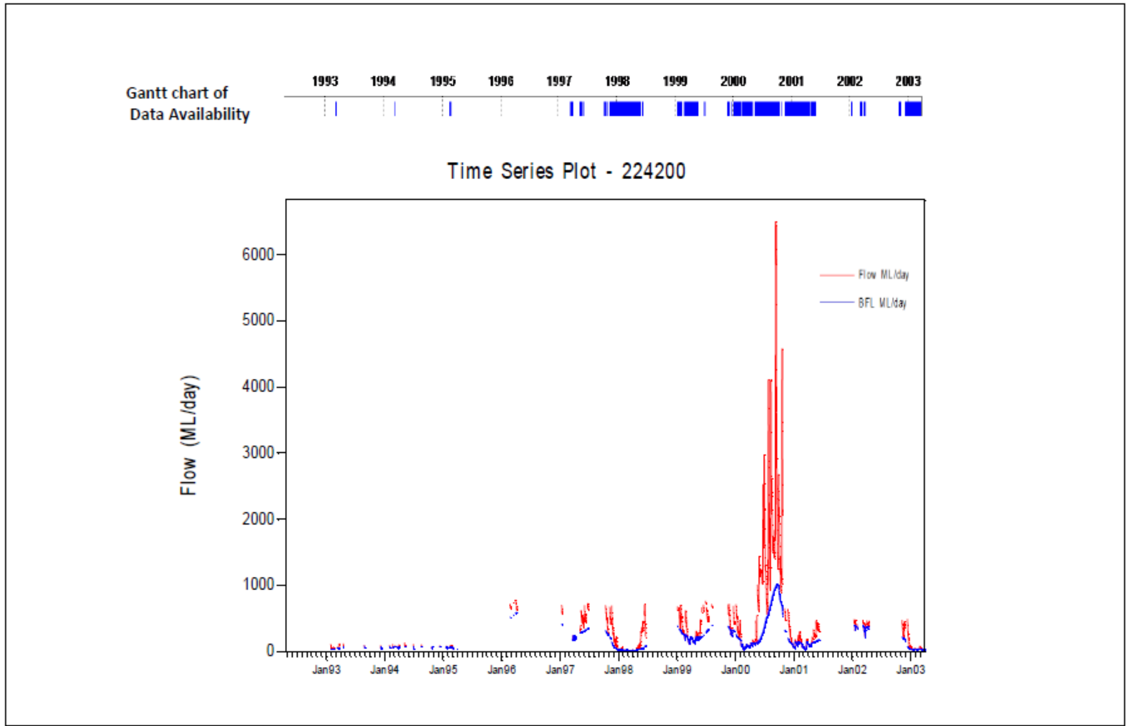
			• During 2006 to 2009, persistent drought occurred, with serious to severe rain deficiencies (5-10% of historical annual rainfall). • Low rainfall, under the long-term averages, started as early as 1997.
3	**Hydrology**	• SKM, 2008 • Alluvium, 2010	**Catchment** • Mitchell River drains an area of around 4,800 km² extending from the alpine areas of the Great Dividing Range to the Gippsland Lakes near Bairnsdale. • Downstream of the study reach, the river discharges to Lake King within the internationally significant Gippsland Lakes. Silt jetties of national and international geomorphological significance (one of the world's finest examples of a digitate delta) are present within Lake King. • A rock barrier north of Bairnsdale defines the boundary between the freshwater reach and downstream estuary. **Water source** • Main water source to the Mitchell River is surface water runoff during and following rainfall events. • Groundwater inflow is likely to occur along the majority of the Mitchell River, except (i) in times of flooding when the river stage is higher than the watertable and hence the river switches to losing conditions or (ii) when extremely dry period or groundwater pumping cause the groundwater level to fall below the river bed and the river also becomes losing. **Water regime** The natural flows in the lower Mitchell River display a typical temperate seasonal pattern, with the lowest average monthly flows in March, and the highest average flows in September. • Jan to May: low flow season (with generally constant low flows – or no flow with infrequent shorter periods of high flow – freshes and floods – due to small localised rainfall events) • Jun to July: a transitional flow season from low to high (higher flows becoming more common with larger more widespread rainfall events) • August to September: a high flow season (higher baseflow with frequent, sometimes extended periods of higher flows from widespread high rainfall events) • November to December: a transitional flow season from high to low (lower flows becoming more common as rainfall events become smaller and more localised). **Naturalness/ Regulation** • The river has no major on-stream storages located along its length. • Private diverters are located throughout the catchment, with most water use being concentrated around the irrigation areas of the Lindenow flats. • Water is also diverted at Glenaladale to supply East Gippsland Water's urban consumers in Bairnsdale, Lakes Entrance and many other smaller towns. • Riparian vegetation has been significantly modified since European settlement, now typically consisting of pasture grasses,

willows, remnant shrubs and occasional eucalypts

- Flood mitigation and erosion works have occurred along the Mitchell River (levees, timber and rock structures)
- Under natural conditions, billabongs/ wetlands/ flood runners would have stored flood waters and promoted recharge over the full width of the floodplain. Now billabongs/ wetlands/ flood runners are no longer connected to the river, causing a reduction in flood storage which leads to a reduction in wide scale recharge of the alluvium aquifer.

Flow





Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	2.05	0.00	Average	402.60	196.30
Maximum	6502.2	1010.3	Standard Deviation	665.27	211.83

Quality

Water quality in the lower Mitchell River is typically good:

- Dissolved oxygen concentrations, even during low flow conditions, does not drop below SEPP objectives and the tolerance thresholds for native fish species present.
- Temperature in the study reach follows seasonal patterns (i.e. higher in summer, lower in winter) and is generally below critical levels for species present. Shading from riparian vegetation is limited.
- Electrical conductivity (EC) levels are compliant with SEPP objectives. During low flow conditions EC increase however they are still well below levels considered detrimental to species present.
- A rock barrier at the upper estuary prevents tidal driven saltwater intrusion into freshwater reaches.
- Turbidity is generally very low, however following the 2006/07 bushfires in the catchment, turbidity was very high.

4	**Hydrogeology**	• Visualising Victoria's Groundwater • SKM, 2008 • Alluvium, 2010 • Thompson, B. 1973 • SKM, 2009.	**<u>Aquifer</u>** The Mitchell River floodplain forms a narrow steep sided valley, where the river flows through a shallow (typically around 10 to 20m thick) unconfined Quaternary (Alluvial) aquifer which typically overlays the Upper Tertiary/ Quaternary (Haunted Hills Formation) aquifer. These two Quaternary aged aquifers are generally unconfined, although they can become semi-confined in local areas. The permeability and porosity of the alluvial aquifer varies considerably across the study area, with the hydraulic conductivity and specific yield of the aquifer thought to be around 30 m/day and 0.1 respectively. The Quaternary aquifer is the most utilised aquifer in the Lindenow Flats area and as such the aquifer is covered by the Wy Yung WSPA which covers the Mitchell River flats and extends to a depth of 25 metres. Underlying the Quaternary (alluvial) aquifer and Upper Tertiary/ Quaternary (Haunted Hill Formation) aquifer are the following the aquifers/ aquitards: • Boisdale Formation - Consists of two units, the Upper Tertiary aquifer (lower Wurruk Sand Member) and the Upper Tertiary Quaternary aquitard (upper Nuntin Clay Member). The aquifer is not exposed at the surface and only subcrops north of Sale where it wedges out and thins beneath the overlying Quaternary sediments. The aquifer is thickest near Sale where it reaches up to 200 m, and thins to the east and west towards Seaspray and Woodside. The Upper Tertiary aquifer is utilised extensively in the Sale area, where it provides the water supply for the township and is used for domestic and stock supply. • The Upper Tertiary/ Quaternary and Upper Mid-Tertiary aquitards (Jemmy's Point Formation/ Tambo River Formation/ Gippsland Limestone) –Impermeable layers/aquitards that overlay the Upper Tertiary aquifer (Boisdale Formation) and restrict groundwater movement between the shallow quaternary aquifers and the deeper aquifers. The Jemmy's Point formation extends south to a maximum thickness of 110 m in the Golden Beach area, east of Lake Wellington and grades into the Upper Tertiary aquifer (Boisdale formation). Beneath the Jemmy's Point Formation are marine sediments of the Tambo River Formation. The Gippsland Limestone consists of two units; the Bairnsdale Limestone and the Wuk Wuk Marl. Both units outcrop in thin beds along the southern side of the Mitchell River, underlying Jemmy's Point Formation where it reaches a maximum thickness of 33 m. • The laterally equivalent Lower Mid-Tertiary aquifer (Latrobe Valley Coal Measures) and Upper Mid –Tertiary aquifer (Balook Formation) and Gippsland Limestone - Regionally, the Upper Mid –Tertiary aquifer (Balook Formation) is considered a significant aquifer and is expected to have a greater transmissivity than the Lower Mid-Tertiary aquifer (Latrobe Valley Coal Measures). There is also limited vertical connectivity between these aquifers and the Boisdale or quaternary aquifers due to the presence of the relatively impermeable Upper Tertiary/ Quaternary aquitards (Jemmy's Point Formation/ Tambo River Formation) above these aquifers. • Lower Tertiary aquifer - The Lower Tertiary aquifer (Latrobe Group) covers the majority of the onshore basin and thickens towards the coastline where it overlies the Palaeozoic basement. It is confined by the Upper Mid-Tertiary aquitards aquitard (Gippsland Limestone). Figure 1 provides a summary of the relative depth and age of these Aquifers/ Aquitards, their associated simplified geology and any resources that they support.

Depth (m)	Age	Period	Epoch	Simplified geology	Aquifer systems	Resource Comment
Shallow	Youngest	Quaternary	Holocence (recent) Pleistocence	Quaternary Sediments / fluvial system / recent alluviums	(QA) Quaternary aquifer	Major aquifer for stock, domestic and irrigation groundwater use mainly in the Macalister Irrigation District and the Mitchell River floodplain. Also major surface aquifers that support ecological values.
		Tertiary	Pliocene	Haunted Hills formation / gravels / Eagle Point Sand	(UTQA) Upper Tertiary/Quaternary aquifer	
				Sale Group	(UTQD) Upper Tertiary Quaternary Aquitard	Includes low permeability Boisdale Formation (Nuntin Clay), Sale Group and Jemmys Point Formation
					(UTAF) Upper Tertiary Aquifer Fluvial*	Includes Boisdale Formation which is a major irrigation aquifer and target aquifer for Sale Town Water Supply.
					(UTD) Upper Tertiary Aquitard	Includes low permeability Hazelwood Formation and Yallourn Formations
					(UMTA) Upper Mid-Tertiary Aquifer*	Includes the Balook Formation which is a major irrigation aquifer and includes the Morwell M1-2 Coal Seam which is targeted in the Latrobe Valley Coal
			Miocence	Gippsland Limestone	(UMTD) Upper Mid-Tertiary Aquitard	Includes low permeability Gippsland Limestone and Lakes Entrance Formation
			Oligocence	Latrobe Valley Group / Coal Measures	(LMTA) Lower Mid-Tertiary Aquifer	Includes the Morwell M2C Coal Seam (not currently mined)
		Cretaceous	Lower	Cretaceous (older) volcanics	Lower Tertiary Basalts	Not heavily used in the Gippsland Basin
					(LTA) Lower Tertiary Aquifer*	Includes the Traralgon Formation which is the CSG prospect unit. Also offshore oil and gas target aquifer and heavily used in Yarram for irrigation.
		Jurasic		Bedrock	Mesozoic and Palaeozoic Bedrock	Includes the Strzelecki Group which is the Tight Gas Prospective Unit.
		Triassic				
		Permian				
		Carboniferous				
		Devonian				
		Silurian				
		Ordovician				
		Cambrian				
Deep	Oldest	Precambrian				

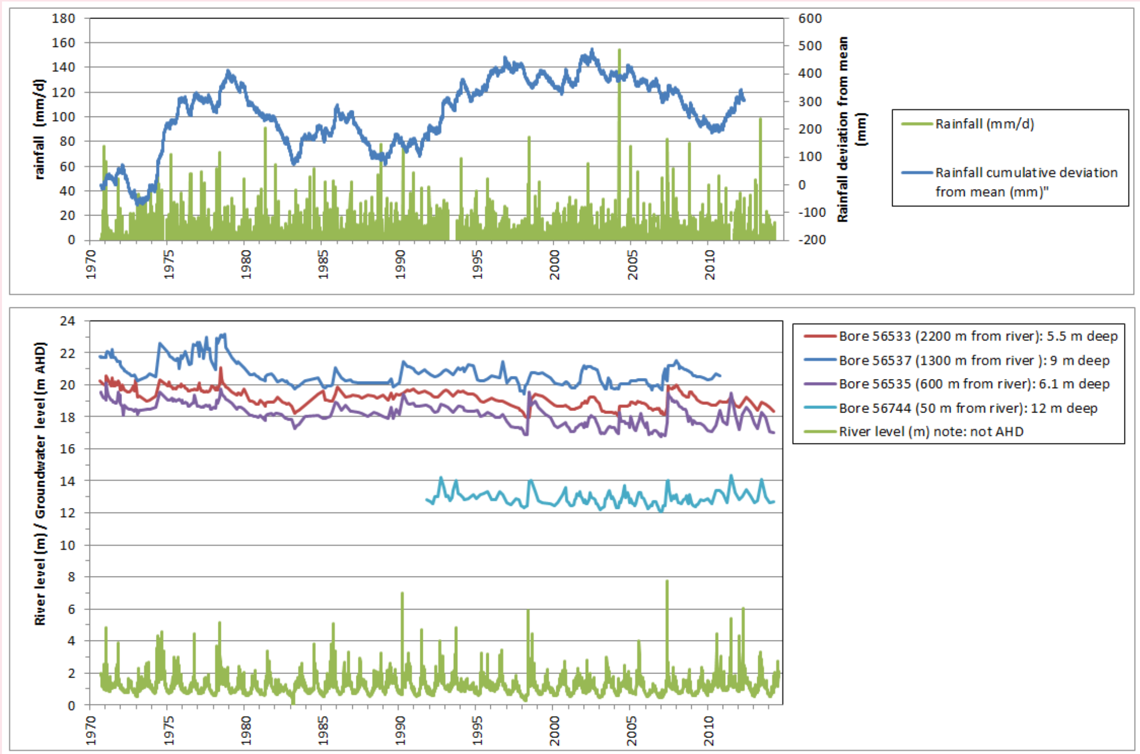
*note this aquifer does not occur at the surface and hence does not correspond to any "surface" geology.

