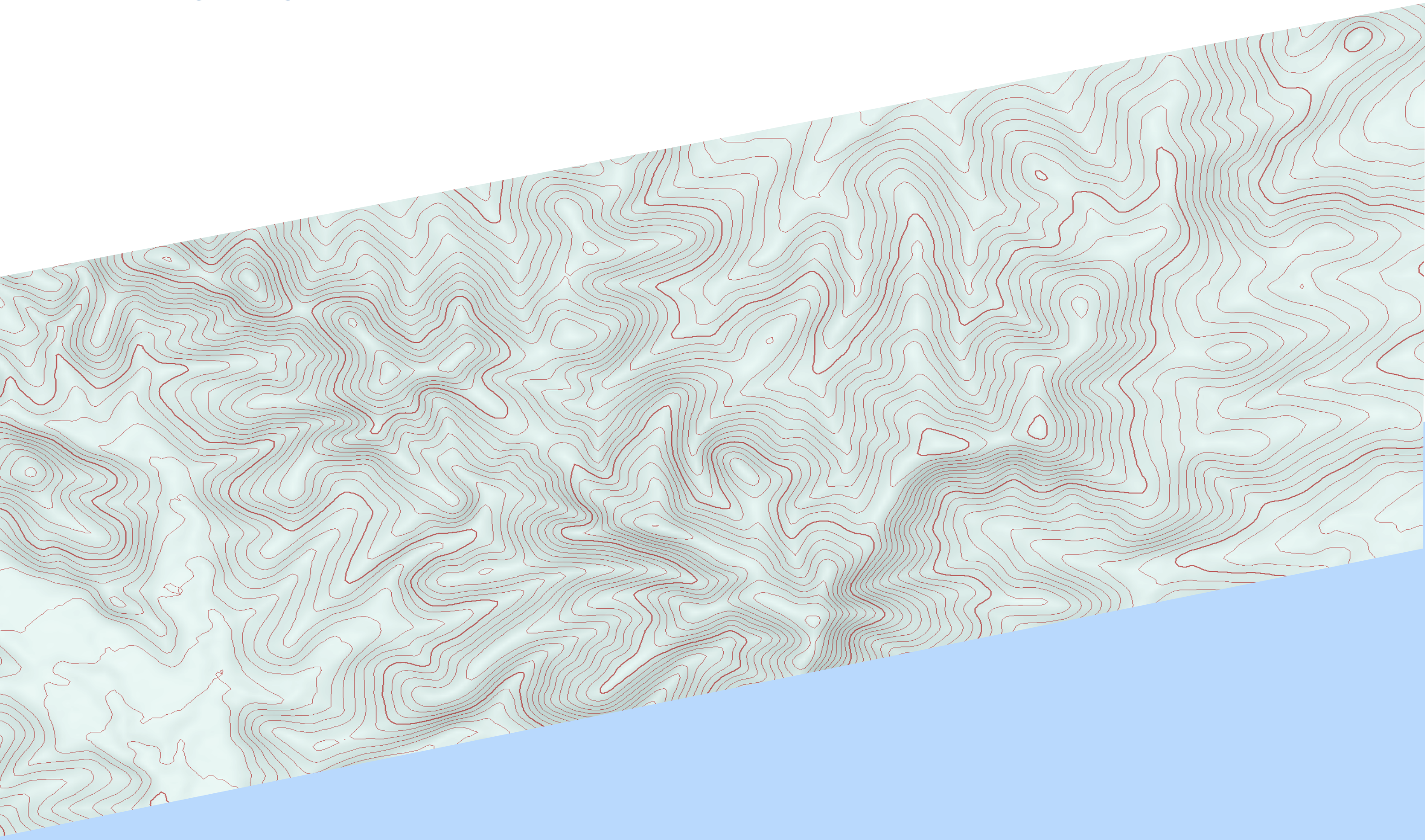

Williamtown Sand Syndicate

Cabbage Tree Road Sand Quarry | Williamtown, NSW

Maximum Extraction Depth Management Plan

May 2019

WATERSHED
HYDROGEO

DOCUMENT REGISTER

Rev/Issue	Description	Date	Comments
1	1st Draft	31 July 2018	Initial draft for comment
2	2st Draft	06 August 2018	Incorporating Kleinfelder comments
3	3rd Draft	22 January 2019	Incorporating Kleinfelder comments
4	Final	24 May 2019	Incorporating agency comments

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QUALITY CONTROL

Function	Staff	Signature	Date
Authors	Will Minchin		24/05/2019
Approved	Will Minchin		

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ABBREVIATIONS

Abbreviation/Term	Meaning
BoM	Bureau of Meteorology
DoI Water	Department of Industry - Crown Lands and Water Division
DPE	NSW Department of Planning and Environment
EPA	NSW Environment Protection Authority
HWC	Hunter Water Corporation
mAHD	metres above Australian Height Datum (effectively elevation as metres above sea level)
mBG	metres below ground
MED	Maximum Extraction Depth
MEL	Minimum Extraction Level, defined as 0.7 m above (estimated) maximum water table
PFAS	Per- and poly-fluorinated alkyl substances
WSS	Williamtown Sand Syndicate (quarry operator)

1. Introduction

Williamtown Sand Syndicate Pty Ltd (WSS) have been approved to construct and operate a sand quarry on 4 lots of land located at 398 Cabbage Tree Road, Williamtown (**Figure 1**), approximately 30 km from the Newcastle central business district. The Project would extract up to 530,000 tonnes per annum of sand products over a period of up to 15 years.

Development Consent (SSD-6125) was granted by the NSW Independent Planning Commission on 9 May 2018 for construction and operation of the quarry subject to a series of conditions.

Potential impacts to groundwater associated with the quarry include effects on groundwater hydrology and groundwater quality as a result of quarry removing vegetation and sediment and potentially from intersecting the water table. However, the operation of the Quarry is approved based on Limit on Consent *Condition 6* which states that the operator "must not undertake quarrying operations within 0.7 metres of the predicted maximum groundwater level".

Condition 37 states that one of the objectives of the rehabilitation programs is "Landform rehabilitated to 1.0 metres above the predicted maximum groundwater level".

In order to comply with *Conditions 6 and 37, Conditions 11 and 12* of Schedule 3 of the Development Consent requires the preparation and implementation of a Minimum Extraction Level (MEL) Report.

This plan has been prepared by Watershed HydroGeo ('Watershed') to satisfy groundwater management *Conditions 11 and 12*, and to inform *Conditions 6 and 37,* of the Development Consent.

Note that the term Maximum Extraction Depth (MED) is less accurate and less practical than Minimum Extraction Level (MEL). The concept and quantification of MEL is assessed in the following report, however the report remains referred to as the MED Report, as per the Conditions.

1.1 Project Overview

Key elements of the operation of the Quarry, relevant to groundwater and extraction depth, are listed in **Table 1-1**.

Table 1-1 Key Aspects of the Cabbage Tree Road Sand Project

Aspect	Key Aspects of the Project
Key elements	Sand quarry extracting up to 530,000 tonnes per annum over 15 years including the construction of an intersection with Cabbage Tree Road, sealed and gravel access roads, site office, workshop and weighbridges. Progressive rehabilitation of quarried land returning to native vegetation communities with potential future use of the facilities area.
Location	398 Cabbage Tree Road, Williamtown, within the Port Stephens local government area.
Area	Total Project Area of approximately 42.3 hectares from a Subject Land Area of approximately 176.2 hectares.
Project Life	Approval is sought to operate the quarry for a period of up to 15 years. At expected demand the quarry is estimated to have an eight-year life, reduced to five years should demand require maximum extraction rates. The proposed scheduling is defined by 27 'sectors' within the 'Northern Resource Area' and 'Southern Resource Area'. These Resource Areas are shown on **Figure 1**.

Aspect	Key Aspects of the Project
Production rate	Up to 530,000 tonnes per annum.
Extraction method	▪ Excavator and/or bulldozer to clear vegetation and strip topsoil. ▪ Bulldozer or grader to windrow sand. ▪ Front-end loader to feed conveyors to convey sand to the processing plant. ▪ Front-end loader and haul truck to convey sand when conveyor unsuitable.

1.2 Scope

The components of the scope are to address consent Conditions 11 and 12 as listed in **Table 1-2**.

