Gippsland Groundwater **Atlas**

Southern Rural Water

Managing Water. Serving Communities.

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Gippsland
Groundwater Atlas

Gippsland Groundwater Atlas

Foreword

Groundwater is a valuable resource but its great potential is hidden. It is complex, often described in unfamiliar technical language and hard to visualise. This atlas provides information in words and graphics that readers can understand to help them develop their knowledge of this vital water resource.

The atlas describes the groundwater resources in the Gippsland region of Victoria: how much there is, where it is, how deep and thick it is, what it could be used for and how it is used now. We have presented the information as clearly as possible. It does not aim to be fully comprehensive, technically unchallengeable or academic. The maps are helpful for guidance on a regional scale but not suitable for making commercial decisions at a property level.

In developing the atlas we drew information from a range of sources: the collective understanding of our staff, agencies, industry experts and groundwater users in the region, and from key technical reports, maps and data. Importantly, the foundation for this work was the ability to describe the basic dimensions of aquifers. This was enabled through three-dimensional groundwater mapping developed by Southern Rural Water for its region. Combined with time series information including groundwater levels, usage and licences, we have a powerful way to present our knowledge.

On behalf of the Board I thank all members of the project team for their exhaustive efforts. General Manager Graham Hawke initiated and provided leadership to the project. Penny Winbanks managed the project and co-authored the atlas along with our team of hydrogeologists: Terry Flynn (technical leader), Elissa McNamara (main author), Liam Murphy (data and mapping) and Eleanor Underwood (stakeholder reference group chair and consultation). We also appreciate the expertise of Spatial Vision who produced this publication.

This publication adds to the South West Victoria Groundwater Atlas completed by Southern Rural Water in 2011. I hope that our work will contribute to conversations that influence the way groundwater information is described and communicated on a national scale.

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Terry Burgi
CHAIRMAN, SOUTHERN RURAL WATER

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Glossary, units and links

Common terms	
Aquifer	A layer of fractured rock, gravel, sand or limestone below the ground that is porous enough to hold groundwater and allow it to flow
Aquitard	A layer of rock or clay that may hold some groundwater but is not porous enough to allow it to flow significantly
Baseflows	The component of streamflow supplied by groundwater discharge
CMA	Catchment Management Authority
Coal Seam Gas (CSG)	A form of natural gas (methane) found in coal seams
Dairy wash	Water used to wash down farm dairies
Desalination	Removing salt from water sources – often for drinking purposes
Dewatering	The process of removing water from an aquifer to gain access to minerals and energy
Domestic and stock	Water used in households and for animals/stock
DPI	Department of Primary Industries
DSE	Department of Sustainability & Environment
Entitlement	The total amount of groundwater authorised to be taken each year under a groundwater licence
EPA	Environment Protection Authority
Evapotranspiration	The loss of water to the atmosphere by the combined processes of evaporation from soils and transpiration through plants
Geothermal energy	The natural heat found within the earth
Groundwater	Groundwater is water that is found under the ground. It is stored in and can flow through layers known as aquifers
Groundwater dependent ecosystem (GDE)	Ecosystems such as wetlands, streams, estuaries or vegetation that rely totally or in part on groundwater to provide water
Groundwater elevation	The height of groundwater relative to sea level (measured in mAHD)
Groundwater management area (GMA)	Discrete area where groundwater resources are suitable for commercial purposes
Groundwater management unit (GMU)	A groundwater management area or water supply protection area
Managed aquifer recharge (MAR)	The purposeful and actively managed recharge of water to aquifers for subsequent recovery and use or environmental benefit
Permissible consumptive volume (PCV)	The volume of water permitted to be allocated. Previously known as Permissible annual volume
Recharge (groundwater)	The process where water moves downward from surface water to groundwater due to rainfall infiltration, seepage or leakage
Land salinisation	The process of soluble salts accumulating in soil through evaporation of high watertables
Southern Rural Water (SRW)	Rural Water Corporation of southern Victoria
Stygofauna	Fauna that live within groundwater systems such as caves and aquifers
Subsidence	The compression of soils caused by a loss of groundwater pressure
Unincorporated area	Areas outside groundwater management units
Water supply protection area (WSPA)	An area declared under the Water Act to protect groundwater and/or surface water resources in the area
Water table	The top of the groundwater surface (or saturated zone)

Common units	
EC	Electrical Conductivity (a measure of salinity)
GL	Gigalitre or a billion litres
L/s	Litres per second (used to measure yield)
mAHD	Metres above sea level (Australian Height Datum)
mg/L	Milligrams per litre (used to measure TDS)
ML	Megalitre or million litres
ML/yr	Megalitres per year
mm/yr	Millimetres per year
µS/cm	Microsiemens per centimetre (used to measure EC)
TDS	Total Dissolved Solids (a measure of salinity)

Useful links	
Climate	www.bom.gov.au/climate
Groundwater entitlements	www.waterregister.vic.gov.au
Groundwater dependent ecosystems	www.nwc.gov.au/water-for-the-environment/groundwater-dependent-ecosystems www.bom.gov.au/water/groundwater/gde
Groundwater data	www.vicwaterdata.net/vicwaterdata
Groundwater mapping	www.srw.com.au www.water.vic.gov.au
Groundwater monitoring	www.srw.com.au www.water.vic.gov.au/monitoring/monthly/groundwater_levels
Groundwater/surface water interaction	www.nwc.gov.au/groundwater/connectivity
Land use	www.dpi.vic.gov.au/vro
Licensing enquiries	www.srw.com.au
Minerals and energy	www.dpi.vic.gov.au/earth-resources
Gippsland Region Sustainable Water Strategy	www.water.vic.gov.au/programs/sws/gippsland
Secure Allocation Future Entitlements	www.water.vic.gov.au/environment/groundwater/management/secure-allocations,-future-entitlements
Understanding groundwater	www.nwc.gov.au/groundwater www.usgs.gov www.water.vic.gov.au/environment/groundwater/news-and-info
Using and managing groundwater	www.srw.com.au www.water.vic.gov.au/environment/groundwater/management
Water quality	www.epa.vic.gov.au/your-environment/water/protecting-victorias-waters www.nhmrc.gov.au/guidelines/publications/eh52 www.environment.gov.au/water/policy-programs/nwqms

Chapter 1: Introduction

Groundwater is not an easily understood resource. Building knowledge about groundwater is important because all water resources are valuable. Informed discussion relies on a base of reliable information.

This atlas describes our understanding of groundwater in Gippsland. The information is based on aquifer mapping, groundwater licence information and the collective knowledge of a stakeholder reference group, verified and enriched through public consultation.

This chapter introduces the study area, assumptions that underpin the atlas, commonly asked questions and basic groundwater terms.

In this chapter you can find information on:

Page heading	Description	Page
Gippsland region	Introduces the landscape and climate of the Gippsland region	6, 7
Reading guide	Outlines the structure, basic assumptions, some quick reference questions that you can use as a guide	8, 9
Understanding groundwater	Explains groundwater theory and concepts at a basic level	10
Using and managing groundwater	Provides background on the importance of groundwater and how it is used and managed	11

Gippsland region

Victoria's Gippsland region is the area south of the Great Dividing Range stretching from the Latrobe River catchment and Strzelecki Ranges east to the New South Wales border.

Landscape

The landscape is highly varied. The northern half is dominated by forested river valleys and mountains in the Great Dividing Range. The Latrobe, Thomson, Macalister, Avon, Mitchell, Tambo and Snowy Rivers rise in these ranges and flow to the south and south east across the plains to the Gippsland Lakes and Bass Strait.

The Tarwin, Agnes and Tarra Rivers flow steeply from the southern face of the Strzelecki Ranges to the coast.

Most of East Gippsland is mountainous and wooded and is managed as a state park. The Buchan Caves near Orbost are one of the few examples of cavernous limestone in Gippsland.

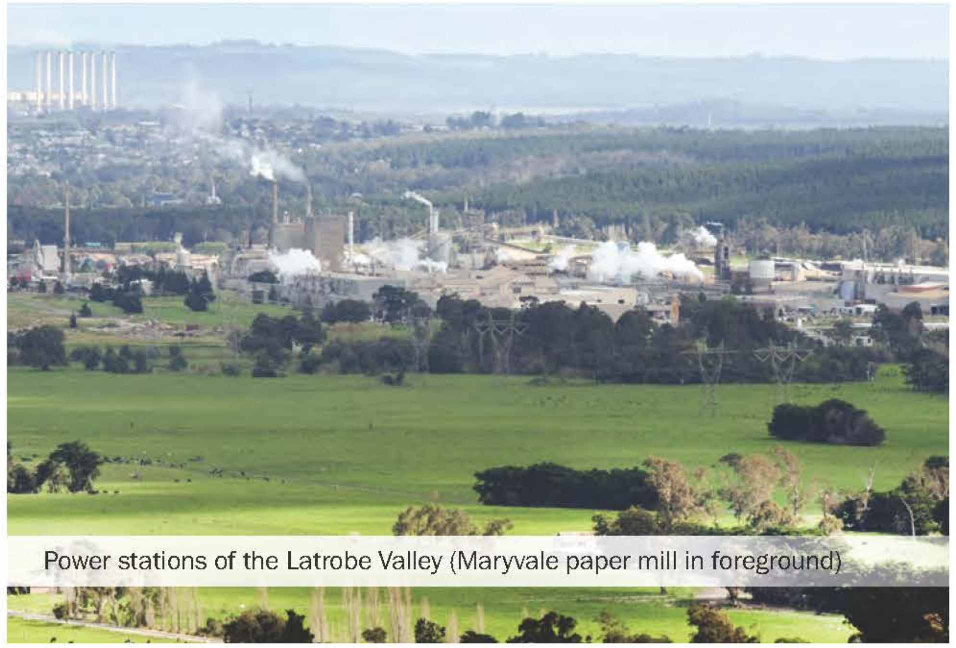
Volcanic activity has occurred in the Strzelecki Ranges stretching from Warragul to Thorpdale and Leongatha.

Springs are common in the volcanic areas and in the Great Dividing Range across the north.

The Gippsland Lakes form the largest estuarine lake system in Australia. Along with Ninety Mile Beach they are major features of the region. Dunes and wetlands are common around the lakes and along the coast.

The grasslands and eucalypts that covered the plains prior to European settlement have been cleared, mainly for agriculture for which the soils are ideal. Over the past century the power industry and the construction of large dams have had a significant impact on the landscape in the north and west. Plantation forests occur throughout the region with the highest density occurring in central Gippsland between Morwell, Yarram and Sale.

Gippsland region (Victoria)



Power stations of the Latrobe Valley (Maryvale paper mill in foreground)

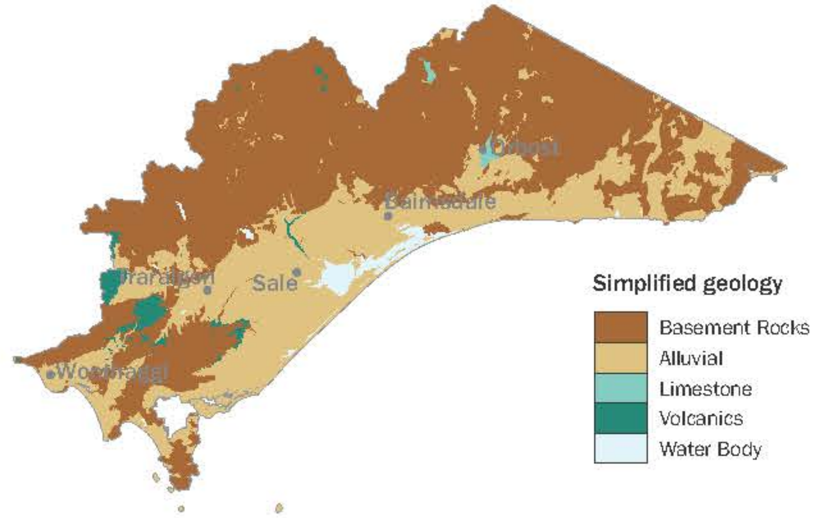
Modern spray irrigation

Gippsland region

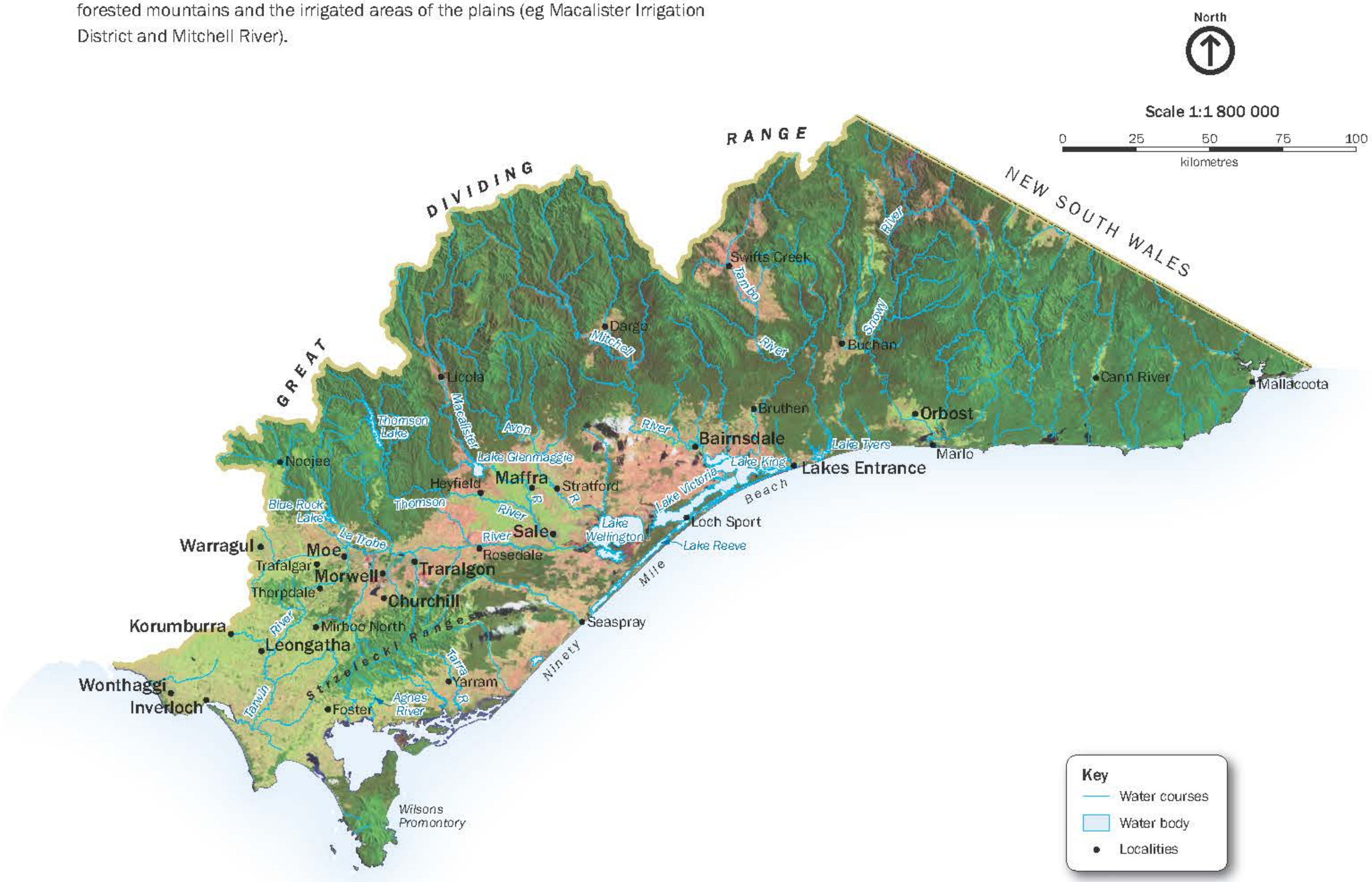
Climate

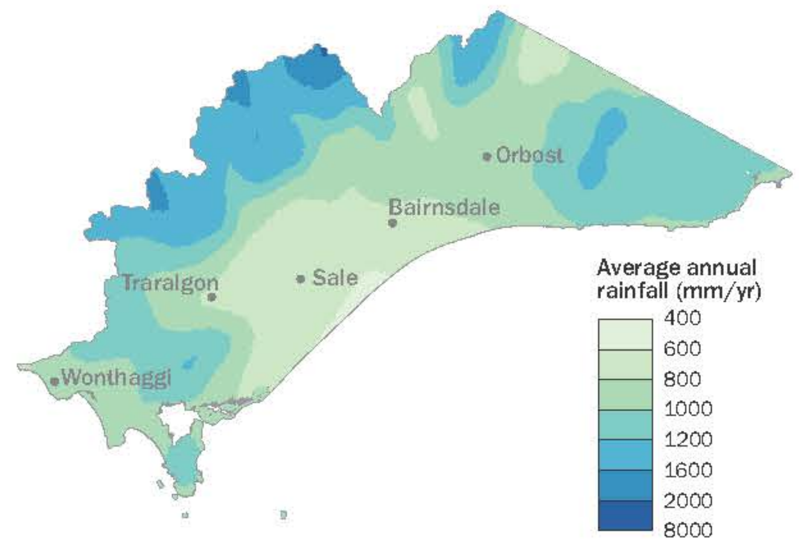
The Great Dividing Range, Strzelecki Ranges and western Gippsland all receive some of the highest rainfall in Victoria, averaging over 1,000 mm annually. This falls as snow on the higher peaks during winter. Further east, rainfall is generally lower, averaging 600 mm annually.

River levels can rise quickly, leaving the valleys and plains prone to flash floods. These floods may be reduced where there are large dams. There are high levels of evapotranspiration (an indicator of water demand from vegetation) in the forested mountains and the irrigated areas of the plains (eg Macalister Irrigation District and Mitchell River).

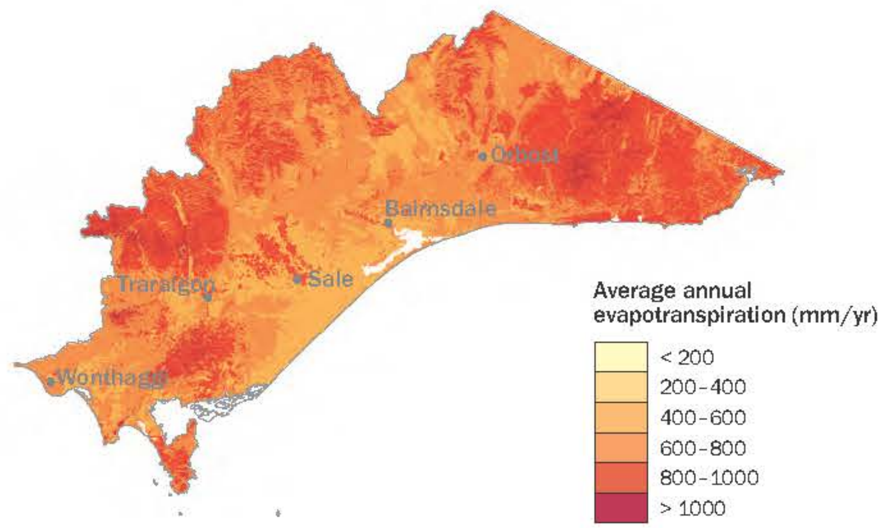


Simplified geology
(Department of Primary Industries (DPI))





Average annual rainfall (mm/yr)
Recorded from 1980-99 (Bureau of Meteorology)



Average annual evapotranspiration (mm/yr)
Modelled from 1958-2005 (EnSysm project, DSE)

Land cover (DSE Landsat 2000)

This map shows satellite imagery of the Gippsland region, the major localities, geological features, water bodies and water courses.

Reading guide

Chapters 1, 2 and 3 introduce groundwater, geology, aquifer behaviour, groundwater management and use.

Chapters 4, 5 and 6 provide more detail for each group of aquifers in the region. Topics include:

- Geology
- Salinity and yield
- Movement of groundwater
- Environmental dependence
- Water balance
- Regional trends
- Users and usage
- Current and emerging issues

User groups

Five groups of groundwater users have been identified based on their use, the type of aquifer they are most likely to access and the value of production (see table below for details).

Plantations (that intercept groundwater) have not been recognised as a separate user group, but these are discussed in the atlas.

User group	Description of user groups	Type of aquifer accessed
Domestic and stock (D&S)	Includes all private right D&S users in the region. Mainly rural users, but includes some private urban users (garden watering). Numerous users generally extracting quite small volumes. Also includes public emergency water supply use.	Mainly use upper and middle aquifers.
Agribusiness	Includes those using groundwater for more intensive agricultural and horticultural purposes (including irrigating vegetables or pasture, dairy-wash and other commercial activities). Occurs mainly in the areas between Traralgon and Bairnsdale and around Yarram. A smaller number of users than the D&S user group but they use larger volumes.	Use all aquifers.
Environment	Groundwater supports springs, streams, lakes, swamps, wetlands and plants which all contribute to the environmental value of the region.	Mainly use upper aquifers, outcropping areas of lower aquifers or exposed basement.
Urban	Includes town supplies drawn from groundwater (and then treated) for residential, commercial and other purposes.	Mainly use middle and lower aquifers.
Industry	Industries such as offshore oil and gas extraction and coal mine dewatering for power production are significant users, mainly around the Latrobe Valley and in Bass Strait.	Mainly use middle and lower aquifers.

Aquifer groups

For the purpose of this atlas, three groups of aquifers have been identified according to their depth and age (see table below). Each group is colour-coded consistently throughout the atlas.

The depth of the aquifers corresponds to the order in time in which they were formed (for example the lower aquifers were formed first). In some cases an aquifer might occur quite close to the surface but it has been grouped with the middle aquifers because of its geological age. The basement rock has been grouped with the lower aquifers.

The Victorian Aquifer Naming Framework groups hydrogeological units according to their geological age (see table below).

Aquifer and aquitard group	Aquifer and aquitard name	Geological age	Groundwater Management Units (GMUs)	Hydrogeological unit(s)
Upper	Quaternary and upper tertiary aquifer	0.01 – 4 million years	Orbost, Wa De Lock, Tarwin, Wy Yung, Denison	Various quaternary deposits, Curlip Gravels
	Quaternary and upper tertiary aquitard			Eagle Point Sand, Boisdale Fm (Nuntin Clay), Haunted Hills Fm, Sale Gp, Jemmys Pt Fm
Middle	Upper middle tertiary aquifer	4 – 34 million years	Sale, Giffard	Boisdale Fm (Wurruk Sand)
	Upper middle tertiary aquitard			Hazelwood Fm, Yallourn Fm
	Lower middle tertiary aquifer		Rosedale, Yarram (part, Balook Fm)	Yarragon Fm, Morwell Fm/Seams, Balook Fm, Alberton Fm/Seams, Seaspray Sands
	Lower middle tertiary aquitard			Gippsland Limestone, Seaspray Gp, Lakes Entrance Fm, Tambo River Fm, Giffard Sandstone Member
Lower	Lower tertiary aquifer (basalt)	34 – 65 million years	Leongatha, Moe	Thorpdale Volcanics, Carrajung Volcanics
	Lower tertiary aquifer		Moe, Stratford, Yarram	Latrobe Gp, Yarram Fm, Honeysuckle Gravels, Childers Fm, Burrong Fm, Traralgon Fm/Seam
	Basement	65-545 million years		All cretaceous and palaeozoic basement rock

The extent of each aquifer group and GMU boundaries are shown in Chapters 4, 5 and 6 for the upper, middle and lower aquifers respectively.

Reading guide

How to use the atlas

Read the introductory chapters first. They will give you an overview of the basic concepts so you can understand, interpret and analyse the text, data and maps throughout the atlas.

Use the tables on page 8 to identify which user group or aquifer group you are interested in. Chapters 4, 5 and 6 provide more detailed information on each of the three aquifer groups respectively: upper, middle and lower.

Example 1: A groundwater user is interested in the Haunted Hills Gravel unit. Using the table on page 8 they can see that this belongs to the upper aquifer group. This aquifer group is discussed in Chapter 4.

Example 2: A groundwater user is interested in the Sale Groundwater Management Unit (GMU). Using the table on page 8 they can see that this belongs to the middle aquifer group. This aquifer group is discussed in Chapter 5.

To provide readers with a starting point the tables below list some questions of interest with page references. These lists are not exhaustive and the atlas can be used to answer many more questions.

The table below lists some commonly asked questions and page references.

	Background	Upper aquifers	Middle aquifers	Lower aquifers
Where are the different aquifers?	8	30	40, 41	52
How much groundwater is there?	16	31	42, 43	53
What can I use groundwater for?	11	31	42, 43	53
How is groundwater monitored and what are the trends?	11, 23	35	47	57
How is groundwater managed?	11, 20, 22, 26	36	48	58
Who uses groundwater in the Gippsland region?	22	36, 37	48, 49	58, 59
How does the energy sector use groundwater?	22, 24, 25	36	48	58

The table below lists some more complex questions. The pages listed here should be used only as a starting point – information relating to these questions can be found throughout the atlas.

	Background	Upper aquifers	Middle aquifers	Lower aquifers
How does groundwater replenish and move?	10, 14, 16	32	44	54
What impacts groundwater levels?	15	34	46	56
How does groundwater interact with the surrounding environment?	10,17	33	45	55
What are the current and emerging issues facing Gippsland?	24, 25, 26	37	49	59
Will the groundwater in our region ever run out?	16	35, 36	47, 48	57, 58

Limitations and assumptions

The groundwater mapping used in this atlas was prepared at a scale of 1:250,000. The data used to create the maps varied in its distribution and some interpretation was required. For this reason, the data is not suitable to identify availability, yield or quality of groundwater at a local or property level.

The content of the atlas is based on data sourced from several organisations and Southern Rural Water does not warrant the accuracy of the data supplied.

The licence data will change over time due to regulatory changes, water trading, unrenewed licences and data verification.

The bore construction data is sourced from the State's Groundwater Management System and is not 100% reliable.

Domestic and stock (D&S) use is estimated at 1.3 ML per known bore.

Bore being drilled in Moe

1 Introduction

Understanding groundwater

What is groundwater?

Groundwater is water that is found under the ground. It is stored in and can flow through layers known as aquifers.

What are aquifers and aquitards?

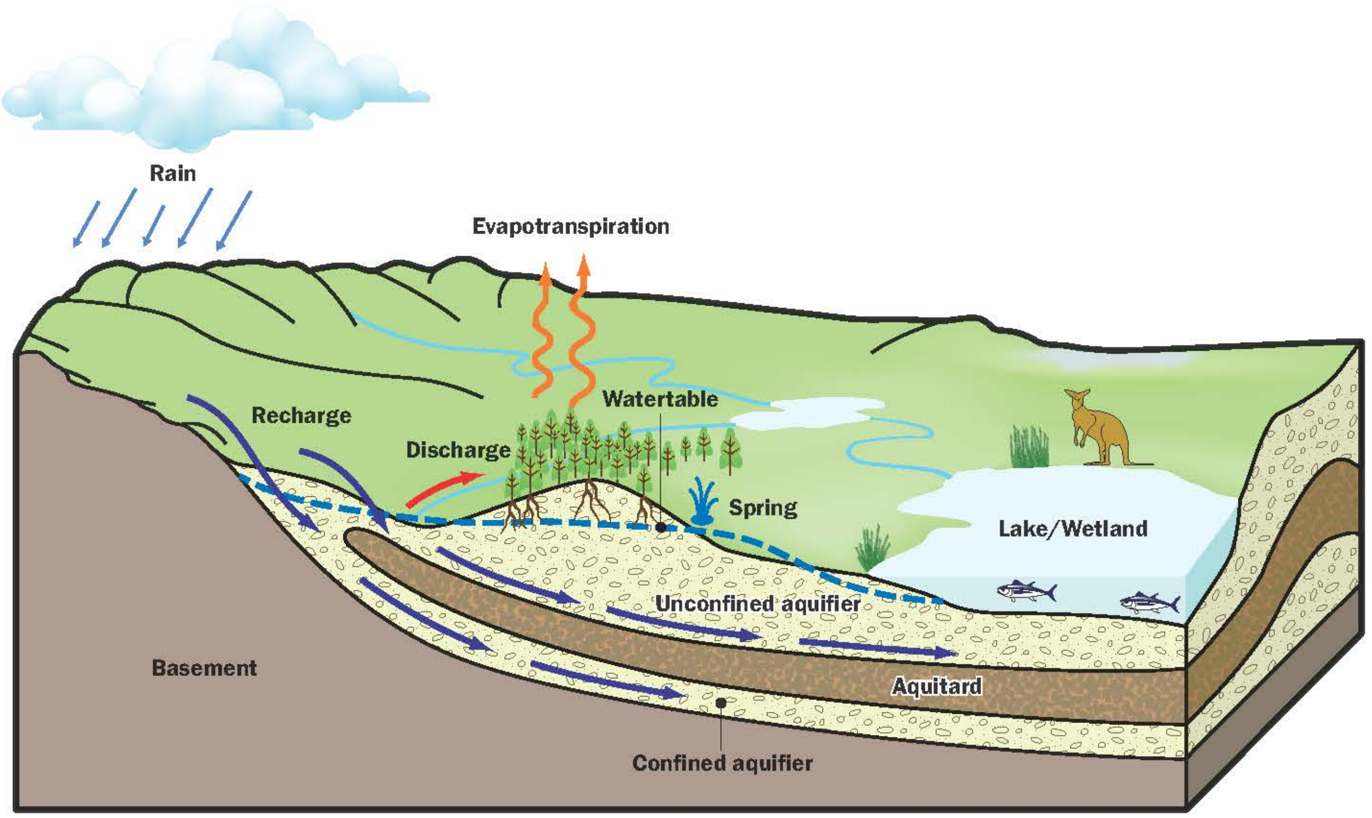
An **aquifer** is a layer of fractured rock, gravel, sand or limestone below the ground that is porous enough to hold groundwater and allow it to flow. An **aquitard** is a layer of rock or clay that may hold some groundwater; groundwater flow is very slow through an aquitard.

Where does groundwater come from?

Surface water from rainfall or other water bodies can **recharge** an aquifer. It percolates through the ground to the **water table** where it is stored as groundwater. An aquifer can receive recharge directly from rainwater or streams, or indirectly from other aquifers. Groundwater may be stored in an aquifer for a few days or thousands of years.

Where does groundwater go?

If it's close to the surface, groundwater can evaporate directly to the atmosphere or be used by vegetation **(evapotranspiration)**. Where the **water table** intercepts the ground surface it can **discharge** (return to the surface) as **springs** or as **baseflow** to surface water (springs, swamps, wetlands, lakes, rivers and creeks). Groundwater can also flow to a neighbouring aquifer (alongside, above or below). It can also be extracted via a bore or a well.



How does groundwater move?

Groundwater movement occurs as a result of differences in groundwater levels or pressure. Water moves through an aquifer at a rate and volume that depends on the connections between the pores and the fractures in the soil and rock. Compared to stream flow, groundwater may take days to thousands of years to move the same distance.

What is the difference between an unconfined and a confined aquifer?

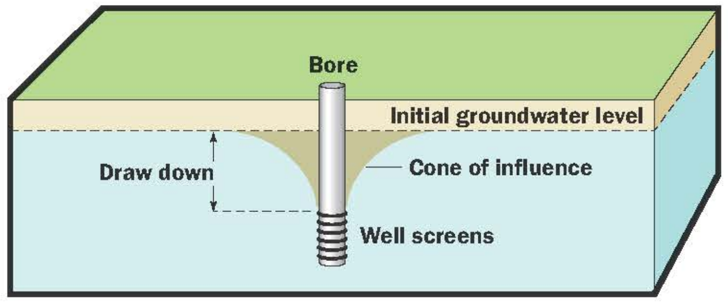
An aquifer is **unconfined** when the rock and soil between the groundwater and the surface of the ground is porous. An aquifer is **confined** when it is overlain by an aquitard. Groundwater in a confined aquifer can be under pressure. Artesian water is groundwater from a confined aquifer that is under sufficient pressure to allow the water to reach the surface without pumping. If this occurs naturally it forms a **spring**.

How does the environment rely on groundwater?

Many surface environments rely on groundwater to stay healthy and survive. These are known as Groundwater Dependent Ecosystems (GDEs). GDEs include wetlands and river baseflows that depend on groundwater flowing (discharging) to the surface, vegetation using groundwater directly from shallow aquifers (evapotranspiration), cave ecosystems and even animals that drink groundwater or eat vegetation sustained by groundwater.

What happens when groundwater is pumped?

When a bore is pumped, it forms a cone of influence that extends out from the bore until pumping stops or to a point where the water being removed is in equilibrium with the water replacing it. This can result in bore **interference** between neighbouring bores. This means that when a neighbour is pumping, there may not be enough water in your bore to achieve the usual yield. Pumping may also cause direct interference with the flow of nearby springs and streams.



Interception occurs when any bore uses water that may otherwise contribute to a stream baseflow or spring flow in the same aquifer, no matter how far away. The impact may not be noticed for weeks, months or even years and is more subdued than interference.

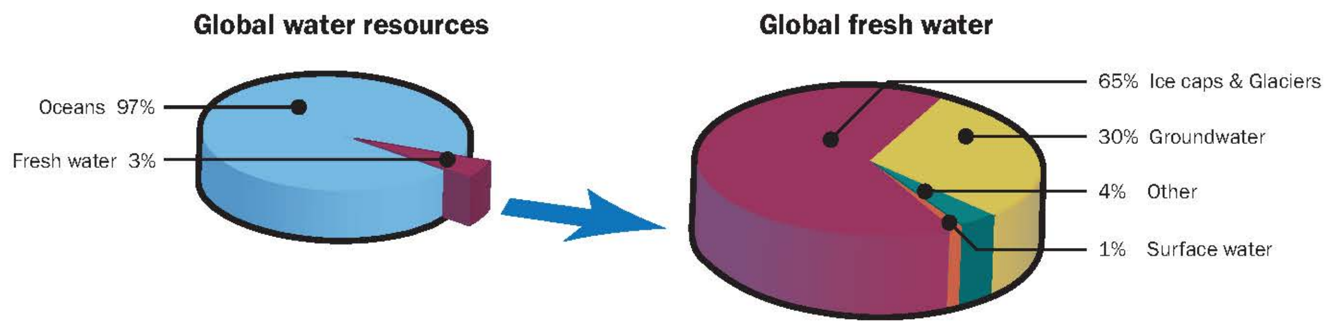
When the total volume of groundwater pumped in a region is greater than the volume of recharge, regional groundwater levels may fall. This leads to lower bore yields, higher pumping costs and a negative impact on the environment.

These concepts are described in more detail in chapter 2.

Using and managing groundwater

How important is groundwater?

Groundwater is a significant global resource. About 30% of the world's fresh water resources is stored as groundwater while less than 1% is stored in our streams, rivers and other surface water environments.



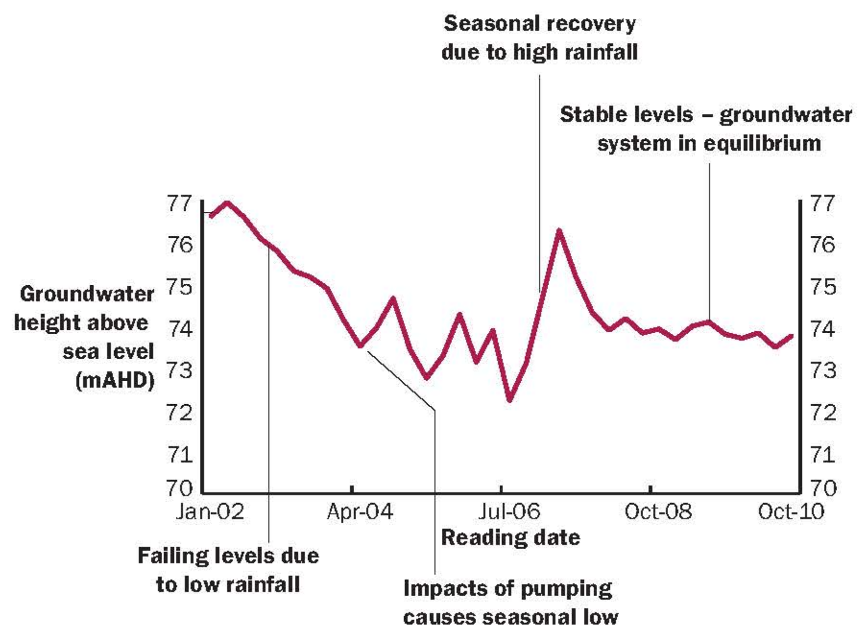
Why is groundwater use managed?

Groundwater is not a limitless resource. Unsustainable development can result in declining groundwater levels or localised impacts such as interference between neighbouring bores and reduced stream flows. Consequently, groundwater use is managed to ensure its sustainability and to limit the impact on other users.

How is groundwater use managed and monitored?

Groundwater use is managed within a Groundwater Management Unit (GMU). The volume of water that can be allocated within a GMU is known as the Permissible Consumptive Volume (PCV) – previously Permissible Annual Volume. The PCV is determined by the Department of Sustainability and Environment. Southern Rural Water regulates individual use by issuing licences. Most licensed groundwater use is now metered, however domestic and stock bores are not metered.

Observation bores are used to monitor groundwater levels. The information is added to a database and analysed using hydrographs that show the fluctuations in groundwater levels over time (see example below). Water quality is tested in all new bores and more regularly in some observation bores.



What licences are needed to access groundwater?

A 'works licence' is required to construct, alter or decommission any bore (previously 'bore construction licence') to ensure they are properly constructed and maintained to protect aquifers from contamination.

A 'take and use' licence is required to extract water from a bore, well, excavation or spring for any commercial purpose, including agribusiness, industry or urban water supply. No 'take and use' licence is required to extract groundwater on a property for stock watering or domestic purposes such as watering a kitchen garden.

What limits groundwater use?

Groundwater use is generally limited by water yield (availability), the cost of drilling and whether the water quality is suitable for the purpose. The table below shows salinity limits for various agricultural uses.

While quality is important for urban drinking supplies and some industrial purposes it is normally treated to meet the high standards required.

The environment has adapted to groundwater of varying salinity levels (eg some environments thrive in fresh water, some in hypersaline water). This means that changes in salinity significantly impact the environment.

Untreated groundwater is not recommended for human consumption. The quality of groundwater should be tested before use.

Salinity EC µS/cm	Salinity TDS (mg/L)	Suitability for stock watering	Suitability for irrigation
<300	<180	Suitable for all stock.	Suitable for most crops and soil types.
300-800	180-480		Suitable for most crops (**note:** may require increased leaching for sensitive crops).
800-2,500	480-1,500		Suitable for some crops (**note:** requires adequate leaching and may be a problem if used on soils with restricted drainage and salt tolerance of plants must be considered).
2,500-5,800	1,500-3,480		Suitable only for salt tolerant crops on permeable, well drained soils (**note:** requires careful management).
5,800-7,500	3,480-4,500	Unsuitable for poultry.	Suitable only for highly salt tolerant crops on soil with excellent drainage and leaching potential (**note:** requires adequate winter rains to ensure excess salts are leached from the soil and requires careful management).
7,500-8,500	4,500-5,100	Unsuitable for poultry and pigs.	Generally considered too saline for any irrigation.
8,500-16,500	5,100-9,900	Unsuitable for poultry and pigs. Generally unsuitable for lambs, calves and weaner stock. Suitable for dry mature sheep and cattle.	
16,500-25,000	9,900-15,000	Suitable only for dry mature sheep and cattle (**note:** requires caution for cattle unaccustomed to water with this salinity level).	
>25,000	>15,000	Suitable for dry mature sheep and cattle.	