Figure 1: Aquifers and aquitards of the Gippsland Basin

Geology

			• The Quaternary sediments along the river (alluvium) is terraced and up to 10 m thick. The formation typically comprises 3 to 8 m of coarse gravels and sands which overlie up to 5 m of medium to fine silt and sand. • The Haunted Hill Formation in the Lindenow Flats area consists of silts and clays which are commonly oxidised to produce brown, yellow, red or mottled sediments with ironstone near the top. • The Boisdale formation consists of well rounded, well-sorted coarse sands with interbedded clay beds which contain ligneous clays and gravels in some places. • The Jemmy's Point formation consists of grey to brown shelly and sandy marl, marly or calcareous sandstone, succeeded by shelly sand and minor gravel. • The Tambo River Formation consists of a mixture of shelly marl, marly limestone and ferruginous fine sandstone. • The Bairnsdale Limestone consists of bryzoal shelly limestone and marly limestone. • The Wuk Wuk Marl consists of fossiliferous marl. • The Latrobe Valley Coal Measures and Balook Formation have similar geology. The Latrobe Valley Coal Measures in the Mitchel River area consists of well-rounded coarse to medium fine sand interbedded with sequences of sands, lignites, ligneous mudstones and brown coals which are mined in the Latrobe Valley. The Balook Formation comprises relatively homogenous, fine to medium grained sands. They were deposited around the same time and respectively they represent on the shore, beach/sand dunes and offshore deposits. The extents of the two formations are not accurately known, nor are the thicknesses due to a lack of detailed mapping, particularly in the central and western regions of the study areas. • The Latrobe Group consists of sands, clays and brown coals and has a similar lithology to the overlying Latrobe Valley Coal Measures and Balook Formation making it difficult to distinguish between the formations. • The substrate of the river is dominated by cobbles and gravel, with particle size decreasing downstream. • Isolated outcrops of underlying marls and limestone are exposed in some downstream sections and sand overlays the gravel substrate near Bairnsdale. • The river bank sediments are generally friable loams (easily erodible) of the alluvial floodplain deposits. • There is a 7 km section near Calulu where limestone cliffs abut the left bank of the river. The limestone is quite resistant to fluvial erosion and provides a significant vertical and lateral control on channel change where it has been exposed. **Soils** • There is a layer of fertile clay loam top soil overlying the alluvium across the floodplain which has low permeability. **Groundwater level, movement and flow** There is currently an extensive network of State Observation Bores monitoring groundwater levels of the shallow Quaternary (alluvial) aquifer on a 3 monthly basis in the Mitchell River area. Hydrographs from a number of these bores are shown in the below Figure indicating a depth to watertable typically between 2 m and 4 m below the ground surface. From these hydrographs the following can be observed: • Wet climate period in the 1970s coincided with high water table levels.

- Dry conditions from 1978 onwards resulted in lower groundwater levels through reduced recharge from river due to lower flows. An increase in extraction of surface water and groundwater for irrigation during the dry conditions also contributed to lowering groundwater levels.
- Wetter conditions in 1990s did not result in an increase in groundwater levels. Groundwater levels continued downwards trend, perhaps due to extraction.
- Groundwater table closest to the river area recharged each year but further away from the river recharge was attenuated and was only significant during flood events (e.g 1989, 1998, 2007).
- Downward trend in groundwater level appeared to cease from 2000s onwards, potentially due to improved surface water and groundwater management, irrigator efficiency and maintenance of base groundwater level through high connectivity with river preventing further decline.



The Mitchell River cuts through the entire thickness of the alluvium, thus providing a hydrogeological barrier to flow from the northern

			side of the river to the southern side. Groundwater moves from the south of the flats in a northerly direction and discharges to the river, whilst groundwater north of the flats flows in a southerly direction and discharges to the river. Down-valley flow is also likely to occur in a south-easterly direction. Groundwater flow in the Upper Tertiary aquifer (Boisdale Aquifer) and the deeper regional aquifers (Latrobe Valley Coal Measure, Balook Formation and Latrobe Group) is generally to the south-east where it discharges to the Gippsland Lakes and/or the ocean. **Recharge/ discharge characteristics** • The primary recharge mechanism for the Quaternary aquifers in which the river is incised is via rainfall recharge, although significant flood events also provide recharge to the aquifer over short durations. These aquifers discharge to the river. • The Upper Tertiary aquifer (Boisdale) is considered to be mainly recharged along the northern margin of the aquifer between the Thomson and Avon Rivers and the region south of Sale. Groundwater flow within the Upper Tertiary aquifer is generally to the south-east where it discharges to the Gippsland Lakes and /or the ocean. • Recharge to the Lower Mid-Tertiary aquifer (Latrobe Valley Coal Measures) and Upper Mid –Tertiary aquifer (Balook Formation) are thought to occur at the margins of the basin from rivers and infiltration from precipitation. Vertical recharge from overlying aquifers is likely to be limited. Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. • Recharge to the Lower Tertiary aquifer system (Latrobe Group) is likely to occur in areas where the formation outcrops and subcrops. Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. **Water quality** There are no bores in the area monitoring groundwater quality and State Observation Bores in the area have a limited number of groundwater chemistry readings (between 1970 and 1987) recorded. • Quaternary (alluvial and Haunted Hills Formation) aquifer salinity is generally less than 1,000 mg/L TDS. • Upper Tertiary aquifer (Boisdale) – salinity typically less than 500 mg/L TDS. • Upper Mid-Tertiary aquitard (Gippsland Limestone) salinities area variable between 1,000 to 2,500mg/L TDS. • Lower Mid-Tertiary aquifer (Latrobe Valley Coal Measures) and Upper Mid –Tertiary aquifer (Balook Formation) salinities range between 820 to 3,100 mg/L TDS. • Lower Tertiary aquifer (Latrobe Group) salinities are suggested to be around 1000 mg/L TDS in the Bairnsdale/ Lakes Entrance area.
5	**Groundwater connection**	• SKM, 2008 • SKM, 2009 • Hofmann, H. & Cartwright, I., 2011.	**Nature of groundwater connection at the site** The shallow, unconfined, Quaternary (alluvial) aquifer is restricted to the Mitchell River valley and has a strong hydraulic connection with the Mitchell River itself and it is though that the Mitchell River bed is reportedly level with the base of the Quaternary (alluvial) aquifer. Therefore: • The majority of the Mitchell River is considered a ‘gaining’ river (i.e. groundwater discharges to the river) along the majority of

			under most conditions. • In higher flows and flood events, the river stage exceeds the watertable and therefore the river switches to 'losing' conditions (i.e. river discharges to the aquifer). • In periods of low flow (drought conditions) and groundwater pumping the groundwater level can fall below the river level, also leading to 'losing' conditions. This groundwater connection is supported by Radon analysis (Hofmann, H. & Cartwright, I., 2011).
6	**Groundwater service**		**Critical groundwater processes/ environmental water requirements of species associated with groundwater** The discharge of groundwater to the river is a critical contributor to base flow, which is important for maintaining habitat for aquatic plants and animals and water quality. The natural flow variation associated with the high and low flows results in: • a range of habitat types for aquatic and semi-aquatic plants and animals • high flows help maintain water quality, flush sediments from pools and riffles and cue fish migration and spawning.
7	**Key Threats**	• SKM, 2008	**Coal seam gas and extraction** The potential impact from coal seam gas extraction activities from the Lower Tertiary aquifer (Latrobe Group) (located to the south) to the Mitchell River is not well understood, particularly the lateral extent of groundwater connection and the interaction between the Mitchell River floodplain aquifer and the deeper regional aquifers in which coal seam gas extraction may occur. It is however considered to be a low risk, due to the location of potential prospective coal seam gas resources in the Gippsland Basin generally not being located in the vicinity of the Mitchell River catchment. Any potential impact is likely to occur outside of the Mitchell River catchment in the deeper regional aquifer (Lower Tertiary Aquifer). **Other water extraction and development** Agricultural development along the floodplain has led to an increase in water use via diversions from the river and from groundwater pumping. Groundwater is mainly extracted for irrigation from the shallow quaternary aquifer (Haunted Hills Formation) that occur beneath the alluvial flats in the valley adjacent to the Mitchell River. The Wy Yung Groundwater Management Area (GMA) has been set up to manage the shallow alluvial aquifers (to a depth of 25 m) in the Mitchell River Valley to the west of Bairnsdale. Although the extracted water is generally being applied back on to the floodplain, efficient irrigation practices and the low permeability clay loam layer on the floodplain surface means that recharge is not significant and overall groundwater levels have fallen since the late 1970s when broadscale irrigation commenced. The lag time from when groundwater extraction occurs and when the river is impacted is small. Therefore any impact of groundwater extraction will be felt by the river during the same low flow period in which the pumping occurred. **Climate change** Altered rainfall patterns and increasing temperatures associated with Climate Change will cause changes to streamflow (surface water and groundwater regime), sediment supply and riparian vegetation in the Mitchell River catchment. Complex interactions between these changes are also likely to cause adjustments in fluvial geomorphology and habitat quality and availability associated with the river.

			Other The combination of flood mitigation, erosion works and agricultural activities, especially irrigation for horticulture, has changed the landscape of the Mitchell River floodplain significantly, notably: • Native vegetation clearing • Billabong and flood runners have been disconnected from the river. Under natural conditions, wide scale flooding of the floodplain would have occurred, filling flood runners and billabongs and promoting recharge to the groundwater over the full width of the floodplain. The flood runners and billabongs were an important source of local groundwater recharge for the river because a large proportion of the remaining floodplain has a clay loam layer overlying the alluvium deposits which restricts aquifer recharge. Under current conditions where the flood runners and billabongs are disconnected from the river and developed for agriculture practices, flood storage is significantly reduced and this source of groundwater recharge is reduced. This is shown in bore hydrographs that shows representative bores close to the river being recharged each year by within-channel high flows, however for bores further away from the river recharge is only significant during large flood events that inundate the entire floodplain.
8	**Site resilience/ sensitivity**	• Zolfaghar, S., 2013 • SKM, 2012	**Resilience/ sensitivity to a change in groundwater** As a result of the high connectivity between groundwater and river flow, changes in groundwater have the potential to impact the flow regime of the river (reduced baseflow), particularly during low flow periods/ dry summers. Conversely, a reduction in high flows and flood events has implications for recharge of the alluvial aquifer within the river bed and across the floodplain. Drought and over extraction that result in a reduction in river base flow have the following ecological consequences: • Reduction in habitat for fish and other aquatic species • Decline in water quality • Loss of high flow cues for migration and spawning • Reduction in freshwater inputs to the Gippsland Lakes.
9	**Knowledge gaps**		**Key knowledge gaps** Due to the high degree of connectivity between groundwater and flow in the Mitchell River, there is a need to understand and manage surface water and groundwater as the same resource to ensure that the environmental requirements of the river are met and the reliability of surface and groundwater extraction is maintained. • More information on the critical interactions between groundwater and surface water in the Mitchell River is required to manage these uses. This could include the development of a water balance of the river and floodplain system to understand the role of local recharge along the floodplain and volume of discharge to the river and inform management of the river and floodplain. • Management may include the re-engagement of the billabongs and flood runners to provide both storage during flood events and an important source of groundwater recharge to increase groundwater levels in the local quaternary (alluvial) aquifer and increase baseflow in the river.

			• Knowledge gaps also exist around interaction between the river, quaternary aquifers and the deeper aquifers along the river. • An understanding of the connection between the alluvial aquifer and deeper aquifers, and the lateral extent of aquifer drawdown associated with gas extraction is required to understand the potential impacts of coal seam gas extraction.
10	**References**		1. SKM, 2002. Lake Wellington Catchment Salinity Management Plan - Bengworden Salinity Investigation. Report for Department of Natural Resources and Environment. 2. Visualising Victoria's Groundwater - http://www.vvg.org.au/ 3. State wide GMU mapping - http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphology 4. SKM and GHD, 9009. Hydrogeological Mapping of Southern Victoria. Report for Southern Rural Water. 5. GHD, 2012. Report on the Development of State-Wide 3D Aquifer Surfaces. Report for Department of Sustainability and Environment. 6. Southern Rural Water, 2012. *Gippsland Groundwater Atlas.* 7. Alluvium, 2010. Minimising the Environmental Impact of Water Extraction from the Lower Mitchell River. 8. SKM, 2007. Groundwater Resource Assessment of Deeper Aquifers in the Lindenow Region, East Gippsland. Report for Southern Rural Water 9. Hofmann, H. & Cartwright, I., 2011. Understanding Connectivity within Groundwater Systems and between Groundwater and Rivers. 10. Thompson, B. 1973. The Geology and Hydrogeology of the Mitchell River Flats and a Study of Artificial Recharge. Geological Survey Report Number 1973/2 11. SKM, 2008. Mitchell River REALM Update. Report for the Department of Sustainability and Environment. 12. SKM, 2009. Groundwater Monitoring Network Review: Wy Yung WSPA. Report for the Department of Sustainability and Environment. 13. SKM, 2012. Impacts of groundwater extraction on streamflow in selected catchments throughout Australia, Waterlines report, National Water Commission, Canberra

Appendix C. Gippsland Red Gum Woodlands and Seasonal Herbaceous Wetlands

Ref	Theme	Data Components, Information Sources	Description
1	**Ecosystem type**	• Dickson C.R., Farrington L., & Bachmann M. 2014 • Commonwealth of Australia, 2010a • Commonwealth of Australia, 2010b • Commonwealth of Australia, 2012a • Commonwealth of Australia, 2012b • State wide GMU mapping	**Ecosystem type** • *Gippsland Red Gum Grassy Woodland* - The tree canopy is dominated by Gippsland Red Gum (*Eucalyptus tereticornis subsp. mediana*) and the ground layer is covered by native perennial tussock grasses and grass-like plants with a variety of wildflowers such as daisies, lilies and orchids • *Seasonally herbaceous wetland (freshwater) of the Temperate Lowland Plains* - Isolated, freshwater wetlands that are usually inundated on a seasonal basis through rainfall, then dry out, so surface water is not permanently present. They have a vegetation structure that is open, i.e. woody cover is absent to sparse, and the ground layer is dominated by herbs (grasses, sedges and forbs) adapted to seasonally wet or waterlogged conditions. • North to south drainage lines –Permanent pools that dissect dunes and generally located deeper in the landscape. They provide permanent habitat for aquatic flora and fauna. **Location** • *Gippsland Red Gum Grassy Woodland* –Only found in Victoria and is limited to the central Gippsland Plain, between Morwell and Swan Reach. The distribution of the ecological community can be defined by the distribution of the Gippsland Red Gum (*Eucalyptus tereticornis subsp. mediana*), which is bounded by the Strzelecki Ranges to the west, the slopes of the Great Dividing Range to the north and the Tambo River valley to the east (See Figure 1). This conceptualisation will specifically focus on the ecological communities located between Stratford and Bairnsdale. Most known remnants are small, under 10 hectares, and comprise isolated fragments surrounded by mostly agricultural landscape. The ecological community typically occurs on undulating to flat plains less than 100 metres above sea level with some occurrences on low hills up to 220 metres. • *Seasonally herbaceous wetland (freshwater) of the Temperate Lowland Plains* –Occur on the lowland plains of Victoria, south-eastern South Australia, and southern New South Wales. This conceptualisation will specifically focus on the ecological communities located between Stratford and Bairnsdale. The ecological community is limited to plains and lower slopes or stony rises at elevations below 500 metres above sea level. These wetlands occur on seasonally-filled drainage lines or depressions, sometimes poorly defined. **Site history** • Please refer to the Mitchell River Floodplain template for history of the region. **Value** • *Gippsland Red Gum Grassy Woodland* listed as critically endangered under Section 266B of the *Environment Protection and Biodiversity Conservation Act 1999* and threatened under the *Victorian Flora and Fauna Guarantee Act 1988.*

			• The *Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains* ecological community is listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act 1999.* • Nationally and State threatened flora and fauna species occurrences in the communities include Swift Parrot, Growling Grass Frog, Southern Bell Frog, Spot-tailed Quoll, Tiger Quoll, Southern Brown Bandicoot, Matted Flax-lily, Metallic Sun-orchid, Gaping Leek-orchid and Dwarf Kerrawang. **Condition** Many areas of the original Gippsland Red Gum Grassy Woodland and Seasonally Herbaceous Wetland communities have been disturbed and degraded and generally only occur now in small, fragmented patches. The best quality remnant of the ecological community are generally found on public land, such parks/ reserves, roadsides or railway verges, cemeteries, and, to a lesser extent, conservation reserves. Some remnants do occur on private tenure, in paddocks that are uncleared or are managed by the community. **Geomorphic description** Eastern Plains GMU - mostly of low relief, ranging from undulating rises to almost level plains. The surficial sediments are mostly alluvial and range in age from Quaternary to Recent. These mainly comprise sediments derived from the Eastern Uplands (EU) to the north. The youngest sediments are the flood plains, swamps and morasses associated with the present rivers and streams.
2	**Climate**	• Commonwealth of Australia, 2010a	**General climatic conditions** The region in which the ecological communities occur falls within a rain shadow bounded by the Strzelecki Ranges and Great Dividing Range. Mean annual rainfall lies within the 400-700 mm/year isohyets. The distribution of rainfall tends to be uniform throughout the year with slight Spring peak
3	**Hydrology**	• DSE, 2003 • Commonwealth of Australia, 2010a • Commonwealth of Australia, 2012	**Catchment** The ecological communities located between Stratford and Bairnsdale are within the Mitchell River catchment. **Water source** • *Gippsland Red Gum Grassy Woodland* – The main water source for the Gippsland Red Gums is rainfall, however they are also likely to access groundwater however only opportunistically and generally during dry periods when soil moisture is low due to low rainfall. • *Seasonally herbaceous wetland (freshwater) of the Temperate Lowland Plains* –Wetlands are not dependent on overbank flooding from riverine systems, but rather fed from local rainfall. In cases where groundwater levels are shallow, there may be some groundwater influence that contributes to retention of the water in wetlands and persistence of wetland flora when climatic conditions are dry. • *North-south drainage lines* - Runoff, groundwater and rainfall provide water to the north-south drainage lines.