Table 1-2 Conditions 11 and 12

Condition	Requirement / tasks	Where addressed
11	The Applicant must commission a Maximum Extraction Depth Report for the site. This report must:	
a)	be prepared by a suitably qualified and experienced expert/s whose appointment has been endorsed by the Secretary;	DPE letter, 14/06/18
b)	be prepared in consultation with Hunter Water and DoI Water;	Section 1.3
c)	be approved by the Secretary prior to the commencement of any ground disturbing activities;	DPE review of this document
d)	establish the predicted maximum groundwater levels for the site based on: ▪ all available HWC groundwater monitoring data; ▪ all available site-specific monitoring data, including all data collected from on-site boreholes; and ▪ modelling software and parameters agreed to by Hunter Water, DoI Water and the Secretary.	Section 2
e)	provide details of how the predicted maximum groundwater level was determined, including justification for the chosen modelling software and parameters;	Section 2.1, Appendix B
f)	establish the maximum extraction depths to which extraction can be undertaken on site, to comply with condition 6 of Schedule 2; and	Section 2.3, Table 2-1
g)	provide a Maximum Extraction Depth [*Minimum Extraction Level*] contour map for the project; and	Section 2.3, Figure 5
h)	provide recommended management measures as to how compliance with the extraction depths specified in the report can be achieved, including consideration of the use of continuous GPS tracking of sand extraction machinery. The Applicant must consider any assessment of the Report by Hunter Water and/or DoI Water and implement the findings and recommendations of the Maximum Extraction Depth Report, to the satisfaction of the Secretary.	Section 3

Condition	Requirement / tasks	Where addressed
12	The Applicant must review and update the Maximum Extraction Depth Report, in consultation with Hunter Water and DoI Water:	
a)	every two years from the date of approval of the Maximum Extraction Depth Report; and	As per Section 2.3
b)	if any groundwater is encountered during quarrying operations or if directed by the Secretary.	As per Section 3.3

To address these items, this plan provides a brief background describing the hydrogeology of the Quarry and surrounds and describe the sources of data used to characterise groundwater levels in the area, specifically focussing on maximum water levels. Furthermore, the items from the Statement of Commitments relevant to this report are listed in **Table 1-3**.

Table 1-3 Commitments related to extraction depth

Item	Action	Timing	Where dealt with?
8.3.8	**Water Management**		
f)	WSS will consult with DPI Water with regards to the locations of and construction of proposed groundwater monitoring points, installation of loggers and selection of sampling points.	Prior to construction	Section 3.2
g)	WSS will install groundwater monitoring wells, so that monitoring can be performed immediately up and down gradient of the main extraction areas after destruction of existing bores.	Prior to construction	Monitoring wells already in place. Proposed water level monitoring as in Section 3.2
h)	Data loggers will be installed in monitoring wells to continuously monitor and provide additional data for input to the groundwater model.	Prior to construction	Logger sites proposed in Section 3.2
i)	Trigger levels for monitoring will be developed in consultation with DPI Water to ensure the groundwater table is not intersected.	Prior to construction	Triggers outlined in Section 3.3
k)	WSS will update the groundwater model every two years from commencement of quarry activities to determine maximum predicted groundwater level along with updated topography showing the progress of the quarry.	Every 2 years	Section 4.2
l)	The quarry floor height will be reviewed every two [years] against the revised groundwater model, unless trigger levels determine a review is required.	Every 2 years	Section 4.2
8.3.18	**Rehabilitation**		
q)	Quarry floor levels to be established on weekly basis.	Weekly	Section 3.1.1
r)	Quarry floor levels to be reviewed on completion of quarrying to confirm required topsoil strip depth.	On completion of sector	Section 3.1.1

Item	Action	Timing	Where dealt with?
s)	Independent registered surveyor to undertake audit	3 months	Section 3.1.2
t)	Operational floor of quarry to be no less than 0.7 m above highest predicted groundwater level. Level relative to thickness of topsoil removal, i.e. if topsoil stripping is less than 0.3 m than the operational floor level must be increased accordingly such that replacement of topsoil achieves final landform requirement of 1 m above highest predicted groundwater level.	At all times	Section 3.1.1
u)	Final landform, including topsoil to be not less than 1 m above highest predicted groundwater level.	Completion of final landform shaping	Section 3.1.1 and 3.1.2

1.3 Consultation with Agencies

Comments on this plan were sought by Kleinfelder, on behalf of WSS, from DPE, HWC and DoI Water.

1.3.1 DPE

DPE provided comments via email on 21/05/2019. Other than editorial corrections and suggestions, DPE's main comments were:

- "*Overall the Maximum Extraction Depth Report (MEDR) is good*".
- Any comments from HWC and DoI Water are to be included as Appendices to this report.

1.3.2 HWC

A letter from HWC dated 18/05/2019 is included in **Appendix C** - Hunter Water Corporation (HWC) review of this report. The main points from HWC's review were:

- HWC concluded: "*In all, the MEDR is considered acceptable*".
- HWC agreed with the proposed groundwater monitoring locations and frequency;
- HWC found that the method for estimating maximum groundwater levels was conservative and acceptable.
- HWC agreed with the proposed methods of monitoring extraction elevation/depth via GPS and the proposed regular auditing.

1.3.3 DoI Water

Comment was sought from DoI Water by Kleinfelder via email on 15/02/2019. Confirmation of receipt of that email, and indication that the report had been forwarded to the Natural Resources Access Regulator (NRAR), was received by Kleinfelder on 19/02/2019. No further comment has been forthcoming.

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Figure 1: Cabbage Tree Rd Sand Quarry and surrounds

1.4 Background

In order to address the key points of the scope, this background section provides a brief summary of the primary components of the hydrogeological conceptual model, including a comparison of recent conditions/knowledge.

1.4.1 Topography

The Quarry is only 1.3 km north of Fullerton Cove, a tidal estuary that is part of the Hunter River system. Topography is shown on **Figure 2**, which displays 5 m contours generated from LiDAR data. Regionally, the highest part of the Tomago Sandbeds dune system is about 45 mAHD, approximately 4 km north-northeast the Site and just north of RAAF Williamtown. From there, topography declines to the south to less than 1-2 mAHD on the fringes of the estuary of Fullerton Cove.

Within the bounds of the Site, the lowest topographic elevation is approximately 2 mAHD, rising to approximately 23 mAHD on the highest dune within the Site. Along the northern boundary of the site, topographic elevation is typically 6-8 mAHD (northwest) and 5-6 mAHD (northeast). Mean topographic elevation across the Site is about 5 to 6 mAHD, averaging 9.5 mAHD within the resource areas.

1.4.2 Climate – Rainfall and Evaporation

Rainfall and evaporation data can be obtained from the Bureau of Meteorology's (BoM) Williamtown RAAF Base station (number 061078). Rainfall averages is approximately 1120 mm/yr (period 1944-2017), while potential evaporation (PE) is approximately 1500 mm/yr.

1.4.3 Geology

Geological mapping available in the Nelson Bay Coastal Quaternary dataset (Hashimoto *et al.*, 2008). provides classification and mapping of relevant Quaternary-age deposits, which are:

- Holocene estuarine and swamp (paludal) deposits (shown on **Figure 2**), including the 'Tilligerry Mud Member' along Tilligerry Creek.
- Holocene dune and beach deposits of the Tomago Sand Beds. These are the 'inner barrier', i.e. inland of the Stockton dune system (and inland of the estuarine deposits). These are generally vegetated.

