Hanson
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Appendix 13

Water Impact Assessment

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Brandy Hill Expansion Project

Environmental Impact Statement

Appendix 13 A

Surface Water Impact Assessment

Brandy Hill Expansion Project

Environmental Impact Statement

Hanson Construction Materials Pty Ltd

Surface Water Assessment:

Hanson's Brandy Hill Quarry Expansion

P1303888JR03V09
May 2016

ENVIRONMENTAL

WATER

WASTEWATER

GEOTECHNICAL

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All enquiries regarding this project are to be directed to the Project Manager.

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1 Introduction

1.1 Overview

This surface water assessment forms part of an Environmental Impact Study (EIS) submitted to the NSW Department of Planning and Environment (DoPE) to address Secretary's Environmental Assessment Requirements (SEARs) for the proposed expansion of Hanson's Brandy Hill Quarry, 979 Clarencetown Road, Seaham, NSW (SSD-5899).

This report should be read in conjunction with Martens and Associates Hydrogeological Assessment of the site (P1303888JR02V04, 2015a).

1.2 Scope

This assessment has been completed in order to satisfy the latest SEARs issued by NSW DoPE on November 11, 2014 relating to preparation of a surface water assessment, and has been updated based on recent DoPE correspondence. It shall:

- Describe existing site conditions and stormwater management system.
- Describe all elements of the proposed surface water management system.
- Provide system design and performance objectives and performance objectives for management elements where relevant.
- Provide sediment and erosion control plans to mitigate potential impacts.
- Assess licencing requirements of the proposed quarry.
- Assess water sources, demands and security for site operations and undertake a site water balance.
- Assess sensitivity of water balance outcomes to meteorological conditions.
- Outline water quality objectives and assess potential impacts.
- Assess flows to the receiving environment and potential impacts.

- Prepare a surface water monitoring plan for sensitive receivers including trigger values, monitoring regime and contingency response plan.

- Outline long term surface water management, auditing and reporting requirements.

1.3 Subject Site

The site is located at 979 Clarencetown Road, Seaham, NSW and comprises 22 individual lots owned by the Client within Port Stephens Shire Council. It has been used for extractive industry and processing of rhyodacite hard rock aggregate since 1983. The site occupies approximately 561 ha of which 18.6 ha is occupied by the quarry; 11.1 ha by the crushing plant; 5.3 ha by the aggregate stockpile area; and the remainder being bushland and cleared lands. The site layout and aerial is provided in Attachment A SK001.

Further details regarding site and surrounding conditions are provided in the project Preliminary Environmental Assessment (Hanson, 2012).

1.4 Proposed Development

Proposed final form development layout is shown overlaying recent site survey in Attachment A SK002. The proposed expansion works include:

1. Expansion of the currently approved extraction boundary of the quarry to extend the life of operations by approximately 30 years.

2. Extraction to a maximum depth of -78 mAHD.

3. Increased annual extraction limit to 1.5 Mt per annum.

4. Relocation of existing plant infrastructure and incorporation of a new concrete batching plant with a capacity of 15,000 m^3 per annum.

1.5 Proposed Extraction Staging

Site extraction operations are proposed to be completed in five stages. Extraction staging is summarised below and is shown in Attachment B:

- Stage 1: Increase extraction extents 140 m west and 160 m south of the existing pit and to a minimum depth of 22 mAHD. Construct concrete batching plant.

- Stage 2: Increase extraction extents 270 m south of the Stage 1 pit boundary (to the site southern boundary) and to a minimum depth of -8 mAHD.

- Stage 3: Increase extraction extents 280 m east of the Stage 2 pit boundary (along the site southern boundary) and to a minimum depth of -38 mAHD.

- Stage 4: Increase extraction extents 430 m east and 80 m south of the Stage 3 pit boundary and to a minimum depth of -58 mAHD. Relocate the site plant and stockpiling area.

- Stage 5: Increase extraction extents 100 m east and 140 m south of the Stage 4 pit boundary and to a minimum depth of -78 mAHD.

- Rehabilitation: The Stage 5 pit void will be filled by inflowing groundwater and surface water to a level of approximately 30 mAHD at which point it shall drain to downslope earth surface.

1.6 Agency Consultation

Consultation with the following agencies was undertaken in preparation of this document:

- NSW Department of Planning and Environment (DoPE)

- NSW Office of Water (NOW).

- NSW Environmental Protection Authority (EPA).

- NSW Office of Environment & Heritage (OEH).

- Hunter Water.

- Hunter Local Land Services (previously Hunter-Central Rivers Catchment Management Authority).

Details of correspondence are provided in Attachment I.

2 Site Description

2.1 Field Investigations

Field investigations were undertaken on 24th September, 2014 and included:

- Inspection of existing water cycle quarry infrastructure (plant, water cart, water storage reservoirs and discharge points).
- Inspection of surface water drainage and bund diversion system.

2.2 Lithology and Geology

2.2.1 Geological Mapping

Carboniferous rocks outcrop principally on the northern side of the Hunter River and are separated from the younger Coal Measure geology to the south by a fault system, known as the Hunter Thrust. The area is highly faulted and these faults cut off geological units abruptly.

The Newcastle Coalfields 1:100 000 geological map indicates the site is Cz – undifferentiated tuff and ignimbrite interbedded with conglomerate, sandstone and shale. The Newcastle 1:100 000 geological sheet indicates the site is Cup – acid lava flows, crystal tuff, interbedded conglomerate and ignimbrite.

2.2.2 Review of Brandy Hill Quarry Geology Investigations

Soils at ten site boreholes were up to 6 m deep comprising clays and sandy loams overlying weathered ignimbrite, sandstone or conglomerate. At boreholes within the quarry void ignimbrite is present at the surface and there is no soil overburden. Where rock overburden is present the weathered sandstone, conglomerate and mudstone layers range from 10 to 58 m deep. Isolated thin lenses of conglomerate, sandstone and granite are present within the ignimbrite rock mass. At the base of the ignimbrite bore holes intercepted either sandstone or mudstone belonging to the Mount Johnson Formation.

Quarried rock has been formerly described as a rhyodacite and comprises three colours; a cream weathered profile, a red-brown layer which is slightly weathered with the colour being due to the alteration of magnetic haematite, and grey fresh rock which lies at the base of the sequence. An examination of the petrology indicates that this is more akin to an ignimbrite in nature (Hanson, 2012). The ignimbrite is described as a hard rock and the specific gravity has been tested at 2.6 (Hanson, 2012).

Further details of geological investigations are given in the site Hydrogeological Assessment (P1303888JR02V04, 2015a).

2.3 Topography and Quarry Landform

The existing extraction pit collects stormwater from the disturbed portion of the site. The top bench of the existing pit represents the top of this catchment. Bunds direct stormwater runoff upslope of the pit north east to Deadmans Creek, west to an unnamed drainage path running to Barties Creek, and south east to the site western dam and through the site processing area. See Section 2.6 and Attachment A SK001 for further details on drainage lines.

The existing quarry pit is approximately 900 m long, 380 m wide and 70 m deep. The quarry has 6 benches and 2 rehabilitated former benches on the uppermost slopes which are no longer used for quarrying. Benches are typically east to south east facing and are stepped down on the mid to lower north-west slopes of Brandy Hill. Benches increase in length from upper to lower with the second last bench wrapping around the quarry to form an amphitheatre shape, with an opening to the east. The final drop cut to the currently approved extraction limit of 30 mAHD was made on 28th March 2014 and is currently being excavated.

The pit has elevations ranging from approximately 95 mAHD at the uppermost bench to 31 mAHD within the currently active base bench.

The crushing plant and stockpiling area is approximately 420 m long and 410 m wide. The plant is located on a mostly flat surface south of the quarry and haul road at approximately 33 to 37 mAHD. Aggregate stockpiles are located on three benches with elevations ranging from 32 to 45 mAHD. The plant area is separated from the quarry floor by a haul road up to 13 m above the quarry floor.

Natural ground levels at the site range from approximately 111 mAHD north-west of the quarry to approximately 32 mAHD south of the processing area.

2.4 Groundwater Levels

The location of site piezometers is shown in Attachment A SK001. A summary of groundwater level data is provided in Table 1 with a detailed description and assessment provided in Martens and Associate's Hydrogeological Assessment of the site.

Mean groundwater levels over the site range from 15.2 mAHD to 95.9 mAHD. Groundwater gradient is generally south east in the direction of Deadmans Creek and south in the direction of Barties Creek. The existing pit is considered likely to be currently exerting some influence on groundwater levels due to its level being below the prevailing regional water table level.

Table 1: Groundwater level monitoring results summary.

Borehole	Mean Groundwater Level	
	mBGL	mAHD
BH401A	2.122	38.878
BH401	1.737	39.893
BH400	33.660	37.100
BH1401	15.524	15.226
BH1403	2.665	27.685
BH1404	44.615	95.854
BH1405	14.707	30.993
BH1406	-0.474	37.274
BH1407	3.846	26.754

2.5 Water Quality

Site specific water quality sampling has been undertaken at site groundwater bores, site surface water bodies and in Deadman's Creek by VGT Environmental Compliance Solutions. 266 samples taken over the period 17 February, 2012 to 25 November, 2015 have been assessed, and the sampling regime is ongoing at the time of writing this report.

Statistical summaries of water salinity, total suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) for site groundwater monitoring bores, site surface water bodies and Deadmans Creek as recorded by VGT are provided in Table 2. Adopted trigger values are also provided in Table 2 to contextualise the observed data, and Table 3 has been provided to contextualise salinity data.

We note several samples were affected by temporary site operations which involved processing compost and biosolids for rehabilitation areas. This gave several outlying values of TN which are not considered representative of typical concentrations given the relatively short term nature of these site impacts. Outlying TN concentrations from these samples have hence been excluded from analysis.

Site groundwater salinity concentrations generally agree with available regional data, as discussed in the project Hydrogeological Assessment.

Table 2: Summarised water quality observations (period 17.12.12 to 25.11.15).

Water Medium	Statistic [1]	Salinity (mg/L) [2]	Total Suspended Solids (mg/L)	Total Nitrogen (µg/L) [3]	Total Phosphorus (µg/L) [4]
Site Groundwater	Minimum	166	(Not tested)	100	10
	Mean	1829	(Not tested)	653	30
	Maximum	5914	(Not tested)	2700	110
Site Surface Water	Minimum	106	1	700	50
	Mean	420	20	1340	52
	Maximum	1286	470	2700	60
Deadmans Creek	Minimum	51	1	600	50
	Mean	370	13	900	55
	Maximum	666	116	1200	60
	Trigger Criteria	(refer Table 3)	50 [5]	350 [6]	25 [6]

Notes:

[1] Values below the instrument practical quantification limit (PQL) are assumed to be at the PQL.

[2] Salinity data in mg/L converted from raw electrical conductivity measurements in µS/cm using a multiplication factor of 0.64 adopted from NSW Office of Environment & Heritage (OEH) website (2013).

[3] The instrument practical quantification limit (PQL) is 100 µg/L for total nitrogen. Several outliers are excluded from statistical analysis as discussed in Section 2.5.

[4] The instrument practical quantification limit (PQL) is 10 µg/L for total phosphorus in groundwater and 50 µg/L in surface water.

[5] Based on site Environmental Protection Licence (EPL) #1879 criteria, as discussed in Section 2.8 and given in Attachment H.[6] Trigger values for groundwater quality are unavailable. We have adopted the ANZECC (2000) trigger values for east flowing lowland coastal rivers assuming this is the likely surface water and groundwater discharge point.

Table 3: Summary of water uses on the basis of salinity.

Class	Salinity (mg/L)	Irrigation Suitability [1]	Suitable for Potable [2]
Fresh	< 1,000	500 – 1,000 can have detrimental effects on sensitive crops	0 – 600 good 600 – 900 fair 900 – 1,000 poor
Brackish	1,000 – 5,000	1,000 – 2,000 adverse effects on many crops, requiring careful management practices	1,000 – 1,200 poor > 1,200 unacceptable / unpalatable
Highly Brackish	5,000 – 15,000	2,000 – 5,000 can be used for salt tolerant plants on permeable soils with careful management practices	No
Saline	15,000 – 30,000	Not suitable	No
Sea Water	30,000 – 40,000	Not suitable	No

Notes:

[1] From NSW Department of Conservation and Land Management (1992).

[2] From Australian Drinking Water Guidelines (2011).

2.6 Drainage Lines and Surface Water Bodies

2.6.1 Drainage Lines

Three main drainage lines exist around Brandy Hill Quarry as shown in Attachment A SK001:

1. Deadmans Creek forms the northern and eastern boundaries of the quarry and drains to Williams River which flows to Hunter River.
2. The site drainage path to the south of the quarry drains to Deadmans Creek.
3. The various unnamed drainage paths to the south west of the quarry drain to Barties Creek which flows to Hunter River.

These drainage lines represent grassed depressions in topography. No channel or standing water was observed in the location of any of the drainage lines.

2.6.2 Surface Water Bodies

One storage dam and five sedimentation basins exist at the site and are shown in Attachment A SK001:

1. Storage dam

    a. Bunds currently divert surface water around the pit at the top of the catchment. Diverted surface water south of the pit flows to the western dam.

    b. The western dam is fed by surface water with no significant groundwater inflows.

    c. The approximate catchment area of the western dam is 13.0 ha.

    d. Site water is stored in the western dam for use in road, pit and plant dust suppression, product moisture conditioning, maintenance and vehicle washing.

    e. The western dam has a surface area of 1.12 ha and is estimated to be approximately 6 m deep based on the embankment height in the site survey (Attachment A SK002).

    f. Based on these parameters and the Farm Dams Assessment Guide (1999) the estimated capacity of the western dam is 27 ML.

2. Sedimentation basins

    a. The crushing plant, stockpile area and western dam overflows drain to sedimentation basin 1.

    b. Sedimentation basin 1 flows to sedimentation basin 2 and then polishing basin 3 for treatment via settlement.

    c. The haul roads and quarry void drain to the northern and eastern sedimentation basins.

    d. Sedimentation basins are fed by surface water with no significant groundwater inflows.

    e. Sedimentation basin surface areas are:

        i. Sedimentation basin 1 = 982 m^2.

        ii. Sedimentation basin 2 = 1,439 m^2.

iii. Polishing basin 3 = 1,529 m^2.

iv. Northern sedimentation basin = 1,244 m^2.

v. Eastern sedimentation basin = 1,387 m^2.

2.7 Existing Site Water Cycle Management

Water is recirculated from the three southern basins via mobile pump to the western dam. This ensures water levels are controlled; stormwater is intercepted and re-used; and uncontrolled 'overflow' discharge from polishing basin 3 is minimised.

Hanson notes that water in the western dam has always been available for site operations throughout the life of the quarry. Town water supply has not been required, and is not expected to be required in the future. The western dam water level typically gets low in summer but has not run dry during the 31 years of quarry operations.

Three pumps run from the western dam to supply a 30 kL water cart which is used for site dust suppression; product moisture conditioning; plant maintenance; and vehicle wash down.

2.8 Discharge Points and Criteria

The site Environmental Protection Licence (EPL) #1879 is given in Attachment H. Under the EPL there are currently three site licenced Discharge Points (DPs) as shown in Attachment A SK001:

1. DP1 – from polishing basin 3 into the unnamed drainage path running to Deadmans Creek.
2. DP2 – from the northern sedimentation basin pumped through the pit wall directly into Deadmans Creek.
3. DP3 – from the eastern sedimentation basin via gravity overflow over the pit wall.

EPL water quality criteria are:

- Total suspended solids (TSS) ≤ 50 mg/L
- Oil and grease non-visible
- Water pH 6.5 – 8.5

Hanson currently discharge water primarily from DP1 when it reaches a TSS concentration of 50 mg/L confirmed by lab testing undertaken by VGT Environmental Compliance Solutions. pH is also tested and visibility of oil and grease is noted. No chemical water treatment is used or required to achieve water quality targets.

Discharge quantities are currently unmetered. Discharges occur once a month on average from DP1, and only infrequently from DP2 and DP3.

Hanson have provided a number of self-notifications to NSW EPA after releases of water from DP1 with greater than 50 mg/L TSS has occurred in the last 12 months. These have occurred during heavy and extended rainfall events.

2.9 Existing Licensing

There are currently no surface water or groundwater access licences for the site. The only water licences on site apply to the nine groundwater monitoring bores and are covered by six licences.

3 Surface Water Management Plan

3.1 Outline

The following sections identify and describe elements of the proposed site surface water system, and provide design objectives and performance criteria where relevant. The surface water management plan for each stage of the proposed expansion is provided in Attachment B SK003 to SK005.

3.2 Clean Water Diversion System

Bunds currently divert surface water around the pit at the top of the catchment. This diversion of clean upslope water will continue with bunds reconfigured as needed, particularly through Stages 1 and 2. A bund will be introduced during the relocation of the plant processing and stockpile area (Stage 4) with bund reconfigurations detailed in Section 3.3.2.

Site rain falling within the pit catchment currently flows to the northern and eastern sedimentation basins. For each stage of extraction sedimentation dams shall, where practical, be constructed at the low point in the pit floor. Runoff shall be directed to these by surface grading and construction of drainage channels or earth mounds as required.

Attachment B provides catchments, dam and diversion system locations for each stage of extraction.

3.3 Sediment and Erosion Control

3.3.1 Potential Impacts

Potential impacts should runoff and sediment be not appropriately managed include:

- Soil loss and land disturbance.
- Degradation of vegetation and land ecological value downstream.
- Alteration of and damage to natural drainage channels and creeks.
- Increased sediment pollution in downstream stormwater.

- Increased salinity and clogging in waterways and surface water bodies.

- Soil degradation through nutrient decline, structural decline and the disturbance of acid sulfate soils.

- Reduced aesthetics of offsite bushland and waterways.

  (DLWC 2000, Landcom 2004)

In order to mitigate these potential impacts, bunds, sediment fences and sedimentation basins shall be installed to protect offsite land. Sediment and erosion control measures have been designed in accordance with:

- Landcom (2004), *Managing Urban Stormwater: Soils & Construction Handbook*

- Department of Environment & Climate Change NSW (2008), *Managing Urban Stormwater Soils & Construction Volume 2E Mines and Quarries*

- Department of Land and Water Conservation NSW (2000), *Soil & Landscape Issues in Environmental Impact Assessment*

3.3.2 Reconfigured Bunds

The existing bund upslope of the pit shall be reconfigured during Stages 1 and 2 along the north western quarry boundary to match enlarged quarry extents and ensure that all stormwater from disturbed portions of the site is contained within the pit. From Stage 3 onwards quarry extents will be enlarged downstream of the void and hence quarry walls and benches will contain stormwater from disturbed portions of the site. Once Stage 5 quarry operations cease the bund will be removed to enable surface water inflow as per the rehabilitation plan (refer to Section 3.10).

During the Stage 4 relocation of the plant processing and stockpile area, a bund will be constructed outside and downslope of the perimeter of the area. The bund will ensure runoff from disturbed portions of the processing area is directed to the plant sedimentation basin (see Section 3.3.4) and clean runoff from upslope is directed around the area. Once Stage 5 quarry operations cease the processing area will be regraded towards the quarry void, and the bund will be removed.

Bund extents for each stage are given in Attachment B.

The existing bund has proven effective in diverting upslope waters to the existing quarry pit, and we expect the reconfigured bund will similarly be reliable. Both bunds shall be removed after Stage 5 and therefore there will be no residual impacts.

3.3.3 Sediment Fences

Sediment fences shall also be installed at the bottom of the outside of the fill batter for new bunds to prevent offsite migration of sediment from the bund itself. The sediment fence shall be installed and maintained regularly in accordance with Landcom (2004) until the bund is vegetated. Sediment fence locations for each stage are given in Attachment B.

The sediment fence is a reliable and effective soil and erosion control measure, and will not cause any residual impacts after implementation and removal.

3.3.4 Sedimentation Basins

Sedimentation basins are proposed to be located within the pit floor to act as a sump and capture and treat stormwater and groundwater prior to reuse on site or discharge. Quarry benches and pit floor surface levels will be graded towards the sedimentation basins. Sedimentation basins will be located downstream of the processing and stockpiling area, this shall be relocated during Stage 4 of works. Refer to Attachment B for indicative sedimentation basin locations for each stage.

Sedimentation basins have been designed and sized in accordance with methods and principles outlined by Landcom (2004) and DECC (2008). 'Type F' basins are designed where site specific information is unavailable. Alternative 'Type C' basin designs are provided and would be appropriate where site sediment material is naturally settleable. Site evidence in the existing basins is that the site sediments are readily settleable.

Commonly adopted design criteria are:

- A volumetric runoff coefficient of 0.9 to account for high runoff from steep, well drained, unvegetated rock quarry faces.
- A basin length to width ratio of 3:1.
- Varying design depths based on available areas.

Adopted 'Type C' design criteria are:

- Able to treat water for up to and including the 1 year Average Recurrence Interval (ARI) design storm to account for a standard receiving environment.
- 1 year ARI design rainfalls varying by catchment area in accordance with Australian Rainfall and Runoff (1987).
- An area factor of 4100 s/m based on a default design particle of 0.02 mm.
- A settling zone depth of at least 0.6 m.
- A sediment storage zone of 25% of the settling zone capacity based on the low erosion hazard for the quarry.

Adopted 'Type F' design criteria are:

- A 5-day rainfall depth for settling zones to allow adequate time for fine material to settle.
- A 90th percentile design rainfall depth to account for a standard receiving environment and a period of disturbance exceeding 3 years.
- A 5-day 90th percentile design rainfall depth of 51.8 mm based on data from Newcastle (closest available reference location).
- A sediment storage zone of 50% of the settling zone capacity based on the low erosion hazard for the quarry.

Design criteria are based on providing a suitable residence time to achieve water quality performance criteria for suspended solids concentration of 50 mg/L or less prior to discharge.

Water for road and site dust suppression, product moisture conditioning and maintenance shall be preferentially sourced from sedimentation basins at all stages of quarry expansion. Further detail is provided in Section 3.5.2.

Sedimentation basin sizing changes at each stage of extraction operations due to the increasing pit catchment area. Minimum sedimentation basin design requirements for each development stage are summarised in Table 4 for 'Type C' basins and Table 5 for 'Type F' basins.

Sedimentation basins are considered effective soil and erosion control measures for quarries. Uncontrolled discharges will not occur due to the position of the basins in the pit floor and their elevation below quarry benches. After rehabilitation (refer to Section 3.7) the Stage 5 sedimentation basin will be submerged and will not cause residual impacts.

Table 4: 'Type C' sedimentation basin requirements.

Stage	Total Volume (ML)	Settling Volume (ML)	Storage Volume (ML)	Indicative Dimensions (m)	Surplus Water Discharge Point [1]
Production & Stockpile area (Stages 1-3)	4.9	3.9	1.0	108 x 36 x 1.3	DP1
Quarry (Stage 1)	6.0	4.8	1.2	72 x 24 x 3.5	DP2
Quarry (Stage 2)	8.6	6.9	1.7	86 x 29 x 3.5	DP2
Quarry (Stage 3)	9.6	7.6	1.9	90 x 30 x 3.5	DP1
Production & Stockpile area (Stages 4-5)	5.6	4.5	1.1	92 x 31 x 2.0	DP1 [2]
Quarry (Stage 4)	12.5	10.0	2.5	104 x 35 x 3.5	DP3
Quarry (Stage 5)	14.4	11.5	2.9	89 x 30 x 5.5	DP3

Notes:

[1] Surplus water is any remaining after reuse demands have been satisfied. Refer to Section 4 for site water balance and Section 3.6 for discharge details.

[2] DP1 is relocated during Stage 4 of works. Refer to Section 3.6.

Table 5: 'Type F' sedimentation basin requirements.

Stage	Total Volume (ML)	Settling Volume (ML)	Storage Volume (ML)	Indicative Dimensions (m)	Surplus Water Discharge Point [1]
Production & Stockpile area (Stages 1-3)	11.5	7.7	3.8	166 x 55 x 1.3	DP1
Quarry (Stage 1)	17.2	11.5	5.7	121 x 40 x 3.5	DP2
Quarry (Stage 2)	26.9	17.9	9.0	152 x 51 x 3.5	DP2
Quarry (Stage 3)	30.5	20.3	10.2	162 x 54 x 3.5	DP1
Production & Stockpile area (Stages 4-5)	13.3	8.9	4.4	141 x 47 x 2.0	DP1 [2]
Quarry (Stage 4)	42.6	28.4	14.2	191 x 64 x 3.5	DP3
Quarry (Stage 5)	50.9	33.9	17.0	167 x 56 x 5.5	DP3

Notes:

[1] Surplus water is any remaining after reuse demands have been satisfied. Refer to Section 4 for site water balance and Section 3.6 for discharge details.

[2] DP1 is relocated during Stage 4 of works. Refer to Section 3.6.

3.3.5 Existing Sedimentation Basins

Adequacy of existing sedimentation basins has been reviewed and compared to design specifications in Table 4 and Table 5. When assessing basin adequacy it has been assumed the average existing basin depth is 1.25 m, if this is found to be incorrect reanalysis may be required.

Existing sedimentation basins 1 and 2 and polishing basin 3 have a combined estimated volume of 4,938 m^3. Provided the sediment type for the site is 'Type C' the provided volume is adequate (Table 4 requires 4.9 ML for this basin). However, if sediment is 'Type F' (i.e. fine grained) then the existing basins would be inadequate.

Importantly, for the purposes of this assessment it is assumed that clean overflows from the western dam are directed to the outlet of polishing basin 3 and are not passed through sedimentation basins 1 and 2 and polishing basin 3. If this cannot be achieved larger basins shall be required.

3.4 Wastewater Management System

As the site is unsewered by Hunter Water's reticulated system an on-site effluent reuse system is required. The Wastewater Management

Assessment (Martens, 2015b) provides further detail on site wastewater requirements.

3.5 Water Storages

3.5.1 Western Dam (Existing)

The western dam is to be used as this site's primary water storage during Stages 1-2. It is supplied by catchment runoff as well as water from sedimentation basins following treatment.

During Stage 1 the quarry footprint expands into the western dam catchment area reducing it by 39% to 7.9 ha (from 13.0 ha). During Stage 2 the quarry expands further into the western dam catchment area reducing it by a further 13% to 6.2 ha. During Stage 3 the western dam is removed by the expanded quarry footprint.

3.5.2 Sedimentation Basins (Existing and Proposed)

As outlined in Sections 3.3.4 and 3.3.5 sedimentation basins (locations shown in Attachment B) have been sized and designed based on Landcom (2004) and DECC (2008) principles to achieve a water quality of TSS < 50 mg/L prior to discharge. Refer to Attachment B for indicative sedimentation basin locations for each stage.

During all stages, sedimentation basins in the quarry pit shall capture and treat surface water, store groundwater ingress, and store water to supply site operations.

Existing sedimentation basins are to be removed as follows:

- The northern sedimentation basin will be removed at Stage 1.
- The eastern sedimentation basin will be removed at Stage 4.
- Sedimentation basins 1 and 2 and polishing basin 3 will be offline for Stage 4 removed at Stage 5.

3.5.3 Treated Stormwater Storage

A treated stormwater storage dam will be constructed during Stage 3 and will be located adjacent to Stage 3 processing area. The storage dam will be relocated during Stage 4 and will be located adjacent to the Stage 4 plant sedimentation basin. It will store treated stormwater pumped from the existing Stage 3 sedimentation basins and the Stage 4 and 5 plant sedimentation basin. The storage dam will be preferentially used as a water source for process water and dust suppression and is to have a capacity of 8.9 ML. Refer to Attachment B for the indicative location. Detailed design to ensure a stable configuration is to be completed prior to construction of this dam.

3.5.4 Rainwater Tanks

Rainwater tanks are to be provided to capture runoff from roof areas and satisfy demands of site amenities and maintenance sheds, estimated at 1.6 kL/day. 5 – 10 kL rainwater tanks are to be provided for each site building/shed. Potable water is to be trucked in should rainwater tanks require 'topping up'.

3.6 Discharge Points and Criteria

The site will continue to operate under existing discharge conditions (EPL #1879, see Section 2.8 and Attachment H). Site discharge regime for excess waters is summarised in Section 6.5.

The reuse of water from sedimentation basins will reduce discharge volumes, with surplus waters discharged differently for each stage of development. Discharges will only occur if EPL conditions are met (i.e. TSS < 50 mg/L) and when all site water storage dams are at capacity.

Discharge regimes are shown in Attachment B, are summarised in Table 6 and are as follows:

- Stage 1: When the western dam is at capacity surplus waters from the pit basin will discharge to DP2. Surplus waters from the western dam shall bypass sedimentation basins 1 and 2 and polishing basin 3 and will discharge to DP1. Sedimentation basins 1 and 2 and polishing basin 3 shall continue to discharge to DP1 and the eastern sedimentation basin shall continue to discharge to DP3.

- Stage 2: When the western dam is at capacity surplus waters from the pit basin will discharge to DP2. All existing sedimentation basins will continue to discharge as per the Stage 1 regime.

- Stage 3: Surplus waters from the pit basin will discharge to DP1. Surplus waters from the storage dam, sedimentation basins 1 and 2 and polishing basin 3 shall discharge to DP1 and the eastern sedimentation basin shall continue to discharge to DP3.

- Stage 4: Surplus waters from the pit basin will discharge to DP3. The plant area sedimentation basin will discharge to the storage dam and thence DP1 (relocated to downstream of the storage dam).

- Stage 5: Surplus waters from the pit basin will discharge to DP3. The plant processing area's basin and the storage dam will continue to discharge to the relocated DP1 as in Stage 4.

Table 6: Discharge regimes for excess water for surface water bodies at each stage of works.

	Discharge Location [1]				
Stage	**Pit Sedimentation Basin**	**Plant Sedimentation Basin**	**Primary Storage Dam** [2]	**Southern Sedimentation Basins**	**Eastern Sedimentation Basin**
1	→ DP2	(Not constructed)	→ DP1	→ DP1	→ DP3
2	→ DP2	(Not constructed)	→ DP1	→ DP1	→ DP3
3	→ DP1	(Not constructed)	→ DP1	→ DP1	→ DP3
4	→ DP3	Storage dam → DP1 (relocated)	→ DP1 (relocated)	(Offline)	(Removed)
5	→ DP3	Storage dam → DP1 (relocated)	→ DP1 (relocated)	(Removed)	(Removed)

Notes:

[1] *Storage dam → DP1* means the water body first flows to the storage dam and then overflows to DP1.

[2] The primary storage dam is the western dam for Stages 1-2 and the storage dam for Stages 3-5.

The site EPL performance criteria for discharge waters (see Section 2.8 and Attachment H) shall remain unchanged. TSS, oil and grease, and pH will continue to be tested prior to any discharge to ensure water quality targets are met.

3.7 Water Transfers & Reuse

Water transfers are proposed during each development stage to maximise reuse and minimise risk of uncontrolled overflow. Water transfers and reuse are shown in Attachment B, are summarised in Table 7 and Table 8 and are as follows:

- Stage 1: Where capacity exists all transfers shall be to the western dam as the primary site storage. Treated water from sedimentation basins 1 and 2 and polishing basin 3 shall be preferentially transferred, followed by treated waters from the eastern sedimentation dam and the pit basin. Treated water from sedimentation basins 1 and 2 and polishing basin 3 shall be preferentially reused, followed by treated waters from the western dam then the pit basin.

- Stage 2: Where capacity exists all transfers shall be to the western dam as the primary site storage. Transfers and reuse priorities shall be as per the Stage 1 regime.

- Stage 3: Where capacity exists all transfers shall be to the new storage dam adjacent to the processing area as the primary site storage. Treated water from sedimentation basins 1 and 2 and polishing basin 3 shall be preferentially transferred, followed by treated waters from the eastern sedimentation dam. Treated water from sedimentation basins 1 and 2 and polishing basin 3 shall be preferentially reused, followed by treated waters from the storage dam then the pit basin.

- Stage 4: Where capacity exists all transfers shall be to the relocated storage dam adjacent to the plant sedimentation basin as the primary site storage. Treated water from the plant sedimentation basin shall be transferred. Treated water from the storage dam shall be preferentially reused, followed by treated waters from the pit basin.

- Stage 5: Where capacity exists all transfers shall be to the storage dam adjacent to the plant sedimentation basin as the primary site storage. Transfers and reuse priorities shall be as per the Stage 4 regime.

Table 7: Transfer priorities for site dams and basins at each stage of works.

	Transfer from Dam/Basin Priority				
Stage	Pit Sedimentation Basin	Plant Sedimentation Basin	Primary Storage Dam [1]	Southern Sedimentation Basins	Eastern Sedimentation Basin
1	2	(Not constructed)	No transfer	1	2
2	2	(Not constructed)	No transfer	1	2
3	No transfer	(Not constructed)	No transfer	1	2
4	No transfer	1	No transfer	(Offline)	(Removed)
5	No transfer	1	No transfer	(Removed)	(Removed)

Notes:

[1] The primary storage dam is the western dam for Stages 1-2 and the storage dam for Stages 3-5.

Table 8: Reuse priorities for site dams and basins at each stage of works.

	Reuse from Dam/Basin Priority				
Stage	Pit Sedimentation Basin	Plant Sedimentation Basin	Primary Storage Dam [1]	Southern Sedimentation Basins	Eastern Sedimentation Basin
1	3	(Not constructed)	2	1	1
2	3	(Not constructed)	2	1	1
3	3	(Not constructed)	2	1	1
4	3	1	2	(Offline)	(Removed)
5	3	1	2	(Removed)	(Removed)

Notes:

[1] The primary storage dam is the western dam for Stages 1-2 and the storage dam for Stages 3-5.

3.8 Basin Operation

To achieve the required level of performance, basins are to be managed as follows:

- Type C basins
  - Stormwater in the settling zone is to be dewatered where possible after a storm event.
  - Sediments removed for drying must be temporarily stored to ensure no downslope pollution occurs.
  - Dewater the pit sedimentation basin as needed to prevent outflow to operations bench.
- Type F basins
  - Stormwater in the settling zone is to be dewatered within 5 days of storm event's end if EPL targets have been met (i.e. TSS < 50 mg/L).
  - Flocculation may be required if EPL targets have not been met within 5 days.
  - Sediments removed for drying must be temporarily stored to ensure no downslope pollution occurs.
  - Dewater the pit sedimentation basin as needed to prevent outflow to operations bench.

3.9 Licencing Requirements

Sedimentation basins within the quarry floor will capture and treat contaminated runoff for recirculation for quarry operations. Surface runoff from stockpile and processing areas shall be directed to the plant sedimentation basin and be similarly recirculated. Neither of the sedimentation basins captures clean water via runoff or pumping. Site sedimentation basins are excluded from the harvestable rights dams capacity calculation and exempt from Water Management Act (2000) licencing in accordance with NSW Government Gazette 40 dated 31 March 2006 (pages 1628 to 1631).

Exemption status of site sedimentation basins has been confirmed by NOW (20.01.15, refer to Attachment I). Site operations should be undertaken in accordance with the soil erosion and control plans described in Section 3.3 and the rehabilitation plan described in Section 3.10 in order to maintain exemption status.

The only proposed surface water structures other than site sedimentation basins are the Stage 3-5 storage dam (8.9 ML) and the western dam (maximum 26.79 ML under existing conditions). These are below the site's maximum harvestable right dam capacity of 49.9 ML based on the NOW online calculator, and hence are also exempt from Water Management Act licencing.

Capture of surface water runoff within the quarry void is an authorised supply and is considered reliable (refer to Section 4 and Section 4.3.5 in particular). The proposed development is consistent with the Water Sharing Plan for the Hunter Unregulated Alluvial Water Sources (2009) as there is no licenced surface water take proposed.

3.10 Rehabilitation Areas Management

According to the project EIS (Hanson, 2015), on completion of quarrying activities the following works shall be undertaken:

- The quarry void will be naturally backfilled with water via direct rainfall, surface water runoff and groundwater infiltration to a level of approximately 30 mAHD.
- Quarry benches above 30 mAHD will be geotechnically stabilised, graded towards the void and revegetated with indigenous vegetation. This will occur progressively after completion of benches to ensure timely rehabilitation of disturbed areas.
- The infrastructure area will be regraded towards the void and revegetated, and a wetland may be constructed.

The site shall generally drain towards the backfilled quarry pit. Runoff from rehabilitated areas within the site is not anticipated to be a potential source of water pollution. All runoff will naturally be captured and detained within the pit, preventing any offsite migration of sediments.

4 Water Balance

4.1 Water Source & Supply Assessment – Average Rainfall Conditions

The project water balance assessment has adopted mean annual rainfall to determine long term water demand and supply balance. Mean annual rainfall is considered appropriate for long-term (i.e. average) water balance assessment with the sensitivity of the water balances assessed using extreme wet / dry conditions in Section 4.4.

4.1.1 Water Sources Overview

Water will be sourced from the following:

1. Surface runoff into the quarry pit.
2. Groundwater inflow into the pit.
3. Harvested roofwater.

4.1.2 Stormwater Flows

Pit stormwater inflows are calculated based on the quarry pit catchment area at each stage of expansion. Mean annual rainfall at Tocal (BOM station 061250) is 934 mm based on data from 1968 – 2013 sourced from Bureau of Meteorology. A runoff coefficient of 0.9 is adopted from DECC (2008) based on high runoff from steep, well drained, unvegetated rock quarry faces. Calculations are provided in Table 9.

The western dam will continue to receive stormwater inflows during Stages 1 and 2 before removal at Stage 3 (see Section 3.5.1 for further information). Western dam stormwater inflows are calculated similarly to pit inflows, except that the volumetric runoff coefficient of 0.2 is applied for the forested catchment area (Landcom, 2004). Calculations are provided in Table 10.

Table 9: Pit average stormwater inflow calculations.

Stage	Pit Catchment Area (ha) [1]	Pit Stormwater Inflow (ML/year) [2]
Stage 1	24.6	207.0
Stage 2	38.4	322.7
Stage 3	43.6	366.4
Stage 4	60.9	511.6
Stage 5	72.8	611.7

Notes:

[1] Refer to Attachment C for pit catchment areas.

[2] Calculated runoff = catchment area x rainfall (934 mm/yr) x runoff coefficient (0.9) / units conversion factor (100).

Table 10: Western dam average stormwater inflow calculations.

Stage	Western Dam Catchment Area (ha) [1]	Western Dam Stormwater Inflow (ML/year) [2]
Stage 1	7.9	14.8
Stage 2	6.2	11.6

Notes:

[1] Refer to Section 3.5.1.

[2] Calculated runoff = catchment area x rainfall (934 mm/yr) x runoff coefficient (0.2) / units conversion factor (100).

4.1.3 Groundwater Inflows

Groundwater inflows determined through modelling completed as part of the EIS (Martens and Associates, 2015a) for each stage of proposed works are summarised in Table 11. These inflow rates are used for this water balance assessment.

Table 11: Groundwater dewatering rates due to the quarry void.

	Dewatering Rate (ML/yr)		
Stage	**Minimum [1]**	**Maximum [1]**	**Average [2]**
Stage 1	103.0	172.0	137.5
Stage 2	172.0	315.1	243.6
Stage 3	315.1	423.7	369.4
Stage 4	423.7	515.7	469.7
Stage 5	515.7	642.2	578.9

Notes:

[1] Minimum and maximum dewatering rates for the given stage.

[2] Take as the mid-point of the minimum and maximum dewatering rates for the given stage.

4.1.4 Roofwater

The roof areas of all staff buildings (amenities, administrations, maintenance etc.) shall be connected to rainwater tanks (5 – 10 kL) to capture roofwater runoff for internal reuse. Current site buildings have a roof area of approximately 800 m^2. Assuming similar roof sizes for future operations, adopting a runoff coefficient of 0.8 for roof areas (percentage capable of capturing rainwater and allowance for splash and evaporative losses) and average annual rainfall of 934 mm, the average daily roof capture is 1.6 kL/day (800 m^2 x 0.8 x 934 mm/year / 365 days/year / 1000 mm/m). Roof water supply of approximately 1.6 kL/day is therefore assumed for all stages of quarry expansion, this assumes adequate roof water tanks are provided. Where required roofwater supplies shall be supplemented by water cart.

4.1.5 Quality of Water Supply

Salinity of water supply sources is considered when assessing their suitability to satisfy site demands (Section 4.2). This data is provided for comparison to irrigation and potable use suitability as summarised in Table 3.

Roofwater runoff is assumed to have a salinity concentration of 500 mg/L (i.e. fresh water), adopted based on upper bound (i.e. worst case) concentrations from sampling of over 150 roofs in eastern Sydney. This value is only provided to demonstrate that water quality will be suitable for staff amenities uses based on Table 3 threshold values. Any water supplied by water truck will similarly be fresh and suitable for all site uses.

During initial stages of operations, water collected for site use will be primarily stormwater runoff, groundwater contribution to overall site supply increases in later extraction stages. Stormwater is assumed to have a salinity concentration of 420 mg/L (i.e. fresh water) based on average of site monitoring (Table 2) and groundwater is assumed to have a salinity concentration of 1,800 mg/L (i.e. brackish water) based on average of site monitoring (Table 2). Resultant water used for site dust suppression, material conditioning and maintenance is likely to be brackish (approx. 1,000 mg/L) which is considered suitable for site operational uses.

4.1.6 Summary

Table 12 summarises water sources at the site during each extraction stage.

Table 12: Summary of water sources.

Stage 1		
Source	**Annual Volume (ML/yr)**	**Salinity (mg/L)**
Pit stormwater inflow	207	420
Western dam stormwater inflow	15	420
Groundwater [1]	138	1,800
Roofwater	0.6	500
Stage 2		
Source	**Annual Volume (ML/yr)**	**Salinity (mg/L)**
Pit stormwater inflow	323	420
Western dam stormwater inflow	12	420
Groundwater [1]	244	1,800
Roofwater	0.6	500
Stage 3		
Source	**Annual Volume (ML/yr)**	**Salinity (mg/L)**
Pit stormwater inflow	366	420
Groundwater [1]	369	1,800
Roofwater	0.6	500
Stage 4		
Source	**Annual Volume (ML/yr)**	**Salinity (mg/L)**
Pit stormwater inflow	512	420
Groundwater [1]	470	1,800
Roofwater	0.6	500
Stage 5		
Source	**Annual Volume (ML/yr)**	**Salinity (mg/L)**
Pit stormwater inflow	612	420
Groundwater [1]	579	1,800
Roofwater	0.6	500

Notes:

[1]. The average dewatering rate is adopted for the water balance assessment as given in Table 11.

4.2 Water Demands – Average Rainfall Conditions

4.2.1 Water Demands Overview

Water demands are from the following:

1. Site operations including:
    a. Production based demands (plant dust suppression, product moisture conditioning and maintenance).
    b. Site based demands (site dust suppression and vehicle / loader wash down).
    c. Concrete batching plant demands.
2. Evaporation loss from site water bodies.
3. Site amenities.

4.2.2 Site Operational Demands

Daily water usage and production volumes have been monitored by Hanson for twelve months (September 2014 – September 2015) and at the time of writing this report monitoring is ongoing. Data has been monitored over a year and captures seasonal demand variations. Site operations and management regimes during this period are typical of a year of production, and hence this data is considered appropriate for long-term (i.e. average) water balance assessment. Readings from three water meters from the western dam and production data is summarised in Table 13. Operational demands are separated into production based demands and site area based demands.

Water from meters 1958 and 1940 is used for plant dust suppression, product moisture conditioning and plant maintenance. This water usage is production based and is used to prepare the average production based water usage rate (see Table 13).

Water from meter 120610 is used for site dust suppression, vehicle exit/entry wash down and loader wash down. Individual uses cannot be isolated further based on the available data. The quarry supervisor has advised that gauged water from the western dam represents approximately 60% of these uses across the site, and the remaining 40% is from 'unmetered' sediment dams. The factor of 60% has therefore been adopted to 'scale up' gauged water usage from the western dam to represent total site based water usage. The majority of water usage from this meter is for dust suppression of active areas, and hence water usage from this meter is grouped and used to prepare the average site area based water usage rate (see Table 13).

Table 13: Summary of water usage and production volumes (September 2014 – September 2015).

Parameter	Units	Value
Monitoring period [1]	days	186
Meter 120610 water usage	m^3	25,584
Meter 1958 water usage	m^3	2,079
Meter 1940 water usage	m^3	4,752
Total water usage	m^3	32,415
Proportion of gauged water (meter 120610) to total site based water usage	%	60
Total product produced	t	557,612
Current site active area [2]	ha	29.8
Production based water usage rate [3]	m^3/t	0.0123
Site based water usage rate [4]	m^3/day	229.2
Site area based water usage rate [5]	$m^3/ha/day$	7.693

Note:

[1] Number of days over the monitoring period with valid water usage and production data.

[2] Estimated based on recent aerials and includes quarry and production/sales areas.

[3] Production based water usage rate calculated based on sum of Meter 1958 and Meter 1940 water usage divided by total product produced [(2079 m^3 + 4752 m^3) / 557,612 t = 0.0123 m^3/t].

[4] Site based water usage rate calculated based on Meter 120610 water usage divided by the number of days in the monitoring period divided by the proportion of gauged water to total site based water usage [25,584 m^3 / 186 days / 60% = 229.2 m^3/day].

[5] Site area based water usage rate calculated based on site based water usage rate divided by the current active site area [229.2 m^3/day / 29.8 ha = 7.693 $m^3/ha/day$].

This data has been reviewed by the quarry supervisor to confirm validity of usage rates. We note the following:

- The production based water usage rate is considered valid and is adopted for production demand analysis.
- Site area based usage rate:
    - The water cart used for site dust suppression has 50 m^3 capacity.

- During average rainfall conditions the filled water cart operates every 2 hours from 6am to 4pm, a total of 5 trips per day.

- On average the site based water usage rate is 250 m^3/day (50 m^3/trip x 5 trips/day). This agrees well with the monitored (scaled up) average site usage rate of 229.2 m^3/day (Table 13) and demonstrates that monitored data represents a typical year of site operations and management.

- The site based water usage rate of 250 m^3/day (or 8.389 m^3/ha/day based on the current site area) is therefore adopted for site demand analysis.

In addition, the client advises the proposed concrete batching plant will have a demand of 15 kL/day (5.5 ML/yr).

The adopted water usage rates are used to predict operational water demands for each stage of works. Table 14 summarises operational water demand input data and Table 15 summarises operational water demand calculations for each stage of expansion.

Table 14: Site operational water demand data.

Stage	Peak Production (Mt/yr)	Active Area (ha) [1]
Stage 1	1.5	41.4
Stage 2	1.5	36.8
Stage 3	1.5	32.8
Stage 4	1.5	42.6
Stage 5	1.5	35.7

Note:

[1] Includes pit active area, plant, stockpile and haul roads. Excludes inactive upper benches.

Table 15: Site operational water demand calculations.

Stage	Production Demand (ML/yr)	Site Demand (ML/yr)	Concrete Plant Demand (ML/yr)	Total Operational Demand (ML/yr)
Stage 1	18.4	126.8	5.5	150.6
Stage 2	18.4	112.7	5.5	136.5
Stage 3	18.4	100.4	5.5	124.3
Stage 4	18.4	130.4	5.5	154.3
Stage 5	18.4	109.3	5.5	133.2

4.2.3 Evaporation

Evaporation loss from standing water bodies is considered as part of the site water balance assessment. Evaporative losses are conservatively estimated based on 'Type F' sedimentation basin surface areas, and would reduce if 'Type C' basins are adopted. Evaporation will be a water 'loss' or demand from:

- Stage 1
  - Existing dams and basins: western dam, eastern basin, sedimentation basins 1 and 2, and polishing basin 3.
  - 17.2 ML design sedimentation basin in quarry floor.
- Stage 2
  - Existing dams and basins: western dam, eastern basin, sedimentation basins 1 and 2, and polishing basin 3.
  - 26.9 ML design sedimentation basin in quarry floor.
- Stage 3
  - Existing basins: eastern basin, sedimentation basins 1 and 2, and polishing basin 3.
  - 30.5 ML design sedimentation basin in quarry floor.
  - 8.9 ML treated water storage dam.

- Stage 4
    - Existing basins: sedimentation basins 1 and 2, and polishing basin 3.
    - 42.6 ML design sedimentation basin in quarry floor.
    - 13.3 ML plant area sedimentation basin.
    - 8.9 ML treated stormwater storage dam.
- Stage 5
    - 50.9 ML design sedimentation basin in quarry floor.
    - 13.3 ML plant area sedimentation basin.
    - 8.9 ML treated stormwater storage dam.

Evaporation loss from these water bodies is estimated in Table 16 for each stage of extraction based on above details and:

- A mean annual Class-A pan evaporation of 1559 mm at Tocal (BOM Station 061250, 1968 – 2013).
- A pan factor of 0.821 at Williamtown RAAF based on McMahon *et al.* (undated).

Table 16: Evaporation from water storages.

Stage	Total Water Body Surface Area (ha) [1]	Annual Evaporation (ML/yr) [2]
Stage 1	2.14	27.4
Stage 2	2.42	30.9
Stage 3	1.85	23.6
Stage 4	2.72	34.8
Stage 5	2.03	26.0

Note:

[1] Existing water body areas given in Section 2.6.2. Indicative dimensions for staged sedimentation basins are given in Section 3.3.4.

[2] Calculated evaporation = total water body surface area x evaporation (1559 mm/yr) x pan A open water body factor (0.821) / unit conversion factor (100).

4.2.4 Site Amenities

Projected employment for the proposed expanded quarry and concrete batching plant is 30 – 31 staff. Assuming a nominal staff water requirement of 50 L/person/day, the daily site amenities demand is 1.55 kL/day. This is proposed to be supplied via site rainwater tanks.

4.3 Water Balance Assessment – Average Rainfall Conditions

4.3.1 Overview

This assessment is based on the water sources (in Section 4.1) and water demands (in Section 4.2) using mean annual rainfall. Sensitivity analysis using extreme wet / dry conditions data is provided in Section 4.4.

4.3.2 Reuse Opportunities

Site stormwater runoff is to be collected and stored in sedimentation basins and recycled to meet operational requirements. This includes site dust suppression, moisture conditioning, maintenance, and vehicle/loader washing. Reuse of this water will reduce the volume and frequency of discharges from sedimentation basins. Refer to Section 3.7 for further information.

4.3.3 Staff Amenities

Staff amenities, administration building and maintenance sheds shall be supplied by harvested rainwater for internal uses. Where required the tank shall be supplemented with trucked in water. Given this system is a minor demand which requires no licensing it has been excluded from the wider water balance assessment.

4.3.4 Water Balance

Staged water balances are provided in Table 17 to Table 21 with a summary provided in Table 22. Water balance assessment shows that there is water supply surplus for all stages of the proposed development.

Site water balance, water reuse and discharge conditions are summarised in Attachment C.

Table 17: Stage 1 water balance.

Supply	Rate (ML/year)	Demand	Rate (ML/year)
Pit stormwater inflow	207.0	Production (plant dust suppression, moisture conditioning, maintenance)	18.4
Western dam stormwater inflow	14.8	Site (site dust suppression, vehicle/loader wash down)	126.8
Groundwater inflow [1]	137.5	Concrete plant	5.5
Total roof runoff [2]	0.6	Evaporation	27.4
		Staff amenities [2]	0.6
TOTALS (nearest ML)	360		179
BALANCE	**excess / (deficit)**		**181 ML**

Note:

[1] Inflow initially 103.0 ML/year at commencement of Stage 1 extraction, increasing to 172.0 ML/year at end of Stage 1. Average (mid-point of minimum and maximum inflow rates) adopted for water balance assessment.

[2] Where roof runoff is inadequate to supply site amenities demand water top up via truck may be required – therefore roof water is assumed to be 'balanced' in supply and demand columns.

Table 18: Stage 2 water balance.

Supply	Rate (ML/year)	Demand	Rate (ML/year)
Pit stormwater inflow	322.7	Production (plant dust suppression, moisture conditioning, maintenance)	18.4
Western dam stormwater inflow	11.6	Site (site dust suppression, vehicle/loader wash down)	112.7
Groundwater inflow [1]	243.6	Concrete plant	5.5
Total roof runoff [2]	0.6	Evaporation	30.9
		Staff amenities [2]	0.6
TOTALS (nearest ML)	578		168
BALANCE	**excess / (deficit)**		**410 ML**

Note:

[1] Inflow initially 172.0 ML/year at commencement of Stage 2 extraction, increasing to 315.1 ML/year at end of Stage 2. Average (mid-point of minimum and maximum inflow rates) adopted for water balance assessment.

[2] Where roof runoff is inadequate to supply site amenities demand water top up via truck may be required – therefore roof water is assumed to be 'balanced' in supply and demand columns.

Table 19: Stage 3 water balance.

Supply	Rate (ML/year)	Demand	Rate (ML/year)
Pit stormwater inflow	366.4	Production (plant dust suppression, moisture conditioning, maintenance)	18.4
Western dam stormwater inflow [1]	0.0	Site (site dust suppression, vehicle/loader wash down)	100.4
Groundwater inflow [2]	369.4	Concrete plant	5.5
Total roof runoff [3]	0.6	Evaporation	23.6
		Staff amenities [2]	0.6
TOTALS (nearest ML)	736		149
BALANCE	**excess / (deficit)**		**587 ML**

Note:

[1] The western dam is removed at Stage 3.

[2] Inflow initially 315.1 ML/year at commencement of Stage 3 extraction, increasing to 423.7 ML/year at end of Stage 3. Average (mid-point of minimum and maximum inflow rates) adopted for water balance assessment.

[3] Where roof runoff is inadequate to supply site amenities demand water top up via truck may be required – therefore roof water is assumed to be 'balanced' in supply and demand columns.

Table 20: Stage 4 water balance.

Supply	Rate (ML/year)	Demand	Rate (ML/year)
Pit stormwater inflow	511.6	Production (plant dust suppression, moisture conditioning, maintenance)	18.4
Western dam stormwater inflow [1]	0.0	Site (site dust suppression, vehicle/loader wash down)	130.4
Groundwater inflow [2]	469.7	Concrete plant	5.5
Total roof runoff [3]	0.6	Evaporation	34.8
		Staff amenities [2]	0.6
TOTALS (nearest ML)	982		190
BALANCE	**excess / (deficit)**		**792 ML**

Note:

[1] The western dam is removed at Stage 3.

[2] Inflow initially 423.7 ML/year at commencement of Stage 4 extraction, increasing to 515.7 ML/year at end of Stage 4. Average (mid-point of minimum and maximum inflow rates) adopted for water balance assessment.

[3] Where roof runoff is inadequate to supply site amenities demand water top up via truck may be required – therefore roof water is assumed to be 'balanced' in supply and demand columns.

Table 21: Stage 5 water balance.

Supply	Rate (ML/year)	Demand	Rate (ML/year)
Pit stormwater inflow	611.7	Production (plant dust suppression, moisture conditioning, maintenance)	18.4
Western dam stormwater inflow [1]	0.0	Site (site dust suppression, vehicle/loader wash down)	109.3
Groundwater inflow [2]	578.9	Concrete plant	5.5
Total roof runoff [3]	0.6	Evaporation	26.0
		Staff amenities [2]	0.6
TOTALS (nearest ML)	1191		160
BALANCE	**excess / (deficit)**		**1031 ML**

Note:

[1] The western dam is removed at Stage 3.

[2] Inflow initially 515.7 ML/year at commencement of Stage 5 extraction, increasing to 642.2 ML/year at end of Stage 5. Average (mid-point of minimum and maximum inflow rates) adopted for water balance assessment.

[3] Where roof runoff is inadequate to supply site amenities demand water top up via truck may be required – therefore roof water is assumed to be 'balanced' in supply and demand columns.

Table 22: All stages annual water balance summary.

Stage	Supply (ML/yr)	Demand (ML/yr)	Balance (ML/yr) excess / (deficit)
Stage 1	360	179	181
Stage 2	578	168	410
Stage 3	736	149	587
Stage 4	982	190	792
Stage 5	1191	160	1031

4.3.5 Surplus Water Management

Surplus water will be available during all stages of quarry development as shown in Table 22. All surplus waters from sedimentation basins shall be discharged via licensed site discharge points in accordance with the Surface Water Management Plan and site EPL #1879 (see Section 3.6).

Discharge will be timed based on rainfall and site requirements. Anticipated annual discharge volumes at each stage are summarised in Table 22. Site discharge flow regime is discussed at Section 6.5.

4.4 Water Balance Assessment – Extreme Dry / Wet Rainfall Conditions

4.4.1 Overview

In recent correspondence DoPE have requested sensitivity analysis be undertaken for water supply sources and water demands to assess water balance sensitivity and the possible range of water balance outcomes. We have undertaken water balance assessment based on extreme wet and dry rainfall conditions.

Extreme 'dry' rainfall conditions assessment has been undertaken based on the 95th percentile lowest annual rainfall depth on record at Tocal (BOM station 061250), which is 679 mm based on data from 1968 – 2013 sourced from Bureau of Meteorology.

Similarly, extreme 'wet' rainfall conditions assessment has been undertaken based on the 95th percentile highest annual rainfall depth on record at Tocal, which is 1235 mm.

4.4.2 Water Source & Supply Assessment

We note the following changed inputs to water supply calculations in Section 4.1:

- Pit and western dam stormwater inflow calculations have been updated based on the 95th percentile lowest / highest annual rainfall depths for dry / wet conditions respectively.
- Groundwater inflow rates:
  - The modelled annual pit dewatering rates were compared for uniform rainfall and annually varying rainfall assessments, as presented in Martens and Associate's Hydrogeological Assessment of the site.
  - The maximum variance between uniform and annually varying dewatering rates over the proposed quarry expansion was determined to be +/- 15% for any given year.
  - Groundwater inflow rates were therefore reduced by 15% for dry conditions (to 'reduce' supply) and increased by 15% for wet conditions (to 'increase' surplus). Thus the sensitivity analysis appropriately considers both variable surface water flows and possible groundwater inflow changes in response to rainfall.

- Roof runoff rates were assumed to be constant (i.e. 1.6 kL/day) as this is a very minor component of the water balance (<0.5% of total water supply in all stages) and any supply deficit will be topped up via truck deliveries.

All other water supply inputs remained constant.

4.4.3 Water Demands

We note the following changed inputs to water demand calculations in Section 4.2:

- Production demand rates:
    - Based on the daily water usage data (refer Section 4.2.2), the 95th percentile highest daily production demand was 0.0318 m^3/t, or approximately 2.6 times the average production demand. This is considered appropriate as plant dust suppression and moisture conditioning needs will increase in dry weather. The data was reviewed by the quarry supervisor and was confirmed as appropriate, and has therefore been adopted for production demand analysis for extreme dry conditions.
    - Based on advice from the quarry supervisor, on wet days there is no production based water usage demand. This matches the monitored daily water usage for 95th percentile lowest daily production demands (refer Section 4.2.2), and has therefore been adopted for production demand analysis for extreme wet conditions.
- Site demand rates:
    - Based on advice from the quarry supervisor, on extreme dry days site water usage (site dust suppression) is double the average rate determined in Section 4.2.2, i.e. 500 m^3/day or 16.8 m^3/ha/day based on the current active area. This is approximately 25% higher than the monitored (scaled up) 95th percentile highest site usage rate of 13.4 m^3/day based on the daily water usage data. The site area usage rate of 16.8 m^3/ha/day has therefore been adopted for site area demand analysis for extreme dry conditions, noting this is a conservative rate compared to site monitoring data.
    - Based on advice from the quarry supervisor, on extreme wet days there is no site based water usage demand for dust suppression, however water for vehicle/loader wash

down is still used. Based on the daily water usage data (refer Section 4.2.2), the 95th percentile lowest site usage rate is 4.0 m^3/day. This usage rate was reviewed by the quarry supervisor and was confirmed as valid for vehicle/loader wash down, and has therefore been adopted for site demand analysis for extreme wet conditions.

- Concrete batching plant, evaporation and staff amenities demands were assumed to be constant.

All other water demand inputs remained constant.

Importantly, we note that application of extreme daily production and site water usage rates over the course of an entire year is highly conservative as it ignores wet days in a dry year (where demands will be greatly reduced) and dry days in wet years where demand will be increased. Therefore, the sensitivity analysis completed provides conservative upper and lower bound values for the site water balance.

4.4.4 Water Balance Assessment

All stages water balance summary for 95th percentile dry conditions and 95th percentile wet conditions are provided in Table 23 and Table 24 respectively.

Table 23: All stages water balance summary for 95th percentile dry conditions.

Stage	Supply (ML/yr)	Demand (ML/yr)	Balance (ML/yr) excess / (deficit)
Stage 1	279	335	(56)
Stage 2	450	310	140
Stage 3	581	278	303
Stage 4	771	349	422
Stage 5	937	298	639

Table 24: All stages water balance summary for 95th percentile wet conditions.

Stage	Supply (ML/yr)	Demand (ML/yr)	Balance (ML/yr) excess / (deficit)
Stage 1	443	35	408
Stage 2	716	39	677
Stage 3	910	31	879
Stage 4	1217	43	1174
Stage 5	1475	34	1441

4.5 Water Balance Sensitivity Analysis

4.5.1 Water Balance Summary

Comparison of water balances for each stage for 95th percentile dry, average and 95th percentile wet conditions is provided in Table 25. These results represent the potential range of water balance outcomes for each stage of the development and demonstrate the sensitivity of water balance to meteorological conditions.

Table 25: All stages annual water balance summary for average, 95th percentile dry and 95th percentile wet conditions (ML/yr).

	Balance (ML/yr) – excess / (deficit)		
Stage	95th Percentile Dry Conditions	Average Conditions	95th Percentile Wet Conditions
Stage 1	(56)	181	408
Stage 2	140	410	677
Stage 3	303	587	879
Stage 4	422	792	1174
Stage 5	639	1031	1441

4.5.2 Water Security

The average annual water balance assessment demonstrated that all stages of the project have adequate water for operations and will have varying volume of surplus water. Analysis for the 95th percentile dry conditions estimates a Stage 1 water deficit of up to 56 ML/year. As mentioned previously, the extreme dry conditions production and site area based usage rates are likely overestimated as they involve extrapolation from daily usages to yearly usages, without consideration of any wet days in the 'dry' year. Review of data for 1968 (which had the lowest number of rainy days on record) indicated 75 rainy days which would have resulted in some reduction in overall site demand.

In addition, the conservative (25% higher than monitored) site area based water usage rate advised by the quarry supervisor was used for analysis. If instead the monitored 95th percentile highest site area based water usage rate is adopted, the Stage 1 water balance deficit would reduce to 4 ML/year.

We therefore conclude it improbable that Stage 1 will experience significant water deficit even in 95th percentile dry conditions. If water deficit is anticipated (prolonged drought conditions and low water storage levels) site management practices can be adapted to reduce water demands. In extreme conditions water may be required to be imported to supplement critical water demands or production rates may require reduction to reduce water demand.

4.5.3 Maximum Discharge

Under 95th percentile wet conditions there is potential for Stage 5 water surplus of up to 1441 ML/year, 40% higher than the average conditions surplus. Potential consequence of this discharge is discussed as part of the excess water discharge regime assessment (Section 6.5).

5 Water Quality Assessment

5.1 Overview

This water quality assessment determines effectiveness of proposed treatment measures in achieving adopted water quality objectives.

5.2 Water Quality Objectives

SEARs issued by NSW DoPE (November 11, 2014) require water discharging from the site to be assessed in accordance with community agreed environmental values and human uses endorsed by the NSW Government. According to DECCW (2006) the site lies within the Hunter River Catchment and the following water quality objectives for receiving waters apply:

- Aquatic Ecosystems: *Maintaining or improving the ecological condition of waterbodies and their riparian zones over the long term.*
- Visual Amenity: *Aesthetic qualities of waters.*
- Secondary Contact Recreation: *Maintaining or improving water quality for activities such as boating and wading, where there is a low probability of water being swallowed*.
- Primary Contact Recreation: *Maintaining or improving water quality for activities such as swimming in which there is a high probability of water being swallowed.*

These values are applied to the proposed development by adoption of a neutral or beneficial effect (NorBe) objective (i.e. post development runoff water quality is to be better than or equal to that of the pre development) for common pollutants (sediments, nitrogen and phosphorus). Impacts on surface water salinity are assessed based on Table 3 to ensure no significant decline in the resource value of Deadman's Creek.

5.3 Assessment Methodology

The following methodology has been adopted for water quality assessment:

- Water quality indicators assessed include total suspended solids (TSS), total phosphorus (TP), total nitrogen (TN) and salinity.

- Assessment compares water quality for existing conditions (i.e. pre development) and proposed Stage 5 conditions (i.e. post development). Stage 5 was adopted considering it would have the highest proportion of runoff and hence the most pollutants.

- Water discharged from the quarry is a combination of surface water runoff and groundwater inflows.

- Surface water contributions were determined through stormwater quality modelling (MUSIC) of flow and pollutant concentrations, and have been supplemented with salinity concentration data from site surface water monitoring (Section 5.4).

- Groundwater contributions were determined based on groundwater flows (modelled as part of Martens and Associate's Hydrogeological Assessment of the site) and based on monitored concentrations to evaluate pollutant groundwater concentrations from the site (Section 5.5).

- Resultant discharge water quality was assessed based on contributions from both surface water and groundwater (Section 5.6).

5.4 Surface Water Contributions

5.4.1 Overview

The Model for Urban Stormwater Improvement Conceptualisation (*MUSIC*, Version 6.1) developed by the CRC for Catchment Hydrology was utilised to evaluate pre and post development surface water flows and pollutants from the site.

Pre and post development MUSIC model layouts are provided in Attachment D.3 SK009.

5.4.2 Model Input Parameters

As catchment specific guidelines are unavailable and NSW guidelines do not consider quarries, modelling has been undertaken in accordance with Sydney Catchment Authority (SCA 2012), *Using MUSIC in Sydney's Drinking Water Catchment*. Input parameters for source and treatment nodes used in MUSIC modelling are consistent with this guideline. It is noted that the SCA adopts runoff quality conditions from a quarry equivalent to an unsealed road. This is likely to significantly overestimate the pollutant generated from the site.

5.4.3 Climate Data

The Bureau of Meteorology climate file from Tocal (BOM station 061250, data from 2001 – 2006) has been used in this study. Average monthly areal potential evapotranspiration (PET) was sourced from 'Climatic Atlas of Australia – Evapotranspiration' (Bureau of Meteorology, 2001).

5.4.4 Catchment Areas

Pre and post development catchment areas used in modelling are summarised in Table 26 and Table 27 respectively. MUSIC model layout is provided in Attachment D.3 SK009.

Table 26: Summary of pre development catchments used in MUSIC model.

Description	Area (ha)	Land Use	Adopted Pervious (%)	Adopted Impervious (%)
Quarry North	22.49	Quarry	90	10
Quarry South	16.54	Quarry	90	10
Forest Bypass	34.75	Forest	0	100
Forest West	11.88	Forest	0	100
Forest South	7.45	Forest	0	100
Sedimentation Basins	1.77	-	-	-
Total	94.88			

Table 27: Summary of post development catchments used in MUSIC model.

Description	Area (ha)	Land Use	Adopted Pervious (%)	Adopted Impervious (%)
Quarry	74.97	Quarry	90	10
Plant	18.98	Quarry	90	10
Sedimentation Basins	0.93	-	-	-
Total	94.88			

5.4.5 Event Mean Concentration Inputs

Event mean concentration (EMC) inputs were derived from Sydney Catchment Authority (2012), *Using MUSIC in Sydney's Drinking Water Catchment* and are summarised in Table 28.

Table 28: Adopted EMCs for source nodes.

		Base Flow (mg/L)		Storm Flow (mg/L)	
Land Use	**Parameter**	**Log (mean)**	**Log (stdev)**	**Log (mean)**	**Log (stdev)**
Quarry	TN	0.11	0.12	0.34	0.19
	TP	-0.85	0.19	-0.30	0.25
	TSS	1.20	0.17	3.00	0.32
Forest	TN	-0.52	0.13	-0.05	0.24
	TP	-1.52	0.13	-1.10	0.22
	TSS	0.78	0.13	1.60	0.20

5.4.6 Sedimentation Basins

Existing and proposed Stage 5 sedimentation basins was included in the MUSIC model. Proposed basins are operated as 'Type F' basins as discussed in Section 3.3.4. Parameters and assumptions for existing and proposed Stage 5 sedimentation basins are summarised in Table 29 and Table 30 respectively.

Table 29: Existing sedimentation basin parameters.

Description	Quarry Basins	Western Dam	Southern Basin	Comment
Low flow by-pass (m^3/s)	0	0	0	Nominal value
High flow by-pass (m^3/s)	100	100	100	Nominal value
Surface area (m^2)	2,631	11,161	3,950	Based on 2014 aerial survey
Extended Detention Depth (m)	15	0.1	0.1	Assumed minimal for farm style dams and large for quarry dams in pit floor
Permanent pool volume (m^3)	5,788	26,786	4,938	Calculated based on assumed average depth from site investigation
Initial Volume (m^3)	2,894	13,393	2,469	Assumed initially 50% full
Exfiltration Rate (mm/hr)	0	0	0	Assumed
Evaporative Loss as % of PET	75	75	75	SCA 2012 guidelines
Equivalent Pipe Diameter (mm)	50	150	150	Assumed equivalent outflow diameter
Overflow Weir Width (m)	20	4	4	Assumed from site investigation
Reuse (kL/yr)	0	71,704	18,000	Changed iteratively to maximise south sed. basin reuse, and western dam has balance of reuse based on all site operational demands determined in water balance
Number of CSTR cells	2	1	3	Basins grouped based on location
TSS exponential decay (m/yr)	15,000	15,000	15,000	SCA 2012 guidelines
TSS background concentration (mg/L)	90	90	90	SCA 2012 guidelines

Table 30: Proposed Stage 5 sedimentation basin parameters.

Description	Quarry Basin	Plant Basin	Storage Basin	Comment
Low flow by-pass (m^3/s)	0	0	0	Nominal value
High flow by-pass (m^3/s)	100	100	100	Nominal value
Surface area (m^2)	9,256	6,644	4,429	By design
Extended Detention Depth (m)	50	0.1	0.1	Assumed minimal for farm style dams and large for quarry dams in pit floor
Permanent pool volume (m^3)	50,909	13,287	8,858	By design
Initial Volume (m^3)	25,454	6,644	4,429	Assumed initially 50% full
Exfiltration Rate (mm/hr)	0	0	0	Assumed
Evaporative Loss as % of PET	75	75	75	SCA 2012 guidelines
Equivalent Pipe Diameter (mm)	50	150	150	Assumed equivalent outflow diameter
Overflow Weir Width (m)	444	376	307	By design
Reuse (kL/yr)	91,667	33,000	8,500	Changed iteratively to maximise plant and storage basin reuse, and quarry basin has balance of reuse based on all site operational demands determined in water balance
Number of CSTR cells	1	1	1	No basin grouping
TSS exponential decay (m/yr)	15,000	15,000	15,000	SCA 2012 guidelines
TSS background concentration (mg/L)	90	90	90	SCA 2012 guidelines

5.4.7 Results

MUSIC outputs for surface water flow and concentrations are summarised in Attachment D.1 and are used as inputs for the flow weighted average assessment for pollutants.

As MUSIC does not account for salinity concentration, flow data from the average conditions water balance (Section 4.3) was used with mean surface water salinity concentration as summarised in Table 2 to provide inputs to the flow weighted average assessment. Inputs and calculation details for the flow weighted average assessment for salinity are summarised in Attachment D.2.

5.5 Groundwater Contributions

Groundwater flows for existing and Stage 5 conditions are taken from modelling in Martens and Associate's Hydrogeological Assessment of the site. Groundwater pollutant concentrations are as per water quality monitoring data as summarised in Table 2. Inputs and calculation details for the flow weighted average assessment are summarised in Attachment D.1 for pollutants and Attachment D.2 for salinity.

5.6 Flow Weighted Average Assessment

Summary of flow weighted average concentrations for existing and proposed Stage 5 conditions is provided in Table 31. Results show concentrations are decreased for TSS, TP and TN, but are slightly increased for salinity. Water quality impact assessment based on these results is discussed in Section 7.2.

We note that flow weighted existing concentrations of TSS and TP are higher than monitored site water concentrations, and resultant TSS concentration is greater than the EPL criteria of 50 mg/L. This would suggest that flow weighted average concentrations have been overpredicted by MUSIC modelling (as groundwater concentrations based on the monitoring data have been adopted). This is likely due to the high EMC concentrations suggested by SCA (2012), which assume the quarry is managed as an unsealed road. In reality EMCs will likely be less due to the nature of the site (numerous exposed rock benches) and site management practices to reduce and control pollutant generation. Calibration of EMCs to site water quality is outside the scope of this assessment and considered unnecessary as, even with the conservative EMCs, water quality objectives are still achieved.

Table 31: Flow weighted average pollutant and salinity assessment results.

	Concentration (mg/L)		Difference		
Pollutant	**Existing**	**Stage 5**	**(mg/L)**	**(%)**	**Meets Objective? (Y/N)**
Total Suspended Solids	72.3	51.0	-21.3	-29%	Y
Total Phosphorus	0.094	0.073	-0.020	-22%	Y
Total Nitrogen	1.110	1.006	-0.104	-9%	Y
Salinity	937	1105	168	18%	(see Section 7.2)

6 Stormwater Quantity Assessment

6.1 Overview

The water balance assessment (Section 4.3 and Section 4.4) has identified that there will likely be excess water requiring discharge from the site during all stages. A stormwater quantity assessment has been undertaken to assess the channel forming discharge flow rate in the receiving natural watercourse (Deadmans Creek) to inform the site excess water discharge regime's design and to allow assessment of the potential for geomorphic impacts.

6.2 Methodology

Channel forming discharge is the 1 in 2 year Average Recurrence Interval (ARI) peak flow rate (U.S. Army Corps of Engineers, 1994). Flow rates below this threshold are unlikely to result in geomorphic impacts to natural channels which Deadman's Creek is.

Deadmans Creek receives all site discharges, and hence the geomorphic impact assessment has been undertaken for that catchment. The DRAINS software package (version 2015.11 – 16 October, 2015) was used with the RATFS hydrological engine to assess the 1 in 2 year ARI peak flow rates for a range of storm durations between 2 hours and 72 hours to determine the maximum channel forming discharge flow rate.

6.3 Modelling Set-up

Parameters used in the DRAINS model are provided in Table 32. Modelling assumptions derive from the following sources:

- Catchment delineation, slopes and flow paths for Deadmans Creek were developed using LIDAR data provided by Land and Property Information NSW (LPI 2013). Catchment assessed is upstream of site discharge point 2 (DP2, the upstream most site discharge point) which represents the smallest catchment area and hence smallest receiving environment flow rate for comparison to discharge flow rates. Refer to Attachment E for Deadmans Creek catchment plan.

- Catchment impervious area was assumed to be 0% based on recent site aerials obtained from LPI (2015) *SIX Maps Viewer*.

- RAFTS parameters and catchment roughness coefficients were based on suggested values in the XP-RAFTS (1996) *User's Manual* for similar catchments.
    - The roughness coefficient for forested catchments (0.100) was adopted based on LPI (2015) *SIX Maps Viewer*.
    - Catchment surface soils are assumed to be sandy clay loams based on the frequency of occurrence as shown on the NSW Government Environment & Heritage (2015) *eSPADE – NSW Soil and Land Information* website.
- Intensity Frequency Duration (IFD) coefficients were based on the Bureau of Meteorology (BOM 2015) *Rainfall IFD Data System* and are given in Attachment F.

Table 32: Catchment, rainfall and RAFTS parameters used in DRAINS modelling.

Parameter	Element	Value
Catchment data	Deadmans Creek Catchment Area (ha) [1]	166.8
	Catchment Slope (%) [1]	3.8
	Impervious (%) [2]	0.0
	PERN Roughness Coefficient [3]	0.100
IFD data [4]	2year 1hour Rainfall Intensity (mm/h)	30.1
	2year 12hour Rainfall Intensity (mm/h)	6.96
	2year 72hour Rainfall Intensity (mm/h)	2.28
	50year 1hour Rainfall Intensity (mm/h)	60.5
	50year 12hour Rainfall Intensity (mm/h)	14.2
	50year 72hour Rainfall Intensity (mm/h)	5.03
	G	0.05
	F2	4.32
	F50	15.98
	Antecedent Moisture Condition [5]	3
RAFTS parameters [6]	Initial Loss – Impervious Areas (mm)	1.5
	Continuing Loss – Impervious Areas (mm/h)	0.0
	Initial Loss – Pervious Areas (mm)	12.5
	Continuing Loss – Pervious Areas (mm/h)	5.0
	Storage Routing Parameter (Bx) [5]	1.0

Note:

[1] Obtained based on LIDAR data provided by LPI (2013). Refer to Attachment E for Deadmans Creek catchment plan.

[2] Adopted based on LPI (2015) SIX Maps Viewer aerials.

[3] Adopted based on forested land use as per LPI NSW (2015) SIX Maps Viewer aerials and based on XP-RAFTS (1996) User's Manual.

[4] Obtained based on Bureau of Meteorology (BOM 2015) Rainfall IFD Data System (Attachment F).

[5] Assumed based on typical values for similar catchments.

[6] Obtained from the XP-RAFTS (1996) User's Manual assuming catchment surface soils are sandy clay loams based on NSW Government Environment & Heritage (2015) eSPADE – NSW Soil and Land Information.

6.4 Results

Results of peak flow rates in Deadmans Creek for the 1 in 2 year ARI storms are summarised in Table 33. The critical 1 in 2 year ARI storm duration was determined to be 9 hours, and the channel forming discharge flow rate was determined to be 3.45 m^3/s, or 3,450 L/s.

Table 33: Peak flow rates estimated by DRAINS modelling for Deadmans Creek upstream of discharge point 2 (DP2).

1 in 2 year ARI Storm Duration	Deadmans Creek Peak Flow Rate (m³/s)
2hr	1.97
3hr	2.35
4.5hr	2.60
6hr	2.90
9hr	3.45 (channel forming discharge)
12hr	3.14
18hr	2.50
24hr	3.14
30hr	2.49
36hr	2.88
48hr	3.32
72hr	2.20

6.5 Excess Water Discharge Regime

Table 25 summarises water balances for each stage and for 95th percentile dry, average and 95th percentile wet conditions. Table 34 converts these flow rates from ML/yr to L/s assuming excess water is constantly discharged over the course of a year.

Table 34: All stages annual water balance summary for average, 95th percentile dry and 95th percentile wet conditions (L/s).

	Balance (L/s) – excess / (deficit)		
Stage	95th Percentile Dry Conditions	Average Conditions	95th Percentile Wet Conditions
Stage 1	(1.8)	5.7	12.9
Stage 2	4.4	13.0	21.5
Stage 3	9.6	18.6	27.9
Stage 4	13.4	25.1	37.2
Stage 5	20.3	32.7	45.7

The maximum average conditions discharge during all stages of the development occurs during Stage 5 and is 1,031 ML/yr, or 32.7 L/s if discharged constantly. The extreme wet / dry conditions assessments show Stage 5 discharge could vary between 639 ML/yr and 1,441 ML/yr, or 20 – 46 L/s on average.

We recommend site discharges only occur on wet days to emulate existing natural flows of receiving waters. There are on average 128 wet days/year based on daily rainfall data from 1967 – 2015 at Tocal (BOM station 061250). The lowest amount of wet days/year on record is 75 days in 1968.

If excess waters are only discharged on wet days for 24 hours a day then the Stage 5 average flow rate would be 93 L/s (over 24 hours). The flow rates for 95th percentile dry and wet years is 58 L/s and 130 L/s (over 24 hours) respectively. These flow rates represent < 5% of the channel forming discharge, and will only occur during Stage 5, as all other stages have less excess water.

Further, if excess waters are only discharged on wet days based on the lowest number of wet days (75) per year on record, the Stage 5 average flow rate would be 160 L/s (over 24 hours). Equivalent 95th percentile dry and wet year flow rates would be 99 L/s and 223 L/s. These flow rates represent < 7% of the channel forming discharge flow rate.

Adoption of this regime for excess waters gives discharge rates which are significantly lower than the channel forming discharge flow rate. Geomorphic impact assessment based on these results is discussed in Section 7.2.

7 Impact Assessment

7.1 Potential Impacts

Potential impacts which may arise due to the proposed development include the following:

- Reductions in downstream water quality due to changes to catchment land use.
- Reductions to off-site surface water flows due to catchment loss.
- Geomorphic impacts to natural watercourses due to changed site discharge regime.
- Increased stormwater runoff from the proposed quarry and increased risk of flood impacts.
- Changes in surface water supply to licensed water users and changes to basic landholder rights of adjacent properties.
- Changes to regional water supply and associated infrastructure.

7.2 Water Quality

Site sediment erosion and control plans (Section 3.3) have been developed in order to address the risk of increased sediment loads. Site sedimentation basins have been conservatively designed using best management practice in accordance with Landcom (2004), DECC (2008) and DLWC (2000). These basins will ensure capture and treatment of stormwater flows and, in conjunction with other sediment and control measures, will ensure there is no increase in sediment loads discharged from the site. Sediment and erosion control measures shall be applied during construction works stages to ensure mitigation of potential water quality impacts.

Site discharges will continue to be regulated under EPL #1879 conditions (see Section 2.8, Section 3.6 and Attachment H) and hence will ensure no changes to TSS concentrations, oil and grease concentrations, and surface water pH.

Reductions to water quality in infrequent storm events are unlikely because bunds ensure clean stormwater from upstream areas are diverted from the pit. Further, the depth of the pit below ground level of > 18 m will ensure stormwater runoff from disturbed portions of the site is contained within the pit.

Changes to discharge water quality are summarised in Table 31. Concentrations of TSS, TP and TN were determined to reduce under proposed conditions, which meet adopted DECCW (2006) objectives and NorBe specification, and also confirms site discharges will not have an unacceptable impact on the environment for these pollutants.

Concentration of salinity was determined to increase by up to 18%, from 937 mg/L in existing conditions to 1,105 mg/L in proposed Stage 5 conditions. We note that Stage 5 salinity is the highest of all stages due to the increased proportion of groundwater to stormwater inflow (refer Section 4.3 and Section 4.4), and hence discharge salinity will gradually increase over proposed development staging up to this maximum concentration.

Review of these salinity concentrations in the context of water usage suitability (Table 3) show existing and Stage 5 salinity concentrations are detrimental/may have adverse effects on crops, and are poorly suited for potable purposes.

The drainage network downslope of the site is an area of agricultural use where existing aquatic values are likely to be already significantly compromised. The most likely use of receiving waters is for stock purposes, we are not aware of any licensed extraction points on Deadmans Creek and use for potable supply is most unlikely given the intermittent flow, degraded agricultural catchment and availability of town water in the area (even if via tanker to supplement rainwater tanks). The minor increase in salinity will not affect this use. We therefore consider that increased salinity concentrations will have not have an unacceptable impact on the environment or the creeks use.

Groundwater quality impact assessment is presented in the project Hydrogeological Assessment of the site and is considered to be acceptable and / or appropriately mitigated.

In summary, we consider that the four DECCW objectives (Section 5.2) are achieved: discharge water quality will be acceptably maintained and aesthetics outcomes will not be adversely affected.

7.3 Water Quantity

The volume of water passing through the drainage lines (see Section 2.6.1) during storm events will be reduced due to reduced catchment area as shown in Table 35.

Table 35: Existing and post development catchment areas of drainage lines.

	Catchment Area (ha)		Reduction	
Drainage Line	**Existing**	**Post Development**	**(ha)**	**(%)**
1. Deadmans Creek [1]	355.3	348.5	6.8	1.9%
2. Site drainage path – to Deadmans Creek [1]	109.7	81.2	28.5	26.0%
3. Unnamed drainage paths – to Barties Creek [2]	140.2	128.7	11.5	8.2%

Note:

[1] As measured from the confluence of drainage lines 1 and 2, 1.7 km south east of the existing quarry.

[2] As measured from the confluence of all unnamed drainage paths to Barties Creek upstream of Clarence Town Road, 1.2 km south west of the existing quarry.

We note the following:

- The change to Deadmans Creek catchment (6.8 ha) is negligible and will not have any environmental impacts downstream. Consequently flow rates and volumes within Deadmans Creek will not be negatively impacted.
- The reduction in the catchment area of drainage line 2 (28.5 ha) represents approximately 2% of the entire Deadmans Creek catchment to Williams River. Consequently the reduction of surface water flows to Williams River will be negligible.
- The change to the unnamed drainage paths to Barties Creek (11.5 ha) is negligible and will not have any environmental impacts downstream.
- Drainage paths 2 and 3 are grassed depressions crossing grazing lands and have little environmental value, therefore reduction to their catchment areas will be of no environmental consequence.
- Pit dewatering of both collected stormwater runoff and groundwater inflow will increase flows overall to downstream drainage lines.

7.4 Geomorphic Impacts

As discussed at Section 6.5, proposed discharge regime for excess waters represent at most <5% of channel forming discharge in the receiving waterway. Sensitivity analysis for extreme wet years shows discharge is <7% of channel forming discharge. The proposed discharge regime is therefore not expected to result in any adverse geomorphic channel change and impacts are therefore considered acceptable.

7.5 Flooding

Flood flows up to and including the Probable Maximum Flood (PMF) will not increase flows from the proposed development compared to existing flows. The depth of the pit below ground level is > 18 m for all stages, and hence any flood flows will be detained within the quarry void. Discharge flows will be controlled by pump out rates and will not increase over existing discharge flow rates.

7.6 Licensed Water Users and Basic Landholder Rights

The three types of basic landholder rights under the Water Management Act (2000) are domestic/stock rights, native title rights, and harvestable rights (dams).

We are not aware of any downstream surface water licenced extractors, and there are no online dams on Deadmans Creek downstream of the site which could have their domestic/stock rights and native title rights impacted by the proposed development. However, if there were downstream licenced surface water users, they would not be adversely affected as described previously:

- Section 4.5 demonstrates that apart from extreme dry conditions during Stage 1 of quarry development, the quarry will discharge excess waters and increase the availability of water to any downstream users.

- As per Section 7.2 there will be no increase to TSS, TP or TN concentrations due to the proposed development, and minor increases to salinity concentration are not expected to materially affect downstream users.

- As per Section 7.4 the proposed discharge regime for excess waters will not result in any adverse geomorphic channel changes downstream of the site.

The proposed development will not reduce the ability of adjacent users to capture 10% of rainfall as per harvestable rights, as the development will not cross Hanson site boundaries or reduce offsite land areas.

The proposed development will therefore not adversely affect downstream licensed water users or adjacent properties basic landholder rights.

7.7 Regional Water Supply

7.7.1 Local Surface Water Supply Infrastructure

Surface water supply infrastructure in the area is operated by Hunter Water Corporation and consists of:

- Seaham Weir: the major offtake point for Grahamstown Dam, separates downstream tidal saltwater from upstream freshwater, located on Williams River 6 km upstream of the confluence with Deadmans Creek.
- Grahamstown Dam: a major drinking water storage dam servicing the Lower Hunter, supplied by Seaham Weir and its own hydrological catchment, located 10 km south east of Seaham Weir.
- Balickera Canal: directs surface water from Seaham Weir to Grahamstown Dam using Balickera pumping station.

There is no other regional surface water supply infrastructure in the local area.

7.7.2 Surface Water Supply Quantity and Quality Data

Surface water quantity and quality data have been provided by Hunter Water Corporation (2016). We note that NSW Department of Primary Industries Water and Port Stephens Council do not have any additional data.

The available daily water quantity data (Hunter Water Corporation, 2016) shows from 1966 (when Seaham Weir was constructed) to 2015 the average annual surface water volume pumped through Balickera Canal from Seaham Weir is 24,870 ML, which equates to an average pumping rate of 68.1 ML/day.

The available water quality data (Hunter Water Corporation, 2016) is summarised in Table 36. Average values for each water quality parameter measured are given based on (typically) weekly sampling from 1983 to 2016 at 4 monitoring locations near the Seaham Weir offtake point.

Table 36: Seaham Weir water quality parameters based on monitoring data provided by Hunter Water Corporation (2016).

Water Quality Parameter	Units	Average Value
Turbidity	NTU	14.2
Conductivity	µS/cm	289
Salinity	mg/L	185 [1]
Dissolved Oxygen	%	65.4
Dissolved Oxygen	mg/L	6.09
Total Nitrogen	mg/L	0.691
Total Phosphorous	mg/L	0.122

Note:

[1] Salinity concentration in mg/L not measured by Hunter Water Corporation but converted from raw electrical conductivity measurements in µS/cm using a multiplication factor of 0.64 adopted from NSW Office of Environment & Heritage (OEH) website (2013).

7.7.3 Surface Water Supply Impact Assessment

All excess surface water from the proposed development discharges to Deadmans Creek, 6 km downstream of Seaham weir. As excess waters will not travel upstream to the location of surface water supply offtakes, any changes to surface water flow and water quality due to the proposed development will have no impact on the quality or quantity of regional surface water supplies. Any further detailed assessment of the Seaham Weirpool infrastructure is therefore not considered necessary as there will be no impacts on upstream infrastructure.

Occasional water demands for supplementary water supply (during periods of prolonged low rainfall) shall be extremely small and shall not impact on regional water supplies.

7.7.4 Groundwater Supply

Groundwater supply assessment, including groundwater quality and impact assessment, is presented in the project Hydrogeological Assessment.

7.8 Mitigation Requirements

Mitigation measures have been incorporated within the quarry's design and proposed management and include: sediment basins; water capture, recycling and reusing systems; and manage water discharge systems to maintain existing downstream flow regimes. No other measures are considered necessary.

8 Surface Water Monitoring Plan

8.1 Sensitive Receivers

The quarry is relatively isolated in the upper slopes of Brandy Hill. There are no identified sensitive receivers located within close proximity to the site with the potential to experience indirect or direct impacts resulting from site operations.

8.2 Discharge Performance Criteria and Trigger Criteria

The site trigger criteria for any discharge as part of the proposed quarry expansion works will be in accordance with site EPL requirements (see Section 2.8 and Attachment H). Exceeding any of these criteria shall trigger the need to investigate the source, cause and any potentially adverse impacts for surface water.

8.3 Monitoring Regime

Site discharges shall be surplus water from pit sedimentation basins, polishing basin 3 in Stages 1-2, and the storage dam in Stages 3-5. The relevant basins require the following monitoring to ensure appropriate operation and functioning:

1. Weekly visual inspection:
    a. Check basin structural integrity.
    b. Check outlet of the downstream basin for signs of scour/failure.
    c. Check sediment volume.
    d. Check and record water level.
2. In the event that discharge is required (surplus water in sedimentation basins):
    a. Compare sample to prepared 50 mg/L reference sample (see below) for initial screening.
    b. Visually inspect for oil and grease.
    c. Collect water sample from overflow and laboratory analyse for total suspended solids and pH.

    d. Record sampling results (see Section 9.2).

    e. Samples TSS concentration to not exceed 50 mg/L and pH to be 6.5 – 8.5. No oil and grease to be visible.

Reference samples are to be prepared using local sediment at 50 mg/L. These reference samples are to be held onsite to allow site staff to assess the quality of overflowing water and allow immediate action in the event of excessive sediment loads. Laboratory analyses are to be used to verify the site reference sample.

During initial phase of operation, an assessment of TSS levels in conjunction with turbidity levels may be undertaken to assess if a valid relationship between the two exists. Where such a relationship can be shown to the satisfaction of the EPA, a modification to the EPL may be sought to allow turbidity testing as the license compliance test *in lieu* of TSS analysis.

Results of monitoring are to be recorded in the site register as outlined in Section 9.

8.4 Contingency and Response Plan

In the event that inspection and/or sampling indicates that TSS, pH or oil and grease in sedimentation basins exceed trigger criteria the following actions shall be taken:

1. Discharge ceased.

2. Additional sampling and laboratory testing shall be undertaken at the downstream basin. Surplus waters shall continue to be stored in sedimentation basins or quarry void.

3. If laboratory testing results confirms trigger values are exceeded:

    a. Water is to continue to be stored in sedimentation basins / quarry void and samples taken daily for comparison with reference sample.

    b. If necessary, flocculation or chemical treatment of basins is to be undertaken.

    c. When monitoring indicates the desired water quality has been achieved, samples are to be laboratory tested to confirm.

4. If sampling results comply with discharge criteria, discharge from site can recommence.

Continued or repeated non-compliance with discharge/trigger criteria may indicate a need to review the site surface water management system and surface water monitoring plan. This is discussed further in Section 9.

9 Long Term Surface Water Management

9.1 Objectives

The objective of the long term surface water management regime at the site is to ensure that operations do not have adverse impacts on the health of downstream receivers for the life of the project.

9.2 Long Term Management Plan

9.2.1 Overview

The management plan in Section 3 shall continue as part of the site's long term operation to protect downstream receivers from adverse impacts as a result of stormwater pollution from the site.

9.2.2 Sedimentation Basins

Sedimentation basins shall be relocated and resized as extraction progresses (see Section 3.3.4 and Attachment B) to ensure that changes in surface water (and groundwater) flow regime is accommodated and appropriately treated to achieve performance criteria. Sedimentation basins may also be resized from time to time to accommodate varying groundwater inflow rates and to provide adequate water storage to satisfy demands.

9.2.3 Monitoring

The monitoring plan as outlined in Section 8 shall also continue as part of the site's long term operation. Further detail is provided in Section 9.3.

9.3 Long Term Monitoring Plan

Prior to any site discharge via licenced discharge points, results of visual inspection, water sample comparison and laboratory analysis (where relevant) shall be recorded in the site Surface Water Monitoring Register (Attachment G) along with sampling records as required by Clause M1.3 of the EPL (Attachment H). Results shall form part of annual reporting and system auditing (Section 9.4).

In accordance with the site EPL, records regarding site sampling must be retained in a legible form for a minimum 4 years from sampling date.

9.4 Auditing and Reporting

Annual surface water management reporting is to be completed as part of the site's long term management. Reporting is to include:

- Rainfall and evaporation conditions for the calendar year.
- Progress of quarrying operations.
- Any changes to the surface water management system.
- Any sediment and erosion 'events' experienced (e.g. major storm event, bank failure).
- Record of discharge events during the year.
- Records of sedimentation/treated stormwater storage dam basin inspection, sampling, testing and maintenance.
- Comparison of records with the previous year and any long term observations/trends.
- Identification of events where trigger criteria were exceeded and management/remedial process.
- An audit of the stormwater management and monitoring system and any recommendations for continued operation.
- Review of metering data and updates to water balance modelling to review surface water licencing requirements.

9.5 Adaptive Management

This surface water management plan is considered a 'living' document that should be reviewed annually and updated as required. Given site surface water conditions will change as quarrying progresses, the management plan needs to be adaptive to remain relevant and effective.

10 References

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Attachments

Attachment A – Site Plan

KEY

SITE BOUNDARY	───
CONTOUR (5M INTERVAL)	35
DRAINAGE LINE	— — —
CREEK / DAM	───
PIEZOMETERS	BH1401
LICENCED DISCHARGE POINT	● DP2

NOTES:
1. BACKGROUND AERIAL FROM SIXMAPS (2014).
2. EXISTING CONTOURS AND BOREHOLE LOCATIONS PROVIDED BY HANSON (2014).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	17.02.15	AN
B	REVISED	02.03.15	AN

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TITLE:

EXISTING SITE LAYOUT AND
SURFACE WATER CONDITIONS

DRAWING ID: **SK001**

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	B

NOTES:
1. PROPOSED DEVELOPMENT IS SHOWN OVERLAYING SITE SURVEY.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).

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TITLE:

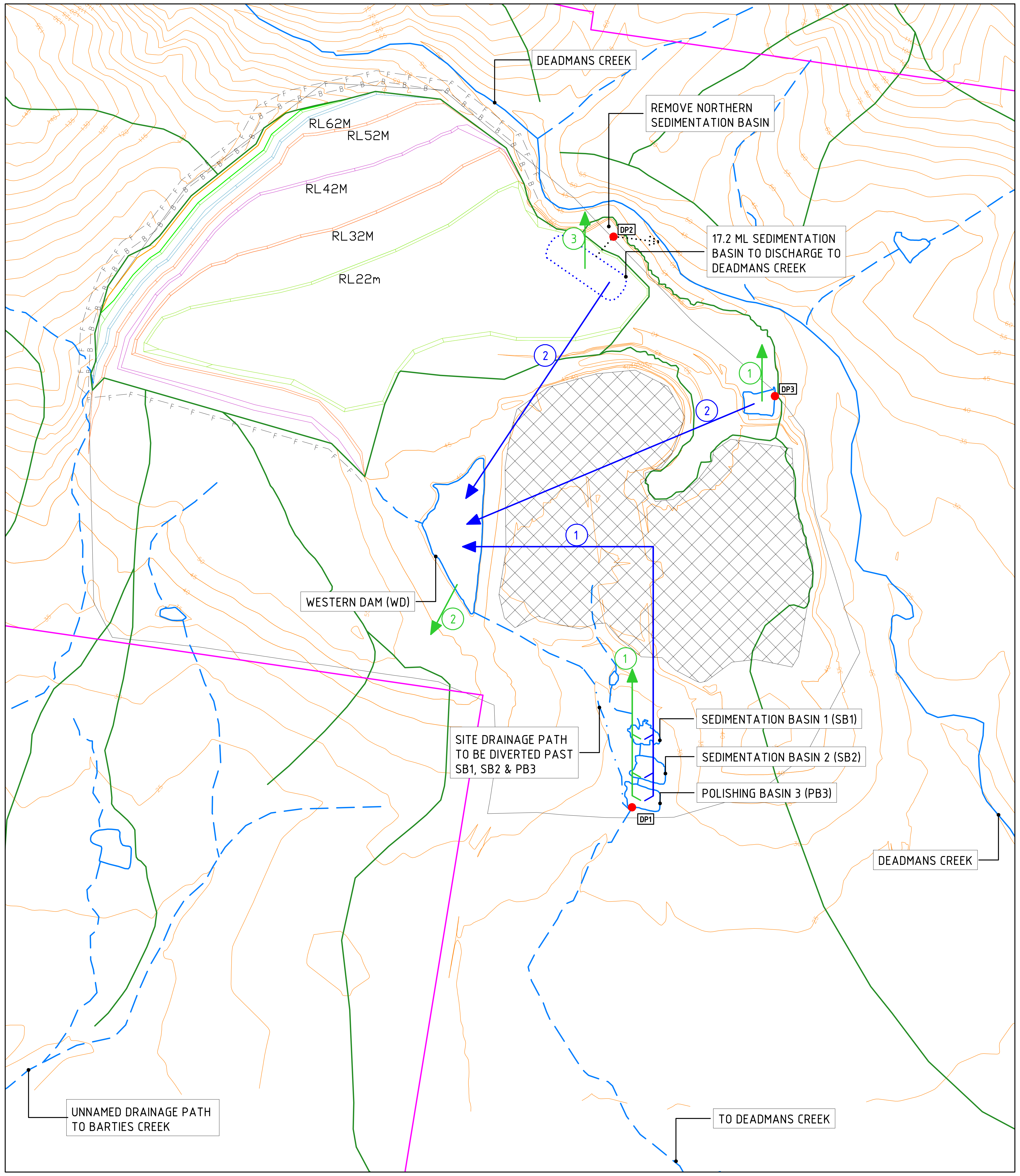
SITE SURVEY AND
STAGE 5 QUARRY LAYOUT

DRAWING ID: **SK002**

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	B

Attachment B – Surface Water Management Plan

STAGE 1



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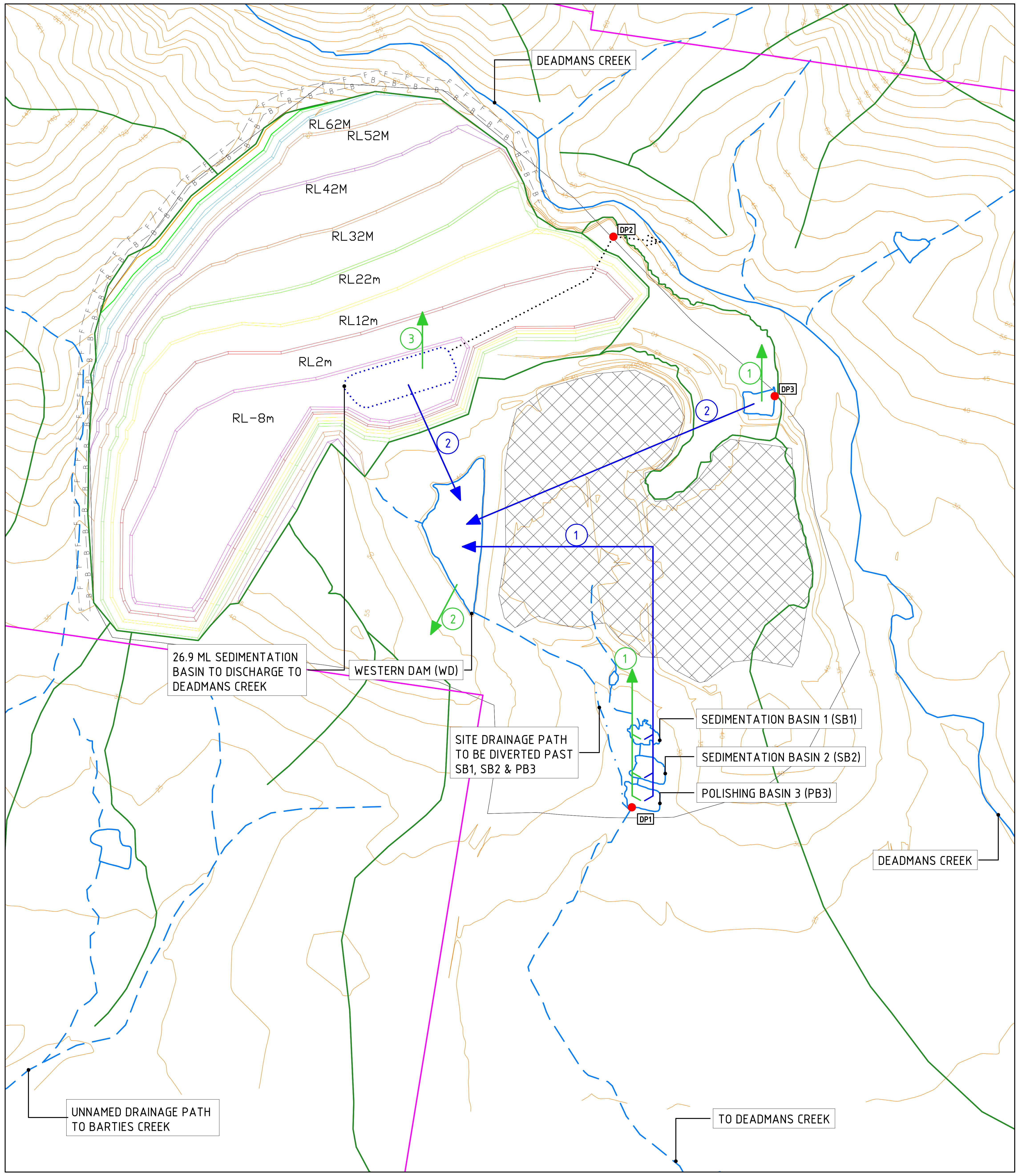

KEY

SITE BOUNDARY	
CONTOUR (5M INTERVAL)	
DRAINAGE LINE	— — —
CREEK / DAM	
QUARRY BENCH ELEVATION (mAHD)	RL22m
QUARRY LAYOUT	
INDICATIVE SEDIMENTATION BASIN LOCATION	
LICENCED DISCHARGE POINT	● DP2
SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH	·········▷
CATCHMENT BOUNDARY	
FILTER FENCE	— F — F — F —
EARTH DIVERSION BUND	— B — B — B — B —
PLANT PROCESSING AND STOCKPILE AREA	▨
WESTERN DAM OVERFLOW REDIRECTION	— · — · —
TREATED STORMWATER TRANSFER	→
REUSE	→

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NOTES:
1. DETAILS OF SITE SURFACE WATER MANAGEMENT PLAN PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. SEDIMENTATION BASIN DIMENSIONS SHOWN ARE INDICATIVE AND BASED ON TYPE F BASINS.
4. NUMERALS ADJACENT TO TREATED STORMWATER TRANSFER ROUTES AND REUSE SOURCES DENOTE PRIORITY FOR TRANSFER/REUSE.

