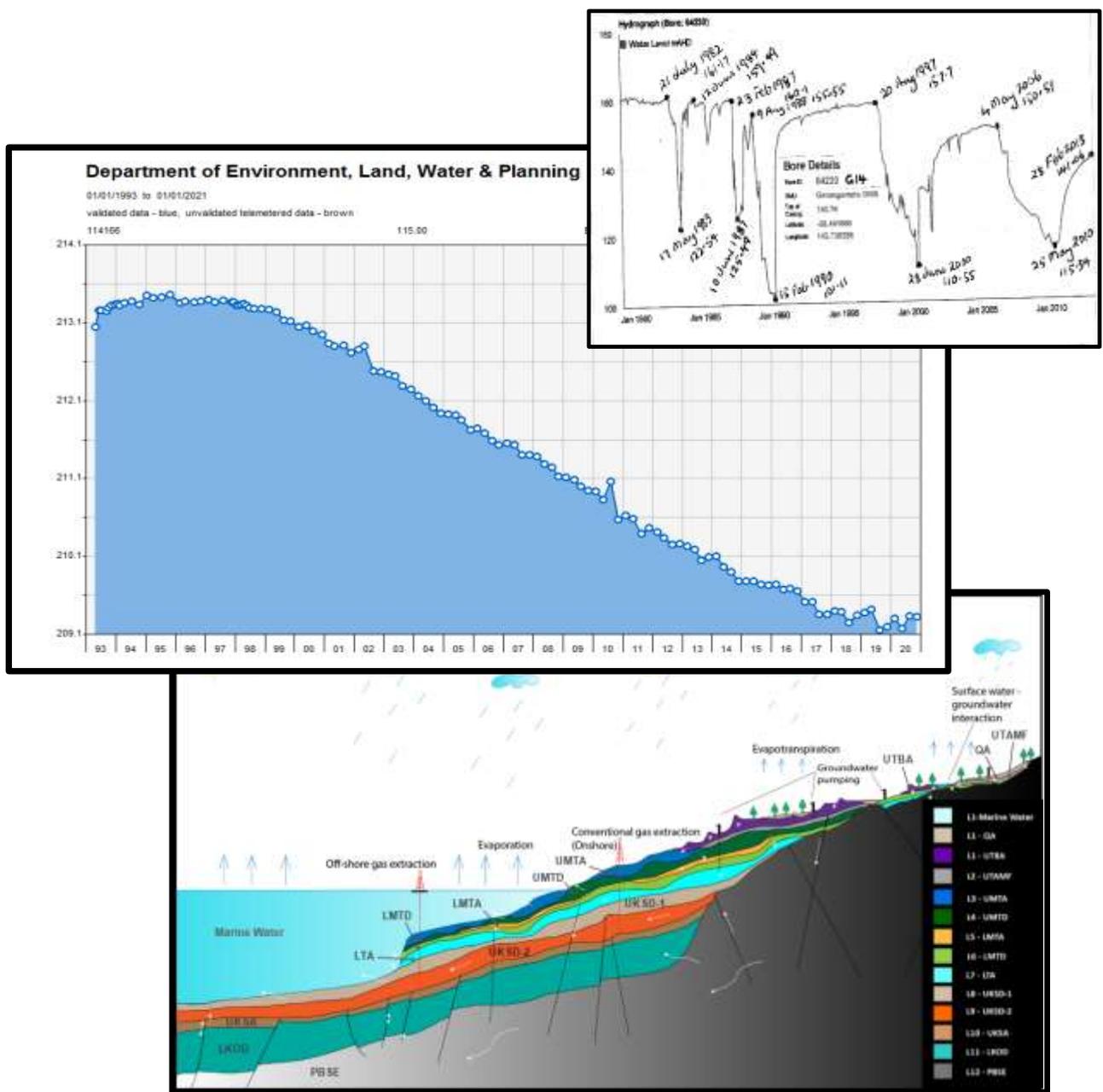


“Continuing Borefield Drawdown Influence on the Extremities, 11 Years After Pumping Has Ceased.”



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This book may be of assistance to you, but there is no guarantee that the publication is without flaw of any kind or is wholly appropriate for your particular purposes and therefore disclaim all liability from error, loss or other consequence that may arise from relying on any information in this book.

This book has been prepared, and supporting documents used, with diligence. Statements within this publication that originate from groups or individuals have not been evidentially tested. No liability is accepted from any action resulting from an interpretation of this book or any part of it. The data in this book is arrived at from information sourced and available in the public domain at the time. The passage of time, manifestation of latent conditions or impacts of future events may necessitate further examination and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this book. This book has been prepared in accordance with care and thoroughness. No warranty or guarantee, whether expressed or implied, is made of the data, observations and findings expressed in this book. This book should be read in full. I accept no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this book by any third party. However, I do sincerely hope this book encourages you to enquire about and or further evaluate the material presented and diligently follow up on any aspect of Otway Ranges water resource management that may have been aroused in your mind but not answered.

February 2021
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INTRODUCTION

A combination of factors including the material and argument presented in Otway Water Books 21 and 28 was convincing enough to prompt the LAWROC Landcare Group to commission Alan Wade to investigate the connectedness between groundwater extraction at the Barwon Downs Borefield and the falling groundwater levels in the Kawarren and Gellibrand area. Alan was eventually asked to conduct three such investigations.⁽¹²⁾⁽¹³⁾⁽¹⁴⁾

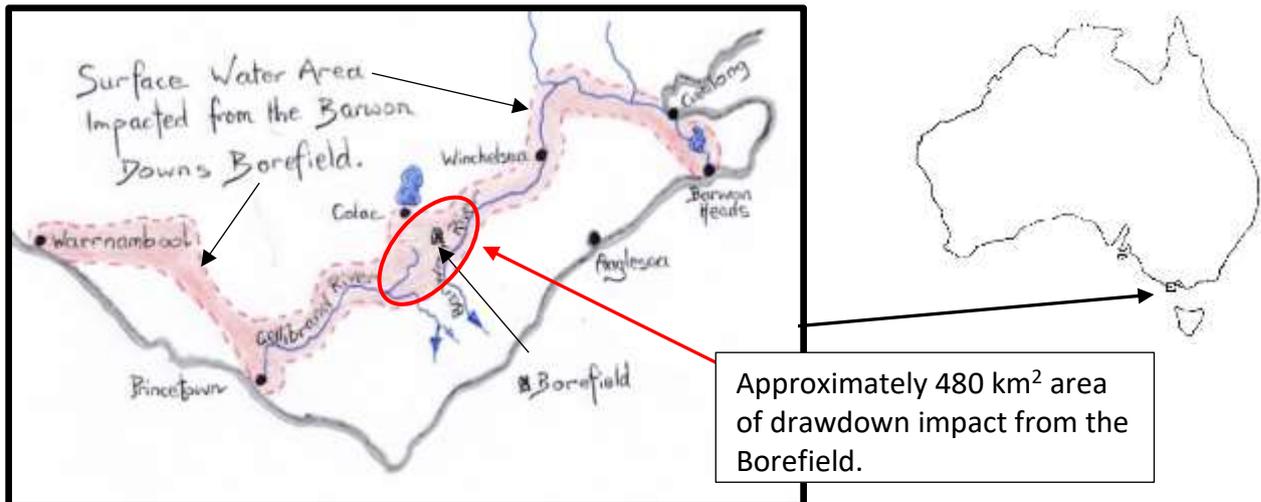
It was obvious from the hydrographs presented in Books 21 and 28 that since groundwater extraction at the Barwon Downs Borefield ceased in 2010, observation bores close to the borefield that had been impacted responded quite differently to the water levels in the observation bores on the extremities of the drawdown. In Wade's last report commissioned by LAWROC, Wade concluded that a significant amount of groundwater normally flowing down the Kawarren Gellibrand corridor was being drawn towards the Barwon Downs Borefield.

When the pumping ceased the groundwater levels in the bores nearest the Borefield began to rise drawing groundwater in from the extremities. However, the cone of depression continued to expand and the groundwater levels in the bores on the extremities continued to drop. By 2019 Loves Creek, a tributary of the Gellibrand River had lost 60% of its natural summer base flow from the Kawarren Gellibrand groundwater flowpath at the south western extremity.⁽¹⁴⁾

To the north east, Jacobs, Barwon Water's consultants, determined that the groundwater flowpath normally flowing past the Barwon Downs Borefield area towards Deans Marsh had been completely reversed during pumping.⁽¹⁰⁾ Deans Marsh is also on an extremity of the Borefield drawdown influence.

Otway Water Book 21 B is a follow on from Book 21 (2013) and Otway Water Book 28 (2015), comparing the 2015 hydrographs with those of 2021.⁽⁸⁾ The marked difference in groundwater levels between those bores closer to the Barwon Downs Borefield and those on the extremities, has become more pronounce.

Location Map.



The red circle indicates the area of drawdown influence made by the cone of depression. Soaks, springs, wetlands, creeks and rivers within this area can be impacted from a reduction of a natural outflowing of water from the aquifers. A reduction in this outflowing of water is then reflected in the arterial water courses that flow out of this region. In this way any impact can spread into those areas that rely on this outflowing of water. This influence spreads as far as Warrnambool in the west and Geelong in the east. A substantial region of south eastern Victoria is impacted to one degree or another from the groundwater extraction that has taken place at the Barwon Downs Borefield.

Surface area influenced by the cone of depression.

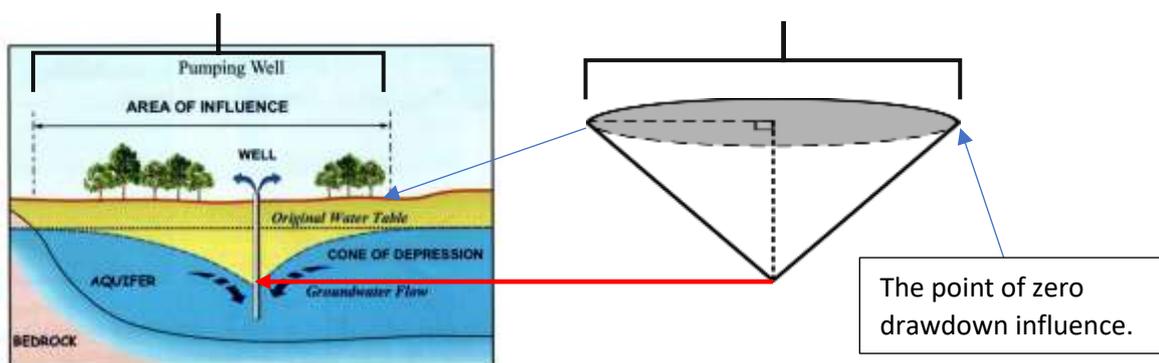
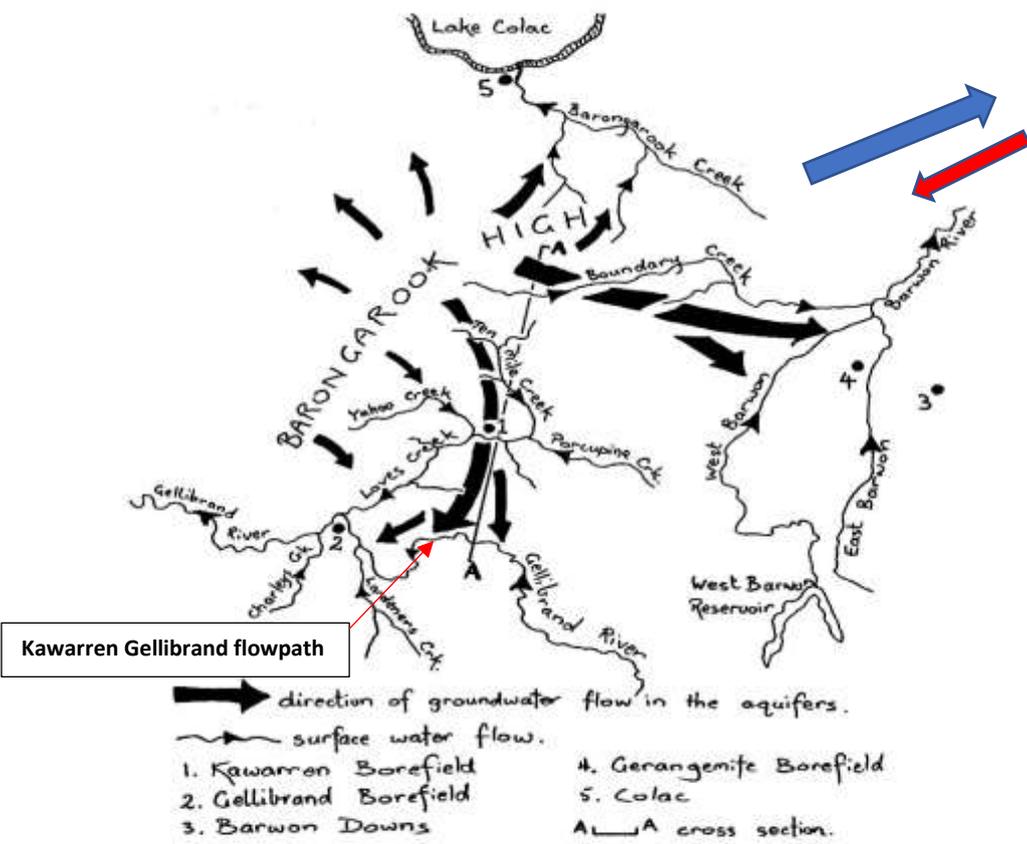


Diagram Source: Centre for Groundwater Studies, Blackwood, South Australia.

The area of influence from a borefield extends across the surface area created by the cone, out to the point of zero drawdown.

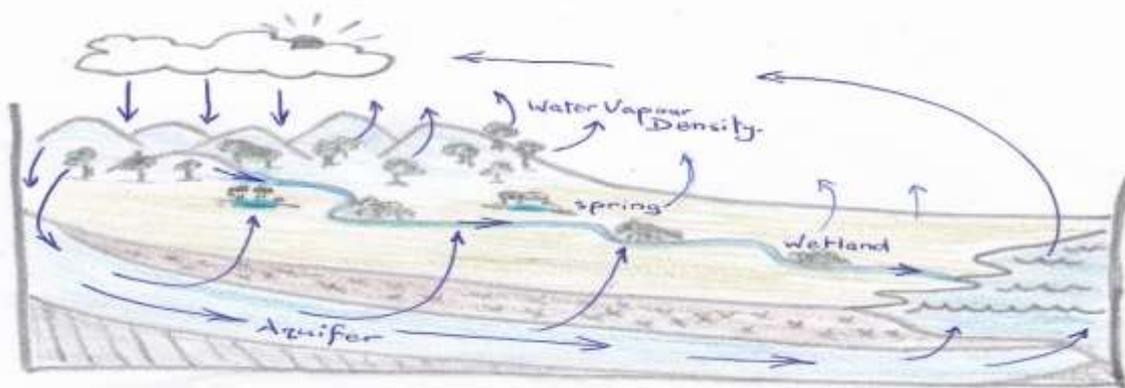
Groundwater Flowpaths from the Barongarook High Recharge Area.



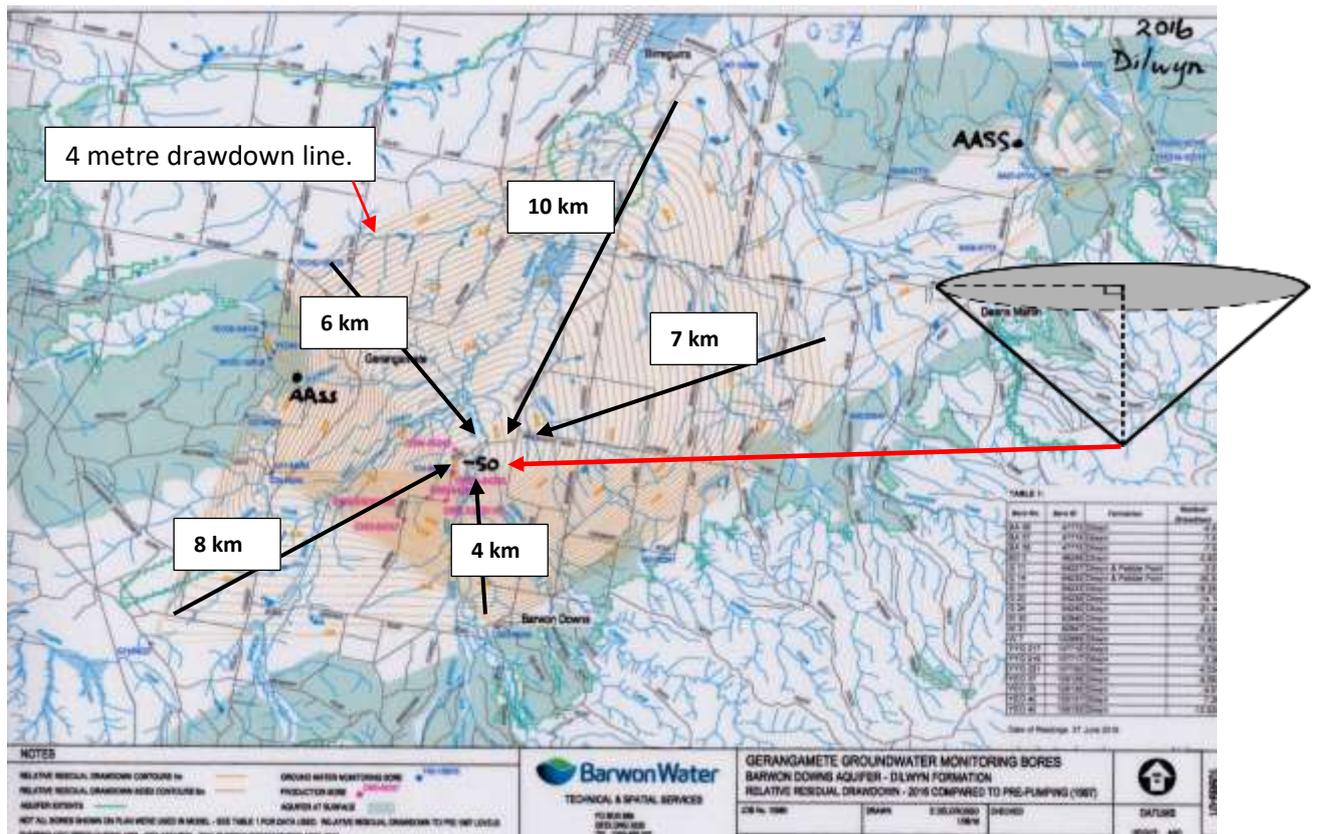
Pre groundwater extraction at the Barwon Downs Borefield a groundwater flowpath Used to flow towards Deans Marsh (blue arrow). However, Deans Marsh to the extreme north east of the Borefield no longer has a west to east hydrological gradient. The groundwater flowpath, if there is any, has been reversed (red arrow) due to extractions from the Barwon Downs Borefield (See pages 22-26).