These concepts are described in more detail in chapter 3

Chapter 2: Aquifers and groundwater

Groundwater movement through aquifers is driven by differences in groundwater levels or pressure and is controlled by how porous the material is that it passes through. Groundwater quality varies greatly across an aquifer, through its profile and over time as a result of physical and chemical processes that change the temperature, salts and minerals it conveys.

This chapter explains how some changes in groundwater movement or quality are influenced by factors that have a relatively immediate impact and are easy to understand. While other changes are influenced by factors that have occurred at a great distance or much earlier in time. These can be complex and difficult to understand.

Groundwater also plays an important role in sustaining environments around streams, lakes and wetlands.

In this chapter you can find information on:

Page heading	Description	Page
Aquifer systems	Describes the formations found in Gippsland, explains flow systems and shows aquifer recharge areas	14
Movement of groundwater	Explains how groundwater moves and reacts to influencing factors such as rainfall	15
Groundwater characteristics	Describes quality, storage, resilience and volume	16
Environmental dependence	Explains the link between groundwater and the surface environment. This page also outlines our current understanding of this relationship which we build on in chapters 4–6	17

Aquifer systems

The aquifers in the Moe, Tarwin and Gippsland Basins are a system of sediments and fractured rock up to 1,500 m thick onshore (and up to 8,000 m thick offshore) formed over the past 65 million years.

The most recent formations are the alluvial aquifers (deposited by rivers) that occur at the surface. The older sand aquifers are deeply buried under younger sediments. Volcanic formations occur at the surface along the Strzelecki Ranges and Great Dividing Range and are deeply buried in the Moe Basin. The coal seams form regional aquitards that confine the middle and lower aquifers. Thick layers of limestone and marl occur in the east of the region that generally behave as aquitards but in some areas are porous enough to be aquifers. Near the basin margins all aquifers occur close to or outcrop at the surface and may converge to act as one unit (see diagram at right).

Aquifers are unconfined if they occur at the surface (see map below). This means they can receive recharge directly from rainfall. If they are buried under sediments they receive recharge by slow leakage from overlying aquifers.

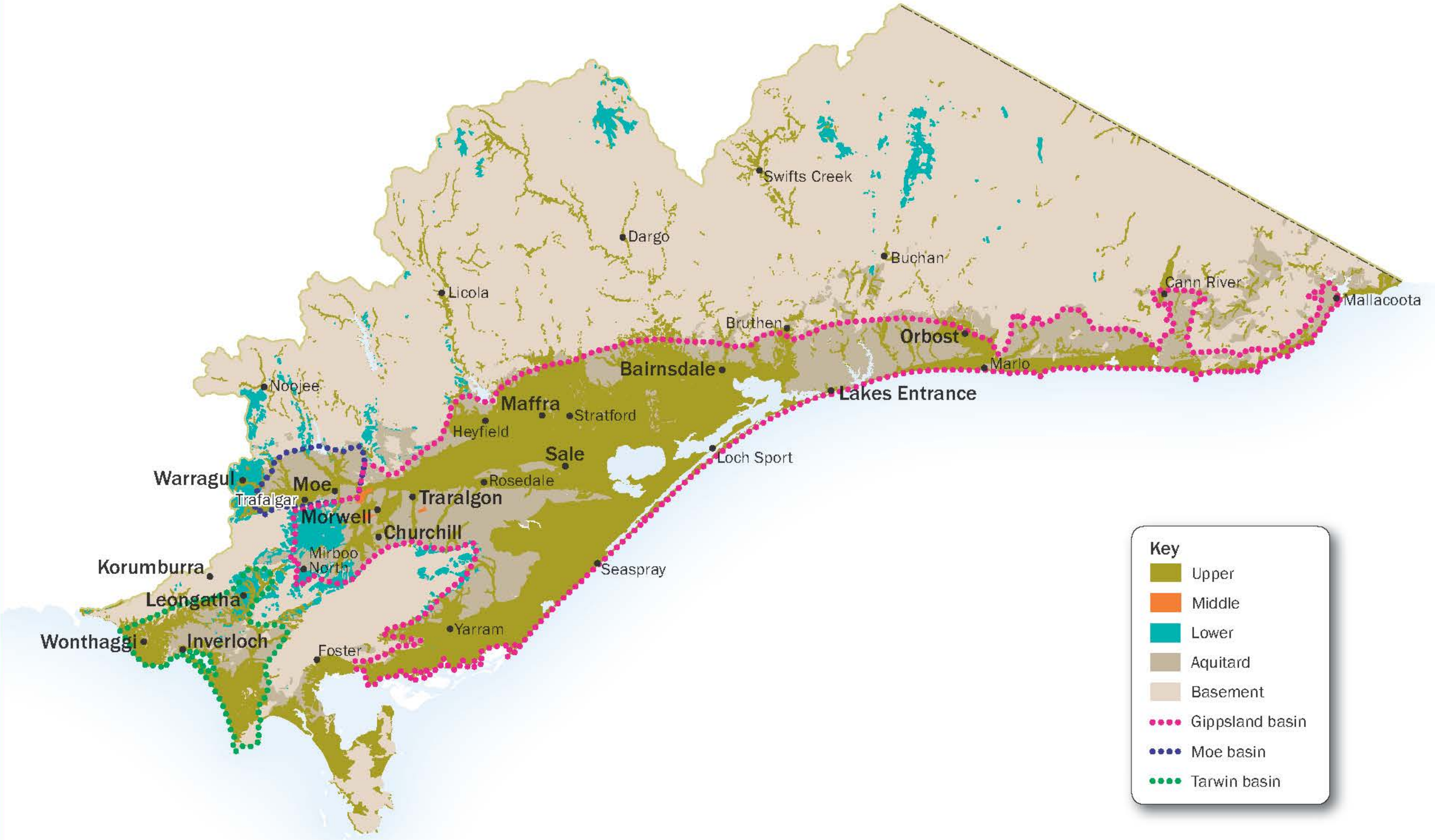
Flow systems

Rainfall percolates through the surface sediments until it reaches the water table. It then flows under gravity through local, intermediate and regional flow systems within the aquifers.

Local flow systems have flow paths of less than 5 km. They mostly occur in upper aquifers or the unconfined fractured rock of the lower aquifers or basement. These aquifers respond quickly to changes in rainfall, extraction or land use. Groundwater in a local system has a relatively short residence time before it discharges to local streams.

Observations

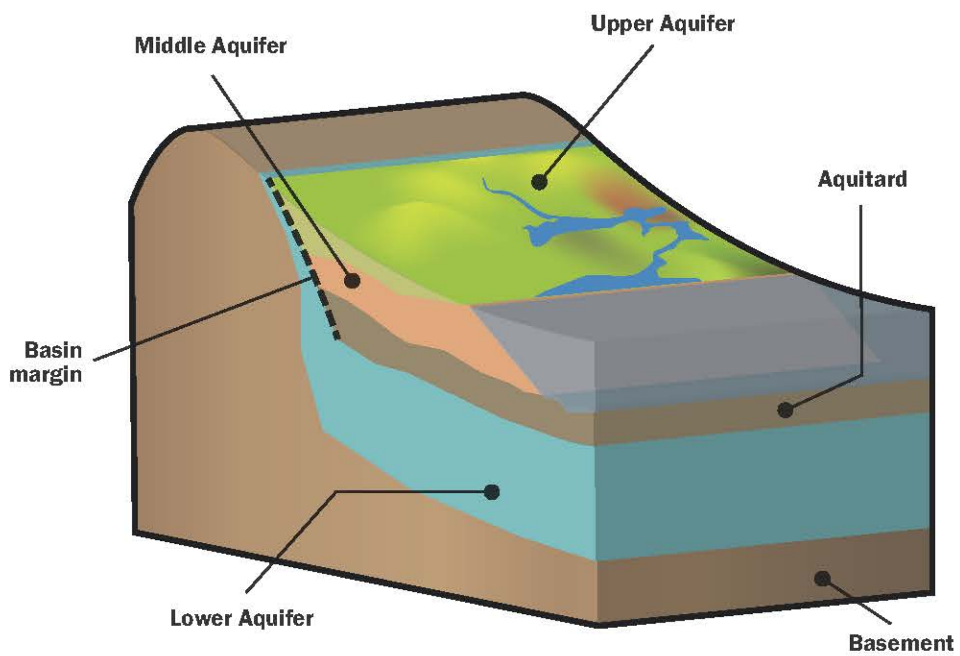
- **Groundwater flow systems describe the movement of groundwater within aquifers from recharge to discharge.**
- **There are three different types of flow systems: local, intermediate and regional. Multiple flow systems can occur within an aquifer.**
- **Local flow systems respond quickly to changes in rainfall, extraction or land use; regional systems may take decades to respond.**
- **Upper aquifers are unconfined and receive recharge directly from rainfall. Middle and lower aquifers are only unconfined near the basin margin and rely mainly on leakage from an overlying aquifer for recharge.**



Groundwater basins

This map shows the extent of the Moe, Tarwin and Gippsland groundwater basins and where the different aquifers (upper, middle and lower) occur at the surface (interpreted from surface geology).

Intermediate flow systems have flow paths of up to 30 km and **regional flow systems** flow beyond 30 km. These flow systems are likely to occur in confined middle and lower aquifers. They react more slowly to change in rainfall, extraction or land use than local flow systems. The impacts of change in regional flow systems may not be seen in a lifetime.



This diagram shows that where the lower aquifer approaches the surface it becomes unconfined and the various aquifers converge and may act as one unit.

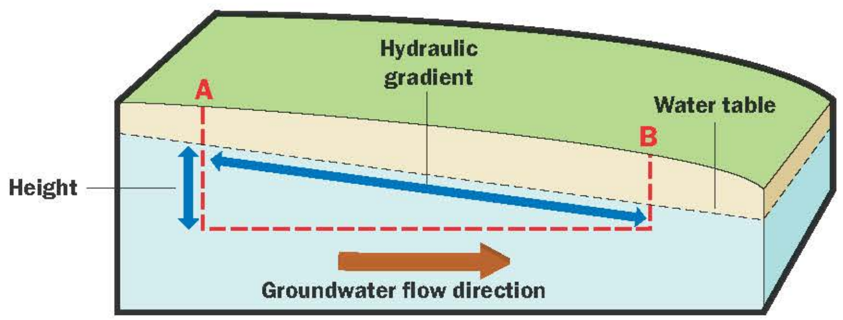
Movement of groundwater

How does groundwater move?

Two factors affect how an aquifer conveys water: its hydraulic conductivity and hydraulic gradient (see diagram below).

Hydraulic conductivity describes how easily water can move through spaces within the aquifer. Sand aquifers tend to have a higher hydraulic conductivity than rock aquifers.

Hydraulic gradient describes the difference in groundwater height (or pressure) between two points. A steeper gradient results in greater pressure difference between two points and means that the water can move more quickly through the aquifer.



How long does it take for an aquifer to respond to change?

The time it takes for an aquifer to respond to a change in rainfall, pumping or land use can range from hours to millions of years. If the change is reversed it can take decades for the aquifer to recover. This means that the groundwater levels we currently observe may be the result of changes that occurred a long time ago (eg deforestation or high rainfall periods).

How does evapotranspiration affect groundwater systems?

Evapotranspiration is the combination of transpiration (groundwater use by vegetation) and evaporation of high water tables (eg less than 5 m from the surface). It is vital to the health of native landscapes and can account for more groundwater use than bores in some areas. In expansive flat terrain it can significantly impact the availability and movement of groundwater. Therefore land use is a significant factor affecting groundwater.

How does rainfall affect groundwater levels?

Unconfined upper, semi-confined middle, confined lower aquifers respond differently to rainfall. See hydrographs below for examples of how different types of aquifers in the region respond to rainfall.

In unconfined upper aquifers the groundwater levels mimic rainfall patterns and there is little time delay.

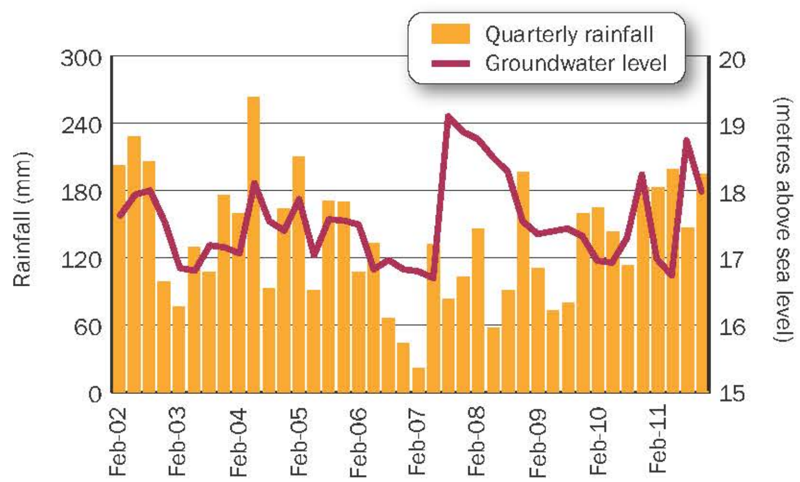
In semi-confined middle aquifers the groundwater levels mimic rainfall patterns, but the response time is delayed and more subdued than in the upper aquifers – this reflects the additional time it takes for the rainwater to percolate down into the aquifer.

The confined lower aquifers are buried deep under other aquifers and aquitards so groundwater levels do not show a relationship with rainfall patterns. Near the basin margin, unconfined lower aquifers have a similar response to rainfall patterns as unconfined upper aquifers.

Other factors impacting groundwater levels

Groundwater levels in the upper aquifers in Gippsland rise and fall as they mimic rainfall patterns. They also rise during floods caused by storms higher in the catchment (see hydrograph below – note winter 2007) and are influenced by seasonal pumping.

Upper aquifer behaviour (Wy Yung)



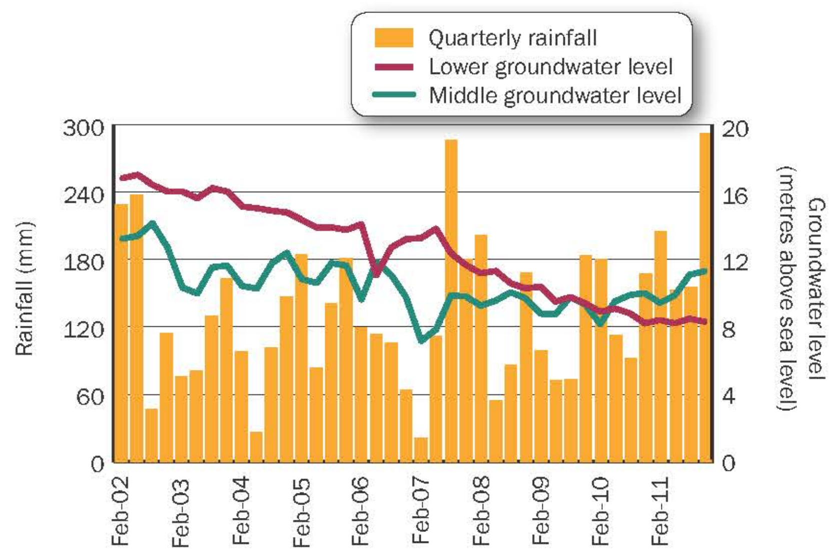
Observations

- The rate and direction of groundwater flow is driven mainly by gravity and pressure as well as how easily water can move through the aquifer material.
- Evapotranspiration significantly impacts the availability and movement of groundwater in expansive flat terrain.
- Unconfined, semi-confined and confined aquifers respond differently to rainfall.
- Unconfined aquifers are highly responsive to rainfall. Confined lower aquifers do not respond quickly to rainfall or changes in climate patterns.

The middle and lower aquifers in the region are generally confined. The middle aquifers show a delayed response to rainfall but an immediate response to extraction (low pumping during wet seasons and high pumping during dry seasons).

The groundwater levels in the lower confined aquifers show little short-term change due to rainfall or local pumping. The long-term falling levels are due to regional depressurisation of the aquifers. These issues are discussed in Chapter 6.

Middle and lower aquifer behaviour (Sale)



Groundwater characteristics

Quality and yield

Quality and yield are the primary measures used to make decisions about the potential use of groundwater (although there are other factors that limit decisions such as the cost of drilling).

Quality can vary greatly across an aquifer, through its profile and over time. This is caused by physical and chemical processes occurring in aquifers that can affect salinity, temperature, pH levels, heavy metals and organic substances such as:

- Dissolved rocks and minerals being transported and redeposited as groundwater moves along the flow path;
- Evaporation from high water tables causing minerals and salts to concentrate in groundwater;
- Changes in groundwater levels resulting in saline water being drawn into an aquifer;
- Chemical reactions that change the chemistry of groundwater or thermal sources such as volcanoes, hot rocks or the sun heating the groundwater.

Salinity is used as an indicator of groundwater quality because it is simple to measure and compare between sites. There are many other measures that are important and need to be considered depending on the end use or purpose of monitoring.

Groundwater samples are taken from all new groundwater bores and are analysed for major ions, salinity, pH and temperature. However data is not collected regularly from the same locations so it is difficult to show changes in water quality over time.

Yield measures how much (volume) and how quickly (flow rate) groundwater can be extracted from an aquifer. Volume and flow rate are usually greater in aquifers where there is plenty of pore space between the aquifer material (eg sand, gravel or fractured rock).

Storage

The storage capacity in an aquifer depends mainly on the space between pores. This means, for example, that a sandy aquifer has more storage capacity than a fractured basalt aquifer.

Unconfined upper aquifers are exposed at or near the ground surface and can be quite thin with little storage. When it rains or a river floods the aquifer's pore spaces fill quickly and this water is held in storage. When the aquifer becomes saturated the water spills into surface drainage lines.

The behaviour of upper aquifers is seasonal. Groundwater levels can fall substantially during a period of dry weather or increased pumping but can recover quickly when it rains.

Recharge to middle and lower aquifers comes from leakage from overlying upper aquifers as well as direct rainfall (where the aquifer is exposed at the surface). Lower aquifers typically have more storage capacity than upper aquifers because they are generally much thicker and cover a greater area. In deeper formations the storage volume of an aquifer can increase under pressure. The enormous pressure in lower aquifers means that groundwater levels can recover quickly after periods of pumping.

Observations

- **Groundwater quality and yield limit the potential uses of groundwater.**
- **An aquifer's storage capacity depends on its pore space (eg a sandy aquifer has more space than a fractured rock aquifer).**
- **The rate at which groundwater levels drop when pumping occurs depends on how much water is stored and how quickly it moves through the aquifer.**
- **Unconfined upper aquifers regularly fill and spill because they respond immediately to changes in rainfall (due to being exposed at the surface) and their storage capacity is smaller than lower aquifers.**
- **The enormous pressure in lower aquifers means that groundwater levels can recover when pumping stops.**

How much groundwater can we access?

The diagram to the right shows the proportion of groundwater stored in aquifers in the region that is both accessible and suitable for use. These aquifers receive recharge at a rate of 80,000 ML/yr and they are being pumped at a rate of 160,000 ML/yr. This means that overall the system is losing water causing a decline in groundwater levels that affects users in the lower and middle aquifers. However this decline is at a rate that only marginally affects the huge volume in storage.

It is estimated that the volume of groundwater stored in the aquifers in the region is 250 million ML in the onshore part of the system and 1,600,000 million ML in the offshore part. Deep recharge is approximately 80,000 ML/yr.

Taking into account water quality (salinity), only 50% of the groundwater in storage is suitable to use for irrigation. The amount that can be extracted is further restricted by bore yields and the depth of the groundwater source.

The volume extracted is approximately 160,000 ML/yr (twice the rate of recharge).

Environmental dependence

The environment is a major user of groundwater. The volume used is difficult to measure but may be observed in ecosystems that persist during dry seasons.

Groundwater Dependent Ecosystems (GDEs)

GDEs can be flora, fauna or habitats that are dependent on groundwater. They can be grouped as:

- Surface water ecosystems that rely on groundwater discharge such as rivers, springs, wetlands and estuaries and the aquatic flora and fauna that depend on these ecosystems
- Terrestrial ecosystems such as vegetation that draw on shallow groundwater through root systems and the fauna that depends on this vegetation
- Subterranean ecosystems such as caves and pores in rocks and the flora and fauna that inhabit these places

Levels of dependence

GDEs have varying levels of dependence on groundwater. They may be completely dependent, highly dependent or periodically dependent.

Completely dependent systems may not survive if slight changes occur in the groundwater they depend on, while periodically dependent systems may rely on groundwater during dry or drought periods only.

Aquifer and stream interactions

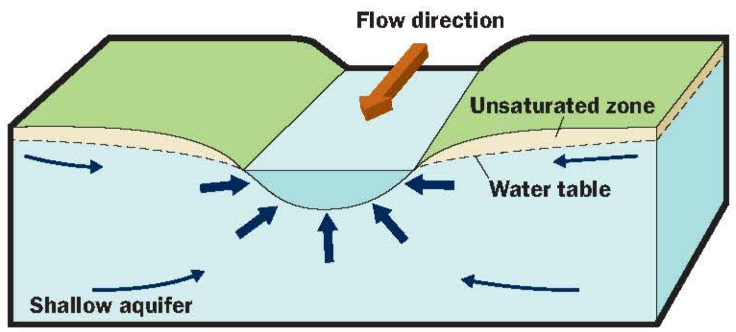
Unconfined aquifers and streams can be closely connected. The more an aquifer is confined the less likely it will be significantly connected.

Water can move in both directions between an aquifer and streams and the level and nature of the connection can change through its profile and over time.

Interaction between aquifers and streams cannot be directly measured. Several estimation methods exist but the results of these may differ significantly.

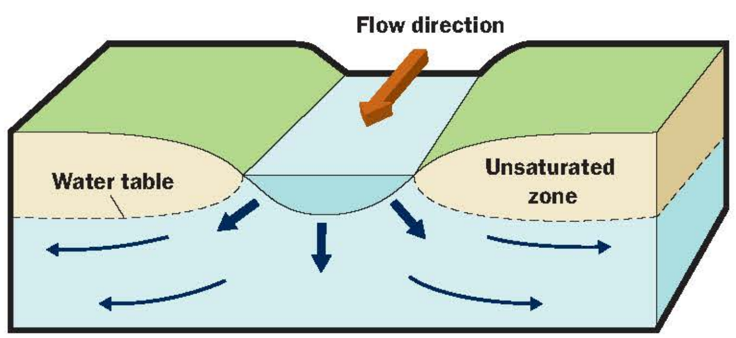
Water will flow from high to low according to gravity or pressure (this is discussed on page 15).

If the water table is higher than the stream bed groundwater can discharge into the stream. The same can occur in other surface water environments such as lakes or wetlands (see diagram below).



Example of a gaining stream

If the stream flow is higher than the water table, the stream can lose water to the aquifer (see diagram below). This may occur during a flood or if groundwater levels drop significantly due to extraction.



Example of a losing stream

Water balances

Water balances describe the flow of water in and out of an aquifer. When recharge into an aquifer exceeds discharge the water balance is positive. Groundwater storage increases, the water table rises and streams may gain water.

When discharge (such as pumping and evapotranspiration) exceeds recharge the water balance is negative. Groundwater is released from storage, the water table falls and streams may lose water.

Observations

- **GDEs can be classified as surface water ecosystems, terrestrial ecosystems or subterranean ecosystems.**
- **Our level of understanding about the location and needs of GDEs is improving but there is still much to discover.**
- **The needs of the environment are considered when assessing new licence applications.**

Current level of understanding

Over the past decade our ability to identify and map potential GDEs has improved greatly. The National Water Commission has produced a GDE atlas* which uses satellite imagery, depth to groundwater maps, vegetation mapping and field surveys to identify a likelihood of GDEs. Unless this information has been ground tested it is probable it includes many sites which are not GDEs. Also, while subterranean ecosystems have not been surveyed in Gippsland, they are likely to be found in shallow aquifers along current and prior streams.

The level of groundwater dependence is difficult to quantify. Some research has identified a level of interaction between streams and groundwater however this information is limited and does not provide insight into the dependence of other GDEs such as wetlands and vegetation.

Management

Groundwater extraction and the impact on groundwater levels is managed to preserve discharges to streams and wetlands that may support GDEs.

When assessing new licence applications, two key considerations are the needs of the environment and the combined allocation of surface water and groundwater and their level of connection.

The Gippsland Sustainable Water Strategy** states that the Department of Sustainability and Environment will provide ministerial guidelines to help authorities consider the risk to GDEs when considering licensing decisions.

For more information please visit:

*GDE Atlas Website **www.bom.gov.au/water/groundwater/gde/**

** **www.water.vic.gov.au/initiatives/sws/gippsland** - Action 4.17

Chapter 3: Management and use

The value of groundwater has risen over time as the demand for it has increased.

The Gippsland region has significant surface water storages that supply towns, industry and irrigation (eg the Macalister Irrigation District). These supply systems are supplemented by groundwater which is vital to the overall water supply.

A large volume of groundwater is used in mining in the Latrobe Valley and Bass Strait. These industries are vital to the local, state and national economies.

New systems of management have been introduced over time as the value of groundwater has risen and management issues have increased.

This chapter explains how the management and use of groundwater have evolved and provides context for some of the regional issues which will be discussed in more detail in chapters 4, 5 and 6.

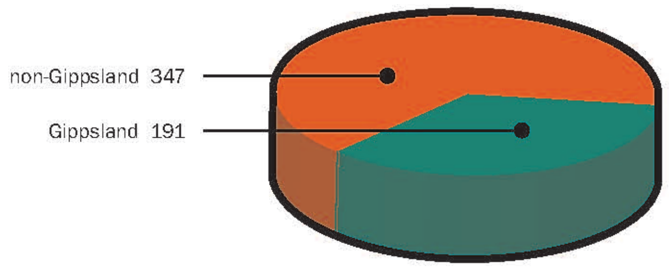
In this chapter you can find information on:

Page heading	Description	Page
Early regulation	Describes the development of groundwater as a resource in Gippsland and the introduction of groundwater regulations	20
Current management	Explains the current regulations and management framework	21
Entitlements	Shows the distribution of licences and registered bores throughout Gippsland and describes Groundwater Management Units	22
Monitoring	Shows the locations of state monitoring bores throughout Gippsland	23
Groundwater management and energy	Provides background information about the energy resources that occur in Gippsland and the associated impacts	24, 25
Groundwater protection	Explains different types of groundwater pollution and how it is regulated and monitored	26
The value of groundwater	Explains the difference between reliability and security and how both impact the relative value of groundwater	27

Early regulation

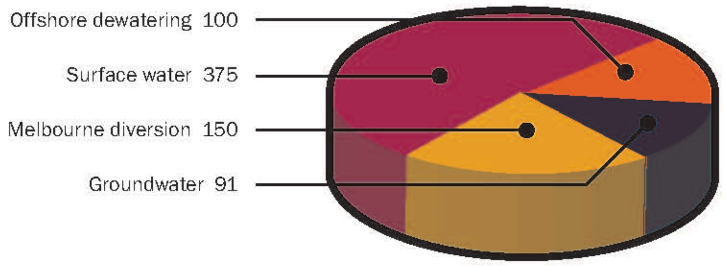
Gippsland accounts for a significant proportion of the total groundwater use in Victoria (this includes Bass Strait dewatering). Close to 100 GL of groundwater is used annually. However groundwater accounts for only a small proportion of the total water use in Gippsland.

Victorian groundwater usage (GL/yr)



The topography, climate and large dams mean that Gippsland relies predominantly on surface water.

Gippsland average annual water usage (GL/yr)



*The data used to produce these charts does not include estimates of small catchment dams or domestic and stock (D&S) use

The evolution of groundwater usage

Windmills that pumped groundwater from hand-dug wells were introduced during the 1870s. The introduction of mechanical bore construction methods made drilling easier and gave landowners improved access to groundwater. Later, the introduction of centrifugal or turbine pumps meant landowners could extract greater volumes.

During the drought in 1968 there was a greater demand for groundwater from the expanding dairy industry and the mining industry (as a result of the need to depressurise the Latrobe Valley mines). This lead to further increases in bore construction and pumping.

The introduction of regulation

Groundwater regulation in Victoria was influenced by two events: the failure of Nhill's town supply in 1967 and plunging groundwater levels near Westernport Bay (caused by pumping) that caused concern about sea water intrusion.

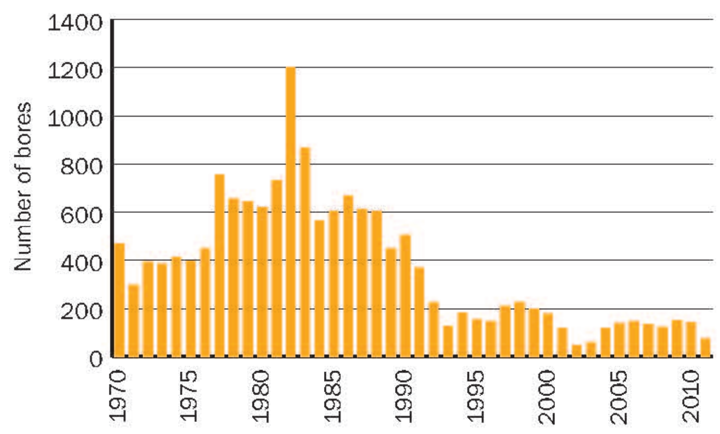
The Groundwater Act was introduced in 1969. 'Take and use' and 'bore construction' (now known as 'works') licences were introduced and managed by the Department of Mines. Groundwater bores are now administered under the Water Act which was enacted in 1989.

Works licence – a licence to construct, alter or decommission a bore for any purpose, including D&S. This licence records the activity and ensures construction standards are adequate.

Take and use licence – a licence to take and use groundwater for any commercial purpose other than D&S. Unintentional water users such as the mining, minerals and energy industry require a licence (excluding offshore operations as they are outside the State's control). Indirect or diffuse users such as the plantation industry do not require a licence.

Private rights – a landowner can take water from a bore on their property for D&S use without requiring a take and use licence. However, they do need a works licence to construct a bore. Private rights are not formally issued and water use is not metered.

Number of bores constructed in Gippsland



This graph shows the number of licences issued to construct bores and bores registered post-construction. The highest number of bore constructions occurred during the 1970s and 1980s, peaking during dry weather in 1983.

The region accounts for 30% of all groundwater bores across the state.

For more information about groundwater licensing requirements please visit www.srw.com.au

Timeline

Pre 1870s
Wells were hand-dug and lined with bricks or concrete and water was lifted to the surface by buckets.

1880
The first town supply bore was constructed in Sale but was replaced by piped supply from the Thomson River in 1888.

Early 1960s
Surface drains and groundwater pumps were established in the Macalister Irrigation District (MID) to manage the effects of irrigation.

Late 1960s
Use of groundwater for dewatering for oil, gas and coal in the Gippsland Basin increased significantly.

Late 1960s
Irrigation bores began operating at Yarram.

1969
The Groundwater Act was introduced.

1969
The first Groundwater Conservation Area was established around Koo Wee Rup.

1970
The State Observation Bore Network was established. The supply to Sale was changed back to groundwater.

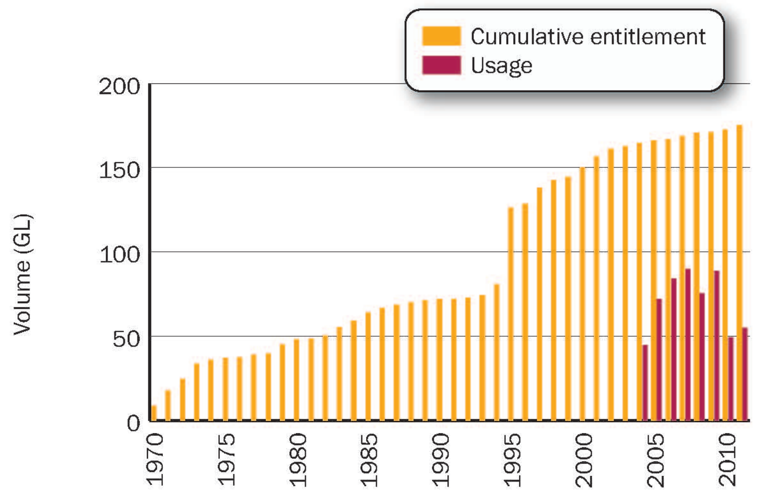
Current management

In recent years, the regulation and management of groundwater resources has increased. This is in response to a greater demand for groundwater combined with periods of low rainfall.

A cap on the allocation of licences in intensively licensed areas was introduced in 1997. This coincided with a period of low rainfall and remaining entitlements were in high demand.

The steep increase in licence volumes in 1996 occurred because licences were granted to power companies in the Latrobe Valley for their mining operations (mine dewatering has actually been occurring since the late 1960s).

Growth of licences in Gippsland



By 2004 most bores were metered. Use is recorded at the end of each season on 30 June. Use is typically less than 50% of the entitlement.

The offshore oil and gas industry also withdraws a substantial volume of fluid (oil, gas and water) from the aquifer system. This occurs outside the State's jurisdiction and is not directly accounted for.

Groundwater Management Units (GMUs)

GMUs are normally established where there is a high concentration of licences. They are defined by their depth and geographical boundaries.

A GMU can be further categorised into Water Supply Protection Areas (WSPAs) and Groundwater Management Areas (GMAs). Unincorporated Areas (UAs) describes any region outside a GMU.

Permissive Consumptive Volume (PCV)

All WSPAs and GMAs have an allocation cap or PCV. The PCV regulates the volume of entitlements – it does not manage use. A PCV is a precautionary cap which fixes the upper limit of entitlements to protect the resource.

This does not necessarily reflect a sustainable yield.

Water Supply Protection Areas (WSPAs) and Groundwater Management Plans (GMPs)

If a WSPA is declared, a GMP must be developed. Originally GMP's were used to formalise metering, monitoring and trading rules within the designated area.

Now that metering is mandatory and State wide monitoring programs are in place, in most cases it is more efficient to manage groundwater without going through the process of initiating a WSPA and preparing a GMP. Less formal management methods are now used such as **local management rules** or **plans**.

Observations

- **High stream flows and large dams have led to a lower reliance on groundwater relative to total water use in Gippsland.**
- **An increased demand for groundwater coinciding with dry periods led to the introduction of regulation in 1969 and allocation caps in 1997.**
- **Groundwater management is currently based on GMUs (covering areas with a high concentration of licences) and PCVs (allocation caps).**
- **Some activities which use groundwater occur outside the State's jurisdiction (such as offshore oil and gas activities).**

The management of groundwater resources continues to evolve. The State has developed three key initiatives that will help shape the future:

- The **Gippsland Region Sustainable Water Strategy** aims to secure water supplies, encourage economically viable and sustainable agriculture and protect the health of the environment.
- The **Water Register** stores and reports water entitlement information (replacing an outdated paper-based system).
- The **Secure Allocation, Future Entitlement project** provides an aquifer-based framework to regulate groundwater allocation and trading.

For more information on these initiatives please refer to the weblinks provided on page 4 – Glossary, units and links.

1980s
Production and dewatering from Morwell and Traralgon coal mines increased significantly.

1989
The Victorian Water Act was passed, replacing the Groundwater Act.

1993
Victoria's first Groundwater Management Strategy was released.

1997
GMAs and PAVs (now PCVs) were established.

2002
The Water Act (1989) was amended to include WSPAs. Groundwater was formally recognised by the National Water Initiative and State policies.

2006
PCVs were established for GMUs.

2007
3D hydrogeological maps were produced for southern Victoria – a significant step in broadening our knowledge of groundwater.

2010
The Yarram Groundwater Management Plan (GMP) was approved by the Minister for Water.

Entitlements

Most bores in the region are used for either domestic and stock (D&S) or agribusiness. Industrial users including the Latrobe Valley mines and ESSO (Longford) are significant users of groundwater. Sale, Briagalong and Mallacoota rely on groundwater for their town supply.

The table to the right summarises the total volumes of water allocated annually and used in each of the aquifer groups. Another substantial user is the offshore oil and gas industry in Bass Strait. Their use is not regulated by the State and is not included in the table.

The map below shows the location and volume of entitlement by user group.

Aquifer group	PCV*	Entitlements**	Metered usage (ML)***
Upper	57,879	67,822	23,936
Middle	49,195	54,261	26,555
Lower	67,662	61,808	41,640

* PCVs listed are correct as at July 2011. Entitlements held in Unincorporated Areas are not accounted for under the PCVs.

