Holcim Pakenham Quarry Extension

Groundwater Impact Assessment

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GROUNDWATER IMPACT ASSESSMENT

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Information

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Executive Summary

MSH Groundwater was engaged by Umwelt (Australia) Pty Ltd to undertake a groundwater impact assessment as part of the Holcim (Australia) Pty Ltd proposed quarry extension ('the Extension') at their Mount Shamrock Quarry; located at 95 Mount Shamrock Road, Pakenham, Victoria.

The proposed Extension would target basalt resources identified to the northeast of the current quarry. The Extension is within the existing Work Authority (WA 174) boundary but outside of the current approved extraction limit boundary.

The groundwater impact assessment ('the assessment') forms one of the technical assessments required to support the associated Environment Effects Act 1978 Environment Effects Statement (EES) referral, Work Plan Variation, Planning Permit Application and Rehabilitation Plan.

Key activities relevant to the assessment were identified to be i) basalt extraction below the water table, ii) discharge of waters beyond the Work Authority boundary, and iii) final landform design.

A site walkover was conducted by MSH Groundwater in March 2024, and a desktop assessment reviewed publicly available data and over 20 years of monitoring data collected during quarry operation.

The assessment describes i) the existing environment and identifies groundwater systems which may be affected by the Extension, ii) key risk areas and potential impacts on groundwater, and iii) measures to avoid or mitigate residual impacts on groundwater.

The assessment focused on the area to the north and east of the Extension, that is, in the direction of the proposed quarry expansion. Groundwater users with the potential to be affected by the Extension were identified as being springs, consumptive use bores and groundwater dependent ecosystems.

Ten springs (SP1 – SP10) have been monitored since 2001 and are monitored annually in summer. A new spring (SP11) was identified in April 2023 and has been added to the annual spring monitoring schedule. Three springs to the north (SP6, SP7 and SP8) and two springs to the east (SP9 and SP10) were identified as being potentially relevant to the assessment.

Six monitoring bores MB01 – MB06 (including replacements) have been monitored since 2001 and are currently monitored monthly. MB07 was installed in March 2024 at the northeast perimeter as part of the Extension investigations and has been added to the monthly monitoring schedule.

Twelve registered consumptive use bores are mapped as being within the study area, with the closest being 860 meters east of the Extension. The nearest potential aquatic GDEs are mapped at 1 km to the northwest (Toomuc Creek) and 1.6 km to the southeast (Deep Creek).

The groundwater impact assessment found limited potential for material impacts on groundwater levels, flow and quality from the operation and rehabilitation of the Extension.

No clearly discernable, measurable or longterm impacts from quarrying have been observed or reported for springs; based on 20 years of monitoring and assessment. Although the proposed Extension does have the potential to influence springs, any such effects beyond Holcim owned land to the north would be no greater than those from the historical and current quarry activities. Although the potential effects on SP09 (to the southeast) are uncertain, the spring is located on Holcim owned land and does not contribute significant flow to the down gradient surface water systems.

Overall, no unacceptable residual impacts were identified based on the project description, hydrogeological setting, 20 years of monitoring data, and continued implementation of the monitoring and management processes in place for the current quarry.

It was recommended that the monitoring schedule in the Environmental Management Plan (version 3) be updated to include monitoring bore MB07. It was also recommended that improved spring monitoring techniques be implemented, and a quantitative assessment of springs be incorporated into an updated Environmental Management Plan.

1 Introduction

MSH Groundwater (MSH) was engaged by Umwelt (Australia) Pty Ltd to undertake a groundwater impact assessment as part of the Holcim (Australia) Pty Ltd (Holcim) proposed quarry extension ('the Extension') at their Mount Shamrock Quarry; located at 95 Mount Shamrock Road, Pakenham, Victoria (refer to **Appendix A – Figure 1**).

This groundwater impact assessment ('the assessment') forms one of the technical assessments required to support the associated Environment Effects Act 1978 Environment Effects Statement (EES) referral, Work Plan Variation, Planning Permit Application and Rehabilitation Plan.

1.1 Aim and objectives

The aim of the assessment is to consider potential effects on the existing groundwater environment due to the operation and rehabilitation of the Extension area only. Potential effects on groundwater from the current quarry form part of the 'existing environment' for this assessment (refer to Section 5).

The objectives of the assessment are therefore to:

- describe the existing environment and identify groundwater systems which may be affected by the Extension
- identify key risk areas and assess the magnitude, extent, and duration of potential effects on groundwater
- recommend measures to avoid or mitigate the main potential effects on groundwater

1.2 Scope

The groundwater impact assessment scope of works included:

- a site walkover
- a desktop review of relevant background information from publicly available data and information provided by Holcim (such as site monitoring data)
- description of current quarry activities
- characterisation of the existing groundwater environment
- development of a hydrogeological conceptual model
- assessment of the potential extent, magnitude and duration of adverse groundwater effects associated with the Extension
- recommendation of mitigation measures (if required)

1.3 Background and site history

Holcim operates the Mt Shamrock Quarry (the Quarry) at 95 Mt Shamrock Road, Pakenham, Victoria on land described as LP200083, Lot 2 PS448233.

In 1971 an application was made for the site to be developed as a quarry, and Extractive Industry License 554 was granted in March 1974. Quarry operations commenced shortly after.

In 1989 the current quarry base (approximately 161 to 163 mAHD) was first reached, and the initial pit outline was established in 1990.

The Quarry, now operating under WA174[1], was subsequently approved for extension in 2008 following an assessment under the Environment Effects Act 1978. The extraction limit extension was 32 hectares (ha) which increased the extraction limit footprint to approximately 108 Ha. The extension was primarily to the southwest with minor components to the north and west. The base of quarry was maintained at approximately 161 to 163 mAHD. The Werribee Formation is not intersected, and a basalt 'cap' is maintained to ensure a suitable surface for extraction activities.

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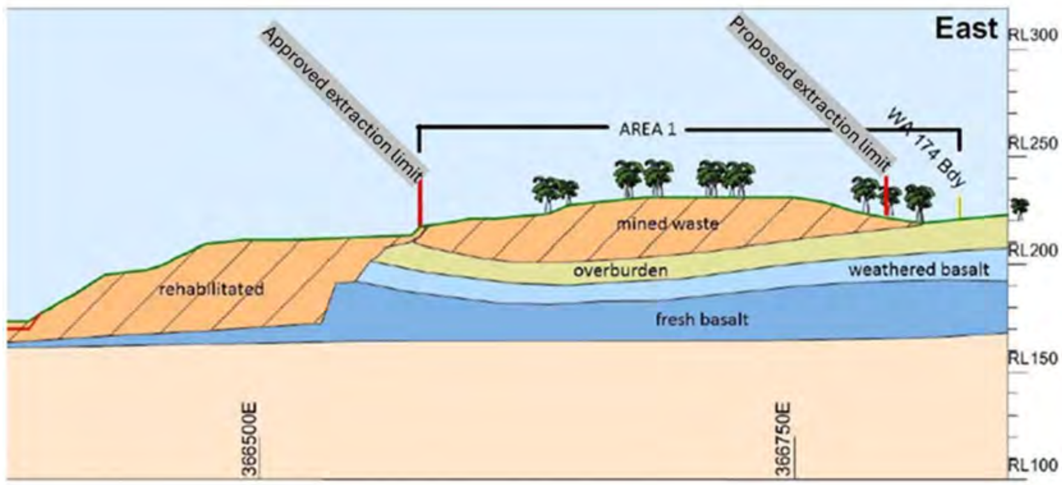
[1] Works Authority (WA) 174 issued under the Mineral Resources (Sustainable Development) Act 1990 (Vic) (MR(SD) Act).

The Work Authority (WA) boundary was also extended to include a 14.35 Ha area at the south-east of the Quarry for management of surface water and includes a water storage area known as Donazzon's Dam.

The area northeast of the current extraction limit, but within WA174, was previously used to store mined overburden. It forms part of the current proposed extension area (refer to Figure 1-1).

FIGURE 1-1 CONCEPTUAL CROSS SECTION OF PROPOSED EXTENSION



Refer to **Appendix A - Figure 2** for the original quarry extraction limit (circa 1974), the southeast extension area (approved in 2008), mined overburden area, and proposed Extension.

2 Project Description

2.1 Overview

Holcim (Australia) Pty Ltd (Holcim) operates the Mt Shamrock, Pakenham Quarry (the Quarry) located at 95 Mount Shamrock Road, Pakenham Victoria 3810. The Quarry is located within the Cardinia Shire Council local government area (LGA) 65km southeast of Melbourne. The nearest urban centers are Pakenham, approximately 5km south of the Quarry and Beaconsfield Upper approximately 5km north-west (refer to **Appendix A - Figure 1**)

The Quarry has approval to carry out quarrying (extractive industry) by Planning Permit T050156 (Permit) issued by the Cardinia Shire Council under the *Planning and Environment Act 1987* (P&E Act) and WA 174 issued under the *Mineral Resources (Sustainable Development) Act 1990* MR(SD) Act.

Holcim has identified older basalt resources at a location to the northeast of the current quarry operations (the Extension). This is within the existing WA 174 boundary but outside of the current extraction limit approved under WA 174. Holcim is seeking to extend the Quarry to include the Extension area to secure an estimated seven to nine million tonnes (Mt) of fresh basalt which is currently located beneath 30 m of overburden and weathered rock against the old quarry faces and unmined resource.

The proposed Extension is approximately 17.2 hectares (Ha) in size, where 6.3 Ha is already within the existing extraction limit (refer to **Appendix A - Figure 2**). The Extension would therefore increase the extraction limit footprint from 108 Ha to 119 Ha; an increase in footprint of approximately 8%.

All operational infrastructure for the current quarry operations will remain in place for the Extension. All existing roads within the Quarry will be utilised and no new infrastructure or access tracks are required. Extraction, crushing, stockpiling and transportation will continue without any change to the location or use of site equipment and facilities, and will take place within the existing WA174 boundary.

The final landform for the Extension will be in line with the current rehabilitation plan which includes batter drains, quarry floor ponds and drainage lines that discharge to the water storage pond known as Donnazon's Dam, that then ultimately discharges to the downstream surface water catchment.

2.2 Study area

The groundwater study area encompasses the proposed Extension area plus an additional 2 km buffer zone (see **Appendix A- Figure 1**).

The buffer zone is based on existing conditions, the scale of the Project and professional judgement. An iterative approach is used, and the buffer zone refined as required throughout the impact assessment. The final buffer zone of 2 km reported here is considered adequate to capture groundwater systems and receptors that may be affected by potential changes to groundwater levels, flow, and quality due to the proposed Project.

The focus of the assessment is primarily to the north and east of the quarry; that is, in the direction of the proposed Extension. Areas to the west and south of the quarry will continue to be managed and monitored through the Environmental Management Plan version 3 (EMP v3) (Holcim, 2021).

2.3 Key activities relevant to groundwater

The operational and post closure activities most relevant to this assessment are:

- Basalt extraction below groundwater levels within the Older Volcanics unconfined aquifer
- Discharge of waters beyond the WA boundary
- Final landform design

Other aspects of quarrying operations that could affect groundwater levels, flow and quality will remain the same as those for the current operation and are listed below. These infrastructure and activities, which are located within the Work Authority, but outside of the Extension, will not introduce new risks, or change existing or future conditions and are not considered further as part of the Extension assessment:

- Mobile plant equipment
- Processing plant and processing operations
- Fuel storage
- Water control and management
- Water supply and water usage volumes

3 Legislation, Guidelines and Policies

Table 3-1 summarises the relevant legislation that applies to the Extension in the context of this groundwater impact assessment as well as the implications and required approvals.

TABLE 3-1 PRIMARY ENVIRONMENTAL LEGISLATION AND ASSOCIATED INFORMATION ON GROUNDWATER

Legislation/ policy	Key policies/strategies	Implications for the Project	Approvals required
State			
Water Act 1989	This Act is the primary legislation for the integrated management of Victoria's water resources. The Act applies to the management of groundwater and imposes licensing requirements in relation to the dewatering of groundwater. For groundwater in southern Victoria, the Department of Environment, Land, Water and Planning (DELWP) has delegated this responsibility (including licensing) to Southern Rural Water (SRW).	It is understood that a groundwater Take and Use Licence is not required for current quarry operations. A T&U licence is therefore not be required for the Extension.	No approvals required
Environment Protection Act 2017 (Environment Protection Act)	The Environment Protection Act aims to protect Victoria's air, water and land by adopting a 'general environment duty' (GED) which imposes a broad obligation on entities and individuals to take proactive steps to minimise risks of harm to human health and the environment from pollution or waste. The Victorian Environment Protection Authority (EPA) administers the Environment Protection Act and subordinate legislation.	The Environment Protection Act regulates discharges to land, surface water or groundwater by a system of development and operating licences. Any discharge into a waterway or groundwater during the construction or operation of the Extension must be in accordance with the requirements of the Environment Protection Act. The GED requires all reasonably practicable steps be taken to minimise impacts from the construction and operation of the project.	EPA permit to discharge held by Holcim.
Environment Reference Standard	This Environment Reference Standard (ERS) is made under section 93 of the *Environment Protection Act 2017*. It sets out the environmental values of the ambient air, ambient sound, land and water environments that are sought to be achieved or maintained in Victoria and standards to support those values.	The Extension would seek to minimise the potential for impacts on groundwater to ensure that existing environmental values are protected, with priority given to maintaining environmental values of areas of high conservation value.	No approvals required but ERS used to inform EPA's decision making under Environment Protection Act.

Legislation/ policy	Key policies/strategies	Implications for the Project	Approvals required
	Environmental values are the uses, attributes and functions of the environment that Victorians value. Standards for the environmental values are comprised of objectives for supporting different uses of the environment and indicators that can be measured to determine whether those objectives are being met.		

4 Current quarry operations

4.1 Basalt extraction

The currently approved extraction limit, under WA174, covers an area of 108 Ha and the final quarry floor elevations are typically around 161 to 163 mAHD.

Staged rock extraction and integrated staged rehabilitation and landscaping is carried out in general accordance with the quarry's Work Plan (BCA, 2005). The excavation staging plan was provided as Figure 4.1 of Work Plan and is included here as Figure 4-1.

Basalt extraction concentrated in the south and southwest areas of the quarry (Stage 1 and 2) between 2009 and 2023. Stage 2 is nearing completion with backfilling and placement of overburden/fill. Stage 3 is currently ongoing.

FIGURE 4-1 GENERAL EXCAVATION STAGING PLAN

Source: Figure 4.1 of Holcim Workplan (2005)

4.2 Quarry infrastructure

The processing plant (including the crushing and screening plant, and the blending plant) is east of the quarry extraction area (and south of the proposed Extension).

To the southeast of the processing plant (and towards the entrance to the Quarry site) are the workshops, above ground bunded diesel tank (next to workshop) and administration buildings.

Refer to **Appendix A - Figure 3** for quarry infrastructure layout.

4.3 Water use and management

Water uses at the quarry include dust suppression, supply for the blending plant, and watering of rehabilitated batters. The water is provided from the Northern Water Hole (also referred to as North Hole) and Southern Water Hole (also referred to as South Hole); refer to **Appendix A - Figure 3**.