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	17.02.15	AN
B	REVISED	02.03.15	AN
C	REVISED	08.04.15	AN

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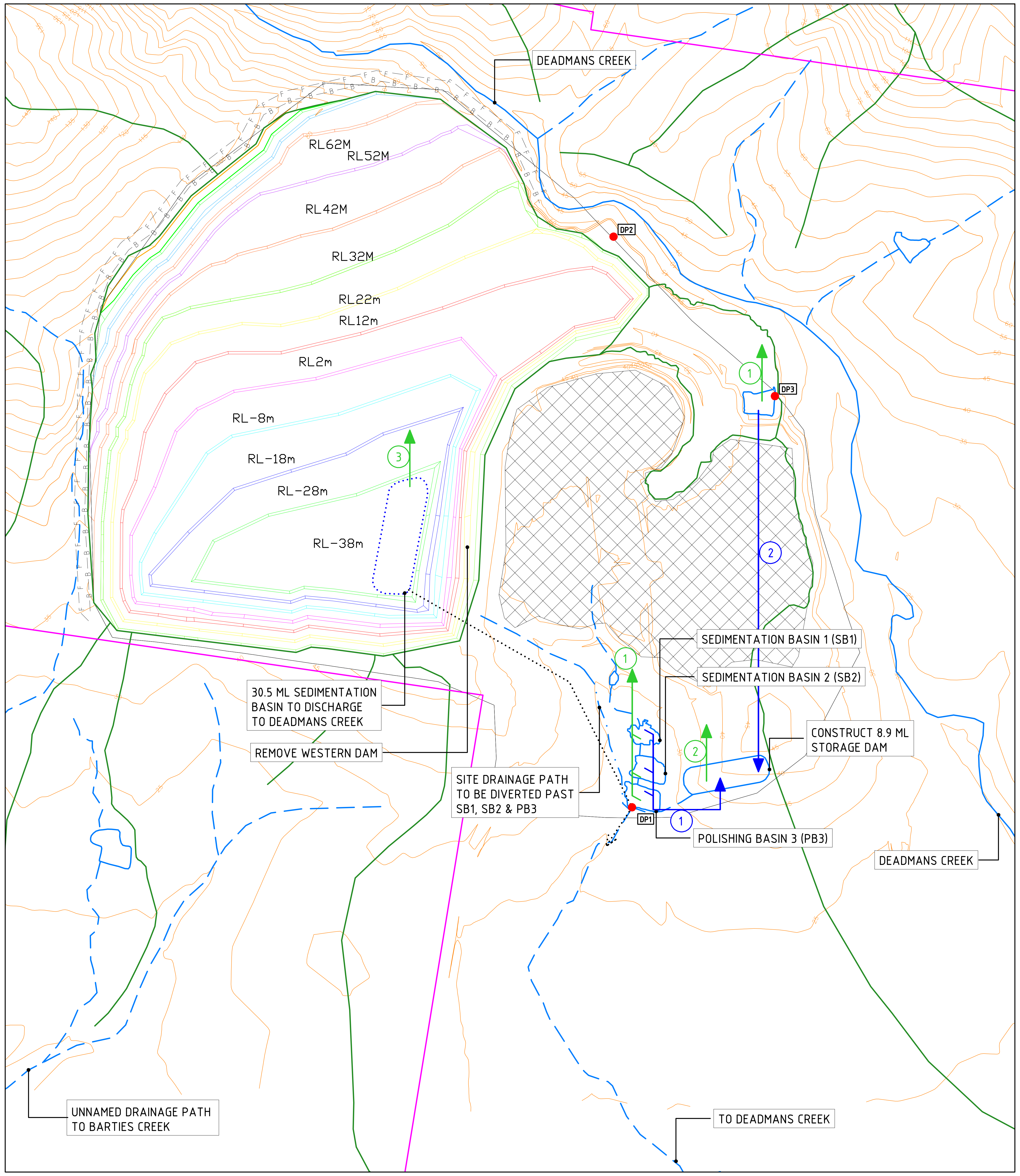
TITLE:
SURFACE WATER MANAGEMENT PLAN
STAGE 1 AND STAGE 2

DRAWING ID: SK003
PROJECT MANAGER: AN
PROJECT NO.: P1303888
FILE: JD02V01
REVISION: C

STAGE 3



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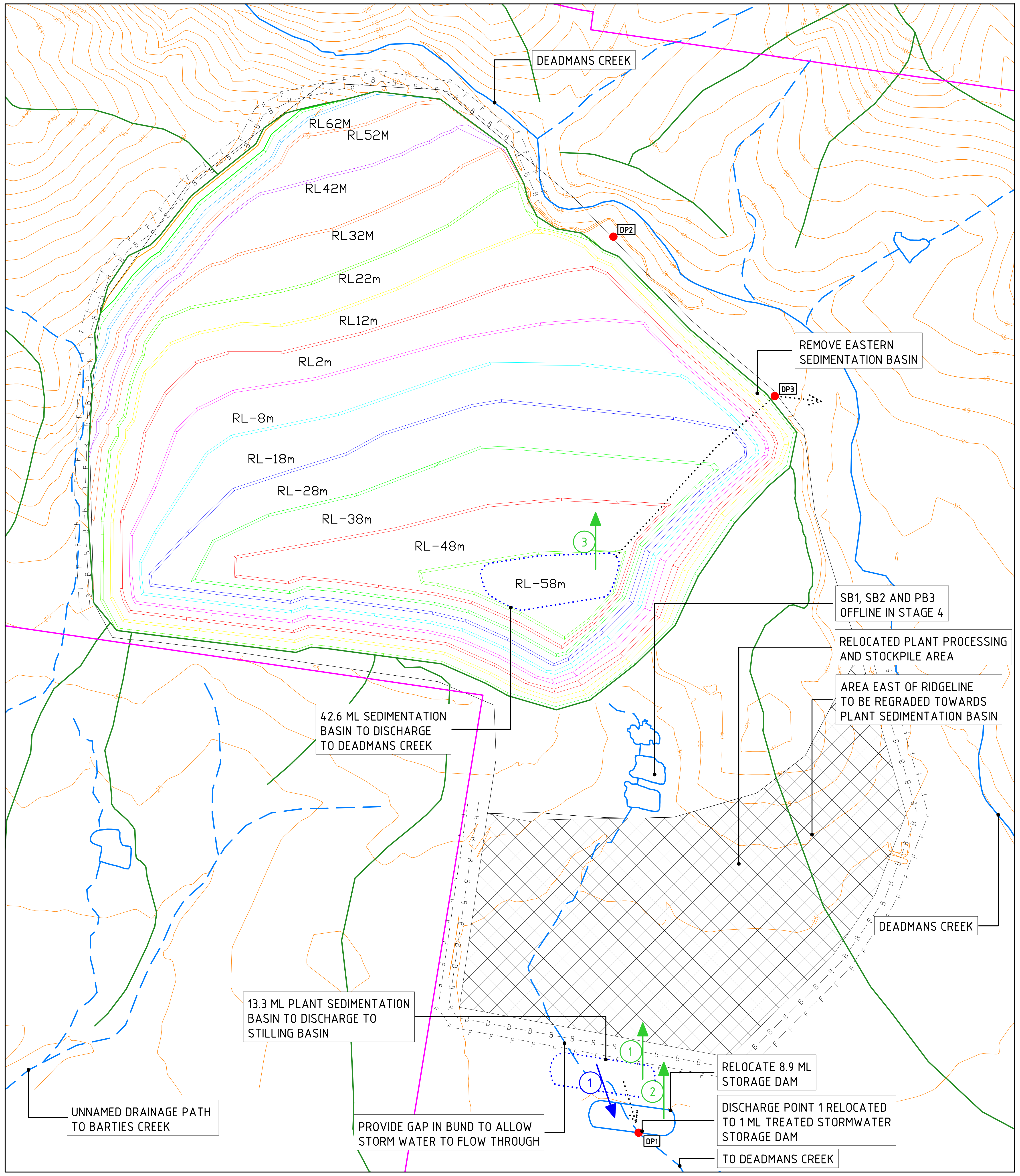

KEY

SITE BOUNDARY	───	QUARRY BENCH ELEVATION (mAHD)	RL22m	SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH	┈┈┈>	PLANT PROCESSING AND STOCKPILE AREA	▨
CONTOUR (5M INTERVAL)	───	QUARRY LAYOUT	═══	CATCHMENT BOUNDARY	───	WESTERN DAM OVERFLOW REDIRECTION	─ · ─ · ─
DRAINAGE LINE	─ ─ ─	INDICATIVE SEDIMENTATION BASIN LOCATION	┈┈┈	FILTER FENCE	— F — F — F — F — F —	TREATED STORMWATER TRANSFER	→
CREEK / DAM	───	LICENCED DISCHARGE POINT	● DP2	EARTH DIVERSION BUND	— B — B — B — B — B —	REUSE	→

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NOTES:
1. DETAILS OF SITE SURFACE WATER MANAGEMENT PLAN PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. SEDIMENTATION BASIN DIMENSIONS SHOWN ARE INDICATIVE AND BASED ON TYPE F BASINS.
4. NUMERALS ADJACENT TO TREATED STORMWATER TRANSFER ROUTES AND REUSE SOURCES DENOTE PRIORITY FOR TRANSFER/REUSE.

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TITLE:
SURFACE WATER MANAGEMENT PLAN
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DRAWING ID: **SK004**

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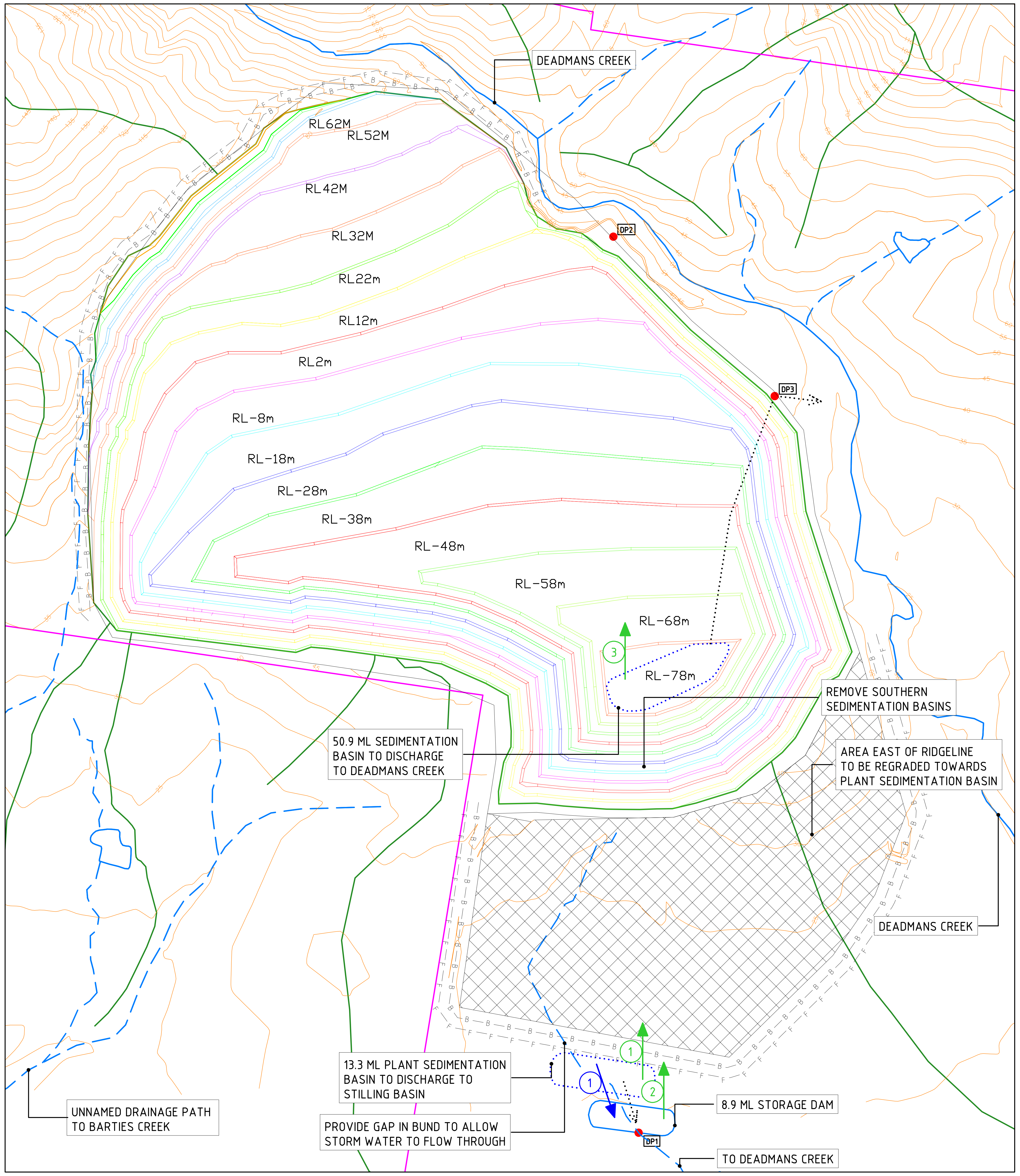
STAGE 5



KEY

SITE BOUNDARY

CONTOUR (5M INTERVAL)

DRAINAGE LINE

CREEK / DAM

QUARRY BENCH ELEVATION (mAHD) RL22m

QUARRY LAYOUT

INDICATIVE SEDIMENTATION BASIN LOCATION

LICENCED DISCHARGE POINT ● DP2

SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH

CATCHMENT BOUNDARY

FILTER FENCE — F — F — F — F — F —

EARTH DIVERSION BUND — B — B — B — B — B —

PLANT PROCESSING AND STOCKPILE AREA ▨

WESTERN DAM OVERFLOW REDIRECTION

TREATED STORMWATER TRANSFER →

REUSE →

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NOTES:
1. DETAILS OF SITE SURFACE WATER MANAGEMENT PLAN PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. SEDIMENTATION BASIN DIMENSIONS SHOWN ARE INDICATIVE AND BASED ON TYPE F BASINS.
4. NUMERALS ADJACENT TO TREATED STORMWATER TRANSFER ROUTES AND REUSE SOURCES DENOTE PRIORITY FOR TRANSFER/REUSE.

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STAGE 5

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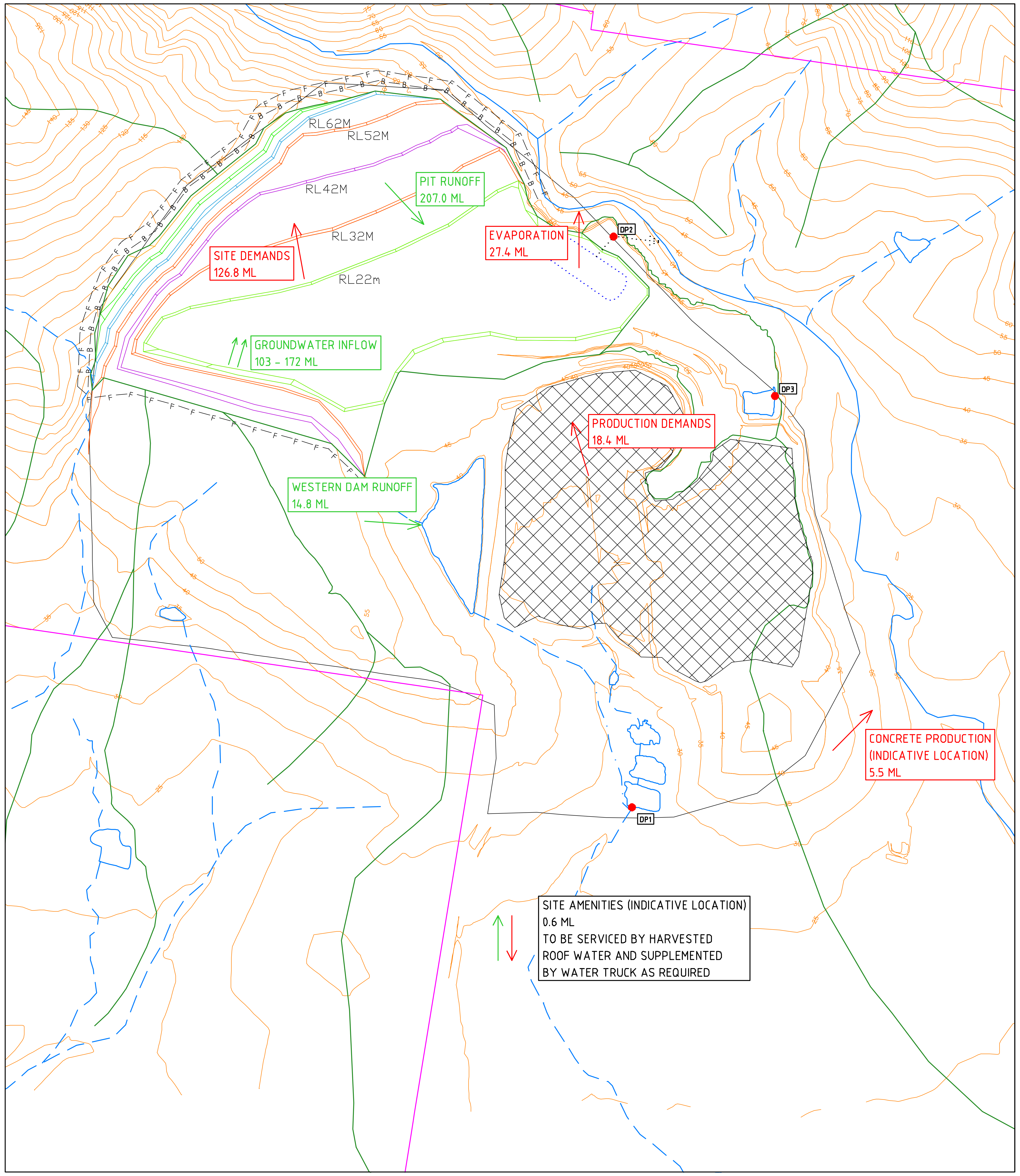
PROJECT NO.: P1303888
FILE: JD02V01
REVISION: B

Attachment C – Site Water Balance

STAGE 1



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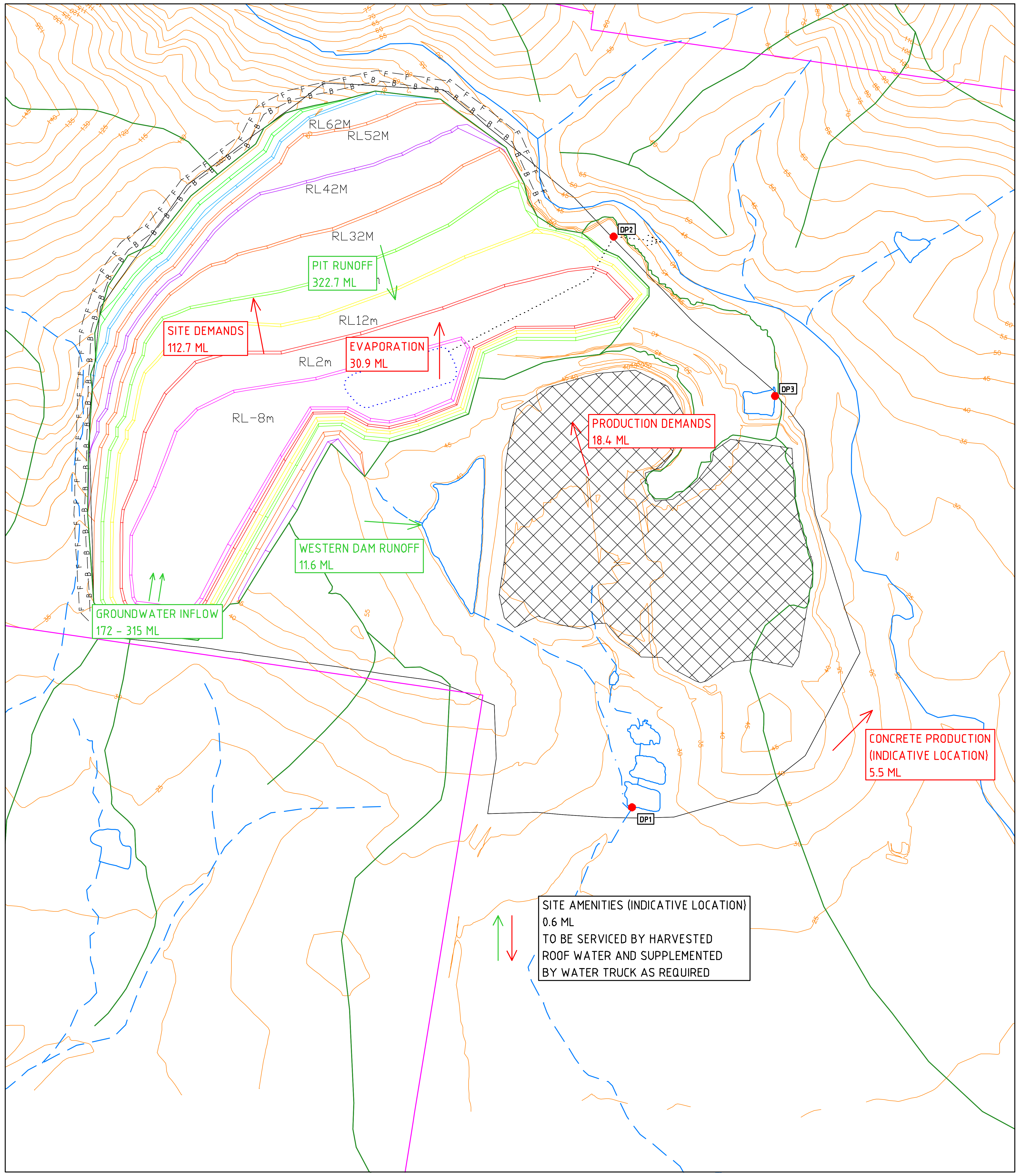

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SITE BOUNDARY	—	QUARRY BENCH ELEVATION (mAHD)	RL22m	SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH	··········>	PLANT PROCESSING AND STOCKPILE AREA	▨
CONTOUR (5M INTERVAL)	—	QUARRY LAYOUT	—	CATCHMENT BOUNDARY	—	SUPPLY	→
DRAINAGE LINE	— — —	INDICATIVE SEDIMENTATION BASIN LOCATION	⬚	FILTER FENCE	— F — F — F — F — F —	DEMAND	→
CREEK / DAM	—	LICENCED DISCHARGE POINT	● DP2	EARTH DIVERSION BUND	— B — B — B — B — B —		

NOTES:
1. DETAILS OF SITE WATER BALANCE PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. PRODUCTION DEMANDS INCLUDE PLANT DUST SUPPRESSION, MOISTURE CONDITIONING AND MAINTENANCE.
4. SITE DEMANDS INCLUDE SITE DUST SUPPRESSION AND VEHICLE/LOADER WASHDOWN.
5. THE SINGULAR EVAPORATION DEMAND SHOWN IS FOR ALL SITE DAMS AND BASINS.

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B	REVISED	02.03.15	AN
C	REVISED	08.04.15	AN
D	REVISED	21.04.15	AN
E	REVISED	16.12.15	AN

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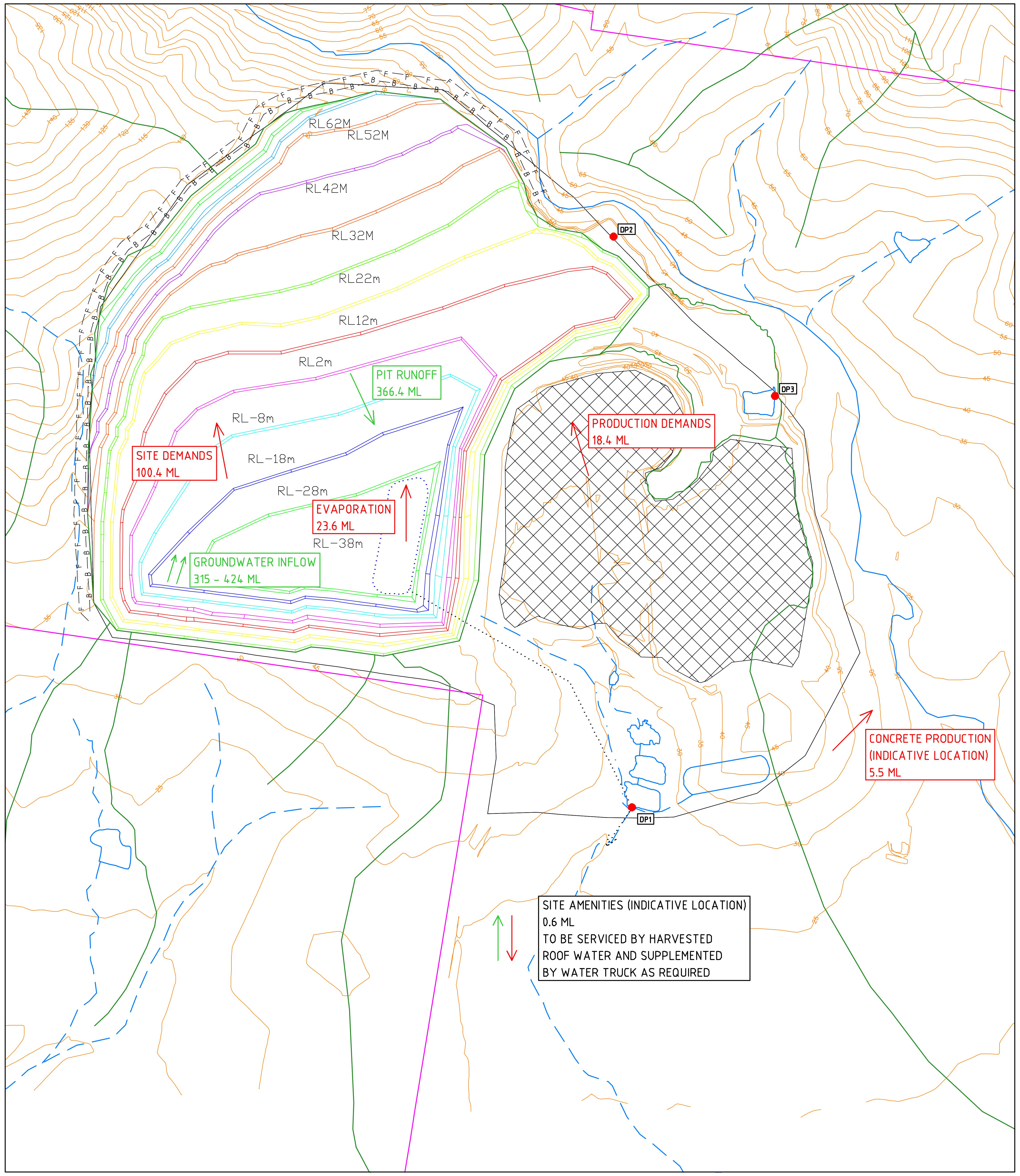
Suite 201, 20 George Street, Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767
Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:
ANNUAL WATER BALANCE ASSESSMENT
STAGE 1 AND STAGE 2

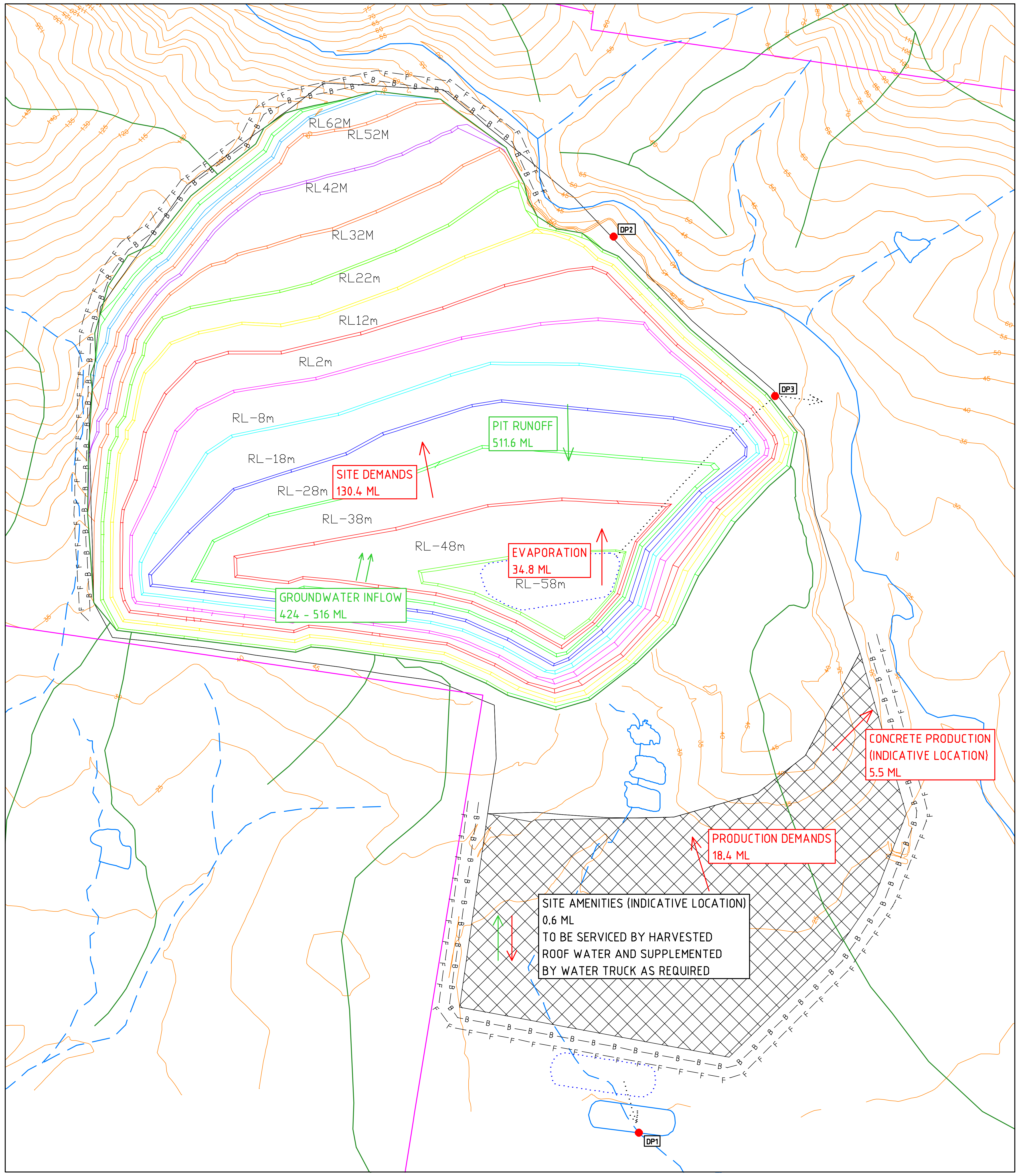
DRAWING ID: SK006

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	E

STAGE 3



STAGE 4



KEY

SITE BOUNDARY

CONTOUR (5M INTERVAL)

DRAINAGE LINE

CREEK / DAM

QUARRY BENCH ELEVATION (mAHD) RL22m

QUARRY LAYOUT

INDICATIVE SEDIMENTATION BASIN LOCATION

LICENCED DISCHARGE POINT DP2

SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH

CATCHMENT BOUNDARY

FILTER FENCE —F—F—F—F—

EARTH DIVERSION BUND —B—B—B—B—

PLANT PROCESSING AND STOCKPILE AREA ▨

SUPPLY →

DEMAND →

N W E S

NOTES:
1. DETAILS OF SITE WATER BALANCE PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. PRODUCTION DEMANDS INCLUDE PLANT DUST SUPPRESSION, MOISTURE CONDITIONING AND MAINTENANCE.
4. SITE DEMANDS INCLUDE SITE DUST SUPPRESSION AND VEHICLE/LOADER WASHDOWN.
5. THE SINGULAR EVAPORATION DEMAND SHOWN IS FOR ALL SITE DAMS AND BASINS.

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	17.02.15	AN
B	REVISED	02.03.15	AN
C	REVISED	21.04.15	AN
D	REVISED	16.12.15	AN

BAR SCALE

0 80 160 240 320 400

UNITS - METRES

DESIGNED: DD	DATUM: mAHD
REVIEWED: AN	HORIZONTAL RATIO: 1:4000
PAPER SIZE: A1	VERTICAL RATIO: NA

CLIENT / PROJECT

HANSON
BRANDY HILL QUARRY
EXPANSION EIS

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All measurements in mm unless otherwise specified

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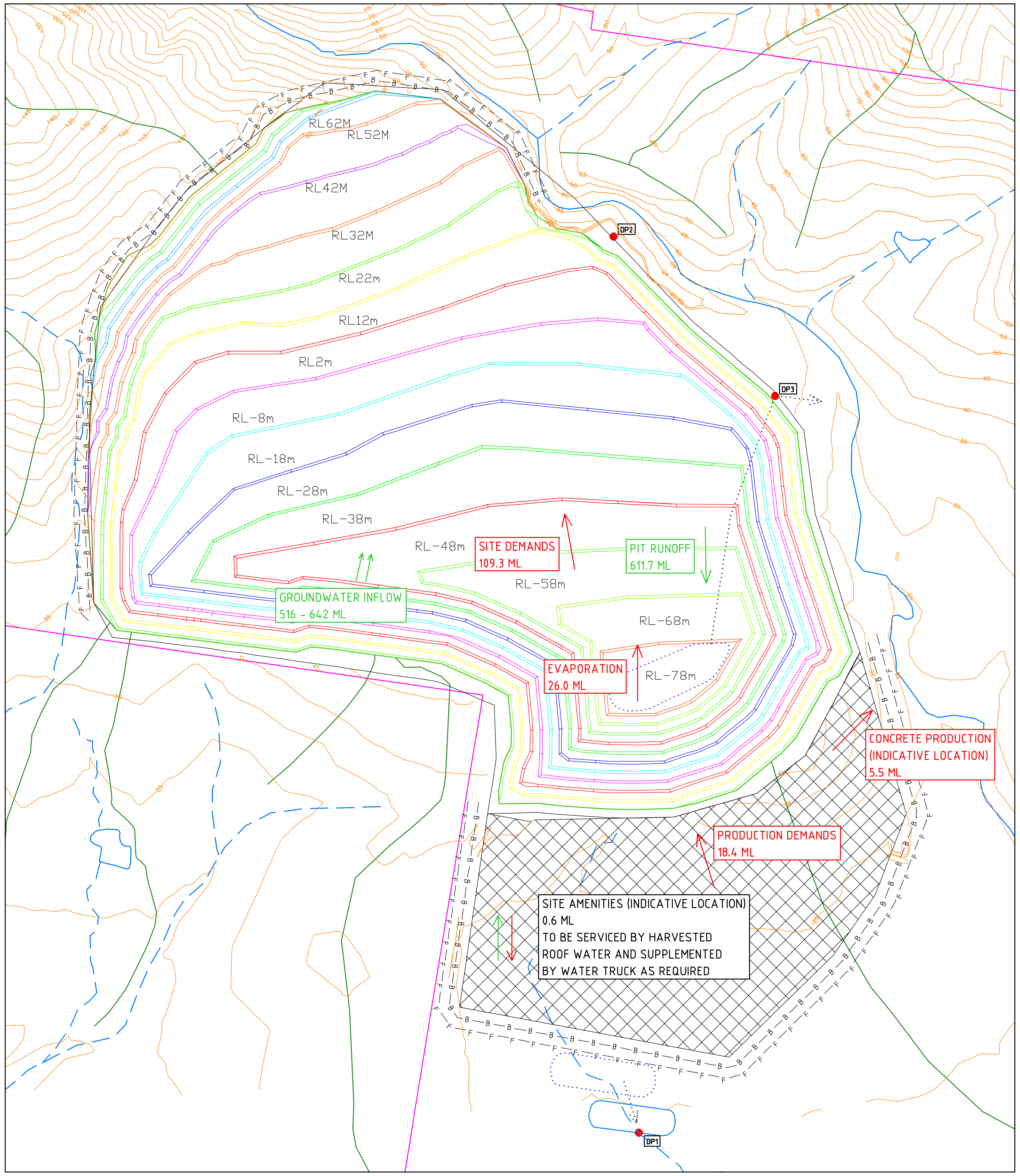
TITLE:
ANNUAL WATER BALANCE ASSESSMENT
STAGE 3 AND STAGE 4

DRAWING ID: **SK007**

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	D

STAGE 5



KEY

SITE BOUNDARY	
CONTOUR (5M INTERVAL)	
DRAINAGE LINE	— — — —
CREEK / DAM	
QUARRY BENCH ELEVATION (mAHD)	RL22m
QUARRY LAYOUT	
INDICATIVE SEDIMENTATION BASIN LOCATION	
LICENCED DISCHARGE POINT	● DP2
SEDIMENTATION BASIN OVERFLOW/DISCHARGE PATH	·······→
CATCHMENT BOUNDARY	
FILTER FENCE	—F—F—F—F—
EARTH DIVERSION BUND	—B—B—B—B—
PLANT PROCESSING AND STOCKPILE AREA	▨
SUPPLY	→
DEMAND	→

NOTES:
1. DETAILS OF SITE WATER BALANCE PROVIDED IN MARTENS AND ASSOCIATES REPORT P1303888JR03V05, APRIL, 2015.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).
3. PRODUCTION DEMANDS INCLUDE PLANT DUST SUPPRESSION, MOISTURE CONDITIONING AND MAINTENANCE.
4. SITE DEMANDS INCLUDE SITE DUST SUPPRESSION AND VEHICLE/LOADER WASHDOWN.
5. THE SINGULAR EVAPORATION DEMAND SHOWN IS FOR ALL SITE DAMS AND BASINS.

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	17.02.15	AN
B	REVISED	02.03.15	AN
C	REVISED	21.04.15	AN
D	REVISED	16.12.15	AN

BAR SCALE
0 80 160 240 320 400
UNITS - METRES

DESIGNED: DD
DATUM: mAHD
REVIEWED: AN
HORIZONTAL RATIO: 1:4000
PAPER SIZE: A1
VERTICAL RATIO: NA

CLIENT / PROJECT
HANSON
BRANDY HILL QUARRY
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TITLE:
ANNUAL WATER BALANCE ASSESSMENT
STAGE 5

DRAWING ID: **SK008**

PROJECT MANAGER: AN
PROJECT NO.: P1303888
FILE: JD02V01
REVISION: D

Attachment D – Water Quality Assessment Inputs and Figures

D.1 Pollutant Impact Assessment Details

D.1.1 Flows

		Water Medium		
Stage	**Parameter**	**Surface Water [1]**	**Groundwater [2]**	**Total**
Existing Conditions	Flow (ML/yr)	185	86.5	271.5
Stage 5 Proposed Conditions	Flow (ML/yr)	399	578.9	977.9

Note:

[1] Site surface water flows determined by MUSIC.

[2] Existing conditions groundwater flow based on steady state quarry modelling as per Martens and Associate's Hydrogeological Assessment of the site. Stage 5 groundwater flow determined from average rainfall conditions water balance (Section 4.1.3).

D.1.2 Pollutant Concentrations

		Water Medium		
Stage	**Parameter**	**Surface Water [1]**	**Groundwater [2]**	**Flow Weighted Average [3]**
Existing Conditions	TSS concentration (mg/L)	96.8	20.0	72.3
	TP concentration (mg/L)	0.123	0.030	0.094
	TN concentration (mg/L)	1.324	0.653	1.110
Stage 5 Proposed Conditions	TSS concentration (mg/L)	96.0	20.0	51.0
	TP concentration (mg/L)	0.135	0.030	0.073
	TN concentration (mg/L)	1.519	0.653	1.006

Note:

[1] Surface water outflow pollutant concentrations determined by MUSIC.

[2] TP and TN groundwater concentrations based on mean of site groundwater monitoring data (Table 2). TSS groundwater concentration based on mean of site surface water monitoring data (Table 2) as TSS concentration is not available for groundwater, and assuming all groundwater inflows will have the same concentration as surface water after entering the quarry void and before discharge. Existing and Stage 5 groundwater concentrations are assumed to be the same.

[3] (Flow weighted average concentration) = [(Staged surface water flow) x (Staged surface water pollutant concentration) + (Staged groundwater flow) x (Staged groundwater pollutant concentration)]/(Total staged water flow).

D.2 Salinity Impact Assessment Details

D.2.1 Flows

		Water Medium		
Stage	Parameter	Surface Water [1]	Groundwater [2]	Total
Existing Conditions	Flow (ML/yr)	149	86.5	235.7
Stage 5 Proposed Conditions	Flow (ML/yr)	612	578.9	1190.6

Note:

[1] Site pit surface water flows determined from average rainfall conditions water balance (Section 4.1.2).

[2] Existing conditions groundwater flow based on steady state quarry modelling as per Martens and Associate's Hydrogeological Assessment of the site. Stage 5 groundwater flow determined from average rainfall conditions water balance (Section 4.1.3).

D.2.2 Salinity Concentrations

		Water Medium		
Stage	Parameter	Surface Water [1]	Groundwater [2]	Flow Weighted Average [3]
Existing Conditions	Salinity concentration (mg/L)	420	1829	937
Stage 5 Proposed Conditions	Salinity concentration (mg/L)	420	1829	1105

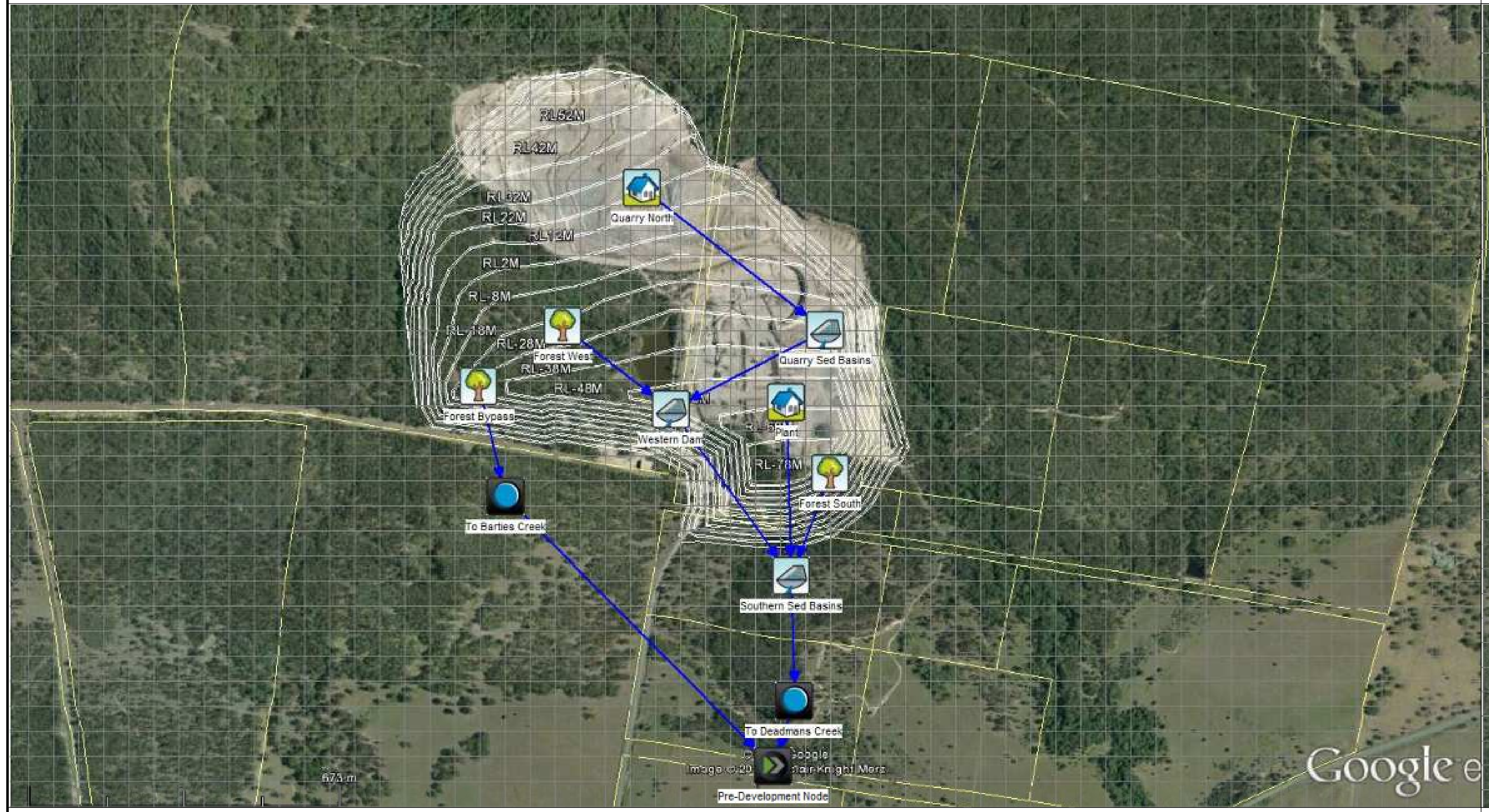
Note:

[1] Surface water outflow pollutant concentrations based on mean of site surface water monitoring data (Table 2). Existing and Stage 5 surface water concentrations are assumed to be the same.

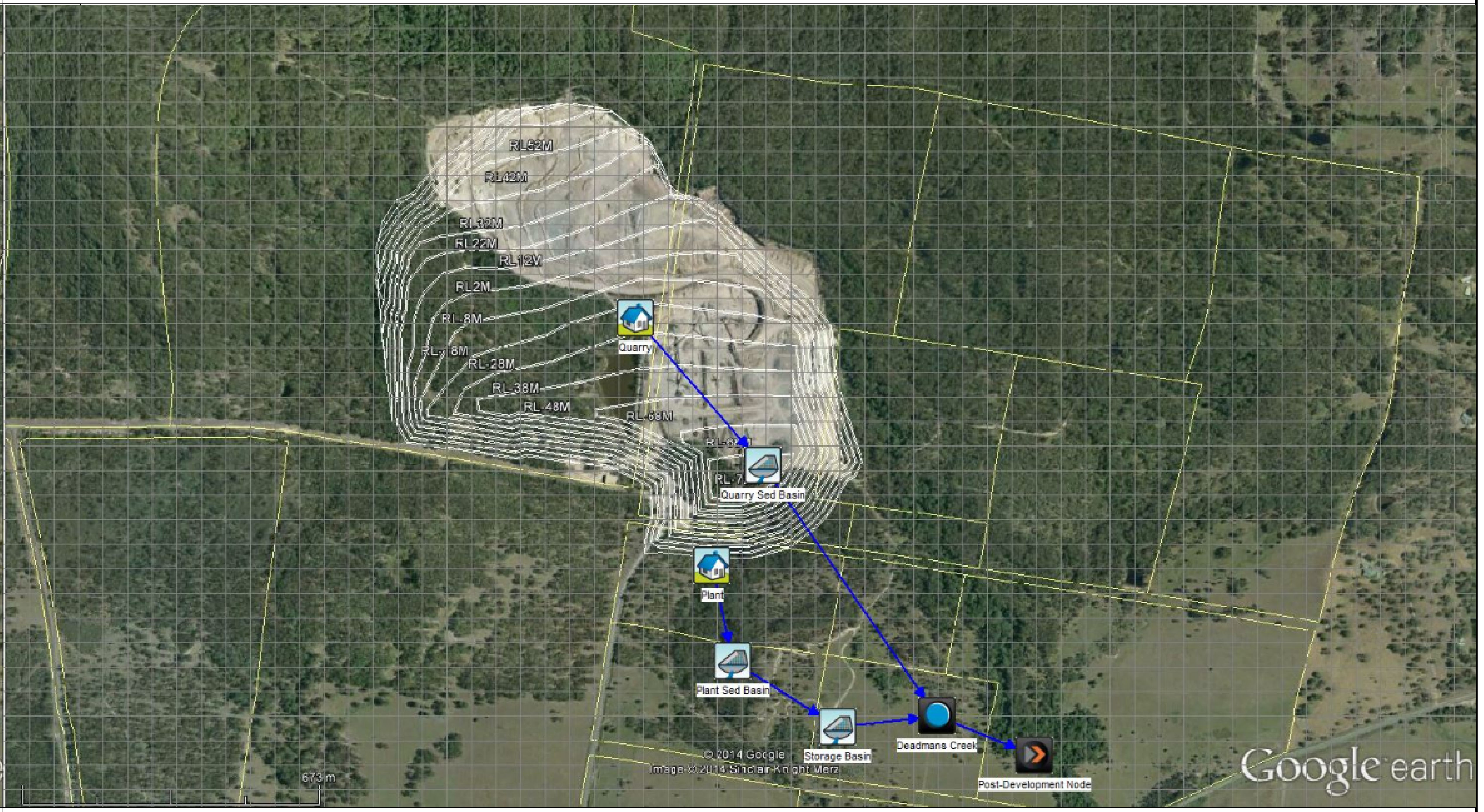
[2] Groundwater outflow pollutant concentrations based on mean of site groundwater monitoring data (Table 2). Existing and Stage 5 groundwater concentrations are assumed to be the same.

[3] (Flow weighted average concentration) = [(Staged surface water flow) x (Staged surface water pollutant concentration) + (Staged groundwater flow) x (Staged groundwater pollutant concentration)]/(Total staged water flow).

D.3 MUSIC Model Layout



EXISTING SCENARIO



PROPOSED STAGE 5 SCENARIO

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	16.12.15	AN

BAR SCALE

DESIGNED: DD	DATUM:
REVIEWED: AN	HORIZONTAL RATIO:
PAPER SIZE: A1	VERTICAL RATIO: NA

CLIENT / PROJECT

HANSON
BRANDY HILL QUARRY
EXPANSION EIS

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TITLE: MUSIC LAYOUT			DRAWING ID: SK009
PROJECT MANAGER: AN	PROJECT NO.: P1303888	FILE: JD02V01	REVISION: A

Attachment E – Deadmans Creek Catchment Plan

NOTES:
1. BACKGROUND AERIAL FROM SIXMAPS (2015).
2. CATCHMENT BOUNDARIES BASED ON LIDAR DATA PROVIDED BY LPI NSW (2013).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	01.12.15	AN

BAR SCALE

0 150 300 450 600 750

UNITS - METRES

DESIGNED: DD	DATUM: mAHD
REVIEWED: AN	HORIZONTAL RATIO: 1:7500
PAPER SIZE: A1	VERTICAL RATIO: NA

CLIENT / PROJECT

HANSON
BRANDY HILL QUARRY
EXPANSION EIS

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All measurements in mm unless otherwise specified

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Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:

DEADMANS CREEK CATCHMENT PLAN

DRAWING ID:
SK010

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	A

Attachment F – BOM IFD Data

Intensity-Frequency-Duration Table

Location: 32.650S 151.675E NEAR.. Brandy Hill Issued: 30/11/2015

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	75.9	98.3	128	146	169	200	224
6Mins	71.2	92.2	120	137	159	188	211
10Mins	58.1	75.3	98.0	112	129	153	171
20Mins	42.1	54.5	70.7	80.4	93.1	110	123
30Mins	34.2	44.1	57.3	65.1	75.3	88.9	99.4
1Hr	23.3	30.1	39.0	44.3	51.3	60.5	67.6
2Hrs	15.5	20.1	26.0	29.6	34.2	40.4	45.2
3Hrs	12.2	15.8	20.5	23.2	26.9	31.8	35.5
6Hrs	8.09	10.5	13.6	15.4	17.9	21.1	23.6
12Hrs	5.37	6.96	9.07	10.3	12.0	14.2	15.9
24Hrs	3.56	4.63	6.08	6.96	8.12	9.65	10.8
48Hrs	2.30	3.01	4.02	4.63	5.43	6.51	7.34
72Hrs	1.74	2.28	3.07	3.56	4.18	5.03	5.69

(Raw data: 30.08, 6.97, 2.29, 59.52, 13.95, 4.97, skew=0.05, F2=4.32, F50=15.98)

Attachment G – Surface Water Monitoring Register

				SAMPLING COMPLETED (Y OR N)			SAMPLING RESULTS			
DATE	TIME	COMPLETED BY (INITIAL)	SAMPLING LOCATION	VISUAL	COMPARISON	LABORATORY	VISUAL	COMPARISON	LABORATORY	COMMENTS

Attachment H – Environmental Protection Licence

Environment Protection Licence

Licence - 1879

Licence Details	
Number:	1879
Anniversary Date:	15-June

Licensee

HANSON CONSTRUCTION MATERIALS PTY LTD

LOCKED BAG 5260
PARRAMATTA NSW 2124

Premises

HANSON CONSTRUCTION MATERIALS PTY LTD
OFF SEAHAM ROAD
SEAHAM NSW 2324

Scheduled Activity

Crushing, Grinding or Separating

Extractive Activities

Fee Based Activity	**Scale**
Crushing, grinding or separating	> 500000-2000000 T processed
Land-based extractive activity	> 500000-2000000 T extracted, processed or stored

Region

North - Hunter
Ground Floor, NSW Govt Offices, 117 Bull Street
NEWCASTLE WEST NSW 2302
Phone: (02) 4908 6800
Fax: (02) 4908 6810

PO Box 488G NEWCASTLE
NSW 2300

Information about this licence

Dictionary

A definition of terms used in the licence can be found in the dictionary at the end of this licence.

Responsibilities of licensee

Separate to the requirements of this licence, general obligations of licensees are set out in the Protection of the Environment Operations Act 1997 (“the Act”) and the Regulations made under the Act. These include obligations to:

- ensure persons associated with you comply with this licence, as set out in section 64 of the Act;
- control the pollution of waters and the pollution of air (see for example sections 120 - 132 of the Act); and
- report incidents causing or threatening material environmental harm to the environment, as set out in Part 5.7 of the Act.

Variation of licence conditions

The licence holder can apply to vary the conditions of this licence. An application form for this purpose is available from the EPA.

The EPA may also vary the conditions of the licence at any time by written notice without an application being made.

Where a licence has been granted in relation to development which was assessed under the Environmental Planning and Assessment Act 1979 in accordance with the procedures applying to integrated development, the EPA may not impose conditions which are inconsistent with the development consent conditions until the licence is first reviewed under Part 3.6 of the Act.

Duration of licence

This licence will remain in force until the licence is surrendered by the licence holder or until it is suspended or revoked by the EPA or the Minister. A licence may only be surrendered with the written approval of the EPA.

Licence review

The Act requires that the EPA review your licence at least every 5 years after the issue of the licence, as set out in Part 3.6 and Schedule 5 of the Act. You will receive advance notice of the licence review.

Fees and annual return to be sent to the EPA

For each licence fee period you must pay:

- an administrative fee; and
- a load-based fee (if applicable).

The EPA publication “A Guide to Licensing” contains information about how to calculate your licence fees. The licence requires that an Annual Return, comprising a Statement of Compliance and a summary of any monitoring required by the licence (including the recording of complaints), be submitted to the EPA. The Annual Return must be submitted within 60 days after the end of each reporting period. See condition R1 regarding the Annual Return reporting requirements.

Usually the licence fee period is the same as the reporting period.

Transfer of licence

The licence holder can apply to transfer the licence to another person. An application form for this purpose is available from the EPA.

Public register and access to monitoring data

Part 9.5 of the Act requires the EPA to keep a public register of details and decisions of the EPA in relation to, for example:

- licence applications;
- licence conditions and variations;
- statements of compliance;
- load based licensing information; and
- load reduction agreements.

Under s320 of the Act application can be made to the EPA for access to monitoring data which has been submitted to the EPA by licensees.

This licence is issued to:

HANSON CONSTRUCTION MATERIALS PTY LTD
LOCKED BAG 5260
PARRAMATTA NSW 2124

subject to the conditions which follow.

1 Administrative Conditions

A1 What the licence authorises and regulates

A1.1 This licence authorises the carrying out of the scheduled activities listed below at the premises specified in A2. The activities are listed according to their scheduled activity classification, fee-based activity classification and the scale of the operation.

Unless otherwise further restricted by a condition of this licence, the scale at which the activity is carried out must not exceed the maximum scale specified in this condition.

Scheduled Activity	Fee Based Activity	Scale
Crushing, Grinding or Separating	Crushing, grinding or separating	> 500000 - 2000000 T processed
Extractive Activities	Land-based extractive activity	> 500000 - 2000000 T extracted, processed or stored

A1.2 Production at the premises must not exceed 700,000 tonnes per annum (measured over the licensing reporting period) of material obtained.

Note:

During 2011 the licensee made application to increase production to 700,000 tpa. The licensee obtained legal advice that the development consent for the quarry does not limit production. Port Stephens Council Development Advisory Panel confirmed that the development consent does not limit the extraction volume from the quarry. The 700,000 tpa limit is based on the 2011 application.

A2 Premises or plant to which this licence applies

A2.1 The licence applies to the following premises:

Premises Details
HANSON CONSTRUCTION MATERIALS PTY LTD
OFF SEAHAM ROAD
SEAHAM
NSW 2324
LOT 1 DP 264033, LOT 100 DP 712886, LOT 101 DP 712886, LOT 1 DP 737844, LOT 2 DP 737844, LOT 19 DP 752487, LOT 20 DP 752487, LOT 21 DP 752487, LOT 36 DP 752487, LOT 56 DP 752487, LOT 57 DP 752487, LOT 58 DP 752487, LOT 59 DP 752487, LOT 236 DP 752487, LOT 1 DP 1006516, LOT 2 DP 1006516, LOT 3 DP 1006516

A3 Information supplied to the EPA

A3.1 Works and activities must be carried out in accordance with the proposal contained in the licence application, except as expressly provided by a condition of this licence.

In this condition the reference to "the licence application" includes a reference to:

a) the applications for any licences (including former pollution control approvals) which this licence replaces under the Protection of the Environment Operations (Savings and Transitional) Regulation 1998; and
b) the licence information form provided by the licensee to the EPA to assist the EPA in connection with the issuing of this licence.

2 Discharges to Air and Water and Applications to Land

P1 Location of monitoring/discharge points and areas

P1.1 The following points referred to in the table below are identified in this licence for the purposes of monitoring and/or the setting of limits for the emission of pollutants to the air from the point.

Air

EPA identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description
1	Dust monitoring		Dust deposition gauge, shown as "Giles Road" on Figure titled "Hanson Construction Materials - Brandy Hill Quarry - Dust Monitoring Locations - September 2010" (on EPA file LIC10/854).
2	Dust monitoring		Dust deposition gauge, shown as "Front Gate" on Figure titled "Hanson Construction Materials - Brandy Hill Quarry - Dust Monitoring Locations - September 2010" (on EPA file LIC10/854).
3	Dust monitoring		Dust deposition gauge, shown as "Cattleyards" on Figure titled "Hanson Construction Materials - Brandy Hill Quarry - Dust Monitoring Locations - September 2010" (on EPA file LIC10/854).

P1.2 The following points referred to in the table are identified in this licence for the purposes of the monitoring and/or the setting of limits for discharges of pollutants to water from the point.

P1.3 The following utilisation areas referred to in the table below are identified in this licence for the purposes of the monitoring and/or the setting of limits for any application of solids or liquids to the utilisation area.

Water and land

EPA Identi-fication no.	Type of Monitoring Point	Type of Discharge Point	Location Description

4	Discharge and Monitoring Point	Discharge and Monitoring Point	Discharge point from "North Sediment Dam 2" as identified on Figure Two from report titled 'Water Management System Works - Brandy Hill Quarry, Brandy Hill' dated 24 September 2012. Copy of report is kept on EPA file LIC10/854-03
5	Discharge and Monitoring Point	Discharge and Monitoring Point	Discharge point from "Polishing Dam 3" as identified on 'Figure Three from report titled 'Water Management System Works - Brandy Hill Quarry, Brandy Hill' dated 24 September 2012. Copy of report is kept on EPA file LIC10/854-03
6	Discharge and Monitoring Point	Discharge and Monitoring Point	Discharge point from "North Sediment Dam 1" as identified on Figure Two from report titled 'Water Management System Works - Brandy Hill Quarry, Brandy Hill' dated 24 September 2012. Copy of report is kept on EPA file LIC10/854-03

3 Limit Conditions

L1 Pollution of waters

L1.1 Except as may be expressly provided in any other condition of this licence, the licensee must comply with section 120 of the Protection of the Environment Operations Act 1997.

L2 Concentration limits

L2.1 Water and/or Land Concentration Limits

POINT 4,5,6

Pollutant	Units of Measure	50 percentile concentration limit	90 percentile concentration limit	3DGM concentration limit	100 percentile concentration limit
Oil and Grease	Visible				non-visible
pH	pH				6.5 - 8.5

Total suspended solids	milligrams per litre	50

L3 Waste

L3.1 The licensee must not cause, permit or allow any waste generated outside the premises to be received at the premises for storage, treatment, processing, reprocessing or disposal or any waste generated at the premises to be disposed of at the premises, except as expressly permitted by the licence.

L3.2 This condition only applies to the storage, treatment, processing, reprocessing or disposal of waste at the premises if it requires an environment protection licence.

L4 Noise limits

L4.1 Noise generated at the premises must not exceed the noise limits in the table below. The locations referred to in the table below are indicated by "Figure 1 - Monitoring Locations" in the report titled '*Hanson Quarry, Brandy Hill - Background Noise Monitoring*' dated March 2011. This report is filed on EPA file LIC10/854.

Locality	**Location**	**NOISE LIMITS dB(A)**	**NOISE LIMITS dB(A)**
		Day / Evening / Night LAeq(15 minute)	Night LA1(1 minute)
R1	13B Giles Road, Seaham	36	45
R2	115 Brandy Hill Drive, Seaham	36	45
R3	13 Mooghin Road, Seaham	36	45
All other noise receiver locations		36	45

L4.2 For the purpose of the table above;
a) Day is defined as the period from 7am to 6pm Monday to Saturday and 8am to 6pm Sunday and Public Holidays;
b) Evening is defined as the period 6pm to 10pm; and
c) Night is defined as the period from 10pm to 7am Monday to Saturday and 10pm to 8am Sunday and Public Holidays.

L4.3 The noise limits set out in the Conditions above, apply under all meteorological conditions except for the following:
a) Wind speed greater than 3 metres/second at 10 metres above ground level; or
b) Stability category F temperature inversion conditions and wind speeds greater than 2 metres/second at 10 metres above ground level; or
c) Stability category G temperature inversion conditions.

L4.4 For the purposes of the condition above, data recorded by the meteorological station identified as the Bureau of Meteorology (BoM) Tocal Automatic Weather Station must be used to determine meteorological conditions.

L4.5 To determine compliance with the LAeq(15 minute) noise limits referred to above, the noise measurement equipment must be located;
a) at the most effected point at a location where there is no dwelling at the location; or
b) approximately on the property boundary, where any dwelling is situated 30 metres or less from the property boundary closest to the premises; or
c) within 30 metres of a dwelling fascade, but not closer than 3 metres, where any dwelling on the property is situated more than 30 metres from the property boundary closest to the premises; or
d) where applicable, within approximately 50 metres of the boundary of a National Park or a Nature Reserve.

L5 Blasting

L5.1 The overpressure level from blasting operations carried out in or on the premises must not:
a) exceed 115 dB(L) for more than 5% of the total number of blasts carried out on the premises within the 12 months annual reporting period; and
b) exceed 120 dB(L) at any time
at any residence or noise sensitive location (such as a school or hospital) that is not owned by the licensee or subject of a private agreement between the owner of the residence or noise sensitive location and the licensee as to an alternative overpressure level.

Error margins associated with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.

L5.2 Ground vibration peak particle velocity from the blasting operations carried out in or on the premises must not exceed:
a) 5mm/sec for more than 5% of the total number of blasts carried out on the premises within the 12 months annual reporting period; and
b) 10mm/sec at any time
at any residence or noise sensitive location (such as a school or hospital) that is not owned by the licensee or subject of a private agreement between the owner of the residence or noise sensitive location and the licensee as to an alternative overpressure level.

Error margins associated with any monitoring equipment used to measure this are not to be taken into account in determining whether or not the limit has been exceeded.

4 Operating Conditions

O1 Activities must be carried out in a competent manner

O1.1 Licensed activities must be carried out in a competent manner.
This includes:
a) the processing, handling, movement and storage of materials and substances used to carry out the activity; and

b) the treatment, storage, processing, reprocessing, transport and disposal of waste generated by the activity.

O2 Maintenance of plant and equipment

O2.1 All plant and equipment installed at the premises or used in connection with the licensed activity:
a) must be maintained in a proper and efficient condition; and
b) must be operated in a proper and efficient manner.

O3 Dust

O3.1 The premises must be maintained in a condition which minimises or prevents the emission of dust from the premises.

O4 Processes and management

O4.1 The drainage from all areas at the premises which will liberate suspended solids when stormwater runs over these areas must be diverted into adequately sized sedimentation basins.

O4.2 The sedimentation basins must be maintained to ensure that their design capacity is available for the storage of all runoff from cleared areas.

O4.3 All above ground tanks containing material that is likely to cause environmental harm must be bunded or have an alternative spill containment system in place.

O5 Waste management

O5.1 The licensee must ensure that any liquid and/or non liquid waste generated and/or stored at the premises is assessed and classified in accordance with the EPA Waste Classification Guidelines as in force from time to time.

O5.2 The licensee must ensure that waste identified for recycling is stored separately from other waste.

5 Monitoring and Recording Conditions

M1 Monitoring records

M1.1 The results of any monitoring required to be conducted by this licence or a load calculation protocol must be recorded and retained as set out in this condition.

M1.2 All records required to be kept by this licence must be:
a) in a legible form, or in a form that can readily be reduced to a legible form;
b) kept for at least 4 years after the monitoring or event to which they relate took place; and

c) produced in a legible form to any authorised officer of the EPA who asks to see them.

M1.3 The following records must be kept in respect of any samples required to be collected for the purposes of this licence:
a) the date(s) on which the sample was taken;
b) the time(s) at which the sample was collected;
c) the point at which the sample was taken; and
d) the name of the person who collected the sample.

M2 Requirement to monitor concentration of pollutants discharged

M2.1 For each monitoring/discharge point or utilisation area specified below (by a point number), the licensee must monitor (by sampling and obtaining results by analysis) the concentration of each pollutant specified in Column 1. The licensee must use the sampling method, units of measure, and sample at the frequency, specified opposite in the other columns:

M2.2 Air Monitoring Requirements

POINT **1,2,3**

Pollutant	Units of measure	Frequency	Sampling Method
Particulates - Deposited Matter	grams per square metre per month	Monthly	AM-19

M2.3 Water and/ or Land Monitoring Requirements

POINT **4,5,6**

Pollutant	Units of measure	Frequency	Sampling Method
Oil and Grease	Visible	Daily during any discharge	Visual Inspection
pH	pH	Daily during any discharge	Grab sample
Total suspended solids	milligrams per litre	Daily during any discharge	Grab sample

M3 Testing methods - concentration limits

M3.1 Monitoring for the concentration of a pollutant emitted to the air required to be conducted by this licence must be done in accordance with:
a) any methodology which is required by or under the Act to be used for the testing of the concentration of the pollutant; or

b) if no such requirement is imposed by or under the Act, any methodology which a condition of this licence requires to be used for that testing; or
c) if no such requirement is imposed by or under the Act or by a condition of this licence, any methodology approved in writing by the EPA for the purposes of that testing prior to the testing taking place.

Note: The *Protection of the Environment Operations (Clean Air) Regulation 2010* requires testing for certain purposes to be conducted in accordance with test methods contained in the publication "Approved Methods for the Sampling and Analysis of Air Pollutants in NSW".

M4 Recording of pollution complaints

M4.1 The licensee must keep a legible record of all complaints made to the licensee or any employee or agent of the licensee in relation to pollution arising from any activity to which this licence applies.

M4.2 The record must include details of the following:
a) the date and time of the complaint;
b) the method by which the complaint was made;
c) any personal details of the complainant which were provided by the complainant or, if no such details were provided, a note to that effect;
d) the nature of the complaint;
e) the action taken by the licensee in relation to the complaint, including any follow-up contact with the complainant; and
f) if no action was taken by the licensee, the reasons why no action was taken.

M4.3 The record of a complaint must be kept for at least 4 years after the complaint was made.

M4.4 The record must be produced to any authorised officer of the EPA who asks to see them.

M5 Telephone complaints line

M5.1 The licensee must operate during its operating hours a telephone complaints line for the purpose of receiving any complaints from members of the public in relation to activities conducted at the premises or by the vehicle or mobile plant, unless otherwise specified in the licence.

M5.2 The licensee must notify the public of the complaints line telephone number and the fact that it is a complaints line so that the impacted community knows how to make a complaint.

M5.3 The preceding two conditions do not apply until 3 months after:
a) the date of the issue of this licence or
b) if this licence is a replacement licence within the meaning of the Protection of the Environment Operations (Savings and Transitional) Regulation 1998, the date on which a copy of the licence was served on the licensee under clause 10 of that regulation.

M6 Blasting

M6.1 The licensee must monitor all blasts carried out in or on the premises at or near the nearest residence or noise sensitive location (such as a school or hospital) that is likely to be most affected by the blast and that is not owned by the licensee or subject of a private agreement between the owner of the residence or noise sensitive location and the licensee relating to alternative blasting limits.

M7 Other monitoring and recording conditions

M7.1 To assess compliance with the noise limits of this licence, attended noise monitoring must be undertaken in accordance with the conditions of this licence and:
a) at the locations R1, R2 and R3 as listed in the limit conditions of this licence;
b) occur annnually in a reporting period, during the times of year when noise propogation from the premises is likely to be at its worst, that is generally winter conditions; and
c) occur during the night period as defined in the NSW Industrial Noise Policy.

M7.2 Noise monitoring must be carried out in accordance with Australian Standard AS 2659.1 - 1998: Guide to the use of sound measuring equipment - Portable sound level metres, and the compliance monitoring guidance provided in the NSW Industrial Noise Policy.

Note: The EPA will consider upon request a review of the noise monitoring results required under this condition after a period of three (3) years (i.e. after August 2014) to assess the suitability and need of the required noise monitoring.

6 Reporting Conditions

R1 Annual return documents

R1.1 The licensee must complete and supply to the EPA an Annual Return in the approved form comprising:
a) a Statement of Compliance; and
b) a Monitoring and Complaints Summary.
At the end of each reporting period, the EPA will provide to the licensee a copy of the form that must be completed and returned to the EPA.

R1.2 An Annual Return must be prepared in respect of each reporting period, except as provided below.

R1.3 Where this licence is transferred from the licensee to a new licensee:
a) the transferring licensee must prepare an Annual Return for the period commencing on the first day of the reporting period and ending on the date the application for the transfer of the licence to the new licensee is granted; and
b) the new licensee must prepare an Annual Return for the period commencing on the date the application for the transfer of the licence is granted and ending on the last day of the reporting period.

R1.4 Where this licence is surrendered by the licensee or revoked by the EPA or Minister, the licensee must prepare an Annual Return in respect of the period commencing on the first day of the reporting period and ending on:
a) in relation to the surrender of a licence - the date when notice in writing of approval of the surrender is given; or
b) in relation to the revocation of the licence - the date from which notice revoking the licence operates.

R1.5 The Annual Return for the reporting period must be supplied to the EPA by registered post not later than 60 days after the end of each reporting period or in the case of a transferring licence not later than 60 days after the date the transfer was granted (the 'due date').

R1.6 The licensee must retain a copy of the Annual Return supplied to the EPA for a period of at least 4 years after the Annual Return was due to be supplied to the EPA.

R1.7 Within the Annual Return, the Statement of Compliance must be certified and the Monitoring and Complaints Summary must be signed by:
a) the licence holder; or
b) by a person approved in writing by the EPA to sign on behalf of the licence holder.

R1.8 A person who has been given written approval to certify a certificate of compliance under a licence issued under the Pollution Control Act 1970 is taken to be approved for the purpose of this condition until the date of first review of this licence.

R1.9 The licensee must report any exceedence of the licence blasting limits to the regional office of the EPA as soon as practicable after the exceedence becomes known to the licensee or to one of the licensee’s employees or agents.

Note: The term "reporting period" is defined in the dictionary at the end of this licence. Do not complete the Annual Return until after the end of the reporting period.

Note: An application to transfer a licence must be made in the approved form for this purpose.

R1.10 The licensee must supply, with each Annual Return, a Blast Monitoring Report which must include the following information relating to each blast carried out within the premises during the reporting period covered by the Annual Return:
a) the date and time of the blast;
b) the location of the blast on the premises;
c) the blast monitoring results at each blast monitoring station; and
d) an explanation for any missing blast monitoring results.

R2 Notification of environmental harm

R2.1 Notifications must be made by telephoning the Environment Line service on 131 555.

R2.2 The licensee must provide written details of the notification to the EPA within 7 days of the date on which the incident occurred.

Note: The licensee or its employees must notify all relevant authorities of incidents causing or threatening material harm to the environment immediately after the person becomes aware of the incident in accordance with the requirements of Part 5.7 of the Act.

R3 Written report

R3.1 Where an authorised officer of the EPA suspects on reasonable grounds that:

a) where this licence applies to premises, an event has occurred at the premises; or
b) where this licence applies to vehicles or mobile plant, an event has occurred in connection with the carrying out of the activities authorised by this licence,
and the event has caused, is causing or is likely to cause material harm to the environment (whether the harm occurs on or off premises to which the licence applies), the authorised officer may request a written report of the event.

R3.2 The licensee must make all reasonable inquiries in relation to the event and supply the report to the EPA within such time as may be specified in the request.

R3.3 The request may require a report which includes any or all of the following information:
a) the cause, time and duration of the event;
b) the type, volume and concentration of every pollutant discharged as a result of the event;
c) the name, address and business hours telephone number of employees or agents of the licensee, or a specified class of them, who witnessed the event;
d) the name, address and business hours telephone number of every other person (of whom the licensee is aware) who witnessed the event, unless the licensee has been unable to obtain that information after making reasonable effort;
e) action taken by the licensee in relation to the event, including any follow-up contact with any complainants;
f) details of any measure taken or proposed to be taken to prevent or mitigate against a recurrence of such an event; and
g) any other relevant matters.

R3.4 The EPA may make a written request for further details in relation to any of the above matters if it is not satisfied with the report provided by the licensee. The licensee must provide such further details to the EPA within the time specified in the request.

R4 Other reporting conditions

R4.1 A noise compliance assessment report must be submitted to the EPA within thirty (30) days of the completion of the yearly noise monitoring. The assessment must be prepared by a suitably qualified and experienced acoustical consultant and include:
a) an assessment of compliance with noise limits detailed in the limit conditions of this licence; and
b) an outline of any management actions taken within the monitoring period to address any exceedences of the limits detailed in the limit conditions of this licence.

R4.2 The licensee must report any exceedence of the licence blasting limits to the regional office of the EPA as soon as practicable after the exceedence becomes known to the licensee or to one of the licensee's employees or agents.

R4.3 The licensee must supply, with each Annual Return, a Blast Monitoring Report which must include the following information relating to each blast carried out within the premises during the reporting period covered by the Annual Return:
a) the date and time of the blast;
b) the location of the blast on the premises;
c) the blast monitoring results at each blast monitoring station; and
d) an explanation for any missing blast monitoring results.

7 General Conditions

G1 Copy of licence kept at the premises or plant

G1.1 A copy of this licence must be kept at the premises to which the licence applies.

G1.2 The licence must be produced to any authorised officer of the EPA who asks to see it.

G1.3 The licence must be available for inspection by any employee or agent of the licensee working at the premises.

8 Special Conditions

E1 Completed Pollution Reduction Programs (PRPs)

E1.1 The licensee has completed the Pollution Reduction Programs (PRPs) as detailed in the table below.

PRP No.	Details	Completed
1	Water Management Investigations	July 2011
2	Operational Noise	March 2011
3	Water Management System Works	September 2012

Dictionary

General Dictionary

3DGM [in relation to a concentration limit]	Means the three day geometric mean, which is calculated by multiplying the results of the analysis of three samples collected on consecutive days and then taking the cubed root of that amount. Where one or more of the samples is zero or below the detection limit for the analysis, then 1 or the detection limit respectively should be used in place of those samples
Act	Means the Protection of the Environment Operations Act 1997
activity	Means a scheduled or non-scheduled activity within the meaning of the Protection of the Environment Operations Act 1997
actual load	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 2009
AM	Together with a number, means an ambient air monitoring method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.
AMG	Australian Map Grid
anniversary date	The anniversary date is the anniversary each year of the date of issue of the licence. In the case of a licence continued in force by the Protection of the Environment Operations Act 1997, the date of issue of the licence is the first anniversary of the date of issue or last renewal of the licence following the commencement of the Act.
annual return	Is defined in R1.1
Approved Methods Publication	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 2009
assessable pollutants	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 2009
BOD	Means biochemical oxygen demand
CEM	Together with a number, means a continuous emission monitoring method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.
COD	Means chemical oxygen demand
composite sample	Unless otherwise specifically approved in writing by the EPA, a sample consisting of 24 individual samples collected at hourly intervals and each having an equivalent volume.
cond.	Means conductivity
environment	Has the same meaning as in the Protection of the Environment Operations Act 1997
environment protection legislation	Has the same meaning as in the Protection of the Environment Administration Act 1991
EPA	Means Environment Protection Authority of New South Wales.
fee-based activity classification	Means the numbered short descriptions in Schedule 1 of the Protection of the Environment Operations (General) Regulation 2009.
general solid waste (non-putrescible)	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997

Environment Protection Licence

flow weighted composite sample	Means a sample whose composites are sized in proportion to the flow at each composites time of collection.
general solid waste (putrescible)	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
grab sample	Means a single sample taken at a point at a single time
hazardous waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
licensee	Means the licence holder described at the front of this licence
load calculation protocol	Has the same meaning as in the Protection of the Environment Operations (General) Regulation 2009
local authority	Has the same meaning as in the Protection of the Environment Operations Act 1997
material harm	Has the same meaning as in section 147 Protection of the Environment Operations Act 1997
MBAS	Means methylene blue active substances
Minister	Means the Minister administering the Protection of the Environment Operations Act 1997
mobile plant	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
motor vehicle	Has the same meaning as in the Protection of the Environment Operations Act 1997
O&G	Means oil and grease
percentile [in relation to a concentration limit of a sample]	Means that percentage [eg.50%] of the number of samples taken that must meet the concentration limit specified in the licence for that pollutant over a specified period of time. In this licence, the specified period of time is the Reporting Period unless otherwise stated in this licence.
plant	Includes all plant within the meaning of the Protection of the Environment Operations Act 1997 as well as motor vehicles.
pollution of waters [or water pollution]	Has the same meaning as in the Protection of the Environment Operations Act 1997
premises	Means the premises described in condition A2.1
public authority	Has the same meaning as in the Protection of the Environment Operations Act 1997
regional office	Means the relevant EPA office referred to in the Contacting the EPA document accompanying this licence
reporting period	For the purposes of this licence, the reporting period means the period of 12 months after the issue of the licence, and each subsequent period of 12 months. In the case of a licence continued in force by the Protection of the Environment Operations Act 1997, the date of issue of the licence is the first anniversary of the date of issue or last renewal of the licence following the commencement of the Act.
restricted solid waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
scheduled activity	Means an activity listed in Schedule 1 of the Protection of the Environment Operations Act 1997
special waste	Has the same meaning as in Part 3 of Schedule 1 of the Protection of the Environment Operations Act 1997
TM	Together with a number, means a test method of that number prescribed by the *Approved Methods for the Sampling and Analysis of Air Pollutants in New South Wales*.

TSP	Means total suspended particles
TSS	Means total suspended solids
Type 1 substance	Means the elements antimony, arsenic, cadmium, lead or mercury or any compound containing one or more of those elements
Type 2 substance	Means the elements beryllium, chromium, cobalt, manganese, nickel, selenium, tin or vanadium or any compound containing one or more of those elements
utilisation area	Means any area shown as a utilisation area on a map submitted with the application for this licence
waste	Has the same meaning as in the Protection of the Environment Operations Act 1997
waste type	Means liquid, restricted solid waste, general solid waste (putrescible), general solid waste (non - putrescible), special waste or hazardous waste

Mr Nigel Sargent

Environment Protection Authority

(By Delegation)

Date of this edition: 25-July-2000

End Notes

1 Licence transferred through application 140392, approved on 02-May-2001, which came into effect on 08-Jun-2000.

2 Licence varied by notice 1012892, issued on 03-Sep-2002, which came into effect on 28-Sep-2002.

3 Licence transferred through application 142945, approved on 17-Sep-2004, which came into effect on 28-Jul-2004.

4 Licence fee period changed by notice 1074523 approved on 12-Jun-2007.

5 Condition A1.3 Not applicable varied by notice issued on <issue date> which came into effect on <effective date>

6 Licence varied by notice 1119156, issued on 07-Oct-2010, which came into effect on 07-Oct-2010.

7 Licence varied by notice 1500035 issued on 01-Sep-2011

8 Licence varied by notice 1501407 issued on 31-Oct-2011

9 Licence varied by notice 1509251 issued on 29-Apr-2013

Attachment I – Agency Consultation

Daniel Dhiacou

From:	Mitchell Isaacs <mitchell.isaacs@dpi.nsw.gov.au>
Sent:	Tuesday, 20 January 2015 6:55 PM
To:	Daniel Dhiacou
Cc:	Rohan Macdonald; vanessa.hornsby@dpi.nsw.gov.au
Subject:	Re: P1303888 Brandy Hill Quarry - Surface Water Licencing
Attachments:	ER22275_SW licensing response.pdf

Hi Daniel

Thanks for your email and earlier letter.

Please find attached the Office of Water's advice for your consideration.

Regards
Mitchell

On Tue, Jan 20, 2015 at 4:40 PM, Daniel Dhiacou <DDhiacou@martens.com.au> wrote:

Hi Mitchell,

I understand that Anthony Bryson passed our surface water licencing correspondence for Brandy Hill Quarry (SSD- 5899) to you to confirm requirements. I have reattached the letter for your reference.

Have you been able to review this correspondence?

Feel free to call me with any queries.

Regards,

Daniel Dhiacou

Civil & Environmental Engineer

BEng (Hons1), DipEngPrac

martens
& Associates Pty Ltd

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PLEASE NOTE MARTENS HAS MOVED TO GEORGE ST, HORNSBY

--

Mitchell Isaacs | Manager Strategic Stakeholder Liaison
Department of Primary Industries | NSW Office of Water
Level 11, 10 Valentine Ave Parramatta NSW 2124 | PO Box 3720 Parramatta NSW 2124
T: 02 8838 7529 | M: 0403 103 823 | E: mitchell.isaacs@dpi.nsw.gov.au
W: www.water.nsw.gov.au

Please note change to @dpi in email address

Requests for review or comment on reports or specific projects can be sent directly to water.referrals@dpi.nsw.gov.au for action

NSW GOVERNMENT
Department of Primary Industries
Office of Water

Contact Rohan Macdonald
Phone 02 4904 2642
Fax 02 4904 2503
Email rohan.macdonald@dpi.nsw.gov.au

Our ref ER22275
Your ref P1303888JC07V01

Martens & Associates P/L
Suite 201, 20 George Street
HORNSBY NSW 2077

Attention: Daniel Dhiacou

Dear Daniel

Brandy Hill Quarry: Surface Water Licensing Requirements for Quarry Expansion EIS

I refer to your request for confirmation regarding the surface water licensing requirements for the Brandy Hill Quarry expansion proposal. The Office of Water has reviewed the information provided and can confirm the following:

1. Dams constructed for the capture of clean water that are located on a minor stream (1st or 2nd order under the Strahler stream order system) and are within the Maximum Harvestable Right Dam Capacity for the landholding do not require licensing;
2. Dams constructed to capture and treat contaminated runoff (e.g. sedimentation basins) are exempt from licensing and approval requirements and are not included in harvestable rights calculations, provided they are consistent with the provisions of the Harvestable Rights Order gazetted 31 March 2006 and the *Water Management (General) Regulation 2011*, are constructed in accordance with best management practice (including the provisions of the publication *Managing Urban Stormwater: Soils and Construction*) and do not capture clean water either via runoff or pumping from other works; and
3. Pumping from an exempt sedimentation dam to a harvestable rights dam will not alter the licensing status of either work.

In order to maintain the exemption status for sedimentation basins, site operations should be conducted in accordance with best management practice for erosion and sediment control, including the minimisation and timely rehabilitation of disturbed areas and the separation of clean runoff from offsite and rehabilitated areas from runoff from disturbed areas.

With respect to the transfer of water from sedimentation basins to a harvestable rights dam, consultation should be undertaken with the EPA to determine discharge licensing implications, including monitoring locations and parameters and discharge limits.

Information regarding harvestable right dams can be found at http://www.water.nsw.gov.au/Water-Licensing/Basic-water-rights/Harvesting-runoff/default.aspx. If you require further information please contact Rohan Macdonald, Water Regulation Officer on (02) 4904 2642.

Yours sincerely,

Mitchell Isaacs
Manager, Strategic Stakeholder Liaison
20 January 2015

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Posted ☐
Faxed ☐
Emailed ☒ anthony.bryson@water.nsw.gov.au
Courier ☐
By Hand ☐
Contact: Daniel Dhiacou / Andrew Norris
Our Ref: P1303888JC07V01
Pages: 2
cc. -

December 19, 2014

NSW Office of Water
Attn: Anthony Bryson

Dear Anthony,

RE: BRANDY HILL QUARRY: SURFACE WATER LICENCING REQUIREMENTS FOR QUARRY EXPANSION EIS

Martens and Associates seek confirmation of the surface water licencing requirements for expansion works at Brandy Hill Quarry, 979 Clarencetown Road, Seaham, NSW.

As part of the expansion EIS (SSD-5899) we propose that the quarry be graded to sedimentation basins within the quarry floor to capture and treat contaminated runoff. This contaminated runoff will be recirculated for quarry operations including dust suppression and product moisture conditioning. Surface runoff from stockpile and processing areas shall be directed to separate sedimentation basins and similarly recirculated. Excess water shall be discharged subject to water quality requirements of the site environmental planning licence.

We believe that the site sedimentation basins are exempt from classification as harvestable rights dams and exempt from Water Management Act (2000) licencing in accordance with NSW Government Gazette 40 dated 31 March 2006 (pages 1628 to 1631) and therefore do not require a licence. Other than sedimentation dams the only other proposed surface water structures would be dams which would be sized to be below the site’s maximum harvestable rights dam capacity.

We would appreciate your confirmation on our understanding of the sedimentation dams as being except from the maximum harvestable rights dam capacity calculation and Water Management Act licensing. We would also appreciate confirmation on any licencing implication should we pump from a sedimentation dam to a maximum harvestable rights dam. This would be beneficial from a water quality treatment perspective but will be removed from the site strategy if it will alter the exemption status of either structure.

If you require any further information, please do not hesitate to contact the writer.

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Groundwater	Hydrogeology	Wetlands	Design	Roads
Catchments	Mining	Water quality	Management	Pavements
Bushfire	Terrain analysis	Irrigation	Monitoring	Parking
Monitoring	Waste management	Water sensitive design	Construction	Structures

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MARTENS & ASSOCIATES P/L
ABN 85 070 240 890 ACN 070 240 890

For and on behalf of
MARTENS & ASSOCIATES PTY LTD

DANIEL DHIACOU
BEng (Hons1), DipEngPrac
Civil & Environmental Engineer

ANDREW NORRIS
BSc (Hons), MEngSc, MAWA
Director/Project Manager

NSW EPA

Our reference: DOC14/244016-01, EF13/3039
Contact: Jocelyn Karsten, 02 4908 6865
Electronic correspondence to: hunter.region@epa.nsw.gov.au

2 - DEC 2014

Daniel Dhiacou
Martens & Associates Pty Ltd
Unit 6/37 Leighton Place
HORNSBY, NSW 2077

Dear Mr Dhiacou

BRANDY HILL QUARRY: OVERVIEW OF SURFACE WATER CONDITIONS AND PROPOSED MODELLING AND ASSESSMENT FOR QUARRY EXPANSION EA

Reference is made to your letter dated 20 October 2014, requesting the Environment Protection Authority (EPA) to provide comments regarding the proposed methodology for the surface water modelling and assessment of the proposed Hanson Brandy Hill quarry expansion EA.

Thank you for providing the EPA with this opportunity to comment, however, the EPA does not have the resources to comment on such methodologies and proposed approaches to the assessment process.

The EPA will conduct a detailed review of the proposal, including water management, when the Environment Assessment is referred to us by the Department of Planning & Environment.

If you have any questions concerning this advice please contact Jocelyn Karsten on (02) 4908 6865 in our Newcastle office.

Yours sincerely

ROSS BRYLYNSKY
A/Head Regional Operations Unit – Hunter Region
Environment Protection Authority

RECEIVED
08 DEC 2014
BY: ....

Daniel Dhiacou

From: Lara Davis <Lara.Davis@environment.nsw.gov.au>
Sent: Friday, 14 November 2014 6:42 PM
To: Daniel Dhiacou
Cc: Steve Lewer; Richard Bath; Andrew Norris; Neil Kelleher
Subject: FW: P1303888 - Brandy Hill Quarry Expansion EA - Surface Water Overview

Hi Daniel,

Further to our conversation today, I can confirm that OEH's comments on the flooding components of the Brandy Hill expansion project were based on the information that was contained in your memo only, thus not a lot of detail was known at the time of comment regarding the extent of the proposed expansion in relation to the adjacent waterways.

Further to your clarification today on the proposed footprint, which is entirely west of Deadmans Creek and entirely to the west of the existing quarry footprint, the comments on the flooding impacts of the proposed development relate to the ultimate flood flows that are estimated to discharge from the site to downstream waterways. It should be ensured that flows from the proposed development site do not increase from existing flows from the site, thus having no impact on the flooding characteristics of the downstream waterways. It is anticipated that this information could be extracted from the site water balance that is being prepared as part of the development application, and thus a separate stand-alone flood study is not required, so long as this information is presented clearly in the documents.

Regards,

Lara

Lara Davis
Senior Natural Resource Officer (Floodplain)
Regional Operations
Office of Environment and Heritage
Suites 36-38, 207 Albany Street North, Gosford NSW
PO Box 1477, Gosford NSW 2250
T: +61 24320 4262 M: +61 4080 05289 F: +61 243204299
W: www.environment.nsw.gov.au

From: Daniel Dhiacou [mailto:DDhiacou@martens.com.au]
Sent: Friday, 14 November 2014 2:03 PM
To: Davis Lara
Cc: Lewer Steve; Bath Richard; Andrew Norris
Subject: RE: P1303888 - Brandy Hill Quarry Expansion EA - Surface Water Overview

Hi Lara,

Thanks for speaking with me earlier.

Further to our discussion, we understand that the comments on flooding impacts refer to the site water balance and proposed discharges, and not to impacts on Deadman's Creek, as the proposed quarry does not encroach on the creek's current extents. As part of the site water balance we are to demonstrate that discharges from the site should not increase or exacerbate flows in downstream tributaries. The volume and frequency of existing and proposed discharges will be quantified and described as part of the site water balance.

Regards,

Daniel Dhiacou

Civil & Environmental Engineer
BEng (Hons1), DipEngPrac

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PLEASE NOTE MARTENS HAS MOVED TO GEORGE ST, HORNSBY

From: Richard Bath [mailto:Richard.Bath@environment.nsw.gov.au]
Sent: Tuesday, 11 November 2014 4:05 PM
To: Daniel Dhiacou
Cc: Steve Lewer; Lara Davis
Subject: RE: P1303888 - Brandy Hill Quarry Expansion EA - Surface Water Overview

Hi Daniel

Please find attached OEH's comments on surface water management for the draft EIS. The original letter will be forwarded by post.

Regards

Richard Bath
Senior Team Leader Planning
Hunter Central Coast Region
Regional Operations Group
Office of Environment and Heritage
PO Box 488G Newcastle NSW 2300
T: 4908 6805
W: www.environment.nsw.gov.au

From: Daniel Dhiacou [mailto:DDhiacou@martens.com.au]
Sent: Monday, 20 October 2014 12:20 PM
To: rohan.mcdonald@water.nsw.gov.au; 'nicolai.cooper@lls.nsw.gov.au'; brendan.liew@planning.nsw.gov.au; EHP Planning Matters Mailbox
Cc: Andrew Norris; Driver, Andrew (Parramatta) AU (Andrew.Driver@hanson.com.au); Cox, Pip (Parramatta) AUS (pip.cox@hanson.com.au)
Subject: P1303888 - Brandy Hill Quarry Expansion EA - Surface Water Overview

Hello,

As per our correspondence last month, I now attach the proposed surface water modelling and assessment methodology for the Brandy Hill Quarry Expansion EA (SSD-5899).

Could you please review and provide any comments at your earliest convenience.

Regards,

Daniel Dhiacou
Civil & Environmental Engineer
BEng (Hons1), DipEngPrac

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NSW GOVERNMENT
Office of Environment & Heritage

Your reference: P1303888JC04V01
Our reference: DOC14/244945-01
Contact: Steve Lewer, 4908 6814

Mr Daniel Dhiacou
Civil & Environmental Engineer
Martens & Associates Pty Ltd
Suite 201, 20 George Street
HORNSBY NSW 2077

Dear Mr Dhiacou

RE: REVIEW OF PROPOSED SURFACE WATER MODELLING AND ASSESSMENT METHODOLOGY FOR BRANDY HILL QUARRY EXPANSION (SSD-5899)

I refer to your letter dated 20 October 2014, seeking comments from the Office of Environment and Heritage (OEH) on the proposed surface water modelling and assessment methodology for the Brandy Hill Quarry Expansion Environmental Impact Statement (EIS). OEH understands that this is a State Significant Development project under Part 4 of the *Environmental Planning and Assessment Act 1979.*

OEH notes that the Director General Requirements (DGRs) issued by the Department of Planning and Environment state that for water management the EIS must address the following issues:

- a detailed assessment of the potential impacts of the development on:
    - the quantity and quality of regional water supplies regional water supply infrastructure; and
    - affected licensed water users and basic landholder rights (including downstream water users);
- a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;
- an assessment of proposed water discharge quantities and quality/ies against receiving water quality and flow objectives;
- identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*;
- demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP);
- a description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo; and
- a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.

In light of the above requirements, OEH acknowledges that the draft document that has been sent to OEH for review includes a section on water management, however, the section on surface water management is considered very brief. OEH is of the opinion that any final version of the EIS must adequately address all the key issues on water management as proposed through the DGRs. If required, OEH is willing to provide further feedback on the surface water management chapter of the EIS prior to Public Exhibition.

Furthermore, given that this mine is located immediately adjacent to a creek, OEH is of the opinion that further detail will be required in the EIS regarding flooding impacts of the proposed development. This detail should include the (i) impact of the development on the existing flooding regime of the creek, and (ii) the impact of the creek flooding on the development, for flood flows up to and including the Probable Maximum Flood.

If you require any further information regarding this matter please contact Steve Lewer, Regional Biodiversity Conservation Officer, on 4908 6814; or if your have an issue pertaining to a technical matter please contact Lara Davis, Senior Natural Resource Officer (Floodplain), on 4320 4262.

Yours sincerely

R Bath 11 NOV 2014

RICHARD BATH
Senior Team Leader Planning, Hunter Central Coast Region
<u>Regional Operations</u>

Daniel Dhiacou

From:	Daniel Dhiacou
Sent:	Monday, 20 October 2014 12:20 PM
To:	rohan.mcdonald@water.nsw.gov.au; 'nicolai.cooper@lls.nsw.gov.au'; brendan.liew@planning.nsw.gov.au; planning.matters@environment.nsw.gov.au
Cc:	Andrew Norris; Driver, Andrew (Parramatta) AU (Andrew.Driver@hanson.com.au); Cox, Pip (Parramatta) AUS (pip.cox@hanson.com.au)
Subject:	P1303888 - Brandy Hill Quarry Expansion EA - Surface Water Overview
Attachments:	P1303888JC04V01 141020.pdf

Hello,

As per our correspondence last month, I now attach the proposed surface water modelling and assessment methodology for the Brandy Hill Quarry Expansion EA (SSD-5899).

Could you please review and provide any comments at your earliest convenience.

Regards,

Daniel Dhiacou
Civil & Environmental Engineer
BEng (Hons1), DipEngPrac

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& Associates Pty Ltd

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By Hand	☐
Contact:	Andrew Norris / Daniel Dhiacou
Our Ref:	P1303888JC04V01
Pages:	6 + Attachment
cc.	-

October 20, 2014

Hanson Construction Materials Pty Ltd
Attn: Andrew Driver

Dear Andrew,

RE: BRANDY HILL QUARRY: OVERVIEW OF SURFACE WATER CONDITIONS AND PROPOSED MODELLING AND ASSESSMENT FOR QUARRY EXPANSION EA

Further to a review of site surface water conditions and initial consultation with DOPI, NSW Office of Water, NSW EPA, Hunter Water and Hunter-Central Rivers Catchment Management Authority, Martens and Associates propose the following methodology for the surface water modelling and assessment of the proposed Hanson Brandy Hill quarry expansion EA. For reference purposes Attachment A includes SK001 which provides detail of existing site surface water elements and SK002 showing proposed Stage 5 (final stage) quarry benching.

SITE WATER BALANCE

A site water balance will be developed to assess site inflows, uses and discharges. Based on a recent site investigation and observations, the water balance will address:

1. Water demand.
    a. Site water is stored in the Western Dam and is currently used for road and plant dust suppression, and product moisture conditioning.
    b. Daily water usage and daily extraction volumes will be monitored for a period of one month. This will be used to determine average water use per tonne of material produced and average daily site dust suppression needs in order to determine current and proposed site water demand.
    c. A 30 kL water cart is filled from the Western Dam and used for site dust suppression.
    d. Water used for dust suppression on roads and stockpiles shall be assumed to be lost due to evapotranspiration. Water used for plant dust suppression shall similarly assumed to be lost, but provision shall be made for treatment of sediment laden flows should they reach the sedimentation ponds.

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ABN 85 070 240 890 ACN 070 240 890

2. Water recycling and infrastructure.

    a. Any overflows from the Western Dam flow to Sedimentation Dam 1 (refer to Attachment A SK001).

    b. Water is recirculated from the three Southern Sedimentation Dams via mobile pump to the Western Dam.

    c. Proposed water supply infrastructure and recycling requirements are to be determined as the project progresses.

3. Water storage structures and intake locations.

    a. Bunds currently divert surface water around the pit at the top of the catchment to the Western Dam. This diversion of “clean” upslope water will continue for proposed conditions.

    b. The Western Dam is fed only by surface water from the upstream catchment. There are no significant groundwater inflows.

    c. Town water supply is not currently supplied to the site and is expected to not be available in future.

    d. The capacity of the Western Dam is to be calculated based on farm dam policy assessment methodology.

    e. The Western Dam is to be removed at Stage 3 of works and replaced by a sedimentation / storage dam in the quarry floor.

    f. The Southern Sedimentation Dams are to be relocated during Stages 4 and 5.

    g. The proposed expansion will only alter site drainage paths and will not extend into Deadman’s Creek to the north east or the unnamed drainage path to the south west (refer to Attachment A SK002).

    h. Proposed water storage structures, volumes and locations are to be determined as the project progresses.

4. Water disposal.

    a. There are currently two site environmental protection licence (EPL) licenced discharge locations: from Polishing Dam 3 and from Northern Sedimentation Dam (pumped through pit wall).

    b. The Eastern Sedimentation Dam does not overflow and has no formal discharge point.

    c. Discharges occur once a month on average.

    d. Hanson minimise uncontrolled ‘overflow’ discharge from Polishing Dam 3 by pumping water to the Western Dam.

    e. No chemical water treatment is used or required.

    f. Hanson discharge water when it reaches a quality of 50 ppm, confirmed by lab testing undertaken by VGT Environmental Compliance Solutions. Discharge quantities are currently unmetered.

    g. Proposed water disposal methods are to be determined as the project progresses with EPL conditions to be maintained (i.e. 50 ppm discharge limit for TSS).

5. Water quality and quantity issues.

    a. Hanson note that water quantity has not been an issue throughout operation of the quarry. Town water supply has not been required. The Western Dam water level typically gets low in summer but has not run out.

    b. Hanson have provided a number of self-notifications to NSW EPA after releases of water from Polishing Dam 3 with greater than 50 ppm sediment has occurred in the last 12 months. These have occurred during rainfall events.

6. Enhanced water management.

    a. Site water usage patterns shall be reviewed and modified where possible to achieve water savings and enhanced sustainability of water use on the site.

    b. Details of the proposed water management system are to be determined as the project EA is developed.

WATER QUALITY CONTROLS

Requirements for water quality controls to mitigate downstream impacts will be determined. This will involve assessment of:

1. Potential impacts on regional water supply quality (including salinity), quantity and infrastructure.

2. Potential impacts to licenced water users and basic landholder entitlements.

3. Water quality and flow objectives of receiving waters, and potential impacts of the proposed development on these objectives.

4. Whether water quality conditions are currently being satisfied. If so, ensure the proposed expansion protects these waters; and if not, ensure the proposed expansion works ensure achievement of these conditions.

LICENSING REQUIREMENTS

There are currently no surface water or groundwater licences for the site. Licensing requirements for the proposed site will be assessed, including:

1. Addressing the requirements of:

    a. *Water Management Act* (2000); and

    b. The *Water Sharing Plan for the Hunter Unregulated & Alluvial Water Sources* (2009).

2. The adequacy and security of water supply for construction and operation phases. Should water entitlement be required, an assessment of the current market depth will be undertaken.

3. Potential impacts to adjacent licenced water users.

4. Provision to regularly review surface water licencing requirements.

SEDIMENT AND EROSION CONTROL

Sediment and erosion control plans will be designed and prepared, including:

1. Addressing the requirements of:

    a. Landcom (2004) "Blue Book" *Managing urban stormwater: soils and construction Volume 1;*

    b. DECC (2008) *Volume 2 E. Mines & Quarries*; and

    c. DLWC (200) *Soil & Landscape Issues in Environmental Impact Assessment*.

2. Assessment of the nature and extent of potential impacts.

3. Description of mitigation options and assessment of their effectiveness and reliability, as well as any potential residual impacts.

SURFACE WATER MANAGEMENT PLAN

A surface water management plan is to be prepared and will include:

1. Documentation of commitments.

2. Description of possible surface water quality and quantity impacts.

3. Contingency plans and provisions for when impacts are identified.

SURFACE WATER MONITORING PLAN

A surface water monitoring plan is to be prepared and will include:

1. Description of surface water monitoring program and how potential impacts will be assessed through construction and operation phases.

2. Adopted indicators and trigger values/criteria sourced from ANZECC (2000).

3. A trigger action response plan should adverse impacts be identified.

Importantly, the surface water management plan for the site is to be developed in parallel with the site groundwater management plan. These two plans shall be integrated to provide a best practice site water management solution.

This information is provided for review and comment to ensure that, as part of the development of the project Environmental Assessment, agencies are adequately consulted and given opportunity to comment and contribute to the development of the EA plan. If you require any further information or have any comments you wish to be considered, please contact the undersigned.

For and on behalf of

MARTENS & ASSOCIATES PTY LTD

D. Dhia

ANDREW NORRIS
BSc(Hons), MEngSc, MAWA
Director, Senior Engineer

DANIEL DHIACOU
BEng (Hons1), DipEngPrac
Civil & Environmental Engineer

ATTACHMENT A – FIGURES

BACKGROUND AERIAL FROM SIXMAPS (2014).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL ASSESSMENT	17.10.14	AN

BAR SCALE

DESIGNED: DD

DATUM: mAHD

REVIEWED: AN

HORIZONTAL RATIO: 1:5000

PAPER SIZE: A3

VERTICAL RATIO: NA

CLIENT / PROJECT

HANSON
BRANDY HILL QUARRY
EXPANSION EA

THIS PLAN MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS APPROVED BY PRINCIPAL CERTIFYING AUTHORITY
All measurements in mm unless otherwise specified

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Environment
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Geotechnical
Civil
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Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:

OVERVIEW OF
EXISTING SITE SURFACE WATER CONDITIONS

DRAWING ID: **SK001**

PROJECT MANAGER: AN

PROJECT NO.: P1303888

FILE: JD02V01

REVISION: A

BACKGROUND AERIAL FROM SIXMAPS (2014).
PROPOSED QUARRY CONTOURS FROM HANSON (2014).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL ASSESSMENT	17.10.14	AN

BAR SCALE

0 50 100 150 200 250

UNITS - METRES

DESIGNED: DD	DATUM: mAHD
REVIEWED: AN	HORIZONTAL RATIO: 1:5000
PAPER SIZE: A3	VERTICAL RATIO: NA

CLIENT / PROJECT

HANSON
BRANDY HILL QUARRY
EXPANSION EA

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All measurements in mm unless otherwise specified

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6/37 Leighton Place, Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767
Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE:

PROPOSED STAGE 5 QUARRY FORM

DRAWING ID:
SK002

PROJECT MANAGER:	PROJECT NO.:	FILE:	REVISION:
AN	P1303888	JD02V01	A

Daniel Dhiacou

From: Nicolai Cooper <nicolai.cooper@lls.nsw.gov.au>
Sent: Thursday, 2 October 2014 4:42 PM
To: Daniel Dhiacou
Subject: Re: P1303888 Brandy Hill Quarry Expansion (SSD-5899)

Hi Daniel,
I have been advised by my manager that we do not provide comment on these documents.