Barongarook High Recharge Region.

Under natural conditions the accepted recharge area for the Gellibrand and Gerangamete Groundwater Management Area groundwater flowpaths is the sand and gravel of the Barongarook High region⁽¹⁰⁾. Rainfall soaks into this area and recharges the flowpaths of groundwater as indicated in the diagram above. Along these flowpaths soaks, springs, wetlands, creeks and rivers are replenished from an overflow of this recharge. Historically many of these receptors received these overflows continuously year after year, until the utilisation of the surface and groundwater resources began.



The Extremities of the Area of Drawdown Influence.



MAP SOURCE: Barwon Water.

Major groundwater extraction at the Barwon Downs Borefield stopped at the end of the Millennium Drought late in 2010. There was an extraction of approximately 3,500 ML during 2016. None since⁽¹⁾.

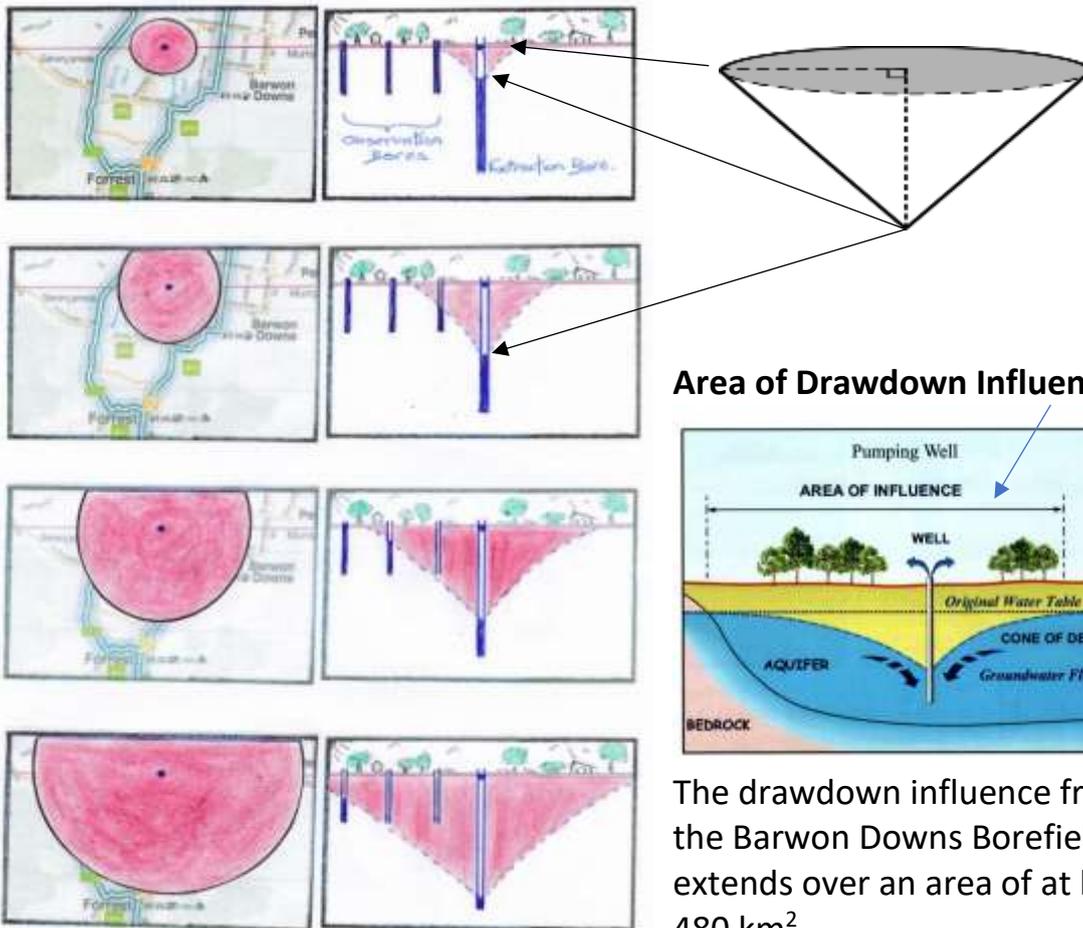
The red contour lines provided by Barwon Water in this 2016 map only extends out to the 4m drawdown levels. However, the area of influence from a borefield extends out to the point of zero drawdown. Consequently the accepted 480 km² cone of depression area of influence can be regarded as a conservative figure.

Last to be Impacted and Last to Recover.

The very outer edges of the cone of depression are the last to be impacted and the last to recover. The area of impact can continue to broaden decades after extractions cease⁽⁴⁾.

Kawarren, Gellibrand and Deans Marsh are areas located on the extremities of the drawdown influence.

Cone of Depression.



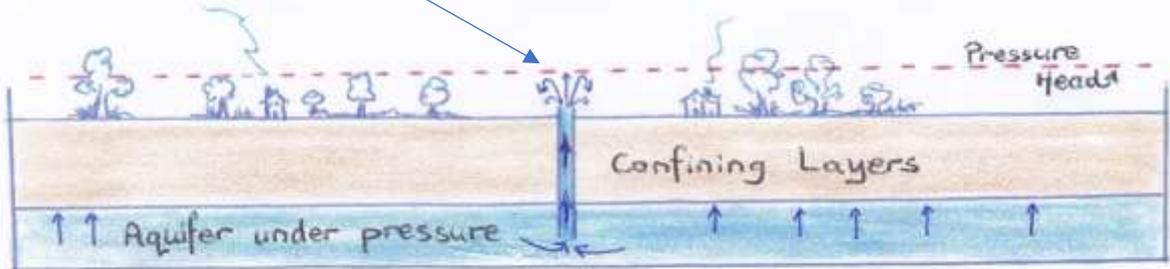
Area of Drawdown Influence.

The drawdown influence from the Barwon Downs Borefield extends over an area of at least 480 km².

Extracting water faster than nature can replace it is groundwater mining. The Barwon Downs Borefield extractions have been regarded as groundwater mining. In this situation as extractions take place the cone of depression gets bigger with the impact across the surface area, and the impact in volume in the *subterranean*, increases. Consequently, the extremities of the cone are the last to be impacted and can continue to spread even after pumping stops.

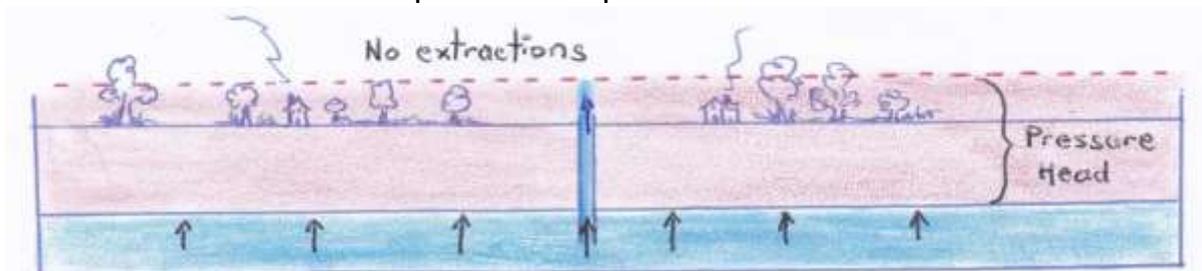
Under Natural Conditions with No Extractions.

When the first bores were drilled at the Barwon Downs Borefield the water squirted metres into the air.

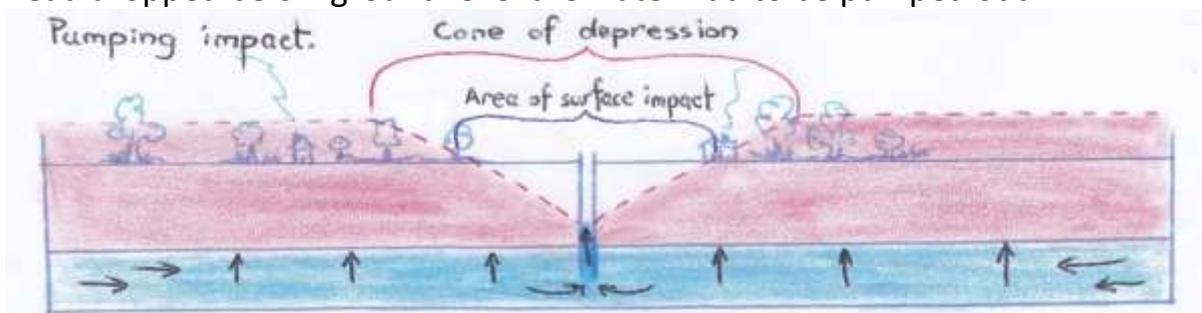


Impact at the Extremities.

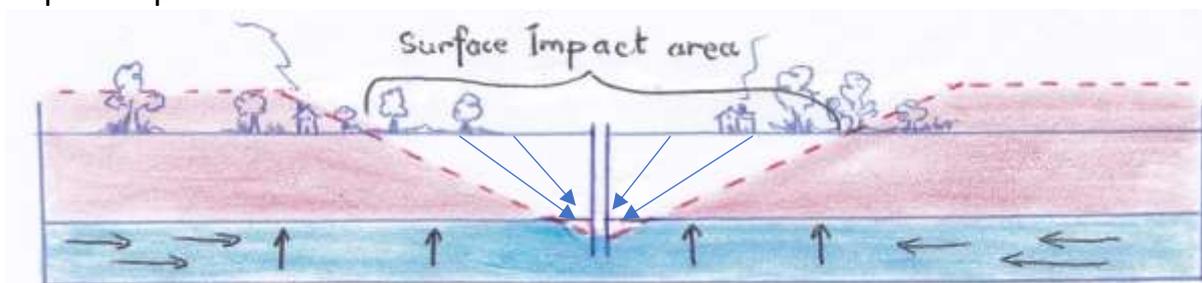
With no extractions the artesian pressure head from bores at the Barwon Downs Borefield used to squirt water up to the red dotted line.



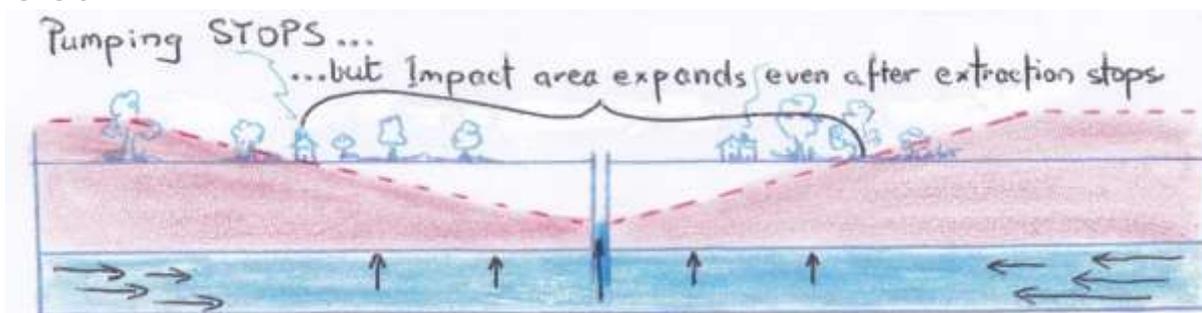
Once extractions started a cone of depression was created. Once the pressure head dropped below ground level the water had to be pumped out.



As the cone expanded water was drawn in from all extremities & the area of impact expands at both the surface and in the subterranean.



Even after pumping stops the area of impact continues to expand as water is drawn into the base of the cone. Bores near the borefield begin to recover but bores on the extremities continue to fall or flatten out at unprecedented levels.

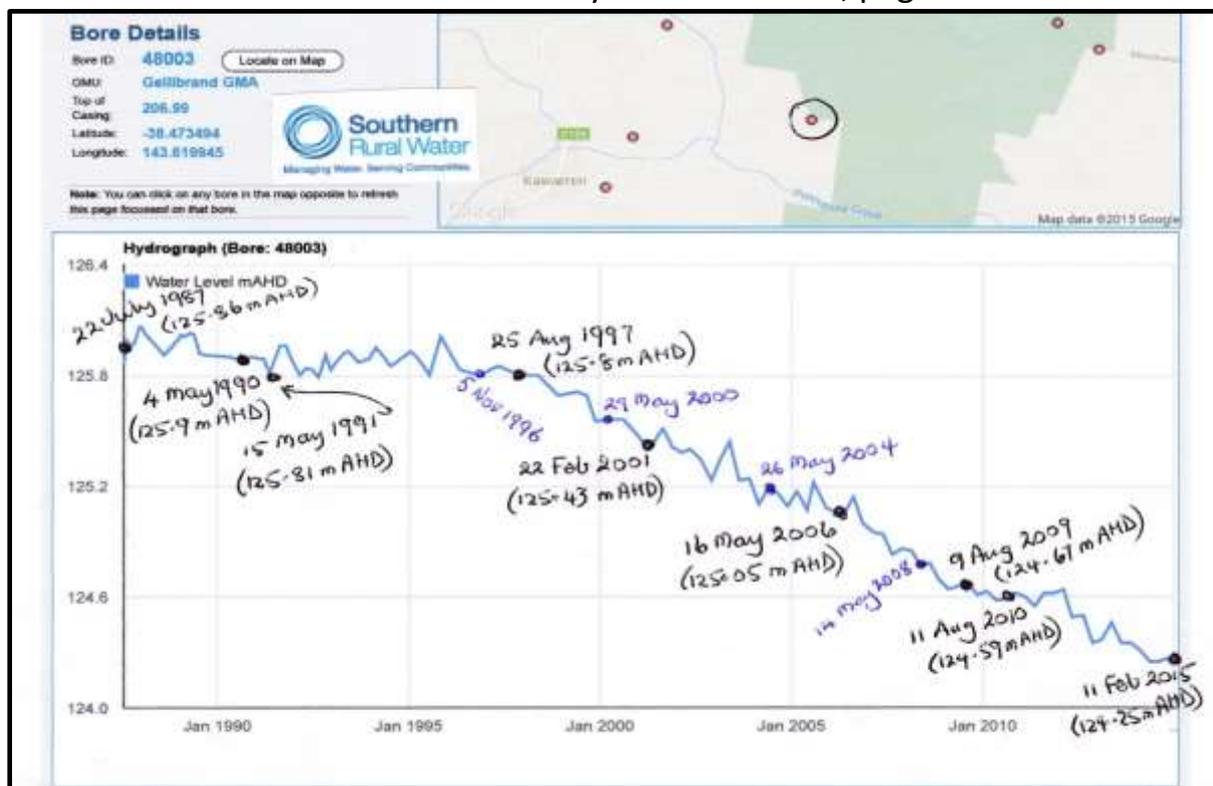


2021 Bore Hydrograph Data is Poorly Presented, if at All.

It is extremely hard for water managers to make informed resource management decisions on limited data. It is even harder for the “citizen scientist” to understand, research and or make comment on this data if the data provided is presented in obscure ways. Another frustrating aspect is difficulty finding what little data has been collected.

What Used to Be.

The hydrograph for Observation Bore 48003, seen below, was taken from a Southern Rural Water data bank in 2015. You could hit any point along the hydrograph and gain the date and height of the water column as metres above sea level (AHD -Australian Height Datum). The hydrograph could be run off and recorded as this one has been in Otway Water Book 28, page 32.



Web Site Shut Down.