Rainwater is collected from office roof areas and used in the amenities.

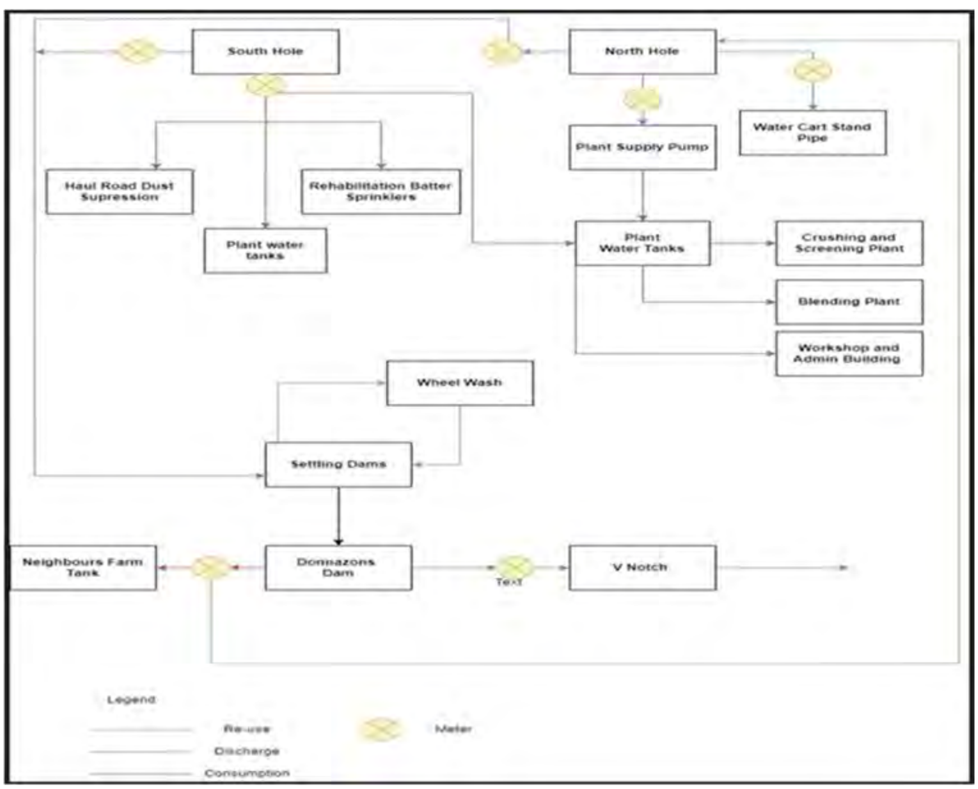
Water meters are located across the site and readings taken monthly to provide information on water use and discharge volumes. Measurements are required as part of Holcim's internal water management guidelines.

Discharge of excess surface water, when required, is from the North and South Water Holes (also known in this report as Northern Dam and Southern Dam) to two settlement ponds located southeast of the administration buildings. Water then flows southeast to Donnazon's Dam before discharging to Kennedy Creek via a V-notch weir. Discharge is managed in accordance with EPA Permit OL00000544.

There will be no material change in water usage and water management as part of the Extension, with no increase in intensity of production or mode of working proposed.

A schematic of water use and water management is provided as Figure 4-2 and the location of key water management components are provided in **Appendix A - Figure 3**.

FIGURE 4-2 WATER MANAGEMENT



Source: Figure 4 EMP v3 (Holcim, 2021).

4.4 Monitoring

Monitoring and management of water usage, groundwater levels, groundwater quality, discharge volumes and discharge quality are undertaken in accordance with Section 2.4 of the Environmental Management Plan version 3 (EMP v3) (Holcim, 2021).

An overview of key monitoring schedule activities and management measures is provided in Table 4-1 and location of monitoring bores and springs are shown **in Appendix A - Figure 4**.

TABLE 4-1 CURRENT MONITORING AND MANAGEMENT SCHEDULE

Activity/location	Action	Who	Frequency
V-notch weir (d/s of Donnazon's Dam)	Flow rate of each discharge event	External	Continuous during discharge
EPA sampling point	As per EPA discharge license (OL00000544)	Holcim	Weekly during discharge
MB01 – MB07	Water level gauging	External	Monthly
In-pit water levels	Standing water level gauging	Holcim	Monthly
Groundwater environmental values	Groundwater use assessment as per S2.4.3 of EMP v3	External	Annually

Source: Based on Sections 2.4.3 and 2.4.4 of EMP v3 (Holcim, 2021)

A review of groundwater levels and spring flow/quality is completed annually to address several aspects of EMP management measures. The *Groundwater and Spring Review* report:

- assesses how groundwater levels respond to seasonal rainfall changes, extension of the quarry, revegetation and progressive rehabilitation of the quarry
- includes visual inspection of springs outside the extraction area
- confirms that the assessed environmental values of groundwater on properties surrounding the quarry are supported by actual practices.

5 Existing conditions

The following section describes the current environmental conditions (baseline conditions) at and around the Site that are relevant to understanding potential effects from the proposed Extension on the groundwater system, groundwater environmental values and groundwater users.

In this assessment, baseline conditions will incorporate any existing effects due to historical and ongoing quarry activities adjacent to the proposed extension area.

5.1 Climate

The study area has a mild temperate climate of hot to very hot summers, and mild to cool winters. Mean annual rainfall in the area is in the order of 800 mm per year.

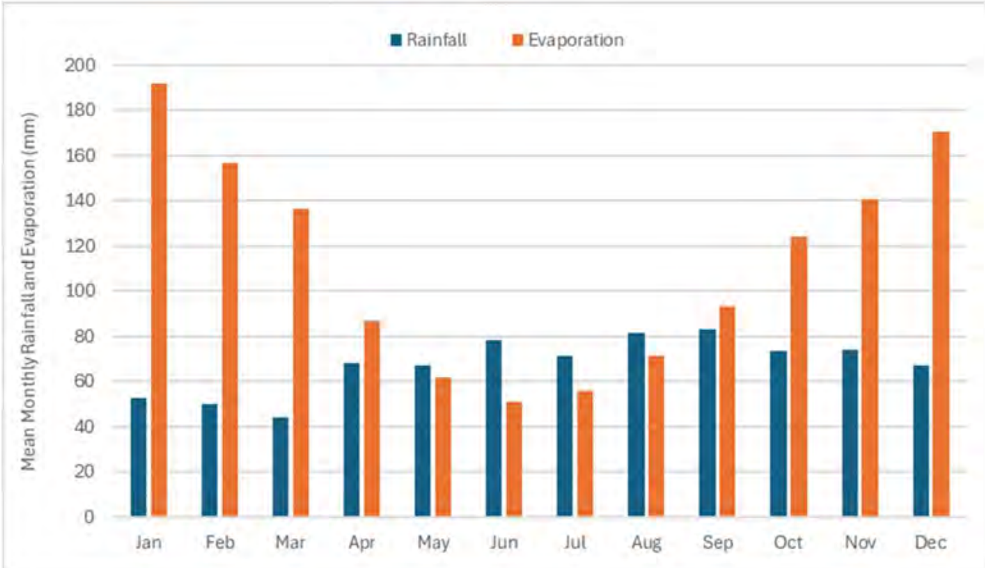
Average monthly rainfall is summarised in Table 5-1 for Bureau of Meteorology (BoM) stations Dandenong (ID 086224) located 23 km to the west, and Cranbourne Botanic Gardens (ID 086375) located 22 km to the southwest.

Table 5-1 Monthly Rainfall Statistics (1991 - 2020)

Month	Dandenong BoM station (ID 086224)	Cranbourne BoM station (ID 086375)
January	57.2	52.5
February	59.6	48.7
March	49.3	44.1
April	68.6	67.3
May	64.5	68.8
June	72.6	78.0
July	67.0	69.9
August	69.1	81.3
September	76.1	83.1
October	65.8	71.9
November	83.6	74.6
December	73.0	68.7
Total	804.4	807.4

Cranbourne Botanic Gardens (ID 086375) is the nearest BoM station with evaporation statistics. The mean monthly rainfall and evaporation data indicate that groundwater recharge will be winter dominated. Mean monthly rainfall exceeds evaporation in May, June, July and August, but is lower throughout other parts of the year (refer to Figure 5-1).

Figure 5-1 Monthly Statistics for Cranbourne Botanic Gardens (Station ID 086375)



5.2 Topography and surface water drainage

Pakenham Quarry is at the southern end of an elevated ridgeline. The ridgeline runs northeast to southwest and marks the boundary between surface water catchments of Toomuc Creek to the west, and Kennedy Creek (a small tributary of Deep Creek) to the east.

Toomuc Creek and Deep Creek join approximately 12km downstream and ultimately discharge a further 7km downstream into Western Port Bay (URS, 2005).

Catchment areas of Toomuc Creek and Deep Creek (including its tributaries) upstream of where they converge have been approximated as 4,100 Ha (Toomuc Creek) and 2,975 Ha (Deep Creek) (refer to URS, 2005). The areas that the Extension would occupy in each catchment is approximated to be in the order of:

- 0 Ha in Toomuc Creek catchment
- 10.9 Ha in Deep Creek catchment (including minor tributary), or 0.35% of the catchment

Topography and creeks are shown in **Appendix A - Figure 5**.

5.3 Geology

The geological setting of the quarry and surrounds was described by URS (2005) and the geological profile was summarised from youngest to oldest by GHD (2023):

- Quaternary aged alluvium primarily deposited in the Toomuc Creek Valley and consisting of silty sands and clays
- Tertiary aged Older Volcanics (**the resource being quarried**). These consist of dense, blue/black, olivine basalt with a maximum thickness of 70 m, and a varied weathered profile of up to 26 m, but generally in the order of 10 m. Inferred to be one basalt flow that was extruded into an ancient valley that sloped towards the south and which now forms the current ridge line; the surrounding sediments having been eroded by more recent drainage lines (URS, 2005)
- Tertiary aged Werribee Formation consisting of clay, poorly consolidated sand and clay, with some organic material. Only mapped as outcropping to the south of the quarry. It has also been suggested that the Werribee Formation may thin out away from the center of the ancient valley towards the valley walls (URS, 2005)
- Palaeozoic aged bedrock consisting of either Devonian aged Lysterfield Granodiorite or Silurian aged micaceous quartz siltstone and sandstone

A map of the surface geology within the study area is provided as **Appendix A - Figure 6**.

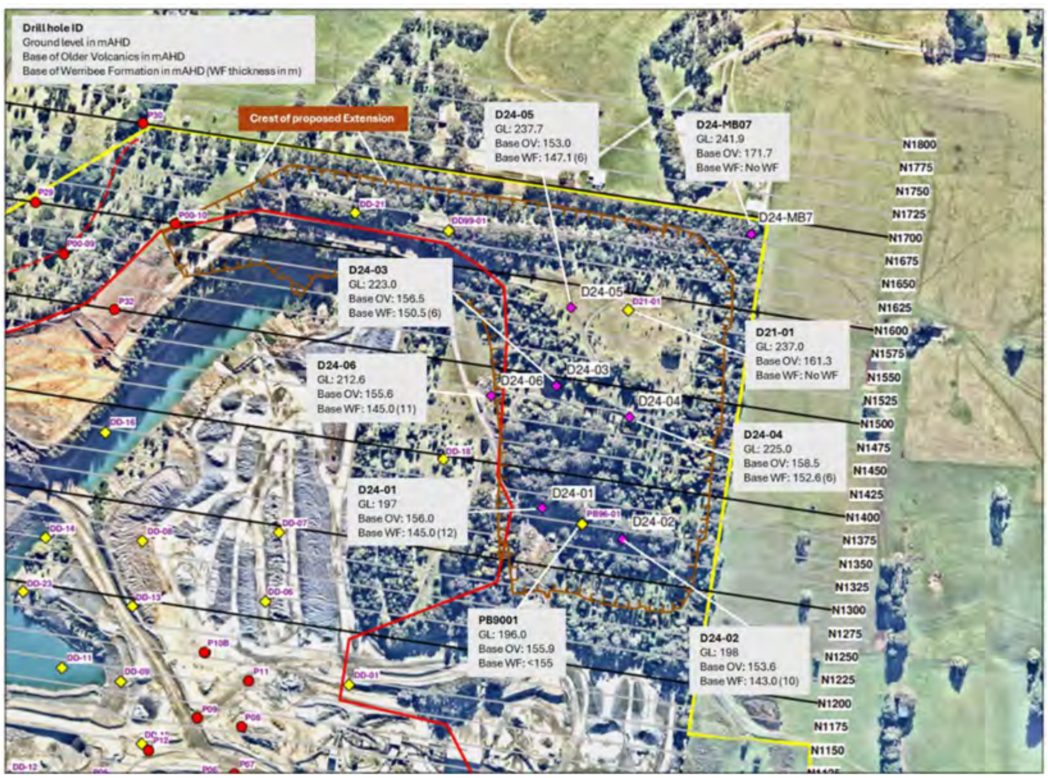
Six monitoring bores (MB01 – MB06) were installed in 2001 as part of the EES groundwater impact assessment (URS, 2005), with several of the in-pit monitoring bores being replaced through the life of the quarry due to extraction activities. The geology encountered in the monitoring bores, and in resource holes drilled during quarry operations, is generally consistent with the regional geological interpretation.

A geotechnical and resource assessment of the Extension was carried out in 2024. Six diamond cored holes were drilled within the proposed pit area (D24-01 to D24-06) and D24-MB07 was drilled to the northeast and converted to monitoring bore MB07 (refer to Figure 5-2).

The drilling program encountered fresh to variably weathered basalt (Older Volcanics) overlying sand and clay sediments (Werribee Formation) which in turn were underlain by granodiorite (Palaezoic bedrock). In the proposed Extension pit area, the base of Older Volcanics was typically at elevations of between 153 and 156 mAHD. The underlying Werribee Formation sediments were between 6 and 12 m thick.

At drillhole D24-MB07 the base of Older Volcanics was encountered at around 172 mAHD and no Werribee Formation sediments intersected above the granodiorite bedrock. This is consistent with the inference in URS (2005) that the Werribee Formation sediments may thin out against the wall of an ancient valley that was later infilled by an Older Volcanics basalt flow.

Figure 5-2 Extension Drilling Program 2024



5.4 Hydraulic parameters

As part of a hydrogeological review of Pakenham Quarry (GHD, 2023) it was recommended that hydraulic testing, in the form of slug tests, be carried out to provide site specific hydraulic conductivity (K) values for the Older Volcanics basalt and Werribee Formation sediments.

The tests were completed in December 2023 and the estimated K values are provided in Table 5-2.