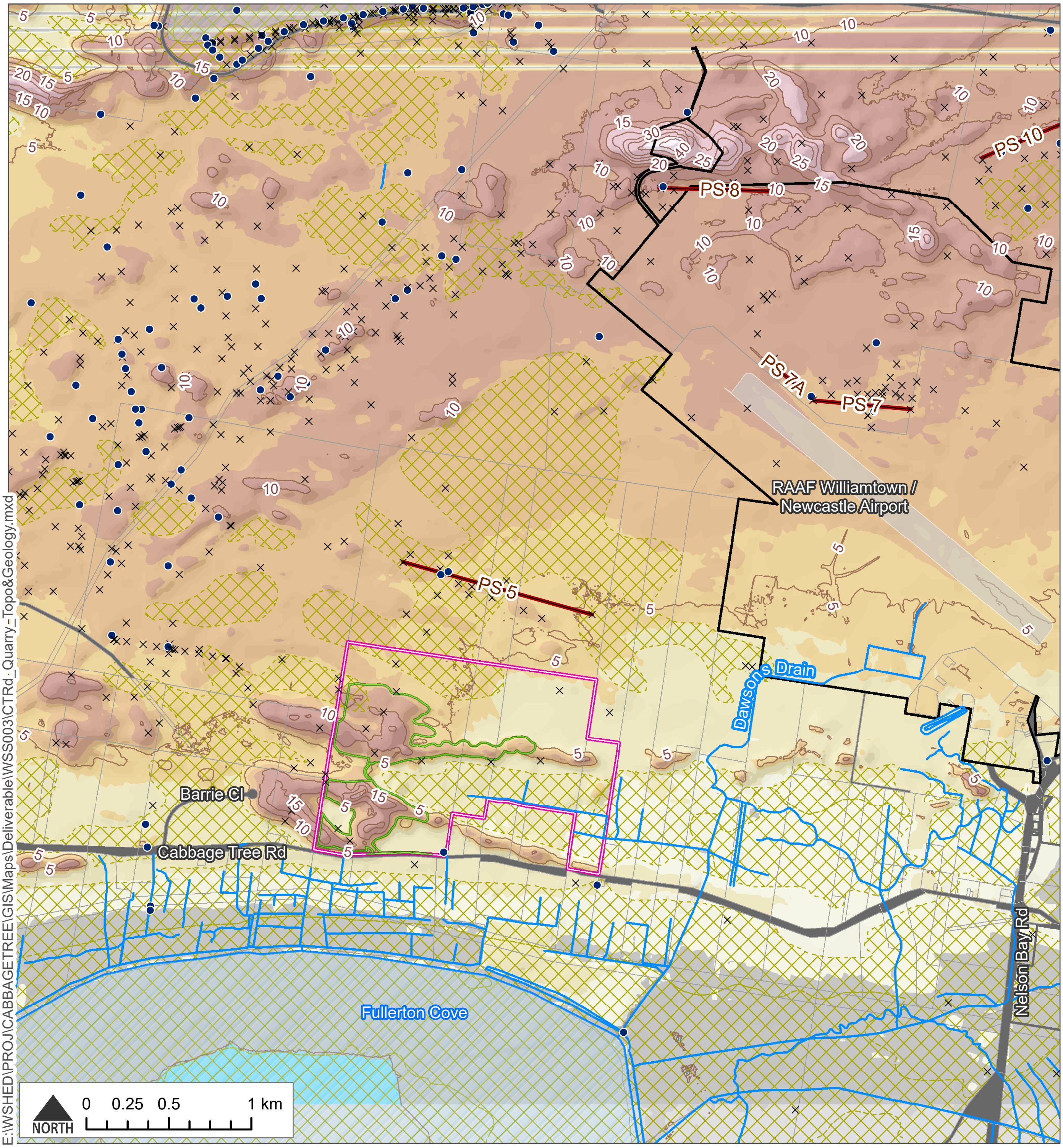
Mineral sand mining occurred in the 1970s-90s across about 60% of the approved resource area. This means that the dune sediment has been disturbed (to a depth below the water table) in these areas.

1.4.4 Hydrogeology - permeability and porosity

Investigations by AECOM (2017) for the RAAF Williamtown Environmental Site Assessment (ESA), included slug testing, grain-size analysis and a pumping test occurred. These tests provide useful data for this project.

The Tomago Sand Beds consist primarily of aeolian dune sands and exhibit high hydraulic conductivity, typically >10 m/d and up to 55 m/d (AECOM, 2017). AECOM stated that "*a representative hydraulic conductivity for the fine - medium sands is likely to range from 20 to 35 m/day*". Specific yield ('drainable porosity') is likely to be 15-30%. Test pumping by AECOM (2017) suggested Sy = 10%, but this seems low given the lithology. Within the Tomago aquifer there are localised variations, either reducing permeability (e.g. coffee rock/indurated sand) or enhancing permeability (e.g. coarser facies, including basal coarse sands and gravels).

The Tilligerry Mud Member, deposited in the floodplains is less permeable, with measured permeability usually in the range 0.1-1 m/d (AECOM, 2017).



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Cabbage Tree Rd Sand Quarry
Quarry Plan | ResourceArea

Property boundary
RAAF Williamtown
other
road reserve

Drainage line
Waterbody
Fines (Estuarine, swamp)

HWC bore
log + elevation
log only
HWC Pumping Station

Topographic Elevation
[mAHD]
<= 0
0.1 - 1
1.1 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
10.1 - 20
20.1 - 40
40.1 - 80

Cabbage Tree Road:
Maximum Extraction Depth Report

WATERSHED HYDROGEO

Figure 2: Topography and Geology

1.4.5 Hydrogeology – water levels

Figure 3 shows the groundwater monitoring bores presented in the vicinity of the Site.

WSS installed a network of 12 monitoring bores on-Site. A short record of water levels is available from these, and monitoring has re-commenced (see **Appendix A**).

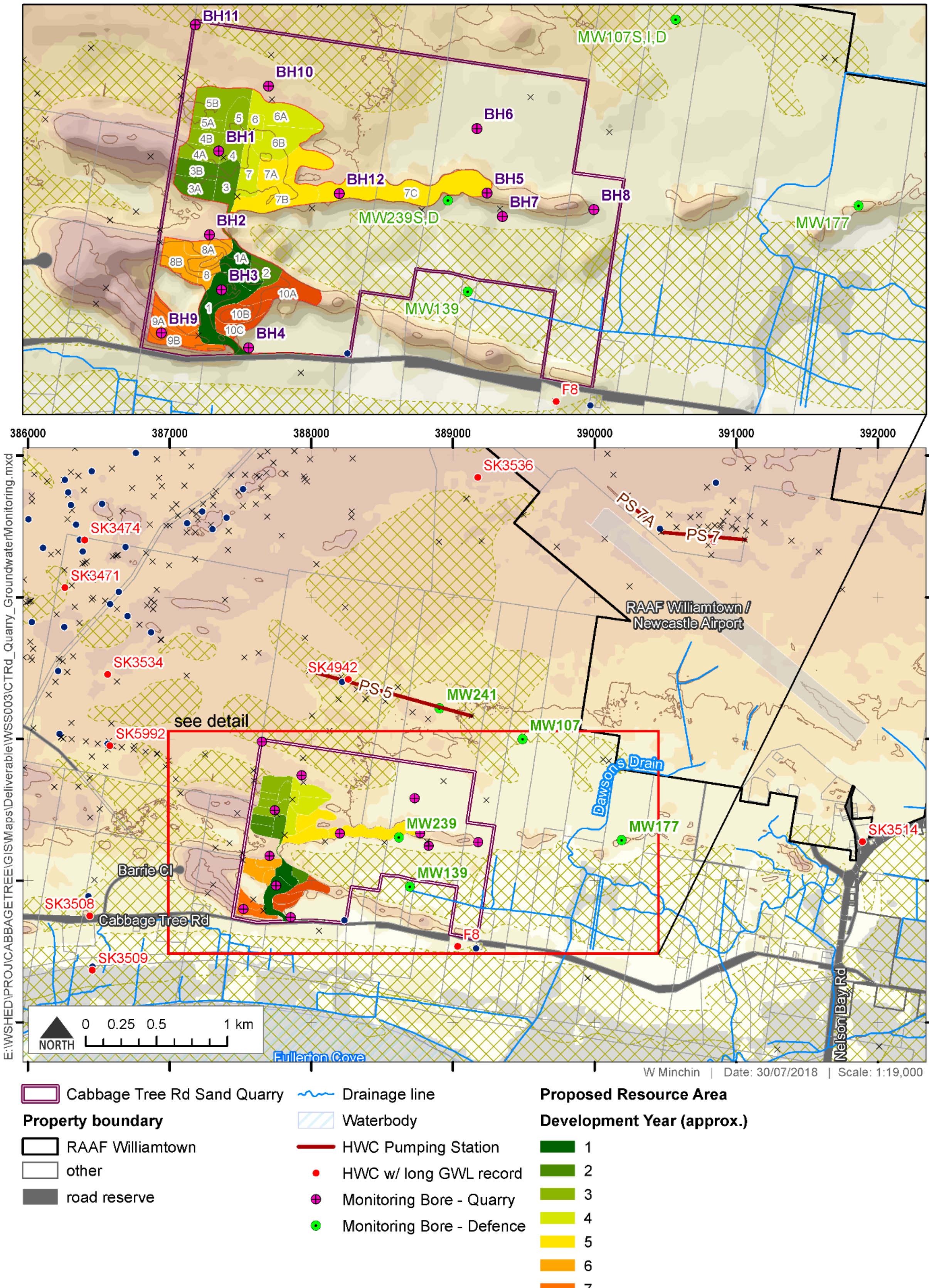
HWC maintain an extensive network of monitoring bores around their Tomago Sandbeds aquifer borefields. These monitoring bores are dipped regularly, and a monthly dataset back to the mid-late 1970s was made available by HWC to WSS for analysis. This 40-year record is a valuable dataset as it allows inspection and analysis of the water level record through a variety of weather or climatic conditions.