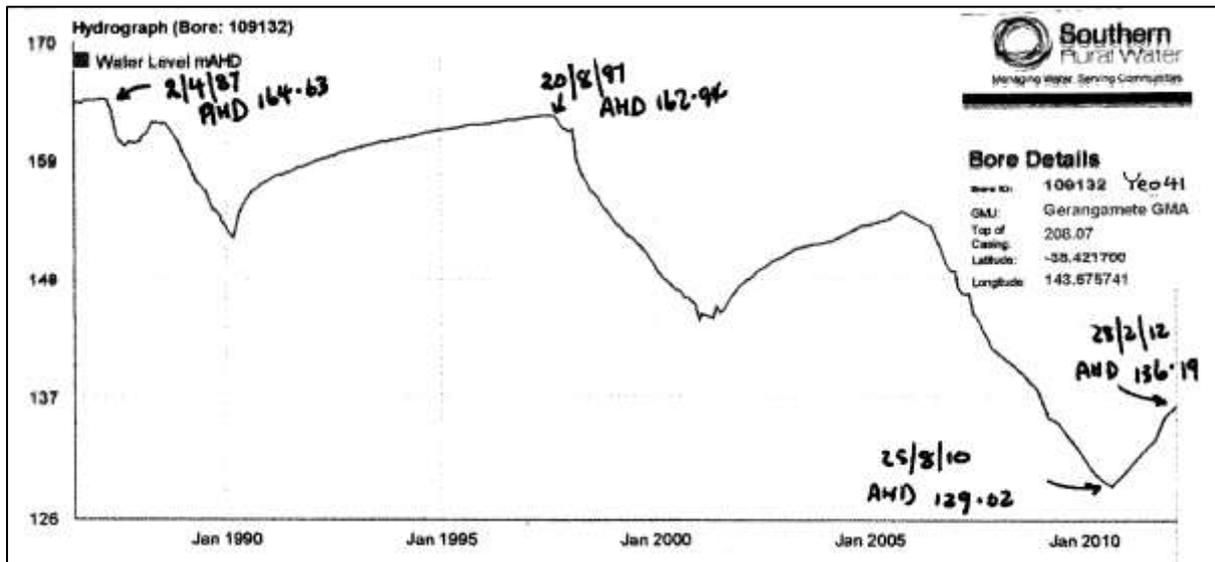
However, this is no longer the case. Southern Rural Water does not have this type of data available anymore. When queried about their site Southern Rural Water referred me to the Victorian Water Data Warehouse⁽⁸⁾ (see Appendix One, page 33). When researching these sites frustrating results were the norm.

For example, when searching for an up to date record of bore 48003 no results could be found anywhere.

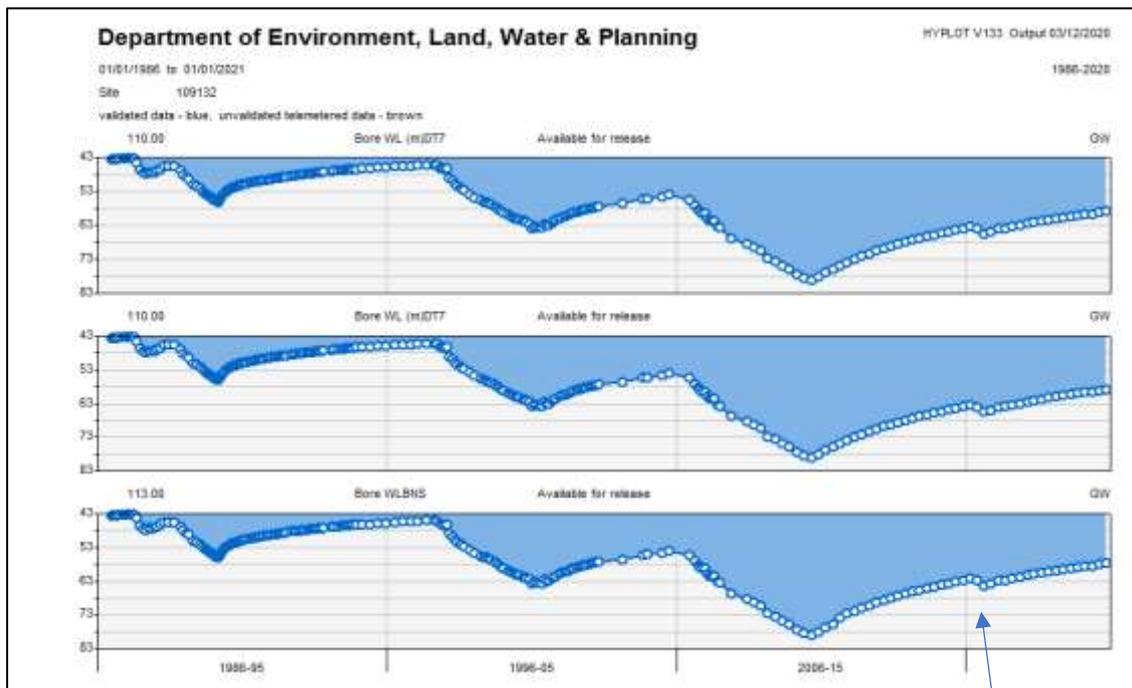
Matters Get Worse.

Another bore, Observation Bore 109132, was found using the other websites recommended by Southern Rural Water but was somewhat difficult to understand and interpret. Nowhere near as easy to interpret and understand as the previous Southern Rural Water hydrographs were.

This Observation Bore hydrograph seen below was available from Southern Rural Water in 2013 (see Otway Water Book 21, page27).



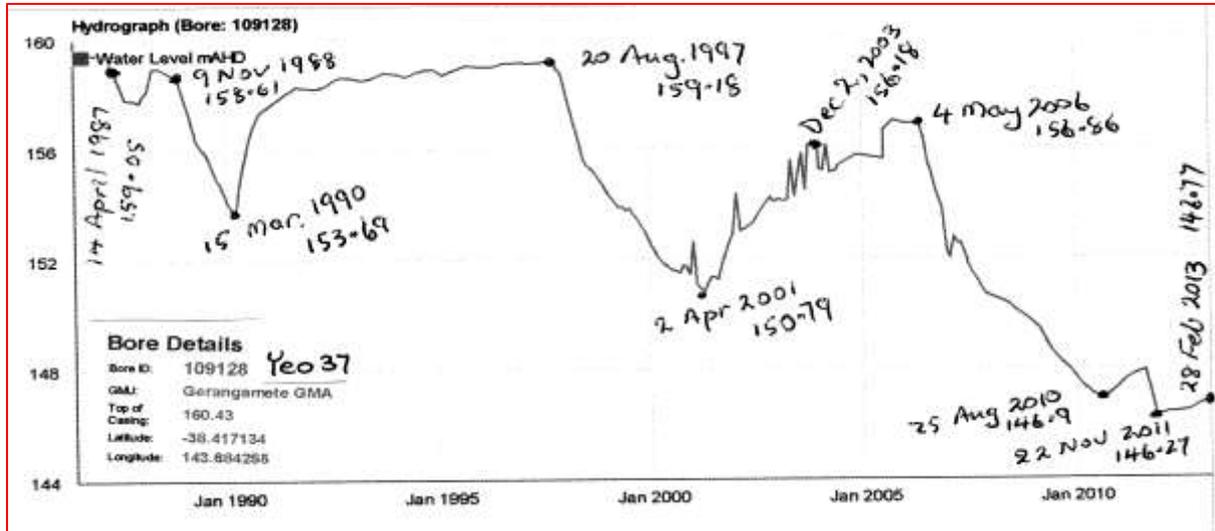
This is the January 2021 version for the same Observation Bore (109132). Not



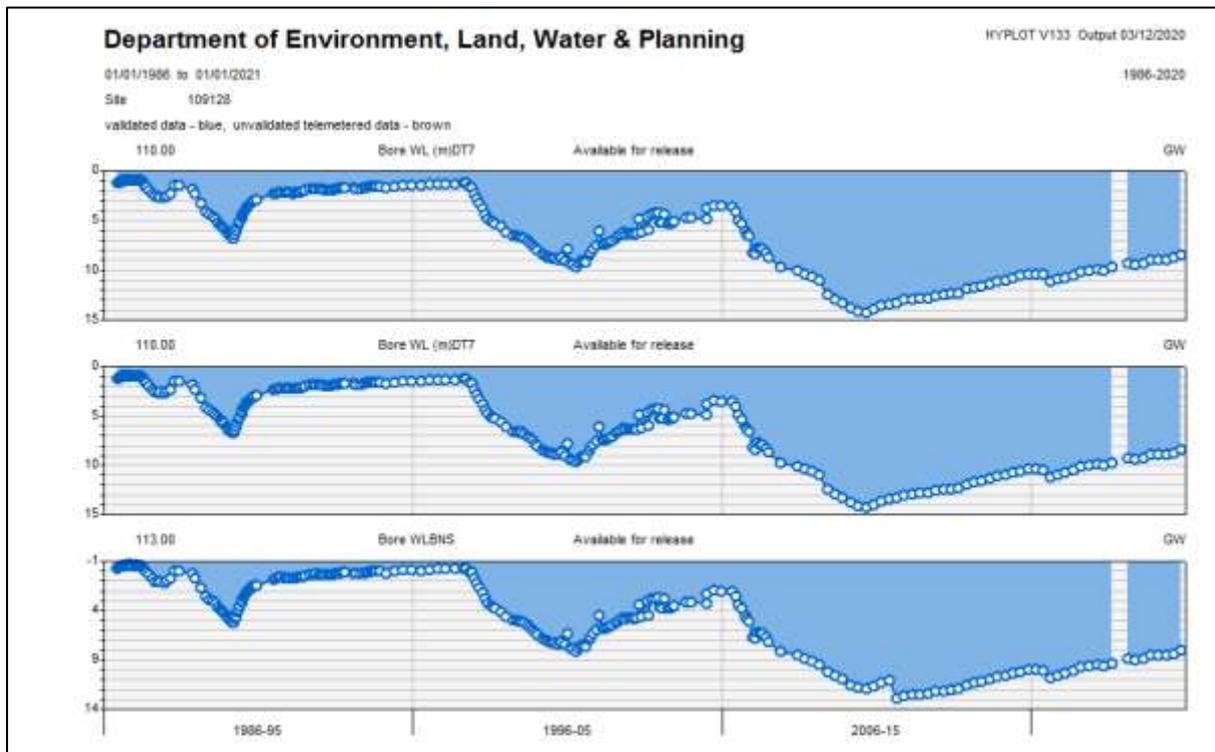
easy to make much sense of the graph. Except, to say since around 2010 it has started to recover. The slight decline in 2016 coincides with the 2016 extraction at the Barwon Downs Borefield.

Another example.

These two hydrographs have been prepared using the same data for Observation Bore 109128. The top hydrograph recorded in 2013 and the bottom one recorded in 2021. Markedly different presentation of the data.



Otway Water Book 21, page 31, 2013. Southern Rural Water Observation Bore 109128 data.

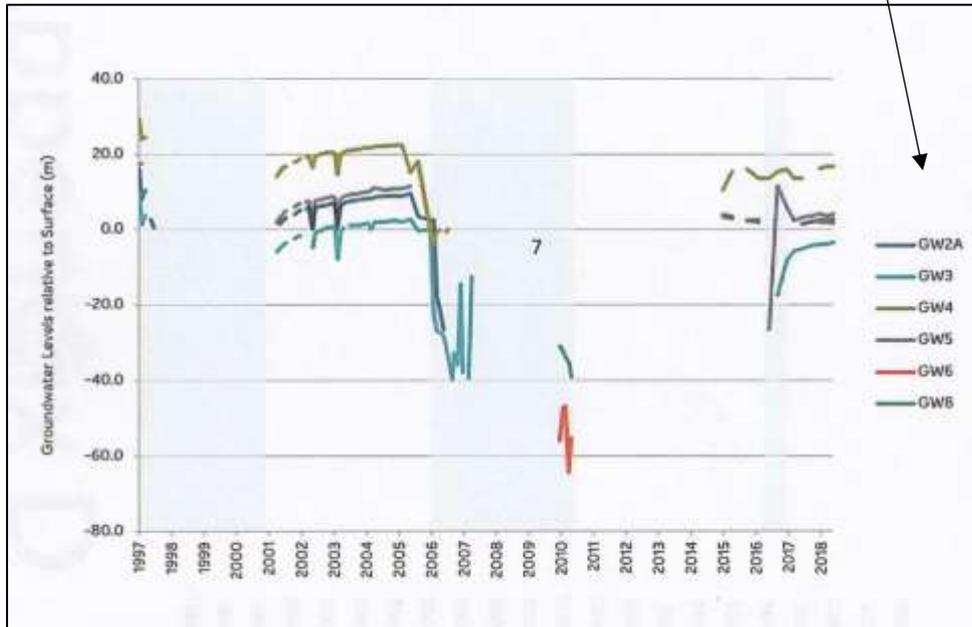


DELWP: 2021. Observation Bore 109128 data. (WLNS - Water Level Below Natural Surface)

Notice the upward trend since groundwater extraction ceased. This bore is within a close influence from the Borefield.

Yet Another Example When Attempting to Gain Worthwhile Data.

Hydrographic data for the 6 extraction bores operated at the Barwon Downs Borefield could only be found in Barwon Water's annual reports to Southern Rural Water. The hydrographs for these 6 extraction bores below, has been taken from the 2017-2018 report.⁽¹⁾ No other site provided any information other than GPS locations.



7. Data collected for the groundwater production bores varies with well head access, infrastructure arrangements and extractions. Groundwater levels are now being recorded at all production bores.

The Vic Water Data Warehouse only had the Eastings and Northings for each of these 6 Extraction Bores, and this notice.

“No variables data found for this site.” This was a common result when searching for bore water level data.

As mentioned earlier it has been an extremely difficult task gaining worthwhile data.

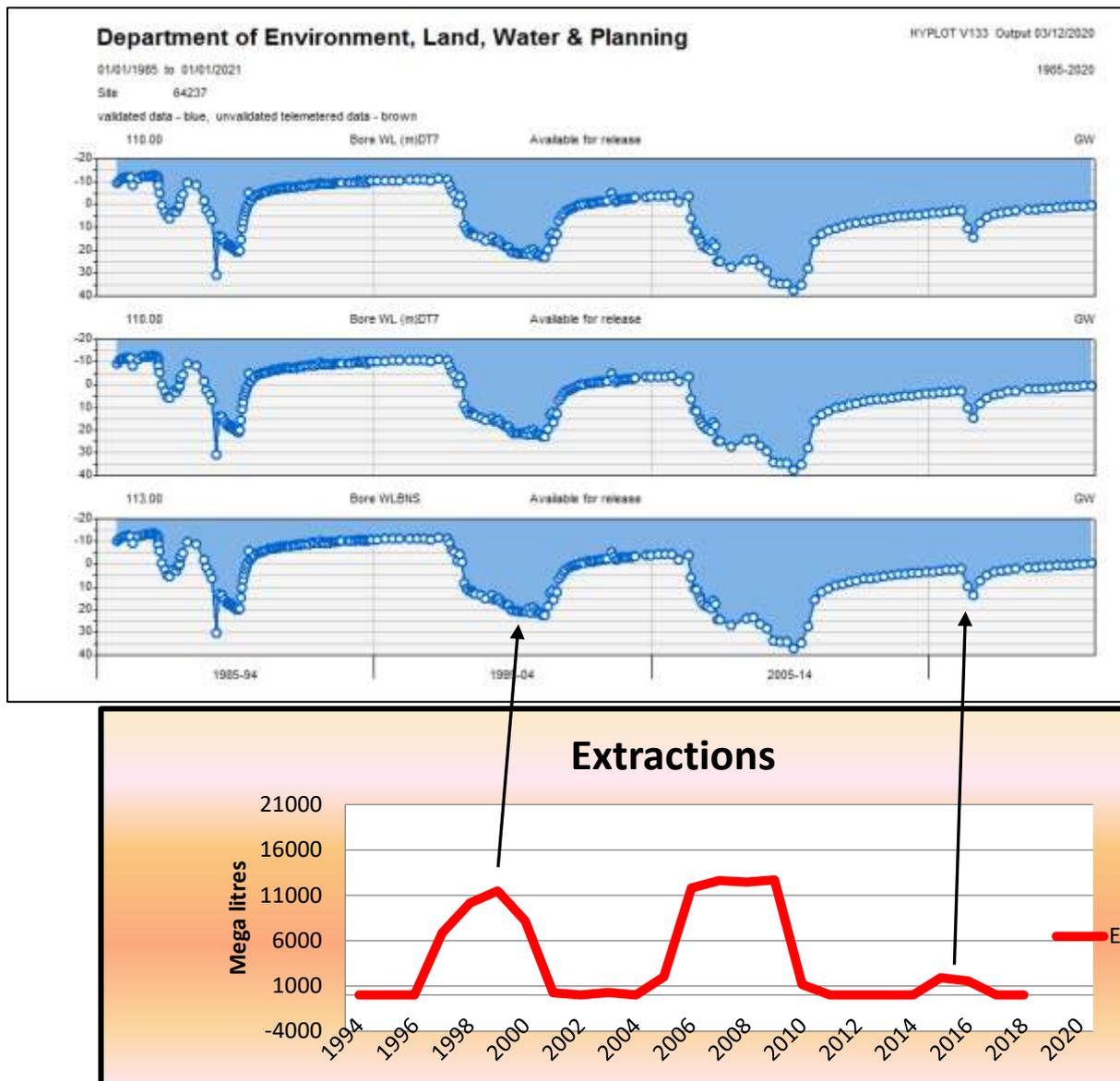
Q. Why isn't the data presented in a uniform manner?

Q. Why do the graphs sometimes have the blue shading under the water level graph and other times above?

Q. Why have different yearly spaces indicating record periods? Sometimes a gap of 1 year, others 9 years and others with 10 year spacing.

