Kawarren Drawdown Investigation

1. Summary and Key Conclusions

This briefing note has been prepared by Jacobs for internal use by Barwon Water. This briefing note is not intended for publication or for distribution outside Barwon Water, as it draws extensively on other studies, but for brevity, only provides a shortened description of these other studies and of the aquifer and drawdown.

The Barwon Downs borefield has been used to augment Geelong water supply over three time periods –1987 to 1990; 1997 to 2001 and 2006 to 2010. Over this time, groundwater levels in the LTA declined in response below average rainfall conditions and extraction from Barwon Downs. Typical of most aquifers, groundwater decline in the LTA is not uniform and some areas show greater decline than others.

Pumping from Barwon Downs has minimal impact on the adjacent Gellibrand catchment, which includes the township of Kawarren. Some drawdown in the aquifer has been observed around Kawarren, however drawdown is less than what would be expected for this distance from the borefield. In addition to this, significant drawdown has not propagated to the overlying aquitard or higher units. Jacobs (2015) postulated that a hydraulic barrier could be present between the borefield and the Kawarren area. Bores located in this area show a subdued response to pumping in comparison to other bores and two bores in particular have negligible drawdown (Bores 48003 and 47990).

The objective of this briefing note is twofold:

- To confirm the integrity of the two bores that have negligible drawdown (48003 and 47990) and
- To consider an alternate hypothesis that drawdown from Barwon Downs does not extend to Kawarren and the observed drawdown can be explained by local groundwater use.

To confirm the integrity of the observed response in bores 48003 and 47990, the screened intervals were checked to ensure the bores are monitoring the same aquifer horizon and the hydrographs were reviewed to assess their integrity. These activities confirmed that:

- Screen depth or screened stratigraphic unit are not the cause for the negligible drawdown in bores 48003 and 47990.
- Failure of bore integrity is not an explanation for the negligible drawdown in bore 48003 and 47990.

To test the hypothesis that the small amount of drawdown observed in Kawarren is not caused by Barwon Downs, the local groundwater use around Kawarren was investigated (e.g. unlicensed groundwater use, stock and domestic, aquifer testing or leaking artesian bores). However a review of potential local groundwater use concluded that there is no local groundwater use of sufficient scale to explain the observed (subdued) drawdown in the Kawarren area.

In summary, the subdued drawdown observed in Kawarren is considered to be the result of pumping from Barwon Downs. The recalibration of the numerical model should include the outcomes of the investigation. The responses observed in Bores 48003 and 47990 are the result of a reduced connection in the aquifer between Barwon Downs and Kawarren. The reduced connection in the aquifer in this area means the subdued drawdown in the Kawarren area is less than would be expected at this distance from the borefield. As described in Jacobs (2015) the reduced connection in the aquifer is postulated to be caused by a change in aquifer parameters (transmissivity or storativity) that is thought to constrain the drawdown response in this part of the aquifer.

2. Background

A sound conceptual understanding of hydrogeological processes to the south west of the Barwon Downs borefield, in the Kawarren area, is important due to the presence of significant groundwater receptors in that area (e.g. springs, Gellibrand River and tributaries). For the purposes of this file note, the Kawarren area is defined as an area 2-3 km radius from Kawarren township (intersection of Colac Lavers Hill Rd and Kawarren East Rd).

The conceptualisation of this area has been discussed in the *Review of Conceptual Model report* (Jacobs, 2015), and in particular the Dudding (2014) review within that report examined various conceptual models that could account for the nature of drawdown observed in the south west area. Jacobs (2015) assumed that the subdued drawdown response in the Kawarren area is due to the Barwon Downs borefield. However there are two observation bores located closer to the borefield that show negligible drawdown (i.e. less drawdown than bores in the Kawarren area). Drawdown in the LTA between 1987 and 2012 is shown in Figure 1 and is consistent with this interpretation in that it shows the drawdown as a continuation of the drawdown associated with the Barwon Downs borefield.

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- To confirm the integrity of the two bores that have negligible drawdown (48003 and 47990) and
- To consider an alternate hypothesis that drawdown from Barwon Downs does not extend to Kawarren and the observed drawdown can be explained by local groundwater use.