Defence have a large monitoring network in this area due to PFAS investigation and remediation programs associated with RAAF Williamtown (AECOM, 2016 and 2017). A selection of the Defence bores is located around the Site.

More on the status and utility of the monitoring network is presented in **Section 3.2**, along with details of the future monitoring program, including the use of loggers in a selection of sites.

It is accepted that groundwater in this part of the Tomago Sandbeds aquifer flows from the recharge areas, located north of the Site, to the south toward Fullerton Cove. This is congruent with higher groundwater levels occurring in the north, lower groundwater levels to the south.

Removal of vegetation and sediment may result in a slight increase in infiltration and/or reduction in evapotranspiration from the water table. However, given the history of previous vegetation clearing (on-Site and in the neighbouring areas) and mining at the Site, the effects are not considered to be significant. However, the monitoring program is designed to address this concept, and updated modelling (carried out every 2 years, as per the Conditions) will be consider the concepts and future data.



Cabbage Tree Road:
Maximum Extraction Depth Report

Figure 3 Groundwater Monitoring Sites

2. Minimum Extraction Level (MEL)

2.1 Estimated Maximum Groundwater Levels

As stated above, the elevation of the quarry floor is related to maximum predicted groundwater levels, being greater than 0.7 m above during operation, and rehabilitated to 1.0 m above this groundwater level after extraction.

Two primary sources of information are relied on to estimate maximum groundwater levels:

- HWC and site groundwater levels (site data from RCA, 2015, analysis in RCA and Umwelt 2015 and 2016), as described in **Section 1.4.5**;
- Numerical modelling (MODFLOW modelling described in Umwelt 2015 and 2016). A summary of the modelling is included as **Appendix B**.

Interpolation of 95th percentile observed water levels from the site was presented in Umwelt (2016) [Figure 1 of that document] and is replicated here in **Figure 4**. These contours are shown alongside the maximum modelled groundwater levels from Umwelt, 2016) [Figure 5 of that document].

Further analysis of the groundwater regime has been carried out by Watershed:

- Comparison and correlation of the 2014-15 data available from the on-Site bores with the HWC records, in effect a hind-casting of the on-Site bore water levels. The 95th percentile contours derived by Umwelt from the HWC data was higher than the hind-cast estimate.
- A further round of interpolation of maximum groundwater level observed at the HWC bores (rather than the 95th percentile). These contours are also plotted in green in **Figure 4**, and are generally similar to 95th percentiles produced by Umwelt.
- An allowance for estimating daily maximum groundwater levels from a sequence of monthly data (as per the HWC dataset). Watershed considered the timing of heavy rainfall in relation to the maximum water levels at key bores from the HWC dataset (**Table A-2**, **Appendix A**). Based on logger data from on-Site bores (RCA, 2015), groundwater levels recede at approximately 2 cm per day, and using this, an allowance for the period of time between the maxima at each bore and preceding heavy rainfall has been applied using this approximated recession rate. This is up to:
  - 0.02 m at bore SK4942 (max water level measured within 1 day of heavy rainfall).
  - 0.4 m at bore SK5992 (based on 20 days recession between preceding heavy rainfall and second highest water level recorded on 12/07/2009) [maximum water level recorded a month earlier, on 18/06/2009, was immediately preceding a period of heavy rainfall];
  - 0.02 m at bore SK3508 (based on 1 day recession prior to water level recorded 30/05/1990);
  - 0.10 m at bore F8 (based on 5 days recession prior to water level recorded 7/07/2013);

Key points to be made from comparison of the contouring on **Figure 4** are:

- Modelled and observed groundwater levels are similar in the southern part of the Site, and trends are similar across the Site as a whole.
- Modelled groundwater levels are lower than the observed water level contours in the northern part of the site (variance of up to 0.5 m, up to 1.0 m in the north-eastern part of the Site).

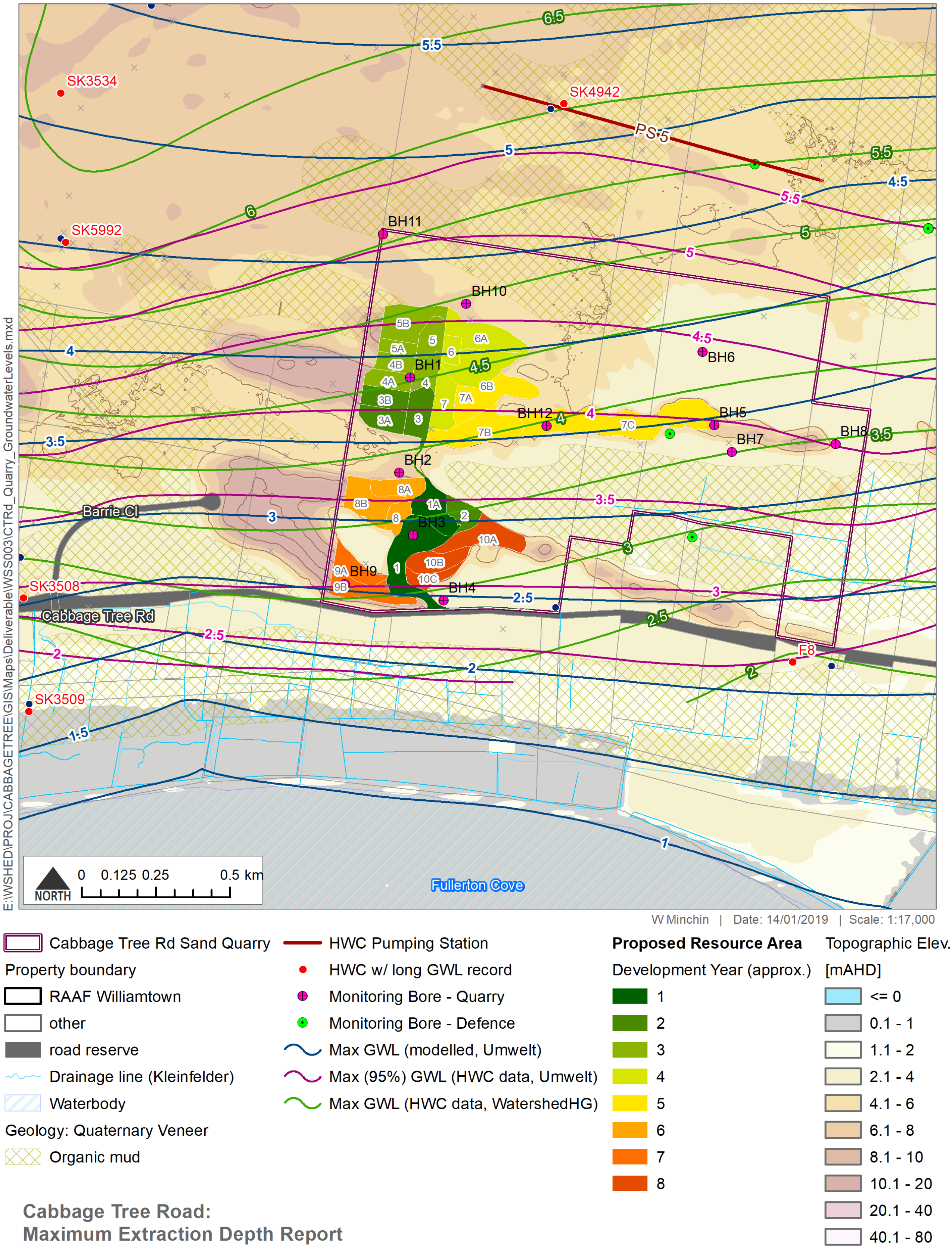


Figure 4 Comparison of interpolated observed and modelled maximum groundwater levels

Based on this, the contours derived from HWC's dataset of observed and modelled groundwater levels, rather than just from the current modelling, have been relied on to make the current estimate of maximum groundwater level. This is a conservative approach to estimating maximum levels.