Regards
Nicky

On 29 September 2014 08:07, Daniel Dhiacou <DDhiacou@martens.com.au> wrote:

Hi Nicolai,

Just wondering whether you have you had a chance to review this SSD yet to consider your groundwater and surface water requirements?

Regards,

Daniel Dhiacou

Civil & Environmental Engineer

BEng (Civil & Environmental), DipEngPrac

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& Associates Pty Ltd

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From: Daniel Dhiacou
Sent: Wednesday, 17 September 2014 10:13 AM
To: nicolai.cooper@lls.nsw.gov.au
Subject: P1303888 Brandy Hill Quarry Expansion (SSD-5899)

Hi Nicolai,

Thanks for talking with me on the phone before.

As discussed, we are undertaking the groundwater and surface water assessments for the Brandy Hill Quarry Expansion. I believe the PEA is available online. Attached are the DGRs we have received, which state on page 5 that we are to consult with Hunter-Central Rivers Catchment Management Authority.

Can you send through any requirements or specific issues you would like us to address in regards to the groundwater and surface water assessments.

We would also like to send through our proposed methodology for these assessments for your comment and to facilitate ongoing consultation. Can you please indicate whether this would be feasible.

Feel free to call me with any queries or for further information.

Regards,

Daniel Dhiacou

Civil & Environmental Engineer

BEng (Civil & Environmental), DipEngPrac

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--

Nicolai Cooper, Acting District Co-ordinator Lower Hunter
Hunter Local Land Services

819 Tocal Road | Private Bag 2010 | Paterson NSW 2421
T: +61 2 4938 4945 | **F:** +61 2 4938 1013|
E: nicolai.cooper@lls.nsw.gov.au |
W: www.hcr.cma.nsw.gov.au |

Daniel Dhiacou

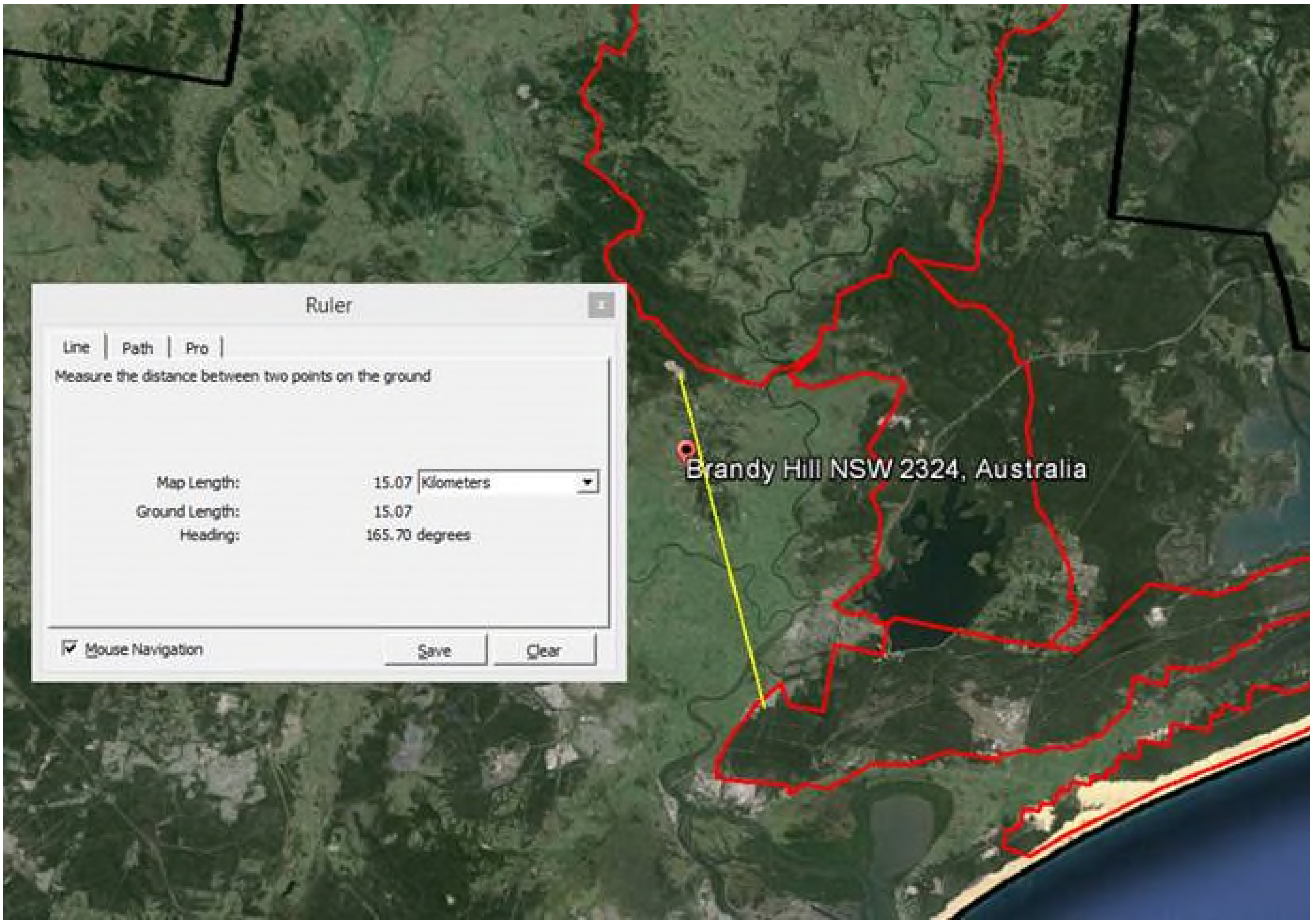
From: Malcolm Withers <malcolm.withers@hunterwater.com.au>
Sent: Monday, 22 September 2014 10:37 AM
To: Daniel Dhiacou
Subject: FW: P1303888 Brandy Hill Quarry Expansion - SSD 5899

Good morning Daniel,

Our nearest drinking water bore is more than 15km from the quarry site.

Regards

Malcolm Withers
Senior Developer Services Engineer | Hunter Water Corporation
36 Honeysuckle Drive Newcastle NSW 2300 | PO Box 5171 HRMC NSW 2310
T 02 4979 9545 | **F** 02 4979 9711 | **M** 0429 372 449 malcolm.withers@hunterwater.com.au
Please consider the environment before printing this email



Measure the distance between two points on the ground

Map Length: 15.07 Kilometers
Ground Length: 15.07
Heading: 165.70 degrees

☑ Mouse Navigation

From: Daniel Dhiacou <DDhiacou@martens.com.au>
Date: 16 September 2014 16:12:35 AEST

To: "malcolm.withers@hunterwater.com.au"
<malcolm.withers@hunterwater.com.au>
Cc: Andrew Norris <ANorris@martens.com.au>
Subject: P1303888 Brandy Hill Quarry Expansion - SSD 5899

Hi Malcolm,

We are undertaking the surface water and groundwater assessment for the Brandy Hill Quarry Expansion (SSD 5899). I refer to the attached email, an extract from the Director General's Requirements for the site, sent by you in April 2013.

I would just like to ask whether Hunter Water have any groundwater bores within a 10km radius of the site.

Feel free to contact me with any queries.

Regards,

Daniel Dhiacou
Civil & Environmental Engineer
BEng (Civil & Environmental), DipEngPrac

Appendix 13 B

Hydrogeological Assessment

Brandy Hill Expansion Project

Environmental Impact Statement

Hanson Construction Materials Pty Ltd

Hydrogeological Assessment:

Hanson's Brandy Hill Quarry Expansion

ENVIRONMENTAL

WATER

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GEOTECHNICAL

CIVIL

PROJECT
MANAGEMENT

P1303888JR02V04
December 2015

Copyright Statement

Limitations Statement

The sole purpose of this report and the associated services performed by Martens & Associates Pty Ltd is to document a Hydrogeological Assessment in accordance with the scope of services set out in the contract / quotation between Martens & Associates Pty Ltd and Hanson Construction Materials Pty Ltd (hereafter known as the Client). That scope of works and services were defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to the site.

Martens & Associates Pty Ltd derived the data in this report primarily from a number of sources which included site inspections, correspondence regarding the proposal, examination of records in the public domain, interviews with individuals with information about the site or the project, and field explorations conducted on the dates indicated. The passage of time, manifestation of latent conditions or impacts of future events may require further examination / exploration of the site and subsequent data analyses, together with a re-evaluation of the findings, observations and conclusions expressed in this report.

In preparing this report, Martens & Associates Pty Ltd may have relied upon and presumed accurate certain information (or absence thereof) relative to the site. Except as otherwise stated in the report, Martens & Associates Pty Ltd has not attempted to verify the accuracy of completeness of any such information (including for example survey data supplied by others).

The findings, observations and conclusions expressed by Martens & Associates Pty Ltd in this report are not, and should not be considered an opinion concerning the completeness and accuracy of information supplied by others. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings and conclusions are based solely upon site conditions, information and drawings supplied by the Client *etc*. in existence at the time of the investigation.

This report has been prepared on behalf of and for the exclusive use of the Client, and is subject to and issued in connection with the provisions of the agreement between Martens & Associates Pty Ltd and the Client. Martens & Associates Pty Ltd accepts no liability or responsibility whatsoever for or in respect of any use of or reliance upon this report by any third party.

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Document and Distribution Status

Author(s)	Reviewer(s)	Project Manager	Signature
Daniel Dhiacou	Andrew Norris	Andrew Norris	

Revision No.	Description	Status	Release Date	Document Location			
				File Copy	Hanson Construction Materials		Void
1	Client Issue	Draft	28.04.2015	1P, 1E, 1H	1P		
2	Revised	Draft	22.05.2015	1P, 1E, 1H	1P		
3	Revised	Draft	10.08.2015	1P, 1E, 1H	1P		
4	Revised	Final	18.12.2015	1P, 1E, 1H	1P		

Distribution Types: F = Fax, H = hard copy, P = PDF document, E = Other electronic format. Digits indicate number of document copies.

All enquiries regarding this project are to be directed to the Project Manager.

Contents

Tables

1 Executive Summary

1.1 Overview

This hydrogeological assessment forms part of an Environmental Impact Study (EIS) submitted to the NSW Department of Planning and Environment (DoPE) to address Secretary's Environmental Assessment Requirements (SEARs) for the proposed expansion of Hanson's Brandy Hill Quarry, 979 Clarencetown Road, Seaham, NSW (SSD-5899).

This report should be read in conjunction with Martens and Associates Surface Water Assessment of the site (P1303888JR03V06, 2015).

1.2 Approved Development

The Client advises that the existing quarry consent is to a maximum excavation depth of 30 mAHD. Consequently, this pit level has been adopted as 'existing development' for modelling scenarios.

1.3 Proposed Development

Proposed final form development layout is shown overlaying recent site survey in Attachment A SK002. The proposed expansion works include:

1. Expansion of the currently approved extraction boundary of the quarry to extend the life of operations by approximately 30 years.
2. Extraction to a maximum depth of -78 mAHD.
3. Increased annual extraction limit to 1.5 Mt per annum.
4. Relocation of existing plant infrastructure and incorporation of a new concrete batching plant with a capacity of 15,000 m^3 per annum.
5. Receiving and recycling 20,000 t of concrete waste per annum. We note this waste will be reused for concrete production only and not for quarry filling.
6. New pre-coat plant and mobile pug mill.

1.4 Quarry Rehabilitation – Proposed Partial Water Filling

The post quarrying void is proposed to be partially filled with water from direct rainfall, upstream runoff and groundwater inflow. Water in the void will rise to an equilibrium level of approximately 25.6 mAHD where total inflow equals total outflow (refer Section 6.3.5 and Section 8.4 for details). The final equilibrated water level is below the current minimum quarry depth (30 mAHD) and below the natural pre quarry ground levels (30 – 85 mAHD).

1.5 Key Assessment Objectives

Key objectives for this assessment included quantification of:

1. Groundwater drawdown at surrounding licensed bores resulting from extraction pit dewatering.
2. Groundwater drawdown at surrounding Groundwater Dependent Ecosystems (GDEs) resulting from extraction pit dewatering.
3. Dewatering rates for the extraction pit.
4. Rehabilitation equilibrium conditions and timing.

1.6 Assessment Methodology

Site field data comprising groundwater level monitoring data, packer test data and borehole data was assessed to develop a conceptual hydrogeological model.

Field data and the subsequent conceptual hydrogeological model were used to develop a 3D numerical groundwater model using MODFLOW. The model was calibrated in both steady state and transient with subsequent predictive and combined sensitivity / uncertainty models used to investigate assessment targets. The models were used to quantify likely drawdown at licensed bores and GDEs, groundwater ingress and quarry dewatering rates using the following predictive modelling scenarios:

1. Pre quarry conditions – contours shown in the 1983 quarry EIS were digitised to represent pre quarrying terrain.
2. Existing development – final form – extraction to 30 mAHD in the base of the quarry pit. The pre quarry model was used to form the initial head for the existing development model.
3. Proposed development – increased extraction area and extraction to –78 mAHD in the base of the quarry pit following proposed extraction staging (Attachment B).
4. Post quarry rehabilitation equilibrium conditions – groundwater levels at the conclusion of proposed development quarrying. The proposed development model was used to form the initial head for the post quarrying model.

1.7 Findings and Conclusion

Assessment indicated that the proposed development can proceed with an acceptable level of impact to stakeholders (environment and licensed bore users).

Licenced bore GW078135 is modelled to be subjected to >2 m of drawdown due to the proposed development. Such a level of drawdown may impact the bore's productivity. Further works are required to determine measures required, to the Minister's satisfaction, to ensure long-term bore viability will not be affected or to assess necessary 'make good' provisions. However, it is recommended that groundwater level monitoring be undertaken at this bore prior to proposed quarrying progression below existing approved quarry floor level to provide a benchmark for impact assessment. The Applicant's statement of commitments is to include measures to monitor and, should negative impacts be identified, address any loss of bore yield.

Groundwater take is required to be licenced in accordance with the Water Act (1912). The grant of water licencing and the management of allocation and share component which attach to it will be bound by the rules of the Water Act. Groundwater take is estimated to require licencing for in the order of 170 years after completion of quarrying, after which permanent licencing is not expected to be required.

The impacts of the proposed quarry extension at Hanson's Brandy Hill Quarry are considered acceptable. The quarry shall not impact on the local hydrogeological system in such a way as to have significant detrimental effects for nearby groundwater users or ecological systems for the duration of the proposed project and after rehabilitation.

2 Introduction

2.1 Overview

This hydrogeological assessment forms part of an Environmental Impact Study (EIS) submitted to the NSW Department of Planning and Environment (DoPE) to address Secretary's Environmental Assessment Requirements (SEARs) for the proposed expansion of Hanson's Brandy Hill Quarry, 979 Clarencetown Road, Seaham, NSW (SSD-5899).

This report should be read in conjunction with Martens and Associates Surface Water Assessment of the site (P1303888JR03V06, 2015).

2.2 Scope

This assessment has been completed in order to satisfy the latest SEARs issued by NSW DoPE on November 11, 2014, relating to preparation of a hydrogeological assessment. It shall:

- Assess the existing groundwater regime.
- Determine site groundwater system properties.
- Identify existing groundwater users or environments which may be influenced by the proposed expansion of operations.
- Develop a finite-difference groundwater flow model to assess likely groundwater drawdown at surrounding licensed bores and Groundwater Dependent Ecosystems (GDEs), groundwater ingress and likely dewatering rates for the extraction pit.
- Assess impacts of the development against the Aquifer Interference Policy and obligations / requirements under the Water Act with regards to licensing of groundwater extraction.

2.3 Subject Site

The site is located at 979 Clarencetown Road, Seaham, NSW and comprises 22 individual lots owned by the Client within Port Stephens Shire Council. It has been used for extractive industry and processing of rhyodacite hard rock aggregate since 1983. The site occupies approximately 561 ha of which 18.6 ha is occupied by the quarry; 11.1 ha by the crushing plant; 5.3 ha by the aggregate stockpile area; and the remainder being bushland and cleared lands. The site layout and aerial is provided in Attachment A SK001, and site location plan is provided in Attachment A Figure 1.

Further details regarding site and surrounding conditions are provided in the project Preliminary Environmental Assessment (Hanson, 2012a). A description of site operations is provided in Section 3.4.

2.4 Approved Development

The Client advises that the existing quarry consent is to a maximum excavation depth of 30 mAHD. Consequently, this pit level has been adopted as 'existing development' for modelling scenarios.

2.5 Proposed Development

Proposed final form development layout is shown overlaying recent site survey in Attachment A SK002. The proposed expansion works include:

1. Expansion of the currently approved extraction boundary of the quarry to extend the life of operations by approximately 30 years.

2. Extraction to a maximum depth of -78 mAHD.

3. Increased annual extraction limit to 1.5 Mt per annum.

4. Relocation of existing plant infrastructure and incorporation of a new concrete batching plant with a capacity of 15,000 m^3 per annum.

5. Receiving and recycling 20,000 t of concrete waste per annum. We note this waste will be reused for concrete production only and not for quarry filling

6. New pre-coat plant and mobile pug mill.

2.6 Proposed Extraction Staging

Site extraction operations are proposed to be completed in five stages. Extraction staging is shown in Attachment B and summarised below:

- <u>Stage 1</u>: Increase extraction extents 140 m west and 160 m south of the existing pit and to a minimum depth of 22 mAHD. Construct concrete batching plant.

- <u>Stage 2</u>: Increase extraction extents 270 m south of the Stage 1 pit boundary (to the site southern boundary) and to a minimum depth of -8 mAHD.

- <u>Stage 3</u>: Increase extraction extents 280 m east of the Stage 2 pit boundary (along the site southern boundary) and to a minimum depth of -38 mAHD.

- Stage 4: Increase extraction extents 430 m east and 80 m south of the Stage 3 pit boundary and to a minimum depth of -58 mAHD. Relocate the site plant and stockpiling area.
- Stage 5: Increase extraction extents 100 m east and 140 m south of the Stage 4 pit boundary and to a minimum depth of -78 mAHD.
- Rehabilitation: The Stage 5 pit void will be partially filled by direct rainfall, inflowing groundwater and surface water.

2.7 Assessment Methodology

Site field data comprising groundwater level monitoring data, packer test data and borehole data was assessed to develop a conceptual hydrogeological model.

Field data and the subsequent conceptual hydrogeological model were used to develop a 3D numerical groundwater model using MODFLOW. The model was calibrated in both steady state and transient with subsequent predictive and combined sensitivity / uncertainty models used to investigate assessment targets. The models were used to quantify likely drawdown at licensed bores and GDEs, groundwater ingress and quarry dewatering rates using the following predictive modelling scenarios:

1. Pre quarry conditions – contours shown in the 1983 quarry EIS were digitised to represent pre quarrying terrain. Refer to Attachment C Figure 2 for surrounding topography and pre quarry contours.

2. Existing development – final form – extraction to 30 mAHD in the base of the quarry pit. The pre quarry model was used to form the initial head for the existing development model.

3. Proposed development – increased extraction area and extraction to –78 mAHD in the base of the quarry pit following proposed extraction staging (Attachment B).

4. Post quarry rehabilitation equilibrium conditions – groundwater levels at the conclusion of proposed development quarrying. The proposed development model was used to form the initial head for the post quarrying model.

2.8 Quarry Rehabilitation – Proposed Partial Water Filling

The post quarrying void is proposed to be partially filled with water from direct rainfall, upstream runoff and groundwater inflow. Water in the void will rise to an equilibrium level of approximately 25.6 mAHD where total inflow equals total outflow (refer Section 6.3.5 and Section 8.4 for details). The final equilibrated water level is below the current minimum quarry floor level (30 mAHD) and below pre quarry ground level (30 – 85 mAHD).

2.9 Agency Consultation

Consultation with NSW Office of Water (NOW) was undertaken in preparation of this document. Details of correspondence are provided in Attachment G.

Peer review of the modelling and this assessment has been undertaken by Dr Noel Merrick of HydroAlgorithmics Pty Ltd. Development of modelling scenarios and detail of assessment methodology has been completed in consultation with the peer reviewer.

2.10 Abbreviations

BH	Borehole
ET	Evapotranspiration
K	Hydraulic conductivity
K_h, K_{xy}	Horizontal hydraulic conductivity
K_v, K_z	Vertical hydraulic conductivity
mAHD	Metres above the Australian Height Datum
mBGL	Metres below ground level
S_s	Specific storage
S_y	Specific yield
SWL	Standing water level

3 Study Area Setting

3.1 Data Set Overview

3.1.1 *Site*

The following site data set has been utilised for this investigation:

1. A total of 10 site boreholes around the quarry expansion area to either sandstone or mudstone. 3 boreholes were drilled as part of previous investigations in 2012 (BH401A, BH401, BH400), and 7 as part of the expansion EIS in 2014 (BH1401, BH1402, BH1403, BH1404, BH1405, BH1406 and BH1407).

2. 9 site groundwater monitoring bores installed at each borehole excluding BH1402. All bores were completed with a sealed screened interval at the bottom of the holes except BH400 which was constructed with an open ended casing. Consequently, monitored groundwater head within all site monitoring bores is the hydraulic transmissivity weighted average of the inherent pressure heads.

3. Hourly interval groundwater level observations at BH401A, BH401 and BH400 over the period 26 April, 2012 to 29 January, 2015 (33 months). This group of three groundwater monitoring loggers are collectively referred to as the '2012 loggers'.

4. Twice daily groundwater level observations at BH1404, BH1405 and BH1406 over the period 22 May, 2014 to 29 January, 2015 (8 months); and at BH1401, BH1403 and BH1407 over the period 21 June, 2014 to 29 January, 2015 (7 months). This group of six groundwater monitoring loggers are collectively referred to as the '2014 loggers'.

5. 78 groundwater quality samples over the 9 site groundwater monitoring bores over the period 26 August, 2014 to 1 May, 2015.

6. 64 packer tests over 5 site boreholes (BH1401, BH1403, BH1404, BH1405 and BH1406).

7. The original Environmental Impact Statement for the currently approved Brandy Hill Quarry (Hunter Valley Mining Corporation, 1983).

8. Two Geology and Drilling Reports for the Brandy Hill Site (Hanson, 2012b & 2014) for the 2012 and 2014 bores respectively.

9. Annual ground truthed LIDAR site survey data from 2011 to 2014.
10. Observations of existing quarry pit faces.

Borehole locations are shown in Attachment A SK001 with graphic drill logs provided in Attachment D.

3.1.2 Regional

Literature review incorporated the following documents, all of which were utilised to some degree in this investigation:

1. Public domain bore data (NSW Government Natural Resource Atlas – www.nratlas.nsw.gov.au) – shown in Attachment C Figure 3.
2. Public domain soil and land information (NSW Government Environment & Heritage eSPADE - www.environment.nsw.gov.au/eSpadeWebApp).
3. Newcastle 1:100 000 Coalfield and Regional Geology Map (Department of Mineral Resources, 1995) – shown in Attachment C Figure 4.
4. Newcastle 1:100 000 Geological Sheet (Department of Mines, 1975) – shown in Attachment C Figure 5.
5. Newcastle 1:100 000 Soil Landscape Sheet (Department of Land and Water Conservation, 1995).
6. Groundwater Resources of Hunter Valley and Associates Tributaries Upstream of Maitland (DLWC Water Resources, 1986).
7. Hydrogeochemistry of the Upper Hunter River Valley, NSW (Kellett, Williams and Ward, 1987).
8. Hydrogeology and Groundwater Management Issues in the Hunter Valley, NSW (De Silva, 1998).

3.2 Regional Geology & Soils

Carboniferous rocks outcrop principally on the northern side of the Hunter River and are separated from the younger Coal Measure geology to the south by a fault system, known as the Hunter Thrust. The area is highly faulted and these faults cut off geological units abruptly.

Within the study area there are two principal geology types, characterised by:

1. High elevation – simplified as land above 40 mAHD.
    a. Newcastle Coalfields 1:100 000 Geological Map (Attachment C Figure 4) indicates that all land within the study area at high elevation is Cz – undifferentiated tuff and ignimbrite interbedded with conglomerate, sandstone and shale.
    b. Newcastle 1:100 000 Geological Sheet (Attachment C Figure 5) contains more detail than the Coalfields Map for land within the study area at high elevation. Geologies consist of:
        i. Cup – Paterson Formation acid lava flows, crystal tuff, interbedded conglomerate and ignimbrite. Located at the quarry site and at other isolated pockets at high elevation.
        ii. Cuj – Mt. Johnson Formation conglomerate, tuff, sandstone and shale. Located over the majority of high elevation land.
        iii. Cus – Seaham Formation tillite, varved shale, conglomerate, tuff, sandstone, mudstone and minor lava. Located at the boundary between high and low elevation land.
2. Low elevation – simplified as land below 40 mAHD. The Newcastle Coalfields and Newcastle Geological Maps largely agree on geologies within the study area.
    a. Newcastle Coalfields 1:100 000 Geological Map (Attachment C Figure 4) indicates that geologies within the study area at low elevation consist of:
        i. Pdz – Dalwood Group undifferentiated (silty/minor/lithic) sandstone, siltstone, marl, conglomerate and basalt. Generally located on land 10 – 40 mAHD.
        ii. Pmb – Brankton Formation conglomerate, sandstone and siltstone. Located on land > 10mAHD generally over the Brandy Hill rural residential area.
        iii. Qa – gravel, sand, silt and clay. Generally located on swamp/agricultural land < 10 mAHD.

b. Newcastle 1:100 000 Geological Sheet (Attachment C Figure 5) indicates that geologies within the study area at low elevation consist of:

    i. Pd – Dalwood Group undifferentiated (lithic) sandstone, mudstone, (micaceous) siltstone, shale, tuff, basalt flows, conglomerates, lithic feldspathic and erratics. Generally located on land 10 – 40 mAHD.
    ii. Pmb – Braxton Formation sandstone, siltstone, conglomerate and erratics. Located on land > 10mAHD generally over the Brandy Hill rural residential area.

    iii. Qa – gravel, sand and silt. Generally located on swamp/agricultural land < 5 mAHD.

The Newcastle 1:100 000 Soil Landscape Sheet describes soils at high elevation (generally > 40 mAHD) as being 0.3 – 1.2 m deep and soils at low elevation (generally < 40 mAHD) as being 1 – 3 m deep. Soils at low elevation are also classified as being swampy and/or drainage plains, and limitations noted include being seasonally waterlogged and/or having a permanently high water table. We consider it likely that the water table would be 0 – 5 mBGL for the majority of low-lying swamp and rural land.

3.3 Site Setting and Borehole Data

The existing quarry (Attachment A SK001) is situated on the eastern slopes of Brandy Hill (approximate elevation 35 to 100 mAHD) adjacent to the Deadman's Creek incised valley (approximate elevation 25 to 55 mAHD). Pre quarrying contours are given in the EIS for the currently approved quarry (Hunter Valley Mining Corporation, 1983) and show slopes of 10 – 30%. Slopes to the south of the site are generally consistent with pre quarrying slopes. Slopes north of the site on the opposite side of Deadman's Creek gradually increase to steeper slopes of > 50%.

Quarried rock has been formerly described as a rhyodacite and comprises three colours; a cream weathered profile, a red-brown layer which is slightly weathered with the colour being due to the alteration of magnetic haematite, and grey fresh rock which lies at the base of the sequence. An examination of the petrology indicates that this is more akin to an ignimbrite in nature (Hanson, 2012b). The ignimbrite is described as a hard rock and the specific gravity has been tested at 2.6 (Hanson, 2012b).

Soils and extremely weathered rock at the ten site boreholes were up to 6 m deep comprising clays and sandy loams overlying weathered ignimbrite, sandstone or conglomerate. At boreholes within the quarry void ignimbrite is present at the surface and there is no soil overburden. Drilling for the 2014 bores confirmed the presence of Seaham Glacial Beds comprising sandstone, mudstone and conglomerate overlying Patterson Volcanics comprising predominantly fine grained mudstone and sandstone (Hanson 2014). Where rock overburden is present the sandstone, conglomerate and mudstone layers range from 10 to 58 m deep. Isolated thin lenses of conglomerate, sandstone and granite are present within the ignimbrite rock mass. Data from the existing bores and the 2014 bores are summarised in Table 1 and Table 2 respectively. Graphic drill logs for the ten site boreholes are provided in Attachment D.

Based on this borehole data, geological cross sections have been produced by Hanson (2014) for the site as part of the Geology and Drilling Report and are provided in Attachment C Figure 6 to Figure 8.

Table 1: Borehole summary – existing bores.

Borehole I.D	**BH400**		**BH401A**		**BH401**	
Element	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**
Ground Level (mAHD) [1]		71		41		42
Soil	0 to 2	71 to 69				
Sandstone [2]	2 to 12	69 to 59				
Conglomerate [2]	12 to 33	59 to 38				
Ignimbrite [2]	33 to 93	38 to -22	0 to 51	41 to -10	0 to 60	42 to -18
Mudstone	93 to 99	-22 to -28				

Notes:

[1] Ground levels are approximate based on ground truthed site LIDAR surveys.

[2] Excludes minor conglomerate, sandstone or granite lenses.

Table 2: Borehole summary – 2014 bores.

Borehole I.D	BH1401		BH1402		BH1403		BH1404		BH1405		BH1406		BH1407	
Element	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**
Ground Level (mAHD) [1]		31		42		30		149		46		37		31
Soil [2]	0 to 4	31 to 27	0 to 6	42 to 36	0 to 3	30 to 27	0 to 3	149 to 146	0 to 3	46 to 43	0 to 3	37 to 34	0 to 5	31 to 26
Sandstone [3]	4 to 8	27 to 23	6 to 21	36 to 21	3 to 9	27 to 21	3 to 13	146 to 136			3 to 29	34 to 8	5 to 18	26 to 13
Mudstone [3]					9 to 29	21 to 1	13 to 17	136 to 132						
Conglomerate [3]	8 to 15	23 to 16	21 to 29	21 to 13	29 to 34	1 to -4			3 to 6	43 to 40	29 to 50	8 to -13	18 to 45	13 to -14
Sandstone [3]			29 to 49	13 to -7	34 to 58	-4 to -28			6 to 10	40 to 36	50 to 58	-13 to -21	45 to 49	-14 to -18
Ignimbrite [3]					58 to 121	-28 to -91			10 to 18	36 to 28	58 to 101	-21 to -64	49 to 85	-18 to -54
Mudstone [3]			49 to 54	-7 to -12	121 to 123	-91 to -93								
Sandstone [3]	15 to 93 [4]	16 to -62	54 to 66	-12 to -24			17 to 81	132 to 68	18 to 112	28 to -66	101 to 113	-64 to -76	85 to 90	-54 to -59

Notes:

[1] Ground levels are approximate based on ground truthed site LIDAR surveys.

[2] Material prior to commencement of rock core unknown.

[3] Excludes minor conglomerate, sandstone, granite, mudstone or clay lenses.

[4] Note that the graphic log for BH1401 terminates at 75 mBGL but drilling and packer testing continued through sandstone to a depth of 93 mBGL.

3.4 Site Operations

The existing quarry pit is approximately 900 m long, 380 m wide and 70 m deep. The quarry has 6 benches and 2 rehabilitated former benches on the uppermost slopes. Benches are typically east to south east facing and are stepped down on the mid to lower north-west slopes of Brandy Hill. Benches increase in length from upper to lower with the second last bench wrapping around the quarry to form an amphitheatre shape, with an opening to the east. The final drop cut to the currently approved extraction limit of 30 mAHD was made on 28th March 2014 and is currently being excavated.

The pit has elevations ranging from approximately 95 mAHD at the uppermost bench to 31 mAHD within the currently active base bench (as of the November 2014 site survey). The pit is considered likely to be currently exerting some influence on groundwater levels due to its elevation below the surrounding natural ground level.

The crushing plant and stockpiling area is approximately 420 m long and 410 m wide. The plant is located on a mostly flat surface south of the quarry and haul road at approximately 33 to 37 mAHD. Aggregate stockpiles are located on three benches with elevations ranging from 32 to 45 mAHD. The plant area is separated from the quarry floor by a haul road up to 13 m above the quarry floor.

Natural ground levels at the site range from approximately 111 mAHD north-west of the quarry to approximately 32 mAHD south of the processing area.

3.5 Surrounding Licensed Groundwater Users

The NSW Natural Resource Atlas lists 13 licensed groundwater users within the project study area. Licenced bores and site monitoring bores are shown in Attachment C Figure 3 and available data is summarised in Table 3.

Of the 13 groundwater bores, 3 bores (GW201693, GW201694 and GW201695) are monitoring bores located on the project site. GW078135 is the closest offsite bore at 2.1 km south east of the quarry and has a recorded standing water level (SWL) of 45 mBGL.

Since GW078135 is a supply bore and therefore comprises long open intervals, the SWL is not indicative of the water table or a discrete water bearing zone, rather the SWL is the hydraulic transmissivity weighted average of the inherent pressure heads. Further, it is likely that levels were taken at the completion of well drilling. Water levels are therefore unlikely to have recovered to equilibrium level at the time of measurement due to low rock permeability. Further, as GW078135 is located at approximately 9 mAHD on rural land, we consider that the SWL of 45 mBGL is incorrect and is more likely to be 1 – 2 mBGL as discussed in Section 3.2.

Table 3: Available hydrogeological information (NSW Natural Resource Atlas, 2014).

Groundwater Bore ID	Distance (km) / Orientation From Site	Depth to Groundwater (mBGL)	Intended Use	Water Bearing Zone Substrate	Salinity (ppm)	Yield (L/s)
GW043451	8.2/NW	15	Public/Municipal	Gravel Clay	NA	NA
GW043452	9.0/NW	14	Public/Municipal	Gravel Sand	NA	NA
GW032966	8.6/NW	21	Domestic	Basalt	NA	0.35
GW043450	8.2/NW	17	Public/Municipal	Gravel Sand	'Salty'	NA
GW016845	7.0/NW	5	Irrigation	Sand River Gravel	0 – 500	1.21
GW053627	5.7/NW	6	Irrigation	Sandstone	NA	0.06 – 2.53
GW053586	5.6/NW	39	Irrigation	Shale	NA	0.00
GW201694 [1]	0.2/N	20	Monitoring Bore	Granite	490	0.10 – 0.20
GW201695 [1]	0.2/E	18	Monitoring Bore	Granite	509	0.10
GW078135	2.0/S	61	Domestic Stock	Sandstone	3,600	0.20
GW201693 [1]	0.4/W	NA	Monitoring Bore	NA	NA	NA
GW54714	5.4/SE	NA	Farming	NA	NA	NA
GW51309	5.4/NE	NA	Domestic Stock	NA	NA	NA

Notes:

[1] Site bores.

3.6 Climate and River Gauge Data

The nearest rainfall station with adequate data is Morpeth (BOM station 61046, rainfall 1884 – 2011) and the nearest station with evaporation records is Tocal (BOM station 061250, 1968 – 2014). Mean annual rainfall is 937 mm at Morpeth and 933 mm at Tocal. As rainfall results are very similar at both stations, records at Tocal are adopted for analysis and comparison purposes to enable consistency between rainfall and evaporation data.

Rainfall and evaporation data is summarised in Table 4, and historical annual rainfall and cumulative annual residual rainfall plots are provided in Attachment C Figure 9. Water balance deficit occurs in all months except June.

The NSW Office of Water (NOW) River and Stream Data website lists two river gauges within the study area, at Raymond Terrace (210452) and Green Rocks (210432). These gauges report water levels but not stream flows.

Table 4: Monthly rainfall data and Class A pan evaporation data for Tocal (Station 061250, 1968 – 2014).

Month	Mean Monthly Rainfall (mm)	Mean monthly Evaporation (mm) [1]	Rainfall Surplus Rainfall – Evap. (mm)
January	102.5	192.2	-89.7
February	121.5	145.6	-24.1
March	115.8	130.2	-14.4
April	80	96.0	-16.0
May	72.6	74.4	-1.8
June	76.8	63.0	13.8
July	40.7	74.4	-33.7
August	37.2	102.3	-65.1
September	48.1	132.0	-83.9
October	65.7	161.2	-95.5
November	85.4	174.0	-88.6
December	80.9	204.6	-123.7
Annual	**933.1**	**1533.0**	**-599.9**

Notes:

[1] Monthly evaporation data has been generated from mean daily evaporation data.

3.7 Groundwater Levels

3.7.1 *Data Logger Groundwater Level Observations*

Statistical summaries of groundwater levels recorded by data logger are provided in:

- Table 5 for the 2012 loggers (BH401, BH401A & BH400) over the period 26.04.12 to 29.01.15.
- Table 6 for half the 2014 loggers (BH1404, BH1405 & BH1406) over the period 22.05.14 to 29.01.15.
- Table 7 for the other half of the 2014 loggers (BH1401, BH1403 & BH1407) over the period 21.06.14 to 29.01.15.

Time series plots of groundwater levels and daily rainfall are provided in Attachment C Figure 10 to Figure 19 for each of the site monitoring bores. Residual groundwater level plots (observed groundwater level – mean of groundwater level for monitoring period) are provided for the 2012 loggers in Attachment C Figure 20 and for the 2014 loggers in Figure 21.

Table 5: Summarised data logger observations (period 26.04.12 to 29.01.15 – 33 months).

Borehole	BH401 Groundwater Level		BH401A Groundwater Level		BH400 Groundwater Level	
Statistic	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**
Minimum	0.947	38.391	1.624	37.500	30.404	30.919
Mean	2.236	39.394	2.695	38.305	35.115	35.645
Median	2.070	39.560	2.608	38.392	35.874	34.886
Maximum	3.239	40.683	3.500	39.376	39.841	40.356
Range (m)	2.292		1.876		9.437	

Table 6: Summarised data logger observations (period 22.05.14 to 29.01.15 – 8 months).

Borehole	BH1404 Groundwater Level		BH1405 Groundwater Level		BH1406 Groundwater Level	
Statistic	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**
Minimum	36.770	84.137	14.922	29.622	-0.438	37.075
Mean	55.598	92.902	15.763	29.937	-0.322	37.122
Median	55.370	93.130	15.865	29.835	-0.319	37.119
Maximum	64.363	111.730	16.078	30.778	-0.275	37.238
Range (m)	27.593		1.156		0.163	

Table 7: Summarised data logger observations (period 21.06.14 to 29.01.15 – 7 months).

Borehole	BH1401 Groundwater Level		BH1403 Groundwater Level		BH1407 Groundwater Level	
Statistic	**mBGL**	**mAHD**	**mBGL**	**mAHD**	**mBGL**	**mAHD**
Minimum	15.237	3.157	3.210	26.710	4.160	25.450
Mean	18.895	11.855	3.444	26.906	4.593	26.007
Median	18.562	12.188	3.460	26.890	4.520	26.080
Maximum	27.593	15.513	3.640	27.140	5.150	26.440
Range (m)	12.356		0.430		0.990	

3.7.2 Cumulative Residual Rain

Historical annual rainfall and cumulative annual residual rainfall plots are provided in Attachment C Figure 9 with cumulative monthly residual rain plots coupled with BH401, BH401A and BH400 groundwater levels on secondary axes provided in Attachment C Figure 22, Figure 23 and Figure 24 respectively.

The largest positive deviation from average monthly rainfall during the monitoring period occurred November 2013 with a value 251 mm above average. The largest negative deviation from average monthly rainfall during the monitoring period occurred January 2014 with a value 83 mm below average.

3.7.3 *Individual Borehole Assessment*

Quarry operations over the monitoring period included quarry bench width reduction and extraction between April 2012 and March 2014, and a final drop cut to the currently approved elevation of 30 mAHD began from 28 March 2014. These operations had some impact on monitored groundwater levels.

We provide the following comments for groundwater data at each bore:

- BH401 and BH401A – BH401A is approximately 110 m away from and 1 m below BH401, and both bores have similar levels and responses. The range of groundwater levels over the 33 month monitoring period for BH401 and BH401A is 2.3 m and 1.9 m respectively. Groundwater slopes are shallow in this area with a 1.0% grade between the mean groundwater levels of each bore. Groundwater levels correlate visually to cumulative monthly residual rainfall trends suggesting that rainfall derived recharge has a strong bearing on groundwater levels (Attachment C Figure 22 and Figure 23). The highest recorded groundwater level coincides with the largest daily depth of rainfall, and the lowest recorded groundwater levels correlate with months of below average rainfall for both bores. Water levels between August and November 2012 are low likely due to several preceding months of below average rainfall. Groundwater levels at both bores are likely not being dewatered by quarry operations due to being > 600 m from quarry bench operations and > 350 m from the final drop cut. The residual groundwater level plot (Attachment C Figure 20) shows close agreement between levels in both bores.

- BH400 – BH400 was purged twice during water quality sampling in August and September 2014, after which groundwater levels quickly respond and return to expected levels (Attachment C Figure 12). Excluding this data, the range of groundwater levels over the 33 month monitoring period is 8.7 m and Attachment C Figure 12 shows a downward trend in groundwater elevation, likely due to quarry operations occurring 300 – 400 m from BH400 and causing localised dewatering. Despite dewatering, the residual groundwater level plot (Attachment C Figure 20) shows BH400 has peaks and troughs in similar locations as BH401 and BH401A, suggesting that rainfall derived recharge also has a strong bearing on groundwater levels in this bore.

- BH1401 – The recorded groundwater levels in BH1401 over the 7 month monitoring period do not represent the regional water table level due to the six purges undertaken on a monthly basis for water quality sampling (Attachment C Figure 13). We expect the regional water table level at BH1401 is approximately 15.5 mAHD as shown by data preceding the first purge on 26 August 2014. After each purge the bore recovers well and continues to rise to the regional water table level. Recorded groundwater level data following the date of the first purge has been excluded from modelling calibration and analysis.

- BH1403 – Hanson advises that the BH1403 logger failed on 28 October 2014. The range of groundwater levels over the 4 month monitoring period is 430 mm and the observed groundwater level is within the soil layer. Attachment C Figure 14 shows a minor downward trend in groundwater elevation. It is unlikely BH1403 is dewatering in the same way as BH400 due to the distance of the bore from quarry operations (> 700 m). Rather, the change is likely due to 4 months of below average rainfall (1.4 mm/day on average for the 4 month monitoring period, compared to average of 2.4 mm/day for the 33 months monitoring period). Attachment C Figure 14 suggests a 3 – 5 day delay in water table response to rainfall. This is likely due to the low hydraulic conductivity of the surface soils. We note that BH1403 is located 30 m from downstream site sedimentation dams, which may be exerting influence on the groundwater levels. The observed groundwater levels may be based on the saturated soil layer, and may not represent the regional water table level.

- BH1404 – Further testing and groundwater level data collection was undertaken at this bore to confirm groundwater levels, as described below and in Attachment C Figure 15 and Figure 16:

    - From the start of the monitoring period to 24.08.14, the groundwater level falls 13.2 m to approximately 50 mBGL and plateaus.

    - Between the start of the monitoring period and 14.11.14 the logger was located at 50 mBGL, and it is surmised the groundwater level fell below the logger level, accounting for the plateau in logger readings.

    - After 14.11.14 the logger was lowered to approximately 65 mBGL, which resulted in a recorded immediate drop in groundwater elevation of 2.65 m. It is likely this was due to the logger being, immediately prior to lowering, out of the water and monitoring an empty well.

    - We consider it most likely that groundwater levels between 24.08.14 and 14.11.14 continued to fall until reaching 95.85 mAHD, which is the level recorded after relocation of the logger. This 'expected fall' is shown in Attachment C Figure 15.

- The 15.9 m fall from the start of the monitoring period to 14.11.14 is likely due to the slow outflow of construction fluids, which Hanson advises were not purged after BH1404's construction.
- 40 L was bailed from the bore on 20.11.14 to assess whether the level of 95.85 mAHD represented the actual groundwater level. The groundwater level fell 11.3 m and the logger relocated to 73 mBGL.
- As of 06.02.15, the groundwater level has risen 9.5 m, and is expected to return to approximately 95.85 mAHD. We therefore expect that this level represents the groundwater elevation at BH1404.

The closest bore to BH1404 is BH400 and is 650 m away. The ground slope between these bores is 12.1% and the slope between the 95.85 mAHD level at BH1404 and the mean groundwater level at BH400 (35.645 mAHD) is 9.3%. The next closest bore to BH1404 is BH1405, to which the ground slope is 16.1% and the groundwater slope to the mean level (29.937 mAHD) is 10.3%. Despite the steep ground slopes, the groundwater slopes are not representative of other groundwater slopes at the site, which are generally ≤ 4%. Rock core photographs and packer test results do not give any indication as to why the groundwater level at BH1404 is higher than other site bores.

We believe the recorded groundwater level at BH1404 is not representative of the regional water table level but rather is a perched aquifer. This is likely caused by water sitting on a very low permeability layer as indicated by packer tests with no flow. Preliminary testing undertaken via MODFLOW groundwater modelling to replicate levels at BH1404 require a recharge or hydraulic conductivity boundary between BH1404 and all other downslope bores, with values in each zone being several orders of magnitude different. Such a variation of values is unsupported by site observations and the available data. We have therefore excluded levels at BH1404 from calibration and analysis on the basis it is a local anomaly not appropriately addressed by the model scope and scale.

- <u>BH1405</u> – The range of groundwater levels over the 8 month monitoring period is 1.2 m, and Attachment C Figure 17 shows a downward trend in groundwater elevation. As with BH1403, this is likely due to 4 months of below average rainfall up to November 2014, after which time groundwater levels visually stabilise. The residual groundwater level trend for BH1405 visually matches the other 2014 loggers (Attachment C Figure 21) however is slightly exaggerated. This is likely due to the higher permeability of BH1405 compared with other site bores as shown by the depth averaged hydraulic conductivity (refer to Table 9).

- <u>BH1406</u> – BH1406 has been freely discharging to the atmosphere since construction and was still flowing at the time of writing this report. As shown in Table 6, the groundwater level is above the ground surface level. Further, the mean groundwater level is 1.5 m above that of BH400 which is located > 30 m higher, and 7.2 m above BH1405 which is located 9 m higher. This is unlikely to be representative of the water table as surface saturation was not observed. Rather, it is likely that discharge is occurring due to the presence of a minor confined aquifer. As with BH1404, to calibrate the MODFLOW model to this level would require introduction of localised zones with values several orders of magnitude different, which is unsupported by the available data. We have therefore excluded levels at BH1406 from calibration and analysis.

- <u>BH1407</u> – The range of groundwater levels over the 7 month monitoring period is 1.0 m, and as with the other 2014 loggers, Attachment C Figure 19 shows a downward trend in groundwater elevation. This is likely due to monitoring during below average rainfall, and is unlikely to be caused by dewatering due to its distance (> 750 m) from quarry operations. The residual groundwater level trend for BH1407 visually matches the other 2014 loggers (Attachment C Figure 21) however is slightly exaggerated. As with BH1405, this may be due to the higher permeability of BH1407 compared with other site bores, however packer testing was not conducted in this bore to confirm this. The larger magnitude of groundwater level fluctuation may also be due to the proximity of the bore to Deadman's Creek, which may be exerting influence on local groundwater levels.

3.7.4 Summary

Available site groundwater level data is considered appropriate for use in MODFLOW model calibration. Data from BH1404 and BH1406 have been excluded from MODFLOW model calibration, and data at BH1403 is included in calibration but we note that levels may not represent the regional water table level. Further, we consider that data from 9 data loggers over 7 – 33 months is sufficient to capture seasonal groundwater level fluctuations, inform the assessment and act as calibration data for the MODFLOW model.

3.8 Hydraulic Conductivity (K)

The hydraulic conductivity (K) of ignimbrite has been recorded to vary by many orders of magnitude due to its high dependence on the spacing, interconnectedness and apertures of fractures, and the density of welding (Kellett *et al* 1989, Breuer *et al* 2000, Smyth & Sharp 2006). Site specific packer testing is therefore preferred to adopting regional values, and is well suited to assessment of hydraulic conductivity in fractured rock.

Summarised results of 64 packer tests conducted in five of the 2014 site boreholes are provided in Table 8. Results indicate that sandstone, conglomerate, ignimbrite and mudstone were unfractured with negligible K at the majority of test sites and depths. In portions where interconnected fracturing is present the K of the rock is generally low with only isolated areas of fracturing and higher hydraulic conductivity.

Depth averaged K at tested boreholes is provided in Table 9. Depth averaged K ranges from no detectable flow at BH1403 to 0.189 m/d at BH1405. The harmonic mean and median depth averaged K is 4.0×10^{-4} m/d and 0.040 m/d whilst the mean is 0.081 m/d. BH1404 and BH1405 were selectively tested at observed fractured layers where flow was more likely, and hence the depth averaged hydraulic conductivity in these bores is most likely overestimated.

Flow results and hydraulic conductivity statistics are summarised by geology in Table 10. Of the total 64 tests completed, 49 (77%) showed no flow. The mean K of all geologies is 0.090 m/d with the mean K for sandstone slightly higher than that of ignimbrite. No flow was observed in all tests in conglomerate and mudstone. We consider the differences in hydraulic conductivities between site geologies to be minor.

Review of bore logs, rock core photographs and packer testing data indicates fractured zones are discontinuous with regards to distribution across site and depth to zone. There is no data to suggest the presence of a continuous highly fractured layer across the site.

Table 8: Packer test results summary.

Bore ID and Surface Level (mAHD) [1]	Top (mBGL)	Bottom (mBGL)	Test Interval Length (m)	Predominant Test Interval Stratum	Lugeon	K (m/d) [2]
BH1401 (30.5)	5.3	10.3	5.0	Sandstone	NA - no flow	< LDL
	8.5	13.5	5.0	Conglomerate	NA - no flow	< LDL
	13.0	18.0	5.0	Sandstone	NA - no flow	< LDL
	17.5	22.5	5.0	Sandstone	89.80	1.01
	22.0	27.0	5.0	Sandstone	83.60	0.939
	26.5	31.5	5.0	Sandstone	22.70	0.255
	31.0	36.0	5.0	Sandstone	NA - no flow	< LDL
	35.5	40.5	5.0	Sandstone	NA - no flow	< LDL
	40.0	45.0	5.0	Sandstone	2.40	2.70×10^{-2}
	44.5	49.5	5.0	Sandstone	3.20	3.59×10^{-2}
	49.0	54.0	5.0	Sandstone	94.00	1.06
	53.5	58.5	5.0	Sandstone	NA - no flow	< LDL
	58.0	63.0	5.0	Sandstone	NA - no flow	< LDL
	62.5	67.5	5.0	Sandstone	NA - no flow	< LDL
	67.0	72.0	5.0	Sandstone	NA - no flow	< LDL
	71.5	76.5	5.0	Sandstone	NA - no flow	< LDL
	76.0	81.0	5.0	Sandstone	NA - no flow	< LDL
	80.5	85.5	5.0	Sandstone	NA - no flow	< LDL
	85.0	90.0	5.0	Sandstone	NA - no flow	< LDL
BH1403 (30.7)	24.3	30.0	5.7	Mudstone	NA - no flow	< LDL
	61.3	68.0	6.7	Ignimbrite	NA - no flow	< LDL
	67.3	74.0	6.7	Ignimbrite	NA - no flow	< LDL
	73.3	80.0	6.7	Ignimbrite	NA - no flow	< LDL
	79.3	86.0	6.7	Ignimbrite	NA - no flow	< LDL
	85.3	92.0	6.7	Ignimbrite	NA - no flow	< LDL
	91.3	98.0	6.7	Ignimbrite	NA - no flow	< LDL
	97.3	104.0	6.7	Ignimbrite	NA - no flow	< LDL
	103.3	110.0	6.7	Ignimbrite	NA - no flow	< LDL
	109.3	116.0	6.7	Ignimbrite	NA - no flow	< LDL
	115.3	122.0	6.7	Ignimbrite	NA - no flow	< LDL
	121.3	126.2	4.9	Mudstone	NA - no flow	< LDL

Notes:

[1.] Ground levels are approximate based on ground truthed site LIDAR surveys.

[2.] < LDL = less than the lower detection limit. This is based on equipment monitoring constraints and is limited to approximately 1.1×10^{-9} m/s or 9.1×10^{-5} m/d.

Bore ID and Surface Level (mAHD) [1]	Top (mBGL)	Bottom (mBGL)	Test Interval Length (m)	Predominant Test Interval Stratum [2]	Lugeon	K (m/d) [2]
BH1404 (148.4)	15.25	21.25	6.0	Sandstone	NA - no flow	< LDL
	17.75	23.75	6.0	Sandstone	NA - no flow	< LDL
	23.75	29.75	6.0	Sandstone	0.41	4.61x10^{-3}
	29.75	35.75	6.0	Sandstone	NA - no flow	< LDL
	43.25	49.25	6.0	Sandstone	NA - no flow	< LDL
	55.25	61.25	6.0	Sandstone	NA - no flow	< LDL
	77.05	80.9	3.85	Sandstone	NA - no flow	< LDL
BH1405 (45.6)	5.75	12.35	6.6	Sandstone	NA - no flow	< LDL
	10.25	16.85	6.6	Ignimbrite	NA - no flow	< LDL
	16.25	22.85	6.6	Sandstone	3.00	3.37x10^{-2}
	83.75	90.35	6.6	Sandstone	NA - no flow	< LDL
	88.25	94.85	6.6	Sandstone	1.60	1.80x10^{-2}
	94.25	100.85	6.6	Sandstone	NA - no flow	< LDL
	100.25	103.85	3.6	Sandstone	5.00	5.62x10^{-2}
	103.25	106.85	3.6	Sandstone	138.10	1.55
	106.25	109.85	3.6	Sandstone	3.60	4.04x10^{-2}
	111.75	115.35	3.6	Sandstone	1291.70 [3]	14.5[3]
BH1406 (37.2)	7.0	13.7	6.7	Sandstone	NA - no flow	< LDL
	13.0	19.7	6.7	Sandstone	NA - no flow	< LDL
	19.0	25.7	6.7	Sandstone	NA - no flow	< LDL
	25.0	31.7	6.7	Sandstone	NA - no flow	< LDL
	31.0	37.7	6.7	Conglomerate	NA - no flow	< LDL
	37.0	43.7	6.7	Conglomerate	NA - no flow	< LDL
	43.0	49.7	6.7	Conglomerate	NA - no flow	< LDL
	49.0	55.7	6.7	Sandstone	NA - no flow	< LDL
	55.0	61.7	6.7	Ignimbrite	4.30	4.83x10^{-2}
	61.0	67.7	6.7	Ignimbrite	NA - no flow	< LDL
	67.0	73.3	6.3	Ignimbrite	52.10	0.585
	79.0	85.7	6.7	Ignimbrite	NA - no flow	< LDL
	85.0	91.7	6.7	Ignimbrite	NA - no flow	< LDL
	91.0	97.7	6.7	Ignimbrite	NA - no flow	< LDL
	97.0	103.7	6.7	Ignimbrite	NA - no flow	< LDL
	103.0	111.35	8.35	Sandstone	NA - no flow	< LDL

Notes:

[1] Ground levels are approximate based on ground truthed site LIDAR surveys.

[2] < LDL = less than the lower detection limit. This is based on equipment monitoring constraints and is limited to approximately 1.1x10^{-9} m/s or 9.1x10^{-5} m/d.

[3] Lugeon behaviour interpreted as wash-out and excluded from statistical assessment as an outlier.

Table 9: Summary of depth averaged hydraulic conductivity derived from packer testing.

Bore	Depth averaged K (m/s)	Depth averaged K (m/d)	Test method
BH1401	$2.02\text{x}10^{-6}$	0.175	Continuous
BH1403	< LDL [1]	< LDL [1]	Continuous in ignimbrite
BH1404	$8.52\text{x}10^{-9}$	$7.36\text{x}10^{-4}$	Discontinuous
BH1405 [2]	$2.19\text{x}10^{-6}$	0.189	Discontinuous
BH1406	$4.59\text{x}10^{-7}$	$3.97\text{x}10^{-2}$	Mostly continuous
Harmonic Mean [3]	$4.66\text{x}10^{-9}$	$4.03\text{x}10^{-4}$	
Median [3]	$4.59\text{x}10^{-7}$	$3.97\text{x}10^{-2}$	
Arithmetic Mean [3]	$9.36\text{x}10^{-7}$	$8.08\text{x}10^{-2}$	

Notes:

[1] < LDL = less than the lower detection limit. This is based on equipment monitoring constraints and is limited to approximately $1.1\text{x}10^{-9}$ m/s or $9.1\text{x}10^{-5}$ m/d.

[2] Wash-out Lugeon value excluded from calculation.

[3] Statistics include all test results (except wash-out Lugeon value) and assume that k is equal to the LDL where no flow is observed.

Table 10: Summary of packer testing results by geology.

Statistic	All	Sandstone	Conglomerate	Ignimbrite	Mudstone
Tests conducted (#)	64	40	4	18	2
Flow results (#)	15	13	0	2	0
No flow results (#)	49	27	4	16	2
No flow results (%)	77%	68%	100%	89%	100%
Hydraulic conductivity Harmonic Mean (m/d) [1]	$1.17\text{x}10^{-4}$	$1.31\text{x}10^{-4}$	< LDL [2]	$1.02\text{x}10^{-4}$	< LDL [2]
Hydraulic conductivity Median (m/d) [1]	< LDL [2]	< LDL [2]	< LDL [2]	< LDL [2]	< LDL [2]
Hydraulic conductivity Arithmetic Mean (m/d) [1]	$8.99\text{x}10^{-2}$	0.129	< LDL [2]	$3.53\text{x}10^{-2}$	< LDL [2]

Notes:

[1] Statistics include all test results (except wash-out Lugeon value) and assume that k is equal to the LDL where no flow is observed.

[2] < LDL = less than the lower detection limit. This is based on equipment monitoring constraints and is limited to approximately $1.1\text{x}10^{-9}$ m/s or $9.1\text{x}10^{-5}$ m/d.

3.9 Storage

The ignimbrite can be likened to a fractured igneous/metamorphic rock, a tertiary volcanic or a fissured/jointed/sound rock mass based on the geology and the infrequent occurrence of flow (only 23% of packer tests had flow – refer Table 10) indicating an absence of significant fracturing.

Bair and Lahm (2006) cite a representative value for specific yield (S_y) of fractured igneous & metamorphic rock of 0.5%, and Belcher *et al* (2002) report a range of S_y for tertiary volcanics from 0.1 – 20% with an arithmetic mean of 3%. The absence of significant fracturing indicates the S_y of the ignimbrite is likely toward the lower end of this spectrum in the order of say 0.1% – 5.0%.

Belcher *et al* (2002) report a range of specific storage (S_s) for tertiary volcanics of 4×10^{-5} – 4×10^{-3} m^{-1} with an arithmetic mean of 1×10^{-3} m^{-1}, and Batu (1998) reports a range of S_s of 3.3×10^{-6} – 6.9×10^{-5} m^{-1} for fissured/jointed rock and < 3.3×10^{-6} m^{-1} for sound rock. The absence of significant fracturing indicates the S_s of the ignimbrite is likely toward the lower end of this spectrum in the order of say 3.3×10^{-7} - 6.9×10^{-5} m^{-1}.

3.10 Groundwater Dependent Ecosystems (GDEs)

The Australian Government National Water Commission (2010) notes GDEs within the Hunter Valley region include:

1. Riparian and aquifer systems which 'are reliant on groundwater discharge to streams and rivers (baseflow)'.
2. Terrestrial systems which 'are reliant on the watertable depth being shallow enough to supply water to root systems'.

GDEs at the site (Attachment C Figure 25) identified in the project's Biodiversity Assessment Report (Biosis, 2015) based on the Bureau of Meteorology (BOM) GDE Atlas include:

1. Escarpment Redgum
2. Ironbark
3. Moist Foothills Spotted Gum
4. Rough-barked Apples
5. Smoothbarked Apple-Sydney
6. Peppermint-Stringybark
7. South Coast Shrubby Grey Gum
8. Stringybark-Apple

Biosis (2015) note that field verification of BOM GDE mapping has not been undertaken, and that vegetation communities mapped by Biosis should supersede BOM vegetation mapping. Vegetation communities identified by Biosis are noted to be reliant on subsurface groundwater, such as soil moisture in the capillary zone and groundwater at the soil rock interface, rather than the regional groundwater table. These findings agree with the findings of the Australian Government National Water Commission (2010) for terrestrial systems, i.e. they are not dependent on baseflow.

We note that the prevailing regional groundwater table at the site outside the active quarry extents is located within very low permeability fractured rock (see Section 3.8) at a depth in the order of 2 – 64 mBGL (see Section 3.7.1). These groundwater system characteristics mean that GDEs mapped on site are not dependent on the regional groundwater table which is modelled and considered in/by this assessment. Rather, they are dependent on shallower soil moisture and perched water at the soil/rock interface.

3.11 Groundwater Quality

Site quality sampling was undertaken at 8 of the site groundwater monitoring bores by VGT Environmental Compliance Solutions. 78 samples were taken over the period 26 August, 2014 to 1 May, 2015, and the sampling regime is ongoing at the time of writing this report. Statistical summaries of groundwater salinity, total nitrogen (TN) and total phosphorus (TP) over all monitoring bores as recorded by VGT are provided in Table 11, and all data is provided in Attachment E. Adopted groundwater trigger values are also provided in Table 11 to contextualise the observed data.

Site groundwater salinity concentrations generally agree with available regional data.

- The DLWC Water Resources Commission report (1986, 'Groundwater Resources of Hunter Valley and Associated Tributaries Upstream of Maitland') provided by NSW Office of Water notes that groundwater is more saline with further distance from the Hunter River, and that salinity in the alluvium is generally < 1000 mg/L.

- An Australian Government National Water Commission report for the Hunter Valley Region (2010, 'Framework for Assessing Potential Local and Cumulative Effects of Mining on Groundwater Resources') notes that the average salinity in Hunter Valley alluvium is 900 mg/L.

- Salinity is higher in carboniferous rock aquifers to the north of the Hunter River (> 1000 mg/L) (De Silva, 1998).

- Public domain bore data from the NSW Government Natural Resource Atlas (Table 3) record salinity values of 490 – 3600 mg/L in three bores within a 2 km radius of the site (3600 mg/L bore is GW078135).

- Based on Table 12 the groundwater of the site's rock aquifer is brackish and therefore of poor quality for potable purposes, but may be of some agricultural use if adequate yield were achieved (which is unlikely given low permeability of rock).

Table 11: Summarised groundwater quality observations at all site groundwater monitoring bores (period 26.08.14 to 01.05.15).

Statistic	Salinity (mg/L) [1]	Total Nitrogen (µg/L) [2]	Total Phosphorus (µg/L) [3]
Minimum [4]	166	100	10
Mean [4]	1,560	3,942	29
Maximum	3,021	24,000	110
Trigger Criteria [5]	(refer Table 12)	350	25

Notes:

[1] Salinity data in mg/L converted from raw electrical conductivity measurements in µS/cm using a multiplication factor of 0.64 adopted from NSW Office of Environment & Heritage (OEH) website (2013).

[2] The instrument practical quantification limit (PQL) is 100 µg/L for total nitrogen.

[3] The instrument practical quantification limit (PQL) is 10 µg/L for total phosphorus.

[4] Excludes values below the instrument detection limit.

[5] Trigger values for groundwater quality are unavailable. Refer to Table 12 salinity water use summary. For TN and TP we have adopted the ANZECC (2000) trigger values for east flowing lowland coastal rivers assuming this is the likely groundwater discharge point.

Table 12: Summary of water uses on the basis of salinity.

Class	Salinity (mg/L)	Irrigation Suitability [1]	Suitable for Potable [2]
Fresh	< 1,000	500 – 1,000 can have detrimental effects on sensitive crops	0 – 600 good 600 – 900 fair 900 – 1000 poor
Brackish	1,000 – 5,000	1,000 – 2,000 adverse effects on many crops, requiring careful management practices	1,000 – 1,200 poor > 1,200 unacceptable / unpalatable
Highly Brackish	5,000 – 15,000	2,000 – 5,000 can be used for salt tolerant plants on permeable soils with careful management practices	No
Saline	15,000 – 30,000	Not suitable	No
Sea Water	30,000 – 40,000	Not suitable	No

Notes:

[1] From NSW Department of Conservation and Land Management (1992).

[2] From Australian Drinking Water Guidelines (2011).

3.12 Groundwater System Productivity

The Department of Primary Industries Office of Water NSW Aquifer Interference Policy (2012) defines groundwater systems as 'high productivity' or 'low productivity', with high productivity groundwater systems characterised by:

1. Groundwater quality – total dissolved solids (TDS) < 1,500 mg/L; and
2. Groundwater supply – yield > 5 L/s.

Site groundwater quality is on average higher than the high productivity threshold (1,560 mg/L, refer Table 11), as is the nearest offsite licenced bore (GW078135 is 3,600 mg/L, refer Table 3). Licenced bores within the study area are below the groundwater supply threshold with an average yield of 0.53 L/s and a maximum yield of 2.53 L/s (refer Table 3) due to the low hydraulic conductivity of the rock mass (refer Section 3.8).

The site and study area groundwater systems do not meet the criteria for groundwater quality or supply and are therefore considered low productivity.

4 Hydrogeological Conceptualisation & Modelling Objectives

4.1 Hydrogeological Conceptualisation

4.1.1 Conceptual Hydrogeological Model

The conceptual hydrogeological model previously provided as part of agency consultation (refer Attachment G) has been updated to include Hanson's geological cross sections (2014) and is provided in Attachment C Figure 26.

4.1.2 Rock Jointing/Fracturing

Water bearing zones in the vicinity of the site comprise localised fractures and structures within the ignimbrite/sandstone. Packer testing indicates an absence of widespread fracturing over the tested boreholes (Table 8).

4.1.3 Hydraulic Conductivity (K), Storage and Confinement

As described in Section 3.2, there are two principal geologies within the study area. For conceptualisation purposes these two rock masses are taken to have different K values but the same storage values.

Ignimbrite K is dependent on spacing, interconnectedness and apertures of fractures, and the density of welding, and varies with depth and location. The available data does not support the presence of a continuous fractured layer across the site but rather a series of discontinuous fractured water bearing zones each separated from zones above and below by very low K rock. Packer testing results indicate the K of the ignimbrite, sandstone, conglomerate and mudstone are within half an order of magnitude of each other where flow occurs (Table 10).

For conceptualisation purposes, K of the high elevation rock mass is likely lower than the low elevation rock mass, as suggested by geological variability. Vertical conductivity is likely to be lower than horizontal conductivity by one order of magnitude in both high and low elevation zones due to layering of strata and the presence of relatively low permeable interbeds.

S_Y and S_s of the rock mass is likely low and in the order of 0.1% – 5.0% and 3.3×10^{-7} - 6.9×10^{-5} m^{-1} respectively based on investigations with similar hydrogeological settings.

Low elevation K, high elevation K, the low/high elevation boundary, S_y and S_s values were evaluated and optimised during steady state and transient groundwater model calibration.

Groundwater likely occurs under semi-confined to confined conditions in the high elevation rock strata and semi-confined to unconfined conditions in the low elevation rock strata.

4.1.4 *Flow Directions and Water Table Elevation*

The main site water table gradient in the groundwater system indicates that groundwater flow occurs away from high elevation areas and towards low elevation areas. Over the site the principal flow direction is south to south east.

The generalised regional flow system comprises areas of rainfall recharge and downward vertical hydraulic gradients in elevated areas with relatively less recharge occurring on side slopes and low elevations. Annual recharge at higher elevations is likely higher than recharge at lower elevations, and recharge over the pit is expected to be higher due to dust suppression and other site operations.

It is likely that localised perched water tables with poor vertical and horizontal connections occur, such as was surmised with BH1404 (refer Section 3.7.3). The presence of localised confined aquifers is also likely as detected at BH1406 (refer Section 3.7.3). Perched water tables and confined aquifers are not considered significant when compared to the entire study area and are not considered in groundwater modelling.

4.1.5 *Sources and Sinks*

Recharge to the groundwater system is from rainfall. Runoff from quarry surfaces and seepage from quarry faces drain to dams in the floor of the void and downstream of the plant processing area. Site dam leakage is an indirect source of rainfall recharge to the groundwater system and is considered a minor inflow compared to direct rainfall.

The system discharges to the atmosphere through evapotranspiration (in areas where the water table is near to the surface), at creeks and depressions (i.e. spring flow) and at seepage faces. Principal discharge is expected to be to Williams River in the east and Hunter River to the south.

The existing quarry is currently dewatering groundwater to a small degree as evidenced by quarry face seepage observations. Minor seeps may also occur which are associated with rainfall infiltration in perched water bearing zones. No monitoring data exists for current groundwater dewatering flows. However, existing groundwater inflows are considered to be minor and are likely to evaporate when arriving at quarry faces.

4.2 Groundwater Model Objectives

Groundwater model objectives for both existing conditions and predictive simulations are:

1. Establish and calibrate a numerical groundwater model for existing quarry conditions.
2. Estimate existing dewatering rates and existing groundwater drawdown at surrounding licensed bores and Groundwater Dependent Ecosystems (GDEs).
3. Estimate changes to site groundwater levels, pit dewatering rates and drawdown at surrounding licenced bores and GDEs as a result of the proposed quarry expansion.
4. Estimate rehabilitation equilibrium conditions and timing.
5. If required outline any mitigation option(s).

5 Existing Conditions Numerical Groundwater Models

5.1 Software

MODFLOW SURFACT Version 4 was utilised within the Visual MODFLOW 2011.1 Pro graphical user interface. SURFACT was utilised to readily simulate variably saturated conditions and avoid the 'dry cell' problem associated with standard MODFLOW.

5.2 Settings and Water Balance Error Criteria

MODFLOW SURFACT's pseudo-soil function was utilised in both steady state and transient models. Closure criterion was kept equal to or below 0.01 m for all simulations.

Convertible layers were used for all layers/models.

A model water balance error threshold of 1% was utilised which represents the typically adopted industry threshold value. If the error was above 1% either time step durations were reduced and/or closure criterion was increased to ensure the model water balance error remained below 1%.

5.3 Model Extents

A model domain of 12.75 km east-west by 10.35 km north-south was utilised (Attachment C Figure 27). Of this, approximately 75% comprised active model area with the remaining portion being inactive. The active model domain extents were assigned as pathline boundaries remote from the proposed excavations, at topographic divides assumed to represent groundwater flow divides, at Williams River where the River Package boundary was applied, and at downstream locations outside the area of interest where the Constant Head Package boundary was applied.

5.4 Grid Cell Configuration

A 100 x 100 m grid cell size was used for the majority of the model domain with finer, 50 x 50 m grid cell size, used over a 2.85 km east-west by 2.35 km north-south area centred on the quarry. The model consisted of 155 active columns and 126 active rows, with 14,715 active cells per layer. Grid cell configuration is summarised in Attachment C Figure 28.

5.5 Layers

The model geology was represented using 10 layers. The top of Layer 1 represents pre quarrying topography and was defined using recent LIDAR data (LPI, 2013) and site pre quarry contours as shown in the EIS for the currently approved quarry (Hunter Valley Mining Corporation, 1983). The bottom of Layer 1 and the remaining layers are evenly distributed between the top of Layer 1 and a uniform model base level of -160 mAHD. The level of -160 mAHD was selected based on the lowest level in the model of -78 mAHD at the end of quarrying. While -160 mAHD does not represent a geological boundary, it is considered acceptable for modelling given scenario assessment includes quarrying no deeper than -78 mAHD, and because hydraulic properties between model layers are uniform.

Model layer thickness is not horizontal but is equal to total thickness (ground level + 160 m base level) divided by 10, hence at higher elevations layers are thicker than at lower elevations. The existing quarry intercepts 2 layers.

5.6 Boundary Conditions

5.6.1 Drain Boundary

Drain boundaries were applied in the pre quarry and existing development steady state models and the transient calibration model to represent:

1. Quarry benches (Attachment A SK001) – drain levels for each cell within the quarry void were assigned to lower linearly on a monthly basis between annual site survey levels (2011 – 2014). This included changing the extents of benches undergoing 'thinning' and introducing the final drop cut after March 2014. Where applicable, drain cells were grouped to represent benches with similar levels and extraction processing, with a total of 30 drain groups utilised to represent quarry operations. Conductance was set at 10,000 m^2/day. Drain levels for the steady state existing development calibration were assigned based on February 2015 levels and bench extents. Quarry bench drains were excluded from the pre quarry steady state model.

2. Drainage lines / Creeks (Attachment C Figure 29) – drain /creek levels were set at 10 mm below Layer 1 cell top elevation (surface level) with drain conductance set at 1.75 m^2/day.

5.6.2 River Boundary

The 'River package' in MODFLOW Surfact was used to simulate groundwater seepage interaction with Williams River (Attachment C Figure 29). A river stage of 0.2 mAHD was adopted based on the mean observed level at Raymond Terrace available from the NOW website (Gauge ID 210452). A riverbed bottom of -6 mAHD was adopted based on an average of bathymetry data available from the NSW Office of Environment & Heritage (OEH) website (2005). River conductance was assigned at 3.33 m^2/d.

5.6.3 Constant Head

A constant head boundary was applied to all layers through the Brandy Hill residential area at the southern model extent to simulate groundwater outflow (Attachment C Figure 29). Three zones based on surface elevation were utilised assuming a constant depth to groundwater for each zone, as summarised in Table 13.

Table 13: Constant head zones and assumptions adopted.

Zone	Extent based on Surface Elevation	Assumed Constant Depth to Groundwater (m)
1	> 10 mAHD	5.0
2	2 – 10 mAHD	1.0
3	< 2 mAHD	0.5

5.6.4 Evapotranspiration (ET)

ET was assigned a rate of 800 mm/year and extinction depth of 1.5 m. The rate was based on an average areal actual annual ET map (BOM, 2001).

5.7 Pre Calibration Model Parameters

5.7.1 Hydraulic Conductivity

A K_h range of 3.5×10^{-3} – 3.5×10^{-1} m/d with fixed K anisotropy ratio of 0.1 was utilised for the bounding of K during calibration. The boundary between the high elevation/low K zone and low elevation/high K zone was also varied between 30 – 60 mAHD due to geological variability as discussed in Section 3.2 and Section 4.1.3.

5.7.2 Recharge

A recharge rate range of 3.0 – 11.0% and 0.5 – 5.5% of mean annual rainfall was used for areas of high and low elevation respectively in steady state calibration. The boundary between the high elevation/high recharge zone and low elevation/low recharge zone was also varied between 30 – 60 mAHD along with K zones. Additional recharge due to site operations over the active quarry extent was also varied between 0 – 120 mm/yr on top of the high elevation recharge (base) rate.

5.7.3 Storage

A S_Y range of 0.1% to 1.0% and S_S range of 7.2 x 10^{-6} to 7.2 x 10^{-5} m^{-1} was utilised for transient model calibration.

5.8 Steady State Calibration

5.8.1 Calibration Period and Targets

The model was calibrated in steady state to mean head observations (over the entire monitoring period for each bore) at all site bores excluding BH1404, BH1406, and observations after the first purge for BH1401 (refer to Section 3.7.3 for detailed explanations). There are two NSW Natural Resource Atlas licenced bores within the model domain (GW078135 and GW51309), however GW078135 was excluded from calibration due to the SWL likely being incorrect (as discussed in Section 3.5) and GW51309 does not have a recorded SWL. A synthetic observation bore was established on the low-lying rural land south east of the quarry (refer Attachment C Figure 3 for location) with an assumed groundwater level of 0.5 mBGL (based on soil landscape mapping as discussed at Section 3.2) to enable checking of model accuracy in this location. A total of 8 head observation targets were assessed within the model domain.

Since all observation bores comprised long open intervals, groundwater levels in the bores are not indicative of the water table or head at a discrete water bearing zone, rather the groundwater water level in the bore is the hydraulic transmissivity weighted average of the inherent pressure heads. Consequently, head observations were situated into the relevant model layer based on the assumption that bore head observations were representative of head at the centre of each bore's open portion.

5.8.2 Calibration Procedure

Hydraulic conductivity values and zone extents as well as recharge values and zone extents were adjusted within the ranges identified in Sections 5.7.1 and 5.7.2 respectively to achieve steady state calibration.

K zonation complexity was increased incrementally starting from a single zone for the entire model and all layers. The single zone produced unsatisfactory calibration and therefore the resulting head residuals (difference between modelled and observed heads) were used to introduce an additional K zone (Zone 2, Attachment C Figure 30), the extent of which was varied within the range identified in Section 5.7.1. This improved head residuals across the model, which were minimised with the K zone boundary at 40 mAHD. However, residuals at BH400 were still higher than desired. To address this, an additional arbitrary zone (Zone 3, Attachment C Figure 30) was established incorporating the western portion of the quarry and BH400. Final calibration utilised uniform K zones between all layers with extents as shown in Attachment C Figure 30.

Recharge zonation complexity was also changed iteratively. Initially four zones were used: high recharge above 50 mAHD, moderate recharge between 10 – 50 mAHD, low recharge below 10 mAHD, and additional recharge over the existing quarry footprint assuming a base recharge equivalent to the high zone recharge. Varying recharge values with the range identified in Section 5.7.2 demonstrated that different recharge rates between moderate and low elevation zones did not significantly affect calibration as the high elevation zone recharge was driving the response, and so the moderate and low elevation zones were merged. The extent of the high elevation zone was varied within the range identified in Section 5.7.2, and residuals were minimised with the boundary at 40 mAHD. The additional recharge applied over the quarry footprint was also varied. Final calibration utilised recharge zones, rates and percentages as shown in Attachment C Figure 31.

5.8.3 Results

A calibration scatter plot of modelled and observed heads along with key calibration statistics is provided in Attachment C Figure 32. The model's NRMS was 6.3% with an absolute residual mean of 1.7 m and a residual mean of -0.81 m (i.e bias towards slight under prediction of head). The mass balance percent discrepancy was 0.0% and therefore acceptable being below the adopted threshold of 1%. We note that the maximum residual occurs at BH1403, and as discussed in Section 3.7.3 the observed levels may be incorrect due to interaction with the water level in site sedimentation dams and possible observation of the saturated soil layer. We further note that if BH1403 was excluded from the calibration then NRMS, residual mean and absolute residual would improve further.

The model's water balance is provided in Table 14 and confirms that the existing quarry is dewatering as discussed in Section 4.1.5. The dewatering rate of 237 m^3/d (equal to 2.7 L/s) is considered minor and the majority of flow will likely evaporate when arriving at quarry faces, hence dewatering will likely go generally unnoticed.

Heads for Layer 1 over the entire model and over the site are provided in Attachment C Figure 33 and Figure 34 respectively. A cross section of the model through the pit is provided in Attachment C Figure 35.

The final calibration was reviewed in the context of a pre quarry model (same model with quarry drains inactive and no additional recharge over the quarry footprint) in order to evaluate if calibration parameters were sensible. The modelled pre quarry heads for Layer 1 over the entire model and over the site are provided in Attachment C Figure 36 and Figure 37 respectively.

The modelled steady state Layer 1 existing conditions drawdown from pre quarry conditions is provided in Attachment C Figure 38. The drawdown plot confirms the existing quarry is drawing down surrounding local groundwater levels as discussed in Section 3.7.3 and Section 4.1.5 The extent of the 2 m drawdown cone is approximately 1.2 km in diameter and is mostly within the site boundaries, to the west and north of the existing quarry. Pre quarry outputs also indicate that calibration parameters are reasonable in the context of the model's water table and model objectives.

Table 14: Steady state model water balance.

Storage (m^3/d) [2]		Recharge (m^3/d)		ET (m^3/d)		River (m^3/d) [3]		Pit Drains (m^3/d) [4]		Creek Drains (m^3/d) [5]		Constant Head (m^3/d)		Total (m^3/d)	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0	0	8812	0	0	9694	75	286	0	237	0	142	1632	160	10519	10520

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] Storage does not occur in steady state modelling.

[3] River representing Williams River.

[4] Drains representing quarry pit.

[5] Drains representing creeks throughout the model domain.

5.9 Transient Calibration

5.9.1 Calibration Period and Targets

Transient calibration was undertaken over a period of 34 months (April 2012 – January 2015 inclusive) to mean monthly monitored head at:

- BH401A, BH401, BH400 for the full 34 months giving a sub total of 102 calibration targets;
- BH1405 for a period of 9 months (May 2014 – January 2015 inclusive) giving a sub total of 9 calibration targets;
- BH1407 for a period of 8 months (June 2014 – January 2015 inclusive) giving a sub total of 8 calibration targets;

- BH1403 for a period of 5 months (June 2014 – October 2014 inclusive) to include data until logger failure (refer to Section 3.7.3 for detailed explanations) giving a sub total of 5 calibration targets; and
- BH1401 for a period of 3 months (June 2014 – August 2014 inclusive) to exclude data after the first purge (refer to Section 3.7.3 for detailed explanations) giving a sub total of 3 calibration targets.

In total 129 calibration targets were utilised, including two data points at the start and end of modelling at the synthetic observation bore (refer to Section 5.8.1). The mean monthly head value at all monitoring bores was entered to coincide with the middle of the month.

As with the steady state model (Section 5.8.1), observed heads were situated into the relevant model layer assuming the head at the centre of each bore's open portion was representative of the hydraulic transmissivity weighted average of the inherent pressure heads.

Recharge varied monthly based on application of recharge rate percentages to observed rain at Tocal BOM station as used in the steady state model (Attachment C Figure 31). Drain boundaries were as described in Section 5.6.1.

The model utilised 34 stress periods based on the 34 month monitoring period. 10 time steps and a time step multiplier of 1.2 were used for each stress period. The calibrated existing conditions steady state groundwater heads were used as the initial heads for the transient calibration model.

5.9.2 Calibration Procedure

K values and recharge rates from the steady state calibration were retained. Only storage parameters (S_y and S_s) were adjusted within the ranges identified in Section 5.7.3 to transient calibration.

Storage zonation remained constant throughout calibration, and was assigned as a single zone for the entire model and all layers. Storage parameters were manipulated within the pre calibration range limits in order to best match modelled and observed hydrographs. Final calibrated storage parameters utilised (S_y of 0.5% and S_s of 3.6×10^{-6} m^{-1}) produced an acceptable hydrograph correlation.

5.9.3 Results

A calibration scatter plot of modelled and observed heads along with key calibration statistics is provided in Attachment C Figure 39. The model's NRMS was 5.2% with an absolute residual mean of 1.6 m and a residual mean of -0.59 m (i.e bias towards slight under prediction of head). The maximum mass balance percent discrepancy over the 34 stress periods was -0.03% and therefore acceptable being below the adopted threshold of 1%. As discussed in Section 5.8.3 the maximum residual occurs at BH1403. If this bore was excluded from calibration (as can be justified) then NRMS, residual mean and absolute residual would improve further.

Modelled versus observed hydrographs for the 2012 loggers (BH401, BH401A & BH400) are provided in Attachment C Figure 40. The 2014 loggers were excluded from this plot due to the short length of their monitoring periods. The shapes of the calculated hydrographs visually match the observed data, including positions of peaks, troughs, rises and falls. The amplitude of the calculated hydrographs for BH401 and BH401A closely match observed hydrographs. The calculated hydrograph for BH400 is not as amplified as the observed hydrograph, but the downward trend due to quarrying is replicated. Overall, results indicate the model is capable of replicating observed hydrograph trends and short term variations.

The average water balance over the transient calibration period is provided in Table 15. We note that values are similar to steady state model results provided in Table 14, except for the difference in storage flows as these are not utilised in steady state. Overall, average inflows and outflows (excluding storage flows) are less than steady state model results due to rainfall being slightly below average over the transient calibration period (average of 885 mm/yr over calibration period compared to 934 mm/yr in steady state model). This demonstrates sensible agreement between steady state and transient results.

As with the steady state analysis, Table 15 confirms the existing quarry is dewatering. The average dewatering rate over the transient calibration period is 178 m^3/day, with a minimum and maximum dewatering rate over the calibration period of 93 m^3/day and 422 m^3/day respectively. The average dewatering rate equates to 2.1 L/s which is expected to largely evaporate when arriving at quarry faces, and hence existing dewatering will likely go generally unnoticed.

Drawdown plots for transient calibration modelling have not been prepared as the monthly fluctuation in rainfall 'washes out' the effect of quarry drawdown over the 34 month model run time. We expect that adoption of constant rainfall throughout the transient modelling period will provide a similar drawdown plot to steady state modelling (Attachment C Figure 38).

Table 15: Average monthly water balance over transient calibration period.

Storage (m^3/d)		Recharge (m^3/d)		ET (m^3/d)		River (m^3/d) [2]		Pit Drains (m^3/d) [3]		Creek Drains (m^3/d) [4]		Constant Head (m^3/d)		Total (m^3/d)	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
2279	2202	8155	0	0	9221	79	272	0	178	0	132	1648	159	12161	12164

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] River representing Williams River.

[3] Drains representing quarry pit.

[4] Drains representing creeks throughout the model domain.

5.10 Model Confidence Level Classification

In accordance with Australian Groundwater Modelling Guidelines (2012), the model is considered to generally represent a 'Class 2' model confidence level classification suitable for impact assessment.

A 'Class 2' classification is justified on the basis of the following:

- Mass balance error is less than 0.5% of total.
- Geotechnical data coverage is reasonable in the vicinity of the proposed pit.
- Availability of almost 3 years of groundwater head observations at 3 site bores, and more than 6 months of groundwater head observations at various other site bores to the present day.
- Seasonal fluctuations are adequately replicated at the site.
- Parameters are generally consistent with conceptualisation.
- Review of modelling by an experienced, independent hydrogeologist with modelling experience.

However, the following applies to the current model:

- Streamflow and baseflow estimates are unavailable.
- Observations of pit dewatering flows are not used in the calibration. This data is unavailable because the existing pit inflows are minor and subject to evaporation.

In spite of these limitations the model's target confidence level is considered suitable to achieve model objectives (Section 4.2).

6 Predictive Numerical Groundwater Models

6.1 Modelling Overview

6.1.1 Model Setup

Predictive simulation models used the calibrated existing conditions transient model as the starting point for model setup. In so doing many of the model setup parameters remain unchanged between existing conditions and predictive groundwater models, including:

- The software and numerical engine utilised (Section 5.1).
- The settings and water balance error criteria (Section 5.2).
- Model extents and active areas (Section 5.3 and shown in Attachment C Figure 27 and Figure 28).
- Grid cell configuration (Section 5.4 and shown in Attachment C Figure 28).
- Adopted layers (Section 5.5).

Several boundary conditions also remained unchanged, including:

- Drain boundaries for drainage lines (Section 5.6.1 and shown in Attachment C Figure 29).
- The River boundary for Williams River (Section 5.6.2 and shown in Attachment C Figure 29).
- The Constant Head boundary at the southern model extent (Section 5.6.3 and shown in Attachment C Figure 29).
- Model domain evapotranspiration (Section 5.6.4).
- Calibrated hydraulic conductivity parameters and zonation (discussed in Section 5.8.2 and shown in Attachment C Figure 30).
- Calibrated recharge rate percentages and zonation (discussed in Section 5.8.2 and shown in Attachment C Figure 31).
- Calibrated storage parameters (discussed in Section 5.9.2).

6.1.2 Predictive Models & Quarry Lifecycle

Two predictive groundwater models were established:

1. Pre quarry conditions to the end of proposed development conditions, described hereafter as the 'proposed development model'.

2. End of proposed development conditions and onward to determine rehabilitation requirements, described hereafter as the 'rehabilitation model'.

Table 16 summarises the quarry life cycle from pre quarry to rehabilitation conditions and the associated calendar and model years. Modelling stages 1 – 8 are included in the proposed development model (Section 6.2) and modelling stage 9 is included in the rehabilitation model (Section 6.3).

To achieve consistency between models the two separate transient models were run and 'stitched' together. This procedure was adopted as the software does not enable hydraulic groundwater system properties to vary throughout a simulation, and this was required for the simulation of pit water level recovery following completion of extraction.

The initial head for the proposed development model comprised pre quarry head from the calibrated steady state model (Section 5.8.3 and shown in Attachment C Figure 36 and Figure 37). The initial head for the rehabilitation model comprised the final head obtained from the last time step of the proposed development model (Section 6.2.4 and shown in Attachment C Figure 41 and Figure 42).

Table 16: Quarry lifecycle stages and associated transient model years.

	Calendar Year		Model Year		
Stage	**Start**	**End**	**Start**	**End**	**Duration (years)** [1]
1 Pre Quarry Conditions	1980	1982	0	3	3
2 Currently Approved Quarry – to Current	1983	2014	3	35	32
3 Currently Approved Quarry – to Final Form [2]	2015	2016	35	37	2 [2]
4 Proposed Expansion Stage 1	2017	2022	37	43	6 [3]
5 Proposed Expansion Stage 2	2023	2028	43	49	6 [3]
6 Proposed Expansion Stage 3	2029	2034	49	55	6 [3]
7 Proposed Expansion Stage 4	2035	2040	55	61	6 [3]
8 Proposed Expansion Stage 5	2041	2046	61	67	6 [3]
9 Rehabilitation [4]	2047	2547	67	567	500

Notes:

[1] Inclusive of calendar start and end years.

[2] The final form of the currently approved quarry is estimated to be completed at the end of 2016.

[3] Estimated in conjunction with Hanson based on a 30 year quarry life and stages of equal durations. Refer to Attachment B for proposed expansion staging.

[4] The proposed development model excludes the rehabilitation stage, ending at year 67. Rehabilitation modelling is detailed in Section 6.3.

6.2 Proposed Development Model

6.2.1 *Simulation Period and Model Progression*

The proposed development transient model runs from year 0 to year 67. The first 35 years (year 0 to year 35) include 3 years of pre quarry conditions to normalise initial groundwater levels and 32 years of quarry progression to date; the last 32 years (year 35 to year 67) model quarry progression to currently approved final form levels (estimated to be completed in 2 years) and 30 years of proposed expanded quarry works (Table 16).

6.2.2 *Stress Periods & Time Steps*

Annual stress periods were utilised as monthly stress periods cause impractically long model run times. 10 time steps and a time step multiplier of 1.2 were used for each stress period.

6.2.3 *Boundary Conditions*

Transient quarry drain boundaries and quarry recharge boundaries were changed for proposed development modelling. As detailed in Section 6.1.1, all other boundary conditions and model parameters remained unchanged from the transient calibration model.

The final quarry intercepts 6 model layers. Drain levels for each cell within the quarry void were assigned on an annual basis. Where applicable, drain cells were grouped to represent benches with the same levels and extraction processing, with a total of 23 drain groups utilised to represent quarry operations. Conductance was set at 10,000 m^2/day. Drain groups becoming active (i.e. changing in elevation) at each modelling stage are as follows:

- Modelling stage 1 – pre quarry conditions: all quarry drains inactive with grid cells at pre quarry levels based on the previous EIS (Hunter Valley Mining Corporation, 1983).
- Modelling stages 2 and 3 – currently approved quarry to final form conditions: all quarry drains within the existing void footprint activated and lowered linearly from pre quarry levels to currently approved quarry levels at a minimum of 30 mAHD based on recent survey data provided by Hanson.
- Modelling stage 4 – Proposed expansion stage 1: quarry drains south of the previous stage quarry footprint activated, and all active quarry drains lowered linearly from previous stage levels to end of expansion stage 1 levels at a minimum of 22 mAHD as shown in Attachment B.
- Modelling stage 5 – Proposed expansion stage 2: quarry drains south of the previous stage quarry footprint activated, and all active quarry drains lowered linearly from previous stage levels to end of expansion stage 2 levels at a minimum of -8 mAHD as shown in Attachment B.
- Modelling stage 6 – Proposed expansion stage 3: quarry drains south and east of the previous stage quarry footprint activated, and all active quarry drains lowered linearly from previous stage levels to end of expansion stage 3 levels at a minimum of -38 mAHD as shown in Attachment B.
- Modelling stage 7 – Proposed expansion stage 4: quarry drains south and east of the previous stage quarry footprint activated, and all active quarry drains lowered linearly from previous stage levels to end of expansion stage 4 levels at a minimum of -58 mAHD as shown in Attachment B.
- Modelling stage 8 – Proposed expansion stage 5: quarry drains south and east of the previous stage quarry footprint activated, and all active quarry drains lowered linearly from previous stage levels to end of expansion stage 5 levels at a minimum of -78 mAHD as shown in Attachment B.

Model recharge rates were assigned based on application of calibrated transient recharge rates to average annual rainfall at Tocal BOM station as shown in Attachment C Figure 31.

Recharge zonation outside the proposed final quarry footprint (Zone 1 and Zone 2 as shown in Attachment C Figure 31) remained unchanged from steady state conditions. Zone 3 (Attachment C Figure 31) was expanded to represent the proposed final quarry footprint including infrastructure area, and divided into 15 separate recharge zones. Zones were defined based on elevation and active bench areas:

- Elevation
    - Zones above the recharge boundary of 40 mAHD receive 8.5% of annual rainfall as a base rainfall in accordance with existing conditions calibration (Section 5.8.2).
    - Zones below the recharge boundary of 40 mAHD receive 1.5% of annual rainfall as a base rainfall in accordance with existing conditions calibration (Section 5.8.2).
    - Note that the previous quarry footprint was principally located above 40 mAHD and hence only the high elevation recharge was applied as a base rate for existing conditions modelling.
- Active bench areas
    - New quarry benches at each stage of expansion shown in Attachment B receive additional dust suppression recharge and are defined as active.
    - Upper quarry benches reaching terminal elevations at each stage of expansion shown in Attachment B no longer receive additional dust suppression recharge and are defined as inactive.
    - Each active bench area receives 120 mm/yr additional recharge in accordance with existing conditions steady state calibration (Section 5.8.2).
    - Inactive bench areas receive base recharge based on elevation above/below 40 mAHD.

6.2.4 *Results*

Layer 1 head for the entire model and over the site, and drawdown to Layer 1 head over the site are provided in Attachment C Figure 41, Figure 42 and Figure 43 respectively with the model's water balance provided in Table 17, all of which represent outputs from the model's last quarrying simulation period. The maximum extent of the 2 m drawdown cone at this time is approximately 5.8 km east-west and 5.0 km north-south, and extends over site boundaries in all directions.

The pre quarry, existing and final proposed groundwater head and drawdown that occurs at the model's last simulation period is in Table 18 for the model's bores. This differs from drawdown in Attachment C Figure 43 as Table 18 drawdown values are drawdown at bore monitoring points (i.e centre of bore's open portion), not drawdown for a particular layer.

Time series head plots are provided in Attachment C Figure 46 and Figure 47 for all model domain bores and for offsite model domain bores respectively. The head plots combine results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250). These graphs are best viewed after reading to the end of Section 6.3.5 (Rehabilitation Model Results).

A time series dewatering rate plot is provided in Attachment C Figure 48 for the quarry void. The dewatering plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to after rehabilitation equilibrium conditions – model year 67 – 250). These graphs are best viewed after reading to the end of Section 6.3.5 (Rehabilitation Model Results). Dewatering rates per stage are summarised in Table 19 for pre quarry conditions to the end of proposed development conditions.

A time series creek and river rate plot is provided in Attachment C Figure 49 for all model domain creeks and Williams River (as shown in Attachment C Figure 29). The rates plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to after rehabilitation equilibrium conditions – model year 67 – 300). These graphs are best viewed after reading to the end of Section 6.3.5 (Rehabilitation Model Results). The maximum impact during quarrying occurs at the end of Stage 5 and results in a 5.8 ML/yr reduction to river baseflow and an 18.8 ML/yr reduction to creek baseflow.

A discussion of results and results summary follows rehabilitation modelling (Section 6.3) and sensitivity/uncertainty analysis (Section 7) in Section 8.

Table 17: Water balance at end of proposed quarrying.

Storage (ML/yr)		Recharge (ML/yr)		ET (ML/yr)		River (ML/yr)[2]		Pit Drains (ML/yr)[3]		Creek Drains (ML/yr)[4]		Constant Head (ML/yr)		Total (ML/yr)	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
37	0	3157	0	0	2995	28	97	0	642	0	37	606	57	3828	3828

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] River representing Williams River.

[3] Drains representing quarry pit.

[4] Drains representing creeks throughout the model domain.

Table 18: Pre quarry, existing and proposed groundwater head and drawdown at bore monitoring points (i.e centre of bore's open portion).

	Modelled Groundwater Head (mAHD)[1]			
Bore	**Pre Quarry**[2]	**Existing**[3]	**Proposed**[4]	**Drawdown (m)**[5]
BH401	41	38	-4.1	45
BH401A	38	37	0.24	37
BH400	40	35	-22	63
BH1401	19	19	-1.8	21
BH1403	22	21	-34	56
BH1404	71	70	50	21
BH1405	32	30	-0.62	33
BH1406	29	26	-16	45
BH1407	27	26	-1.6	29
Lake Obs[6]	24	23	-78	102
Synthetic[7]	-0.15	-0.15	-0.19	0.04
GW078135	8.2	8.1	4.7	3.5
GW51309	9.6	9.6	9.6	0.04

Notes:

[1] Head at bore reported at observation point (i.e centre of bore's open portion) to two significant figures.

[2] Head from transient model at first timestep (start of 1980, refer Table 16).

[3] Head from transient model for current conditions (end of 2014, refer Table 16).

[4] Head from transient model at conclusion of proposed development simulation (end of 2046, refer Table 16).

[5] Drawdown = pre quarry head – proposed head.

[6] Synthetic bore at the bottom bench of the quarry to model rehabilitation lake head. Note that the proposed head is equal to the bottom bench level of -78 mAHD.

[7] Synthetic observation bore on low-lying rural land south east of the quarry (refer Section 5.8.1).

Table 19: Pre quarry, existing and proposed groundwater dewatering rates due to the quarry void.

		Calendar Year		Dewatering Rate (ML/yr)	
	Stage [1]	**Start**	**End**	**Minimum** [2]	**Maximum** [2]
1	Pre Quarry Conditions	1980	1982	-	-
2	Currently Approved Quarry – to Current	1983	2014	5.3	77
3	Currently Approved Quarry – to Final Form [3]	2015	2016	77	103
4	Proposed Expansion Stage 1	2017	2022	103	172
5	Proposed Expansion Stage 2	2023	2028	172	315
6	Proposed Expansion Stage 3	2029	2034	315	424
7	Proposed Expansion Stage 4	2035	2040	424	516
8	Proposed Expansion Stage 5	2041	2046	516	642

Notes:

[1]. Excludes rehabilitation conditions which are discussed in Section 6.3.5.

[2]. Minimum and maximum dewatering rates for the given stage.

[3]. The final form of the currently approved quarry is estimated to be completed at the end of 2016.

6.3 Rehabilitation Model

6.3.1 Equilibrium Water Balance Assessment

Prior to rehabilitation modelling in MODFLOW a water balance assessment was undertaken to determine the final lake surface area and recharge parameters at equilibrium. The following assumptions were made for the final lake at equilibrium:

1. Inflows to the final lake consist of stormwater inflow from various areas:
    a. Direct rainfall over the final lake surface.
        i. A runoff coefficient of 1.0 was assumed as all rainfall enters the lake without loss.
        ii. This area was determined iteratively as discussed below.
    b. Rainfall over the upper rehabilitated benches which flow into the lake.
        i. A runoff coefficient of 0.5 was assumed as the area will be revegetated but will be steep and consists of shallow soils.
        ii. The total final footprint of the quarry benches is 72.08 ha. The area of the upper rehabilitated

        benches is 72.08 ha minus the final lake surface area, which was determined iteratively as discussed below.

    c. Rainfall over upstream vegetated areas which will flow into the quarry void.

        i. This inflow will begin upon removal of the upstream diversion bund in accordance with the surface water management plan prepared as part of the EIS (Martens and Associates, 2015).

        ii. A runoff coefficient of 0.2 was assumed for this area in accordance with Landcom (2004) based on forested areas.

        iii. This area is 5.98 ha.

    d. Rainfall over the revegetated infrastructure area which will be regraded towards the quarry void in accordance with the project EIS (Hanson, 2015).

        i. A runoff coefficient of 0.2 was assumed for this area in accordance with Landcom (2004) based on forested areas.

        ii. This area is 20.17 ha.

    e. Mean annual rainfall is 933 mm/yr at Tocal (BOM Station 061250, 1968 – 2014).

2. Outflows from the final lake consist of evaporation and are based on:

    a. A mean annual Class-A pan evaporation of 1559 mm at Tocal (BOM Station 061250, 1968 – 2014).

    b. A pan factor of 0.821 at Williamtown RAAF based on McMahon *et al* (undated).

    c. A mean annual open water annual evaporation of 1279.9 mm (1559 mm x 0.821).

3. At equilibrium net groundwater inflow to the lake will equal net groundwater outflow from the lake.

4. No other significant inflow or outflow sources have been identified.

5. At equilibrium of the final lake the total stormwater inflow rate equals the total evaporation outflow rate.
    a. The total stormwater inflow is dependent on the ratio of the final lake surface area to the upper rehabilitated benches surface area.
    b. The total evaporation outflow is dependent on the final lake surface area.

To determine the final lake surface area the above was simplified to several equations which were solved simultaneously. Results for equilibrium conditions are summarised in Table 20.

Table 20: Final lake water balance at equilibrium conditions.

Inflow – Stormwater to Final Lake				
Catchment	**Area (ha)**	**Runoff Coefficient**	**Mean Inflow (ML/yr) [1]**	**Mean Lake Recharge (mm/yr) [2]**
Vegetated areas (upstream & infrastructure)	26.15	0.2	48.9	103.0
Upper rehabilitated benches	24.66 [3]	0.5	115.2	242.9
Final lake surface [4]	47.42 [4]	1.0	442.9	934.0
Total	**98.23**	**0.66 [5]**	**606.9**	**1279.9**

Outflow – Evaporation from Final Lake				
Catchment	**Area (ha)**	**Evaporation (mm/yr) [6]**	**Mean Outflow (ML/yr) [7]**	**Mean Lake Evaporation (mm/yr)**
Total (final lake surface) [4]	**47.42 [4]**	**1,279.9**	**606.9**	**1279.9**

Notes:

[1] Mean Inflow (ML/yr) = Catchment Area (ha) x Runoff Coefficient x Mean Annual Rainfall (934 mm/yr) / 100 (units conversion factor).

[2] Mean Lake Recharge (mm/yr) = Mean Inflow (ML/yr) / Final Lake Surface Area (ha) x 100 (units conversion factor). Assumes that all runoff from upstream catchment areas flows to the final lake area.

[3] Upper rehabilitated benches area (ha) = Total quarry benches footprint (72.08 ha) – final lake surface (ha).

[4] Determined by simultaneously solving for total inflow and total outflow, and setting total mean inflow = total mean outflow.

[5] Weighted average runoff coefficient.

[6] Equal to the mean open water annual evaporation as discussed previously.

[7] Mean Outflow (ML/yr) = Catchment Area (ha) x Mean Open Water Annual Evaporation (mm/yr) / 100 (units conversion factor).

We note the following:

- Total mean inflow is equal to total mean outflow (606.9 ML/yr) when the lake surface area reaches 47.42 ha.
- Total mean lake recharge is equal to the total mean lake evaporation (1,279.9 mm/yr) when the lake surface area reaches 47.42 ha.
- The final lake surface area is smaller than the maximum surface area of the lake (which occurs at 30 mAHD) indicating that equilibrium occurs before the lake reaches maximum capacity. This occurs because inflow to the lake is initially high, but eventually the outflow due to evaporation of the increasing lake surface 'catches up' to the inflow rate. When the inflow and outflow rates are equal the final lake reaches the equilibrium surface area.