			Water regime • *Gippsland Red Gum Grassy Woodland* – Red Gums rely on flooding, rainwater and groundwater to provide their water requirements. • *Seasonally herbaceous wetland (freshwater) of the Temperate Lowland Plains* –Inundation is typically seasonal. The wetland is subject to predictable annual wet and dry periods, usually filling during the wet season and drying out in most years (except during drought periods). The depth, duration and frequency of inundation of the ecological community are highly variable, reflecting the catchment, the physical properties of the site and the prevailing weather conditions. However, in 'typical' years (determined by long-term climatic trends) the wetlands are inundated for up to a few months and the depth of water is usually shallow (<1 metre). Occasionally there may be little to no inundation for one to several years, as was the case in the drought of the mid-2000s. **Naturalness/ Regulation** • Some communities are location within reserves, but not all are managed primarily for nature conservation. • The north-south drainage lines are unregulated. • Woodland sites are largely cleared of native vegetation and used for agricultural purposes. • Wetlands have been permanently converted to cropland, pasture, plantation forests, artificial dams or have undergone some other substantial modification that has removed their natural hydrological and biological characteristics (e.g. drainage). **Quality** • *Seasonally herbaceous wetland (freshwater) of the Temperate Lowland Plains* –Due to being rainfall fed, they are predominately fresh, sometime brackish systems when wet. Generally salinity is less than 1000 mg/L but can increase to 3000 mg/L as water evaporates during drying.
4	**Hydrogeology**	• Visualising Victoria's Groundwater • SKM, 2002 • SKM, 2007 • Southern Rural Water, 2012 • SKM and GHD, 9009	**Aquifer** The Gippsland Red Gum Woodlands and Seasonally Herbaceous Wetlands typically lie within the unconfined Quaternary (alluvial) aquifer which generally overlays the Upper Tertiary/ Quaternary aquifer (Haunted Hills Formation). These two Quaternary aged aquifers are generally unconfined, although they can become semi-confined in local areas. Underlying the Quaternary (alluvial) aquifer and the Upper Tertiary/ Quaternary (Haunted Hill Formation) aquifer and the following the aquifers/ aquitards: • Boisdale Formation - consists of two units, the Upper Tertiary aquifer (lower Wurruk Sand Member; higher permeability) and the Upper Tertiary/ Quaternary aquitard (upper Nuntin Clay Member; lower permeability). The aquifer/ aquitard is not exposed at the surface and only subcrops north of Sale where it wedges out and thins beneath the overlying Quaternary sediments. The aquifer is thickest near Sale where it reaches up to 200 m, and thins to the east and west towards Seaspray and Woodside.

			• The Upper Mid Tertiary aquifer (Balook Formation) and Upper Mid Tertiary aquitard (Gippsland Limestone) – The Upper Mid Tertiary aquifer is considered a significant aquifer regionally. There is also limited vertical connectivity between the aquifer and the Upper Tertiary aquifer (Boisdale; Wurruk Sand Member) or quaternary aquifers due to the presence of the relatively impermeable Upper Tertiary/ Quaternary aquitard (Boisdale Formation; Nuntin Clay) above this aquifer/ aquitard, however where not present there is likely connection. • Lower Tertiary aquifer - The Lower Tertiary aquifer (Latrobe Group) aquifer covers the majority of the onshore basin and thickens towards the coastline where it overlies the Palaeozoic basement. It is confined by the Upper Mid-Tertiary aquitard (Gippsland Limestone) in some areas and where not is likely to be hydraulically connected to the Balook Formation. Figure 1 provides a summary of the relative depth and age of these Aquifers/ Aquitards, their associated simplified geology and any resources that they support.

Depth (m)	Age	Period	Epoch	Simplified geology	Aquifer systems	Resource Comment
Shallow	Youngest	Quaternary	Holocene (recent)	Quaternary Sediments / fluvial system / recent alluviums	(QA) Quaternary aquifer	Major aquifer for stock, domestic and irrigation groundwater use mainly in the Macalister Irrigation District and the Mitchell River floodplain. Also major surface aquifers that support ecological values.
			Pleistocence			
		Tertiary	Pliocene	Haunted Hills formation / gravels / Eagle Point Sand	(UTQA) Upper Tertiary/Quaternary aquifer	
				Sale Group	(UTQD) Upper Tertiary Quaternary Aquitard	Includes low permeability Boisdale Formation (Nuntin Clay), Sale Group and Jemmys Point Formation
					(UTAF) Upper Tertiary Aquifer Fluvial*	Includes Boisdale Formation which is a major irrigation aquifer and target aquifer for Sale Town Water Supply.
					(UTD) Upper Tertiary Aquitard	Includes low permeability Hazelwood Formation and Yallourn Formations
					(UMTA) Upper Mid-Tertiary Aquifer*	Includes the Balook Formation which is a major irrigation aquifer and includes the Morwell M1-2 Coal Seam which is targeted in the Latrobe Valley Coal
			Miocence	Gippsland Limestone	(UMTD) Upper Mid-Tertiary Aquitard	Includes low permeability Gippsland Limestone and Lakes Entrance Formation
			Oligocence	Latrobe Valley Group / Coal Measures	(LMTA) Lower Mid-Tertiary Aquifer	Includes the Morwell M2C Coal Seam (not currently mined)
		Cretaceous	Lower	Cretaceous (older) volcanics	Lower Tertiary Basalts	Not heavily used in the Gippsland Basin
					(LTA) Lower Tertiary Aquifer*	Includes the Traralgon Formation which is the CSG prospect unit. Also offshore oil and gas target aquifer and heavily used in Yarram for irrigation.
		Jurasic		Bedrock	Mesozoic and Palaeozoic Bedrock	Includes the Strzelecki Group which is the Tight Gas Prospective Unit.
		Triassic				
		Permian				
		Carboniferous				
		Devonian				
		Silurian				
		Ordovician				
		Cambrian				
Deep	Oldest	Precambrian				

*note this aquifer does not occur at the surface and hence does not correspond to any "surface" geology.

Figure 2: Aquifers and Aquitards of the Gippsland Basin

Geology

The surface geology typically comprises of recent alluvial deposits with patches of overlying aeolian (wind formed) sand dunes and sand sheets. These sandy substrates are aligned parallel to the coast (i.e. south west to north east) and form gentle rolling hills across the plains, while steeper slopes occur locally. Between the dunes are sand and gravel depressions and flats. More deeply incised drainage lines run north to south across the plain. The process of deposition and dune formation in the Gippsland Plains varies from north (typically north of the Princes Highway) to south. The deposits to the north have well-developed dune cores of clay to clayey sand. These dune clay cores are close to the surface and impede drainage and restrict recharge to the underlying aquifer. In comparison, the dune deposits to the south are less developed, do not have clay cores and fine sand occupies the dune surface meaning they are very permeable.

These surface formations overlay older geological units including:

- The Haunted Hill Formation consists of sand, silts and clays.
- The Boisdale formation (Nuntin Clay) consists of well-rounded, well-sorted coarse sands with interbedded clay beds which contain ligneous clays and gravels in some places.
- The Balook Formation comprises relatively homogenous, fine to medium grained sands. They represent the shore, beach/sand dunes and offshore deposits. The extent of this formation is not accurately known, nor are the thicknesses due to a lack of detailed mapping, particularly in the central and western regions of the study areas.
- The Latrobe Group consists of sands, clays and brown coals and has a similar lithology to the overlying Balook Formation making it difficult to distinguish between the formations.

Soils

- The plains to the north are sands or loamy sands over clays, have slow drainage and low permeability.
- The plains to the south are sandy loams to loamy sands over loamy clays to light clay, and have higher permeability than the clays to the north.

Groundwater level, movement and flow

There is no groundwater data available in the surface aquifers representative of those underlying the Gippsland Red Gum Woodlands and Seasonally Herbaceous Wetlands.

State-wide regional depth to watertable mapping indicated that shallow local groundwater system is generally within depth to water table rage of < 5-20 m below the ground surface.

In the local Quaternary aquifer system the groundwater flow path is likely to follow local topography, flowing from areas of higher elevation (e.g. dunes) towards lower elevation areas such as drainage lines.

In the deeper regional aquifers systems (associated with the Upper Mid-Tertiary aquifer and Lower Tertiary aquifer and Latrobe Group formations) groundwater movement is generally from north to south where it discharges to the Gippsland Lakes and/or the ocean.

Recharge/ discharge characteristics

- The primary recharge mechanism for the surface Quaternary (alluvial) and Upper Tertiary/ Quaternary (Haunted Hills Formation) aquifer is via rainfall recharge, although flood events also provide recharge to the aquifer over short durations. These aquifers discharge to the drainage lines.
- The Upper Tertiary aquifer (Boisdale) is considered to be mainly recharged along the northern margin of the aquifer between the Thomson and Avon Rivers and the region south of Sale. Groundwater flow within the Upper Tertiary aquifer is generally to the south-east where it discharges to the Gippsland Lakes and /or the ocean.

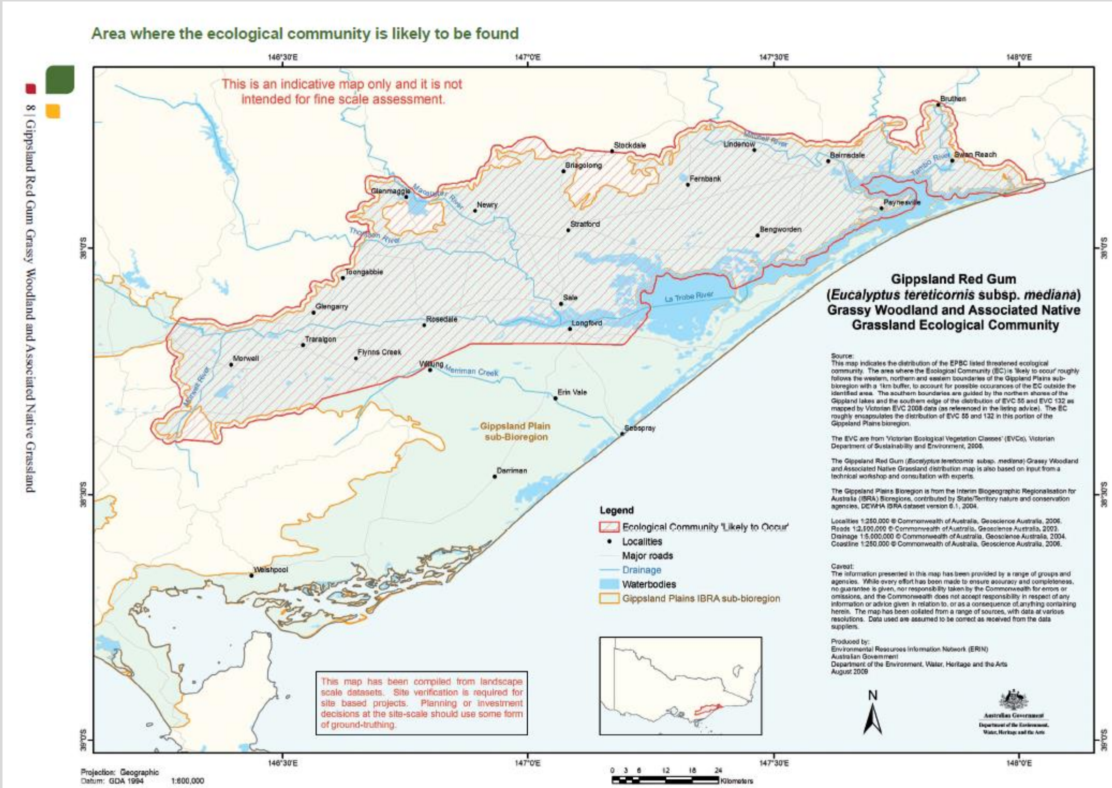
			• Recharge to the Upper Mid-Tertiary aquifer (Balook Formation) is thought to occur at the margins of the Gippsland Basin from rivers and infiltration from precipitation. Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. • Recharge to the Lower Tertiary Aquifer (Latrobe Group) is likely to occur in areas where the formation outcrops and subcrops. Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. **Water quality** A lack of groundwater data in the area means that it is difficult to comment on the water quality of groundwater beneath the ecological communities. State-wide salinity mapping of the area of interest between Stratford and Bairnsdale indicated that salinity is generally less than 1,000 mg/L with some patches of higher salinity (7000 – 13000 mg/L), particularly around the area of Bairnsdale.
5	**Groundwater connection**		**Nature of groundwater connection at the site** Where groundwater is located close to the surface it can provide an important source of water for rivers, wetlands and vegetation (termed Groundwater Dependent Ecosystems – GDEs). A lack of groundwater level data for the shallow (watertable) aquifers in the Gippsland Plains means that the classification of groundwater connection with surface GDEs in this area can only be hypothesised from conceptualisation and previous studies undertaken in similar hydrogeological settings: • It is likely that groundwater discharge provides base flow to the deeper north-south drainage lines with chain of ponds morphology (e.g. Perry River around Providence Ponds) where the water table intersects the stream channel. When the water table is high this could occur along the entire length of the drainage lines however if the water table is lowered (e.g. due to reduced recharge after a long dry period or excessive drawdown from groundwater extraction), discharge would only occur in deeper pools. • The Gippsland Red Gums are also likely to access groundwater however only opportunistically and generally during dry periods when soil moisture is low due to low rainfall. • The Seasonal Herbaceous Wetlands are unlikely to be connected to groundwater as they are generally located higher in the landscape within shallow depressions that are unlikely to intersect the watertable. The water source for these wetlands comes from surface water runoff during local rainfall events. Seasonal rainfall over the Winter and Spring period likely sustains their water levels for a period of time but they dry out over Summer and Autumn.
6	**Groundwater service**		**Critical groundwater processes/ Environmental water requirements of species** • The deep pools of the north-south drainage lines provide permanent habitat for aquatic flora and refuge habitat for aquatic fauna during low flow and drought periods. • Groundwater provides an alternate source of water to Gippsland Red Gums, particularly important during dry periods when soil moisture is low due to low rainfall.