At a later date (within 2 years of commencement), following further data gathering and consistent with the Conditions, the modelling will be updated to improve the match to observed data in the northern part of the site (Section 4.2).

2.2 Effect of Sand Removal on Groundwater Levels

Observed groundwater levels suggests that the presence of a dune does not affect significantly the shape of the local water table, for example groundwater levels in BH9 or BH1 (both on dunes) show similar or even lower groundwater levels, than nearby bores off those dunes (BH4 and BH10 respectively). This is despite 15 m and 2 m differences in topographic elevation. Furthermore, the thickness of the unsaturated zone is approx. 14 m and 2 m respectively. The high hydraulic conductivity of the Tomago Sandbeds results in low hydraulic gradients and a relatively 'flat' or subdued water table surface (as suggested by Umwelt, 2015). This suggests that the removal of sand from the dunes should not have a significant effect on water levels.

The modelling of Umwelt (2016) suggested that the removal of sand would not have a significant effect on increasing groundwater levels within the extraction area, either via the removal of sand or via the lowering of the evaporation surface to the quarry floor.

These concepts will be assessed further by data collection and in revised modelling (Section 4.2).

2.3 Current specification of Minimum Extraction Levels (MEL)

Based on the preceding section on the estimated maximum groundwater levels, the MEL has been set as per **Table 2-1**. A plan is presented as **Figure 5**, showing the MEL calculated on a 25 x 25 m grid.

Table 2-1 MEL (2019) for Williamtown Sand Quarry (calculation 2c, Jan 2019).

Area	Sectors	Year	MEL - Min	MEL - Median	MEL - Max [mAHD]
Intersection at Cabbage Tree Rd		0	3.6	3.6	3.6
Southern Resource Area	1	1	3.6	3.9	4.1
	1A	1	4.0	4.2	4.3
	2	2	4.1	4.1	4.2
	8	6	4.1	4.1	4.2
	8A	6	4.3	4.3	4.4
	8B	6	4.1	4.3	4.5
	9A	7	3.8	3.8	3.9
	9B	7	3.6	3.7	3.8
	10A	8	3.9	4.0	4.1
	10B	8	3.8	3.9	3.9
	10C	8	3.7	3.8	3.9
Northern Resource Area	3	2	4.4	4.8	5.0
	3A	2	4.7	4.9	5.0
	3B	2	4.9	5.0	5.1
	4	3	5.0	5.1	5.2
	4A	3	5.1	5.1	5.2
	4B	3	5.2	5.3	5.3
	5	3	5.3	5.4	5.5
	5A	3	5.3	5.4	5.4
	5B	3	5.4	5.5	5.7
	6	4	5.2	5.3	5.4
	6A	4	5.2	5.3	5.5
	6B	4	5.0	5.1	5.3
	7	4	4.7	4.9	5.1
	7A	5	4.8	4.9	5.0
	7B	5	4.6	4.7	4.8
	7C	5	4.6	4.7	4.8

Notes:
- MEL = Max GWL + 0.7 m; final landform level = MEL + 0.3 m
- Max GWLs estimated from maximum of observed and modelled datasets (**Section 2.1**).

The MEL Report is scheduled to be reviewed every two years to confirm compliance of recent activity as well as to review, and potentially revise, the MEL as additional data becomes available.

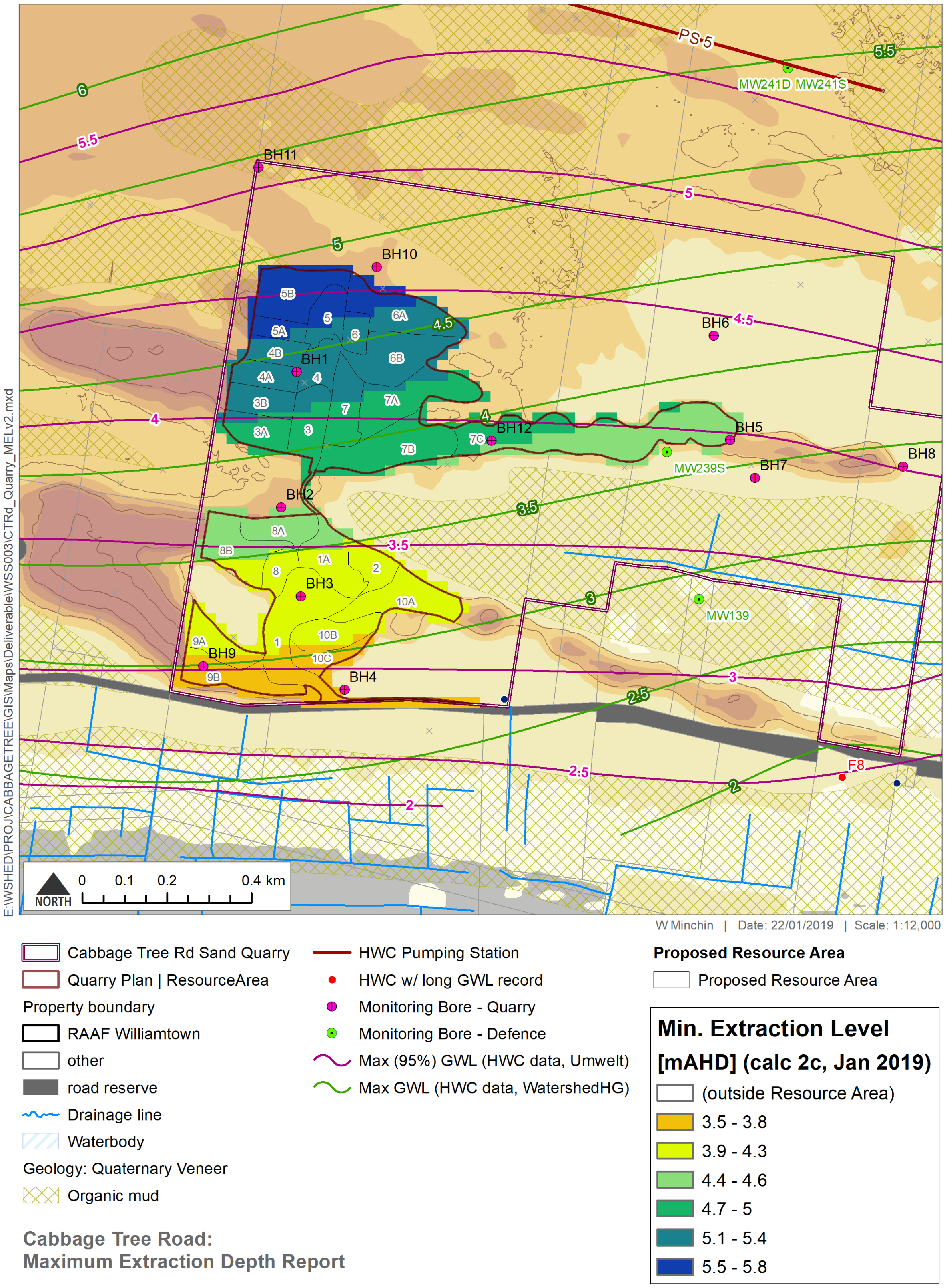


Figure 5 Contour Map of Minimum Extraction Level (MEL)

3. On-going Monitoring and Compliance

The key requirements of the operator with regard to operating above the maximum water table are:

- Ensuring that a sufficient depth of topsoil is stripped and stockpiled to meet the difference between operational floor elevation (MEL) and rehabilitated elevation, which is to be >0.3 m above MEL.
- How to maintain floor elevation above MEL based on the previous analysis;
- Monitoring for rising water levels, which respond to natural stresses and potentially as a result of or enhanced by the operation of the quarry.

3.1 Monitoring - Floor Elevation

DPE (2016) audited 19 approved sand quarries across NSW and found that one of the primary sources of non-compliance of approval conditions was 'management of extraction depth'. DPE stated that "Common [depth] controls included surveyed sight pegs for loader operators to estimate depth from and annual survey checks. It is recommended that operations consider GPS control for Loading/ Excavating machinery, more extensive network of survey peg control and quarterly registered survey control and/or stabilise the extraction floor to ensure depth is maintained."

