Draft Environmental Audit of Landfill Operations (s. 53V) (EPA Ref CARMS 64171-15; SO No. 8004950)

Melbourne Regional Landfill, 1100-1152 Christies Road, Ravenhall, VIC 3023

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Prepared for
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7 Groundwater

This section provides the Auditor's response to an aspect of the Audit scope, which is to assess the current risk of any possible harm or detriment to the groundwater environment with regard to the objectives set out in SEPP *Groundwaters of Victoria (GoV)*. This section has been written with the assistance of the Auditor's EPA-approved expert support team member hydrogeologist, Jon Bartley.

7.1 Environmental Objectives

EPA licence 12160 condition LI_DL1 requires that operations at the site do not contaminate land or groundwater.

The water quality guidelines applying to the assessment of groundwater contamination in Victoria are those specified in Table 3 of the *SEPP Groundwaters of Victoria*. These are presented in Table 7-1.

Table 7-1: Water Quality Criteria for Groundwater

Beneficial Use Category	Applicable Water Quality Criteria
Maintenance of Aquatic Ecosystems	Those applicable under the relevant SEPP for receiving waters. In this case the SEPP *Waters of Victoria* applies and the water quality guidelines are found in Chapter 2 of the ANZECC (2000) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Potable Water Supply	Chapter 4 of the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Agriculture, Parks & Gardens	Chapter 5 of the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Stock Watering	Chapter 5 of the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Industrial Water use	Chapter 6 of the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Primary Contact Recreation	Chapter 3 of the ANZECC (1992) *Australian Water Quality Guidelines for Fresh and Marine Waters*
Potable Mineral Water	Australian Food Standards Code (1987) – *Standard 08 Mineral Water*
Buildings & Structures	No criteria – "shall not be corrosive to structures".

The National Environment Protection Council (NEPC) formulated the National Environment Protection (Assessment of Site Contamination) Measure (NEPM) in relation to investigation levels for soil and groundwater in the assessment of site contamination in 1999 (NEPC 1999). In April 2013, amendment to NEPM was officially approved and registered on 15 May 2013 (NEPC 2011). This is referred to from now on as "the NEPM" or "NEPM (2013)".

The NEPM presents guidelines for soil and groundwater in the assessment of site contamination and specifies Investigation and Screening Levels at which further assessment of human or ecological risks or management of contamination is required. The human health levels are referred to as HIL or HSL, and the ecological levels as EIL or ESL.

"Investigation levels" and "screening levels" presented in the NEPM are not intended to be interpreted as "maximum permissible levels", "clean up levels" or "safe levels", rather, they are levels at which further investigation or assessment should be undertaken to provide assurance that unacceptable contamination does not occur. Subsequent assessment on a site-specific basis often results in higher levels being acceptable. However, since the "investigation levels" and "screening levels" are generally set at conservatively low levels, they are often taken to be the acceptable levels.

In addition, the NEPM stipulates the following more recent guidelines for the risk-based assessment of groundwater contamination depending on the different environmental values to be protected:

> ANZECC/ARMCANZ (2000) Australian and New Zealand Guidelines for Fresh and Marine Water Quality:
  - Livestock drinking water guidelines: For the beneficial use 'Stock watering'
  - Water quality for irrigation and general use: For the beneficial use 'Agriculture, parks and gardens'

> NHMRC/NRMCANZ (2011) *Australian Drinking Water Guidelines 6 version 3.1*

> NHMRC (2008) *Guidelines for Managing Risks in Recreational Water* for primary contact for bathing and swimming[9].

7.2 Response to Previous Audit

The 2014 LOA (T&T, 2014) assessed the historic groundwater data, monitoring locations and the analytical suite. The 2014 LOA (T&T, 2014) included recommendations which are reproduced in Table 7-2, with comments by LOPL regarding the status of actions taken to implement the recommendation.

Table 7-2: 2014 Audit Recommendations (Monitoring and Reporting - Groundwater)

2014 Audit Recommendation (T&T 2014)	LOPL Comments
Develop a comprehensive reporting format for presenting monitoring results in advance of the next audit. This should include finalisation of the draft hydrogeological assessment and a review of the effectiveness of the current monitoring well network in light of the findings of the hydrogeological assessment. The conceptual hydrogeological model should be refined for the Stage 2 area and the appropriateness of the current monitoring well network confirmed. Historic data should be analysed to develop meaningful data trends for key indicator parameters. (Implementation 6 months)	AECOM (2016) has completed the HA for the extension which indicates there are no impacts to groundwater. As part of this assessment the groundwater monitoring network was expanded to include baseline levels and quality the full Boral quarry works area.

7.3 Groundwater Monitoring Program

This section includes groundwater monitoring bores located at the landfill, and in the proposed landfill extension area. Groundwater bore locations are shown on Figure 3, Appendix A.

Key bore details and the aquifer monitored are summarised in Table 7-3.

Table 7-3: Bore Construction Details

Bore ID	Year Drilled	Depth Drilled (m)	Ground Elevation (m AHD)	Top of Casing Elevation (m AHD)[1]	Screen interval (m bgl)	Filter pack interval (m bgl)	Aquifer Monitored
MB01	13/06/1995	30.5	-	75.3	18.5-30.5	-	Upper NVA
MB02A	24/01/2001	30	-	75.64	24.0-30.0	-	Upper NVA
MB03	14/06/1995	24.5	-	62.06	18.5-24.5	-	Upper NVA
MB04	14/06/1995	25	-	59.25	15.5-24.0	-	Upper NVA
MB05	14/06/1995	25.5	-	60.49	19.5-25.5	-	Upper NVA

[9] Water quality criteria for toxicants for primary contact recreation are based on the NHMRC 2008 Guidelines for Managing Risks in Recreational Water (Section 9.3.2). The Australian Drinking Water Guidelines 2004 (revised in 2011) criteria for health have been multiplied by 10, to account for the assumed ingestion of 200 mL during recreational activities. It is the Auditor's opinion that this factor does not apply to organic contaminants as exposure pathways other than ingestion exist (e.g. inhalation).

