Lower Tertiary Aquifer Groundwater Resource Appraisal

LOWER TERTIARY AQUIFER GROUNDWATER RESOURCE APPRAISAL

- 23rd September 2010

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Executive Summary

This report provides an appraisal of the groundwater resources of the Lower Tertiary Aquifer (*LTA*) of southwest Victoria (*refer to the glossary on page xvii for italicised terms*). Urban, industrial and agricultural enterprises all utilise the groundwater within the LTA. Resource managers require a greater understanding of the resource to manage current demand and to evaluate opportunities for increased demand, should it arise. This study provides knowledge that can be used to inform future management of the aquifer's resources. The key products are a series of maps and cross sections and a water balance. The key findings relevant to the management of the resource are detailed below.

The geology of the region influences the groundwater flow. Management should be tailored to the specifics of each area within the region.

The LTA is made up of layers of gravel, sand, silt and mudstone. Underlying the LTA are layers of very low permeability rock and sediment (the *basement*). The LTA is present at the surface (i.e. it *outcrops*) around the margins of the Dundas Plateau and the Otway Ranges. In the rest of the study area, the LTA is buried under a sequence of other *aquifers* and *aquitards* (Figure A). The LTA is very deeply buried in the coastal regions and under the ocean floor.

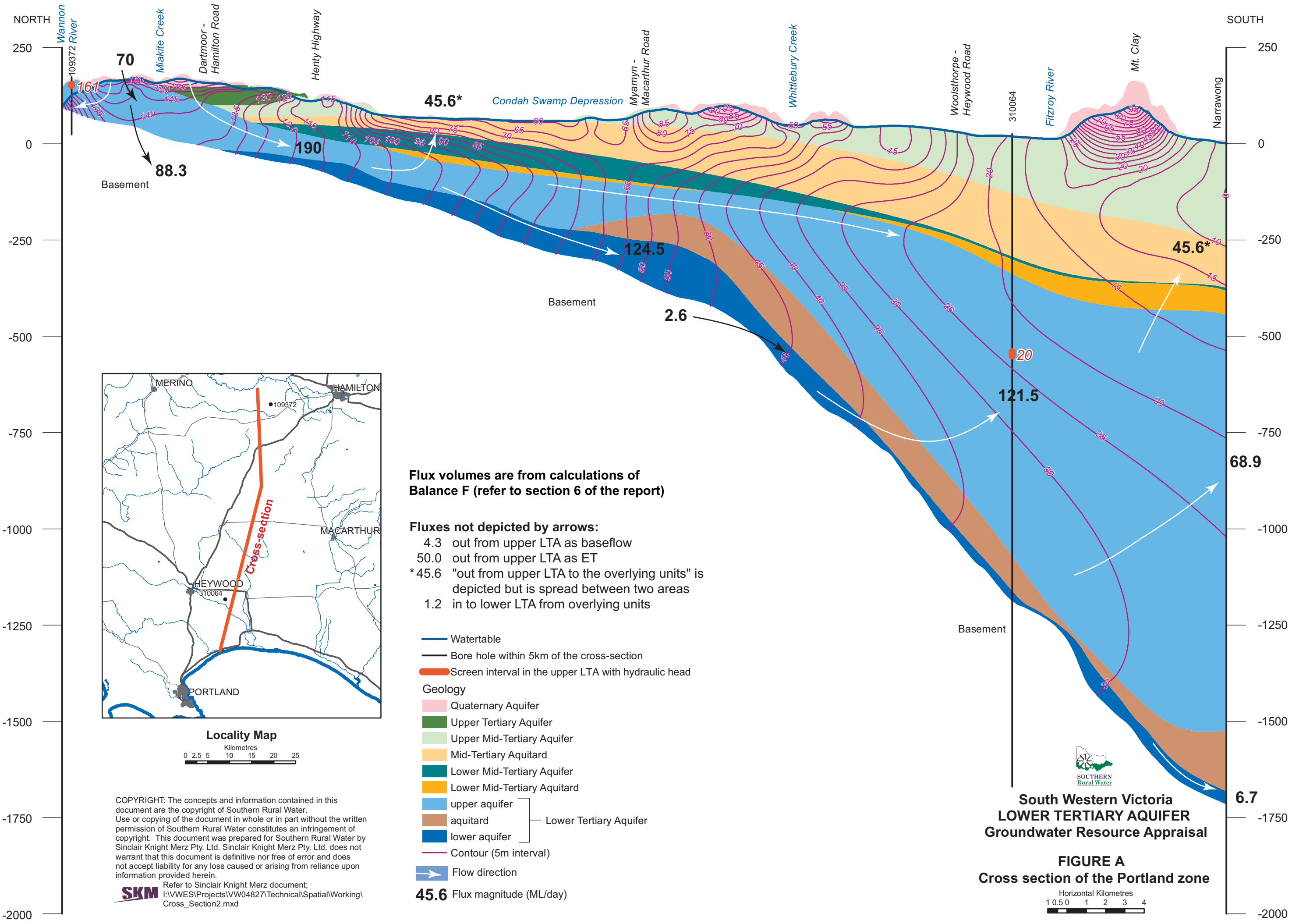
This study divided the LTA into 5 zones: Glenelg, Portland, Warrnambool, Port Campbell and Newlingrook. Each zone has specific geographical and geological features that influence *groundwater flow.* Therefore, management must be tailored to specific areas' needs. Groundwater flow between the zones is minimal, as the boundaries are aligned with the flow directions. However, management decisions for one area should take into account those of neighbouring areas.