3.1.1 GPS Tracking

WSS has committed to equipping the primary loader with GPS tracking, linked to a nearby base station that will be accessed by subscription to the local network. This system tracks the elevation of the loader wheels and will alert operators where necessary. Key aspects of this monitoring system are:

- The loader be fitted with a GPS receiver / sensor to record the base elevation of the wheel(s).
- The loader will have a pre-loaded boundary with corresponding visual alarm to limit the potential for extraction beyond the approved lateral boundaries of the Resource Areas.
- The system will have a pre-loaded set of elevation data (i.e. MEL surface), with a visual alarm system warning the operator of a breach of the MEL.
- GPS trace (X, Y, Z) to be saved daily to allow periodic analysis and verification of GPS performance. **Commitment 8.3.18 (q)** requires weekly review of the working floor elevation.
- At the end of each sector, this data to be reviewed to confirm topsoil thickness, as per **Commitment 8.3.18 (r)**.

3.1.2 Routine survey

Surveys by a registered surveyor of current working areas, recently extracted areas and recently rehabilitated sectors to be undertaken, as per **Commitment 8.3.18 (s)**. UAV/drone surveys recommended if accuracy can be achieved. This will allow confirmation of:

- Working floor is at or above MEL (max. groundwater level + 0.7 m).
- Rehabilitated areas are, on average, higher than MEL, as per the condition of max. groundwater level +1.0 m.
- Rehabilitated areas will require sufficient survey to demonstrate the predominant level of rehabilitated surface is at or above the required level. Given the surface will be likely to be subject to slumping and compression (from vehicles, rehabilitation planting and log placement,

rainfall etc), the recording of the levels at multiple locations within each sector (>20, preferably more) will be essential. UAV survey would achieve this, providing analysis of a 'point cloud'.

Doing this quarterly will allow the performance of the GPS tracking system to be verified and ensure that rehabilitation areas meet the required elevation. Practically, it is recommended that the survey of rehabilitation areas is conducted before re-vegetation measures occur.

3.2 Monitoring – Groundwater Levels

A network of groundwater monitoring bores exists on site (details in **Appendix A**). A number of these bores will be destroyed or decommissioned due to quarry operations at some point during excavation. The status of these bores is summarised in **Table 3-1**, including specification of bores to be instrumented with a data logger.

While groundwater levels remain relatively low, most on-site bores will be dipped monthly. Five of the bores listed in **Table 3-1** will be fitted with dataloggers to log groundwater levels every 24 hours. Two of these, BH11 and BH2 will be used to analyse short-term response to rainfall, and to govern when more frequent, i.e. weekly, monitoring of all dipped bores is carried out, as per the "high frequency threshold" (see details of potential higher frequency monitoring in **Section 3.3**).

Table 3-1 Monitoring Bore Network

Bore	Constructed by	Operational for life of quarry?	Max GWL [mAHD]		Monitoring method	High frequency monitoring threshold [mAHD]
			Measured	Inferred*		
BH1*	WSS	N - destroyed in Year 3^	2.95	4.5	dip	
BH2	WSS	Y	3.5	3.8	datalogger	3.3
BH3	WSS	N - Year 1	1.93	3.4	datalogger	
BH4	WSS	Y	2.14	3.0	datalogger	
BH5	WSS	N - Year 5	2.13	4.0	dip	
BH6	WSS	Y	2.37	4.4	dip	
BH7	WSS	Y	1.75	3.7	dip	
BH8	WSS	Y	2.24	4.0	dip	
BH9	WSS	N - Year 7	1.6	3.0	dip	
BH10	WSS	Y	3.19	4.9	dip	
BH11	WSS	Y - upgradient control	4.82	5.5	datalogger	4.5
BH12	WSS	N - Year 5	2.26	4.0	dip	
MW239S	AECOM /	Y		3.9	datalogger	

^ Note that BH1 was severely affected by fire in 2018, and may not be continued.

* means that maximum water level has been inferred from comparison of short record for each site BH vs long-term HWC dataset

WSS also will obtain relevant groundwater level data from the HWC network, specifically from bores:

- SK5992
- SK4942
- SK3508 and
- F8.

All this data will be used in periodic updates to the MEL Report. All this data will also be used if unscheduled reviews are required, as in **Section 3.3**, **Table 3-3**. Site data (monthly dips) to be published on website in excel format.

3.3 Trigger Action and Response Plan (TARP)

Table 3-2 Compliance Measures for Floor Elevation

Level	Trigger Levels - variance from operational level (MEL or Rehab. Level) [metres]			Comment	Response
	L75	L90	L98		
Compliant	0	0.1	0.2	Tolerances allowed to accommodate localised slumping and compaction.	Demonstrate compliance via quarterly audits and Annual Reporting.
Non-Compliant	< 0	< 0.1	< 0.2	**TARP triggered if 2 of 3 breached.**	Report to DPE, HWC, DoI Water. Manual survey area(s) of where L75, L90, L98 have failed. Confirm accuracy of initial GPS/survey data. Re-grade non-compliant areas as required by DPE, confirm with survey. Review MEL, operational and rehab methods.
L75 = 75% of all elevation measurements within a sector are above operational or rehab level minus X m. L90 = 90% of all elevation measurements within a sector are above operational or rehab level minus X m. L98 = 98% of all elevation measurements within a sector are above operational or rehab level minus X m. X = metres variance for each of L75, L90 and L98 as stated above.					

Repeated breaches of floor elevation TARP might mean that the elevation control needs to be strengthened via:

- Improvement to GPS tracking system/base station;
- More frequent independent surveying and pegging of the working floor;
- "Stabilisation" of the floor (DPE, 2016).
- An increase in the specified MEL to allow a factor-of-safety, e.g. by 0.2 m to 0.9 m above maximum predicted groundwater level, in agreement with DPE and other stakeholders.

Groundwater level monitoring will be carried out, in part for early warning, but also to ensure that the analysis and prediction of maximum groundwater levels from historical data remains robust. Groundwater monitoring will be conducted at the sites identified in **Table 3-1**, with actions based on **Table 3-3.**

Table 3-3 Groundwater Level Monitoring TARP rules

Level	Trigger	Action and Response	Report to
0	Groundwater levels more than 0.5 m below *inferred* maximum historical level at BH1 and BH10. (**Table 3-1**).	Standard operations - monthly dipping of operational on-site monitoring bores.	n/a
1	Groundwater levels within 0.5 m below inferred maximum historical level (**Table 3-1**) at any on-site bore.	Weekly (or more frequent) monitoring (dipping) of groundwater levels until water level declines to below high frequency level bores listed in **Table 3-1**.	Internal and environmental consultant. Include note in Annual Report.
2	Groundwater levels within 0.25 m of inferred maximum historical level (**Table 3-1**) at any on-site bore.	Weekly (or more frequent) monitoring (dipping) of groundwater levels. Re-analysis and review of MEL.	WSS to issue letter to DPE, documenting groundwater level and rainfall trends, and review and recommendations regarding of MEL.
3	Groundwater levels within resource area rise above previously inferred maximum groundwater level (**Table 3-1**).	Analysis of recent data by hydrogeologist, including site data and data from local HWC wells and local Defence wells (if available). Revision of MEL. Remediation of earlier excavations to revised MEL if required by DPE.	WSS to issue letter to DPE, DoI Water and HWC, documenting groundwater level trends, and revision (if necessary) of MEL. Letter to outline remedial options, considering access, vegetation condition in previously rehabilitated areas. Re-grading of previously rehabilitated areas if required by DPE.

4. Recommendations

4.1 Monitoring

Monitoring of groundwater levels to occur at monthly intervals at all the sites in **Table 3-1**. The use of data loggers has been recommended for five sites (see below), but periodic dipping should be undertaken to confirm logger accuracy. Monitoring to occur in line with the other groundwater monitoring detailed in the GWMP (Kleinfelder, 2019).

Although five of the 12 existing bores at the Site will be destroyed by the proposed sand extraction operation, the current aim is to replace BH3 after extraction and continue monitoring at that site.

Data loggers have been recommended for five sites; listed below, based on spatial distribution and location inside and adjacent to proposed extraction areas.

- BH11 - upgradient 'reference site'
- BH2.
- BH4.
- MW239S.
- BH3.