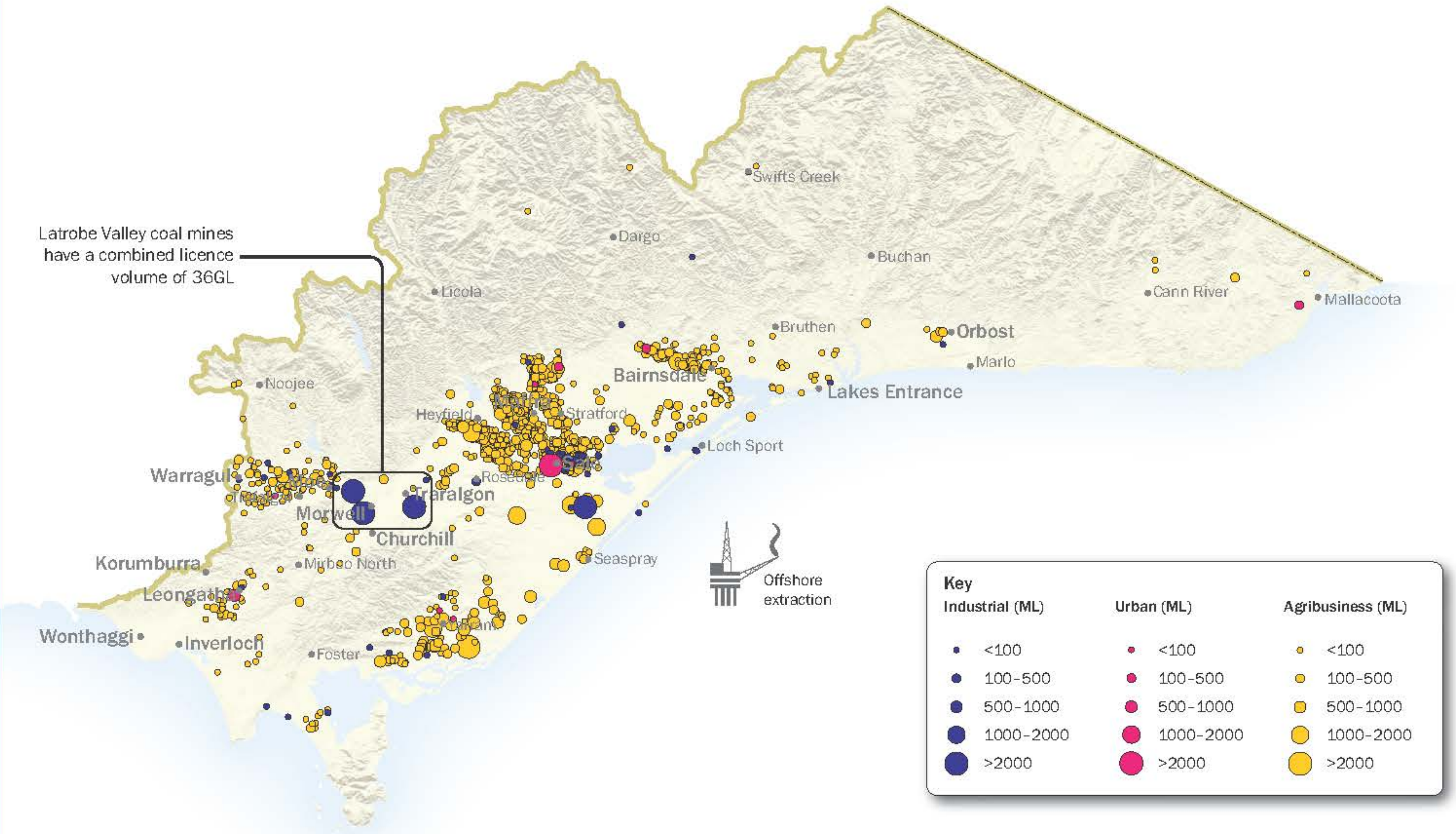
** Latrobe Valley coal mines have a combined licence volume of 36,870 ML

*** Average metered use from 2004-11 (does not include D&S bores)

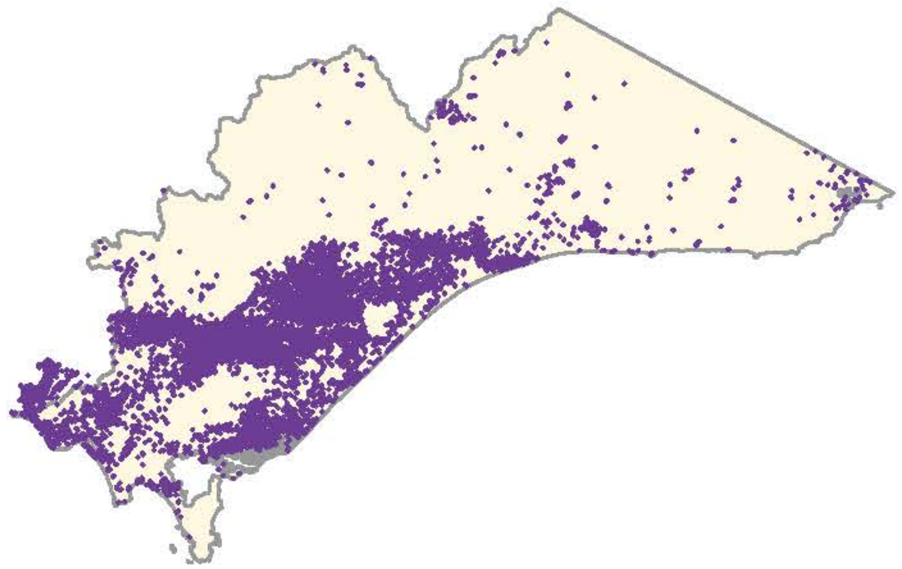
Note: Offshore fluid usage (oil, gas and groundwater) is approximately 100,000 ML/yr.

Observations

- **Most groundwater development occurs along the river valleys in the northern half of the Gippsland Basin.**
- **The Macalister Irrigation District, situated along the Thomson, Macalister and Avon Rivers, has the highest concentration of licences.**
- **Registered D&S bores are assumed to use approximately 9,000 ML per year.**



Groundwater licences and volumes



Registered bores 2012

The map above shows all registered groundwater bores, including D&S bores. There are an estimated 6,975 D&S bores in the region with each assumed to use 1.3 ML/yr.

Monitoring

Across the region, there are 168 observation bores that form part of the State Observation Bore Network (SOBN). The state government maintains these bores and uses them to monitor groundwater levels and, in some cases, salinity.

Groundwater level and salinity data is collected either monthly or quarterly and reviewed on a regular basis to assess trends.

A large amount of data is also collected from bores that are not part of the SOBN. The Latrobe Valley mines operate a monitoring bore and subsidence measurement network of about 180 sites in the Rosedale and Stratford GMUs. The West Gippsland Catchment Management Authority operates a salinity bore network in the Lake Wellington catchment with 155 bores. These bores are important for managing Denison and Wa De Lock GMUs.

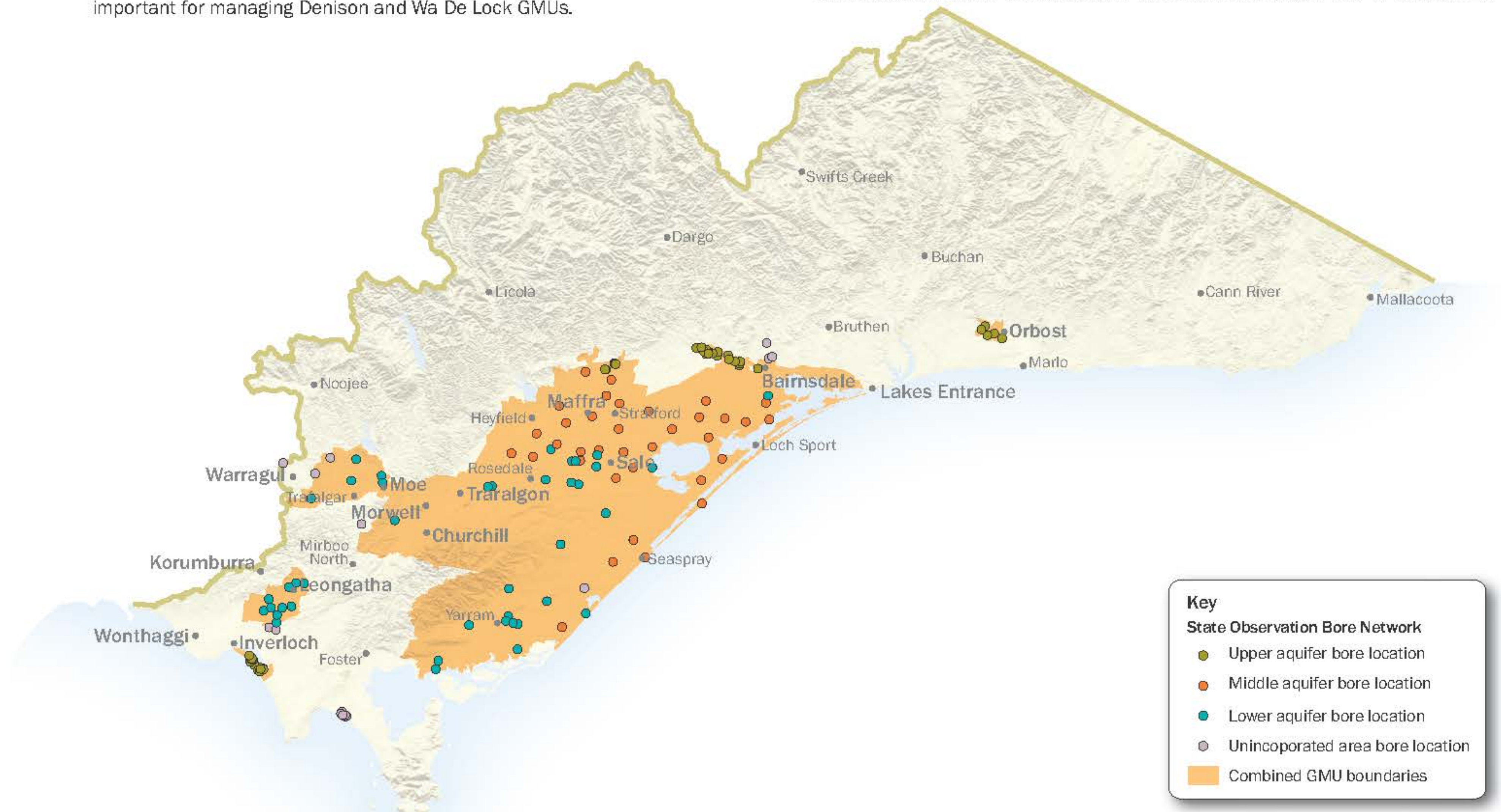
Additional groundwater data is collected for mineral, oil and gas exploration purposes from numerous investigation bores.

Data is also collected from bore logs, pumping tests, weather stations and stream gauges. Along with metered usage data, this can be used to help understand the extent, condition and behaviour of groundwater.

GMU boundaries

There are 12 declared GMUs in the region. GMUs are defined by their depth and geographical boundaries. This means that there may be more than one GMU in an area. For example, Stratford GMU is very deep and is overlain by Rosedale and Wa De Lock GMUs.

The map below shows the total area defined by all GMUs and the location of observation bores (for individual GMU boundaries see pages 30, 40-41 and 52).



Groundwater observation bores and GMUs

This map illustrates the location of State observation bores and the combined boundaries of all GMUs (i.e. the area under active management)

Observations

- **State Observation Bores are concentrated in GMUs but their spacing is not proportional to the licence volumes.**
- **Observation bores are used to measure groundwater levels and salinity to help responsibly manage the use of groundwater.**
- **A large amount of data is collected from bores not in the SOBN.**

The table below lists the number of observation bores that measure groundwater levels and salinity in specific GMUs. The colour coding represents the different aquifer groups – upper (green), middle (orange) and lower (blue).

Unincorporated areas (purple) can occur in any aquifer group outside the designated GMU's.

	Number of observation bores	
GMU name	**Water level**	**Salinity**
Orbost	5	5
Tarwin	25	0
Wa De Lock	5	4
Wy Yung	21	2
Giffard	6	2
Rosedale	8	0
Sale	24	2
Leongatha	11	0
Moe	11	0
Stratford	17	0
Yarram	19	0
Unincorporated areas	16	0

* Note: there are no State Observation Bores in Denison

Groundwater management and energy

Since the 1960s energy resources in the Gippsland Basin have contributed significantly to the state and national economy. The basin contains strategically important reserves of coal, oil and gas. Accessing these resources uses approximately 100 GL of groundwater per year.

Coal is a fossil fuel formed by the decomposition of plants in swampy or low-lying areas. Peat, brown coal and black coal are the progressively mature products of this process.

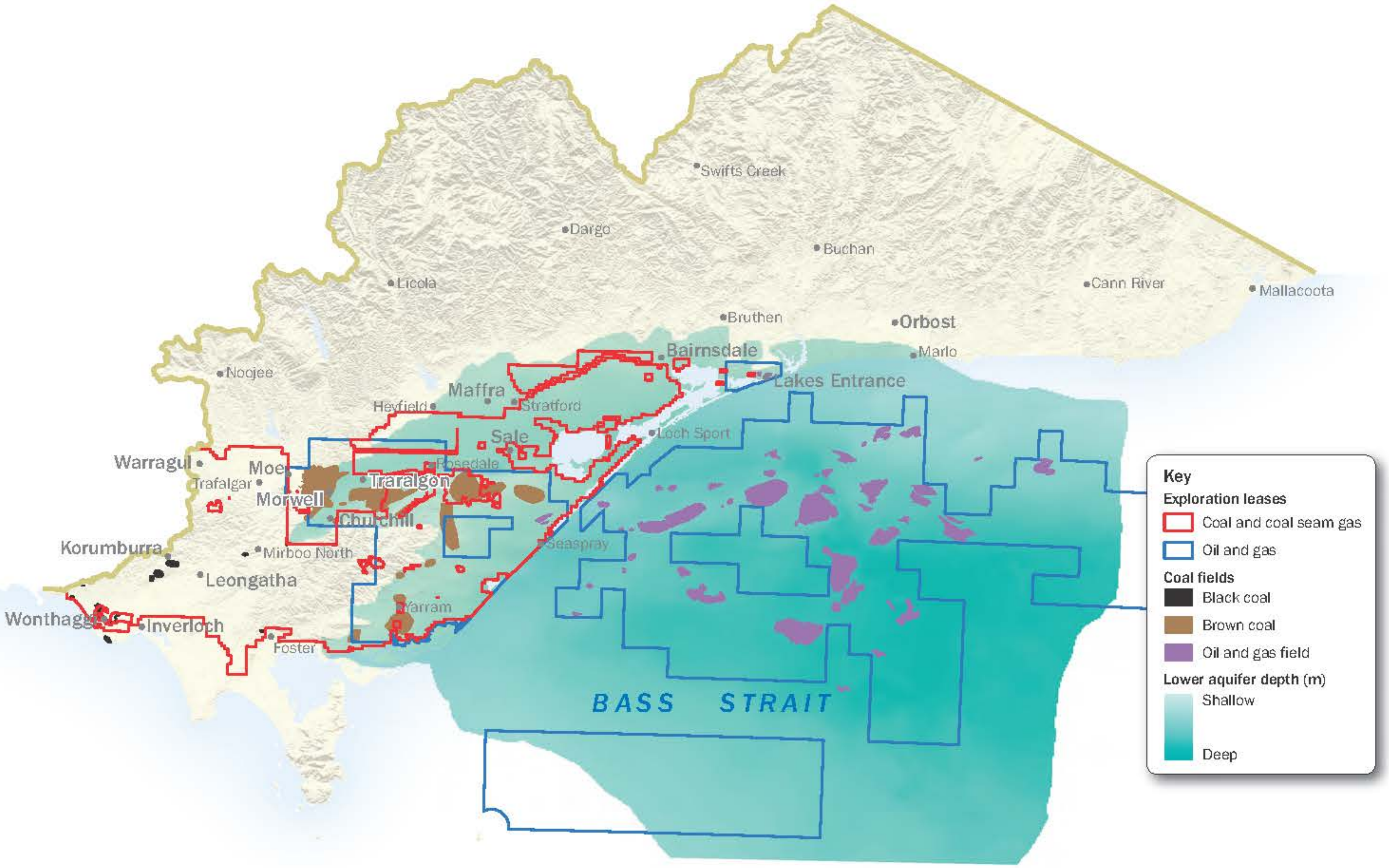
Until the late 1960s **black coal** fields were mined in the south west of Gippsland. Black coal occurs at greater depths, has much smaller reserves and is at greater risk of gas explosion than brown coal. It has lower moisture content (5-10%) than brown coal, so is more efficient and produces less carbon emissions. Black coal was originally mined for use in steam locomotives, however since the introduction of electric engines the need has diminished.

The **brown coal** deposits in the Latrobe Valley are the largest of their type in the world. The total area of coal reserve covers 55,000 hectares. The coal occurs in seams hundreds of metres thick near the ground surface. Electricity generation using brown coal produces more carbon emissions than black coal because of its high moisture content (about 65%). Carbon capture and storage projects to manage the emissions are being tested. An example is **geosequestration** where carbon gases are injected deep underground (>800 metres).

Coal seam gas (methane) development is being explored in Gippsland at depths of approximately 800 metres. Some processes may inject substances into coal seams (fraccing) to improve gas extraction. Gas may also be produced by burning the coal seam. The low methane content in brown coal, compared to black coal, presents technical challenges.

Oil, gas and water all occur as fluids under pressure approximately 2,000 metres below sea level in the offshore part of the Gippsland Basin aquifers. Reservoirs have formed where the oil and gas is trapped. The current reserves of Bass Strait oil and gas are expected to continue for several decades and exploration is under way into deeper formations to find new reservoirs.

Geothermal energy exploration for deep groundwater (>1,000 metres) warmer than 70°C, is under way in the basement formations that underlie the coal bearing sediments. The heat in the deep rocks can be brought to the surface by water pumped up from the basement rock or by circulating water from the surface through the rock back to the surface.



Map of Gippsland basin, oil and gas fields, and exploration licences

Regulation

Exploration and production within Victoria's state boundary (including three nautical miles offshore) is licensed by the State through the Department of Primary Industries (DPI). Most of the Gippsland Basin is covered by exploration licences for coal, gas and oil. Although not shown on the map, there are many other licences for minerals exploration and extraction (eg metals and sand) that also pump groundwater.

Mining activities in the Latrobe Valley are regulated by the Department of Primary Industries (DPI) and groundwater licences are issued by Southern Rural Water (SRW). The three mines own and maintain a shared observation bore network and they are required to comply with annual reporting requirements.

Similarly, coal seam gas projects are regulated by DPI. They require groundwater and bore construction licences from SRW if they intend to extract water and they require approval if they intend to inject chemicals underground. The Environment Protection Authority also regulates the injection of chemicals underground.

Geothermal and geosequestration projects are also subject to SRW's licensing and approval processes.

Exploration and production offshore is subject to Federal regulation but managed in cooperation with DPI. SRW does not regulate groundwater in Bass Strait.

For more information about current water regulations see Southern Rural Water's fact sheets visit www.srw.com.au

Groundwater management and energy

Groundwater use

To access the coal and maintain mine stability, aquifers are depressurised by pumping groundwater. This groundwater is used in the operations of the power stations. The open cut mines are likely to operate for many more decades. While rehabilitation options are being investigated, post-closure rehabilitation is difficult. The volume of the pits is too large to fill with soil or water. Unless the pits are filled the recovering groundwater pressures will cause their slopes to fail and collapse. The seeping groundwater will evaporate in great volumes.

As **offshore oil and gas** reservoirs are depleted the pressure in the basin falls. This has been observed in onshore observation bores as falling groundwater levels (see Chapter 6: Regional trends).

Finding a replacement supply for Victoria's dwindling gas resources is a high priority. Deeper resources are being explored offshore. Coal to gas processes that take advantage of the brown coal resources are an option.

Another option is **coal seam gas** which uses approximately 100 ML/yr of groundwater per well to release the gas from the coal. Commercial operations could involve several hundred wells. This process has the potential to use large volumes of groundwater. The groundwater used in the wells could be disposed, re-injected or reused.

Geothermal production is likely to use much less groundwater because the groundwater is often recirculated in the bore.

Subsidence

Subsidence occurs when groundwater is removed and the aquifer compresses. It can decompress if the aquifer pressure is restored but permanent compression may also occur.

Subsidence has occurred in the Latrobe Valley due to depressurisation of the open-cut mines. The most severe occurrence is up to 2.5 metres of settlement immediately adjacent to the mines where it has affected buildings, dams, roads and rivers. Subsidence in the Latrobe Valley is monitored and reported regularly.

Falling groundwater pressure may cause subsidence along the Ninety Mile Beach. Estimates range from 100 mm to 800 mm based on a range of assumptions. Satellite surveys conducted from 2004-05 by DPI found that no measurable movement had occurred in that period. A 2007 study by CSIRO concluded that the subsidence calculation was uncertain and that a greater risk to the coast was rising sea levels and storm surges due to climate change. DSE is committed to further investigation as part of the Gippsland Sustainable Water Strategy.

Seawater intrusion

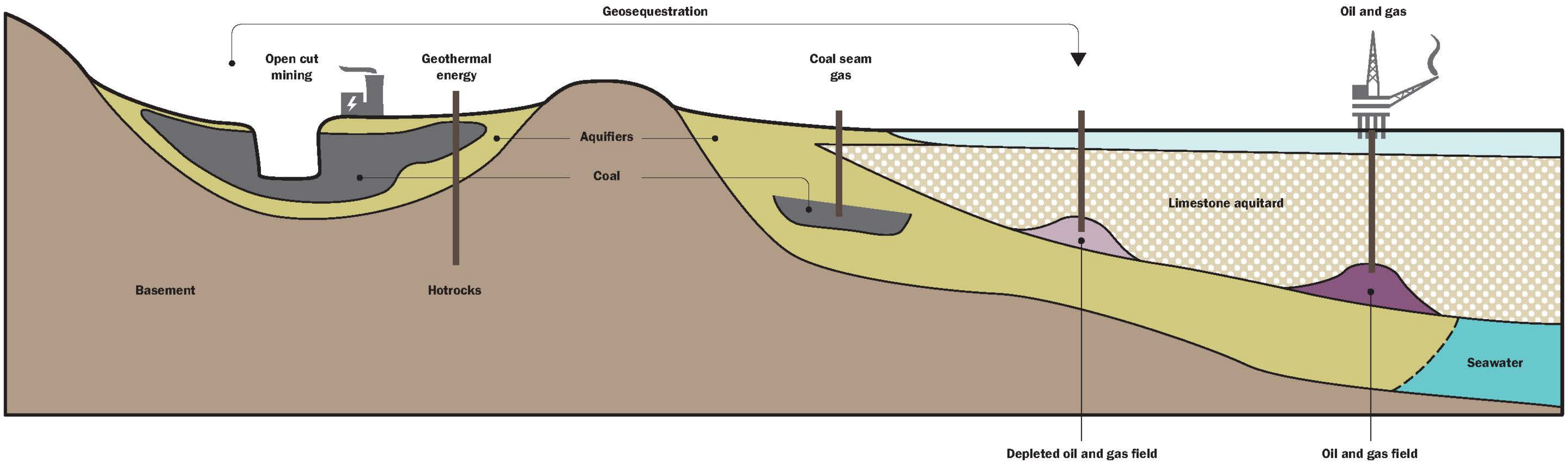
Falling groundwater pressures may lead to sea water intrusion. As the fresh groundwater pressure falls, the denser sea water advances towards the coast. Fresh groundwater can be found well offshore which indicates there is no immediate problem. The Yarram Water Supply Protection Area Groundwater Management Plan proposes that groundwater salinity be monitored in observation bores along the coast. It also prescribes transfer rules that encourage the transfer of groundwater licences away from the coast.

For more information about energy production visit:

www.dpi.vic.gov.au/earth-resources

Observations

- **Brown coal reserves in the Latrobe Valley and oil and gas reserves in Bass Strait are strategically and economically important resources.**
- **Onshore mining activities are regulated by DPI and the associated water use is regulated by Southern Rural Water.**
- **Offshore oil and gas extraction is regulated by the Federal Government.**
- **Energy production has a regionally significant impact on groundwater and this may continue well into the future.**
- **Subsidence has occurred in the Latrobe Valley, however it has not been observed anywhere else in the region.**



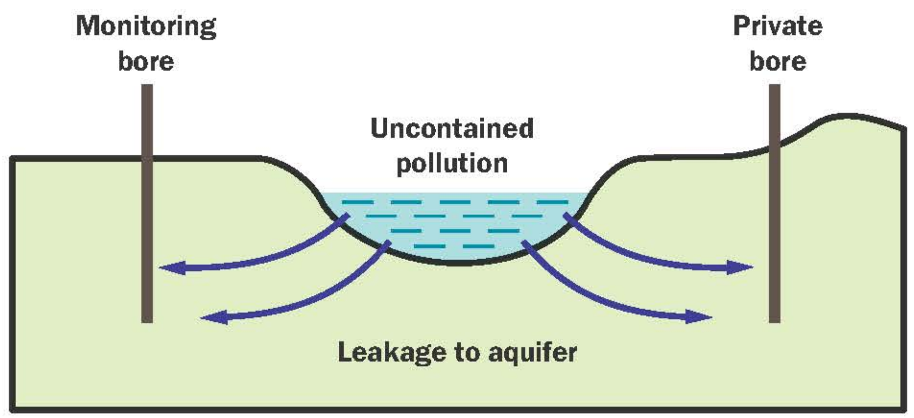
Groundwater protection

Groundwater is a valuable resource used by humans and the environment. It is therefore a matter of public interest to protect it from pollution and degradation.

The Environment Protection Authority (EPA) is responsible for developing and enforcing policies in this area. Other agencies such as the Department of Sustainability and Environment (DSE) and Southern Rural Water (SRW) are responsible for implementing policies.

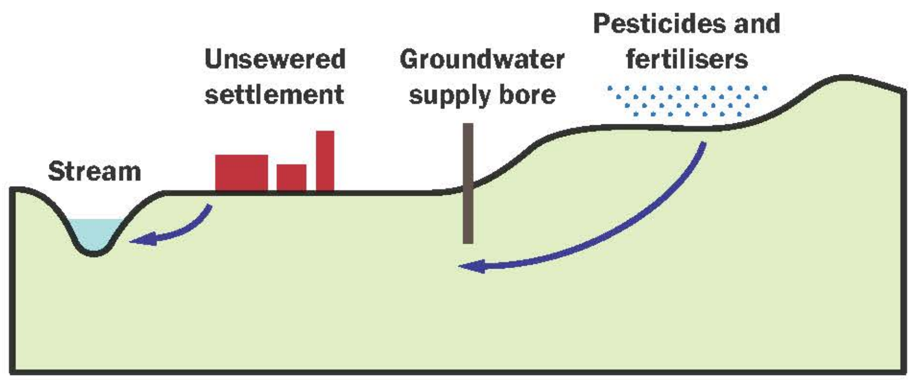
Types of pollution

Point source pollution refers to a single identifiable source of pollution and may be very concentrated. Examples include landfills, industrial sites, intensive agriculture (eg feedlots), service stations and hazardous materials or waste storage areas.



Example of point source pollution

Diffuse pollution refers to pollution that occurs over a wide area and cannot be easily attributed to a single source. Many small sources can add up to have a significant impact on regional groundwater quality. Examples include agricultural chemicals (fertilisers, pesticides and herbicides), septic tanks and saltwater intrusion.



Examples of diffuse pollution

Policy and regulation

The State Environment Protection Policy for Groundwater (SEPP GoV) is regulated by the EPA. It is responsible for protecting existing and potential beneficial groundwater uses.

The EPA regulates existing and potential pollution sources through a licensing system that includes pollution prevention, monitoring and reporting. Non-compliance can result in users being prosecuted and required to clean up polluted sites. Sites with significant groundwater pollution that cannot be completely cleaned up are listed as Groundwater Quality Restricted Use Zones (GQRUZs). There is one identified GQRUZ in Gippsland. A change of land use may trigger a site investigation. This means that sites polluted prior to the introduction of strict regulation can be identified.

SRW regulates “disposal of matter underground”. This includes activities that occur under controlled conditions such as aquifer storage and recovery and in-bore desalination.

Diffuse pollution is managed through guidelines, codes of practice (eg for chemical use, septic tank performance) and education. For example the installation of septic tanks is managed in accordance with the EPA’s code of practice for on-site wastewater management that recommends a setback distance between septics and bores.

Groundwater pollution from septic tanks may occur in unsewered towns such as Venus Bay and Sandy Point (eg there are over 2,500 septic systems in Venus Bay). In these areas investigations have found bacteria and nitrate contamination in aquifers that are used by bore owners.

There is no guarantee of groundwater quality for bore owners. Groundwater users are responsible for assessing the suitability for the end purpose and for treating the water if necessary.

Monitoring

Point source pollution is regularly monitored to comply with EPA requirements. Data collected is normally held in private databases and reported to the EPA.

The SEPP GoV requires appropriate groundwater quality monitoring. DSE has responded with a risk-based approach to its state-wide groundwater monitoring program. Groundwater quality risks from diffuse sources do not justify a scheduled program. Groundwater quality data collected is recorded on the Groundwater Management System which is hosted by DSE.

Environmental monitoring for nutrient and salinity management is conducted in the Lake Wellington catchment to manage the impact of irrigation in the Macalister Irrigation District (MID).

Nutrient monitoring (including nitrates) is conducted from groundwater pumps in the MID and around Lake Wellington. The concentration of nutrients has not changed over time, suggesting that nutrients from farming activities are not accumulating in the groundwater.

Observations

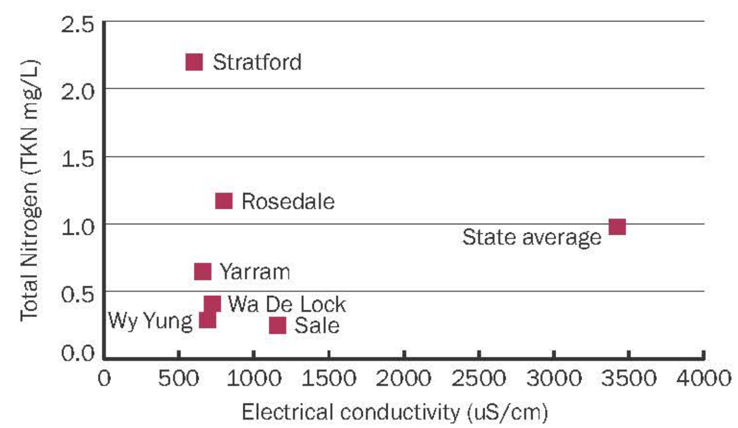
- **Groundwater quality is regulated by the EPA. Other agencies such as DSE and SRW are responsible for implementing policies.**
- **High risk point source pollution is more highly regulated, monitored and reported than diffuse pollution.**
- **Groundwater users are responsible for assessing the suitability for the end purpose and for treating the water if necessary.**
- **Testing indicates that groundwater quality in Gippsland is good relative to the rest of the state.**

Salinity is measured in the Lake Wellington salinity plan bore network. Salinity monitoring is also conducted in areas considered to be at risk from saltwater intrusion (eg along the coast and the Gippsland Lakes). No evidence of saltwater intrusion has been detected to date.

In 2008 groundwater quality across Victoria was analysed for parameters including pH, temperature, electrical conductivity, common salts, nutrients, metals, bacteria, pesticides, volatile chemicals and carbon date.

Harmful pollution such as pesticides and volatile chemicals were not detected in high risk areas in other parts of the state. The chart below shows how the Gippsland GMUs compare with the state averages for electrical conductivity and nitrogen.

Average groundwater quality by measured GMUs



This suggests that Gippsland’s groundwater quality is very good. Even though the nitrogen content measured in the Stratford and Rosedale GMUs is higher than average it is suitable for most purposes.

For more information on groundwater quality please refer to the weblinks on page 4: Glossary, units and links.

The value of groundwater

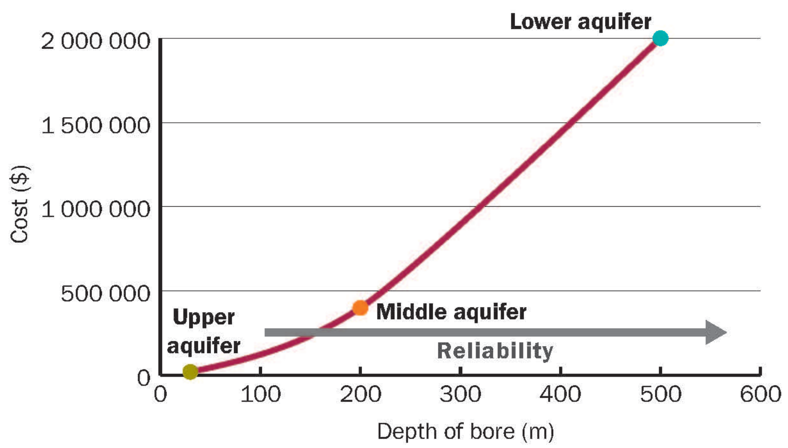
Reliability and security strongly influence the value of groundwater.

Reliability refers to a bore that is always able to supply at the rate and volume needed. Security refers to the certainty of the user being able to access their legal entitlement (specifically a licence or protection to access water enabled by the Water Act 1989).

Reliability

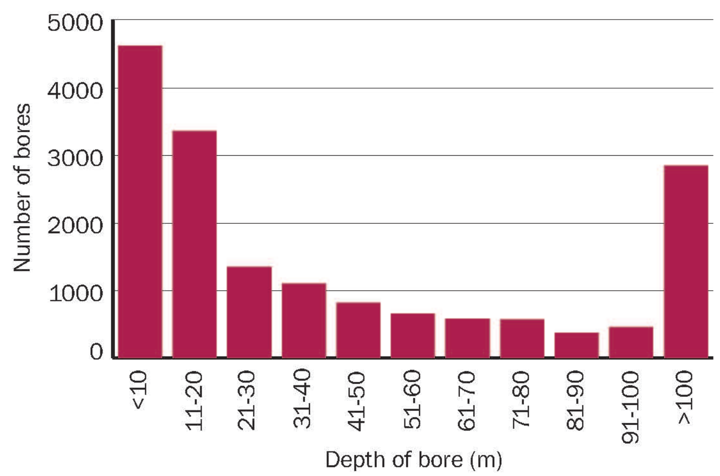
Bores drilled into deep thick aquifers are usually the most reliable. However they cost more to construct (see graph below) and to pump.

Depth of bore versus cost to construct



Over 60% of registered bores are less than 50 metres deep.

Number of bores by depth



Depth of bores sourced from GMS 2011

The willingness of a user to pay for reliability is influenced by their return on investment and the cost of finding an alternative water supply. The table below shows the estimated groundwater value for the different user groups in the region.

Value of production

Value	Domestic & stock*	Agribusiness**	***Urban	***Industrial
$	5,936,000	70,639,000	13,133,000	111,000
$/ML	900	1,400	3,800	3,800

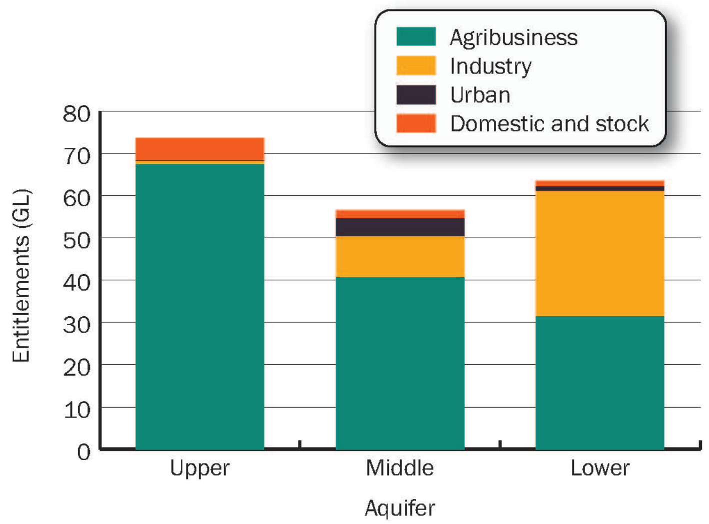
Source: RMCG 2011

* Domestic and stock value is based on the annualised cost to replace a bore

** Agribusiness value is based on the average additional production from using groundwater. The value could also be estimated by adding the cost of replacing bores eg ~900 - 3,000 ($/ML)

*** Urban and industrial value is based on the cost of an alternative water supply. These industrial use figures do not include the power and energy industries that dewater aquifers to access coal, oil and gas. If value was based on the cost of replacing bores in these industries it would be enormous (many billions) compared to the values estimated above.

Entitlements by aquifer



Security

Most known groundwater sources are fully allocated and capped and it is becoming increasingly difficult to find new sources. However, users generally use less than 50% of their entitlement. This means that there is potential for trade.

Observations

- Users want a secure entitlement with a reliable supply at a cost they can afford.
- Users with higher value needs are willing to increase reliability by drilling deeper – this influences the distribution of users across aquifers.
- In the coal, oil and gas extraction industries where groundwater is used for operational purposes its value is enormous compared to other uses.
- Although opportunities to obtain a new entitlement are limited, a large proportion of entitlement is unused. This volume may be accessed by transfers (trading).

Future development opportunities for new or existing groundwater users include:

- **Trading an existing entitlement** – the price of traded groundwater is not fixed and is generally not reported. Anecdotally it costs approximately $1,000/ML per year for a permanent transfer and $100/ML per year for a temporary transfer.
- **Managed Aquifer Recharge (MAR)** – this means taking a nearby surplus of surface water, storing it in an aquifer and extracting it when needed. The annualised cost of MAR projects ranges from $2,000/ML per year for small projects to $1,000 /ML per year for large projects. The higher costs for small projects is due to high initial infrastructure costs.

For more information about MAR visit www.nwc.com.au

Chapter 4: Upper Aquifers

Upper aquifers occur along the river valleys of the Thomson, Macalister, Avon, Mitchell and Snowy Rivers. They comprise thin, sand and gravel sediments at shallow depths. Recharge occurs directly from rainfall and discharge is to streams and lakes.

The better parts of these aquifers are high yielding and good quality. This makes them suitable for uses such as agribusiness (pasture, dairy wash and horticulture), domestic and stock, and the town supply at Briagolong.

Public groundwater pumps are used to control high water tables caused by irrigation in the aquifers underlying the Macalister Irrigation District.

In this chapter you can find information on:

Page heading	Description	Page
Geology	Describes the aquifers and aquitards in the region according to the aquifer grouping shown on page 8, and maps their spatial extent	30
Salinity and yield	Maps are included showing the expected salinity and yield, and a combined salinity and yield map that indicates the groundwater use potential	31
Movement of groundwater	Describes how groundwater movement, explained on page 15, occurs within the upper aquifers of Gippsland	32
Environmental dependence	Discusses how groundwater interacts with the environment, discussed on page 17, particularly with groundwater dependent ecosystems	33
Water balance	Describes the water balance, introduced on page 17, in terms of water volumes entering and leaving these aquifers. It includes a case study from the Macalister Irrigation District	34
Regional trends	Presents data from selected State Observation Bores and indicates regional groundwater level trends	35
Users and usage	Provides licensing information about who uses groundwater from upper aquifers, how much they use and the value derived from this use	36
Current and emerging issues	Discusses some of the key issues facing groundwater managers	37

Geology

These aquifers consist of coarse sand and thick gravel along the river valleys in the top 50 metres of the sedimentary basin and in dune deposits near the coast.

Porous sand and gravel aquifers underlie productive farmland along the river valleys and flood plains of the Latrobe, Thomson, Macalister, Avon and Mitchell Rivers. The aquifers originate from an alluvial fan (Haunted Hills Formation) that formed at the foot of the mountain ranges in the period from 4 million to 10 thousand years ago. Prior and current streams have eroded the fan into beds of sand and gravel. The aquifers occur at or near the ground surface and receive recharge directly from rainfall and floods. These beds are surrounded by a clay aquitard.

Other sand and gravel alluvial deposits that form aquifers occur in the eastern rivers of Gippsland. The most notable of these are the Curlip Gravels along the Snowy River near Orbost. Sand and gravel aquifers occur along the river valleys at Licola, Dargo and Swifts Creek.

Dune deposits

Sandy dune deposits occur in coastal areas and are particularly important aquifers in the Sandy Point, Venus Bay and Loch Sport areas but are not significant east of Lakes Entrance. These aquifers are an important source of fresh water in an otherwise saline environment.