If there is another process driving drawdown in this area, the area of potential impact from the borefield would be reduced. This has implications for the extent of the area that needs to be included in potential impact assessments for the licence renewal.

To confirm the integrity of the observed response in bores 48003 and 47990, the screened intervals were checked to ensure the bores are monitoring the same aquifer horizon and the hydrographs were reviewed to assess their integrity.

To test the hypothesis that the small amount of drawdown observed in Kawarren is not caused by Barwon Downs, local groundwater use around Kawarren was investigated. Possible uses include:

- Local groundwater use, including licensed and potentially unlicensed use
- Test pumping from bore 108910
- The leaking SOBN bore at Kawarren (Bore 108910)

All bores in the confined Lower Tertiary Aquifer (LTA) located between the Kawarren area and the borefield were assessed in this investigation.

Table 1 shows the interpreted induced drawdown from groundwater extraction at Barwon Downs for the bores in the Kawarren area. This was calculated by subtracting the 2012 water level from that measured prior to borefield extraction in 1987 The regional decline in groundwater levels observed in bores not impacted by borefield extraction was also subtracted. Groundwater levels across the region have declined due to cumulative below average rainfall across the 1987 to 2012 period. The regional decline was quantified by examining monitoring records in observation bores well outside the influence of the Barwon Downs borefield during that period. A regional decline of 1.4 m in confined LTA was estimated based on the decline at bores 108905 and 80733 to the west of Gellibrand which is located beyond the cone of depression. This was subtracted from the drawdown data to provide the “calculated drawdown” shown in Table 1.

The results show that bores 108909, 108910, 108911, 108913 and 47986 which are located around Kawarren, show more than 2 m of drawdown. It should be noted that a drawdown of more than 2 m at this location is less

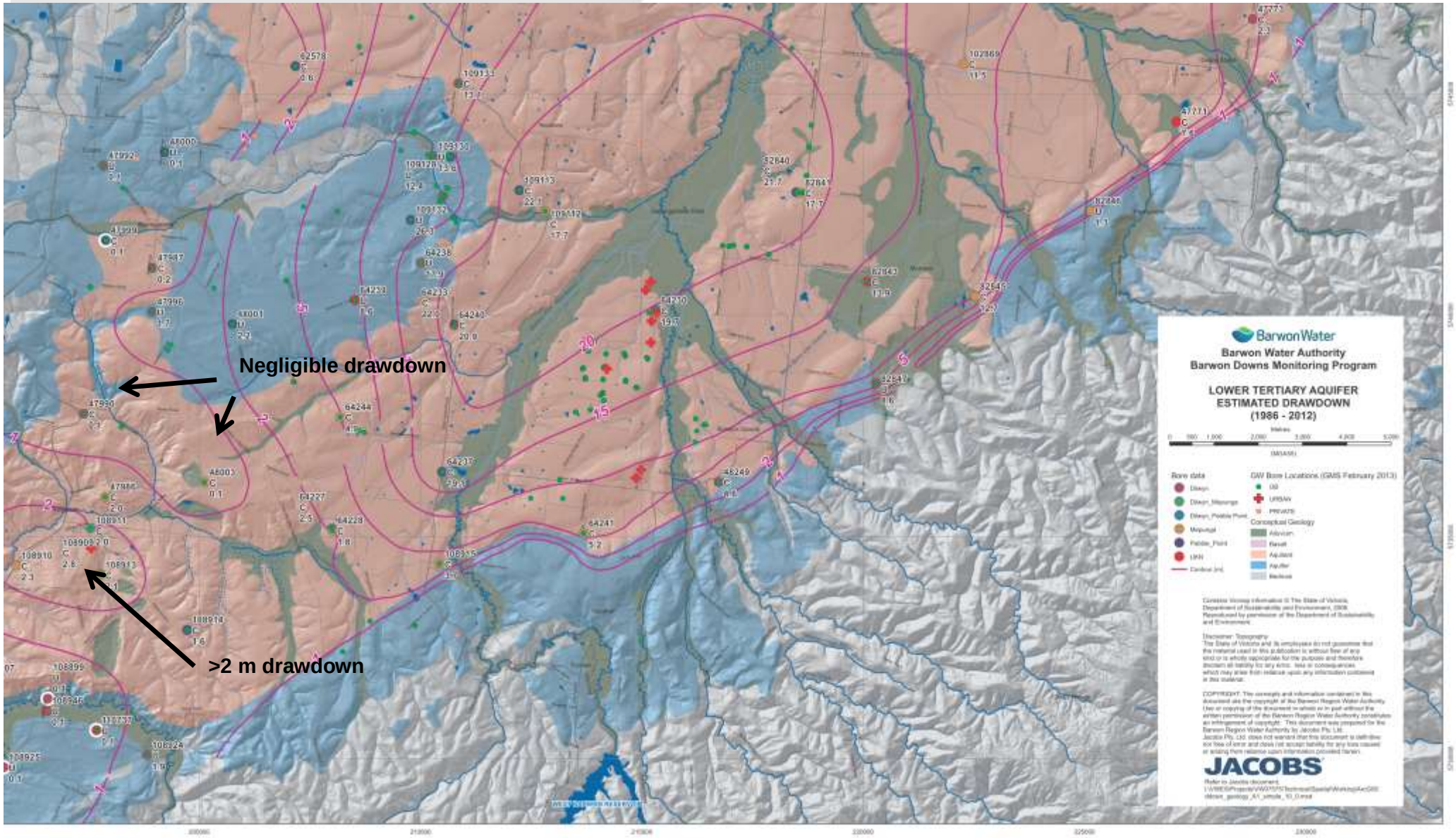
than would be expected at this distance from the borefield (i.e. if the aquifer was the same as it is at the borefield). However bores 48003 and 47990, which are at a similar distance or closer to the borefield, show negligible drawdown.