7	**Key Threats**	• DSE, 2003 • Commonwealth of Australia, 2010a • Commonwealth of Australia, 2012	**Coal seam gas extraction** The potential extent of impacts from potential coal seam gas development are not well understood. In some areas, the Lower Tertiary Aquifer is separated from overlying surface aquifers by a layer of low permeability clays and silts (Upper Mid Tertiary Aquitard) which may prevent dewatering of the surrounding aquifer affecting the surface aquifers. However, in some locations, the low permeability layers become very thin or absent. In these locations there is a potential risk that drawdown in Lower Tertiary Aquifer could result in a decline in the water table level in the surface aquifers, however further work is required to quantify these risks. **Other water extraction and development** Groundwater extraction in the region may lower the watertable, impacting on the hydrological regime of those communities reliant on groundwater. The combination of changes in rainfall-driven recharge (due to climate change) and extraction for irrigation are likely to represent the greatest threat to groundwater levels in the middle and northern parts of the plain. **Climate change** • Climate change may directly threaten species that cannot adapt and also exacerbate existing threats, including loss of habitat, altered hydrological regimes, altered fire regimes and invasive species Wetlands dependant on rainfall may be strongly influenced by a continuing decline and a shift away from a regular pattern in rainfall and more frequent and severe droughts. This means that wetlands which are now seasonally inundated could shift to a more intermittent or unpredictable filling cycle. • The longer a wetland system is dry (prolonged drought) the greater the likelihood of loss from the egg and seed bank. Repeat droughts will further reduce the species richness and resilience of wetlands, largely through impacts on the seed and egg banks. The loss of propagules from wetlands across entire landscapes or regions has long-term consequences for future species composition and abundance. **Other** • Since European settlement, both Communities have been under threat from clearing, plantation forests, artificial dams and other modifications to their natural hydrological and biological characteristics (e.g. draining). As a result, Red Gum remnants are typically small and fragmented with little connectivity across the landscape, and the number and ecological integrity of the wetlands has declined. Many of the Gippsland Red Gum sites are long, linear road or rail remnants with a high edge to area ratio. • The impacts of fragmentation on biodiversity include a decrease in habitat quality for native fauna and greater susceptibility to disturbances and threats arising from the surrounding agricultural development, notably weed invasion, fire and grazing regimes, altered hydrology (drainage and flooding) and water quality (salinity, nutrient loads, pollution) of wetlands, and Gippsland Red Gum dieback (mostly from insect attack).
8	**Site resilience/**	• Zolfaghar, S., 2013	**Resilience/ sensitivity to a change in groundwater**

	sensitivity	• SKM, 2012 • UTS, 2010	Both the deeper north-south drainage lines and Gippsland Red Gums will be sensitive to changes in groundwater due to their reliance on groundwater as a water source. • The drainage lines will be extremely sensitive to even small declines in groundwater level due to their permanent connection to the watertable and any change in groundwater is likely to impact habitat quality and species survival in deeper pools. • Gippsland Red Gums are relatively drought resistant, therefore it is likely that the species are likely to be able to tolerate some lowering of the water table without being significantly negatively impacted. The amount of lowering tolerable is difficult to quantify. The Red Gums will be most sensitive to changes in groundwater levels during drier periods when they are more likely to be accessing groundwater. • Recent study has shown (Zolfaghar, S., 2013) that < 5.5m depth to groundwater had significantly larger above-ground biomass and productivity than sites with > 9.8m depth to groundwater. Therefore sensitivity is related to percentage of groundwater as a water source (dependent on initial depth to watertable, climatic regime and if asset has single source of water) and rate of groundwater quantity or quality change. • Seasonal Herbaceous Wetlands are not considered to rely on groundwater; changes in surface water runoff is the biggest risk to the hydrological regime of these wetlands.
9	**Knowledge gaps**		**Key knowledge gaps** • Knowledge gaps exist around the nature of groundwater connection of the Gippsland Plains River Red Gum Woodlands and Seasonal Herbaceous Wetlands. • A lack of groundwater level data in the area makes it difficult to confirm the nature of connection along the drainage lines. • More information on the depth to water table and variations in water table depth relative to the pools and the root zone of the River Red Gums is required to better understand both the spatial and the temporal contributions that groundwater may make to these ecosystems. • The application of remote (ET) sensing analysis, coupled with the depth to water table data and forest/ plan water us (sap) studies will also help understand both the spatial and the temporal contributions that groundwater may make to these ecosystems. • Additional groundwater data is also required to confirm the hypothesised water regime for the seasonal wetland communities, particularly in relation to confirming or otherwise any groundwater connection. • An understanding of the connection between the alluvial aquifer and deeper aquifers, and the vertical and lateral extent of aquifer drawdown associated with gas extraction is required to understand the potential impacts of coal seam gas extraction (to the south). The outcomes of regional hydrogeological modelling, including connectedness and interdependencies between various aquifers, may help to clarify potential impacts associated with coal seam gas extraction.

10	**References**		

1. Dickson C.R., Farrington L., & Bachmann M. (2014) Survey and description of the Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains in the South East of South Australia. Report to Department of Environment, Water and Natural Resources, Government of South Australia. Nature Glenelg Trust, Mount Gambier, South Australia.
2. SKM, 2012. Water Recovery for Basin Plan – Gunbower Forest Transmission Losses. Report for Department of Sustainability and Environment
3. Australia Government, 2010a. Gippsland Red Gum (E. tereticornis subsp. mediana) Grassy Woodland and Associated Native Grassland Listing Advice.
4. Australia Government, 2010b. Gippsland Red Gum Grassy Woodland and Associated Native Grassland (Policy Statement 3.22).
5. Australia Government, 2012. Seasonal Herbaceous Wetlands (Freshwater)of the Temperate Lowland Plains Listing advice
6. SKM, 2002. Lake Wellington Catchment Salinity Management Plan - Bengworden Salinity Investigation. Report for Department of Natural Resources and Environment.
7. Visualising Victoria's Groundwater - http://www.vvg.org.au/
8. Australia Government, 2010. Gippsland Red Gum (E. tereticornis subsp. mediana) Grassy Woodland and Associated Native Grassland Listing Advice.
9. State wide GMU mapping - http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphology
10. Environmental Resources Information Network (ERIN) Australian Government Department of the Environment, Water, Heritage and the Arts, 2008. Gippsland Red Gum (Eucalyptus tereticornis subsp. mediana) Grassy Woodland and Associated Native Grassland Ecological Community Map.
11. SKM and GHD, 9009. Hydrogeological Mapping of Southern Victoria. Report for Southern Rural Water.
12. DSE, 2003. Flora and Fauna Guarantee Act 1988, Action Statement No. 182. Central Gippsland Plains Grassland Forest Red Gum Grassy Woodland Northern Plains Grassland South Gippsland Plains Grassland Western (Basalt) Plains Grassland
13. GHD, 2012. Report on the Development of State-Wide 3D Aquifer Surfaces. Report for Department of Sustainability and Environment.
14. Southern Rural Water, 2012. *Gippsland Groundwater Atlas.*
15. Zolfaghar, S., 2013. *Comparative Ecophysiology of Eucalyptus Woodlands Along a Depth-to-Groundwater Gradient.*
16. SKM, 2007. Groundwater Resource Assessment of Deeper Aquifers in the Lindenow Region, East Gippsland. Report for Southern Rural Water

			17. SKM and GHD, 9009. Hydrogeological Mapping of Southern Victoria. Report for Southern Rural Water. 18. GHD, 2012. Report on the Development of State-Wide 3D Aquifer Surfaces. Report for Department of Sustainability and Environment.
11	**Site Location**	• Australia Government, 2010b.	 **Figure 3 Area where Gippsland Red Gum Grassy Woodland and Associated Grassland Ecological Community is likely to be found (**

Appendix D. Latrobe River

Ref	Theme	Data Components, Information Sources	Description
1	**Ecosystem type**	• SKM, 2012 • DSE, 2005 • EarthTech, 2005a • DSE 2011 • EPA Victoria 2002 • EarthTech, 2005b • Pers. Comm East Gippsland CMA	**Ecosystem type** • Latrobe River baseflow and permanent pools. • Floodplain billabongs, wetlands and flood runners. **Location** The Latrobe River catchment is east of Melbourne and extends from the Strzelecki Ranges in the south to the Great Dividing Range in the north, and from Warragul in the west to Lake Wellington in the east. To the north-west, the catchment comprises the steep valleys and forests of the Great Dividing Range, reaching elevations above 1400 m AHD. This conceptualisation will specifically focus on the section of River from Morwell to downstream of Rosedale (not including the estuary). **Site history** • The lower reaches of the Latrobe River and tributary streams comprise floodplains that have been largely cleared of native vegetation. Much of the lower catchment is devoted to agriculture, including the Macalister Irrigation District (MID), but also includes most of the area's industrial and residential catchments. Irrigation water from the MID is returned to the Latrobe, Thomson and Macalister Rivers via man-made and natural drains. • A number of large impoundments have also been built within the Latrobe River catchment (Blue Rock Dam and Lake Narracan on the Latrobe River, Thomson Reservoir and Cowwarr Weir on the Thomson River. Moondara Reservoir on the Tyers River, and Lake Glenmaggie on the Macalister River). These are used to supply irrigation and potable water, and to generate electricity. Consequently, the Latrobe River downstream of these impoundments has a heavily modified flow regime. Other historical modifications to the river and surrounding area include: • clearing, agricultural and industrial development of the southern portion of the catchment and the majority of the floodplain • construction of artificial meander cut offs, resulting in a reduction of 21.5% in stream length below Lake Narracan • significant de-snagging of the main channel • floodplain drainage channelisation of the lower reaches of the Moe and Morwell Rivers • major industrial, mining and power generation developments (particularly around Morwell and Yallourn) impacting directly on the rivers and catchments • flow regulation of major tributaries, including the Tanjil and Tyers Rivers • incision of some tributaries

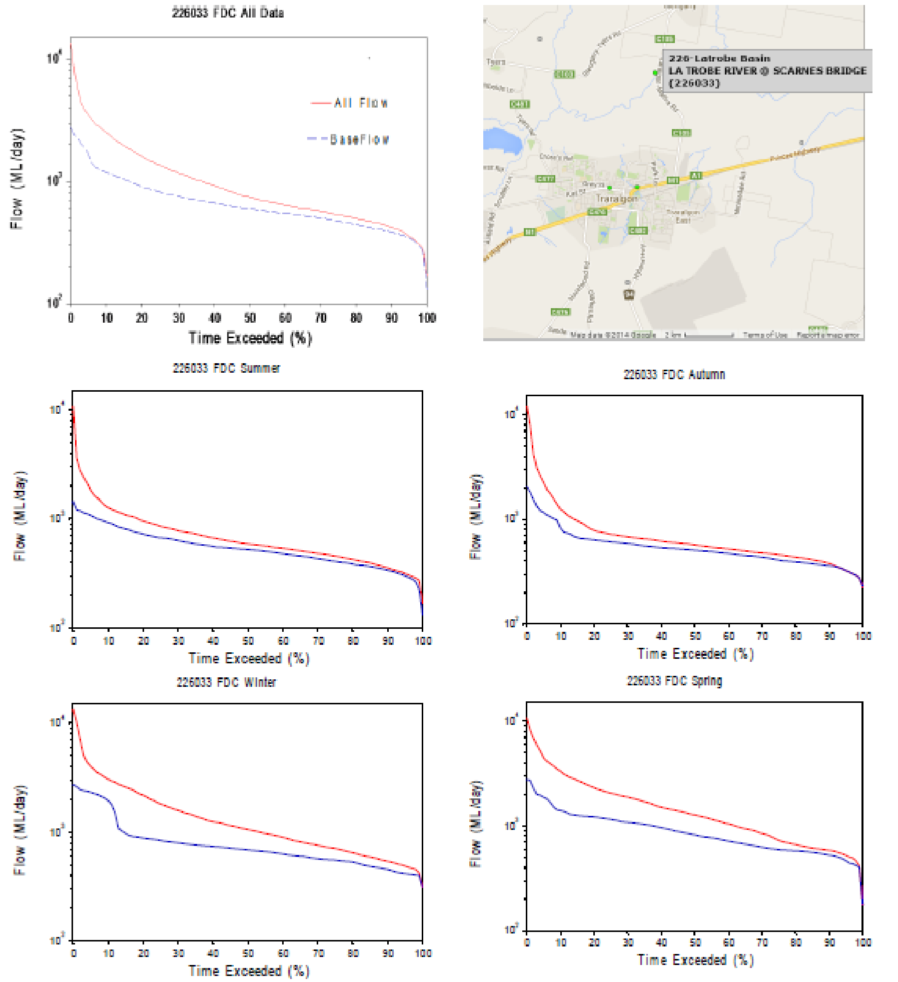
			Value • The river supports a population of the threatened Australian Grayling (*Prototroctes maraena*) and is also important regionally for River Blackfish (*Gadopsis marmoratus*). • Remnant native riparian vegetation is present and the floodplain supports a number of billabongs and flood runners, which are important biodiversity features and act as recharge zones for the alluvial aquifer during flood events. • The river flows into Lake Wellington, which forms part of the Gippsland Lakes Ramsar wetlands site, including the lower Latrobe Wetlands (Heart Morass and Dowd Morass). The River supplies approximately 26% of inflows to Lake Wellington. • Latrobe River also plays a significant role in water supply for consumptive, agricultural and industrial use **Condition** The Index of Stream Condition (ISC) reported the lower Latrobe River (from Yallourn to the confluence with the Thomson River) to be in poor condition with poor rankings for physical habitat, streamside zone, hydrology, water quality and aquatic life (DSE 2005). Downstream of the confluence with the Thomson River, the Latrobe River is rated moderate, due to an improvement in the condition of the streamside zone (physical habitat and flow remain poor and water quality and aquatic life were not assessed) (DSE 2005). Significant inroads that have been made in recent years to restore/improve the condition of the Latrobe River, particularly the lower and mid reaches, through activities such as fencing, revegetation, weed control, meander reinstatement and stability control. **Geomorphic description** Between Lake Narracan to Scarnes Bridge the river is: • Fully confined by valley sides in the upper section • Channel confinement decreases in a downstream direction • Near Sandbanks Reserve the stream is unconfined and displays sinuous meander patterns, and presence of in-channel benches. • Reach has been subject to a reduction in sediment load as a result of trap efficiency of Lake Narracan. • Largely intact stream bed conditions. • Some bank instability associated with stock access and loss of riparian vegetation
2	**Climate**	• Southern Rural Water, 2014	**General climatic conditions** The Latrobe River catchment has a temperate climate and precipitation varies greatly, from about 1600mm in high elevation northern areas, approximately 1200mm in the Strzelecki Ranges, to about 600mm in the eastern part of the Latrobe Valley near Rosedale
3	**Hydrology**	• SKM, 2012 • Southern Rural Water, 2014	**Catchment** The Latrobe River catchment has an area of 4767 km^2, and the main tributaries of the 80 km-long Latrobe River are the Toorongo, Tanjil and Tyers rivers in the north of the catchment, Moe River in the west and Morwell River in the south. Major water storages include Blue