TABLE 5-2 SLUG TEST RESULTS

Well ID	Average K value (m/day)	Lithology	Screened interval (mbgs)
MBO1	0.09	Silty CLAY (Werribee Formation)	67 – 72.5
MB02C	0.17	Silty CLAY (Werribee Formation)	33.8 – 36.8
MB03B	0.05	Silty CLAY (Werribee Formation)	49 - 52
MB04C	3.28	Basalt (Older Volcanics)	30.4 – 30.9
MB05B	0.46	Basalt (Older Volcanics)	40 - 46
MB06	0.55	Basalt (Older Volcanics)	44 – 50

SOURCE: Based on Table 1 of AECOM. 2024a

AECOM (2024a) reported that the hydraulic conductivity (K) of basalt in a particular well is greatly influenced by the presence of fractures. The K of fractured rock was considered '*inherently difficult to estimate with slug testing due to both the small radius around the well tested and the heterogenous nature of fractured aquifer*'. The report further concluded that slug test estimates should not be relied on for larger scale analysis such as drawdown curve predictions.

It is considered that a more reliable 'bulk' hydraulic conductivity for basalt is gained from literature value ranges rather than aquifer testing, and an Older Volcanics basalt K value in the order of 0.05 to 0.1 m/day was provided by URS (2005). Those are consistent with K values in the order of 0.001 to 0.1 m/day reported for basalt to factured basalt in literature sources; including Heath (1983), and Domenico and Schwartz (1990).

A K range in the order of 0.01 to 0.1 m/day is considered reasonable for the Werribee Formation from literature sources including Heath (1983), and Domenico and Schwartz (1990); based on the silty clay to sandy clay lithology encountered on site. This is generally consistent with the estimates of 0.05 to 0.17 m/day derived from slug tests (AECOM, 2024a).

5.5 Groundwater occurrence

There is limited groundwater data available away from the quarry to infer groundwater levels and flow on a regional scale. It is typical however for the water table to reflect a subdued version of topography, with flow from higher relief areas (recharge areas) to areas of lower relief (for example groundwater discharge areas along creek lines). Prior to development of the quarry, the water table within the unconfined Older Volcanics would have been mounded beneath the ridgeline and local groundwater flowpaths would have been 'radially' away from the ridgeline towards lower lying discharge areas.

Close to the quarry, groundwater levels are measured monthly at six monitoring bores. The original bores MB01 – MB06 were installed in 2001 and drilled at four locations to provide spatial coverage across the site. Several bores have been damaged or lost over time and replaced as close as practicable to original bores (within the constraints of a working quarry). Water levels at the in-pit dams, Northern Dam and Southern Dam, (also known as North and South Water Holes) have also been recorded quarterly since October 2020. Perimeter bores MB01 and MB06 have been operational since 2001 and provide a consistent groundwater level record from before the southwest quarry expansion in 2008.

Monitoring bore MB07 was installed in March 2024 to the northeast of the proposed Extension and within the WA174 boundary.

A summary of the current monitoring bore network is provided in Table 5-3 and locations of current and former monitoring bores are provided in **Appendix A - Figure 4**.

TABLE 5-3 CURRENT MONITORING BORE NETWORK

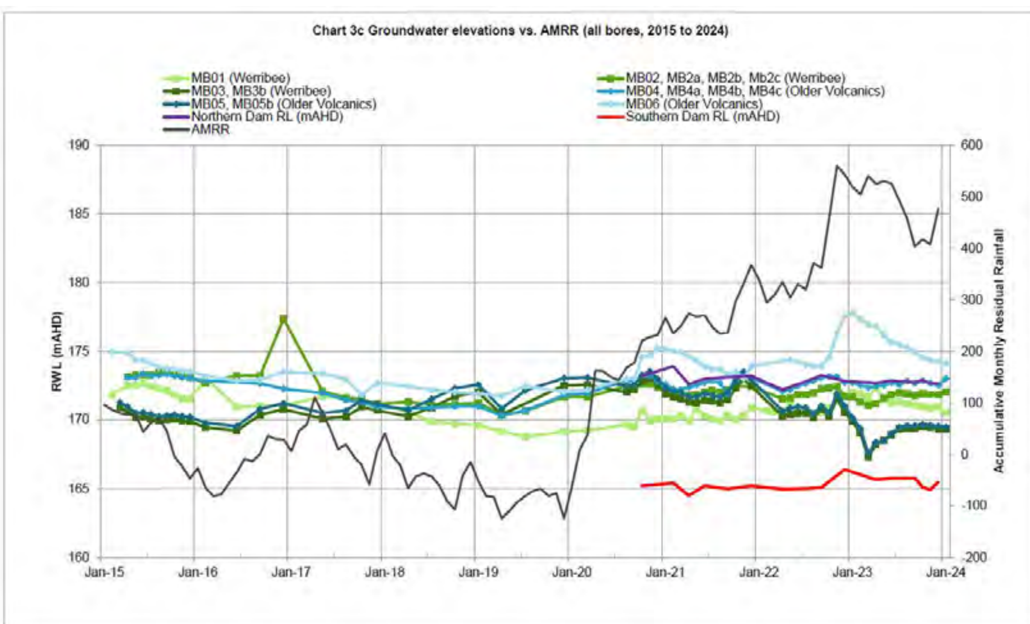
Well ID	Installation date	Top of casing (mAHD)	Screen (mAHD)	Aquifer	Comment
MBO1	7-Mar-01	216.52	149.5 – 144.0	Werribee	Southern perimeter
MB04C	17-Jan-17	191.84	161.2 – 160.9	Older Volcanics	In-pit nested set
MB02C	17-Jan-17	191.68	157.9 – 154.9	Werribee	
MB05B	27-Oct-14	209.55	169.6 – 163.6	Older Volcanics	Southwest perimeter nested set
MB03B	21-Oct-14	209.90	160.9 – 157.9	Werribee	
MB06	13-Mar-01	219.84	175.6 – 169.6	Older Volcanics	Northwest perimeter
MB07	28-Mar-24	242.88	177.9 – 171.9	Older Volcanics	Northeast perimeter

The hydrographs in Figure 5-3 and the conceptual cross section in Figure 5-4 show groundwater gradients adjacent to the quarry are inwards towards the groundwater low point created by the in-pit dams, and in particular the Southern Dam where water levels are typically between 165 to 167 mAHD.

The water level in the Northern Dam is similar to that in the nearby Older Volcanics (OV) in-pit bore MB04. Groundwater levels in the OV northwest perimeter bore MB06 have remained above the Northern Dam level since 2020 (when in-pit water level measurements commenced), and a local hydraulic gradient towards the quarry has been maintained. The groundwater level was 173.94 mAHD (17 April 2024) at the newly installed OV bore MB07 (located northeast of the Extension). This is consistent with historical and recent groundwater levels at MB06, indicating a local hydraulic gradient towards the quarry in the northeast area also.

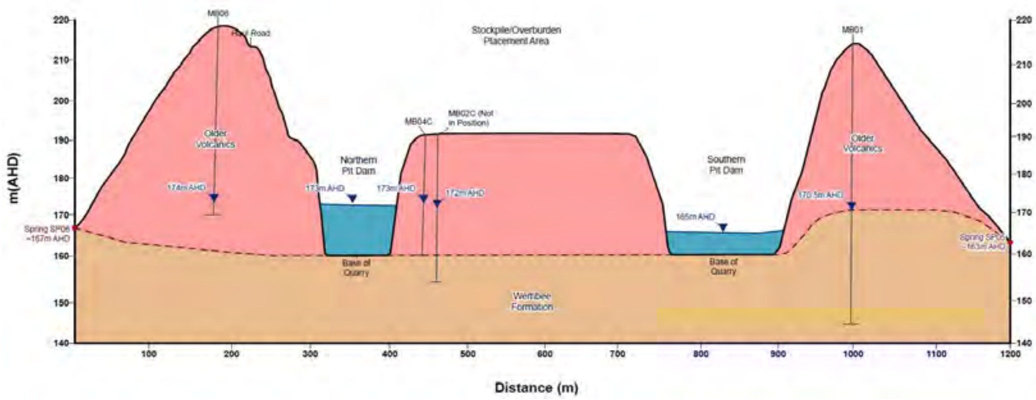
Groundwater levels in perimeter bores to the south (WF bore MB01) and southwest (OV bore MB05B and WF bore MB03B) have also been consistently higher than water levels in the Southern Dam, with a local hydraulic gradient towards the quarry maintained.

FIGURE 5-3 ALL GROUNDWATER HYDROGRAPHS AND PIT LEVELS



SOURCE: Chart 3c – Attachment 3 (AECOM, 2024b)

FIGURE 5-4 CONCEPTUAL CROSS SECTION



SOURCE: Figure 4 – Attachment 1 (AECOM, 2024b)

Annual reporting of groundwater levels and spring flow/quality is undertaken to meet certain requirements of the Environmental Management Plan (Holcim, 2021). The reports include a detailed review of groundwater level hydrographs and assessment of potential correlations with climate/rainfall and quarry operations. The latest annual report (AECOM, 2024b) and recent hydrogeological review (GHD, 2023) have been used to provide the following summary of groundwater level trends.

Groundwater level data are available from 2002 to 2024, but data from 2015 to 2024 are considered the most reliable. The reviews of groundwater level trends have focused primarily on MB06 (Older Volcanics) located 100 m north of the northern quarry face, and WF bore MB01 located 25 m south of the southern quarry face.

Groundwater elevation fluctuations can be compared to accumulative monthly residual rainfall (AMMRR) trends to assess possible effects of rainfall recharge on the groundwater system. An increasing AMMR trend shows wetter than average conditions and a falling trend shows drier than average conditions. The relationship between changes in groundwater levels and AMRR can then be considered.

The trends in OV bore MB06 and WF bore MB01 are generally similar over the monitoring period 2002 to 2024. Declining groundwater levels have occurred during droughts and drier conditions, such as 2000 to 2010 and 2014 to 2020. This has been followed by a subsequent groundwater level rebound with a return to wetter conditions, such as in 2010 to 2013 and 2020 to 2024 (refer to Figure 5-5).

The Werribee Formation aquifer response is often delayed (lagging behind that within the Older Volcanics) or dampened. This was interpreted by URS (2005) to reflect more rapid recharge to the Older Volcanics which is the water table aquifer.

Figure 5-5 MB01 and MB06 Hydrographs with AMRR

SOURCE: Chart 3c – Attachment 3 (AECOM, 2024b)

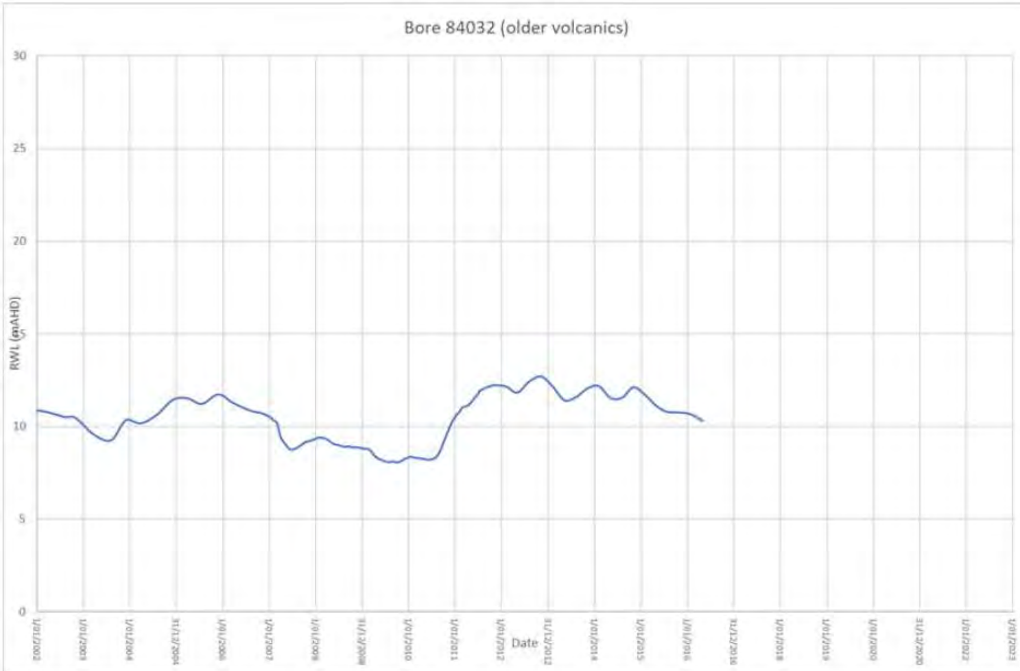
Current levels in MB06 (Older Volcanics) have recovered to the historical highs recorded in 2002-2004 and 2012-2014, and within 2 m of the maximum levels recorded in 2005.

Groundwater levels in MB01 (Werribee) are yet to recover fully and are currently several metres below the groundwater levels in 2002-2004 and 2012-2014. The decline in groundwater level between 2014 – 2019 is greater in MB01 than MB06, and the subsequent recovery is slower and smaller.

Although the MB01 response may, in part, be due to effects from quarrying activities in the southern part of the quarry (including water levels in the Southern Dam) the local groundwater levels generally appear to be influenced by climatic conditions.

The primary influence of climate was concluded by AECOM (2024a) and is supported by the similar groundwater level trends in MB06 to the north of the quarry and MB01 to the south of the quarry. Further evidence of the groundwater levels trends being regional responses to climate is provided by comparison with a State Observation Network (SON) Bore 84032 (Older Volcanics) located 10 km south of the quarry (GHD, 2023). Although no longer actively monitored, the hydrograph for the period 2002-2016 showed very similar groundwater level responses to those for MB01 and MB06 (refer to Figure 5-6).

FIGURE 5-6 HYDROGRAPH FOR SON BORE 84032



The current nested set of monitoring bores MB05B (OV) and MB03B (WF) were installed in 2014, providing ten years of data during quarrying activities in the south and southwest area of the quarry. Groundwater elevations remained between around 170 and 173 mAHD from 2015 to late-2022. A notable decline in groundwater levels occurred in both bores from late-2022 to March 2023 when they fell to around 167 mAHD. AECOM (2024b) reported that the decline occurred during extraction in the southwest area of the quarry close to the monitoring bores. The area was backfilled in April 2023 and groundwater levels in the bores have subsequently recovered but are currently several metres lower than 2015 – 2022 levels.

Overall, groundwater level trends in MB05B/MB03B do not correlate with wetter and drier periods in the same way that MB01 and MB06 are seen to. This suggests greater influence from quarrying activities that mask the climatic conditions to some extent. This could be due to a combination of proximity to the main area of extraction and greater connectivity between the quarry and monitoring bores in this area (due to heterogeneity of the basalt).

The potential effect of quarrying activities on groundwater levels in MB03B/MB05B is consistent with the 150 to 300 m radius of influence estimated by URS (2005). It is important to note that potential effects in perimeter monitoring bores do not indicate springs located further from the quarry will also be affected. Annual spring surveys are undertaken to assess potential changes to spring condition and function (and is discussed in Section 5.7.2).

Additional selected groundwater level hydrographs from AECOM (2024b) are provided as **Appendix B**.

5.6 Recharge and discharge

Recharge to the unconfined Older Volcanics basalt aquifer will be via direct rainfall infiltration. The rate of recharge will vary but preferentially occur in areas of rock outcrop. In areas where the basalt has been weathered to clay or is covered by colluvium the rate of recharge will be negligible with rainfall runoff increasing.

Rain falling on the open quarry areas will either infiltrate into the exposed basalt floor or be captured as part of the water management system of sumps and in-pit dams.