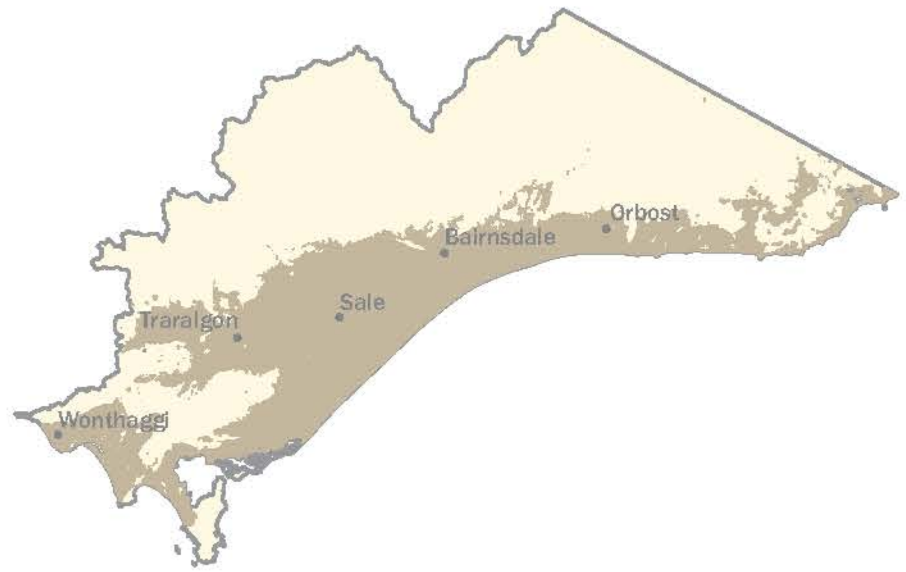
Observations

- **Sand and gravel deposits form localised but important aquifers along the river valleys, flood plains and near the coast.**
- **A clay aquitard known as the Haunted Hills Formation overlies most of the sedimentary basin.**
- **These aquifers occur at or near the ground surface so they receive recharge directly from rainfall and floods.**

Aquifer structure

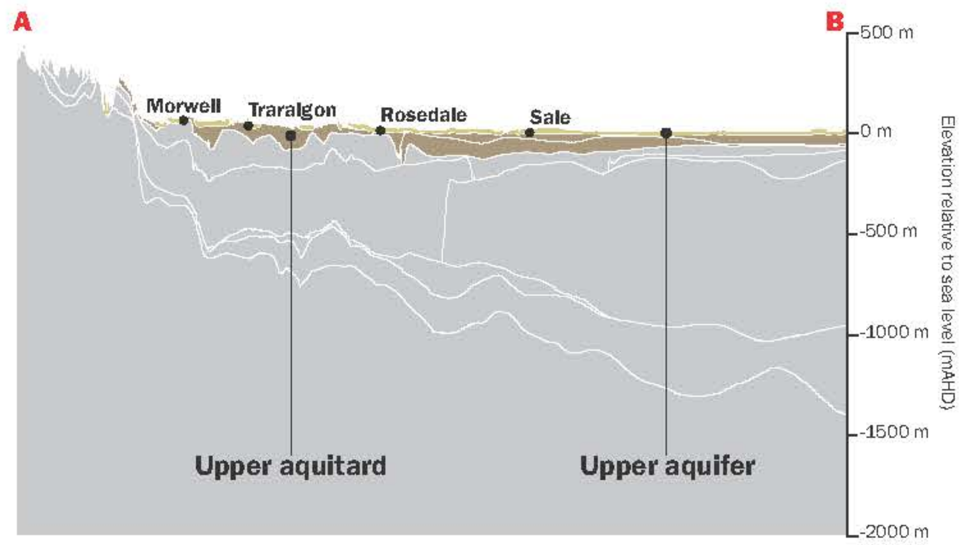
Upper aquifer thickness (Quaternary Alluvials) and underlying upper aquitard extent (Haunted Hills Formation)

Light colours show where the aquifer is thin and dark colours where it is thick. The brown shading shows the extent of the underlying aquitard.



Upper aquitard extent

The upper aquitard exists between the upper aquifers and the upper middle aquifers (discussed in Chapter 5).



Cross-section A-B

Created from map on left showing the upper aquifer and aquitard.

Salinity and yield

Groundwater development of the upper aquifers is substantial in the Lake Wellington catchment and Mitchell River valley due to high yielding (greater than 10 L/s) and low salinity (less than 1000 mg/L) aquifers. Elsewhere, salinity and yield is less suitable for commercial usage.

Smaller, localised areas of usable groundwater occur near Moe, Orbost and the South Gippsland coast and in the upper valleys of the Macalister, Mitchell, Tambo and Snowy Rivers (at Licola, Dargo and Swifts Creek).

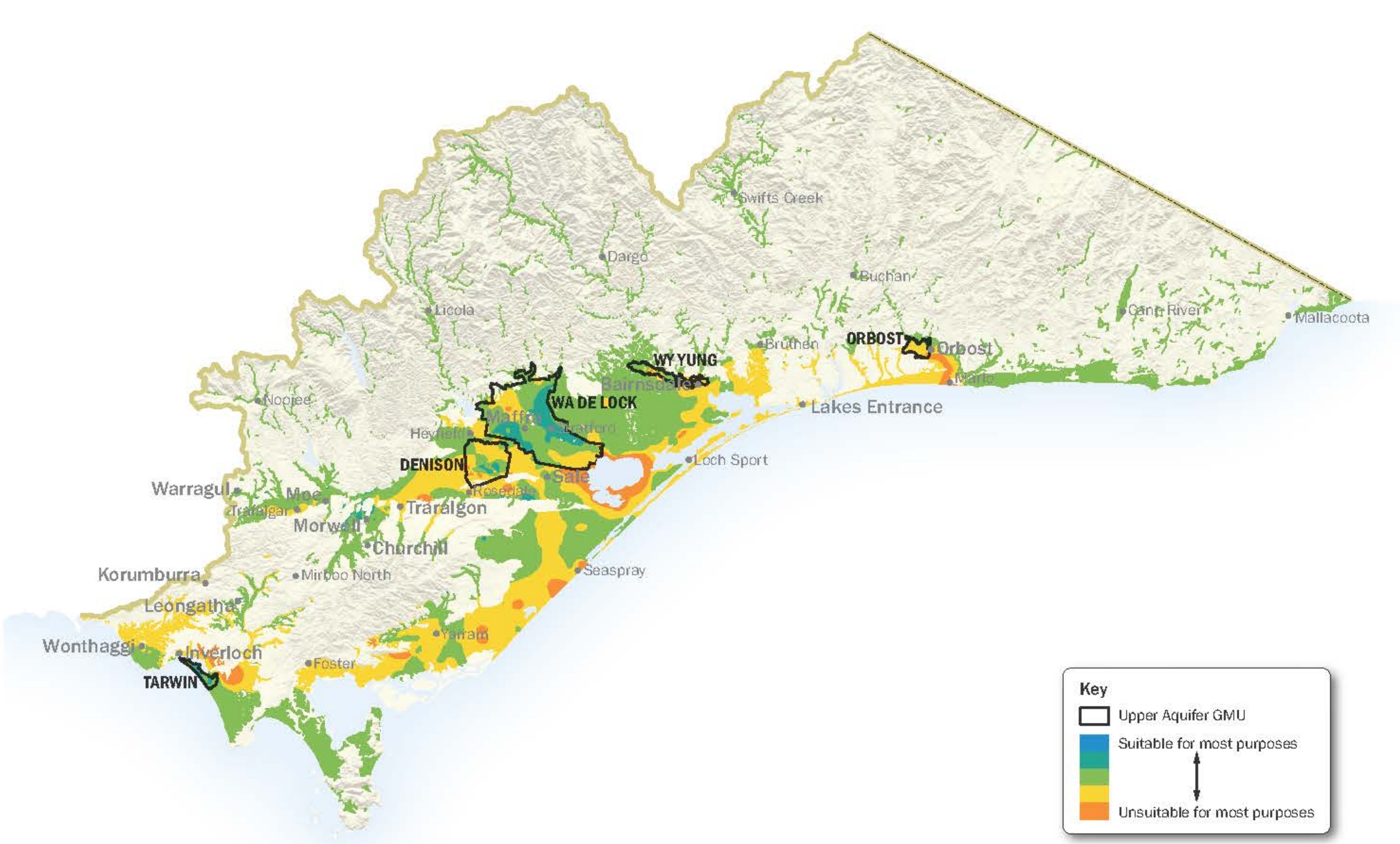
Outside the valleys, low yielding, poor quality aquitards cover most of the region. The high clay content makes them too low yielding for most purposes.

It is estimated that about 10,000 GL of fresh water (less than 1000mg/L) is stored in these aquifers.

The maps below are more reliable in areas where there is a high density of bores and groundwater development. Outside these areas there is very little data and most of the mapping has been extrapolated from areas with similar characteristics.

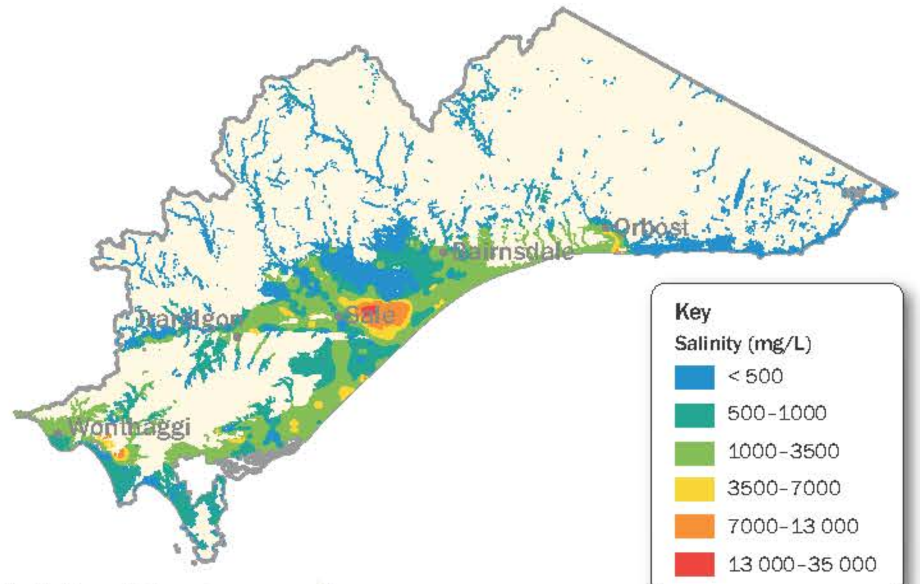
Observations

- **The aquifers along the river valleys particularly in the Lake Wellington catchment contain groundwater that is suitable for most purposes.**
- **Much of the area outside the groundwater management unit boundaries is too low yielding or saline for most commercial uses.**

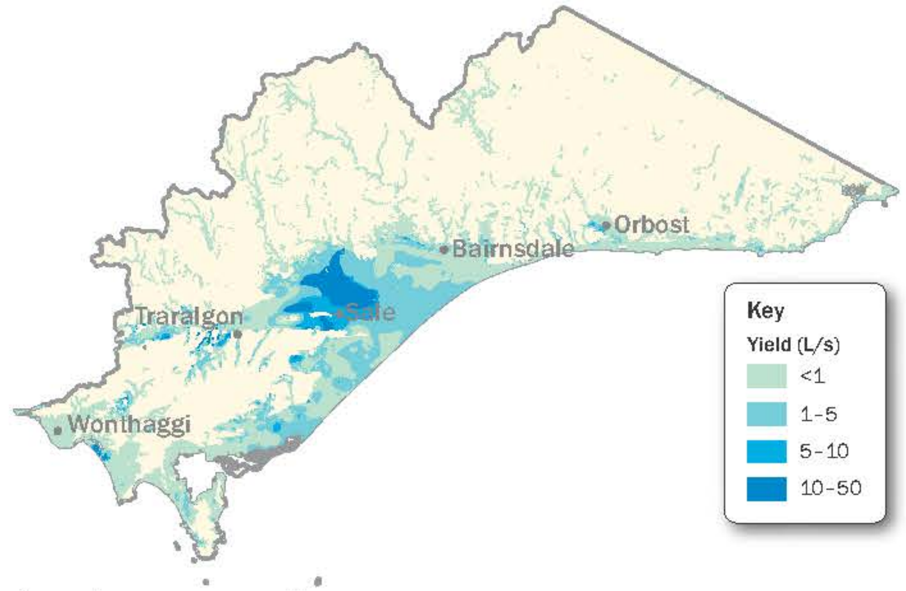


Groundwater use potential based on salinity and yield

This map combines salinity and yield information to show a snapshot of the potential for groundwater use in the region. This map should not be used to make commercial decisions. Potential users should seek information from hydrogeologists and drillers with expertise in the area as well as local information about existing bores.



Salinity of the upper aquifers



Yield of the upper aquifers

Movement of groundwater

Horizontal groundwater movement in the unconfined upper aquifers follows the structure of each aquifer from high to low elevation. Vertical movement through to the underlying formations also occurs.

Flow systems

Local flow systems occur around the basin margins along the flanks of the mountain ranges. Here the flow paths are steep and short before the water intercepts the ground surface in depressions and stream beds.

Intermediate and regional flow systems occur in the flatter gradients of the central flood plains and coastal sections of the Gippsland Basin. In these systems shallow groundwater moves very slowly and discharges to the Gippsland Lakes and surrounding wetlands.

Interception

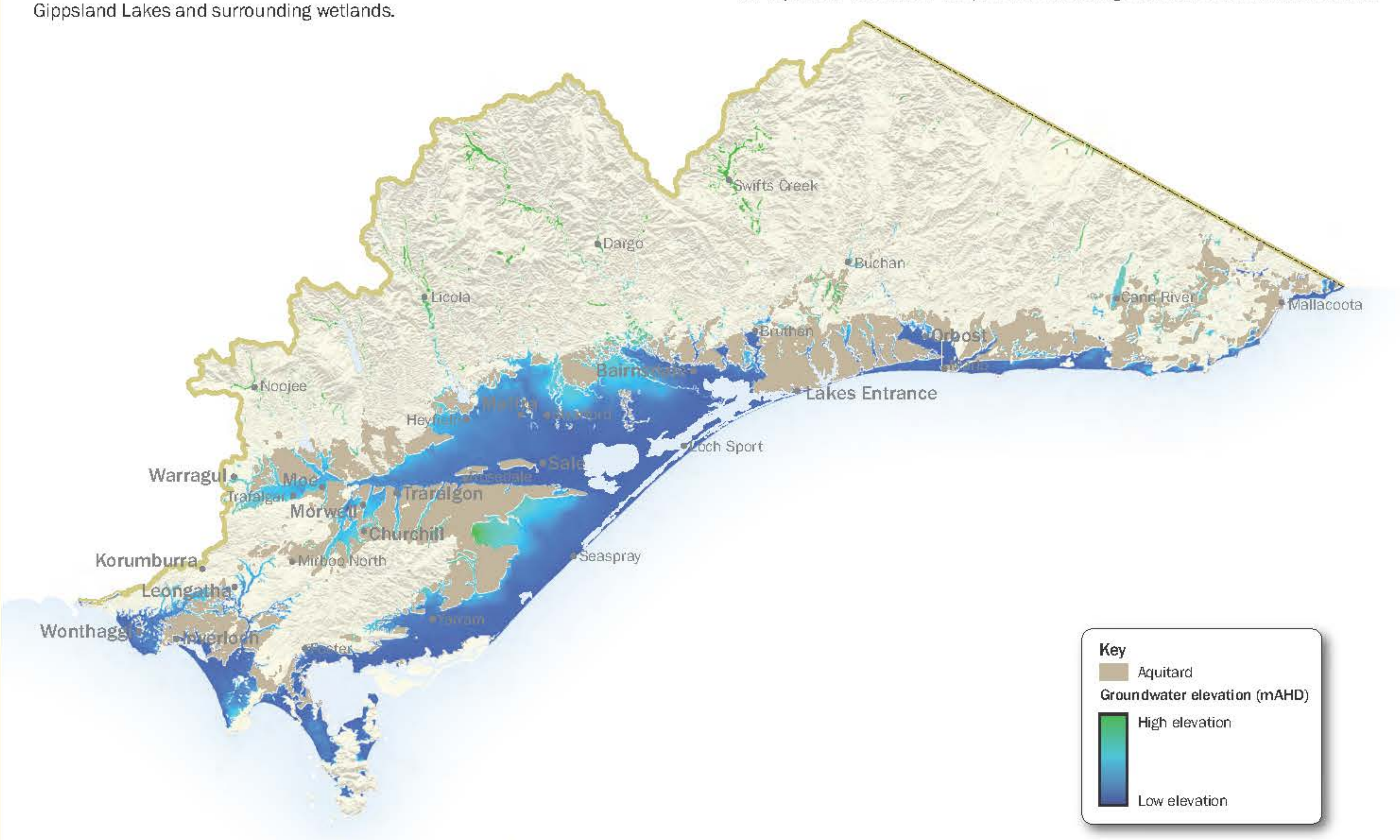
A bore anywhere along a flow system can intercept groundwater before it discharges to surface water environments such as streams or lakes. For example bores in the local systems along the Freestone Creek near Briagolong, intercept groundwater that could otherwise contribute to stream flows. The further a bore is from a stream the lesser and more delayed is the impact of its interception on groundwater.

Vertical movement

Vertical movement is generally much slower than horizontal movement. This is because the underlying material such as clay has a low permeability compared to sand or gravel. The exceptions are in areas around the basin margins where the aquitards are thin or not present and along fault lines that transmit water.

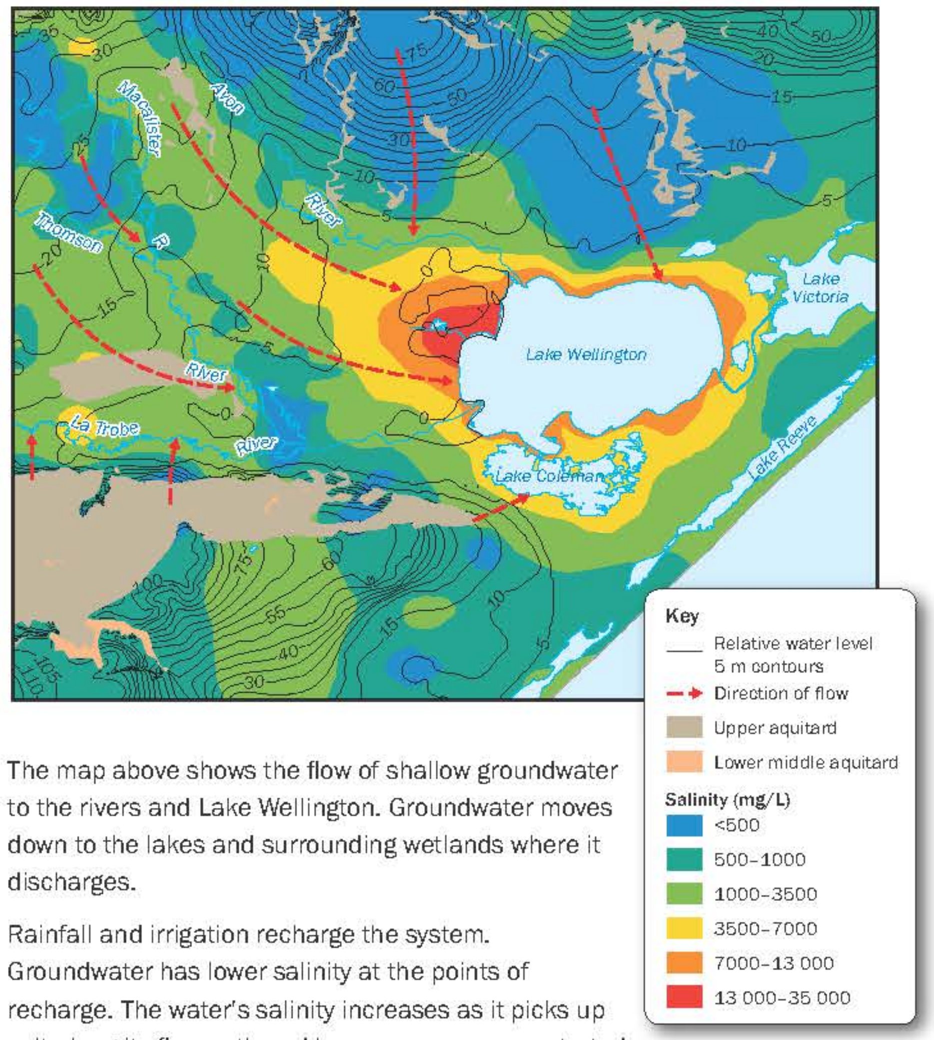
Observations

- **Local flow systems occur around the basin margins along the flanks of the mountain ranges.**
- **Regional flow systems occur in the flood plains of the Gippsland Lakes system.**
- **If groundwater is intercepted along a flow system it can affect the discharge to streams and other surface water environments.**
- **In these aquifers salinity increases when the water table approaches the surface where the system discharges (eg lakes and wetlands).**



Groundwater elevation

Groundwater flows from areas of high (shown in green) elevation to low elevation (shown in blue).



The map above shows the flow of shallow groundwater to the rivers and Lake Wellington. Groundwater moves down to the lakes and surrounding wetlands where it discharges.

Rainfall and irrigation recharge the system. Groundwater has lower salinity at the points of recharge. The water's salinity increases as it picks up salt along its flow path and become more concentrated as a result of evaporation when it discharges around Lake Wellington.

Environmental dependence

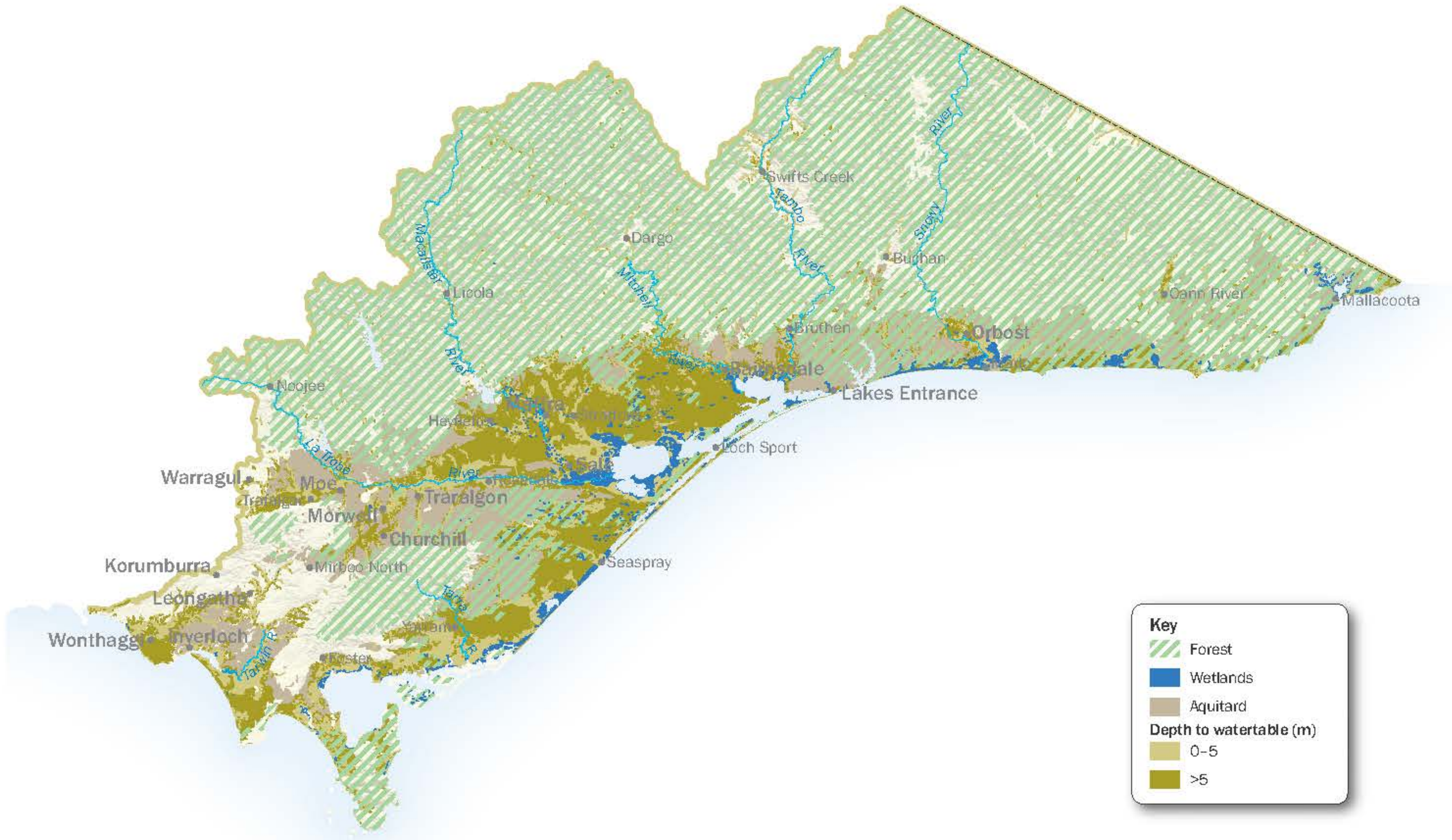
Upper aquifers interact closely with surface water environments such as streams, lakes and wetlands. They help to support ecosystems and also provide a direct source of water for deep-rooted vegetation.

Groundwater Dependent Ecosystems (GDEs)

The map below shows potential GDEs. It includes areas that may receive saline discharges such as coastal lakes and internationally recognised wetlands near the Gippsland Lakes. Fresher groundwater discharges occur to streams higher in the catchment. Vegetation overlies shallow watertable in some areas.

The environment uses vast amounts of groundwater by evapotranspiration of shallow watertables. The estimated evapotranspiration from the Avon River catchment is approximately 60 GL/yr. By comparison licensed groundwater extraction is around 4 GL/yr from the same area of aquifer and average stream flows are 150 GL/yr.

It is most likely that subterranean ecosystems occur in the valleys along the Thomson, Macalister, Avon, Mitchell and Snowy Rivers in shallow aquifers with good water quality (eg neutral pH and electrical conductivity less than 5,000 us/cm) along present or historic river beds.



Groundwater and the environment

The map above shows potential GDEs, forested areas and shallow watertables. The GDE mapping can be found at **www.bom.gov.au/water/groundwater/gde/**

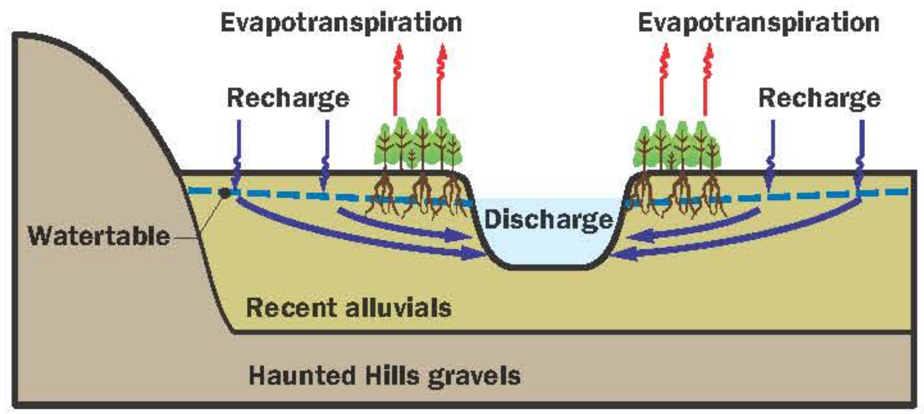
Observations

- **Surface water environments with significant ecological value along the rivers, near the coast and around the Gippsland Lakes may interact with groundwater.**
- **Significant amounts of groundwater are accessed by the environment using evapotranspiration.**
- **Groundwater contributions to rivers can be significant during low flow periods (summer and autumn).**

Baseflow to rivers

Most of Gippsland's rivers receive baseflow from groundwater. Studies have shown the importance of groundwater to the flows of the Avon, Mitchell and Tarra Rivers.

The Avon and Mitchell Rivers are connected to groundwater in the sand and gravel alluvium of their floodplains. The rivers gain groundwater during low flows as shown in the diagram below. During floods the river recharges the alluvial aquifers.



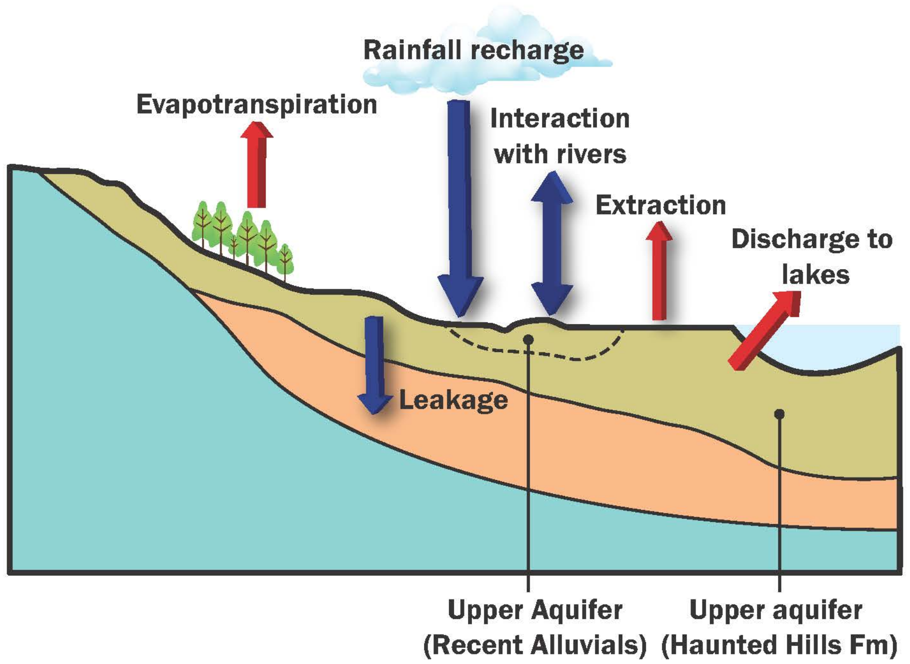
Groundwater pumping

Rivers are most likely to be affected by groundwater pumping in dry years when river flows are low and pumping peaks. It is estimated that groundwater pumping next to the Mitchell River at Wy Yung can reduce river flows by up to 13% during dry summers. This reduction in river flows happens with very little lag time because the bores are close to the river and groundwater moves quickly through the sand and gravel aquifer.

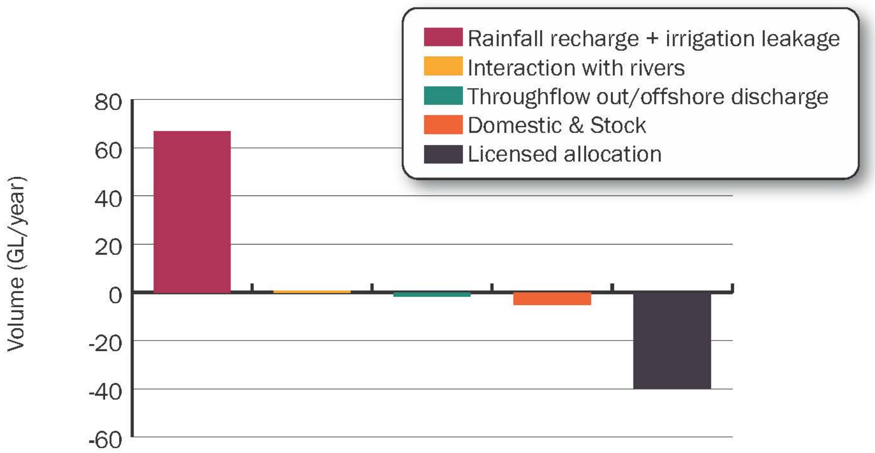
Water balance

There are several isolated basins that comprise the upper aquifers. These aquifers are generally unconfined and interconnected with local streams. Apart from the Lake Wellington catchment, few detailed water balance studies have been conducted.

The diagram below shows the elements of the water balance for the upper aquifers. Recharge is highest in the porous alluvium. Discharge occurs through baseflow to streams, evapotranspiration, discharge to lakes and offshore, leakage to deeper aquifers and extraction.



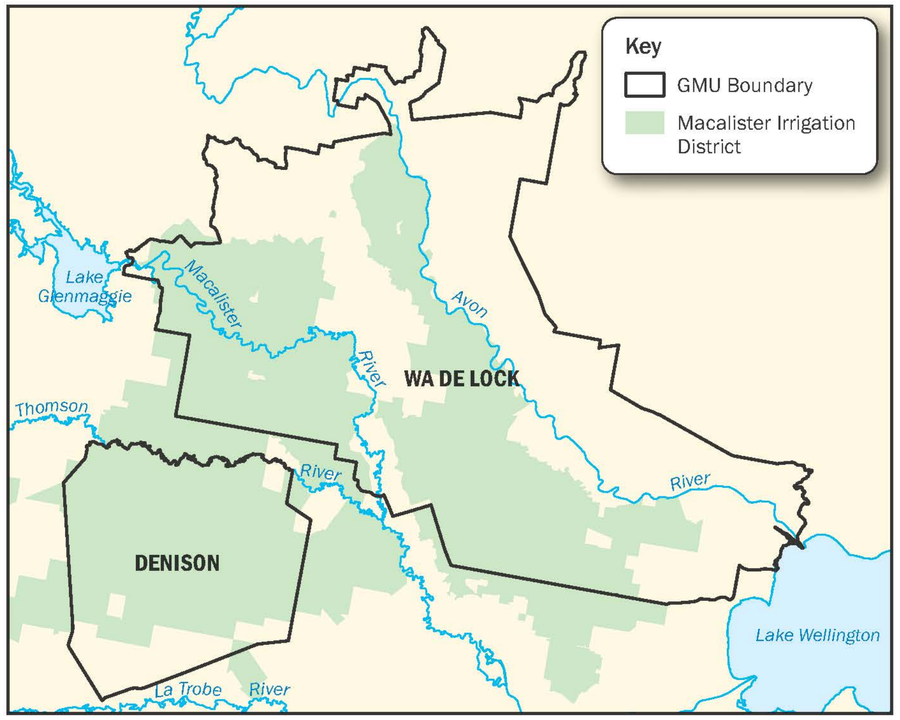
The graph below shows the estimated water balance of the upper aquifer groundwater management units (GMUs) in Wy Yung, Wa De Lock, Denison, Tarwin and Orbost. Overall, the estimated recharge is approximately equal to current allocation.



The major influences on water balances of these upper aquifers are rainfall recharge and pumping. Evapotranspiration and land use were not analysed in this estimate, however these factors are known to impact the water balances of upper aquifers elsewhere.

Macalister Irrigation District (MID) case study

The MID covers large areas of the lower Lake Wellington catchment. Groundwater use is greatest in the areas covered by the Denison and Wa De Lock GMUs where low salinity, high yielding alluvial aquifers occur.

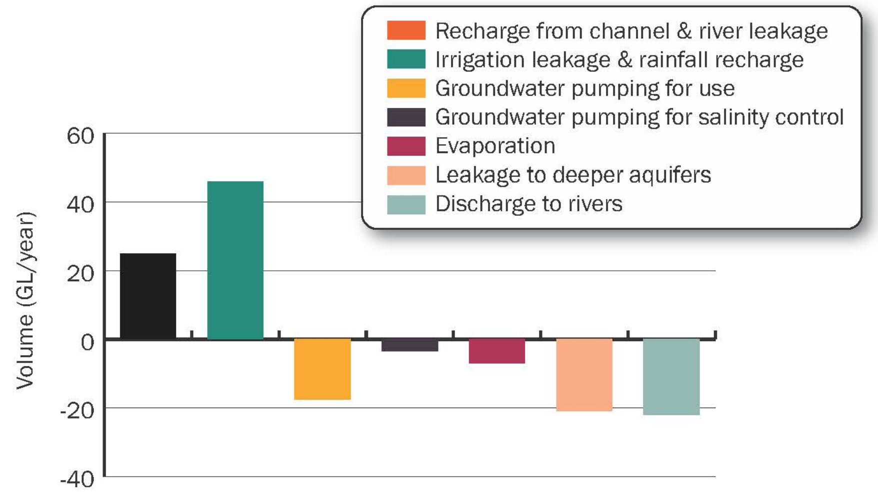


The graph to the right shows the MID water balance in an average year. Leakage from irrigation contributes to high water tables and land salinisation. Groundwater control pumps are used to pump excess water (irrigation leakage). In wet seasons when recharge is high and groundwater usage is low, up to 4 GL is pumped for groundwater control.

Observations

- **Direct recharge from rivers, rainfall and irrigation leakage contribute significantly to the water balance in the upper aquifers**
- **Irrigation leakage can significantly impact the water balance in intensive irrigation districts like the MID.**
- **Compared to deeper aquifers, upper aquifers are more sensitive to recharge and pumping.**

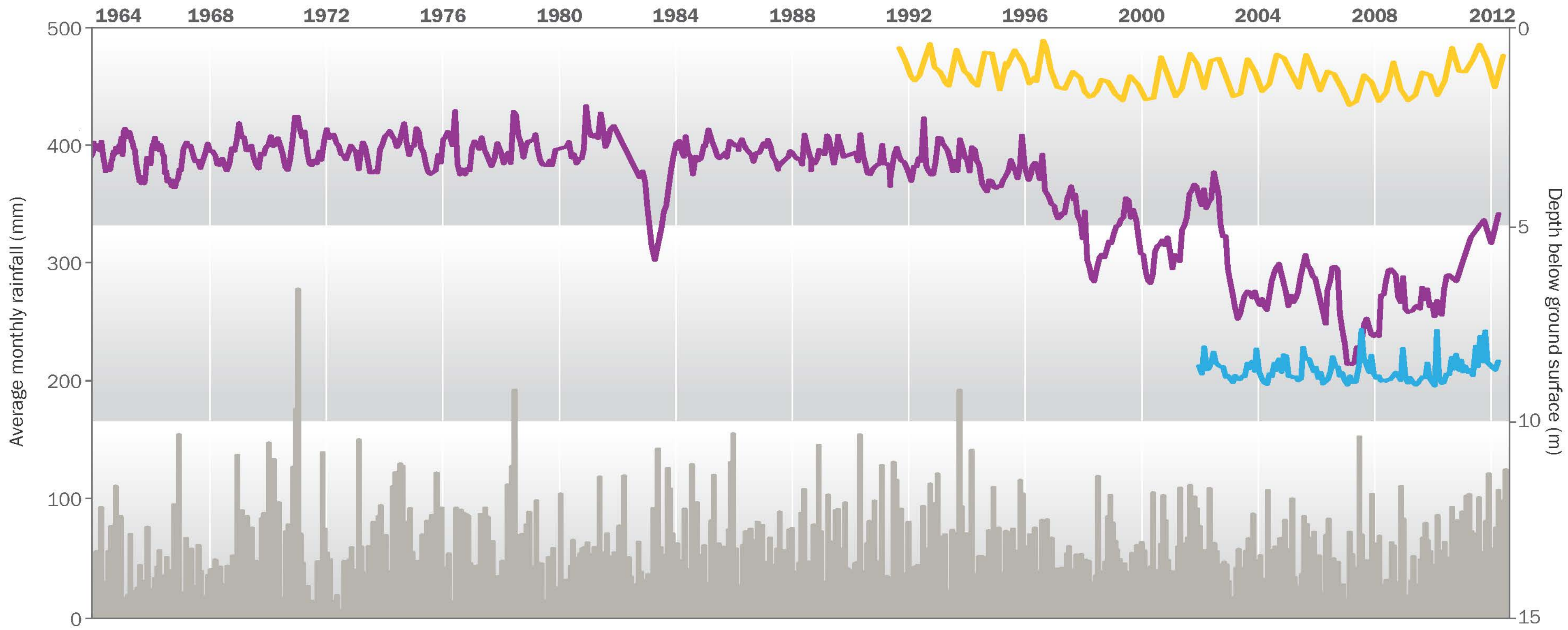
MID groundwater balance

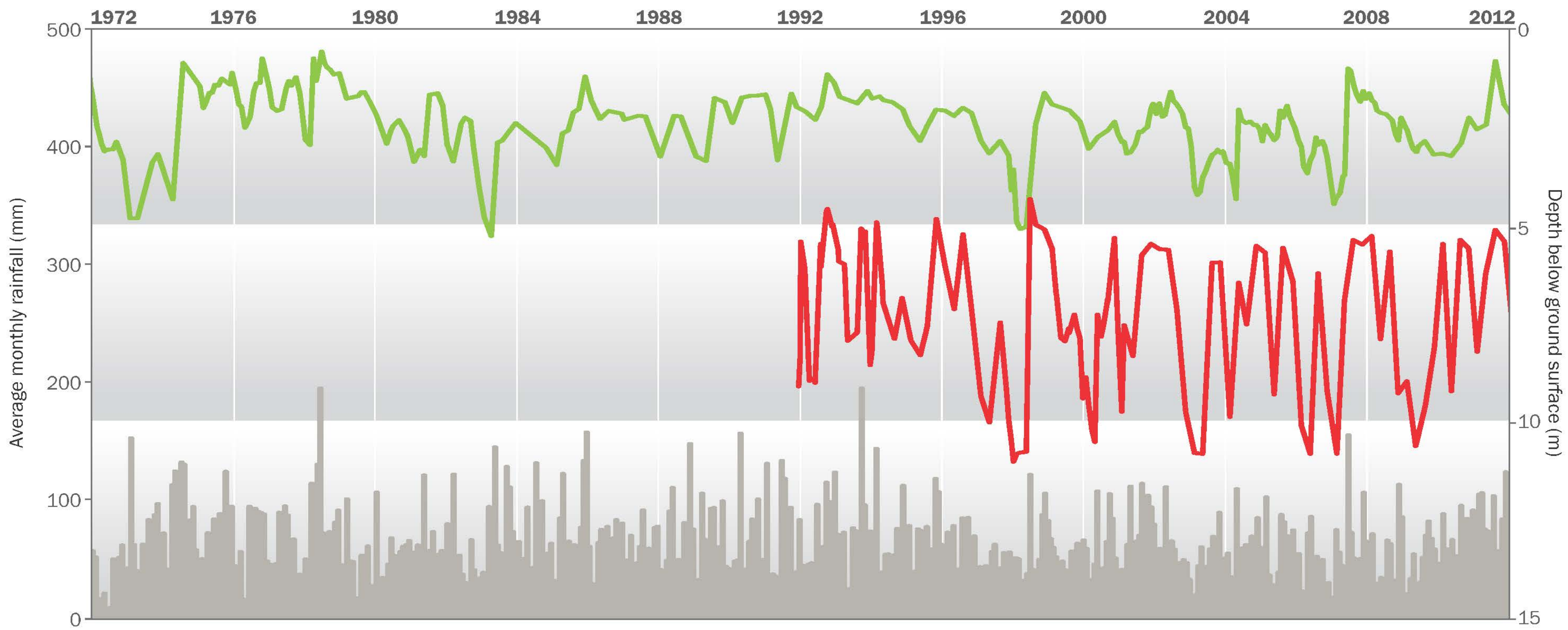


Water balances of intensive irrigation areas like the MID are influenced by the volume of irrigation deliveries, channel leakage and on-farm application (eg flood or spray). These factors also affect the depth to the water table, river height, movement of water between the aquifers and rivers and the need for salinity control.