Q. Why isn't there a data warehouse of “old” data?

Hydrographs Close to the Borefield readily Respond to Borefield Extractions.



The extractions periods from the Barwon Downs Borefield closely correspond to and reflect the falls in the water levels in Observation Bore 64237.

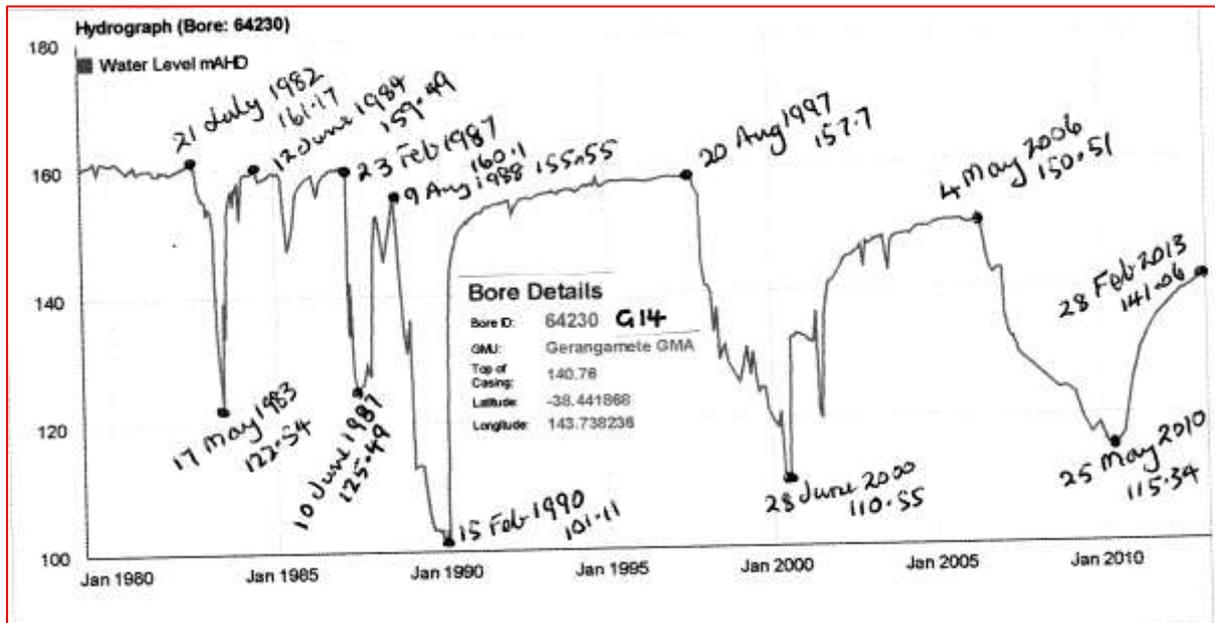
Observation Bores Close to the Borefield, Clearly Showing Extraction and Recovery Periods.

The following 5 Bore hydrographs, pages 15-17, are well within the drawdown influence of the borefield. They are **not** on the extremities and show an upward trending movement since pumping ceased in 2010. Unfortunately, any up to date hydrograph for Bore 64230 is another bore's data that can no longer be found. Other than the sketchy information available for the

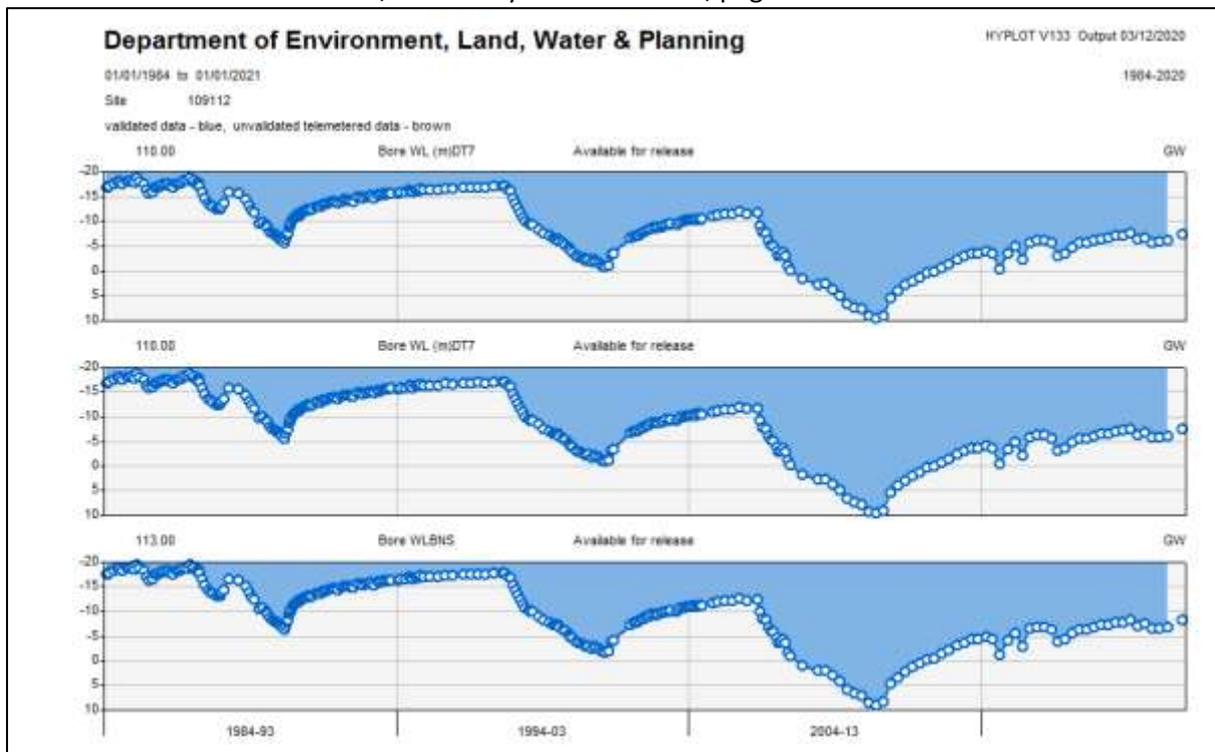
extraction bores, it is difficult to gain a “picture” of what is taking place at the borefield location (See page 13).

Observation Bore 64230’s hydrograph up to February 2013.

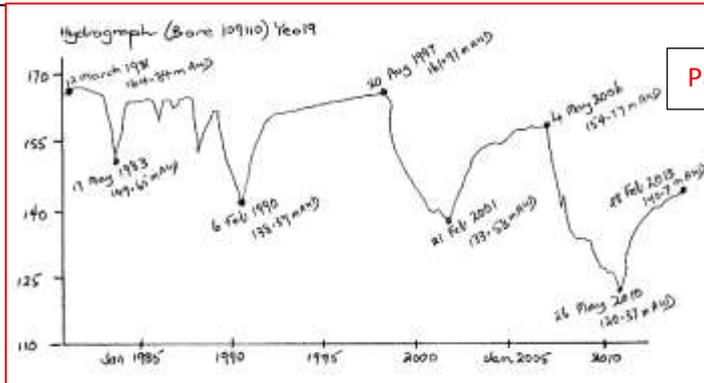
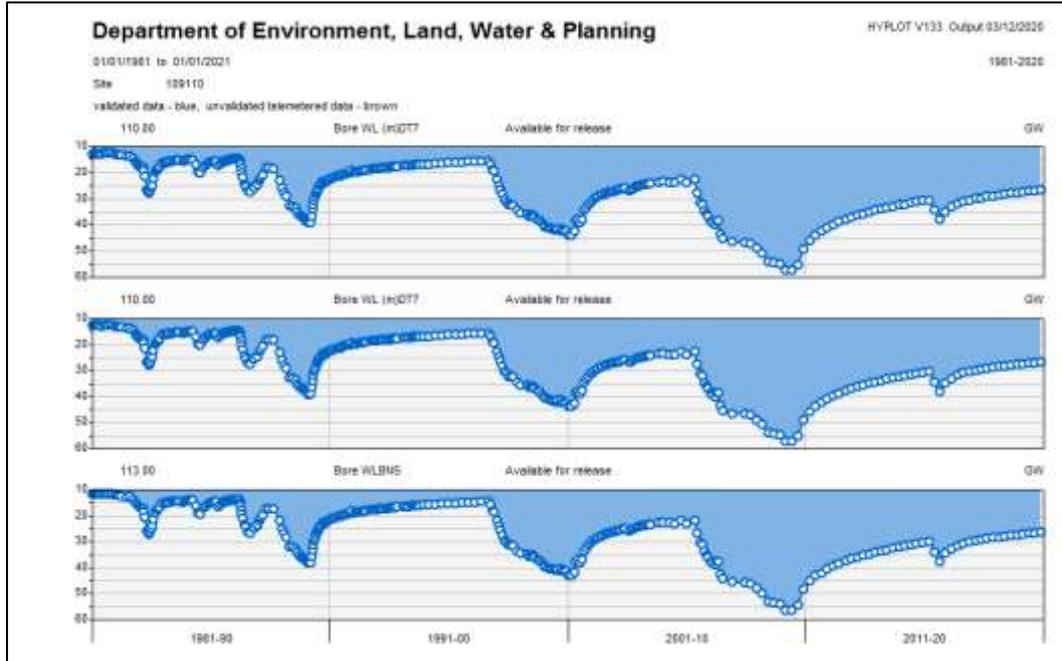
After several attempts,. no record past 2013 can be found for this bore.



Observation Bore 109112. Also, see Otway Water Book 21, page26.

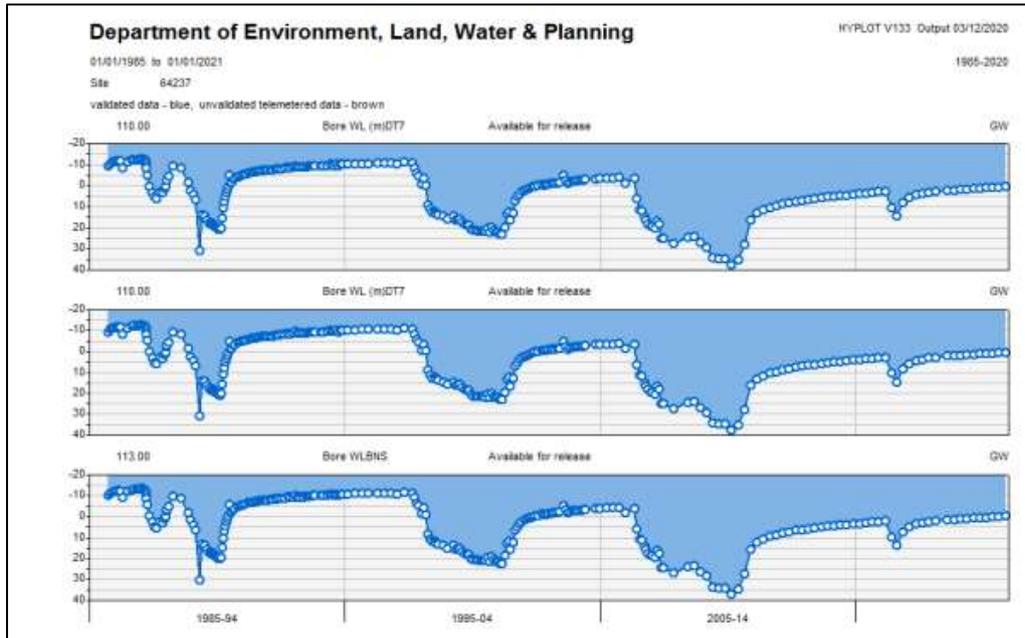


Observation Bore 109110. See Otway Water Book 21, page 29 for this comparison.

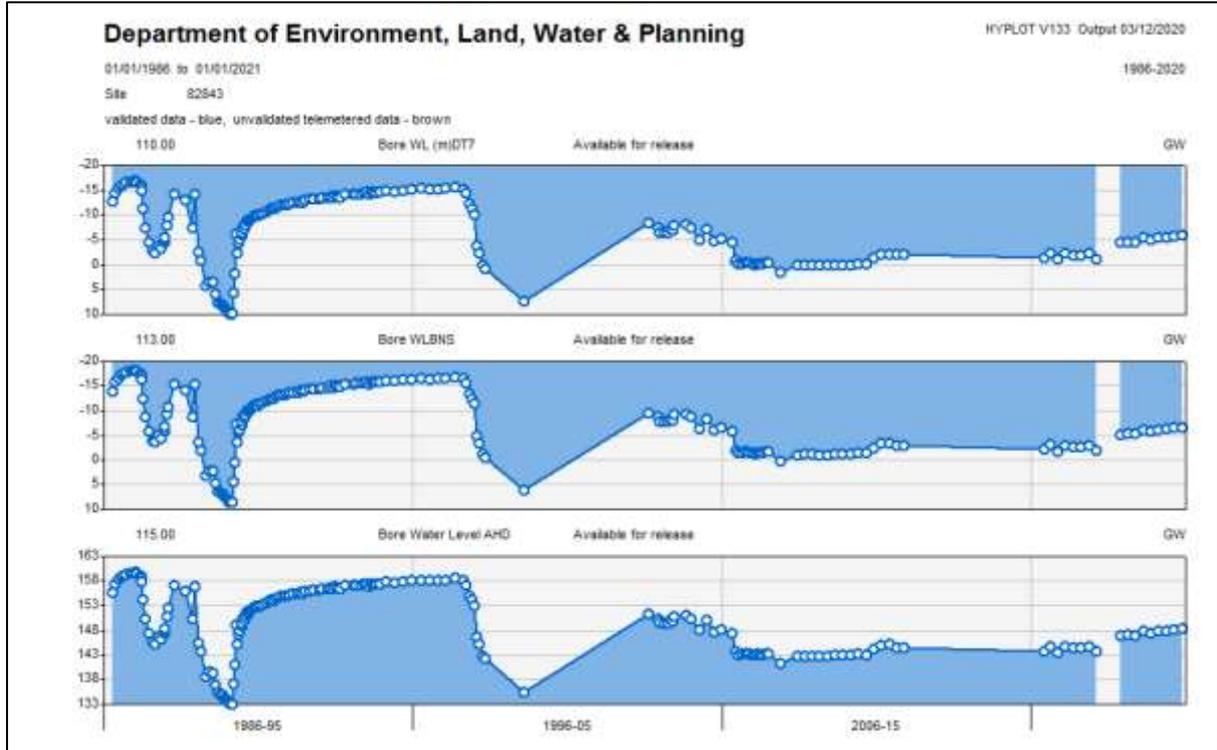


Page 29

Observation Bore 64237. Also, see Otway Water Book 21, page 34 for comparison.

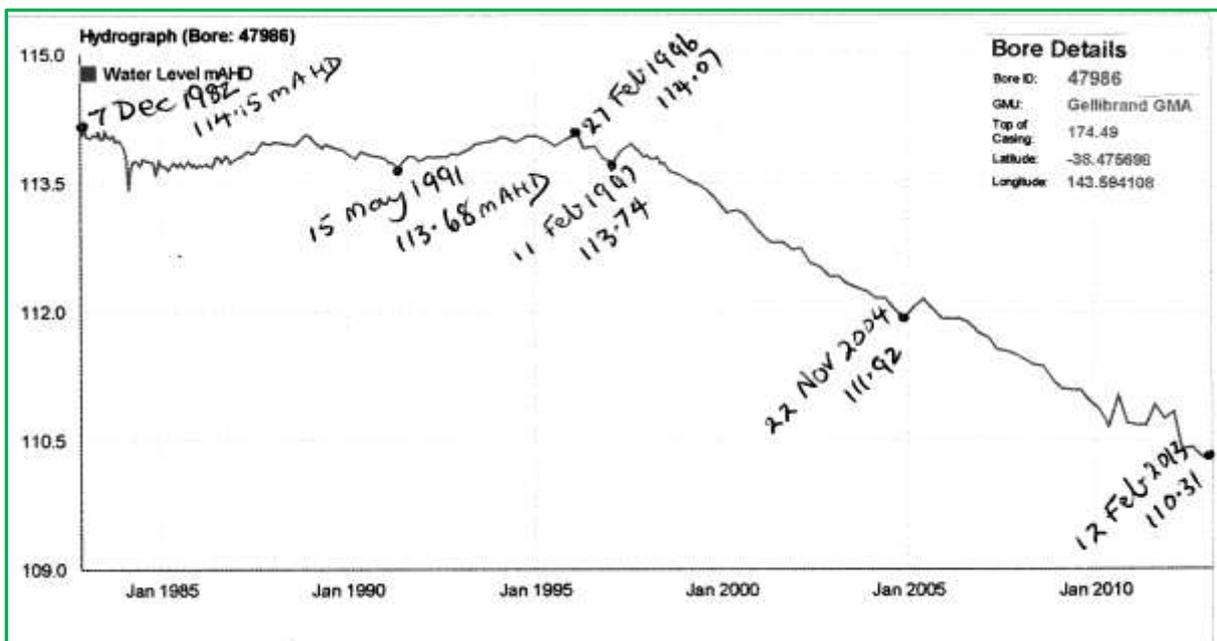


Observation Bore 82843. Also, see Otway Water Book 21, page 36 for comparison.