Recharge to the Werribee Formation sediments (where present) and/or bedrock will occur as leakage from the overlying Older Volcanics basalt where a downward hydraulic gradient is present.

Groundwater discharge from the Older Volcanics basalt was considered by URS (2005) to occur as seeps into the quarry or leakage into the underlying Werribee Formation. It was inferred that discharge directly from the basalt to surface along the plateau slopes was likely to be minimal due to the presence of clayey colluvium. However, the hydrogeological review (GHD, 2023) highlighted a lack of clear evidence for this and suggested that direct discharge from the basalt might be possible (particularly to the north). Direct discharge from the basalt to surface (as springs) is considered a potential mechanism but does not materially affect the previous conceptual model or the impact assessment (Section 6).

Discharge from the Werribee Formation aquifer will occur as springs on the plateau slopes (where the Werribee Formation outcrops), and potentially upward leakage into the Older Volcanics basalt where quarrying activities have lowered the water level in the basalts.

5.7 Springs

5.7.1 Inside the quarry

No significant seeps were observed during the MSH site visit by Mark Wakeman on 5 March 2024. No observable flows on the quarry walls have been noted by Holcim during operation, except for occasional small flows immediately following significant rainfall events, and no significant pit inflows have needed to be managed.

The absence of significant or measurable flows was also observed during a URS site visit in July 2005 that noted only damp patches on some areas of the quarry walls. The URS report (2005) concluded that any minimal inflows/seepages were evaporated on the quarry walls, and only the salt load flushed from quarry walls during rainfall events would contribute to the water budget.

The observations are consistent with quarry inflow estimates of between 1 and 3 litres per second using the Dupuit-Forcheimer well discharge equation and Monte Carlo simulation (URS, 2005).

5.7.2 Outside the quarry

URS (2005) identified ten springs surrounding the quarry (SP01 to SP10), however two were subsequently re-classified by AECOM as seeps[2] (SP07 and SP10). In April 2023, Holcim personnel identified a new spring (SP11) on the Toomuc Valley (west) side of the quarry. It was investigated in January 2024 but there was insufficient outflow present to collect parameters or perform flow assessments.

Spring locations do not appear to be related to significant changes in slope, but typically coincide with inferred outcropping of the WF sediments and/or contact between the OV basalts and underlying bedrock formations. It was interpreted by URS (2005) that the WF sediments act as a drainage layer beneath the OV basalts, and springs occur where groundwater discharges via permeable portions of the outcropping WF sediments. The GHD report (GHD, 2023) considers it likely that the springs could be from the base of the OV basalts. To the north and east of the quarry the springs may coincide with the OV basalts and bedrock contact or the thinned-out edge of WF sediments (that is, at the sides of the ancient, infilled valley interpreted to be running from north to south).

The springs are monitored annually in summer in accordance with the EMP v3 (Holcim, 2021). The assessment includes a visual inspection with photographic records of spring condition, observations on flow, and measurement of water quality parameters (where possible). The objective being to identify changes to flow, level, or quality of the springs that could be associated with the quarry development.

The locations of the springs and seeps are provided in **Appendix A - Figure 4** and findings from the most recent spring survey (AECOM, 2024b) summarised in

Table 5-4.

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[2] A spring is considered a reliable perennial source of water that discharge to surface, seeps emit water from underground that does not always reach the surface.

TABLE 5-4 SUMMARY OF MONITORED SPRINGS

Spring ID	RL estimate (mAHD)	Location relative to Quarry	Distance from current quarry face (m)	Comment
SP01	150	West	240	Spring provides irrigation and stock water to properties in the local area
SP02	155	Southwest	220	Water emanating from the spring terminates at small dam. The dam catchment would include both surface water run-off and groundwater (spring flow).
SP03	165	West	220	Spring flows towards small dam, healthy vegetation surrounding this.
SP04	155	North	320	Adjacent northern dam. Pooled water, but historically dry or damp seep with healthy vegetation.
SP05	165	South	200	Spring is historically observed to be dry with healthy vegetation.
SP06	170	North	350	Spring flow into a dam. The spring is accessible by livestock. Audible flow out of dam, but discharge cannot be accessed (dense vegetation and steep slope).
SP07	110	North	640	Downslope and down catchment from SP06. **Reclassified as seep in 2005**, and not monitored.
SP08	160	North	500	In an adjacent creek line to SP06. Spring flow into a wetland.
SP09	160	East	320	Spring flow into an old dam.
SP10	170	East	220	**Reclassified as a seep in 2005**, and not monitored.
SP11	-	West	-	Identified in April 2023.

The springs relevant to this impact assessment are those to the north (SP06, SP07 and SP08) and east (SP09 and SP10) of the proposed Extension.

At SP06 pooled water or boggy ground has typically been observed since 2001 (when accessible), except for 2009 and 2012 when SP06 was observed to be dry.

SP07 is at a much lower elevation (110 mAHD) than other springs and is located downslope and down catchment from SP06. There was no evidence of a spring reported by URS (2005) and it was considered likely to be a natural drainage point. SP07 was reclassified as a seep in 2005.

SP08 is 500 m north of the quarry. A recent hydrogeological review (GHD, 2023) did not expect impacts from the quarry at SP08 and identified it as an appropriate background spring to measure natural trends.

SP09 and SP10 have not been considered discrete groundwater discharge points since the 2014 survey. This is due to significant surface water and seepage influences, and changes in topography and infrastructure (including fire track access construction). It is further noted that SP09 and SP10 have been influenced by the creation of dams near the springs, making them more susceptible to rainfall runoff (AECOM, 2024b).

Changes that have been observed to date in flows, levels and function of springs to the north and east of the quarry are not likely to have been due to quarrying activities. This is based on i) the distance of springs SP06-SP10 to extraction in the south and southwest of the quarry, ii) the absence of groundwater level effects in OV bore MB06, and iii) consistent water levels of 171 to 173 mAHD in the Northen Dam acting as a 'constant head' boundary between extraction in the south of the quarry (since 2005) and springs to the north.

These springs are a combination of runoff, interflow and groundwater discharge, with climatic conditions and physical changes to discharge areas affecting spring condition outside of any quarry activities. Overall, spring monitoring and assessment (from 2001 to 2023) and the hydrogeological review (GHD, 2023) have not identified any clear, obvious or measurable impacts on the springs due to quarrying activities to date.

GHD (2023) identifies that clear conclusions are difficult to determine based on limited consistent information gathered to date in terms of measured flow rates and or water levels. Recommendations were made to improve the qualitative and quantitative information recorded and a program for implementing these is currently ongoing.

5.8 Registered bores

A search of WMIS[3] database of registered groundwater bores was carried out by MSH Groundwater on 25 March 2024. The radial search of 2.5km (from the centre of the proposed NE pit) identified a total of 21 registered bores.

Six bores are mapped within the WA174 boundary. Based on the mapped locations and dates drilled, these are inferred to be associated with bores installed as part of the quarry's historical groundwater monitoring network. A further 15 bores are mapped as being beyond the WA174 boundary, with 12 for consumptive use and three installed as observation bores.

A summary is provided in Table 5-5 and bore locations shown in **Appendix A - Figure 7**.

Table 5-5 Registered bores (within 2.5 km)

WMIS number	Year drilled	Distance from Extension pit centre (m)	Drilled Depth (m)	Use	Screened lithology
Inside WA174 Boundary					
84073	1977	505	30.5	Not known	Not known
WRK082149 (MW02B)	2014	532	12	Observation	Clayey SILT
WRK082152 (MB04B)	2014	534	1.5	Observation	BASALT
84072[a]	1977	598	58	Not known	Not known
WRK990207[a]	Not known	625	25	Not known	Not known
84074	1977	807	88	Not known	Not known
Outside WA174 Boundary					
84069	1977	861	55	Domestic and stock	BASALT
84106	1990	919	14.9	Domestic and stock	BASALT
114867	1992	992	103	Domestic and stock	TILLITE
114934	1992	1019	65.5	Domestic and stock	BASALT
WRK057123	2010	1256	5	Observation	Not known
WRK057121	2010	1267	5	Observation	Silty CLAY
WRK057122	2010	1269	5	Observation	Not known
121918[a]	1992	1375	74	Domestic and stock	Basalt[b]

[3] Water Management Information System maintained by DEECA (formerly DELWP)

115444	1993	1583	79	Domestic and stock	BASALT
124394	1995	1583	38.5	Stock	SAND
132497	1997	1586	91	Domestic	BASALT
64201	1985	1632	57.3	Domestic and stock	BASALT
64195	1980	2176	48.8	Domestic and stock	BASALT
64210	1990	2373	83.6	Domestic and stock	SAND
WRK960359	2002	2444	99	Domestic	BASALT
Notes: a – not used; b – screened lithology interpreted from total depth and drilling log					

5.9 Groundwater dependent ecosystems

The Groundwater Dependent Ecosystems Atlas (GDE Atlas) was developed as a national dataset of Australian GDEs (http://www.bom.gov.au/water/groundwater/gde/map.shtml).

The Atlas contains information about aquatic ecosystems that rely on the groundwater that discharges to the surface, including rivers, springs and wetlands.

The mapping is from two broad sources:

- national assessment: national scale assessment based on available geographic information system (GIS) data and a set of rules that describe the potential for groundwater and ecosystems to interact
- regional studies: more detailed assessment by state and/or regional agencies using field work, satellite imagery or application of conceptual models.

It is important to note that the identification of potential GDEs in the Atlas does not confirm that a particular ecosystem is groundwater dependent. Fieldwork is needed to verify whether an ecosystem is groundwater dependent.

A summary of mapped potential aquatic GDEs in the vicinity of the Extension is provided below and their locations shown in **Appendix A - Figure 8**.

Toomuc Creek is mapped as being a high potential aquatic GDE (from national assessment) and is approximately 1 km to the northwest at its closest point to the proposed Extension.

Kennedy Creek is also mapped as a high potential aquatic GDE (from national assessment) and is approximately 1.6 km to the southeast at its closest point to the proposed Extension.

Groundwater interaction with Toomuc Creek and Kennedy Creek is likely to be shallow local scale groundwater flow within alluvial sediments (associated with the creeks) and/or baseflow from outcropping bedrock which the creeks are mapped as flowing across. The risk posed to these potential aquatic GDEs is considered negligible based on distances to the quarry and the quarry's hydrogeological setting (refer to Section 7.2).

Scattered fragments of low potential terrestrial GDEs (from national assessment) are mapped at the eastern boundary of the proposed Extension, as well as to the north and east. To the north they are described as riparian scrub/swampy riparian woodland. To the east the descriptions include shrubby foothill forest and damp forest. These areas do not coincide with significant flora or fauna previously documented within 5 km of the proposed Extension; refer to the Biodiversity Assessment report by Ecology and Heritage Partners Pty Ltd (E& H Partners, 2024). The Biodiversity Assessment report also included a detailed field survey and assessment of the proposed Extension area. The proposed Extension area was largely cleared in the 1980s and no national or state significant flora species were recorded during the 2024 survey.

5.10 Groundwater quality and environmental values

An assessment of environmental values is completed each year as part of the annual groundwater and spring review, undertaken in accordance with the current EMP v3 (Holcim, 2021). The latest assessment is summarised below (from AECOM, 2024b).

The Environmental Reference Standard (2021) sets the regulatory framework for assessment and management of surface water and groundwater. This is to maintain surface and groundwater water quality such that it protects existing and potential environmental values of surface and groundwaters throughout Victoria.

In Victoria the environmental values of groundwater are classified by its salinity as total dissolved solids (TDS).

Salinity at the ten springs around the quarry have ranged from 149 mg/l (SP09 in February 2002) to 2,808 mg/L (SP02 in January 2003) as TDS. However, spring salinity is a combination of runoff, interflow, and groundwater discharge, and therefore not representative of actual groundwater salinity.

A DELWP groundwater resource report places the quarry in the Westernport groundwater catchment and reports a water table salinity in the range of 1,001 – 3,500 mg/ L as TDS (refer to **Appendix A - Figure 9**).

The salinity of groundwater measured during development of quarry monitoring bores ranged from between 1,140 mg/l (MB03B in October 2014) and 2,318 mg/L (MB04C in January 2017). The regional salinity mapping and site- specific measurement are consistent and indicate groundwater quality at the Site can be classified as 'Segment B'.

Table 5-6 shows the environmental values based on groundwater salinity segments. The relevance of each in the context of the site setting are shown for Segment B environmental values (AECOM, 2024b).

TABLE 5-6 ENVIRONMENTAL VALUES FOR GROUNDWATER AND RELEVANCE

Environmental value	Segments (mg/L TDS)						
	A1 (0-600)	A2 (601–1,200	B (1,201–3,100)	C (3,001–5,400)	D (5,401–7,100)	E (7,101–10,000)	F (>10,001)
Water dependent ecosystems and species			Y				
Potable water supply (desirable)							
Potable water supply (acceptable)							
Potable mineral water supply			N				
Agriculture and irrigation (irrigation)			Y				
Agriculture and irrigation (stock watering)			Y				
Industrial and commercial			N				
Water based recreation (primary contact recreation)			Y				
Traditional Owner cultural values			Y				
Buildings and structures			N				
Geothermal properties			N				

5.11 Hydrogeological conceptual model summary

Key aspects of the hydrogeological conceptual model (HCM) for the proposed Extension are briefly described below and schematic cross sections provided in **Appendix A - Figure 10**:

- variably weathered Older Volcanics (OV) basalt (the resource being quarried) overlies clays and sands of the Werribee Formation (WF) sediments. The WF sediments in turn overlie granodiorite of the Paleozoic bedrock
- elevation of the base of OV basalts varies from 153 to 156 mAHD, and WF sediments are between six and 12 m thick
- the underlying bedrock is thought to provide a relatively impermeable boundary to the base and sides of the ancient valley in-filled by extruded OV basalts
- the base of the OV basalt is 18 m higher to the northeast of the proposed Extension and WF sediments are absent (from the drilling of MB07). This is consistent with WF sediments thinning out against the wall of an ancient valley infilled by Older Volcanics basalt flows (URS, 2005)
- the OV basalt forms an unconfined aquifer that receives recharge via direct rainfall. Across the Extension area the rate of recharge will vary depending on the degree of weathering and mined overburden present
- recharge to the Werribee Formation sediments (where present) and/or bedrock will occur as leakage from the overlying OV basalt where a downward hydraulic gradient is present
- discharge from the OV basalts will occur as seepage into the existing quarry (likely evaporated on quarry walls), leakage to underlying WF and/or bedrock, and discharge as springs
- spring flow is thought to be a combination of rainfall runoff, interflow and groundwater discharge
- the groundwater discharge component to the springs in the north and east (if any) will be from the OV basalt or WF sediments,
- the OV basalts and WF sediments are inferred to be of relatively low hydraulic conductivity based on the limited seepages to the current quarry and limited response to quarrying activities in the perimeter monitoring bores
- the nearest potential aquatic GDEs are mapped at 1km to the northwest (Toomuc Creek) and 1.6 km to the southeast (Deep Creek)
- the nearest registered groundwater bore is 860 m from the centre of the proposed Extension area

Quarrying in the extension area would lower groundwater levels immediately behind quarry faces. The local hydraulic gradient would be towards the pit, producing groundwater seepage into the pit and a cone of depression (area of groundwater level drawdown) away from the quarry. Possible effects of the proposed Extension on the above HCM and subsequent potential impacts on the groundwater environment are considered in Section 6.