NOTE: The two water balance graphs on this page are not directly comparable as they were completed for different purposes and using different methods. However, they are useful for looking at the relative sizes of each component within an area or aquifer.

Regional trends





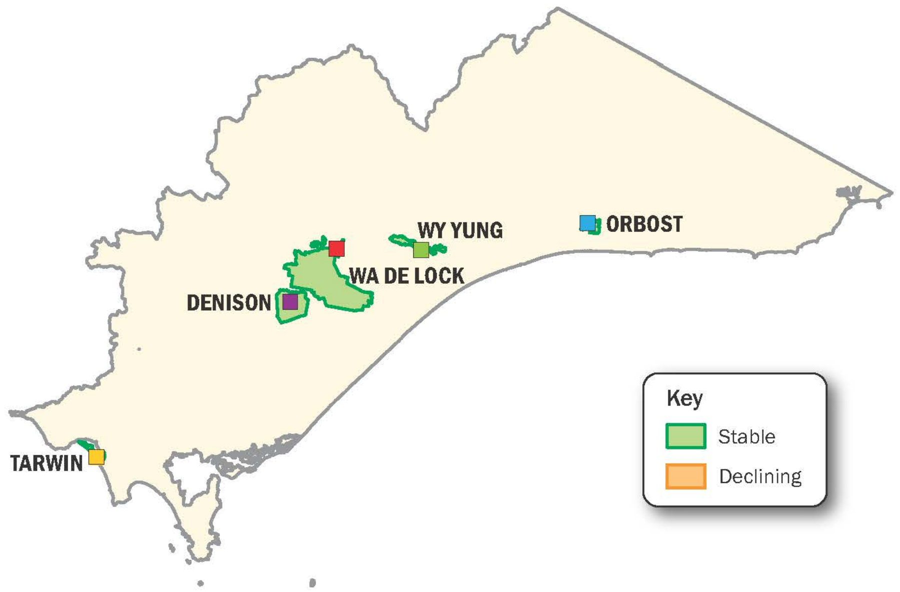
Hydrographs from all monitored State Observation Bores are available on the Southern Rural Water website **www.srw.com.au**

Observations

- **Groundwater levels in the upper aquifers are seasonal and responsive to rainfall, pumping and stream interaction (eg floods).**
- **Groundwater levels at four of the sites have recovered seasonally even during the dry period from 1996 to 2010.**
- **Groundwater levels at Denison site have not recovered to pre-1996 levels. This may be due to modernisation of the delivery system and more efficient irrigation practices.**

The hydrographs to the left show depth to groundwater below ground surface in the upper aquifers at specific bore locations together with rainfall.

The map below indicates the regional trend observed in the monitoring bore network for each GMU.



Tarwin GMU: Bore 94815 is located in beach sands at Venus Bay. Seasonal variations occur, however levels have remained stable over 20 years of records.

Denison GMU: Bore 42069 is located in the MID. Groundwater levels declined from 1996, however recent data suggests no further decline.

Orbost GMU: Bore 115733 is located near the Snowy River. Short-term seasonal variations occur, however the long-term trend is stable.

Wy Yung GMU: Bore 80760 is located near the Mitchell River. Long-term trend is stable. Step rises indicate groundwater response to floods (eg 2007).

Wa De Lock GMU: Bore 110167 is located near near Freestone Creek (Briagolong). Seasonal pumping and recovery cycle with stable long-term trend.

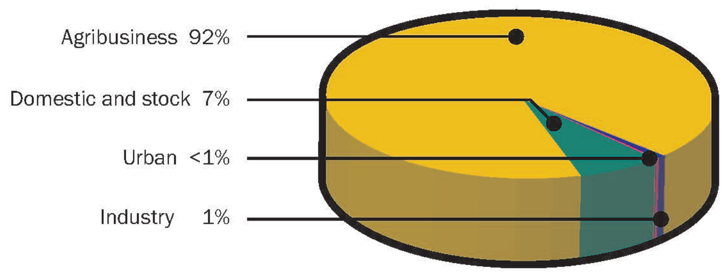
Rainfall in millimetres

Users and usage

The upper aquifers with yield and quality most suitable for commercial usage occur mainly along the river valleys. These aquifers interact closely with the environment.

Licensed users

Most licences are used for agribusiness. There is an urban licence at Briagolong. Denison and Wa De Lock groundwater management units (GMUs) in the Lake Wellington catchment and Wy Yung GMU on the Mitchell River have the highest number of licences with an average volume of 116 to 147 ML.



Unincorporated areas (UAs) account for a large proportion of licences but the average volume is small. Most of the volume in Orbost and Tarwin is accounted for by one licence in each GMU.

GMU	Number of licences	Average licence size (ML/yr)	Largest licence (ML/yr)
Denison	126	110	621
Orbost	4	304	723
Tarwin	3	13	35
Wa De Lock	252	116	2,166
Wy Yung	60	124	1,145
UAs	201	64	913

An entitlement of 4,677 ML is held by Southern Rural Water to manage high water tables in the Lake Wellington catchment.

Domestic and stock users

There are an estimated 4,000 domestic and stock (D&S) bores that use approximately 5,200 ML/yr.

The environment

Environmental use of groundwater is significant in these aquifers because of interaction with the surface water features and the reliance of vegetation on shallow water tables. It is too difficult to quantify this usage with the information available.

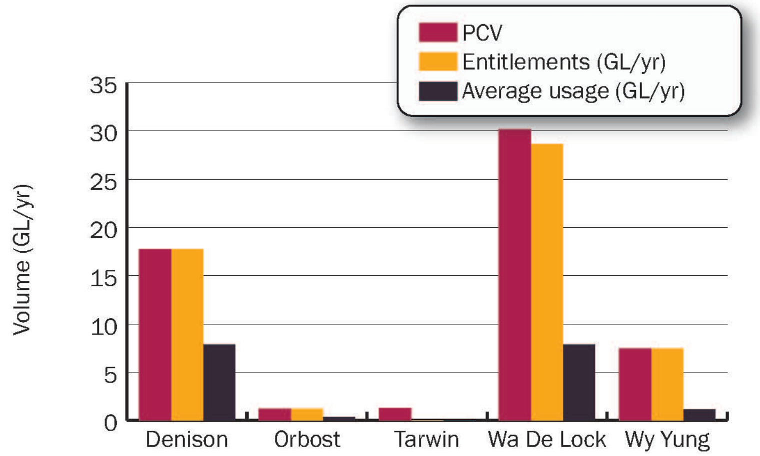
Licensed use

The average use is around one third of the licensed volume.

	PCV	Entitlements	Average use
Totals (ML/yr)	57,879	67,822	23,936

Entitlements in unincorporated areas are included in this table. PCVs do not apply to unincorporated areas.

Denison GMU has the highest proportion of use (44% of entitlements). Wy Yung has the lowest (15% of entitlements). Orbost and Wa De Lock GMUs use an average of 31% and 27% of entitlements respectively.



Sustainable use

Compared to the lower aquifers these aquifers are less reliable for long-term planning. This is because of their short-term reliance on rainfall, small storage and low yields. They are seasonal in nature, rapidly draining during dry seasons but recovering in the spring, even during the prolonged dry period from 1995 to 2010. This suggests that the current level of use (one third of entitlements) is sustainable with the current rainfall patterns.

In contrast to other areas, groundwater use is encouraged in the Macalister Irrigation District (MID) to help manage high water tables there. The high water tables occur as a result of leakage from irrigation and cause water logging and land salinisation.

Value

The upper aquifers are cheap to access and are normally used as a backup supply to surface water during dry seasons. Agribusiness users are located in areas where better quality water coincides with rich soils and surface water irrigation. Prominent agribusiness users are dairy (in the Lake Wellington catchment) and vegetables (along the Mitchell River). Compared to the deeper aquifers, a significant proportion of the value of upper aquifers is attributed to D&S users.

The environmental value is hard to quantify but groundwater contributes to the water cycle that sustains the internationally recognised wetlands of the Gippsland Lakes.

Observations

- **The upper alluvial aquifers are highly valued as a backup supply during dry seasons.**
- **These aquifers rely on rainfall for their recovery. Compared to deeper aquifers they have less storage and are less reliable.**
- **There is a substantial volume of unused entitlements – these could be retained by licence holders as a backup during dry periods or traded to other users.**
- **In the MID groundwater is pumped to manage high water tables**

The table below shows estimates of the annualised gross value of groundwater for different uses. This emphasises the relative importance of these aquifers for D&S and agribusiness uses.

GMU	D&S ($)	Agribusiness ($)	Urban ($)	Industrial ($)
Denison	392,000	3,940,000	0	0
Orbost	14,000	257,000	0	0
Tarwin	736,000	0	0	15,000
Wa De Lock	593,000	6,868,000	159,000	0
Wy Yung	122,000	2,068,000	0	123,000
UA	1,711,000	15,831,000		2,119,000
TOTALS	3,568,000	28,964,000	159,000	2,257,000

Source: RMCG 2011

D&S value based on cost to replace bore.
Agribusiness value based on farm gate value.
Urban and industrial value based on cost of alternative supply.
Table does not include Unincorporated Areas.

Future development

Most of the upper aquifer entitlements are capped. In most cases new water entitlements can only be obtained by trading.

The use data suggests there is potential to develop the unused proportion of entitlements (65%). This is provided that the yield and salinity are adequate to sustain this volume and that the impact on other users is acceptable.

Licence holders place a value on sleeper (unused) entitlements to use during dry seasons or to grow their businesses.

The areas of the aquifers that have poorer water quality but reasonable yield can be treated before use or for managed aquifer recharge projects that store water for later usage.

Current and emerging issues

The upper aquifers are important because they can be accessed quickly and cheaply when needed. They support deep-rooted vegetation, wetlands and provide stream baseflows, which is particularly important during periods of low rainfall.

The map below shows the extent of the upper aquifers overlain with licence distribution, forests and high value wetlands.

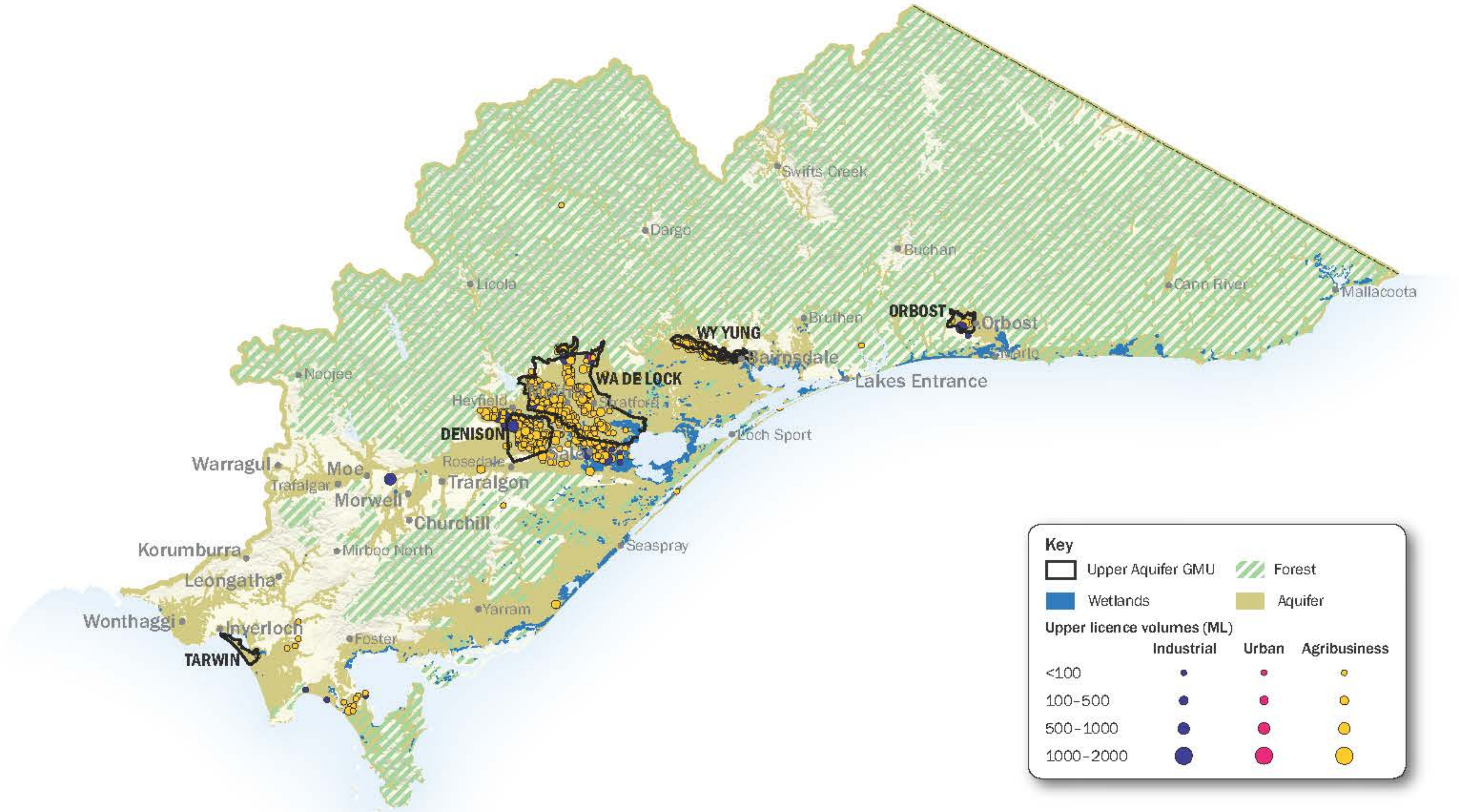
Regional Issues

- Competition between the environment and other users
- Land salinisation caused by high water tables in intensive irrigation areas
- Modernisation in the MID reduces groundwater recharge. This lowers high water tables but decreases access to groundwater.
- Protection of groundwater from pollution sources such as septic tanks (refer to page 26 for more information)

The Gippsland Sustainable Water Strategy sets the policy direction for future water sharing. The Water Act manages groundwater issues between users at a local and regional level.

Observations

- **Management of the upper aquifers needs to account for the strong relationship between rainfall, land use and groundwater users.**
- **It is important to manage groundwater and surface water together where they interact along the river valleys.**
- **Upper aquifers can be susceptible to groundwater pollution where they occur near the ground surface.**
- **Legislation, policy and operational strategies are in place to manage regional issues.**



Land cover and licences

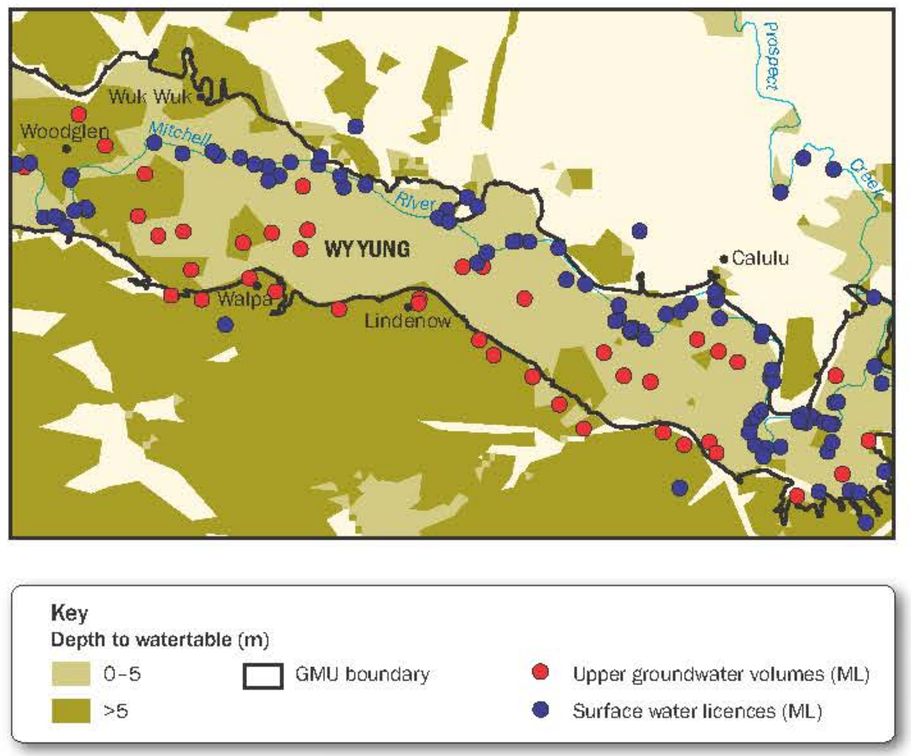
The map above shows the extent of the upper aquifers, distribution of licences by user and size, land cover and where potential groundwater dependent ecosystems coincide with the upper aquifers.

Dewatering and recharge control strategies are in place to minimise environmental damage and production loss in areas where land salinisation has occurred.

Managing groundwater and surface water

Along the major river valleys users have both groundwater and surface water licences that they rely on at different times (eg groundwater is used more heavily during dry periods when access to surface water is restricted, however it may not be used at all when river flows are high). The map below shows the distribution of licences along the Mitchell River in the Wy Yung GMU.

Groundwater is strongly connected with surface water in the major river valleys. Studies suggest there are short lag times between local pumping and the impact on streams (refer to page 33).



4 Upper aquifers

Chapter 5: Middle Aquifers

Middle aquifers cover a large part of the basin from Moe to Bairnsdale. They comprise thick seams of sand aquifers separated by clay and coal aquitards. Recharge occurs from leakage through the overlying and surrounding sediments and discharge is to the limestone aquitards to the east and along the coast.

Agribusiness (pasture and horticulture) and the town supply at Sale use the shallower higher yielding, good quality parts of the aquifers. The Latrobe Valley power companies depressurise the aquifers to enable mining.

In this chapter you can find information on:

Page heading	Description	Page
Geology	Describes the aquifers and aquitards present according to the aquifer grouping shown on page 8, and maps their spatial extent	40
Salinity and yield	Maps are included showing the expected salinity and yield, and a combined salinity and yield map that indicates the groundwater use potential	41, 42
Movement of groundwater	Describes how groundwater movement, explained on page 15, occurs within the upper aquifers of Gippsland	43, 44
Environmental dependence	Discusses how groundwater interacts with the environment, discussed on page 17, particularly with groundwater dependent ecosystems	45
Water balance	Describes the water balance, introduced on page 17, in terms of water volumes entering and leaving these aquifers. It includes a case study from the Macalister Irrigation District	46
Regional trends	Presents data from selected State Observation Bores and indicates regional groundwater level trends	47
Users and usage	Provides licensing information about who uses groundwater from upper aquifers, how much they use and the value derived from this use	48
Current and emerging issues	Discusses some of the key issues facing groundwater managers	49

Geology

The middle aquifers in the region were formed 34 to 4 million years ago. These aquifers are confined by the overlying upper aquifer and a thick clay aquitard. The aquifer group has upper and lower parts, separated by aquitards. The aquitards are generally clay and coal seams (in the north-west of the Gippsland Basin) and Gippsland Limestone (in the east and centre of the Basin).

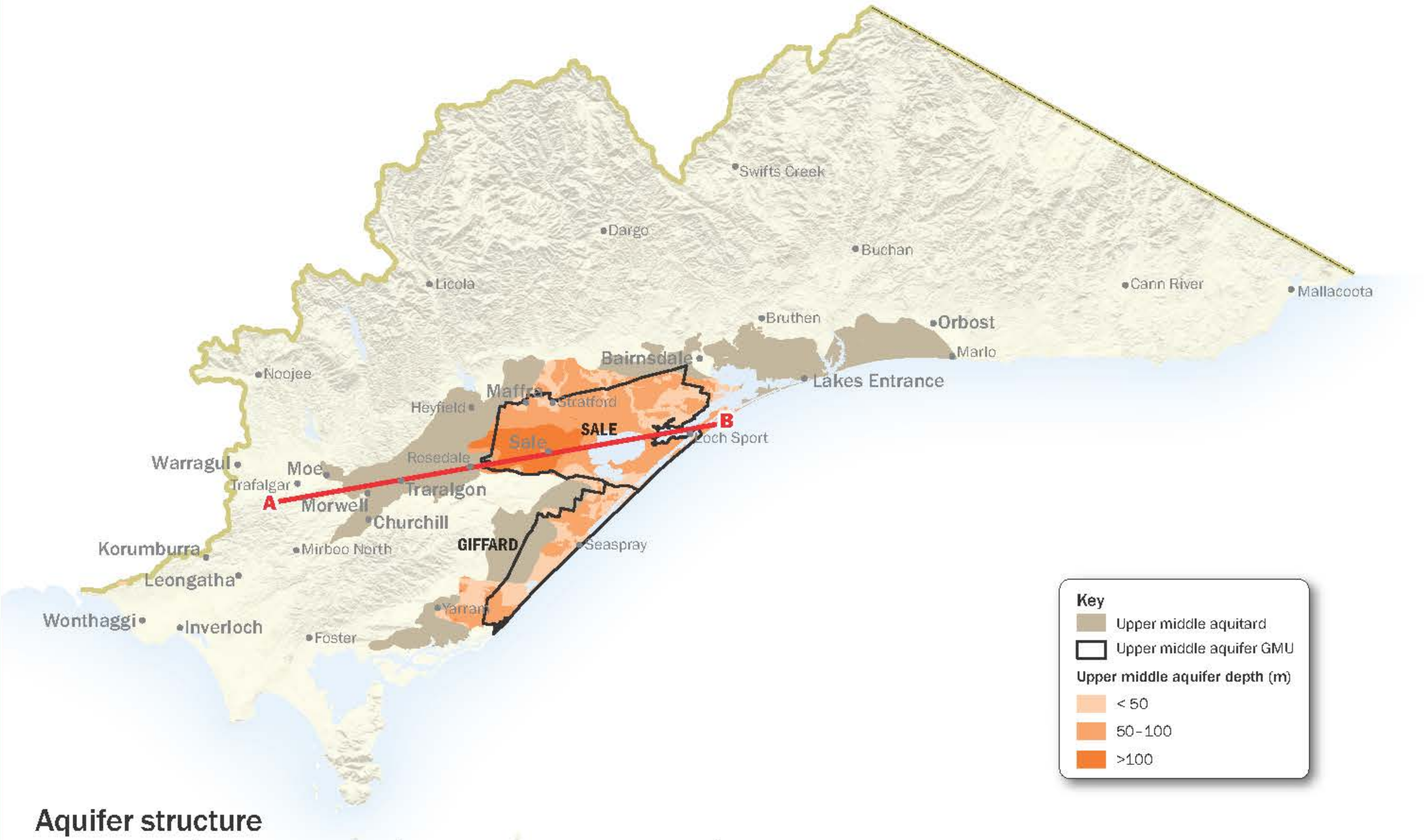
Upper middle aquifer

The aquifer is mostly comprised of the Boisdale Formation sands that occur up to 200m below ground surface. It is around 50m thick across most of its extent and is up to 200m thick at Sale.

This aquifer is generally confined with little or no outcrop. Between Sale and Lake Wellington it has sufficient pressure to flow from bores. Along the coast it changes into a clay marl aquitard known as the Jemmy's Point Formation.

Observations

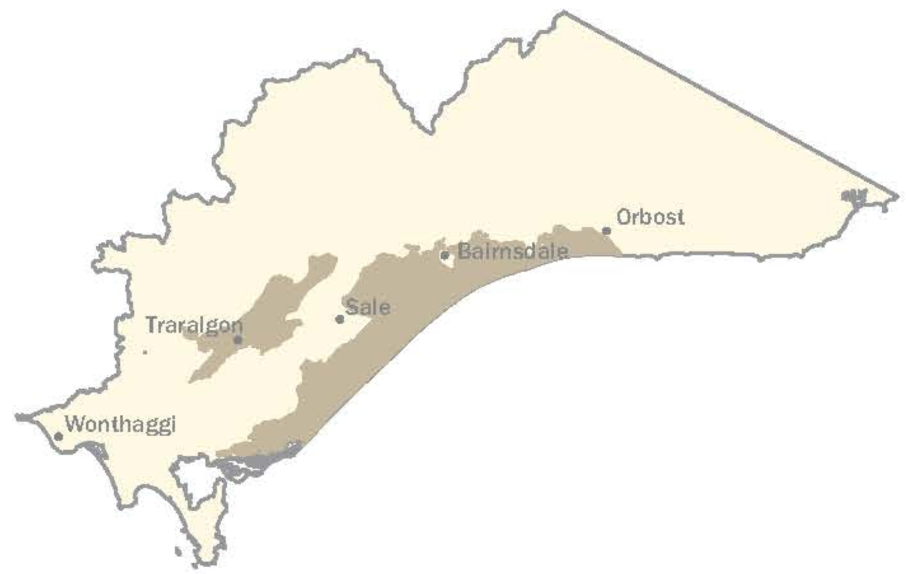
- **The upper middle aquifers are comprised mainly of sand and underlie the upper aquifer and aquitards.**
- **They are confined from lower aquifers by clay, coal and limestone aquitards.**
- **Free flowing bores occur in the area between Sale and Lake Wellington.**



Aquifer structure

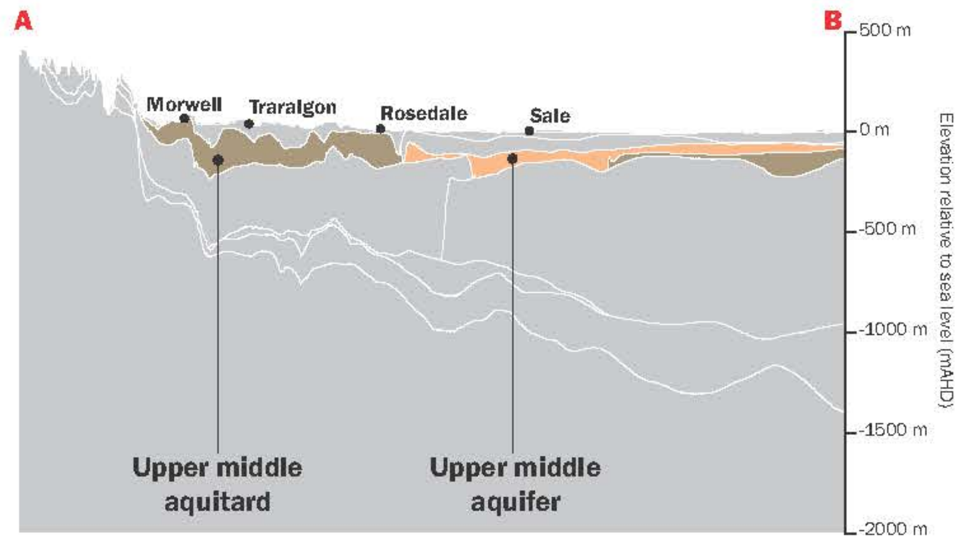
Depth to the top of the upper middle aquifer (Boisdale Formation) and extent of underlying upper middle aquitard

Light shading shows where the upper middle aquifer occurs at or near the surface and dark shading shows where it occurs deeper (eg overlain by other aquitards and aquifers). The brown shaded area shows the extent of the underlying upper middle aquitard.



Upper middle aquitard extent

The upper middle aquitard exists between the upper middle aquifers and the lower middle aquifers (discussed on page 41).



Cross section A-B

Created from map on left showing upper middle aquifer and aquitard.

Geology

Lower middle aquifer

The lower middle aquifers are confined sand aquifers. They are made up of a number of formations, including the Latrobe Valley Group (Yallourn and Morwell Formations), Balook Formation and the Lakes Entrance Formation.

They occur close to the surface in the coal fields between Yallourn and Morwell, near Orbost and around the basin margin but are otherwise buried under several hundred metres of overlying sediments.

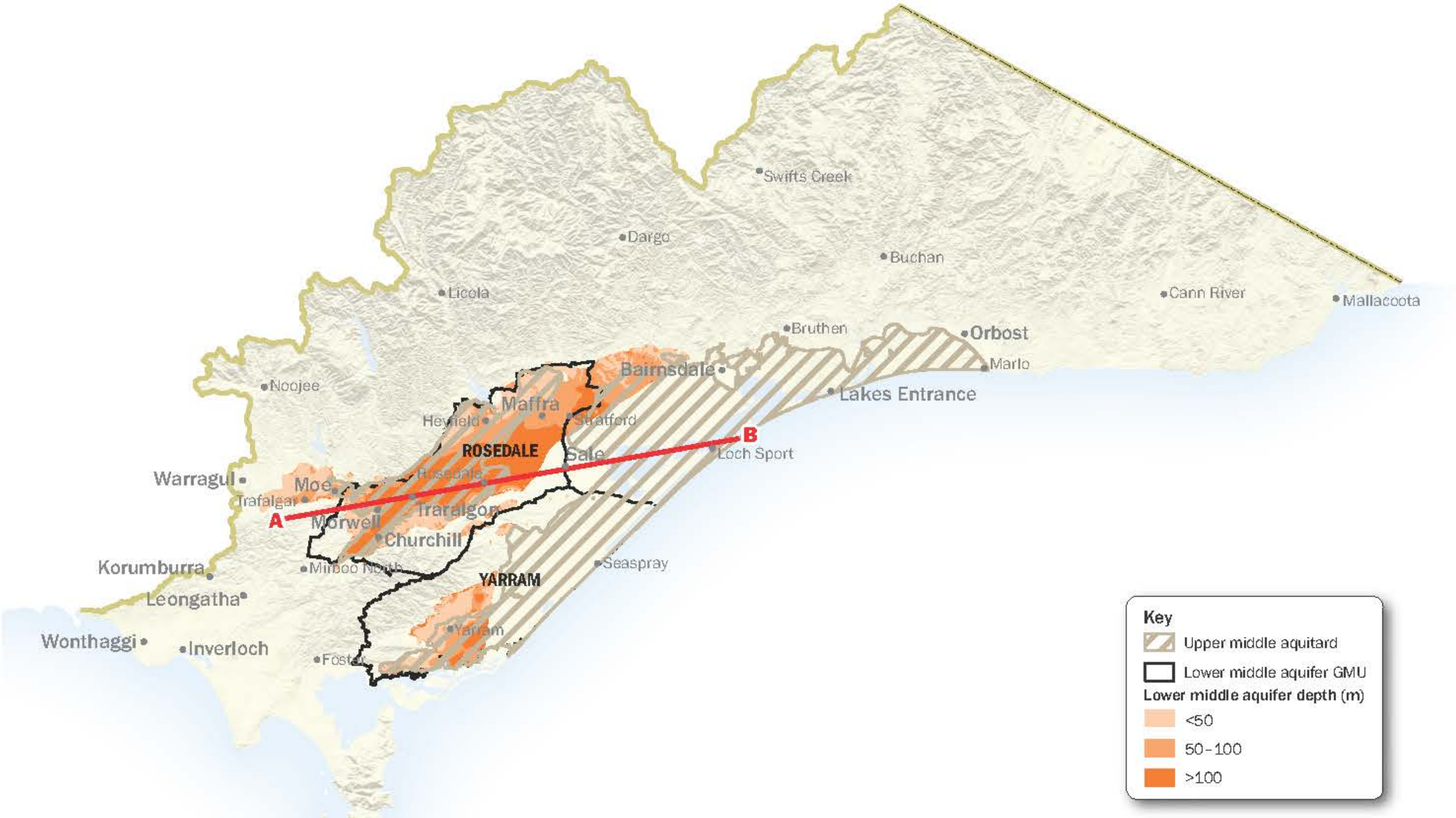
The Morwell and Yallourn Formations are thick sand, clay and coal layers. The coal seams within them form impervious aquitards but these are not continuous and they are faulted, allowing connection between the sand units within each formation.

The lower middle aquifers are thickest in the Sale and Yarram areas. This coincides with the occurrence of barrier beach sands known as the Balook Formation (refer to schematic on page 45). The Balook Formation sits immediately under the upper middle aquifers and above the lower aquifers. It acts as a conduit connecting groundwater pressure across these aquifers. Where the Balook Formation is absent the upper and lower aquifers are confined from one another by thick clay, coal or limestone aquitards.

These aquifers are absent in the Strzelecki Ranges where the basement occurs at the surface. This means there is no direct connection between the aquifer at Traralgon and the aquifer at Yarram.

Observations

- **The lower middle aquifers are buried under several hundred metres of overlying sediments.**
- **They are confined from overlying and underlying aquifers by coal and clay seams except where the Balook Formation occurs.**
- **The Balook Formation is a sand unit that transmits groundwater pressure across the lower and middle aquifers.**
- **The Latrobe Valley and South Gippsland sections of the aquifers are separated by the Strzelecki Ranges.**



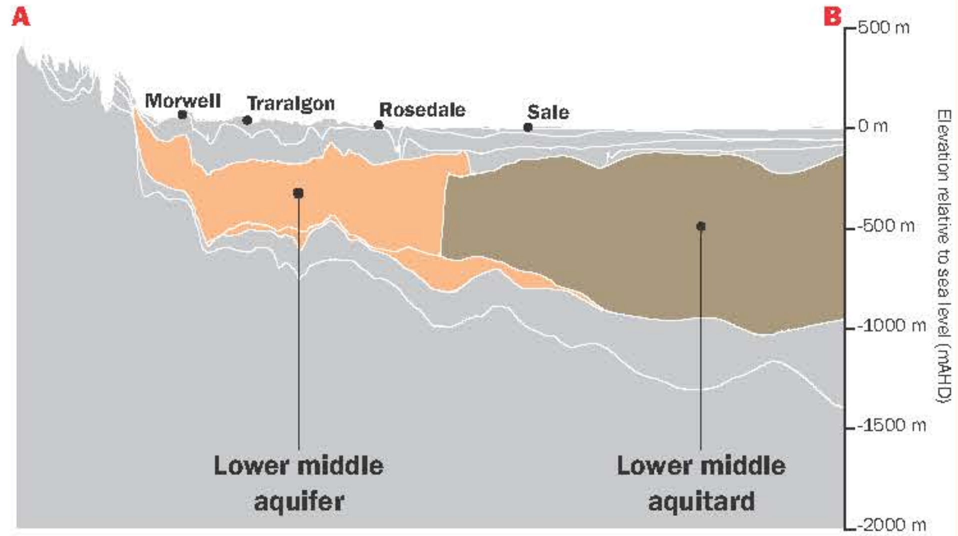
Aquifer structure

Depth to the top of the lower middle aquifer (Latrobe Valley Group and Balook Formations) and overlying upper middle aquitard

Light shading shows where the aquifer occurs at or near the surface and dark shading shows where it occurs deeper (eg overlain by other aquitards and aquifers). The cross hatching shows the extent of the overlying aquitard.

Lower middle aquitard extent

The lower middle aquitard occurs between the lower middle aquifers and the lower aquifers (discussed in Chapter 6).



Cross section A-B

Created from map on left showing lower middle aquifer and aquitard

Salinity and yield

Upper middle aquifer

The aquifer provides an important supply of high yielding, good quality water for urban supply and irrigating productive farming land.

Between Sale and Lake Wellington it is a high yielding aquifer (greater than 50 L/s) and has low salinity (less than 500 mg/L).