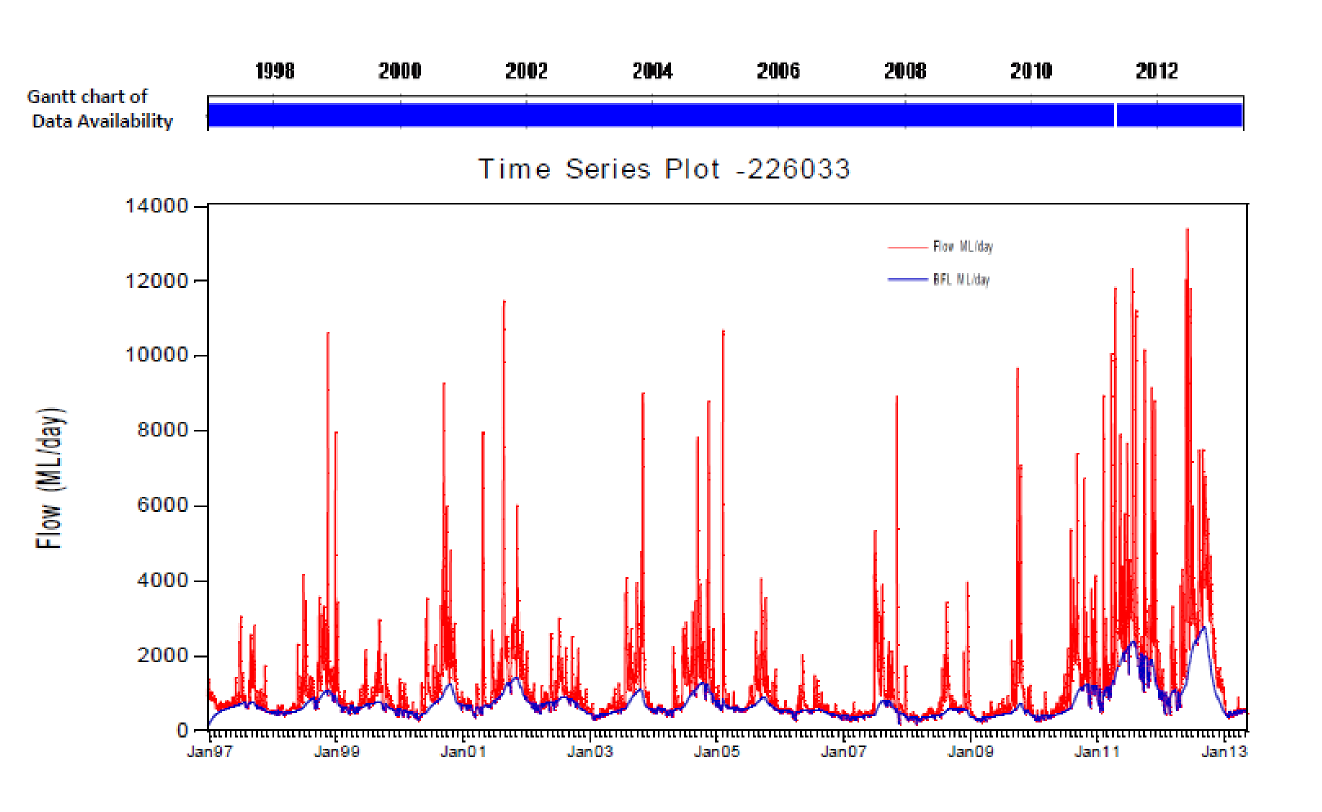
		• EarthTech, 2005a • EarthTech, 2005c	Rock (capacity 208 GL) and Moondarra (30 GL) reservoirs, and Lake Narracan (8.6 GL). The catchment area of the Latrobe River represents approximately 23 percent of the total catchment of the Gippsland Lakes. **Water source** • Main water source to the Latrobe River is surface water runoff during and following rainfall events. • Groundwater inflow is likely to occur along sections of the Latrobe River where the river levels are lower than groundwater levels, allowing groundwater to discharge into the river. • Local groundwater is also likely to be an important source of water for some vegetation on the floodplain, especially red gum trees whose roots can extend into the water table to access water during dry periods. **Water regime** The water regime of the river is permanent and controlled by regulations along the Latrobe River and tributaries that flow in to the River. The hydrologic impacts of flow regulation on the River vary reach by reach, with a complete regime change and considerable decrease in volume immediately downstream of each storage and lesser impacts on annual flows as the downstream distance from dams increases. **Naturalness/ Regulation** The Latrobe River system is one of the most significantly modified river systems in Victoria outside of the major urban areas. Major modifications to the river and catchment are summarised in Section 1 of the table. The key regulating structures on the Latrobe River primarily used to supply irrigation and potable water, and to generate electricity are: • Blue Rock Dam – capacity 200,000 ML • Lake Narracan – capacity 30,400 ML. 20% of Latrobe River flows at Lake Narracan diverted for SECV consumption. • Moondara Reservoir – capacity 8,020 **Flow** The Latrobe River has significantly modified flows resulting from river regulation at Lake Narracan and regulation of major tributaries (Tanjil River and Tyers River).

Gauge Station: LA TROBE RIVER @ SCARNES BRIDGE

Gauge Number: 226033

Applicable Wetlands: Latrobe River from around Morwell to downstream of Rosedale (not including the estuary)





Statistics	Flow (ML/day)	BFL(ML/day)		Flow (ML/day)	BFL(ML/day)
Minimum	171	131	Average	1,222	726
Maximum	13,406	2,758	Standard Deviation	1,356	421

4	**Hydrogeology**	• GHD, 2006 • H. Hofmann, I. Cartwright 2013 • Southern Rural Water, 2012	**<u>Aquifer</u>** The Latrobe River from Morwell to downstream Rosedale occurs at the western end of the onshore part of the Gippsland Basin. The aquifer systems are very complex in terms of lithologic variability, hydraulic properties and groundwater flow. Some aquifers cover large areas, into the offshore part of the Gippsland Basin and other aquifers are only of local extent. These aquifers are separated by less permeable zones (aquitards) which include the Yallourn Formation, Hazelwood Formation, Boisdale Formation (Nuntin Clay), Gippsland Limestone and Lakes Entrance Formation which limit the connectivity between the shallow aquifers and the deeper regional aquifers.

		• SKM and GHD, 9009 • Visualising Victoria's Groundwater	The major aquifers/ aquifer systems in the area include: • Quaternary (alluvium) aquifer – unconfined aquifer, considered part of the shallow aquifer system. • Upper Tertiary/ Quaternary aquifer (Haunted Hills) – unconfined to semi-confined aquifer, considered part of the shallow aquifer system. • Upper Tertiary aquifer (Boisdale Formation) – unconfined to semi-confined aquifer, considered part of the shallow aquifer system. This aquifer is heavily used for irrigation in the Latrobe River catchment. • Upper Mid-Tertiary aquifer (Latrobe Valley Group Aquifer system including the Morwell Formation) – confined aquifer system consisting of interbedded sands and clays within coal seams and minor fractured basalts of the Morwell Formation. The coal seams within them form impervious aquitards but these are not continuous and they are faulted, allowing connection between the sand units within the formation. Groundwater is extracted as a result of the mining operations at Yallourn, Hazelwood and Loy Yang Mines and for stock and domestic purposes. The aquifer system generally occurs between 100 and 500 metres beneath the ground surface, apart from structural highs where they may subcrop at shallower depths beneath the younger aquifer systems. The depth of the Upper Mid-Tertiary aquifer limits the vertical hydraulic connection between the regional aquifer and the shallow aquifer systems. • Lower Tertiary aquifer – this system extends across the entire Gippsland Basin and consists of both the onshore aquifers (M2, Traralgon Formation Aquifer) and offshore (Latrobe Group Aquifer). Apart from the structural highs on the basin margins where these sediments may be exposed, aquifers in this system generally occur between 150 and 1500 metres below the ground surface. Groundwater is extracted from this aquifer as part of mining and irrigation extraction onshore and oil production activities offshore. The Lower Tertiary aquifer is the coal seam gas prospective unit. The depth of the Morwell Formation limits the vertical hydraulic connection between the regional aquifer and the shallow aquifer systems. The depth of the Traralgon Formation limits the vertical hydraulic connection between the regional aquifer and the shallow aquifer systems. • Mesozoic and Palaeozoic Bedrock (basement) aquifer – is generally a confined aquifer and includes the Strzelecki Group. Although regionally extensive, the bedrock aquifers are not considered significant in terms of regional groundwater flow as they are generally of low permeability. The aquifer outcrops (i.e. is unconfined) in the Eastern and South Gippsland Highlands . Figure 1 provides a summary of the relative depth and age of these Aquifers/ Aquitards, their associated simplified geology and any resources that they support.

Depth (m)	Age	Period	Epoch	Simplified geology	Aquifer systems	Resource Comment
Shallow	Youngest	Quaternary	Holocence (recent)	Quaternary Sediments / fluvial system / recent alluviums	(QA) Quaternary aquifer	Major aquifer for stock, domestic and irrigation groundwater use mainly in the Macalister Irrigation District and the Mitchell River floodplain. Also major surface aquifers that support ecological values.
			Pleistocence			
		Tertiary	Pliocene	Haunted Hills formation / gravels / Eagle Point Sand	(UTQA) Upper Tertiary/Quaternary aquifer	
				Sale Group	(UTQD) Upper Tertiary Quaternary Aquitard	Includes low permeability Boisdale Formation (Nuntin Clay), Sale Group and Jemmys Point Formation
					(UTAF) Upper Tertiary Aquifer Fluvial*	Includes Boisdale Formation which is a major irrigation aquifer and target aquifer for Sale Town Water Supply.
					(UTD) Upper Tertiary Aquitard	Includes low permeability Hazelwood Formation and Yallourn Formations
					(UMTA) Upper Mid-Tertiary Aquifer*	Includes the Balook Formation which is a major irrigation aquifer and includes the Morwell M1-2 Coal Seam which is targeted in the Latrobe Valley Coal
			Miocence	Gippsland Limestone	(UMTD) Upper Mid-Tertiary Aquitard	Includes low permeability Gippsland Limestone and Lakes Entrance Formation
			Oligocence	Latrobe Valley Group / Coal Measures	(LMTA) Lower Mid-Tertiary Aquifer	Includes the Morwell M2C Coal Seam (not currently mined)
		Cretaceous	Lower	Cretaceous (older) volcanics	Lower Tertiary Basalts	Not heavily used in the Gippsland Basin
					(LTA) Lower Tertiary Aquifer*	Includes the Traralgon Formation which is the CSG prospect unit. Also offshore oil and gas target aquifer and heavily used in Yarram for irrigation.
		Jurasic		Bedrock	Mesozoic and Palaeozoic Bedrock	Includes the Strzelecki Group which is the Tight Gas Prospective Unit.
		Triassic				
		Permian				
		Carboniferous				
		Devonian				
		Silurian				
		Ordovician				
		Cambrian				
Deep	Oldest	Precambrian				

*note this aquifer does not occur at the surface and hence does not correspond to any "surface" geology.

Figure 4: Aquifers and Aquitards of the Gippsland Basin

Geology

- Alluvial sediments – silts, sands and gravels along floodplain terraces.
- Haunted Hill Formation - silts and clays.
- Morwell formation– interbedded sands and clays (M1 to M2C) within coal seams and minor fractured basalts (Morwell

			Formation). • Latrobe Group/ Traralgon Formation – interbedded sands, clays, coals and basalts onshore (M2, Traralgon Aquifers) and interbedded sandstones, mudstones, coals and basalts offshore (Latrobe Group Aquifer). **Groundwater level, movement and flow** Groundwater connected to the Latrobe River generally lies in the surface Quaternary (alluvial) aquifer and the Upper Tertiary/ Quaternary aquifer (Haunted Hills Formation). The Latrobe Valley regional groundwater monitoring network extend from west of Yallourn Mine to east of Rosedale. The majority of the monitoring bores monitor groundwater levels in the major regional aquifers of the Upper Mid-Tertiary Aquifer and the Lower Tertiary Aquifer. There are also a limited number of bores monitoring the underlying basement aquifer and the overlying shallow aquifer systems, and of those bore monitoring the shallow aquifer systems, none were located in close proximity of the Latrobe River. Regional groundwater mapping suggest that the water table depth is generally > 5 metres below ground level along the Latrobe River and floodplain. Local groundwater flow in the shallow surface aquifers follow local topography, flowing from areas of higher elevation to areas of lower elevations such as rivers and creeks. Groundwater flow in the deeper regional systems (Upper Mid-Tertiary aquifer and the Lower Tertiary aquifer) flows towards the Gippsland Lakes and/or the ocean. The impact on groundwater levels and flow from the dewatering of the coal pits in the centre of the basin is apparent with the development of a groundwater depression and consequent modification of groundwater flow paths. Groundwater levels in the Latrobe Group have fallen by approximately 20 m in bores around the coal pits between 1980 and 2010. A comparison between head data from 1990 and 2008 in the Latrobe Group indicates that the cone of depression was located around Morwell in the 1990s and spread west towards Traralgon, where head values dropped by 68 m between 1990 and 2008. Local groundwater flow direction changed in the area around Morwell and Traralgon with flow directions shifting toward the cone of depression. Potentiometric surface contour plans created using the regional groundwater monitoring network data and State Observation Bores (for regional aquifers only) clearly show the impact of mine depressurisation on the regional aquifers over time. The Lower Tertiary aquifer system (Traralgon Formation) potentiometric surface shows the most significant impact of mine depressurisation is around the Hazelwood and Loy Yang Mines. The Upper Mid-Tertiary aquifer potentiometric contours also shows the same trend, however the cones of depressurisation are less regionally extensive compared to the Lower Tertiary aquifer (Traralgon Formation) due to the lower aquifer transmissivity. **Recharge/ discharge characteristics** • The primary recharge mechanism for the Quaternary aquifers in which the River is incised is via rainfall recharge, although significant flood events also provide recharge to the aquifer over short durations. These aquifers discharge to areas of low elevations such as drainage lines, creeks and rivers. • Recharge to the Upper Mid-Tertiary aquifer (Latrobe Valley Group/ Morwell Formation) occurs generally from leakage through