6 Impact Assessment

The proposed Extension is to the north and east of the current limit of extraction, as shown in **Appendix A - Figure 2**. This would extend the quarry face by approximately 55 m to the north and 220 m to the east.

The proposed extension would increase the extraction limit area from 108 Ha to 119 Ha, an increase of 10% on the currently approved extraction limit area. The quarry floor elevation of the proposed Extension would be similar to that of the existing quarry, being approximately 162 mAHD.

Any effects from the approved quarry have been considered in the assessment as constituting 'existing conditions' and form the baseline against which the assessment has been made. Additional (or cumulative) effects and potential impacts to groundwater from the Extension have then been considered.

The potential impacts to groundwater from the proposed Extension during operation and post-operation have been identified as being:

- reduced recharge to the regional groundwater system.
- reduced flow to springs such that their environmental values are adversely affected.
- reduced available drawdown to existing consumptive use bores.
- quarry discharge quality impacts the down gradient surface water environment.

These are consistent with potential impacts identified in the groundwater impact assessment (URS, 2005) which was completed as part of the EES for the previous quarry extension. They also address the critical issues identified in the panel report (Pitt et al, 2005) during the 2005 EES, which were:

- the rate of discharge of groundwater, and hence dissolved salts, to the quarry and hence to the surface water by way of discharge from the site; and
- the impact of the quarry extension on the natural discharge of groundwater to the surface

6.1 Regional aquifer recharge

The hydrogeological setting at the quarry is a local groundwater flow system. Direct recharge to the unconfined Older Volcanics basalt will discharge via nearby springs either directly from the basalt or from the underlying Werribee Formation sediments (following leakage from the overlying basalt).

The springs are evidence that the underlying bedrock impedes vertical flow with little of the recharge expected to enter the underlying bedrock and contribute to regional flow system.

Therefore, intercepted recharge and changes to groundwater levels in the Older Volcanics and Werribee Formation will not have a material impact on the recharge and flow of regional aquifers.

6.2 Registered bores

The available drawdown of a bore is the height of the water column between standing water level and depth of submersible pump inlet. If drawdown effects from a nearby extraction (such as another bore or quarry dewatering) reduces the SWL in an existing bore, the available drawdown is reduced. In some cases, the pump would need to be lowered and/or depth of bore extended if available drawdown is reduced too much.

The magnitude and extent of groundwater level declines (i.e. drawdown) due to quarry dewatering can be estimated using analytical equations. URS (2005) estimated an extent of drawdown of 150 m to 300 m from the quarry face. Given the similar hydrogeological setting and depth of quarrying at the proposed Extension, a similar drawdown extent would be anticipated.

By way of comparison and verification of URS (2005) estimates, the Marinelli equation (Marinelli, 2000) has been used here to estimate the extent of a steady state drawdown from the proposed Extension. The conceptual model and equation are reproduced below (Figure 6-1).

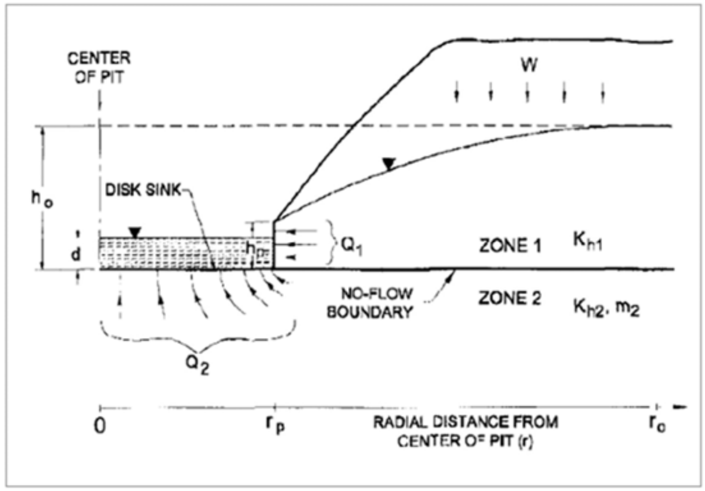
FIGURE 6-1 MARINELLI PIT INFLOW ANALYTICAL MODEL

$$(1)\ h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{(r_o^2 - r_p^2)}{2}\right]}$$

$$(2)\ Q_1 = W\pi\left(r_o^2 - r_p^2\right)$$

$$Q_2 = 4 r_p \left(\frac{K_{h2}}{m_2}\right)(h_o - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$



An assumed quarry floor level of 162 mAHD for the Extension and ‘undisturbed’ groundwater level of 172 mAHD (refer to Section 5.5) equates to h_0 value of 10 m in the above equation. The extent of drawdown value (r_0) can then be changed until the required h_0 value is matched. The corresponding estimate of flow into the pit is then estimated.

A range of hydraulic conductivities were considered, and the corresponding extent of drawdown (r_0) and pit inflows (Q) estimated. The results are provided in **Appendix C** and summarised in Table 6-1.

TABLE 6-1 MARINELLI EXTENT OF DRAWDOWN AND PIT INFLOWS FOR NE EXTENSION

Scenario	OV Kh_1 (m/d)	WF Kh_2 (m/d)	Drawdown extent from pit centre r_0 (m)	Drawdown extent from quarry face* (m)	Pit inflows Q (L/sec)
Upper K from literature values	0.1[a]	0.2[b]	355	245	3.7
Lower K from literature values	0.05[a]	0.05	290	180	1.1
Lowest K from literature values	0.001	0.01	140	30	0.2

Notes: OV – Older Volcanics; WF – Werribee Formation; # - K consistent with URS (2005); b – upper K from slug tests; * - Approx. pit radius 110m

As discussed in Section 5.4, the K values of 0.46 to 3.28 m/day estimated from slug tests (AECOM, 2024a) for the Older Volcanics basalt are at a local scale. The K values are not representative of bulk K values of the basalt encountered at the site. These higher values would therefore provide an overly conservative and unrealistic estimate of the potential drawdown extent and have not been used in this assessment.

For this assessment, a conservative estimate for the extent of drawdown from the proposed Extension quarry face of 180 to 245 m is used. This is considered conservative given that the estimated 30 m extent of drawdown (using the lowest K literature values) corresponds to an inflow seepage rate of 0.2 L/sec. This seepage rate is closer to that considered reasonable based on comparison of the Extension footprint and current quarry footprint (refer to Section 6.5).

The nearest registered bores located beyond the current WA174 boundary are over 850 m from the centre of the Extension pit, and beyond the estimates of drawdown extent.

Therefore, no measurable impacts to water levels in off-site registered bores are predicted due to the proposed Extension.

6.3 Spring flows

The proposed Extension has the potential to affect the flow and/or quality of spring flows that discharge from the slopes of the plateau.

Springs to the west and south of the current quarry will not be affected by the proposed Extension as the approved quarry footprint is between the proposed Extension and springs to the west and south. The extraction and dewatering activities, in-pit pond levels and final landform of the existing quarry will control effects on groundwater levels (if any) to the west and south; shown to be negligible during 20 years of monitoring.

It is further noted that, based on topographical contours, the proposed Extension is to the southeast of the inferred pre-quarry groundwater divide shown in **Appendix A - Figure 6**. The component of rainfall across the proposed Extension area that recharges the groundwater system would flow towards the east and southeast based on topography. The proposed Extension is not within the catchment area of springs to the north of the quarry and would not be expected to intercept rainfall recharge that may currently discharge at those springs.

A summary of current and future lateral distances between springs (not including seeps) to the north and east of the proposed Extension is provided in Table 6-2.

Table 6-2 Distances from Springs to Current Quarry and Extension

Spring Number	Spring Elevation (mAHD)	Distance From Centre of Extension[a] (m)	Distance from Approved Quarry Face[a] (m)	Distance from Extension Face[a] (m)	Estimated Extent of Drawdown from Extension Face (m)
SP06	165	570	395	350	180 to 245
SP08	160	630	550	460	
SP09	160	360	370	200	
Notes: a – distance from quarry face. Assumes 50 m buffer from quarry face crest (extraction limit) to base of quarry face					

For this assessment, the conservative extent of drawdown estimate of 180 to 245 m from the proposed Extension quarry face is used. This is considered conservative given that the estimated 140 m extent of drawdown (Section 6.2) corresponds to an inflow seepage rate of 0.2 L/sec (using the lowest K literature values). This seepage rate is closer to that considered reasonable based on comparison of the Extension footprint and current quarry footprint (refer to Section 6.5).

Springs SP06 and SP08 are beyond the estimated extent of drawdown from the proposed Extension. Beyond the extent of drawdown the hydraulic gradient will remain away from the pit and towards the springs beyond the estimated extent of drawdown.

Although SP09 is within the estimated extent of drawdown from the Extension, a reversal of hydraulic gradient would not be expected at the spring. That is, the proposed quarry floor elevation of 161 to 163mAHD is slightly higher than the elevation of SP09.

Further, the distances between the current south and southwest quarry faces and springs SP01, SP02 and SP05 are less than those between the proposed Extension and springs SP06 and SP08. It is further noted that no clearly discernable, measurable or longterm impacts have been observed or reported for springs SP01, SP02 and SP05 during quarrying activities in the south and southwest portions of the site (between 2008 and 2023). Therefore, no unacceptable residual impacts are expected at SP06 and SP08 due to the Extension.

Spring SP09 will be around 170 m closer to the proposed Extension quarry face than the current quarry extraction limit boundary and is within the estimated extent of drawdown from the Extension. Some level of impact might therefore be expected at SP09, however the magnitude of any such impact is not certain. It is noted however that SP09 is located within Holcim's site boundary and does not contribute significant flow to the down gradient surface water systems.

Overall, no clearly discernable or measurable impacts on springs outside Holcim owned land are expected from the proposed Extension. This is based on results from 20 years of monitoring data for the approved quarry and comparison with the proposed Extension including: the same hydrogeological setting, same quarry floor elevation and smaller Extension footprint.

6.4 Groundwater quality

During operation the elevation of the Extension's pit floor will be below the surrounding groundwater levels. The local hydraulic gradient will therefore be towards the pit immediately beyond the quarry face.

The rehabilitated final landform of the Extension will be in line with that of the current rehabilitation plan for the currently approved quarry. Batter drains, and quarry floor ponds and drainage lines will maintain a local hydraulic gradient towards the rehabilitated Extension.

Groundwater flow will be towards the Extension throughout operation, during rehabilitation and post-rehabilitation (final landform). Therefore, groundwater quality beyond the pit cannot be impacted.

6.5 Quarry discharge

There is the potential for water discharged from the quarry to adversely affect the quality and environmental value of the downstream surface water system. The key influences on the quality of the quarry discharge are the volume and salinity of groundwater seepage into the quarry (and subsequently discharged).

Water is managed at the site using a pump and containment system. Water is collected in the Northern and Southern Dams, and used for dust suppression, in the processing plants or to water vegetation on rehabilitated batters. To manage excess water within the quarry, Holcim holds an off-site discharge licence from the Environment Protection Agency (EPA). This allows for discharge to Kennedy Creek via a v-notch weir at Donnazon's Dam.

During off-site discharge the quality (primarily total dissolved solids) and flow is monitored weekly in line with parameters required to be monitored as part of the EPA license. Discharge is allowed only if the quality meets limits set in the EPA licence, and potential downstream impacts are thereby mitigated.

The proposed Extension is expected to have a negligible effect on groundwater inflow volumes and quality to the current water budget.

The proposed Extension will excavate into the same aquifer currently being quarried and will not intersect any other groundwater system. The salinity seeping into the Extension would therefore not be significantly different to that currently entering the quarry and being managed by the water management process.

Also, groundwater seepage rates to the Extension were estimated to be in the order of 1.1 to 3.7 L/sec (Section 6.2[4]). These are considered conservative estimates given that seepage rates to the larger quarry footprint at the time of the 2005 EES were estimated to be between 1 and 3 L/sec (URS, 2005). Those estimates were considered reasonable in the Panel report (Pitt et al, 2005). Further, the Panel report suggested that an increase in groundwater seepage with quarry extension would be roughly proportional to the increase in the quarry face area. The maximum increase in quarry face area during the proposed Extension would be less than 10% of the quarry (circa 2005). The increased inflow as the quarry expands to the northeast would therefore be expected to be less than 0.1 to 0.3 L/sec (consistent with inflow estimates using lowest literature values for hydraulic conductivities; see Table 6-1). The low seepage rates are expected to evaporate on the quarry walls (URS, 2005) and the absence of observable groundwater inflows during historical and current quarry operations supports this.

Based on the expected small additional flow and salt load from the proposed Extension, no significant change to off-site discharge quality and flow is expected during operation of the proposed Extension.

Further, given the small additional flow and salt load from the proposed Extension, no significant change is expected to the long-term quarry discharge following rehabilitation. The water management system has been developed to minimise erosion and sediment transportation. The water bodies provide sedimentation areas and act as a retardation basin to reduce peak flow rates from the site. Retaining Donazzon's Dam also provides

[4] Higher (conservative) seepage rates are considered suitable to a provide a conservative estimate of the extent of drawdown from the Extension (Sections 6.2 and 6.3).

additional mixing capacity from capture of surface water runoff from within the dam's catchment area and helps reduce salinity prior to discharging into the downstream catchment.

Overall, no unacceptable residual impact is expected from off-site discharge of water from the quarry due to the proposed Extension.

7 Mitigation measures, monitoring and management

No mitigation measures are proposed beyond those in the current Environmental Management Plan (EMP), based on findings of the impact assessment in Section 6.

However, the following recommendations are made with respect to environmental monitoring and management for the proposed Extension.

Water level monitoring

The current monitoring schedule in EMP v3 (Holcim, 2021) should be maintained and updated to include the newly installed Older Volcanics monitoring bore MB07.

MB07 is located at the northeastern perimeter and will provide baseline data for groundwater levels within the Older Volcanics aquifer adjacent to the proposed Extension (prior to quarrying activities).

Ongoing monitoring during the quarrying of the Extension area would allow changes in groundwater levels to be monitored and assessed as part of current monitoring and reporting requirements.

Spring assessments

Improved monitoring techniques for the springs should be considered to allow more quantitative and consistent measurements to be taken. In-line with recommendations provided in the *Pakenham Quarry Hydrogeological Review* (GHD, 2023) this could include, where practicable:

- the establishment of v-notch weirs and/or gauge boards and/or stilling wells to allow level and/or flow to be measured
- increased frequency of measurements (for example with the use of data loggers)
- survey spring elevations

A quantitative assessment of springs should be incorporated into an updated Environmental Management Plan.

8 Summary and conclusions

This groundwater impact assessment has considered possible effects of the proposed Extension on groundwater levels, flow and quality. An assessment of potential impacts to groundwater environmental values and groundwater users was completed, and management and mitigation options recommended where appropriate to reduce residual impacts.