The thickness and spatial distribution of the gravel, sand, silt and mudstone of the LTA are mapped in this study and a link is made with the distribution of the *hydraulic conductivity* within the LTA. The *hydraulic conductivity* of the LTA influences groundwater flow and the results of the water balance calculations, as do the hydraulic conductivity values of the layers overlying the LTA. Calculations in this report provide the first quantitative estimates of the vertical hydraulic conductivity of the aquitard that overlies the upper LTA.

The groundwater flow of the LTA must be understood to be properly managed. Horizontal flow is mainly southward and vertical flow is important in all zones. In some zones surficial processes are also important.

The mechanisms of groundwater flow in the LTA are:

- Rainfall *recharge* (surficial process);
- *Evapotranspiration* (surficial process);
- *Baseflow* (surficial process);
- Lateral flow (horizontal component); and
- Interaquifer leakage (vertical component).


NORTH
SOUTH
Wannon River
109372
Miakite Creek
Dartmoor - Hamilton Road
Henty Highway
Condah Swamp Depression
Myamyn - Macarthur Road
Whittlebury Creek
Woolsthorpe - Heywood Road
310064
Fitzroy River
Mt. Clay
Narrawong
161
70
88.3
190
45.6*
124.5
2.6
20
121.5
45.6*
68.9
6.7
Basement
Basement
Basement
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
Locality Map
Kilometres
0 2.5 5 10 15 20 25
MERINO
HAMILTON
109372
MACARTHUR
HEYWOOD
310064
PORTLAND
Cross-section
Flux volumes are from calculations of Balance F (refer to section 6 of the report)
Fluxes not depicted by arrows:
4.3 out from upper LTA as baseflow
50.0 out from upper LTA as ET
*45.6 "out from upper LTA to the overlying units" is depicted but is spread between two areas
1.2 in to lower LTA from overlying units
Watertable
Bore hole within 5km of the cross-section
Screen interval in the upper LTA with hydraulic head
Geology
Quaternary Aquifer
Upper Tertiary Aquifer
Upper Mid-Tertiary Aquifer
Mid-Tertiary Aquitard
Lower Mid-Tertiary Aquifer
Lower Mid-Tertiary Aquitard
upper aquifer
aquitard
lower aquifer
Lower Tertiary Aquifer
Contour (5m interval)
Flow direction
45.6 Flux magnitude (ML/day)
SOUTHERN Rural Water
South Western Victoria
LOWER TERTIARY AQUIFER
Groundwater Resource Appraisal
FIGURE A
Cross section of the Portland zone
Horizontal Kilometres
1 0.5 0 1 2 3 4
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SKM
Refer to Sinclair Knight Merz document; I:\VWES\Projects\VW04827\Technical\Spatial\Working\Cross_Section2.mxd

These influx and outflux mechanisms have varying importance in each zone and occur in specific areas of the study region (see table below).