It should be noted that waterlevels prior to 1987 in Bore 108909 are inconsistent with the remainder of the water levels collected since then and are not considered to be reliable. The waterlevel response in this bore prior to 1987 requires further consideration and this would be undertaken when recalibrating the numerical model.

Table 1 Calculated drawdown in bores surrounding the Kawarren area

Site No	Location	Water level (mAHD)		Change	Calculated drawdown due to borefield
		1987	2012	(m)	(m)
108909	Kawarren	112.0*	107.8	4.1	2.7
108910	Kawarren	111.1	107.5	3.7	2.3
108911	Kawarren	111.7	108.3	3.4	2.0
108913	Kawarren	112.0	108.6	3.5	2.1
108914	Kawarren	109.7	106.7	3.0	1.6
47986	Kawarren	113.7	110.4	3.3	1.9
48003		125.9	124.5	1.4	<0.1
47990		126.0	124.7	1.4	<0.1

** Inferred waterlevel from amended waterlevel data*


Negligible drawdown
>2 m drawdown
BarwonWater
Barwon Water Authority
Barwon Downs Monitoring Program
LOWER TERTIARY AQUIFER
ESTIMATED DRAWDOWN
(1986 - 2012)
JACOBS

3. Results and discussion

As mentioned, the integrity of bores 48003 and 47990 was confirmed by reviewing the screened intervals to ensure the bores are monitoring the same aquifer horizon and the hydrographs were reviewed to assess their integrity.

To test the hypothesis that the small amount of drawdown observed in Kawarren is not caused by Barwon Downs, local groundwater use around Kawarren was investigated. Possible uses investigated were:

- Local groundwater use, including licensed and potentially unlicensed use
- Test pumping from bore 108910
- The leaking SOBN bore at Kawarren (Bore 108910)

Each of these are discussed in the following sections.

3.1 Depth and stratigraphy of observation bores

As described earlier, bores screened in different stratigraphic units could potentially account for the difference in observed water levels. For example, if two neighbouring bores are screened at widely varying depths or in different stratigraphic units, it is possible that the observed groundwater responses will be different. To evaluate this possibility, the screen depths and stratigraphy at each of the above bores were reviewed. These are provided in Table 2 below. Table 3 shows the stratigraphy in the Barwon Downs area.