The effects and potential impacts to groundwater have been considered for the Extension only. Any effects from the current and historical quarrying operations have been considered in the assessment as constituting 'existing conditions' and form the baseline against which the assessment has been made.

MSH Groundwater carried out a site walkover in March 2024 and a desktop assessment was carried out between April and July 2024. The assessment reviewed publicly available data and over 20 years of monitoring data collected during operation of the quarry.

Potential impacts considered for the proposed Extension were i) reduced recharge to regional aquifers, ii) reduced flow to springs, iii) reduced available drawdown in registered groundwater bores, and iv) quarry discharge quality impacts on the down gradient surface water environment.

The groundwater impact assessment found limited potential for material impacts on groundwater levels, flow and quality from the operation and rehabilitation of the Extension.

No clearly discernable, measurable or longterm impacts from quarrying have been observed or reported for springs; based on 20 years of monitoring and assessment. The proposed Extension is not expected to result in additional material effects at springs outside Holcim owned land to the north. Some level of effect might be expected at SP09 (to the southeast), however the magnitude of any potential impact on SP09 is uncertain. It is noted however that SP09 is located on Holcim owned land and does not contribute significant flow to the down gradient surface water systems.

Overall, no unacceptable residual impacts were identified based on the project description, hydrogeological setting, 20 years of monitoring data, implementation of an updated monitoring program (Section 7) and continued implementation of the management processes in place for the current quarry.

9 References

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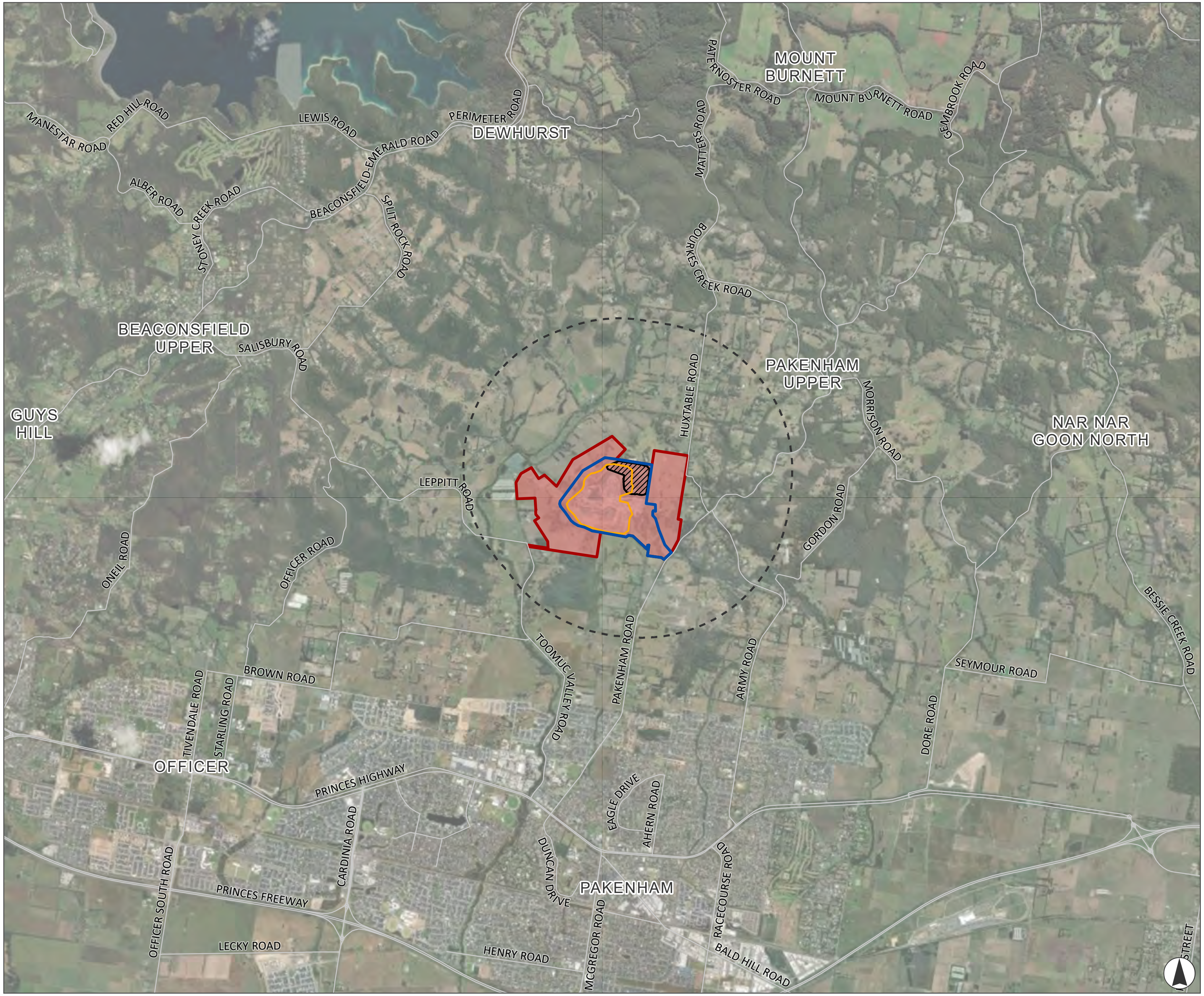
Appendix A – Figures

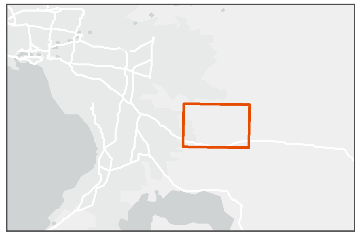
FIGURE 1

Site Location and Study Area



Legend

- Roads
- Proposed Extension Area (2km buffer)
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land
- Proposed Extension Area



0 0.5 1 1.5 2

Kilometres

Scale 1:75,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

FIGURE 2

Quarry Development

Legend

- Roads
- Limit of Extraction (circa 2005)
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

0 0.2 0.4 0.6

Kilometres

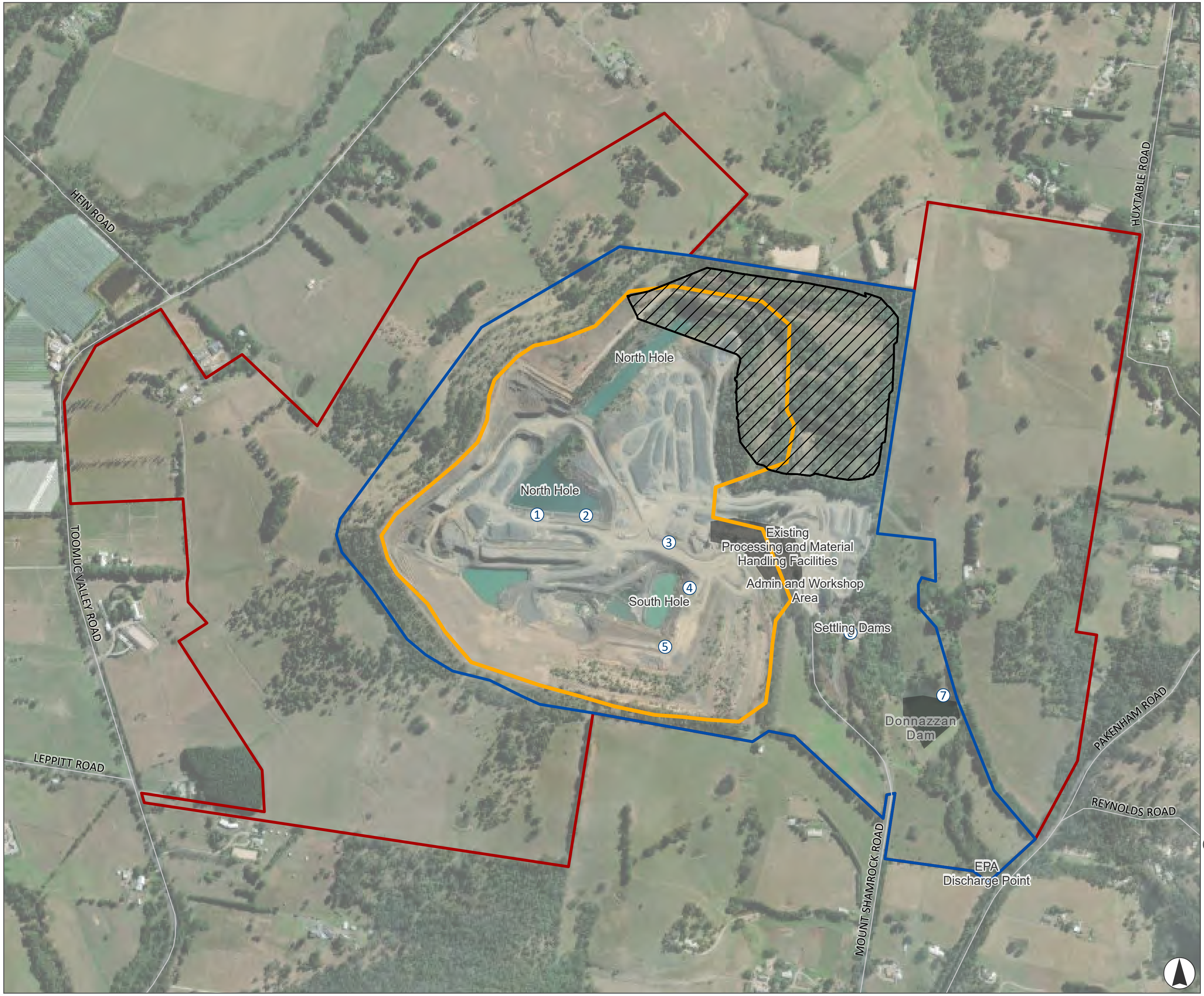
Scale 1:20,000 at A4

GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

FIGURE 3

Water Use and Water Management



Legend

- Roads
- Proposed Extension
- CurrentLimit Of Extraction
- WA174 Boundary
- Quarry Boundary

Meter Point

1. Standpipe (watercart)
2. North Hole Discharge (when needed)
3. Plant water Supply (North hole)
4. Plant Water Supply / Sprinklers / Watering (South hole)
5. South Hole Dishcharge
6. Wheel Wash Supply
7. Donnazons Dam Pump (farm supply)

0 0.2 0.4 0.6

Kilometres

Scale 1:12,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

umwelt

FIGURE 4

Monitoring Bore and Spring Locations

Legend

- Springs
- Roads
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

Monitoring Bores

- Operational
- Decomissioned

Monitoring Bores Formations

- MB01 - Werribee Formation
- MB04c - Older Volcanics
- MB02c - Werribee Formation
- MB05b - Older Volcanics
- MB03b - Werribee Formation
- MB06 - Older Volcanics
- MB07 - Older Volcanics

0 250 500

Metres

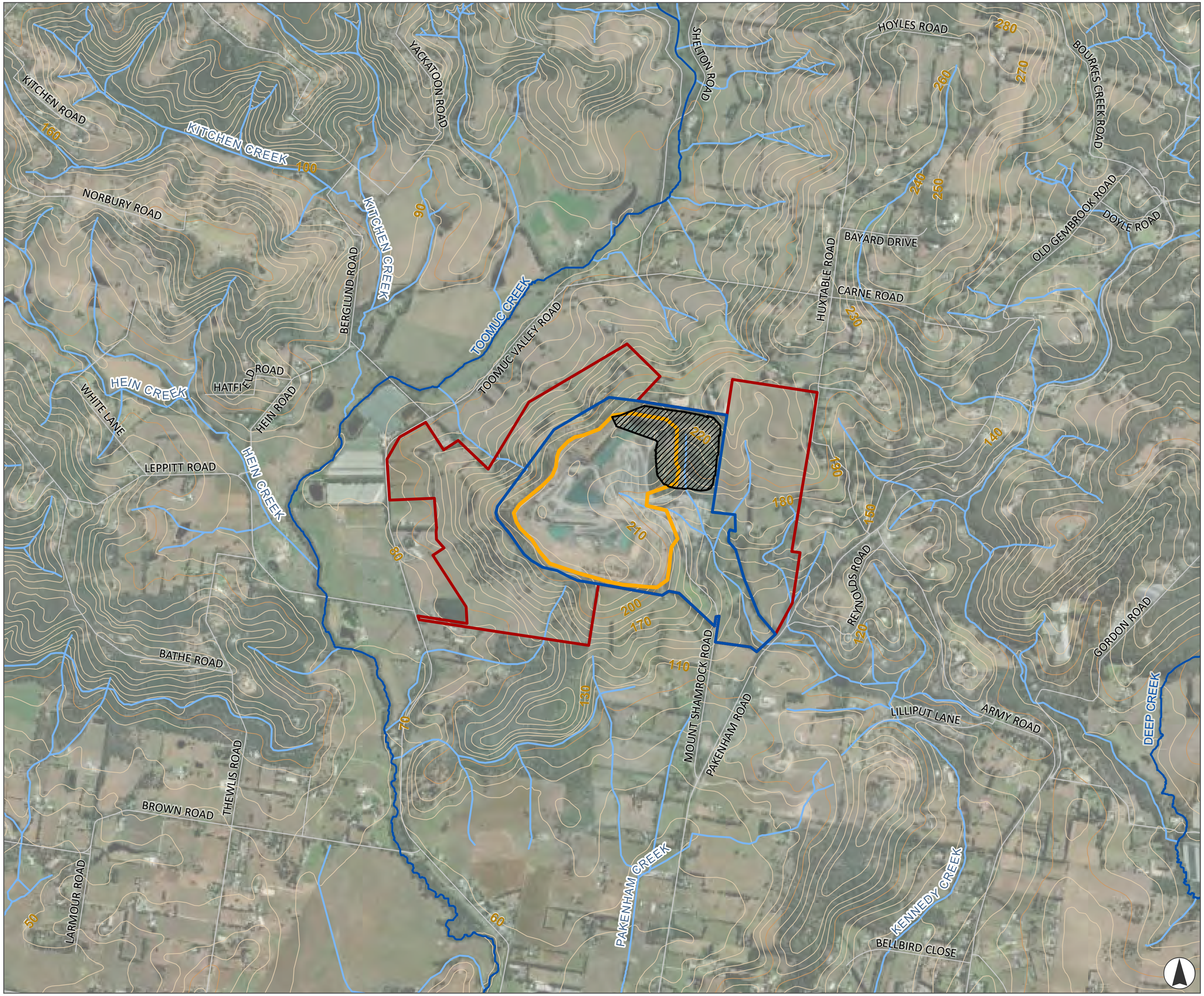
Scale 1:16,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

umwelt

FIGURE 5

Topography and Creeks



Legend

- Roads
- Watercourse
- Major Watercourse
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