Influx mechanism		**Outflux mechanism**	
Rainfall recharge	Prevalent in vicinity of Glenelg and Gellibrand Rivers	Evapotranspiration	Prevalent in vicinity of Glenelg and Gellibrand Rivers
		Baseflow	
Interaquifer leakage (downward)	Prevalent in many areas	Interaquifer leakage (downward)	Prevalent in some northern areas
Interaquifer leakage (upward)	Rare (some southern areas only)	Interaquifer leakage (upward)	Prevalent in some southern areas
Lateral flow	Rare	Lateral flow into offshore area	Prevalent

For example, groundwater may enter the LTA in the Portland zone via recharge (where rainwater seeps directly into the aquifer) in areas where the LTA is close to the surface (Figure A). In these areas, the processes of evapotranspiration and baseflow also occur. In other areas, the LTA receives inflow of groundwater via leakage from the overlying units. Groundwater mainly exits the LTA of the Portland zone by flowing into: the basement below; the overlying units; and the offshore part of the LTA. The horizontal flow within the LTA is generally southward (Figure A).

The conceptual model of the Portland zone also applies to the Glenelg and Port Campbell zones. The Warrnambool zone is different in that no surficial processes exist due to the thickness of the overlying units. The Newlingrook zone is the inverse, where the surficial processes are the most important because the LTA outcrops in much of that area. Management should be sensitive to the differences of each zone.

The water balance provides quantifications of the above mentioned fluxes and reinforces the conceptual model. Current extraction rates can now be compared to regional fluxes, as well as the proximity of extraction sites to recharge and discharge sites.

The conceptual model is reinforced by the steady state water balance calculations, which addressed each flux mechanism in each zone. The results for the upper part of the LTA are provided below in Table A. Importantly, the water balance implies that water can flow downward from the LTA into the underlying layers (the *basement*) and *vice versa*. Vertical leakage is generally the largest flux in the balance and there is a lot of uncertainty as to the value of one of its parameters (vertical *hydraulic conductivity* of the overlying units). Therefore, vertical leakage contributes the most significant uncertainty to the water balance. Uncertainty in future water balance iterations would be reduced if the hydraulic characteristics of the LTA and the overlying units were to be investigated further.

The balance is a steady state representation of average recent conditions (over about 50 years). The fluxes can be directly compared to extraction or entitlement volumes. Also, the proximity of influx zones to extraction bores can be gauged. Additionally, the balance can be adjusted to emulate

Table A: Water balance for the upper part of the LTA

UPPER AQUIFER			Glenelg	Portland	Warrnambool	Pt Campbell	Nwgrk Sth	Nwgrk Nth
FLUX TYPE	**FLUX DIRECTION**	**FLUX DESCRIPTION**	**INFLOWS [ML/day]**					
vertical	down	in from overlying units	280.0	190.0	47.5	225.2	6.9	4.1
vertical	up	in from lower LTA	62.0	121.5	73.7	10.0	0.3	23.6
vertical	up	in from basement	0.0	0.0	0.0	0.0	0.0	0.0
lateral	SE	in from the SA border	0.5	NA	NA	NA	NA	NA
lateral	SE	in across Kennedy Ck	NA	NA	NA	NA	4.9	NA
lateral	SW	in from Barwon Downs	NA	NA	NA	NA	NA	11.6
surficial		rainfall recharge	78.4	70.0	NA	119.3	77.6	55.0
FLUX TYPE	**FLUX DIRECTION**	**FLUX DESCRIPTION**	**OUTFLOWS [ML/day]**					
vertical	up	out to overlying units	14.2	45.6	11.1	25.1	3.6	5.7
vertical	down	out to lower LTA	164.2	124.5	38.2	270.0	57.9	63.3
vertical	down	out to basement	36.6	88.3	34.1	18.6	0.0	0.0
lateral	SW	out across the SA border	28.1	NA	NA	NA	NA	NA
lateral	SE	out across Kennedy Ck	NA	NA	NA	4.9	NA	NA
lateral	SW	out across Gellibr. Saddle	NA	NA	NA	NA	NA	9.7
lateral	S	out towards offshore	25.6	68.9	37.8	26.5	12.5	NA
surficial		out as baseflow	30.0	4.3	NA	1.2	1.8	6.7
surficial		out as ET	122.1	50.0	NA	8.3	13.9	8.7

anticipated future conditions relating to climate change and/or land use change.

Some terrestrial, riparian and aquatic ecosystems partly rely on groundwater from the LTA.

The baseflow from the LTA contributes to the natural flow levels of the Glenelg and Gellibrand Rivers and some of their tributaries. Therefore, the rivers' aquatic ecosystems are in part supported by the baseflow. Discharge of groundwater via *transpiration* supports ecosystems by supplying water to plants. This can only occur where the LTA and the watertable are close to the surface. Regions of potential ecosystem dependence on the LTA are mapped in this project.

The quality of the groundwater makes it amenable for many uses, although areas of poor quality water exist. It is very difficult to predict the quality of the water; hence management must rely on current and future observations.