			• the overlying and surrounding sediments and discharge is to the limestone aquitards (Gippsland Limestone and Lakes Entrance Formation) to the east and along the coast. • Recharge to the Lower Tertiary aquifer (Latrobe Group/ Traralgon Formation) is likely to occur from rainfall and streams in areas where the formation outcrops (western margin of the basin). Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. **<u>Water quality</u>** A lack of groundwater monitoring of surface aquifers in the area means that it is difficult to comment on the water quality of groundwater beneath the Latrobe River. State wide salinity mapping of the area of interest between Morwell and downstream Rosedale indicated that salinity is generally between 500 mg/L and 1,000 mg/L around Yallourn and Rosedale, however the section of the River through Traralgon is higher with the area being mapped as 1,000-3,000 mg/L.
5	**Groundwater connection**	• GHD, 2013	**<u>Nature of groundwater connection at the site</u>** The Latrobe River has a some degree of connection with the shallow alluvial aquifer: • Sections of the Latrobe River are considered a 'gaining' river (i.e. groundwater discharges to the river) under most conditions. • In higher flows and flood events, if the river stage exceeds the watertable and therefore the river switches to 'losing' conditions (i.e. river discharges to the aquifer). • In periods of low flow (drought conditions) coupled with groundwater extraction, the groundwater level can fall below the river level, also leading to 'losing' conditions.
6	**Groundwater service**	• GHD, 2006	**<u>Critical groundwater processes/ environmental water requirements of species associated with groundwater</u>** The discharge of groundwater to the river is a contributor to base flow, which is important for maintaining habitat for aquatic plants and animals and water quality. The natural flow variation associated with the high and low flows results in: • a range of habitat types for aquatic and semi-aquatic plants and animals • high flows help maintain water quality, flush sediments from pools and riffles and cue fish migration and spawning. Aside from influencing river flow, local groundwater is also likely to be an important source of water for some vegetation on the floodplain, especially red gum trees whose roots can extend into the water table to access water during dry periods.
7	**Key Threats**	• EarthTech, 2005b • GHD, 2006	**<u>Coal seam gas extraction</u>** The potential impact from coal seam gas extraction on the Latrobe River is not well understood. Gas could potentially be extracted from the deeper regional aquifers to the south and east of the catchment. There is uncertainty about the degree to which the Lower Tertiary Aquifer is connected both vertically and laterally to the surface aquifers, however generally the impact of potential coal seam gas development on the Latrobe River will depend on several factors, including the: • proximity of the GDE to a potential gas development,

			• potential connection between the Lower Tertiary Aquifer and the overlying watertable aquifer, • presence of an aquitard or "seal" to protect the watertable aquifer from the gas development. **<u>Coal mining</u>** Coal mining has had a significant impact on groundwater levels around Morwell and Traralgon. Groundwater is extracted from the aquifers below the coal mines and this has created an area of drawdown around the mines. Depending on location and proximity to the drawdown cone, the lowering of the groundwater level has the potential to impact on river flow. This is particularly the case in the reach from Lake Narracan to Scarnes Bridge, adjacent to the Yallourn Coal Mine. The impact is likely to be limited by the fact that the greatest groundwater extraction occurs in the Traralgon Formation aquifer which extends the whole of the Gippsland Basin and discharge originally occurred offshore. **<u>Other water extraction and development</u>** Groundwater extraction from the Quaternary (alluvial) aquifer along the downstream floodplain for irrigation is also likely to contribute to stream flow depletion. Groundwater is mainly extracted for irrigation from the shallow Quaternary aquifers (alluvium and Haunted Hills Formation) and the Upper Tertiary aquifer (Boisdale Formation). To help manage the groundwater resource a number of Groundwater Management Areas (GMAs) have been established in the Latrobe River catchment including Moe, Rosedale, Stratford, Denison, Sale and Yarram GMAs. GMAs are areas where groundwater has been intensively developed or has the potential to be further developed. Unfortunately, GMAs do not specifically account for the impacts of groundwater drawdown on stream flow. Hence, any significant increase in groundwater table drawdown, particularly during dry periods, could further impact on base flows in the Latrobe River, with consequent ecological impacts. This may require additional flow releases from upstream reservoirs to compensate for stream flow reduction. **<u>Climate change</u>** Altered rainfall patterns and increasing temperatures associated with Climate Change will cause changes to streamflow (surface water and groundwater regime), sediment supply and riparian vegetation in the Latrobe River catchment. Complex interactions between these changes are also likely to cause adjustments in fluvial geomorphology and habitat quality and availability associated with the river. **<u>Other</u>** The Latrobe River is subject to a range of other impacts including: • flow regulation - storages and diversions regulating the Latrobe River have adversely impacted sediment transport, fish passage and connectivity along the river. Water quality and macroinvertebrate health generally decrease in a downstream direction. • Agricultural and industrial land use along the floodplain has resulted in degradation of riparian vegetation condition and a reduction in floodplain connectivity, habitat and geomorphic diversity.
8	**Site resilience/ sensitivity**		**<u>Resilience/ sensitivity to a change in groundwater</u>** As a result of the high connectivity between groundwater and river flow, changes in groundwater has the potential to impact on the flow regime of the river (reduced baseflow) where there is a groundwater connection, particularly during low flow periods/ dry summers.

			Although sections of the Latrobe River are likely to rely on groundwater as baseflow (i.e. reduced groundwater discharge to the river), the regulation of river flow via releases from Blue Rock Dam means that the ecosystem is potentially less sensitive to changes in groundwater levels compared with un- regulated systems, such as the Mitchell River.
9	**Knowledge gaps**		**Key knowledge gaps** Due to the connectivity between groundwater and flow in some reaches of the Latrobe River, there is a need to understand and manage surface water and groundwater as the same resource to ensure that the environmental requirements of the river are met and the reliability of surface and groundwater extraction is maintained for economic uses. • More information on the impact of the water table connected to the Latrobe River from the coal mines is required. Currently there is a lack of groundwater data for the shallow water table aquifers in region of the coal mines. • Critical interactions between groundwater and surface water in the Latrobe River is required to meet environmental flow requirements. • An understanding of the connection between the alluvial aquifer and deeper aquifers, and the vertical and lateral extent of aquifer drawdown associated with gas extraction is required to understand the potential impacts of coal seam gas extraction.
10	**References**		1. Visualising Victoria's Groundwater - http://www.vvg.org.au/ 2. State wide GMU mapping - http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphology 3. SKM and GHD, 9009. Hydrogeological Mapping of Southern Victoria. Report for Southern Rural Water. 4. GHD, 2012. Report on the Development of State-Wide 3D Aquifer Surfaces. Report for Department of Sustainability and Environment. 5. Southern Rural Water, 2012. Gippsland Groundwater Atlas. 6. SKM, 2012. Impacts of groundwater extraction on streamflow in selected catchments throughout Australia, Waterlines report, National Water Commission, Canberra 7. DSE (2005). 2005 Index of Stream Condition Assessment. Department of Sustainability and Environment, Victoria. 8. DSE (2011). Gippsland Region Sustainable Water Strategy. Department of Sustainability and Environment, Victoria. 9. Earthtech (2005a). Assessment of the Environmental Flow Requirements for the Latrobe River and Wetlands of the Lower Latrobe River – Site Paper (Revision C). Report by Earthtech for the West Gippsland CMA 10. Earthtech (2005b). Assessment of the Environmental Flow Requirements for the Latrobe River and Wetlands of the Lower Latrobe River - Issues Paper (Revision A). Report by Earthtech for the West Gippsland CMA 11. Earthtech (2005c). Assessment of the Environmental Flow Requirements for the Latrobe River and Wetlands of the Lower Latrobe River – Amended Final Recommendations Report (Revision D.6). Report by Earthtech for the West Gippsland CMA 12. Ecos (2008). Discussion Paper: Understanding the Environmental Water Requirements of the Gippsland Lakes System. Report

			prepared for the West Gippsland Catchment Management Authority 13. EPA Victoria (2002). Environmental Condition of Rivers and Streams in the Latrobe, Thomson and Avon Catchments. Publication 832, Freshwater Sciences, EPA Victoria, Southbank. 14. Reinfelds, I., I. Rutherford and P. Bishop (1995) History and effects of channelization on the Latrobe River, Victoria. Australian Geographical Studies, 33: 60-76. 15. SKM (2008). Ecological monitoring program for the Gippsland Lakes Ramsar site and lower catchment: final report and implementation plan. Report prepared for the Gippsland Coastal Board 16. Robinson, D.P. (1995). Water quality and nutrient status of Lake Wellington. Catchment and Marine Studies, EPA Victoria. 17. Sinclair Knight Merz (2012), Impacts of groundwater extraction on streamflow in selected catchments throughout Australia, Waterlines report, National Water Commission, Canberra 18. Southern Rural Water, 2014. Local Management Plan: Latrobe River Basin. 19. GHD, 2013. Groundwater Assessment – Baseflow Dependent Rivers. Characterising Groundwater Contribution to Baseflow Dependent Waterways. Report for the Department of Environment and Primary Industries. 20. GHD, 2006. Latrobe Valley Regional Groundwater and Land Level Monitoring Report: Five Year Review. 21. Hoffman, H. and Cartwright, I., 2012. Using hydrogeochemistry to understand inter-aquifer mixing in the on-short part of the Gippsland Basin, southeast Australia.

Appendix E. Corner Inlet and Nooramunga

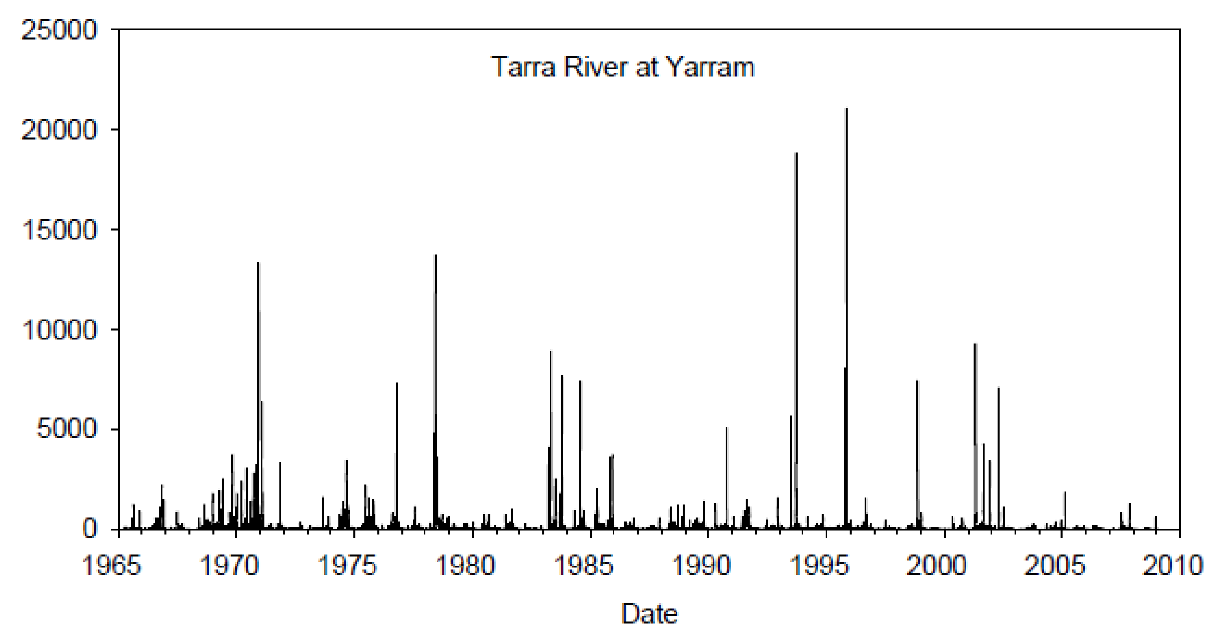
Ref	Theme	Data Components, Information Sources	Description
1	**Ecosystem type**	• CSIRO, 2005 • BMT WBM, 2011 • Alluvium, 2008 • West Gippsland Catchment Management Authority, 2013	**Ecosystem type** Corner Inlet is a large tide-dominated embayment located adjacent to the southernmost tip of the Australian mainland. The inlet consists of a submerged plain covered by sand or mud flats with well-developed seagrass beds, and large sand islands. A radiating system of deeper channels supports efficient tidal exchange over the flats and the areas between the islands. The main ecosystems include: • Coastal wetlands including saltmarsh, mangrove seagrass meadows • Mainland drainages, rivers or creeks (estuaries) **Location** Corner Inlet, including Nooramunga Marine and Coastal Parks and the Corner Inlet Marine National Park, is bounded by the South Gippsland coastline to the west and north, a series of barrier islands, sandy spits and Bass Strait to the south-east and the hills of Wilsons Promontory to the south. A number of rivers and creeks enter the inlet from the north. These waterways rise on the south eastern flanks of the Strzelecki Ranges and flow across a narrow coastal plain to discharge in to the inlet. This conceptualisation will specifically focus on the ecosystems within Corner Inlet and Nooramunga. **Site history** • Pre-European settlement - Aboriginal middens post date 6000 years BCE, about when sea level transgression reached its present level. Low impact fire and other land management activities practiced by the indigenous communities were occurring. • 1797 – George Bass discovered Corner Inlet. Opportunistic use of area by sealers and whalers. • 1841 Port Albert established. • 1863 – 17 squatting runs were located in the more open grassy forested areas. • 1850s – Area services the mining of central Gippsland, provides limited prospects for agriculture, timber, stone and fishing industries. • 1870s – Shipping facilities at Port Albert enable transport of cattle and other produce to markets in Van Dieman's Land and Melbourne, and also provide access to the Gippsland goldfields. Little or no natural pasture in the region, the land is cleared and pastures sown with introduced grasses, which allowed dairy to become one of the dominant industries. Native forests provide timber for development of settlements, infrastructure and industry in the region, with limited volumes exported. The commercial fishery was established to feed the settlers and miners, and has operated continuously since. • 1870 – Alluvial gold rush at Stockyard Creek (1870-71). Alluvial and quartz gold at Foster sustains a large permanent mining population – Victory Mine operated 1887-1908, producing 26,000 oz. • 1871 – The region is opened for selection – the hills and areas along water courses are occupied first – land is cleared with fire and axe, but erosion, bracken, caterpillars and the introduced rabbit, ragwort and blackberry come.

			• 1875 – Alluvial tin first recorded in 1875 at Toora, with various leases worked sporadically up to 1939. • 1892 – The opening of the rail link to Melbourne and the increasing network of roads resulted in the shipping of goods decline. • 1900s – Dairy remains the dominant industry. Fires continue to cause periodic havoc – major fires in 1906. Wilson Promontory declared a National Park in 1905 and 1908 • Bulga and Tarra Valley National Parks were reserved in 1904 and 1909 respectively, protecting vegetation communities which were characteristic of the Strzelecki Ranges prior to European settlement. • 1920s – Post WW1, the farming sector develops further, includes solider settlement development Levee banks (earth walls with flood gates) built by farmers to protect from tidal inundation and increase available agricultural land. • 1930s – Long Pier at Port Welshpool constructed to encourage coastal trade – subsequently used by RAN in WW2. Bushfires continue as major threat to the area – significant damage from the 1939 fires. Spartina planted in Tidal Creek (Old Hat Creek) and successfully transplanted to other Corner Inlet sites thereafter. Foster Beach impacted by erosion – led to construction of various protection works, and finally 168m of masonry wall in early 1960s. • 1934 – Levee bank at Blacks Swamp removed, which results in significant inundation by sea water, and subsequent long-lasting salt impact. • Post WW2 – Further development of the farming sector occurs including solider settlement development and other government programs – estates at Yanakie cover large areas of virgin bush; requires clearing and ploughing prior to being sown; area also included draining of swamps. • 1960s – APM Forests entered into the reforestation of the Strzelecki Ranges in 1960 and had begun purchasing land for plantation establishment a decade earlier. Likewise the Forest Commission had begun purchasing freehold land in the early 1930s for the same purpose. Large-scale plantings began in 1946 resulting in today's extensive plantations of Radiata Pine and Mountain Ash in the Strzelecki Ranges. • 1968 – Barry Beach Terminal established by Esso Australia Ltd to service Bass Strait oil and gas fields. • 1972 – Seagrass decline highlighted by commercial fisherman. • 1975 – Marram Grass planted at Barry Beach for stabilization of mainly dredged sands. • 1982 – Corner Inlet listed as wetlands of international significance under the Ramsar Convention. • 1986 – Corner Inlet and Nooramunga Marine and Coastal Parks declared. • 1995 – Landcare groups established in the Yarram region and South Gippsland. • 1996 – Spartina – control of infestations using the herbicide Fusilade® commences. • 2004 – Corner Inlet Marine National Park declared and covers an area of 1550ha. **Value** • Corner Inlet supports internationally significant populations of a number of aquatic and semi-aquatic species due to its large extent and the diversity of habitats it supports. The inlet was listed as a Wetland of International Importance under the Ramsar Convention in 1982. Of particular importance is that Corner Inlet has the largest Posidonia australis seagrass beds in Southern Australia.