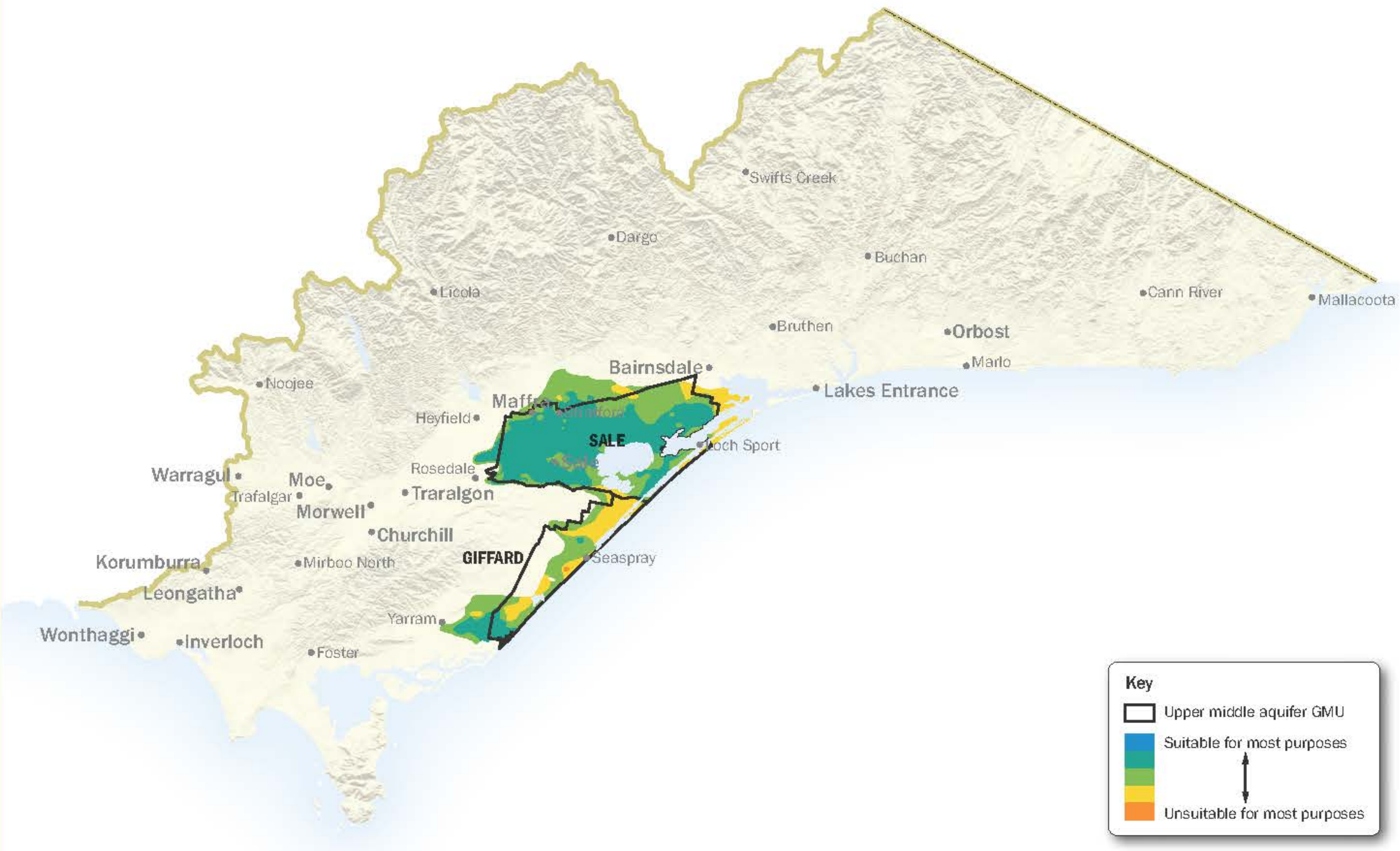
In the north between Stratford and Bairnsdale and along the coast between Seaspray and Yarram this aquifer provides an important source of water for agribusiness where other water supplies are limited.

The better quality water found in the middle aquifers may be due to deep river leakage, or upward leakage from the good quality lower aquifer. Yield and salinity are poorer near the coast and around the eastern extent where the aquifer changes into a clayey marl aquitard.

It is estimated that approximately 3,000 GL of fresh water (less than 1000mg/L) is stored in this aquifer.

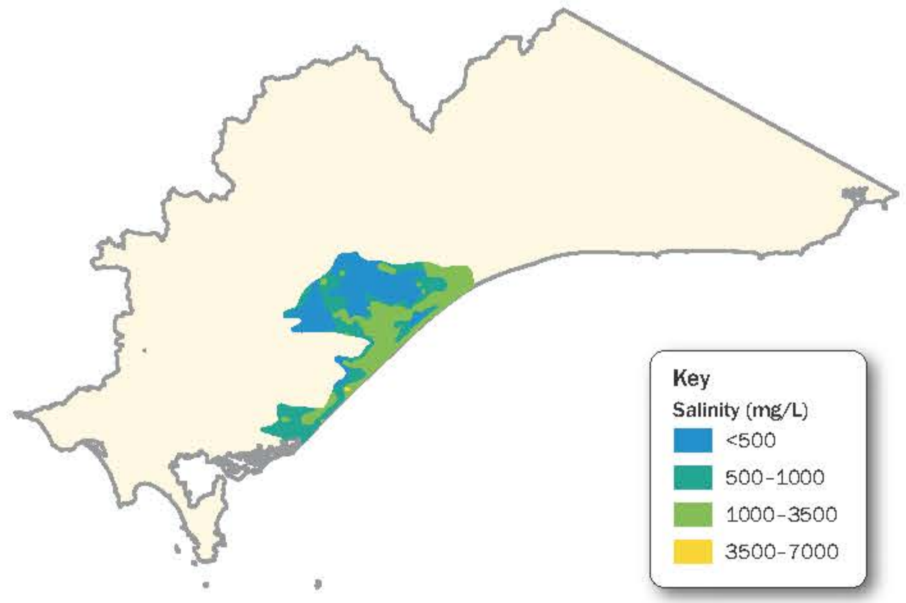
Observations

- **Yield and salinity are suitable for most purposes across most of the aquifer.**
- **This aquifer provides an important source of water in the areas west of Bairnsdale and east of Stratford where other water supplies are limited.**
- **Sale and Giffard groundwater management units cover the higher yielding, low salinity areas of this aquifer.**

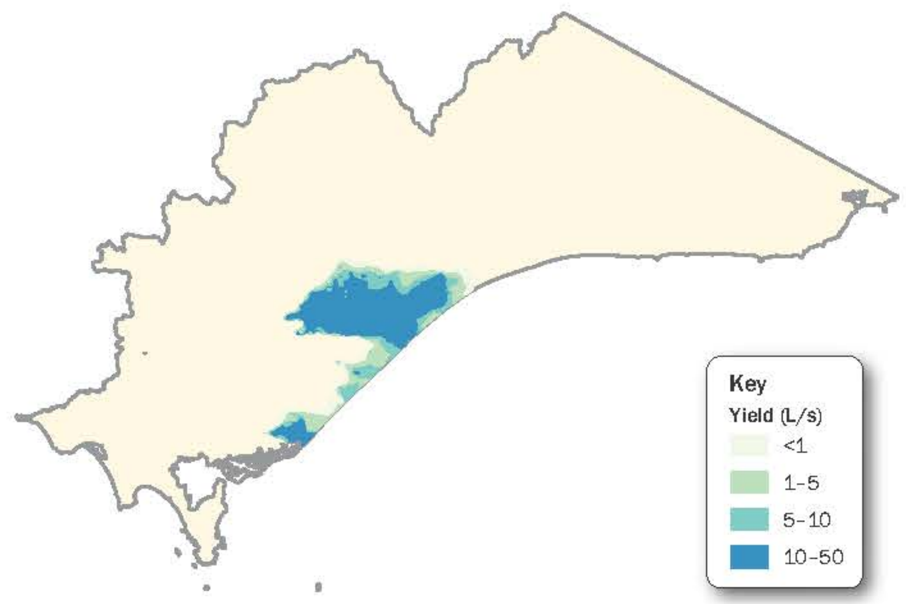


Groundwater use potential based on salinity and yield

This map combines salinity and yield information to show a snapshot of the potential for groundwater use in the region. This map should not be used to make commercial decisions. Potential users should seek information from hydrogeologists and drillers with expertise in the area as well as local information about existing bores.



Salinity of the upper middle aquifer



Yield of the upper middle aquifer

Salinity and yield

Lower middle aquifer

This aquifer provides a valuable resource for agribusiness and industry throughout the Latrobe Valley and along the basin margin near Bairnsdale and Yarram.

The highest yields of over 50 L/s occur between Moe and Sale and also around Yarram. The yield is lower where the aquifer becomes thin in the central and eastern parts of the basin.

Most irrigation occurs where the aquifer rises towards the surface near Stratford, Sale and Yarram.

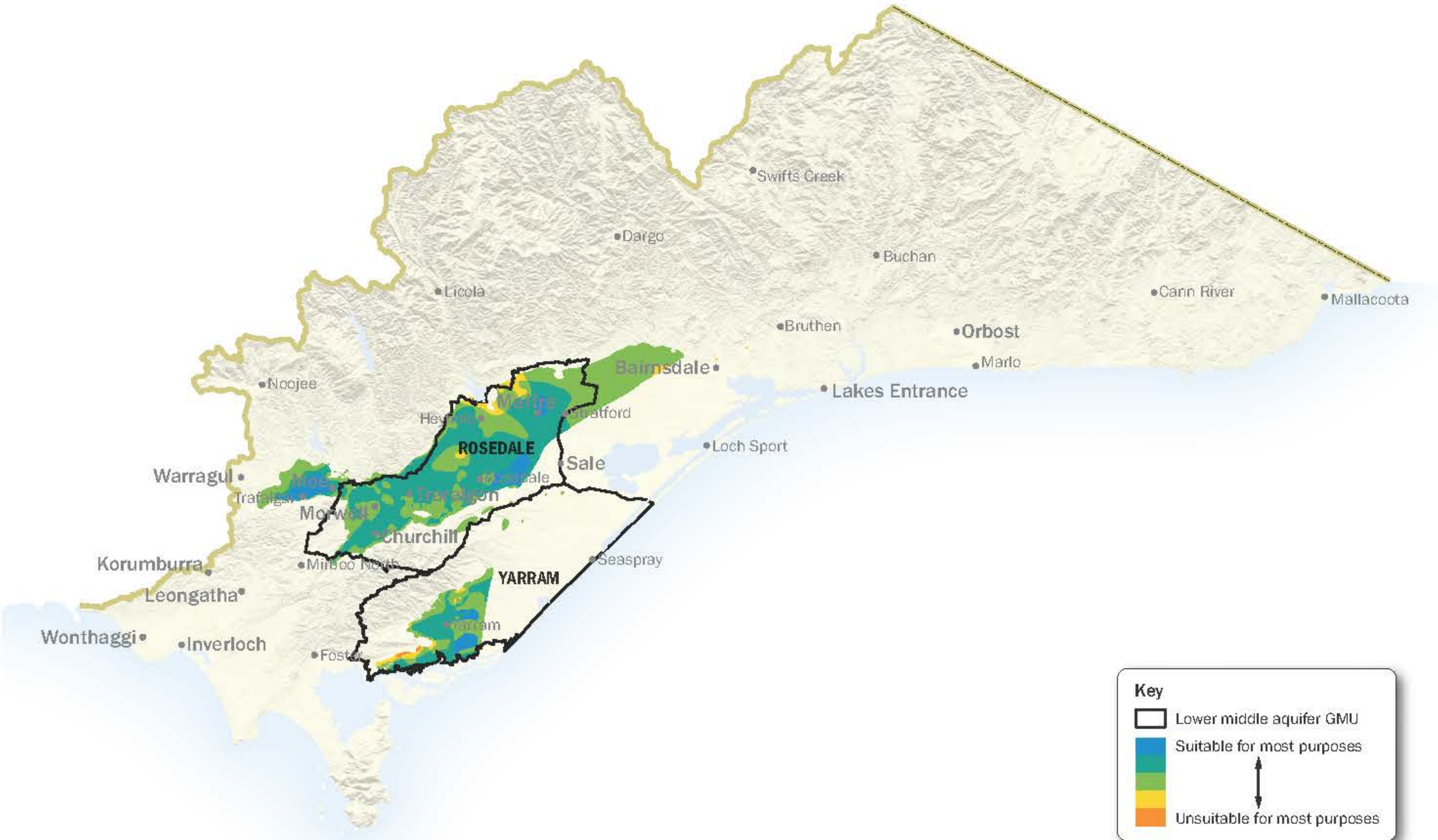
Salinity is lowest where the aquifer occurs close to the surface around the basin margin. In these areas, the aquifer is recharged directly by rainfall or by leakage from the shallow overlying aquifers.

Salinity is higher away from the recharge areas where the groundwater has been in the aquifer longer and picked up more salt along its flow path.

It is estimated that approximately 60,000 GL of fresh water (less than 1000mg/L) is stored in this aquifer.

Observations

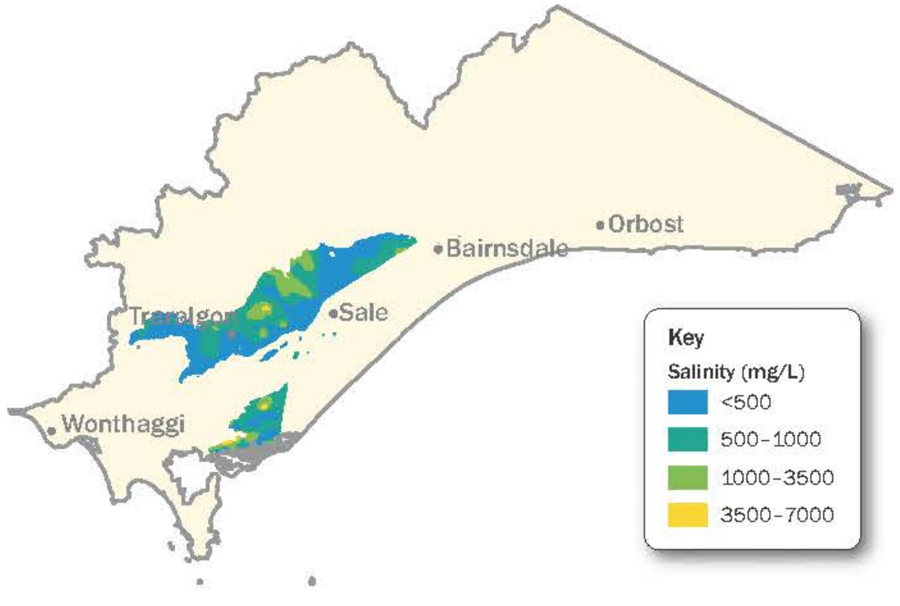
- **The lower middle aquifer is highest yielding in the western areas of the Gippsland Basin.**
- **Salinity is lowest around the basin margin where the aquifer occurs close to the surface and receives recharge.**
- **Rosedale and Yarram groundwater management units cover the higher yielding, low salinity areas of this aquifer.**



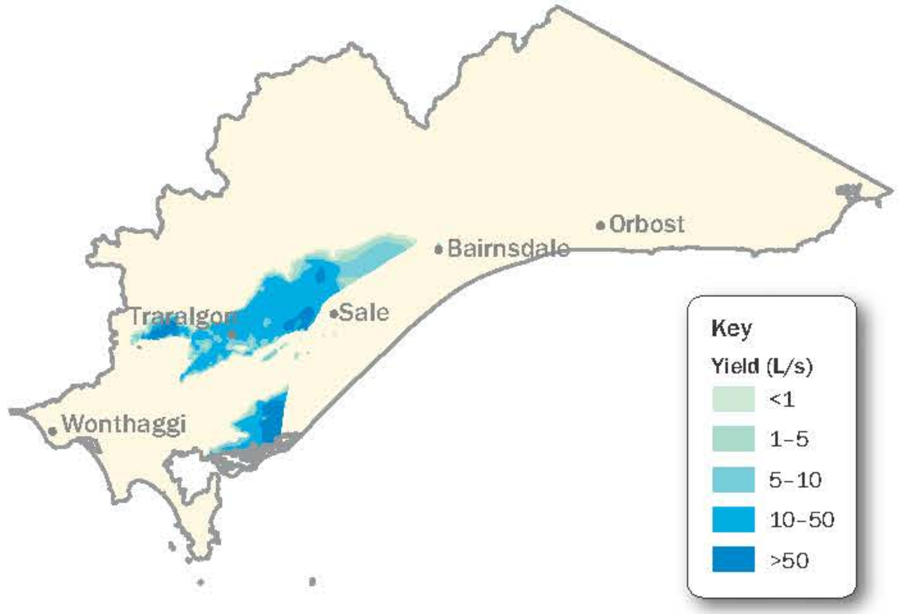
Groundwater use potential based on salinity and yield

(Lower middle aquifer – Balook Formation and Latrobe Valley Group)

This map combines salinity and yield information to show a snapshot of the potential for groundwater use in the region. This map should not be used to make commercial decisions. Potential users should seek information from hydrogeologists and drillers with expertise in the area as well as local information about existing bores.



Salinity of the lower middle aquifer



Yield of the lower middle aquifer

5 Middle aquifers

Movement of groundwater

The flow in the upper middle and lower middle aquifers is mainly horizontal, from high to low elevation. Significant vertical movement also occurs between the underlying and overlying formations across faults and where there are changes in formation materials.

Flow systems

The upper and lower middle aquifers have large regional flow systems. The natural direction of flow is from north-west, where water enters the systems, to south-east. Groundwater flow west of Rosedale is drawn towards the Latrobe Valley due to depressurisation of the open-cut mines. There is a local 'cone of depression' at Sale due to local pumping. Groundwater in both the upper and lower middle aquifers flows into coastal aquitards. The rate of flow is very slow. It may take groundwater hundreds of years to travel tens of kilometres.

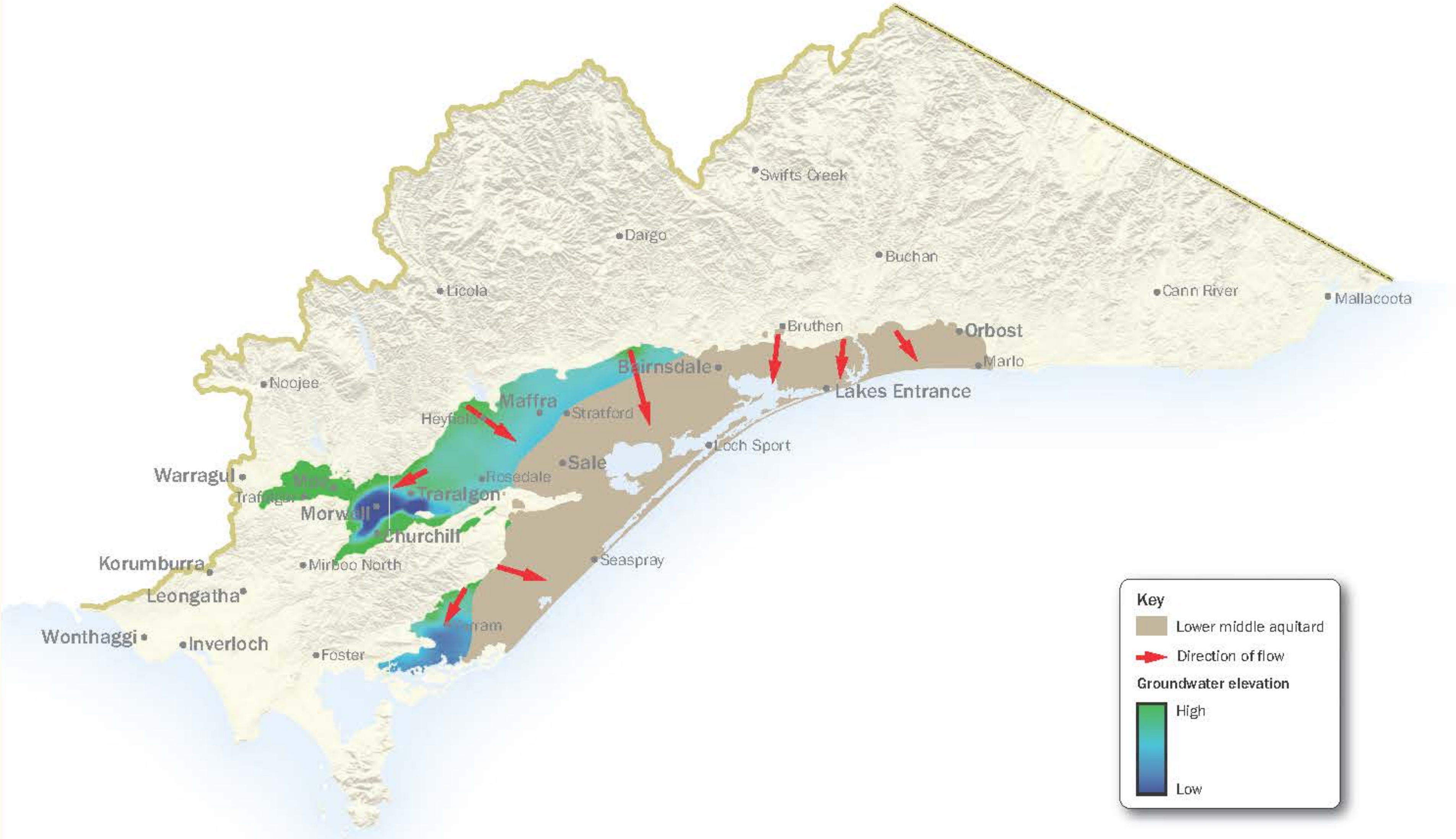
Recharge

The upper middle aquifer doesn't outcrop at the ground surface. It recharges from throughflow around the basin margin and the northern flank of the Strzelecki Ranges, downward leakage from overlying sediments particularly along the river valleys of the Thomson and Avon Rivers and upward leakage in areas where the lower aquifer has a higher pressure (eg Rosedale area).

The lower middle aquifer mainly receives recharge from throughflow around the basin margin, leakage from overlying sediments and upward leakage from lower aquifers.

Observations

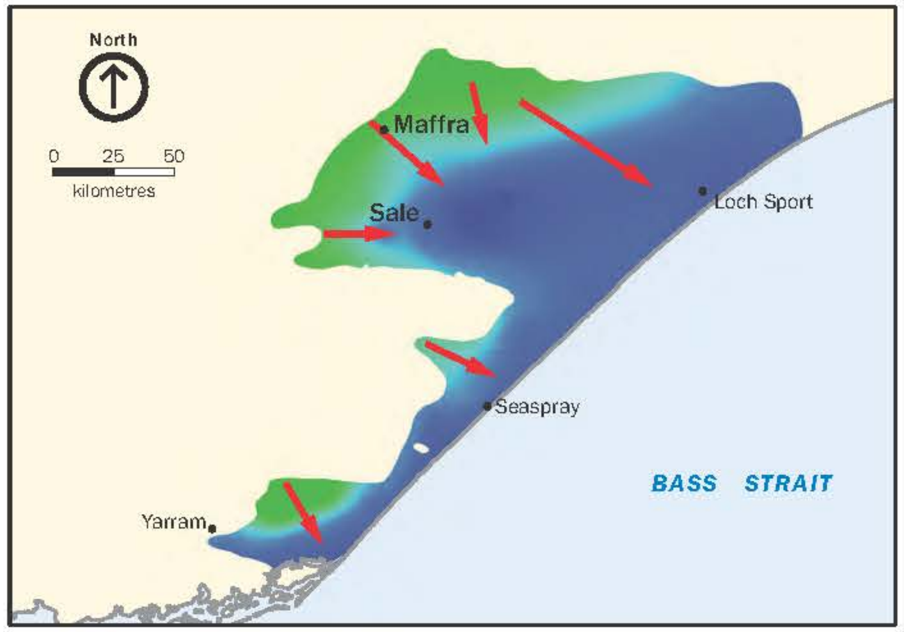
- **Generally groundwater flows south and south-east towards the centre of the Gippsland Basin and on to the coast where it discharges offshore.**
- **Groundwater moves slowly in regional flow systems through the upper middle and lower middle aquifers.**
- **The upper middle and lower middle aquifers receive some recharge via leakage from shallower aquifers and aquitards.**
- **Some vertical flow occurs between aquifers along faults or where aquitards are absent.**



Groundwater elevation and flow direction in the lower middle aquifer (see inset for the upper middle aquifer)

Pressure

The groundwater in the middle aquifers is pressurised by its head of water and the weight of overlying sediments. Groundwater flows freely from bores that have a pressure head higher than the ground surface. This situation may reverse seasonally when groundwater pressures are reduced by pumping during summer. Complete loss of flow may occur as a result of regional depressurisation of aquifers.



Groundwater elevation and flow direction upper middle aquifer – Boisdale Formation

The map above shows groundwater flow in the upper middle aquifer. This aquifer covers a much smaller area than the lower middle aquifer and so this map is zoomed in compared to the map on left.

Environmental dependence

Interaction between the upper middle and lower middle aquifers and the surface environment is limited by the overlying upper aquifers and aquitards. The limestone aquitards along the coast may provide a subterranean habitat if caves have formed in the formation.

Rivers and lakes

There is no significant outcrop of the middle aquifers at the surface even around the basin margin. There is no significant interaction with rivers. Indirect interaction with rivers occurs from leakage into the middle aquifers from the upper aquifers along the major river flats.

Several studies over the past few decades suggest that the upper middle aquifer may discharge to the Gippsland Lakes (southern parts of Lake Wellington, Lake Victoria and Lake Reeve). Nearby significant wetlands such as Dowds Morass, Sale Common, Heart Morass and Clydebank Morass may also rely on discharge from the middle aquifers due to upward groundwater pressure.

There is potential for saline water from the Gippsland Lakes to enter the upper middle aquifer if pressure falls below the lake level. This is called saline intrusion. However the available data is inconclusive and no firm conclusions can be drawn from it.

Interaction with other aquifers

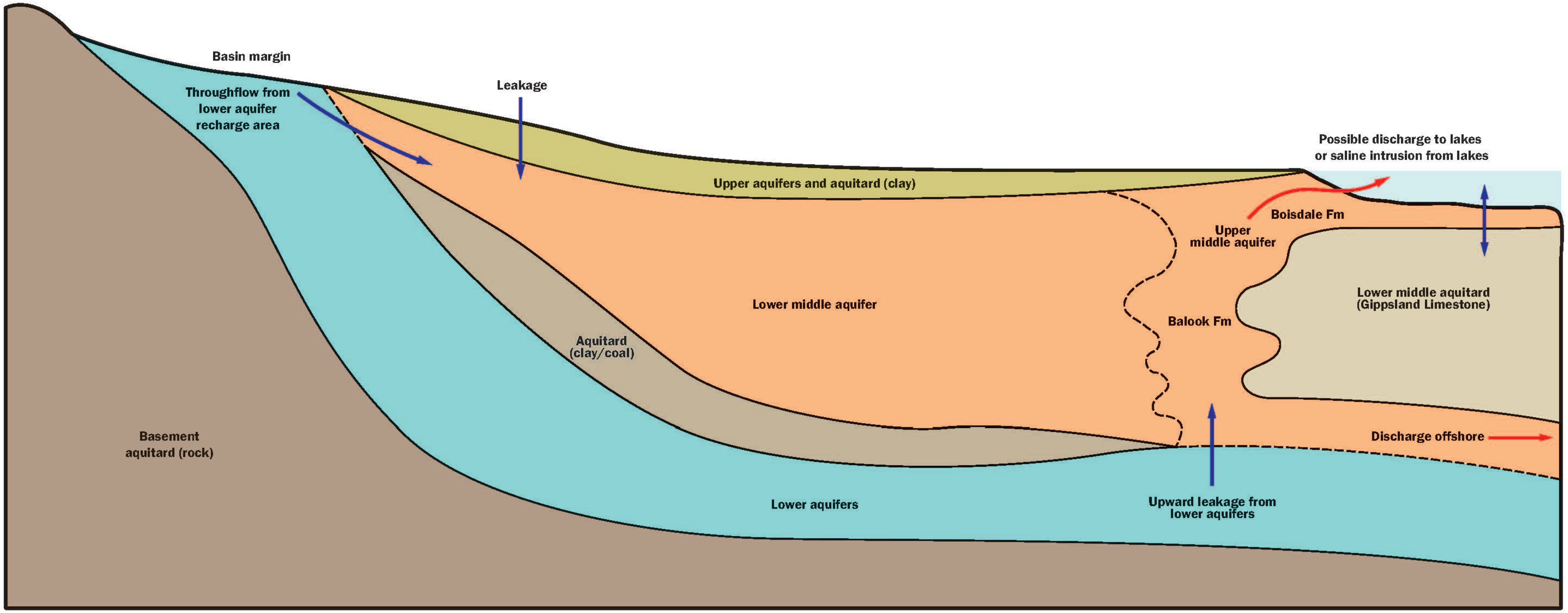
The middle aquifers are semi-confined or confined by the overlying shallow aquitards and aquifers. They receive recharge via leakage through the upper units. Downward leakage is greater along the major river flats where the overlying soils are sandy or gravelly.

In contrast, there are large areas where the pressure in the upper middle aquifer is higher than in the overlying shallow units and so upward leakage may also occur.

There may also be leakage between the lower middle and lower aquifers, in both directions, where there is no aquitard between them.

Observations

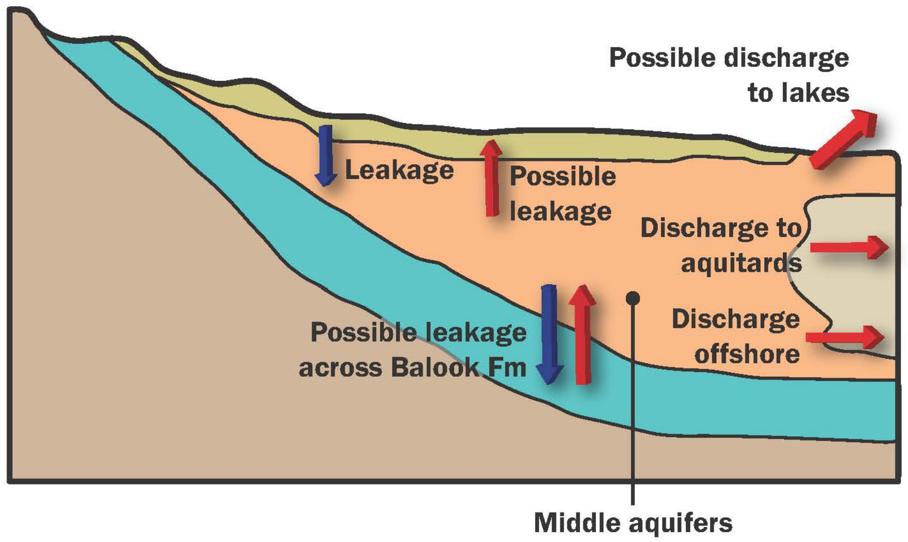
- **Interaction between the middle aquifers and surface ecosystems is limited because they are separated by the overlying upper aquifers and aquitards.**
- **The upper middle aquifer may discharge some groundwater to the Gippsland Lakes. Saline water from the lakes could intrude into the aquifer if groundwater pressure in the aquifer declines below the lake level.**
- **The middle aquifers mainly discharge to limestone and marl aquitards beneath the Gippsland Lakes and along the coast. These aquitards could provide a habitat for cave ecosystems.**



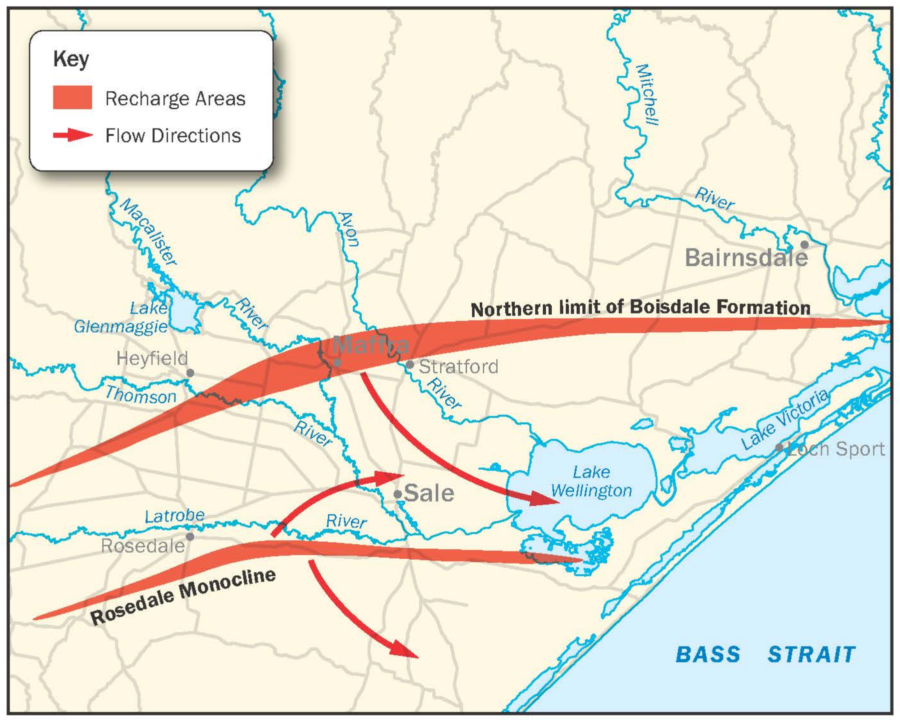
Water balance

There are two main sections in each of the upper and lower middle aquifers. The sections are divided by the ridge of the Strzelecki Ranges which extends towards the Gippsland Lakes.

The cross section below shows a simple water balance model for the middle aquifers. Downward leakage (recharge) from the upper units is likely to be highest in the more sandy or gravelly river valley areas. Upward leakage may also occur in areas where groundwater pressure is higher in the lower aquifers than in the middle units, particularly across the Balook Formation.

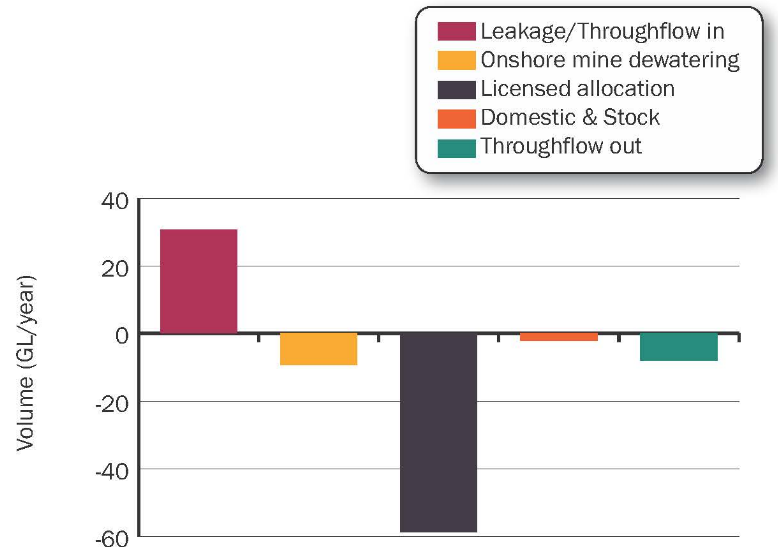


The Boisdale Formation, of upper middle aquifer, has been studied in detail. The diagram below shows its narrow recharge areas and coastal discharge.



The graph below shows the estimated combined major inputs and outputs to the middle aquifer groundwater management units (GMU) at Sale, Rosedale and Giffard. The licensed allocation includes all licences within the middle aquifers including the unincorporated areas.

Water balance middle aquifer



This graph shows results from water balance studies completed to date – these studies *do not* include all elements in the diagram on left. The recharge shown may be less than the actual total recharge as only the GMUs are included (not the total aquifer system).

Overall, the estimated recharge is less than current allocation. The estimates for leakage/throughflow in and out are highly uncertain as they cannot be directly measured.

The net water balance (per graph above) is estimated to be negative 48,000 ML/yr assuming all allocation is extracted. Total metered use including the mines but not domestic and stock is significantly lower than allocation. Based on use the net water balance is negative 13,000 ML/yr.

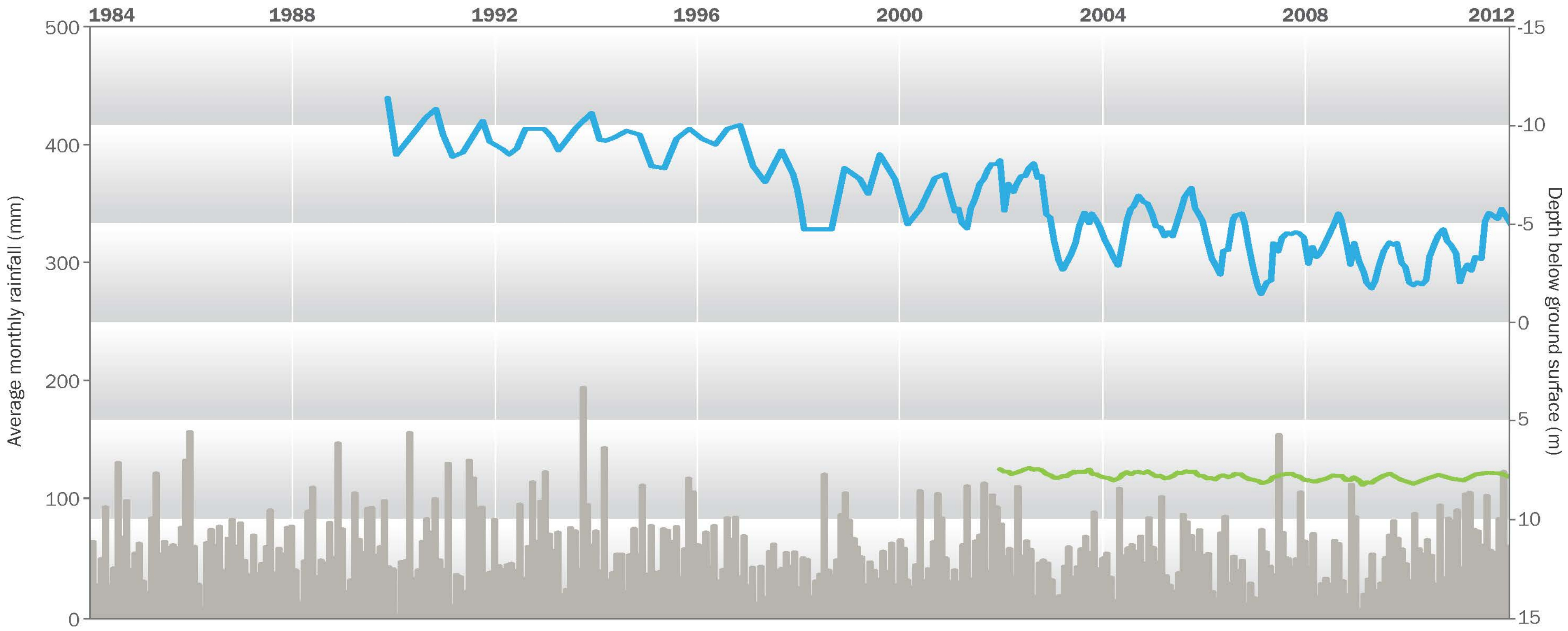
The negative water balance means that the aquifers have been losing water (eg the groundwater storage has been decreasing). This is consistent with the groundwater level trends in many parts of the aquifers (see Regional Trends on page 47). It is also consistent with the rapid increase in groundwater use across the aquifer in the 1980s and 90s. Groundwater allocation was capped across most of the aquifer in the late 1990s.