Data should be revised alongside BoM Williamtown or SILO rainfall data and selected HWC groundwater level data.

4.2 Modelling

Watershed does not consider that modification or revision of the earlier analysis and modelling by Umwelt is necessary at this stage. However, further data gathering at the site, in tandem with HWC's continued monitoring, will provide useful data. HWC's data will extend that excellent dataset, and monitoring at the site will allow the localised dataset to be extended, as well as any effects of quarry operation to be assessed and the conceptual model updated if necessary.

The numerical modelling will then be updated as required within 2 years of the commencement of extraction, as per **Commitment 8.3.8 (k)**. A summary of the current modelling (by Umwelt) is presented in **Appendix B**.

5. References

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Appendix A – Groundwater Level data

WATERSHED HYDROGEO

Table A-1 Site GW Monitoring Bores

BoreID	Easting	Northing	Date Drilled	Top Casing	Ground Surface	Depth	Screen Top	Screen Bot	Max GWL	Comment
	[m, GDA 94 z56]			[mAHD]	[mAHD]	[m]	[mBG]	[mBG]	[mAHD]	
BH1	387741.2	6369495.8	24/11/2014	8.64	8.21	9.45	6.45	8.6	2.95	damaged by fire, 2018
BH2	387704.7	6369175.1	25/11/2014	7.79	7.4	9.45	5.6	8.6	3.5	
BH3	387751.7	6368964.4	25/11/2014	7.57	7.03	9.45	5.45	8.45	1.93	
BH4	387855.0	6368742.8	26/11/2014	3.06	2.81	6.45	2.65	5.65	2.14	
BH5	388768.5	6369334.7	26/11/2014	7.36	6.76	9.28	8.1	5.1	2.13	
BH6	388729.8	6369582.3	27/11/2014	3.62	3.01	4.95	3.9	2.4	2.37	
BH7	388827.8	6369245.3	27/11/2014	2.98	2.6	4.95	2.6	4.1	1.75	
BH8	389178.3	6369271.7	28/11/2014	3.88	3.28	6.28	3	5.5	2.24	
BH9	387520.4	6368798.9	10/12/2014	17.75	17.07	18.18	14.6	17.6	1.6	
BH10	387931.2	6369744.4	10/12/2014	6.69	6.09	5.45	2	5	3.19	
BH11	387650.7	6369979.8	11/12/2014	6.63	6.02	5.95	1.6	4.6	4.82	
BH12	388203.0	6369333.0	11/12/2014	8.67	8.06	8.39	4.8	7.8	2.26	
MW239S	388619.1	6369306	15/03/2017	3.04	3.09	4.0	1.0	4.0		Installed by AECOM/Defence

E:\WSHED\PROJ\CABBAGETREE\Tech\Groundwater\WaterLevel\WSS_GroundwaterLevels.xlsx

Table A-2 Key HWC monitoring bores

BoreID	Easting	Northing	Date Drilled	Top Casing	Ground Surface	Depth	Screen Top	Screen Bot	Max GWL	Comment
	[m, GDA 94 z56]			[mAHD]	[mAHD]	[m]	[mBG]	[mBG]	[mAHD]	
SK4942	388260	6370421	20/03/1975	6.54	5.90	27.4			6.01	520 m upgradient (north)
SK5992	386577	6369953	10/11/1977	6.74	6.30	16			5.89	1050 m west of site
SK3508	386435	6368752	21/08/1970	4.46	4.10	22.8			2.6	1020 m west of site
F8	389033	6368536		4.00	3.50				1.84	80 m downgradient (southwest)

Table A-3 On-site Groundwater Dip Data (SWL, mBG)

BoreID	Drilling (Nov/Dec-2014)	18/12/2014	4/02/2015	17/02/2015	3/03/2015	5/05/2015	6/12/2018
BH1	5.3	5.26	5.32	5.34	5.39	---	5.27
BH2	5.1	5.09	5.06	5.1	5.16	3.9	5.15
BH3	5.1	5.19	5.12	5.18	5.24	---	5.49
BH4	1.5	1.32	---!	1.27	1.35	0.67	0.4
BH5	5	5.14	4.82	5.05	5.12	4.63	5.52
BH6	1.1	0.98	0.64	0.92	0.95	---	1.19
BH7	1.1	1.15	0.85	1.06	1.12	---	1.38
BH8	1.7	1.81	1.35	1.66	1.73	1.04	2.14
BH9	15.65	15.47	---	15.48	15.55	---	15.98
BH10	2.9	3.02	3.03	3.08	3.15	---	3.96
BH11	2.3	2.28	2.3	2.38	2.44	1.2	2.41
BH12	5.8	6	5.9	5.97	6.03	---	6.27
MW239S							1.17

*= suspect

Table A-4 On-site Groundwater Dip Data (RWL, mAHD)

BoreID	Drilling (Nov/Dec-2014)	18/12/2014	4/02/2015	17/02/2015	3/03/2015	5/05/2015	6/12/2018
BH1	2.91	2.95	2.89	2.87	2.82	---	3.37*
BH2	2.3	2.31	2.34	2.3	2.24	3.5	2.64
BH3	1.93	1.84	1.91	1.85	1.79	---	2.08
BH4	1.31	1.49	---	1.54	1.46	2.14	2.66
BH5	1.76	1.62	1.94	1.71	1.64	2.13	1.84
BH6	1.91	2.03	2.37	2.09	2.06	---	2.43
BH7	1.5	1.45	1.75	1.54	1.48	---	1.6
BH8	1.58	1.47	1.93	1.62	1.55	2.24	1.74
BH9	1.42	1.6	---	1.59	1.52	---	1.765
BH10	3.19	3.07	3.06	3.01	2.94	---	2.73
BH11	3.72	3.74	3.72	3.64	3.58	4.82	4.22
BH12	2.26	2.06	2.16	2.09	2.03	---	2.4*
MW239S							

*= suspect

Appendix B – Numerical Model

Groundwater Model Assumptions

The modelling of Umwelt (2015 and 2016) was reviewed against checklists from the relevant guidelines (Barnett et al, 2012). The key features and assumptions of the current model are outlined as follows.

Model layering

The groundwater model used 1 layer to represent the Tomago Sandbeds, with the bas elevation of the model being set at a constant -40 mAHD. This is a simplification of the thickness of the aquifer but should not affect the ability of the model to simulate the water table.

Model parameters

Umwelt (2015) specified a constant horizontal hydraulic conductivity of 32.5 m/d for the Tomago Sandbeds. This is a reasonable value (between 20-50 m/d, as per Section 1.4.4), although possibly slightly high for a uniform value. Umwelt specified a vertical K of 3.5 m/d, which again seems reasonable, although given that the model has a single layer then it is irrelevant to the simulation.

Modelled specific yield is set at 14.7%.

The match between the modelled values and field data is considered reasonable (**Section 1.4.4**). The match between Sy values is less certain, but appropriate given caveats around the uncertainty in Sy measurements obtained from the analysis of pumping test in this area (AECOM, 2017).

Model extent

Figure 6 shows the extent of the model in relation to the quarry (site) boundary [red line], RAAF Williamtown [black line] and Fullerton Cove [blue area to the south of the quarry]. The extent is appropriate for simulating heads around the quarry.