Bore ID	Year Drilled	Depth Drilled (m)	Ground Elevation (m AHD)	Top of Casing Elevation (m AHD)[1]	Screen interval (m bgl)	Filter pack interval (m bgl)	Aquifer Monitored
MB06	15/06/1995	24	-	65.36	18.0-24.0	-	Upper NVA
MB07	17/12/2013	9	-	55.87	2.0-8.0	1.7-8.0	Upper NVA
MB08	26/11/1998	9.5	57	57.5	6.0-9.0	4.6-9.0	Upper NVA
MB09	30/11/1998	60	-	75.35	51.0-57.0	50.0-57.0	Lower NVA
MB10	30/11/1998	46.5	-	59.98	40.0-46.0	35.5-46.0	Lower NVA
MB11	23/02/2012	30	-	69.86	18.0-30.0	17.0-30.0	Upper NVA
MB12	17/05/2004	35.5	63.98	64.92	29.5-35.5	28.0-35.5	Lower NVA? [4]
MB13[3]	27/05/2004	13.0	-	54.72	7.0-13.0	-	Upper NVA
MB14	11/12/2013	18.5	58.1	58.72	11-18.5	10.5-18.5	Upper NVA
MB15	10/12/2013	19.3	60.2	60.87	13.3-19.3	12.8-19.3	Upper NVA
GW01	21/01/2014	21.5	106.8	107.32	18.5-21.5	17.0-21.5	Upper NVA
GW02	22/01/2014	28.5	89.9	90.52	21.0-28.5	20.0-28.5	Upper NVA
GW03	20/01/2014	30	85.4	86.02	22.5-30.0	21.0-30.0	Upper NVA
GW04	17/12/2013	30	79.7	80.33	24.0-30.0	22.0-30.0	Upper NVA
GW04d	1/05/2014	46	-	80.74	40.0-46.0	39.5-46.0	Lower NVA
GW05	16/01/2014	24.5	72.9	73.63	17.0-24.5	-	Upper NVA
GW06	24/01/2014	26	68.5	69.01	20.0-26.0	19.0-26.0	Upper NVA
GW07	20/01/2014	16	65.8	66.46	10.0-16.0	9.5-16.0	Upper NVA
GW08	23/01/2014	17	62	62.57	14.0-17.0	13.0-17.0	Upper NVA
GW09	1/05/2014	25	-	86.56	19.0-25.0	18.5-25.0	Upper NVA
GW10	2/05/2014	26	-	95.95	20.0-26.0	19.5-26.0	Upper NVA
GW11	2/05/2014	27	-	75.89	21.0-27.0	20.5-27.0	Upper NVA
GW12	2015	27.2	-	77.97	21.2-27.2	20.7-27.2	Upper NVA
GW13	2015	32.9	-	83.59	21.9-32.9	17.0-32.9	Upper NVA

Notes:
1. TOC elevations from Table 4.1 of the 2016 MP (T&T, 2016b) - TOC mAHD survey of 27 February 2014 by Charter Keck Kramer.
2. ‘ – ‘ unknown
3. MB 13 has been decommissioned
4. The bore log shows MB12 screens clay between the Upper and Lower NVA. Assumed to be Lower NVA, but this is uncertain.

The Auditor notes that the groundwater monitoring bores in the south east corner of the site are located in an area designated as the “Southern stormwater runoff area” (see Figure 4 and section 9 of this LOA report). The LEMP should include the annual checking of headworks and integrity of the surface seals at all monitoring bores, and document measures to minimise the risk of ingress of surface water into monitoring bores.

The Auditor notes that the top of casing elevation of groundwater bore MB04 shown in Table 7-3 is 2.94 m lower than that listed in the 2014 Monitoring Plan (MP) (URS, 2014). It is understood that the 2014 MP survey levels of MB04, MB09 and MB11, required confirmation following 2010 Auditor recommendations to replace or rehabilitate these bores.

Therefore, the Auditor considers a further survey of groundwater bores MB04, MB09 and MB11, for measurement reference point elevation and ground elevation, is recommended.

The Auditor notes that bore MB12, located on the eastern side of the Stage 2 landfill, is screened in basaltic clay between the Upper NVA and Lower NVA. The bore log indicates that when drilled in May 2004, the Upper NVA was unsaturated at this location, and therefore the Lower NVA is shown on Figure 3 as the aquifer monitored by this bore. However, it is uncertain under current conditions whether data collected at this bore represents groundwater in the Upper NVA or Lower NVA.

Therefore the Auditor considers two additional bores should be installed at this location. One bore into the Lower NVA, and one bore into the Upper NVA.

Table 4-3 of the 2014 MP (URS, 2014) requires bi-annual gauging of six (6) bores (MB01, MB02A, MB03, MB06, MB09 and MB11) of which three (3) are sampled annually (MB03, MB06 and MB11). Bi-annual sampling is also required for six (6) bores (MB04, MB05, MB07, MB08, MB10 and MB12).

Eurofins-mgt currently undertakes the scheduled monitoring and sampling of groundwater bores, leachate sumps and stormwater ponds.

The proposed groundwater monitoring schedule presented in the 2016 LEMP (T&T, 2016b) is summarised in Table 7-4.

Table 7-4: Groundwater Monitoring Program (T&T, 2016b)

Type of Analysis	Frequency	Requirements
Groundwater levels	**Bi-annually** (MB01, MB02A, MB03, MB04, MB05, MB06, MB07, MB08, MB09, MB10, MB11, MB12, MB14, MB15, GW01 and GW04 only)	Groundwater levels to be measured before groundwater sampling using an interface probe.
Groundwater field parameters	**Bi-annually** (MB04, MB05, MB07, MB08, MB10, MB12, MB14 and MB15)	DO, Redox, EC, pH and temperature.
	Annually (MB03, MB06, MB07, MB11 and GW01)	
Laboratory analysis of groundwater	**Bi-annually** (MB04, MB05, MB07, MB08, MB10, MB12, MB14 and MB15)	TOC, TDS, calcium, magnesium, potassium, chloride, sodium, sulphate (as S), bicarbonate alkalinity (as HCO3), Nitrate nitrogen (as N), nitrite nitrogen (as N), ammonia (NH3 as N), iron, arsenic, manganese, copper, cadmium, lead, chromium, mercury, nickel and zinc.
	Annually (MB03, MB06, MB07, MB11 and GW01)	

The Auditor notes that the locations of monitoring bore MB07 and MB13 are plotted incorrectly in the 2016 LEMP Figure 2 (T&T, 2016b). The correct position of MB07 is near the location of decommissioned bore MB13. It is recommended that Figure 2 of the 2016 LEMP (T&T, 2016) is updated to show the correct position of MB07, and also the former location of MB13.

The Auditor notes that the proposed groundwater monitoring program in the LEMP includes annual sampling at all groundwater monitoring bores located within the landfill licence boundary, and selected bores outside the landfill license boundary. Some of the bores located inside the license area are also sampled biannually.

The following sections discuss groundwater monitoring data and trends based on groundwater monitoring events (GMEs) conducted during the Audit period from July 2014 to June 2016, as well as from consideration of some historic data.

7.4 Adequacy of Management of Groundwater

7.4.1 Groundwater Monitoring History

The following summarises the groundwater monitoring history (AECOM, 2016):

> The initial network included six groundwater monitoring bores, MB1 to MB6, in 1995 which were constructed from the drilling investigations to support the Works Approval application for the landfill development of the quarry.

> Four additional bores (MB7 to MB10) were installed in 1998.

> MB11 was installed and MB02A replaced the decommissioned MB2 well in 2001.

> MB12 and MB13 were installed in 2004.

> GW1 to GW8, MB14 and MB15 were installed in December 2013 to January 2014. Decommissioned bore MB07 was replaced and headworks of MB08 was repaired.

> GW04d, GW09 to GW11 were installed in May 2015 to assess the impact of the proposed landfill extension.

All bores were drilled using air rotary techniques and each bore was constructed for long term groundwater monitoring purposes using 50 mm diameter Class 18, threaded uPVC casing with machine slotted screen sections, gravel pack and a bentonite seal. A lockable steel protective monument was centred over the uPVC bore and cemented to the surface.

The Auditor notes that there are no groundwater monitoring bores off-site downgradient (i.e. south east, east and south) of the landfill premises. With regard to the Upper NVA, there are no groundwater monitoring bores on the eastern site boundary between MB14 and MB06 and with regard to the Lower NVA, there is no bore adjacent the Stage 1 landfill or on the southern site boundary west of MB10.

7.4.2 Groundwater Elevation

As described in Section 4.1 groundwater occurs within the Upper and the Lower Newer Volcanics Aquifers (NVA). Groundwater elevation contours for the Upper NVA in September 2015 and June 2016 are presented in Figure 3 in Appendix A. This shows an overall groundwater flow direction in the Upper NVA across the site to the east, south east and south.

There is insufficient data for the Lower NVA to construct groundwater elevation contours, or confirm the groundwater flow in the Lower NVA direction beneath the site.

The historical groundwater levels are plotted as hydrographs against the Accumulated Monthly Residual Rainfall (AMRR) until May 2015 (AECOM, 2016). Figure 7-1 shows hydrographs of bores MB09 and MB10 which are screened across the Lower NVA, plotted against the AMRR. The long term monitoring record indicates a correlation in groundwater levels with the AMRR with lower groundwater levels during times of lower residual rainfall. Following the decline of groundwater levels during the decade-long drought prior to 2010, there was a general increase from 2010 to 2012. During 2013 and 2014, groundwater levels have declined slightly in MB10. There is a noticeable increase from 2010 in response to the occurrence of average and above average rainfall.

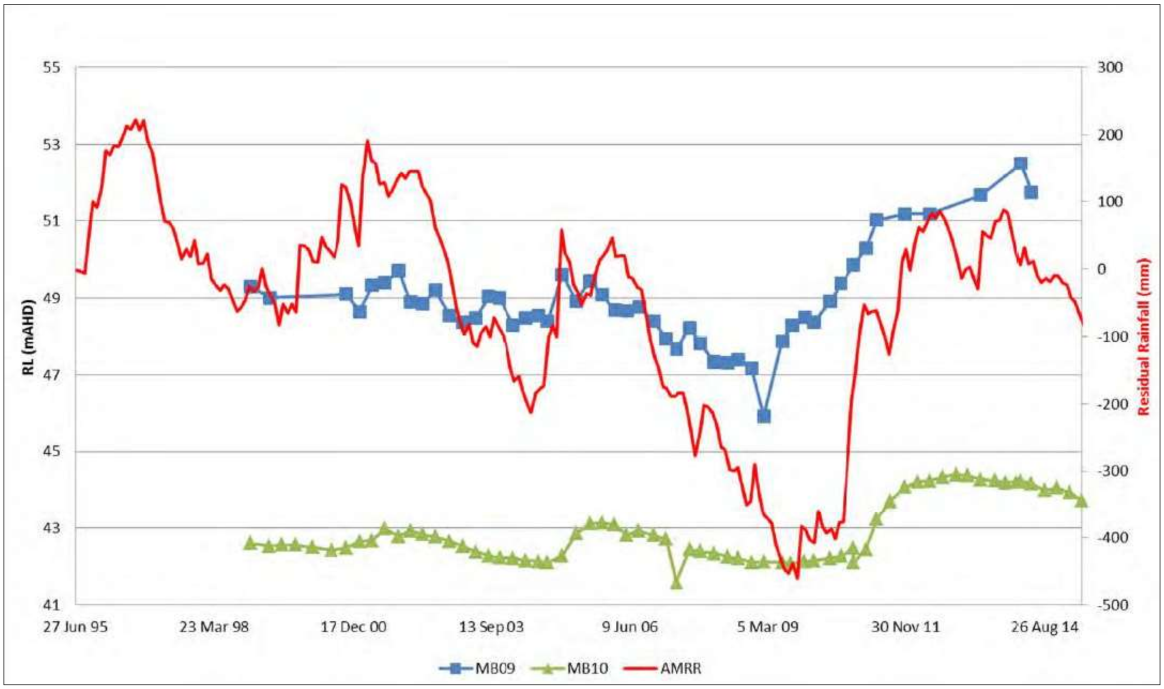

Figure 7-1: Groundwater Elevations in Lower NVA (AECOM, 2016)

Figure 7-2 shows hydrographs of groundwater elevations at selected bores screened in the Upper NVA. It is evident that the groundwater levels have generally displayed a similar trend, regardless of the bore locations at the site. As with the hydrographs for the Lower NVA, there appears to be a strong correlation in groundwater levels with the AMRR, with a significant rise in groundwater levels in response to above average rainfall.

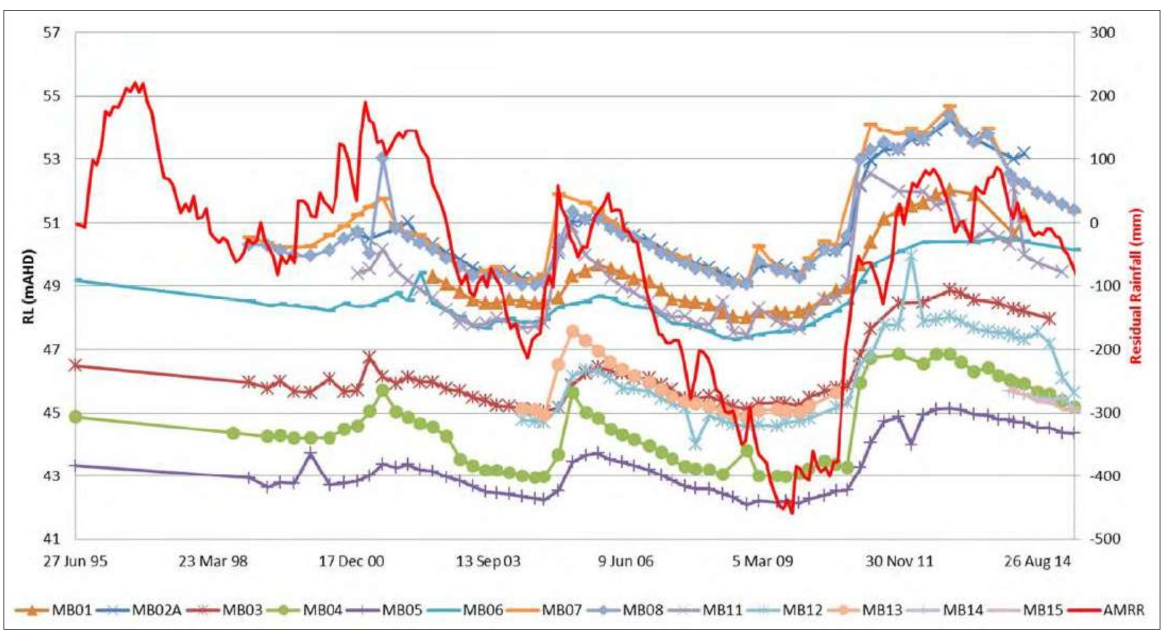

Figure 7-2: Groundwater Elevations in Upper NVA (AECOM, 2016)

Groundwater monitoring bores separately screening the Upper and Lower NVA show a large downward hydraulic gradient (Table 7-5) at GW04 and GW04D to the west of the site, and a slight downward hydraulic gradient at MB05 and MB10, which are located on the southern premises boundary. It is possible that the groundwater level at MB01 has been lowered by groundwater extraction from nearby Boral extraction bores, Bore 1 and Bore 3, and there is a slight upward hydraulic gradient at MB01 / MB09. The Boral extraction bores are shown in Appendix A, Figure 3.

Table 7-5: Groundwater Elevation – Neighbouring Upper and Lower NVA bores

Bore ID	Bore Depth (mbgl)	Aquifer NVA	TOC (mAHD)	Groundwater Elevation (mAHD)	Difference in Elevation (Upper - Lower)
GW04	30.0	Upper	80.33	52.981	7.241 (Jun-16)
GW04D	46.0	Lower	80.74	45.740	
MB01	30.5	Upper	75.30	48.679	-1.506 (Nov-15)
MB09	60.0	Lower	75.35	50.185	
MB05	25.5	Upper	60.49	44.070	0.467 (Jun-16)
MB10	46.5	Lower	59.98	43.603	

7.4.3 Groundwater Quality Interpretation

The Auditor has reviewed the data in terms of:

> Geochemistry of the groundwater as a hydrogeological and CSM interpretation aid; and

> The status of groundwater and protected beneficial uses (discussed in Section 7.5).

Groundwater laboratory chemistry data for monitoring events until 2015 are presented in the Hydrogeological Assessment (AECOM, 2016), and shown in Table B3, Appendix B. This includes data collected since 2012.

The 2014 LOA assessed the groundwater chemistry by grouping the data for bores that were considered “up-gradient or “down-gradient” (T&T, 2014; Table 5-4), comprising MW03, MW05, MW07, MW08, and MW12.

The Auditor notes that at this site such grouping of data could lead to confusion or misinterpretation, as bores downgradient of the Stage 1 landfill could be considered up-gradient of the Stage 2 landfill. Also as groundwater mounding associated with the landfill is possible, it is debatable as to whether certain bores are up-gradient of the landfill. Furthermore, when presenting a range of values it is unclear which, if any, values are anomalous and also if different bores being sampled it is not possible to make a valid comparison over time.

Therefore the Auditor prefers to look at the data collected over time at each bore, consider the position of the bore in the overall groundwater flow system and proximity to the landfill, and evaluate the trend in the data as well as the spatial distribution of contaminants.

Twelve monitoring bores installed since the 2014 LOA are located outside the landfill premises to the west and north-west, and provide background groundwater data. Also, two groundwater monitoring bores, MB14 and MB15, were installed downgradient of the Stage 2 landfill.

The July 2014 to June 2016 data from bores in the upper NVA distant from the landfill (MB03, MB06, GW01 and GW04) show groundwater salinity in the range of 3,000 to 15,000 mg/L TDS, with an average of 9,611 mg/L. These results are consistent with the 2014 LOA and confirms that groundwater is generally classified as Segment C.

The July 2014 to June 2016 data from a background bore in the Lower NVA (GW04D) shows groundwater salinity beneath that part of the site in the range of 3,000 to 3,400 mg/L TDS with an average of 3,220 mg/L. On that basis, the groundwater in the lower NVA would be classified as Segment B, however, the bore is at least 1 km from the landfill, and the background salinity of the Lower NVA closer to the landfill is not known. As four extraction bores at the quarry are reportedly extracting groundwater from the lower NVA, sampling groundwater from these bores during the next GME would provide valuable additional data on the groundwater chemistry in the Lower NVA.

AECOM (2016) includes groundwater and leachate chemistry for April - May 2014 plotted on a Piper trilinear diagram, as shown in Figure 7-3. AECOM (2016) concluded that local groundwater is chloride dominant and leachate (LP01 to LP18) is bicarbonate dominant.

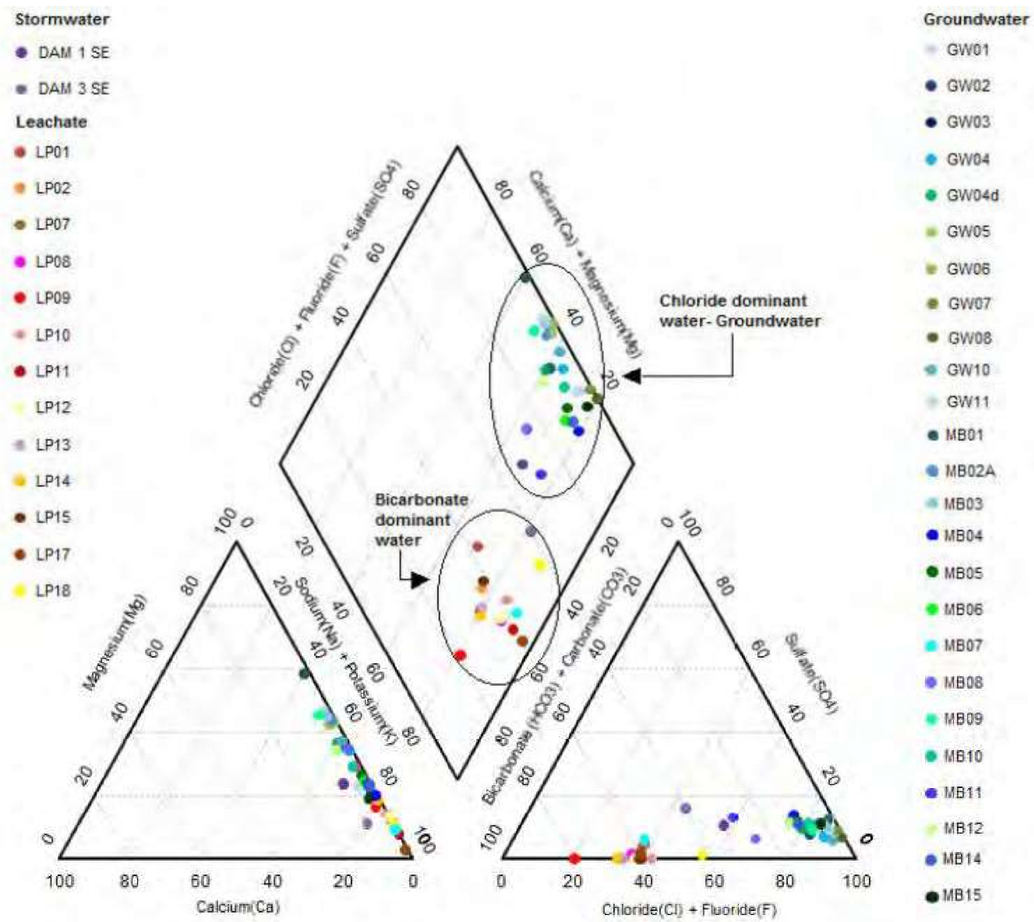

Figure 7-3: Piper Plot - Leachate, Stormwater and Groundwater. April-May 2014 (AECOM, 2016)

7.4.4 Leachate Indicators

A Piper trilinear diagram for March 2016, shown in Figure 7-4, also shows the groundwater is sodium chloride dominant at background and down-gradient bores, except for MB07. Bore MB07 has a higher proportion of bicarbonate which may reflect impact by leachate from Stage 1.

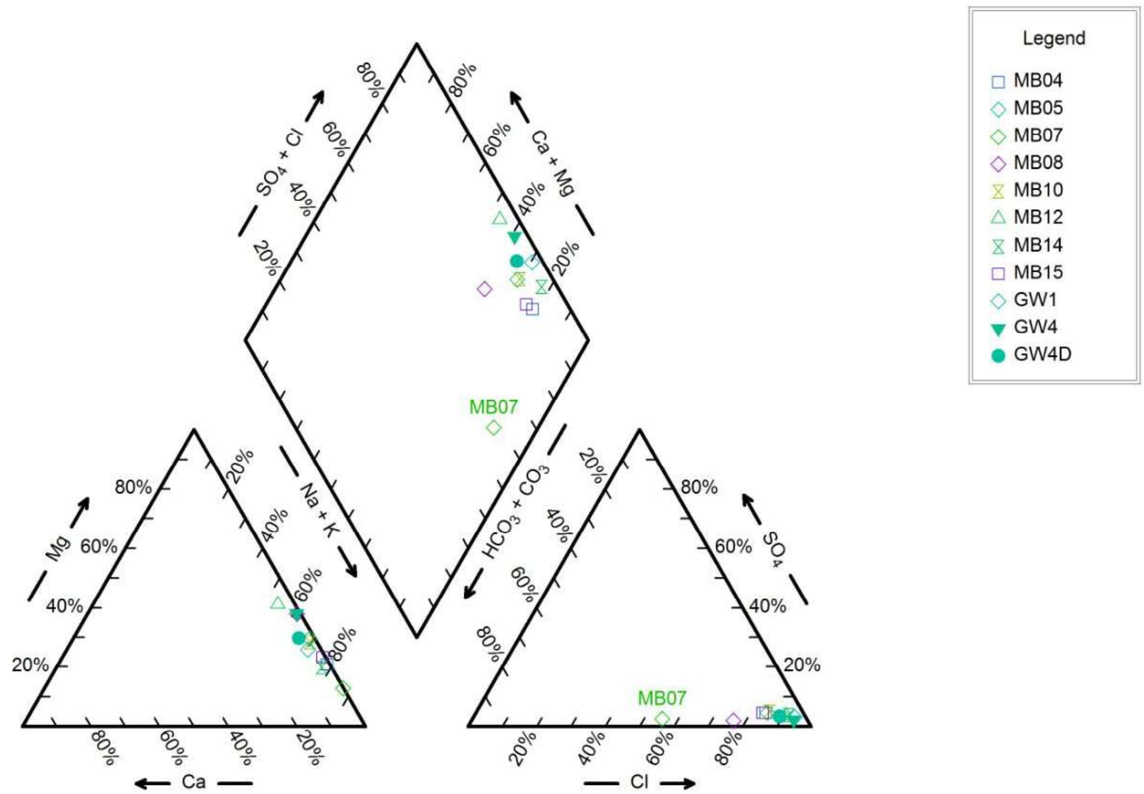

Figure 7-4: Piper Plot – Groundwater, March 2016

Indicators of leachate in groundwater are elevated ammonia (N) and nitrate (N) concentrations in groundwater bores MB08 and MB11, respectively, and bicarbonate at MB07. This suggests leachate is impacting groundwater on the premises, down-gradient of the Stage 1 cells.

As shown in Table B3 (Appendix B) and summarised in Table 7-6 below, for data collected in the Audit period (2015-2016), there are elevated concentrations of some metals and nitrate in bores located in the south east corner of the site, downgradient of the Stage 2 landfill. The data also shows indications of increasing concentration of manganese and salinity (TDS) at MB12, bicarbonate at MB10 and MB15, and nitrate at MB04.

Table 7-6: Bores Downgradient of Stage 2 Landfill – Key Parameters Range

Bore	Aquifer NVA	n	TDS (mg/L)	Bicarbonate as $CaCO_3$	Nitrate as N (mg/L)	Manganese (mg/L)	Nickel (mg/L)
MB04	Upper	8	3000-3500	330-430	3.5-6.2	<0.005	<0.001-0.006
MB05	Upper	6	6600-7400	690-870	1.2-1.8	<0.005	0.003-0.014
MB10	Lower	4	6000-7100	490-780	1.2-1.5	<0.005-0.010	0.004-0.018
MB12	Lower?	6	3000-4100	210-260	<0.02-0.03	0.088-0.160	0.002-0.008
MB14	Upper	10	5400-9900	430-690	0.9-2.4	<0.005-0.029	0.003-0.013
MB15	Upper	10	5100-9900	440-800	0.51-2.8	<0.005-0.030	0.003-0.008

Notes:
The range of values is for analyses undertaken for GME in 2015 and 2016.
n is the number of samples in the range

As these bores are inferred to be hydraulically down-gradient (south and east) of the early Stage 2 landfill cells, the possible increasing concentration in these parameters could be indications of leachate impact on groundwater at this location.

7.4.5 Summary of Adequacy of Groundwater Monitoring

The groundwater monitoring bores at the site generally provide sufficient coverage across the site and data, to allow conclusions to be made regarding the condition of groundwater and to support the effective management of groundwater at the site. Recommendations are made below in Section 7.7 to improve the monitoring bore coverage, data collection and reporting.

7.5 Groundwater Risk Assessment

As discussed in Section 4.1.4, the beneficial uses for Segment C are protected at and in the vicinity of the site. In assessing the protection/pollution status of groundwater, all beneficial uses protected under this segment must be considered. The following is the Auditor's assessment of the protection status of the groundwater with regard to each beneficial use relative to the relevant water quality criteria. This assessment is based on results from the monitoring events conducted during the review period of July 2014 to June 2016.

7.5.1 Maintenance of Aquatic Ecosystems

This beneficial use is protected for all segments of groundwater in Victoria. Groundwater results (July 2014 to June 2016) which exceeded the ANZECC (2000) *Freshwater Ecosystem Guidelines* are presented in Table 7-7.

Table 7-7: Groundwater Exceeding Ecosystem Maintenance Criteria (March 2016)

ANZECC 2000 Freshwater (95% Protection) Criteria	Number of GME	Cu (mg/L)	Mn (mg/L)	Ni (mg/L)	Zn (mg/L)	Ammonia (N) (mg/L)	Nitrate (as N) (mg/L)
		0.0014	***1.9***	***0.011***	***0.008***	***0.9***	***7.2***
MB03	2	0.002, 0.006	-	-	0.009 – 0.025	-	-
MB06	2	0.002, 0.003	-	-	0.011 – 0.024	-	-
MB11	2	-	-	-	-	-	13
GW01	7	0.002 - 0.004	-	-	-	-	-
GW04	6	0.002 – 0.007	-	-	0.009	-	-
GW04D	5	0.002	-	-	0.009 – 0.026	-	-
MB04	8	-	-	-	0.01	-	-
MB05	8	0.002 – 0.004	-	0.014	0.009 – 0.011	-	-
MB07	8	0.002	-	0.014 - 0.019	-	-	-
MB08	8	-	2.2	0.038 – 0.091	-	0.91 - 1.1	-
MB10	6	0.002 – 0.004	-	0.018	0.01 – 0.012	-	-

ANZECC 2000 Freshwater (95% Protection) Criteria	Number of GME	Cu (mg/L)	Mn (mg/L)	Ni (mg/L)	Zn (mg/L)	Ammonia (N) (mg/L)	Nitrate (as N) (mg/L)
		0.0014	***1.9***	***0.011***	***0.008***	***0.9***	***7.2***
MB12	8	0.005	-	-	-	-	-
MB14	8	0.002 – 0.003	-	0.013	0.009 – 0.012	-	-
MB15	8	0.002 – 0.003	-	-	0.009	-	-

Metals

The elevated copper and zinc concentrations could be naturally occurring in the basalt aquifer as elevated copper and zinc concentrations are reported in bores up-gradient of the landfill. The Auditor notes that copper and zinc in leachate is generally higher than the concentration in groundwater, and therefore the possible contribution from leachate cannot be excluded. The Auditor notes that elevated manganese concentrations in down-gradient bores is not apparent in up-gradient bores, indicating landfill operations could be impacting groundwater down-gradient of Stage 2 cells, in the south-east corner of the premises.

Nitrogen Compounds

Elevated ammonia (as N) concentrations in MB08 (Stage 1) and elevated nitrate (as N) concentrations in MB11, and no elevated concentrations in up-gradient bores, indicate that landfill operations may be impacting groundwater downgradient of Stage 1 cells. Elevated nitrate (as N) downgradient of Stage 2 cells in groundwater is indicated at bore MB04 located on the site boundary.

Conclusion

There appears to be impact of landfill leachate on groundwater on the premises, downgradient of the Stage 1 landfill. There is possible impact on groundwater on the premises at the south east part of the site, down gradient of the Stage 2 landfill.

As the exceedances are relatively low, and the nearest down-gradient receptor is Port Philip Bay (approximately 12 km to the south-east of the site) the Auditor considers that the beneficial use of groundwater for maintenance of aquatic ecosystems is **not precluded** downgradient of the site.

7.5.2 Potable Water Supply

This is not a protected beneficial use for groundwater of this salinity.

7.5.3 Potable Mineral Water

This is not a protected beneficial use for groundwater of this salinity.

7.5.4 Agriculture, Parks and Gardens

This is not a protected beneficial use for groundwater of this salinity.

7.5.5 Stock Watering

This is a protected beneficial use for this segment, meaning that stock could be sustained by drinking water supplies drawn from bores with pumps or windmills. Given the local setting with neighbouring properties which may have livestock, stock watering is a likely beneficial use near the site.

Concentrations of all analytes tested, except salinity (TDS), are below the Stock Watering assessment criteria, although the relevant salinity (TDS) criteria is subject to the type of stock.

For the bores shown on figure 3 (Appendix A) onsite and in the vicinity and up-gradient, the groundwater salinity (TDS) concentrations varies considerably, from 24600 mg/L at GW08 to 2900 mg/L TDS at MB11. At bores where there are indications of possible leachate impact in the south east corner of the site, the salinity in the Upper NVA ranges from 3,400 mg/L (MB04) to 9,100 mg/L TDS (MB14). The Auditor notes the TDS concentration appears to be increasing at MB14 and MB12, with reflecting increasing sodium and chloride concentrations.

Therefore, although the increasing TDS concentration at two bores in the south east corner suggest an impact from leachate, this is not conclusive, and given the naturally high background salinity in some off-site bores, the Auditor concludes that this beneficial use of groundwater is **not precluded** downgradient of the site.

7.5.6 Industrial Water Use

Industrial water uses defined in the ANZECC 1992 (Chapter 6 Industrial Water Quality) relevant to groundwater extractive use are generic processes (heating and cooling), textile industry, chemical and allied industry, food and beverage industry, iron and steel industry, tanning and leather industry, pulp and paper industry and the petroleum industry.

Table 7-8: Salinity Limits for Industrial Water Uses (ANZECC, 1992)

Industrial Water Use	TDS
Once through cooling and make-up water systems for fresh water	<1000 and <500, respectively
Textile industry	<100 mg/L
Food and beverage industry	<850 mg/L
Iron and steel industry	<1000 mg/L
Pulp and paper industry	<500 m/L
Petroleum industry	<750 mg/L

The groundwater cannot be used for the industries listed above, given that the TDS required is less than the background water quality from this site. In addition, the groundwater indicator for pH for generic processes (heating and steam generation) is alkaline at 8 to 10 units. The pH measured in the bores at the site commonly equals or exceeds 8.0 units

Generic processes (heating and cooling) are the only industrial beneficial uses listed in the ANZECC 1992 guidelines that are not precluded by salinity levels, with no criteria specified. However, it was noted in Table 6.2 of the ANZECC 1992 guidelines, *Effects of some water quality parameters on heating equipment*, that dissolved solids "*Process interfere and cause foaming in the boilers*".

While the natural salinity of the groundwater may restrict its use for a range of industrial purposes, the low concentration of contaminants would not further restrict the use of the groundwater. Therefore, this beneficial use of groundwater is considered **not to be precluded** by contamination from the landfill at the site. In addition, the quality of the groundwater and the low bore yields in the NVA suggest that this is an unlikely use.

7.5.7 Primary Contact Recreation

This beneficial use relates to the use of groundwater to fill swimming pools, or in cases where a water body occurs on a site where it receives groundwater discharge and may be used for swimming.

Water quality criteria for toxicants for primary contact recreation are the same as for drinking water. Based on the NHMRC 2008 guideline (Risks in Recreational Water, Section 9.3.2), the Australian Drinking Water Guidelines criteria (NHMRC/NRMMC 2013) have been multiplied by 10 to account for the assumed ingestion of 200 mL during recreational activities. This factor does not apply to organic contaminants, as exposure pathways other than ingestion exist (e.g. inhalation).

The data indicates that, using the 10 times factor, none of the analytes exceeded the applicable water quality guideline criteria for Recreational Water (Health), except pH which was reported slightly above the criteria range.

Aesthetic criteria for Primary Contact Recreation waters is generally exceeded for both up-gradient and down-gradient for concentrations of chloride, sodium and sulphate (as S). The elevated concentrations are not considered to represent contamination of the groundwater from landfilling operations, and are believed to be naturally occurring in the basalt aquifer.

Elevated ammonia and iron concentrations were reported down-gradient of Stage 1 cells in MB07 and MB08 on-site, but not in any other down-gradient bore which suggests that these contaminants are not leaving the site at the site boundary. Elevated manganese concentrations in down-gradient bores, is not apparent in up-gradient bores, suggesting landfill operations may be impacting groundwater down-gradient of Stage 2 cells, in the south-east corner of the premises.

However, as the manganese concentration at only one bore in this part of the site (MB12) exceeds the criteria for PCR (Aesthetics) the Auditor concludes that the beneficial use of groundwater for Primary Contact Recreation **is not precluded** downgradient. The likelihood of this use being realised is considered **unlikely**, given that the land use is not compatible with such activity and the high cost of a bore and pump for the limited purpose of filling a swimming pool.

7.5.8 Buildings and Structures

This beneficial use is protected for all segments of groundwater in Victoria. Groundwater should not be made corrosive to building elements due to contamination.

The groundwater at this site is generally deep with respect to natural ground level, with little potential to intersect building footing elements. However, buildings constructed at or near the quarry floor may be impacted by groundwater.

Comparison of monitoring data against AS2159 criteria, as shown in Table 7-9, indicates that, due to low sulphate and chloride concentrations and the slightly alkaline pH, groundwater would have a “mild” to “non-aggressive” effect on concrete piles should it come into contact with them. Therefore, groundwater at the site is not corrosive and will not attack the building element.

Table 7-9: Exposure Classification for Concrete Piles (after AS2159-2009)

Sulphate (as SO_4)	pH	Chloride	Soil Conditions	
Groundwater (mg/L)	*Soil or Groundwater*	*Groundwater (mg/L)*	*High Permeability(sands and gravels), below groundwater*	*Low Permeability(silts and clays) below groundwater& all soils above groundwater*
<1,000	>5.5	<6,000	Mild	Non-aggressive
1,000 - 3,000	4.5-5.5	6,000 to 12,000	Moderate	Mild
3,000 - 10,000	4.0-4.5	12,000 to 30,000	Severe	Moderate
>10,000	<4	>30,000	Very severe	Severe

This beneficial use of groundwater is **not precluded** by contamination from the landfill at the site.

7.6 Summary of Auditor’s Opinion on Groundwater Risk

Contamination was reviewed with respect to all beneficial uses in Segment C, given the classification of the groundwater salinity (measured as TDS) in the aquifer. Table 7-10 summarises these findings.

Table 7-10: Summary of Groundwater Pollution Assessment

Beneficial Use Category	Protected Beneficial Uses of this Segment of Groundwater	Precluded	Existing Use	Likely Use	Unlikely Use
Maintenance of Aquatic Ecosystem	✓	No			✓
Potable Water Supply					
Potable Mineral Water					
Agriculture, Parks & Gardens					
Stock Watering	✓	No		✓	
Industrial Water use	✓	No			✓
Primary Contact Recreation	✓	No			✓
Buildings & Structures	✓	No			✓

The Auditor concludes that beneficial uses of the groundwater outside the site are not precluded, and notes a wide range of background groundwater salinity and metals concentrations. Ongoing monitoring in accordance with MP and the recommendations of this report, will provide further understanding of the background concentrations in groundwater, and the extent of impact of landfill operations on groundwater at the premises.

7.7 Recommendations - Groundwater

In accordance with the objectives and scope of the Audit in compliance with EPA Licence, the Auditor is to recommend measures to reduce and manage risks to beneficial uses at acceptable levels.

The Auditor makes the following recommendations relating to groundwater management at the site:

1. Upgrade the groundwater monitoring network:
   a. Survey groundwater bores MB04, MB09 and MB11, for measurement reference point elevation and ground elevation.
   b. Install two additional monitoring bores at the location of MB12. One bore into the Lower NVA, and one bore into the Upper NVA.
   c. Install two additional monitoring bores close to the northern boundary of the Stage 2 landfill cells - in the Upper NVA and Lower NVA.
   d. Install a groundwater bore to monitor the Lower NVA adjacent MB04.
2. Revise the Monitoring Program to include gauging of water levels in all on-site and off-site groundwater monitoring bores in each monitoring event.
3. Measure groundwater level, field chemistry and obtain a groundwater sample for laboratory analysis from the four groundwater extraction bores during a GME undertaken in the next Audit period.
4. Add VFA (volatile fatty acids) to the laboratory analytical suite for groundwater.