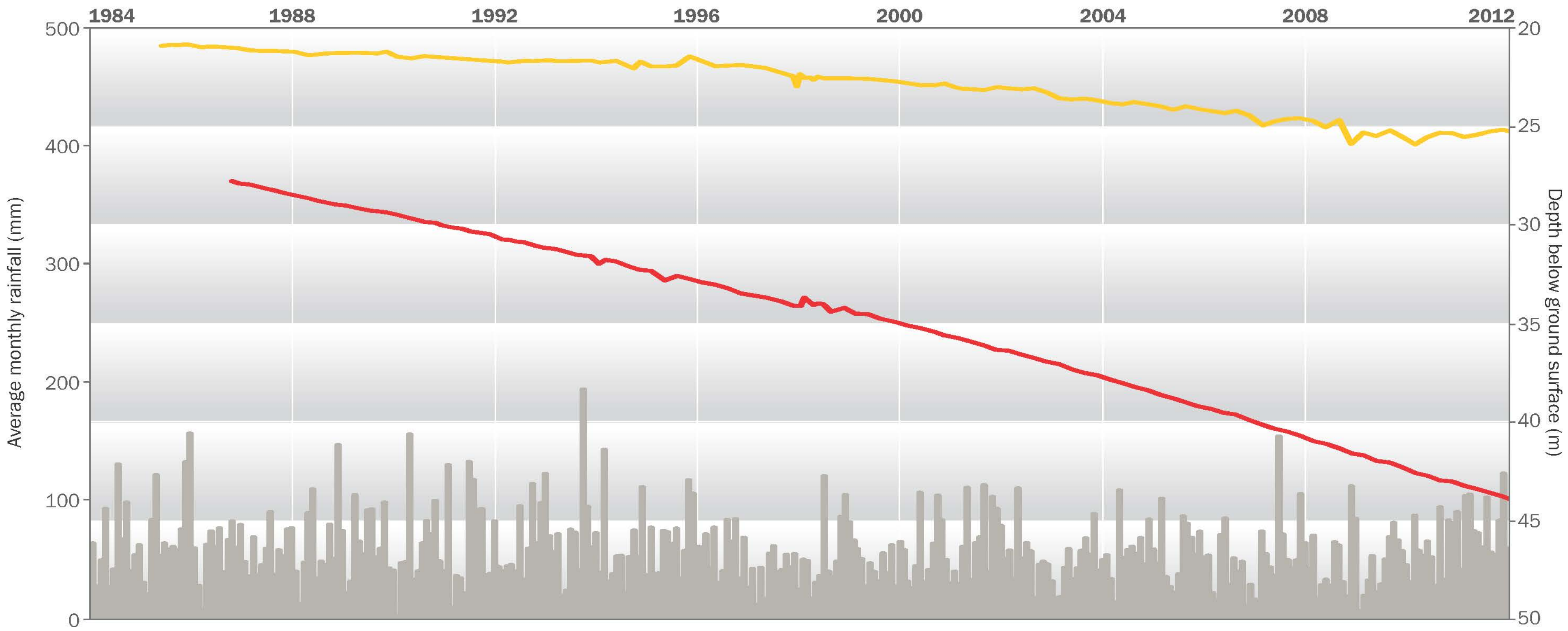
Observations

- **The water balance of the upper middle aquifer is influenced mostly by recharge from leakage and by pumping.**
- **The estimates for leakage/throughflow in and out are highly uncertain components of the water balance and actual recharge may be higher than estimates shown here.**
- **These aquifers are estimated to have been losing water (13 GL/yr) over the past decade.**

Irrigating potatoes at Thorpdale

Regional trends





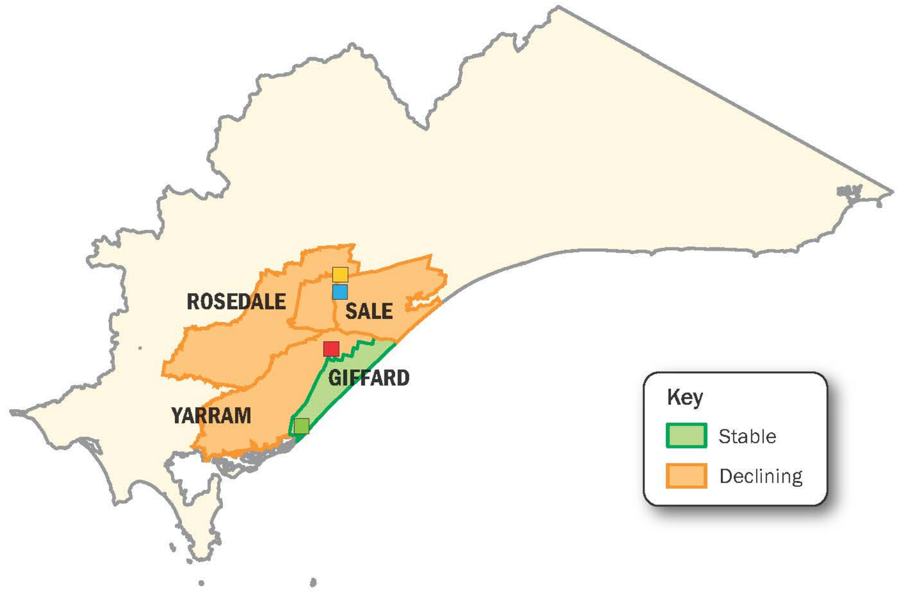
Hydrographs from all monitored State Observation Bores are available on the Southern Rural Water website **www.srw.com.au**

Observations

- **Groundwater levels in the bores shown for the upper middle aquifer show seasonal variation with relatively stable trends over the past decade.**
- **Groundwater levels in the bores shown for lower middle aquifer bores indicate a long term declining trend.**
- **With the exception of Giffard, all areas indicate some level of regional decline.**

The hydrographs at left show depth to groundwater below ground surface in the middle aquifers at specific bore locations together with rainfall.

The map below indicates the regional trend observed from all observation bores for each GMU. Sale and Giffard GMUs are in the upper middle aquifer. Rosedale and Yarram GMUs are in the lower middle aquifer.



Sale GMU: Bore 86669 is located near Stratford. Seasonal pumping and recovery pattern occur. Annual maximum levels have fallen by 5 metres in step declines since 1996.

Giffard GMU: Bore 145090 is located near Woodside. Small seasonal changes in groundwater levels occur. Long-term trend is stable.

Rosedale GMU: Bore 92177 is located north of Stratford. Steady regional decline of 5 metres has occurred since 1985. There is no observable impact from rainfall or summer pumping.

Yarram GMU: Bore 64835 is located near Longford. Steady regional decline at a rate of 0.5 metres per year has occurred over recorded period. There is no observable impact from rainfall or summer pumping.

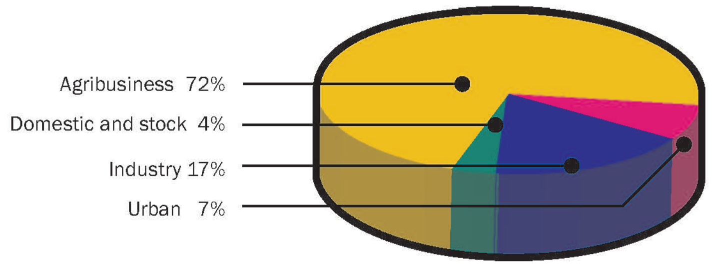
Rainfall in millimetres

Users and usage

Usage from the middle aquifers occurs in the Latrobe Valley, the area from Sale to Bairnsdale and in Yarram. It is attractive to users in these areas because of its high yield, relatively shallow depth and suitability for most uses.

Licensed users

As in the upper aquifers agribusiness users hold most of the licensed volume. Urban and industrial users also account for a significant proportion of entitlement.



Sale and East Gippsland urban supplies rely on these aquifers which are also depressurised by Latrobe Valley mines.

GMU	Number of licences	Average licence size (ML/year)	Largest licence (ML/year)
Giffard	16	356	1,198
Sale	110	193	3,500
Rosedale	65	340	3,470
UAs	74	71	488

Domestic and stock users

There are an estimated 1,600 domestic and stock (D&S) bores and they use approximately 2,000 ML/yr.

The environment

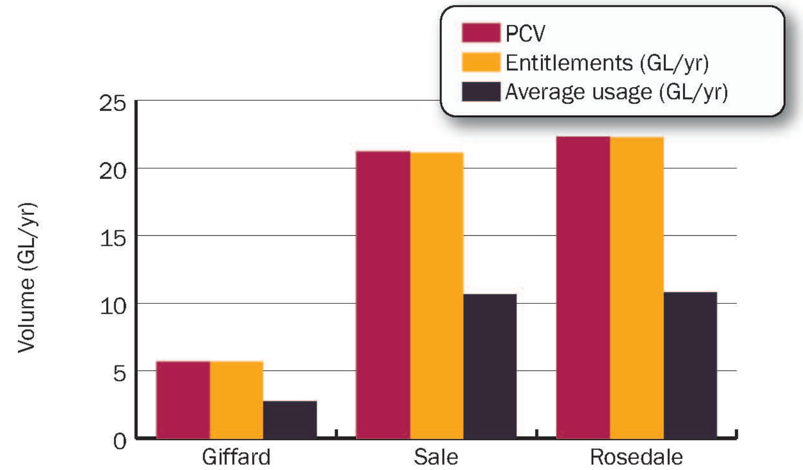
These aquifers are generally confined. Indirect interaction may occur between these aquifers and the environment from groundwater leaking to the surface or discharges into the limestone aquitard where cave ecosystems may be present.

Licensed use

Similar usage is recorded in each GMU with between 47% and 50% of entitlements used annually.

	PCV	*Entitlements	Average use
TOTALS (ML/yr)	49,195	54,261	26,555

Entitlements in unincorporated areas are included in this table. PCVs do not apply to unincorporated areas.



Sustainable use

In the western part of the upper middle aquifer near Sale falling groundwater levels (0.5 m/yr) have led to a gradual loss of artesian conditions. This may be occurring basin-wide, caused by onshore and offshore pumping. This underlying trend in the upper middle aquifer cannot be managed locally. Pumping from irrigation and urban bores near Sale causes a seasonal rise (winter) and fall (summer) of up to several metres. Average use in the range of 10 to 13 GL/yr allows the aquifer to recover. Greater use as in 2002/2003, has led to a step change in the level of recovery.

Further east where the aquifer is thinner and lower yielding use is much lower and groundwater levels have remained stable. It is possible that groundwater levels are maintained by interaction with the nearby lakes (King and Victoria).

Groundwater development in Giffard GMU has occurred more recently. Although some seasonal rise and fall occurs no underlying groundwater trends have developed.

Managing the lower middle aquifer requires balancing the need to depressurise the Latrobe Valley mines and the need to sustain the availability of water for other users. Records show groundwater levels are falling at a rate of approximately 0.5m/yr. These falling levels are manageable for users as long as bores are drilled deep enough to access lower levels.

Observations

- **The middle aquifers provide a highly reliable resource as long as bores are drilled deep enough to allow for seasonal falls in groundwater levels.**
- **There is potential for groundwater trading because there is a high number of entitlements and unused licence volume (50%).**
- **Increased use in the Sale GMU may lead to regional depressions or bore interference.**

Value

The table below shows estimates of the annualised gross value of groundwater for different uses. This emphasises the relative importance of these aquifers for D&S and agribusiness uses.

In the past decade in the dry country in the Giffard GMU and north of the Sale GMU has been converted into an irrigation area increasing the value derived from agribusiness.

GMU	D&S ($)	Agribusiness ($)	Urban ($)	Industrial ($)
Giffard	31,000	1,967,000	0	543,000
Rosedale	390,000	6,722,000	0	16,720,000
Sale	270,000	10,375,000	8,038,000	0
UA	479,000	6,453,000	2,309,000	15,000
TOTAL	1,170,000	25,517,000	10,346,000	17,278,000

Source: RMCG 2011

D&S value based on cost to replace bore.
Agribusiness value based on farm gate value.
Urban and industrial value based on cost of alternative supply.
Table does not include Unincorporated Areas.

Future development

Most of Gippsland is now capped. However there is a great deal of potential to develop the unused proportion of entitlements (50%). The data indicates that it may be sustainable to activate the unused entitlements if this is well managed. Given the continuous nature of the upper middle aquifer and the high number of licences distributed across its total area, it would appear suited to a groundwater trading market if demand increases and regulation allows.

Current and emerging issues

Groundwater levels are declining across the northwestern and central areas of the middle aquifers. Both agribusiness and industrial users substantially increased their entitlements and use during the 1980s and 90s.

The middle aquifers are heavily used by agribusiness, urban and industrial users (including mine dewatering).

The map below shows the distribution of licences by size and user group. There is a dense distribution of large licences between Morwell and Sale. Actual use is generally significantly lower than allocation (refer to page 48).

Regional issues

- Declining regional groundwater levels in heavily developed areas
- Bore interference and loss of flowing artesian conditions
- Potential for saline intrusion into the upper middle aquifer from the Gippsland Lakes
- Increasing demand from agribusiness, urban and industrial users for groundwater resources

Observations

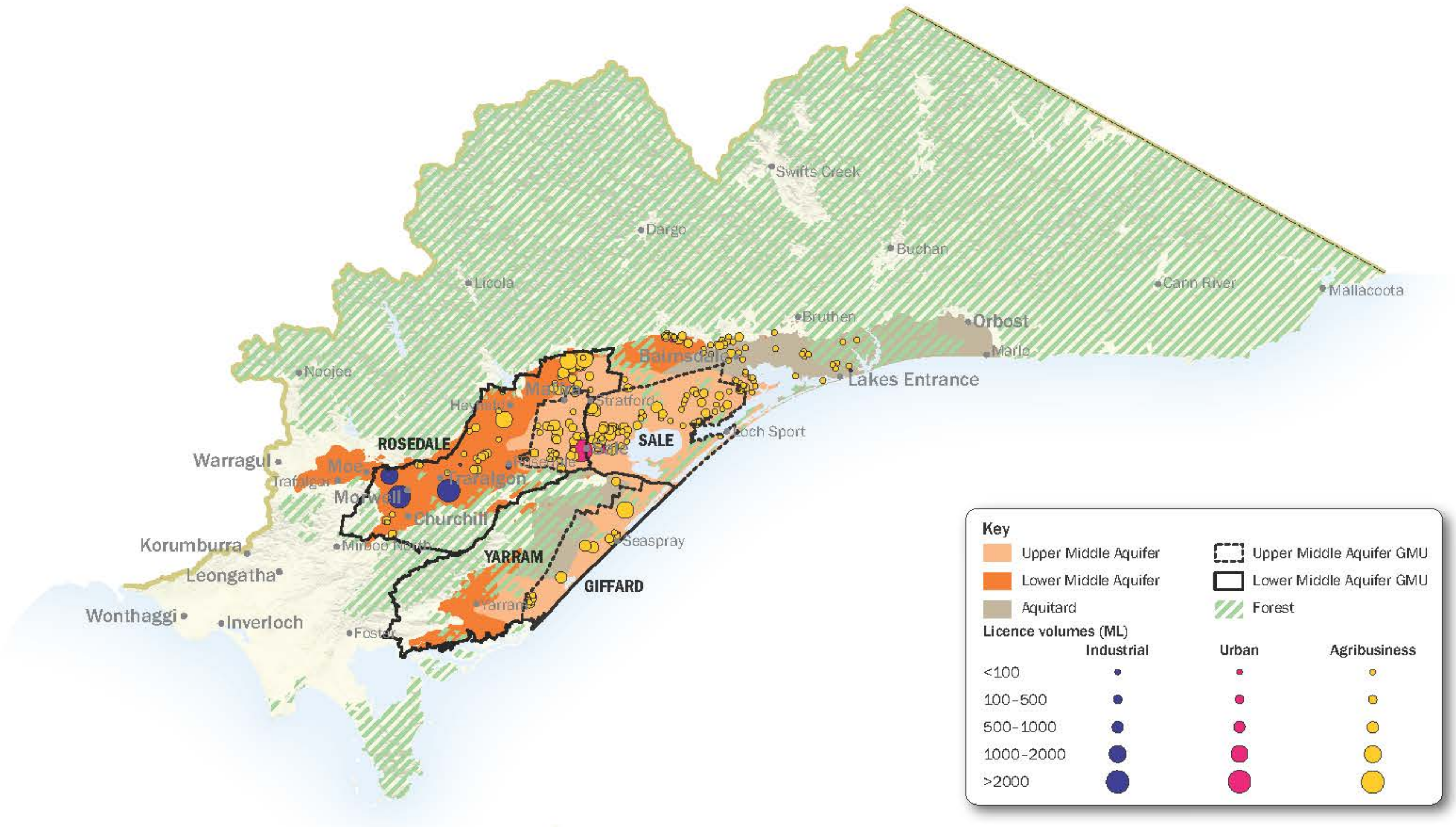
- **Regional drawdown cones and bore interference occur in the most heavily used areas of the middle aquifers during periods of high use.**
- **These aquifers are impacted by regional depressurisation due to mining activity.**
- **The State government and relevant agencies have management strategies in place to address local and regional issues.**

The Gippsland Sustainable Water Strategy sets the policy direction for future water sharing. The Water Act manages groundwater issues between users at a local and regional level.

Future water resources

There are no major dams east of the Macalister River. Industries such as mining and urban development around towns such as Loch Sport may need to rely on groundwater as a resource.

The middle aquifers are an attractive potential resource for future development because of their relatively shallow depths, high yields and low salinity.



Land use and licences

This map shows the extent of the middle aquifers and aquitards overlain by the distribution of licences by size, GMU boundaries and forested areas.

Chapter 6: Lower Aquifers

Lower aquifers extend across the Gippsland Basin and well offshore. They comprise thick sand sediments that rise to the surface along the basin margin but are very deep along the coast and offshore. They are underlain by basement rock. Recharge occurs directly where the aquifers occur near the surface and by downward leakage in the deeper basin. Discharge occurs offshore in Bass Strait.

The aquifers are used for agribusiness (pasture and horticulture) and town supplies (Bairnsdale, Leongatha and Yarram). Coal mine depressurisation and offshore oil and gas developments are the major user of the resource. Although the basement rock acts mainly as an aquitard, it discharges groundwater to streams and has sufficient yield and quality to supply Mallacoota.

In this chapter you can find information on:

Page heading	Description	Page
Geology	Describes the aquifers and aquitards in the region according to the aquifer grouping shown on page 8, and maps their spatial extent	52
Salinity, yield and temperature	Maps are included showing the expected salinity and yield, and a combined salinity and yield map that indicates the groundwater use potential	53
Movement of groundwater	Describes how groundwater movement, explained on page 15, occurs within the lower aquifers of Gippsland including the basement	54
Environmental dependence	Discusses how groundwater interacts with the environment, discussed on page 17, particularly with groundwater dependent ecosystems	55
Water balance	Describes the water balance, introduced on page 17, in terms of water volumes entering and leaving these aquifers. It includes a case study from the Latrobe Group.	56
Regional trends	Presents data from selected State Observation Bores and indicates regional groundwater level trends	57
Users and usage	Provides licensing information about who uses groundwater from lower aquifers, how much they use and the value derived from this use	58
Current and emerging issues	Discusses some of the key issues facing groundwater managers	59

Geology

The lower aquifers of the Gippsland Basin were formed from 65 to 34 million years ago. They are overlain by the upper and middle aquifers and thick silt, clay, coal and limestone aquitards. They are underlain by the basement.

Latrobe Group

The most widespread formation of the lower aquifers is the Latrobe Group. It comprises sand and gravel aquifers, and clay, silt and coal aquitards. The Latrobe Group occurs at or near the surface around the basin margin but is buried up to 1,000 metres at Loch Sport. Its offshore extent (see page 59) is deeply buried beneath a thick limestone formation and contains oil and gas fields.

The Latrobe Group receives direct recharge from rainfall or river leakage around the basin margin where it occurs near the surface. Slow leakage from the overlying sediments occurs where thick coal and clay aquitards are absent (see lower middle aquitard page 41)

Older Volcanics

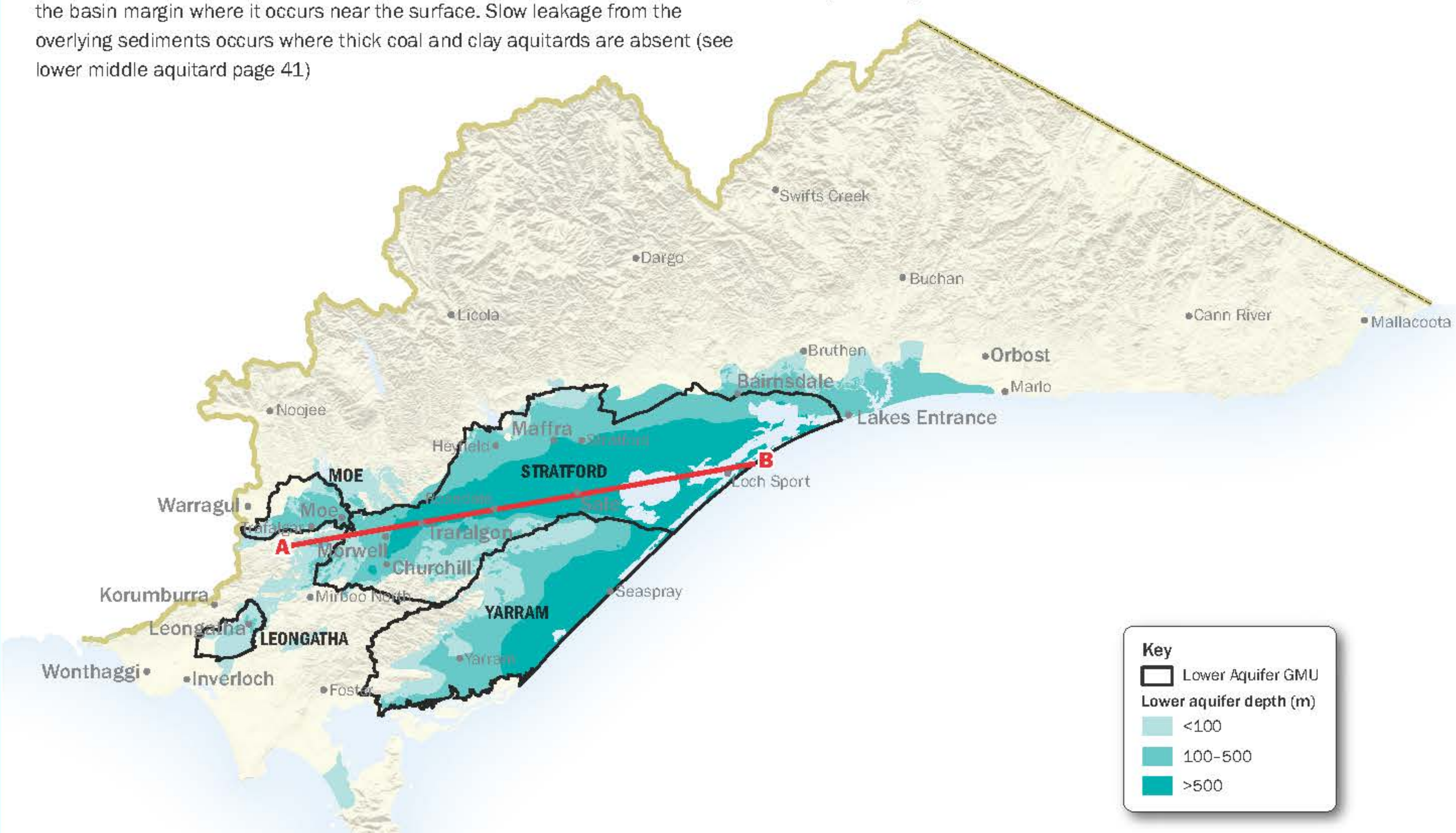
In the west around Warragul, Thorpdale and Leongatha, the lower aquifer is mainly the fractured basalt Older Volcanics. In these areas the Older Volcanics occurs at or near the surface where it receives direct recharge from rainfall. It does not extend offshore.

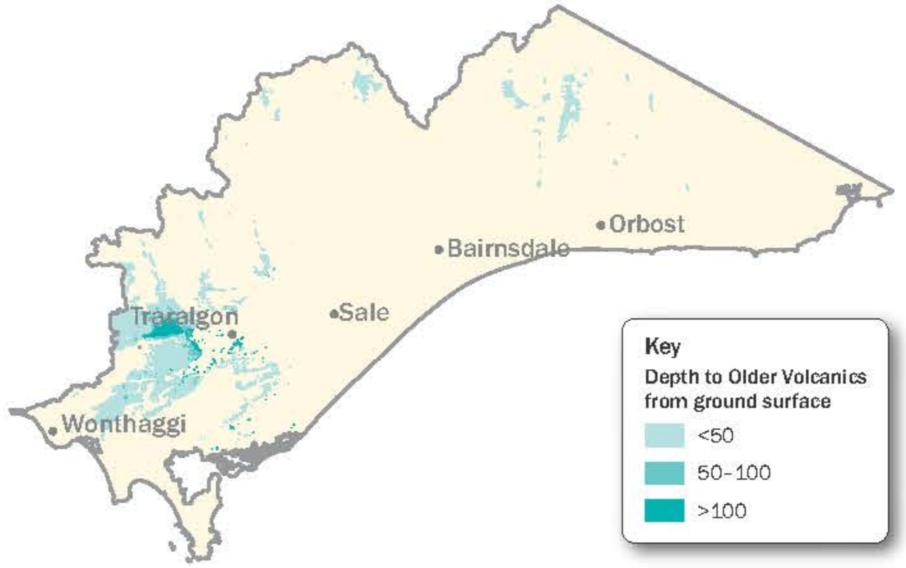
Basement

In the north, the basement occurs at the surface forming the Great Dividing Range and comprises mainly siltstone, sandstone, claystone and granite. In the south, the basement occurs at the surface forming the Strzelecki Ranges and comprises sandstone and siltstone. In the mountain ranges, the basement acts as a low yielding, fractured rock, watertable aquifer. Where it is buried by sedimentary basin, the basement acts as an aquitard with confined reservoirs of water, oil and gas.

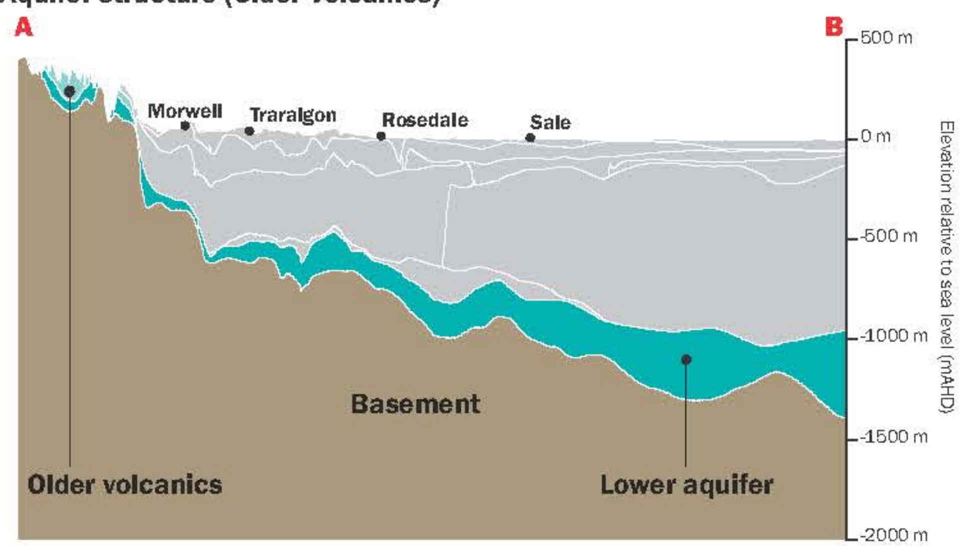
Observations

- **The lower aquifers occur at or near the surface in the west and around the basin margin, where they receive direct recharge from rainfall or river leakage.**
- **The lower aquifers dip downwards around the centre of the basin and near the coast, becoming thicker, up to 1,000 metres and more deeply buried. They also extend well offshore.**
- **The basement occurs at the surface in the north (forming the Great Dividing Range) and in the south (forming the Strzelecki Ranges).**
- **The basement dips downwards around the centre of the basin where it is overlain by the lower, middle and upper formations.**





Aquifer structure (Older Volcanics)



Cross section A-B

Created from map on left showing the lower aquifers and basement.

Aquifer structure

Depth to the top of the lower aquifer (Latrobe Group)

Light shading shows where the lower aquifer occurs at or near the surface and dark shading shows where it occurs deeper (eg overlain by other aquitards and aquifers).

Salinity, yield and temperature

The lower aquifers are very high yielding, low salinity and have warm temperatures at depth. They are an important resource for industry and agribusiness, particularly around Stratford and Yarram.

The Latrobe Group aquifer that occurs throughout the Latrobe Valley and along the coast is a thick sandy formation with a very high yield (up to 100 L/s). Salinity is generally less than 1,000 mg/L and relatively fresh groundwater is known to extend well into Bass Strait.

Groundwater in the Older Volcanics around Warragul, Thorpdale and Leongatha also has low salinity and is suitable for most uses. The yield here is lower but is still relatively high compared with the upper aquifers.

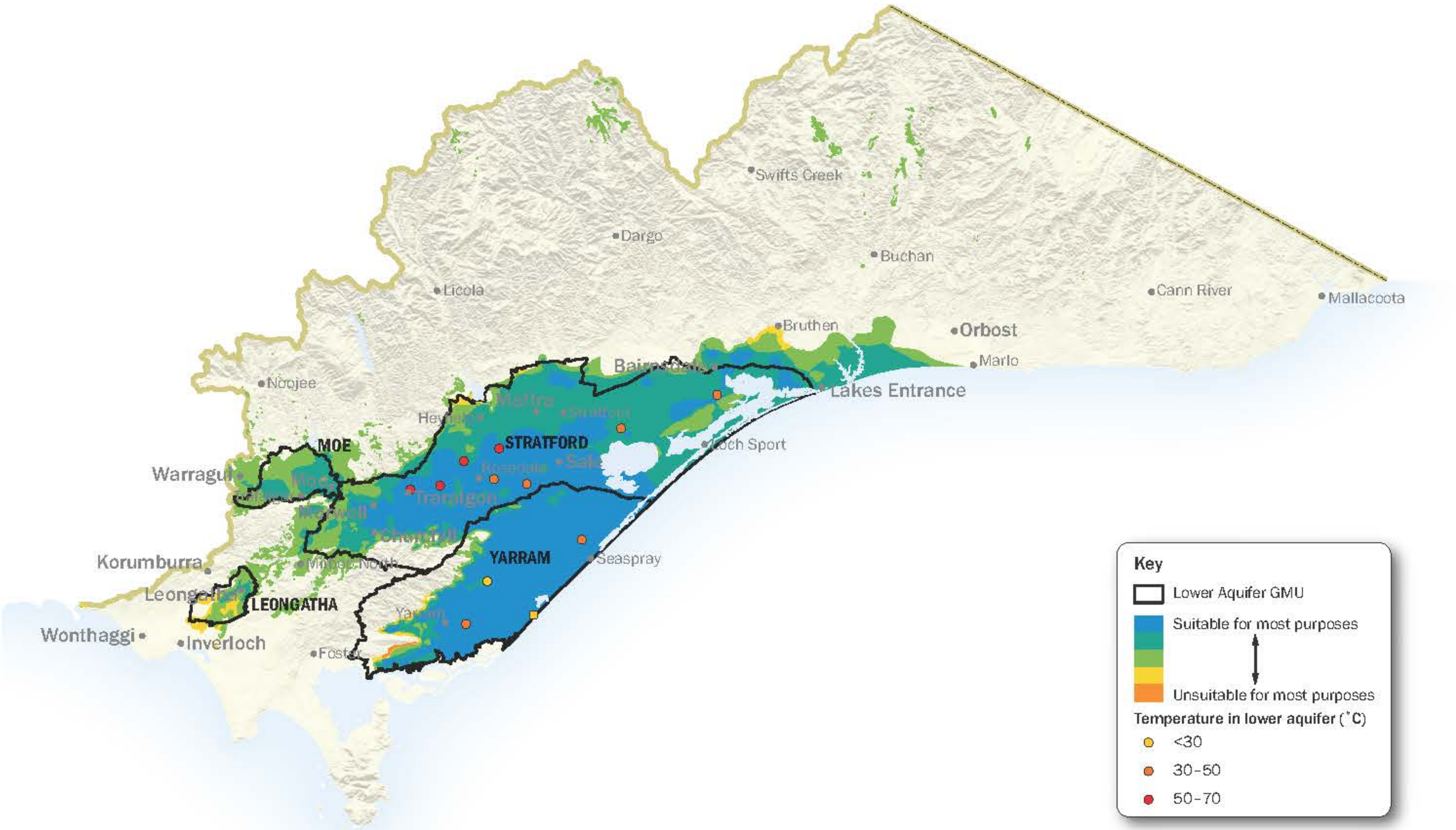
The lowest yielding areas occur around the basin margin and in the north of the Latrobe Group. Outcropping areas in the highlands near Swifts Creek and north of Dargo have relatively low salinity but the yields are very poor. Although not shown on these maps the yield is very low in the basement, which effectively acts as an aquitard.

The temperature of the groundwater in the Latrobe Group ranges from 30°C to 70°C but may be greater at depth or due to local heat sources. These temperatures make it suitable for heating and aquaculture.

It is estimated that the onshore part of the lower aquifers contains approximately 70,000 GL of groundwater.

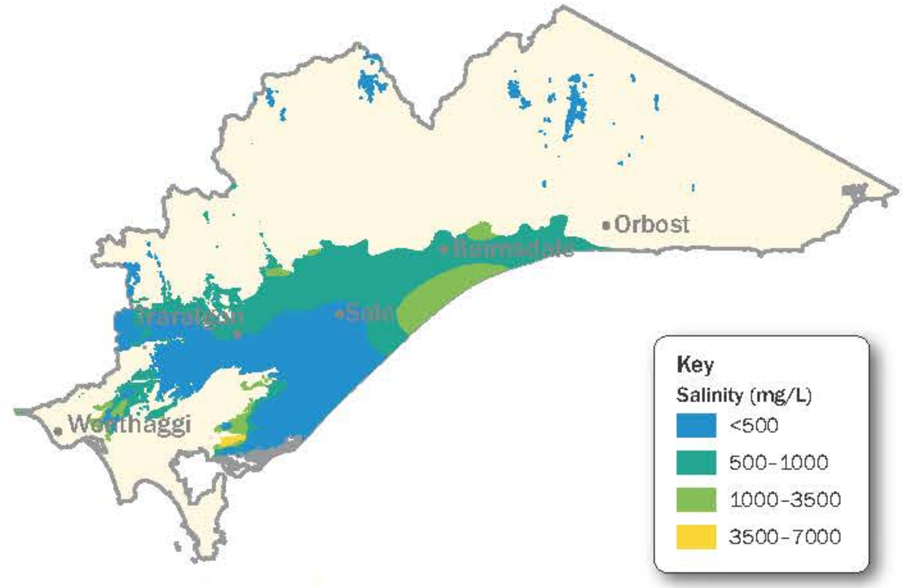
Observations

- **The lower aquifers have very low salinity and areas of very high yield, particularly in the Latrobe Valley and coastal areas.**
- **Yield is lower around the basin margin but the salinity is still suitable for most uses.**
- **Stratford and Yarram groundwater management units cover the areas with the best salinity and yield.**
- **The basement is very low yielding and acts mainly as an aquitard.**

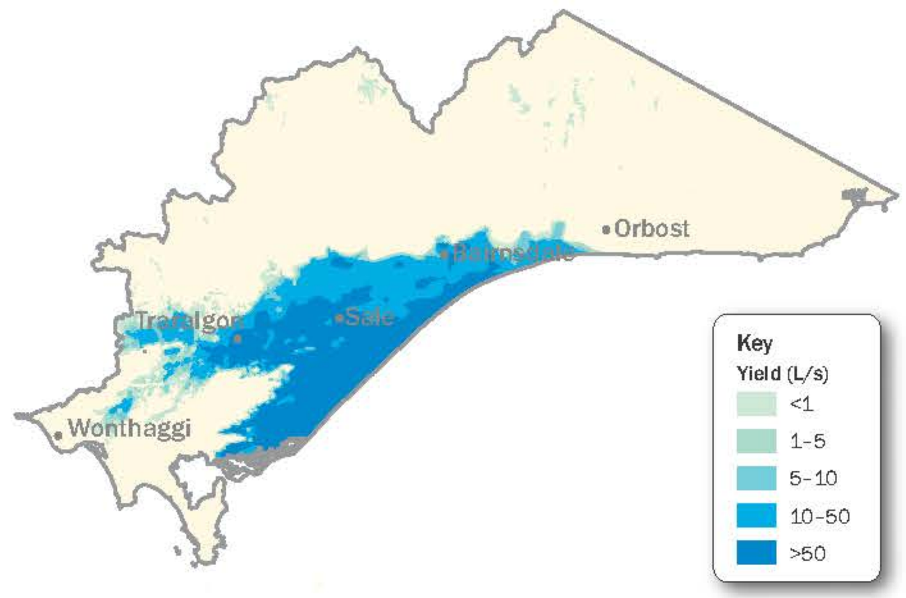


Groundwater use potential based on salinity, yield and temperature

This map combines salinity yield and temperature information to show a snapshot of the potential for groundwater use in the region. This map should not be used to make commercial decisions. Potential users should seek information from hydrogeologists and drillers with expertise in the area as well as local information about existing bores.



Salinity of the lower aquifers



Yield of the lower aquifers

Movement of groundwater

Groundwater in the lower aquifers and basement generally flows towards the coast and continues offshore.

Flow systems

Local and intermediate flow systems with travel distances of less than 30 km occur in the Older Volcanics outcrop areas around Warragul, Thorpdale and Leongatha and where the basement outcrops in the Strzelecki Ranges and the Great Dividing Range. In these areas, groundwater discharges to springs and feeds streams.

Regional flow systems with long travel distances (greater than 30 km) occur where the lower aquifers (mainly the Latrobe Group) and basement are deeper. Groundwater flows from the areas of high elevation at the basin margin towards the coast. The Strzelecki Ranges act as a barrier forcing flow from the north towards the Gippsland Lakes. This groundwater may take up to thousands of years to discharge offshore.

Although the basement is very low yielding and generally acts as an aquitard, it contains groundwater that moves very slowly in a regional flow system. Its groundwater flows from the highest areas of the Great Dividing and Strzelecki Ranges to lower areas.

