Hydrogeological Review

Ballarat West Employment Zone

Prepared for:
City of Ballarat
25 Armstrong Street South
Ballarat Vic 3350

29 September 2014

Distribution

Historical Information Review, Ballarat West Employment Zone

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Executive Summary

Senversa Pty Ltd (Senversa) was engaged by Victorian Rail Track Corporation (VicTrack) on behalf of Major Projects Victoria (MPV) and The City of Ballarat (COB) to conduct a Hydrogeological Review of a 438 hectare parcel of Crown Land located south and east of Ballarat Airport in the suburb of Mitchell Park, Ballarat (the site). The site is proposed to be redeveloped to form part of the Ballarat West Employment Zone (BWEZ), which will also include the Ballarat Airport (excluded from this review).

The key results and findings of this Hydrogeological Review can be summarised as follows:

- The geology at the BWEZ comprises highly weathered basalt, scoria and tuff of the Newer Volcanics Formation, with the exception the areas adjacent to Winters Swamp which comprises river alluvium including gravel, sand and clay.
- The water table aquifer at the site is within the upper flow of the basalt aquifer (upper aquifer) which separated by a 'leaky' clay palaeosol to the lower basalt flow (lower aquifer). The upper aquifer is considered to be unconfined at the site, while the lower aquifer is considered to be semi-confined.
- Senversa's Historical Information Review (Senversa, 2013) identified the Ballarat Airport to the north of the site as a potential source of groundwater contamination due to the current and historical storage of fuels (diesel, avgas, unleaded petrol) in USTs and ASTs, the use of pesticides and other agricultural chemicals, and other historical activities. Based on available groundwater information from the airport and the distance of these potential sources from the BWEZ site, it is considered unlikely that significant airport contamination has migrated beneath the BWEZ site.
- Between July 2007 and October 2010, CHW Central Highlands Water extracted water from the lower section of the basalt aquifer to supplement the Ballart region's potable water supply during the drought period. Although the extraction was from the lower aquifer, monitoring of the upper aquifer also identified some drawdown in the upper aquifer during this period, which resulted in reversal of the groundwater flow direction from the west (towards Lake Burrumbeet) to the south east (towards the Ballarat West Bore Field, where extraction was occurring.

As widespread evidence of groundwater contamination has not been identified across the BWEZ, no specific groundwater contaminant management measures are presently considered warranted. However, the following elements of ongoing groundwater management should be considered:

- CoB may wish to review the general sensitivity of the groundwater resource and historic use of groundwater in supplementing Ballarat's water supply, in particular in relation to future BWEZ land uses in proximity to the Ballarat West Bore Field.
- Ongoing review of the potential for groundwater contamination to be present at the site (including associated with the neighbouring Ballarat Airport to the north) as additional information becomes available.

Contents

List of Acronyms

Acronym	Definition
AS	Australian standard
BTEX	Benzene, toluene, ethylbenzene, xylenes
CoB	City of Ballarat
CHW	Central Highlands Water
DEPI	Department of Environment and Primary Industries
EIL	Ecological investigation level
EPA	Victorian Environment Protection Authority
ESL	Ecological screening level
HASP	Health and safety plan
HIL	Health based investigation level
HSL	Health screening level
JSA	Job safety analysis
m AHD	Elevation in metres relative to the Australian Height Datum
MGA	Map Grid Australia
MW	Monitoring well
NEPM	National Environment Protection Measure. Typically referred to is the *Site Contamination* NEPM issued by the National Environment Protection Council
QA/QC	Quality Assurance / Quality Control
OCP	Organochlorine pesticide
SEPP	State Environment Protection Policy. Commonly used SEPPs include: - Protection and Management of Contamination of Land (SEPP PMCL) - Groundwaters of Victoria (SEPP GoV) - Waters of Victoria (SEPP WoV)
SWMS	Safe work method statement
SWL	Standing Water Level
TDS	Total dissolved solid
TPH	Total petroleum hydrocarbons, a typical analytical result for petroleum hydrocarbons
TRH	Total recoverable hydrocarbons
UST	Underground storage tank

1.0 Introduction

Senversa Pty Ltd (Senversa) was engaged by City of Ballarat (CoB), in conjunction with Victorian Rail Track Corporation (VicTrack) and Major Projects Victoria (MPV), to conduct a Hydrogeological Review at a 438 hectare parcel of Crown Land located south and east of Ballarat Airport in the suburb of Mitchell Park, Ballarat (the site), as defined in **Figure 1**. The site is proposed to be redeveloped as the Ballarat West Employment Zone (BWEZ), which will also include the Ballarat Airport (excluded from this report).

1.1 Project Understanding

The BWEZ is an area that has been proposed as Ballarat's future employment area, to create significant employment opportunities for Ballarat's growing population to include industrial, manufacturing, freight logistics, aviation, residential and open space areas.

AECOM previously completed a Soil Contamination Assessment at the site (AECOM, 2011) which involved an investigation to identify significant contamination issues which may potentially influence the design of the Master Plan. Senversa later completed a Historical Information Review (Senversa, 2013) for the site in June 2013 to provide information to MPV and the CoB on the likelihood of contamination and suitability of the land for the proposed land uses outlined within the Master Plan. The Historical Information Review confirmed the Ballarat Airport as a potential source of groundwater contamination at the site due to the presence of underground storage tanks (USTs) formerly used for aviation gas storage, as well as the likely use of pesticides, herbicides and fungicides at the Airport.

The Historical Information Review identified the site hydrogeology as consisting of an unconfined to semi confined aquifer system within an upper and lower section of the Newer Volcanics Aquifer. These two volcanic flows are separated by a clay palaeosol. The BWEZ is adjacent to the Ballarat West Bore Field which has been used by Central Highlands Water to extract groundwater to supplement the Ballarat region's water supply during drought. Central Highlands Water extracts water from the bottom section of the aquifer. The effect of the groundwater extraction on the hydrogeological regime in the area, and the potential for potential contaminants at the Ballarat Airport to migrate onto the site has been further investigated in this Hydrogeological Review.

1.2 Project Objectives

The project objectives of the Hydrogeological review are to:

- Undertake a review of the hydrogeological conditions at the site through review of relevant reports and records held by Central Highlands Water.
- Gauge water levels in accessible groundwater wells with known elevations at and adjacent to the surrounding the site to assess the groundwater flow direction.
- Provide recommendations on the location of groundwater wells to be installed to identify potential contamination migrating onto the site (if required).

1.3 Scope of Works Undertaken

Based on the project understanding and objectives described above, Senversa undertook the following scope of works:

- Preparation of a Health and Safety Plan for gauging works; including a job safety risk assessment safe work method statements, site-specific rules, completion of City of Ballarat Contractor HSE, site access and training requirements for review by VicTrack prior to mobilisation to site.

- Attendance at the Central Highlands Water (CHW) office in Ballarat to meet John Frdelja, Hydrogeologist. Further hydrogeological information/reports about the site were obtained for review.
- Gauging of six previously installed groundwater monitoring wells (four confirmed to be screened within the upper basalt aquifer) to assess groundwater flow direction in the area.
- Review of hydrogeological information/reports provided by CHW to assess the following:
    - Groundwater extraction details (uses, volumes).
    - Relationship between the lower and upper New Volcanics aquifer units.
    - Groundwater flow direction in both upper and lower aquifers (and influence of extraction).
- Review of available contamination assessment reports for the Field Air environmental audit site located at the Ballarat Airport.
- Preparation of this report.
- Meeting with CoB, VicTrack and MPV to discuss findings of the Draft Hydrogeological Review.