Table 2 Bore details

Site	Aquifer	Site Elevation	Screen depth (m bgl)	
		m AHD	From	To
108909	Dilwyn	124	197	202
108910	Mepunga	100	135	140
108911	Dilwyn/Mepunga	119	100	203
108913	Mepunga	124	140	145
108914	Pebble Point	191	207	214
47986	Mepunga	174	182	187
48003	Mepunga	206	275	278
47990	Dilwyn	182	39	43

Table 2 shows that there is no obvious correlation between screen depth or screened stratigraphic unit in accounting for observed drawdown. For example, the bores around Kawarren are screened in both the Dilwyn and Mepunga Formation, but show a consistent response of 2-3m drawdown. The bores showing very little drawdown (48003 and 47990) are also screened in the Mepunga and Dilwyn respectively, and hence also suggest no relationship between drawdown and stratigraphic unit. This is consistent with conceptual understanding of the study area which indicates that the Mepunga and Dilwyn generally behave as one aquifer system.

There is only bore screened in the Pebble Point Formation, 108914, which shows a slightly lower drawdown (1.6m) compared to its neighbouring bores in the Kawarren area, despite being closer to the borefield. Given that this is the bore most likely to be stratigraphically separated from bores screened in the Dilwyn and/or Mepunga formation (by the Pember Mudstone), it is possible that at this bore, the difference in screened interval does account for the lower drawdown compared to the more distant bores with greater drawdown at Kawarren. However, this does not explain the main discrepancy which is the focus of this assessment.

In summary, it does not appear that screen depth or screened stratigraphic unit are responsible for the negligible drawdown observed in bores 48003 and 47990.

Table 3 Stratigraphy in the in the Barwon Downs area (note grey units are generally considered to be aquitards)

Geological Unit	Description	Type	System
Quaternary Alluvium	Sands, silts and gravels.	Aquifer (minor)	Minor surficial aquifer restricted to river and creek channels
Gellibrand Marl	Calcareous silty clay and clayey silt. Fossiliferous.	Aquitard	Mid Tertiary Aquitard (MTD)
Clifton Formation	Calcarenite with marine fossils and minor quartz and limonite sands	Aquifer (minor)	
Narrawaturk Marl	Calcareous mudstone with thin carbonaceous beds, sand beds and fossiliferous beds	Aquitard	
Mepunga Formation	Medium to coarse grained quartz sand with some carbonaceous clays and silt layers	Aquifer	Lower Tertiary Aquifer (LTA)
Dilwyn Formation	Carbonaceous, sandy clays and silts, with some quartz sand and silty sand beds, and minor gravel. Coal and carbonaceous clays also occur in this unit.	Aquifer	
Pember Mudstone	Clays, silts and fine grained sand with carbonaceous, micaceous and pyritic horizons.	Aquitard (minor)	
Pebble Point Formation	Fine-grained sand with carbonaceous silt and quartz pebble beds. This unit is an equivalent to the Moomowroong Sand Member, Wiridjil Gravels that occur in the Gellibrand sub-basin to the south west of the study area.	Aquifer (minor)	
Bedrock	Sandstone, siltstone and mudstone with feldspar and quartz grains, well-bedded and consolidated.	Aquitard	

3.2 Failure of bore integrity

Compromised or failure of bore integrity also has the potential to drive discrepancies in the observed water level responses in bores. For example, if a bore screen becomes clogged with sediment, water level responses can be reduced and appear flat. Similarly, if a bore annulus isn't effectively sealed from the surface during construction, water level responses may become variable and appear erratic compared to nearby bores.

Figure 2 below shows the hydrograph responses for the bores in the study area. The figure shows relatively higher groundwater levels in bores 48003 and 47990, as well as negligible groundwater response compared to bores in the Kawarren area. The higher relative water levels in these two bores are also illustrated in the potentiometric surface in Figure 3, which shows these bores are located higher in the groundwater catchment.