Recharge

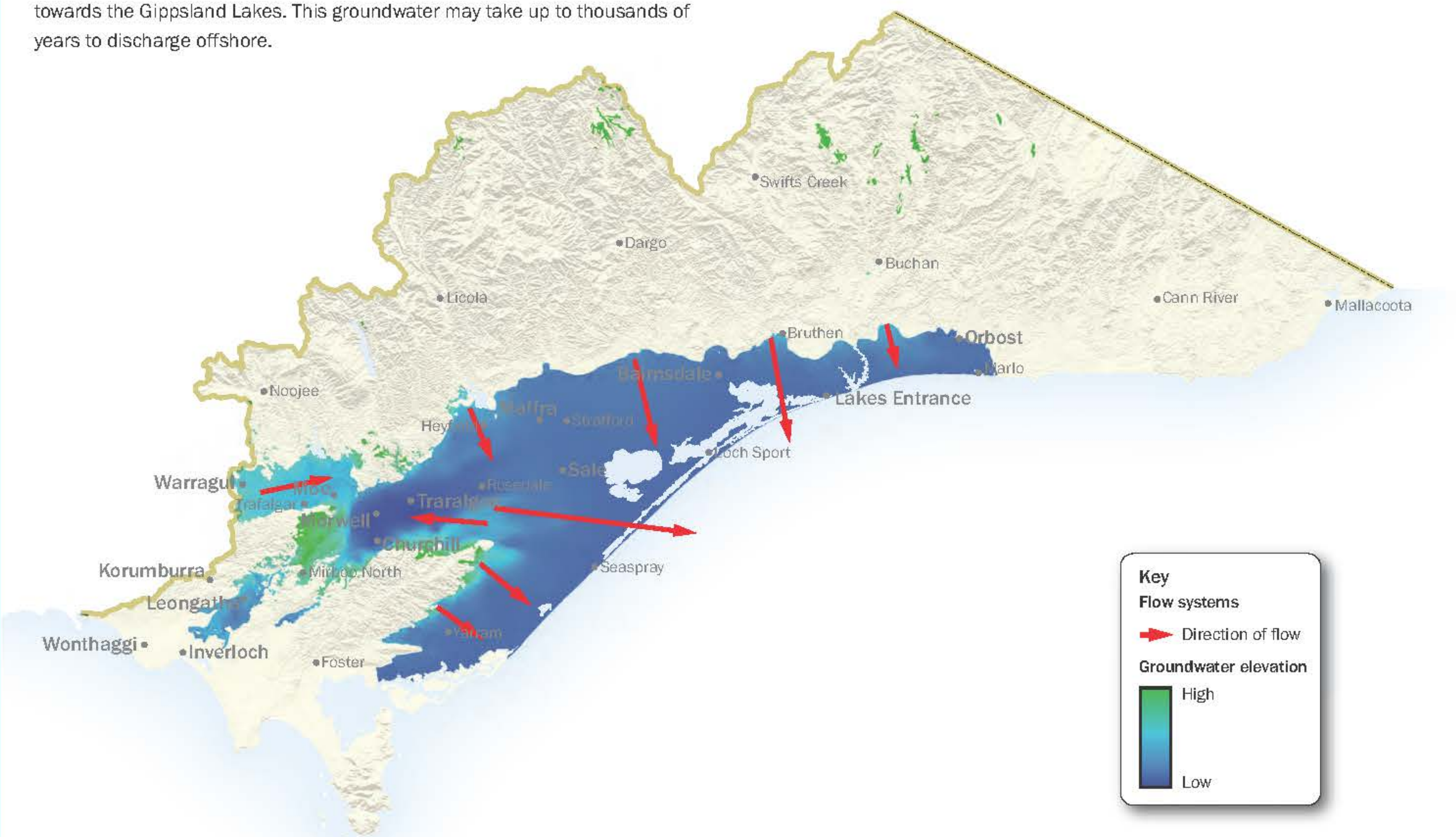
The lower aquifers mainly receive recharge from rainfall and stream leakage around the basin margin as well as leakage from overlying sediments.

Pressure

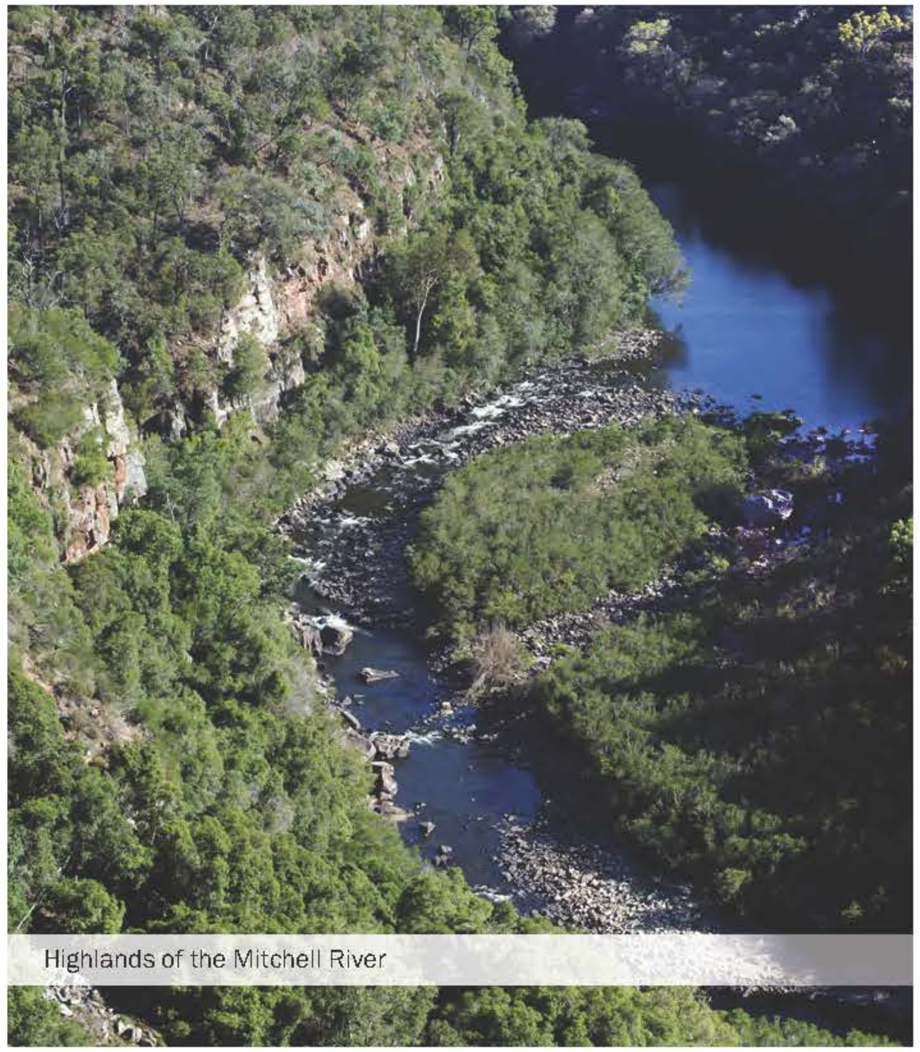
Pumping in the Latrobe Valley mines has caused a change in pressure in the lower aquifers. This has resulted in a local cone of depression that draws flow westward from Rosedale. This is illustrated on the map below.

Observations

- **The overall direction of groundwater flow in the lower aquifers and basement is from the highlands or basin margin towards the coast.**
- **Local flow systems occur where the lower aquifers and basement are at or near the surface. These systems discharge to rivers and streams.**
- **Intermediate flow systems occur where the lower aquifers and basement are near the surface. These systems discharge to streams and other aquifers.**
- **Regional flow systems occur where the lower aquifers and basement are buried deeper. These systems discharge offshore.**



Groundwater elevation and flow direction in the lower aquifers



Highlands of the Mitchell River

Environmental dependence

Unconfined, fractured rock in the lower aquifers and the basement interact strongly with streams in the highlands. The lower sand aquifer (Latrobe Group) rises to the surface in small areas where it interacts with surface environments.

Baseflows and ecosystems

Spring flows from the basement contribute to ecosystems (rivers) across the highland areas in the north and east. Some of these ecosystems are 'Heritage Rivers' (eg the Thomson, Mitchell, Snowy, Bemm and Genoa Rivers) and are in very good condition. High value coastal ecosystems may partially rely on the contribution of baseflows to streams (eg Corner Inlet, Gippsland Lakes).

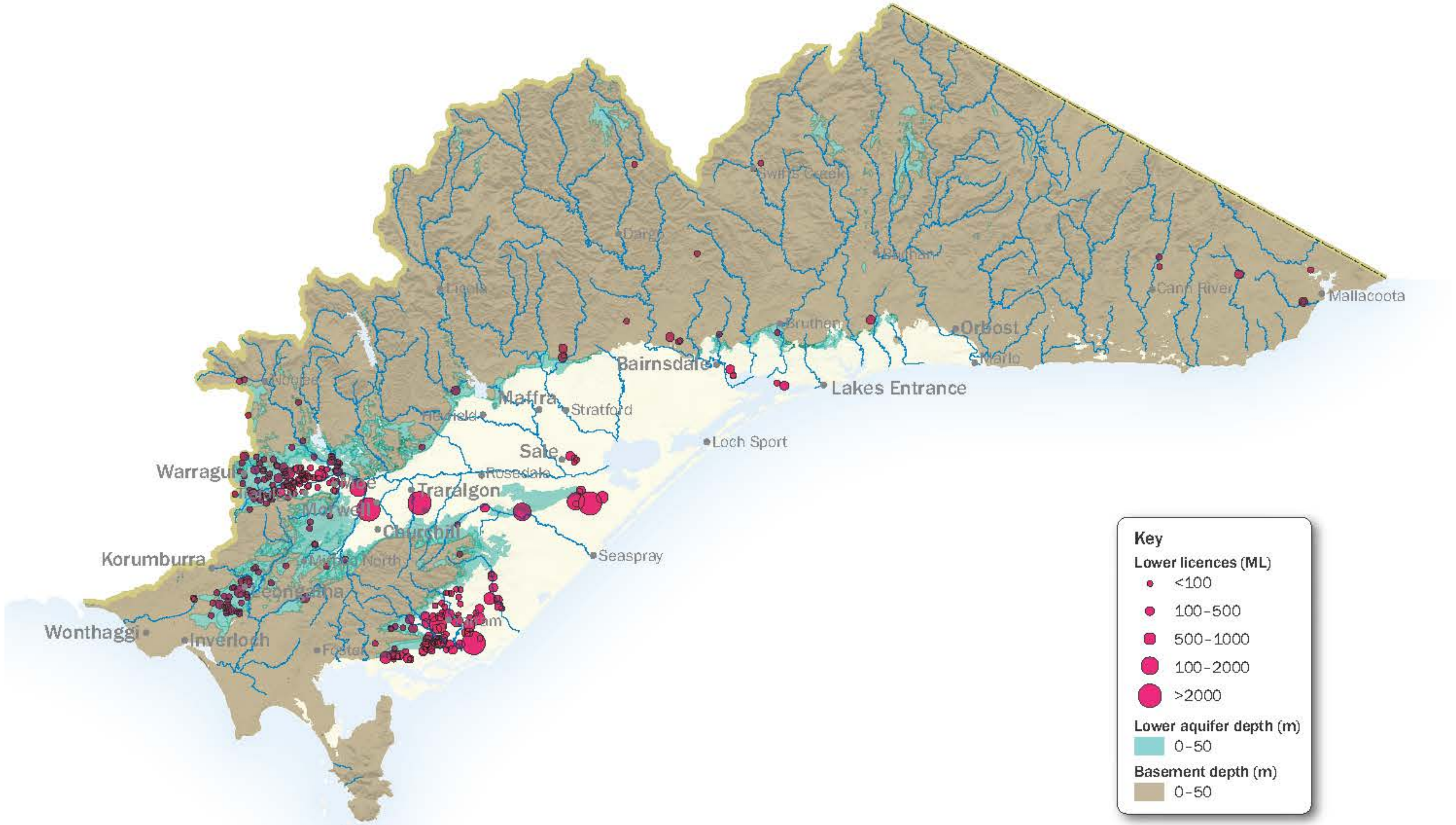
Groundwater pumping

Groundwater extraction can affect stream flows where the fractured rock aquifers occur at or near the surface around Warragul, Thorpdale and Leongatha. However the volume of stream flow intercepted by catchment dams and large storages is much greater than the volume pumped from bores.

Regional groundwater declines in the lower sand aquifer may affect the Tarra River near Yarram. It is estimated that the average annual baseflow in the Tarra River is 13% or 5 ML/day less now that it was in the 1950s when records started. A new observation bore has been drilled near the Tarra River to better understand the relationship between surface water and groundwater.

Observations

- **The lower aquifers and basement receive direct rainfall recharge where they occur at or close to the surface.**
- **Groundwater interacts with surface water in these areas and may contribute to high value ecosystems.**
- **The impact of groundwater pumping on baseflow to the Tarra River is being investigated.**
- **Large storages and farm dams have a more significant impact on stream flows than groundwater pumping.**



Groundwater and the environment

This map shows the region's major rivers crossing areas where the lower aquifers (light blue/green) and basement (brown) occur at or close to the surface. Groundwater licences in the lower aquifers and basement are also shown (pink dots). White areas show where the lower aquifers and basement are deeply buried by shallower aquifers.

Licensed groundwater use in the basement areas is rare because the yield is very low and most of the basement areas occur in state and national parks. Large dams such as Blue Rock, Thomson and Glenmaggie have a much greater impact on stream flows than groundwater pumping.

Thorpdale dams and springs

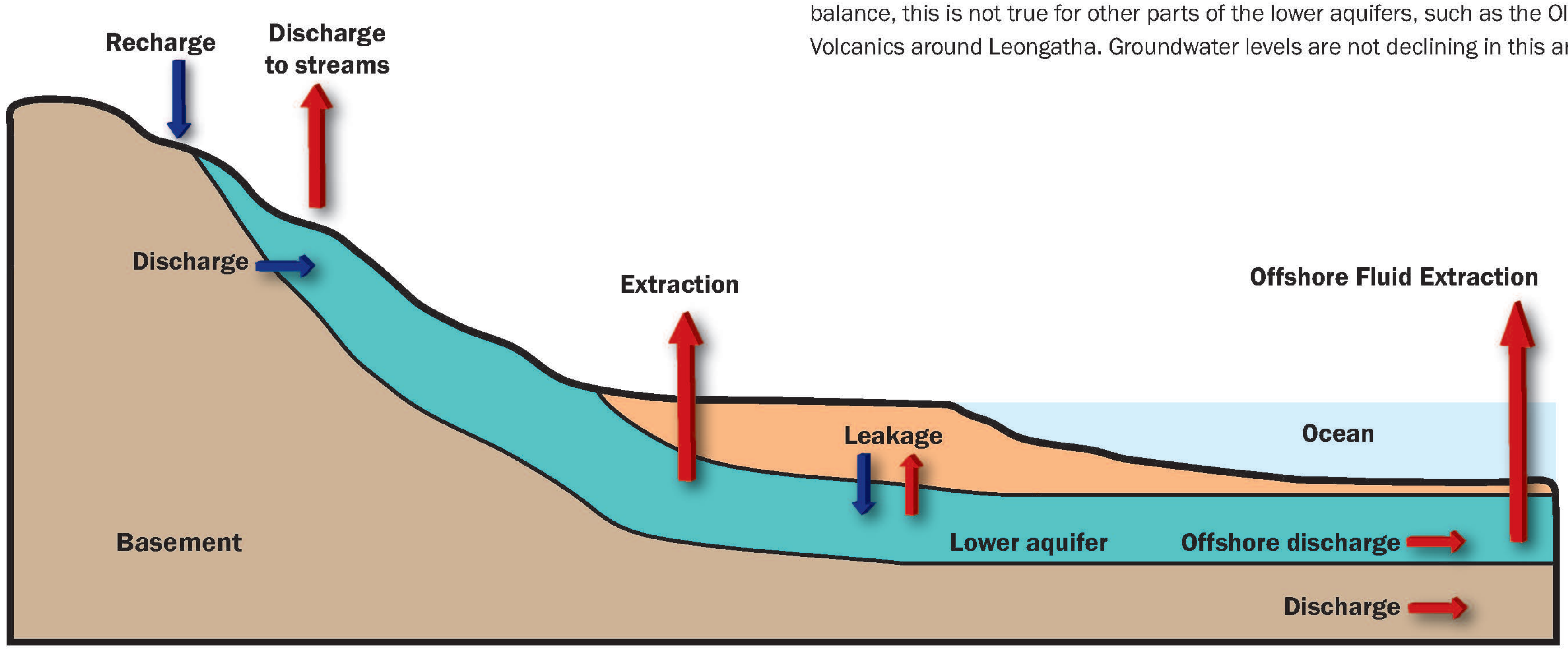
This map shows a high number of farm dams on the spring fed streams near Thorpdale in the Strzelecki Ranges, indicating groundwater interaction. It is probable that many of the dams are fed by springs that flow through the dry months. There are few bores in this area.

Water balance

Water balances have been estimated for the lower aquifers and basement combined and separately for the Latrobe Group (main lower aquifer).

The diagram below shows the elements of the water balance for the lower aquifers and basement. The lower aquifers and basement receive direct rainfall recharge where they occur at the surface in the highlands and around the basin margin. There is likely to be some leakage in both directions between the lower and shallower aquifers but the rate is uncertain. Some horizontal groundwater flow between the basement, lower and shallower aquifers is also likely.

Groundwater discharge to streams occurs from the fractured rock basement in the highlands and where the lower aquifers outcrop. Extraction occurs onshore and offshore. Natural discharge also occurs offshore. Not all of the elements in the diagram below have been included as part of the water balance studies completed to date.



The graph below shows the water balance for the Latrobe Group aquifer only. This aquifer is influenced onshore by industry (primarily mining) and irrigation and offshore by oil and gas extraction (see map on page 59).

Latrobe Group water balance

Overall the estimated recharge to the Latrobe Group aquifer is lower than current extraction causing a deficit of 60,000 ML/yr.

The negative water balance means that this aquifer has been losing water in the long term, which suggests that groundwater storage has been decreasing. This is consistent with the groundwater level trends in many parts of the lower aquifers and basement (see page 57).

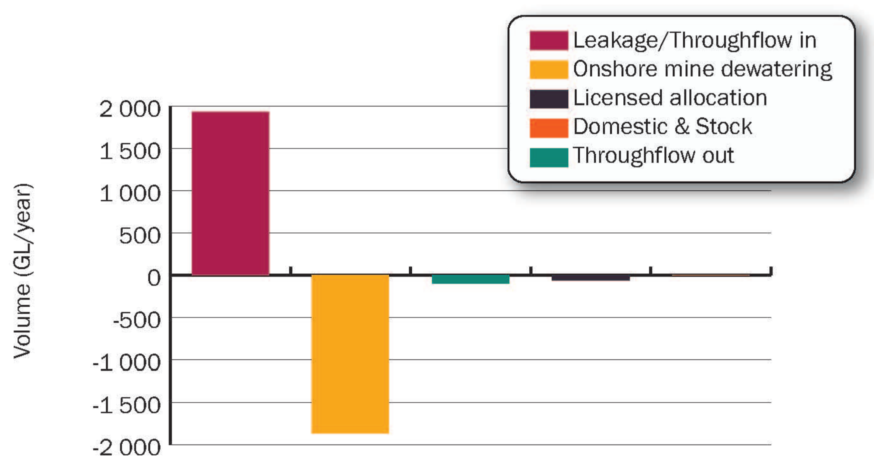
Although the Latrobe Group aquifer is estimated to have a negative water balance, this is not true for other parts of the lower aquifers, such as the Older Volcanics around Leongatha. Groundwater levels are not declining in this area.

Observations

- **The water balance of the basement and lower aquifers combined is influenced mostly by rainfall recharge across the very large areas of basement outcrop and baseflow to rivers.**
- **The water balance of the Latrobe Group aquifer is influenced mostly by recharge (rainfall and leakage) and offshore extraction.**
- **The Latrobe Group (main lower) aquifer is estimated to have been losing water (45-60 GL/year) over the past two to three decades.**

The graph below shows the major inputs and outputs to the lower aquifers and basement. Most of the recharge is from rainfall and most of the discharge is as baseflow to rivers due to the extensive basement outcrop across Gippsland. Recharge and discharge in the basement and Older Volcanics is via local and intermediate flow systems (see page 54). This clearly shows the importance of spring flows from the highlands to the region's rivers. Recharge is significantly higher than in the previous graph because of the much greater area of basement outcrop across the region.

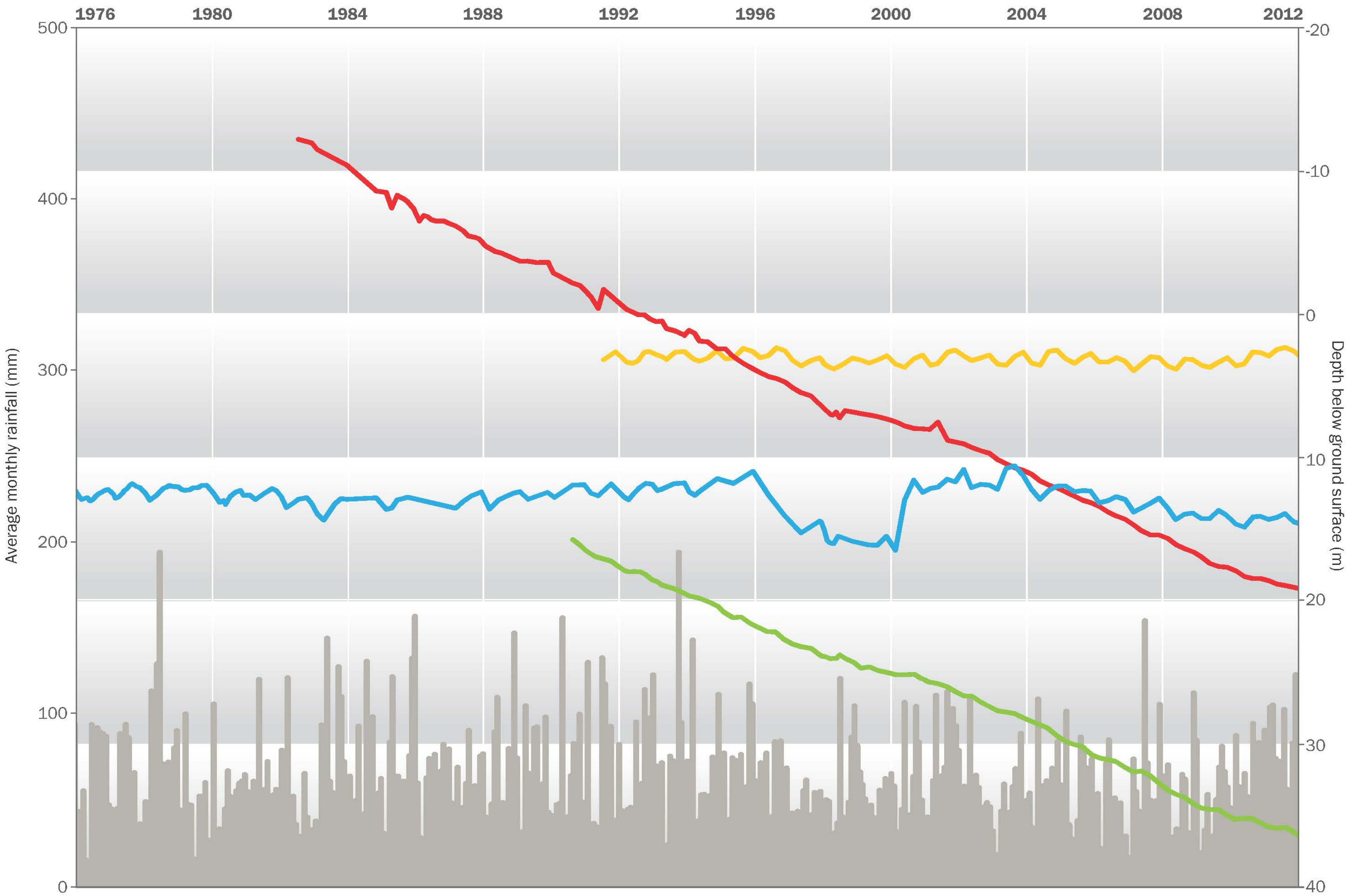
Lower aquifers and basement water balance



The basement is not estimated to have a negative water balance or declining groundwater levels.

NOTE: The two water balance graphs on this page are not directly comparable as they were completed for different purposes and using different methods. However, they are useful for comparing the relative sizes of each component within an area or aquifer.

Regional trends



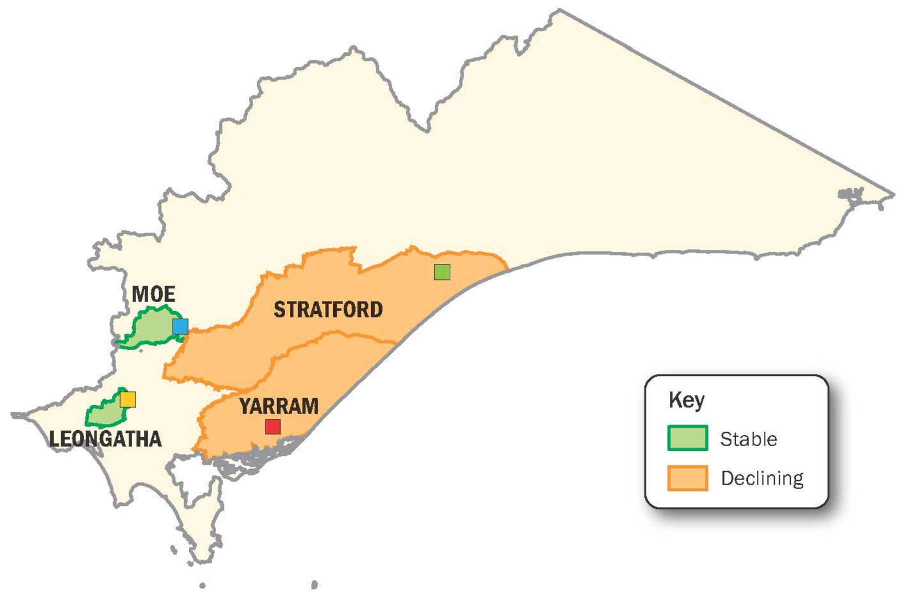
Hydrographs from all monitored State Observation Bores are available on the Southern Rural Water website **www.srw.com.au**

Observations

- The two main formations in the lower aquifers and basement (Latrobe Group and Older Volcanics) show very different behaviour over time.
- Groundwater levels in bores in the fractured basalt of the Older Volcanics show seasonal patterns similar to the upper aquifers.
- Observation bores in Yarram and Bairnsdale show a remarkably similar rate of decline (1 m/yr) despite the large distance between the bore sites.

The hydrograph at left shows depth to groundwater below ground surface in the lower aquifers and basement at specific bore locations together with rainfall.

The map below indicates the regional trend observed from all monitoring bores for each GMU. Bores in the Leongatha and Moe GMUs are in the Older Volcanics. Bores in the Yarram and Stratford GMUs are in the Latrobe Group.



Moe GMU: Bore 107971 is located near Moe. Shows groundwater levels fell during dry period in late 1990s and recovered but are falling slowly.

Leongatha GMU: Bore 71148 is located north east of Leongatha. Shows seasonal rise and fall but no longer term trends. This is typical of water table aquifers.

Yarram GMU: Bore 110726 is located near Yarram away from irrigation bores. Shows long-term declining trend. No seasonal influences observed indicating that the cause is regional.

Stratford GMU: Bore 47063 is located near Bairnsdale away from irrigation bores. Shows long-term declining trend. No seasonal influences observed indicating that the cause is regional.

Rainfall in millimetres

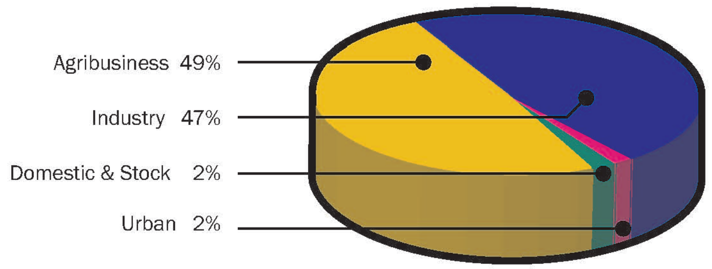
6 Lower aquifers

Users and usage

Agribusiness and industry are the major users onshore. Offshore oil and gas activities also intercept the lower aquifers but do not require a groundwater licence.

Licensed users

Agribusiness and industry are the major licence holders in these aquifers. There are urban licences in Yarram, Leongatha groundwater management units (GMUs) and in the unincorporated area at Mallacoota. The mining industry is the major users of the Stratford GMU.



The largest licence is in Stratford GMU and is used for mine depressurisation. In comparison, licences in the Leongatha and Moe GMUs are typically small.

GMU	Number of licences	Average licence size (ML/yr)	Largest licence (ML/yr)
Leongatha	33	56	715
Moe	96	42	721
Stratford	9	3,776	13,614
Yarram	92	279	2,640
UA	67	46	400

The volume of fluids taken offshore is approximately 100,000 ML/yr. This does not require a licence.

Domestic and stock users

There are approximately 1,000 bores registered for domestic and stock (D&S) use that use around 1,300 ML/yr.

The environment

Springs and vegetation may interact with groundwater in the fractured rock outcrops of the Great Dividing and Strzelecki Ranges where the connection between the aquifers and the surface environment is strongest. Stream interaction may also occur where the Latrobe Group sands rise to the surface around the basin margin in the area north of Yarram and around the flanks of the Latrobe Valley.

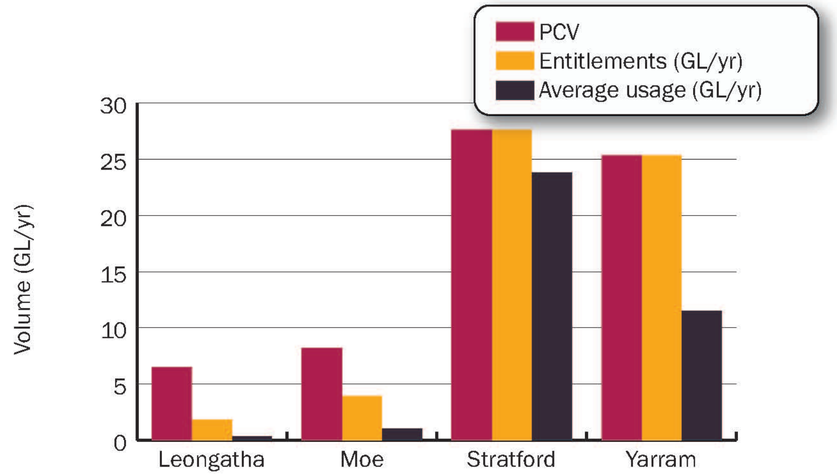
Licensed usage

The Stratford and Yarram GMUs account for approximately 75% of licensed entitlement. There are a small amount of unallocated groundwater entitlements in the Moe and Leongatha GMUs. Surface water interaction and existing interference issues restrict further allocations.

	PCV	Entitlements	Average use
TOTALS (ML/yr)	67,662	61,808	41,640

Entitlements in unincorporated areas are included in this table. PCVs do not apply to unincorporated areas.

A high proportion of entitlements are used to depressurise mines in the Stratford GMU. The mining licences vary over time based on a model that estimates how much depressurisation is necessary to enable mining. This may need to be reviewed if the demand for coal changes.



Sustainable use

Pumping from the lower sand aquifer (Latrobe Group) exceeds its rate of recharge. This is causing significant groundwater decline. The decline in the Latrobe Valley is caused by mine depressurisation. Declines along the coast have been attributed to offshore extraction. As a consequence licensees in the Yarram and Stratford GMUs received an assistance package to replace their bores or failing pumps. These aquifers may recover when offshore pumping stops.

Interaction with the upper and middle aquifers occurs in recharge areas and in areas where there is upward pressure in the lower aquifers. This means that allocation and usage in upper formations impacts and is impacted by the lower aquifers.

Sustainability in the Latrobe Group is impacted by several factors: dewatering for minerals and energy development; the impact of falling groundwater levels on other users (eg the high cost of sinking deeper bores); the impact of pumping on the streams that flow across the sand outcrops at the basin margin; and whether the aquifer can recover once mineral and energy operations reduce or stop.

Observations

- **The lower aquifers are a very important resource for industry and agribusiness.**
- **Management of this resource needs to take account of onshore and offshore extraction.**
- **Yarram GMU has the best potential for trading. The Stratford GMU has the highest licence volume but few entitlements are available for transfer.**

The Older Volcanics aquifer near Warragul, Thorpdale and Leongatha discharges groundwater to streams that are under stress due to surface water diversions. This means that any further allocation, transfer of licences and increase in pumping patterns need to be carefully managed.

Value

The table below shows estimates of the annualised gross value of groundwater for different uses. This emphasises the relative importance of these aquifers for D&S, and agribusiness uses.

The value derived from the Stratford GMU (Latrobe Group) due to industry in the Latrobe Valley greatly exceeds the other GMUs. Where the Latrobe Group occurs close to the surface in the Yarram GMU provides a valuable resource for agribusiness.

GMU	D&S ($)	Agribusiness ($)	Urban ($)	Industrial ($)
Leongatha	122,000	360,000	361,000	254,000
Moe	129,000	968,000	0	220,000
Stratford	63,000	36,000	0	86,207,000
Yarram	392,400	10,970,000	1,431,000	4,292,000
UA	491,000	3,825,000	836,000	473,000
TOTALS	1,198,000	16,159,000	2,628,000	91,445,000

Source: RMCG 2011

D&S value based on cost to replace bore.
Agribusiness value based on farm gate value.
Urban and industrial value based on cost of alternative supply.
Table does not include Unincorporated Areas.

Future development

Groundwater regulation does not allow for substantive new licences from the lower aquifers. A large proportion of the licence volume is held in the Latrobe Valley mines. This volume is required for dewatering mines and is not available to new users through trading. The greatest opportunity is through trades from the Yarram GMU because it has a greater number of licences and unused entitlement than elsewhere. The demand for minerals and energy resources may stimulate groundwater exploration and trades.

Current and emerging issues

The lower aquifers and basement are used intensively by the energy and agricultural sectors. These aquifers have a relatively high storage capacity but the rate of recharge is less than the rate of extraction.

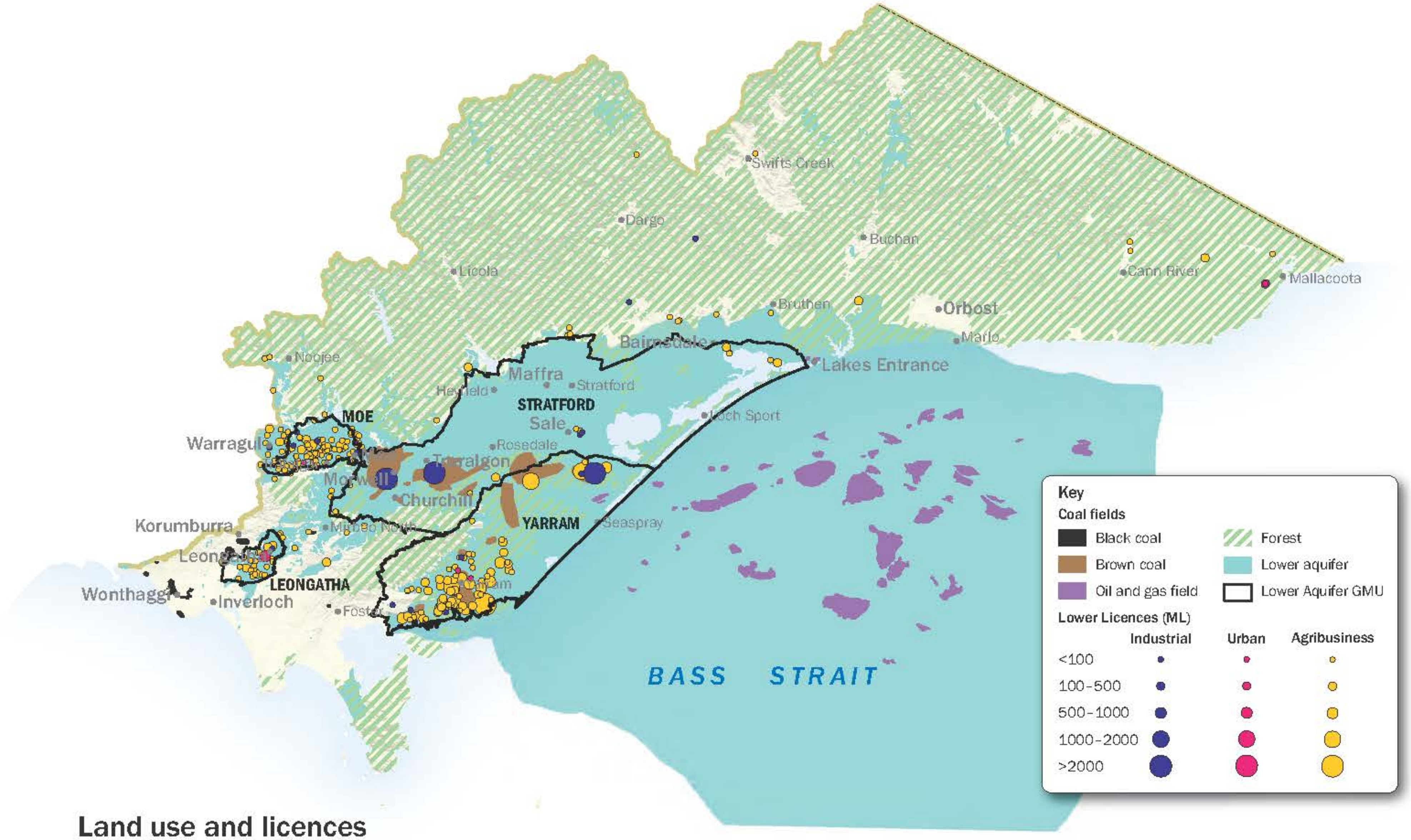
The map below shows the distribution of mapped coal fields, oil and gas fields, groundwater licences and forested areas. These areas are where current and future competition between users is most likely to occur (see pages 24 and 25 for more information about the energy resources of Gippsland).

Regional issues

- Ongoing regional groundwater level decline in most areas (see page 57)
- Potential sea water intrusion due to aquifer depressurisation
- Potential cross-aquifer contamination due to faulty or poorly constructed bores
- Potential groundwater contamination due to new techniques to extract energy resources
- Land subsidence due to aquifer depressurisation

Observations

- **Intensive extraction in the lower aquifers and basement has led to ongoing declines in regional groundwater levels and aquifer depressurisation.**
- **The lower aquifers are being explored for coal, coal seam gas, natural gas and oil development.**
- **Very deep basement aquifers are a future target for geothermal energy and carbon sequestration.**
- **The complex groundwater management issues for these deep aquifers require coordinated planning and administration.**



Land use and licences

This map shows the forested areas (native forest and plantation) and fossil fuel resources in the lower aquifers and basement. Groundwater licences in the lower aquifers are also shown.

These issues are very complex and require a cooperative management approach. The investigations and monitoring required are expensive due to the large area and depth covered. The Gippsland Sustainable Water Strategy sets out a whole-of-government approach that reduces duplication and coordinates the requirements of the regulating agencies.

The energy and mineral industries are typically regulated by multiple agencies.

Basement development potential

The basement mainly acts as an aquitard; however it has confined reservoirs of water, oil and gas. These deep reservoirs (which occur up to several kilometers below the surface) are potential targets for geothermal energy and carbon sequestration. The potential impact of such activities on the overlying aquifers is limited by the great depth and confinement of these reservoirs.

Permissible consumptive volumes restrict access to these reservoirs because they apply to all depths. The State government and relevant agencies are working together to revise groundwater management boundaries so that these very deep basement aquifers can be managed appropriately and separately to the water supply aquifers.

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Wy Yung PAV report, SKM, 1998	Water balance	4

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Further weblinks that may be of interest can be found on page 4.

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