2.0 Site Environmental Setting

The following section provides a summary of the site environmental setting that was previously provided in the Historical Information Review previously prepared by Senversa (Senversa, 2013). The following table summarises the key site details of the site.

Item	Relevant Site Information
Site Address	The site comprises seven separate parcels of Crown Land located within Ballarat West, bounded by Sturt Street, Learmonth Road, Ring Road and McCartneys Roads.
Site Area	Approximately 438 hectares (total BWEZ area including Ballarat Airport is 623 hectares).
Current Site Owner	State Government of Victoria (Crown Land)
Current Zoning	The site is predominantly zoned Special Use Zone 6 (SUZ6), with the southern segment of the site bounded by the Ballarat to Ararat Railway and Sturt Street zoned Farming (FZ).
Municipality	City of Ballarat

2.1 Site History and Land Use

The predominant use of the site was for farming (grazing), as much of the land was part of the Ballarat West Common, an area of public land set aside for running stock. The northern half of the site (north of the Ararat – Ballarat Railway Line) was temporarily used as a part of the Ballarat Airport during between the 1940s – 1960s, however the predominate use of the site was as a grass landing strip and some residential accommodation, with little other development of the site occurring during this period.

The site is now predominantly used for farming (mainly sheep) with a light car club and operational railway (Ballarat to Ararat and Ballarat to Skipton Lines) also present. Under the BWEZ development plans, it is proposed that the future land use of the site will consist of a mix of land uses including industrial, manufacturing, commercial, freight, logistics, residential, open space areas and other employment generating activities.

The current land use surrounding the site consists of the following:

- **North**: A mixture of agricultural land, low density residential and the Ballarat Airport.
- **East**: Predominantly commercial / industrial and the Ballarat Golf Club.
- **South**: Winters Swamp, low density residential and commercial / industrial use.
- **West**: Agricultural land, low density residential and sporting facilities (Ballarat Polocrosse Club).

2.2 Topography and Surface Water Bodies

The topography of the site is relatively flat with an elevation of approximately 440 to 450 m AHD, based on the Ballarat Topographic map obtained from Land Victoria.

A gradual slope from southeast to northwest (towards the airport) is present north of the Ballarat-Ararat Railway Line and continues off-site towards Lake Burrumbeet located northwest of the site. A draining line is present in the middle of the site, north of the Ballarat Ararat Railway Line which drains towards the airport. It is understood that the surface water at the airport drains to the west - northwest away from the site towards Lake Burrumbeet to the west.

The nearest surface water bodies located to the site are:

- Winters Swamp located immediately south west of Parcels 4 and 7.
- Flax Mill Swamp located approximately 200 m east of Parcels 4 and 7.
- Lake Wendouree located approximately 2.1 km south east of the site area.
- Lake Burrumbeet and ponds located approximately 10.5 km west of the site area.

The Flax Mill Swamp is known to overflows through Parcel 7 into Winter Swamp, while a small unnamed creek flows to the northwest through the airport towards Lake Burrumbeet draining much of the site north of the Ararat-Ballarat Railway Line.

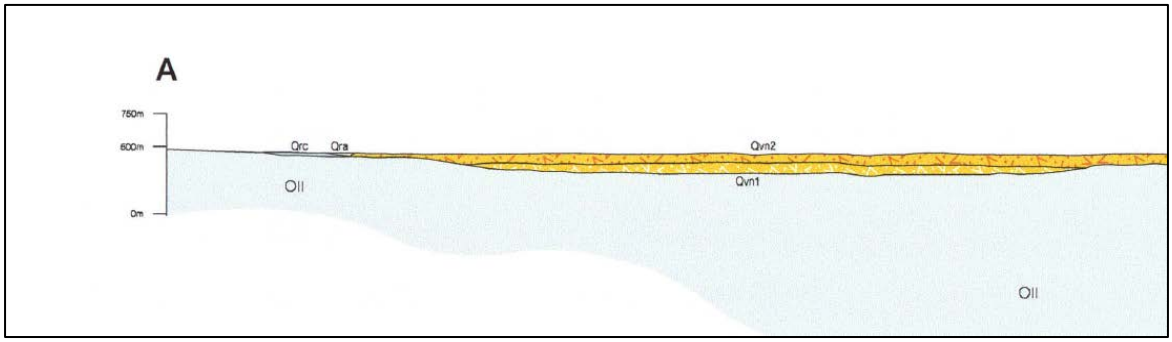
2.3 Regional Geology, Geomorphology and Hydrogeology

As a part of the site history review (Senversa, 2013), Senversa undertook a review of the following available plans:

- 1:63,360 scale Geological Survey of Victoria *Ballarat* Geology Sheet (GSV, 1964)
- 1:50,000 scale Geological Survey of Victoria *Ballarat* Geology Sheet (GSV, DNRE 1996)
- 1:100,000 scale Geological Survey of Victoria *Ballarat* Regolith Sheet (GSV, DNRE, 1997)

These resources indicated the surface geology at the site is likely to comprise highly weathered basalt, scoria and tuff of the Newer Volcanics Formation, with the exception of some isolated locations of recent swamp deposits and the area immediately to the east. The surficial geology at and around Winter Swamp comprises river alluvium including gravel, sand and clay.

The Newer Volcanics Formation consists of two flows beneath the site (as shown below), that host two the Upper and Lower Basalt Aquifers. The aquifers are considered to be partially connected as discussed in more detail in **Section 4**.



Extract from 1996 *Ballarat* (1:50,000) Map Sheet, depicting two lava flows in the region and basement Ordovician sediments.

The *Murray Basin Hydrogeological Map Series – Ballarat* published by the Australian Geological Survey Organisation (AGSO, 1994) indicated the primary aquifer of concern occurs within the Newer Volcanics to have a typical salinity of 1,500 to 3,000 mg/L, classifying the groundwater as Segment B as defined under the *State Environment Protection Policy (Groundwaters of Victoria), 1997* (SEPP *Groundwater).*

This broad scale map indicates that groundwater in the water table aquifer below the site **Section 4**, indicates that a groundwater divide is present west of the site before Lake Burrumbeet. Prior to review of the additional hydrogeological reports identified in Section 4, this indicated that groundwater flow at the site could be to the east or south, however following review of these reports it is now understood that groundwater flow is the west unless groundwater extraction is being undertaken. Groundwater flow has been observed to switch to the south east (from the airport to the site) when extraction is being undertaken.

3.0 Groundwater Gauging

3.1 Fieldworks Methodology

The following section details the groundwater gauging that was undertaken as a part of this assessment.

Activity	Item	Description
Standing Water Level Measurement (Gauging)	Date	20 November 2013
	Methodology	The groundwater gauging methodology employed was as follows: • Four existing groundwater monitoring wells, B9, B23, B30, B31, were identified by John Frdelja at Central Highlands Water as being screened within the upper basalt aquifer and available for gauging. An additional lower aquifer well available for gauging included WMB (windmill bore). During field works, an additional well, B12, located in Parcel 7A was also identified and gauged. All six wells are shown on **Figure 2** and were gauged using a calibrated Heron oil / water interface meter. The meter probe was decontaminated with Decon 90 and rinsed with tap water before and after each measurement. Groundwater levels were measured relative to the top of the PVC casing from marks indicating the point surveyed (where present). • Survey data for the wells was provided by Central Highlands Water to allow the calculation of the standing water levels at each well. However, wells B30 and B31 have not yet been surveyed and are due to be surveyed in late December 2013, while no survey data is available for windmill well WMB. • Wells with depths to water greater than 30 m could not be gauged due to the depth being greater than the length of the interface probe.
	Accuracy	Recorded to nearest 0.001 m, accuracy approximately +/- 0.003 m

3.2 Groundwater Gauging Results

A summary of the standing water level data and calculated groundwater elevations are provided in the table below. Full gauging and survey details are presented in **Table 1**, with the location of the groundwater wells shown in **Figure 2**.

Well ID	Aquifer Unit	Surveyed Level - Top of Casing	Total Well Depth	Gauged Depth to Water	Groundwater Elevation	Gauging Comments
		(mAHD)	(mBTOC)	(mBTOC)	(mAHD)	
B9	Upper	434.60	18.00	8.843	425.757	
B23	Upper	457.23		-	-	Could not be gauged - well deeper than 30m length of interface probe.
B30	Upper	TBA	60.00	30.131	TBA	Recently installed by CHW. To be surveyed in late December.

Well ID	Aquifer Unit	Surveyed Level - Top of Casing	Total Well Depth	Gauged Depth to Water	Groundwater Elevation	Gauging Comments
		(mAHD)	(mBTOC)	(mBTOC)	(mAHD)	
B31	Upper	TBA	60.00	27.039	TBA	Recently installed by CHW. To be surveyed in late December.
B12	Unknown	-		9.820	-	Well owner unknown. No survey dta available.
B2	Lower	449.87	82.00	Not gauged in this gauging round	-	Could not be gauged - well deeper than 30m length of interface probe.
WMB	Lower	NK	38.00	17.328	-	Windmill bore. Not CHW bore - details unknown

3.3 Groundwater Levels and Flow Direction – November 2013

A summary of the groundwater level determinations and gauging observations are provided below:

- The standing water levels in the upper aquifer bores ranged from 8.843 m below ground level (bgl) (B9) to 30.131 m bgl (B30). Within the lower aquifer bores, only the windmill bore (WMB) could be gauged.
- The water table elevation could only be calculated for bore B9 in the upper aquifer, at 425.757 m relative to the Australian Height Datum (AHD).
- Water table elevations could not be calculated for the other wells gauged due to no available survey being currently available for the wells, or no data being collected as the depth to water being greater than the length of the standard interface meter (30 m). It should be noted that groundwater elevations for B30 and B31 will be able to be calculated when CHW is due to have these newly installed wells gauged in late December 2013. It is expected that this information will be provided before the issue of the final report in order to generate the groundwater elevation contours and calculate the inferred groundwater flow direction.

4.0 Review of Hydrogeological Assessment Reports

4.1 Summary of Reports / Information Reviewed

The following reports and information, supplied by CHW, were reviewed as part of the Hydrogeological Review. Relevant information from these reports has been summarised in the following sections and included in **Appendix A**.

- CHW, 2013. Bore data for particular wells including bore construction details and monthly gauging data from 2007, Central Highlands Water.
- GHD, 2004. Cardigan Borefield, Hydrogeological Assessment, August 2004, GHD Australia Pty Ltd.
- GHD, 2007. Report for Licence No 9026895: Central Highlands Water: Ballarat West Borefield, July 2007, GHD Australia Pty Ltd.
- GHD, 2008. Ballarat West Borefield, Regional Water Level Monitoring Program, Annual Report for 2007-2008, November 2008, GHD Australia Pty Ltd.
- GHD, 2009. Report for Ballarat West Borefield, Ballarat West / Cardigan Groundwater Model Update, December 2009, GHD Australia Pty Ltd.
- GHD 2010a. Ballarat West Borefield, Regional Water Level Monitoring Program and Assessment of Potential Surface Water and Salinity Impacts, Annual Report for 2008-2009, August 2010, GHD Australia Pty Ltd.
- GHD, 2010b. Ballarat West Borefield, Regional Water Level Monitoring Program and Assessment of Potential Surface Water and Salinity Impacts, Annual Report for 2009-2010, October 2010, GHD Australia Pty Ltd.
- GHD, 2011. Ballarat West Borefield, Regional Water Level Monitoring Program and Assessment of Potential Surface Water and Salinity Impacts, Annual Report for 2010-2011, December 2011, GHD Australia Pty Ltd.
- GHD, 2012. Ballarat West Borefield, Groundwater System Review, March 2012, GHD Australia Pty Ltd.
- GHD, 2013. Ballarat West Borefield, Regional Water Level Monitoring Program and Assessment of Potential Surface Water and Salinity Impacts, May 2013, GHD Australia Pty Ltd.

In addition, the following contamination assessment reports for the Field Air environmental audit site at the Ballarat Airport were supplied by SKM for review:

- Sinclair Knight, 1991. Investigation of Site Contaminated with Pesticides: Ballarat Aerodrome, August 1991, Sinclair Knight Pty Ltd.
- Sinclair Knight Merz, 2005. Field Air History Review, Letter Report, 15 June 2005, Sinclair Knight Merz Pty Ltd.
- SKM, 2005. Report on Environmental Site Assessment to Support Environmental Audit, 9 December 2005, Sinclair Knight Merz Pty Ltd.
- SKM, 2013. Environmental Site Assessment works (unpublished) drilling logs, soil, sediment and groundwater results, figures, field sheets, Sinclair Knight Merz Pty Ltd.

4.2 Groundwater Resource Utilisation

Senversa undertook a search of the Department of Sustainability and Environment (DSE) Groundwater Management System Data Extract (dated 28 May 2013) for registered groundwater bores within 1 km of the site boundary, shown in **Figure B1** (within **Appendix A**). The search located 53 registered groundwater bores within 1 km of the site boundary, 31 of these located within 500 m of the site boundary.

Of the 31 groundwater bores located within 500 m of the site boundary, 12 were listed for unspecified use, with eight of the unspecified use bores located predominantly south east from the site boundary, situated in the inferred down gradient direction and may be considered receptors of any impacts sources from the site. The identified bores were reported to be used for domestic, stock, investigation, aquaculture, non-groundwater use, industrial and irrigation use, where information was available for bore use. Tabulated results of the search are provided in **Appendix A**.

Groundwater extraction occurred between July 2007 and October 2010 immediately east of the site (Parcel 7), on the eastern side of the Ring Road at the Ballarat West Borefield (shown on **Figure 1**). The wells were used by Central Highlands Water to extract groundwater for potable water use as well as a supplementary water supply for the Ballarat region.

Although CHW ceased extracting groundwater to supplement the Ballarat region water supply in 2007, the licence to extract groundwater for this purpose exists for an additional 15 years and the potential use has been included in the CHW Water Supply Demand Strategy for the next 50 years.

4.3 Groundwater Flow Direction in Upper Aquifer

Based on a review of the reports listed in **Section 4.1**, groundwater flow direction prior to groundwater extraction was found to be to the west towards Burrumbeet Creek and Lake Burrumbeet. This is shown most clearly in the pre-pumping groundwater contours provided in the Ballarat West Borefield Groundwater Model Update (GHD 2009), provided in **Appendix A**.

Further review of this report finds that the groundwater flow direction in both the Lower and Upper Basalt Aquifers is westerly towards Lake Burrumbeet, with a groundwater divide present south of the borefield (located near the south east corner of the site), where groundwater flows south towards Sebastopol. The groundwater gradient around the site was found to be relatively flat (0.003 to 0.005 m/m).

The Ballarat Borefield was commissioned in 2007, with extraction occurring until at least October 2010. During this period of extraction the groundwater flow direction was observed to change from the west to the south east as shown in the groundwater contours shown in the Ballarat West Borefield Annual Report 2011-2012 (GHD, 2012). The impact that extraction had on water levels in the upper and lower is also shown in **Table 2,** which documents extraction from the groundwater wells B9 & B23 (upper) v B2 (lower), together with the post pumping groundwater contours shown in **Appendix A** (GHD 2012).

Additional groundwater contour maps provided in **Appendix A** (Figures 22, 24 and 26 from GHD (2012)), clearly show the groundwater flow direction across the site and airport to be to the south-east between 2007 - 2010. The volume of groundwater extracted from the Ballarat West Borefield during each of these drought years is provided below.

Year	Period	Volume Extracted
1	Jul 2007 – Jun 2008	2,199 ML
2	Jul 2008 – Jun 2009	1,690 ML

Year	Period	Volume Extracted
3	Jul 2009 – Jun 2010	531 ML
4	Jul 2010 – Oct 2010	211 ML

Source: GHD, 2012.

Information on the groundwater flow direction post extraction was not available, however it is considered likely that the groundwater flow direction may have either flattened or reversed to a westerly flow direction. Confirmation of this is likely to be able to be provided by CHW early in 2013, following finalisation of reports.

Although CHW ceased extracting groundwater to supplement the Ballarat region water supply in 2010, the licence to extract groundwater for this purpose exists for an additional 15 years and the potential use has been included in the CHW Water Supply Demand Strategy for the next 50 years. Therefore there is the potential for the localised variations or reversals in groundwater flow due to extraction again in the future.

The SKM environmental site assessment report (2005a) calculated the inferred groundwater flow direction (to the north of the site at the Ballarat Airport) as being towards the south, based on groundwater levels in five wells in the Field Air site at the Ballarat Airport. In a later assessment by SKM in 2013, the inferred groundwater flow direction was towards the west-south west, based on groundwater levels from the five existing and three additional wells. The 2013 direction towards the west-south west appears to be generally consistent with the pre-extraction regional flow direction (GHD, 2009) and the expected post-extraction flow directions reverting back towards the west.

Other potential anthropogenic impacts on groundwater flow directions at the site are Aquifer Storage and Recharge trials that have been taking place periodically over the past six months by CHW. Reports on these trials was not available, however CHW verbally confirmed that given the relatively small volumes of water, these trials are unlikely to have had an impact on the groundwater flow direction in both the upper and lower aquifers.

4.4 Potential for Contamination to be present beneath BWEZ

Based on the site history and recent soil investigations (Senversa, 2013a and 2014), the BWEZ site is considered to have posed a relatively low risk of being the source of extensive groundwater pollution.

Ballarat Airport (located immediately to the north of the BWEZ) has been identified as a potential source of groundwater contamination. Previous contamination assessment reports completed by SKM (1991, 2005, 2005a, 2013) detail assessment works completed to investigate the nature and extent of contamination resulting from a spill of pesticides and herbicides in aircraft wash water that occurred in 1989. These chemicals were used at the Field Air agricultural spraying business located at the Ballarat Airport. These reports were prepared as part of a statutory environmental audit requirement of the EPA Clean Up Notice issued for the site. The audit site area is 10,100 m^2 and makes up a portion of the Airport site located approximately 500 m from the BWEZ northern site boundary.

Localised soil and groundwater contamination was noted to exist at the site as a result of the wash water spill and the associated on-site management of wash water in a sedimentation tank and later in an evaporation basin. This included localised pesticide (including DDD, DDT) pollution to groundwater remaining in the area of the reported spill. The 2005 assessment by SKM, which utilised data from five on-site groundwater monitoring wells, indicates that the groundwater impact from the spill is restricted to the audit site area. This appears to be consistent with data provided by SKM for the 2013 assessment, although the report for this assessment has not been finalised.

In addition to the investigation of chemicals from the wash water spill, a 4,500 litre diesel aboveground storage tank (AST) and a 9,000 litre A1 jet fuel UST were also identified on this site. However, as no hydrocarbon impact has been detected in wells down gradient of the spill site (SKM 2013), and given

the distance from this area to the BWEZ site (>500 m), these potential sources of contamination are considered unlikely to have to have impacted the BWEZ site.

Other potential sources of hydrocarbon impact at the site were identified in the AECOM (2011) report and include an aviation gas (avgas) AST located to the north east of the Field Air site, and a 4,500 litre unused unleaded petrol UST located at the rear of the Field Air Offices and was approximately 30 years old in 2011. A site plan showing the fuel infrastructure at the airport site was provided by City of Ballarat (CoB, 2013) which also identified three 50,000 litre former fuel tanks which are now used for water storage, and a mobile fuel tanker located towards the south east corner of the site at the flight school. All current and former fuel infrastructure is located greater than 500 m from the BWEZ site boundary, with the exception of the mobile fuel tanker which is located approximately 270 m from the BWEZ site boundary.

Other potentially contaminating activities at the site include aircraft and vehicle maintenance in sheds at the airport where waste oil and waste water is contained and transported off-site. Small-scale manufacturing (such as fibreglass glider manufacture) is also undertaken at leased facilities at the airport. Other historical potentially contaminating activities at the site included a burn-off area to the north of the airport apron, a former sewage treatment plant which operated during the airport's military base period located to the north of the airport apron, and a buried solid and liquid disposal and fuel storage areas during the period as a military base. Locations of historical activities are unknown, although anecdotally there may be buried material below the Polocrosse grounds located off-site adjacent to the western site boundary.

John Hartigan of the City of Ballarat confirmed no other groundwater monitoring wells exist at the Airport site apart from those installed within the Field Air audit site. Although potentially contaminating activities listed above are located at least 270 metres from the BWEZ site boundary, assessment of potential groundwater contamination resulting from these activities to be present within these locations has not been assessed.

As discussed in **Section 4.3** above, during the approximate three year period of groundwater extraction from the Ballarat West Borefield by CHW (July 2007 – October 2010), the groundwater flow direction changed from the west to the south-east (GHD, 2012). In this scenario, the Ballarat Airport was located up-hydraulic gradient from the BWEZ site, therefore potential contamination from the Ballarat Airport may have migrated onto the BWEZ site during this period. However, given the distance to the BWEZ site from any potentially contaminating activities / infrastructure at the airport (the closest was a mobile oil tanker located 270 m from the site boundary), together with the lack of reported widespread groundwater pollution, significant pollution migration onto the BWEZ site from the Ballarat Airport is considered unlikely.

4.5 Chronological Timeline of Events

Based on review of the reports listed in **Section 4.1**, and the site observations undertaken a summary of the groundwater flow direction and potential sources of contamination is provided below.

Period	Potential Sources of Contamination	Likely Generalised Groundwater Flow Direction at Site
1989	• Spill of pesticide and herbicide wash water at the Ballarat Airport site. Wash water travelled overland and entered a tributary to the Burrumbeet Creek.	• West
Pre-July 2007	• Chemicals used for farming practices – herbicides, pesticides, fungicides, fertilizers, nutrients, biological contaminants. • Fuel storage in ASTs and USTs at the Ballarat Airport. • Historical activities / practices at the Ballarat Airport.	• West

Period	Potential Sources of Contamination	Likely Generalised Groundwater Flow Direction at Site
July 2007 – October 2010 (Groundwater extraction undertaken by CHW)	• Potential contaminants from the Ballarat Airport site – fuels (aviation gas), and other chemicals, fuels and solvents used for maintenance of the site. • Leaching of nutrient loadings in surface soils from historical farming activities.	• South east
Post October 2010	• Potential for residual airport sourced contamination to be present which may provide a secondary source of contamination to groundwater. • Leaching of nutrient loadings in surface soils from historical farming activities	• West

5.0 Conclusions and Recommendations

5.1 Conclusions

The key results and findings of this Hydrogeological Review can be summarised as follows:

- The geology at the site comprises highly weathered basalt, scoria and tuff of the Newer Volcanics Formation, with the exception the areas adjacent to Winters Swamp which comprises river alluvium including gravel, sand and clay.
- The water table aquifer at the site is within the upper flow of the basalt aquifer (upper aquifer) which separated by a 'leaky' clay palaeosol to the lower basalt flow (lower aquifer). The upper aquifer is considered to be unconfined at the site, while the lower aquifer is considered to be semi-confined.
- Senversa's Historical Information Review (Senversa, 2013) identified the Ballarat Airport to the north of the site as a potential source of groundwater contamination due to the current and historical storage of fuels (diesel, avgas, unleaded petrol) in USTs and ASTs, the use of pesticides and other agricultural chemicals, and other historical activities. However given the distance of these potential sources from the BWEZ site (the closest was a mobile fuel tanker located 270 m from the site boundary), it is considered unlikely that airport contamination has migrated beneath the BWEZ site.
- Between July 2007 and October 2010, CHW Central Highlands Water extracted water from the lower section of the basalt aquifer to supplement the Ballart region's potable water supply during the drought period. Although the extraction was from the lower aquifer, monitoring of the upper aquifer also identified some drawdown in the upper aquifer during this period, which resulted in reversal of the groundwater flow direction from the west (towards Lake Burrumbeet) to the south east (towards the Ballarat West Bore Field), where extraction was occurring.

5.2 Recommendations

As widespread evidence of groundwater contamination has not been identified across the BWEZ, no specific groundwater contaminant management measures are presently considered warranted. However, the following elements of ongoing groundwater management should be considered:

- CoB may wish to review the general sensitivity of the groundwater resource and historic use of groundwater in supplementing Ballarat's water supply, in particular in relation to future BWEZ land uses in proximity to the Ballarat West Bore Field.
- Ongoing review of the potential for groundwater contamination to be present at the site (including associated with the airport) as additional information becomes available.

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7.0 Uncertainty and Limitations

Environmental reports are typically based on a limited set of data. Additional collection of information and/or sampling may improve the confidence or yield different results, due to a range of factors such as the variable or heterogeneous nature of environmental contaminants in the subsurface. Specific uncertainties and limitations noted for this investigation are as follows:

- An intrusive soil investigation was not conducted, and direct assessment of groundwater or surface waters was not conducted. Given the size of the site (438 Ha) there is potential for additional sources of contamination to be present across the site aside from the potential sources identified at the Ballarat Airport.
- An assessment of whether hydrocarbons associated with the storage of petroleum and aviation gas, together with storage and use pesticides, herbicides and fungicides are present within groundwater at and down-hydraulic gradient of the airport has not been undertaken.

This document was prepared to meet the objectives outlined in the Senversa proposal for the works. This report was prepared for the use of City of Ballarat, VicTrack and Major Projects Victoria and should not be relied on by another other party without approval by Senversa. The following principles are an integral part of site contamination assessment practices and are intended to be referred to in resolving any ambiguity or exercising such discretion as is accorded the user or site assessor.

Limitations of Information

The effectiveness of any site investigation may be compromised by limitations or defects in the information used to define the objectives and scope of the investigation, including inability to obtain information concerning historic site uses or prior site assessment activities despite the efforts of the user and assessor to obtain such information.

Comparison with Subsequent Inquiry

The justification and adequacy of the investigation findings in light of the findings of a subsequent inquiry should be evaluated based on the reasonableness of judgments made at the time and under the circumstances in which they were made.

Nature of Advice

The investigation works herein are intended to develop and present sound, scientifically valid data concerning actual site conditions. Senversa does not seek or purport to provide legal or business advice.

Figures

Path: Y:\16_GIS\Jobs\M1075100 - Ballarat West\MXDs\M1075105 Fig1_site location plan.mxd

senversa
Address: Ground Floor 51 Clarke Street Southbank Victoria 3006
Phone: (03) 9606 0070
Fax: (03) 9606 0074
Website: www.senversa.com.au

Legend

ID, Parcel Number

- 1, P103732 5B 1
- 2, 5C 1 P103737
- 3, P103728 R
- 4, R3 P110103
- 5, P110104 R4
- 6, R5
- 7, S1 P365374

Site Boundary

Aerial sourced from Nearmap.com

Designed:	C. Sandiford	Scale:	1:20,200
Drawn:	S. Koroblitsas	Date:	6/12/2013
Checked:		Revision:	A
File:	M1075105 Fig1_site location plan		

0 140 280 560 840 1,120 Metres

Datum GDA 1994, Projection MGA Zone 55

Figure No: 1

Title: Site Location Plan

Project: Groundwater Assessment

Location: Ballarat West

Client: VicTrack

Path: Y:\16_GIS\Jobs\M1075100 - Ballarat West\MXDs\M1075105 Fig2_gw levels.mxd

senversa
Address: Ground Floor 51 Clarke Street
Southbank Victoria 3006
Phone: (03) 9606 0070
Fax: (03) 9606 0074
Website: www.senversa.com.au

Legend

- Groundwater Well Location
- Parcels
- Area of Interest

Well ID
Reduced Water Level (mAHD)

Aerial sourced from Nearmap.com

Designed:	S. Krelle	Scale:	1:12,500
Drawn:	S. Koroblitsas	Date:	6/12/2013
Checked:		Revision:	A
File:	M1075105 Fig2_gw levels		

0 100 200 400 600 800 Metres

Datum GDA 1994, Projection MGA Zone 55

Figure No:	**2**
Title:	**Groundwater Levels**
Project:	Groundwater Assessment
Location:	Ballarat West
Client:	VicTrack

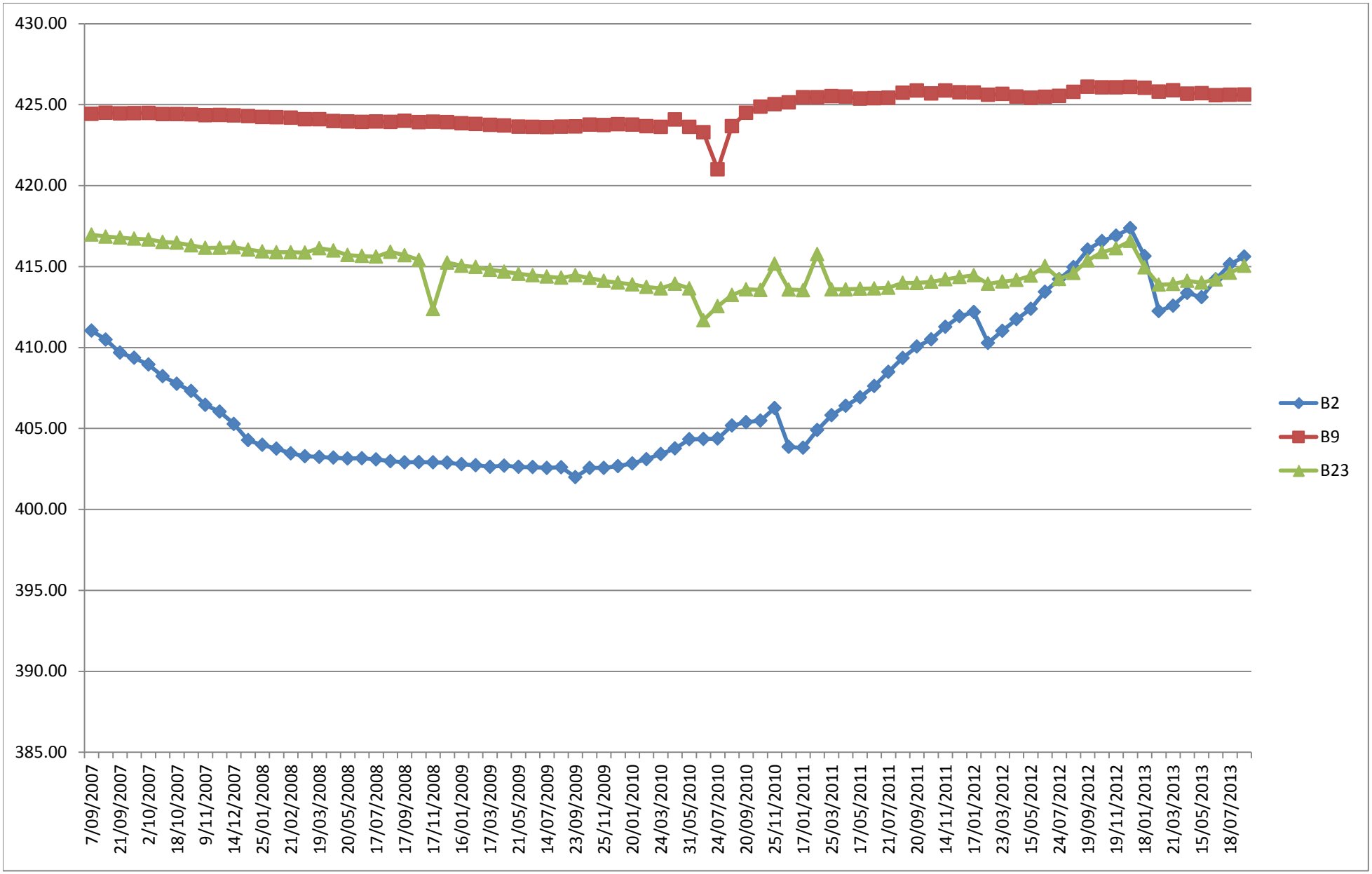
Tables

Table 1: Groundwater Gauging Results

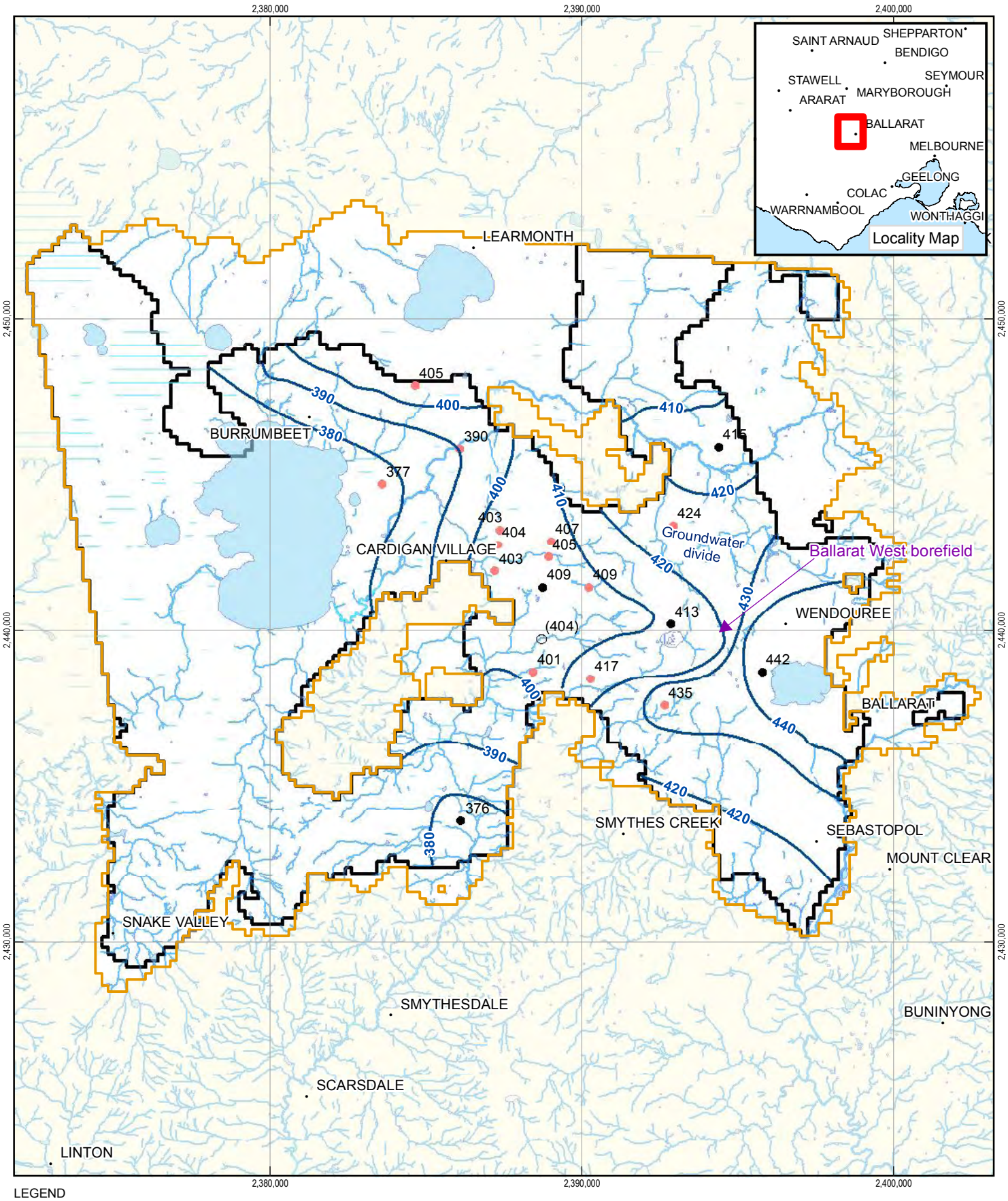
Monitoring Well Information						Survey Data			Gauging Data					
Well ID	Installed By	Aquifer Unit	Screen Interval	Highest point of screen	Screen Depth	Easting	Northing	Top of Casing	Date Gauged	Total Well Depth	Depth to Water	Groundwater Elevation	Gauging Comments	Bore Locality
			(mBGL)	(mBGL)	(mAHD)	(MGA)	(MGA)	(mAHD)		(mBTOC)	(mBTOC)	(mAHD)		
B2	CHW	Lower	12.00	70.00	82.00	746298	5842380	449.87	-	82.00	-	-	Not gauged during this gauging round	Blind Creek Road (north of Winter Swamp)
B9	CHW	Upper	6.00	12.00	18.00	746533	5845536	434.60	20/11/2013	18.00	8.843	425.757		McCartneys Road (north of Ballarat Airport)
B23	CHW	Upper?	NK	NK	NK	747587	5841748	457.23	20/11/2013		-	-	Could not be gauged - well deeper than 30m length of interface probe.	Ring Road, Ballarat West (opposite Blind Creek Road)
B30	CHW	Upper	12.00	48.00	60.00	747342	5841226	-	20/11/2013	60.00	30.131	-	Recently installed by CHW. To be surveyed in late December.	Ring Road (opposite Production Drive) - nested with B21
B31	CHW	Upper	12.00	48.00	60.00	747445	5841482	-	20/11/2013	60.00	27.039	-	Recently installed by CHW. To be surveyed in late December.	Ring Road (opposite Production Drive) - nested with B32
B33	CHW		48.00	48.00	#REF!	746984	5843908	-	20/11/2013	54.00	-	-	Recently intalled by CHW. To be surveyed in late December.	
WMB	Crown Land	Lower	NK	NK	38.00	746781	5841546	NK	20/11/2013	38.00	17.328	-	Windmill bore. Not CHW bore - details unknown	In paddock on Crown Land
B12	VicRoads?	Lower?	NK	NK	NK	NK	NK	-	20/11/2013		9.820	-	Well owner unknown. No survey data available.	Parcel 7A