			• The extensive tidal flats, together with fringing wetland habitats, provides food, nesting, nursery areas, migratory routes for many animals including a variety of reptiles, amphibians, mammals, fish and birds, including a number of nationally threatened fauna species such as orange-bellied parrot, growling grass frog, fairy tern and Australian grayling. The saltmarsh and mangrove communities also act as a filter of pollutants, stabilise sediments, trap and process nutrients and protect the shoreline from erosion. • Terrestrial freshwater runoff in Corner Inlet can supply a significant proportion of organic matter, which can settle or be filtered into the intertidal sediments. Another source of organic material is microalgae growing on or in the sediments of intertidal flats. The breakdown of this organic material by bacteria can lead to a significant release of nutrients. • In addition to supporting significant environmental values, Corner Inlets has important economic, social and cultural values. Corner Inlet has high cultural heritage significance to indigenous groups with the Bratauolong clan of the Gunai / Kurnai people having strong cultural traditions and practices associated with the catchment. Many Aboriginal sites can be found along the coastline including scarred trees, burial sites, artefact scatters, camps and shell middens have been recorded in the area. Recreation and tourism is also significant in Corner Inlet, with the value generally relating to nature-based activities such as recreational fishing, boating/yachting, sightseeing, horse riding, scuba diving, bird watching, and bushwalking • Corner Inlet's catchment is also a highly productive area, supporting dairy, beef and mixed grazing enterprises and significant areas of production forestry. Significant Victorian commercial bay and inlet fishery practices are also undertaken, with the inlet one of only three estuaries or bays where commercial fishing is allowed in Victoria. **<u>Condition</u>** The state-wide Index of Stream Condition (ISC) assessment in 2004 included a set of reaches across the Corner Inlet sub-catchments. The assessment found sites visited to generally be in a moderate condition whereas the lower reaches of Bruthen Creek and the Jack River were identified as in poor condition. Increased groundwater salinity (resulting from seawater intrusion), reduced base-flows and coastal subsidence, are potential consequences of declining groundwater levels that are impacting on the condition of the Corner Inlet Ramsar Site. **<u>Geomorphic description</u>** • The landforms of the region are the end result of a long period of geological and geomorphological change. • The three major periods of geological activity, include the formation and subsequent uplifting of a major marine trough in the Palaeozoic era; the rifting and infilling of a trough formed in the Mesozoic and Tertiary eras; and the uplift of the Eastern Highlands in the Pliocene period. These differences in age and depositional environment provide a large variety of sediment type, although the extent of actual outcrop may be small. • Physiographically the region can be divided into three types: the Southern Highlands (includes the Strzelecki Ranges), Coastal Lowlands that include the plains from Yarram eastward to the Gippsland Lakes, and the coastal areas from Alberton around the Inlet to Wilson Promontory.
2	**Climate**	• Water	**<u>General climatic conditions</u>**

		Technology, 2008 • CSIRO, 2005	• Climatic conditions vary across the Corner Inlet catchment, depending on elevation, topography and distance from the coast. • Maximum temperatures and minimum rainfall are experienced in summer. However, these are tempered in coastal areas and the east of the region by frequent coastal depressions, creating milder temperatures and a more evenly distributed annual rainfall. • There is a prominent rainfall gradient across the region, where significantly more rain falls on the Strzelecki and Hoddle Ranges to the north of the inlet compared to the low-lying coastal areas.
3	**Hydrology**	• CSIRO, 2005 • WaterTech, 2008 • Boon, 2015 • BMT WBM, 2011 • West Gippsland Catchment Management Authority, 2013	**Catchment** • The Corner Inlet catchment occupies an area of 2100 km^2, and the inlet an area of about 600 km^2 of the central portion of the South Gippsland drainage basin that surrounds and drains into the Corner Inlet site. • The catchment is bounded by the Strzelecki Ranges to the north and incorporates the various river systems between Bruthen River in the east and the Franklin River system in the west, all of which run south into Corner Inlet and the Nooramunga region. It also includes the section of Wilsons Promontory north-east of Mt Latrobe which discharges to Corner Inlet. • The hydrography of the area is comprised of an integrated system of surface streams, tidal flows and channels, low swampy land areas, groundwater aquifers as well as the coastal waters. The most important streams entering Corner Inlet from east to west are the Franklin, Agnes, Albert, Jack and Tarra Rivers and Bruthen Creek. Each of these catchments have their headwaters in the Hoddle or Strzelecki Ranges, with these water courses following deeply incised paths in the highland areas and forming meandering courses in the lowlands where they are often associated with cut-offs and ox bow lakes, as on the Albert River. • The local catchments to the west (e.g. Stockyard Creek and Yanakie area) and east (e.g. McLoughlans Beach) consist of small localised streams draining the land or have no natural drainage at all. These areas are characterised by low swampy land, and are particularly susceptible to flooding and saline infiltration. • Of interest is the relative shortness of the river systems, the small catchments they drain and their subsequent rapid response to significant rain events that create large flows with higher concentrations of contaminants than during normal dry weather flows. This close relationship with rainfall means that there is significant variation in annual flows for each of the steams. **Water source** • Main water sources to the coast wetlands are ocean and freshwater inputs. Freshwater inputs include rainfall, runoff from immediate catchment, river flood flows and groundwater discharge. • The main water sources to the mainland drainages, rivers or creeks are surface water runoff during and following rainfall events and ocean inputs due to tidal influences. Groundwater may however discharge along these drainages, rivers or creeks. **Water regime** • Permanent saline wetlands include permanent shallow marine waters typically less than six metres at low tide; includes sea bays and straits. Intertidal mud, sand or salt flats and intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests are also included in this category. • Semi-permanent saline wetlands include intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes;

			includes tidal brackish and freshwater marshes • Estuarine waters are also considered permanent saline. **Naturalness/ Regulation** • Most of the catchment has been cleared of forest vegetation, and is now mainly used for agricultural purposes, most notably for dairying and grazing • The main coastal urban settlements adjacent to Corner Inlet include Manns Beach, Roberstons Beach, and McCoughlins Beach • The drainages, rivers and creeks are generally not regulated. • Sea walls and surface drains have also been constructed along large areas of the coastal plains to protect agricultural assets from tidal influences • Some entrances at the eastern end have been artificially enlarged to provide access to the sea for boats **Flow** The Corner Inlet's hydrological flow regime can be separated into: • *Surface freshwater inflows (fluvial hydrology)* - The largest streams entering Corner Inlet are the Franklin, Agnes, Albert, Jack and Tarra Rivers, as well as Bruthen Creek. Due to the relative shortness of these river systems and the small catchments they drain, significant rain events create large flows. However, daily rainfall can be highly variable and resulting stream flows are therefore also highly variable. Significant seasonal trends can be observed with higher flows during winter-spring (August to September) and lower flows in summer, but there is also highly variable inter-annual flow. Occurrence of high flow events is infrequent (see figure below) and flows generally revert to their normal dry weather flow within a week. High flow events may lead to a complete flushing of the estuarine reaches of the rivers and make them completely fresh, although these events occur only for short periods (days).



igure 3-5 Average Daily Flow (Calculated) for Tarra River at Yarram from 1965 to 2009. Data Sourced from Victorian Water Resources Data Warehouse

Figure 5 Average Daily Flow (calculated) for Tarra River at Yarram form 1965 to 2009 (BMT WBM, 2011)

- *Marine in-flows (coastal hydrodynamic processes)* – Corner Inlet is a tide dominated estuary and there are five permanent entrances which allow exchange of water with Bass Strait. The extensive intertidal area within Corner Inlet (approximately 390 square kilometres) is dissected by a network of channels that drain and fill from the entrance in the east. Tides at Port Welshpool are classed as mixed with two high tides per day. Maximum tidal range can reach up to 2.5 m, however average daily tidal range is about 2.0 m. Tidal variations are influenced by changes in wind speed and direction, high and low pressure systems, wave action and storm surges, which may lead to large variations in the width of the intertidal zone. It is predicted that more than 40 per cent of Corner Inlet is exposed during a typical low spring tide. However, due to the relatively flat slope of the intertidal flats and due to frictional effects, there is insufficient time for the water to drain completely off the tidal flats prior to the next incoming tide. This means that not all of the tidal flats are exposed during low tide.
- *Groundwater inflows and influences* –Groundwater may contribute flows to the Corner Inlet Ramsar Site either directly as a

			groundwater discharge into the marine embayment or indirectly via discharge to inflowing streams. Groundwater may also be discharged across the sea floor to the coastal ocean. This submarine groundwater discharge is primarily driven by hydraulic gradient (gravity) due to the difference in water level between the groundwater table and seawater level. **Quality** Water quality is a key driver of aquatic ecosystem health within Corner Inlet. In particular, the generally low levels of turbidity and nutrients are required to maintain the health of seagrass meadows (and associated biodiversity and fisheries values) within the site. There is concern that that nutrient and sediment flowing into the embayment may be putting seagrass meadows and other habitats, including mangroves, mudflats and saltmarsh, at risk. There is little water quality data available, however key findings of data collected include: • Results for TP and Turbidity at sites in Nooramunga were typically low (below the SEPP guideline of 0.03mg/L TP) with the exception of the site at McLoughlins Beach (Bruthen Creek estuary) which exceeded the SEPP guideline by two times. • The surface waters within the embayment of Corner Inlet and Nooramunga are usually of oceanwater salinity, except for short periods in summer when evaporation can cause salinities to slightly exceed those of sea water. • Nutrient sampling indicates that Phosphate concentrations were typically quite low • Elevated Nitrogen concentrations (ammonium and nitrate/nitrite) were apparent, particularly around Yanakie but also around Port Franklin, Foster and Welshpool. The levels of ammonium in water samples at some sites were more than 20 times the SEPP guideline for estuaries. • Nutrient levels throughout Corner Inlet and Nooramunga were lower than those recorded in the Gippsland Lakes, but significantly higher than those found in Port Phillip Bay. • Metals and pesticides do not appear to be significant issues in Corner Inlet and Nooramunga. • A number of the sites were influenced by the operation of wastewater treatment plants, most of which have since been phased out or have diverted waste material for re-use. • Fine sediment that enters the embayment during high flows does not settle in the energetic main channels and sandflats and is only found in backwater areas. Sediments within Corner Inlet and Nooramunga all fall within the ANZECC guidelines for sediment quality.
4	**Hydrogeology**	• Visualising Victoria's Groundwater • Southern Rural Water, 2012 • SKM and GHD, 9009 • Visualising	**Aquifer** The Strzelecki Ranges are a deeply dissected range of foothills formed in the Basement that form the headwaters of the rivers that drain into Corner Inlet. At the base of the foothills, Older Volcanic deposits occur and the landscape shifts to lowland coastal and alluvial plains which are characterised by generally flat to gently undulating terrain. The unconfined Quaternary aquifer (shallow coastal and alluvial plains) overlay a number of impermeable formations (aquifers), including: • Upper Tertiary/ Quaternary aquifer (Haunted Hills) – unconfined to semi-confined aquifer, considered part of the shallow aquifer system. • Upper Mid-Tertiary aquifer (Latrobe Valley Group Aquifer system including the Morwell Formation) – confined aquifer system

		Victoria's Groundwater • Alluvium, 2008	consisting of interbedded sands and clays within coal seams and minor fractured basalts of the Morwell Formation and is a source of water for irrigation. The coal seams within them form impervious aquitards but these are not continuous and they are faulted, allowing connection between the sand units within the formation. The aquifer system generally occurs between 100 and 500 metres beneath the ground surface, apart from structural highs where they may subcrop at shallower depths beneath the younger aquifer systems. The depth of the Upper Mid-Tertiary aquifer (Morwell Formation) limits the vertical hydraulic connection between the regional aquifer and the shallow aquifer systems. • Lower Tertiary aquifer – this system extends across the entire Gippsland Basin and consists of both the onshore aquifers (M2, Traralgon Formation Aquifer) and offshore (Latrobe Group Aquifer). Apart from the structural highs on the basin margins where these sediments may be exposed, aquifers in this system generally occur between 150 and 1500 metres below the ground surface. Groundwater is extracted from this aquifer as part of mining and irrigation extraction onshore and oil production activities offshore. The Lower Tertiary aquifer (Traralgon Formation) is the coal seam gas prospective unit. The depth of the Lower Tertiary aquifer (Traralgon Formation) limits the vertical hydraulic connection between the regional aquifer and the shallow aquifer systems. • Mesozoic and Palaeozoic Bedrock (basement) aquifer – includes the Strzelecki Group. Although regionally extensive, the bedrock aquifers are not considered significant in terms of regional groundwater flow as they are generally of low permeability. The Aquifer outcrops (i.e. is unconfined) in the Eastern and South Gippsland Highlands. Towards the coast, these layers are separated by the relatively impermeable layer of the Yallourn/ Hazelwood Formation which limits limited the vertical hydraulic connection between the shallow watertable aquifers and the deeper aquifers. Figure 1 provides a summary of the relative depth and age of these Aquifers/ Aquitards, their associated simplified geology and any resources that they support.

Depth (m)	Age	Period	Epoch	Simplified geology	Aquifer systems	Resource Comment
Shallow	Youngest	Quaternary	Holocence (recent) Pleistocence	Quaternary Sediments / fluvial system / recent alluviums	(QA) Quaternary aquifer	Major aquifer for stock, domestic and irrigation groundwater use mainly in the Macalister Irrigation District and the Mitchell River floodplain. Also major surface aquifers that support ecological values.
		Tertiary	Pliocene	Haunted Hills formation / gravels / Eagle Point Sand	(UTQA) Upper Tertiary/Quaternary aquifer	
				Sale Group	(UTQD) Upper Tertiary Quaternary Aquitard	Includes low permeability Boisdale Formation (Nuntin Clay), Sale Group and Jemmys Point Formation
					(UTAF) Upper Tertiary Aquifer Fluvial*	Includes Boisdale Formation which is a major irrigation aquifer and target aquifer for Sale Town Water Supply.
					(UTD) Upper Tertiary Aquitard	Includes low permeability Hazelwood Formation and Yallourn Formations
					(UMTA) Upper Mid-Tertiary Aquifer*	Includes the Balook Formation which is a major irrigation aquifer and includes the Morwell M1-2 Coal Seam which is targeted in the Latrobe Valley Coal
			Miocence	Gippsland Limestone	(UMTD) Upper Mid-Tertiary Aquitard	Includes low permeability Gippsland Limestone and Lakes Entrance Formation
			Oligocence	Latrobe Valley Group / Coal Measures	(LMTA) Lower Mid-Tertiary Aquifer	Includes the Morwell M2C Coal Seam (not currently mined)
		Cretaceous	Lower	Cretaceous (older) volcanics	Lower Tertiary Basalts	Not heavily used in the Gippsland Basin
					(LTA) Lower Tertiary Aquifer*	Includes the Traralgon Formation which is the CSG prospect unit. Also offshore oil and gas target aquifer and heavily used in Yarram for irrigation.
		Jurasic		Bedrock	Mesozoic and Palaeozoic Bedrock	Includes the Strzelecki Group which is the Tight Gas Prospective Unit.
		Triassic				
		Permian				
		Carboniferous				
		Devonian				
		Silurian				
		Ordovician				
		Cambrian				
Deep	Oldest	Precambrian				

*note this aquifer does not occur at the surface and hence does not correspond to any "surface" geology.