Two aspects of the hydrographs are relevant in terms of indicating sound bore integrity:

1. There is nothing in the water level record for Bore 48003 or 47990 that suggests the integrity of the bore is compromised, e.g. a flat / static water level or erratic jumps in water level.

2. The very similar response between the two bores suggests it is very unlikely that the bores have been constructed with a similar defect or developed a defect over time. The likelihood of this is considered to be very small. Instead, the most probable explanation is that both bores are functional, but respond differently to other bores in the area due to some other hydrogeological reason.

In summary, it is considered unlikely that issues relating to bore integrity explain the negligible drawdown in the two observation bores.

Figure 2 Groundwater hydrographs of bores around Kawarren

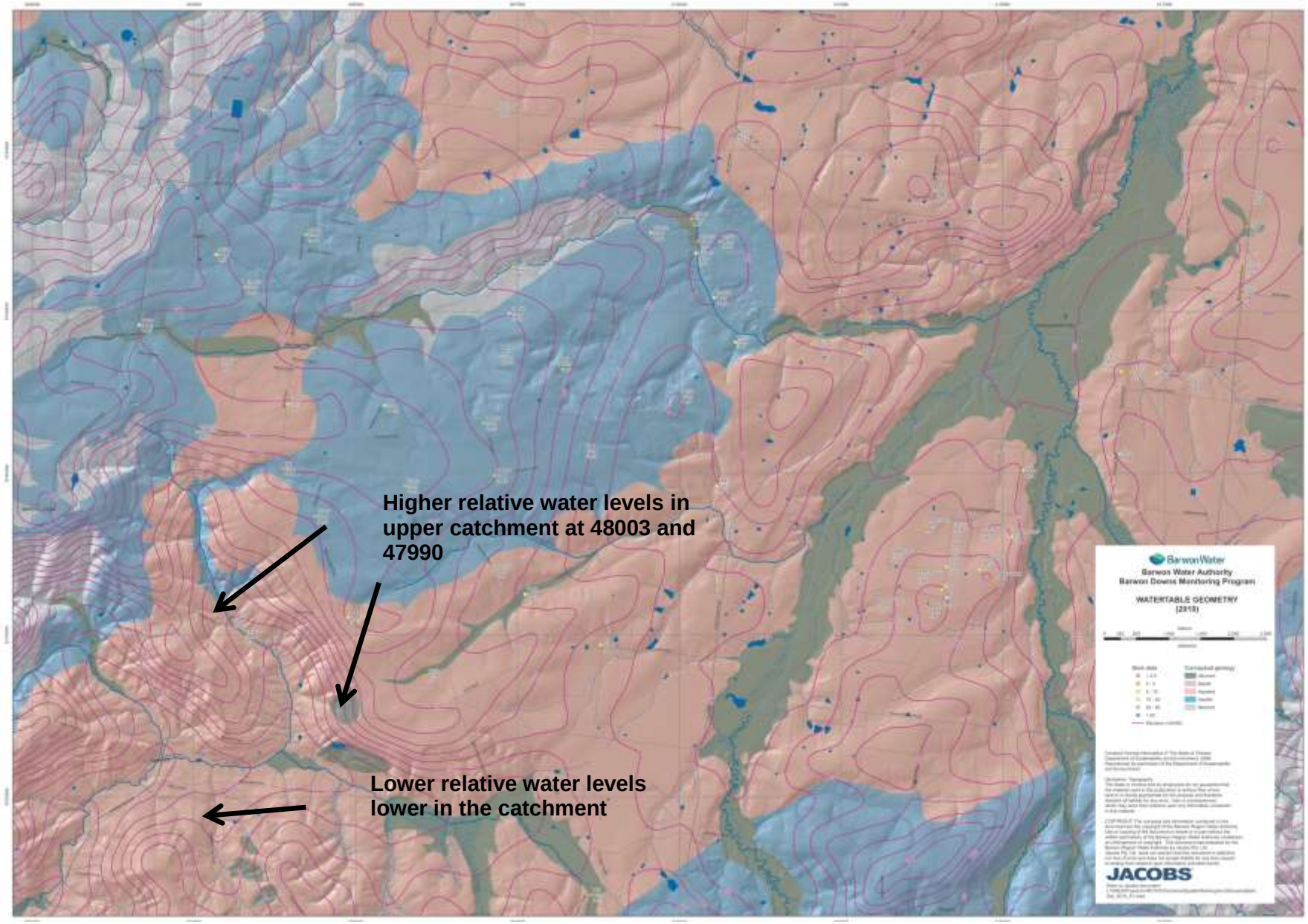


Figure 3 Water table potentiometric surface 2010

3.3 Assessment of local groundwater use as cause of drawdown

This section uses analytical analysis to investigate whether local groundwater extraction is a potential source of the drawdown observed in in the Kawarren area. For the observed drawdown in bores 108909, 108910, 108911, 108913 and 108914 to be a local phenomenon (i.e. un-related to the Barwon Downs borefield), groundwater extraction would need to have created 2 to 3 m of drawdown over an approximate 25 year period.

In order to assess the likelihood of this, the Theis equation has been used to estimate extraction rates required to generate the magnitude and extent of the observed drawdown. The equation requires an estimate of the hydrogeological parameters of the aquifer (i.e. the transmissivity and storativity) and these are relatively well understood for the Lower Tertiary Aquifer in this area.