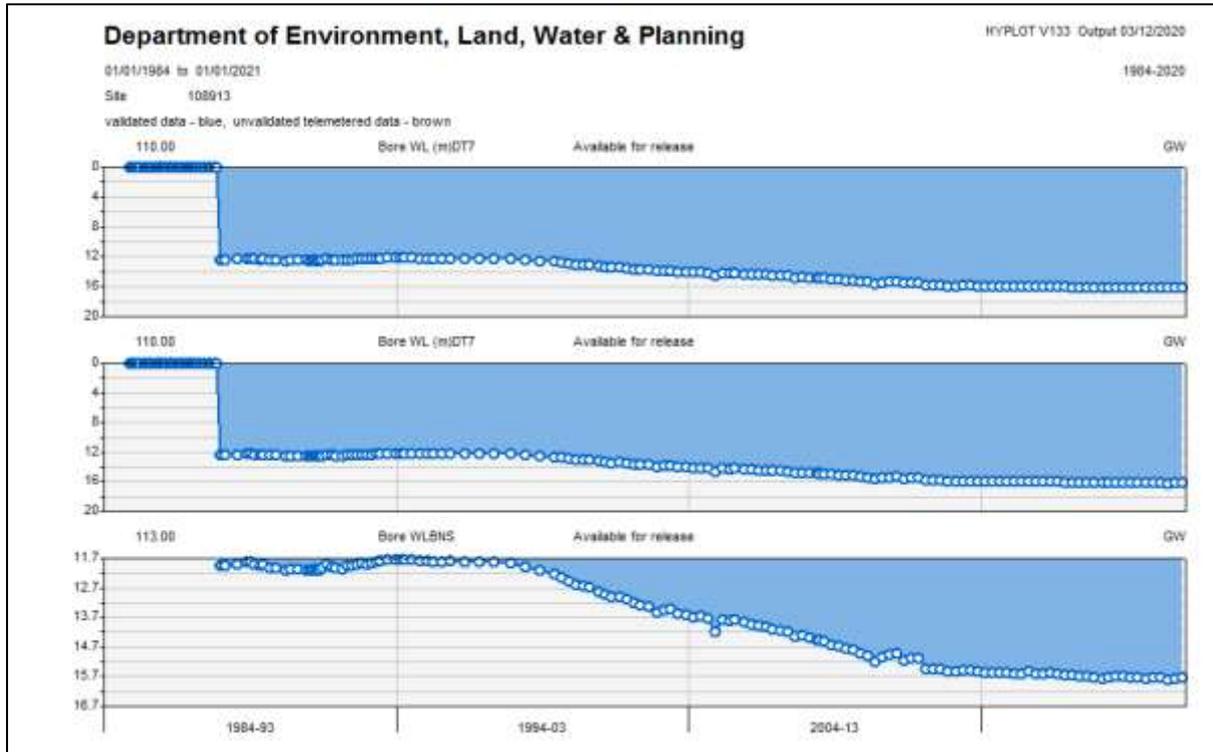
The Kawarren Gellibrand Flowpath.

Observation Bore Hydrographs Located on the Extremities of the Drawdown.
 The following 7 hydrographs show a continuing downward trend despite pumping having stopped in 2010 (A small extraction took place in 2016).

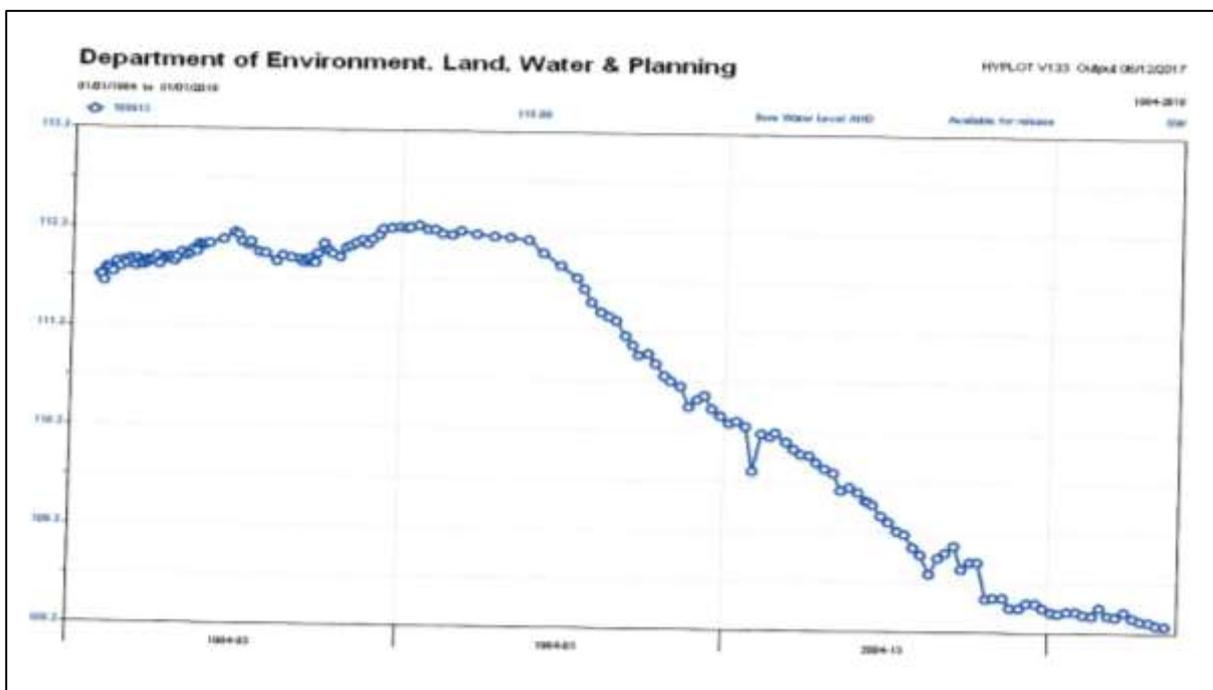


Otway Water Book 21, page 31. Southern Rural Water data.

Two Versions of Observation Bore 108913.



Taken from the DELWO website in 2021.



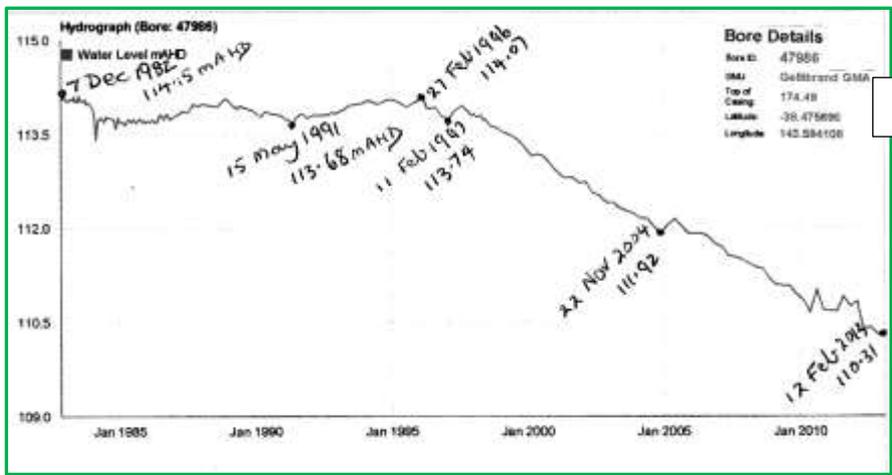
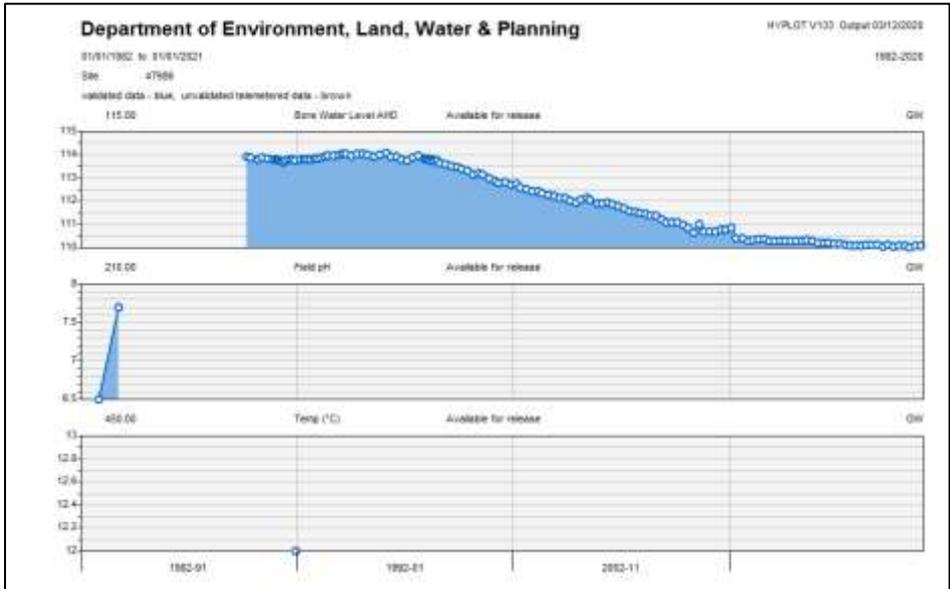
Observation Bore 108913 taken off the DELWP site in 2019.

The hydrograph found on page 25 of Otway Water Book 21, page 25 shows a third variation of this bore's data.

Observation Bore 47990. Also, see Otway Water Book 21, page 30 for a comparison.



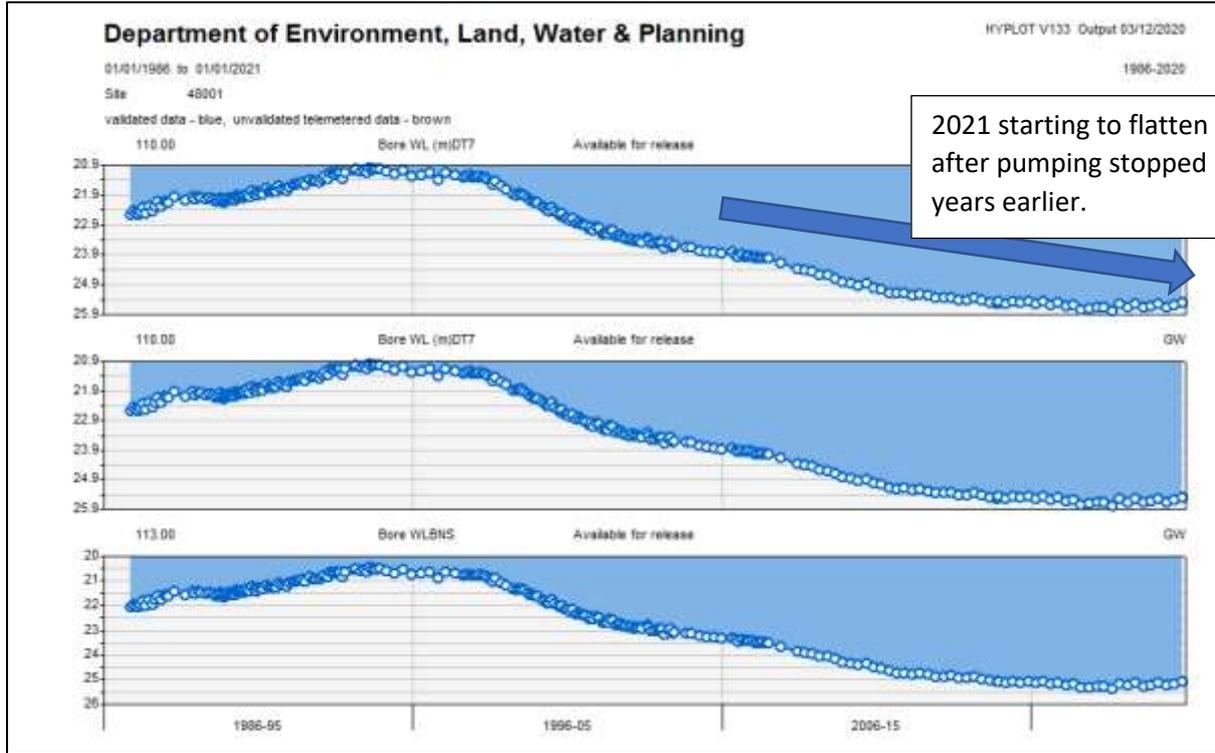
Observation Bore 47986. See Otway Water Book 21, page 31.



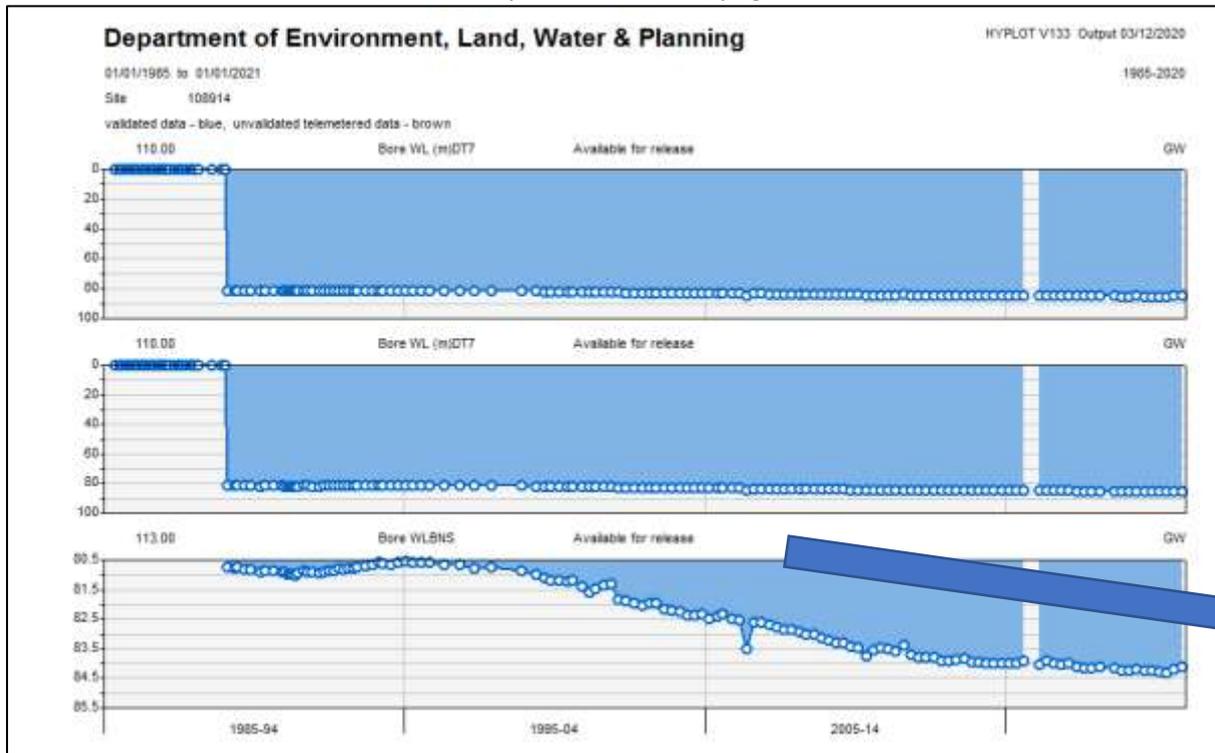
Bore Details
 Bore ID: 47986
 GMA: Geibrand GMA
 Top of casing: 174.48
 Latitude: -36.475696
 Longitude: 142.584106

Page 31

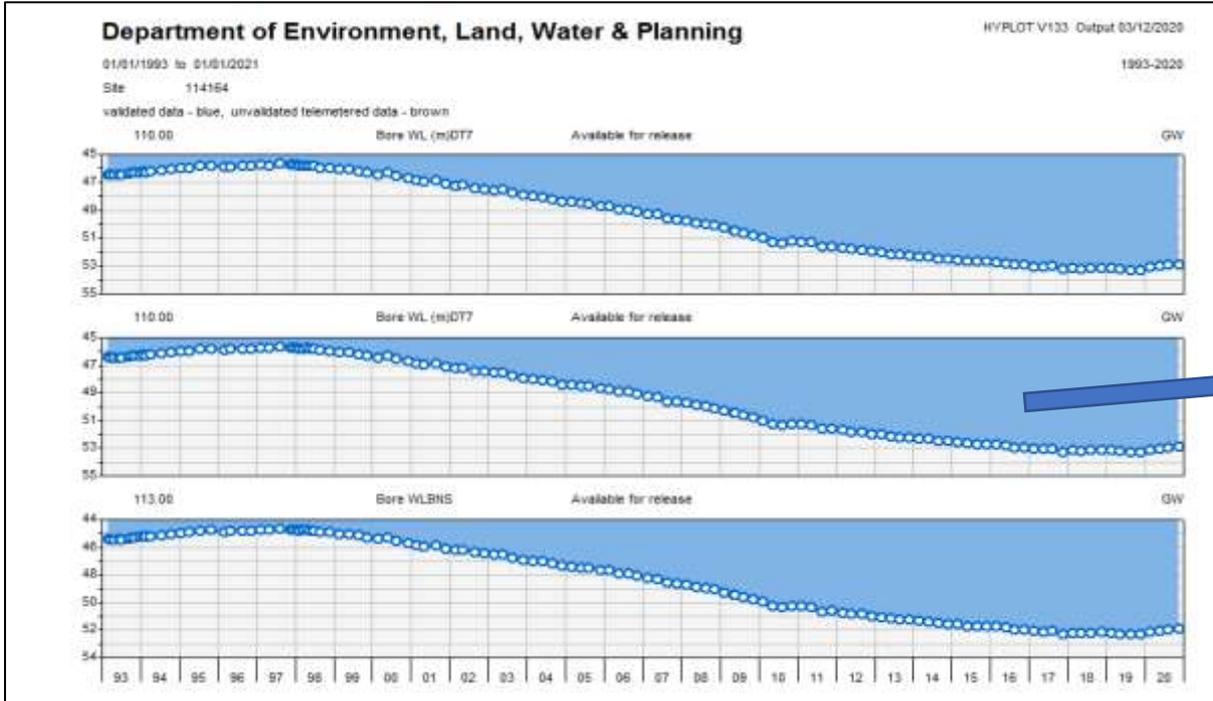
Observation Bore 48001. Also, see Otway Water Book 21, page 32 for a comparison.