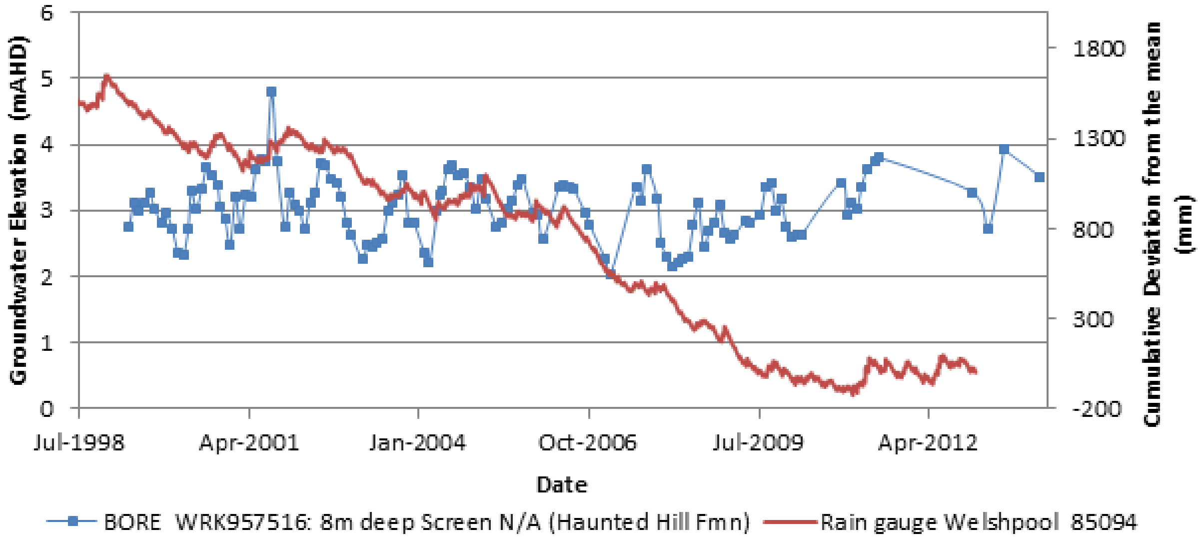
Figure 6: Aquifers and Aquitards of the Gippsland Basin

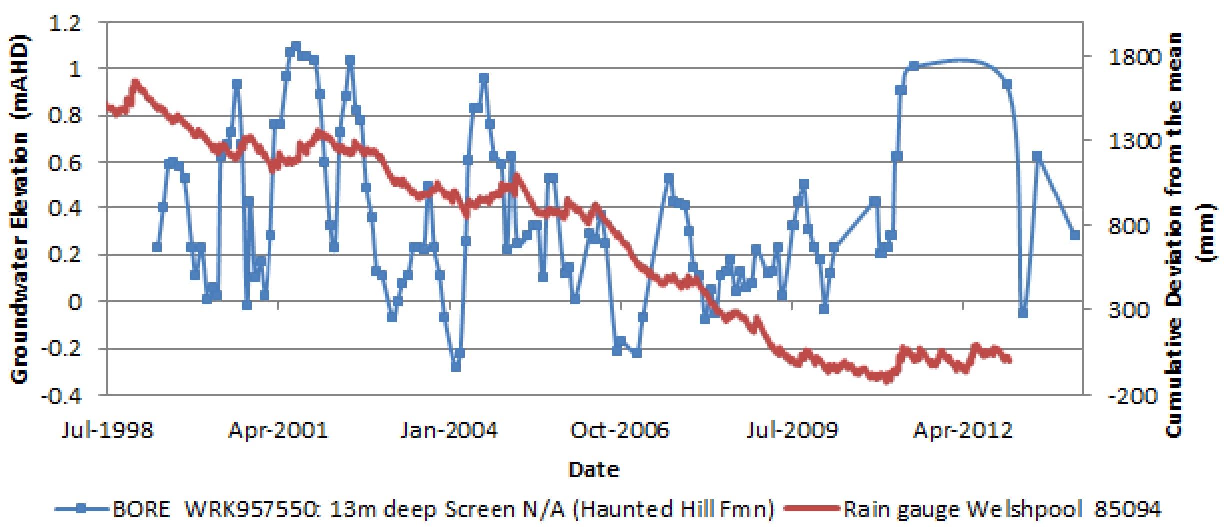
Geology

The landforms of the Corner Inlet catchment are a result of three major periods of geological activity:

- Formation and uplifting of a major marine trough in the Palaeozoic era

			• Rifting and infilling of a trough formed in the Mesozoic and Tertiary eras • Uplift of the Eastern Highlands in the Pliocene period. The temporal and spatial variation in geologic process has led to the development of a variety of geologies in the Corner Inlet catchment, these include: • Quaternary (Alluvial) sediments – silts, sands and gravels along floodplain terraces. • Upper Tertiary/ Quaternary aquifer (Haunted Hill Formation) –silts and clays. • Upper Mid-Tertiary aquifer – interbedded sands and clays (M1 to M2C) within coal seams and minor fractured basalts (Morwell Formation). • Lower Tertiary aquifer – interbedded sands, clays, coals and basalts onshore (M2, Traralgon aquifers) and interbedded sandstones, mudstones, coals and basalts offshore (Latrobe Group aquifer). • Bedrock (Strzelecki Group) – sandstone, mudstone, black coal. **Soils** • The soils within the coastal area have considerable variation, with 27 different soil units identified. • The soils vary from deep sands in the coastal dunes to clay soils further inland. • The soils are generally of low porosity. • Corner Inlet soil types classified as acid sulfate prone are those found on tidal flats and composed of recent marine sediments. Examples include soils around Black Swamp Yanakie, Old Hat Road Foster, Toora foreshore and Port Albert. Acid sulfate soils were initially formed under marine conditions and are therefore often found in coastal areas. These soils contain iron sulfide layers, and when these layers are disturbed oxidisation of the iron sulfide results in the formation of sulfuric acid. **Groundwater level, movement and flow** • Groundwater lies in the Quaternary aquifer (coastal and alluvial sediments) and the Upper Tertiary/ Quaternary aquifer (Haunted Hills Formation). • There are no groundwater bores located within the Corner Inlet coastal environment monitoring the shallow surface aquifers, however State-wide water table mapping indicates that the water table depth is generally less than 5 metres below ground level along the coastline and coastal wetland environments. • There are some bores being monitored further inland, however still within the Corner Inlet catchment. Hydrographs of these bores located within the Haunted Hills formation are provided below. These hydrographs confirm that groundwater levels are generally less than 5 metres below ground level.





- Groundwater levels in the Latrobe Aquifer are currently declining (average drop of one metre per year over the last few

			decades), with dewatering activities associated with off shore extraction of oil and gas being identified as the underlying influence, however localised impacts such as irrigation extraction are also believed to have increased the rate of the decline. • Local groundwater flow in the shallow surface aquifers follow local topography, flowing from areas of higher elevation to areas of lower elevations such as rivers and creeks and near shore environments. • Groundwater flow in the deeper regional systems (Morwell Formation and Latrobe Group/Traralgon Formation/ Basement) flows towards the Gippsland Lakes and/or the ocean. **Recharge/ discharge characteristics** • The primary recharge mechanism for the coastal and alluvial plains aquifers is via rainfall recharge, although significant flood events also provide recharge to the aquifer over short durations. Groundwater discharge from this aquifer is primarily driven by hydraulic gradient (gravity) due to the difference in water level between the groundwater table and seawater level, therefore these aquifers may discharge to the near shore environments. These aquifers may also discharge to areas of low elevations such as drainage lines, creeks and rivers/ estuaries. • Recharge to the Latrobe Valley Group/ Morwell Formation occurs generally from leakage through the overlying and surrounding sediments and discharge is to the limestone aquitards (Gippsland Limestone and Lakes Entrance Formation) to the east and along the coast. • Recharge to the Latrobe Group/ Traralgon Formation aquifer system is likely to occur from rainfall and streams in areas where the formation outcrops (western margin of the Basin). Groundwater discharges from this aquifer is likely to the Gippsland Lakes and/or the ocean. **Water quality** • Saline intrusion is a potential risk to the water quality of any coastal plain aquifers and as such monitoring of groundwater as part of the Yarram Groundwater Management Plan is undertaken to identify any potential impacts. • Currently there is no evidence of saline intrusion; however the combination of any future declines in groundwater levels and sea level rise can have the potential to cause increased risk from landward intrusion of saline water in to the coastal plain aquifers
5	**Groundwater connection**	• Boon, P., 2015 • West Gippsland Catchment Management Authority, 2013	**Nature of groundwater connection at the site** The ecology of coastal wetlands are fundamentally controlled by the ratio of saline water inputs from the ocean and freshwater inputs from the catchment. Sources of freshwater are from a number of sources: • directly via rainfall • indirectly as runoff from their immediate catchment • river flood flows (coastal floodplain wetlands); and • groundwater discharge Therefore groundwater can play a play a significant role for the coastal wetlands in Corner Inlet and those wetlands that do receive groundwater as a freshwater input can be considered groundwater dependent ecosystems (GDEs). Groundwater discharge may also provide base flow to the mainland drainages, rivers or creeks where the groundwater level intersects

			the channel. This is of particular importance during low flow and drought periods.
6	**Groundwater service**	• Boon, P., 2015	**<u>Critical groundwater processes/ environmental water requirements of species associated with groundwater</u>** Groundwater discharge (and other freshwater input sources) to coastal wetland environments can: • decrease soil salinities and thus allowing the seeds from salt tolerant plants to germinate and for less salt tolerant plants to survive in otherwise saline environments, • allow for the creation and maintenance of shallow pools in coastal wetlands above the high tide line (e.g. saltmarsh) • import nutrients into coastal environments that are otherwise nutrient-limited • help the physical integrity of sediments around roots of woody vegetation such as mangroves. Groundwater discharge providing base flow to the mainland drainages, rivers or creeks is important during low flow and drought periods, where groundwater may sustain deep pools along the length of the channels, providing refuge habitat for aquatic fauna.
7	**Key Threats**	• SKM, 2008 • BMT WBM, 2011 • West Gippsland Catchment Management Authority, 2013	**<u>Coal seam gas extraction</u>** The possible impact from potential coal seam gas development on Corner Inlet is not well understood. Gas could potentially be extracted from the deeper regional aquifers to the northeast which outcrop at the foothills of the Strzelecki Ranges. There is uncertainty in the degree to which the deeper aquifers are directly connected to GDEs in the Corner Inlet catchment and also the connection between these aquifers both vertically and laterally to the surface aquifers along the coastal plain. Consequently, it is difficult to assess the nature of risk of gas extraction on Corner Inlet. **<u>Other water extraction and development</u>** The Latrobe Group Aquifer underlies the Corner Inlet catchment and contains significant volumes of good quality water that is used predominately for irrigation (approximately 11,300ML/year) around the town of Yarram (SRW, 2010). A further 110,000ML/year is extracted through dewatering activities associated with off-shore oil and gas production. Evidence suggests that this off-shore extraction has made a significant and consistent contribution to decline in groundwater levels on-shore, with levels dropping by an average of 1m/year over the last few decades. **<u>Climate change</u>** Victoria's climate is expected to become warmer, with an increased frequency of extreme storm events and reduced availability of water. Increased sea level rise is predicted across the Victorian coast. In addition, there is evidence that sea temperatures are rising and will continue to rise, and that there will be more hot days. These factors are known to affect seagrass health and other coastal wetlands. **<u>Other</u>** The size and diversity of habitats within Corner Inlet means that there are a large range of threats to the values of the inlet including recreational use impacts, invasive plants and animals, poor water quality, oil spills, land use and development, flow modifications, changes in runoff and climate change.
8	**Site resilience/ sensitivity**	• Zolfaghar, S., 2013	**<u>Resilience/ sensitivity to a change in groundwater</u>** Groundwater extraction in the Corner Inlet catchment may threaten the inlet's GDEs by lowering groundwater levels in the surface

		• SKM, 2012	aquifers causing a reduction in the volume of freshwater input to wetlands, a reduction in base flow to rivers and an increase in groundwater salinities as a result of increased dominance of seawater. All these consequences of declining groundwater levels may lead to significant ecological changes to the GDEs, reduced water quality and an overall decline in the condition of the Corner Inlet coastal environment.
9	**Knowledge gaps**		**Key knowledge Gaps** There is still much investigation required to understand the role that groundwater plays in Corner Inlet, particularly in relation to: • The extent and nature of groundwater connection to coastal wetland environments and mainland drainages, rivers or creeks • Confirmation of the importance of groundwater in ecological processes associated with coastal wetlands • The nature of connections between different aquifers, including those containing gas reserves.
10	**References**		1. Visualising Victoria's Groundwater - http://www.vvg.org.au/ 2. State wide GMU mapping - http://vro.depi.vic.gov.au/dpi/vro/vrosite.nsf/pages/landform_geomorphology 3. SKM and GHD, 9009. Hydrogeological Mapping of Southern Victoria. Report for Southern Rural Water. 4. GHD, 2012. Report on the Development of State-Wide 3D Aquifer Surfaces. Report for Department of Sustainability and Environment. 5. Southern Rural Water, 2012. *Gippsland Groundwater Atlas.* 6. BMT WBM (2011). Ecological Character Description of the Corner Inlet Ramsar Site – Final Report. Prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities. Canberra 7. CSIRO (2005) Corner Inlet Environmental Audit. Report to the Gippsland Coastal Board. Prepared by Molloy R., Chidgey S., Webster I., Hancock G. and Fox D. 8. Adams, R., Costelloe, J. and Western, A. (2008). Enhancing the Capabilities of the Corner Inlet Decision Support System to Improve Water Quality for the Corner Inlet and Nooramunga Ramsar areas – Analysis of Groundwater Contribution to Nutrient Loads in Corner Inlet. Centre for Environmental Applied Hydrology, The University of Melbourne. 9. Alluvium, 2008. *Fluvial Geomorphology of the Tributaries of Corner Inlet Ramsar Site.* 10. West Gippsland Catchment Management Authority, 2013. *Corner Inlet Water Quality Improvement Plan 2013*. 11. Boon, P. 2015. *Coastal Wetlands and Groundwater Draft Paper*.