Pump test results from bore 108912 indicate a transmissivity of 800 m^2/day and a storativity of 0.00047 (SKM, 2007). This bore is located approximately 60 m to the east of bore 108911 (Figure 1) and is screened between approximately 100 and 200 m, in the Lower Tertiary Aquifer. This suggests that the physical hydrogeological parameters should be similar for both bores, however given that 108912 is a production bore (designed and located in an area of the aquifer to be as productive as possible) it is likely to represent an upper transmissivity estimate of the aquifer in the wider Kawarren area. Hence a transmissivity estimate of 400 m^2/day is considered more realistic for use in this assessment.

As illustrated in Figure 1, if drawdown is un-related to the borefield, there would need to be approximately 2m of drawdown radiating to a distance of around 1.5 km, approximately centred on Kawarren. **Error! Reference source not found.** below shows the estimated drawdown vs distance expected for the extraction of 1 ML/day over a 25 year period. This shows that for a cone of depression similar to that observed in the Kawarren area, extraction would have to average around 1 ML/day.

If the transmissivity of the aquifer were higher (closer to 800 m^2/day as suggested by 108912), groundwater extraction from around 108909 would need to be closer to 2 ML/day to induce 3 m of drawdown at the cone centre and 2m of drawdown at 1.5 km distance. This is illustrated in Figure 5 which shows the expected drawdown vs distance for an extraction rate of 2 ML/day over 25 years.