Observation Bore 108914. Also, see Otway Water Book 21, page 35.

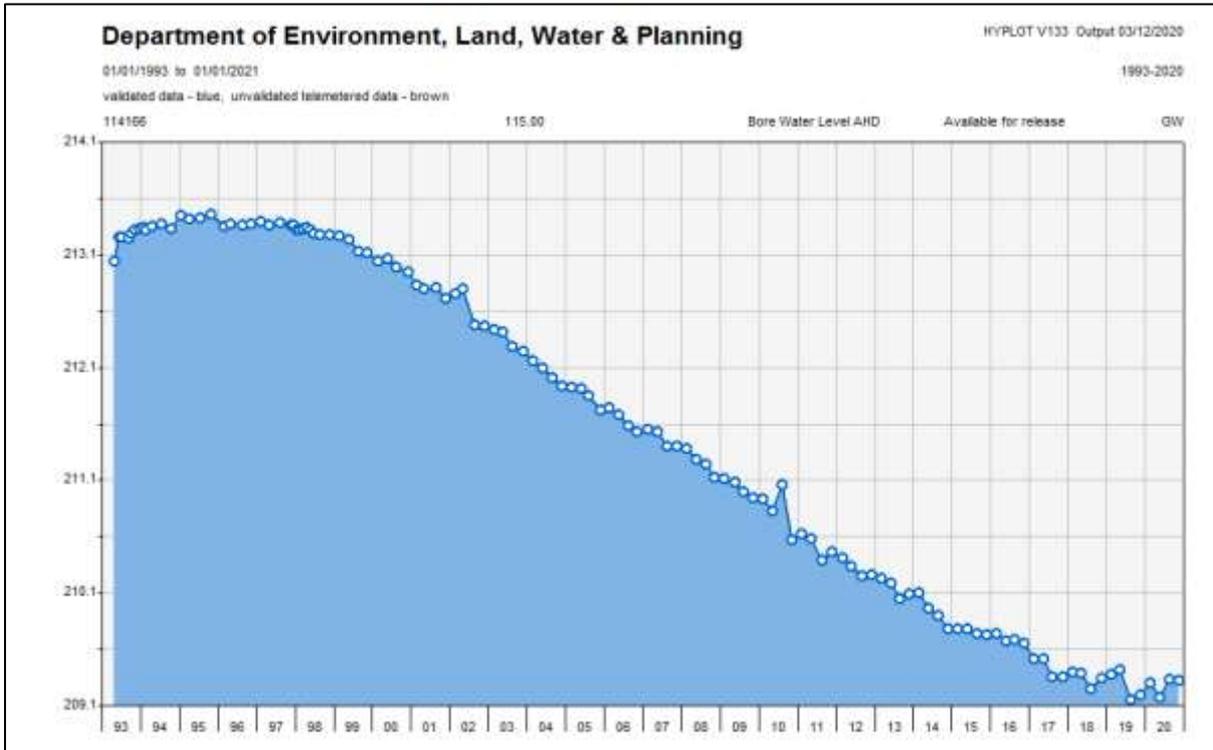


Observation Bore 114164. Also, see Otway Water Book 21, page 33.



The water levels of the bores down the Kawarren Gellibrand groundwater flowpath exhibit a persistent downward trend. At the very best some of them appear to be flattening out. The Barwon Downs Borefield cone of depression is continuing to draw groundwater water away from the Kawarren Gellibrand flowpath eleven years after serious extraction was halted.

Observation Bore 114166. Also, see Otway Water Book 21, page 27.



Hydrographs at the Extremities Around Kawarren Continue to Fall.

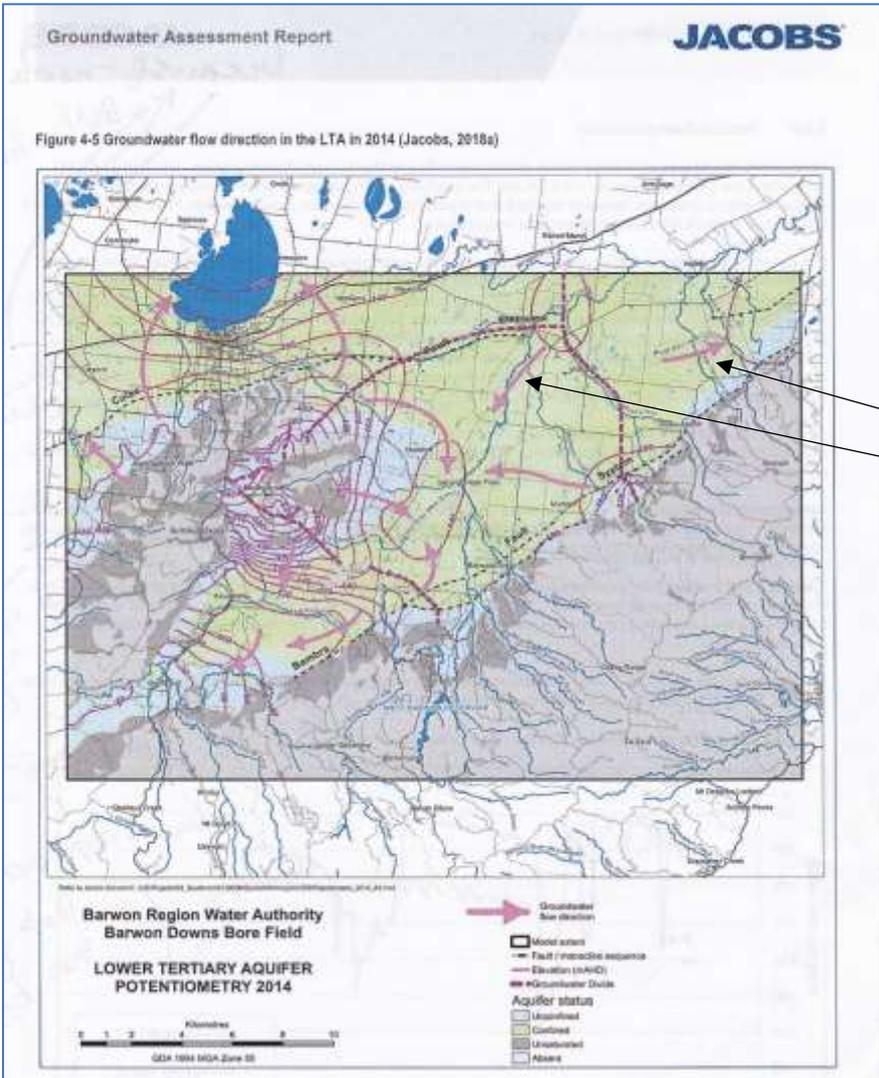
Jacobs, Barwon Water's consultants, have determined that the groundwater flowpath down the Kawarren corridor has been impacted. In a Jacob's 2018 report⁽¹⁰⁾ it states quite clearly that groundwater extraction from the Barwon Downs Borefield extends as far as Kawarren. *"Investigation by Jacobs (2016e) confirmed that the drawdown extends to the Kawarren area."*⁽¹⁰⁾

The Deans Marsh Flowpath Reversed.

On the north easterly extremity of the cone of depression the flowpath was reported to have been reversed during groundwater extraction, no longer flowing away from the borefield but in fact changing into a recharge zone drawing groundwater back towards the borefield.⁽¹⁰⁾ See the map on page 23.

"...at the peak of borefield extraction, drawdown in the borefield reversed groundwater flow directions in some areas. For example, groundwater flow near Deans Marsh is currently north east (as it was in 1987), however, at the height of borefield operation, groundwater flow was south west – towards the borefield."⁽¹⁰⁾

In these situations *"...groundwater that previously discharged to surface water can be reversed so that the surface water feature becomes a recharge zone for the aquifer."*⁽¹⁰⁾



This 2014 map showing the groundwater flowpath directions, shows at least 3 interesting things:

1. This flowpath is heading north easterly.
2. This flowpath has been reversed.
3. The reversal was still taking place 4 years after pumping ceased.

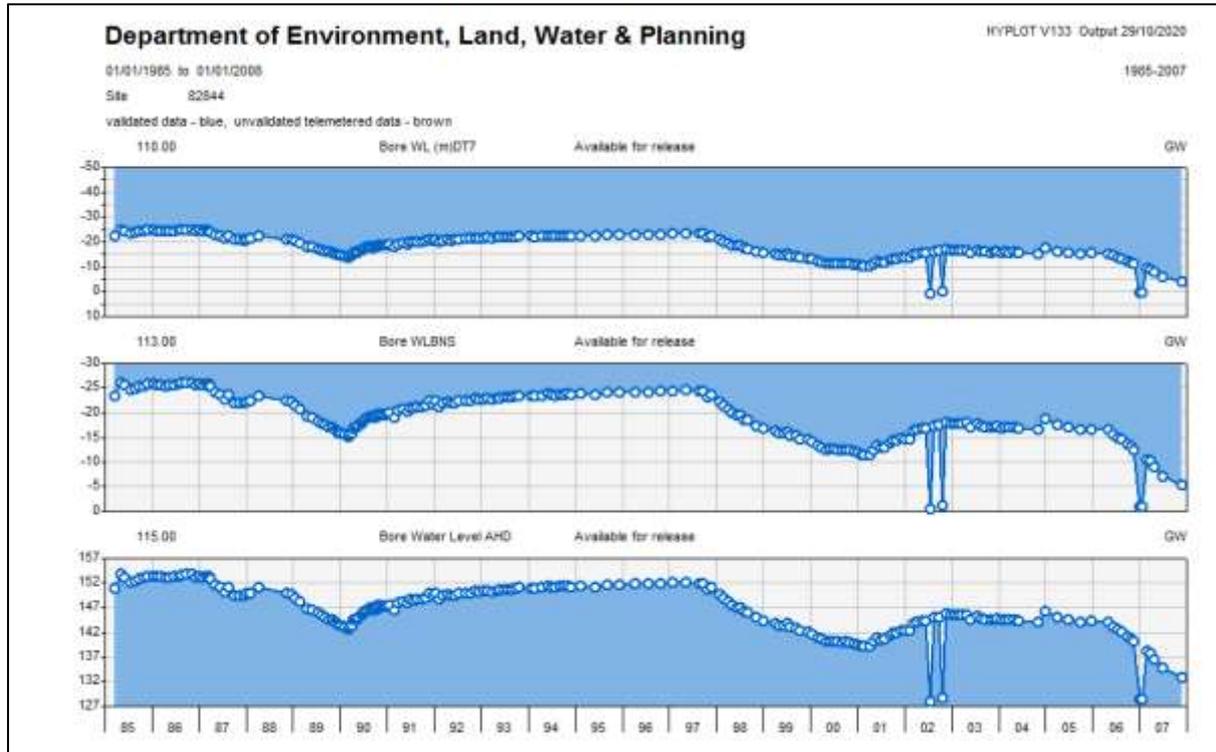
The following hydrographs suggest that this reversal is still taking place in 2021 at the north easterly extremity.

2021 Hydrographs in the Flowpath Reversal Zone.

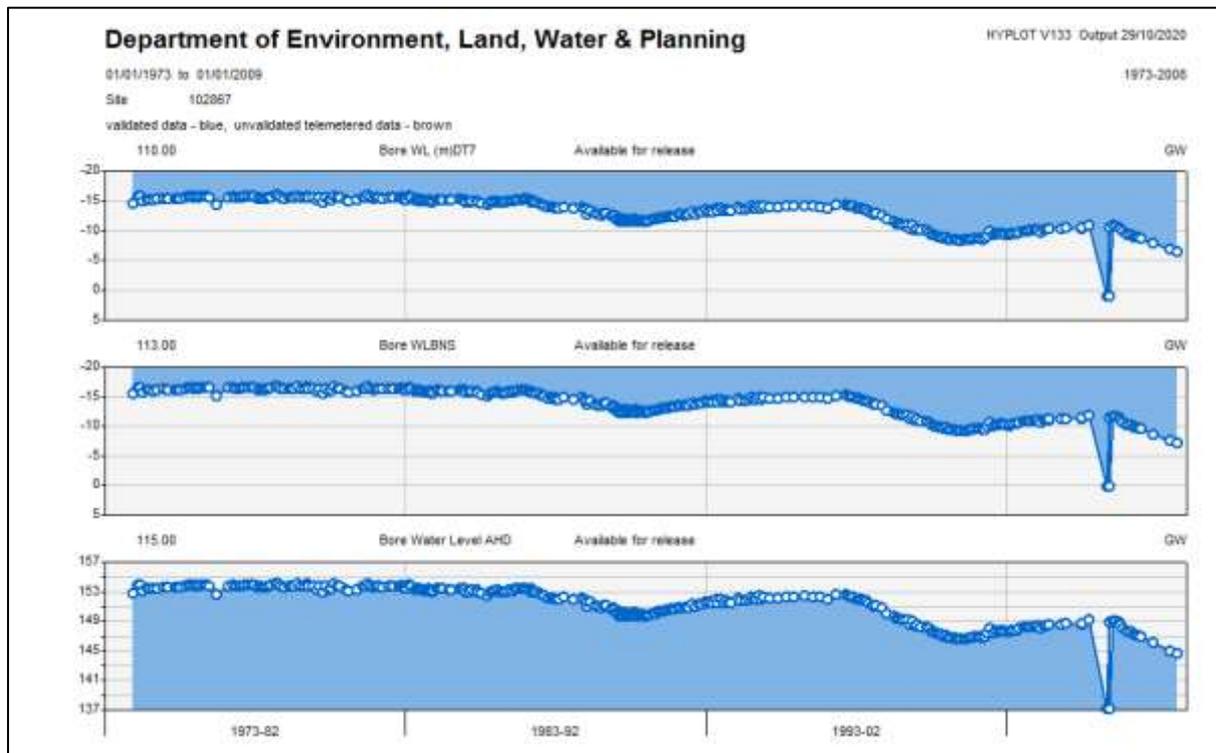
The hydrographs below have been copied from observation bores along the Deans Marsh groundwater flowpath that has been recognised by Jacobs as being reversed in its 2014 diagram (see above). These hydrographs on the extremity of the drawdown cone of depression, give the impression that the water levels are still being impacted.

Unfortunately, there is very little water level data that could be found in this groundwater flowpath zone. However, there is enough indicating that impact in this area from the Barwon Downs Borefield extractions may still be occurring and requires further investigation.