NK Data not available

Table 2: Impact of Groundwater Extraction - Groundwater Elevations in Three Key Wells



Appendix A: Information from Reports Held by Central Highlands Water



LEGEND

- Town
- Potentiometric contour (mAHD)
- Active Model Extent
- Upper Basalt Aquifer Extent

Watercourse
- River
- Stream
- Channel / Drain
- Connector

Water Body
- Lake
- Salt Lake
- Watercourse Area

Wetland / Swamp
- Flat
- Pondage

RWL Bore Locations
(Latest pre-pumping available)
- (Obs Sep 1999 (low reliability)
- ! Obs Feb 2005 (moderate reliability)
- ! Obs Jan-Mar 2007 (best reliability)

1:165,000(at A4)
0 6251,250 2,500 3,750 5,000
Metres
Map Projection: Lambert Conformal Conic
Horizontal Datum: Geocentric Datum of Australia
Grid: Vicgrid94

O

GHD
CLIENTS | PEOPLE | PERFORMANCE

Client Logo

Central Highlands Water - Ballarat West / Cardigan Groundwater Model Update

Job Number 31-23719
Revision A
Date 29 May 2009

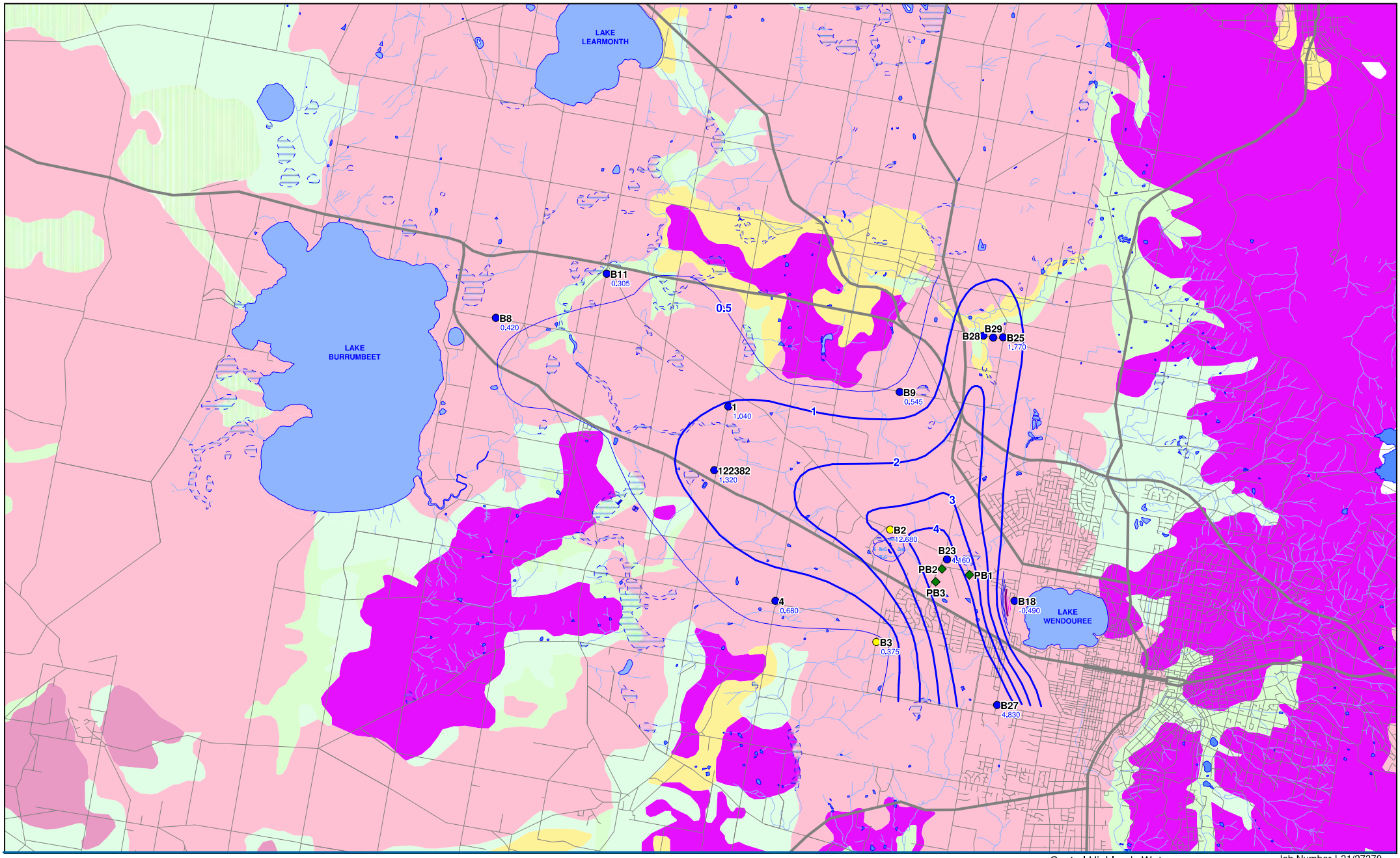
Pre-Pumping Groundwater Levels
Upper Basalt Aquifer

Figure 13

G:\31\23719\CADD\GIS\Projects\026_RWL_PrePumping_UpperBasalt.mxd

8/180 Lonsdale St Melb VIC 3000 Australia 61 3 8687 8000 61 3 8687 8111 melmail@ghd.com.au www.ghd.com.au

Data source: Vicmap, CHW, G-MW, SRW. Created by: Chris Nicol



Scale 1:80,000 (at A3)

0 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid Of Australia, Zone 54

N W E S

LEGEND

- Shallow Observation Bore
- Undefined Observation Bore
- Production Bore
- 0.680 Drawdown (m)
- Drawdown Contour

Central Highlands Water
Ballarat West Borefield

Job Number 31/27370
Revision B
Date 16/08/2011

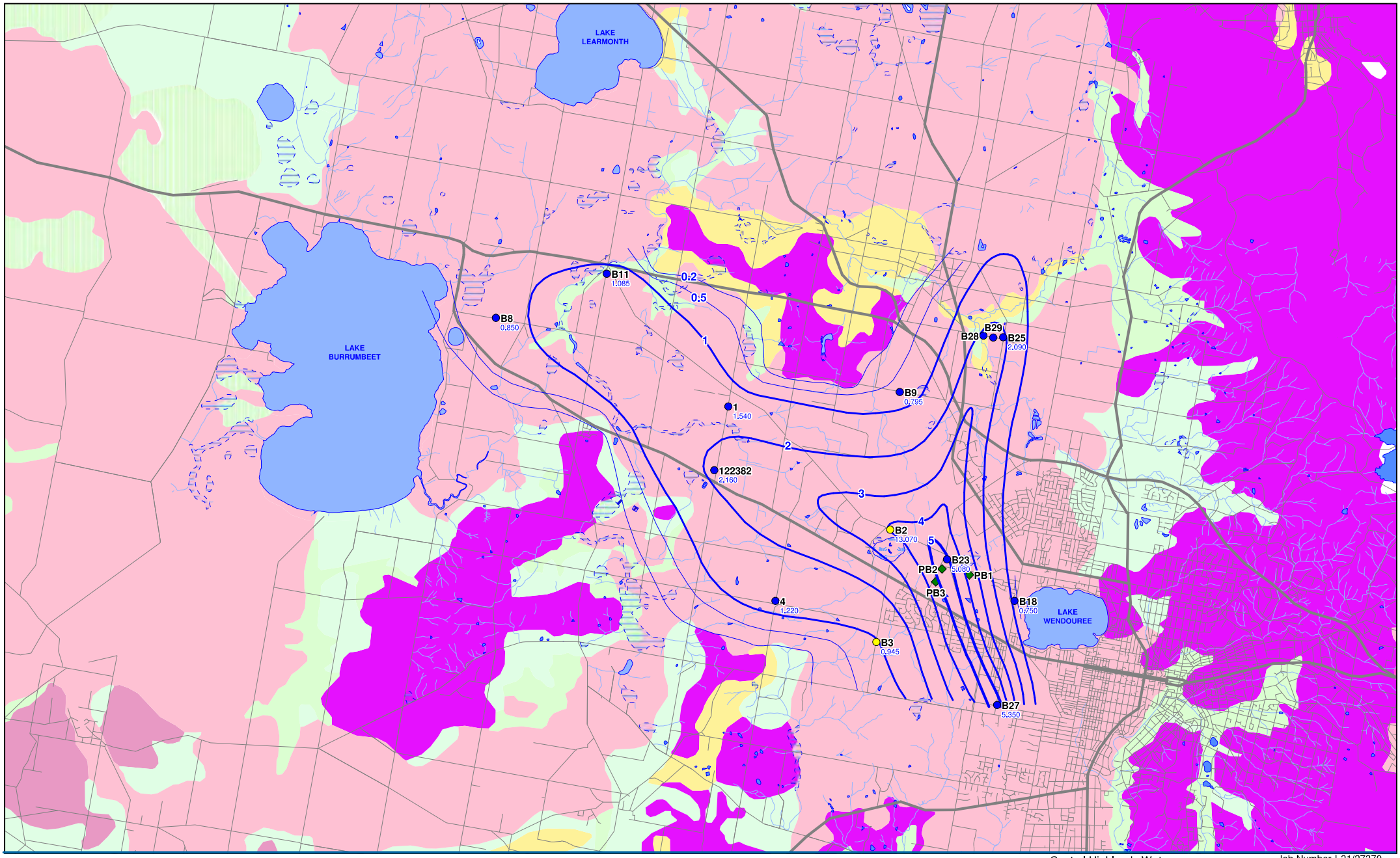
Drawdown Contours 17/07/2008
Upper Basalt Aquifer

Figure 22

G:\31\26502\GIS\MapInfo\Workspaces\drawdown shallow 17Jul08.wor

Data Source GHD, CHW, VicMap (2010). Created by: D Murfitt

8/180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au



Scale 1:80,000 (at A3)

0 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid Of Australia, Zone 54

N W E S

LEGEND

- Shallow Observation Bore
- Undefined Observation Bore
- Production Bore
- 1.220 Drawdown (m)
- Drawdown Contour

Central Highlands Water
Ballarat West Borefield

Job Number	31/27370
Revision	B
Date	16/08/2011

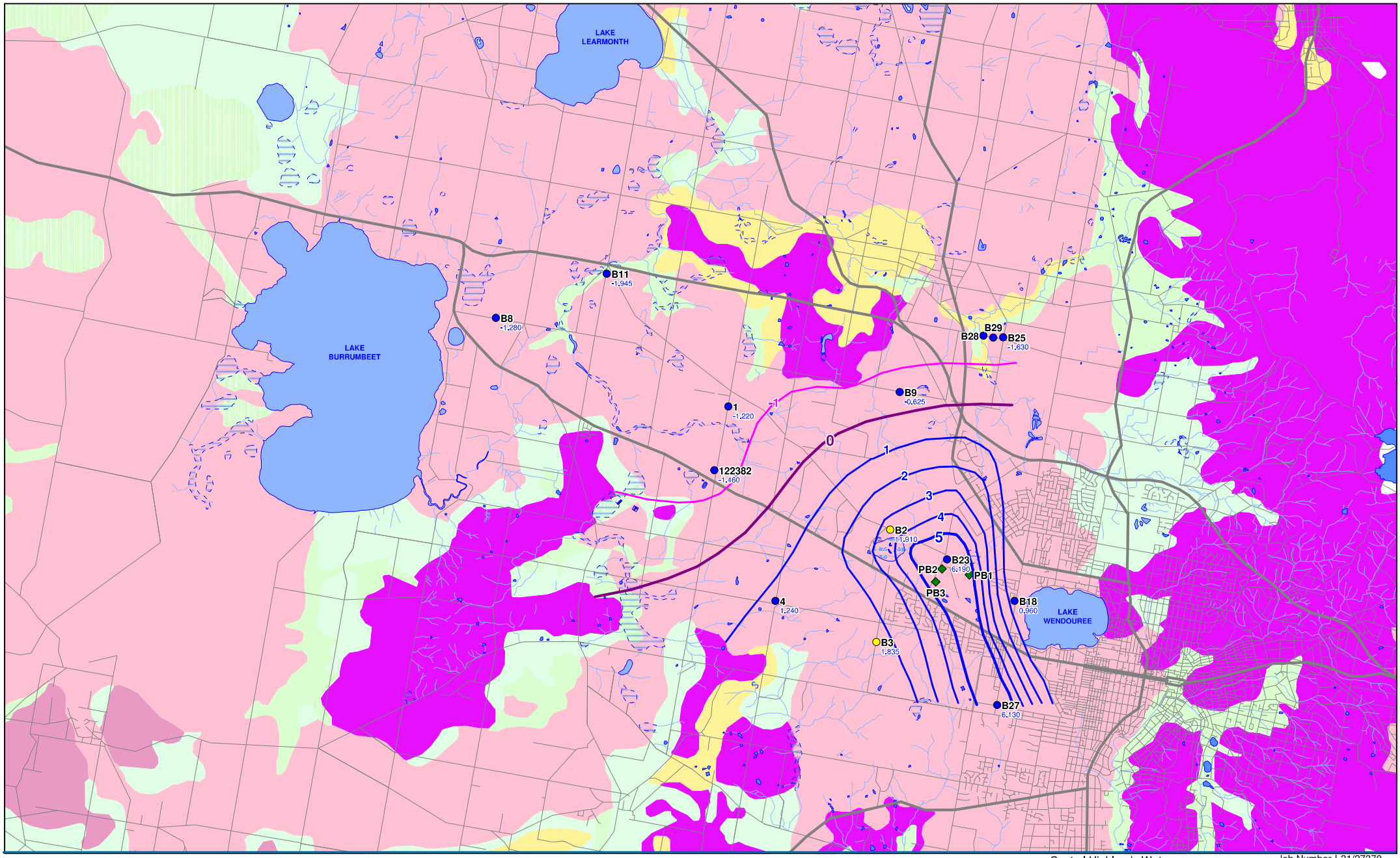
Drawdown Contours 15/04/2009
Upper Basalt Aquifer

Figure 24

G:\31\26502\GIS\MapInfo\Workspaces\drawdown shallow 15Apr09.wor

Data Source GHD, CHW, VicMap (2010). Created by: D Murfitt

8/180 Lonsdale St Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com.au W www.ghd.com.au



Scale 1:80,000 (at A3)

0 0.8 1.6 2.4 3.2

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994
Grid: Map Grid Of Australia, Zone 54

N W E S

LEGEND

- Shallow Observation Bore
- Undefined Observation Bore
- Production Bore
- 1.240 Drawdown (m)
- Drawdown Contour

Central Highlands Water
Ballarat West Borefield

Job Number	31/27370
Revision	A
Date	21/04/2011

Drawdown Contours 14/12/2010
Upper Basalt Aquifer

Figure 26

G:\31\26502\GIS\MapInfo\Workspaces\drawdown shallow 14Dec10.wor

Data Source GHD, CHW, VicMap (2010). Created by: D Murfitt

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