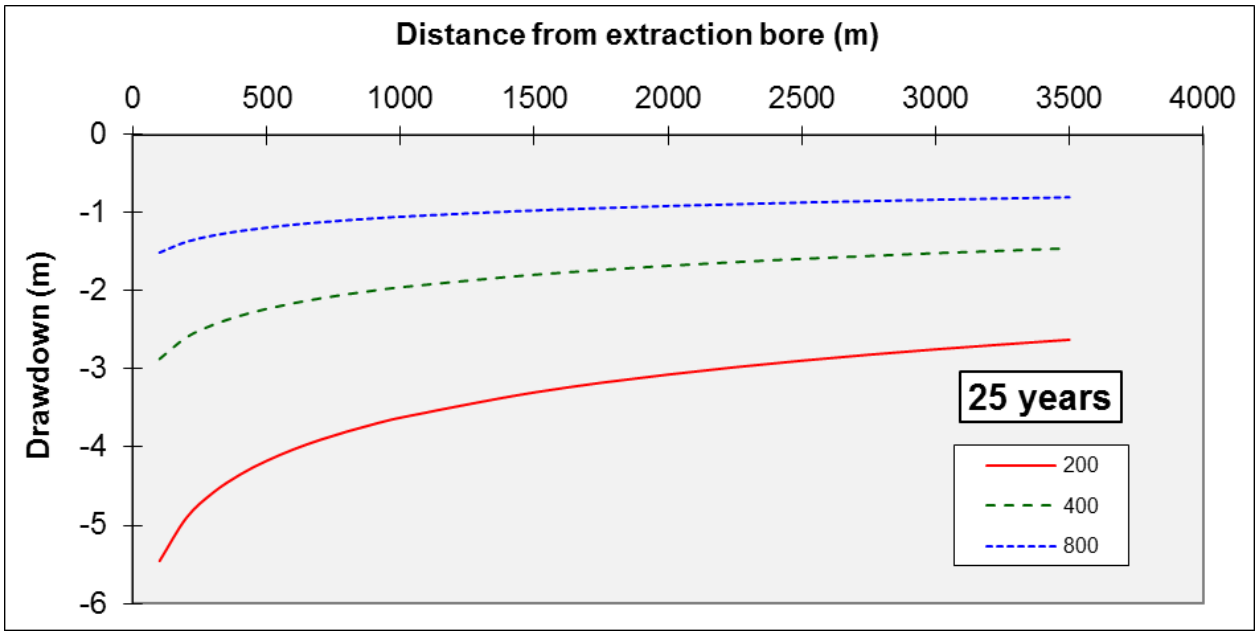


Figure 4 Theis analysis result for 1 ML/day extraction over 25 years

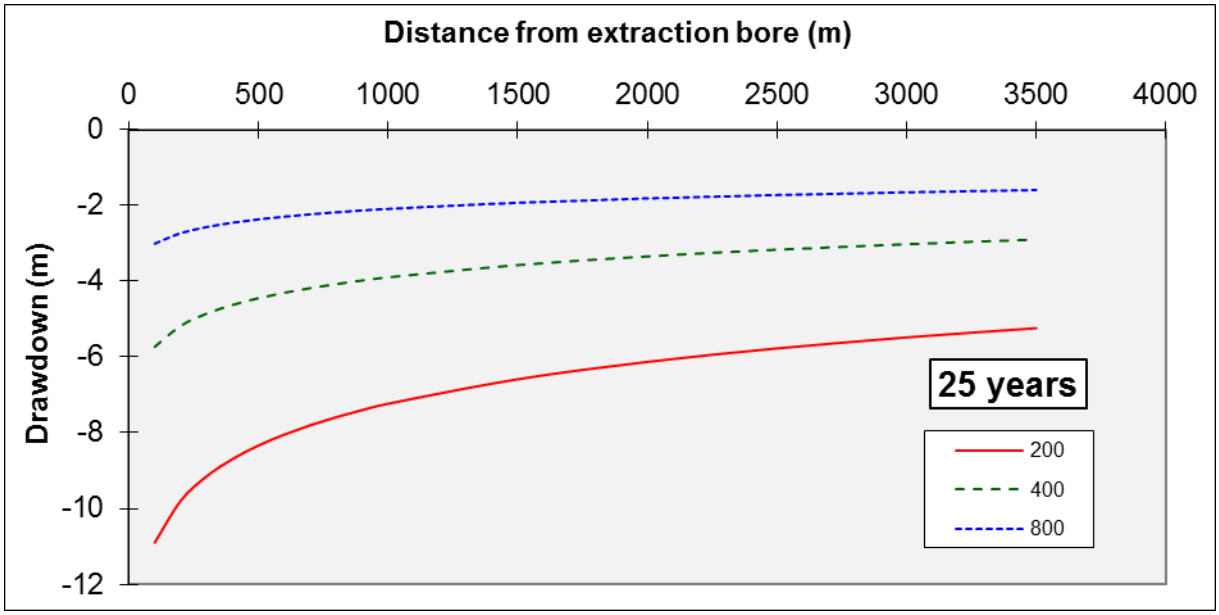


Figure 5 Theis analysis result for 2 ML/day extraction over 25 years

The potential for local sources to contribute to the magnitude of extraction rates determined in the above assessment are discussed below:

- Local groundwater extraction, registered bores – The VVG indicates one bore located near the corner of Bull Hill Rd and Kawarren East Rd, Bore WRK968097, which is known to have been used for groundwater extraction in the past (pers. comm. M.Gardiner, December 2015). The bore is identified as being 50m deep, but there is no other information available on the VVG for the bore. M.Gardiner indicated that the bore had been used for small amounts of pumping for stock and domestic use but has not been used for 5 years. This information is consistent with a site assessment at the property as part of a springs assessment during the Newlingrook groundwater investigation in 2007/2008 ,whereby the bore was identified, but was clearly not equipped for use at rates of 1-2 ML/day. Further, discussions with local landownders and previous site investigations, has shown that the property contains a number of springs suitable for stock watering. Finally, the registered bore depth of 50m means the bore is not screened in the LTA, but in the aquitard (probably the Clifton Formation which can act as a low yielding aquifer), which is further evidence that the bore is not pumping at rates of 1-2 ML/day.

- Local groundwater extraction, un-registered bores – It is possible that there are other un-registered bores being used for groundwater extraction in the area. However, for an exaction volume in the order of 400 ML/year (i.e. 1 ML/day) it is extremely unlikely that this could occur and remain concealed (i.e this volume would be used for irrigation or industrial purposes and hence would be very likely known by the community). This was discussed with M.Gardiner who has resided in the area for many decades and is an active member in the community in terms of water related issues - he is unaware of any groundwater use in the area apart from the bore described above (pers. comm. M.Gardiner, December 2015). Further, groundwater use of this volume would likely stand out in aerial photographs of the area, and this was not observed in aerial images inspected as part of this assessment.

- Leaking artesian bore 108910 – For a number of years, artesian bore 108910 was observed to be leaking. If leakage rates were high enough this could potentially explain the observed drawdown. However, visual assessment of the bore suggests leakage rates were certainly less than 0.5 L/s (0.05 ML/day) and probably less than 0.1 L/s (0.01 ML/day) (S.Parsons, pers. Comm. 6 Jan 2016). These extraction rates are rates far lower than required to explain the drawdown in the Kawarren area. Further, if leakage from this bore was the source of the drawdown, then drawdown at this bore would be

significantly greater than other bores and centred on the leaking bore, however this is not the observed pattern of drawdown shown in Figure 1.

- Test pumping from bore 108912 – This bore has been used in the past for test pumping, most recently in July 2007 as part of the Newlingrook groundwater investigation. However, during that test the bore was only pumped for 48 hours at a rate of 36 L/s (approximately 3 ML/day). This very short term use of the bore cannot account for the long term drawdown in the Kawarren area.

In summary, neither the (previously) leaking artesian bore or small scale local groundwater use in the area is considered close to be of a scale to be viable explanation of the observed drawdown in the Kawarren area.

4. Conclusion

This assessment has considered various explanations for the drawdown observed in the Kawarren area and bores located closer to the borefield. The assessment concludes that:

- Screen depth or screened stratigraphic unit are not the cause for the negligible in bores 48003 and 47990.
- Failure of bore integrity is not an explanation for the negligible drawdown in 48003 and 47990.
- There is no local groundwater use sufficient to explain the observed drawdown in the Kawarren area.

In summary, the subdued drawdown observed in Kawarren is considered to be the result of pumping from Barwon Downs. The recalibration of the numerical model should include the outcomes of this investigation. The responses observed in Bores 48003 and 47990 are the result of a reduced connection in the aquifer between Barwon Downs and Kawarren. The reduced connection in the aquifer in this area means the subdued drawdown in the Kawarren area is less than would be expected at this distance from the borefield. As described in Jacobs (2015) the reduced connection in the aquifer is postulated to be caused by a change in aquifer parameters (transmissivity or storativity) that is thought to constrain the drawdown response in this part of the aquifer.

5. References

Dudding, M. (2014) Barwon Downs Hydrogeological Conceptual Model - Analysis of drawdown to refine conceptual model at the SW and NE Barwon Downs numerical model boundaries. 11 December 2014.

Jacobs (2015) Barwon Downs Monitoring Program - Review of Conceptual Model at Numerical Model Boundaries. 28 August 2015.

SKM (2007) Newlingrook and Gellibrand Groundwater Investigation - Kawarren pumping Bore Assessment Report. 28 August 2007.