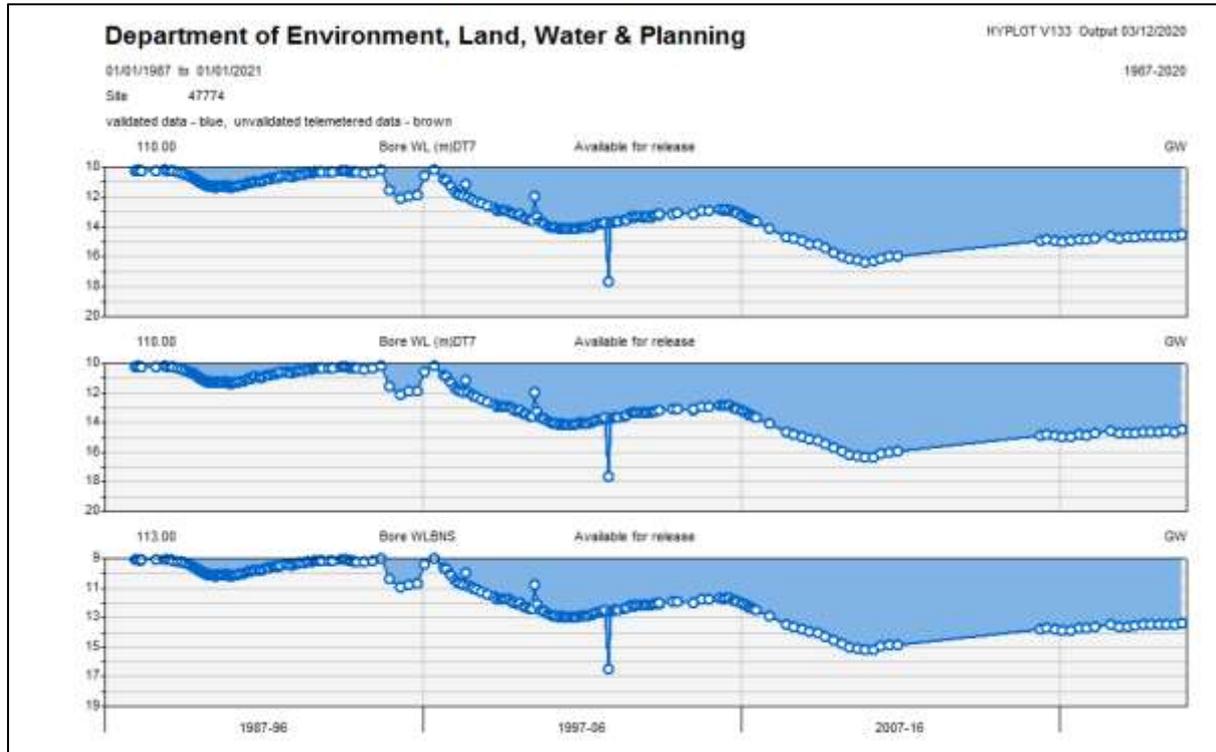
Observation Bore 82844



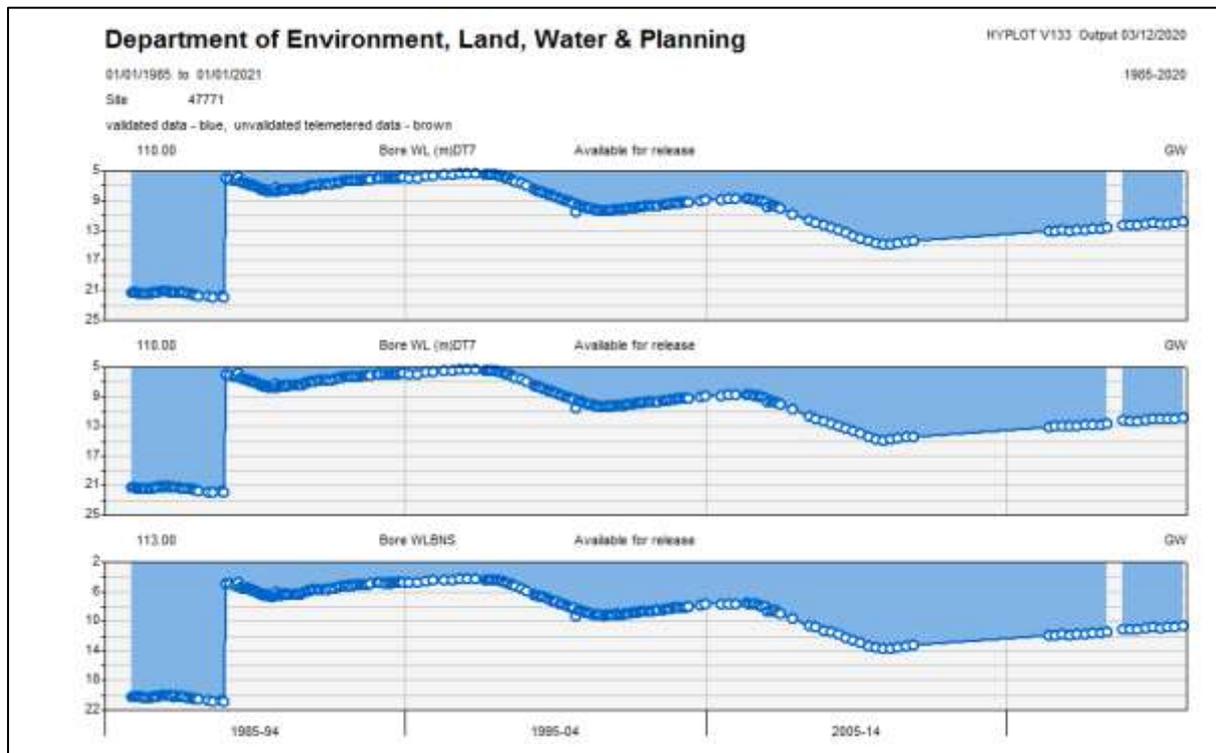
Observation Bore 102867



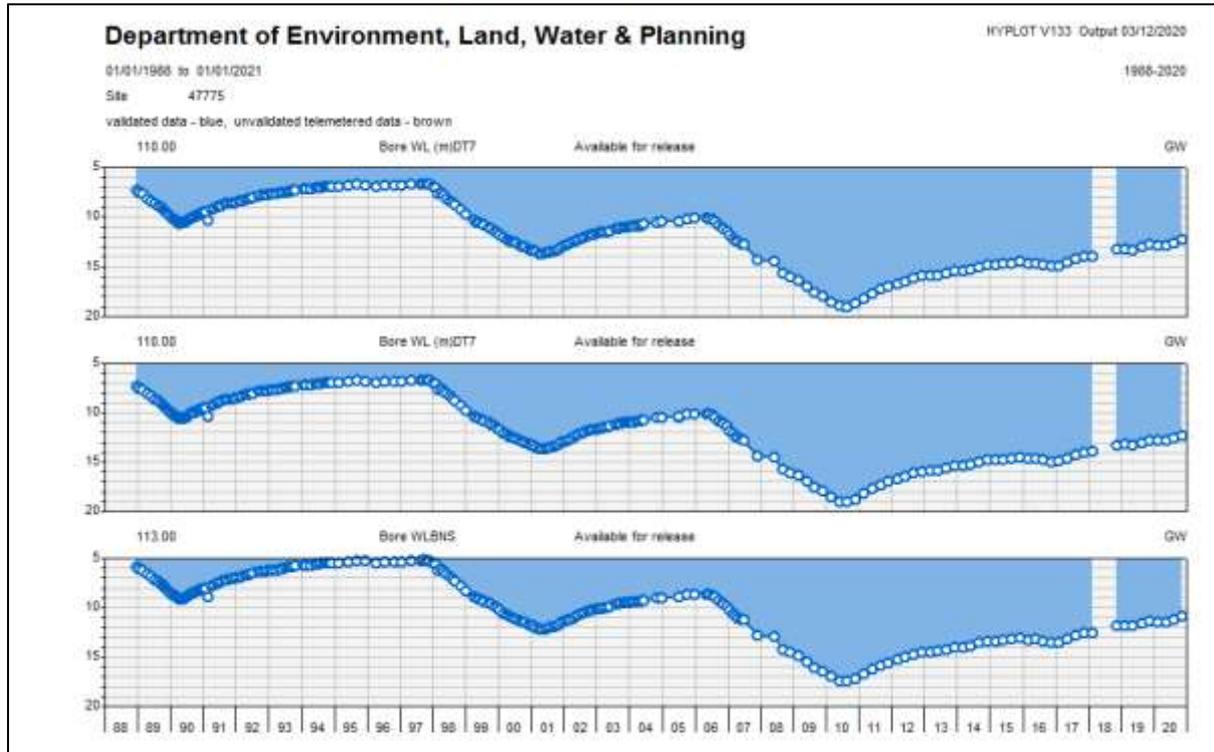
Observation Bore 47774



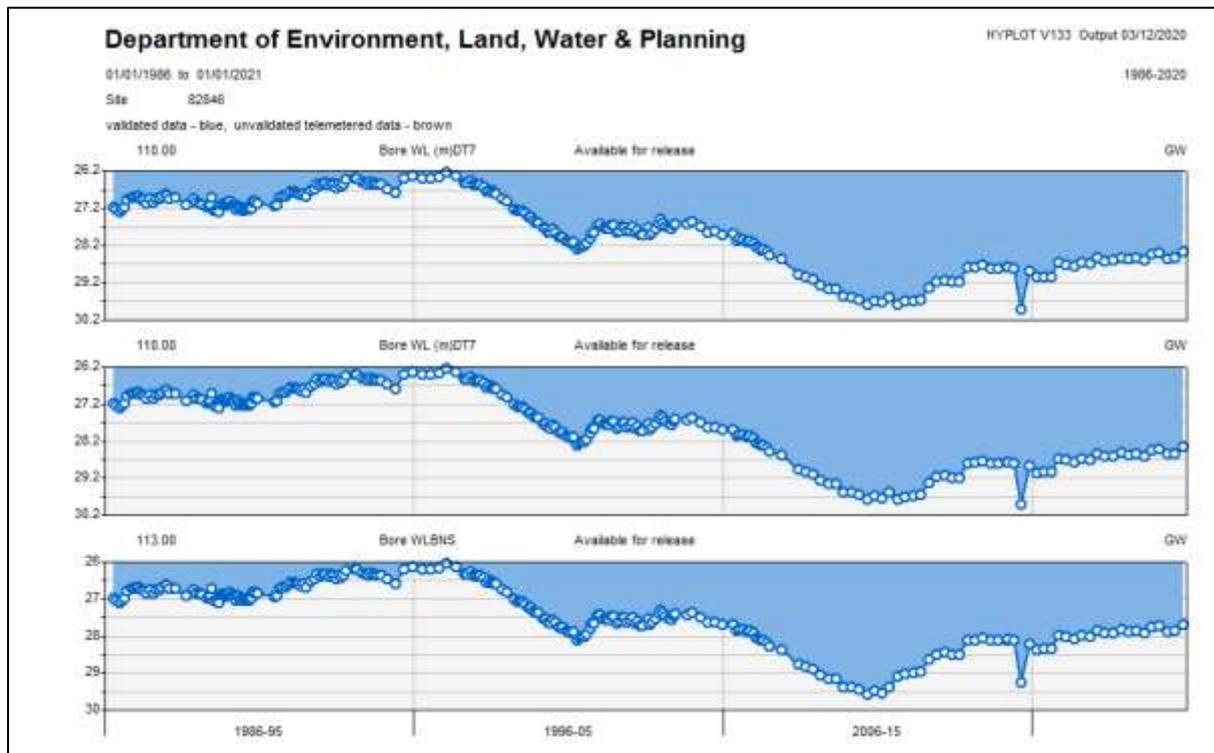
Observation Bore 47771



Observation Bore 47775



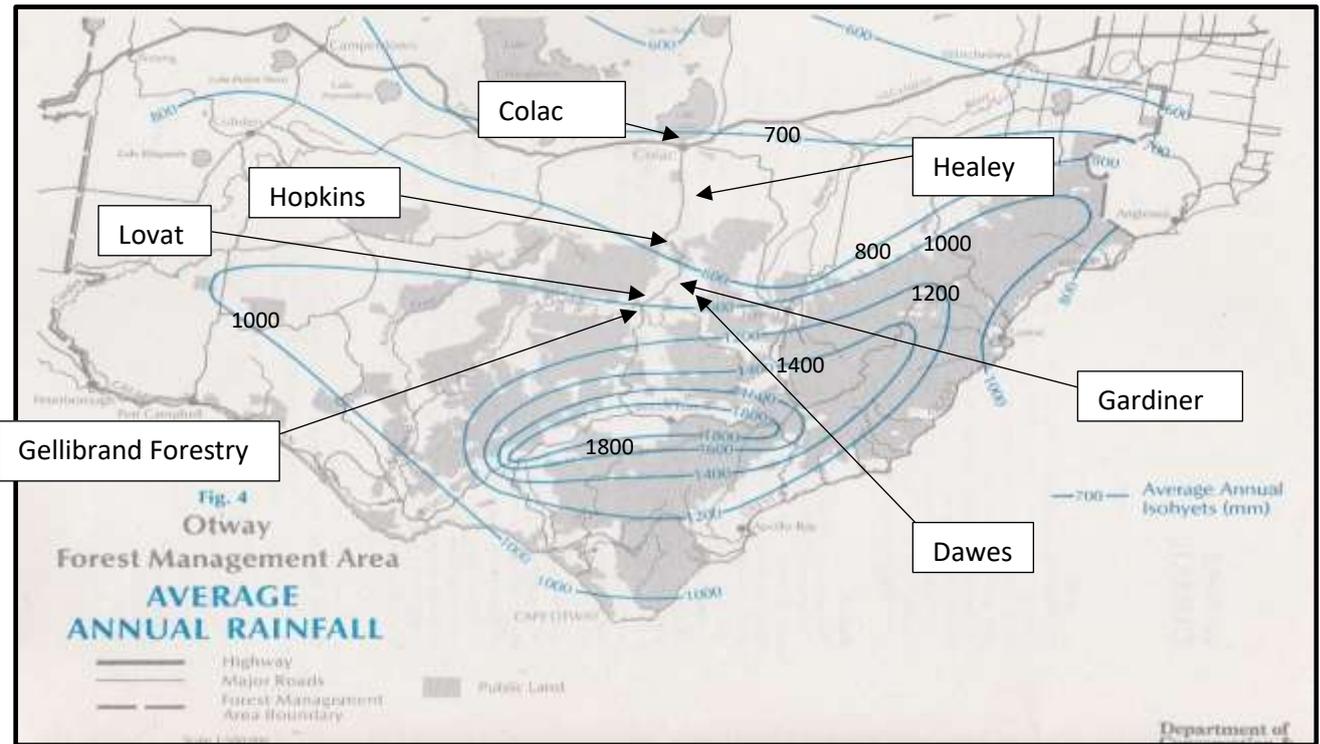
Observation Bore 82846



As with earlier research requests asked of the Vic Water Data Warehouse,⁽⁸⁾ numerous bores in the area had the grid reference but followed up with the statements “*No variables data found for this site.*” Or site “*not found*”.
Not much use.

Rainfall.

Location of Rainfall Gauges.



SOURCE: 1990 Otway Forestry Management Plan, Victorian State Government.

The Healey rain gauge is located between the 700 and 800 mm rain bands. The Hopkins gauge is just outside the 800 mm band. The Gardiner and Lovat gauges fall within the 800 to 1,000 mm range and the Gellibrand Forestry is right on the 1,000 mm boundary.

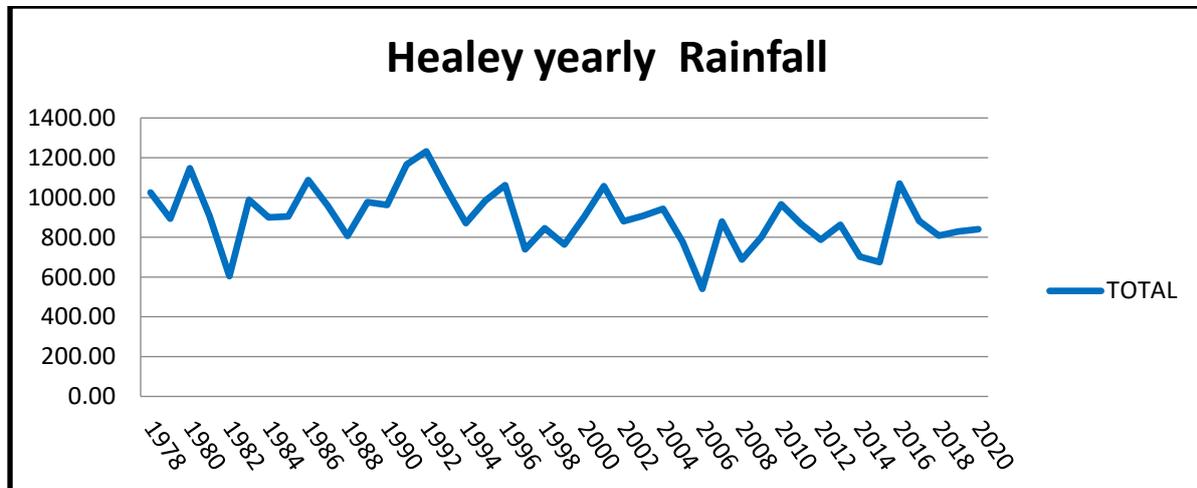
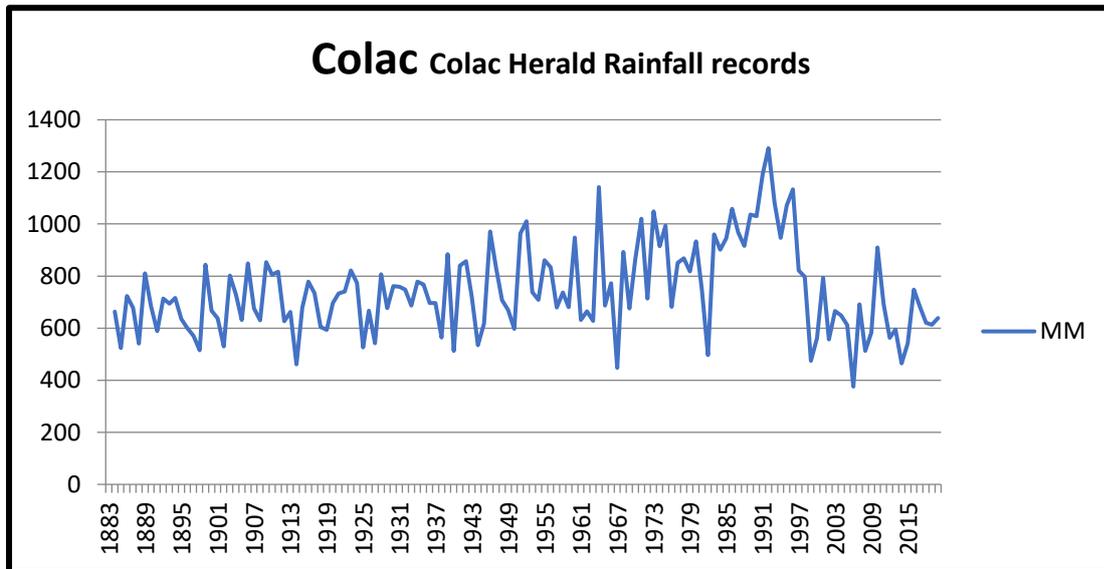
Little Change in 30 Years.