To simplify these results to enable MODFLOW modelling of varying recharge a recharge factor was utilised:

- The mean total recharge over the lake is 1279.9 mm/yr based on the mean rainfall of 934.0 mm/yr.
- The recharge factor for equilibrium conditions is 1.3704 (1,279.9 mm/yr divided by 934.0 mm/yr).
- The recharge factor can be multiplied by annual rainfall depths to determine average recharge for that year over the lake area.

6.3.2 *Simulation Period and Model Progression*

The rehabilitation transient model runs from year 67 to year 567. The 500 year period was chosen for the purpose of water table/pit lake recovery modelling. The initial head used to start the rehabilitation simulation comprised the final output from the proposed development transient model as shown in Attachment C Figure 41 and Figure 42.

6.3.3 *Stress Periods & Time Steps*

For the first 100 years of the rehabilitation model a 5 year interval was adopted for the stress period as annual stress periods cause impractically long run times. 20 time steps and a time step multiplier of 1.2 were used for each stress period for the first 100 years of model run time, except for the first stress period (year 67 to 72) which utilised 100 time steps to smooth out the effect of sudden boundary condition changes (as discussed in Section 6.3.4).

For the remaining 400 years of the rehabilitation model a single stress period was used as boundary conditions were constant over this period (as discussed in Section 6.3.4). 100 time steps and a time step multiplier of 1.2 was used for this stress period.

6.3.4 *Boundary Conditions*

Transient quarry drains, transient quarry recharge, evaporation, conductivity and storage boundaries were changed from proposed development modelling for rehabilitation modelling. As detailed in Section 6.1.1, all other boundary conditions and model parameters remained unchanged from the transient calibration model.

The drain boundaries representing the quarry benches were removed from the rehabilitation model and hydraulic groundwater system properties altered. Cells representing the pit void were assigned relatively high hydraulic conductivity ($K_h = K_v = 100$ m/d); S_y of 0.99 (maximum allowable value); and S_s equivalent to the compressibility of water (5×10^{-6} m^{-1}) as a proxy to allow simulation of water level recovery.

The area representing the final lake surface was assigned an evapotranspiration rate of 1279.9 mm/yr based on the mean annual open water evaporation (refer Section 6.3.1).

Recharge rates remained unchanged from the proposed development model (i.e. uniform rainfall as shown in Attachment C Figure 31). Recharge zonation outside the proposed final quarry footprint (Zone 1 and Zone 2 as shown in Attachment C Figure 31) remained unchanged from previous steady state and transient models. The 15 separate recharge zones previously used to model the proposed development (see Section 6.2.3) were grouped into a single zone (Zone 3) which was subsequently reduced in size to represent the final lake surface area (see Section 6.3.1). All areas outside the final lake surface were assigned as Zone 1 and Zone 2 for areas below and above 40 mAHD respectively.

Recharge values for Zone 1 and Zone 2 were based on 1.5% and 8.5% of mean annual rainfall respectively in accordance with existing conditions steady state calibration (Section 5.8.2). Recharge rates for the final lake surface area (Zone 3) were determined by multiplying the recharge factor for equilibrium conditions (1.3704 – refer Section 6.3.1) by the mean annual rainfall.

6.3.5 *Results*

Layer 1 heads for the entire model and over the site are provided in Attachment C Figure 44 and Figure 45 respectively, both of which represent outputs from the model's last rehabilitation simulation period (500 years post development quarry operations). Lake water levels within the quarry void equilibrated to a level of approximately 25.6 mAHD after 163 years of rehabilitation modelling (calendar year 2209).

The model's water balance at the last rehabilitation simulation period is given in Table 21. Note that quarry drains have been removed from the rehabilitation model and the water balance. Vertical and lateral groundwater flows into and out of the void at this time are summarised in Table 22.

Time series head plots are provided in Attachment C Figure 46 and Figure 47 for all model domain bores and for offsite model domain bores respectively. The head plots combine results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250). Attachment C Figure 46 shows that all observation bores within the final lake extent (BH400, BH401, BH401A, BH1403 and Lake Obs) have identical heads, or similar heads for the case of BH1403 which has its screen located in a deeper model layer.

A time series dewatering rate plot is provided in Attachment C Figure 48 for the quarry void. The dewatering plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250).

A time series creek and river rate plot is provided in Attachment C Figure 49 for all model domain creeks and Williams River (as shown in Attachment C Figure 29). The rates plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to after rehabilitation equilibrium conditions – model year 67 – 300). The maximum during rehabilitation occurs shortly after the end of Stage 5 quarrying and results in a 7.9 ML/yr reduction to river rates and a 20.6 ML/yr reduction to creek rates. At rehabilitation equilibrium conditions there is a 1.6 ML/yr reduction to river rates and a 7.3 ML/yr reduction to creek rates due to the rehabilitated lake.

The pre quarry, existing and final rehabilitated groundwater head and drawdown that occurs at the rehabilitation model's last simulation period is in Table 23 for the model's bores. A rehabilitation equilibrium conditions drawdown plot is given in Attachment C Figure 50. The maximum extent of the 2 m drawdown cone at this time is approximately 2.6 km east-west and 2.3 km north-south, and extends over the northern site boundary.

A discussion of results and results summary follows sensitivity/uncertainty analysis (Section 7) in Section 8.

Table 21: Water balance for rehabilitation equilibrium conditions (500 years post development quarry operations).

Storage (ML/yr)		Recharge (ML/yr)		ET (ML/yr)		River (ML/yr) [2]		Creek Drains (ML/yr) [3]		Constant Head (ML/yr)		Total (ML/yr)	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0	0	3665	0	0	4065	28	101	0	49	598	58	4291	4273

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] River representing Williams River.

[3] Drains representing creeks throughout the model domain.

Table 22: Water balance for rehabilitation equilibrium conditions over the quarry void (500 years post development quarry operations).

Recharge (ML/yr)		ET (ML/yr)		Vertical Flow (ML/yr)		Lateral Flow (ML/yr)		Total (ML/yr) [2]	
In	Out	In	Out	In	Out	In	Out	In	Out
608	0	0	596	102	98	115	122	825	817

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] We note that final mass balance error is approximately 1.05%. Whilst this is above the adopted error threshold of 1% (Section 5.2) we consider it acceptable as it only occurs over a small area compared to the entire model domain. Model mass balance error is 0.28% and is considered acceptable.

Table 23: Pre quarry, existing and rehabilitation equilibrium groundwater head and drawdown at bore monitoring points (i.e centre of bore's open portion).

	Modelled Groundwater Head (mAHD) [1]			
Bore	**Pre Quarry [2]**	**Existing [3]**	**Rehabilitation [4]**	**Drawdown (m) [5]**
BH401	41	38	26	16
BH401A	38	37	26	12
BH400	40	35	26	15
BH1401	19	19	21	-1.2
BH1403	22	21	24	-1.8
BH1404	71	70	64	7.0
BH1405	32	30	26	5.7
BH1406	29	26	23	5.6
BH1407	27	26	23	1.9
Lake Obs [6]	24	23	26	-1.8
Synthetic [7]	-0.15	-0.15	-0.16	0.01
GW078135	8.2	8.1	8.1	0.06
GW51309	9.6	9.6	9.6	0.03

Notes:

[1]. Head at bore reported at observation point (i.e centre of bore's open portion) to two significant figures.

[2]. Head from transient model at first timestep (start of 1980, refer Table 16).

[3]. Head from transient model for current conditions (end of 2014, refer Table 16).

[4]. Head from transient model at conclusion of rehabilitation simulation (end of 2547, refer Table 16).

[5]. Drawdown = pre quarry head – rehabilitation head. Negative drawdown values denote increased rehabilitation head over pre quarry head.

[6]. Synthetic bore at the bottom bench of the quarry to model rehabilitation lake head.

[7]. Synthetic observation bore on low-lying rural land south east of the quarry (refer Section 5.8.1).

6.4 Varying Rainfall Predictive Models

The proposed development and rehabilitation models were also run with annually varying rainfall. Modelling procedure and summary of results is provided in Attachment F with associated outputs given in Figure 51 to Figure 60. These results have not been relied upon for impact analysis but have been referred to in discussion of natural fluctuation in study area groundwater characteristics.

7 Sensitivity/Uncertainty Analysis

7.1 Overview

The following sensitivity/uncertainty runs were completed using the transient calibration model over the monitoring period and involved deviation from the base case parameters as provided in Table 24 and as summarised below.

- Sensitivity Runs S1 & S2 – 50% decrease (S1) and 50% increase (S2) to hydraulic conductivity (K_h and K_v) of all model zones (as shown in Attachment C Figure 30).
- Sensitivity Runs S3 & S4 – 50% decrease (S3) and 50% increase (S4) to specific yield (S_y). Note that specific storage (S_s) remained constant as it was found during initial transient model calibration that altering this parameter did not significantly affect model outcomes.
- Sensitivity Runs S5 & S6 – 50% decrease (S5) and 50% increase (S6) to transient recharge values of all model zones (as shown in Attachment C Figure 31).
- Sensitivity Runs S7 & S8 – one order of magnitude decrease (S7) and one order of magnitude increase (S8) to the hydraulic conductivity anisotropy ratio of all model zones (as shown in Attachment C Figure 30).

Table 24: Sensitivity analysis input parameters summary.

		Scenario [1]							
Parameter	**Base Case [2]**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Anisotropy ratio	0.1	0.1	0.1	0.1	0.1	0.1	0.1	**0.01**	**1.0**
<40 mAHD [3] K_h (m/d)	0.175	**$8.75x10^{-2}$**	**0.263**	0.175	0.175	0.175	0.1.75	0.175	0.175
<40 mAHD [3] K_v (m/d)	$1.75x10^{-2}$	**$8.75x10^{-3}$**	**$2.63x10^{-2}$**	$1.75x10^{-2}$	$1.75x10^{-2}$	$1.75x10^{-2}$	$1.75x10^{-2}$	**$1.75x10^{-3}$**	**$1.75x10^{-1}$**
>40 mAHD [3] K_h(m/d)	$1.75x10^{-2}$	**$8.75x10^{-3}$**	**$2.63x10^{-2}$**	$1.75x10^{-2}$	$1.75x10^{-2}$	$1.75x10^{-2}$	$1.75 x10^{-2}$	$1.75 x10^{-2}$	$1.75 x10^{-2}$
>40 mAHD [3] K_v (m/d)	$1.75x10^{-3}$	**$8.75 x10^{-4}$**	**$2.63 x10^{-3}$**	$1.75 x10^{-3}$	$1.75 x10^{-3}$	$1.75 x10^{-3}$	$1.75 x10^{-3}$	**$1.75 x10^{-4}$**	**$1.75 x10^{-2}$**
S_y (%)	0.50	0.50	0.50	**0.25**	**0.75**	0.50	0.50	0.50	0.50
<40 mAHD [3] recharge (mm/yr) [4]	15	15	15	15	15	**7.5**	**22.5**	15	15
>40 mAHD [3] recharge (mm/yr) [4]	80	80	80	80	80	**40**	**120**	80	80
Pit recharge (mm/yr) [4]	200	200	200	200	200	**100**	**300**	200	200

Notes:

[1] Values in bold represent changes from base case parameter values.

[2] Base case parameter values derive from calibration and match those used in all existing conditions and predictive models.

[3] The low/high elevation boundary of 40 mAHD was derived from calibration and corresponds to conductivity and recharge zonation boundaries.

[4] Recharge values given represent steady state recharge values. All sensitivity runs use transient recharge varying monthly as per the base case (Section 5.9.1). S5 and S6 alter the previously utilised monthly recharge values by a 50% decrease and a 50% increase respectively.

7.2 Calibration Results

The primary sensitivity/uncertainty target assessed was model calibration. Results are summarised in Table 25 and indicate:

- NRMS is <10% for all modelled scenarios and hence each scenario is considered to achieve adequate calibration.
- In general results show the model is not highly sensitive to changes within the adopted ranges for each parameter tested.
- Calibration is slightly sensitive to conductivity (S1 & S2) and recharge (S5 & S6), but insensitive to S_y (S3 & S4).
- The anisotropy ratio (S7 & S8) gives the broadest range of calibration results, however, it was altered by an order of magnitude whereas all other parameters were altered by 50%. We therefore consider calibration to have similar sensitivity to anisotropy ratio as to conductivity and recharge, that is, being slightly sensitive.

- All scenarios worsened calibration overall except S8 (one order of magnitude higher anisotropy ratio) which slightly improved most calibration statistics.

Table 25: Sensitivity analysis results summary.

		Scenario [1]							
Sensitivity Criteria	**Base Case [2]**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
NRMS (%)	5.21	7.90	7.44	5.34	5.22	8.75	6.58	9.03	**4.88**
Maximum residual (m)	-6.20	7.28	-8.24	-6.63	**-6.00**	-8.78	6.53	-9.70	**-5.44**
Maximum residual location	BH1403	BH400	BH1403	BH1403	BH1403	BH1403	BH400	BH1403	BH1403
Residual mean (m)	-0.59	1.31	-2.32	-0.74	**-0.53**	-2.94	0.80	-2.63	-0.80
Absolute residual mean (m)	1.64	2.21	2.50	1.72	**1.62**	2.97	1.86	2.95	**1.64**
Correlation coefficient	0.957	0.910	**0.965**	**0.958**	0.956	**0.964**	0.932	0.942	**0.966**

Notes:

[1] Values in bold represent better calibration from base case conditions.

[2] Base case results are presented in Section 5.9.3 and are summarised in Attachment C Figure 39.

7.3 Uncertainty Analysis

The Scenario 8 sensitivity run (one order of magnitude increase to the hydraulic conductivity anisotropy ratio of all model zones) gave slightly better calibration statistics than the base case, except for the residual mean. For this reason the parameters in this scenario were utilised to test proposed and rehabilitation model predictions and uncertainty.

The proposed development model described in Section 6.2 and the rehabilitation model described in Section 6.3 were both utilised, with the only change to input parameters being Kz of all layers in accordance with Table 24.

Key output results are as follows:

- The peak pit dewatering rate at the end of proposed Stage 5 quarrying is 727 ML/yr (increased from 642 ML/yr).
- The maximum offsite licenced bore drawdown occurs at GW078135 and is 6.2 m (increased from 5.0 m)
- The final rehabilitated lake water level is 23.3 mAHD (decreased from 25.6 mAHD).

7.4 Conclusion

Results for sensitivity runs represent equivalent or worse calibration with respect to base case results. We consider that the adopted base case scenario parameters are therefore well suited to represent the groundwater system and evaluate development associated impacts and that model calibration is generally insensitive to variation of selected parameters.

Results of the uncertainty analysis show similar results in terms of the final rehabilitated lake water level and maximum offsite licenced bore drawdown. Dewatering rates are increased over base case conditions. Such a level of uncertainty is expected in similar models and demonstrates the possible range of model predictions. As required by site SEARs, the groundwater model should be regularly updated and informed by ongoing data collection to increase accuracy of predictions and decrease the level of uncertainty.

8 Discussion and Impact Assessment

8.1 Drawdown at GDEs

The GDEs identified by Biosis (Section 3.10) are all terrestrial vegetation which is dependent on the soil moisture 'groundwater' system in the shallow soil profile and at the soil rock interface. This groundwater system will not be significantly impacted by proposed quarrying as it is reliant on local rainfall recharge and infiltration which will be unchanged by the project.

Importantly, the GDEs identified are not dependent on the regional ground water table being drawn down, and the drawdown predicted shall have no adverse impact on the GDEs as identified.

8.2 Drawdown at Offsite Licenced Bores

Impact assessment at licenced bores used drawdown >2 m as a criterion. 2 m was chosen as this number accords with the maximum permissible drawdown before 'make good provisions' apply in accordance with the NSW Aquifer Interference Policy (2012).

Of the two offsite licenced bores within the model domain, only GW078135 is affected by proposed quarry operations. GW51309 head reduces by 0.04 m at the end of proposed Stage 5 quarrying (Table 18) and by 0.03 m at equilibrium conditions (Table 23) which is considered acceptable. Further, Attachment C Figure 57 shows GW51309 fluctuates by approximately ± 300 mm over the model duration due to varying recharge values and is a natural response.

Attachment C Figure 47 shows GW078135 is affected by >2 m drawdown from the pre quarry head level. >2 m drawdown begins during proposed development stage 5 (model year 63, calendar year 2043) and returns to <2 m drawdown 29 years after rehabilitation of the quarry (model year 96, calendar year 2076), a total of 33 years of effect. The maximum drawdown in this period is 4.9 m.

As drawdown of the proposed development exceeded 2 m at a licenced bore, in accordance with the NSW Aquifer Interference Policy (2012) further studies are required to demonstrate to the Minister's satisfaction that long-term bore viability will not be affected unless make good provisions apply.

8.3 Dewatering Rates

Pit dewatering rates are shown in Attachment C Figure 48 from pre quarry to rehabilitation equilibrium conditions, and are summarised in Table 19 for pre quarry conditions to the end of proposed development conditions.

Pit dewatering rates peak at the conclusion of proposed development quarrying when the pit is at its lowest invert level (-78 mAHD) at a rate of 642 ML/yr (equal to 1.8 ML/d or 20 L/s). This represents an increased dewatering rate of 7.5 times the steady state existing dewatering rate (237 m^3/d).

Refer to Martens and Associates Surface Water Assessment of the site (P1303888JR03V06, 2015) for details of the proposed management system for excess groundwater including retention, reticulation and disposal schemes.

8.4 River and Creek Rates

8.4.1 Overview

Creek and river rates are shown in Attachment C Figure 49 from pre quarry to rehabilitation equilibrium conditions.

8.4.2 River Rates Impact Assessment

The maximum reduction to Williams River baseflow caused by the proposed quarry expansion is 7.9 ML/yr, and the permanent reduction at rehabilitation equilibrium conditions is 1.6 ML/yr.

The closest available Williams River flow data is at Glen Martin (Mill Dam Falls), 20 km upstream of the study area (along Williams River) and 16 km from the site itself. The catchment area and river flow rates at the study location are much larger than those at Glen Martin, and hence consideration of Glen Martin rates is conservative. Data was sourced from the NOW River and Stream Data website (2015) for Glen Martin (site # 210010).

Mean annual flow at Glen Martin is 332,018 ML/yr. A reduction in baseflow of 7.9 ML/yr represents 0.002% of flow in Williams River, and even less considering the increased Williams River flow rates at the study area. The permanent reduction of 1.6 ML/yr is similarly insignificant compared to annual river flow rates. We therefore consider that impacts to Williams River baseflow rates caused by the development are negligible.

Further, we note that quarry operations and associated maximum drawdown extents are sufficiently far from the Hunter River alluvium to not cause impacts to alluvial water.

8.4.3 Creeks Rates Impact Assessment

The maximum reduction to model domain creek baseflow caused by the proposed quarry expansion is 20.6 ML/yr, and the permanent reduction at rehabilitation equilibrium conditions is 7.3 ML/yr. This represents a 36.8% and a 13.0% reduction from initial creek flow rates respectively.

We note the following:

- The character of streams on steep hillsides is that they are normally surface water fed and do not have perennial flow.

- Creeks/streams surrounding the site including Deadman's Creek are predominantly grassed depressions in topography and have not been observed as perennial streams.

- It is likely that any baseflow entering creeks is quickly evaporated and hence adds little riparian value.

- The maximum and permanent reductions to creek baseflow are well within natural response variations to annual rainfall, which may vary by up to 35 ML/yr in a single year (refer to Attachment C Figure 59 for annually varying recharge model results).

- Basic landholder rights in accordance with Water Management Act (2000) licencing and the farm dam policy give a maximum harvestable right dam capacity of 49.9 ML/yr (refer to the Surface Water Assessment of the site P1303888JR03V06, 2015). Considering this volume can be filled and emptied multiple times in the year, and there is no permanent licenced surface water take proposed, the maximum 20.6 ML/yr reduction to creek flow is considered to be well within basic landholder entitlement.

Based on the above, we consider that impacts to creek baseflow caused by the development are not significant and are acceptable.

8.5 Post Quarry Rehabilitation

Rehabilitation modelling results agree with the equilibrium water balance assessment (Section 6.3.1) and predicts the lake doesn't equilibrate to its maximum capacity at a level of 30 mAHD. The equilibrium lake water level is approximately 25.6 mAHD and occurs after 163 years of rehabilitation following quarry closure (model year 230, calendar year 2210).

At equilibrium the net groundwater inflow to the lake equals the net groundwater outflow from the lake (Table 22), which also agrees with the equilibrium water balance assessment.

The equilibrated lake causes permanent changes to the groundwater regime within the model domain. The rehabilitation equilibrium drawdown plot (Attachment C Figure 50) shows:

- A permanent drawdown cone from pre quarry conditions approximately 2.6 km in diameter (bounded by the 2 m drawdown contour in layer 1).
- The maximum drawdown within the model domain occurs within the quarry footprint and is approximately 34 m due to the pre quarry head being pulled down to the lake level.
- The maximum drawdown on the site outside the quarry footprint is approximately 20 m immediately adjacent to the pit, reducing to a maximum of 10 m at the site boundary. All offsite drawdown impacts are <10 m and are mostly located north of the quarry.
- A small area south of the quarry has increased head of almost 6 m as the regional groundwater table is mounded due to the presence of the lake.
- There are no offsite licenced bores permanently affected by the changed groundwater regime at the quarry.

We conclude that the permanent changes to regional groundwater table surrounding the rehabilitated quarry will not be significant for current or future groundwater users.

8.6 Salinisation

8.6.1 Overview

After rehabilitation the quarry void will act as a flow through lake rather than a groundwater sink. Evaporation from the lake surface will remove water but leave behind salinity, which will increase lake salinity over time and may lead to downslope groundwater salinisation.

Salt mass balances have been undertaken to quantify the potential impacts of surface water and groundwater salinisation. The equilibrium salinity concentration within the rehabilitated lake has been calculated and used to estimate impacts on downstream surface water and groundwater receivers.

8.6.2 *Quarry Lake Equilibrium Concentration*

The rehabilitated quarry lake with final (equilibrated) water levels will reach salinity equilibrium conditions when the lake salinity concentration equals the groundwater outflow concentration.

Flow volumes determined through the equilibrated lake water balance assessment (Section 6.3.1) and from the MODFLOW model results (Section 6.3.5) were multiplied by adopted salt concentrations to determine salt inflow and outflow masses. The groundwater outflow salinity was determined by simultaneously solving for inflow salt mass equal to outflow salt mass. Calculation details, assumptions and results are summarised in Table 26.

Table 26: Rehabilitated quarry lake salt mass balance at equilibrium conditions.

Inflow			
Source	**Flow Volume (ML/yr) [1]**	**Salt Concentration (ppm)**	**Salt Mass (kg/yr) [2]**
Groundwater Inflow	217	1,560 [3]	338,520
Direct Rainfall	443	100 [4]	44,290
Runoff	165	400 [4]	66,039
Total	825	-	448,849
Flow Weighted Average	-	544	-
Outflow			
Source	**Flow Volume (ML/yr) [1]**	**Salt Concentration (ppm)**	**Salt Mass (kg/yr) [2]**
Evaporation	608	0	0
Groundwater Outflow	217	2,068 [5]	448,849
Total	825	-	448,849
Flow Weighted Average	-	544	-

Notes:

[1] Inflow and outflow volumes derive from a combination of the lake water balance at equilibrium conditions (Table 19) and MODFLOW lake water balance results 500 years post quarry development (Table 21). Volumes have been altered slightly where necessary to ensure total inflow equals total outflow, due to discrepancies which arose from model coarseness and minor mass errors.

[2] Salt Mass (kg/yr) = Flow Volume (ML/yr) x Salt Concentration (ppm).

[3] Based on average site bore water quality (Table 11).

[4] Assumed.

[5] Solved simultaneously to make inflow salt mass equal outflow salt mass.

Results show that at equilibrium conditions groundwater entering the pit lake at 1,560 ppm salinity will exit at 2,068 ppm salinity which represents an increase in 508 ppm or 33% over existing conditions. The additional salt load in the groundwater leaving the site is 110,329 kg/yr (addition of direct rainfall and runoff inflow salt masses).

8.6.3 Surface Water Salinity Impact Assessment

The NSW Aquifer Interference Policy (2012) requires that changes caused by a development to the salinity of a nearby reliable river are <1% of average river salinity. This assessment was undertaken for the Hunter River which will receive the majority of groundwater flow passing through the rehabilitated void lake.

The following assumptions were made for the impact assessment:

1. All additional rehabilitated void lake groundwater salt arrives at the Hunter River south of Brandy Hill (refer Figure 1).
2. The closest available Hunter River flow data is at Greta, 53 km upstream of the inflow location (along the Hunter River) and 27 km from the site itself. The catchment area and river flow rates at the inflow location are much larger than those at Greta, and hence adoption of Greta rates is conservative. Data was sourced from the NOW River and Stream Data website (2015) for Greta (site # 210064).
3. The closest available Hunter River salinity data is at Raymond Terrace, 8.5 km downstream of the inflow location (along the Hunter River). Data was sourced from the NOW River and Stream Data website (2015) for Raymond Terrace (site # 210452).

The resultant river outflow salinity was determined by simultaneously solving for inflow salt mass equal to outflow salt mass. Calculation details, assumptions and results are summarised in Table 27.

Table 27: Hunter River salt mass balance at quarry equilibrium conditions.

Source	Flow Volume (ML/yr)	Salt Concentration (ppm)	Salt Mass (kg/yr) [1]
Additional Groundwater Salt [2]	-	-	110,329
Upstream River Flow	709,518 [3]	3,751 [4]	2,661,354,398
Total Downstream River Flow	709,518	-	2,661,464,727
Flow Weighted Average	-	3,751 [5]	-

Notes:

[1] Salt Mass (kg/yr) = Flow Volume (ML/yr) x Salt Concentration (ppm).

[2] As per Table 26 assuming all additional salt from direct rainfall and runoff arrives at Hunter River.

[3] Based on average annual flow data at Greta (site # 210064) from NOW (2015). Actual flows at the inflow location would be much higher.

[4] Based on average daily salinity data at Raymond Terrace (site # 210452) from NOW (2015). Salinity data in ppm converted from raw electrical conductivity measurements in µS/cm using a multiplication factor of 0.64 adopted from NSW Office of Environment & Heritage (OEH) website (2013).

[5] Solved simultaneously to make inflow salt mass equal outflow salt mass.

Results show that due to the large existing salt mass in the Hunter River there is no significant change in average salinity caused by additional salt from the rehabilitated quarry lake. Consideration of the minimum annual flow recorded at Greta (45,496 ML/yr) results in an outflow concentration of 3,753 ppm which represents a 0.06% change in river salinity. Impacts of increased development salt are therefore acceptable for receiving rivers in accordance with the NSW Aquifer Interference Policy (2012).

8.6.4 Groundwater Salinity Impact Assessment

The NSW Aquifer Interference Policy (2012) requires assessment of any change in beneficial groundwater use caused by a development. This assessment was undertaken for the offsite licenced bore GW078135 which will receive the majority of groundwater flows passing through the rehabilitated void lake.

The following assumptions were made for the impact assessment:

1. The extents of the groundwater flow path from the rehabilitated void lake flowing between topographical depressions passing through bore GW078135 was observed in all layers of the rehabilitated model at the last simulation period.

2. All additional rehabilitated void lake groundwater salt passes through this observation arc.

3. Groundwater salinity at bore GW078135 was adopted as given in Table 3.

The resultant groundwater outflow salinity passing through bore GW078135 was determined by simultaneously solving for inflow salt mass equal to outflow salt mass. Calculation details, assumptions and results are summarised in Table 28.

Table 28: Groundwater passing through bore GW078135 salt mass balance at quarry equilibrium conditions.

Source	Flow Volume (ML/yr)	Salt Concentration (ppm)	Salt Mass (kg/yr) [1]
Additional Groundwater Salt [2]	-	-	110,329
Groundwater Inflow	244 [3]	3,600 [4]	878,400
Total Groundwater Outflow	244	-	988,729
Flow Weighted Average	-	4,052 [5]	-

Notes:

[1] Salt Mass (kg/yr) = Flow Volume (ML/yr) x Salt Concentration (ppm).

[2] As per Table 26 assuming all additional salt from direct rainfall and runoff arrives at the observation arc.

[3] Based on MODFLOW observed groundwater flow path from the rehabilitated void lake flowing between topographical depressions passing through bore GW078135 in all layers of the rehabilitated model at the last simulation period.

[4] GW078135 groundwater salinity (refer Table 3).

[5] Solved simultaneously to make inflow salt mass equal outflow salt mass.

Results show that at equilibrium conditions groundwater salinity at bore GW078135 will increase by 452 ppm which represents an increase of 12.6%. While this is not insignificant, there is no change in beneficial groundwater use in accordance with Table 12 as the groundwater is still classified as brackish and is unsuitable for potable and most agricultural purposes. The existing groundwater is likely brackish due to high evaporation rates compared to recharge rates on low-lying swampy land. Impacts of increased development salt are therefore acceptable for receiving rivers in accordance with the NSW Aquifer Interference Policy (2012).

8.6.5 Summary

The assessment of salinisation as a result of the quarry void lake concluded:

- Evaporation from the rehabilitated void flow through lake will cause groundwater salinity to increase from 1,560 ppm to up to 2,068 ppm.
- Additional salt arriving at the Hunter River will have a negligible impact (<1% change) to salinity concentration.
- Additional salt arriving at downstream licenced groundwater bore users will increase groundwater salinity by up to 12.6% but will not change the beneficial use category of the groundwater.
- Salinity impacts are considered acceptable in accordance with the NSW Aquifer Interference Policy (2012).

9 Water Licensing

The site is to be located within the *North Coast Fractured and Porous Rock Groundwater Sources Water Sharing Plan (WSP)*, however at the time of writing this report this plan is still in development and has not been gazetted. Site groundwater licencing is therefore covered by the Water Act (1912).

It is anticipated that water licencing with sufficient share component for the taking of water shall be required. The grant of the water licence and the management of allocation and share component which attach to it are bound by the rules within the Water Act.

Any water taken from a Water Act regulated water source as part of or as a result of the Project must be authorised by appropriate water licencing.

As a consequence of Part 4 Division 4.1 Section 89J(1)(g) of the EP&A Act, approvals under Section 89 – Water Use Approval, 90 – Water Management Work Approval or 91 – Controlled Works Approval are not required for the Project should a SSD Approval be granted.

At equilibrium conditions there is no net groundwater outflow from the quarry void and hence no permanent groundwater licencing is required. Importantly, it is estimated that reaching equilibrium shall take of the order of 165 years after quarrying is completed. Therefore, there is a long term requirement for the site to maintain groundwater extraction licences. Prior to the sale or transfer of the licences from site approval by the Minister administrating the Water Act is required to assess that the licencing will only be relinquished at the appropriate time.

Annual groundwater licencing requirements are to be regularly reviewed. The groundwater model will be updated, and will be informed by ongoing data collection including continued groundwater level monitoring and dewatering rates monitoring.

Preliminary estimates of the licensable take at each stage's completion and through the rehabilitation period is provided in Table 29.

Table 29: Licensable groundwater take at each stage of proposed development and through the rehabilitation period.

Stage	Calendar End Year	Licensable Groundwater Take (ML/yr) [2]
Proposed Expansion Stage 1	2022	172
Proposed Expansion Stage 2	2028	315
Proposed Expansion Stage 3	2034	424
Proposed Expansion Stage 4	2040	516
Proposed Expansion Stage 5	2046	642
10 Years of Rehabilitation	2056	452
20 Years of Rehabilitation	2066	356
30 Years of Rehabilitation	2076	277
40 Years of Rehabilitation	2086	197
50 Years of Rehabilitation	2096	142
60 Years of Rehabilitation	2106	111
70 Years of Rehabilitation	2116	86
80 Years of Rehabilitation	2126	66
90 Years of Rehabilitation	2136	50
100 Years of Rehabilitation	2146	37
163 Years of Rehabilitation [1]	2209	0 [1]

Notes:

[1] Based on rehabilitation water balance at equilibrium (Section 6.3.5).

[2] Dewatering rates are based on uniform annual rainfall as discussed at Section 6.2.3 and Section 6.3.4.

10 Monitoring Program

A site specific groundwater and water quality monitoring program is to be formulated in consultation with NOW and any other relevant agencies following project approval. Based on the predicted maximum drawdown extent, we recommend two additional groundwater monitoring bores be installed at the south and south eastern site boundaries as shown in Attachment C Figure 43.

11 Conclusions and Recommendations

Numerical groundwater modelling including combined sensitivity/uncertainty analysis indicates that the proposed development can proceed with an acceptable level of impact to stakeholders (environment and licensed bore users).

Licenced bore GW078135 is modelled to be subjected to >2 m of drawdown due to the proposed development. Such a level of drawdown may impact the bore's productivity. Further works are required to determine measures required, to the Minister's satisfaction, to ensure long-term bore viability will not be affected or to assess necessary 'make good' provisions. However, it is recommended that groundwater level monitoring be undertaken at this bore prior to proposed quarrying progression below existing approved quarry floor level to provide a benchmark for impact assessment. Approval should be issued conditional on the Applicant's commitment to ensure the ongoing yield of the bore is available to the licenced user or their commitment to provide additional works to 'make good' any loss of bore yield.

Predicted groundwater take is required to be licenced in accordance with the Water Act (1912). The grant of water licencing and the management of allocation and share component which attach to it will be bound by the rules of the Water Act. Groundwater take is estimated to require licencing for in the order of 170 years after completion of quarrying, after which permanent licencing is not expected to be required.

The impacts of the proposed quarry extension at Hanson's Brandy Hill Quarry are considered acceptable. The quarry shall not impact on the local hydrogeological system in such a way as to have significant detrimental effects for nearby groundwater users or ecological systems for the duration of the proposed project and after rehabilitation.

12 References

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13 Attachment A – Quarry Layout

NOTES:
1. BACKGROUND AERIAL FROM SIXMAPS (2014).
2. EXISTING CONTOURS AND BOREHOLE LOCATIONS PROVIDED BY HANSON (2014).
3. ALL BOREHOLES EXCEPT BH1402 CONTAIN A PIEZOMETER.

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	24.04.15	AN

BAR SCALE

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DATUM: mAHD
REVIEWED: AN
HORIZONTAL RATIO: 1:2500
PAPER SIZE: A1
VERTICAL RATIO: NA

CLIENT / PROJECT

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BRANDY HILL QUARRY
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All measurements in mm unless otherwise specified

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TITLE:

EXISTING SITE LAYOUT AND
SURFACE WATER CONDITIONS

DRAWING ID: **SK001**

PROJECT MANAGER: AN
PROJECT NO.: P1303888
FILE: JD02V01
REVISION: A

NOTES:
1. PROPOSED DEVELOPMENT IS SHOWN OVERLAYING SITE SURVEY.
2. PROPOSED LAYOUT AND SITE SURVEY PROVIDED BY HANSON (2014).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	24.04.15	AN

BAR SCALE

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DATUM: mAHD
REVIEWED: AN
HORIZONTAL RATIO: 1:3000
PAPER SIZE: A1
VERTICAL RATIO: NA

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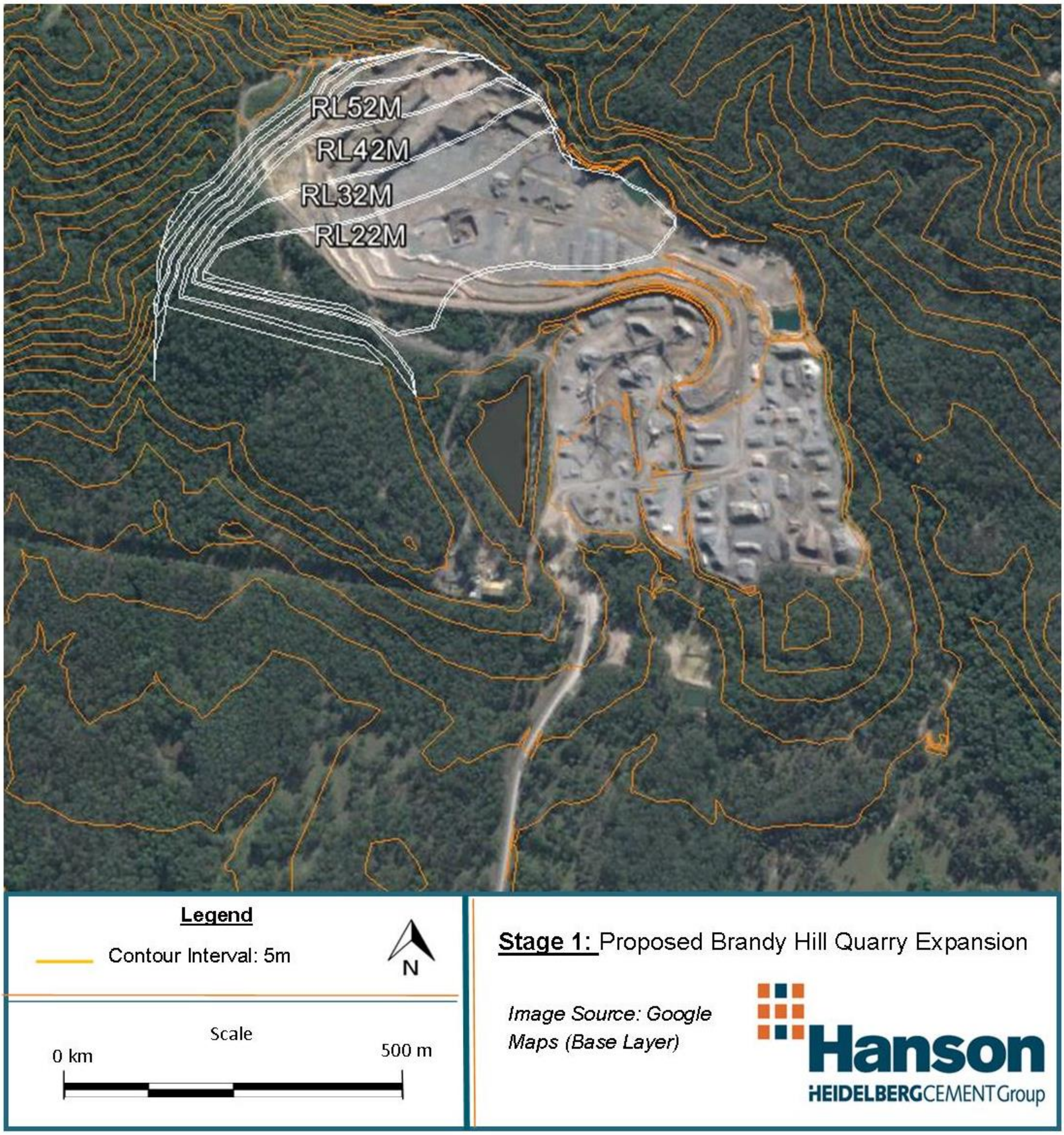
TITLE:
SITE SURVEY AND
STAGE 5 QUARRY LAYOUT

DRAWING ID: **SK002**

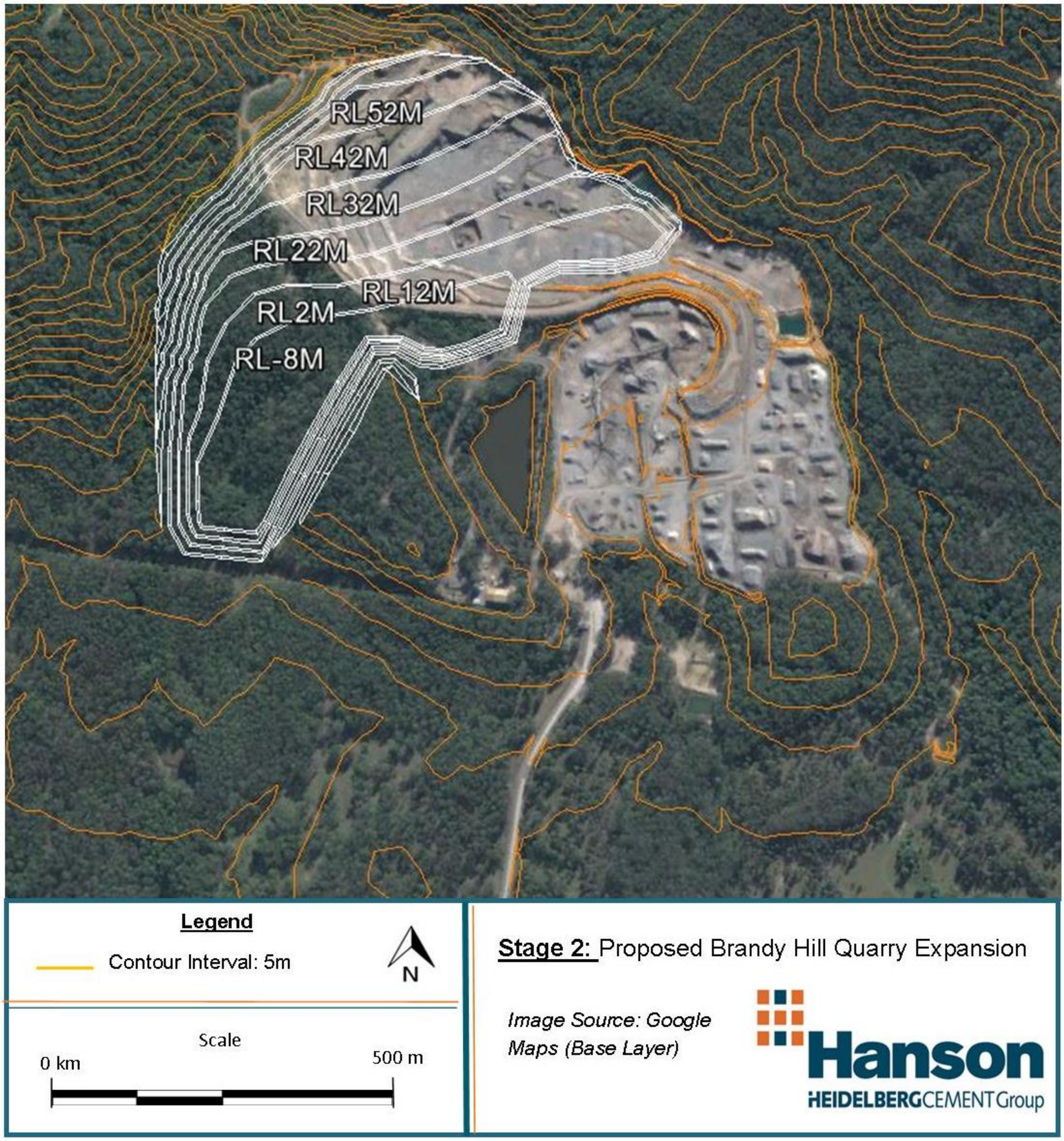
PROJECT MANAGER: AN
PROJECT NO.: P1303888
FILE: JD02V01
REVISION: A

14 Attachment B – Extraction Staging



Stage 1: Proposed Brandy Hill Quarry Expansion

Image Source: Google Maps (Base Layer)



Stage 2: Proposed Brandy Hill Quarry Expansion

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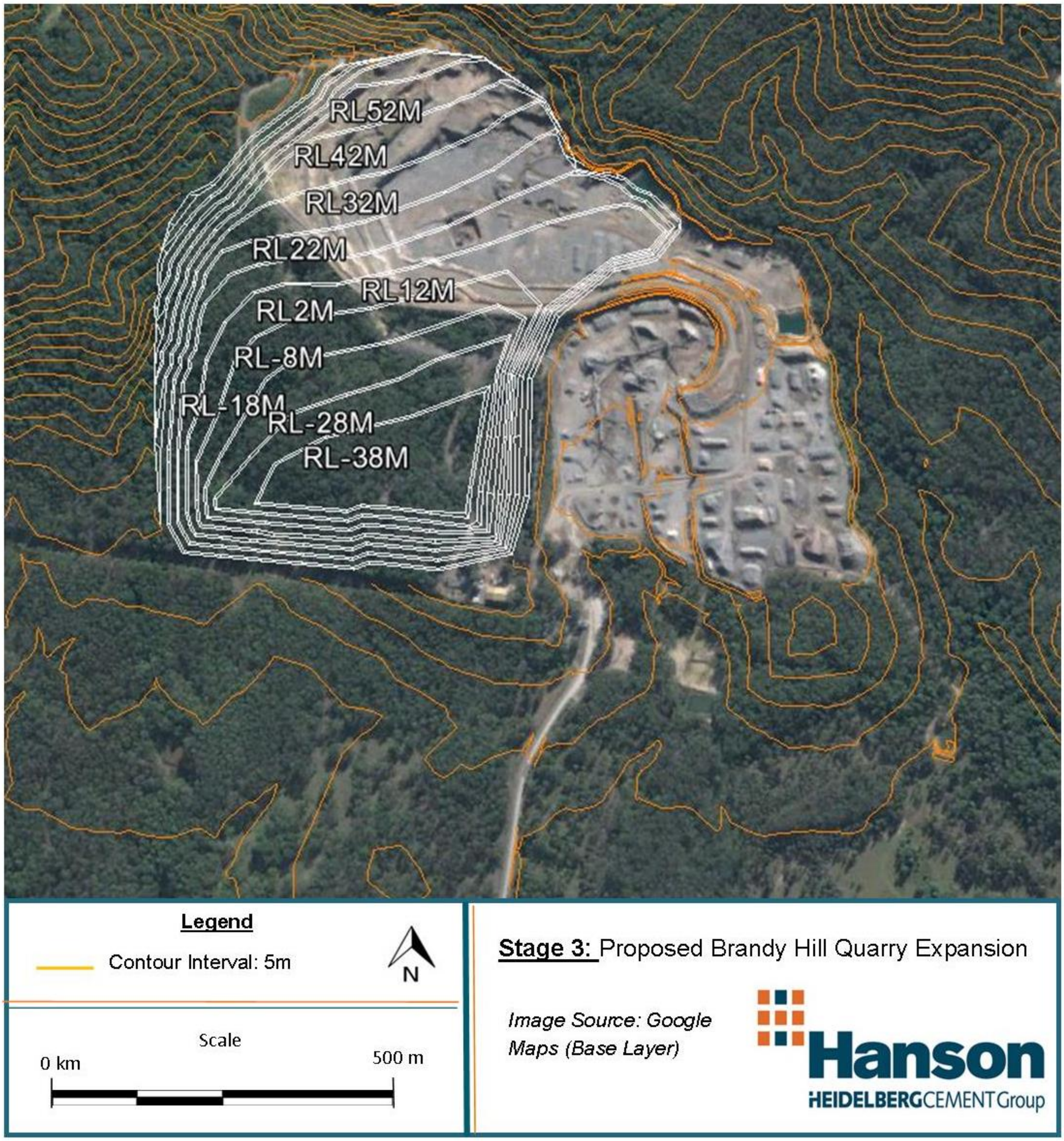

Stage 3: Proposed Brandy Hill Quarry Expansion

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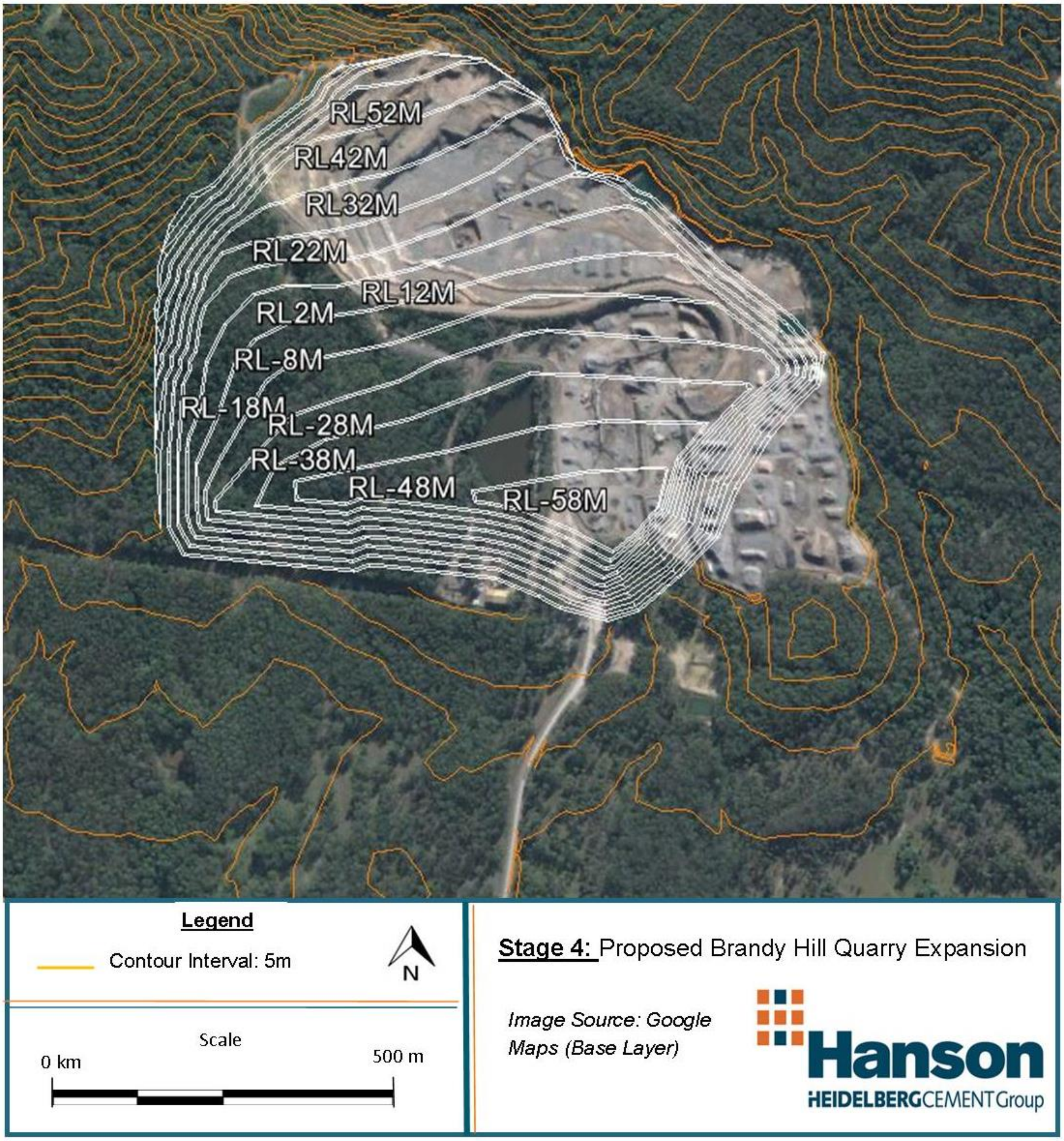

Stage 4: Proposed Brandy Hill Quarry Expansion

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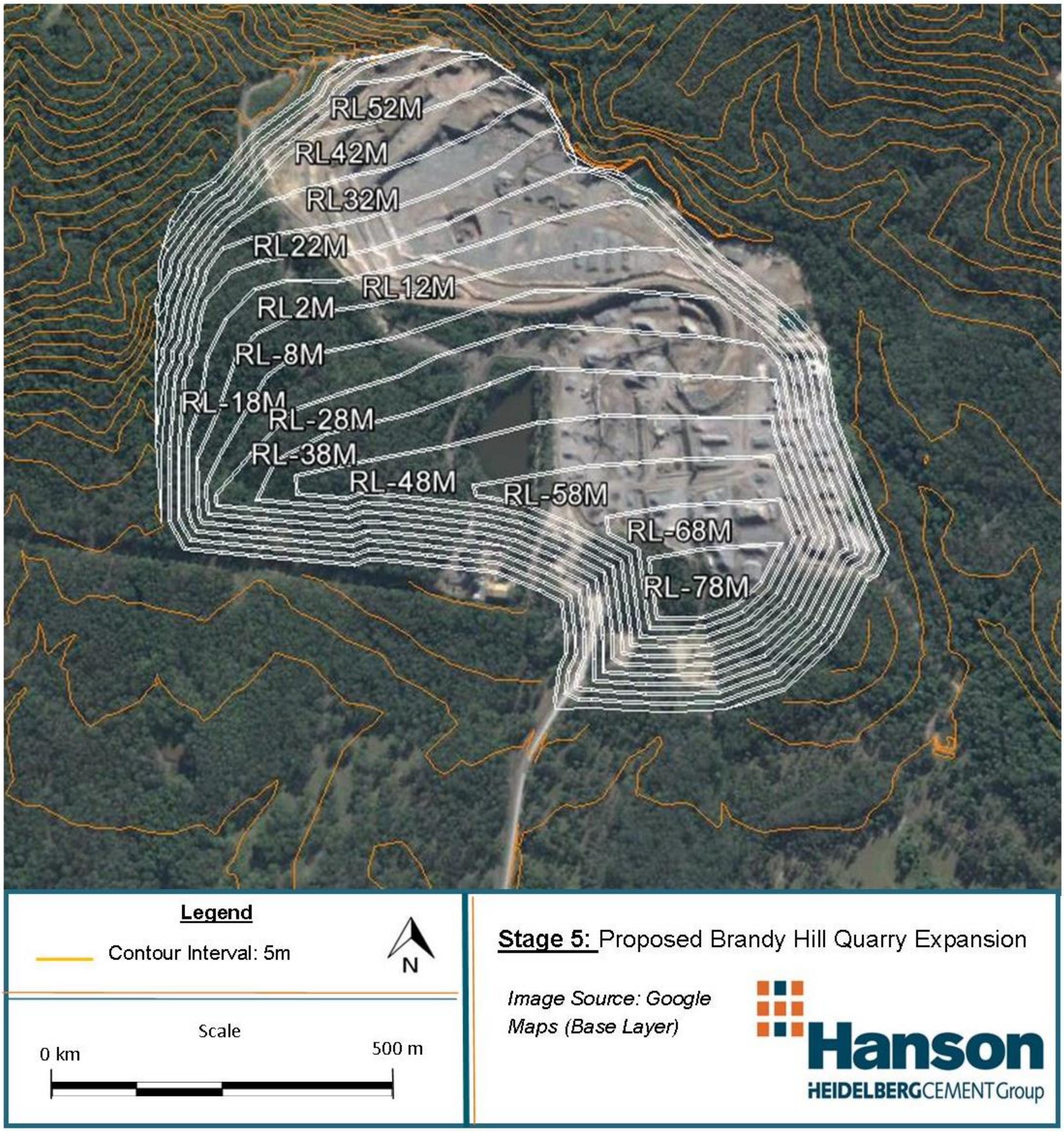
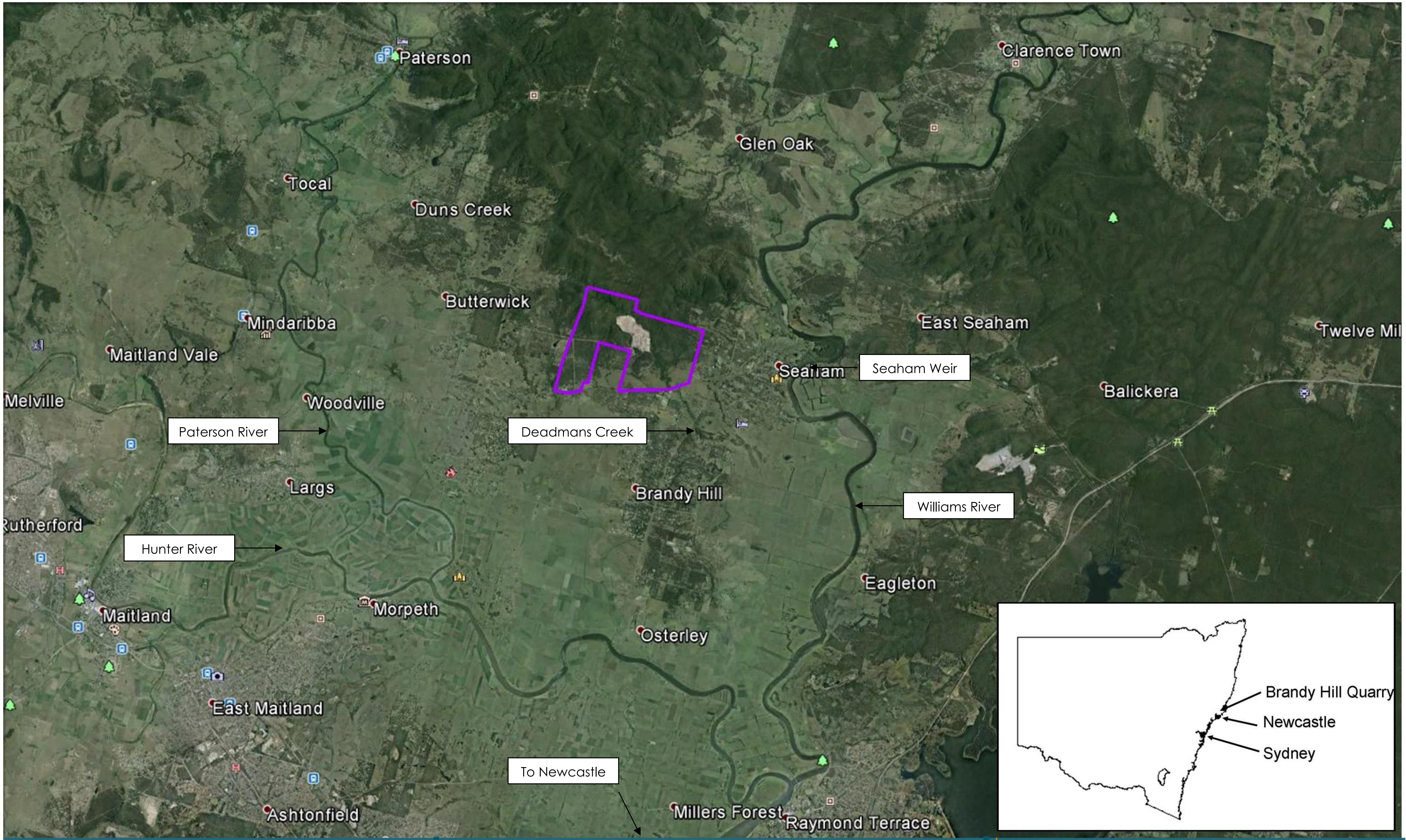


Stage 5: Proposed Brandy Hill Quarry Expansion

Image Source: Google Maps (Base Layer)

15 Attachment C – Figures



Legend

▬ Property Boundary

Brandy Hill Quarry Regional Location

Image Source: Google Maps (Base Layer)

N

Scale

0 km 7 km

Hanson

HEIDELBERGCEMENT Group

FIGURE 1

KEY

SITE BOUNDARY	—
EXISTING CONTOURS (10M INTERVAL)	20.0

NOTES:
1. BACKGROUND AERIAL FROM SIXMAPS (2015).
2. PRE QUARRY CONTOURS AT SITE HAVE BEEN DIGITIZED FROM THE 1983 QUARRY EIS.
3. ALL OFFSITE CONTOURS PRODUCED FROM LIDAR DATA (LPI, 2013).

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL IMPACT STATEMENT	28.07.15	AN

BAR SCALE

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PAPER SIZE: A1	VERTICAL RATIO: NA

CLIENT / PROJECT

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TITLE:

TOPOGRAPHIC MAP

DRAWING ID:

FIGURE 2

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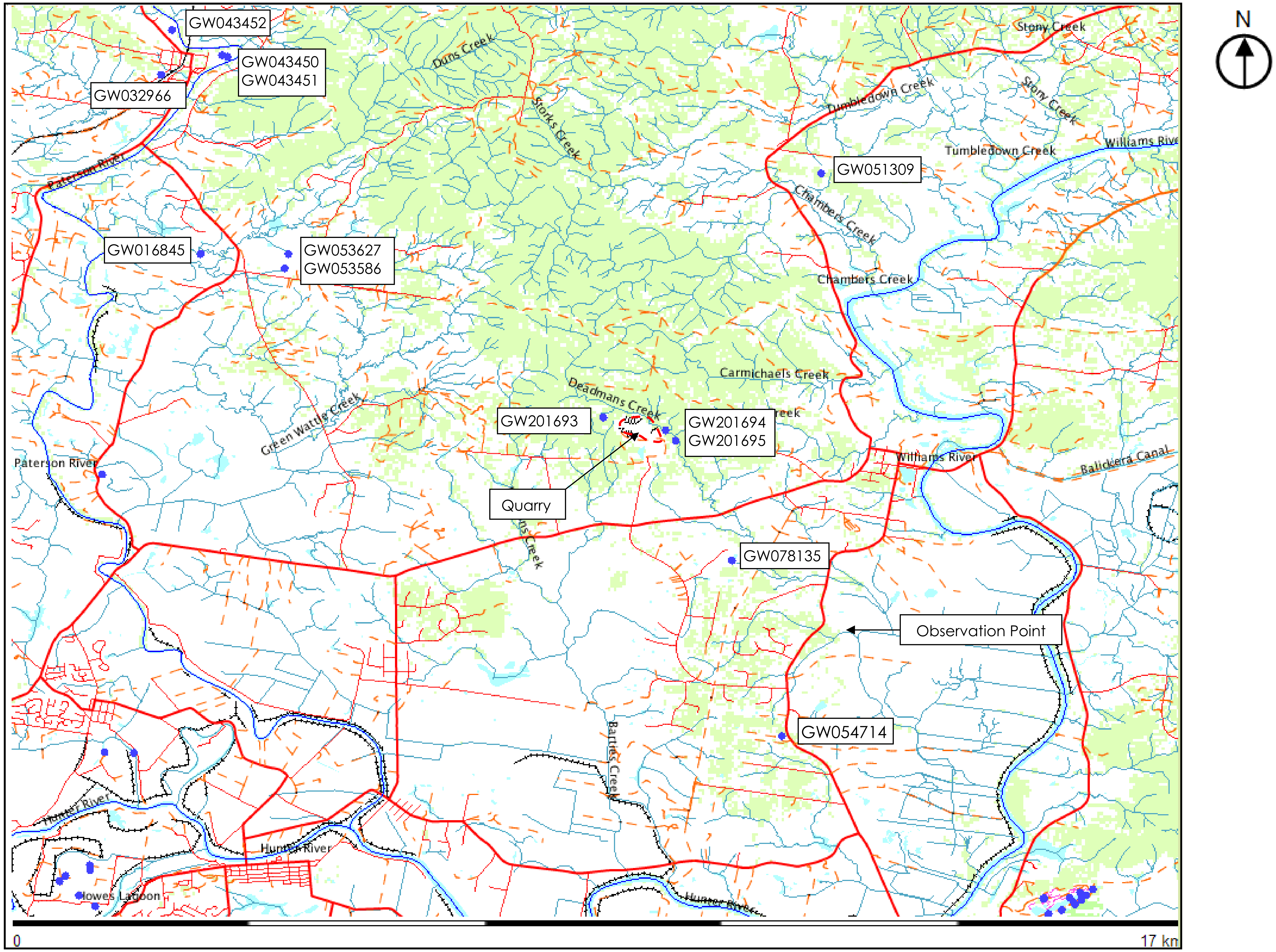

Note:
1. Background map from Natural Resource Atlas (NSW Government, 2015).
2. Synthetic bore for calibration is shown in addition to licenced bores.
3. Refer to Attachment A SK001 for detailed layout of site monitoring bores.

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Approved:	AN
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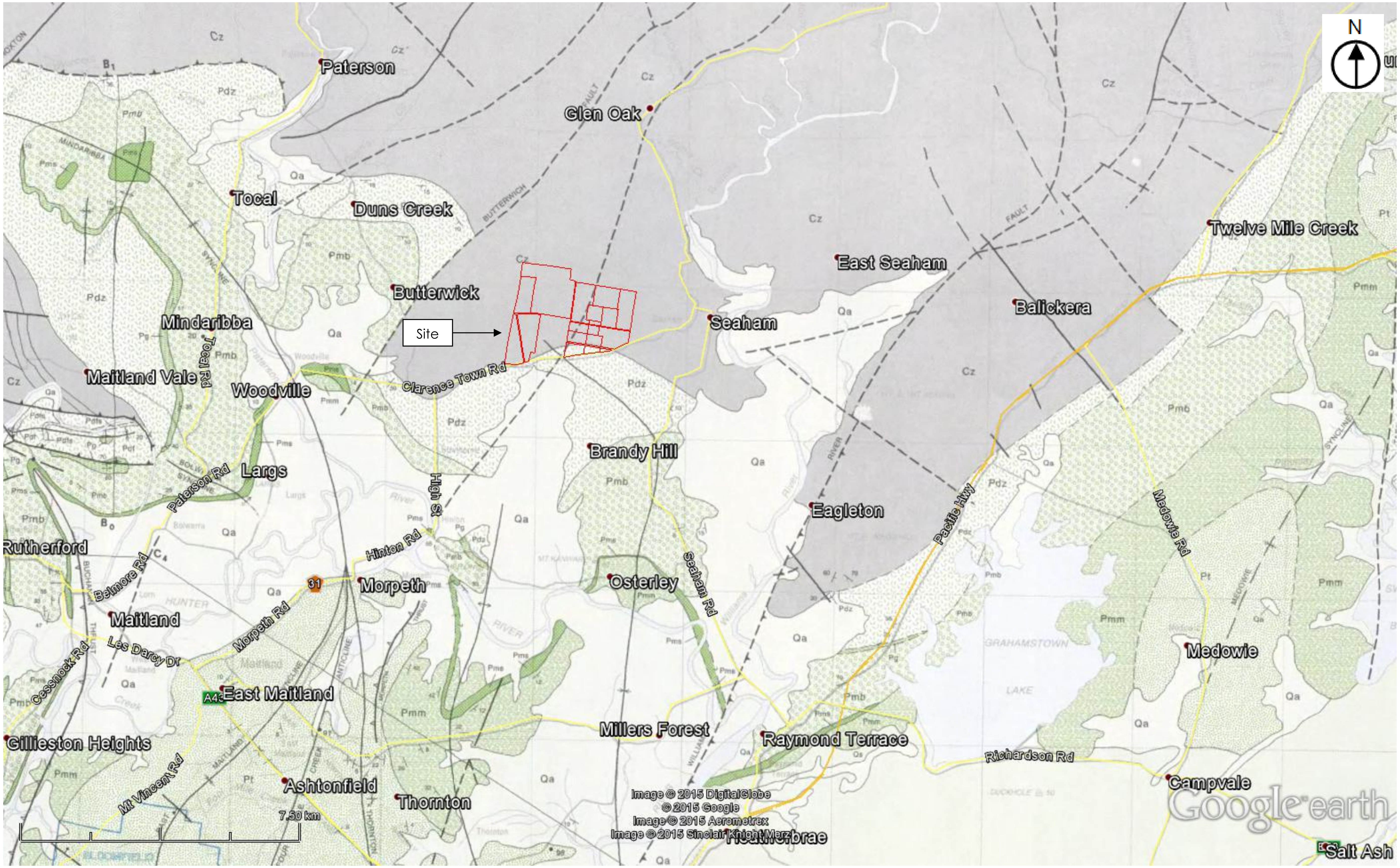
Scale:	As shown

LICENSED BORES

Drawing No:

FIGURE 3

Job No: P1303888JR02V04



Note:
1. Background basemap from Google Earth (2015).
2. Geological map from Newcastle 1:100 000 Coalfield and Regional Geology Map (Department of Mineral Resources, 1995).
3. Refer to report Section 3.2 for geology descriptions.

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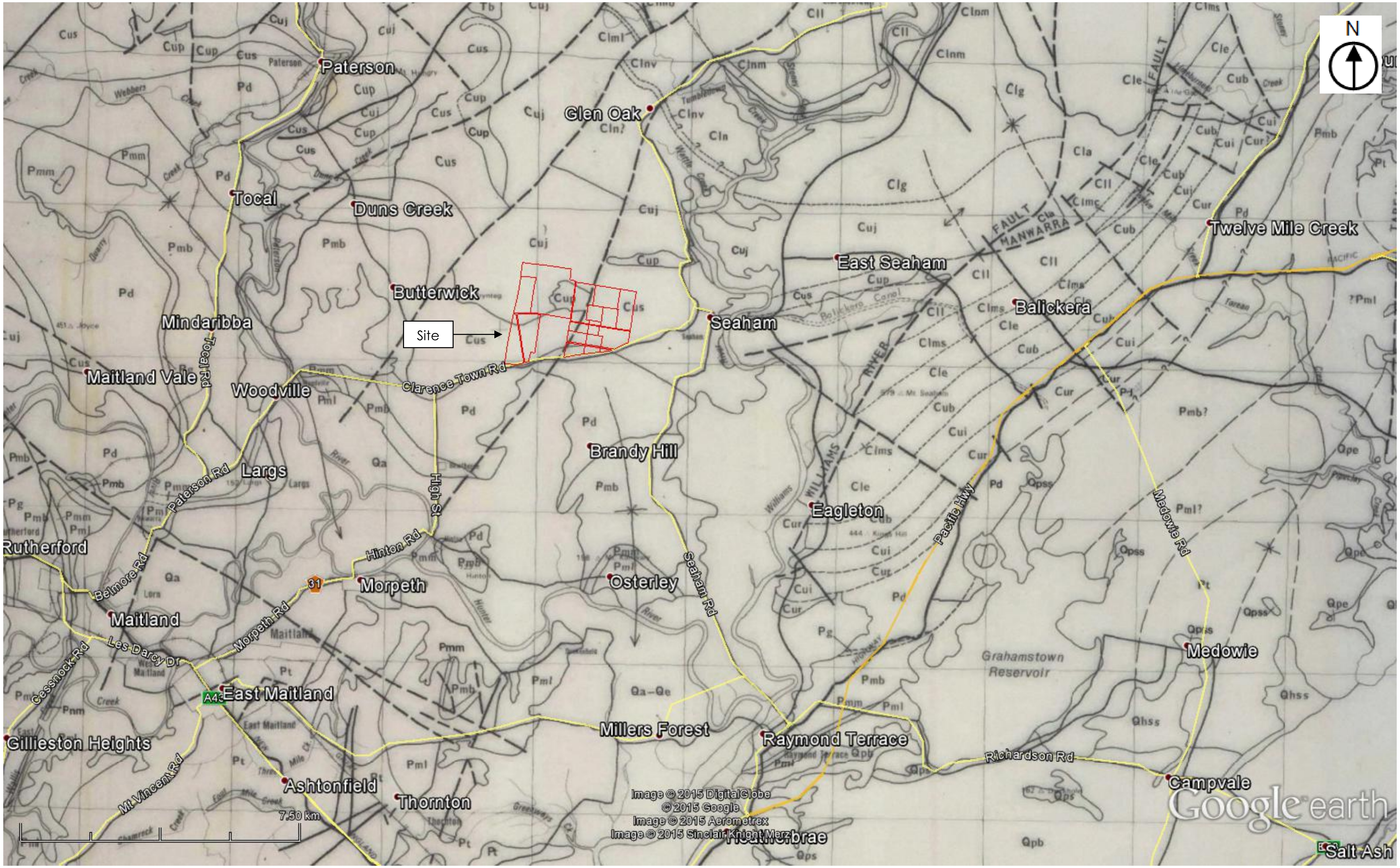
GEOLOGICAL MAP 1 – NEWCASTLE 1:100 000 COALFIELD AND REGIONAL GEOLOGY MAP

Drawing No:

FIGURE 4

Job No: P1303888JR02V04



Note:
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2. Geological map from Newcastle 1:100 000 Geological Sheet (Department of Mines, 1975).
3. Refer to report section 3.2 for geology descriptions.

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Scale:	As shown

GEOLOGICAL MAP 2 – NEWCASTLE 1:100 000 GEOLOGICAL SHEET

Drawing No:

FIGURE 5

Job No: P1303888JR02V04

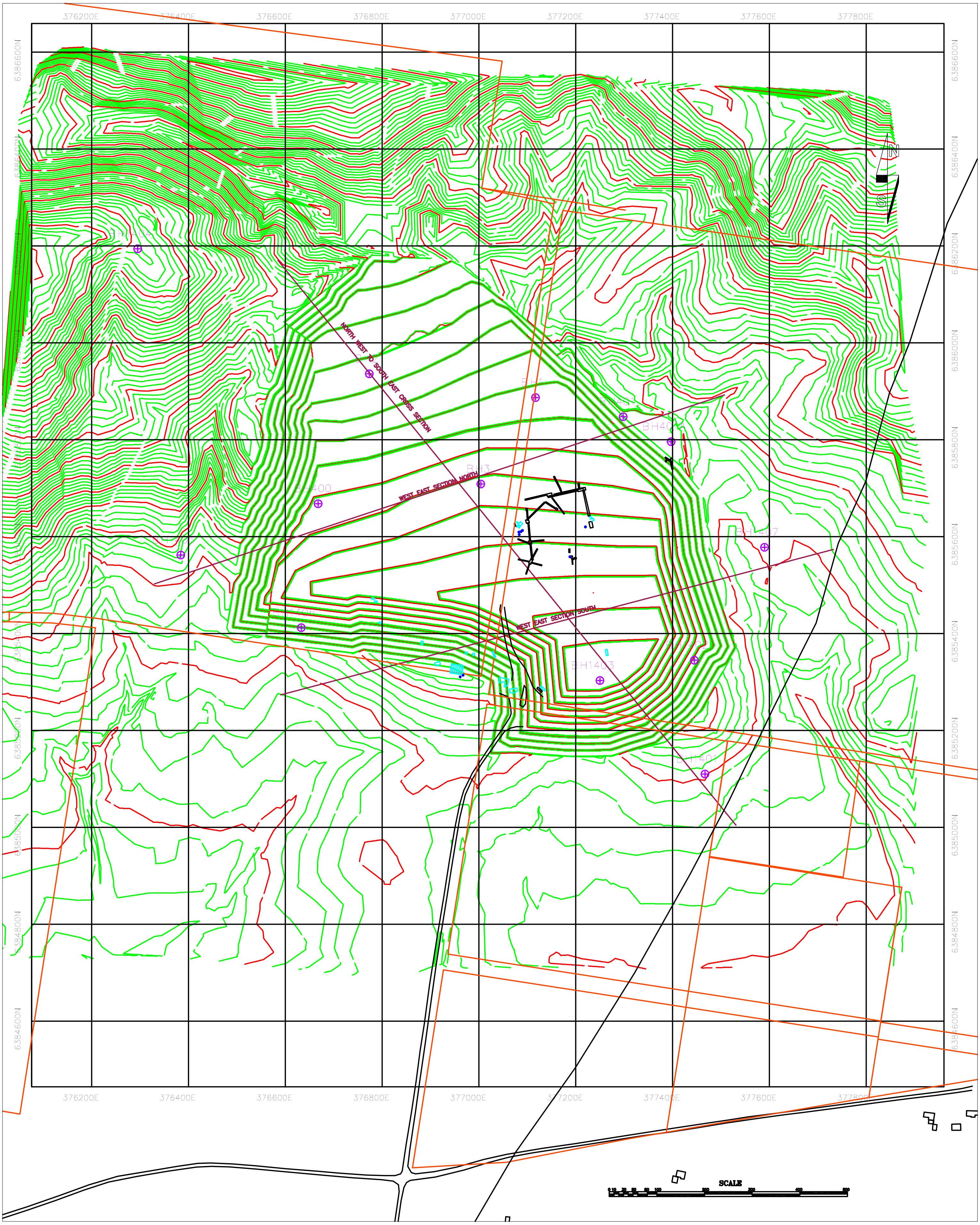

FIGURE 6

BRANDY HILL QUARRY EXTENSION
BOREHOLE, CROSS SECTION LOCATIONS
PIT DESIGN (2m CONTOURS)
TITLE BOUNDARIES (RED)
SCALE 1:10,000

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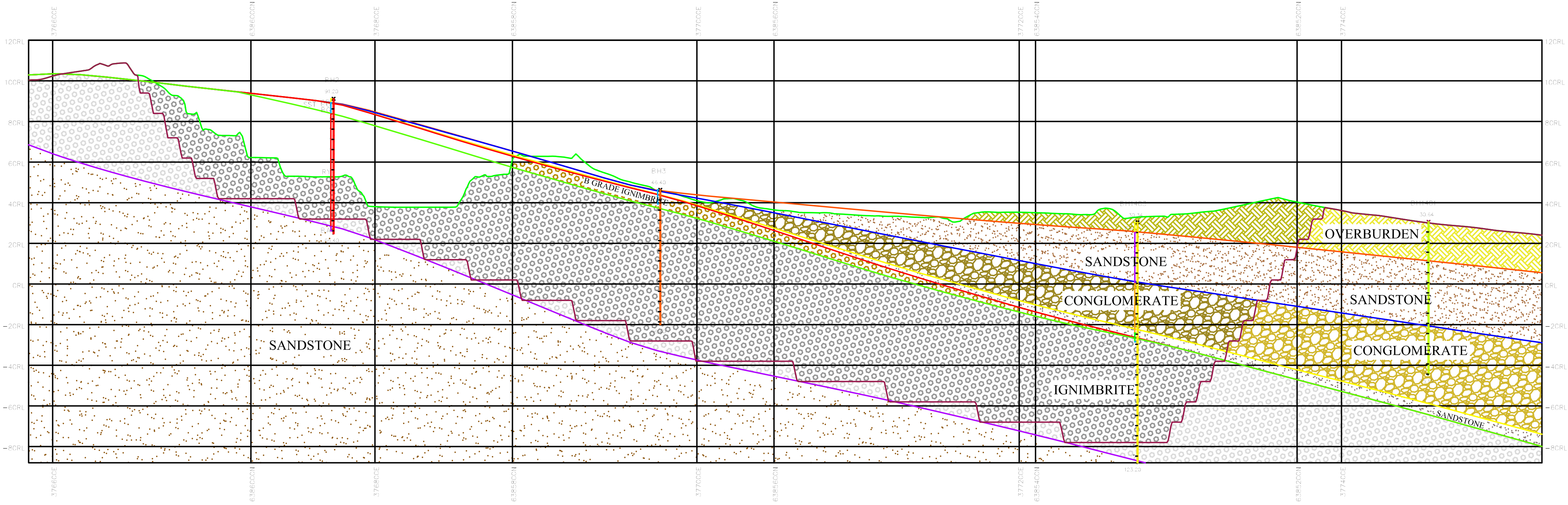

FIGURE 7

BRANDY HILL QUARRY EXTENSION
NORTH WEST TO SOUTH EAST
CROSS SECTION

NOT TO SCALE
VERTICAL EXAGGERATION 2 TIMES

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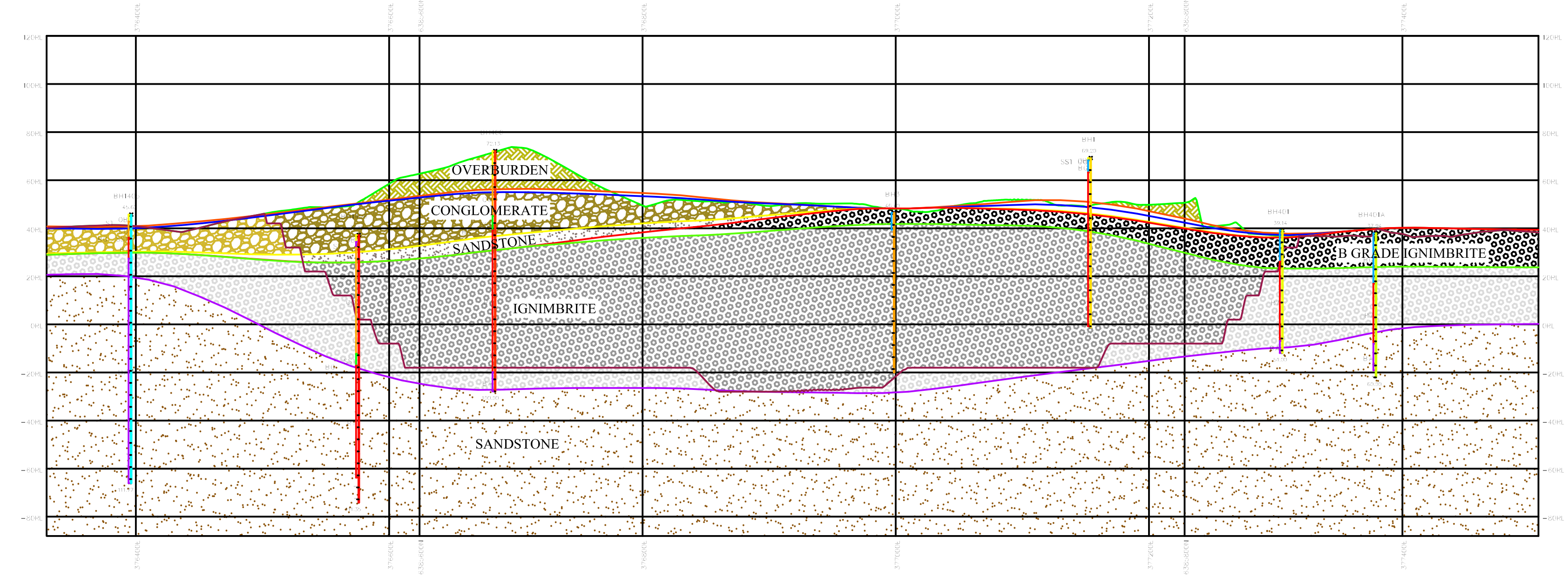
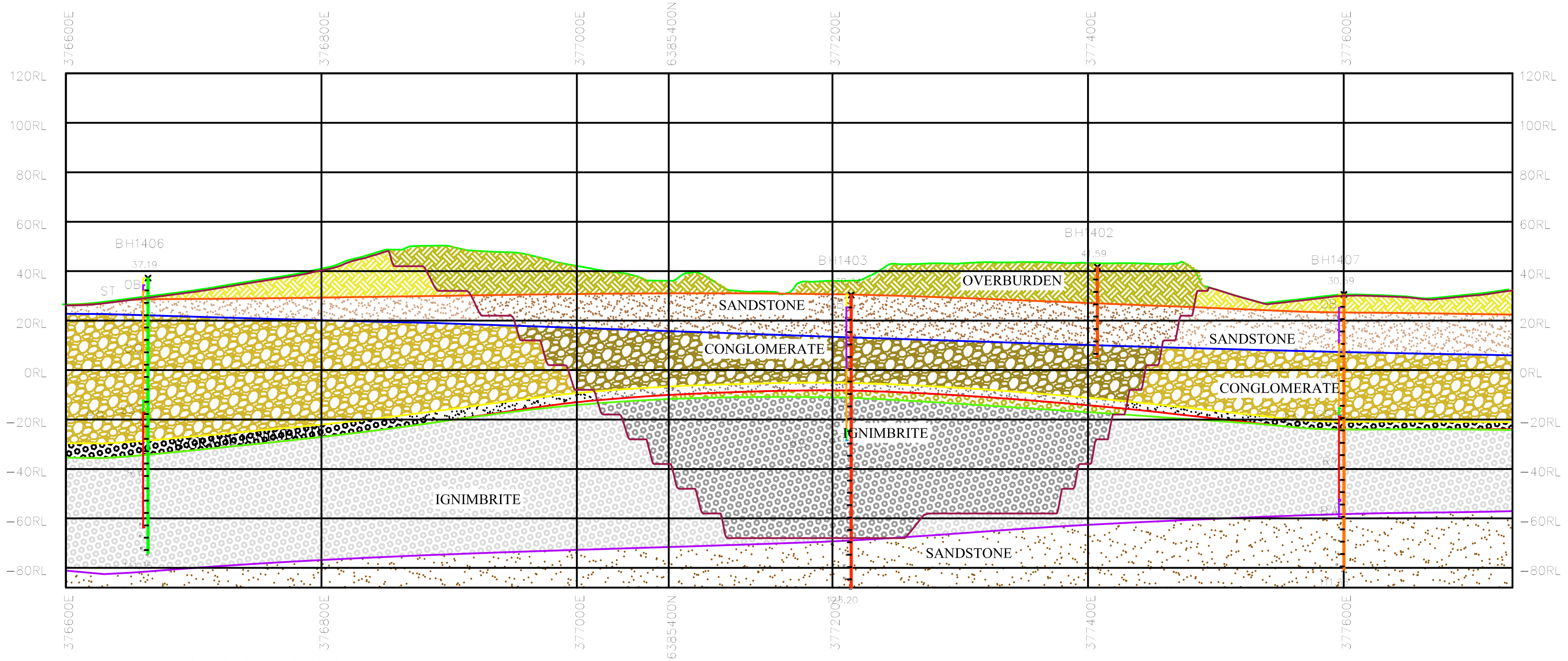


NORTH WEST TO EAST CROSS SECTION



SOUTH WEST TO EAST CROSS SECTION

FIGURE 8

BRANDY HILL QUARRY EXTENSION
WEST TO EAST CROSS SECTIONS

NOT TO SCALE
VERTICAL EXAGGERATION 2 TIMES

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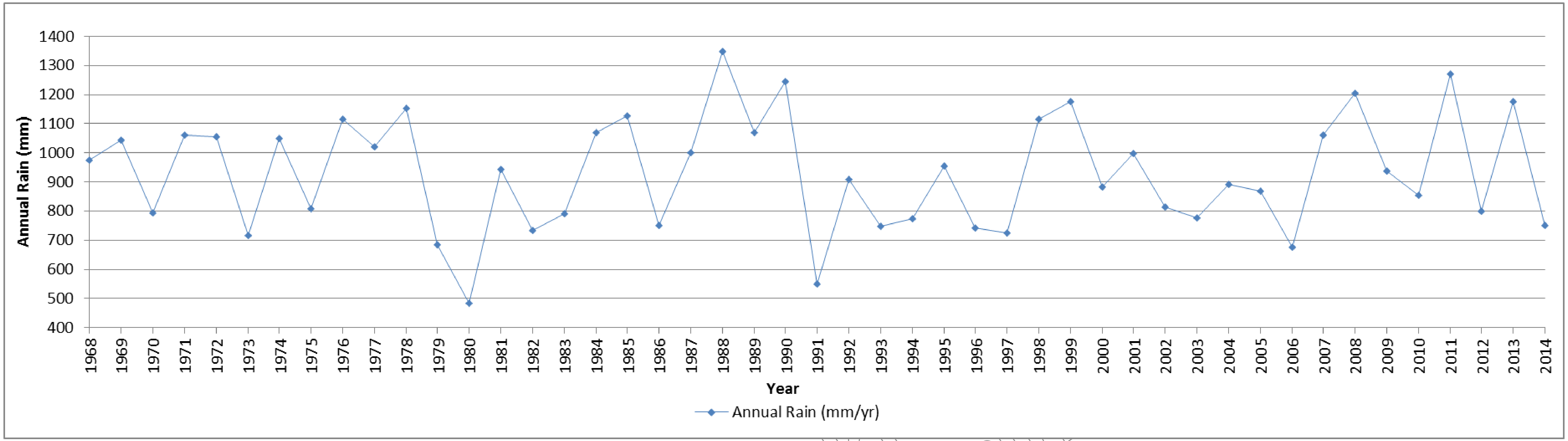

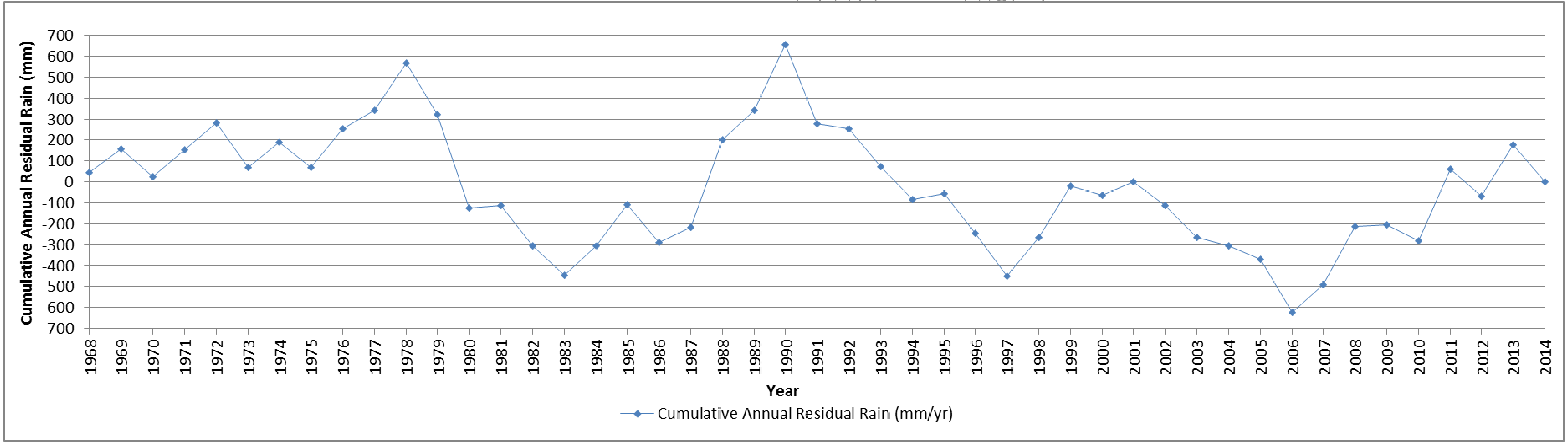

Note:
1. Cumulative annual residual rain = cumulative of observed annual residual rainfall – mean annual rainfall.