Contour 10m

- Major Contour
- Minor Contour

0 0.2 0.4 0.6

Kilometres

Scale 1:30,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

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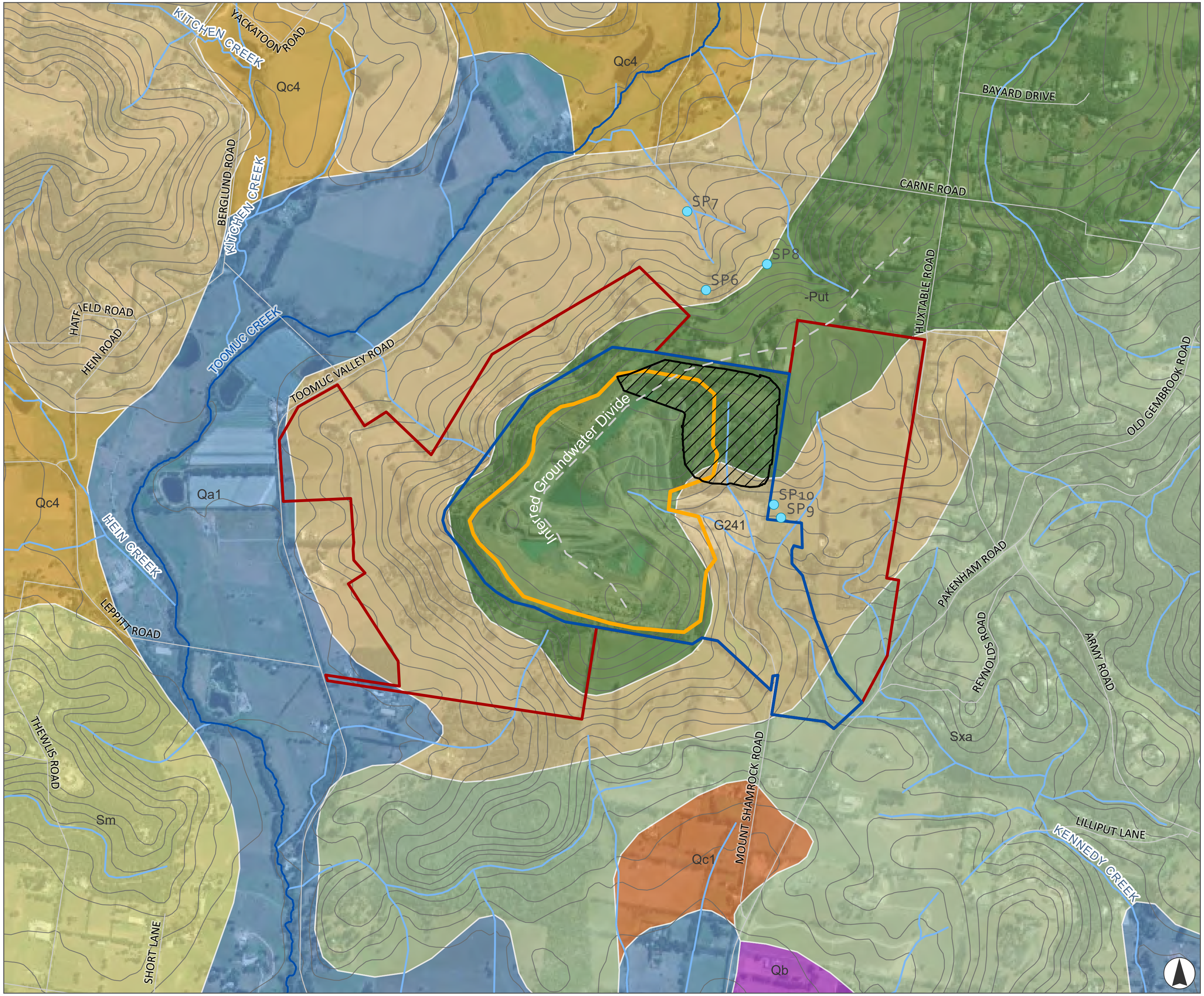
FIGURE 6

Geological Map



Legend

- Springs
- Inferred Groundwater Divide
- Roads
- Contour 10m
- Watercourse
- Major Watercourse
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

Geology

- alluvium and colluvium(Qb): generic
- alluvium(Qa1): generic
- colluvium(Qc1): generic
- granite-derived colluvium (Qc4): generic
- Thorpdale Volcanic Group (-Put): Generic
- Lysterfield Granodiorite (G241): generic
- Anderson Creek Formation(Sxa): hornfels
- Murrindindi Supergroup(Sm): hornfels

0 0.2 0.4 0.6
Kilometres

Scale 1:20,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

FIGURE 7

Registered Bores

Legend

- Registered Bores
- Roads
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

0 0.2 0.4 0.6

Kilometres

Scale 1:25,000 at A4

GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

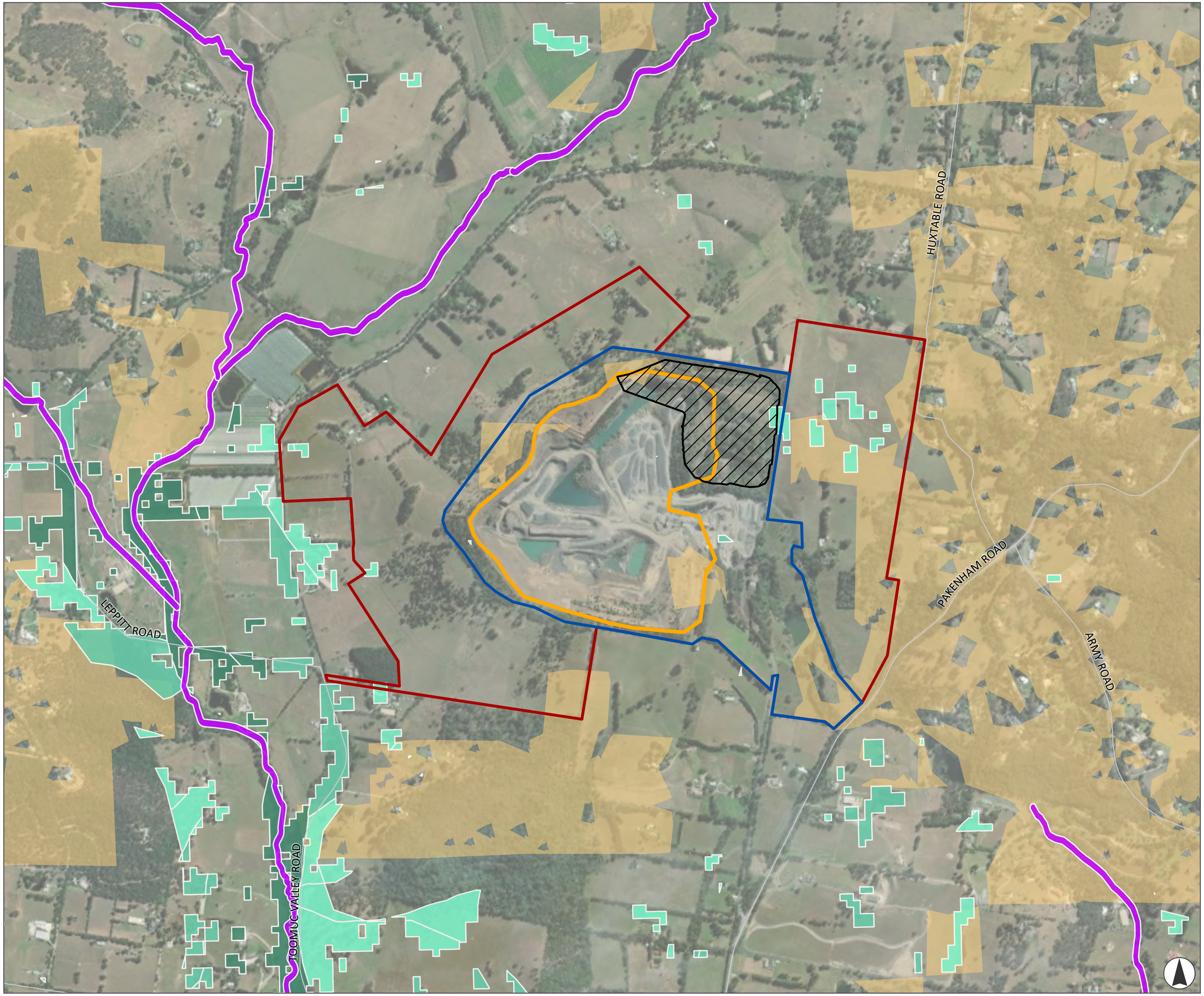


FIGURE 8

Potential Groundwater Dependent Ecosystems

Legend

- Proposed Extension
- Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land
- Potential Terrestrial GDE (DEECA)

Terrestrial GDE (BoM)

- High potential GDE - from national assessment
- Moderate potential GDE - from national assessment
- Low potential GDE - from national assessment

Potential Aquatic GDE (BoM)

- High potential GDE - from national assessment

0 0.2 0.4 0.6

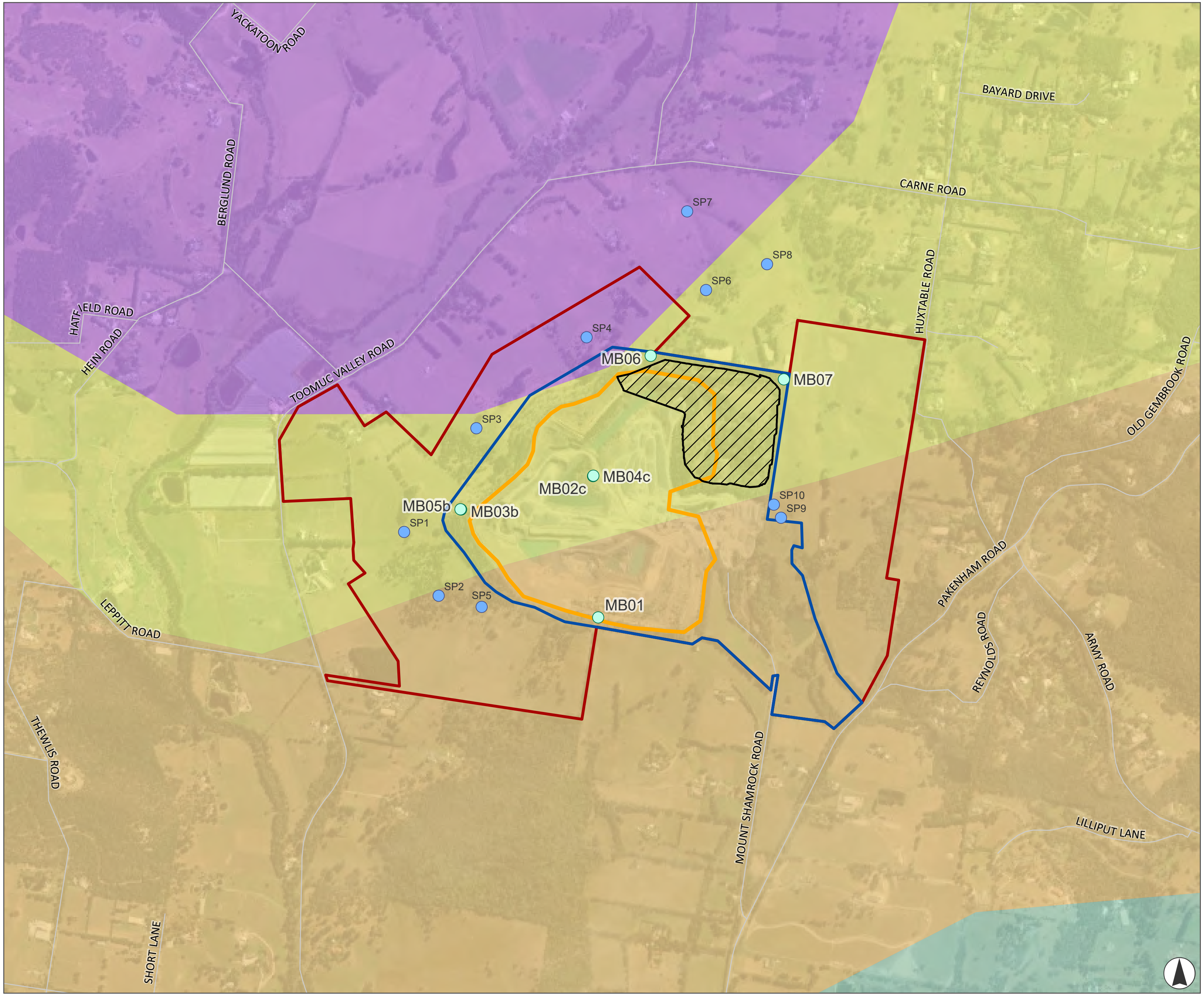
Kilometres

Scale 1:20,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

FIGURE 9

Groundwater Salinity



Legend

- Springs
- Roads
- Proposed Extension
- Current Limit Of Extraction
- WA174 Boundary
- Holcim Freehold Land

Monitoring Bores

- Operational

Watertable Salinity

- A1 (0 - 600)
- A2 (601 - 1200)
- B (1201 - (3100)
- C (3100 - 5400)

0 0.2 0.4 0.6

Kilometres

Scale 1:20,000 at A4
GDA 1994 MGA Zone 55

Image Source: ESRI Basemap (2023) | **Data Source:** Vic Government (2023)