The blue lines on this map shows where the rainfall bands fell in the 1990’s. The following 6 rainfall graphs support the following statements made by Wade.⁽¹⁴⁾

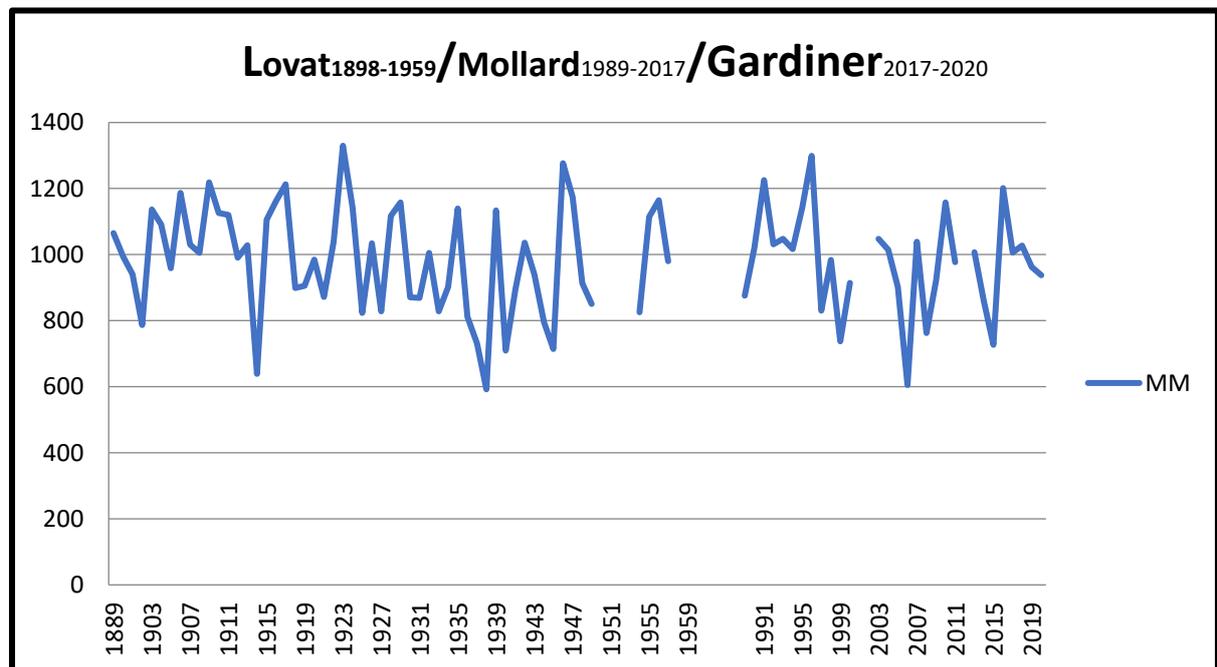
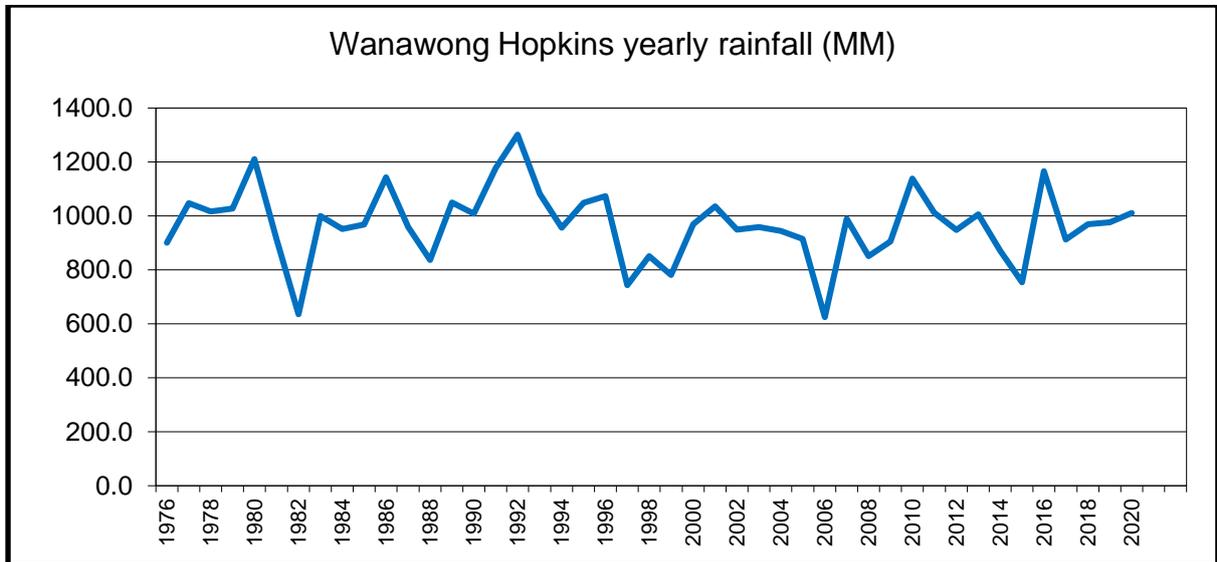
“Contrary to what it says in the Executive Summary of Jacobs (2018a)⁽¹⁴⁾ report low rainfall climate conditions between 1980 and 2016, have not caused a regional decline in groundwater levels across the study area. There is no significant evidence of this in the groundwater data (WMIS).”

“The effect of local rainfall variations on baseflow in Loves Creek is insignificant in comparison to the effect of Barwon Downs groundwater extraction.”

The rainfall graphs support this work of Wade’s and it would appear that the rain bands and rainfall have varied very little in the last 30 years.

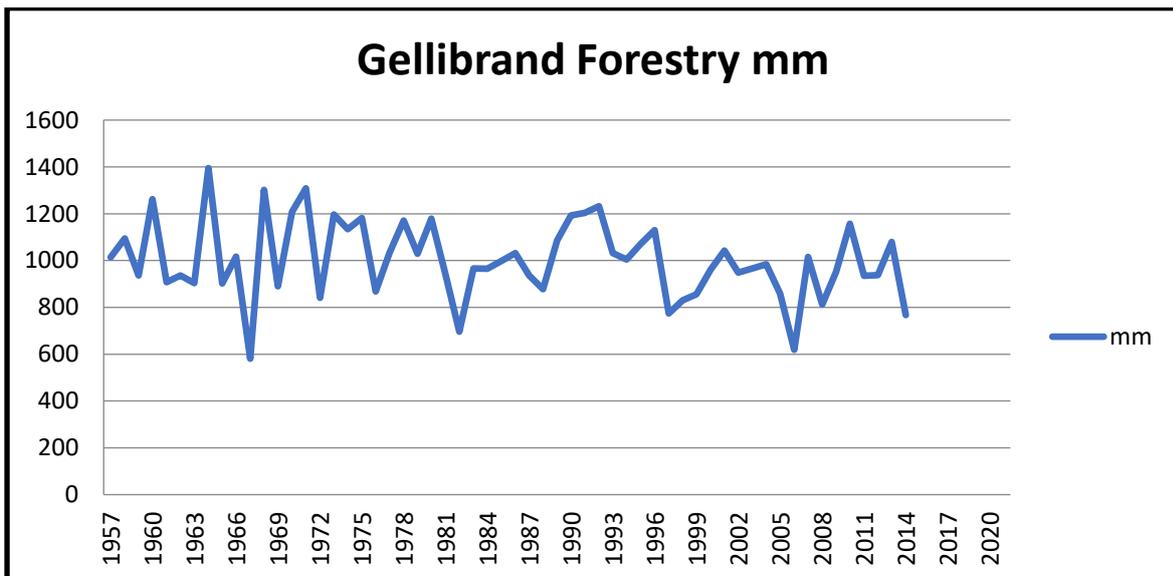
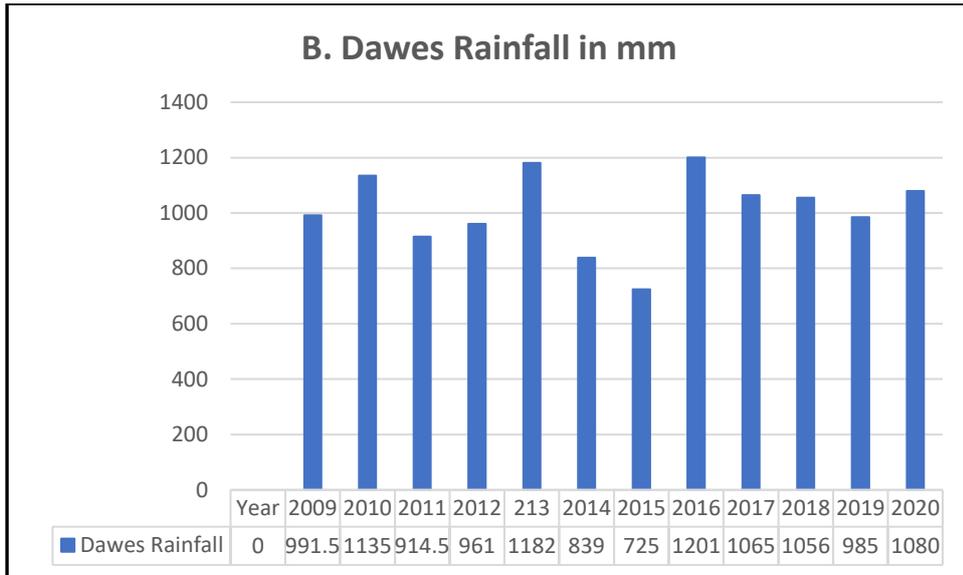


Healey Rainfall Station Yearly Totals.



No Upward Trending of Levels as a Result of Yearly Rainfalls.

Despite plentiful rains and wet winters leading up to and since the Millennium Drought, the observation bore hydrographs down the Kawarren Gellibrand flowpath (pages 17-21) show no indication of recharge recovery.



No records for 2015-2020. Up to April in 2015 there was 451.6 mm.

The Kwarren Gellibrand Flowpath Corridor.

With rainfall records such as these since the Millennium Drought there should have been an upward spike in the hydrographs - pages 17-21. With so many high yearly rainfalls over the last few years, at the very least there should have been a gradual upward trend in the water table levels in the Kwarren Gellibrand groundwater flowpath corridor. This has not been the case. The extremities are still being drawn down. Since serious groundwater extraction finished in 2010 the Kwarren Gellibrand area hydrographs have continued their downward trend. At the very best some have flattened out. The major

contributing factor to these declines can squarely be attributed to the groundwater extraction that has taken place at the Barwon Downs Borefield. *“The 10% reduction in rainfall is not sufficient to explain the significant reduction in the minimum baseflow in Loves Creek. The approximately 60% reduction between the minimum flow rate before 2000 and the minimum flow rate after 2000 is clearly due to the widespread drawdowns in the Kawarren Sub-Basin caused by the Barwon Downs Borefield.”*⁽¹⁴⁾ (Wade 2019)

The North Easterly Extremity.

Over on the north easterly extremity of the drawdown influence the few hydrographs that could be located also indicate a continuing impact – pages 22-26. Even though it has been reported by Jacobs that the groundwater flowpath has been reversed in this area there is still no acknowledgement of the resulting impacts from this. Otway Water Books 20, 40 and 44 discuss some of the resulting problems encountered on the Campbell property located in this area.⁽⁵⁾⁽⁶⁾⁽⁷⁾ Problems indicating that there needs to be a close examination of the impacts from groundwater extraction taking place in this location.

CONCLUSION.

It is not easy researching groundwater levels in the Otway Ranges and foothills. Data is sketchy, confusing, withheld, omitted and or apparently lost to examination by the “citizen scientist.” There appears to be no uniformity in the way data is presented. Therefore, it is doubtful that water resource managers would find it anything but a difficult task to make informed decisions.

What can be determined is that since groundwater pumping ceased at the Barwon Downs Borefield the recovery of the aquifers continues. The lower section of the cone of depression is filling as indicated by those observation bores close to the borefield. However, and despite high levels of yearly rainfall, flowpaths on the extremities of the drawdown continue to be affected as groundwater water is being drawn towards the lower section of the cone near the borefield. Observation bores in the extremities continue to exhibit a downward trend with little to no recovery from significant rainfall events.

At this rate of recovery it is anticipated that the extremities will take some considerable time to stop being impacted, and, even much longer to start any recovery. In advice to the Minister for Water in 2019, her advisors determined that three observation bores they analysed, would take between 24 to 309

years to recover 100% (see Appendix Two). What is frightening, these bores are not at the extremity of the drawdown area of influence.



Appendix One.

On Wednesday, 6 January 2021, 01:55:30 pm AEDT, Internet Email (Registration)
<srw@srw.com.au> wrote:

Some web sites where you can get bore depth information

The Groundwater Hub of Southern Victoria:

<http://gwhub.srw.com.au/>

This website brings groundwater information to the community in an engaging way to encourage your interest, awareness and conversation.

It combines theory, interactive maps, licensing information, operational advice and useful links to meet your needs.

Groundwater Resource Reports:

<http://www.depi.vic.gov.au/water/groundwater/groundwater-resource-reports>

This provides a one page summary of the aquifers and groundwater quality of any point clicked on a google based map.

Visualising Victoria's Groundwater:

<http://www.vvg.org.au/>

This site is hosted by Federation Uni, and includes data such as water table levels, groundwater bores, EPA sites and much more data.

Water Information Management System (WMIS)

<http://data.water.vic.gov.au/monitoring.htm>

This is a DEPI site, where you can download all groundwater data relating to bores in any part of Victoria.

GDE Atlas

<http://www.bom.gov.au/water/groundwater/gde/map.shtml>

This site is hosted by BOM, and shows all of the groundwater dependent ecosystems across Australia.

A direct link to groundwater information at the 'Water' web site is www.water.vic.gov.au/environment/groundwater

At this site, you will find links to:

- Groundwater Management Information
This link provides access to maps of Victorian groundwater management areas, Management plans and rules and other useful information
- Groundwater News and Information
This link provides fact sheets, brochures and reports advising of a wealth of groundwater information
- Groundwater beneficial use
This link includes broad scale maps of the general quality of water in an area

The site has numerous other links which can be explored, all of which provide further information about water and the environment.
I trust these search suggestions are useful to you.

Kind Regards,
Southern Rural Water Staff

Information Management Officer | Southern Rural Water
Managing Water. Serving Communities
Ph: 1300 139 510 **Email:** srw@srw.com.au

SRW acknowledges and respects the traditional owners of the land and waters upon which we work

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Appendix Two.

Review of the PVC for the Gerangamete GMA
6 May 2019 – IN CONFIDENCE

Annex C – Recovery levels in groundwater monitoring bores and estimated recovery times

Using the groundwater levels from the last pumping period, an estimate of the time to recovery (to pre-development levels) is provided in the table below. This is based on a log-linear relationship. Based on visual inspection of the recovery curve for Bore 64230 it appears that the curve has plateaued and will not recover to pre-development levels, even with cessation of pumping.

Table C1 – Estimated recovery time from pumping events

Bore	Pre-pumping level (mAHD)	Lowest level (mAHD)	Recovery time from 2010 (years)	
			100%	90%
109110	165	120	93	49
64230	160	115	24	15*
64233	160	126	309	154

*Groundwater levels were not available for the full record for bore 64230.

Figure C1 shows the full period of record of the monitoring with the blue box highlighting the last pumping period, which is shown in Figure C2. The predicted recovery curves are not shown on these figures.

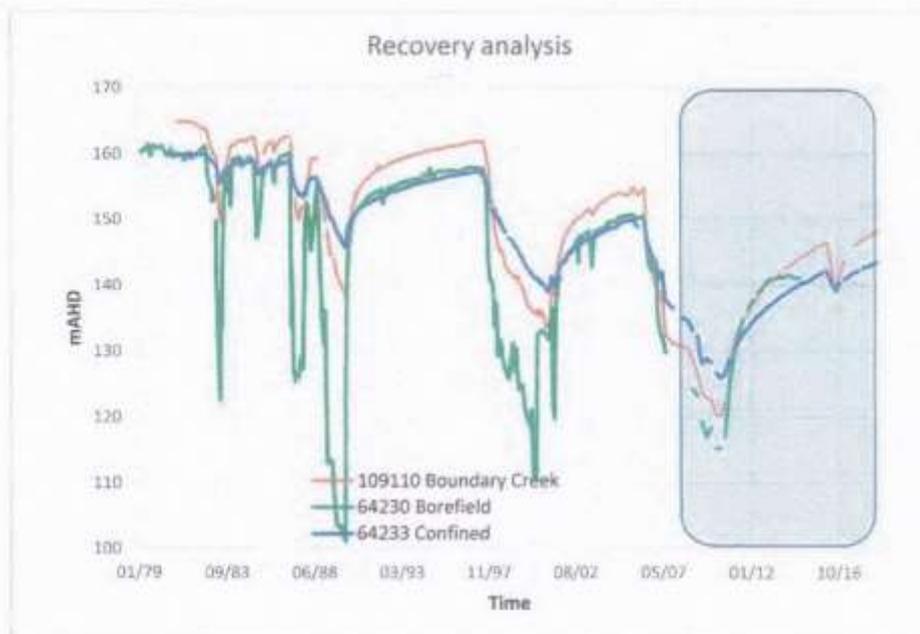


Figure C1 – groundwater levels near the borefield for the entire period of pumping at Barwon Downs

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