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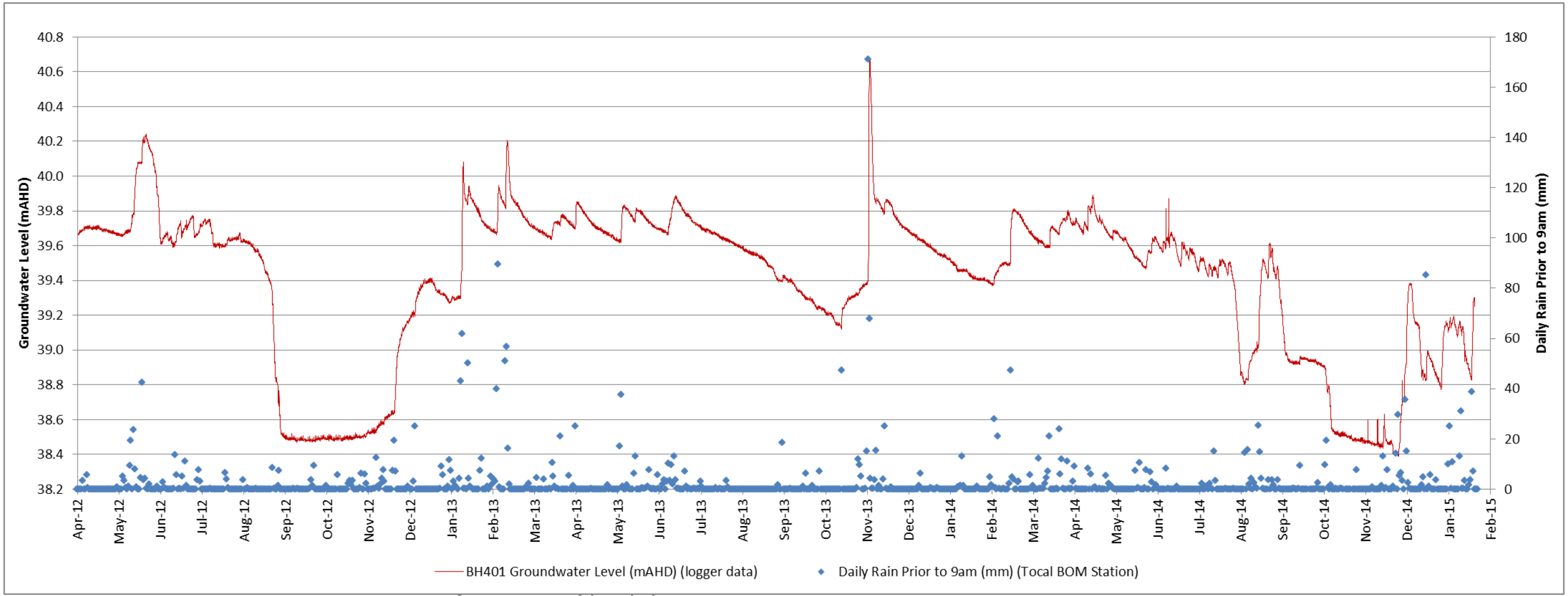
HISTORICAL ANNUAL RAINFALL AND CUMULATIVE ANNUAL RESIDUAL RAINFALL

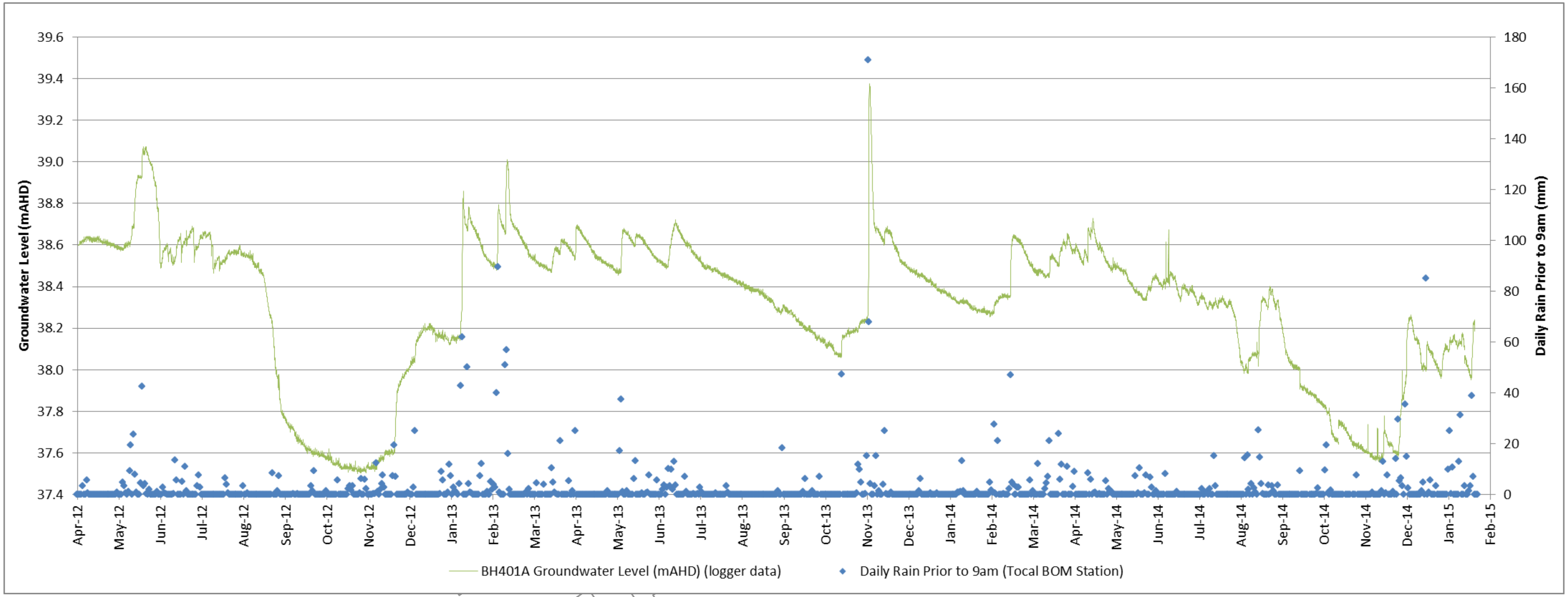
Drawing No:

FIGURE 9

Job No: P1303888JR02V04



Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH401 GROUNDWATER LEVELS AND DAILY RAINFALL**	Drawing No: **FIGURE 10**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



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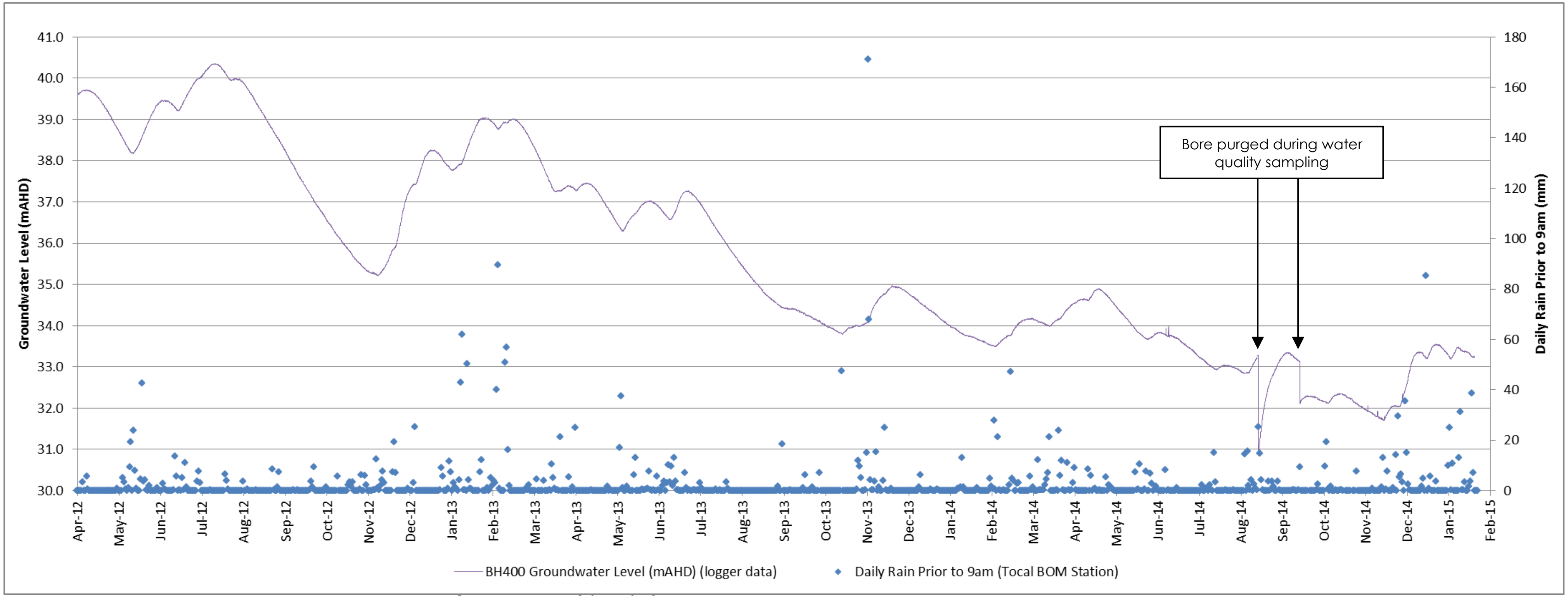
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

BH401A GROUNDWATER LEVELS AND DAILY RAINFALL

Drawing No:

FIGURE 11

Job No: P1303888JR02V04



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Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

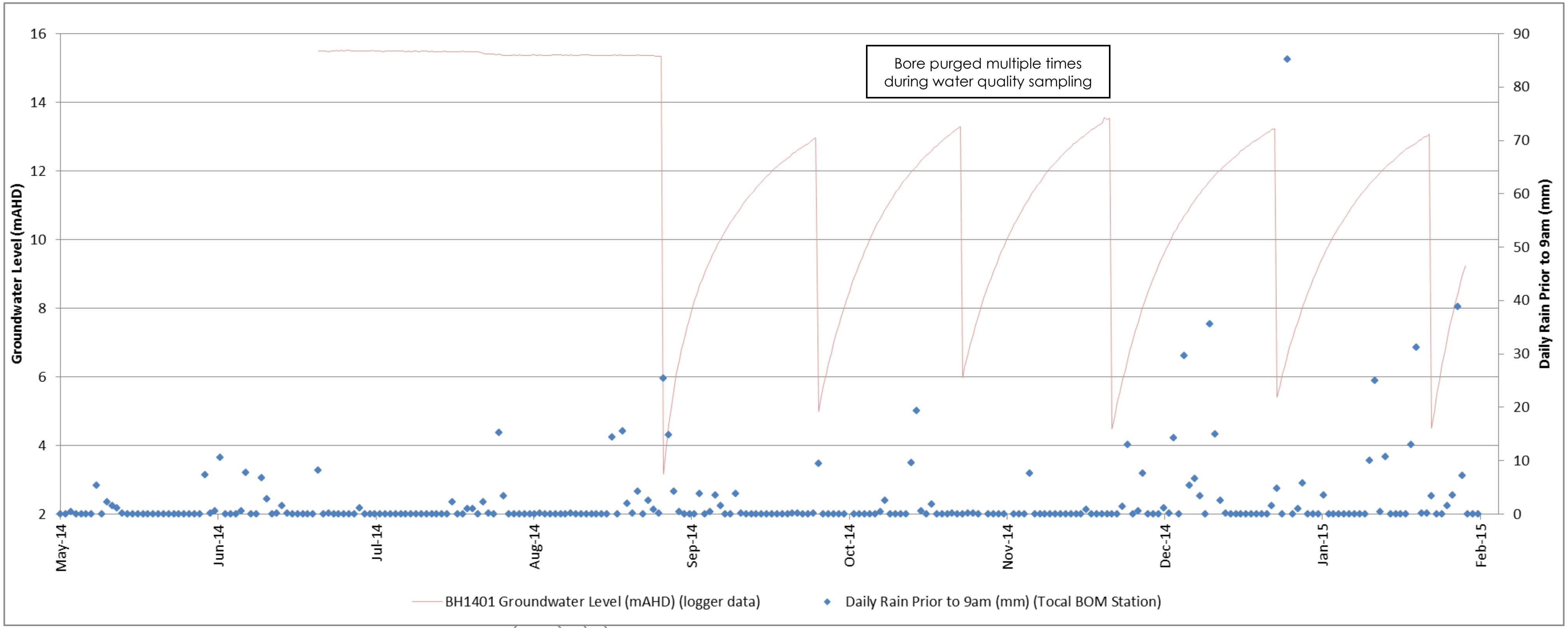
BH400 GROUNDWATER LEVELS AND DAILY RAINFALL

Drawing No:

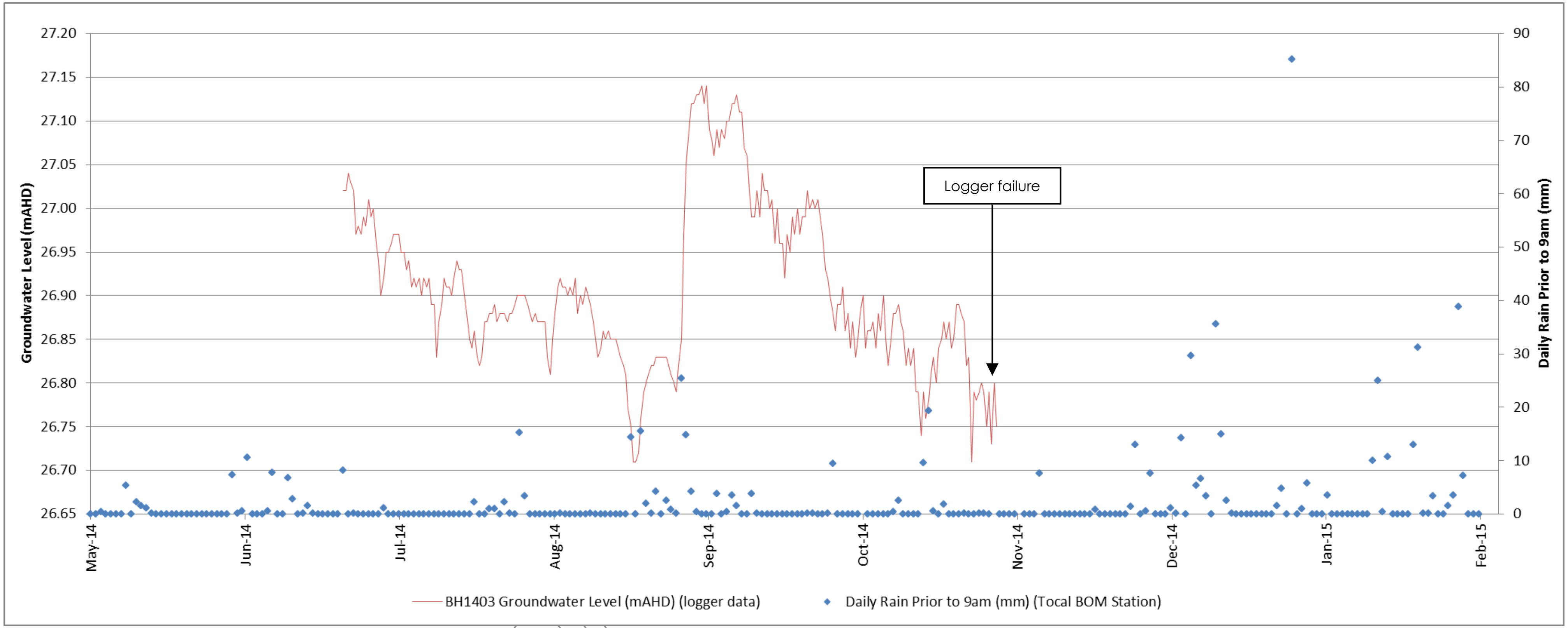
FIGURE 12

Job No: P1303888JR02V04

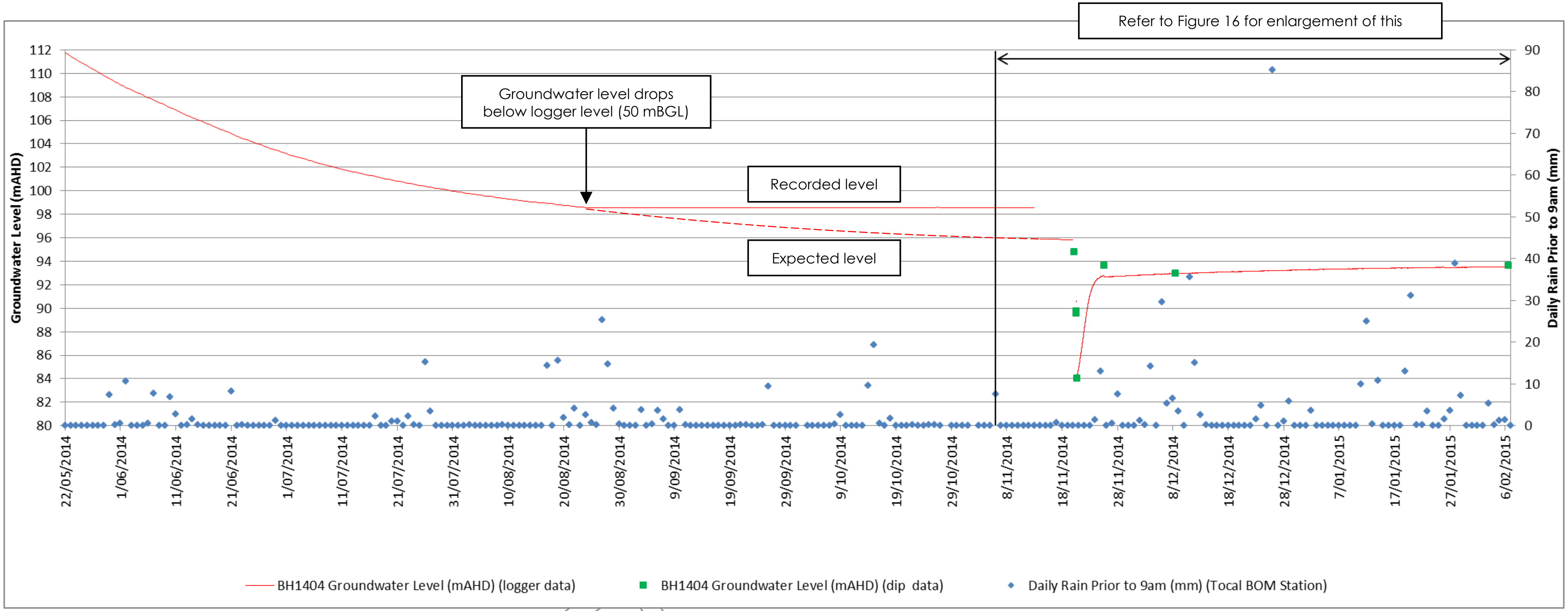
martens



Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH1401 GROUNDWATER LEVELS AND DAILY RAINFALL**	Drawing No: **FIGURE 13**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH1403 GROUNDWATER LEVELS AND DAILY RAINFALL**	Drawing No: **FIGURE 14**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Refer to Figure 16 for enlargement of this

Groundwater level drops below logger level (50 mBGL)

Recorded level

Expected level

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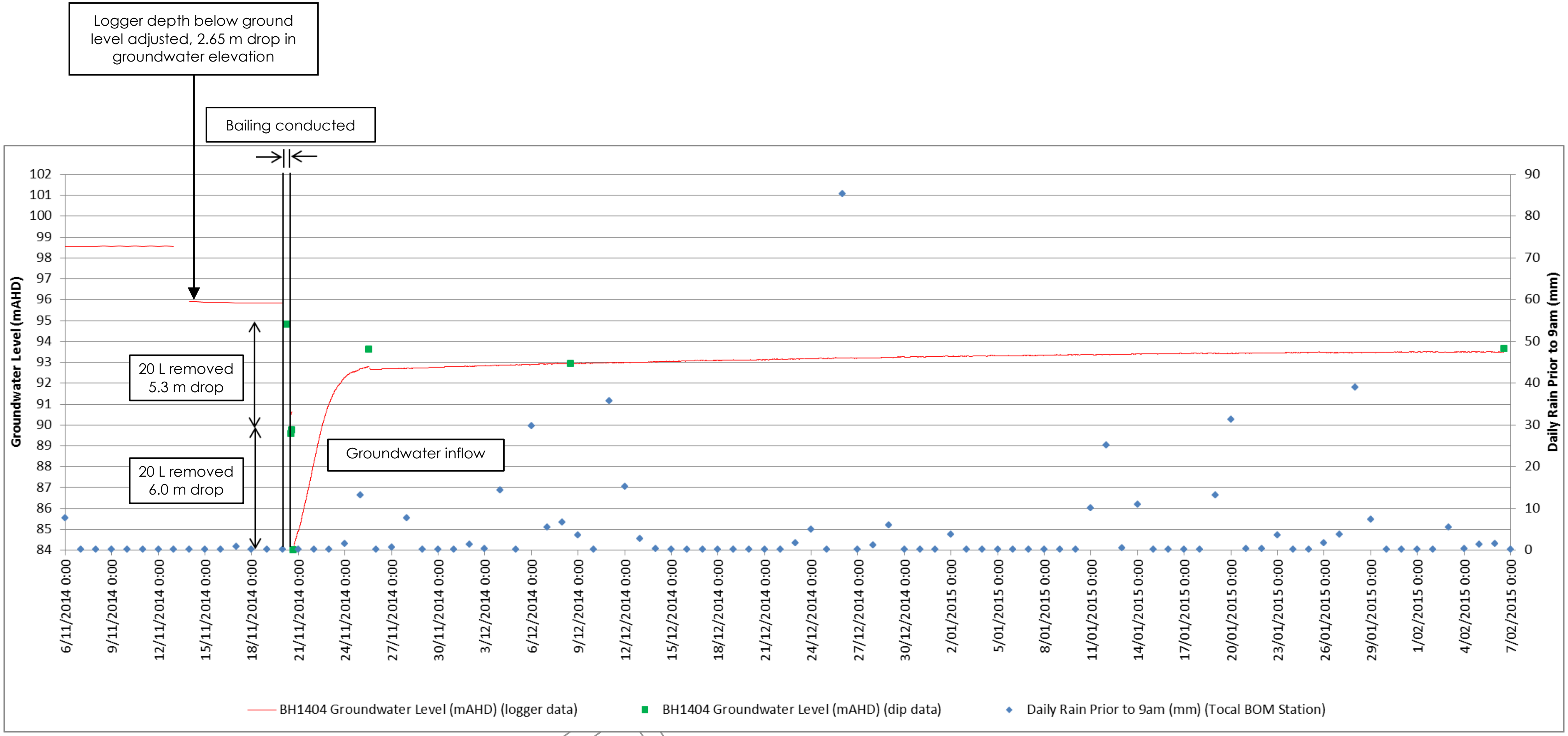
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

BH1404 GROUNDWATER LEVELS AND DAILY RAINFALL – ALL DATA

Drawing No:

FIGURE 15

Job No: P1303888JR02V04



Logger depth below ground level adjusted, 2.65 m drop in groundwater elevation

Bailing conducted

20 L removed 5.3 m drop

20 L removed 6.0 m drop

Groundwater inflow

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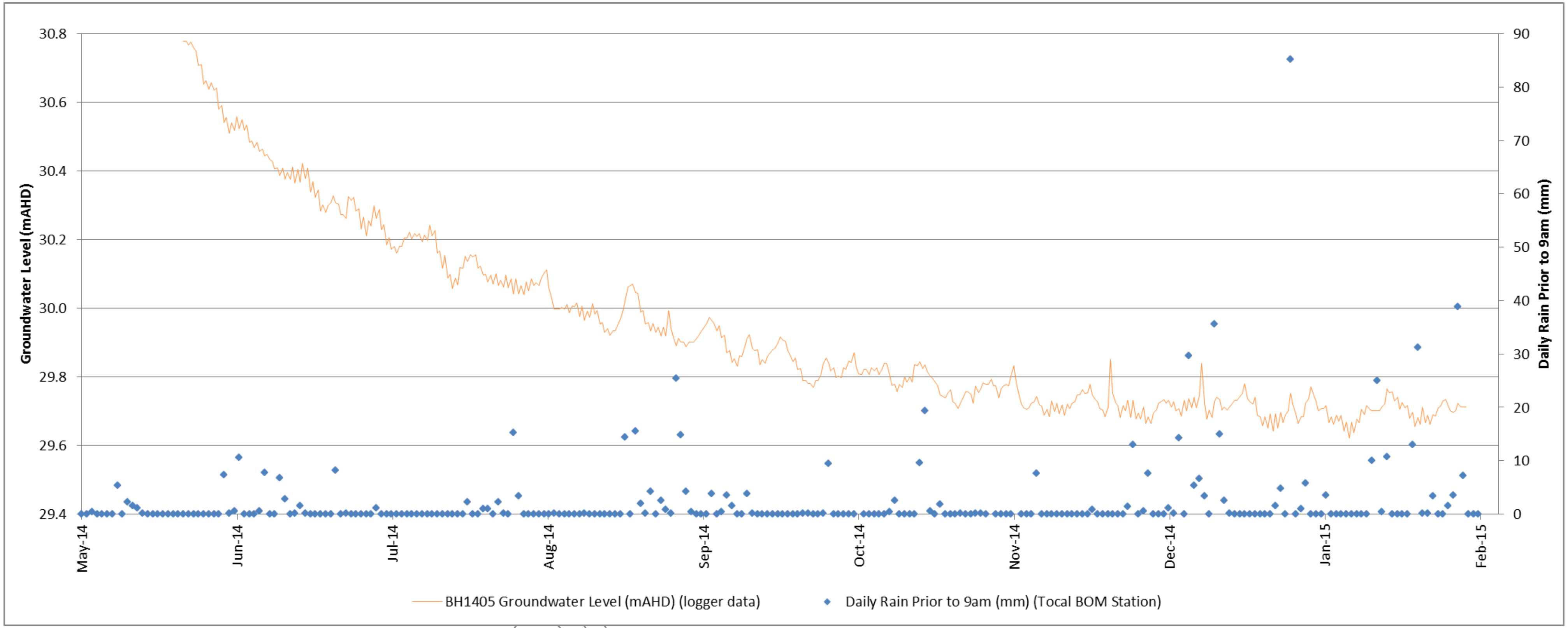
Drawn:	DD	**BH1404 GROUNDWATER LEVELS AND DAILY RAINFALL – RECENT DATA**	Drawing No: **FIGURE 16**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



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Drawn:	DD	**BH1405 GROUNDWATER LEVELS AND DAILY RAINFALL**	Drawing No: **FIGURE 17**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04

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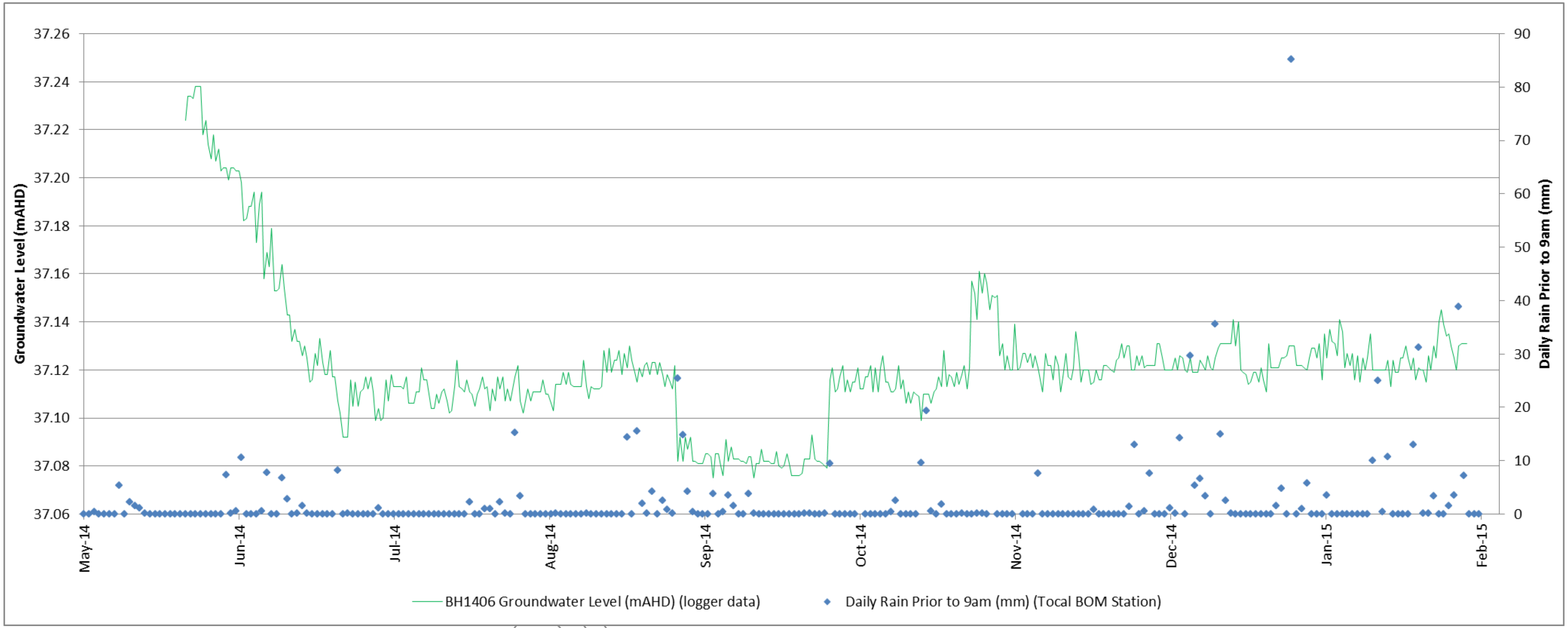

Martens & Associates Pty Ltd ABN 85 070 240 890

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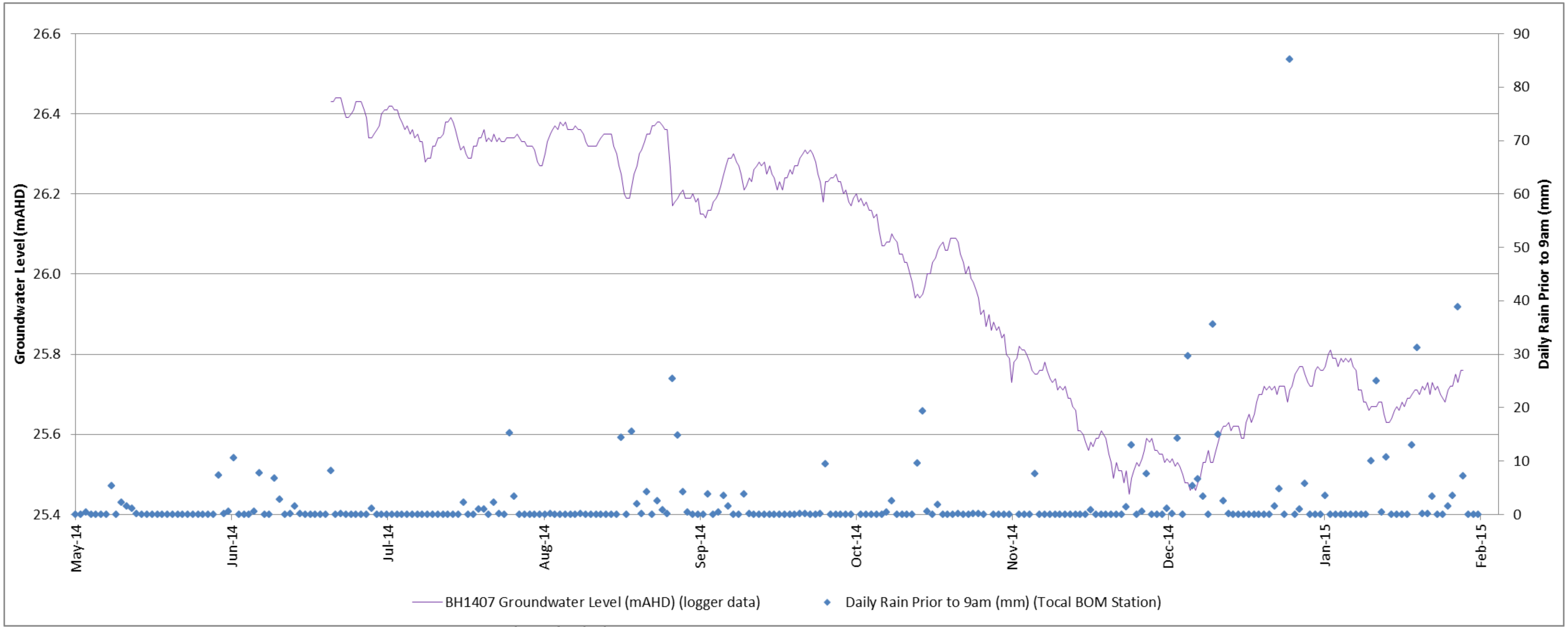
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

BH1406 GROUNDWATER LEVELS AND DAILY RAINFALL

Drawing No:

FIGURE 18

Job No: P1303888JR02V04



Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH1407 GROUNDWATER LEVELS AND DAILY RAINFALL**	Drawing No: **FIGURE 19**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04

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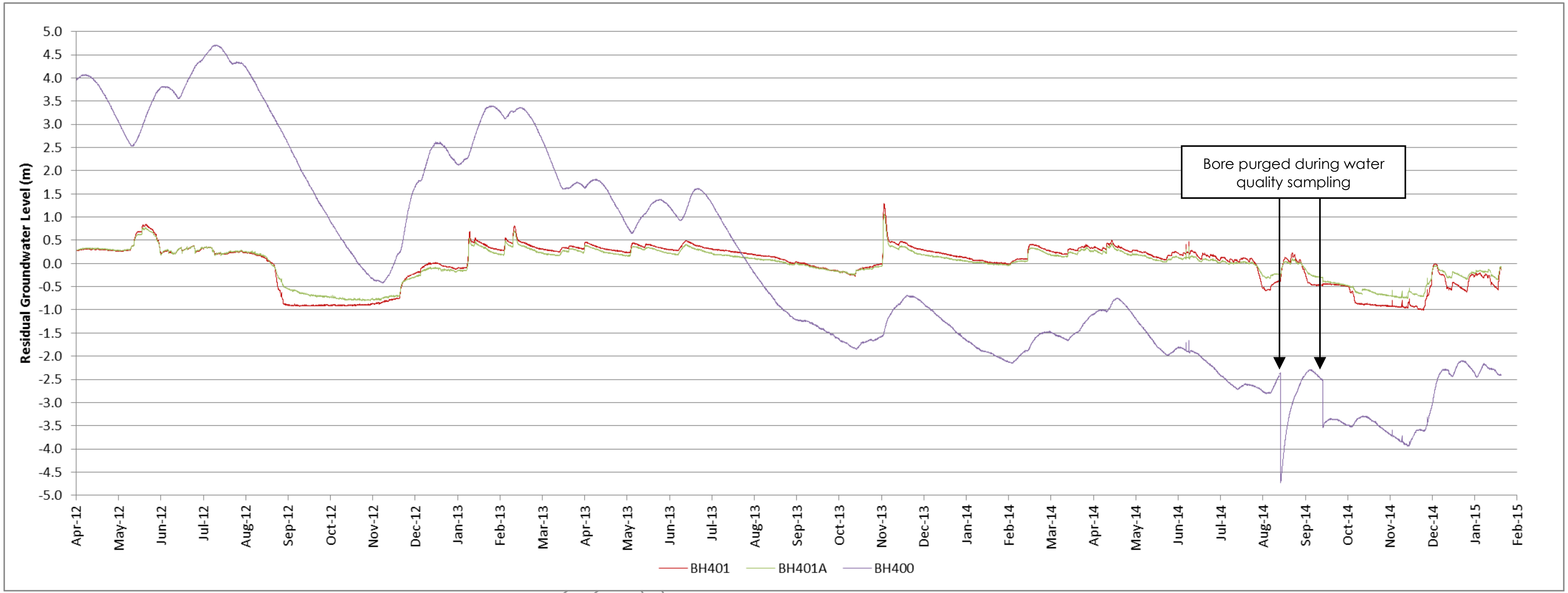
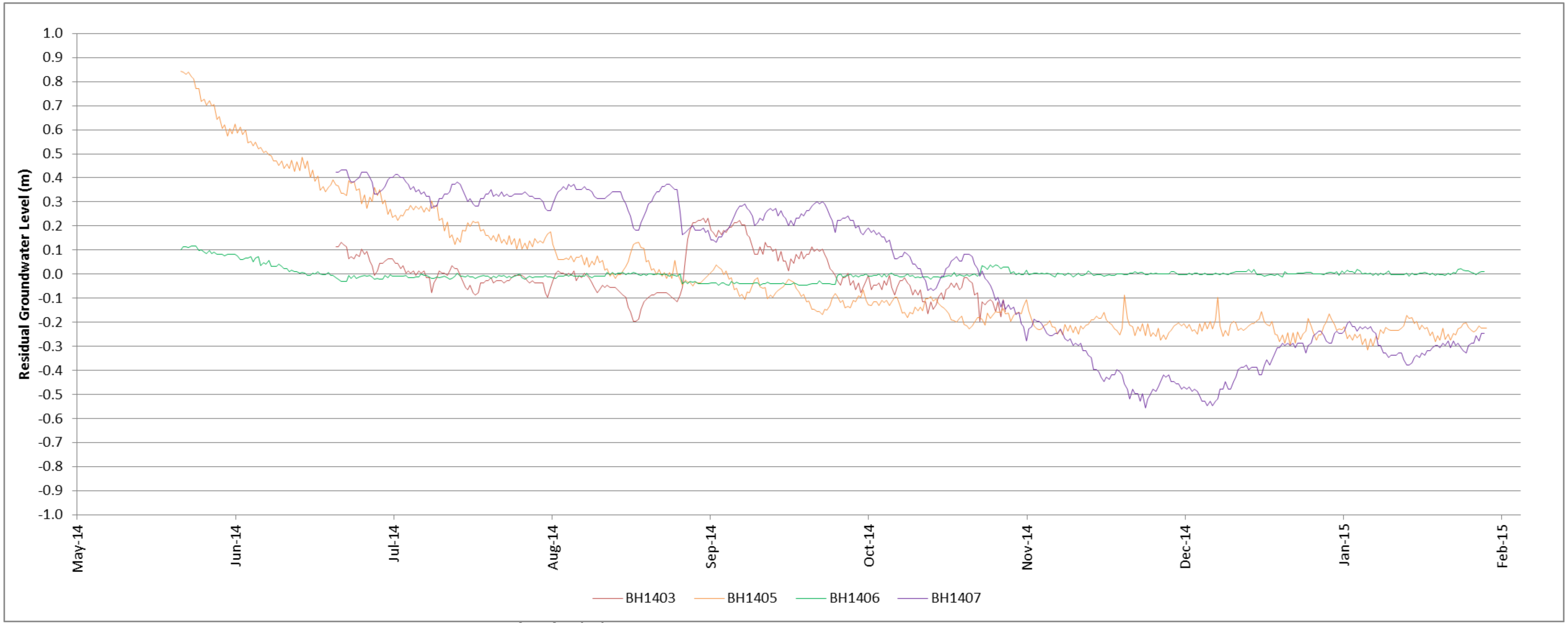


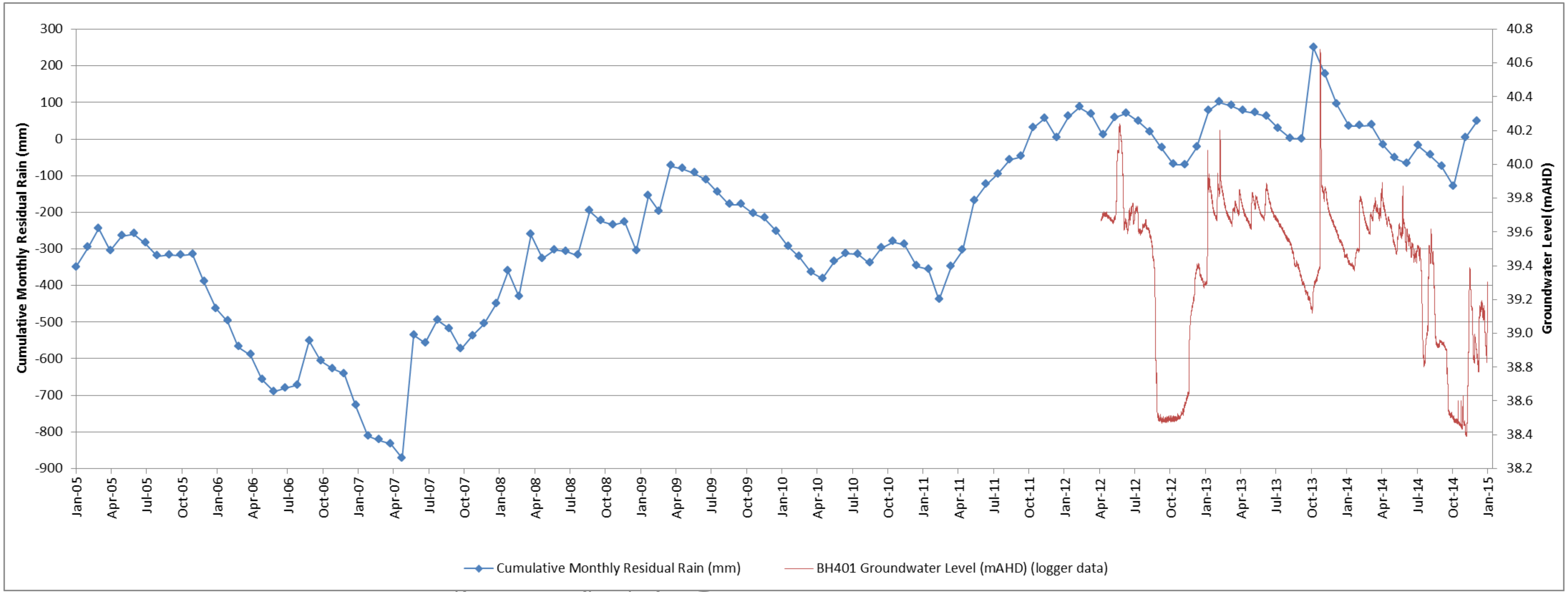
Note:
1. Residual groundwater level = observed groundwater level – mean groundwater level over entire monitoring period.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH401, BH401A & BH400 RESIDUAL GROUNDWATER LEVELS**	Drawing No: **FIGURE 20**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



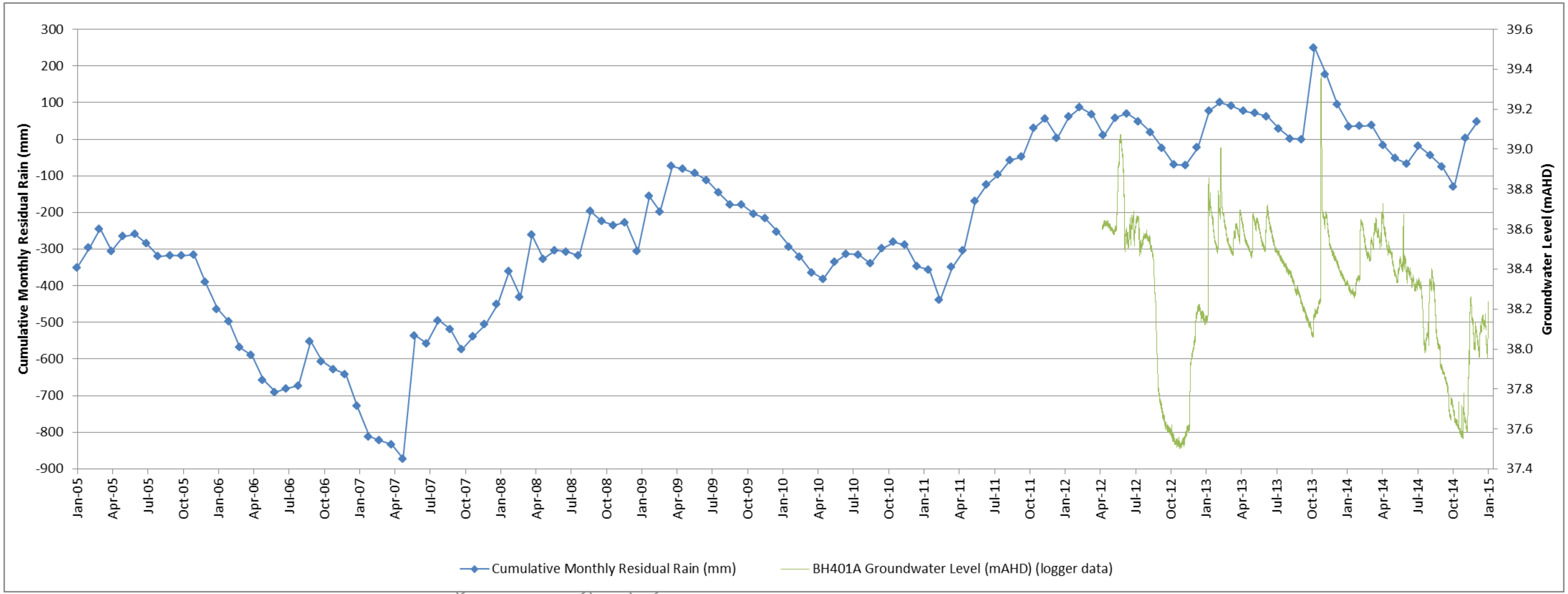
Note:
1. Residual groundwater level = observed groundwater level – mean groundwater level over entire monitoring period.
2. BH1401 excluded from graph due to multiple purges.
3. BH1404 excluded from graph due to the large range of variation over the monitoring period.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH1403, BH1405, BH1406 & BH1407 RESIDUAL GROUNDWATER LEVELS**	Drawing No: **FIGURE 21**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Note:
1. Cumulative monthly residual rain = cumulative of observed monthly residual rainfall – mean monthly rainfall.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BH401 GROUNDWATER LEVELS AND MONTHLYCUMULATIVE RESIDUAL RAINFALL**	Drawing No: **FIGURE 22**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Note:
1. Cumulative monthly residual rain = cumulative of observed monthly residual rainfall – mean monthly rainfall.

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Environment | Water | Wastewater | Geotechnical | Civil | Management

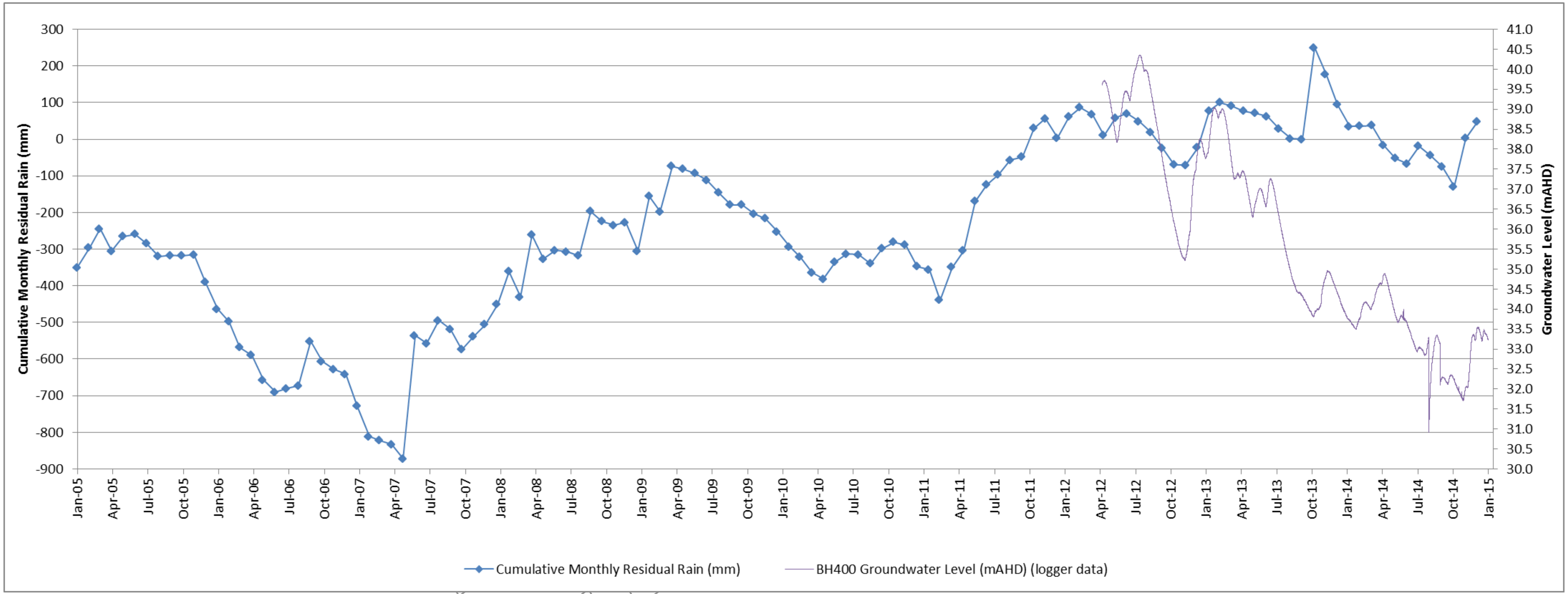
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

BH401A GROUNDWATER LEVELS AND MONTHLYCUMULATIVE RESIDUAL RAINFALL

Drawing No:

FIGURE 23

Job No: P1303888JR02V04



Note:
1. Cumulative monthly residual rain = cumulative of observed residual monthly rainfall – mean monthly rainfall.

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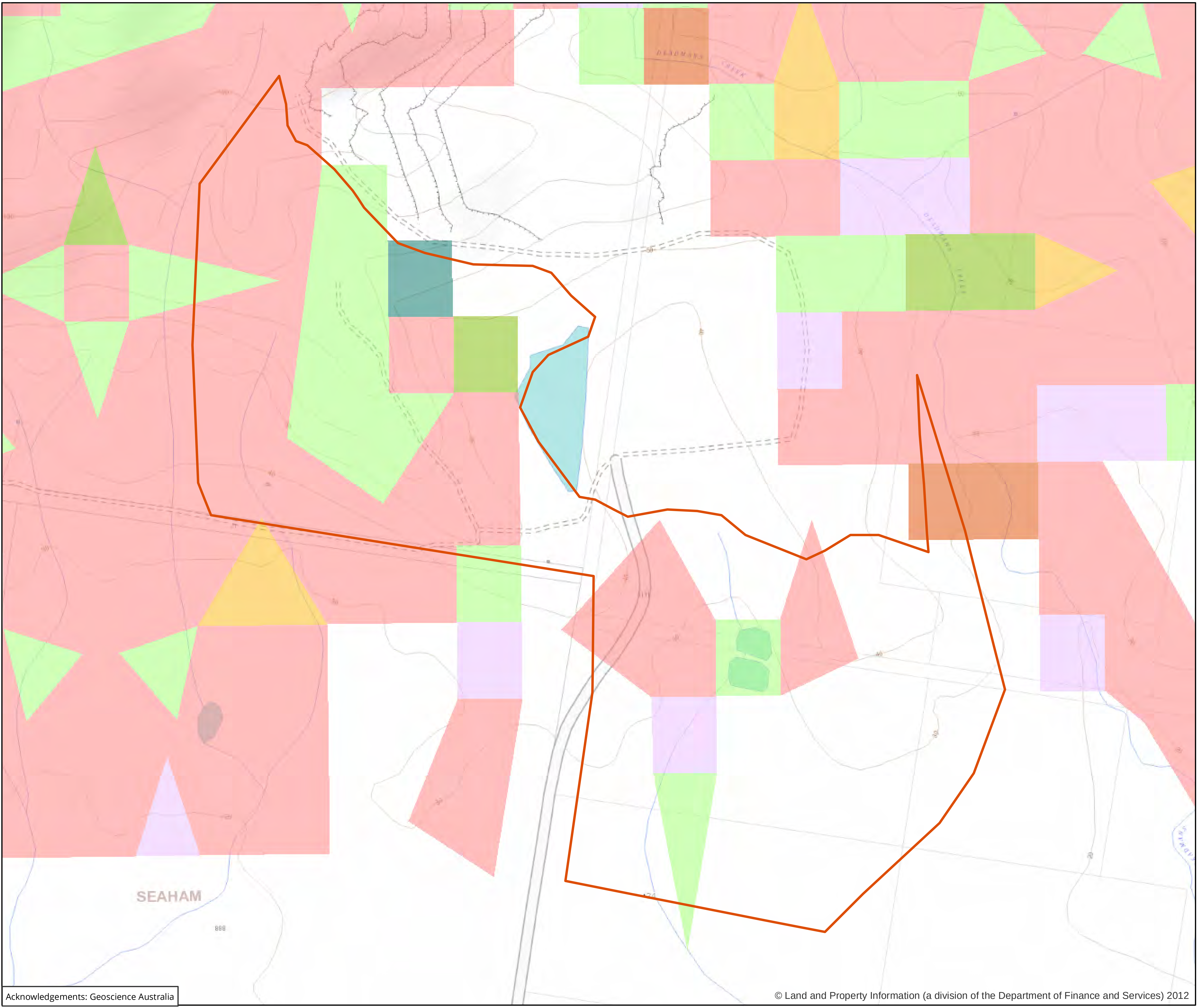
Drawn:	DD	**BH400 GROUNDWATER LEVELS AND MONTHLYCUMULATIVE RESIDUAL RAINFALL**	Drawing No: **FIGURE 24**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Acknowledgements: Geoscience Australia

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Legend

□ Study area

Groundwater Dependent Ecosystems

- 🟪 Escarpment Redgum
- 🟥 Ironbark
- 🟨 Moist Foothills Spotted Gum
- 🟦 Rough-barked Apples
- 🟩 Smoothbarked Apple-Sydney Peppermint-Stringybark
- 🟩 South Coast Shrubby Grey Gum
- 🟧 Stringybark-Apple

Figure 6: Groundwater Dependent Ecosystems

FIGURE 25

0 50 100 150 200 250

Metres

Scale: 1:5,000 @ A3

Coordinate System: GDA 1994 MGA Zone 56

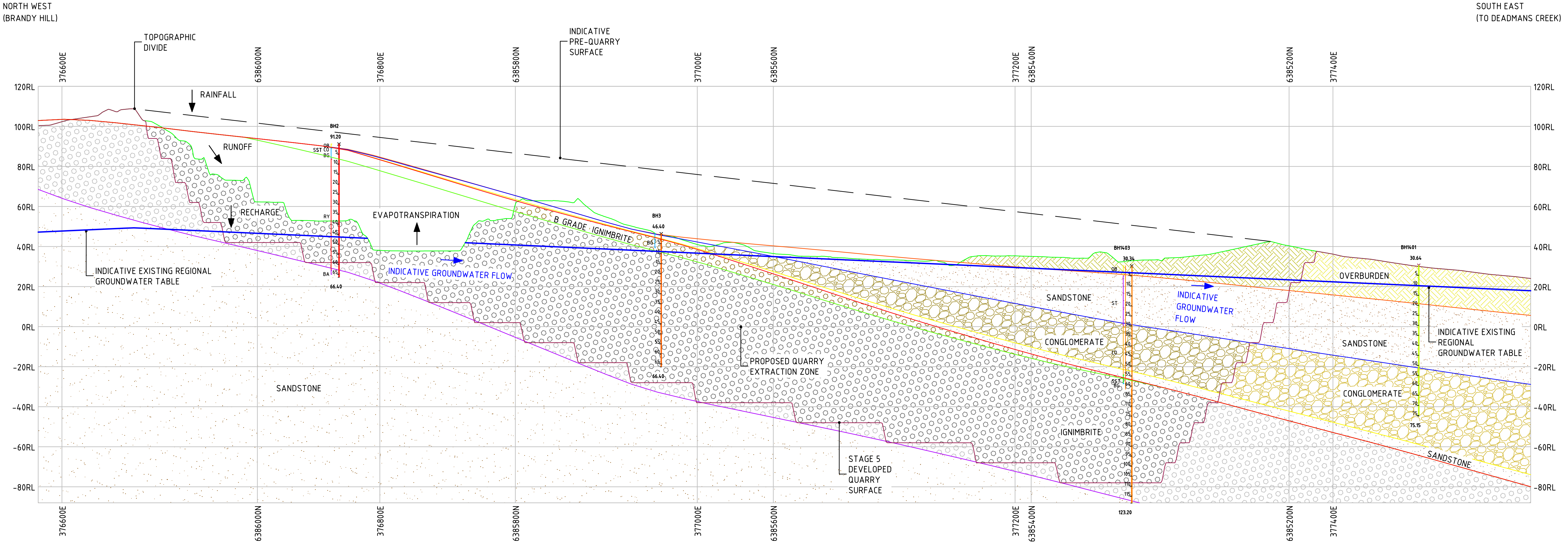
biosis

Biosis Pty Ltd

N

Ballarat, Brisbane, Canberra, Melbourne,
Sydney, Wangaratta & Wollongong

Matter: 18371
Date: 16 January 2015,
Checked by: EC, Drawn by: JMS, Last edited by: jshepherd
Location:P:\18300s\18371\Mapping
18371_F5_GDE



NOTES:

1. BACKGROUND GEOLOGICAL CROSS SECTION DATA PROVIDED BY HANSON (2014).
   REFER TO FIGURE 6 FOR SECTION LOCATION.
2. REGIONAL GROUNDWATER TABLE AND GROUNDWATER FLOW DIRECTIONS ARE INDICATIVE ONLY.

REV.	DESCRIPTION	DATE	ISSUED
A	ENVIRONMENTAL ASSESSMENT	28.07.15	AN

BAR SCALE
0 40 80 120 160 200
HORIZONTAL - 1:4000
0 20 40 60 80 100
VERTICAL - 1:2000

DESIGNED: DD
DATUM: mAHD
REVIEWED: AN
HORIZONTAL RATIO: 1:4000
PAPER SIZE: A3
VERTICAL RATIO: 1:2000

CLIENT / PROJECT
HANSON
BRANDY HILL QUARRY
EXPANSION EA

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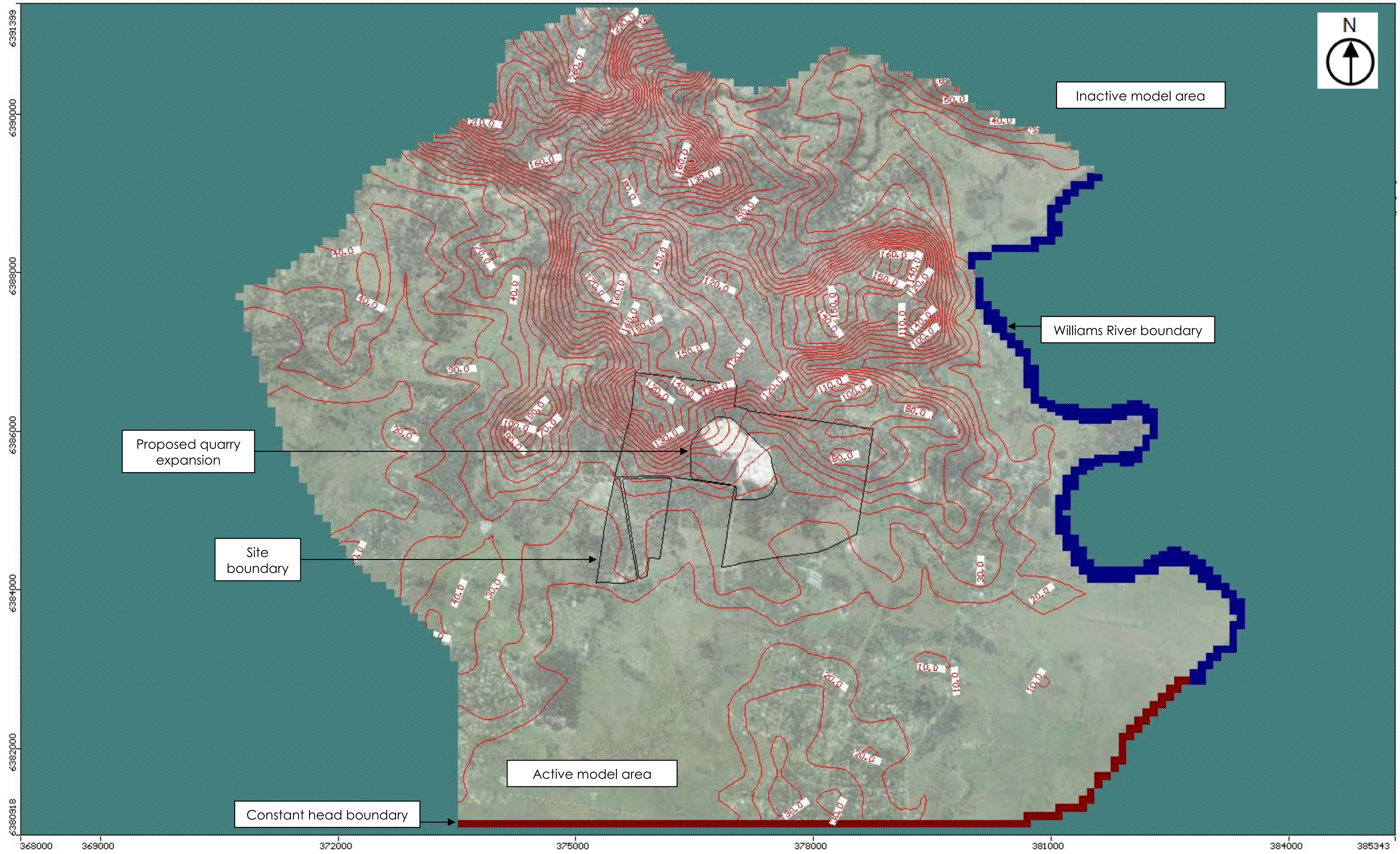
& Associates Pty Ltd
Consulting Engineers
Environment
Water
Geotechnical
Civil
Suite 201, 20 George Street, Hornsby, NSW 2077 Australia Phone: (02) 9476 9999 Fax: (02) 9476 8767
Email: mail@martens.com.au Internet: http://www.martens.com.au

TITLE: CONCEPTUAL HYDROGEOLOGICAL MODEL
DRAWING ID: **FIGURE 26**
PROJECT MANAGER: AN
PROJECT NO.: P1303888
FILE: JD05V01
REVISION: A



Note:
1. Contours are pre-quarry ground contours at 10 m intervals.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**MODEL EXTENTS, AERIAL & PRE QUARRY TERRAIN CONTOURS**	Drawing No: **FIGURE 27**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04

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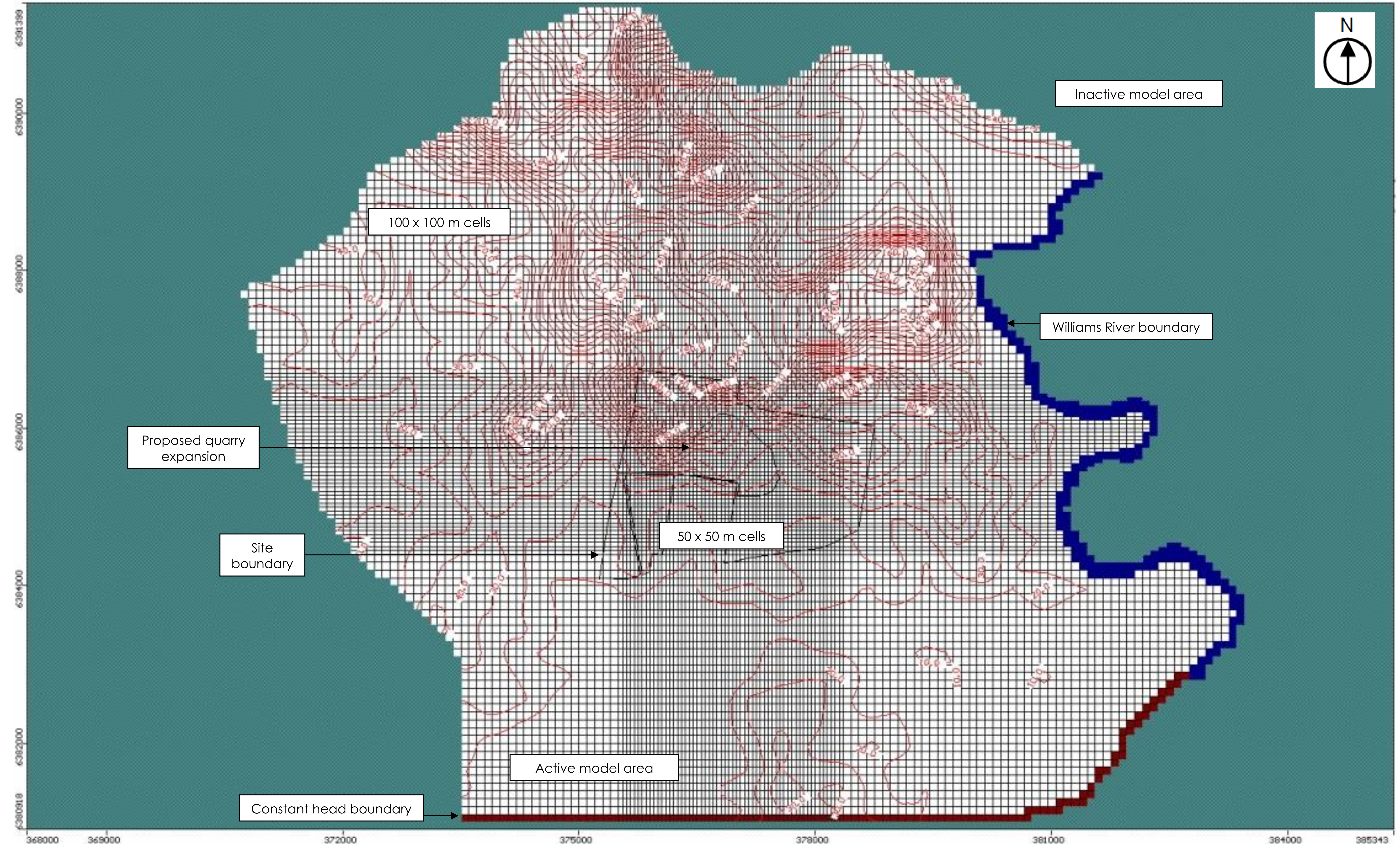

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Note:
1. Contours are pre-quarry ground contours at 10 m intervals.

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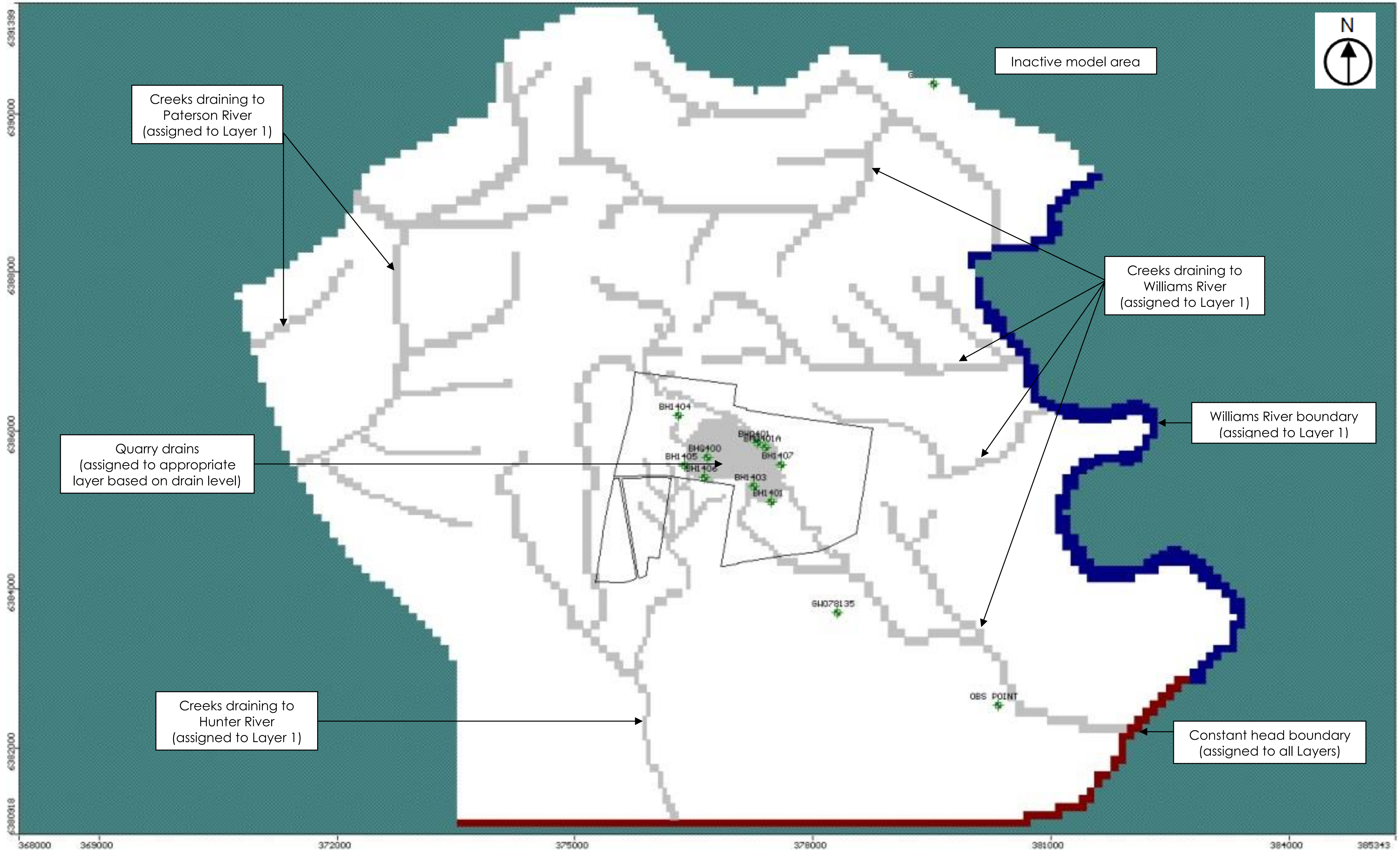
Drawn:	DD	**PRE QUARRY TERRAIN CONTOURS & GRID CELL CONFIGURATION**	Drawing No: **FIGURE 28**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



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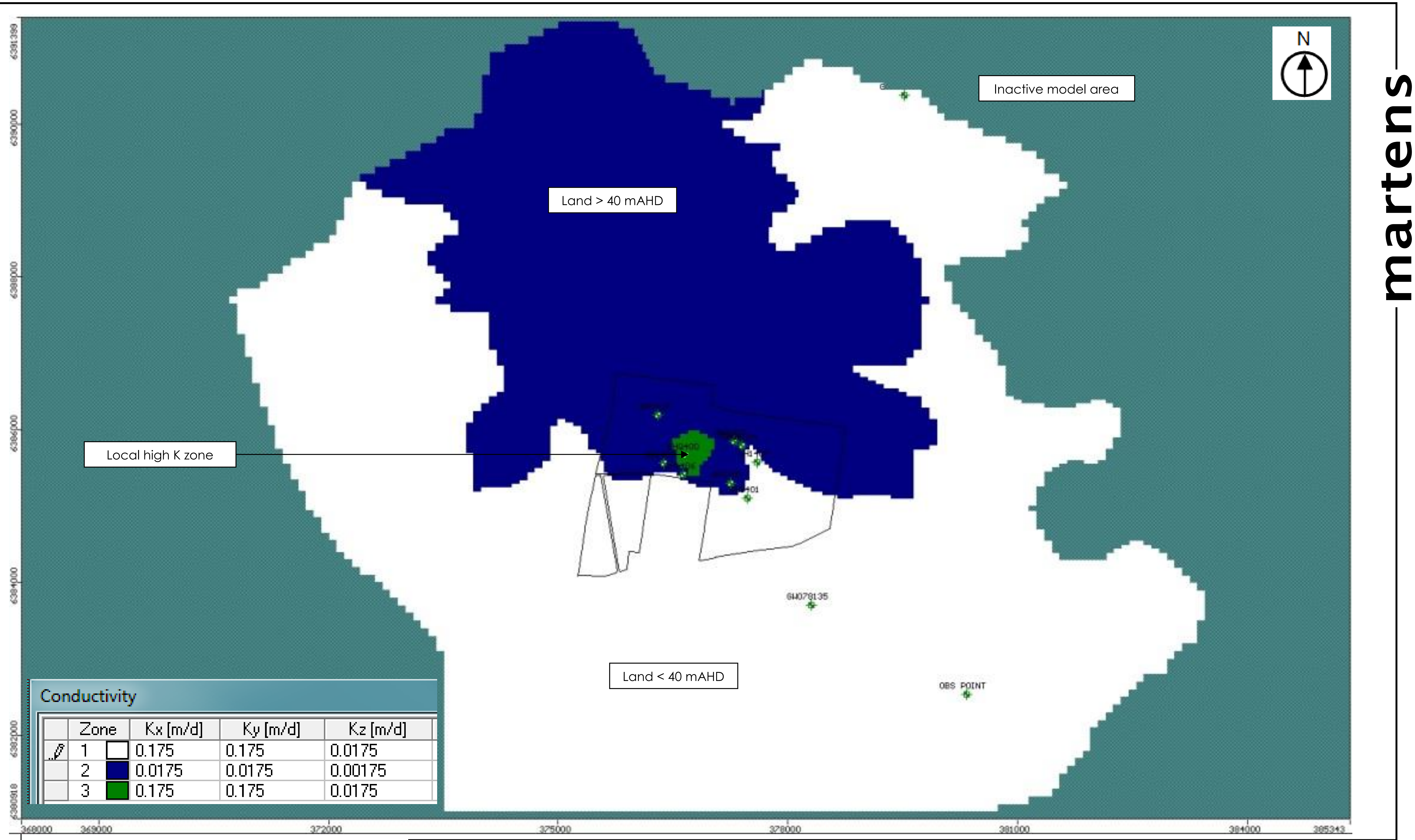
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**BOUNDARY CONDITIONS**	Drawing No: **FIGURE 29**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Conductivity

	Zone		Kx [m/d]	Ky [m/d]	Kz [m/d]
✎	1	☐	0.175	0.175	0.0175
	2	■	0.0175	0.0175	0.00175
	3	🟩	0.175	0.175	0.0175

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Environment | Water | Wastewater | Geotechnical | Civil | Management

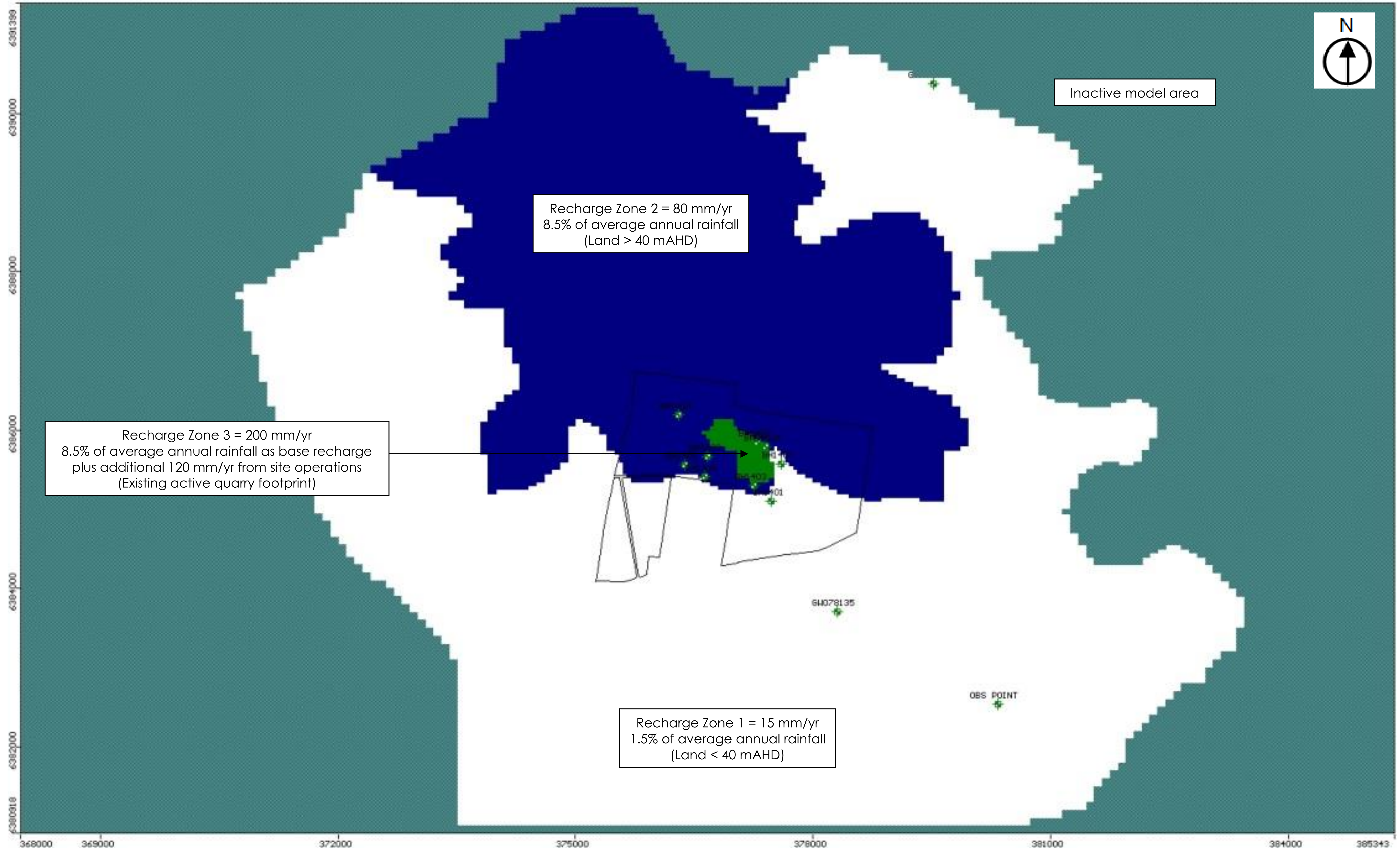
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

HYDRAULIC CONDUCTIVITY (K) ZONES

Drawing No:

FIGURE 30

Job No: P1303888JR02V04



Inactive model area

Recharge Zone 2 = 80 mm/yr
8.5% of average annual rainfall
(Land > 40 mAHD)

Recharge Zone 3 = 200 mm/yr
8.5% of average annual rainfall as base recharge
plus additional 120 mm/yr from site operations
(Existing active quarry footprint)

Recharge Zone 1 = 15 mm/yr
1.5% of average annual rainfall
(Land < 40 mAHD)

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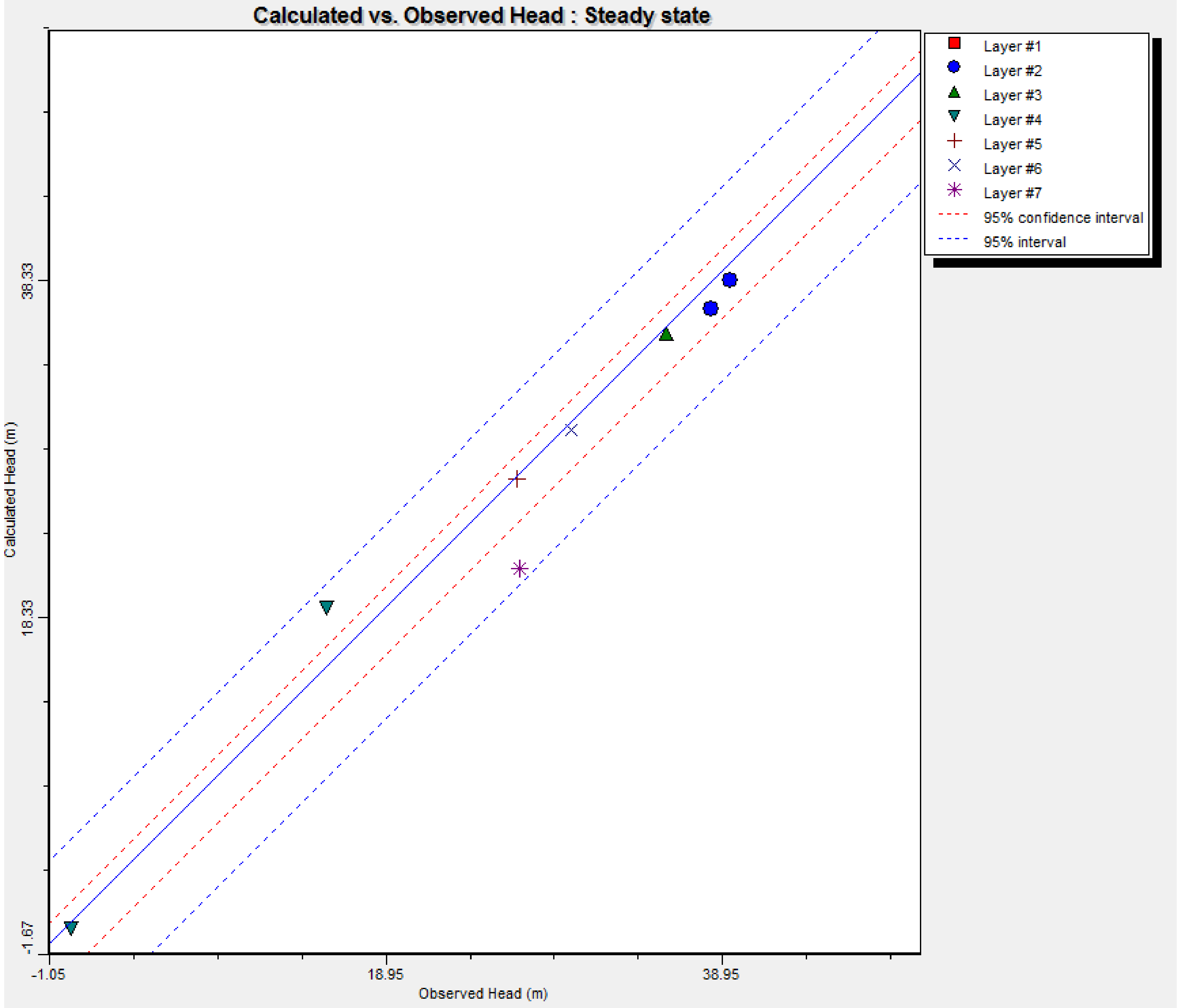
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

STEADY STATE RECHARGE ZONES AND RECHARGE RATES

Drawing No:

FIGURE 31

Job No: P1303888JR02V04



Max. Residual: -5.683 (m) at BH1403/*
Min. Residual: -0.183 (m) at BH1407/*
Residual Mean : -0.808 (m)
Abs. Residual Mean : 1.675 (m)

Num. of Data Points : 8
Standard Error of the Estimate : 0.883 (m)
Root Mean Squared : 2.472 (m)
Normalized RMS : 6.315 (%)
Correlation Coefficient : 0.982

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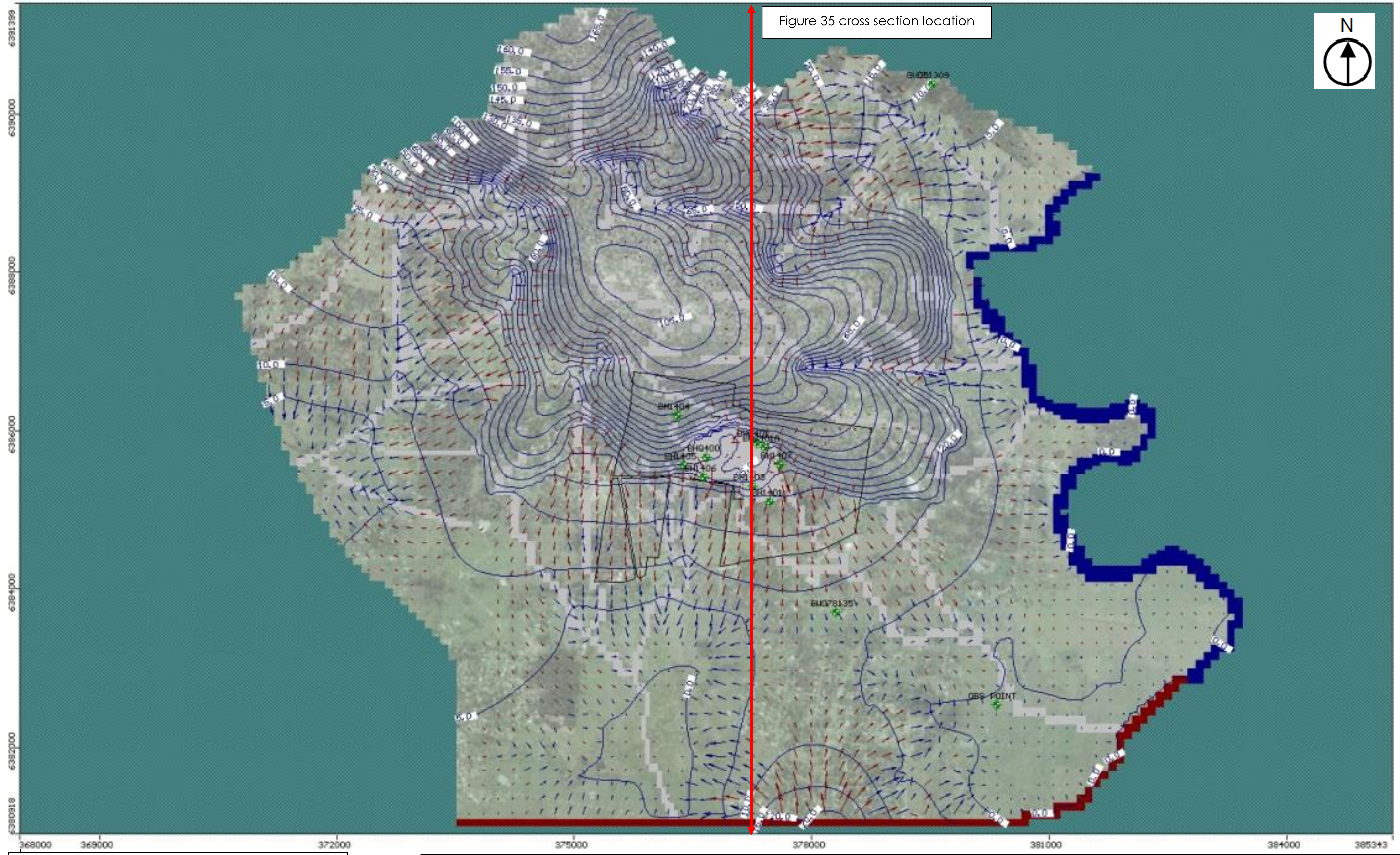
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

EXISTING CONDITIONS STEADY STATE CALIBRATION PLOT

Drawing No:

FIGURE 32

Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

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Environment | Water | Wastewater | Geotechnical | Civil | Management

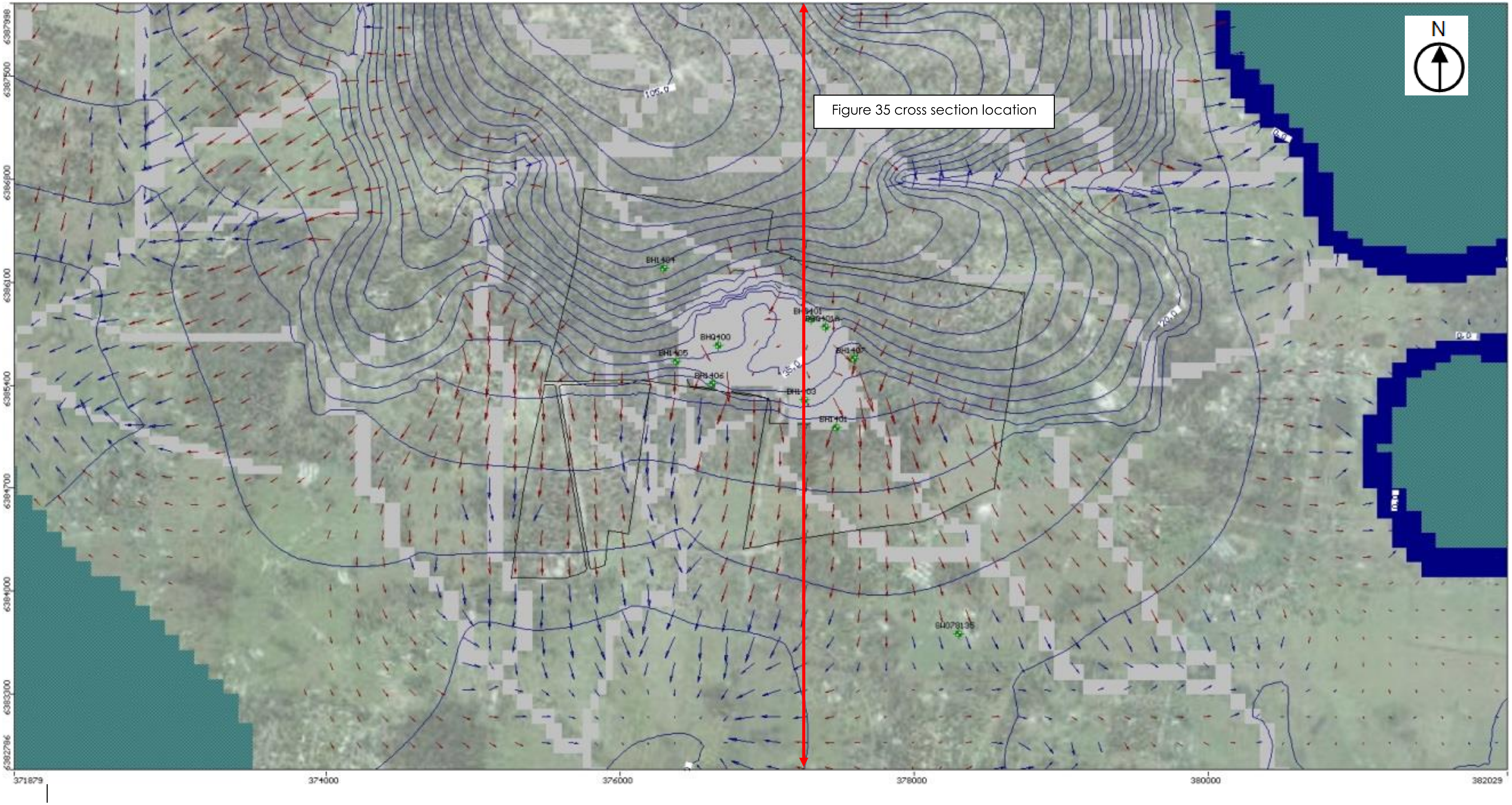
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

EXISTING CONDITIONS STEADY STATE LAYER 1 HEAD

Drawing No:

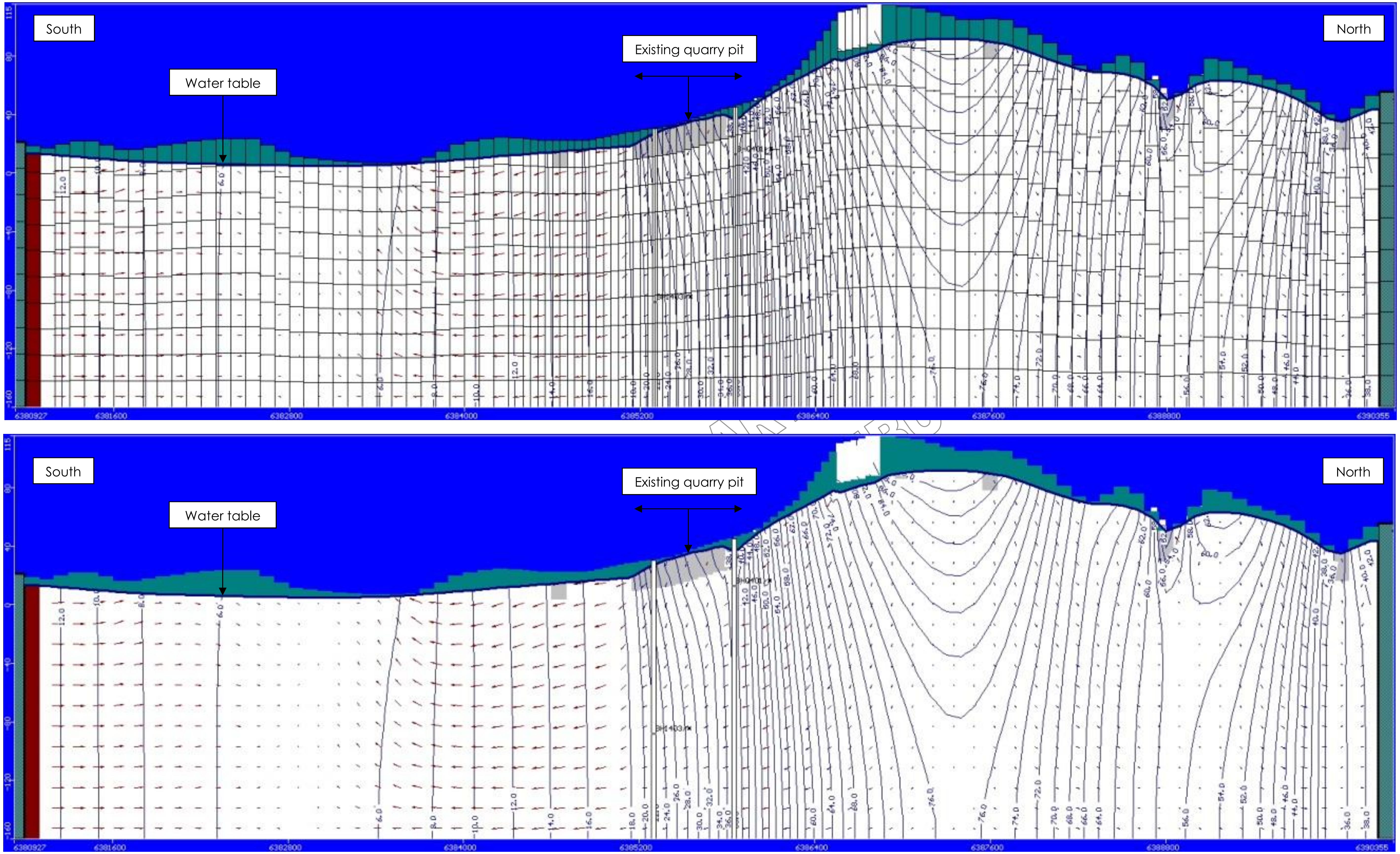
FIGURE 33

Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**EXISTING CONDITIONS STEADY STATE LAYER 1 HEAD AT SITE**	Drawing No: **FIGURE 34**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



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Note:
1. See Figure 33 and Figure 34 for section location.
2. Vertical exaggeration = 10.
3. Contour interval = 2 m.

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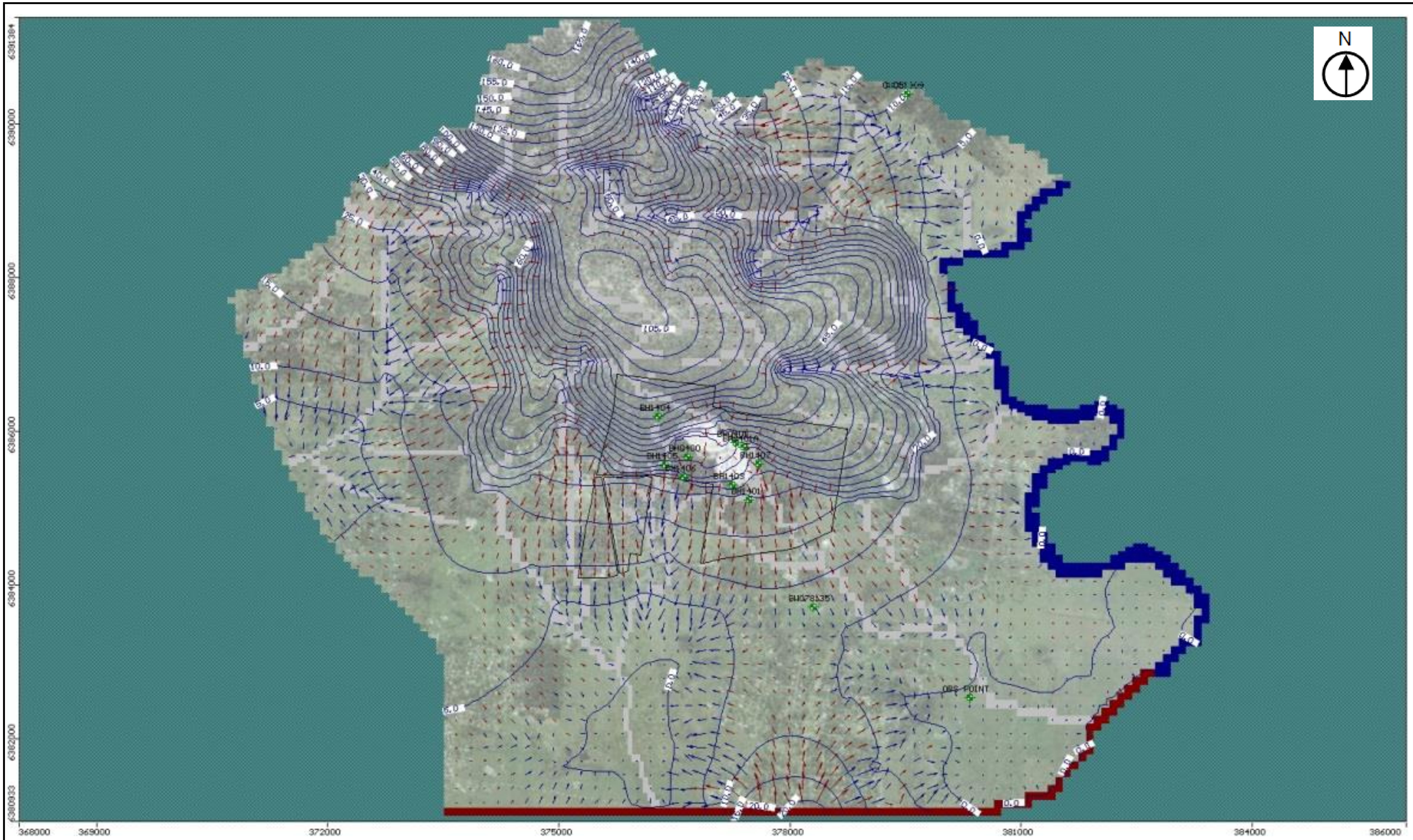
Drawn: DD
Approved: AN
Date: 28.07.2015
Scale: As shown

EXISTING CONDITIONS STEADY STATE HEAD SECTIONS (SHOWN WITH & WITHOUT CELLS)

Drawing No:

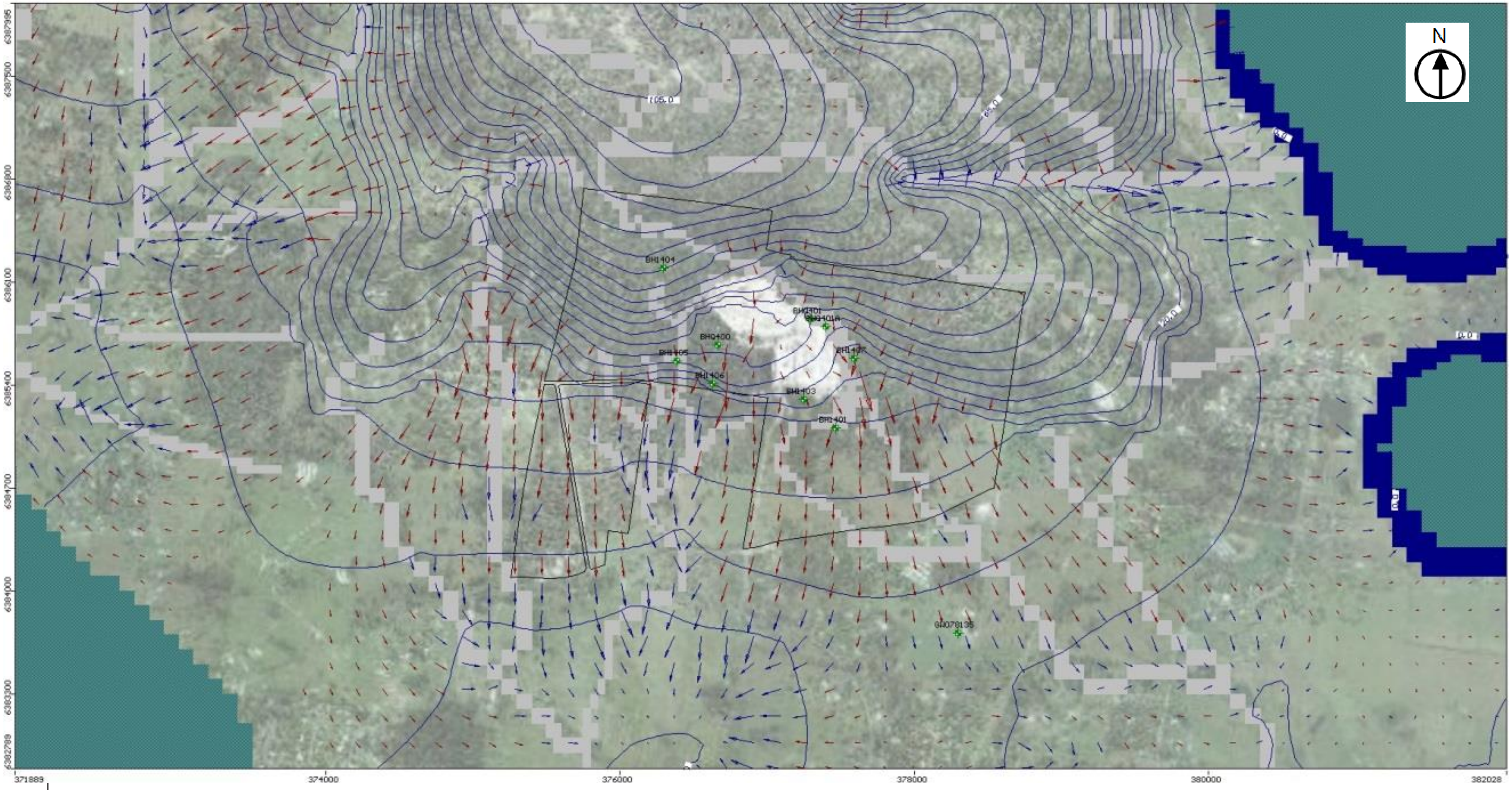
FIGURE 35

Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**PRE QUARRY CONDITIONS STEADY STATE LAYER 1 HEAD**	Drawing No: **FIGURE 36**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd	ABN 85 070 240 890	**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**PRE QUARRY CONDITIONS STEADY STATE LAYER 1 HEAD AT SITE**	Drawing No: **FIGURE 37**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04

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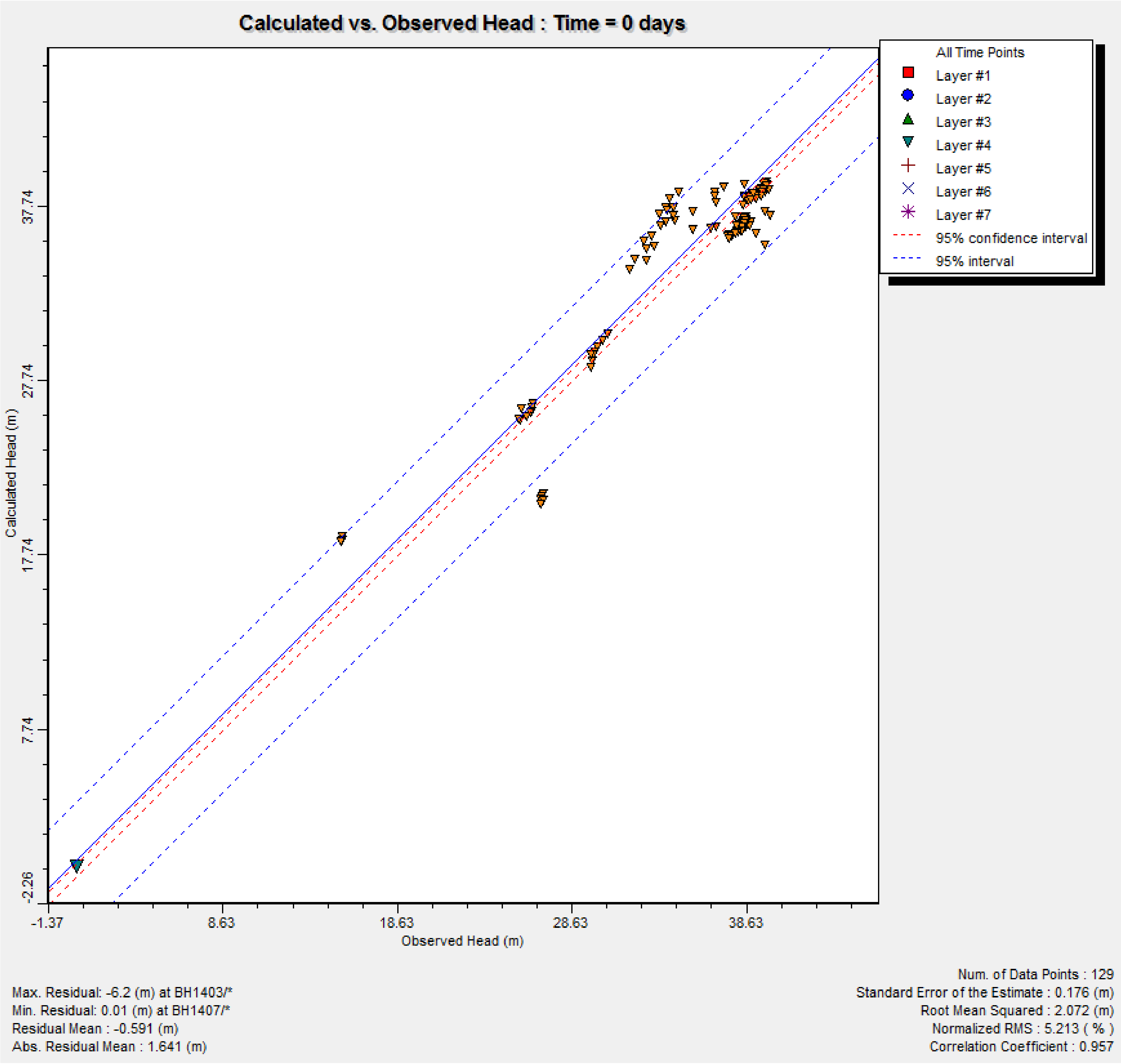
Note:
1. Drawdown = Layer 1 steady state head for pre quarry conditions – Layer 1 steady state head for existing conditions.
2. Contour interval = 2 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**EXISTING CONDITIONS STEADY STATE LAYER 1 DRAWDOWN FROM PRE QUARRY CONDITIONS AT SITE**	Drawing No: **FIGURE 38**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Max. Residual: -6.2 (m) at BH1403/*
Min. Residual: 0.01 (m) at BH1407/*
Residual Mean : -0.591 (m)
Abs. Residual Mean : 1.641 (m)

Num. of Data Points : 129
Standard Error of the Estimate : 0.176 (m)
Root Mean Squared : 2.072 (m)
Normalized RMS : 5.213 (%)
Correlation Coefficient : 0.957

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Drawn:	DD	**TRANSIENT CALIBRATION PLOT OF ALL MONTHLY AVERAGED OBSERVATIONS**	Drawing No: **FIGURE 39**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04

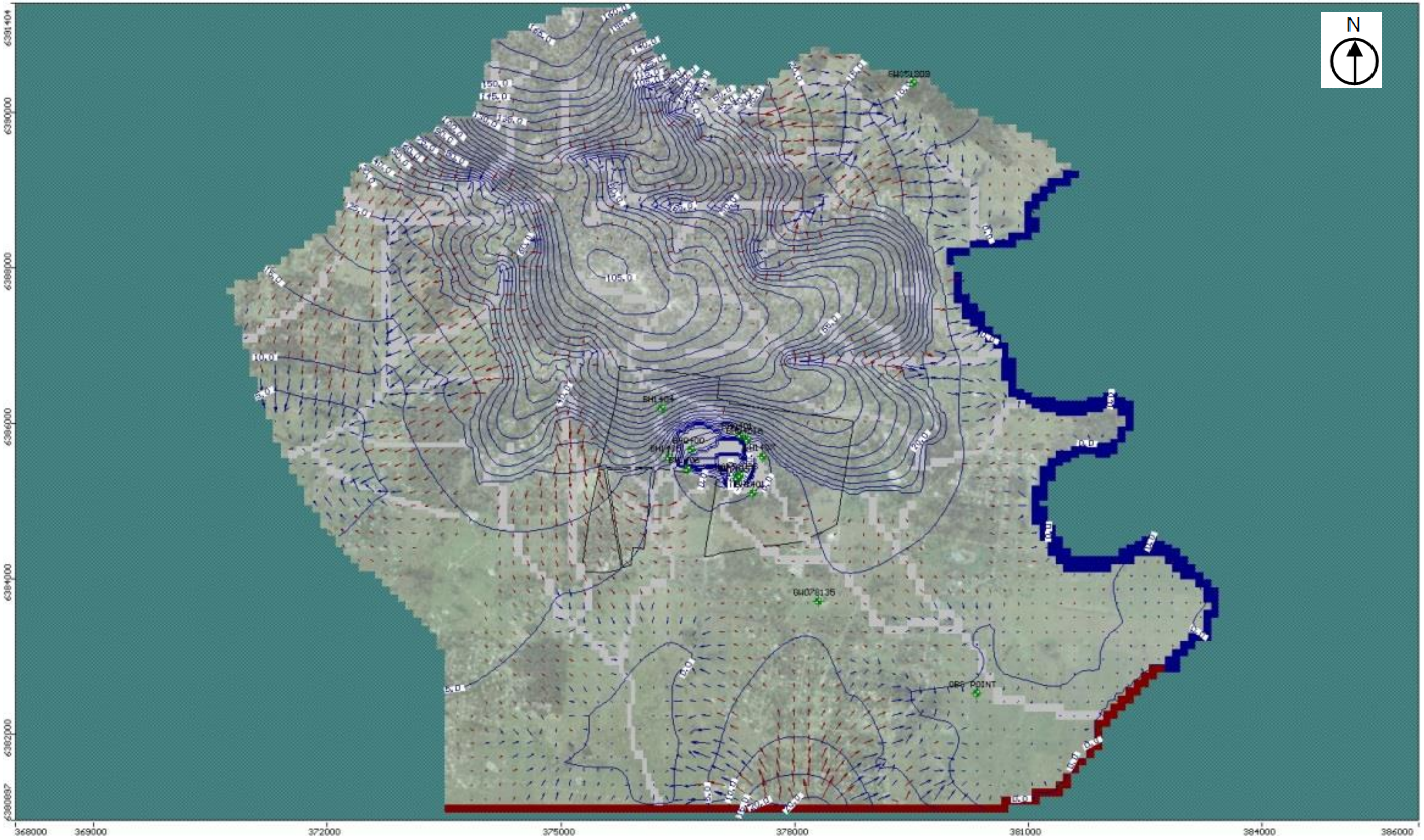
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**
Drawn:	DD	
Approved:	AN	
Date:	28.07.2015	
Scale:	NA – NTS	

BH401, BH401A & BH400
OBSERVED VS MODELLED HYDROGRAPHS

Drawing No:

FIGURE 40

Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890	**Environment | Water | Wastewater | Geotechnical | Civil | Management**
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING

Drawing No:

FIGURE 41

Job No: P1303888JR02V04

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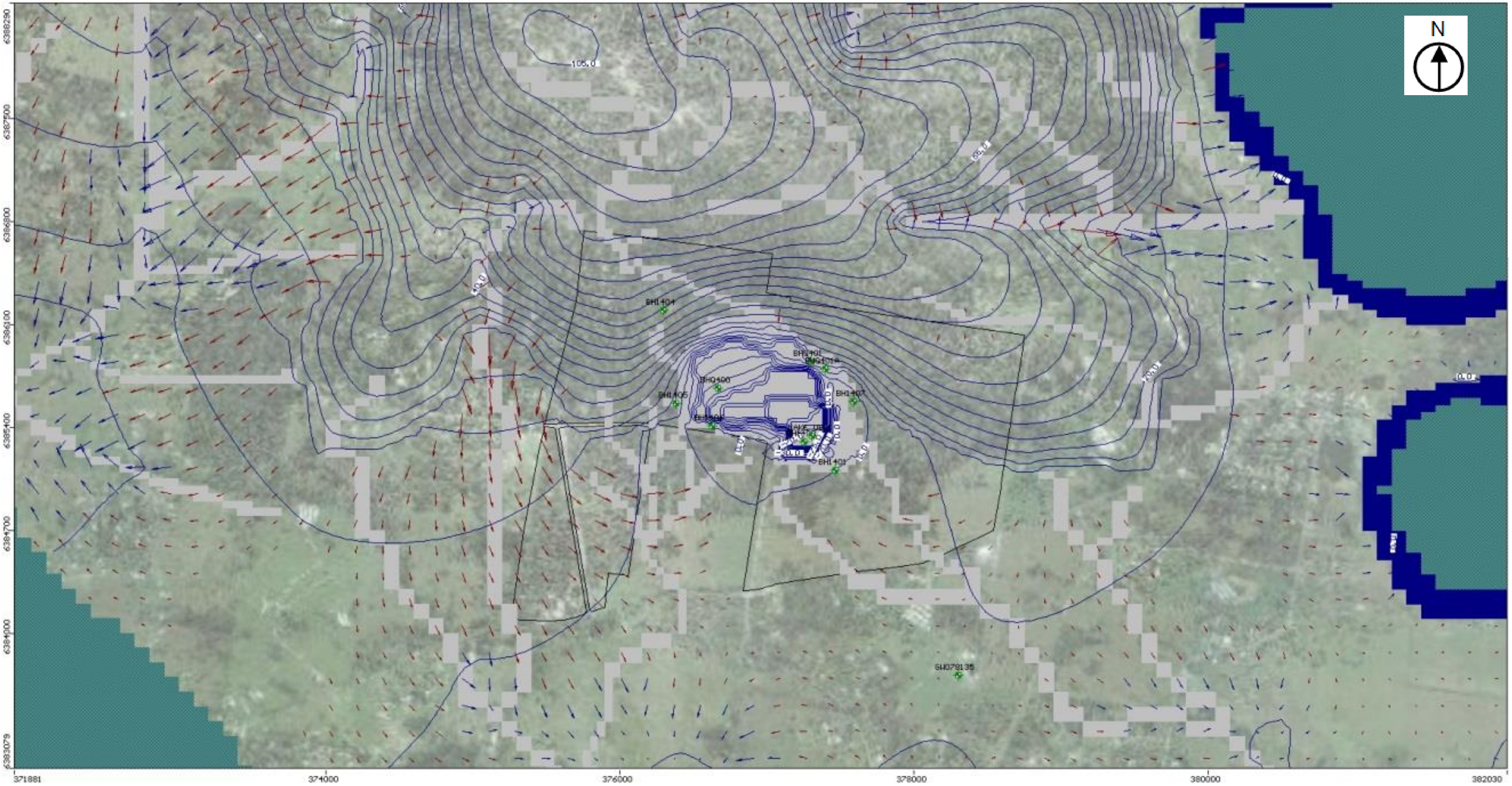


Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

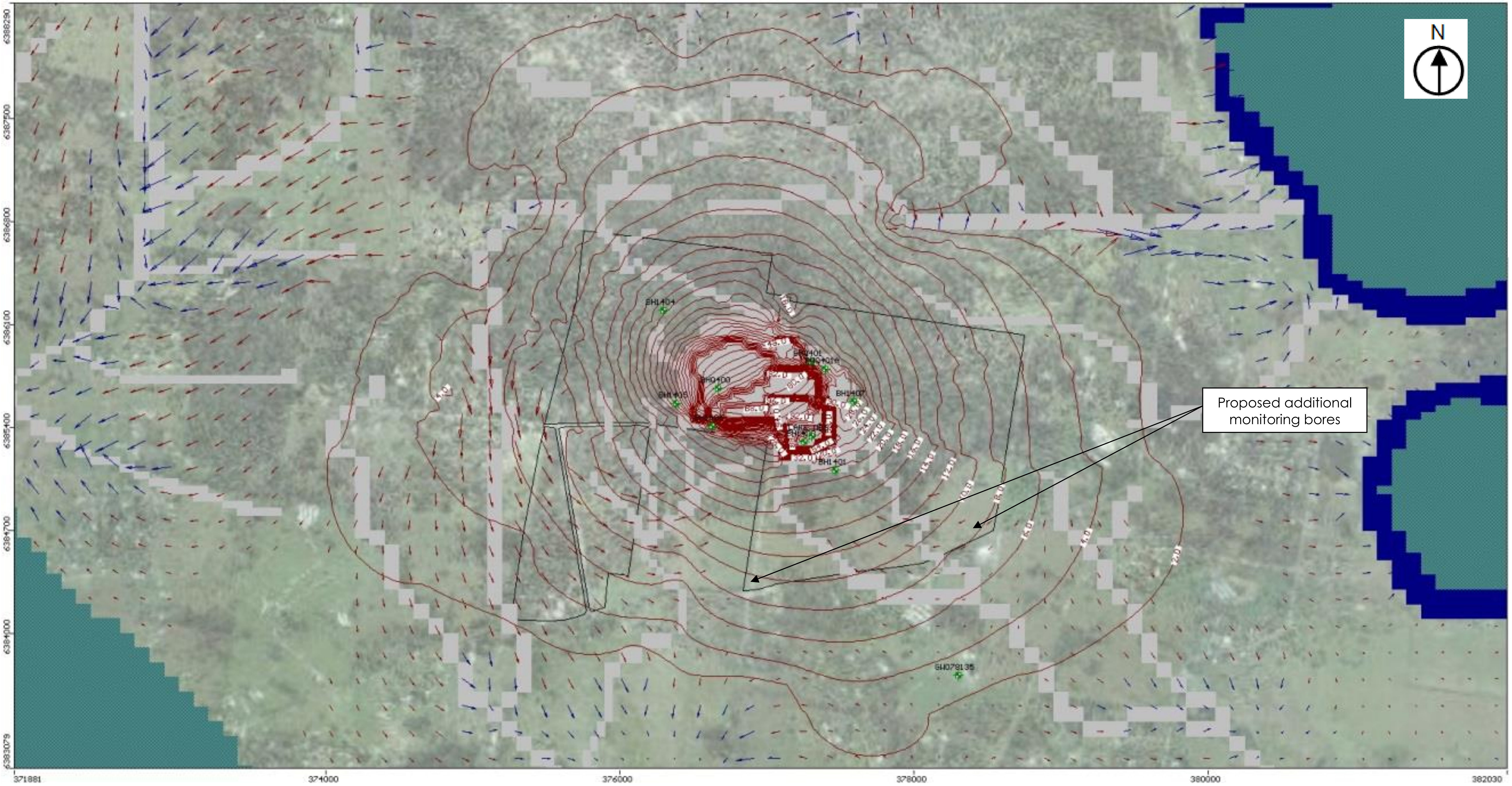
LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING AT SITE

Drawing No:

FIGURE 42

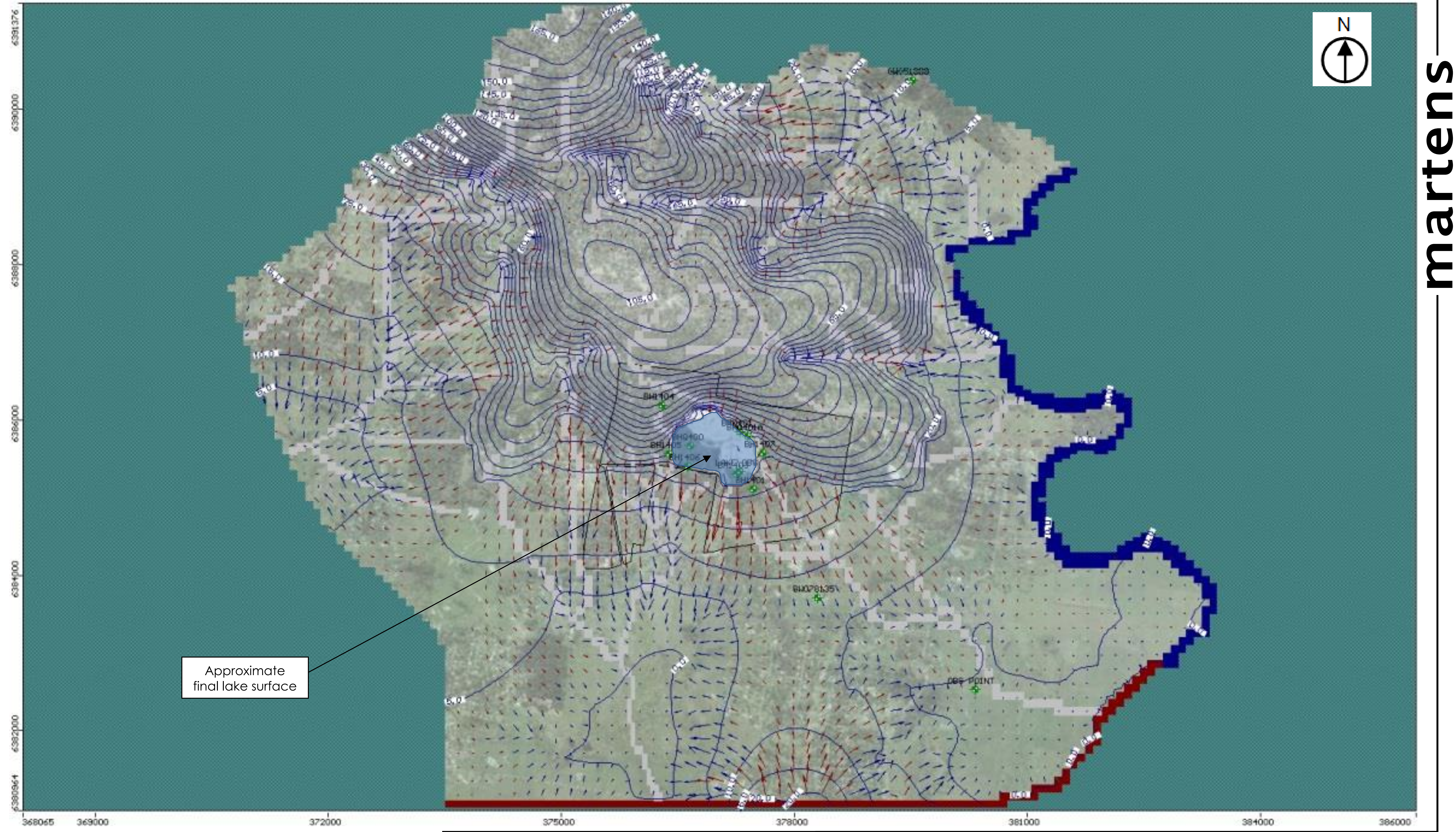
Job No: P1303888JR02V04

martens



Note:
1. Drawdown = Layer 1 steady state head for pre quarry conditions – Layer 1 head at completion of proposed development quarrying.
2. Red arrows denote groundwater moving down to a lower layer.
3. Blue arrows denote groundwater moving up to a higher layer.
4. Contour interval = 2 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**DRAWDOWN TO LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING AT SITE**	Drawing No: **FIGURE 43**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

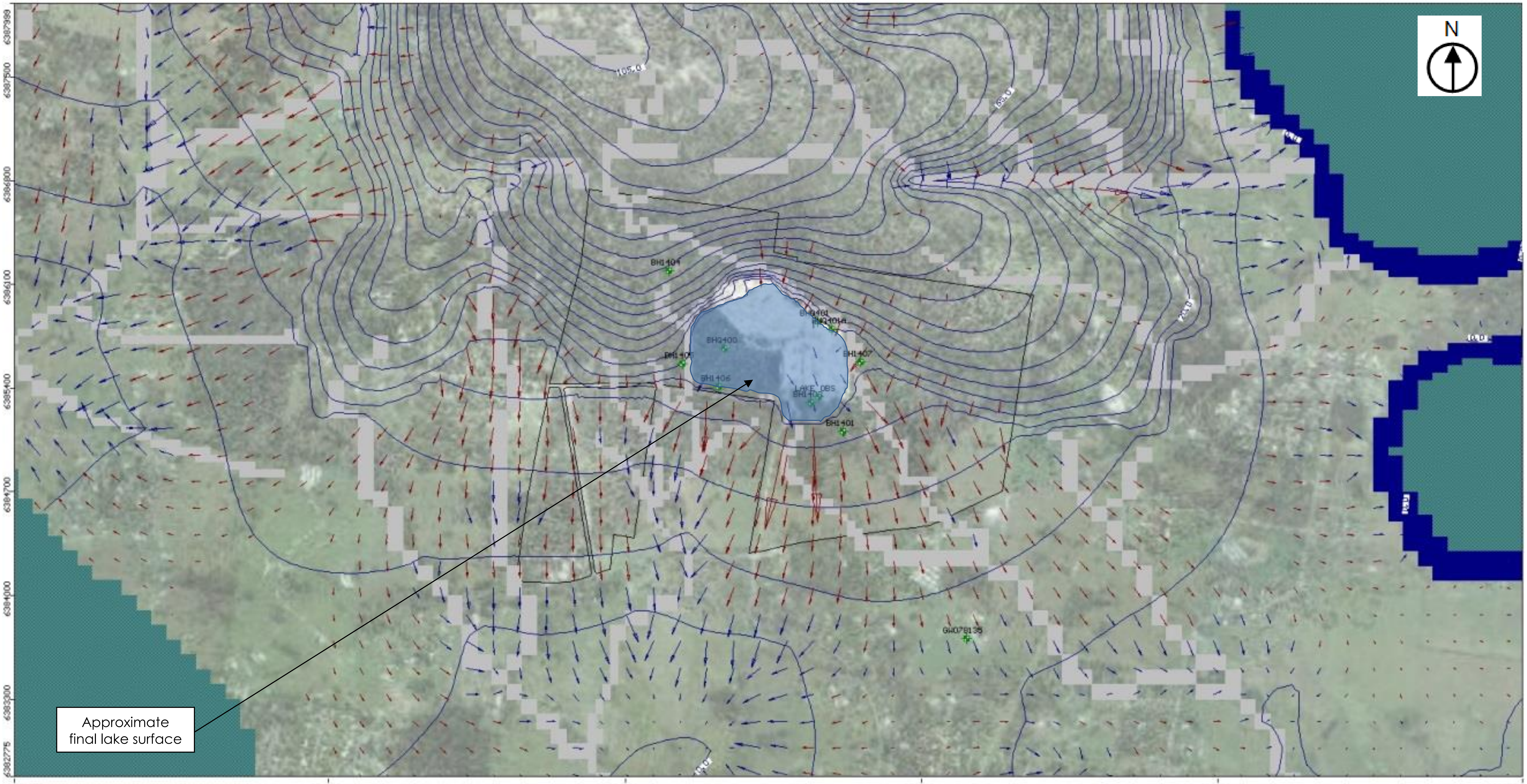
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

LAYER 1 HEAD FOR EQUILIBRIUM REHABILITATION CONDITIONS (500 YEARS POST QUARRYING)

Drawing No:

FIGURE 44

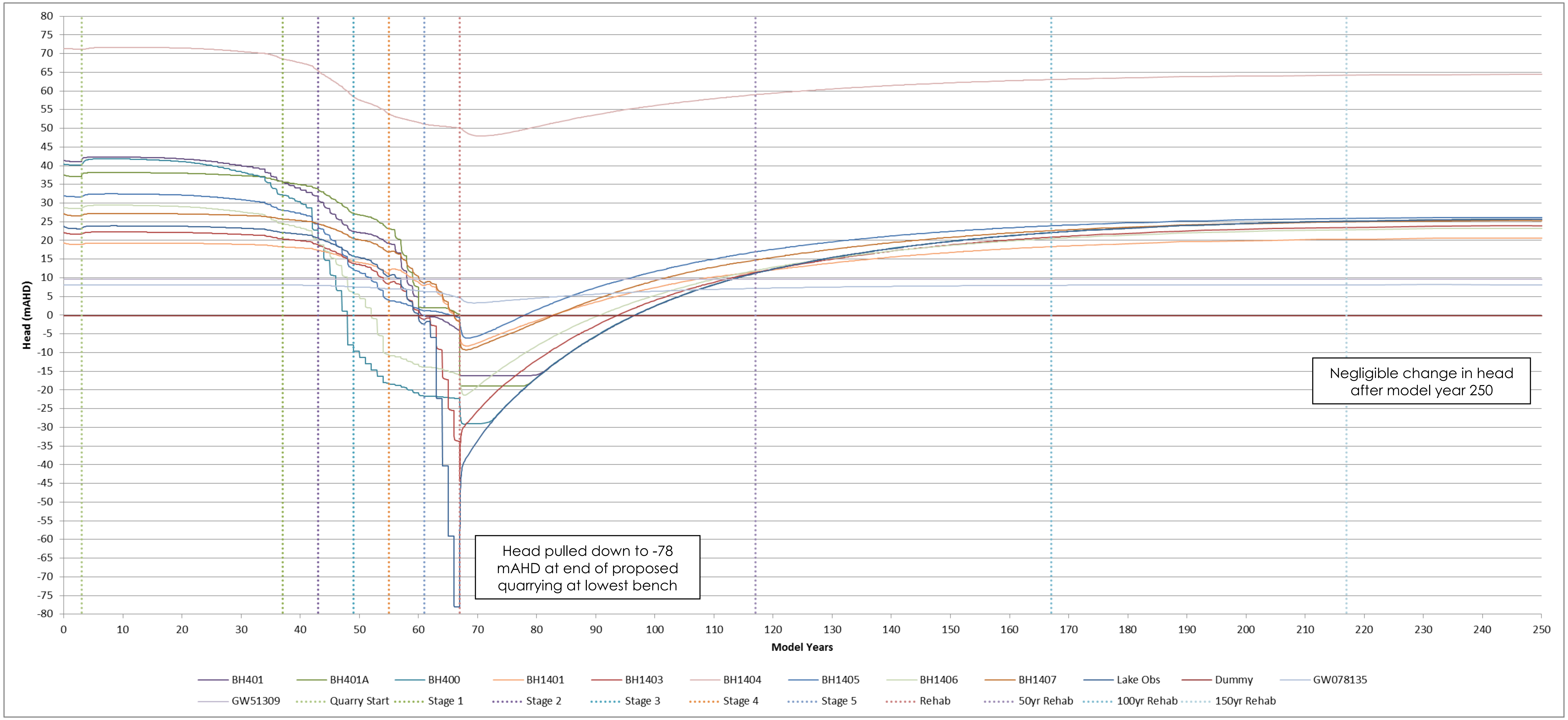
Job No: P1303888JR02V04



Approximate final lake surface

Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**LAYER 1 HEAD FOR EQUILIBRIUM REHABILITATION CONDITIONS AT SITE (500 YEARS POST QUARRYING)**	Drawing No: **FIGURE 45**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Head pulled down to -78 mAHD at end of proposed quarrying at lowest bench

Negligible change in head after model year 250

Note:
1. Calendar Year = Model Year + 1980 (model start calendar year – refer Table 16).
2. Head results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

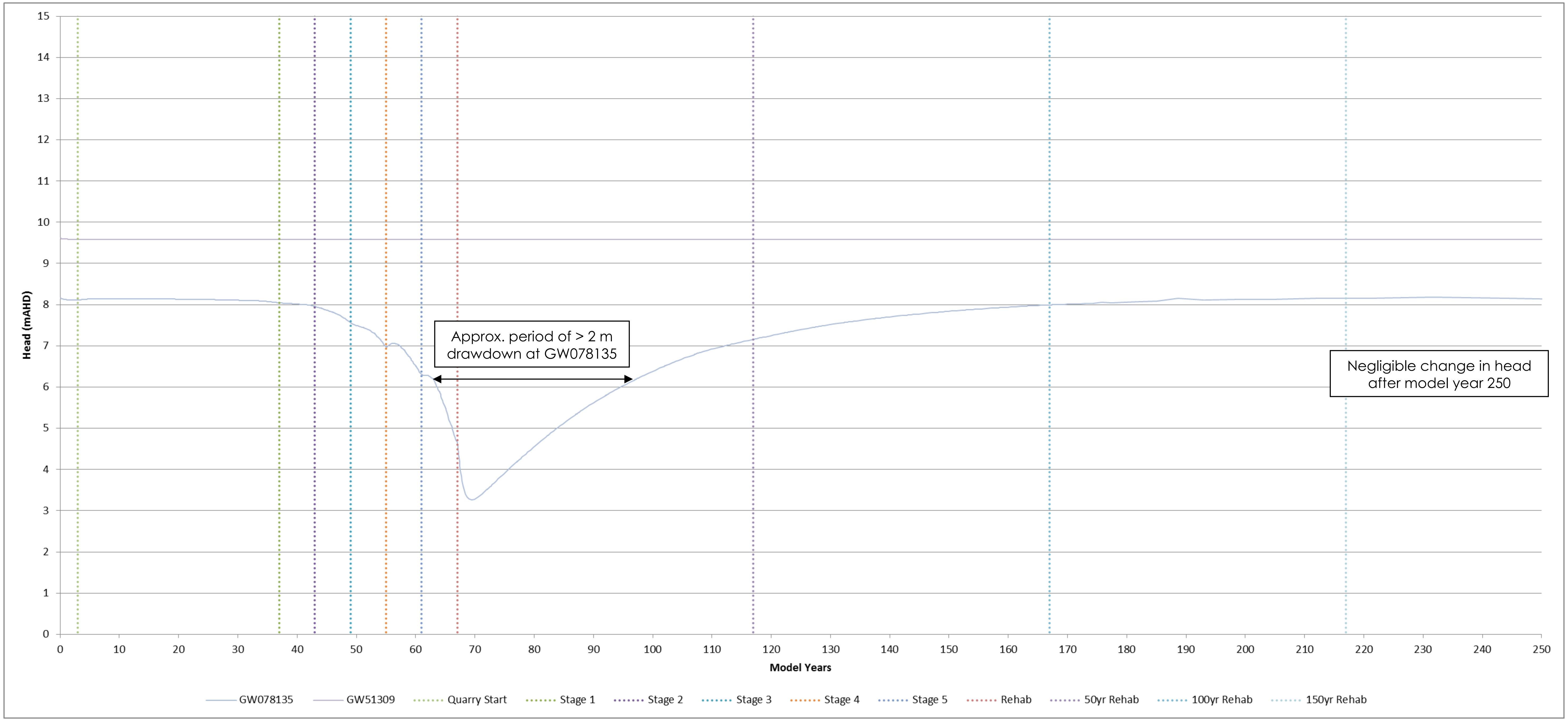
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL HEAD RESULTS AT ALL BORES WITHIN MODEL DOMAIN – PRE QUARRY TO REHABILITATION EQUILIBRIUM

Drawing No:

FIGURE 46

Job No: P1303888JR02V04



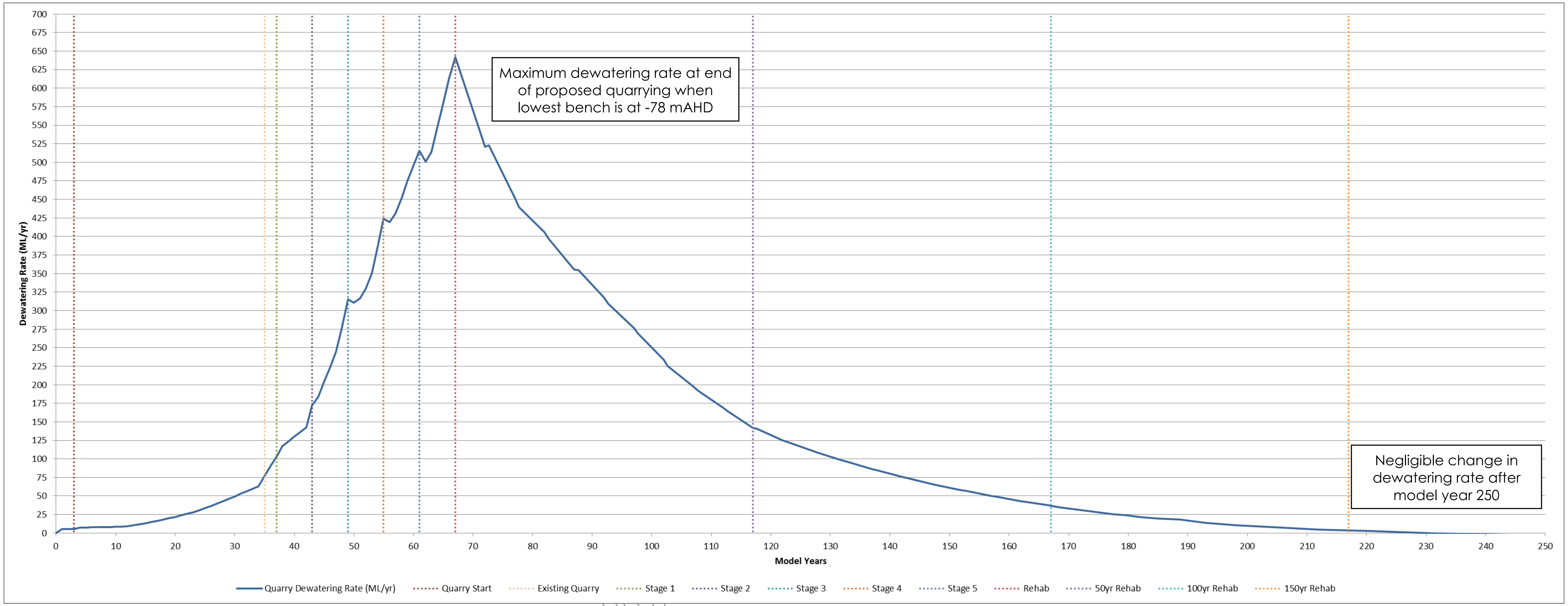
martens

Note:

1. Calendar Year = Model Year + 1980 (model start calendar year – refer Table 16).

2. Head results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**TRANSIENT MODEL HEAD RESULTS AT OFFSITE LICENCED BORES WITHIN MODEL DOMAIN – PRE QUARRY TO REHABILITATION EQUILIBRIUM**	Drawing No: **FIGURE 47**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Maximum dewatering rate at end of proposed quarrying when lowest bench is at -78 mAHD

Negligible change in dewatering rate after model year 250

Note:
1. Calendar Year = Model Year + 1980 (model start time – refer Table 16).
2. Dewatering results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.
3. Dewatering to end of quarrying due to pumping.
4. Dewatering post quarrying is due to flow to void.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

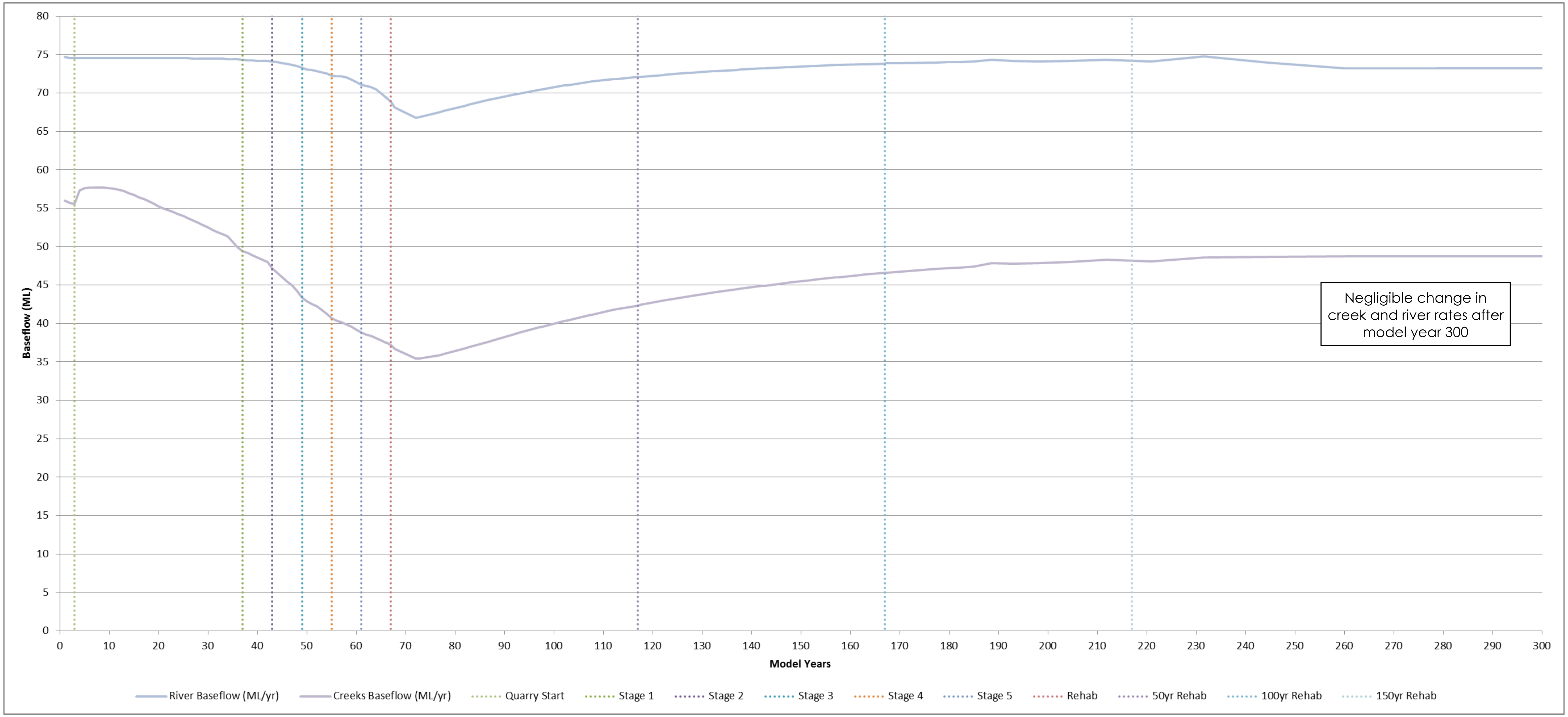
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL DEWATERING RATE RESULTS FOR QUARRY VOID – PRE QUARRY TO REHABILITATION EQUILIBRIUM

Drawing No:

FIGURE 48

Job No: P1303888JR02V04



Negligible change in creek and river rates after model year 300

Note:
1. Calendar Year = Model Year + 1980 (model start time – refer Table 16).
2. Creek and river rates results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL CREEK AND RIVER RATES – PRE QUARRY TO REHABILITATION EQUILIBRIUM

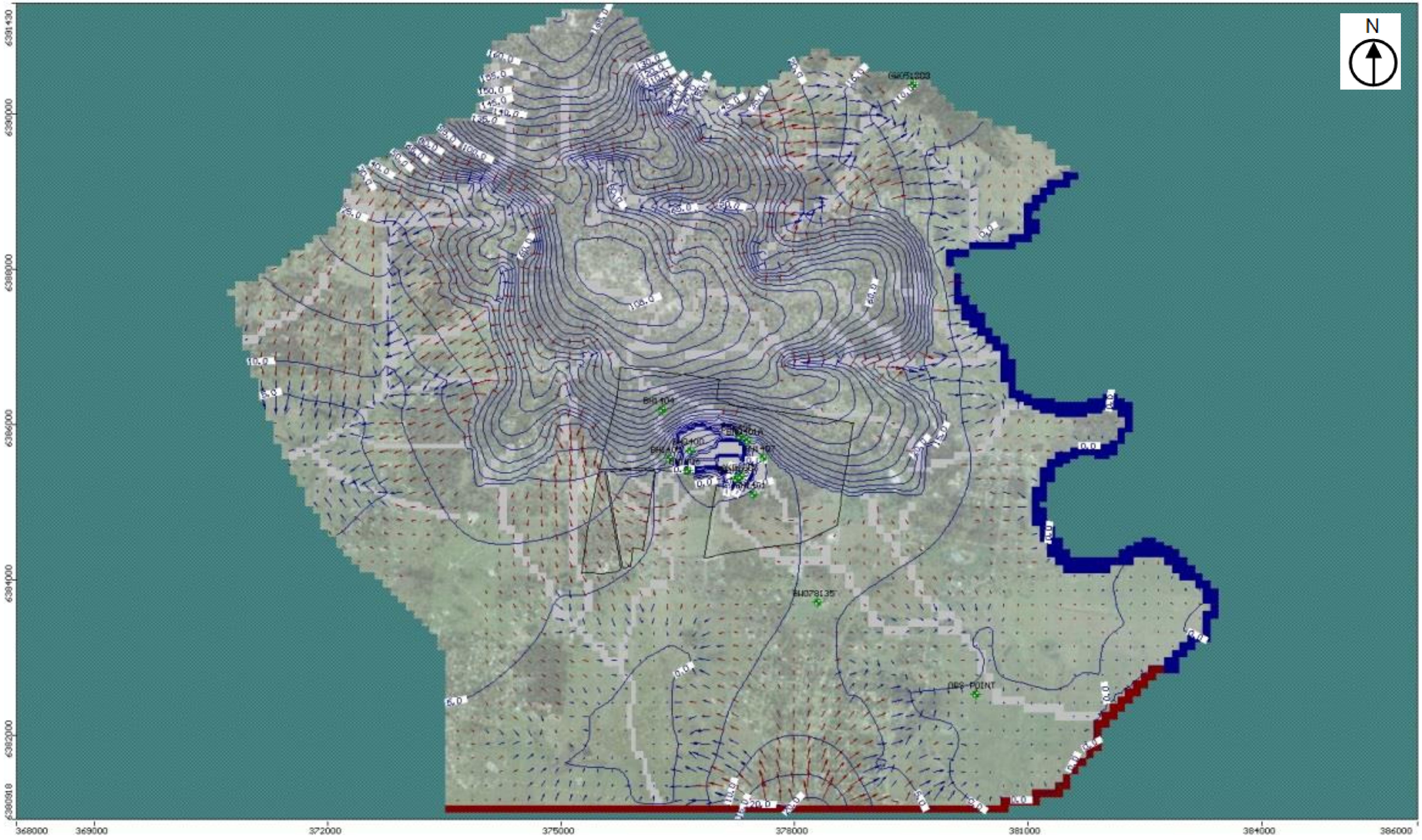
Drawing No:

FIGURE 49

Job No: P1303888JR02V04

Note:
1. Drawdown = Layer 1 head at rehabilitation equilibrium conditions (500 years post quarrying) – Layer 1 steady state head for pre quarry conditions.
2. Different to conventional drawdown plots, negative values represent drawdown (lowering of head) and positive values represent draw up (rising of head).
3. Contour interval = 2 m.

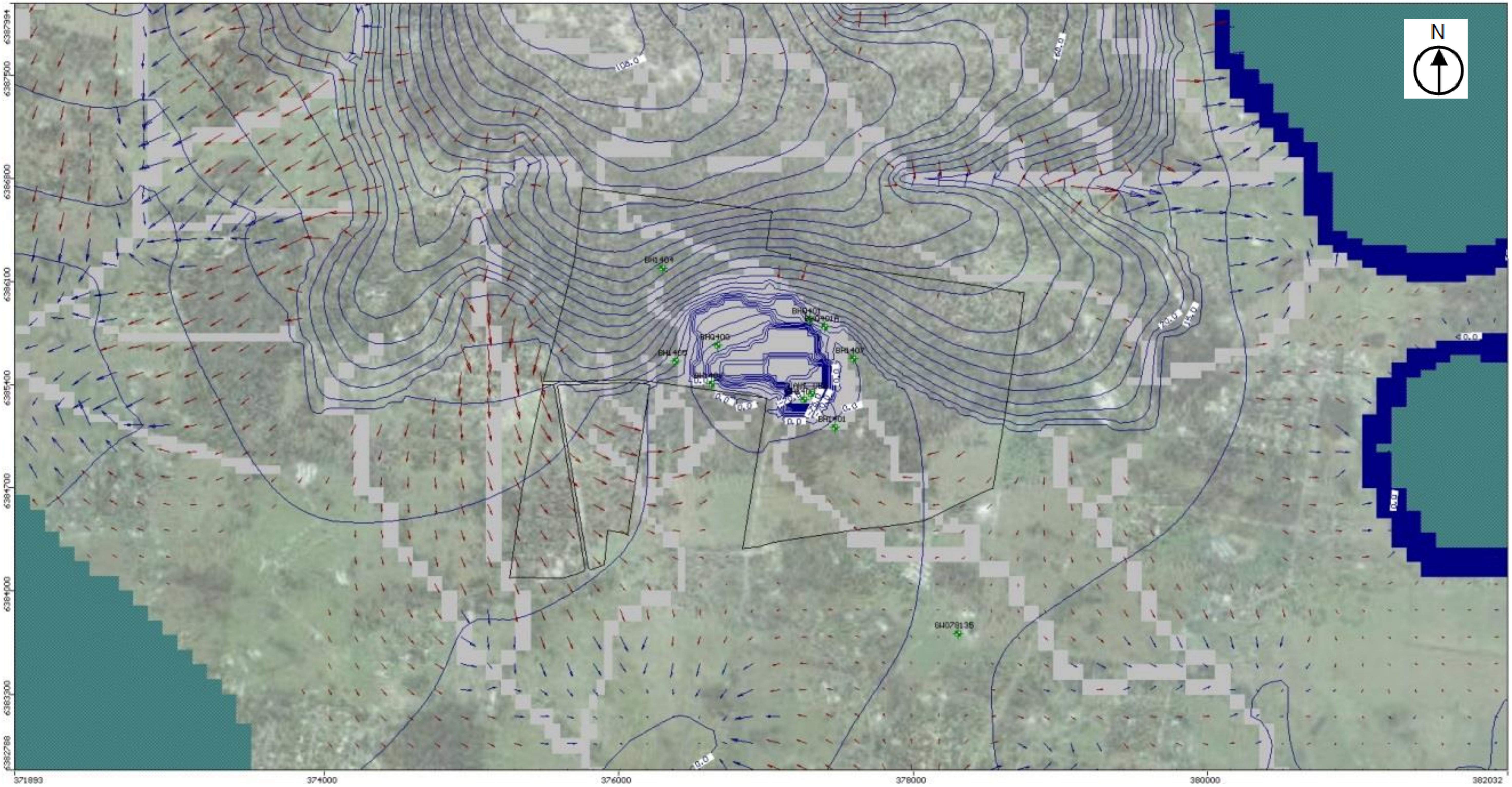
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**DRAWDOWN TO LAYER 1 HEAD AT REHABILITATION EQUILIBRIUM CONDITIONS AT SITE**	Drawing No: **FIGURE 50**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



martens

Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

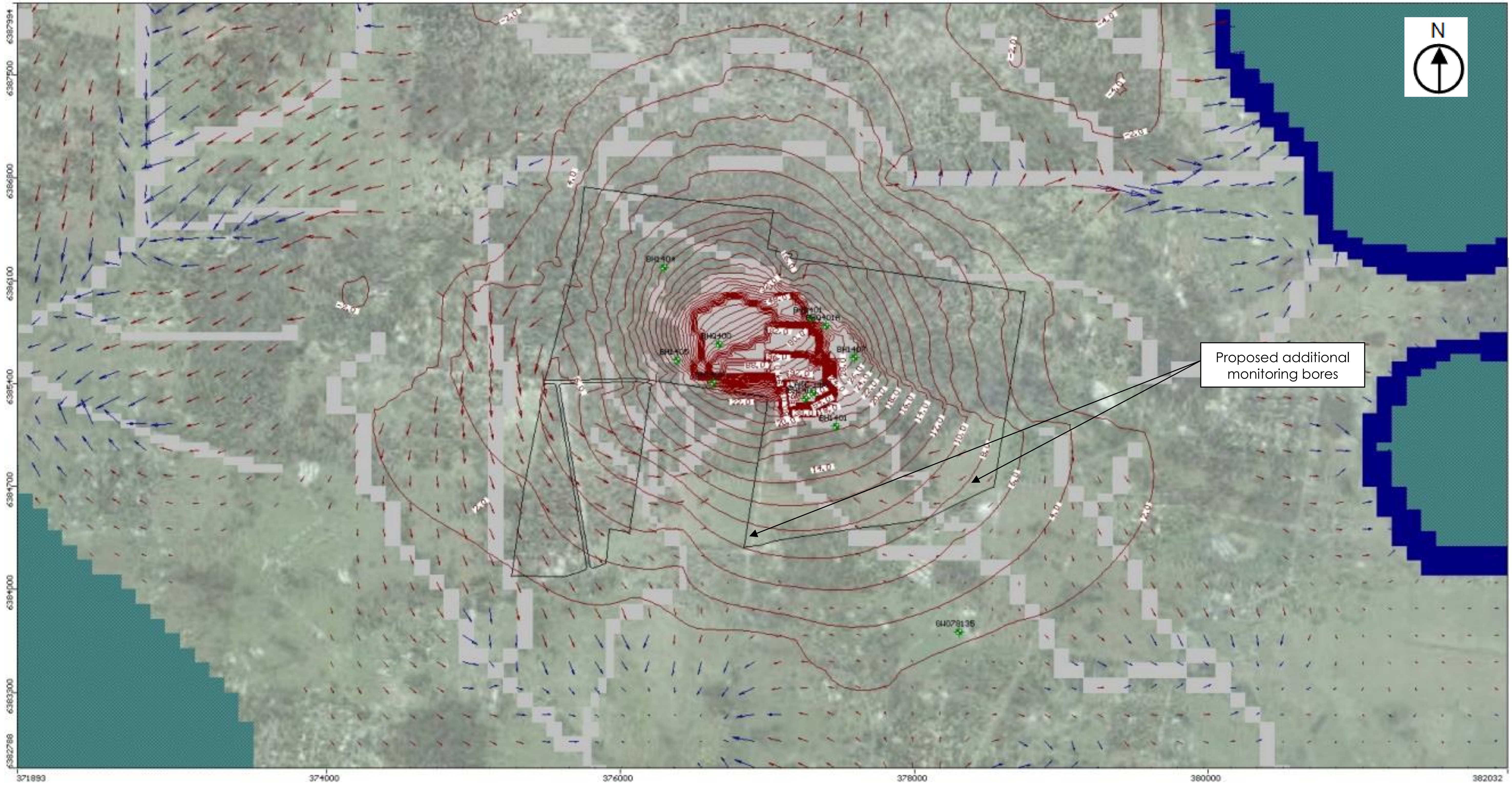
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING – VARYING RAINFALL**	Drawing No: **FIGURE 51**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



martens

Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING AT SITE – VARYING RAINFALL**	Drawing No: **FIGURE 52**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



martens

Note:
1. Drawdown = Layer 1 steady state head for pre quarry conditions – Layer 1 head at completion of proposed development quarrying.
2. Red arrows denote groundwater moving down to a lower layer.
3. Blue arrows denote groundwater moving up to a higher layer.
4. Contour interval = 2 m.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

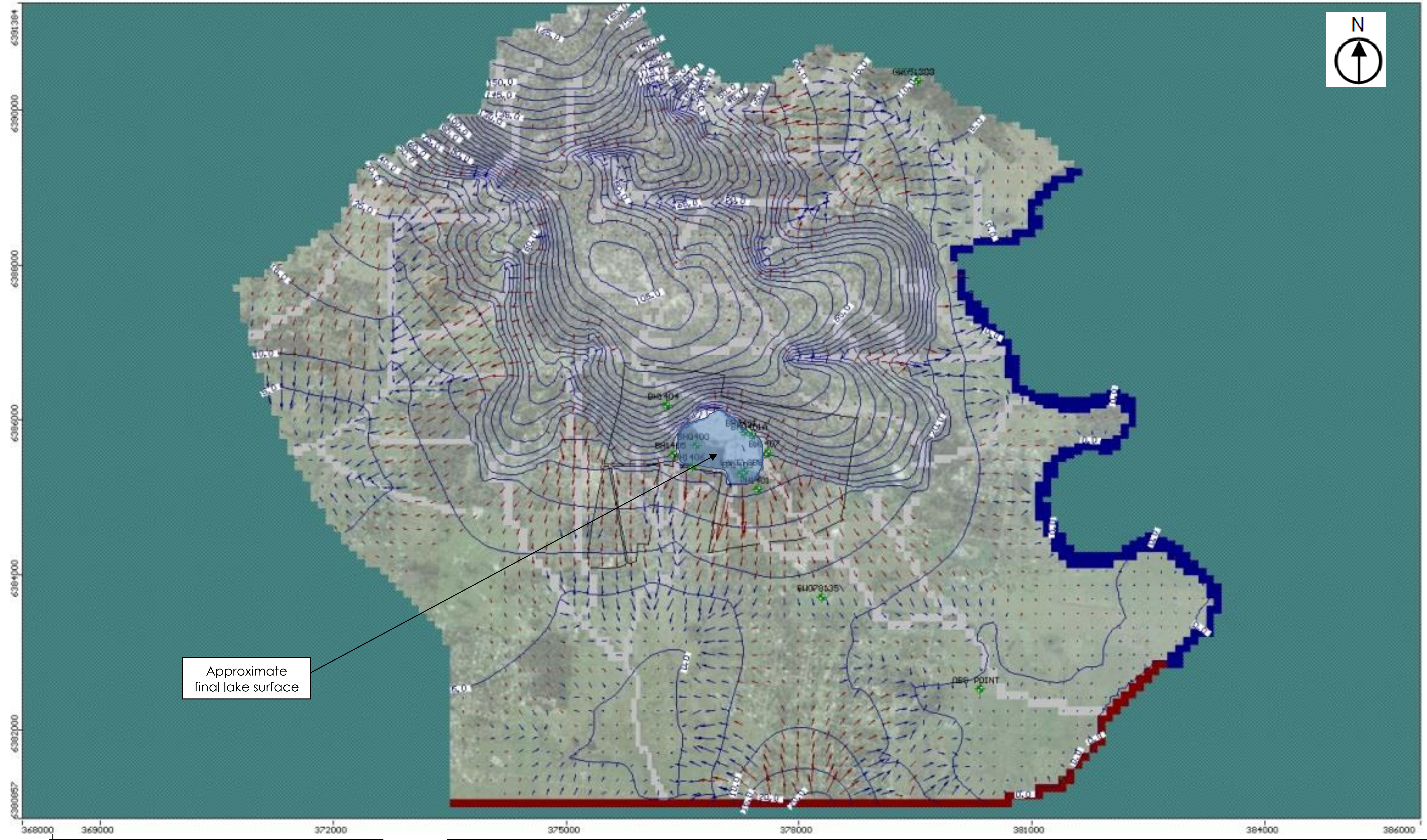
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	As shown

DRAWDOWN TO LAYER 1 HEAD AT COMPLETION OF PROPOSED DEVELOPMENT QUARRYING AT SITE – VARYING RAINFALL

Drawing No:

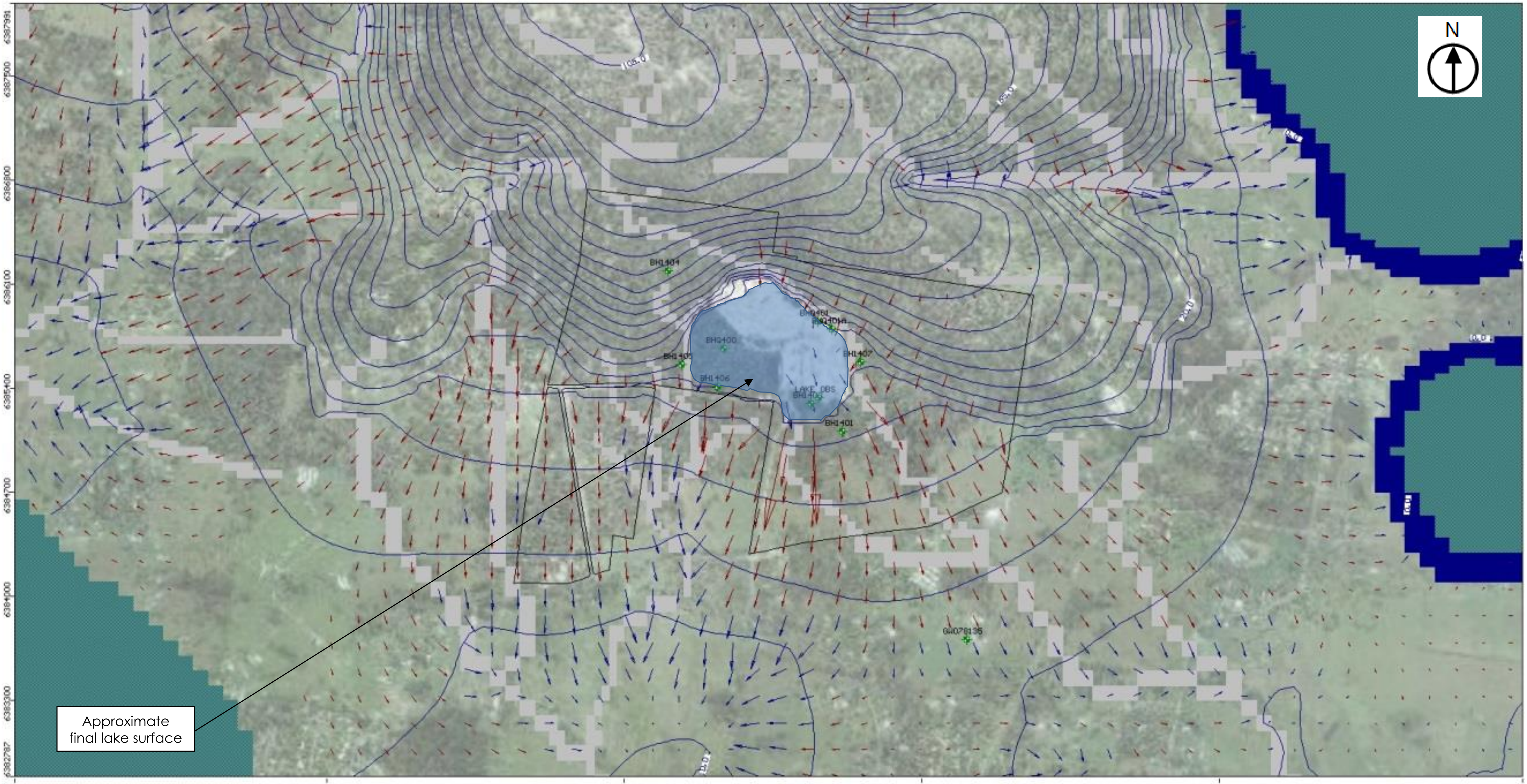
FIGURE 53

Job No: P1303888JR02V04



Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

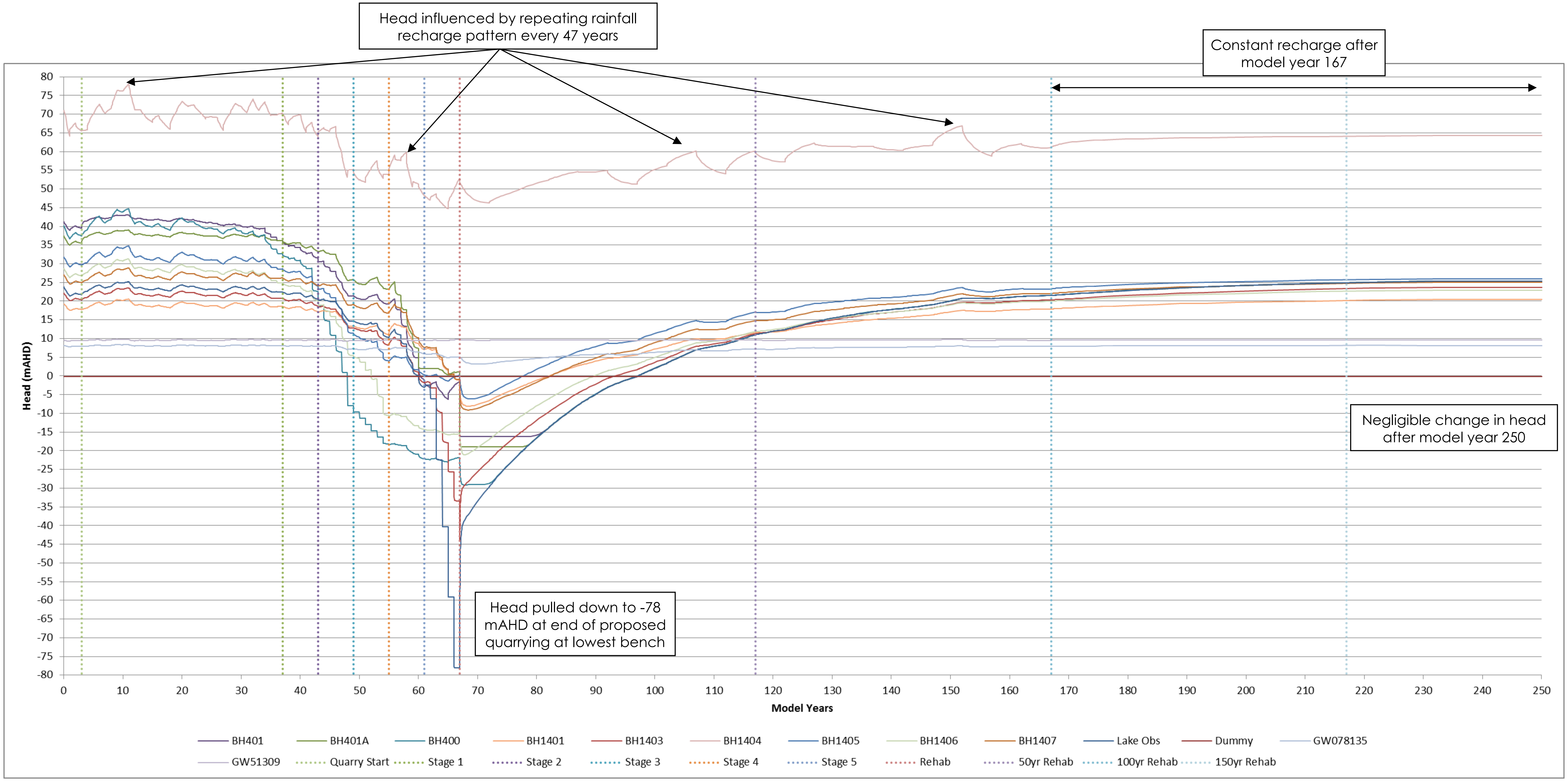
Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**LAYER 1 HEAD FOR EQUILIBRIUM REHABILITATION CONDITIONS (500 YEARS POST QUARRYING) – VARYING RAINFALL**	Drawing No: **FIGURE 54**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Approximate final lake surface

Note:
1. Red arrows denote groundwater moving down to a lower layer.
2. Blue arrows denote groundwater moving up to a higher layer.
3. Contour interval = 5 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**LAYER 1 HEAD FOR EQUILIBRIUM REHABILITATION CONDITIONS AT SITE (500 YEARS POST QUARRYING) – VARYING RAINFALL**	Drawing No: **FIGURE 55**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04



Head influenced by repeating rainfall recharge pattern every 47 years

Constant recharge after model year 167

Negligible change in head after model year 250

Head pulled down to -78 mAHD at end of proposed quarrying at lowest bench

martens

Note:
1. Calendar Year = Model Year + 1980 (model start calendar year – refer Table 16).
2. Head results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890

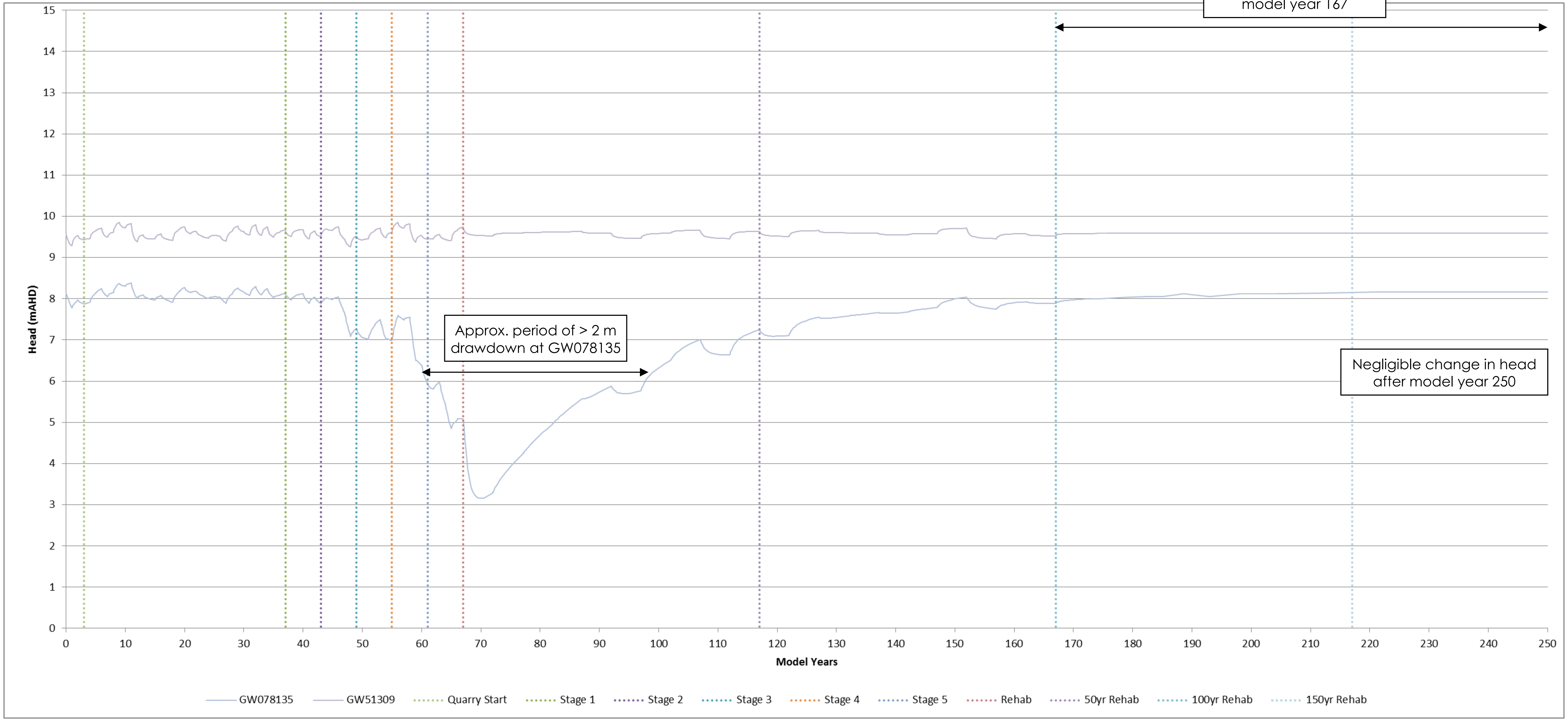
Environment | Water | Wastewater | Geotechnical | Civil | Management

Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL HEAD RESULTS AT ALL BORES WITHIN MODEL DOMAIN – PRE QUARRY TO REHABILITATION EQUILIBRIUM – VARYING RAINFALL

Drawing No:
FIGURE 56

Job No: P1303888JR02V04



Constant recharge after model year 167

Approx. period of > 2 m drawdown at GW078135

Negligible change in head after model year 250

Note:
1. Calendar Year = Model Year + 1980 (model start calendar year – refer Table 16).
2. Head results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

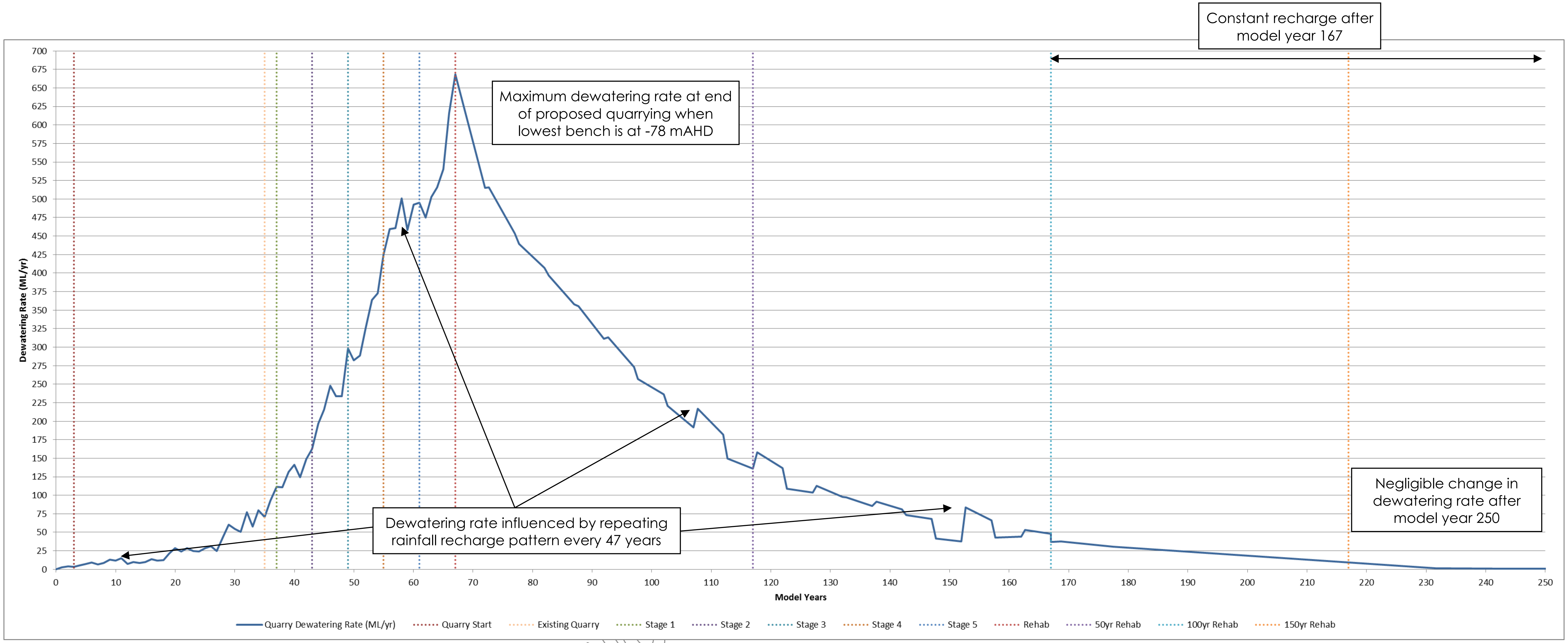
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL HEAD RESULTS AT OFFSITE LICENCED BORES WITHIN MODEL DOMAIN – PRE QUARRY TO REHABILITATION EQUILIBRIUM – VARYING RAINFALL

Drawing No:

FIGURE 57

Job No: P1303888JR02V04



Note:
1. Calendar Year = Model Year + 1980 (model start time – refer Table 16).
2. Dewatering results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.
3. Dewatering to end of quarrying due to pumping.
4. Dewatering post quarrying is due to flow to void.

Martens & Associates Pty Ltd ABN 85 070 240 890

Environment | Water | Wastewater | Geotechnical | Civil | Management

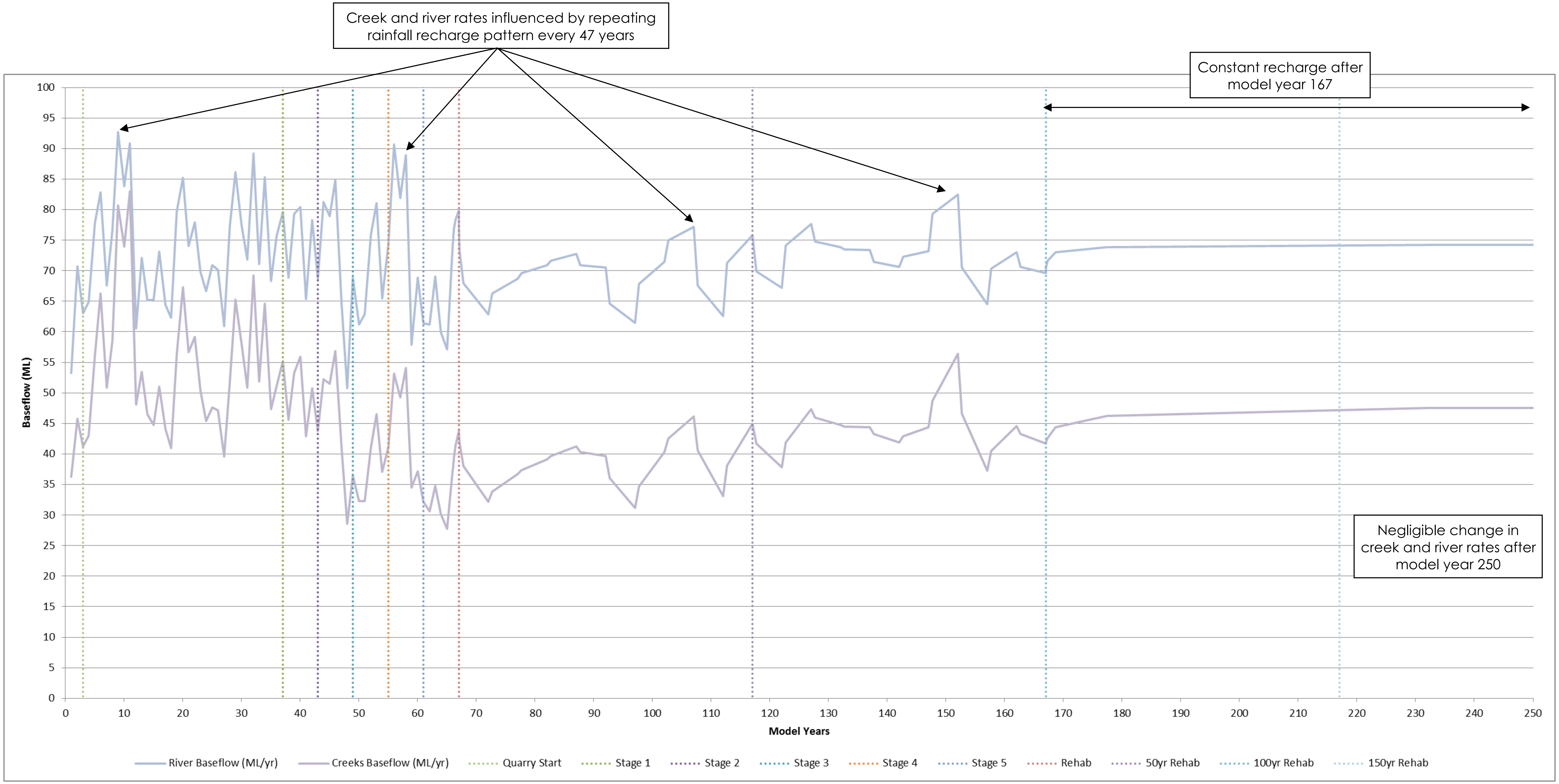
Drawn:	DD
Approved:	AN
Date:	28.07.2015
Scale:	NA – NTS

TRANSIENT MODEL DEWATERING RATE RESULTS FOR QUARRY VOID – PRE QUARRY TO REHABILITATION EQUILIBRIUM – VARYING RAINFALL

Drawing No:

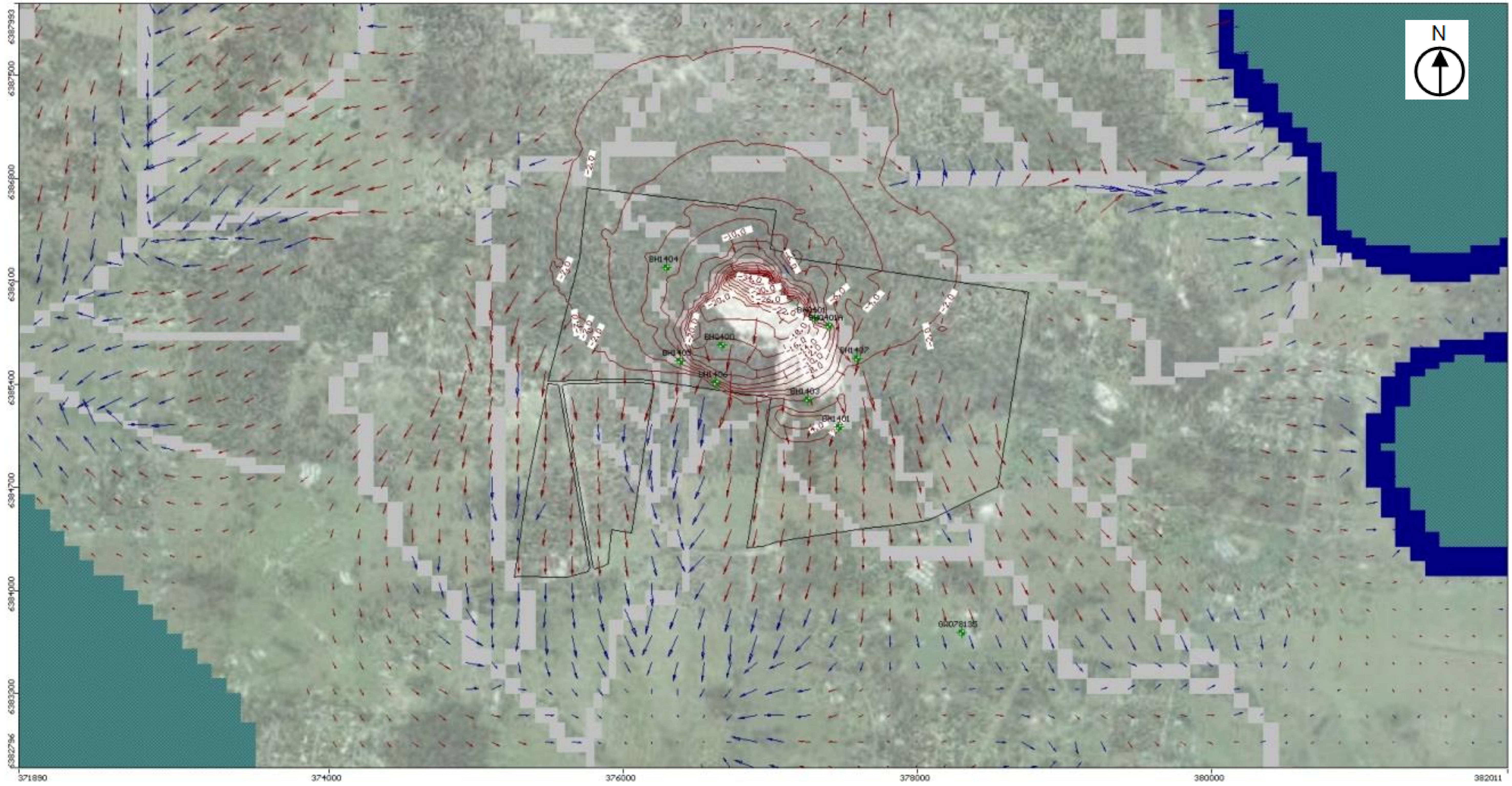
FIGURE 58

Job No: P1303888JR02V04



Note:
1. Calendar Year = Model Year + 1980 (model start calendar year – refer Table 16).
2. Creek and river rates results from model year 0 – 67 are from the post development predictive model and results from model year 67 onwards are from the rehabilitation predictive model.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**TRANSIENT MODEL CREEK AND RIVER RATES – PRE QUARRY TO REHABILITATION EQUILIBRIUM – VARYING RAINFALL**	Drawing No: **FIGURE 59**
Approved:	AN		
Date:	28.07.2015		
Scale:	NA – NTS		Job No: P1303888JR02V04



Note:
1. Drawdown = Layer 1 head at rehabilitation equilibrium conditions (500 years post quarrying) – Layer 1 steady state head for pre quarry conditions.
2. Different to conventional drawdown plots, negative values represent drawdown (lowering of head) and positive values represent draw up (rising of head).
3. Red arrows denote groundwater moving down to a lower layer.
4. Blue arrows denote groundwater moving up to a higher layer.
5. Contour interval = 2 m.

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**DRAWDOWN TO LAYER 1 HEAD AT REHABILITATION EQUILIBRIUM CONDITIONS AT SITE – VARYING RAINFALL**	Drawing No: **FIGURE 60**
Approved:	AN		
Date:	28.07.2015		
Scale:	As shown		Job No: P1303888JR02V04

16 Attachment D – Graphic Drill Logs

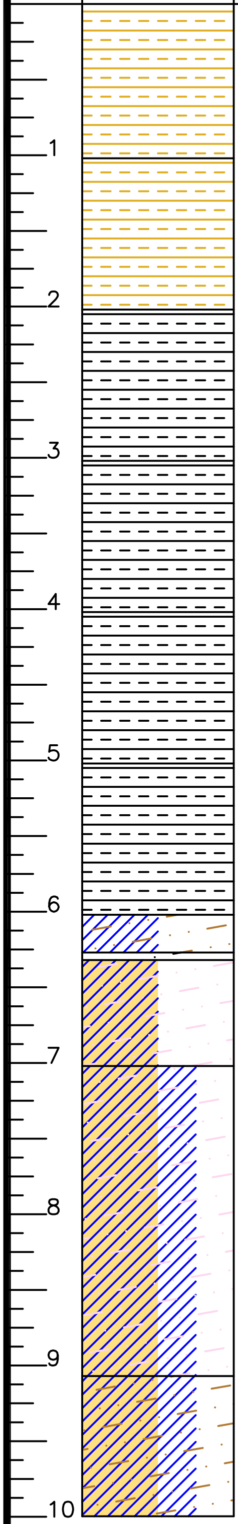
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH−400−DH
PROJECT: BRANDY HILL EXTENSION
PAGE 1 OF 5

LOCATION:56 376668,6385668
DRILLED:
LOGGED: P BROWNE 13/9/11

DPH LOG DESCRIPTION



YELLOW BROWN CLAY..

YELLOW BROWN CLAY..

OFF WHITE SANDSTONE AND CLAY..

OFF WHITE SANDSTONE AND CLAY..

OFF WHITE SANDSTONE AND RED BROWN CLAY..

OFF WHITE SANDSTONE AND CLAY..

BROWN MEDIUM HARD FINE GRAINED SANDSTONE..FRACTURES 20cm APART

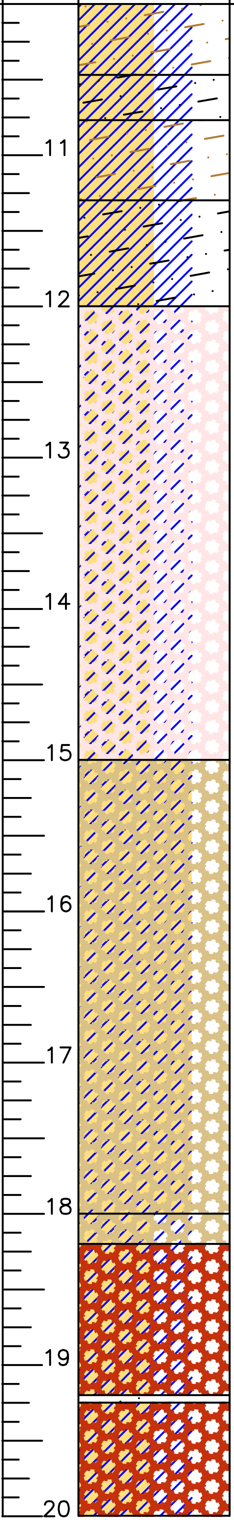
BROWNE MEDIUM HARD FINE GRAINED SANDSTONE..

VIOLET AND WHITE FINE GRAINED MEDIUM HARD SANDSTONE FRACTURES 30cm APART.

VIOLET AND WHITE FINE GRAINED MEDIUM HARD SANDSTONE FRACTURES 100cm APART.

BROWN FINE GRAINED MEDIUM HARD SANDSTONE FRACTURES 60cm APART. 80° TO CORE AXIS

DPH LOG DESCRIPTION



BROWN FINE GRAINED MEDIUM HARD SANDSTONE FRACTURES 60cm APART. 80° TO CORE AXIS

VIOLET AND WHITE FINE GRAINED MEDIUM HARD SANDSTONE.

BROWN STAINED FINE GRAINED, MEDIUM HARD SANDSTONE

VIOLET AND WHITE FINE GRAINED MEDIUM HARD SANDSTONE FRACTURES 10cm APART.

LIGHT PINK TO WHITE MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 7mm FRACTURES 30cm APART.

LIGHT YELLOW TO WHITE MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 14mm, POORLY SORTED, FRACTURES 30cm APART.

LIGHT YELLOW TO WHITE MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 14mm, POORLY SORTED, FRACTURES 30cm APART.

MULTICOLORED MEDIUM GRAINED MEDIUM HARD CONGLOMERATE, .

RED BROWN MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 5mm FRACTURES 100cm APART.

VIOLET FINE GRAINED MEDIUM HARD SANDSTONE.

RED BROWN MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 4mm FRACTURES 40cm APART.

COMMENTS:

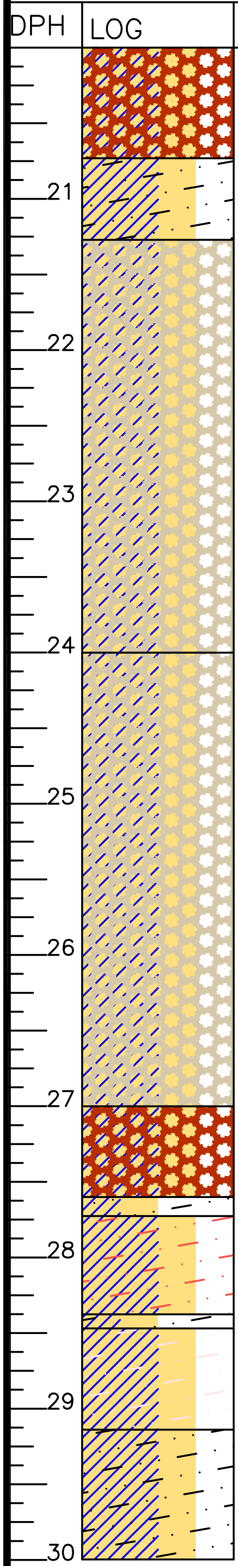
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BHQ-400-DH
PROJECT: BRANDY HILL EXTENSION
PAGE 2 OF 5

LOCATION: 56 376668, 6385668
DRILLED:
LOGGED: P BROWNE 13/9/11

DPH | LOG | DESCRIPTION



RED BROWN MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 4mm FRACTURES 40cm APART.

WHITE FINE TO COARSE GRAINED MEDIUM HARD SANDSTONE, FRACTURES 40cm APART.

MULTI COLOURED MEDIUM TO COARSE GRAINED MEDIUM HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 20mm, SOME SHALES INCLUDED, FRACTURES 30 TO 60cm APART.

LIGHT BROWN TO WHITE MEDIUM GRAINED HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 7mm, FRACTURES 30 TO 60cm APART. MINOR CROSS BEDDING.

RED BROWN MEDIUM GRAINED HARD CONGLOMERATE, PEBBLES MAINLY SANDSTONE ROUNDED TO 5mm,

LIGHT GREEN FINE GRAINED HARD SANDSTONE, PEBBLES MAINLY SANDSTONE

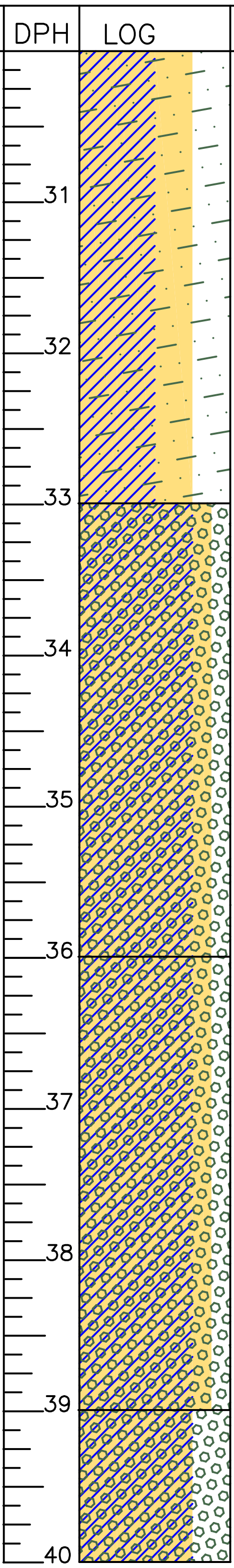
LIGHT RED FINE GRAINED HARD SANDSTONE, FRACTURES 30cm APART. MINOR CROSS BEDDING.

RED FINE GRAINED HARD SANDSTONE

PINK FINE GRAINED HARD SANDSTONE,

LIGHT RED FINE GRAINED SANSTONE FRESH HARD

DPH | LOG | DESCRIPTION



OFF WHITE TO LIHT GREEN VERY FINE GRAINED SANDSTONE HARD, FRACTURES 100cm APARTR. CALCITE VEINS 80° T CORE AXIS.

GREY GREEN FINE GRAINED IGNIMBRITE, FRESH, VERY HARD, EVEN TEXTURED, FELDSPAR PHENOCRYSTS TO 5mm. FRACTURES 20 TO 70 cm APART

GREY GREEN FINE GRAINED IGNIMBRITE, FRESH, VERY HARD, EVEN TEXTURED, FELDSPAR PHENOCRYSTS TO 5mm. FRACTURES 20 TO 70 cm APART

GREY GREEN FINE GRAINED IGNIMBRITE, FRESH, VERY HARD, EVEN TEXTURED, FELDSPAR PHENOCRYSTS TO 5mm. FRACTURES 20 TO 70 cm APART

COMMENTS:

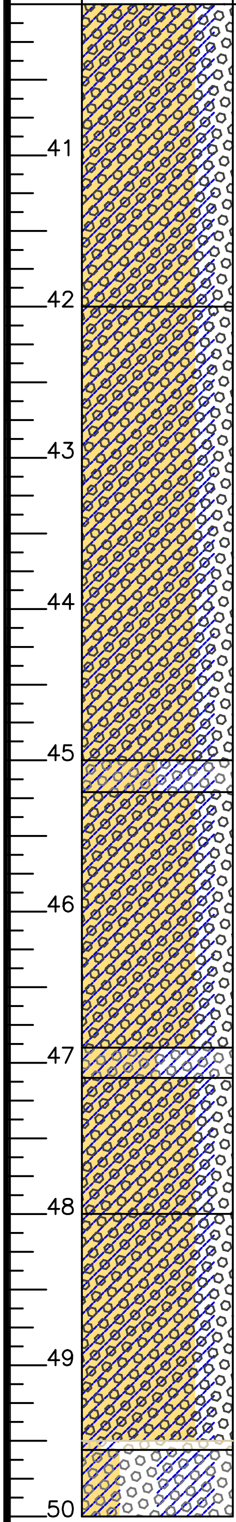
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-400-PC
PROJECT: BRANDY HILL EXTENSION
PAGE 3 OF 5

LOCATION:56 376668, 6385668
DRILLED:
LOGGED: P BROWNE 13/9/11

DPH LOG DESCRIPTION



DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 40cm APART..

DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 40cm APART..

GREY, AND PINK FINE GRAINED IGNIMBRITE, SLIGHTLY WEATHERED, MEDIUM HARD, EVEN TEXTURED, FRACTURES 45° TO CORE AXIS..

DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 30cm APART.. CALCITE VEINS 45° TO CORE AXIS

GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED..

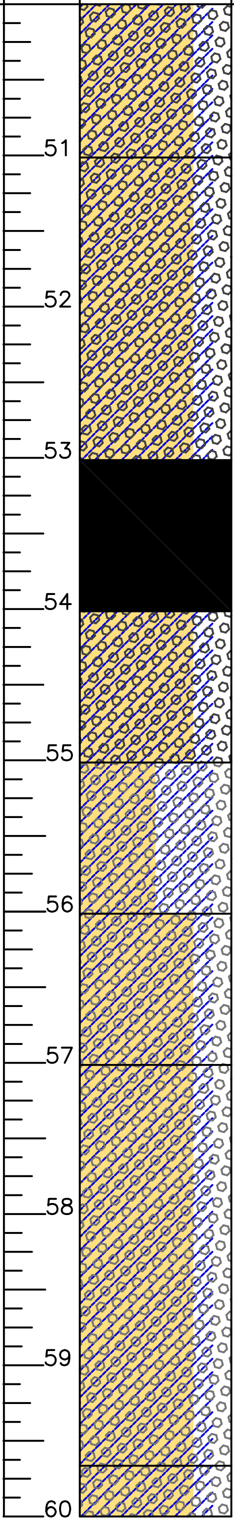
GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 40cm APART SOME 45° TO CORE AXIS..

DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 40cm APART..

LIGHT BROWN WEATHERED IGNIMBRITE FRACTURED..

GREY GREEN, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 60cm APART..

DPH LOG DESCRIPTION



DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 50cm APART, MINOR CALCITE PRESENT..

DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 25cm APART, MINOR CALCITE PRESENT..

DARK GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED,.

GREY, GREEN FINE GRAINED IGNIMBRITE,SLIGHTLY WEATHERED, HARD, EVEN TEXTURED, FRACTURES 25cm APART, MINOR CALCITE PRESENT., BROWN CLAYS ON FRACTURES.

GREY,MINOR RED WEATHERING, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 30cm APART. MINOR CALCITE PRESENT..

GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 25cm APART 45 to 90° TO CORE AXIS, MINOR CALCITE PRESENT..

GREY, FINE GRAINED IGNIMBRITE,VERY SLIGHTLY WEATHERED, VERY HARD, EVEN TEXTURED, FRACTURES 25cm APART 45 to 90° TO CORE AXIS, MINOR CALCITE PRESENT..

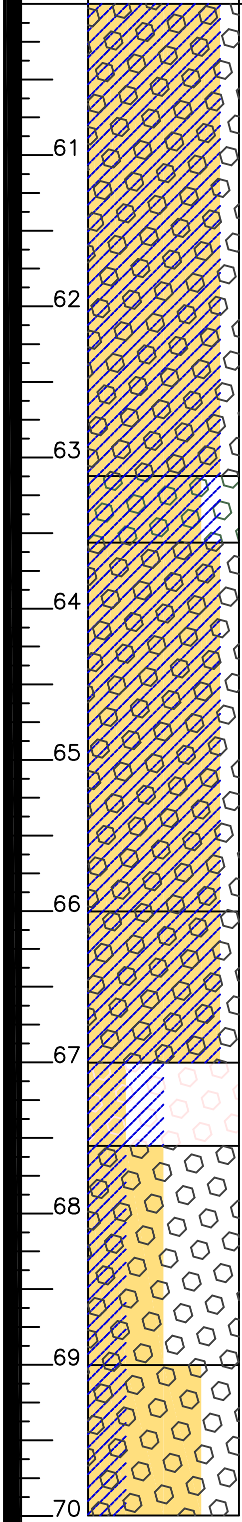
COMMENTS: 1 METRE INTERVAL MISSSING IN 51 TO 54 METRE INTERVAL. THIS IS PROBALY A LABELLING ERRROR WITH THE HOLE FINISHING AT 98 METRES. I HAVE KEPT TEH INTERVALS AS PER THE MARKING

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-400-PC
PROJECT: BRANDY HILL EXTENSION
PAGE 4 OF 5
LOCATION: 56 376668, 6385668
DRILLED:
LOGGED: P BROWNE 13/9/11

PH | LOG | DESCRIPTION



GREYI GNIMBRITE, EQUANT HARD FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART AT 10 TO 45° TO CORE AXIS, CALCITE VEINS 10° TO CORE AXIS. BROWN CLAY ON FRACTURES.

GREY GREEN IGNIMBRITE, HARD FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART AT 10° TO CORE AXIS, CALCITE VEINS 10° TO CORE AXIS. BROWN CLAY ON FRACTURES.

GREYI GNIMBRITE, EQUANT HARD FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART AT 10 TO 45° TO CORE AXIS, CALCITE VEINS 10° TO CORE AXIS. BROWN CLAY ON FRACTURES.

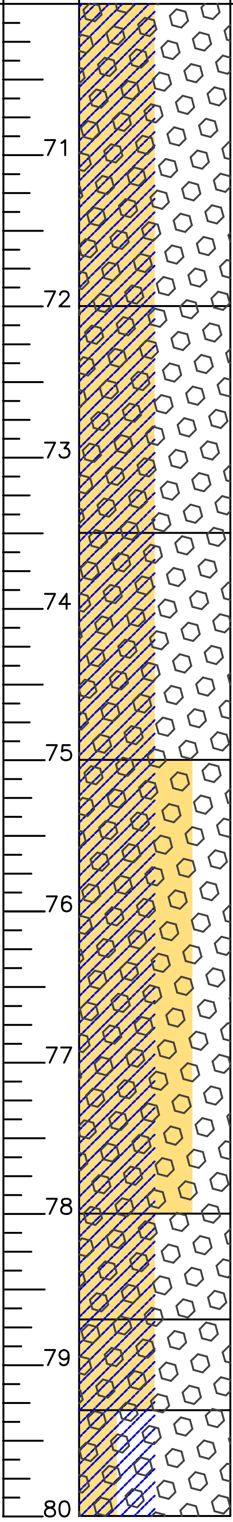
GREYI GNIMBRITE, EQUANT HARD FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART AT 10 TO 45° TO CORE AXIS, CALCITE VEINS 10° TO CORE AXIS. BROWN CLAY ON FRACTURES.

PINK,BROWN AND GREYI WELDED GNIMBRITE, HARD WEATHERED, FELDSPAR WHITE ALTERED TO 5mm.

GREY GREEN IGNIMBRITE, HARD FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART AT 45° TO CORE AXIS,. BROWN CLAY ON FRACTURES.

GREYI GNIMBRITE, HARD, FRESH TO SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 20cm APART, CALCITE VEIN PARALLEL TO CORE AXIS ALTERED. BROWN CLAY ON FRACTURES.

DPH | LOG | DESCRIPTION



GREYI GNIMBRITE, HARD, SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15cm APART, ALSO A VERTICAL FRACTURE IN THIS INTERVAL.

GREYI GNIMBRITE, HARD, SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15cm APART, BROWN CLAY ON FRACTURES

GREYI GNIMBRITE, HARD, VERY SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15 TO 30cm APART, RED CLAY ON FRACTURES

GREYI GNIMBRITE, HARD, VERY SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15 TO 30cm APART, RED CLAY ON FRACTURES

GREY IGNIMBRITE, HARD, MEDIUM WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15 TO 30cm APART, RED CLAY ON FRACTURES

GREYI GNIMBRITE, HARD, VERY SLIGHTLY WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15 TO 30cm APART, RED CLAY ON FRACTURES

GREY IGNIMBRITE, HARD, MEDIUM WEATHERED, FELDSPAR WHITE ALTERED TO 5mm, FRACTURES 15 TO 30cm APART, RED CLAY ON FRACTURES

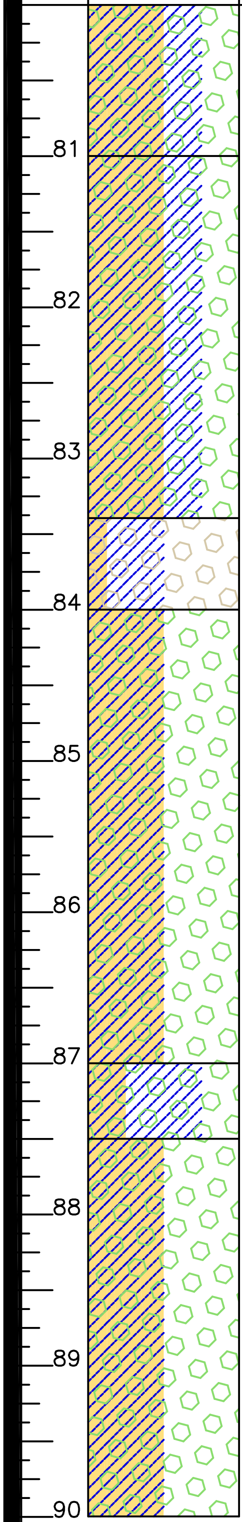
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–400–PC
PROJECT: BRANDY HILL EXTN
PAGE 5 OF 5

LOCATION: 56 376668, 6385668
DRILLED:
LOGGED: P BROWNE 13/9/11

DPH	LOG	DESCRIPTION



GREY GREEN, FINE GRAINED IGNIMBRITE EQUANT QUARTZ ANGULAR 3mm, FELDSPAR WHITE HIGHLY WEATHERED 2mm FRACTURES 80cm APART 45° TO CORE AXIS.

GREY GREEN, FINE GRAINED IGNIMBRITE EQUANT FELDSPAR WHITE HIGHLY WEATHERED 5mm FRACTURES 20cm APART 80° TO CORE AXIS. CALCITE VEINS 10° TO CORE AXIS, LARGER VEIN AT 82.0m

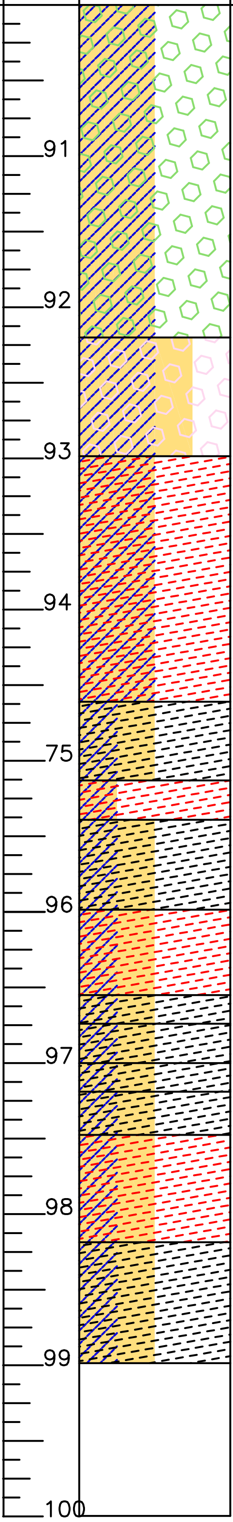
BROWN AND GREY GREEN, FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE EQUANT FRACTURES 20cm APART 80° TO CORE AXIS. CALCITE VEINS 10° TO CORE AXIS, NOW BROWN CLAYS

GREY GREEN, WITH MINOR RED ALTERATION IN PLACES, FINE GRAINED IGNIMBRITE. SLIGHTLY WEATHERED FRACTURES 30cm APART 80° TO CORE AXIS. CALCITE VEINS 10 TO 45° TO CORE AXIS, LARGER VEIN AT 85.0m, VERTICAL VEIN AT 86m

GREY GREEN,FINE GRAINED IGNIMBRITE. SLIGHTLY WEATHERED FRACTURES 10cm APART 10° TO CORE AXIS CALCITE FILLED AND WITH BROWN RED ALTERATION

GREY GREEN, WITH MINOR RED ALTERATION IN PLACES, MEDIUM GRAINED SLIGHTED WEATHERED IGNIMBRITE. FELDSPAR WHITE SLIGHTLY WEATHERED. FRACTURES 30cm APART 80° TO CORE AXIS. CALCITE VEINS 10 TO 45° TO CORE AXIS,

DPH	LOG	DESCRIPTION



GREY GREEN MINOR PINK AND GREEN FINE GRAINED HARD IGNIMBRITE, FRACTURES 40cm APART. CALCITE FILLED VEINS 45 TP 80° TO CORE AXIS

PINK FINE GRAINED HARD IGNIMBRITE.

RED TO PINK AND MINOR GREEN FINE GRAINED MEDIUM HARD TUFFACEOUS MUDSTONE

GREY GREEN FINE GRAINED MEDIUM HARD TUFFACEOUS MUDSTONE

RED FINE GRAINED MEDIUM HARD TUFFACEOUS MUDSTONE

PINK, MINOR GREEN, VERY FINE GRAINED MUDSTONE, CALCITE FRACTURE 45° TO CORE AXIS

RED FINE GRAIED MEDIUM HARD MUDSTONE CROSS BEDDED

GREEN FINE GRAINED FRACTURED MUDSTONE

PINK VERY FINE GRAINED MUDSTONE, CALCITE FRACTURE 45° TO CORE AXIS

GREEN AND VIOTEL MYLOTISED MUDSTONE.

PINK VERY FINE GRAINED MUDSTONE, FRACTURE 20cm APART

RED, VIOLET AND GREEN MYLOTISED MUDSTONE

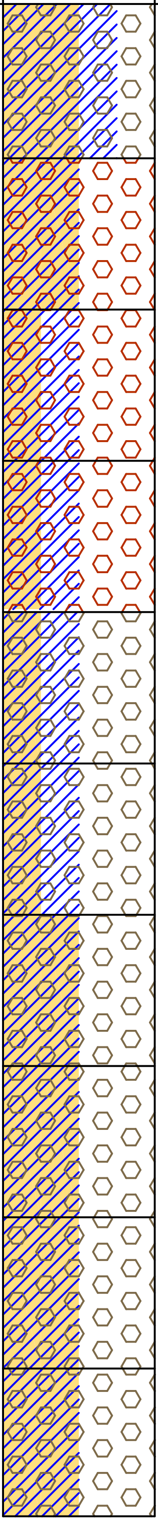
LIGHT GREY GREEN VERY FINE GRAINED MEDIUM HARD MUDSTONE CALCITE VEINS 90° TO CORE AXIS FRACTURES 60cm APART

HANSON CONSTRUCTION MATERIALS

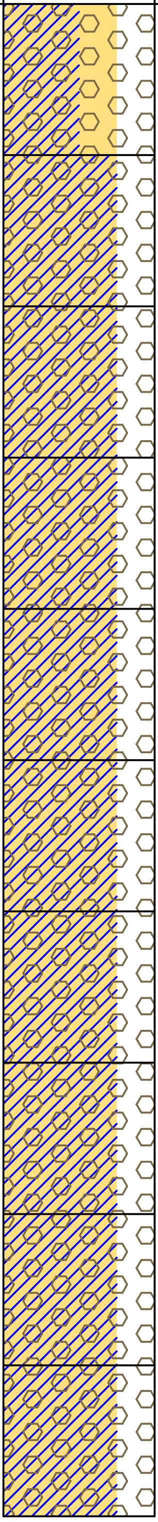
GRAPHIC DRILL LOG

HOLE: BH−401−DH
PROJECT: BRANDY HILL EXTENSION
PAGE 1 OF 3

LOCATION: 56 377298, 6385847
DRILLED:
LOGGED: P BROWNE 13/9/11



DPH	DESCRIPTION
1	RED BROWN AND GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
2	RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
3	RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
4	RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
5	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
6	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
7	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
8	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
9	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
10	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..



DPH	DESCRIPTION
11	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
12	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
13	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
14	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
15	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
16	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
17	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
18	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
19	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
20	RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..

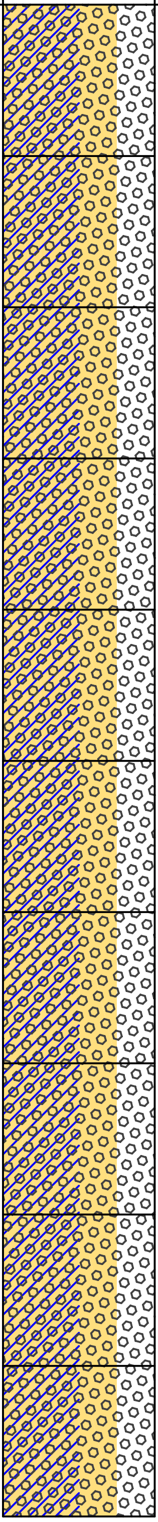
COMMENTS:

HANSON CONSTRUCTION MATERIALS

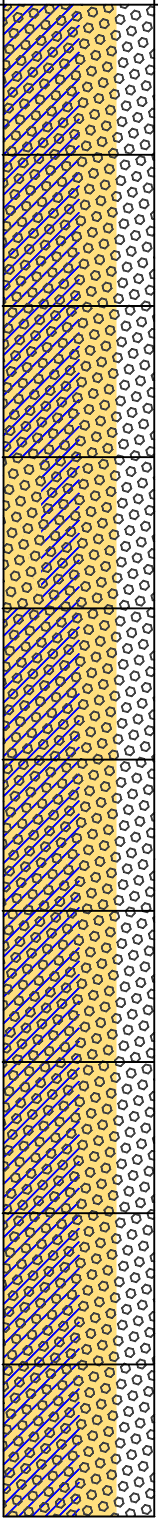
GRAPHIC DRILL LOG

HOLE: BHQ-401-DH
PROJECT: BRANDY HILL PIT
PAGE 2 OF 3

LOCATION: 473475,7696862 GDA
DRILLED:
LOGGED: P BROWNE 13/9/11



DPH	DESCRIPTION
	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
21	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
22	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
23	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
24	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
25	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
26	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
27	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
28	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
29	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
30	



DPH	DESCRIPTION
	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
31	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
32	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
33	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
34	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
35	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
36	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
37	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
38	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
39	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
40	

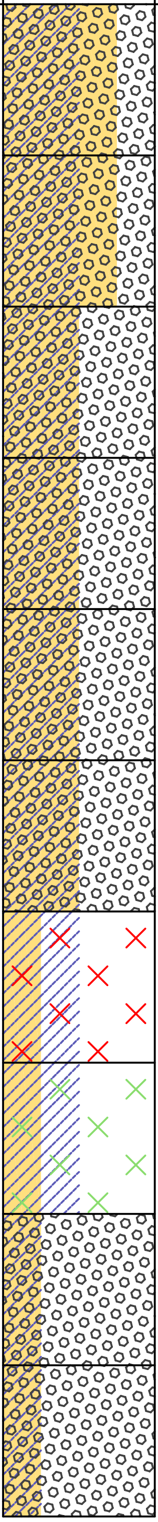
COMMENTS:

HANSON CONSTRUCTION MATERIALS

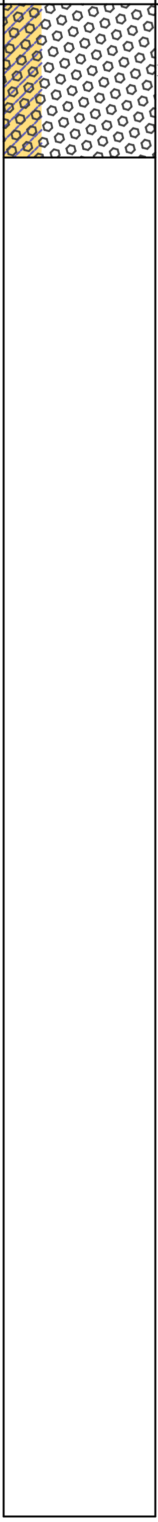
GRAPHIC DRILL LOG

HOLE: BH-401-PC
PROJECT: BRANDY HILL PIT
PAGE 3 OF 3

LOCATION:56 377298, 6385847
DRILLED:
LOGGED: P BROWNE 13/9/11



DPH	DESCRIPTION
41	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
42	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
43	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
44	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
45	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
46	DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
47	RED GRANITE
48	GREY NAD GREEN GRANITE
49	DARK GREY FINE GRAINED ALTERED IGNIMBRITE.
50	DARK GREY FINE GRAINED ALTERED IGNIMBRITE.



DPH	DESCRIPTION
51	DARK GREY FINE GRAINED ALTERED IGNIMBRITE.
52	
53	
54	
55	
56	
57	
58	
59	
60	

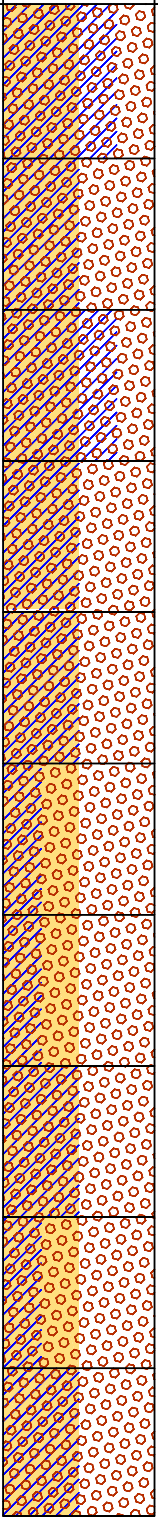
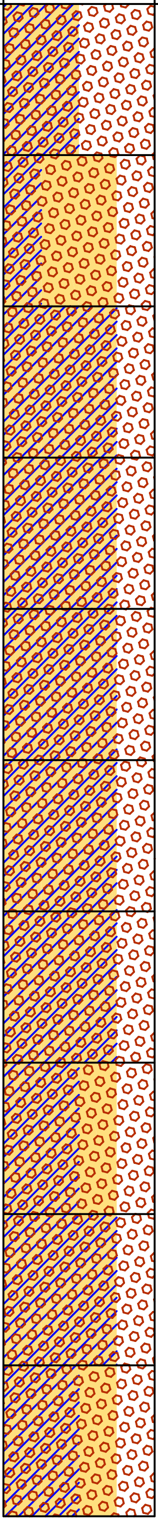
COMMENTS:

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH−400A−DH
PROJECT: BRANDY HILL PIT
PAGE 1 OF 3

LOCATION: 56 377937,6385796
DRILLED:
LOGGED: P BROWNE 13/9/11

DPH	LOG	DESCRIPTION
1		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
2		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
3		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
4		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
5		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
6		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
7		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
8		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
9		RED BROWN MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
10		RED BROWN AND GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
11		RED BROWN AND GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
12		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
13		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
14		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
15		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
16		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
17		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
18		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
19		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..
20		RED BROWN AND MINOR GREY MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE..

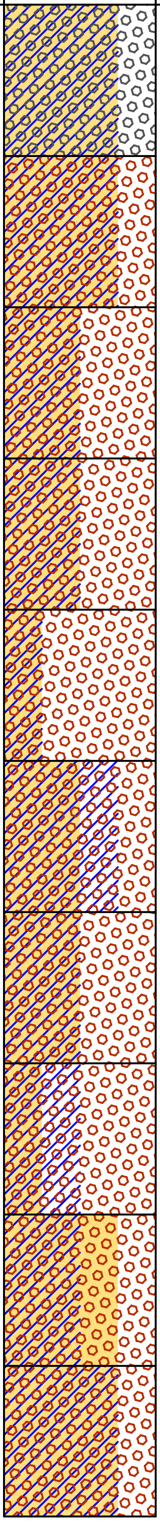
COMMENTS:

HANSON CONSTRUCTION MATERIALS

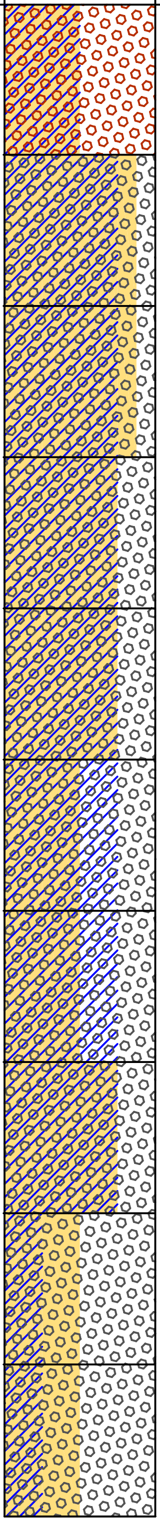
GRAPHIC DRILL LOG

HOLE: BHQ-401A-DH
PROJECT: BRANDY HILL PIT
PAGE 2 OF 3

LOCATION: 56 377937, 6385796
DRILLED:
LOGGED: P BROWNE 13/9/11



DPH	LOG	DESCRIPTION
21		DARK GREY FINE GRAINED MEDIUM HARD FRESH IGNIMBRITE.
22		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
23		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
24		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
25		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
26		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
27		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
28		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
29		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
30		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.



DPH	LOG	DESCRIPTION
31		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
32		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
33		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
34		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
35		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
36		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
37		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
38		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
39		DARK GREY AND RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
40		DARK GREY AND RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.

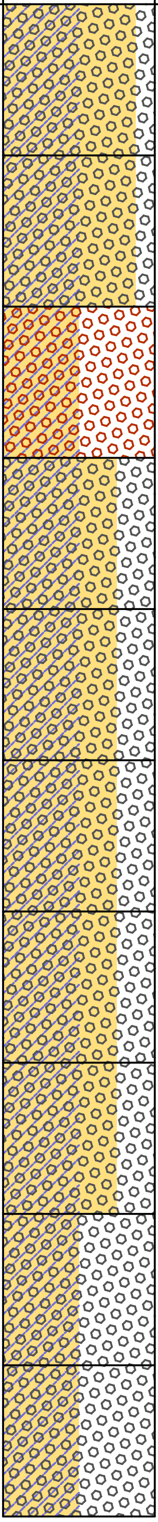
COMMENTS:

HANSON CONSTRUCTION MATERIALS

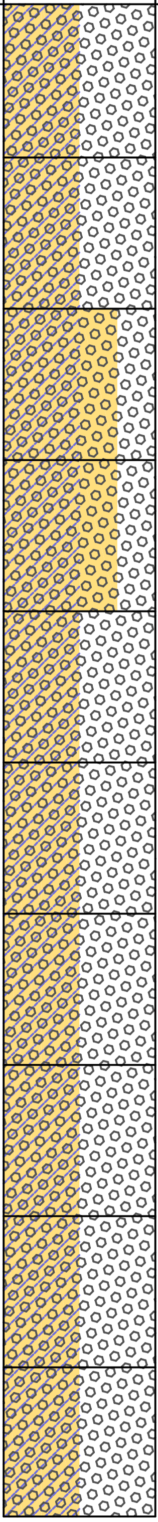
GRAPHIC DRILL LOG

HOLE: BH-401A-PC
PROJECT: BRANDY HILL PIT
PAGE 3 OF 3

LOCATION:56 377937, 6385796
DRILLED:
LOGGED: P BROWNE 13/9/11



DPH	LOG	DESCRIPTION
41		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
42		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
43		RED BROWN FINE GRAINED MEDIUM HARD WEATHERED IGNIMBRITE.
44		DARK GREY FINE GRAINED MEDIUM HARD IGNIMBRITE.
45		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
46		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
47		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
48		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
49		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
50		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.



DPH	LOG	DESCRIPTION
51		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
52		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
53		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
54		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
55		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
56		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
57		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
58		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
59		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.
60		DARK GREY FINE GRAINED MEDIUM HARD SLIGHTLY WEATHERED IGNIMBRITE.