The groundwater of the LTA is of potable quality in many areas. It is used as the municipal supply in several towns, such as Portland (700 mg/L), Port Fairy (800–900 mg/L), Port Campbell (270 mg/L), Heywood (600–700 mg/L) and Dartmoor (400–600 mg/L). However, in some areas, for example the regions of the LTA below Warrnambool and Camperdown, the groundwater is poorer quality (e.g. salinity >3,500 mg/L and >7,000 mg/L respectively). In addition to these lateral variations in salinity, complex vertical variation in water quality is also observed. Some vertical mixing of water of different qualities may be facilitated by failed bores (also see finding below). A preliminary assessment of the risk posed by this failed infrastructure on the resource is recommended.

The salinity has become naturally concentrated in the groundwater over thousands of years via the process of evapotranspiration. Evapotranspiration occurs at the surface and is controlled by factors such as topography, climate, soil type and vegetation type. Therefore, all of these factors are relevant to devising management plans aimed at protecting the quality of the groundwater in areas where it is potable but where salinity approaches or exceeds 1,000 mg/L (e.g. the margins of the Dundas Plateau). Management should take into account the long residence times of groundwater, which mean that only receptor sites that are sufficiently close to the influx zones (e.g. Dartmoor and the Glenelg River) will benefit within the management timeframe.

Gaps exist in the monitoring network of the LTA, preventing more detailed characterisation of flow paths. This, together with inconsistencies in data, results in problems for managers.

In some parts of the LTA, or the overlying layers, there is no knowledge of the groundwater pressure from bores, past or present. These gaps inhibit the constraint of the groundwater flow paths in particular areas. An investigation within this study found that many boreholes, both private and state-owned, which were thought to be tapping the LTA are now destroyed or their data are incorrectly recorded. Therefore, several data capture and data auditing tasks are recommended, as well as improved collection of data at the time of borehole drilling.

Future changes to the groundwater flow in the LTA are expected as a result of past and ongoing effects from: groundwater extraction and changes in climate, sea level and land use.

The investigations of the transient state of the LTA undertaken in this study have revealed that the above factors can cause changes to the equilibrium of the study area. Lag times between cause and effect are to be expected and are calculated in this study for the LTA with respect to extraction. Groundwater extraction from the LTA has been underway for several decades now and has contributed to a lowering of groundwater levels in some areas. Estimated lag times indicate that current and/or past pumping from the LTA is likely to have a further effect on surface water systems and groundwater of the overlying units in the future. The magnitude of the impact of pumping on specific discharges, e.g. baseflow or ET, at any particular time is dependent on the volume of extraction, the proximity of the pumping location and the consequence of discharge reduction (e.g. effects on ecosystems). The quantification of fluxes in the water balance aids in the determination of these impacts.

It appears that climate change in about the last 200 years has resulted in a general lowering of the ratio of precipitation to evaporation in most of the region, meaning that a reduction in recharge and/or an increase in discharge via evaporation can be anticipated and has already been observed in some areas. The effect of this change is also observable through the recorded decline in lake levels over more than a century (e.g. Lakes Keilambete and Bullen Merri).

Sea level is an important controlling condition for the LTA. Because of its coastal location, the groundwater of the LTA, especially that contained in the offshore part of the LTA, is in hydraulic connection with the ocean. Between about 20,000 and 6,000 years ago, sea level increased significantly due to global glacial cycles. Since then it was relatively stable until about 1800 AD, when it began to rise at a more subdued rate as a result of global warming. It is possible that these changes have yet to be fully accommodated in the LTA groundwater regime. As a result, it is likely that the *freshwater-saltwater interface*, which is currently in an unknown position offshore, is likely to migrate landward in the future. This may pose a risk to the coastal groundwater resources. Saline intrusion would be detected first at the deepest levels of the aquifer and it could take less than a year for the water at a certain point to become unusable for certain purposes.

Land use change is also anticipated to affect the groundwater flow systems of the LTA in the future. A significant expansion of the forestry industry in parts of the study area is likely to increase discharge via transpiration and reduce recharge in some regions (depending on development scale).

Overall, the groundwater of the LTA is a valuable resource which must be managed appropriately for the sake of all users and the environment. The groundwater resources of the LTA have been shown to be susceptible to several risks in terms of both the water levels and water quality. Factors such as climate, land use, sea level, topography and groundwater use are all influential. Further investigations and work have been recommended in this report in response to the identified key knowledge gaps.