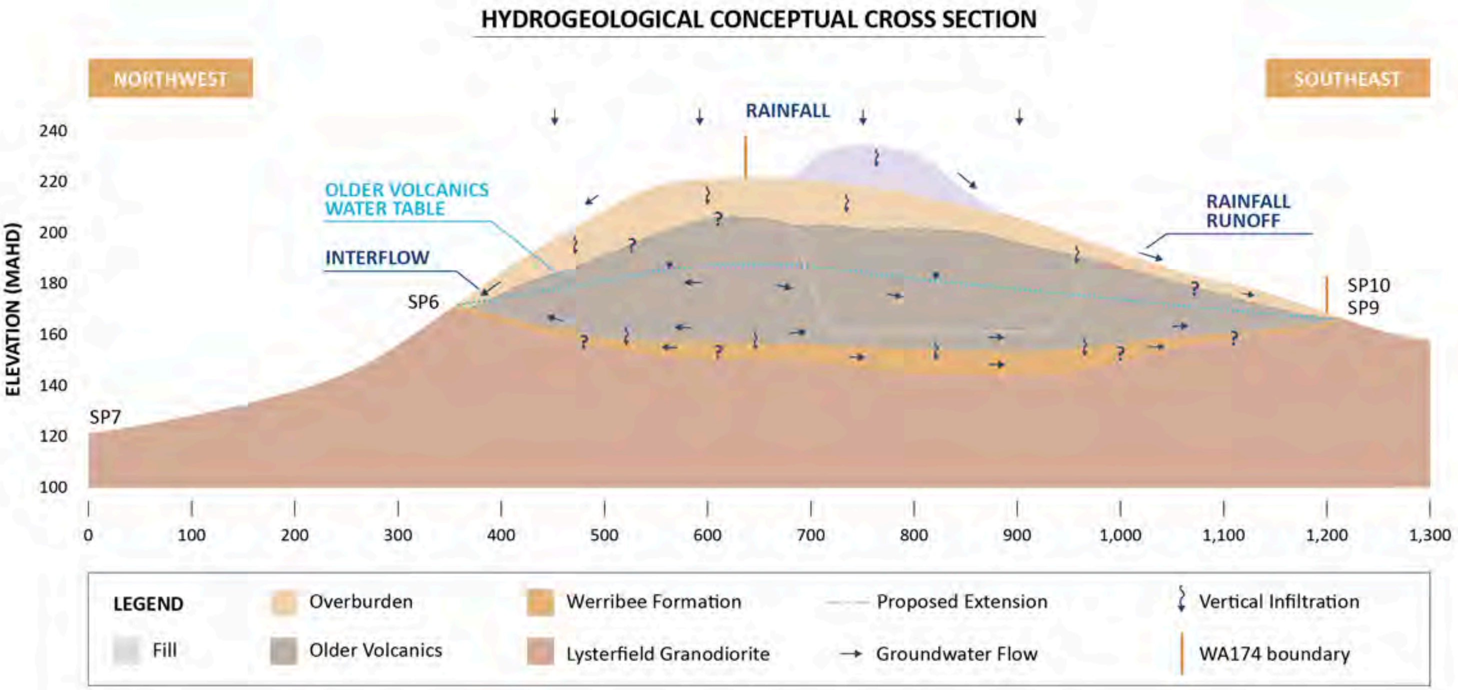
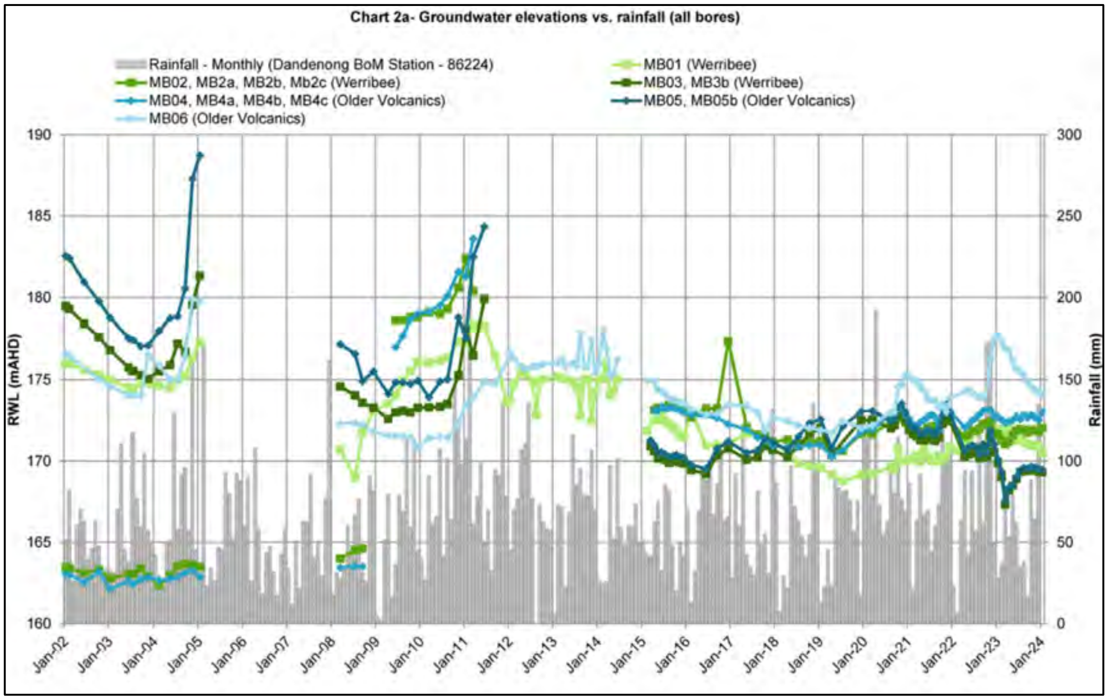
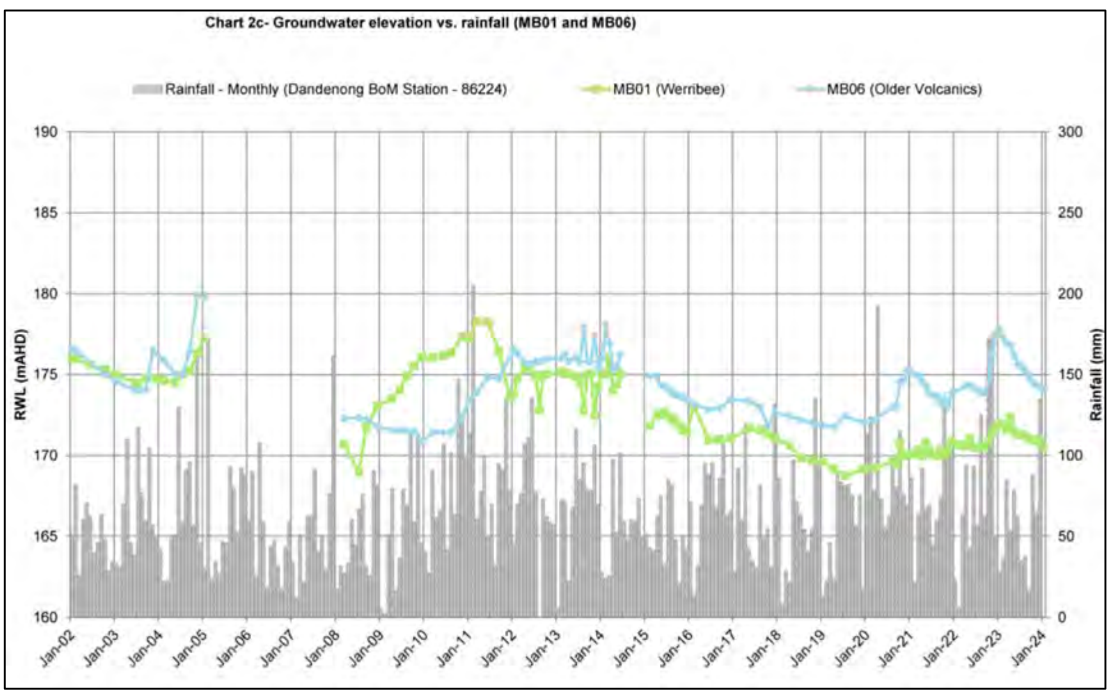

HYDROGEOLOGICAL CONCEPTUAL CROSS SECTION
NORTHWEST
SOUTHEAST
RAINFALL
OLDER VOLCANICS WATER TABLE
INTERFLOW
RAINFALL RUNOFF
SP6
SP7
SP10
SP9
ELEVATION (MAHD)
240
220
200
180
160
140
120
100
0
100
200
300
400
500
600
700
800
900
1,000
1,100
1,200
1,300
LEGEND
Fill
Overburden
Older Volcanics
Werribee Formation
Lysterfield Granodiorite
Proposed Extension
Groundwater Flow
Vertical Infiltration
WA174 boundary

FIGURE 10

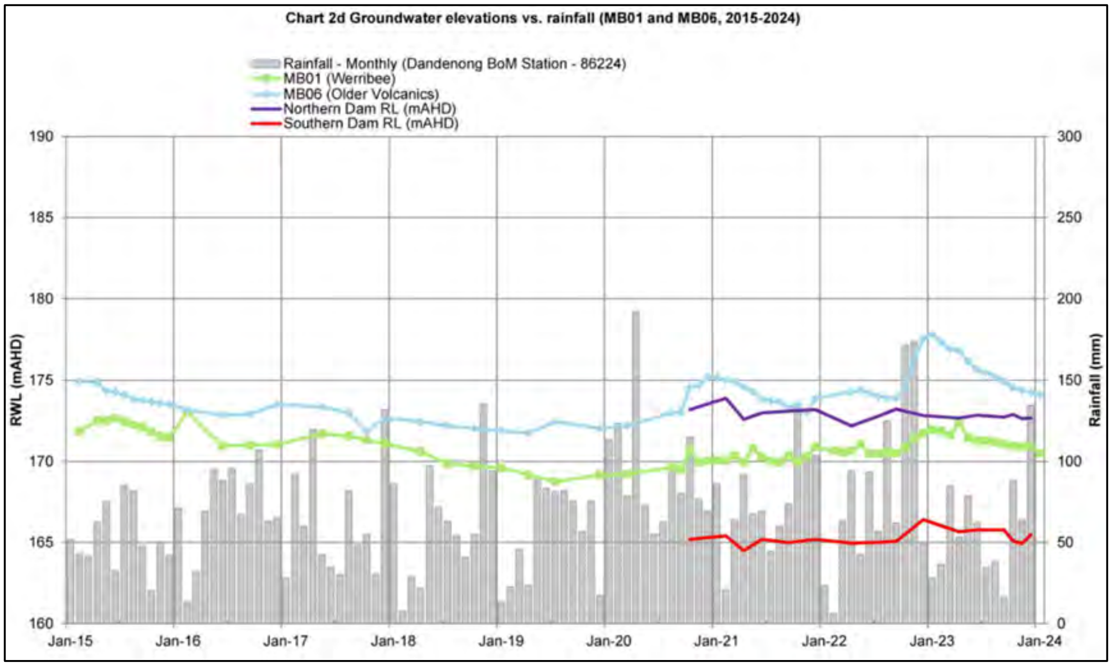
Appendix B – Selected Hydrographs



Sourced from 2023 Groundwater and Spring Review, Pakenham Quarry (AECOM, 2024b)



Sourced from 2023 Groundwater and Spring Review, Pakenham Quarry (AECOM, 2024b)



Sourced from 2023 Groundwater and Spring Review, Pakenham Quarry (AECOM, 2024b)

Appendix C – Extent of Drawdown Estimates

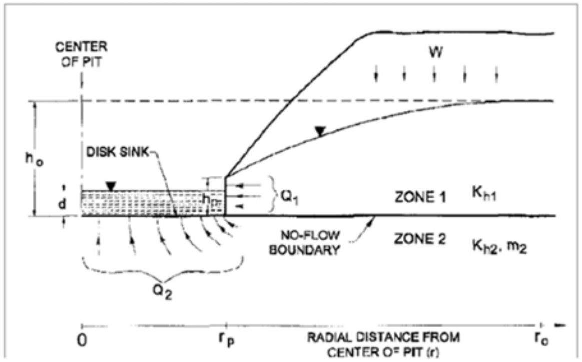
Marinelli Pit Flow Analytical Model

$$(1)\ h_o = \sqrt{h_p^2 + \frac{W}{K_{h1}}\left[r_o^2 \ln\left(\frac{r_o}{r_p}\right) - \frac{(r_o^2 - r_p^2)}{2}\right]}$$

$$(2)\ Q_1 = W\pi(r_o^2 - r_p^2)$$

$$Q_2 = 4 r_p \left(\frac{K_{h2}}{m_2}\right)(h_o - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$



Marinelli Analytical Model
Scenario 1: upper end hydraulic conductivity from literature values

Symbol	Value	Unit	Assumptions	Description
hp	0	m	Pit fully dewatered	Saturated thickness above pit base following dewatering (if pit fully dewatered = 0) (=d in equation below)
d	0	m	Pit lake depth	No seepage face where Hp = d
Kh1	36.5	m/year	K (Older Volcanics basalt)	Horizontal K in Zone 1 . Kh = 0.1 m/d
Kh2	73	m/year	K (Werribee Formation)	Horizontal K in Zone 2. Kh=0.2 m/d
Kv2	7.3	m/year	Kv=0.1*Kh (Werribee Formation)	Vertical K in Zone 2 = 10%Kh. Layered silty and sandy CLAYS of Werribee Formation
W	0.04	m/year	5% of annual rainfall	Areal average recharge. Annual rainfall taken as 800mm
rp	110	m	GIS estimation - assuming pit is circular	Approximate Pit radius.
r0	355	m	Iterative value to the nearest 10 metres	Radius of influence of dewatering (maximum extent of cone of depression)
m2	3.16	-		Anisotropy parameter
h0	9.97	m		Initial saturated thickness above pit base. SWL (172 mAHD) - Pit floor (162 mRL) = 10m
Q1	14316	m3/year		Pit inflow from Zone 1
Q2	101262	m3/year		Pit inflow from Zone 2
Total Q	**3.66**	**L/sec**		Total pit inflows

Marinelli Analytical Model
Scenario 2: lower end hydraulic conductivity from literature values

Symbol	Value	Unit	Assumptions	Description
hp	0	m	Pit fully dewatered	Saturated thickness above pit base following dewatering (if pit fully dewatered = 0) (=d in equation below)
d	0	m	Pit lake depth	No seepage face where Hp = d
Kh1	18.25	m/year	K (Older Volcanics basalt)	Horizontal K in Zone 1 . K = 0.05 m/day
Kh2	18.25	m/year	K (Werribee Formation)	Horizontal K in Zone 2. K = 0.05 m/day
Kv2	1.825	m/year	Kv=0.1*Kh (Werribee Formation)	Vertical K in Zone 2 = 10%Kh. Layered silty and sandy CLAYS of Werribee Formation
W	0.04	m/year	5% of annual rainfall	Areal average recharge. Annual rainfall taken as 800mm
rp	110	m	GIS estimation - assuming pit is circular	Approximate Pit radius.
r0	290	m	Iterative value to the nearest 10 metres	Radius of influence of dewatering (maximum extent of cone of depression)
m2	3.16	-		Anisotropy parameter
h0	9.99	m		Initial saturated thickness above pit base. SWL (172 mAHD) - Pit floor (162 mRL) = 10m
Q1	9048	m3/year		Pit inflow from Zone 1
Q2	25366	m3/year		Pit inflow from Zone 2
Total Q	**1.09**	**L/sec**		Total pit inflows

Marinelli Analytical Model
Scenario 3: lowest hydraulic conductivity from literature values

Symbol	Value	Unit	Assumptions	Description
hp	0	m	Pit fully dewatered	Saturated thickness above pit base following dewatering (if pit fully dewatered = 0) (=d in equation below)
d	0	m	Pit lake depth	No seepage face where Hp = d
Kh1	0.365	m/year	K (Older Volcanics basalt)	Horizontal K in Zone 1 . K = 0.05 m/day
Kh2	3.65	m/year	K (Werribee Formation)	Horizontal K in Zone 2. K = 0.05 m/day
Kv2	0.365	m/year	Kv=0.1*Kh (Werribee Formation)	Vertical K in Zone 2 = 10%Kh. Layered silty and sandy CLAYS of Werribee Formation
W	0.04	m/year	5% of annual rainfall	Areal average recharge. Annual rainfall taken as 800mm
rp	110	m	GIS estimation - assuming pit is circular	Approximate Pit radius.
r0	140	m	Iterative value to the nearest 10 metres	Radius of influence of dewatering (maximum extent of cone of depression)
m2	3.16	-		Anisotropy parameter
h0	10.35	m		Initial saturated thickness above pit base. SWL (172 mAHD) - Pit floor (162 mRL) = 10m
Q1	942	m3/year		Pit inflow from Zone 1
Q2	5254	m3/year		Pit inflow from Zone 2
Total Q	**0.20**	**L/sec**		Total pit inflows

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b) This report is dated 22 October 2024 and is based on information and conditions at the time of writing. MSH accepts no responsibility for any event arising from any changes in conditions or information reviewed that have occurred after completion of the report.
c) The report has been prepared in accordance with prudent practice and reference to appliable environmental regulatory authority and industry standards, guidelines, and assessment criteria in existence at the date of the report.
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