COMMENTS:

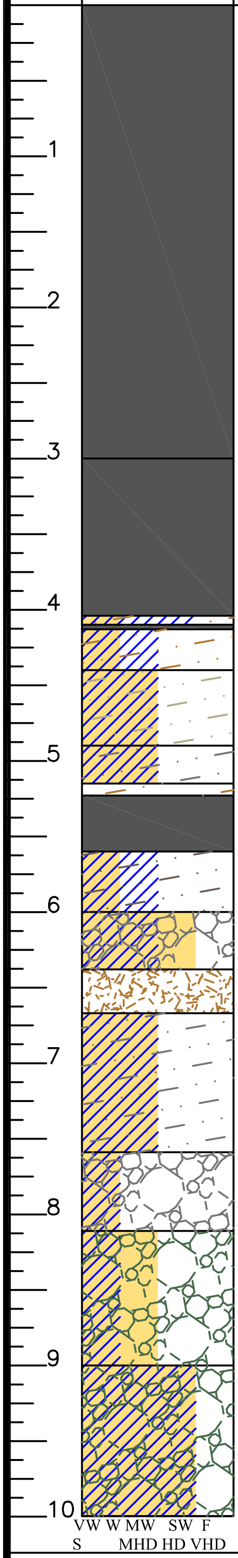
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1401-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 4

LOCATION: 377467,6385110 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



NO CORE

NO CORE

BROWN SANDSTONE VERY FINE GRAINED

NO CORE

BROWN SANDSTONE VERY FINE GRAINED, FRACTURES 9cm APART

GREY BROWN FINE GRAINED SANDSTONE, FRACTURES BROWN CLAY FILLED IRON STAINING

GREY MEDIUM SANDSTONE, MANY FRACTURES AT ALL ANGLES BROWN CLAY LINED

BROWN SANDSTONE FINE GRAINED

NO CORE

BROWN GREY SANDSTONE MEDIUM GRAINED BROWN, FRACTURES 20cm APART BROWN CLAY LINED

GREY CONGLOMERATE GRAINS TO 40mm ROUNDED EQUANT QUARTZ & SANDSTONE. VERTICAL FRACTURE BROWN CLAY

VERTICAL FRACTURE BROWN CLAY LINED

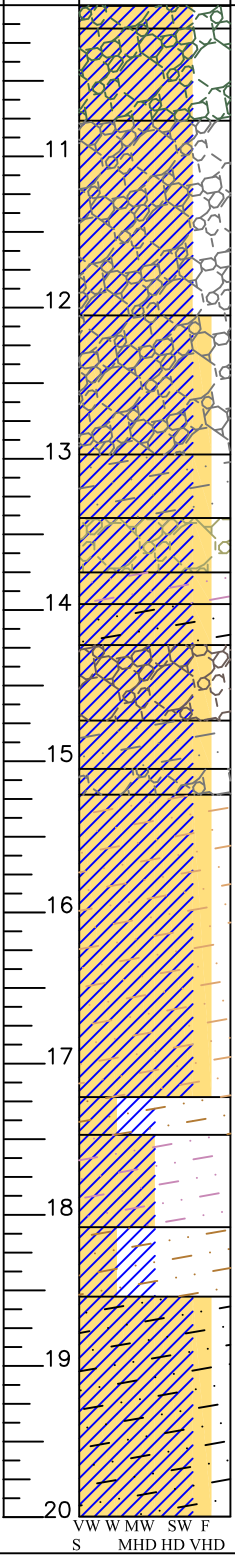
GREY SANDSTONE

GREY CONGLOMERATE GRAINS TO 30mm ANGULAR EQUANT VERTICAL FRACTURE

GREY GREEN CONGLOMERATE GRAINS TO 50mm SANDSTONE EQUANT ANGULAR

GREY GREEN CONGLOMERATE GRAINS TO 50cm ROUNDED, EQUANT QUARTZ & SANDSTONE, FRACTURES 23cm APART, FRACTURES

DPH | LOG | DESCRIPTION



A/A VERTICAL FRACTURE BROWN CLAY LINED

GREY CONGLOMERATE GRAINS TO 20mm SANDSTONE SOME OXIDISED, FRACTURES 20cm APART, FRACTURES

GREY & BROWN CONGLOMERATE GRAINS TO 30mm SANDSTONE & QUARTZ EQUANT ROUNDED, FRACTURES 20cm

GREY QUARTZ SANDSTONE, FRACTURES 45° TO CORE AXIS

BROWN GREEN CONGLOMERATE GRAINS TO 30mm SANDSTONE AND SILTSTONE

VIOLET GREY VERY FINE GRAINED SANDSTONE

VIOLET VERY FINE GRAINED SANDSTONE BANDED

BROWN GREY CONGLOMERATE GRAINS TO 50mm SANDSTONE

GREY FINE GRAINED SANDSTONE F 0.05cm BROWN CLAY ON FRACTURES

GREY CONGLOMERATE GRAINS TO 14mm

PINK GREY MEDIUM SANDSTONE, FRACTURES 30cm APART

BROWN SANDSTONE HIGHLY FRACTURED

VIOLET GREY MEDIUM GRAINED SANDSTONE, FRACTURES .2cm APART BROWN CLAY ON FRACTURES

BROWN FINE GRAINED SANDSTONE, FRACTURES 25cm APART

PINK & GREY SANDSTONE VERY FINE GRAINED SMALL LENS COARSE SANDSTONE , FRACTURES 50cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

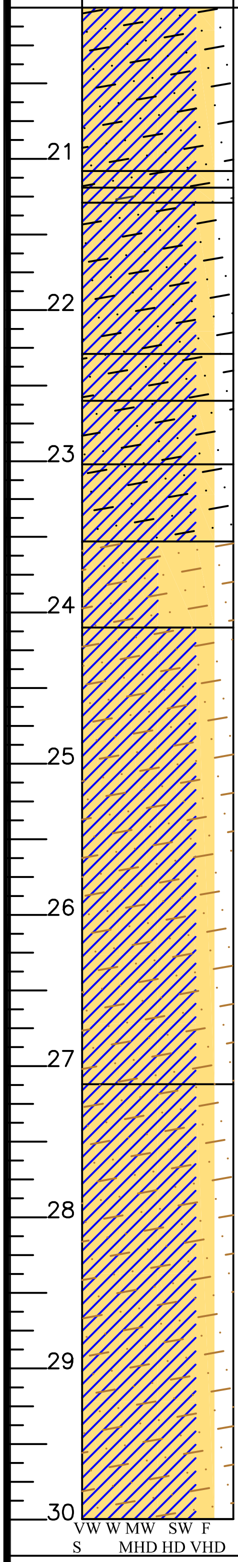
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1401-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 4

LOCATION: 377467,6385110 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



A/A

DARK GREY SANDSTONE, FRACTURES 45° TO CORE AXIS

PINK & GREY SANDSTONE VERY FINE GRAINED SMALL LENS COARSE SANDSTONE , FRACTURES 20cm APART

PINK & GREY SANDSTONE HIGHLY FRACTURED BROWN CLAY ON FRACTURES

PINK & GREY SANDSTONE VERY FINE GRAINED SMALL LENS COARSE SANDSTONE

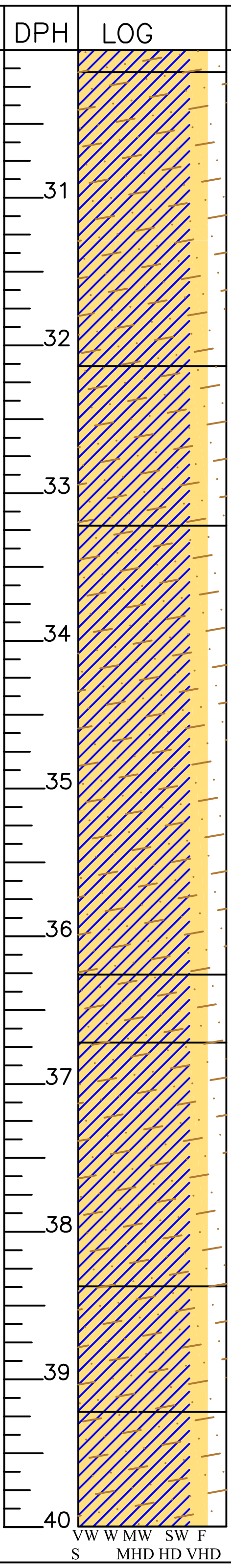
PINK & GREY SANDSTONE MEDIUM GRAINED SMALL LENS COARSE SANDSTONE

BROWN SANDSTONE VERY FINE GRAINED WITH GREY CLASTS

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS, FRACTURES 10 TO 100cm APART

DPH | LOG | DESCRIPTION



BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS, FRACTURES 10cm APART

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

BROWN FINE GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED AND CC SANDSTONE AND CLAY CLASTS

BROWN FINE GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED AND CC SANDSTONE AND CLAY CLASTS

BROWN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

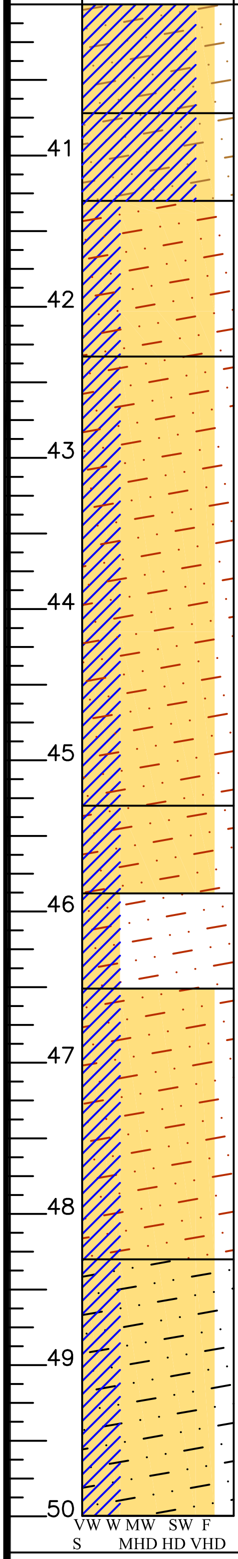
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1401–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 3 OF 4

LOCATION: 377467,6385110 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



BROWN & GREEN MEDIUM GRAINED SANDSTONE WITH BANDS VERY FINE GRAINED SANDSTONE AND CLAY CLASTS

ALTERNATING RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE

ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE, FRACTURES 40cm APART

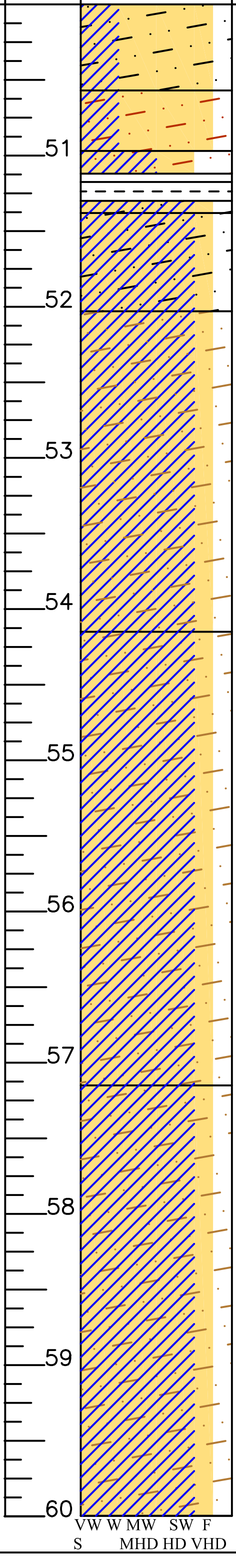
ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE, FRACTURES 40cm APART

HIGHLY FRACTURED ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE

ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE

ALTERNATING MAINLY GREEN AND RED BROWN LAYERED VERY FINE GRAINED SANDSTONE, FRACTURES 40cm APART

DPH | LOG | DESCRIPTION



ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE, FRACTURES 40cm APART

ALTERNATING MAINLY RED BROWN AND GREEN LAYERED VERY FINE GRAINED SANDSTONE, FRACTURES 5cm APART

CLAYS

LAYERED SANDSTONE

RED MEDIUM GRAINED SANDSTONE

BROWN MEDIUM GRAINED SANDSTONE

BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

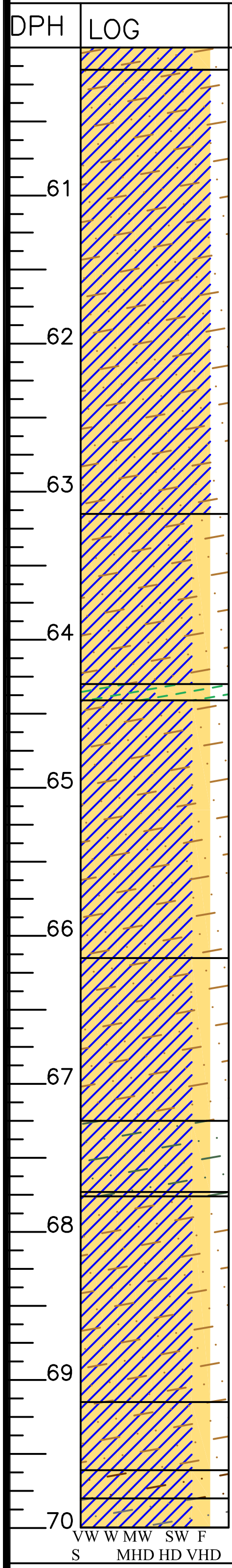
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1401-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 4

LOCATION: 377467,6385110 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED AND COARSE SANDSTONE LAYERS PERPENDICULAR TO CORE AXIS

BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

GREEN VERY FINE GRAINED SILTSTONE LAYERS 50° TO CORE AXIS

BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

GREEN GREY MEDIUM GRAINED SANDSTONE POORLY SORTED SOME SILTSTONE LAYERS

COARSE SANDSTONE LAYER

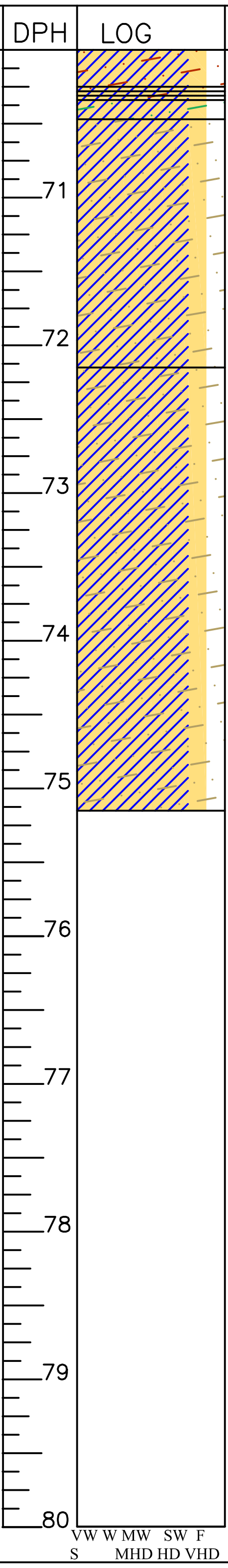
BROWN MEDIUM GRAINED SANDSTONE MINOR VERY FINE GRAINED LAYERS

BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED AND MINOR VERY FINE GRAINED LAYERS, FRACTURES 100cm APART

DARK BROWN MEDIUM GRAINED SANDSTONE MOTTLED VIOLET ALTERATION

GREY MEDIUM GRAINED SANDSTONE MOTTLED VIOLET ALTERATION

DPH | LOG | DESCRIPTION



RED BROWN VERY FINE GRAINED SANDSTONE

COARSE SANDSTONE LAYER

RED BROWN VERY FINE GRAINED SANDSTONE

COARSE SANDSTONE LAYER

GREEN AND RED BROWN FINE GRAINED SANDSTONE

LIGHT & CHOCOLATE BROWN MEDIUM GRAINED SANDSTONE MOTTLED VIOLET ALTERATION FRACTURES 100cm

LIGHT & CHOCOLATE BROWN MEDIUM GRAINED SANDSTONE MOTTLED VIOLET ALTERATION FRACTURES 30 TO 100cm

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

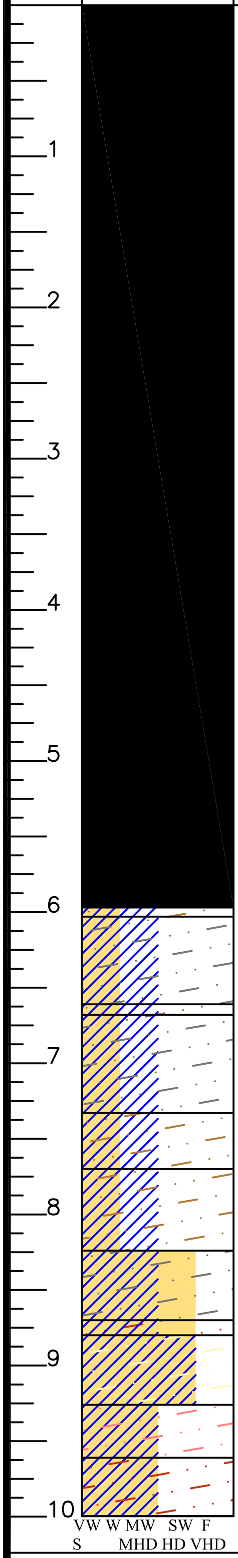
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1402-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 4

LOCATION: 377445, 6385345GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



NO CORE

BROWN VERY FINE GRAINED SANDSTONE

GREY VERY FINE GRAINED SANDSTONE CLAY CLASTS, FRACTURES 45° TO CORE AXIS

BROWN VERY FINE GRAINED SANDSTONE

GREY VERY FINE GRAINED SANDSTONE CLAY CLASTS, FRACTURES 10 TO 30cm APART BROWN LIGHT

BROWN VERY FINE GRAINED SANDSTONE ONION WEATHERING

BROWN VERY FINE GRAINED SANDSTONE ONION WEATHERING

GREY VERY FINE GRAINED SANDSTONE CLAY CLASTS, FRACTURES 10 TO 30cm APART BROWN LIGHT

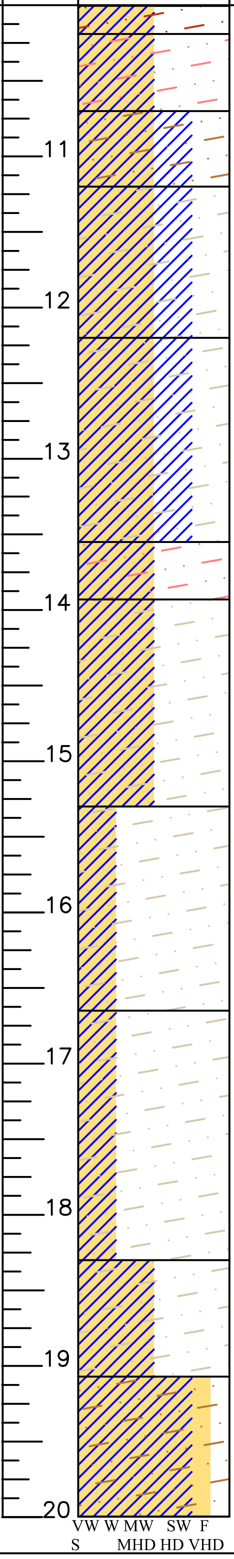
RED BROWN VERY FINE GRAINED SANDSTONE LAYERED

OFF WHITE VERY FINE GRAINED SANDSTONE MINOR CLAY LAYERS, FRACTURES

PINK VERY FINE GRAINED SANDSTONE

RED BROWN VERY FINE GRAINED SANDSTONE ONION WEATHERING

DPH | LOG | DESCRIPTION



PINK VERY FINE GRAINED SANDSTONE

BROWN VERY FINE GRAINED SANDSTONE MINOR LIMONITE

LIGHT BROWN VERY FINE GRAINED SANDSTONE WITH CHOCOLATE BROWN LAYERS 80° TO CORE AXIS

LIGHT BROWN VERY FINE GRAINED SANDSTONE WITH CHOCOLATE BROWN LAYERS 80° TO CORE AXIS, FRACTURES 50cm AND ONE 10° TO CORE AXIS LIMONITE FILLED. ONION WEATHERING

PINK VERY FINE GRAINED SANDSTONE

LIGHT BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED AND ONE 10° TO CORE AXIS LIMONITE FILLED

LIGHT BROWN VERY FINE GRAINED SANDSTONE WITH CHOCOLATE BROWN LAYERS PERPENDICULAR TO CORE AXIS, FRACTURES 16cm APART FRACTURED AND ONE 10° TO CORE AXIS LIMONITE FILLED

LIGHT BROWN VERY FINE GRAINED SANDSTONE

BROWN MEDIUM COARSE SANDSTONE GRAINS TO 5mm CLASTIC & QUARTZ FRAGMENTS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

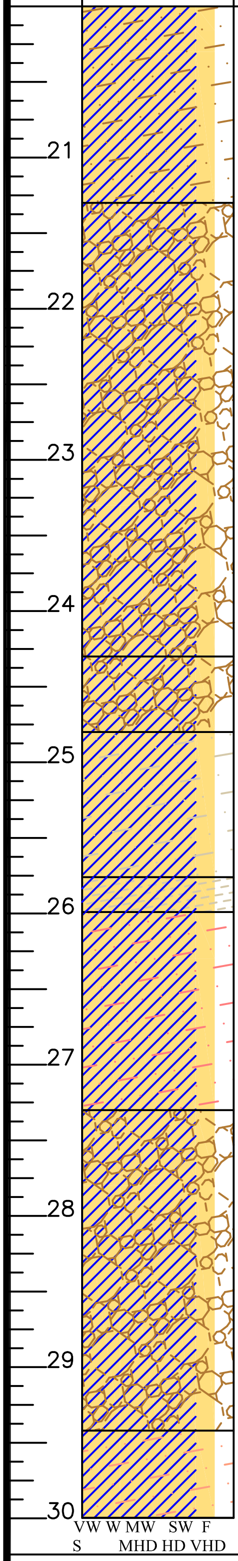
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1402–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 4

LOCATION: 377445, 6385345GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



BROWN MEDIUM COARSE CONGLOMERATE GRAINS TO 14mm CLASTIC & QUARTZ FRAGMENTS POORLY SORTED WITH NO BEDDING

BROWN MEDIUM COARSE CONGLOMERATE GRAINS TO 14mm CLASTIC & QUARTZ FRAGMENTS POORLY SORTED WITH NO BEDDING

LIGHT BROWN VERY FINE GRAINED SANDSTONE NO BEDDING

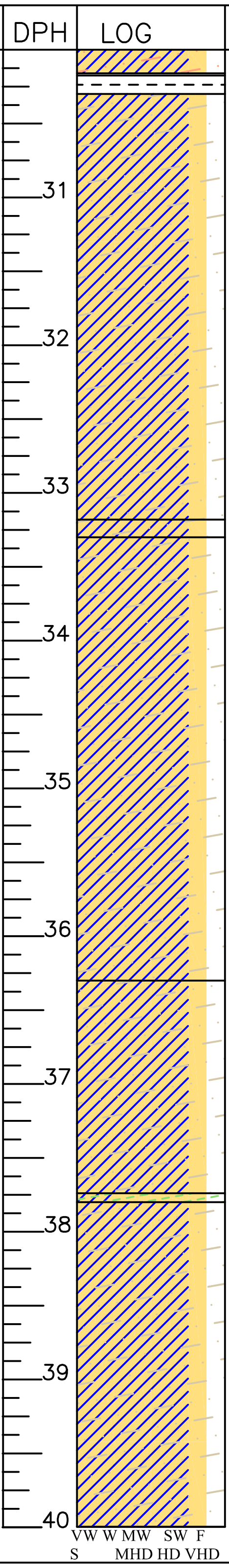
LIGHT BROWN MUDSTONE BEDDING 80° TO CORE AXIS

PINK MEDIUM GRAINED SANDSTONE WEAK BEDDING

BROWN MEDIUM COARSE CONGLOMERATE GRAINS TO 14mm CLASTIC & QUARTZ FRAGMENTS POORLY SORTED WITH NO BEDDING

LIGHT PINK MEDIUM GRAINED SANDSTONE SOME COARSE SANDSTONE LAYERS

DPH | LOG | DESCRIPTION



CORE LOSS

PINK AND LIGHT BROWN FINE GRAINED SANDSTONE, FRACTURES 30cm APART MEDIUM

PINK AND LIGHT BROWN FINE GRAINED SANDSTONE FRACTURED MEDIUM

PINK AND LIGHT BROWN FINE GRAINED SANDSTONE, FRACTURES 30cm APART MEDIUM

LIGHT BROWN COARSE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS, FRACTURES 10 TO 100cm APART MEDIUM

LIGHT GREEN GREY MUDSTONE

LIGHT BROWN FINE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS AND RARE LARGE PEBBLES, FRACTURES 30cm APART MEDIUM

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

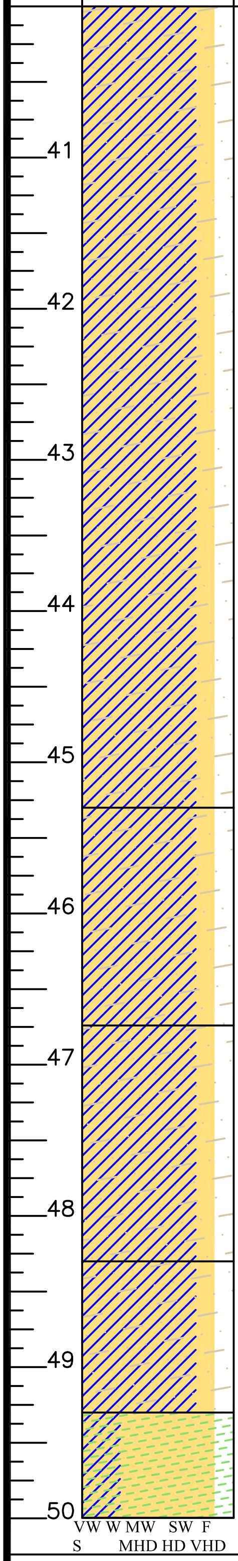
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1402–DH
PROJECT BRANDY HILL, ZONE 56
PAGE 3 OF 4

LOCATION:377445, 6385345GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



LIGHT BROWN WITH VIOLET BANDS COARSE GRAINED SANDSTONE POORLY SORTED, FRACTURES 10 TO 100cm APART MEDIUM

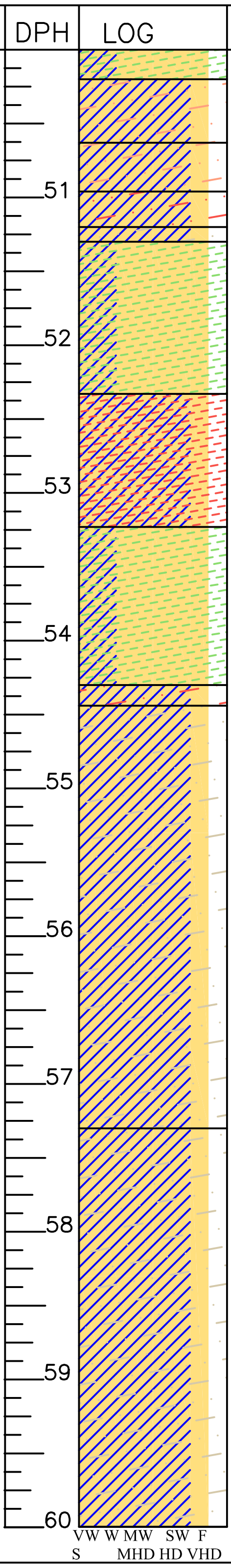
LIGHT BROWN WITH VIOLET BANDS COARSE GRAINED SANDSTONE POORLY SORTED, FRACTURES 10 TO 100cm APART MEDIUM

LIGHT BROWN FINE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS AND RARE LARGE PEBBLES, FRACTURES 20cm APART MEDIUM

LIGHT BROWN COARSE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS, FRACTURES 10 TO 100cm APART MEDIUM

LIGHT GREEN GREY MUDSTONE

DPH LOG DESCRIPTION



LIGHT PINK COARSE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS, MEDIUM

LIGHT PINK FINE GRAINED SANDSTONE FRACTURES 15cm APART MEDIUM

LIGHT RED FINE GRAINED SANDSTONE FRACTURES 15cm APART MEDIUM

LIGHT BROWN FINE GRAINED SANDSTONE POORLY SORTED MINOR LIGHT PINK LAYERS AND RARE LARGE PEBBLES, FRACTURES 30cm APART MEDIUM

LIGHT GREEN GREY MUDSTONE

LIGHT RED FINE GRAINED MUDSTONE FRACTURES 15cm APART MEDIUM

LIGHT GREEN GREY MUDSTONE

LIGHT RED MEDIUM GRAINED SANDSTONE FRACTURES 35cm APART MEDIUM

LIGHT BROWN FINE GRAINED WITH LAYERS OF MEDIUM GRAINED SANDSTONE FRACTURES 25cm APART

LIGHT BROWN FINE GRAINED WITH LAYERS OF MEDIUM GRAINED SANDSTONE FRACTURES 25 TO 70cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

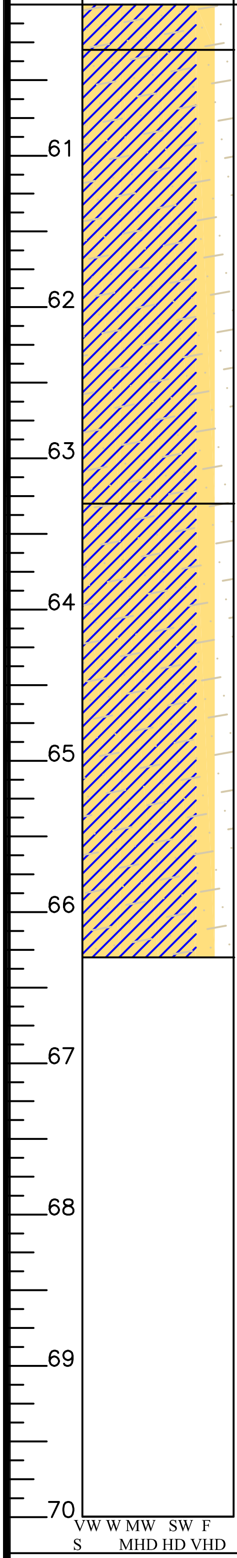
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1402-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 4

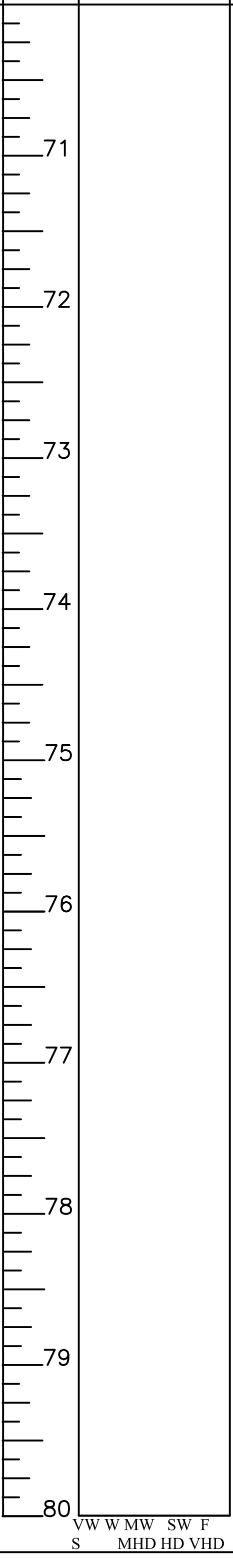
LOCATION: 377445, 6385345GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH	LOG	DESCRIPTION	DPH	LOG	DESCRIPTION



LIGHT BROWN FINE GRAINED WITH LAYERS OF MEDIUM GRAINED SANDSTONE APART

LIGHT BROWN FINE GRAINED WITH LAYERS OF MEDIUM GRAINED SANDSTONE APART



COMMENTS:

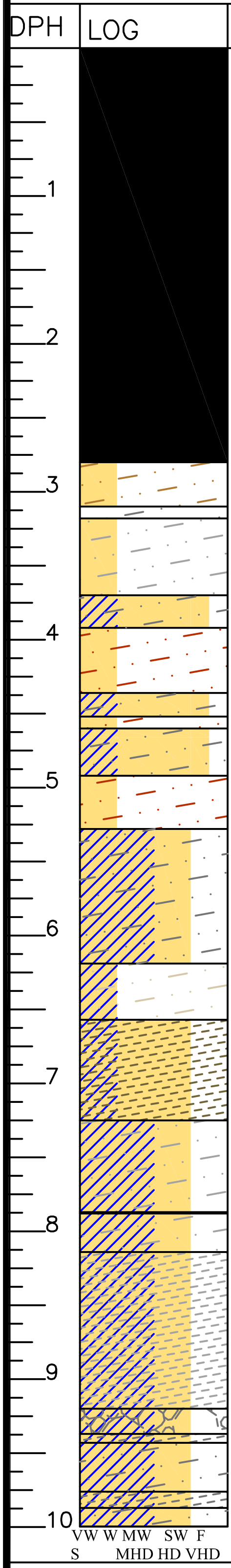
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1403-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14



DESCRIPTION

NO CORE

BROWN VERY FINE GRAINED SANDSTONE

FRACTURED ZONE

LIGHT GREY MINOR BROWN VERY FINE GRAINED SANDSTONE LAYERED WITH BLACK CLAY CLASTS, FRACTURES 30cm APART

GREY VERY FINE GRAINED SANDSTONE BLACK LAYERED CLASTS

RED BROWN VERY FINE GRAINED SANDSTONE LAYERED FRACTURED

GREY VERY FINE GRAINED SANDSTONE BLACK LAYERED CLASTS

RED BROWN VERY FINE GRAINED SANDSTONE LAYERED FRACTURED

GREY VERY FINE GRAINED SANDSTONE BLACK LAYERED CLASTS

RED BROWN VERY FINE GRAINED SANDSTONE LAYERED FRACTURED

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & CLASTS TO 5mm, FRACTURES 20cm APART

LIGHT BROWN VERY FINE GRAINED SANDSTONE POOR BEDDING, FRACTURES 5cm APART

OFF WHITE WITH DARK CHOCOLATE BROWN MUDSTONE LAYERS PERPENDICULAR TO CORE AXIS, FRACTURES 15cm APART

LIGHT GREY COARSE GRAINED SANDSTONE POORLY SORTED

FRACTURED ZONE

LIGHT GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & CLASTS

LIGHT GREY VERY FINE GRAINED MUDSTONE BLACK LAYERS

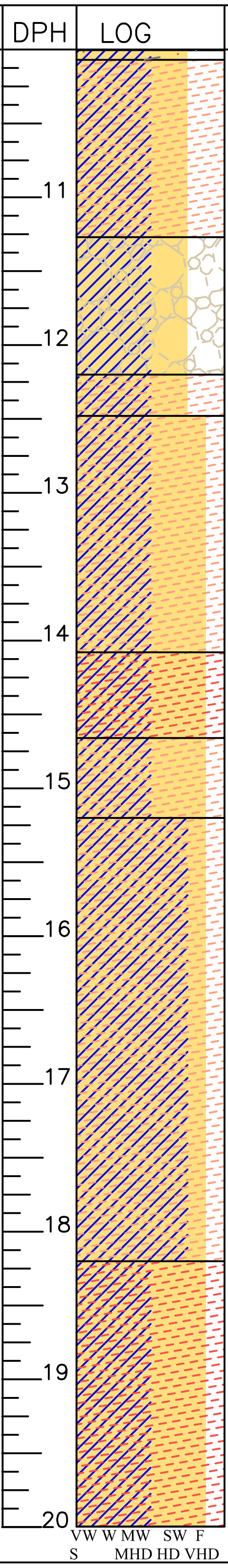
GREY CONGLOMERATE GRAINS TO 30mm MAINLY FELDSPAR & SANDSTONE

GREY MUDSTONE LAYERS 80° TO CORE AXIS

GREY VERY COARSE GRAINED SANDSTONE POORLY SORTED

GREY MUDSTONE

GREY VERY COARSE GRAINED SANDSTONE POORLY SORTED



DESCRIPTION

LIGHT PINK MUDSTONE WITH CHOCOLATE BROWN LENS

LIGHT BROWN CONGLOMERATE GRAINS TO 20mm POORLY SORTED

LIGHT PINK MUDSTONE WITH LIMONITE 45° TO CORE AXIS AND PERPENDICULAR TO CORE AXIS

LIGHT PINK MUDSTONE MINOR COARSE SANDSTONE CLASTS

LIGHT RED MUDSTONE WITH CHOCOLATE BROWN LIMONITE BANDS

LIGHT PINK MUDSTONE

LIGHT PINK MUDSTONE MINOR, FRACTURES 45° TO CORE AXIS

LIGHT RED MUDSTONE,, FRACTURES 30cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

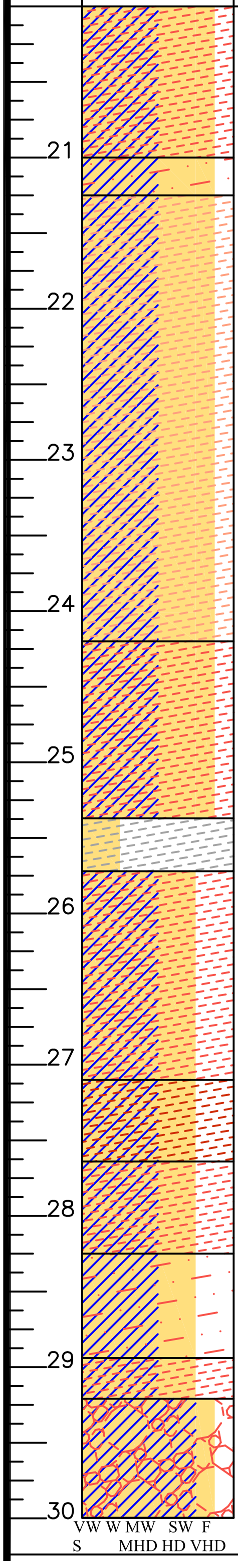
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1403-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



LIGHT RED VERY FINE TO COARSE GRAINED SANDSTONE POORLY SORTED

RED AND LIGHT PINK MUDSTONE LAYERED 80° TO CORE AXIS FR100cm APART

LIGHT RED MUDSTONE SOME DARK RED CLASTS

LIGHT GREY MUDSTONE FRACTURED

LIGHT RED MUDSTONE WITH DARK RED LAYERS 80° TO CORE AXIS, FRACTURES 30cm APART

RED MUDSTONE WITH DARK RED LAYERS 70° TO CORE AXIS

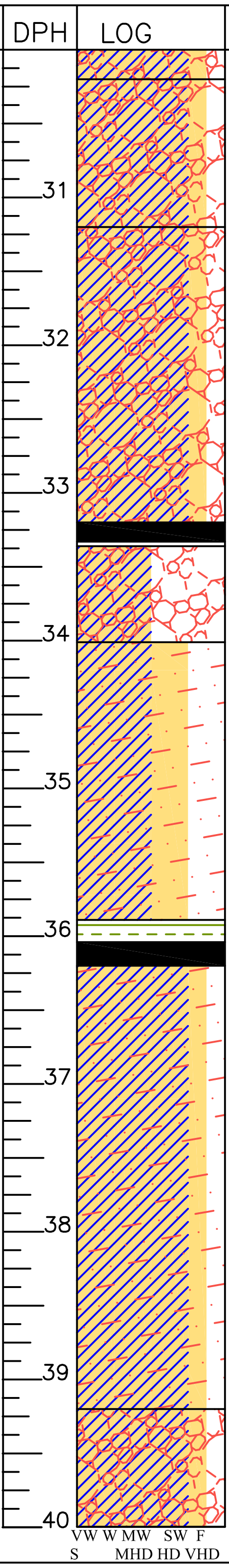
LIGHT RED & LIGHT GREEN MUDSTONE LAYERS 80° TO CORE AXIS

LIGHT RED VERY FINE GRAINED SANDSTONE POORLY SORTED

MAINLY LIGHT RED MINOR LIGHT GREEN MUDSTONE

LIGHT RED CONGLOMERATE WITH FRAGMENTS TO 14mm MAINLY FELDSPAR & MINOR QUARTZ

DPH | LOG | DESCRIPTION



LIGHT RED CONGLOMERATE WITH FRAGMENTS TO 14mm MAINLY FELDSPAR & MINOR QUARTZ

LIGHT RED CONGLOMERATE WITH FRAGMENTS TO 14mm MAINLY FELDSPAR & MINOR QUARTZ

NO CORE
OLIVE CLAY

LIGHT RED MEDIUM GRAINED CONGLOMERATE, FRACTURES 20cm

LIGHT RED VERY FINE GRAINED SANDSTONE MINOR DARK RED BANDS 80° TO CORE AXIS

OLIVE CLAY

NO CORE

LIGHT RED COARSE GRAINED SANDSTONE POORLY SORTED SANDSTONE FRAGMENTS, FRACTURES 50cm

LIGHT RED CONGLOMERATE FRAGMENTS TO 60mm WITH ROCK FRAGMENTS FELDSPAR & AND MINOR QUARTZ AND VOLCANIC, FRACTURES 30 TO 100cm

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

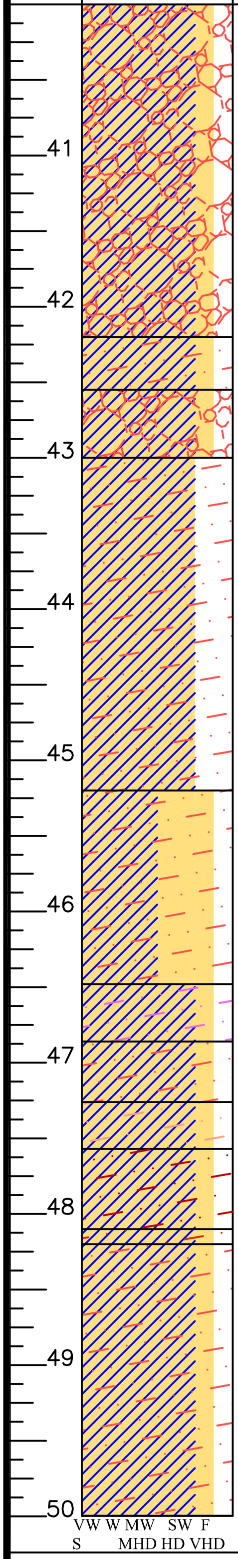
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1403–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 3 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



LIGHT RED COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR FRAGMENTS

LIGHT RED CONGLOMERATE FRAGMENTS TO 30mm MAINLY SANDSTONE SOME VOLCANIC

LIGHT RED AND PINK COARSE GRAINED SANDSTONE POORLY SORTED

LIGHT RED MEDIUM GRAINED SANDSTONE POORLY SORTED SOME LAMINAE INCLINED

VIOLET & RED MEDIUM GRAINED SANDSTONE LAMINAE PERPENDICULAR TO CORE AXIS

LIGHT RED MEDIUM TO COARSE GRAINED SANDSTONE POORLY SORTED

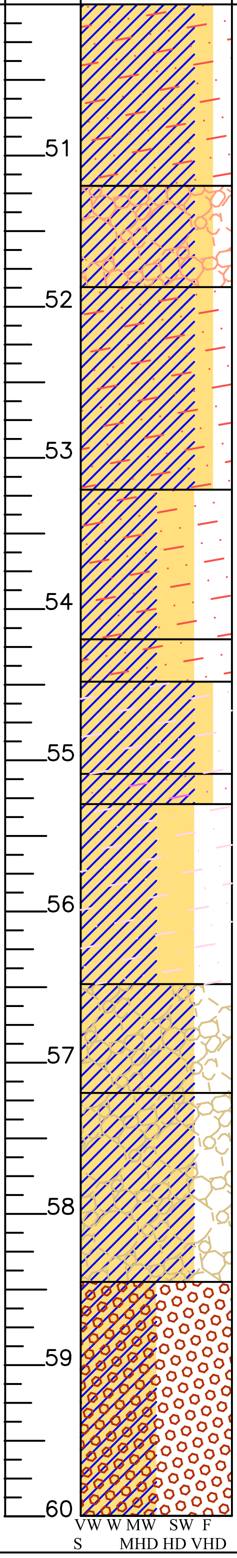
LIGHT PINK FINE GRAINED SANDSTONE NO BEDDING

DARK RED MEDIUM GRAINED SANDSTONE LAMINAE PERPENDICULAR TO CORE AXIS

RED MEDIUM GRAINED SANDSTONE

LIGHT RED MEDIUM GRAINED SOME COARSE GRAINED SANDSTONE MINOR X BEDDING POORLY SORTED, FRACTURES 60cm

DPH | LOG | DESCRIPTION



LIGHT PINK CONGLOMERATE FRAGMENTS 40mm MAINLY FELDSPAR

LIGHT RED VERY COARSE GRAINED SANDSTONE POORLY SORTED LITHIC FRAGMENTS TO 10mm FELDSPAR

LIGHT RED MEDIUM GRAINED SANDSTONE VERTICAL FRACTURE

LIGHT RED MEDIUM GRAINED SANDSTONE VERTICAL FRACTURE

LIGHT VIOLET MEDIUM GRAINED SANDSTONE SOME LARGER FRAGMENTS ROUNDED

VIOLET FINE GRAINED SANDSTONE

VIOLET LIGHT RED VERY FINE GRAINED SANDSTONE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 25cm

LIGHT YELLOW BROWN CONGLOMERATE FRAGMENTS 14mm FELDSPAR POORLY SORTED

LIGHT YELLOW BROWN CONGLOMERATE FRAGMENTS 14mm FELDSPAR POORLY SORTED

RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm APART SOME CALCITE ON FRACTURES

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

Hanson HEIDELBERGCEMENTGroup

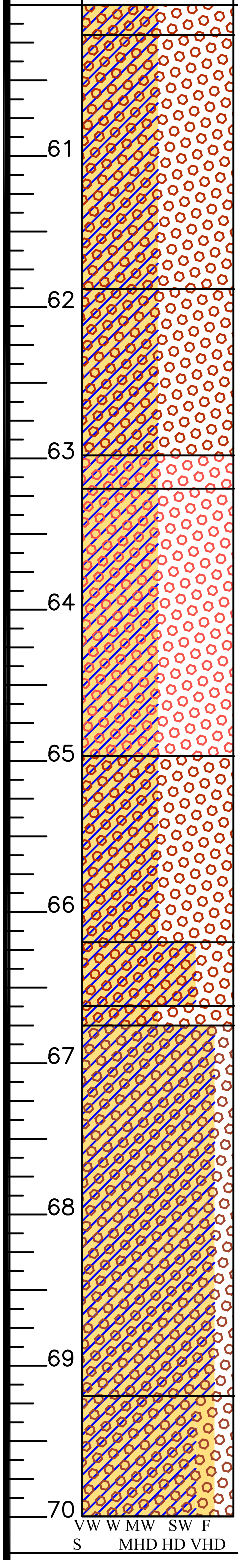
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1403-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm APART SOME CALCITE ON FRACTURES

RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm APART AND 15° TO CORE AXIS SOME CALCITE ON FRACTURES

LIGHT RED FINE GRAINED IGNIMBRITE FELDSPAR 2mm SOME CALCITE ON FRACTURES

LIGHT RED FINE GRAINED IGNIMBRITE FELDSPAR 2mm SOME CALCITE ON FRACTURES

RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm SOME CALCITE ON FRACTURES

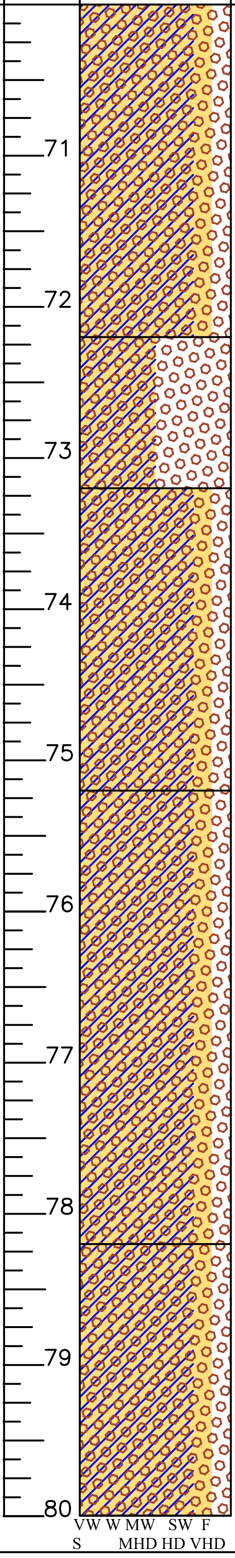
RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm

RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm CALCITE ON FRACTURES

DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 40cm CALCITE LINED

DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 35cm SOME CALCITE ON FRACTURES ALSO VERTICAL FRACTURE

DPH | LOG | DESCRIPTION



DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm HIGHLY FRACTURED CALCITE VEINS ALL ANGLES

DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 40cm

DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 40cm

DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 40cm

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

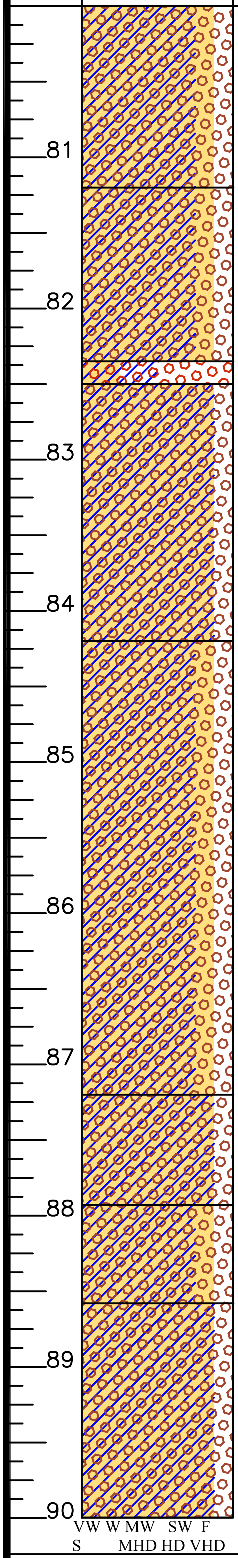
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1403–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 5 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm

RED FINE GRAINED IGNIMBRITE

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm

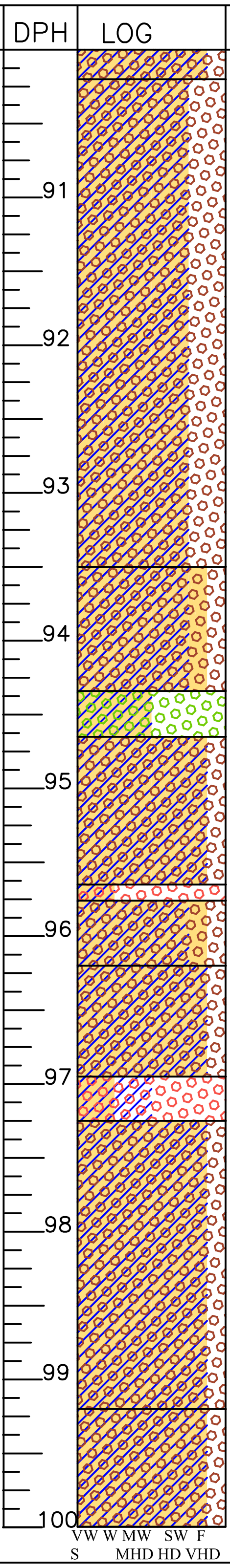
DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm VERTICAL CALCITE
VEIN @ 86.2m

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm VERTICAL FRACTURE

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm APART

DPH | LOG | DESCRIPTION



DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm APART CALCITE
FILLED

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm APART CALCITE
FILLED

LIGHT RED GREEN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm FRACTURED CALCITE FILLED

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm

LIGHT RED VERY FINE GRAINED IGNIMBRITE
CALCITE VEIN

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 30cm

LIGHT RED DARK FINE GRAINED IGNIMBRITE
CALCITE PRESENT

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm CALCITE FILLED

DARK RED BROWN FINE GRAINED IGNIMBRITE
FELDSPAR 2mm, FRACTURES 40cm CALCITE VEIN
@ 100

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

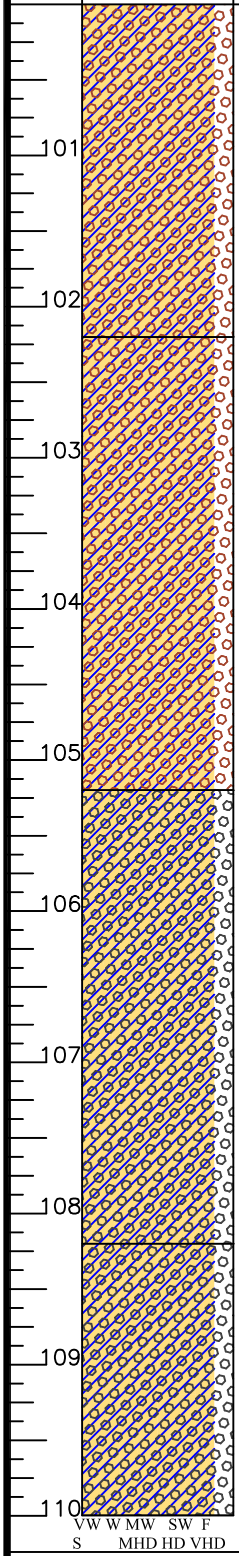
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1403–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 6 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION

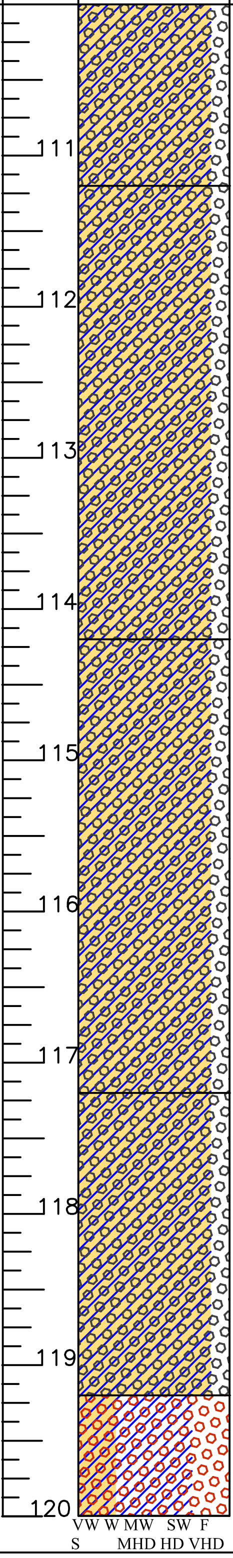


DARK RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR 2mm, FRACTURES 40cm

DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 3mm, FRACTURES 40 TO 80cm

DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 4mm, FRACTURES 30cm SOME 45° TO CORE AXIS

DPH | LOG | DESCRIPTION



DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 3mm, FRACTURES 40cm

DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 3mm, FRACTURES 40cm

DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 3mm, FRACTURES 40cm

RED FINE GRAINED IGNIMBRITE GROUNDMASS LIGHT

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨 ▨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD

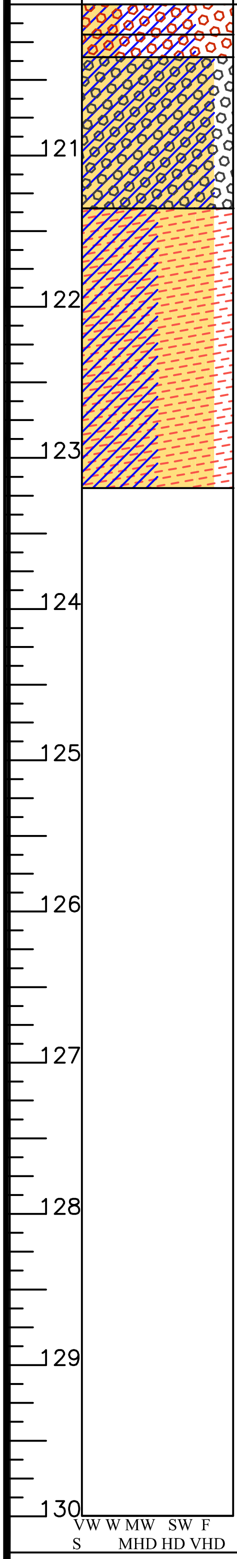
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1403-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 7 OF 7

LOCATION: 377250, 6385303GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH	LOG	DESCRIPTION	DPH	LOG	DESCRIPTION



RED FINE GRAINED IGNIMBRITE GROUNDMASS LIGHT

DARK GREY FINE GRAINED IGNIMBRITE FELDSPAR 3mm, FRACTURES 40cm

LIGHT RED MUDSTONE

131
132
133
134
135
136
137
138
139
140

VW W MW SW F
S MHD HD VHD

COMMENTS:

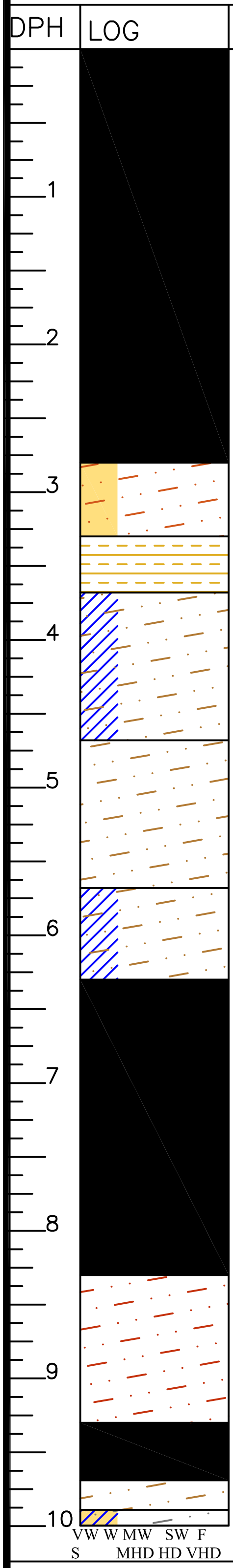
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1404-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 5

LOCATION: 376295, 6386194GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14



DESCRIPTION

NO CORE

LIGHT RED BROWN SANDSTONE

YELLOW BROWN CLAY

BROWN VERY FINE GRAINED SANDSTONE

BROWN VERY FRACTURED SANDSTONE

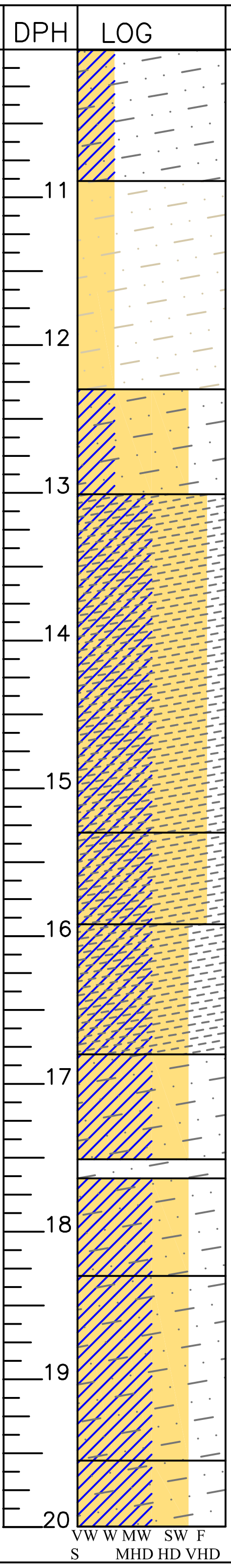
BROWN & VIOLET VERY FRACTURED SANDSTONE

NO CORE

BROWN RED VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

NO CORE

BROWN SANDSTONE VERY FRACTURED



DESCRIPTION

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART LINED WITH RED CLAY

LIGHT BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

GREY VERY FINE GRAINED SANDSTONE VERTICAL FRACTURE RED CLAY LINED

GREY MUDSTONE WITH DARK GREY LAMINAE, FRACTURES 30cm

GREY MUDSTONE WITH DARK GREY LAMINAE, FRACTURES 30cm

GREY MUDSTONE, FRACTURES 30cm AND ONE 45° TO CORE AXIS

GREY FINE GRAINED SANDSTONE WITH WHITE AND DARK GREY LITHIC FRAGMENTS, FRACTURES 30cm

FRACTURED ZONE

GREY FINE GRAINED SANDSTONE WITH WHITE AND DARK GREY LITHIC FRAGMENTS, FRACTURES 30cm

GREY FINE GRAINED SANDSTONE WITH WHITE AND DARK GREY LITHIC FRAGMENTS, FRACTURES 30cm

GREY FINE GRAINED SANDSTONE WITH WHITE LITHIC FRAGMENTS, FRACTURES 30cm

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

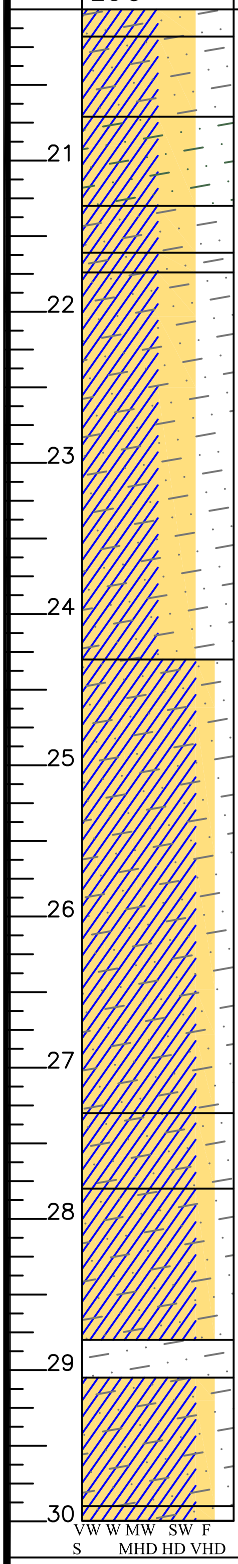
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1404–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 5

LOCATION: 376295, 6386194GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



GREY FINE GRAINED SANDSTONE WITH, FRACTURES 30cm 45° TO CORE AXIS

GREY GREEN VERY FINE GRAINED SANDSTONE, FRACTURES 30cm APART

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm

GREY VERY FINE GRAINED SANDSTONE BLACK LAMINAE

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm

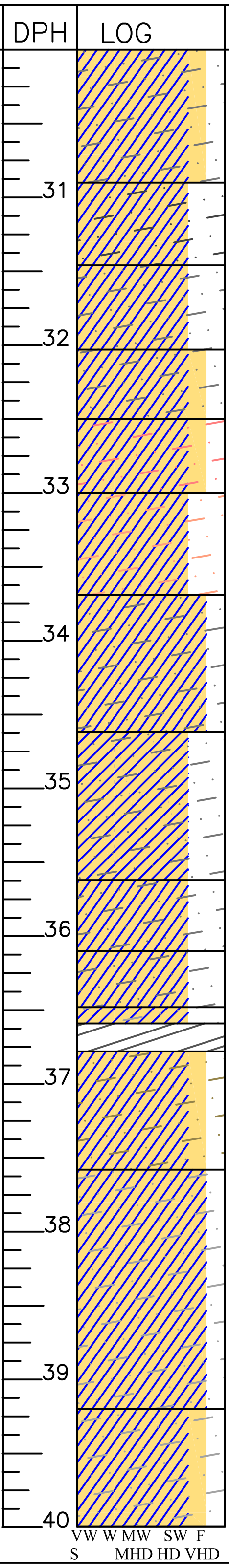
GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm

GREY VERY FINE GRAINED SANDSTONE FRACTURED

FRACTURED ZONE

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm

DPH LOG DESCRIPTION



GREY FINE GRAINED SANDSTONE MINOR BLACK LAMINAE

DARK GREY FINE GRAINED SANDSTONE FELDSPAR CLASTS POORLY SORTED

GREY & BROWN COARSE GRAINED SANDSTONE WITH LARGE FELDSPAR CLASTS

GREY VERY FINE GRAINED SANDSTONE WITH BLACK LAMINAE PERPENDICULAR TO CORE AXIS

PINK VERY FINE GRAINED SANDSTONE

LIGHT PINK VERY FINE GRAINED SANDSTONE, FRACTURES 40cm

GREY MINOR BROWN FINE GRAINED SANDSTONE MINOR FELDSPAR CLASTS

GREY FINE GRAINED SANDSTONE, FRACTURES 20cm

GREY RED BROWN VERY FINE GRAINED SANDSTONE MINOR CALCITE VEIN

GREY RED BROWN VERY FINE GRAINED SANDSTONE MINOR

LIGHT GREY VERY FINE GRAINED SANDSTONE

BLACK SHALE LAMINAE

CHOCOLATE BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED

LIGHT GREY VERY FINE GRAINED SANDSTONE

LIGHT GREY PINK FINE GRAINED SANDSTONE LAYERS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

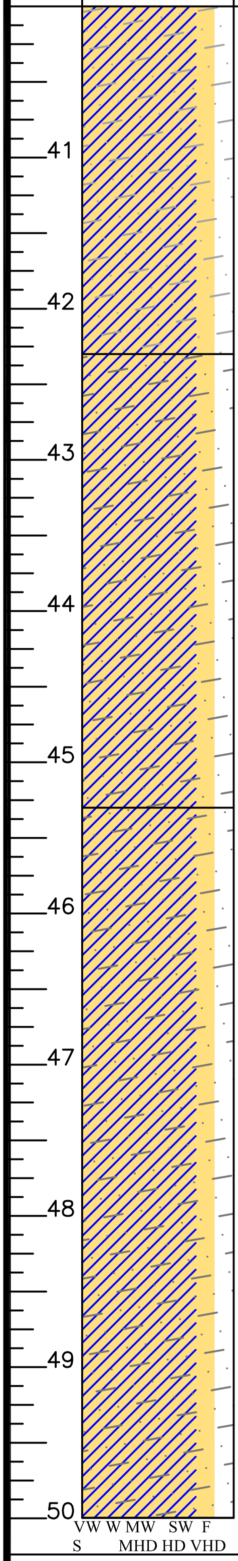
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1404–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 3 OF 5

LOCATION: 376295, 6386194GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

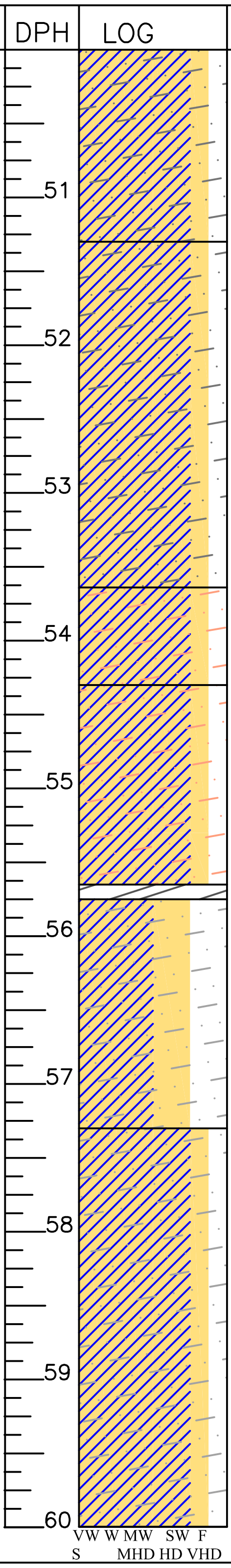
DPH | LOG | DESCRIPTION



GREY VERY FINE GRAINED SANDSTONE MINOR LAMINAE BLACK AND BROWN MINOR CALCITE VEIN

GREY VERY FINE GRAINED SANDSTONE MINOR LAMINAE BLACK AND BROWN MINOR CALCITE VEIN

DPH | LOG | DESCRIPTION



GREY VERY FINE GRAINED SANDSTONE MINOR LAMINAE BLACK AND BROWN MINOR CALCITE VEIN

LIGHT PINK VERY FINE GRAINED SANDSTONE

LIGHT PINK VERY FINE GRAINED SANDSTONE MINOR BLACK LAMINAE

BLACK SHALE

LIGHT GREY AND LIGHT PINK VERY FINE GRAINED SANDSTONE, FRACTURES 25cm APART

LIGHT GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30 TO 100cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

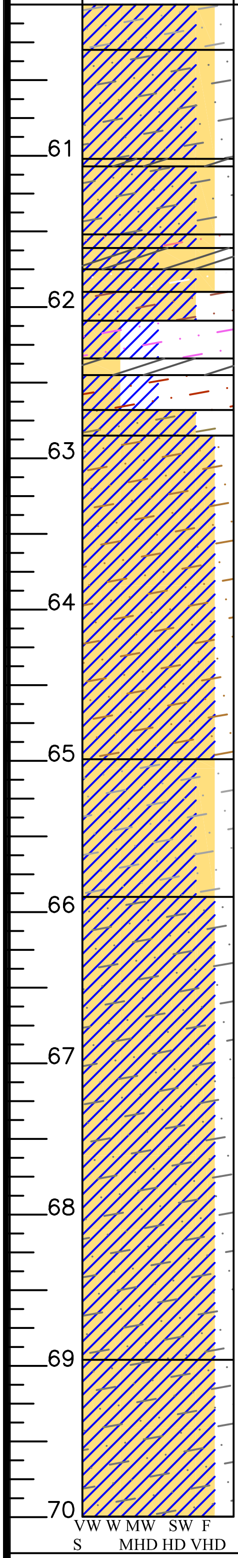
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1404–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 5

LOCATION: 376295, 6386194GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



GREY MEDIUM GRAINED SANDSTONE POORLY SORTED

BLACK SHALE

GREY MEDIUM GRAINED SANDSTONE POORLY SORTED

PINK VERY FINE GRAINED SANDSTONE POORLY SORTED

BLACK SHALE

WHITE VERY FINE GRAINED SANDSTONE

CHOCOLATE RED BROWN FINE GRAINED SANDSTONE

VIOLET VERY FINE GRAINED SANDSTONE & MUDSTONE LAYERS 80° TO CORE AXIS

BLACK SHALE

RED BROWN VERY FINE GRAINED SANDSTONE

CHOCOLATE BROWN FINE GRAINED SANDSTONE FELDSPAR CLASTS POORLY SORTED

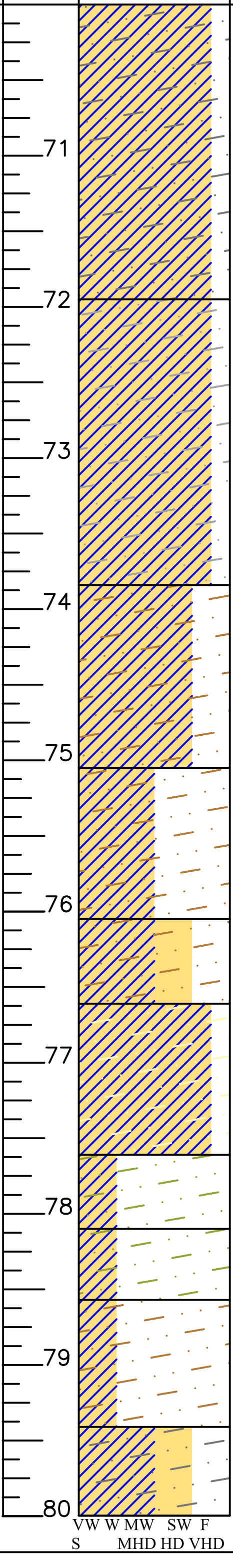
BROWN & VIOLET VERY FINE GRAINED SANDSTONE

LIGHT GREY MEDIUM GRAINED SANDSTONE FELDSPAR GRAINS, FRACTURES 10 TO 60cm APART

GREY MEDIUM GRAINED SANDSTONE FELDSPAR GRAINS, FRACTURES 20 TO 150cm APART

GREY FINE GRAINED SANDSTONE FELDSPAR GRAINS SHALE LAMINAE 80° TO CORE AXIS FRACTURES 20 TO 150cm APART

DPH | LOG | DESCRIPTION



LIGHT GREY MINOR BROWN FINE GRAINED SANDSTONE

BROWN VERY FINE GRAINED SANDSTONE LAYERED PERPENDICULAR TO CORE AXIS

BROWN VERY FINE GRAINED SANDSTONE ;LAYERED PERPENDICULAR TO CORE AXIS

BROWN GREEN & WHITE FINE GRAINED SANDSTONE LAYERED

OFF WHITE VERY FINE GRAINED SANDSTONE MINOR BROWN LAMINAE

OLIVE GREEN MEDIUM GRAINED SANDSTONE, FRACTURES 40° TO CORE AXIS 20cm APART

OLIVE GREEN MEDIUM GRAINED SANDSTONE, FRACTURES 40° TO CORE AXIS 20cm APART

BROWN MEDIUM GRAINED SANDSTONE

GREY FINE GRAINED SANDSTONE WITH BLACK LAMINAE 80° TO CORE AXIS

COMMENTS:

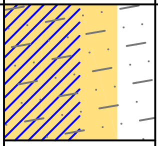
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1404-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 5 OF 5

LOCATION: 376295, 6386194GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH	LOG	DESCRIPTION	DPH	LOG	DESCRIPTION
		GREY FINE GRAINED SANDSTONE WITH BLACK LAMINAE 80° TO CORE AXIS			
81			91		
82			92		
83			93		
84			94		
85			95		
86			96		
87			97		
88			98		
89			99		
90	VW W MW SW F S MHD HD VHD		100	VW W MW SW F S MHD HD VHD	

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

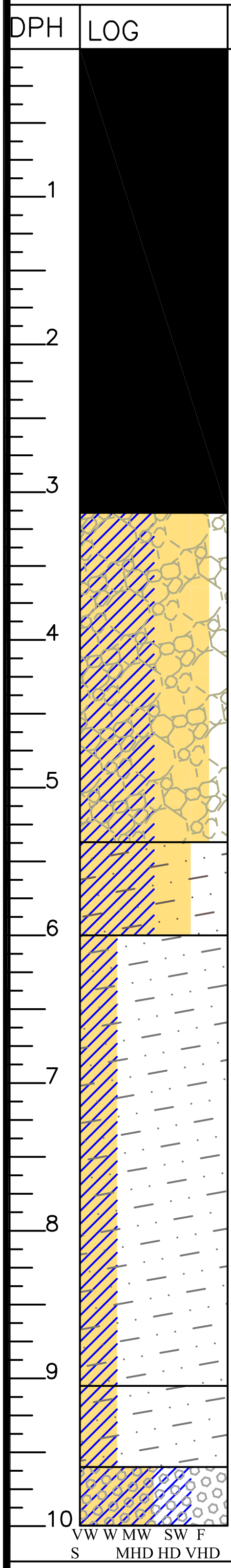
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1405-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



NO CORE

GREY BROWN CONGLOMERATE FRAGMENTS TO 90mm QUARTZ AND SANDSTONE

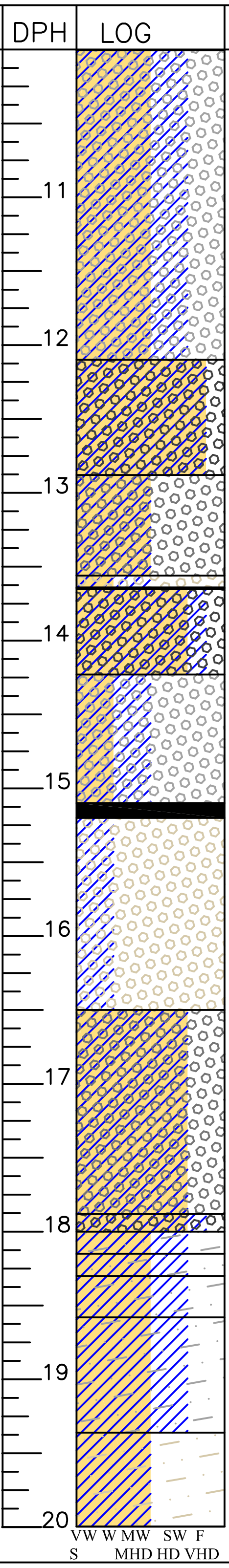
BROWN GREY FINE GRAINED SANDSTONE POORLY SORTED, FRACTURES 25cm

GREY FINE GRAINED SANDSTONE FINE GRAINED BROWN WEATHERED ON FRACTURES HIGHLY FRACTURED

GREY FINE GRAINED SANDSTONE FINE GRAINED BROWN WEATHERED ON FRACTURES HIGHLY FRACTURED

LIGHT GREY FINE GRAINED IGNIMBRITE HIGHLY FRACTURED BROWN CLAY ON FRACTURES AND VERTICAL FRACTURED

DPH | LOG | DESCRIPTION



DARK GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR QUARTZ 3mm

GREY FINE GRAINED IGNIMBRITE HIGHLY FRACTURED BROWN CLAY ON FRACTURES

LIGHT BROWN FINE GRAINED IGNIMBRITE

BROWN CLAY

DARK GREY FINE GRAINED IGNIMBRITE, FRACTURES 10cm APART BROWN CLAY LINED

LIGHT GREY FINE GRAINED IGNIMBRITE VERY FRACTURED ALSO VERTICAL F

CORE LOSS

LIGHT BROWN VERY FINE IGNIMBRITE VERY FRACTURED

GREY FINE GRAINED IGNIMBRITE, FRACTURES 20cm APART AND VERTICAL BROWN CLAY LINED

DARK GREY FINE GRAINED IGNIMBRITE

LIGHT GREY VERY FINE GRAINED SANDSTONE

LIGHT GREY VERY FINE GRAINED SANDSTONE

LIGHT GREY VERY FINE GRAINED SANDSTONE VERY FRACTURED BROWN CLAY LINED

LIGHT GREY VERY FINE GRAINED SANDSTONE MINOR BLACK CLASTS, FRACTURES 20cm APART BROWN CLAY LINED

LIGHT BROWN VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

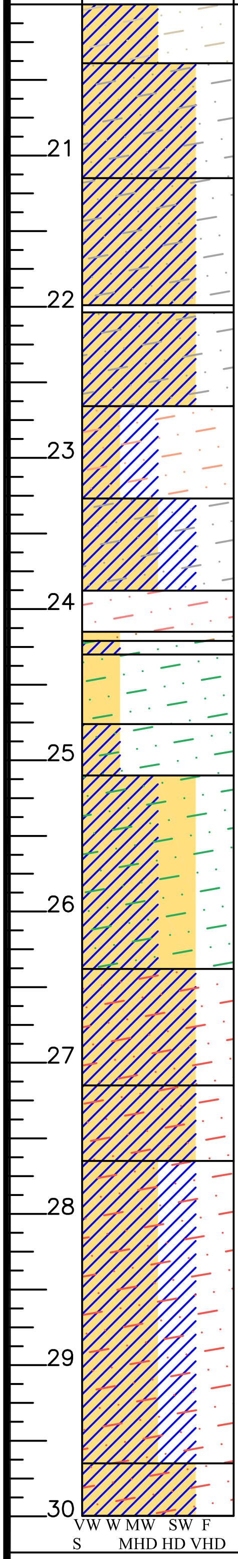
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1405–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



LIGHT GREY VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART MICROFRACTURE AND CALCITE IN GROUNDMASS

LIGHT GREY VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART MICROFRACTURE AND CALCITE IN GROUNDMASS

WEATHERED ZONE

LIGHT GREY VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART MICROFRACTURE AND CALCITE IN GROUNDMASS

LIGHT PINK VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART LAYERS

LIGHT GREY VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

PINK VERY FINE GRAINED SANDSTONE

BROWN VERY FINE GRAINED SANDSTONE

GREEN MEDIUM GRAINED SANDSTONE POORLY SORTED

GREEN AND PINK LIGHT LAYERS GREEN WEATHERED SOFT PINK

GREEN MEDIUM GRAINED SANDSTONE POORLY SORTED

GREEN MEDIUM GRAINED SANDSTONE POORLY SORTED

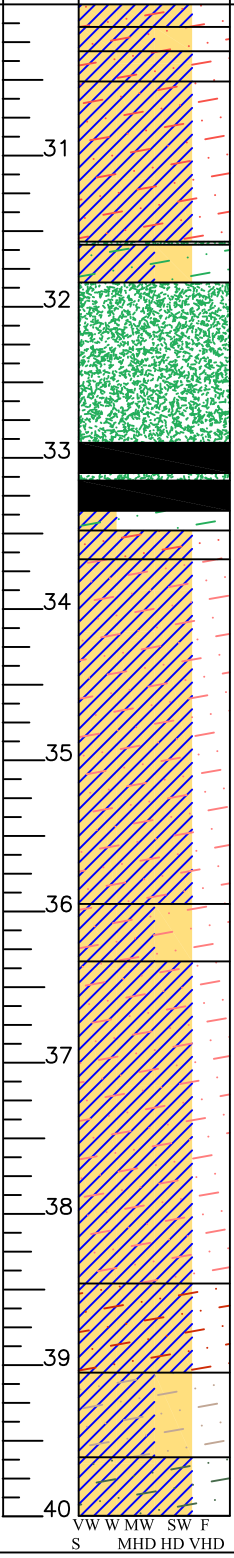
LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH , FRACTURES 10cm APART

LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH , FRACTURES 10cm APART

GREEN AND LIGHT RED COARSE GRAINED SANDSTONE, FRACTURES 10 TO 30cm APART CALCITE VEIN VERTICAL FRACTURED

LIGHT RED MEDIUM GRAINED SANDSTONE, FRACTURES 10cm APART

DPH | LOG | DESCRIPTION



LIGHT RED MEDIUM GRAINED SANDSTONE

LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH , FRACTURES 45o TO CORE AXIS

LIGHT RED MEDIUM GRAINED SANDSTONE FELDSPAR FRAGMENTS, FRACTURES 30cm APART

GREEN AND RED FRACTURED ZONE

GREEN MEDIUM GRAINED SANDSTONE FELDSPAR FRAGMENTS, FRACTURES 10cm APART

HIGHLY FRACTURED ZONE

CORE LOSS

HIGHLY FRACTURED ZONE

CORE LOSS

GREEN MEDIUM GRAINED SANDSTONE

LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH VERY FRACTURED

PINK VERY FINE GRAINED SANDSTONE MINOR CALCITE IN GROUNDMASS MINOR BLACK CLASTS, FRACTURES 40cm

PINK AN BLACK VERY FINE GRAINED SANDSTONE CALCITE IN VEINS

PINK VERY FINE GRAINED SANDSTONE MINOR CALCITE IN GROUNDMASS MINOR BLACK CLASTS

RED VERY FINE GRAINED SANDSTONE WITH QUARTZ VEINS FAULTING ZONE

VIOLET GREEN GREY VERY FINE GRAINED SANDSTONE CALCITE IN GROUNDMASS

GREEN GREY MINOR VIOLET VERY FINE GRAINED SANDSTONE, FRACTURES 45° TO CORE AXIS

COMMENTS:

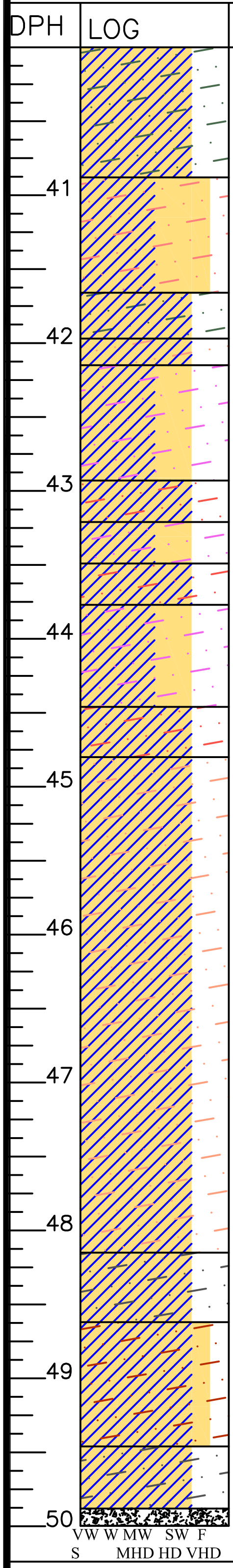
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1405–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 3 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14



DESCRIPTION

PINK VERY FINE GRAINED SANDSTONE MINOR CALCITE VEINS

GREY GREEN VERY FINE GRAINED SANDSTONE LAYERED 45° TO CORE AXIS

LIGHT PINK VERY FINE GRAINED SANDSTONE

VIOLET & GREEN VERY FINE GRAINED SANDSTONE WITH SHALE LENS 45° TO CORE AXIS

LIGHT RED VERY FINE GRAINED SANDSTONE QUARTZ RICH

VIOLET & GREEN VERY FINE GRAINED SANDSTONE WITH SHALE LENS 45° TO CORE AXIS

LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH , FRACTURES 45° TO CORE AXIS

VIOLET & GREEN VERY FINE GRAINED SANDSTONE WITH SHALE LENS 45° TO CORE AXIS

LIGHT RED MEDIUM GRAINED SANDSTONE QUARTZ RICH , FRACTURES 45° TO CORE AXIS

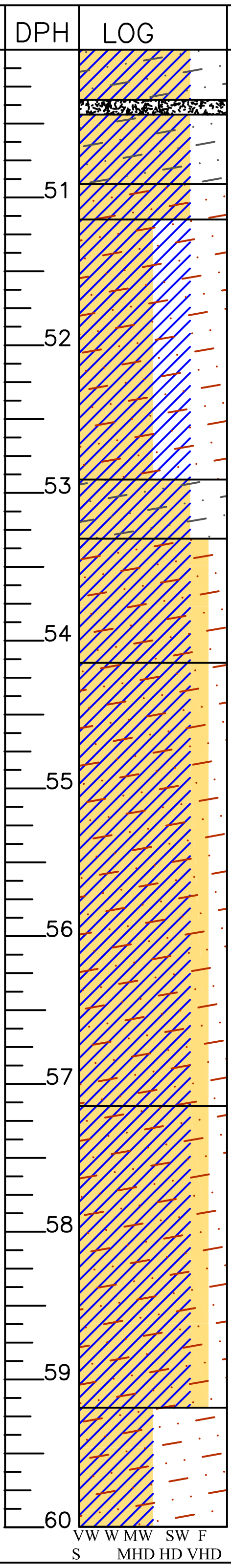
LIGHT PINK VERY FINE GRAINED SANDSTONE SHALE CLASTS

BLACK AND RED BROWN VERY FINE GRAINED SANDSTONE SHALE LAMINAE FRACTURE 10cm APART

RED BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR MINOR RED SHALE

BLACK COARSE GRAINED SANDSTONE POORLY SORTED SOME FINE GRAINED FELDSPAR

FRACTURED ZONE



DESCRIPTION

BLACK VERY FINE GRAINED SANDSTONE WITH CALCITE VEINS

FRACTURED ZONE

BLACK VERY FINE GRAINED SANDSTONE WITH CALCITE VEINS

RED BROWN MEDIUM GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

RED BROWN MEDIUM GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

BLACK VERY FINE GRAINED SANDSTONE WITH CALCITE VEINS

RED BROWN MEDIUM GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

RED BROWN MEDIUM GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS CALCITE VEINS IN GROUNDMASS SHALE LAMINAE

RED BROWN MEDIUM GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS, FRACTURES 20 TO 100cm

GREEN AN RED BROWN MEDIUM GRAINED SANDSTONE LAYERED, FRACTURES 10cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

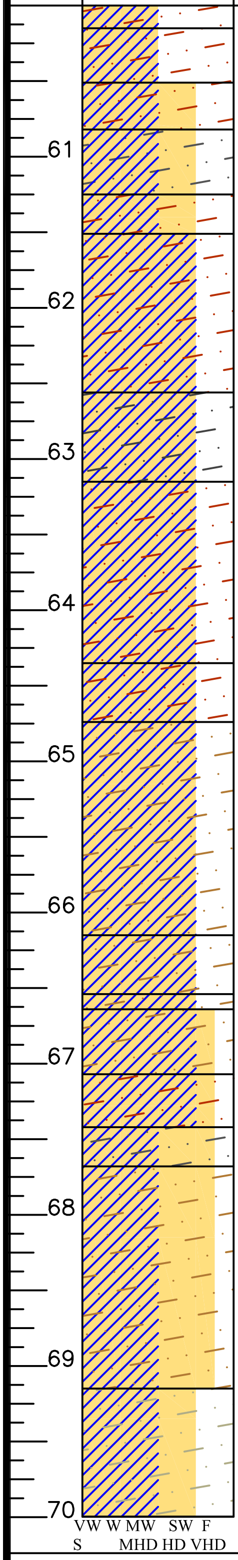
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1405–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



GREEN AND RED BROWN MEDIUM GRAINED SANDSTONE LAYERED, FRACTURES 10cm APART CALCITE VEINS

GREEN AND RED BROWN MEDIUM GRAINED SANDSTONE LAYERED, FRACTURES 10cm APART

BLACK FINE GRAINED SANDSTONE CALCITE VEINS IN GROUNDMASS

GREEN AN RED BROWN MEDIUM GRAINED SANDSTONE

RED BROWN COARSE GRAINED SANDSTONE QUARTZ AND FELDSPAR FRAGMENTS

DARK GREY COARSE GRAINED SANDSTONE POORLY SORT, FRACTURES 40cm

RED BROWN COARSE GRAINED SANDSTONE QUARTZ AND FELDSPAR FRAGMENTS

RED BROWN MEDIUM GRAINED SANDSTONE QUARTZ AND FELDSPAR FRAGMENTS LAMINAE 40° TO CORE AXIS

BROWN MEDIUM GRAINED SANDSTONE QUARTZ AND FELDSPAR FRAGMENTS RARE QUARTZ VEIN

BROWN COARSE GRAINED SANDSTONE QUARTZ AND FELDSPAR FRAGMENTS

BROWN WITH BLACK LAMINAE MEDIUM GRAINED SANDSTONE

BROWN VERY FINE GRAINED SANDSTONE

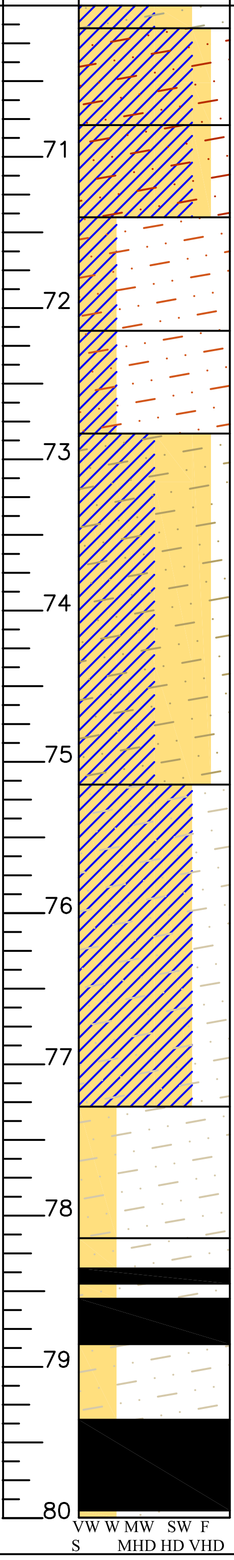
RED BROWN COARSE GRAINED SANDSTONE LAYERS 45° TO CORE AXIS QUARTZ FELDSPAR FRAGMENTS, FRACTURES 15cm APART

BLACK FINE GRAINED SANDSTONE SHALE LAMINAE

BROWN VERY FINE GRAINED SANDSTONE CALCITE VEINS IN GROUNDMASS, FRACTURES 10cm APART

GREY BROWN FINE GRAINED SANDSTONE CALCITE VEINS IN GROUNDMASS ALL ANGLES

DPH | LOG | DESCRIPTION



RED BROWN FINE GRAINED SANDSTONE POORLY SORTED, FRACTURES 40cm APART

RED BROWN FINE GRAINED SANDSTONE POORLY SORTED, FRACTURES 20cm APART

LIGHT RED BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT RED BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT CHOCOLATE BROWN MEDIUM GRAINED TO COARSE GRAINED SANDSTONE FELDSPAR AND QUARTZ FRAGMENTS LAMINAE 30° TO CORE AXIS

LIGHT BROWN FINE GRAINED SANDSTONE GETTING COARSE GRAINED AT BASE CALCITE VEIN @76m

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CORE LOSS

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CORE LOSS

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CORE LOSS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

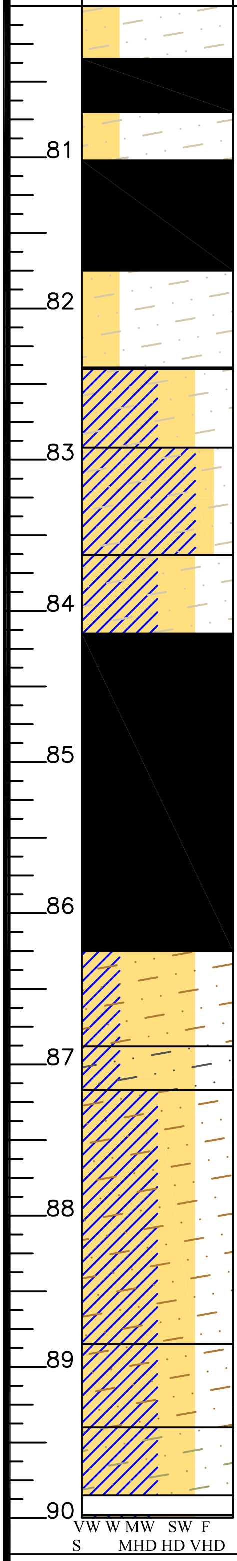
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1405-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 5 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CORE LOSS

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CORE LOSS

LIGHT BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

CALCITE VEIN
LIGHT BROWN VERY FINE GRAINED SANDSTONE, FRACTURES 15cm APART

LIGHT BROWN COARSE GRAINED SANDSTONE QUARTZ FELDSPAR LAMINAE AND BEDDING 45° TO CORE AXIS

LIGHT BROWN VERY FINE GRAINED SANDSTONE, FRACTURES 10cm APART

CORE LOSS

BROWN MEDIUM GRAINED SANDSTONE FELDSPAR & QUARTZ FRAGMENTS POORLY SORTED

BLACK VERY FINE GRAINED SANDSTONE AND SHALE, FRACTURES 7cm APART

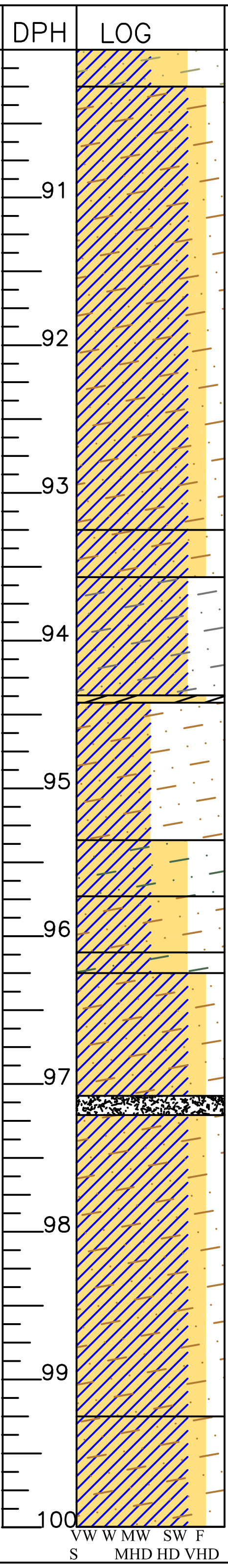
BROWN FINE GRAINED SANDSTONE LAMINAE 80° TO CORE AXIS, FRACTURES 40cm APART

BROWN FINE GRAINED SANDSTONE LAMINAE 80° TO CORE AXIS, FRACTURES 40cm APART

GREEN BROWN FINE GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

CALCITE VEINS

DPH | LOG | DESCRIPTION



GREEN BROWN FINE GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

BROWN COARSE GRAINED SANDSTONE QUARTZ FELDSPAR LAMINAE AND BEDDING 45° TO CORE AXIS, FRACTURES 30cm APART

BROWN MEDIUM GRAINED SANDSTONE QUARTZ FELDSPAR, FRACTURES 15cm APART

GREY MINOR BROWN COARSE GRAINED SANDSTONE POORLY SORTED, FRACTURES 40cm APART

BLACK SHALE HIGHLY FRACTURED

BROWN MEDIUM GRAINED SANDSTONE MINOR FINE GRAINED FELDSPAR & FRAGMENTS POORLY SORTED PINK CALCITE VEINS

GREY GREEN FINE GRAINED SANDSTONE LAMINAE 80° TO CORE AXIS

BROWN FINE GRAINED SANDSTONE LAMINAE 80° TO CORE AXIS

GREY GREEN FINE GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

BROWN VERY FINE GRAINED SANDSTONE

FRACTURED ZONE
BROWN VERY FINE GRAINED SANDSTONE

BROWN VERY FINE GRAINED SANDSTONE

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

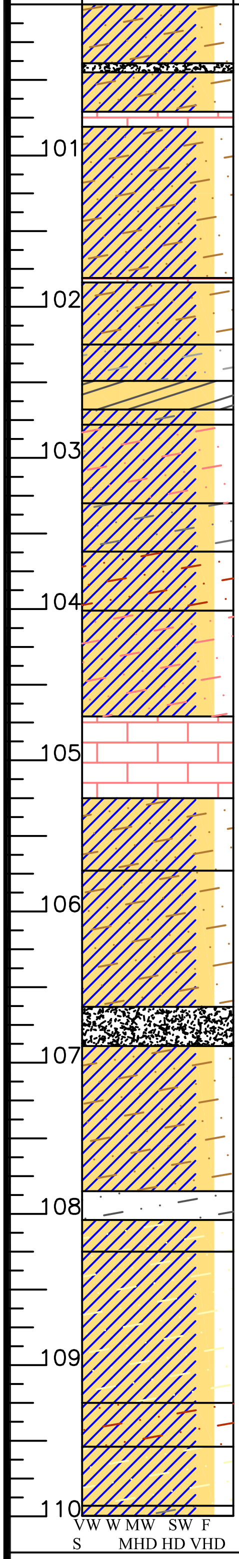
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1405–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 6 OF 6

LOCATION: 376384, 6385562GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



FRACTURED ZONE
BROWN VERY FINE GRAINED SANDSTONE

PINK CALCITE VEIN AND FRACTURED ZONE
BROWN VERY FINE GRAINED SANDSTONE, FRACTURES 30cm APART

CALCITE VEIN
BROWN VERY FINE GRAINED SANDSTONE SOME MOTTLED

LIGHT GREY VERY FINE GRAINED SANDSTONE

BLACK SHALE LAMINAE

GREY MEDIUM GRAINED SANDSTONE
PINK VERY FINE GRAINED SANDSTONE

GREY VERY FINE GRAINED SANDSTONE CALCITE VEINS IN GROUNDMASS

RED BROWN VERY FINE GRAINED SANDSTONE

PINK VERY FINE GRAINED SANDSTONE LAMINAE 60° TO CORE AXIS, FRACTURES 15cm APART

CALCITE VEIN AND FRACTURED ZONE

BROWN AND BLACK VERY FINE GRAINED SANDSTONE BLACK SHALE BROKEN UP

BROWN FINE GRAINED SANDSTONE POORLY SORTED

FRACTURED ZONE

BROWN FINE GRAINED COARSE GRAINED AT BASE SANDSTONE, FRACTURES 30cm APART

BLACK SANDSTONE FRACTURED ZONE

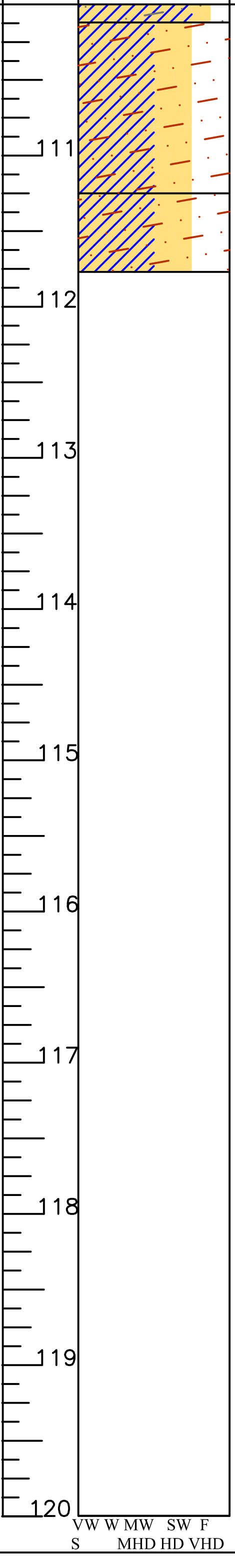
OFF WHITE FINE GRAINED SANDSTONE

OFF WHITE FINE GRAINED SANDSTONE

RED BROWN WHITE FINE GRAINED SANDSTONE

OFF WHITE FINE GRAINED SANDSTONE

DPH | LOG | DESCRIPTION



GREY FINE GRAINED SANDSTONE
RED BROWN MEDIUM GRAINED SANDSTONE COME LARGE FELDSPAR FRAGMENTS, CALCITE VEINS IN GROUNDMASS

RED BROWN VERY FINE GRAINED SANDSTONE WITH CALCITE VEINS 50° TO CORE AXIS, FRACTURES 15cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

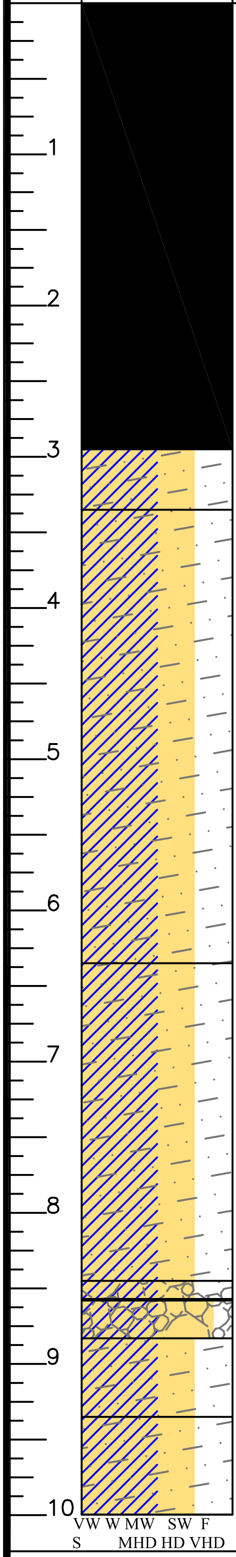
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1406-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 6

LOCATION: 376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



NO CORE

GREY MEDIUM GRAINED SANDSTONE BLACK LAMINAE AND MINOR FINE GRAINED FELDSPAR & FRAGMENTS

GREY MEDIUM GRAINED SANDSTONE BLACK LAMINAE AND MINOR FINE GRAINED FELDSPAR & FRAGMENTS , FRACTURES 20 TO 50cm APART

GREY MEDIUM GRAINED SANDSTONE BLACK LAMINAE AND MINOR FINE GRAINED FELDSPAR & FRAGMENTS

GREY CONGLOMERATE FRAGMENTS TO 50mm RED SANDSTONE

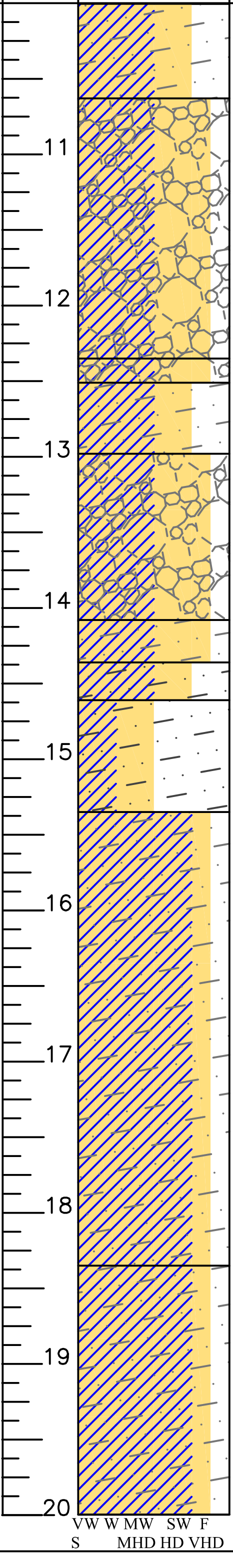
NO CORE

GREY CONGLOMERATE FRAGMENTS TO 50mm GREY SANDSTONE

GREY MEDIUM GRAINED SANDSTONE BLACK LAMINAE AND MINOR FINE GRAINED FELDSPAR & FRAGMENTS

GREY VERY FINE GRAINED SANDSTONE BLACK LAMINAE, FRACTURES 25cm APART

DPH LOG DESCRIPTION



GREY CONGLOMERATE FRAGMENTS TO 70mm GREY SANDSTONE

GREY CONGLOMERATE FRAGMENTS TO 70mm GREY SANDSTONE

GREY VERY FINE GRAINED SANDSTONE BLACK LAMINAE

GREY CONGLOMERATE FRAGMENTS TO 30mm GREY, FRACTURES 30cm APART SANDSTONE

GREY MEDIUM GRAINED SANDSTONE POORLY SORTED

DARK GREY VERY FINE GRAINED SANDSTONE BLACK LAMINAE

DARK GREY COARSE GRAINED SANDSTONE WITH FELDSPAR AND QUARTZ FRAGMENTS

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & AND SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 100cm APART

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 30 TO 100cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