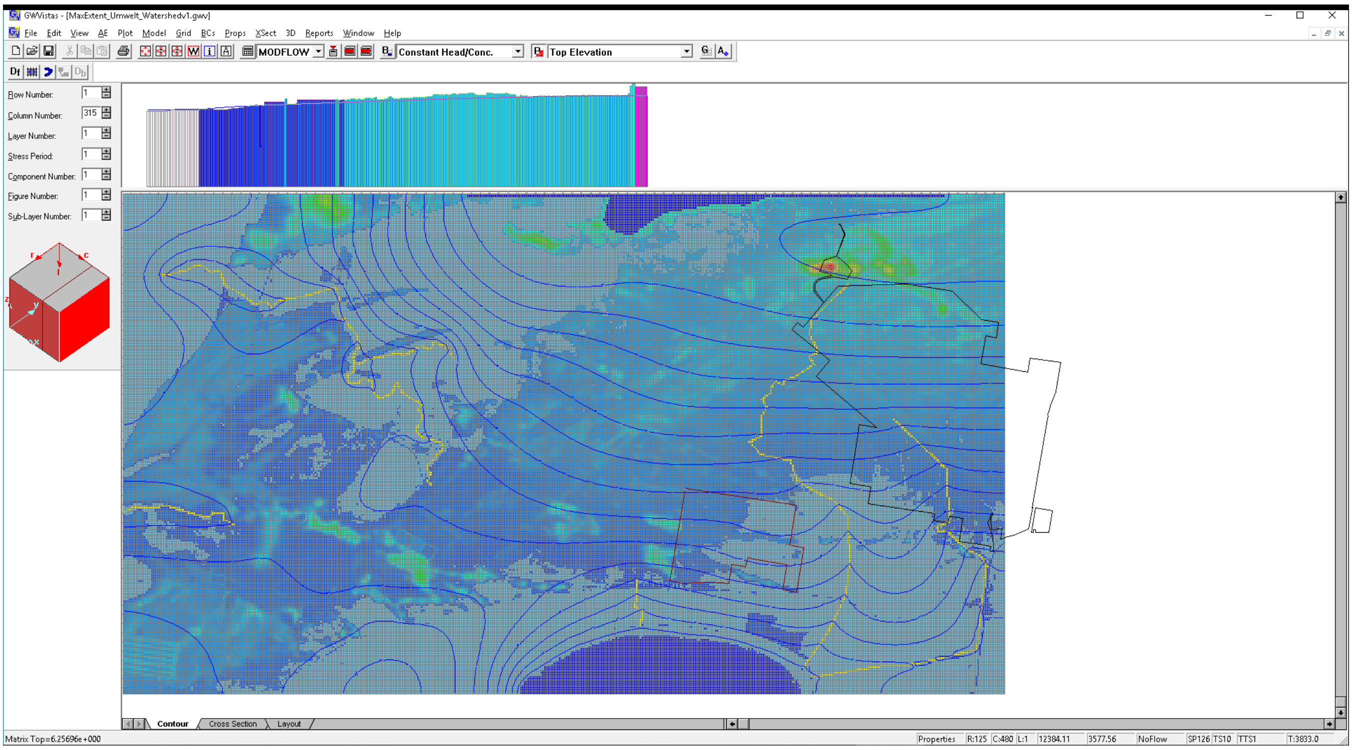

Figure 6 Screenshot of the Umwelt groundwater model in Groundwater Vistas

Model boundary conditions

The Umwelt groundwater model employs a number of important boundary conditions.

- Constant head at Fullerton Cove, set to 0.6 mAHD, which is appropriate (**Figure 6**).
- Constant head at Grahamstown Dam, set to 7.75 mAHD. The level itself is reasonable, but in reality, this waterbody does not interact with the groundwater in the Tomago Sandbeds due to the clay liner installed along the southern wall/bank of the reservoir.
- Recharge and evapotranspiration are estimated as % of rainfall and potential evaporation (PE). As stated in Umwelt (2015), recharge is set to 35% of rainfall, while evapotranspiration from the water table is set to a maximum rate of 60% of PE. Extinction depth for evapotranspiration has been set at a base level of 2.5 m, and lower value of 1 m also considered. These are appropriate for the area around the quarry.
- Watercourses are represented using MODFLOW ‘Drain’ package (yellow lines on **Figure 6**), which accounts for baseflow, but not leakage.
- The model does not incorporate pumping from the HWC borefields. As noted by Umwelt, this makes the predictions more conservative with respect to high groundwater levels, so is appropriate.

Future verification and revision

The model will be verified/updated every two years after commencement of the operation, as per **Commitment 8.3.8 (k)**.

Appendix C – Hunter Water Corporation (HWC) review

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18 March 2019

Our Ref: HW2015-1413/52

Jonathan Berry
Kleinfelder Australia Pty Ltd
95 Mitchell Road
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Via email: jberry@kleinfelder.com

Dear Jonathan

CABBAGE TREE ROAD SAND QUARRY – COMMENT ON SOIL AND WATER MANAGEMENT PLAN AND MAXIMUM EXTRACTION DEPTH REPORT

Thank you for your letter of 15 February 2019 seeking Hunter Water's comments on the Soil Water Management Plan and Maximum Extraction Depth Report prepared as required by Condition 15 of Schedule 3 and Condition 11 of Schedule 2, respectively, of the Development Approval for the Cabbage Tree Road Sand Quarry (SSD-6125). Our comments on the reports are provided below.

Soil Water Management Plan

The Soil and Water Management Plan (SWMP) was required to provide a variety of information, including a site water balance, a surface water management plan, and a groundwater management plan. Most of the information provided is considered sufficient. A few issues of concern were noted, which are summarised below.

Clean Water Minimisation

The proposed water saving strategies relate to vegetation planning and the inclusion of rainwater tanks on the site. These do not contribute significantly to the minimisation of clean water use on site, as the main use of potable water will be dust suppression. While it is noted that the area requiring dust suppression will be miniimised through the bitumen sealing of part of the road and use of conveyors to transport sand, the development will still use a significatn amount of potable water for dust suppression. Hunter Water has regulatory and policy drivers to minimise potable water use, and supports the investigation of alternatives to potable water use for dust suppression. It is not clear whether such alternatives have been considered to date.

Potable Water Supply

An application for preliminary servicing advice for the supply of potable water to the development was lodged with Hunter Water in October 2014, which stated the water requirements for the site were 30 – 40 kL of water per day (around 11 – 15 ML/year). A copy of Hunter Water's response to that application is atatched for your information.

The SWMP, however, indicates that the quarry will use 10 – 29 ML of potable water per year, which equates to an average of 27 – 79 kL/day, although the maximum water consumption may be up to 125 kL/day. As the proposed water demand is now substantially higher than that originally proposed, a new application **must** be made to Hunter Water. This application should detail the maximum required water use and flow rates, and be accompanied by a hydraulic assessment. Details of the application process and information requirements can be found on our website at https://www.hunterwater.com.au/Building-and-Development/Land-and-Property-Development/Our-Application-Process.aspx.

Stormater Runoff from Roads

The management measures for stormwater runoff from roads is not clearly addressed in the SWMP. Sections 4.2.2 and 5.2.3.4 say the bitumen will be shaped to run water to table drains, which infiltrate into groundwater, while Section 5.1.2 indicates that runoff from access roads is considered to be 'dirty water' that will be managed using "infiltration and sediment controls". The plan does not indicate how pollutants, such as hydrocarbons, will be removed from this water. The jute/coir log, rock or sandbag check dams intended to be installed in the table drains are designed to control water flows and reduce scouring, and do not strictly have a pollutant removal function (particularly rock dams). The SWMP needs to demonstrate that all discharges from the site, including infiltration to groundwater, meet Hunter Water's neutral or beneficial effect (NorBE) requirement.

It is also noted that jute/coir and sandbags degrade over time, and rocks can be displaced. The SWMP states that erosion and sediment control measures will be monitored monthly and after significant rainfall, but it is recommended that the plan explicitly state the criteria for assessment of the condition of the check dams and the circumstances and/or frequency with with the materials should be replaced.

Maximum Extraction Depth Report

It is understood from the information provided in the MEDR that there are currently 12 groundwater monitoring bores on site, five of which will be removed during the course of the extraction operations with only one being replaced, leaving eight bores available for ongoing monitoring. Of these eight bores, five will be equipped with automatic data loggers, while the remaining three bores will be measured manually. This is considered to be acceptable. The proposed monthly monitoring frequency is considered to be reasonable, as are the locations of the monitoring bores.

The methodology for determining maximum proposed extraction depths, using conservative expected groundwater levels with an added 0.7 m buffer, is considered to be acceptable. It is further acknowledged that these levels will be reviewed, and modified as required, every two years. Hunter Water also supports the proposal to monitor extraction depths using GPS tracking, together with regular auditing and surveying.

Please note that Figures 1 and 2 did not display correctly in our electronic copy of the report.

In all, the MEDR is considered to be acceptable.

Additional Comments

In addition, Condition 11 of Schedule 5 requires the Annual Reviews to be made available to Hunter Water (as part of the Community Consultative Committee) on request. We wish to notify the Proponent of our desire to receive these Annual Reviews as soon as possible following their preparation. Further, Condition 14 of Schedule 5 requires the Proponent to publish independent environmental audit reports on a website; Hunter Water requests notification of when new reports are published.

If you require further advice or clarification regarding the submission, please contact me on (02) 4979 9545.

Yours sincerely

Malcolm Withers
Account Manager Major Development