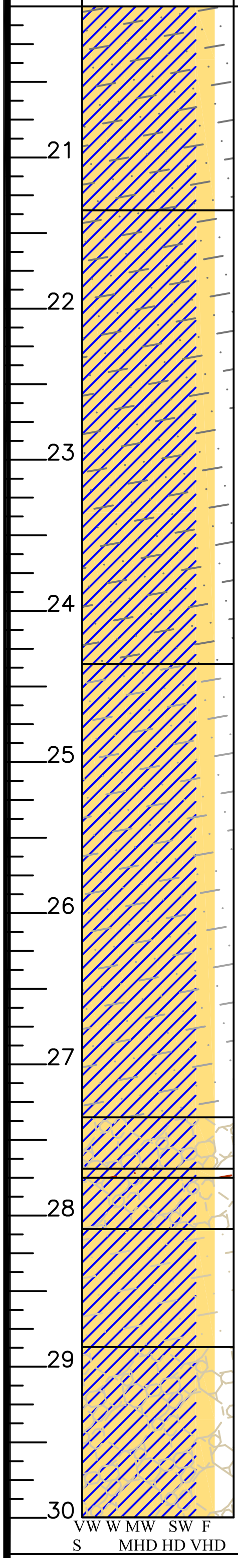
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1406-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 2 OF 6

LOCATION: 376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH	LOG	DESCRIPTION



GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm, FRACTURES 50cm APART

LIGHT GREY AND PINK COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 40cm APART

LIGHT BROWN COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 14mm, FRACTURES 15cm APART

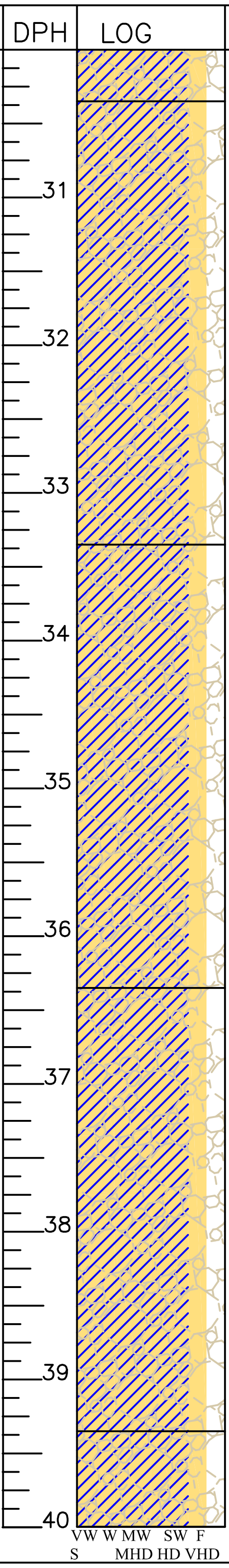
RED BROWN FINE GRAINED SANDSTONE MINOR LARGE FRAGMENTS

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & AND SANDSTONE FRAGMENTS TO 40mm

LIGHT BROWN COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm

DPH	LOG	DESCRIPTION



LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 30 TO 100cm APART

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 60 TO 100cm APART

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, RED FINE GRAINED SANDSTONE @ 37.35m, FRACTURES 30 TO 100cm APART

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 14mm, FRACTURES 30 TO 100cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

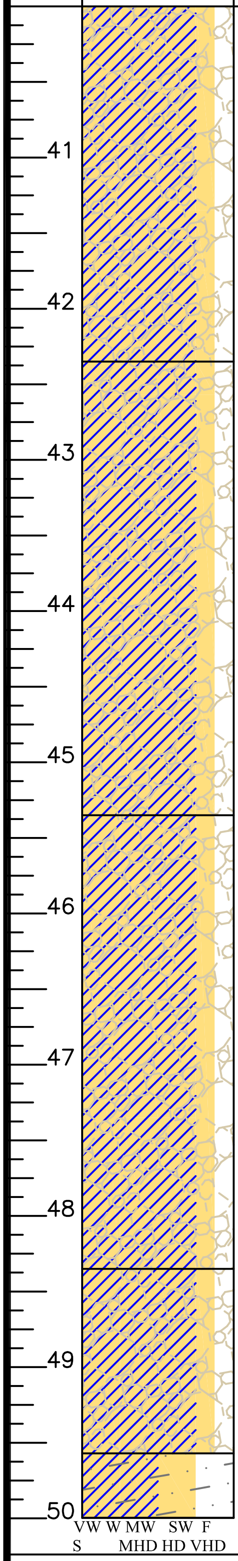
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1406–DH
PROJECT BRANDY HILL, ZONE 56
PAGE 3 OF 6

LOCATION:376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



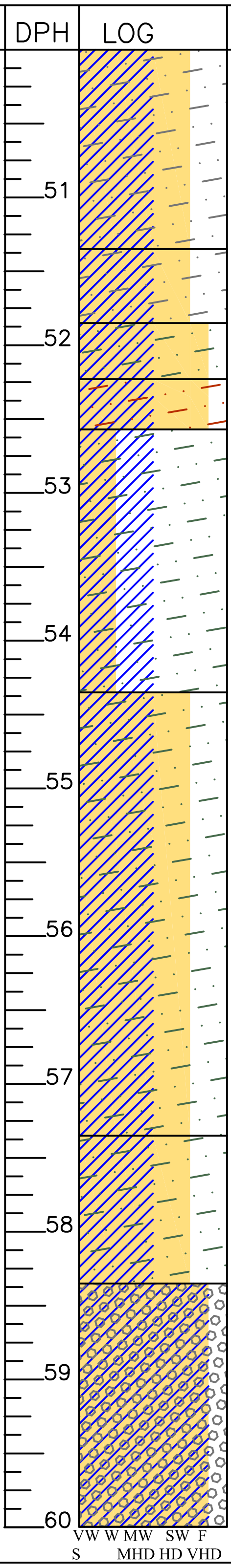
LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm, FRACTURES 30 TO 100cm APART

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm, FRACTURES 30 TO 100cm APART

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 20mm, FRACTURES 30 TO 100cm APART

GREY F TO COARSE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART

DPH LOG DESCRIPTION



GREY FINE TO COARSE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART

GREY GREEN MEDIUM TO COARSE GRAINED SANDSTONE SHALE FRAGMENTS TO 4mm

RED BROWN MEDIUM TO COARSE GRAINED SANDSTONE SHALE FRAGMENTS TO 4mm

GREY GREEN FINE GRAINED SANDSTONE WITH SHALE FRAGMENTS, BLACK LAMINAE AN CALCITE VEINS IN GROUNDMASS

GREY GREEN FINE GRAINED SANDSTONE WITH SHALE FRAGMENTS, BLACK LAMINAE AN CALCITE VEINS IN GROUNDMASS, FRACTURES 30 TO 100cm APART

GREY GREEN FINE GRAINED SANDSTONE WITH SHALE FRAGMENTS, BLACK LAMINAE AN CALCITE VEINS IN GROUNDMASS, FRACTURES 30 TO 100cm APART

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR TO 4mm, FRACTURES 25cm APART, FRACTURES

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

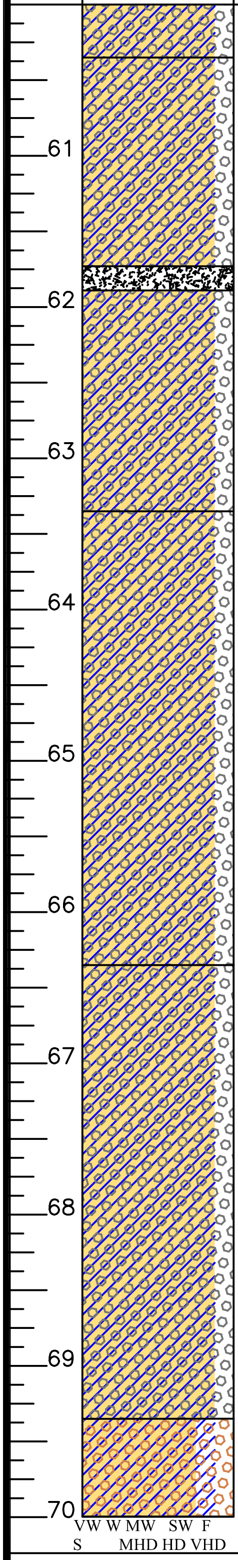
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1406-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 6

LOCATION: 376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 10° TO CORE AXIS, FRACTURES

FRACTURED ZONE

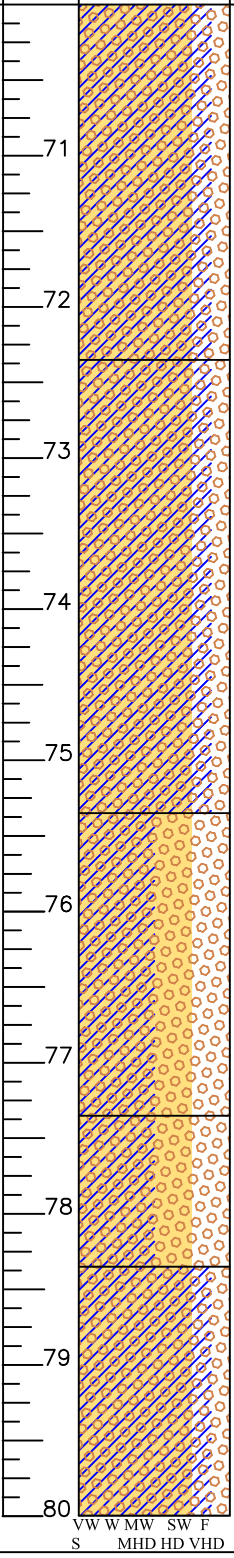
GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 80° TO CORE AXIS, FRACTURES

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 80° TO CORE AXIS AND IN GROUNDMASS, FRACTURES

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 80° TO CORE AXIS, FRACTURES

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 45° TO CORE AXIS

DPH | LOG | DESCRIPTION



GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART MANY CALCITE VEINS 60° TO CORE AXIS

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 80° TO CORE AXIS

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEIN LARGE 10° TO CORE AXIS

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART PINK CALCITE VEINS 80° TO CORE AXIS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

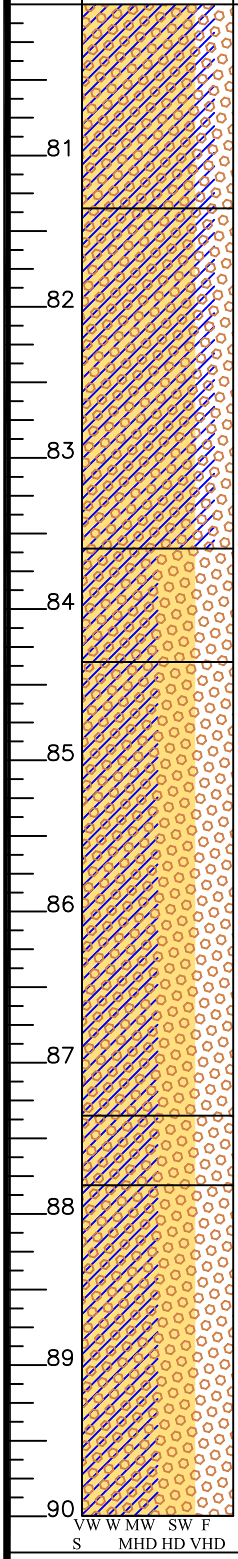
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1406-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 5 OF 6

LOCATION: 376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART CALCITE VEINS 45° TO CORE AXIS

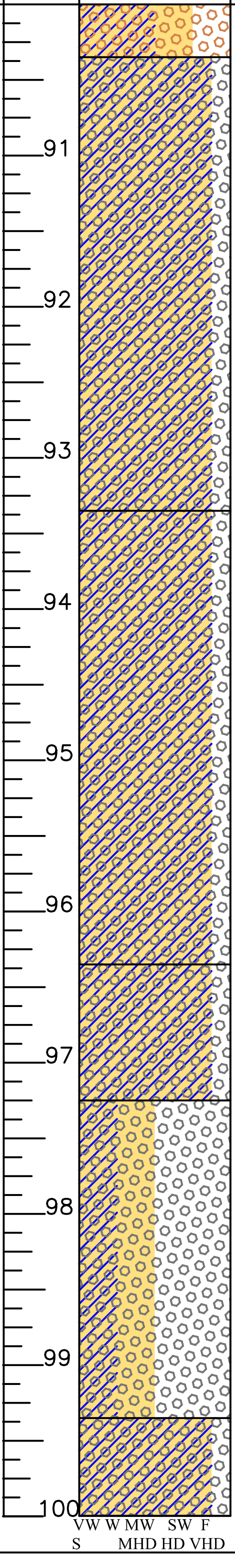
GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART PINK CALCITE VEINS PERPENDICULAR TO CORE AXIS

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART PINK CALCITE VEIN PERPENDICULAR TO CORE AXIS

GREY RED VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART PINK CALCITE VEIN PERPENDICULAR TO CORE AXIS

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 15cm APART PINK CALCITE VEIN 45° TO CORE AXIS

DPH | LOG | DESCRIPTION



GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 45cm APART PINK CALCITE VEIN 75° TO CORE AXIS

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 45cm APART PINK CALCITE VEIN 75° TO CORE AXIS

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 45cm APART PINK CALCITE VEIN 75° TO CORE AXIS

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 45cm APART HIGH PROPORTION OF PINK CALCITE VEINS 75° TO CORE AXIS

GREY VERY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ TO 4mm, FRACTURES 45cm APART PINK CALCITE VEIN 75° TO CORE AXIS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

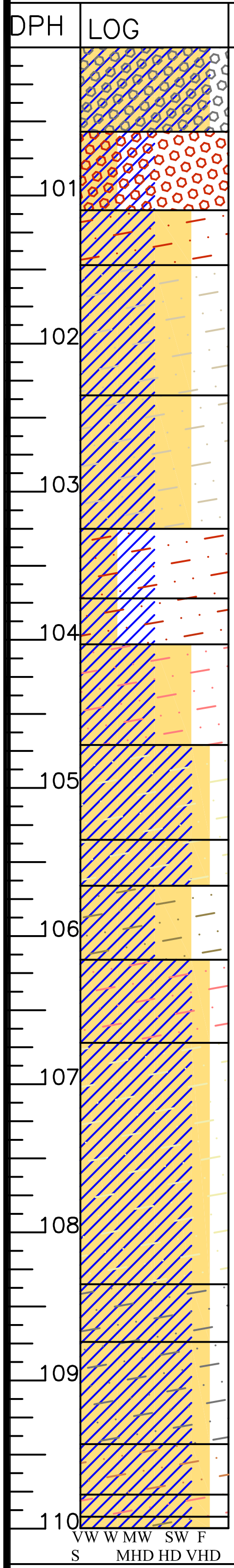
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1406-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 6 OF 6

LOCATION: 376633, 6385412GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



RED VERY FINE GRAINED IGNIMBRITE, FRACTURES 45cm APART PINK CALCITE VEIN 75° TO CORE AXIS

RED MEDIUM GRAINED SANDSTONE POORLY SORTED

LIGHT BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED

LIGHT BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED

RED VERY FINE GRAINED SANDSTONE

BROWN RED VERY FINE GRAINED SANDSTONE CHOCOLATE BROWN LAMINAE PERPENDICULAR TO CORE AXIS

PINK VERY FINE GRAINED SANDSTONE BLACK LAMINAE 80° TO CORE AXIS

CREAM VERY FINE GRAINED SANDSTONE

CREAM VERY FINE GRAINED SANDSTONE

CHOCOLATE BROWN VERY FINE GRAINED SANDSTONE LAYERS PERPENDICULAR TO CORE AXIS

PINK VERY FINE GRAINED SANDSTONE

CREAM VERY FINE GRAINED SANDSTONE RARE BLACK LAMINAE

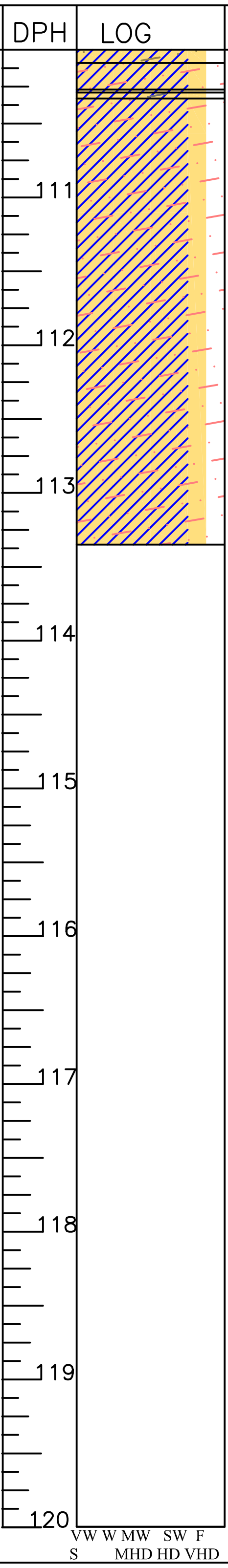
GREY VERY FINE GRAINED SANDSTONE

GREY MEDIUM GRAINED SANDSTONE POORLY SORTED RARE BLACK LAMINAE

RED GREY MEDIUM GRAINED SANDSTONE POORLY SORTED RARE BLACK LAMINAE

PINK MEDIUM GRAINED SANDSTONE POORLY SORTED

CHOCOLATE BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED



PINK MEDIUM GRAINED SANDSTONE POORLY SORTED

RED LIMONITE

GREY MEDIUM GRAINED SANDSTONE POORLY SORTED

PINK MEDIUM GRAINED SANDSTONE POORLY SORTED

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

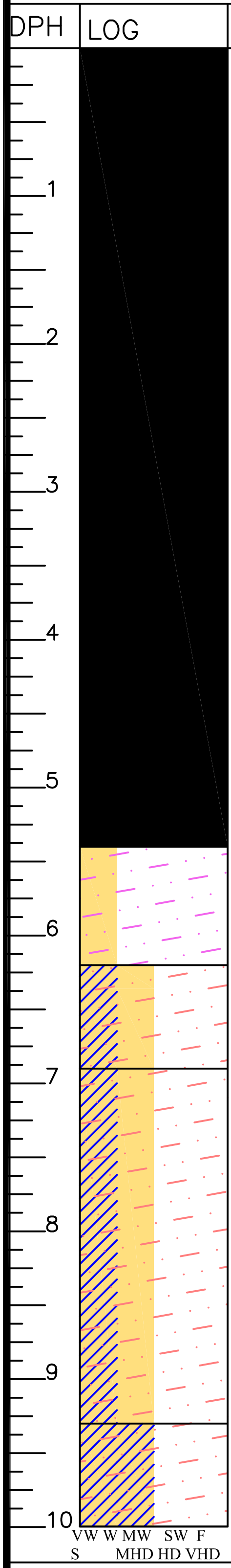
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1407–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 1 OF 5

LOCATION: 377590, 6385578GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



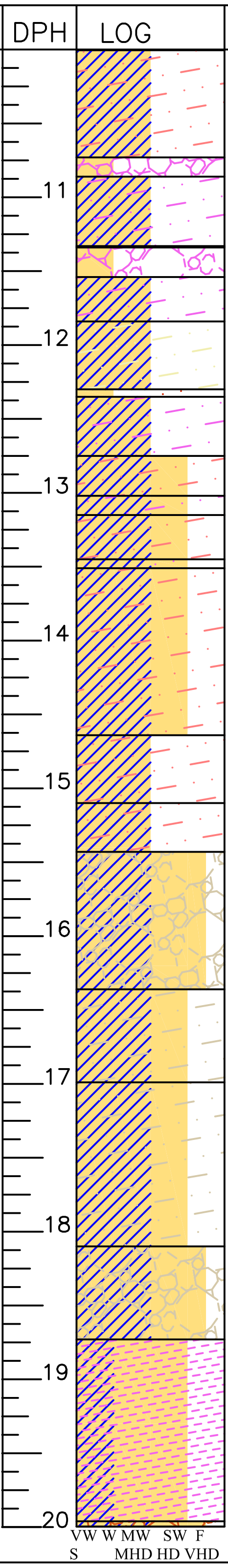
NO CORE

VIOLET MEDIUM GRAINED SANDSTONE HIGH FRACTURED

PINK MEDIUM GRAINED SANDSTONE VIOLET MOTTLED PATCHES AND BROWN LIGHT ON FRACTURES, FRACTURES 15cm APART

PINK MEDIUM GRAINED SANDSTONE VIOLET MOTTLED PATCHES AND BROWN LIGHT ON FRACTURES, FRACTURES 15cm APART

PINK MEDIUM GRAINED SANDSTONE VIOLET MOTTLED PATCHES



VIOLET CONGLOMERATE FRAGMENTS 30mm

VIOLET MEDIUM GRAINED SANDSTONE VIOLET POORLY SORTED LAMINAE 45° TO CORE AXIS

WEATHERED ZONE

VIOLET CONGLOMERATE FRAGMENTS 30mm

VIOLET MEDIUM GRAINED SANDSTONE VIOLET POORLY SORTED LAMINAE 80° TO CORE AXIS

CREAM FINE GRAINED SANDSTONE POORLY SORTED

RED SANDSTONE

VIOLET MEDIUM GRAINED SANDSTONE VIOLET POORLY SORTED LAMINAE 80° TO CORE AXIS

PINK MEDIUM GRAINED SANDSTONE POORLY SORTED SANDSTONE FRAGMENTS

VIOLET FINE GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

PINK MEDIUM GRAINED SANDSTONE POORLY SORTED SANDSTONE FRAGMENTS

VIOLET FINE GRAINED SANDSTONE LAMINAE 70° TO CORE AXIS

PINK MEDIUM GRAINED SANDSTONE POORLY SORTED SANDSTONE FRAGMENTS

PINK MEDIUM GRAINED SANDSTONE VIOLET MOTTLED PATCHES

PINK MEDIUM GRAINED SANDSTONE VIOLET MOTTLED PATCHES

LIGHT BROWN CONGLOMERATE FRAGMENTS TO 50mm SANDSTONE AND IGNIMBRITE POORLY SORTED

LIGHT BROWN VERY FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT BROWN TO BROWN FINE GRAINED SANDSTONE POORLY SORTED

LIGHT BROWN CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE AND POORLY SORTED

VIOLET VERY FINE GRAINED MUDSTONE CROSS BEDDING AT ALL ANGLES AND SOME LARGE FELDSPAR FRAGMENTS INCLUDED

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

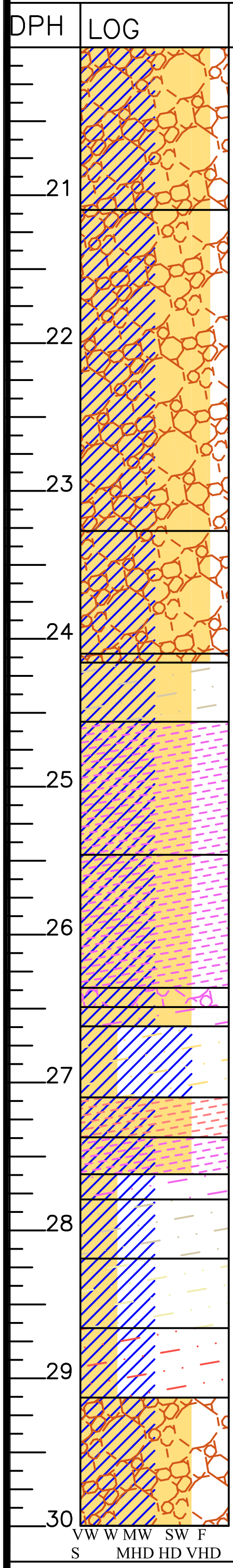
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1407-DH
PROJECT BRANDY HILL, ZONE 56
PAGE 2 OF 5

LOCATION:377590, 6385578GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



LIGHT BROWN RED CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE AND POORLY SORTED

LIGHT BROWN RED CONGLOMERATE FRAGMENTS TO 50mm SANDSTONE AND POORLY SORTED RES SHALE LAMINAE 45° TO CORE AXIS

LIGHT BROWN RED CONGLOMERATE FRAGMENTS TO 20mm SANDSTONE AND POORLY SORTED

LIGHT BROWN RED CONGLOMERATE FRAGMENTS TO 20mm SANDSTONE AND POORLY SORTED

LIGHT BROWN FINE GRAINED SANDSTONE POORLY SORTED RARE LARGE FRAGMENTS

VIOLET TO PINK VERY FINE GRAINED MUDSTONE LAMINAE ALL ANGLES, FRACTURES 25cm APART

VIOLET TO PINK VERY FINE GRAINED MUDSTONE LAMINAE ALL ANGLES, FRACTURES 25cm APART VERTICAL CALCITE VEIN

VIOLET CONGLOMERATE FRAGMENTS TO 10mm

VIOLET VERY FINE GRAINED SANDSTONE

ORANGE VERY FINE GRAINED SANDSTONE

PINK VERY FINE GRAINED MUDSTONE LAMINAE 70° TO CORE AXIS FRACTURED

VIOLET VERY FINE GRAINED MUDSTONE LAMINAE 70° TO CORE AXIS FRACTURED

VIOLET MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR FRAGMENTS

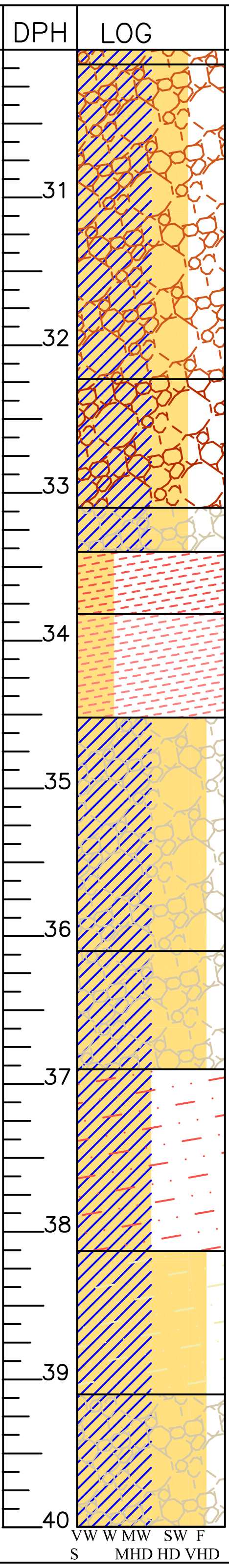
LIGHT BROWN MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR FRAGMENTS

CREAM MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR FRAGMENTS

LIGHT RED MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR FRAGMENTS

LIGHT RED BROWN CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

DPH LOG DESCRIPTION



LIGHT RED BROWN CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

RED BROWN CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

LIGHT BROWN CONGLOMERATE FRAGMENTS TO 30mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

LIGHT RED VERY FINE GRAINED MUDSTONE, FRACTURES 7cm APART

PINK VERY FINE GRAINED MUDSTONE, FRACTURES 7cm APART

LIGHT BROWN CONGLOMERATE FRAGMENTS SANDSTONE SHALE AND QUARTZ

LIGHT BROWN CONGLOMERATE FRAGMENTS SANDSTONE SHALE AND QUARTZ

LIGHT RED TO LIGHT BROWN COARSE GRAINED SANDSTONE RARE SHALE CLASTS

CREAM MEDIUM GRAINED SANDSTONE POORLY SORTED

LIGHT BROWN CONGLOMERATE FRAGMENTS SANDSTONE SHALE AND QUARTZ TO 30mm, FRACTURES 30 TO 100cm

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

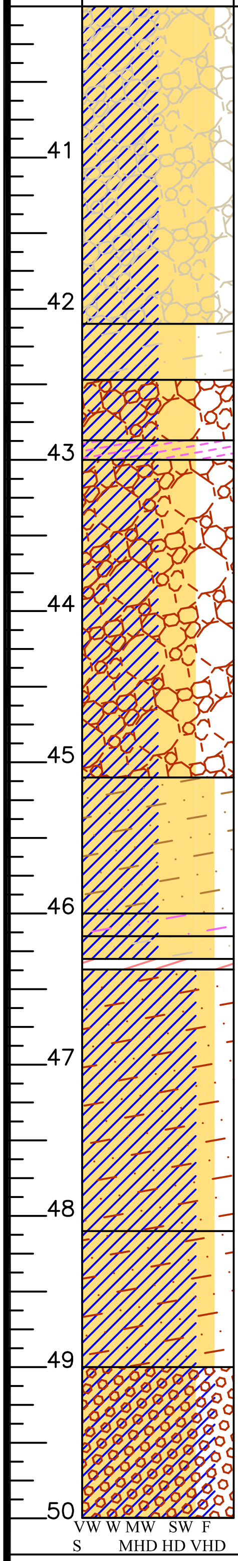
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH-1407-DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 3 OF 5

LOCATION: 377590, 6385578GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



LIGHT BROWN COARSE GRAINED SANDSTONE RARE SHALE CLASTS

RED BROWN CONGLOMERATE FRAGMENTS TO 40mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

VIOLET VERY FINE GRAINED MUDSTONE LAMINAE 70° TO CORE AXIS FRACTURED

RED BROWN CONGLOMERATE FRAGMENTS TO 40mm SANDSTONE & QUARTZ, FRACTURES 20cm APART

BROWN FINE GRAINED SANDSTONE MINOR COARSE GRAINED BANDS PERPENDICULAR TO CORE AXIS

VIOLET FINE GRAINED SANDSTONE MINOR COARSE GRAINED BANDS PERPENDICULAR TO CORE AXIS

LIGHT BROWN FINE GRAINED SANDSTONE MINOR COARSE GRAINED BANDS PERPENDICULAR TO CORE AXIS

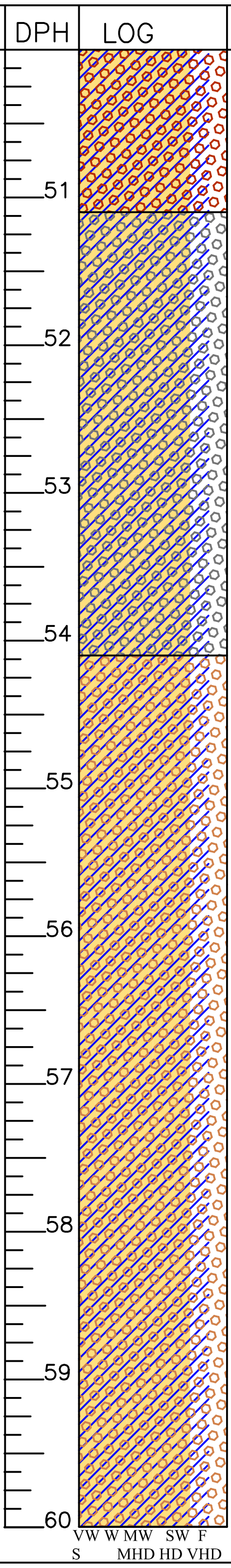
PINK SHALE LAMINAE PERPENDICULAR TO CORE AXIS

RED BROWN FINE GRAINED SANDSTONE FELDSPAR FRAGMENTS MINOR LAMINAE

RED BROWN FINE GRAINED SANDSTONE FELDSPAR FRAGMENTS MINOR LAMINAE

RED BROWN FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTSL, FRACTURES 45° TO CORE AXIS RED CALCITE LINED

DPH LOG DESCRIPTION



GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTSL, FRACTURES 50cm APART

RED GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTSL, FRACTURES 50cm APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

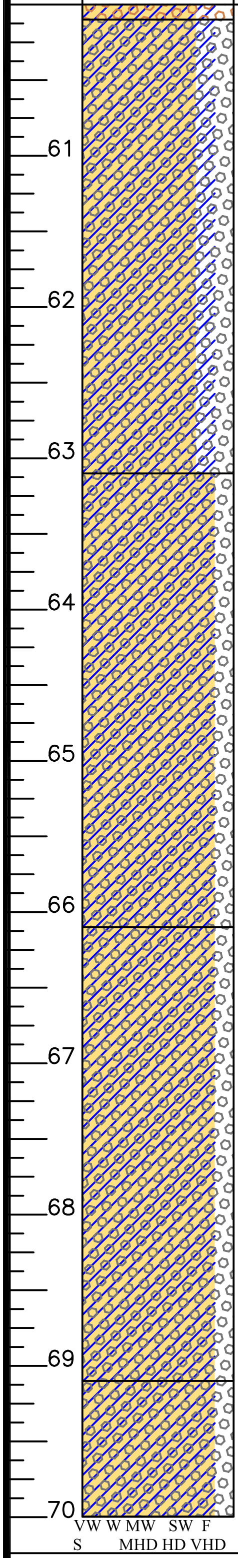
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH−1407−DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 4 OF 5

LOCATION: 377590, 6385578GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH | LOG | DESCRIPTION



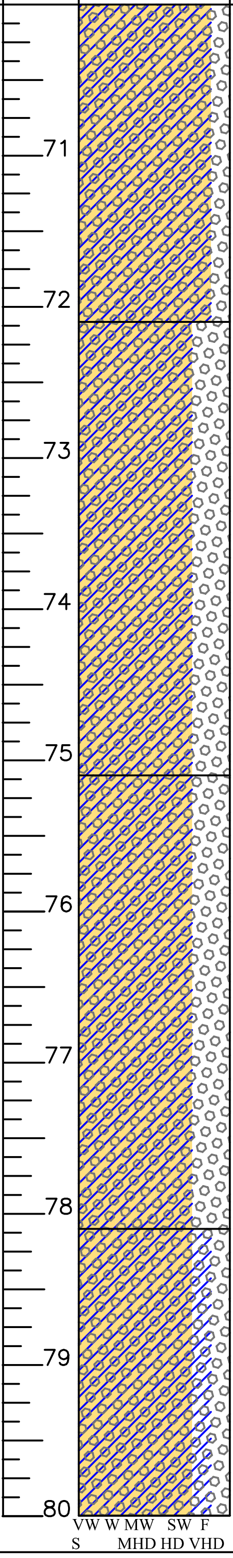
GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART CALCITE IN GROUNDMASS

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART CALCITE VEINS IN GROUNDMASS

DPH | LOG | DESCRIPTION



GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART SIGNIFICANT CALCITE VEINS IN GROUNDMASS

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART SIGNIFICANT CALCITE VEINS IN GROUNDMASS

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS, FRACTURES 50cm APART SIGNIFICANT RED CALCITE VEINS IN GROUNDMASS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

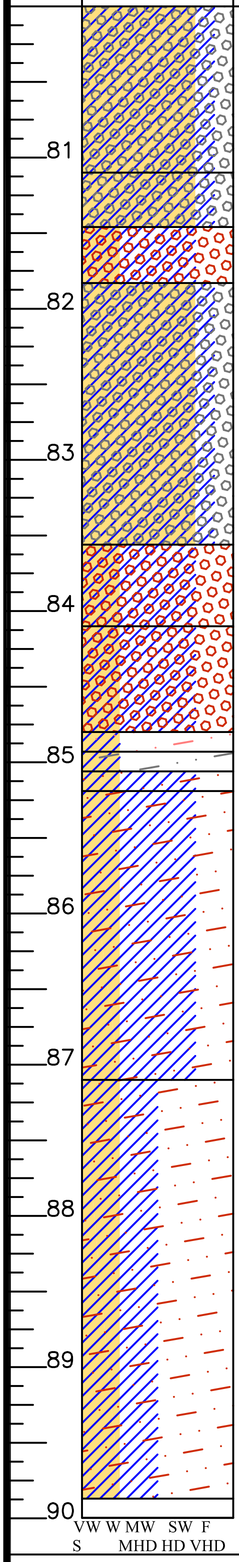
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: BH–1407–DH
PROJECT: BRANDY HILL, ZONE 56
PAGE 5 OF 5

LOCATION: 377590, 6385578GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 22/5/14

DPH LOG DESCRIPTION



GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS SIGNIFICANT CALCITE VEINS IN GROUNDMASS

RED FINE GRAINED IGNIMBRITE

GREY FINE GRAINED IGNIMBRITE FELDSPAR & QUARTZ PHENOCRYSTS SIGNIFICANT CALCITE VEINS IN GROUNDMASS

RED FINE GRAINED IGNIMBRITE

RED FINE GRAINED IGNIMBRITE

PINK VERY FINE GRAINED SANDSTONE

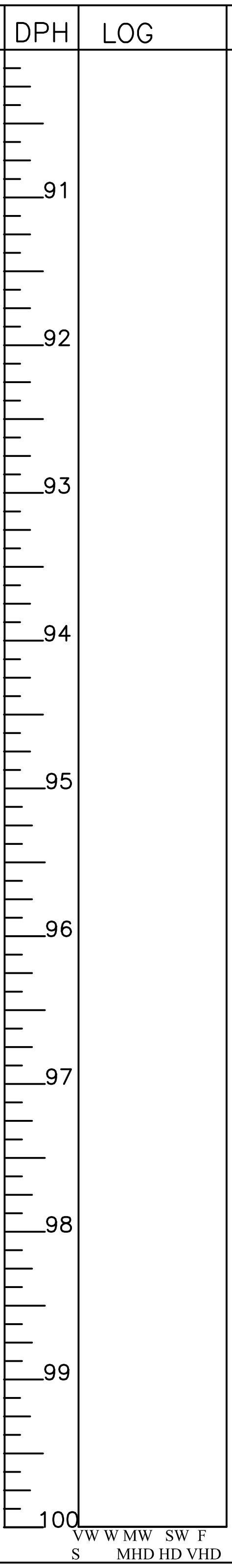
GREY FINE GRAINED SANDSTONE

RED FINE GRAINED SANDSTONE LIGHT FRACTURED HIGH

RED FINE GRAINED SANDSTONE, FRACTURES 40cm APART

RED FINE GRAINED SANDSTONE, FRACTURES 20cm APART

DPH LOG DESCRIPTION



COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

17 Attachment E – Site Groundwater Quality Data

	Testing Date																							
	26/08/2014			25/09/2014			23/10/2014			21/11/2014			23/12/2014			22/01/2015			23/02/2015			1/05/2015		
Bore ID	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)	Salinity (mg/L)	TN (mg/L)	TP (mg/L)
BH1401	2182.40	0.50	0.02	2444.80	0.20	0.02	2611.20	0.30	0.03	2662.40	0.40	0.02	2816.00	0.20	0.11	2918.40	0.40	<0.05	3020.80	0.40	0.02	[NT]	[NT]	[NT]
BH1403	857.60	2.30	0.03	889.60	2.00	0.02	896.00	1.90	0.06	902.40	2.50	0.03	921.60	2.10	0.03	1100.80	2.10	<0.05	1644.80	1.80	0.05	2790.40	1.40	0.03
BH1404	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
BH1405	420.48	0.70	0.01	474.88	0.40	0.01	2272.00	0.20	<0.01	166.40	<0.1	<0.01	2400.00	<0.1	<0.01	2393.60	0.20	<0.05	2368.00	<0.1	<0.01	1376.00	0.70	0.02
BH1406	1958.40	<0.1	<0.01	1971.20	<0.1	<0.01	1977.60	<0.1	0.01	1964.80	<0.1	<0.01	1952.00	0.10	<0.01	1926.40	0.20	<0.05	1721.60	0.20	<0.01	1875.20	<0.1	<0.01
BH1407	2540.80	2.70	0.01	2630.40	1.70	<0.01	2563.20	0.45	0.01	2473.60	0.25	0.01	2451.20	0.10	0.03	2435.20	0.20	<0.05	2406.40	0.30	0.01	[NT]	[NT]	[NT]
BH400	2144.00	0.30	0.03	2163.20	0.20	0.03	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]	[NT]
BH401	684.80	24.00	<0.01	659.20	0.20	<0.01	646.40	4.30	<0.01	631.68	7.10	0.02	633.60	7.80	<0.01	636.80	6.20	<0.05	623.36	7.90	<0.01	601.60	9.70	<0.01
BH401A	625.28	0.50	<0.01	697.60	12.85	<0.01	684.80	12.90	<0.01	579.84	2.60	<0.01	668.80	11.95	0.06	665.60	12.00	<0.05	665.60	12.00	<0.01	688.00	9.85	<0.01

General Notes:

[1] Site groundwater quality sampling undertaken by VGT Environmental Compliance Solutions.

[2] Site groundwater quality data is summarised in Table 11.

[3] Salinity data in mg/L converted from raw electrical conductivity measurements in µS/cm using a multiplication factor of 0.64 adopted from NSW Office of Environment & Heritage (OEH) website (2013).

[4] Field duplicates have been averaged.

[5] TN = total nitrogen.

[6] TP = total phosphorus.

18 Attachment F – Varying Rainfall Predictive Numerical Groundwater Models

18.1 Modelling Overview

The predictive groundwater models described in Section 6 were utilised as the basis for varying rainfall model setup. All settings, parameters and boundaries used in the uniform rainfall models remained unchanged, with the only change being to recharge inputs.

18.2 Proposed Development Model

18.2.1 Boundary Condition Changes

The only change to the uniform rainfall proposed development model (discussed in Section 6.2) was to recharge rates. Model recharge rates were assigned based on application of calibrated transient recharge rates (in the form of % of rainfall as shown in Attachment C Figure 31) to annual rainfall records sourced from Tocal BOM station from 1968 to 2014 (47 years representing all available data). Any missing rainfall observations were populated with mean rainfall for the given month in order to permit calculation of annual rainfall. This rainfall pattern was assumed to repeat every 47 years after 2014, i.e. 1968 rainfall = 2015 simulated rainfall, 1969 rainfall = 2016 simulated rainfall and so on.

Recharge zonation and all other inputs remained unchanged from uniform rainfall model runs.

18.2.2 Results

Layer 1 head for the entire model and over the site, and drawdown to Layer 1 head over the site are provided in Attachment C Figure 51, Figure 52 and Figure 53 respectively with the model's water balance provided in Table 30, all of which represent outputs from the model's last quarrying simulation period. The maximum extent of the 2 m drawdown cone at this time is approximately 5.3 km east-west and 4.6 km north-south, and extends over site boundaries in all directions.

The pre quarry, existing and final proposed groundwater head and drawdown that occurs at the model's last simulation period is in Table 31 for the model's bores. This differs from drawdown in Attachment C Figure 53 as Table 31 drawdown values are drawdown at bore monitoring points (i.e centre of bore's open portion), not drawdown for a particular layer.

Time series head plots are provided in Attachment C Figure 56 and Figure 57 for all model domain bores and for offsite model domain bores respectively. The head plots combine results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250). These graphs are best viewed after reading to the end of Section 18.3.2 (Rehabilitation Model Results).

A time series dewatering rate plot is provided in Attachment C Figure 58 for the quarry void. The dewatering plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250). These graphs are best viewed after reading to the end of Section 18.3.2 (Rehabilitation Model Results). Dewatering rates per stage are summarised in Table 32 for pre quarry conditions to the end of proposed development conditions. We note the peak dewatering rate of 670 ML/yr at the last year of proposed development quarrying coincides with a year of high rainfall (1175.3 mm – 26% higher than the average 933.1 mm).

A time series creek and river rate plot is provided in Attachment C Figure 59 for all model domain creeks and Williams River (as shown in Attachment C Figure 29). The rates plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to after rehabilitation equilibrium conditions – model year 67 – 250). These graphs are best viewed after reading to the end of Section 18.3.2 (Rehabilitation Model Results). River and creek impacts during quarrying are not clearly evident as the annual fluctuation in rainfall 'washes out' the effect of quarry drawdown.

Table 30: Water balance at end of proposed quarrying – varying rainfall.

Storage (ML/yr)		Recharge (ML/yr)		ET (ML/yr)		River (ML/yr) 2		Pit Drains (ML/yr) 3		Creek Drains (ML/yr) 4		Constant Head (ML/yr)		Total (ML/yr)	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0	320	3960	0	0	3385	27	107	0	669	0	44	596	59	4583	4583

Notes:

1. 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).
2. River representing Williams River.
3. Drains representing quarry pit.
4. Drains representing creeks throughout the model domain.

Table 31: Pre quarry, existing and proposed groundwater head and drawdown at bore monitoring points (i.e centre of bore's open portion) – varying rainfall.

	Modelled Groundwater Head (mAHD) [1]			
Bore	**Pre Quarry [2]**	**Existing [3]**	**Proposed [4]**	**Drawdown (m) [5]**
BH401	41	38	-1.5	43
BH401A	37	36	1.2	36
BH400	40	35	-22	62
BH1401	19	19	-1.0	20
BH1403	22	21	-33	55
BH1404	71	70	53	18
BH1405	32	29	0.25	32
BH1406	29	26	-15	44
BH1407	27	26	-0.79	28
Lake Obs [6]	24	23	-78	102
Synthetic [7]	-0.16	-0.17	-0.16	-0.01 [8]
GW078135	8.1	8.0	5.1	3.0
GW51309	9.6	9.5	9.7	-0.16 [8]

Notes:

[1] Head at bore reported at observation point (i.e centre of bore's open portion) to two significant figures.

[2] Head from calibrated pre quarry steady state model (start of 1980, refer Table 16).

[3] Head from transient model for current conditions (end of 2014, refer Table 16).

[4] Head from transient model at conclusion of proposed development simulation (end of 2046, refer Table 16).

[5] Drawdown = pre quarry head – proposed head.

[6] Synthetic bore at the bottom bench of the quarry to model rehabilitation lake head. Note that the proposed head is equal to the bottom bench level of -78 mAHD.

[7] Synthetic observation bore on low-lying rural land south east of the quarry (refer Section 5.8.1).

[8] Drawdown at these bores is outside the quarry drawdown cone (Attachment C Figure 53) and hence represent natural groundwater head variation due to annual rainfall variation.

Table 32: Pre quarry, existing and proposed groundwater dewatering rates due to the quarry void – varying rainfall.

	Stage [1]	Calendar Year Start	 End	Dewatering Rate (ML/yr) Minimum [2]	 Maximum [2]
1	Pre Quarry Conditions	1980	1982	-	-
2	Currently Approved Quarry – to Current	1983	2014	3.4	71
3	Currently Approved Quarry – to Final Form [3]	2015	2016	71	112
4	Proposed Expansion Stage 1	2017	2022	112	163
5	Proposed Expansion Stage 2	2023	2028	163	298
6	Proposed Expansion Stage 3	2029	2034	298	425
7	Proposed Expansion Stage 4	2035	2040	425	495
8	Proposed Expansion Stage 5	2041	2046	495	669

Notes:

[1] Excludes rehabilitation conditions which are discussed in Section 18.3.2.

[2] Minimum and maximum dewatering rates for the given stage.

[3] The final form of the currently approved quarry is estimated to be completed at the end of 2016.

18.3 Rehabilitation Model

18.3.1 Boundary Condition Changes

The only change to the uniform rainfall rehabilitation model (discussed in Section 6.3) was to recharge rates. As with the proposed development transient model with varying recharge, recharge rates were assigned based on application of calibrated transient recharge rates (in the form of % of rainfall as shown in Attachment C Figure 31) to annual rainfall records sourced from Tocal BOM station from 1968 to 2014 (47 years representing all available data). This rainfall pattern was assumed to repeat every 47 years after 2014 up to 100 years after the conclusion of quarrying. 5 year mean rainfall based on this repeating pattern was utilised for each stress period. After 100 years of rehabilitation modelling a constant annual rainfall based on the mean from 1968 to 2014 (934 mm/yr) was used to determine recharge rates.

Recharge zonation and all other inputs remained unchanged from uniform rainfall model runs.

18.3.2 Results

Layer 1 heads for the entire model and over the site are provided in Attachment C Figure 54 and Figure 55 respectively, both of which represent outputs from the model's last rehabilitation simulation period (500 years post development quarry operations). Lake water levels within the quarry void equilibrated to a level of approximately 25.3 mAHD after 170 years of rehabilitation modelling (calendar year 2217).

The model's water balance at the last rehabilitation simulation period is given in Table 33. Note that quarry drains have been removed from the rehabilitation model and the water balance. Vertical and lateral groundwater flows into and out of the void at this time are summarised in Table 34.

Time series head plots are provided in Attachment C Figure 56 and Figure 57 for all model domain bores and for offsite model domain bores respectively. The head plots combine results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250). Attachment C Figure 56 shows that all observation bores within the final lake extent (BH400, BH401, BH401A, BH1403 and Lake Obs) have identical heads, or similar heads for the case of BH1403 which has its screen located in a deeper model layer.

A time series dewatering rate plot is provided in Attachment C Figure 58 for the quarry void. The dewatering plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to rehabilitation equilibrium conditions – model year 67 – 250).

A time series creek and river rate plot is provided in Attachment C Figure 59 for all model domain creeks and Williams River (as shown in Attachment C Figure 29). The rates plot combines results from the proposed development model (from pre quarry conditions to end of proposed development conditions – model year 0 – 67) and the rehabilitation model (end of proposed development conditions to after rehabilitation equilibrium conditions – model year 67 – 250). As with the varying rainfall proposed development model, river and creek impacts during quarrying are not clearly displayed as the annual fluctuation in rainfall 'washes out' the effect of quarry drawdown. River rates seem to fluctuate normally throughout quarrying. Creek rates seem to slightly decrease up to the end of proposed Stage 5 quarrying, after which they return to initially estimated rates.

The pre quarry, existing and final rehabilitated groundwater head and drawdown that occurs at the rehabilitation model's last simulation period is in Table 35 for the model's bores. A rehabilitation equilibrium conditions drawdown plot is given in Attachment C Figure 60. The maximum extent of the 2 m drawdown cone at this time is approximately 2.8 km east-west and 2.4 km north-south, and extends over the northern site boundary.

Table 33: Water balance for rehabilitation equilibrium conditions (500 years post development quarry operations) – varying rainfall.

Storage (ML/yr)		Recharge (ML/yr)		ET (ML/yr)		River (ML/yr) [2]		Creek Drains (ML/yr) [3]		Constant Head (ML/yr)		Total (ML/yr) [4]	
In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0	0	3665	0	0	4005	28	102	0	47	599	58	4292	4212

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] River representing Williams River.

[3] Drains representing creeks throughout the model domain.

[4] We note that mass balance error is 0.98% which is below the adopted error threshold of 1% and is therefore considered acceptable.

Table 34: Water balance for rehabilitation equilibrium conditions over the quarry void (500 years post development quarry operations) – varying rainfall.

Recharge (ML/yr)		ET (ML/yr)		Vertical Flow (ML/yr)		Lateral Flow (ML/yr)		Total (ML/yr) [2]	
In	Out	In	Out	In	Out	In	Out	In	Out
608	0	0	596	101	97	114	120	823	813

Notes:

[1] 'In' and 'out' volumes from the perspective of groundwater system (MODFLOW convention).

[2] We note that mass balance error is approximately 1.3%. Whilst this is above the adopted error threshold of 1% (Section 5.2) we consider it acceptable as it only occurs over a small area compared to the entire model domain. Model mass balance error is 0.98% and is considered acceptable.

Table 35: Pre quarry, existing and rehabilitation equilibrium groundwater head and drawdown at bore monitoring points (i.e centre of bore's open portion) – varying rainfall.

	Modelled Groundwater Head (mAHD) [1]			
Bore	**Pre Quarry [2]**	**Existing [3]**	**Rehabilitation [4]**	**Drawdown (m) [5]**
BH401	41	38	25	16
BH401A	37	36	25	12
BH400	40	35	25	15
BH1401	19	19	20	-1.0
BH1403	22	21	24	-1.5
BH1404	71	70	64	7.1
BH1405	32	29	26	6.0
BH1406	29	26	23	5.8
BH1407	27	26	25	2.1
Lake Obs [6]	24	23	25	-1.5
Synthetic [7]	-0.16	-0.17	-0.15	-0.01 [8]
GW078135	8.1	8.0	8.1	0.04 [8]
GW51309	9.6	9.5	9.6	0.00 [8]

Notes:

[1] Head at bore reported at observation point (i.e centre of bore's open portion) to two significant figures.

[2] Head from calibrated pre quarry steady state model (start of 1980, refer Table 16).

[3] Head from transient model for current conditions (end of 2014, refer Table 16).

[4] Head from transient model at conclusion of rehabilitation simulation (end of 2547, refer Table 16).

[5] Drawdown = pre quarry head – rehabilitation head. Negative drawdown values denote increased rehabilitation head over pre quarry head.

[6] Synthetic bore at the bottom bench of the quarry to model rehabilitation lake head.

[7] Synthetic observation bore on low-lying rural land south east of the quarry (refer Section 5.8.1).

[8] Drawdown at these bores is outside the quarry drawdown cone and hence represent natural groundwater head variation due to annual rainfall variation.

19 Attachment G – Agency Consultation

From:	Rohan Macdonald <Rohan.Macdonald@water.nsw.gov.au>
Sent:	Tuesday, 11 March 2014 5:02 PM
To:	Andrew (Parramatta) AU Driver; Mitchell Isaacs
Cc:	Andrew Norris; referrals; Tim Baker
Subject:	RE: FW: Hanson- Brandy Hill Quarry GW impact assessment
Attachments:	ER22275_Brandy Hill Quarry_GW assessment response.pdf

Hi Andrew,
Please find attached the Office of Water's comments on the proposed groundwater assessment for the Brandy Hill Quarry expansion. Feel free to give me a call if you have any further questions.

Regards,
Rohan Macdonald

Rohan Macdonald | Water Regulation Officer, Major Projects
Department of Primary Industries | NSW Office of Water
3/26 Honeysuckle Dr | Newcastle NSW 2300
PO BOX 2213 DANGAR NSW 2309
T: 02 4904 2642
F: 02 4904 2503
E: rohan.macdonald@water.nsw.gov.au
W: www.water.nsw.gov.au

>>> "Driver, Andrew (Parramatta) AU" <Andrew.Driver@hanson.com.au> 19/02/2014 8:34 am >>>
Hello Mitchell,

Thanks for the prompt response.

Regards,

Andrew Driver
Development Manager

T +61 2 9354 2644 | M +61 417 234 774 | F +61 2 9354 2619

Andrew.Driver@hanson.com.au | **www.hanson.com.au**

From: Mitchell Isaacs [mailto:Mitchell.Isaacs@water.nsw.gov.au]
Sent: Tuesday, 18 February 2014 8:05 PM
To: Driver, Andrew (Parramatta) AU
Cc: Andrew Norris (ANorris@martens.com.au); Rohan Macdonald
Subject: Re: FW: Hanson- Brandy Hill Quarry GW impact assessment

Thanks Andrew

I've asked Rohan Macdonald in the Newcastle Office to coordinate a meeting and any necessary input. Rohan is attending training all week, so should be in contact on his return to the office next week.

Regards
Mitchell

Mitchell Isaacs | Manager Strategic Stakeholder Liaison
Department of Primary Industries | NSW Office of Water
Level 11, 10 Valentine Ave Parramatta NSW 2124 | PO Box 3720 Parramatta NSW 2124

T: 02 8838 7529 | M: 0403 103 823 | E: mitchell.isaacs@water.nsw.gov.au
W: www.water.nsw.gov.au

>>> "Driver, Andrew (Parramatta) AU" <Andrew.Driver@hanson.com.au> 17/02/2014 10:39 am >>>
Hello Mitchell,

Following on from my e-mail to you in November last year, I have attached our GW assessment strategy for NOW's perusal. We would appreciate any feedback from NOW on the matters raised (or not raised) in the document prior to the commencement of the detailed EA work in late March 2014.

We would be happy to meet with you at your convenience to go over the document in detail and the proposed quarry expansion in general.

If you have any queries please feel free to contact me on the details below.

Kind Regards,

Andrew Driver
Development Manager

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From: Driver, Andrew (Parramatta) AU
Sent: Wednesday, 6 November 2013 1:42 PM
To: 'mitchell.issacs@water.nsw.gov.au'
Cc: Lloyd, Kathy (Parramatta) AUS; Andrew Norris <ANorris@martens.com.au> (ANorris@martens.com.au)
Subject: Hanson- Brandy Hill Quarry GW impact assessment

Hello Mitchell,

Thanks for meeting with us to discuss the AI policy last Monday. I thought the meeting was very beneficial in providing a forum for our industry to have certain matters heard.

Further to our brief discussion after the meeting Hanson would like to meet with the appropriate NOW officers to ensure that our strategic approach to conducting an adequate GW assessment for the Brandy Hill quarry project meets NOWs expectation prior to the commissioning of field work and the detail analysis. To facilitate this, and taking your advice into account, my colleague Kathy Lloyd will prepare a brief of the proposed GW assessment strategy for NOW's perusal. Subsequent to this we would like to arrange a meeting between Hanson, NOW and our GW consultants.

If you have any queries please feel free to contact me on the details below.

Kind Regards,

Andrew Driver
Development Manager- Eastern Region

Hanson
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Department of
Primary Industries
Office of Water

Contact Rohan Macdonald
Phone 02 4904 2642
Fax 02 4904 2503
Email rohan.macdonald@water.nsw.gov.au

Our ref ER22275

Hanson Construction Materials
Level 5, 75 George Street
PARRAMATTA NSW 2150

Attention: Andrew Driver

Dear Andrew

Hanson Brandy Hill Quarry
Groundwater impact assessment

I refer to your request for feedback regarding the proposed groundwater assessment strategy for the Brandy Hill Quarry expansion proposal. The Office of Water has reviewed the information provided and is generally satisfied with the proposed assessment approach. The following comments are provided for consideration in the refinement and implementation of the assessment.

Scope of works

The Office of Water understands the scope of works for the assessment to include:

1. Establish monitoring bores at each of the proposed resource investigation holes surrounding the quarry. Each new bore as well as BH400 and BH401 (existing) shall be fitted with automated data loggers to monitor groundwater levels in order to obtain a minimum six months of groundwater data.
2. Groundwater quality sampling at all site bores to test for salinity, pH, total dissolved solids (TDS) and nutrients (nitrogen and phosphorous).
3. Packer testing at all site bores to determine the hydraulic conductivity of the ignimbrite and underlying mudstone and adjacent conglomerate at varying depths.
4. A Visual MODFLOW model be established to develop an accurate groundwater model for the Brandy Hill quarry.
5. Determine the impact of an increased extraction zone to groundwater conditions and any identified local groundwater users or groundwater dependent ecosystems (GDEs).

Comments and recommendations

Aquifer drawdown

The groundwater assessment will need to address the minimal impact considerations of the Aquifer Interference Policy (AIP) in order to satisfy point 5 above. Given the relatively shallow depth to groundwater, the extensive vegetation surrounding the quarry and the intent to significantly deepen the quarry as part of the expansion, there is a potential risk to any GDEs which may surround the quarry as a result of aquifer drawdown.

The AIP provides some guidance as to GDE water table impacts being less than or equal to 10% cumulative variation in the water table. Point 1 of the scope of works identifies that a minimum of 6 months of groundwater monitoring data will be used to inform the assessment and develop the groundwater model. This limited dataset may limit the assessment against the minimal impact consideration as seasonal variations in water level may not have been measured. A flora survey for potential GDEs within 100m of the proposed quarry extraction area and identification of their ecological value should be considered. Observations of floristic impacts against the existing quarry operations may help provide supporting information.

An assessment of the uncertainty associated with limited monitoring data and an evaluation of the associated risk to GDEs will need to be provided and where relevant options proposed for mitigation of the risk.

Groundwater quality

The procedures and/or standards to be followed for water quality sampling should be documented.

Hydraulic conductivity

Packer testing to determine the hydraulic conductivity is considered satisfactory.

Groundwater modelling

Visual MODFLOW is considered a satisfactory modelling platform. The Australian Groundwater Modelling Guidelines (2012) should be followed for model development and report preparation.

Licensing requirements

The information provided does not discuss licensing requirements for the proposal. The groundwater model and water balance will provide information as to volumes required for licensing. The groundwater resource on site is currently managed under the *Water Act 1912* and is not presently subject to embargo. As such application may be made for a licence under Part 5 of that act to address licensing requirements.

If you require further information please contact Rohan Macdonald, Water Regulation Officer on (02) 4904 2642 at the Newcastle office.

Yours sincerely

Tim Baker
A/Manager, Strategic Stakeholder Liaison
11 March 2014

martens
consulting engineers since 1989

Posted ☐
Faxed ☐
Emailed ☐
Courier ☐
By Hand ☐
Contact: Andrew Norris
Our Ref: P1303888JC01V02.doc
Pages: 10
cc. -

February 14, 2014

Hanson Construction Materials Pty Ltd
Attn: Andrew Driver / Kathy Lloyd

Dear Andrew/Kathy,

RE: BRANDY HILL QUARRY: HYDROGEOLOGICAL ASSESSMENT

BACKGROUND INFORMATION

A detailed review of available public record data sets have been undertaken to inform the development of the proposed hydrogeological investigation and assessment of the proposed Hanson Brandy Hill quarry expansion EA. To date review of datasets has included:

1. NSW Department of Planning and Infrastructure major project website – no major projects with significant hydrogeological datasets or information have been identified within the Brandy Hill area. No relevant or useful information was developed.

2. NSW Department of Planning (Sydney – mining section) – no information was available and no likely sources of relevant datasets identified.

3. NSW Department of Trade and Investment – no information was available and no likely sources of relevant datasets identified.

4. Port Stephens Council – no information was available and no likely sources of relevant datasets identified.

5. NSW Office of Water – provided a conference paper and a Water Resources Commission report relating to Hunter Valley geology. The conference paper notes carboniferous rocks of the area have mean hydraulic conductivity of 0.01 m/d and mean effective porosity of 0.02. The WRC report related to alluvial aquifers.

6. A summary of groundwater information contained in the NSW Government's NRAtlas website is provided below. Information for the nearest bores indicate the geology as granite – further information from these records is presently being sourced to determine the nature of the local geology and characteristics of groundwater in these locations.

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EIS & REF	Foundations	Supply & storage	Treatment	Earthworks
Streams & rivers	Geotechnical survey	Flooding	Re-use	Excavations
Coastal	Contamination	Stormwater & drainage	Biosolids	Pipelines
Groundwater	Hydrogeology	Wetlands	Design	Roads
Catchments	Mining	Water quality	Management	Pavements
Bushfire	Terrain analysis	Irrigation	Monitoring	Parking
Monitoring	Waste management	Water sensitive design	Construction	Structures

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7. Newcastle Coalfields 1:100 000 geological map – indicates the site is Cz – undifferentiated tuff and ignimbrite interbedded with conglomerate, sandstone and shale.

8. Newcastle 1:100 000 geological sheet – indicates the site is Cup – acid lava flows, crystal tuff, interbedded conglomerate and ignimbrite.

9. Hanson Brandy Hill Site Geology and Drilling Report (March 2012).

GEOLOGICAL CONDITIONS

Carboniferous rocks outcrop principally on the northern side of the Hunter River and are separated from the younger Coal Measure geology to the south by a fault system, known as the Hunter Thrust. The area is highly faulted and these faults cut off geological units abruptly.

The site has been previously investigated with three diamond drill holes located in the centre and west of the site followed with recent resource holes (BH400, BH401 and BH401A). Quarried rock has been formerly described as a rhyodacite and comprises three colours; a cream weathered profile, a red-brown layer which is slightly weathered with the colour being due to the alteration of magnetic haematite, and grey fresh rock which lies at the base of the sequence. An examination of the petrology indicates that this is more akin to an ignimbrite in nature (Browne, 2012).

The drill holes intercepted mudstone at the base of the ignimbrite, belonging to the Mount Johnson Formation. Field measurements indicate the base of the ignimbrite dipping at 10 degrees to the south east (Hunter Valley Mining Corp, 1983). Drill holes completed in 2012 indicated overlying conglomerate and sandstone of 33m to the south west (BH400) of the operating pit.

The ignimbrite is described as a hard rock and the specific gravity has been tested at 2.6 (Browne, 2012).

GROUNDWATER LEVELS

NSW Department of Natural Resources (DNR) groundwater bore database was consulted to examine recorded groundwater levels in the local area. Locations of bores are shown in Figure 1 and a summary of relevant bore data is provided in Table 1. Information indicates that depth to groundwater in the Brandy Hill area is typically > 5 mBGL (and up to 61 mBGL).

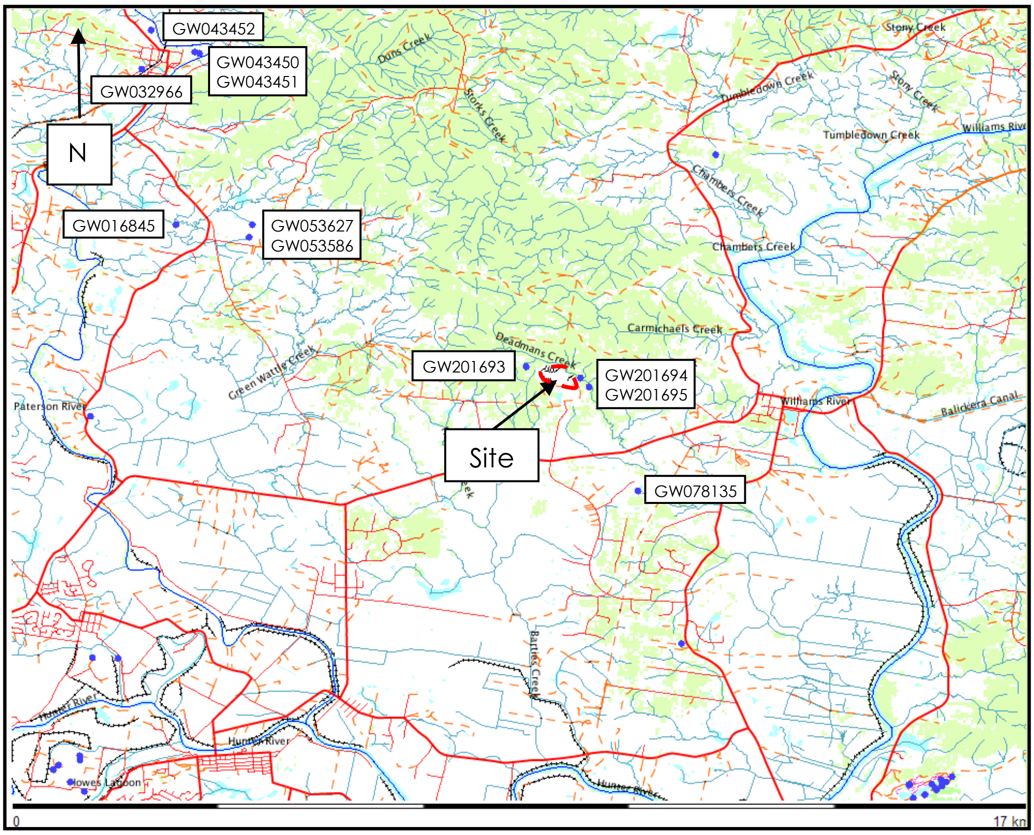


Figure 1: NSW Department of Natural Resources groundwater bore database search within 9km of the site.

Table 1: Available hydrogeological information.

Groundwater Bore Identification	Distance (km) / Orientation From Site	Depth to Groundwater (mBGL	Intended Use	Water Bearing Zone Substrate
GW043451	8.2/NW	15	Public/Municipal	Gravel Clay
GW043452	9.0/NW	14	Public/Municipal	Gravel Sand
GW032966	8.6/NW	21	Domestic	Basalt
GW043450	8.2/NW	17	Public/Municipal	Gravel Sand
GW016845	7.0/NW	5	Not Known	Sand River Gravel
GW053627	5.7/NW	6	Irrigation	Sandstone
GW053586	5.6/NW	39	Irrigation	Shale
GW201694	0.2/N	20	Monitoring Bore	Granite
GW201695	0.2/E	18	Monitoring Bore	Granite
GW078135	2.0/S	61	Domestic Stock	Sandstone
GW201693	0.4/W	NA	Monitoring Bore	NA

Data from three site groundwater monitoring bores contained within the project area was provided by Hanson (Kathy Lloyd 19.11.13). Groundwater depths were measured at hourly intervals over a five month period from 26 April 2012 to 18 September 2012. Locations of site monitoring bores are shown in Figure 2, and the data is summarised in Table 2 (datum = mBGL) and Table 3 (datum = mAHD). The data indicates that the groundwater depth varies by a maximum of 2.2 m over the five month monitoring period. The depth to groundwater within the existing extraction area is typically 1.0 – 2.5 mBGL and the depth outside of the extraction area is typically 30.5 mBGL.

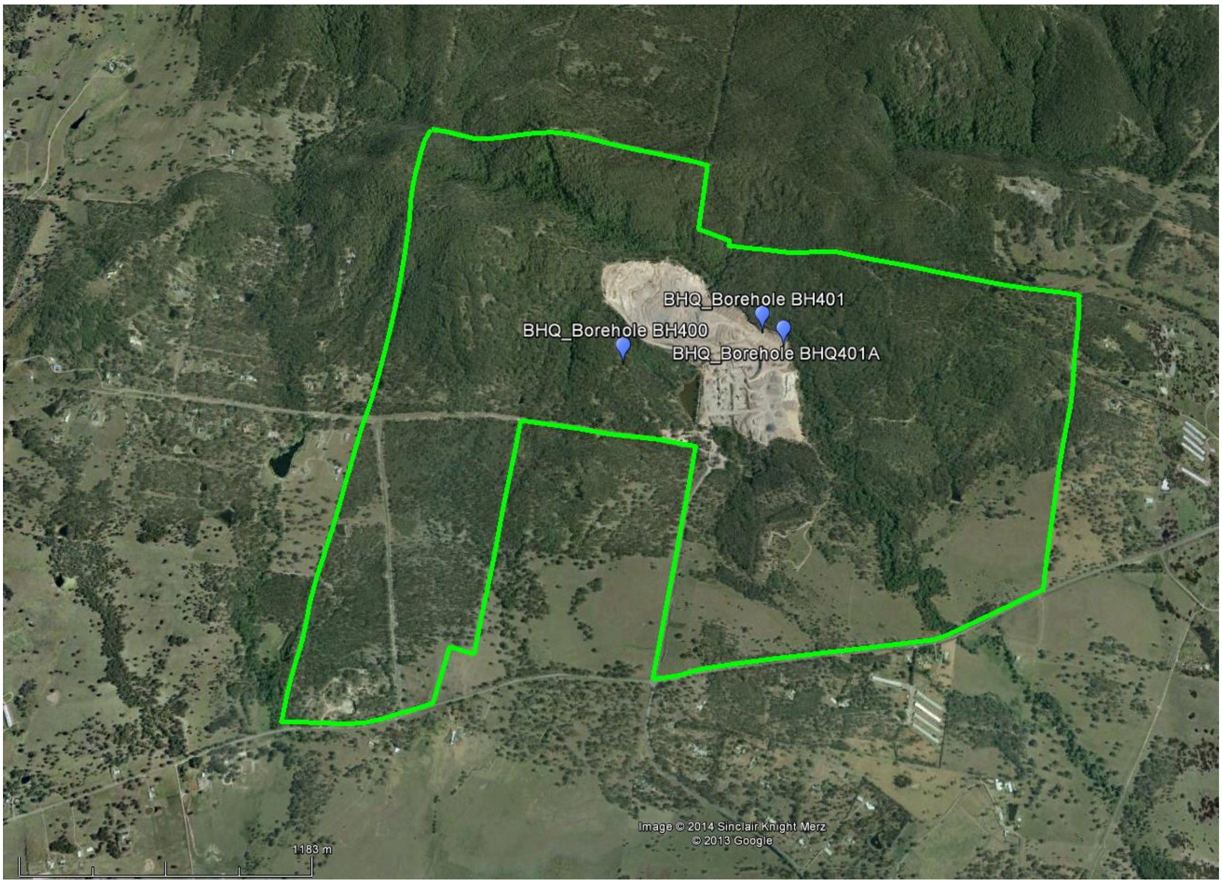


Figure 2: Brandy Hill Quarry project area and site groundwater monitoring bore locations (Google Earth 2014).

Table 2: Statistical summary of groundwater levels (mBGL) monitored by data logger at site bores between 26.04.2012 and 18.09.2012.

	Groundwater Depth (mBGL) [1]		
Bore	**BHQ_Borehole BH400**	**BHQ_Borehole BH401**	**BHQ_Borehole BHQ401A**
Minimum	29.554	0.989	1.428
Mean	30.511	1.550	1.895
Maximum	31.739	2.550	2.597
Range	2.185	1.561	1.169

Notes:

[1] Groundwater depth is assumed to be measured from ground elevation.

Table 3: Statistical summary of groundwater levels (mAHD) monitored by data logger at site bores between 26.04.2012 and 18.09.2012.

	Groundwater Depth (mAHD) [1]		
Bore	**BHQ_Borehole BH400**	**BHQ_Borehole BH401**	**BHQ_Borehole BHQ401A**
Minimum	40.761	34.450	33.403
Mean	41.989	35.450	34.105
Maximum	42.946	36.011	34.572
Range	2.185	1.561	1.169

Notes:

[1] Groundwater depth is assumed to be measured from ground elevation.

GROUNDWATER HYDRAULIC GRADIENTS

Groundwater hydraulic gradients (Table 4) were analysed between site bores using the mean groundwater level observed by data logger over the monitoring period and the distance between bores measured in on a site survey plan. Hydraulic gradients are low and are operating as expected. BH400 groundwater levels are above BH401 and BHQ401A levels, and BH401 levels are above BHQ401A levels, generally in accordance with their respective elevations. Based on this, it is likely that the majority of groundwater flows towards the east in the direction of Deadmans Creek. A small portion at the southern end of the site may flow towards the unnamed drainage channel, which runs into Deadmans Creek downstream.

Table 4: Summarised hydraulic gradients.

Bores	Inter Bore Hydraulic Gradient (m/m)
BH400 to BH401	0.00969
BH400 to BHQ401A	0.01035
BH401 to BHQ401A	0.01222

GROUNDWATER QUALITY

Site specific groundwater quality data is unavailable, however there are several regional studies available. The Water Resources Commission report (1986) provided by NSW Office of Water notes that groundwater is more saline with further distance from the Hunter River, and that salinity in the alluvium is generally < 1000 mg/L. An Australian Government National Water Commission report for the Hunter Valley Region (2010) notes that the average salinity in Hunter Valley alluvium is 900 mg/L. Salinity is higher in carboniferous rock aquifers to the north of the Hunter River (> 1000 mg/L) (De Silva 1998). Based on Table 5 the groundwater of the site's rock aquifer is likely brackish and therefore of poor quality for potable purposes, but may be used for irrigation purposes.

Table 5: Summary of water uses on the basis of salinity.

Class	Salinity (mg/L)	Irrigation Suitability [1]	Suitable for Potable [2]
Fresh	< 1,000	500 – 1,000 can have detrimental effects on sensitive crops	0 – 600 good 600 – 900 fair 900 – 1000 poor
Brackish	1,000 – 5,000	1,000 – 2,000 adverse effects on many crops, requiring careful management practices	1000 – 1200 poor > 1,200 unacceptable / unpalatable
Highly Brackish	5,000 – 15,000	2,000 – 5,000 can be used for salt tolerant plants on permeable soils with careful management practices	No
Saline	15,000 – 30,000	Not suitable	No
Sea Water	30,000 – 40,000	Not suitable	No

Notes:

[1] From NSW Department of Conservation and Land Management (1992).

[2] From Australian Drinking Water Guidelines (2011).

HYDRAULIC CONDUCTIVITY

Site specific hydraulic conductivity data is unavailable, and there are limited regional studies available. The conference paper provided by the NSW Office of Water notes that carboniferous rocks in the Upper Hunter Valley have a mean hydraulic conductivity of 0.01 m/d and mean effective porosity of 0.02.

There are no regional studies available for the hydraulic conductivity of ignimbrite. The hydraulic conductivity of ignimbrite is highly dependent on the spacing, interconnectedness and apertures of the fractures, as well as the density of welding (Kellet et al 1989, Breuer et al. 2000). Medium density ignimbrite has been recorded to have a range of conductivities from 0.5 – 250 m/d (Breuer et al. 2000), however values between 7 x 10^{-7} – 500 m/d have been recorded (Smyth & Sharp 2006). This range of values is too high to justify adoption of a single value or a range of values useful for modelling. Therefore site-specific hydraulic conductivity testing is required to establish a narrower range of values to be used in the site's assessment.

GROUNDWATER DEPENDANT ECOSYSTEMS

The Australian Government National Water Commission report for the Hunter Valley Region (2010) identifies groundwater dependant ecosystems (GDEs) including riparian, aquifer and terrestrial ecosystems. Site specific GDEs have not been identified.

SOURCES AND SINKS

Brandy Hill is a local highpoint at 185 mAHD, rising above the Hunter floodplain to the south and west at levels of the order of 30 – 50 mAHD. Rain falling on the western side of the hill will run towards Heydons Creek and to an unnamed drainage channel which runs into Heydons Creek; rain falling on the northern and eastern sides will run towards Deadmans Creek; and rain falling on the southern side will run towards an unnamed drainage channel which runs into Deadmans Creek. As a result of the hill being a highpoint the groundwater catchment is likely localised, and is not significantly intercepted by other groundwater tables.

Recharge to the groundwater system is likely predominately from local rainfall. Runoff from quarry surfaces drains to dams in the floor of the void which also collects seepage from quarry faces. Site dam leakage may be a source of recharge to the groundwater system. The system likely discharges to Deadmans Creek via throughflow, and to the atmosphere via evapotranspiration in areas where the water table is near to the surface.

The extent of dewatering due to the existing quarry is unknown due to the limited groundwater monitoring data outside of the extraction area and the absence of groundwater information predating the quarry's operation.

CONCEPTUAL GROUNDWATER MODEL

Based on data presented in preceding sections, a conceptual groundwater model (CGM) was prepared (Figure 4). The CGM indicates:

- The geology of the site is dominated by ignimbrite and may have areas of tuff, conglomerate, sandstone and shale. The distribution of these shall be fully assessed through site testing.
- Groundwater flow is to the east towards the Deadmans Creek for the majority of the site. There may also be a small portion of the southern for which groundwater flows south towards an unnamed drainage channel, which runs into Deadmans Creek downstream.
- Site hydraulic gradients are low, of the order of 0.9 – 1.3 %.
- Groundwater depth below ground is variable due to varying land surface levels. Maximum depth is in the order of 42.5 mBGL, and there is a 5.4 mAHD variation in the mean groundwater level between all site bores.
- Groundwater is likely brackish however site specific data is unavailable.
- Hydraulic conductivity is likely to be highly variable and is dependent on site specific factures and welding density. Local hydraulic conductivity testing is required to obtain a more accurate value or range of values for modelling purposes.
- Site specific GDEs have not been identified.
- The groundwater catchment is localised to the Brandy Hill area and is likely not intercepted by other groundwater catchments.
- Groundwater is recharged via rainfall and exits the study area via throughflow and evapotranspiration.

RECOMMENDATIONS

Further groundwater monitoring is required to determine the hydrogeological character of the site and possible impacts of quarry extension. We recommend the following works and monitoring are undertaken:

- Establish monitoring bores at each of the proposed resource investigation holes surrounding the quarry. Each new bore as well as BH400 and BH401 shall be fitted with automated data loggers to monitor groundwater levels in order to obtain a minimum six months of groundwater data. Proposed monitoring bore locations are given in Figure 3.

- Groundwater quality sampling at all site bores to test for salinity, pH, total dissolved solids (TDS) and nutrients (nitrogen and phosphorous).

- Packer testing at all site bores to determine the hydraulic conductivity of the ignimbrite and underlying mudstone and adjacent conglomerate at varying depths.

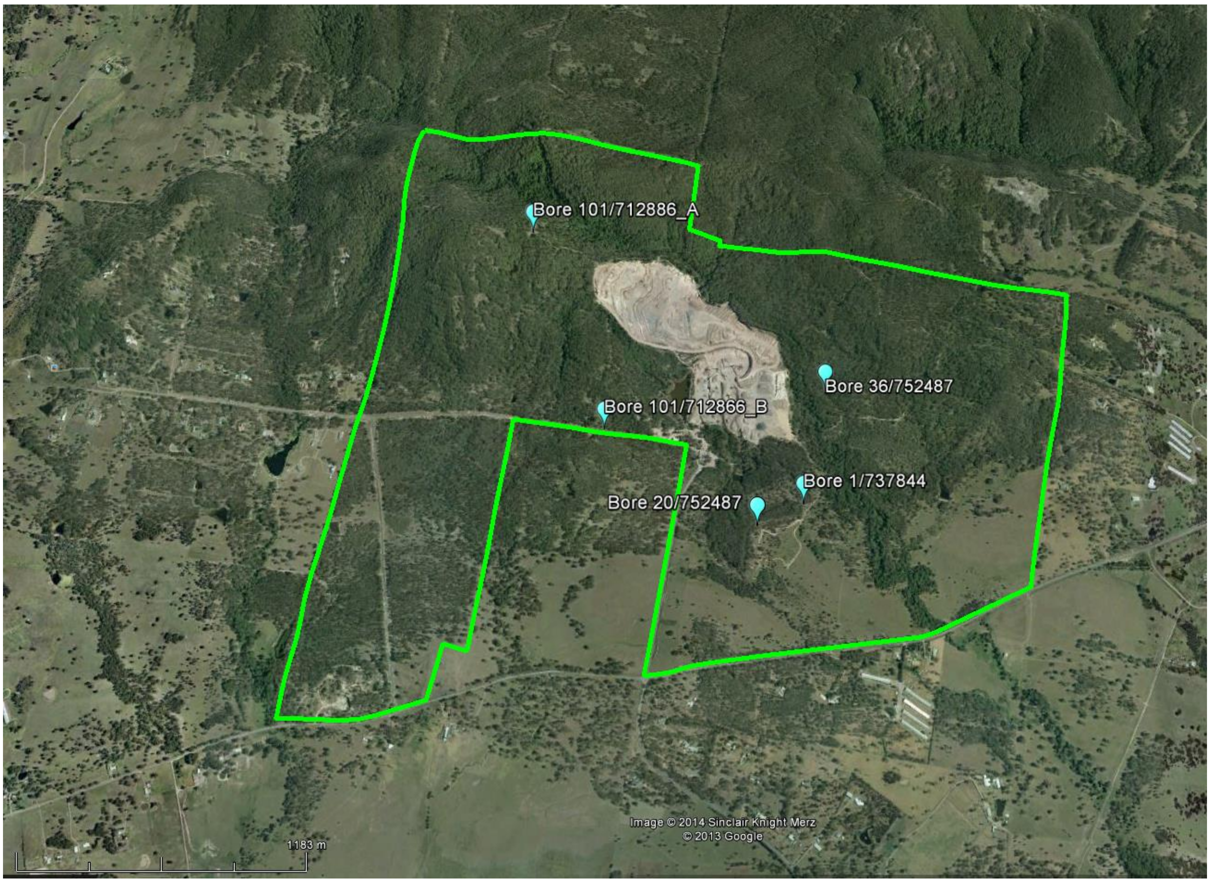


Figure 3: Brandy Hill Quarry project area and proposed additional site groundwater monitoring bore locations (Google Earth 2014).

PROPOSED GROUNDWATER MODELLING APPROACH

We recommend a Visual MODFLOW model be established to develop an accurate groundwater model for the Brandy Hill quarry. The proposed modelling approach is as follows:

- Utilise MODFLOW SURFACT to readily accommodate unsaturated cells and avoid the 'dry cell' problem associated with standard MODFLOW.

- Establish a preliminary steady state model using the the groundwater monitoring data provided by Hanson and the DNR bore data for calibration, giving a higher weighting to site monitoring results.

- Review the preliminary model in the context of a pre-quarry model in order to evaluate if calibration parameters were sensible.

- Establish a transient model using the groundwater data from the existing three bores and proposed new bores after a minimum of six months of monitoring for calibration, giving a higher weighting to site monitoring results.

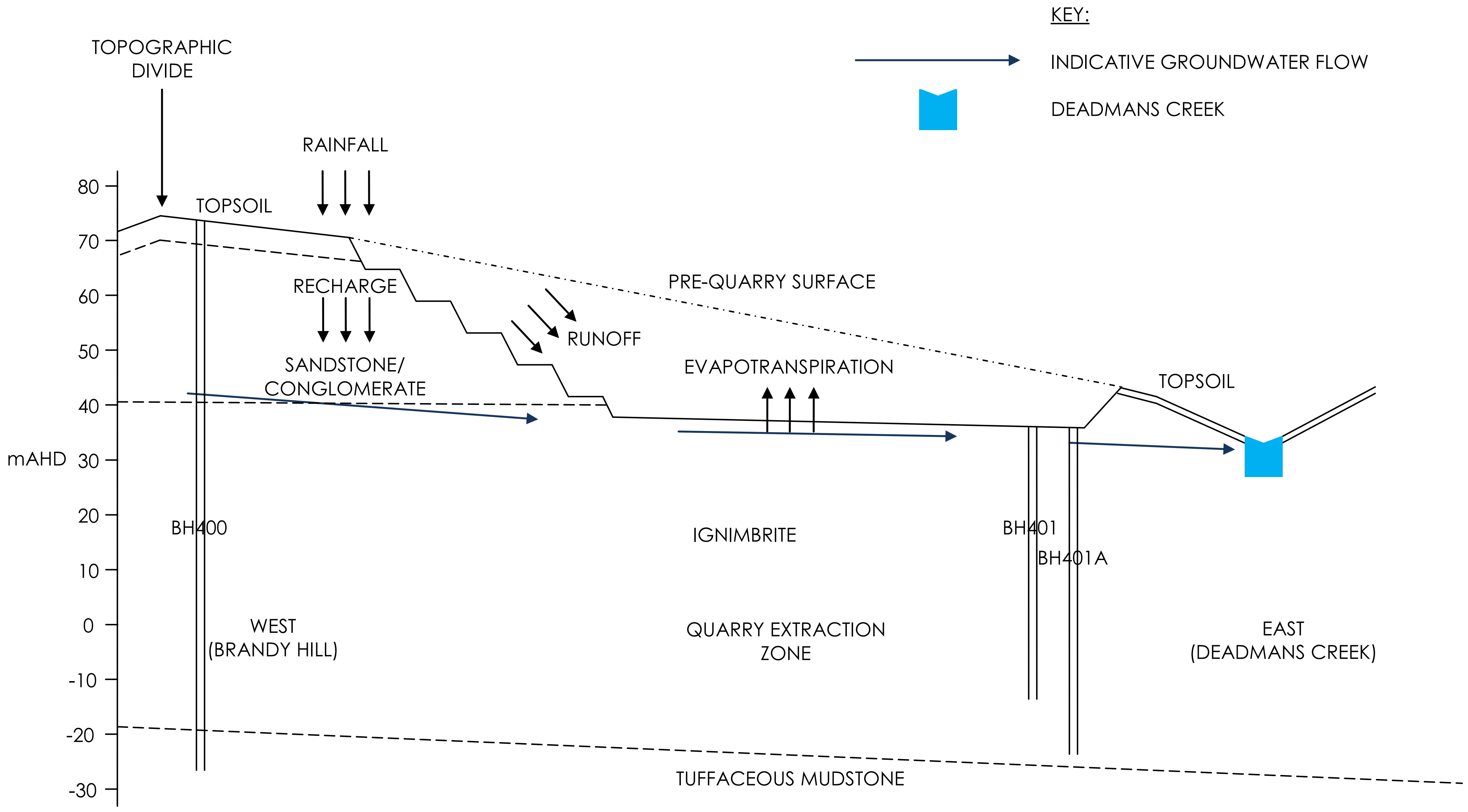
- Determine the impact of an increased extraction zone to groundwater conditions and any identified local groundwater users or groundwater dependant ecosystems.

If you require any further information, please do not hesitate to contact the writer.

For and on behalf of

MARTENS & ASSOCIATES PTY LTD

ANDREW NORRIS
BSc(Hons), MEngSc, MAWA
Director, Senior Engineer



martens

Martens & Associates Pty Ltd ABN 85 070 240 890		**Environment | Water | Wastewater | Geotechnical | Civil | Management**	
Drawn:	DD	**CONCEPTUAL HYDROGEOLOGICAL MODEL**	Drawing No: **FIGURE 4**
Approved:	AN		
Date:	23.01.2014		
Scale:	NA		Job No: P1303888

Appendix 13 C

Peer Review Report

Brandy Hill Expansion Project

Environmental Impact Statement

HydroAlgorithmics Pty Ltd ● ABN 25 163 284 991
PO Box 241, Gerringong NSW 2534. Phone: (+61 2) 4234 3802

noel.merrick@hydroalgorithmics.com

DATE: 2 September 2015

TO: Andrew Driver
Development Manager
Hanson Construction Materials Pty Ltd
Level 5, 75 George Street
Parramatta NSW 2150

FROM: Dr Noel Merrick

RE: Brandy Hill Quarry – Groundwater Peer Review

OUR REF: HA2015/3

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1. Introduction

Hanson Construction Materials Pty Ltd (Hanson) is proposing to expand its Brandy Hill Quarry at Seaham NSW, about 40 km north of Newcastle. As part of the Environmental Assessment, Martens and Associates (Martens) has undertaken a hydrogeological assessment of the impacts of the project, based primarily on numerical groundwater modelling.

Dr Noel Merrick of HydroAlgorithmics Pty Ltd has been engaged by Hanson to perform a peer review of the assessment by Martens.

2. Documentation

The peer review has been conducted progressively since January 2015 through a number of direct communications with Martens staff, which provided regular feedback on progress and direction on the modelling approach to be adopted, and on a draft hydrogeological assessment report dated 22 May 2015 (V02).

Following an interim peer review, a revised assessment report was provided for final review:

> *Martens, 2015, Hydrogeological Assessment: Hanson's Brandy Hill Quarry Expansion. Report P1303888JR02V03 for Hanson Construction Materials Pty Ltd, August 2015. 75p + 7 Attachments.*

No other documentation has been relied upon for this review.

The hydrogeological assessment report has the following sections:

1. Executive Summary
2. Introduction
3. Study Area Setting
4. Hydrogeological Conceptualisation & Modelling Objectives
5. Existing Conditions Numerical Groundwater Models

6. Predictive Numerical Groundwater Models
7. Sensitivity/Uncertainty Analysis
8. Discussion and Impact Assessment
9. Water Licensing
10. Monitoring Program
11. Conclusions and Recommendations
12. References.

The Attachments are:

A. Quarry Layout
B. Extraction Staging
C. Figures
D. Graphic Drill Logs
E. Site Groundwater Quality Data
F. Varying Rainfall Predictive Numerical Groundwater Models
G. Agency Consultation.

3. Review Methodology

While there are no standard procedures for peer reviews of entire groundwater assessments, there are two accepted guides to the review of groundwater models: the Murray-Darling Basin Commission (MDBC) Groundwater Flow Modelling Guideline[1], issued in 2001,and guidelines issued by the National Water Commission in June 2012 (Barnett *et al*., 2012[2]). Both guides also offer techniques for reviewing the non-modelling components of a groundwater impact assessment.

The 2012 national guidelines have built on the 2001 MDBC guide, with substantial consistency in model conceptualisation, design, construction and calibration principles, and the performance and review criteria, although there are differences in details. The new guide is silent on quarry or mine modelling and offers no direction on best practice methodology for such applications. There is, however, an expectation of more effort in uncertainty analysis, although the guide is not prescriptive as to which methodology should be adopted.

The Brandy Hill Quarry groundwater impact assessment has been reviewed according to the 2-page Model Appraisal checklist[3] in MDBC (2001). This checklist has questions on (1) The Report; (2) Data Analysis; (3) Conceptualisation; (4) Model Design; (5) Calibration; (6) Verification; (7) Prediction; (8) Sensitivity Analysis; and (9) Uncertainty Analysis. Non-modelling components of the groundwater impact assessment are addressed by the first three sections of the checklist.

The review has also considered compliance with the Secretary's Environmental Assessment Requirements (SEARs) issued on 11 November 2014, and summarised in Section 2.2 of the report. Particular attention is given to whether the minimal harm considerations of the NSW Aquifer Interference Policy (AIP) (NSW Government, 2012[4]) have been addressed adequately.

A detailed assessment has been made in terms of the peer review checklists in **Table 1** and **Table 2**. Supplementary comments are offered in the following sections.

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[1] MDBC (2001). Groundwater flow modelling guideline. Murray-Darling Basin Commission. URL: www.mdbc.gov.au/nrm/water_management/groundwater/groundwater_guides

[2] Barnett, B, Townley, L.R., Post, V., Evans, R.E., Hunt, R.J., Peeters, L., Richardson, S., Werner, A.D., Knapton, A. and Boronkay, A. (2012). *Australian Groundwater Modelling Guidelines*. Waterlines report 82, National Water Commission, Canberra.

[3] The new guidelines include a more detailed checklist with yes/no answers but without the graded assessments of the 2001 checklist, which this reviewer regards as more informative for readers.

[4] NSW Government, 2012, NSW Aquifer Interference Policy – NSW Government policy for the licensing and assessment of aquifer interference activities. Office of Water, NSW Department of Primary Industries, September 2012.

4. Report Matters

An interim review conducted by HydroAlgorithmics on 21 June 2015 recommended substantial changes to the draft report, mainly on report structure, quality and comprehensiveness of figures, clarification of some data processing and modelling procedures, attention to additional AIP considerations, and editorial matters. A major recommendation was to replace the rainfall-varying prediction modelling with a scenario in which rainfall recharge is fixed at constant long-term average rates. Otherwise, the required water licences are compromised by rainfall variations beyond the control of the quarry.

In all there were 28 material matters requiring attention and 45 editorial corrections. This reviewer can affirm that all requested changes have been done satisfactorily, without exception, and the revised report is a substantial improvement. In particular, the constant-recharge scenario gives a much more reasonable indication of the takes caused by the quarry. The time-varying recharge scenario is retained in Attachment F as an indication of the effect of climatic variation.

The revised report is now of a high standard.

The main figures for the report are to be found in Attachment C. This is a little unusual, as normally they would be immediately after the body of the report or within the body of the report. It is disconcerting that there is no List of Figures for Attachment C, and the figures are not always in sequence when referenced in the report. Also, the captions for the cross-sections in Figure 8 are confusing as they are said to be "North West to East" (meaning "West to East - North Section") and "South West to East" (meaning "West to East - South Section").

The revised report includes new and innovative assessment of water quality impacts and calculations of likely salinity in the final void, at the nearest private bore downgradient of the final void, and in the Hunter River.

In Section 5.6.1, dot point 2, it might not be obvious to a reader that the "Drainage lines" represent creeks. This could be clarified.

In Section 5.8.2, the final paragraph should be deleted. This refers to variation of the storage properties during steady-state calibration. Such properties are irrelevant in steady-state simulation, as there is no variation of groundwater levels with time, and there is no storage term in the steady-state groundwater flow equation. The stated procedure might have been applied during transient calibration.

There was also an error in the reported water balance magnitudes in Table 21, but this has been corrected in an email communication dated 31 August 2015.

5. Data Matters

Section 3.1 has a good and substantial list of data sources.

Although the monitoring network is limited (10 bores), there is a sufficient spread of bores of sufficient monitoring duration to permit understanding of the spatial character of groundwater heads and the degree of groundwater response to rainfall and quarrying stresses.

A very large database of packer test permeabilities has been assembled (64 tests at 5 sites). Also, 78 water quality samples have been analysed across 9 sites.

In my opinion, the characterisation of the groundwater system has been performed competently and the findings are reasonable and generally well substantiated. This includes several observations of probable perched conditions.

There is a particularly thorough cause-and-effect analysis of hydrographic responses to candidate stresses.

6. Model Matters

An informative conceptual model graphic is included in the report, and the key processes acting on the groundwater system have been identified and described.

Overall, the numerical modelling has been done competently and thoroughly, given that the reviewer often provided advice during model development and application. Calibration to groundwater hydrographs is satisfactory, especially in replication of observed trends over 2-3 years.

There is exploration of uncertainty in results through a thorough sensitivity analysis, with examination of the effect of alternative models on calibration performance. Only one of eight trial models was found to give better calibration performance than the Base Case model. The prediction outputs of this model and the Base Case model have been compared to give an indication of the uncertainty in groundwater takes and environmental impacts. This approach, of course, does not bracket the full range of uncertainty in predictions but it is a useful guide.

There is no specific calculation of the take from the Hunter River alluvium, in the form of increased downwards movement of groundwater from alluvium to rock, or reduced upflow from rock to alluvium. However, given the distance of the alluvium from the quarry, and the predicted drawdown extent, the take is likely to be negligible.

A Class 2 confidence classification, according to the NWC 2012 guidelines, is appropriate.

7. Conclusion

This reviewer is of the opinion that the Brandy Hill Quarry groundwater model is *fit for purpose*.

The hydrogeological assessment report is considered to be of an adequate standard for submission. The report maintains a logical investigation sequence of data analysis, conceptualisation and modelling, followed by interpretation of the results in terms of licensing requirements and environmental impacts in accordance with the Aquifer Interference Policy minimal harm considerations.

This reviewer agrees with the findings of the likely level of impacts, as a rigorous assessment methodology has been adopted.

Yours sincerely,

NPMerrick

Dr Noel Merrick

Table 1. MODEL APPRAISAL: Brandy Hill Quarry Model Preparation

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
1.0	THE REPORT								
1.1	Is there a clear statement of project objectives in the modelling report?		Missing	Deficient	[✓ Adequate]	Very Good			Section 2.2 Scope. To address SEARs.
1.2	Is the level of model complexity clear or acknowledged?		Missing	No	[✓ Yes]				Class 2 confidence classification. Equivalent to Impact Assessment Model, medium complexity.
1.3	Is a water or mass balance reported?		Missing	Deficient	[✓ Adequate]	Very Good			Tables for steady-state & end of transient calibration, end of transient prediction and end of recovery. Averages over time.
1.4	Has the modelling study satisfied project objectives?		Missing	Deficient	Adequate	[✓ Very Good]			SEARs requirements are assessed. All potential impacts are considered. Graphics of presentation quality.
1.5	Are the model results of any practical use?			No	Maybe	[✓ Yes]			The predicted findings are plausible.
2.0	DATA ANALYSIS								
2.1	Has hydrogeology data been collected and analysed?		Missing	Deficient	Adequate	[✓ Very Good]			Good cause & effect analysis. Some distinct quarrying effects. Small but adequate monitoring network and monitoring record..
2.2	Are groundwater contours or flow directions presented?		Missing	Deficient	[✓ Adequate]	Very Good			Insufficient data for regional contour map. Local hydraulic gradients are calculated..
2.3	Have all potential recharge data been collected and analysed? (rainfall, streamflow, irrigation, floods, etc.)		Missing	Deficient	[✓ Adequate]	Very Good			Rainfall analysed by residual mass. No investigation of hydrology but far enough away to be inconsequential.
2.4	Have all potential discharge data been collected and analysed? (abstraction, evapotranspiration, drainage, springflow, etc.)		Missing	Deficient	[✓ Adequate]	Very Good			Actual ET (BoM) used correctly in place of evaporation. Private groundwater usage assumed negligible.

2.5	Have the recharge and discharge datasets been analysed for their groundwater response?		Missing	Deficient	Adequate	[✓ Very Good]			Residual mass compared with groundwater hydrographs - good rain correlation; definite quarrying evidence.
2.6	Are groundwater hydrographs used for calibration?			No	Maybe	[✓ Yes]			Some hydrographs date back nearly 3 years. Variable natural fluctuation examined by normalising to average at each bore.
2.7	Have consistent data units and standard geometrical datums been used?			No	[✓ Yes]				
3.0	CONCEPTUALISATION								
3.1	Is the conceptual model consistent with project objectives and the required model complexity?		Unknown	No	Maybe	[✓ Yes]			
3.2	Is there a clear description of the conceptual model?		Missing	Deficient	[✓ Adequate]	Very Good			
3.3	Is there a graphical representation of the modeller's conceptualisation?		Missing	Deficient	[✓ Adequate]	Very Good			Processes diagram and geology x-sections.
3.4	Is the conceptual model unnecessarily simple or unnecessarily complex?			Yes	[✓ No]				Major processes are included. Indistinct stratigraphy is approximated by arbitrary divisions.
4.0	MODEL DESIGN								
4.1	Is the spatial extent of the model appropriate?			No	Maybe	[✓ Yes]			Outer dimensions 18 km x 14 km (but effectively 13km x 10km due to unnecessary inactive cells). Cell size 50-100m. 10 layers, 126 rows, 155 columns, 14,715 active cells.
4.2	Are the applied boundary conditions plausible and unrestrictive?		Missing	Deficient	[✓ Adequate]	Very Good			Reasonable no-flow boundaries at topo divides to north and west. Williams River to east; assumed general head boundary to south. RCH algorithm is %rain. Predicted drawdown contours for proposed development do not reach boundaries.
4.3	Is the software appropriate for the objectives of the study?			No	Maybe	[✓ Yes]			MODFLOW-SURFACT and Visual MODFLOW.

Table 2. MODEL APPRAISAL: : Brandy Hill Quarry Model Implementation

Q.	QUESTION	Not Applicable or Unknown	Score 0	Score 1	Score 3	Score 5	Score	Max. Score (0, 3, 5)	COMMENT
5.0	CALIBRATION								April 2012 - January 2015
5.1	Is there sufficient evidence provided for model calibration?		Missing	Deficient	Adequate	Very Good			Sufficient for performance against groundwater levels and historical negligible quarry inflow. Spatial distribution of residuals at monitoring bores is clear. Scattergrams and performance statistics are given.
5.2	Is the model sufficiently calibrated against spatial observations?		Missing	Deficient	Adequate	Very Good			Steady state model gives sensible head contour pattern..
5.3	Is the model sufficiently calibrated against temporal observations?		Missing	Deficient	Adequate	Very Good			Hydrographs for 3 longer-term bores are presented for comparison in Figure 40. Simulated hydrographs follow trends well.
5.4	Are calibrated parameter distributions and ranges plausible?		Missing	No	Maybe	Yes			Consistent with local measurements.
5.5	Does the calibration statistic satisfy agreed performance criteria?		Missing	Deficient	Adequate	Very Good			Steady state 6.3%RMS, 2.5mRMS. Transient 5.2%RMS, 2.1mRMS.
5.6	Are there good reasons for not meeting agreed performance criteria?	N/A	Missing	Deficient	Adequate	Very Good			
6.0	VERIFICATION								Not a necessary procedure
6.1	Is there sufficient evidence provided for model verification?	N/A	Missing	Deficient	Adequate	Very Good			All data used for calibration.
6.2	Does the reserved dataset include stresses consistent with the prediction scenarios?	N/A	Unknown	No	Maybe	Yes			

6.3	Are there good reasons for an unsatisfactory verification?	[✓ N/A]	Missing	Deficient	Adequate	Very Good			
7.0	PREDICTION								
7.1	Have multiple scenarios been run for climate variability?		Missing	Deficient	Adequate	[✓ Very Good]			Future rain is assumed to be constant in the Base Case or to follow an historical cycle which covers wet and dry periods. A single average climate is appropriate for estimating the licensing requirement.
7.2	Have multiple scenarios been run for operational /management alternatives?		Missing	Deficient	[✓ Adequate]	Very Good			One proposed quarrying sequence. Plus 500 years recovery.
7.3	Is the time horizon for prediction comparable with the length of the calibration / verification period?		Missing	[✓ No]	Maybe	Yes			The time period for transient calibration is <3 years from 2012 to 2015. Prediction period is 30 years.
7.4	Are the model predictions plausible?			No	Maybe	[✓ Yes]			Plausible drawdown magnitudes and drawdown extent.
8.0	SENSITIVITY ANALYSIS								
8.1	Is the sensitivity analysis sufficiently intensive for key parameters?		Missing	Deficient	Adequate	[✓ Very Good]			8 sensitivity runs. Investigated by 50% perturbations on K, S, recharge, and order of magnitude for Kz. Base Case overall is generally the best; Scenario 8 is better.
8.2	Are sensitivity results used to qualify the reliability of model calibration?		Missing	Deficient	Adequate	[✓ Very Good]			Table 25. All sensitivity runs are sufficiently calibrated but the Base Case is probably the best.
8.3	Are sensitivity results used to qualify the accuracy of model prediction?		Missing	Deficient	[✓ Adequate]	Very Good			Base Case and Scenario 8 alternative models. are investigated for effects on predictions.
9.0	UNCERTAINTY ANALYSIS								
9.1	If required by the project brief, is uncertainty quantified in any way?		Missing	No	Maybe	[✓ Yes]			Investigated by comparing Base Case and Scenario 8 alternative models.
	TOTAL SCORE								PERFORMANCE: