APPENDIX 7

FATE AND TRANSPORT MODEL – ONSITE CONTAINMENT CELL

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Hydro Aluminium Kurri Kurri Pty Ltd

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FATE AND TRANSPORT OF LEACHATE

PROPOSED HYDRO CONTAINMENT CELL

RAMBOLL ENVIRON

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PROPOSED HYDRO CONTAINMENT CELL

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Description	**This report presents a prediction of the fate and transport of leachate from the proposed Hydro Containment Cell should leachate escape through the base layers in the future.**

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EXECUTIVE SUMMARY

Ramboll Environ was commissioned by Hydro Aluminium to undertake preliminary groundwater contaminant fate and transport modelling for input to a waste management options study for remediation planning of their Kurri Kurri site. Hydro proposed to contain wastes containing leachable fluoride within an onsite containment cell. Whilst the cell is designed not to leak and for dry entombment, Ramboll Environ has been asked to model the fate of fluoride in leachate from the cell under a hypothetical leak scenario. The modelling has considered leachate containing fluoride at three concentrations representing maximum concentrations (worse case), average concentrations and fluoride concentrations predicted for treated wastes.

The model used known geological and hydrogeological conditions and a one-dimensional analytical groundwater flow model to predict the movement of leachate toward the closest groundwater receptor. Parameters were based on field measurements or relevant literature values. The model used a combination of conservative and reasonable assumptions to evaluate fluoride concentrations at the receptor impact distance.

The modelling showed:

- Chemical and physical contaminant transport processes restrict the movement of leachate to less than 50m from the leakage point after 10000 years of simulation. Modelling predictions indicate it would several hundred thousand years for a plume to reach the receptor.
- The model demonstrates sensitivity to a number of input parameters including the soil partition coefficient, (Kd), however even with the application of extremely conservative values it is considered that there is not a significant risk of migration to the nearest environmental receptor under the adopted conceptual site model.

The conceptual site model for the groundwater modelling is presented graphically, below, (**Figure ES1 1**).

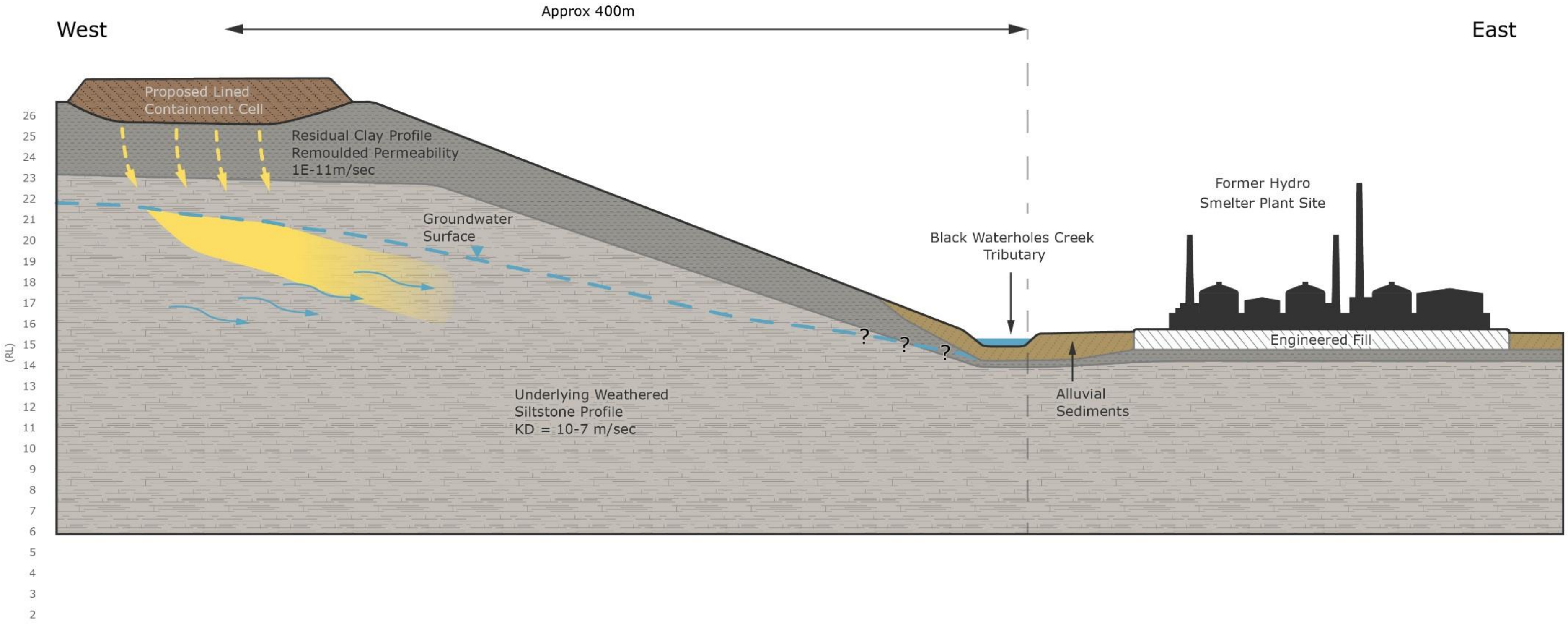


Figure ES1 1 Conceptual Site Model

1. INTRODUCTION

1.1 Preamble

Ramboll Environ Australia Pty Ltd (Ramboll Environ) was commissioned by Hydro Aluminium Kurri Kurri Pty Ltd (Hydro) to undertake preliminary groundwater contaminant fate and transport modelling for input to a waste management options study as part of the development of remediation strategies for the smelter.

The options study addresses the management options available for contaminated soils and the on-site historical landfill known as the Capped Waste Stockpile. The Capped Waste Stockpile contains aluminium smelter wastes with leachable fluoride concentrations based on laboratory analysis to be have a 95% upper confidence limit of the mean of 337mg/L. The Chemical Control Order for Aluminium Smelter Wastes, which is being applied by the EPA to these wastes, prohibits the disposal of aluminium smelter wastes with concentrations of leachable fluoride greater than 150mg/L. The CCO also prohibits the disposal of aluminium smelter wastes with concentrations of leachable cyanide greater than 10mg/L. Laboratory analysis of samples from the Capped Waste Stockpile has found maximum and average concentrations of cyanide to be below 10mg/L.

Management options (Volume 2 of the Capped Waste Stockpile Waste Management Options Study (the Options Study)) for the waste include the construction of a containment cell at the location of the former "clay borrow pit", (CBP) which was the source of clay-capping material used in the construction of the CWS in 1995. The CBP is located on a topographical high point immediately west of the smelter and has been assessed as a suitable site for a containment cell due to the cleared vegetation, height above flood level, distance to receptors and low permeability geology.

The containment cell is purpose designed and includes a number of safety factors including multiple liner and capping systems comprising geotextiles and low permeability clays; testing of liner materials for site specific leachate to confirm long term performance; a primary and secondary leachate collection system; a groundwater collection system; and cell construction quality controls. The scenario modelled herein describes a leachate escape, and reflects the low probability scenario where leachate breaches the liners, leachate collection system and groundwater collection system and migrates to the underlying bedrock aquifer.

The Options Analysis considered the need for treatment of the waste to achieve a leachable fluoride concentration of below 150mg/L. Separately an evaluation of net environmental benefit (Volume 2 of the Options Study) for all management options has concluded that there is a minor environmental benefit from the treatment of the wastes. The analysis found that there was no risk to the environment from the escape of either untreated or treated leachate or therefore no overall benefit from the treatment of the material prior to placement within the cell.

This modelling is to further explore the fate and transport of contaminants from the proposed cell

The report describes the hydrogeological conditions, the methodology of the model, the specific inputs to the model and the model results.

The location of the site, and of the relevant areas within the site are presented in **Figure 1, Appendix 1.**

1.2 Objective

The objective of the groundwater contaminant transport modelling was to predict the concentration profile for fluoride migration in groundwater under a hypothetical cell leak scenario.

1.3 Scope of Work

The following scope of work was undertaken as part of this study:

- Review existing site data relating to site topography, geology, hydrogeology;

- Prepare a conceptual groundwater flow model for the site, based on the geology and hydrogeology information;
- Collate literature information on the retardation of fluoride ions within the aquifer;
- Input of the data into a one-dimensional, analytical model based on well understood groundwater flow and contaminant transport principles;
- Simulate groundwater flow scenarios and present results; and
- Evaluate the uncertainty and sensitivity of the model.

2. BACKGROUND

A discussion of background information is presented in detail in the overarching Options Study of which this this report forms an appendix. A summary of background information is presented below.

2.1 Hydro Aluminium Smelter Site

The Former Hydro Aluminium Kurri Kurri Smelter is located approximately 30km west of the city of Newcastle and 150km north of Sydney, in New South Wales, Australia. The smelter includes a 60ha plant area surrounded by approximately 2,000ha of buffer zone lands.

Aluminium smelting wastes and other site wastes have been produced over the life of the smelter and are currently stored on-site in a capped waste stockpile to the east of the plant.

As part of this Options Study, construction of a containment cell is proposed to store those wastes which cannot be recycled or reused.

A containment cell has been designed to mitigate against production and loss of leachate from the wastes. Analysis of the wastes for leachable concentrations has found the wastes to contain fluoride above the chemical control order of 150mg/L. The average concentration for wastes was 337mg/L. Historical monitoring of the Capped Waste Stockpile determined a maximum historically recorded concentration of 1880mg/L.

2.2 Proposed Location of Containment Cell

The location of the containment cell is proposed for the area known as the "Clay Borrow Pit", **Figure 1, Appendix 1**.

This area, is located immediately to the west of the plant site, on a small cleared hillock.

The CBP had been excavated as a source of clay during the construction of the low permeability cap on the CWS in the 1990's. Subsequent to the clay removal, parts of the excavated area served as a waste storage area, mainly for inert materials such as concrete and used refractory bricks from the smelter. The materials were removed as part of preliminary works during 2015 – 2016.

The topography of the CBP area comprises a south-west north-east trending ridge line with heights up to approximately 26 mAHD. The ridge rises towards the west south-west and slopes away to the north-west, south-east and east, and is bisected by tributaries of Black Waterholes Creek, in the lower valleys. The CBP is a mainly open area surrounded on three side (north, west and south) by bushland of mature trees and lower scrub. The land slopes down towards the east where a water course and associated wetlands of Black Waterholes Creek (a tributary of Swamp Creek) separates the site from the main smelter area.

Environ (2013) presents a preliminary study which was completed to assess the feasibility of siting a waste containment cell (landfill) on Hydro owned land as an option for waste disposal as part of the site management activities.

The study assessed several potential sites however the most feasible site was identified as the CBP area. The CBP site, based on a review of existing information at the time, represented the best combination of available area, suitable geology (generally clay-containing residual soils from in-situ weathering of bedrock), groundwater at depth, location away from surface water bodies and major infrastructure, and proximity to the capped waste stockpile (the major source of waste destined for the proposed containment cell). A conceptual plan from the report showing the cell siting constraints is presented in **Figure 2-1**.

A further study of this area was completed during 2014, which involved a preliminary geotechnical assessment of the CBP area (ENVIRON 2015). Boreholes and test pits were drilled/excavated across the site, the soil/geology logged and representative soil samples were collected and underwent laboratory testing for a range of geotechnical parameters. Groundwater monitoring wells were installed into selected bores, which supplemented wells which had been installed in the initial 2012 Environ environmental investigation.

A supplementary geotechnical investigation was undertaken by GHD in 2016 which targeted the soil profile and upper weathered rock profile. Additional geotechnical laboratory testing was undertaken. The GHD investigation confirmed the findings of the 2014 Environ investigation.

A summary of the findings of these investigations is presented in the following sections. Borelogs from both the 2014 Environ investigation and the 2016 GHD investigation are attached as **Appendix 2**. Summary tables showing the results of laboratory testing of clay soils from the 2014 Environ investigation and the 2016 GHD 2016 investigation are presented in **Appendix 3**.

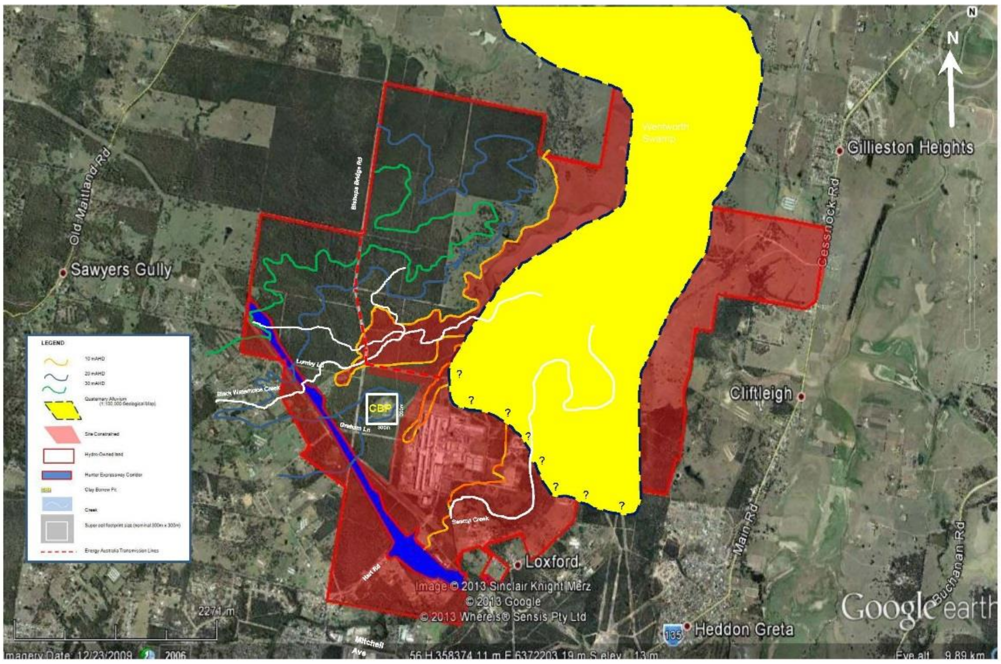


Figure 2-1 Plan of Site Constraints (Environ 2013)

2.3 Site Geology

The Sydney Basin Geological Sheet indicates that the Smelter Site is underlain by siltstone, marl and minor sandstone from the Permian aged Rutherford Formation (Dalwood Group) in the Sydney Basin. Undifferentiated Quaternary alluvium occurs in the east and northeast of the smelter site and is connected to the surrounding surface water bodies. Quaternary sediments which are associated with Swamp Creek (located to the east of the site) and Wentworth Swamps consist of complex interbedded fluvial and marine sands and estuarine muds deposited within an estuarine environment during periods of sea level rise and fall.

A series of investigations were conducted in the CBP area, including a preliminary environmental investigation in 2012 (Environ 2012), a landfill siting assessment (Environ 2013); and geotechnical investigations in 2014 (Environ 2014) and 2016 (GHD 2016).

Boreholes and test pits drilled across the CBP area generally encountered a weathered residual clay soil profile comprising medium to high plasticity clays between 3 to 5 m thick, overlying weathered siltstone, (with minor shale, sandstone and conglomerate). The siltstone was identified as highly to extremely weathered near the surface (as noted in the GHD investigation), becoming less weathered with depth. The 2014 Environ investigation which included coring of the underlying less weathered siltstone encountered massive rock with minimal defects.

Further details of the CBP area are presented in **Section 2.2**.

2.4 Hydrogeology

Groundwater was not encountered within the overlying residual clays on the CBP site, however monitoring wells installed into the underlying weathered siltstone recorded groundwater levels between approximately 3 and 7 m below ground surface with one well in the north-west corner at approximately 14m below ground surface.

This was interpreted as the groundwater on site present as a confined aquifer in the secondary porosity of the underlying rock mass, and the depth of water below the ground surface reflects piezometric pressure.

The disparity in the water level in the north-west corner of the site, also suggests a potentially discontinuous character to the aquifer.

Water levels measured in the 2014 Environ investigation and corrected to mAHD indicate a general groundwater flow direction to the south, approximately down topographic slope to the smelter site at a nominal gradient of 0.02 m/m.

The results of field aquifer testing for hydraulic conductivities found ranges of approximately 1E-7 m/sec to 1E-8 m/sec.

The laboratory testing of soil samples indicated very low permeability clays with permeabilities between 5E-10 to 5E-12 m/sec. These samples were remoulded samples at a compaction of 100% of maximum dry density and tested using potable water and samples of leachate as a permeant;

Laboratory analysis using leachate as a permeant found hydraulic conductivities in remoulded clays equal to or lower than those determined using de-ionised water. The reduction in hydraulic conductivity was up to an order of magnitude, (shown in Table 1 of **Appendix 3**).

2.5 Conceptual Design of Proposed Contaminant Cell

The detailed containment cell design consists of:

- Triple base lining system consisting of low permeability clay overlain by two geocomposite liners each comprising a geosynthetic clay liner and high density polyethylene liner.
- Primary and secondary leachate and groundwater collection system
- Liner durability testing using site won leachate
- Dry entombment work methodology to minimise moisture entrainment
- Double capping system comprising a linear low density polyethylene liner and 1.5 m soil and vegetation layer
- Precautionary gas venting system
- Leachate collection including ability for long term periodic pump out

The detailed containment cell design is include as **Volume 1**, **Appendix 5** of this Options Study.

Modelling of leachate generation within the cell following cell closure was completed by GHD as part of this design. This modelling predicts less than 400L/year of leachate will be generated within the cell from the minimal infiltration through the cap layer. The waste itself will not generate leachate. It is reasonable to estimate that less than 0.01% of this leachate could potentially escape the lining and leachate collection system in the event of breach in the system, though this itself is considered unlikely. The leachate estimate is around 4L/year, and should this occur is an insignificant volume.

2.6 Site Contaminant of Concern

Fluoride was selected as the primary contaminant of concern, appropriate for the groundwater model. Specifically, the model is used to assess the migration of Fluoride at three concentrations.

- Firstly, the average concentration for leachable fluoride determined from sampling of the capped wastes stockpile materials. These results are presented in **Volume 1**, **Appendix 2** and show that the average concentration of the data set (N=54) is 337 mg/L.
- The maximum concentration observed in groundwater within the current capped waste stockpile is 1880 mg/L. This concentration was measured during Hydro's routine monitoring of perched water within the Capped Waste Stockpile. The sample was from MW202 on the 11/11/15. The concentration is reflective of a worse case leachate condition.
- The treated leachate concentration of 150 mg/L required to be achieved for the disposal of aluminium smelter wastes consistent with the Chemical Control Order.

The behaviour of fluoride within the clay and bedrock strata and the adoption of contaminant transport properties was determined from the paper, *Landfill of Aluminium Smelter Wastes at Wallaroo, NSW, Australia* (Sulllivan & Knight 1992). The study was originally undertaken as part of a smelter waste disposal options assessment for the Tomago Aluminium Smelter.

This paper presents a series of investigations which included field investigation of the geological properties of the area and soil adsorbtion capacity for fluoride and sodium. Of particular interest is the similar nature of the geology in this study to that of the CBP site where both sites comprise of a weathered profile of residual clays overlying Permian aged siltstones and mudstones.

Batch testing was carried out to assess clay behaviour to fluoride in leachate. Leachate concentrations up to 1000 mg/L and between a pH of 5.5 to 7.5 were iteratively analysed over ten days.

Testing found:

- Adsorbtion distribution coefficients (kd) were determined at 3.3 ml/g (L/kg) for pH 7-7.5 and 3.1 ml/g at pH 5-5.5;
- Adsorbtion was largely complete within the first 24 hours;
- The leachate underwent slightly better adsorbtion in alkaline conditions than acid conditions;
- Adsorbtion increased with increasing concentrations of fluoride.

In addition, testing was undertaken to assess the change of permeability over time as a result of leaching using a fluoride/sodium solution. A decrease in permeability of almost an order of magnitude was observed interpreted to be the sodium interacting with the clay. Similar results were observed using CBP won clay soils and testing with leachate as the permeant medium, from Environ (2015) and presented in Table 1 of **Appendix 3**).

2.7 Environmental Receptor

The environmental receptor at the site is identified to be a tributary of Black Waterholes Creek located 400m to the east of the CBP. The creek is ephemeral and flows to the north and discharges to the topographically lower wetlands area of Wentworth Swamp, approximately 1.5 km to the north-east of the CBP. Ultimately the wetlands discharge to the Hunter River within the Fishery Creek Catchment, approximately 7km northeast, near Maitland.

Declining stream water quality and a reduction in diversity of native plants and animals has occurred within the Fishery Creek Catchment and water quality down gradient of the site has been impacted by historical coal mining. The Hunter River Groundwater Management Unit (GMU) is used for irrigation, urban supply, drought supply, stock, domestic and commercial/ industrial use but it is not the main drinking water supply in the region. (NSW Water Quality and River Flow Objectives). (www.environment.nsw.gov.au/ieo/Hunter/index.htm).

The surface water features are shown in **Figure 1, Appendix 1**.

2.8 Conceptual Site Model

Leachate generation and mobilisation from the proposed Containment Cell is considered to occur by a combination of retained moisture within emplaced wastes and infiltration from incident storm water events through the operational surface capping layers ("daily cover") creating 'new' leachate.

A worst case scenario envisages the leachate collecting at the base of the contaminant cell and discharging to the underlying environment as a result of a multiple failure of the lining system, and leachate collection systems.

The leakage from the cell is further assumed to migrate through the residual clay underlying the cell and into the underlying weathered siltstone bedrock profile.

The aquifer in the siltstone was confirmed during the geotechnical investigation which described the groundwater as representing an aquifer present in the secondary porosity of the underlying rock profile (i.e. within the rock defects- -joints etc.), confined by the overlying clays. The water levels represent the piezometric pressure produced by groundwater recharge at higher topographic levels, up-hydraulic gradient.

Based on boreholes drilled across the CBP site bedrock is present beneath overlying topsoils and residual clays at a depth of approximately 3.5 to 7m depth. The siltstone weathering ranged from extremely weathered at the soil interface to highly weathered at the depth of investigation. Cored sections (between 5 and 12 m depth) generally indicated a tight structure with little bedding or defects (jointing/fractures).

The movement of groundwater from leakage through the base of the cell to the down-gradient groundwater receptor is anticipated to be within rock defects and potentially more weathered zones within the bedrock. Preliminary aquifer tests indicated an average hydraulic conductivity of 5E-8 m/sec. Testing has shown that the use of leachate as a permeant resulted in lower permeabilities, (**Appendix 3**). Plotting of groundwater contours indicated a flow direction approximately south at a gradient of 0.02.

The conceptual site model is presented in **Figure 2**, **Appendix 1**.

3. GROUNDWATER MODELLING

To predict potential impacts from fluoride in the groundwater on downstream receptors, the “Remedial Targets Worksheet”, model was used. Originally developed for the UK environmental regulator, (UK Environment Agency), it is used as a tool to predict the impacts of soil and groundwater contamination.

The model selected is a one-dimensional, analytical model originally to assist with remediation planning and is presented in an Excel spreadsheet format. The model is applied to a conceptual site model of the known site conditions.

The model uses a solution to the contaminant flow equation in groundwater using a selection of published solutions Domenico, (time variant or steady state), depending on assessment of vertical horizontal and longitudinal dispersivity.

The model is used to predict groundwater concentrations at a required distance from a source, starting with soil contaminant concentrations and a variety of known or assumed input parameters, and, if required, back-calculate groundwater remediation goals.

In this case, the range of groundwater source contaminant concentrations are well understood from a large database of monitoring results. As such the soil components of the spreadsheet model, “Level 1, 2 and 3 Soil” sheets, are not used and inputs are made directly into the groundwater sheet, (Level 3).

The inputs to the model were:

- Geometry of the subject aquifer including depth, saturated thickness, and hydraulic gradient;
- Flow properties of the aquifer including hydraulic conductivity and porosity;
- Properties of the assumed contaminant plume including, plume width, depth, initial contaminant concentration;
- specific contaminant properties including degradation rate (if applicable), partition coefficient, (i.e. the propensity for the contaminant to come out of solution and be adsorbed onto the soil particles of the aquifer) and the effects of lateral and vertical dispersion;
- Receptor impact assessment information including guideline criteria concentration, and linear distance to receptor.

The above parameters are based on values measured in the field, values derived from literature and assumptions made depending on the site conditions.

A summary of the input parameters for the proposed containment cell model is presented in the following section.

Modelling was undertaken using the adopted input parameters as initial settings, and calculating the output which is presented as a curve of concentrations against distance from source. The model was then re-calculated using variable input parameter in order to obtain a range of results considered to be realistic to conservative for the conditions.

A sensitivity analysis, assessing variation in the major parameters, was also undertaken to provide an indication of uncertainty in the model.

3.1 Model Inputs

Model parameters were developed from site specific and contaminant specific information presented above as well as standard parameters adopted for groundwater fate and transport modelling as follows.

3.1.1 Flow Path Length

The length of the groundwater flow path from the hypothetical contamination source (the containment cell as a result of a leakage event, has been set at 400 m which is the approximate distance from the centre of the clay borrow pit area to the tributary of Black Waterholes Creek which flows northwards on the west side of the smelter plant site, ultimately to discharge into

Wentworth Swamp wetlands. Based on the actual groundwater flow direction (north to south) the distance is closer to 700 to 800 m. **Figure 2, Appendix 1** shows the groundwater flow direction and intersection with the Creek.

3.1.2 Aquifer Parameters

Preliminary aquifer testing (rising head tests) undertaken during the 2014 geotechnical investigation indicated hydraulic conductivities of approximately 1E-7 m/sec to 1E-8 m/sec. The aquifer is assumed to be contained within the existing rock locally confined by the overlying residual clay profile. Details of the aquifer testing is presented in Section 4.2 and Appendix F of the 2014 Geotechnical report.

An average hydraulic conductivity of approximately 5E-7 m/sec was adopted (0.00423 m/day).

3.1.3 Contaminant Source

The hypothetical source of the fluoride concentrations in the groundwater is assumed to be a leakage event from the proposed containment cell.

In the model, the initial settings have assumed a constant source concentration. This is considered to be a very conservative case given:

- The mitigation of leachate production by the proposed final capping works; and
- The design of the cell which includes:
    - Its location on the very low permeability residual clay across the CBP;
    - The planned multicomponent liner system using a combination of membranes, compacted clay layers and geo-synthetic liners with ongoing leachate drainage, recovery and treatment.

3.1.4 Soil/Water Partition Coefficient

The default value for fluoride in the model help files is set at 0.8 L/kg which represents minimal adsorption and a highly conservative value.

Sullivan and Knight 1992 presents the results of a study of field investigation and laboratory testing on Permian-aged residual clays (from weathered siltstones) for the effects of smelter waste-derived leachate. Among other results, the soil water partition coefficient (Kd) was determined to be between 3.1 and 3.3 ml/g (L/kg) with increased coefficient values for increased fluoride concentrations.

The adopted value for this model has been set at 3 L/kg.

3.1.5 Adopted Parameters

Table 3.1 summarises inputs to the model, including values and data sources.

Table 3.1: Model Input Parameters

Parameter	Unit	Initial Value	Source/Comment
Saturated aquifer thickness	m	10	Obtained from field data during installation of wells across the site and based on a reasonable value
Porosity of aquifer material	d/less	0.2	Based on average value for fractured sandstone (Fetter 1988)
Bulk density of aquifer	T/m^3	2.5	Average value for siltstone.
Hydraulic gradient	d/less	0.02	Average value of water levels for wells north to south across the site.
Hydraulic conductivity	m/day	0.00432	Based on the 2014 Environ aquifer testing calculated average value of 5E-8 m/sec, (0.00432 m/day).

Parameter	Unit	Initial Value	Source/Comment
Distance to receptor	m	400	This distance is based on groundwater flow direction from the CPB midpoint to the nearest receptor, a tributary of Black Waterholes Creek (**Figure 2**, **Appendix 1**)
Contaminant	-	Fluoride	Fluoride has been identified as the principal contaminant of concern from the capped waste stockpile – the principal source of wastes to the proposed cell.
Plume thickness	m	5	Set at half the saturated aquifer thickness to allow for vertical dispersion.
Width of plume at source (perpendicular to flow)	m	100	Set at a nominal 100 m.
Initial Concentration	mg/L	Various as discussed	Maximum, average and treated concentrations
Target Concentration	mg/L	1.5	Guideline criteria for fluoride in water (recreational use).
Degradation half life	days	1e99	Assumed no degradation. Conservative.
Longitudinal Dispersivity	m	10% of pathway	Standard default assumption for model
Transverse Dispersivity	m	1% of pathway	Standard default assumption for model
Vertical Dispersivity	m	0.1% of pathway	Standard default assumption for model
Soil/water partition coefficient	L/kg	3	Based paper - Sullivan and Knight July 1992 results from an assessment for disposal of aluminium smelter waste.
Analytical Solution	-	-	A range of solutions Domenico – time variant solutions over a range of assumed times.
Vertical dispersion	m	in one direction	Assumed to be entering at surface of groundwater

1. d/less is dimensionless
2. m is metes
3. L/kg litres per kilogram
4. T/m^3 is tonnes per cubic metre
5. m/sec and m/day is metres per second and metres per day

4. MODELLING RESULTS

The following section presents the model predictions for the input parameters assuming a reasonable conservative case and moving to a highly conservative case.

4.1 Reasonable Conservative Case – Time Variant Solution

The model used the Domenico time variant solution with the initial parameter settings time set at 100 years, the assumed containment cell life span; 10,000 years, considered to be representative of steady state; and the initial concentration at the average measured concentration of 337 mg/L. The results are presented in **Figure 4-1**.

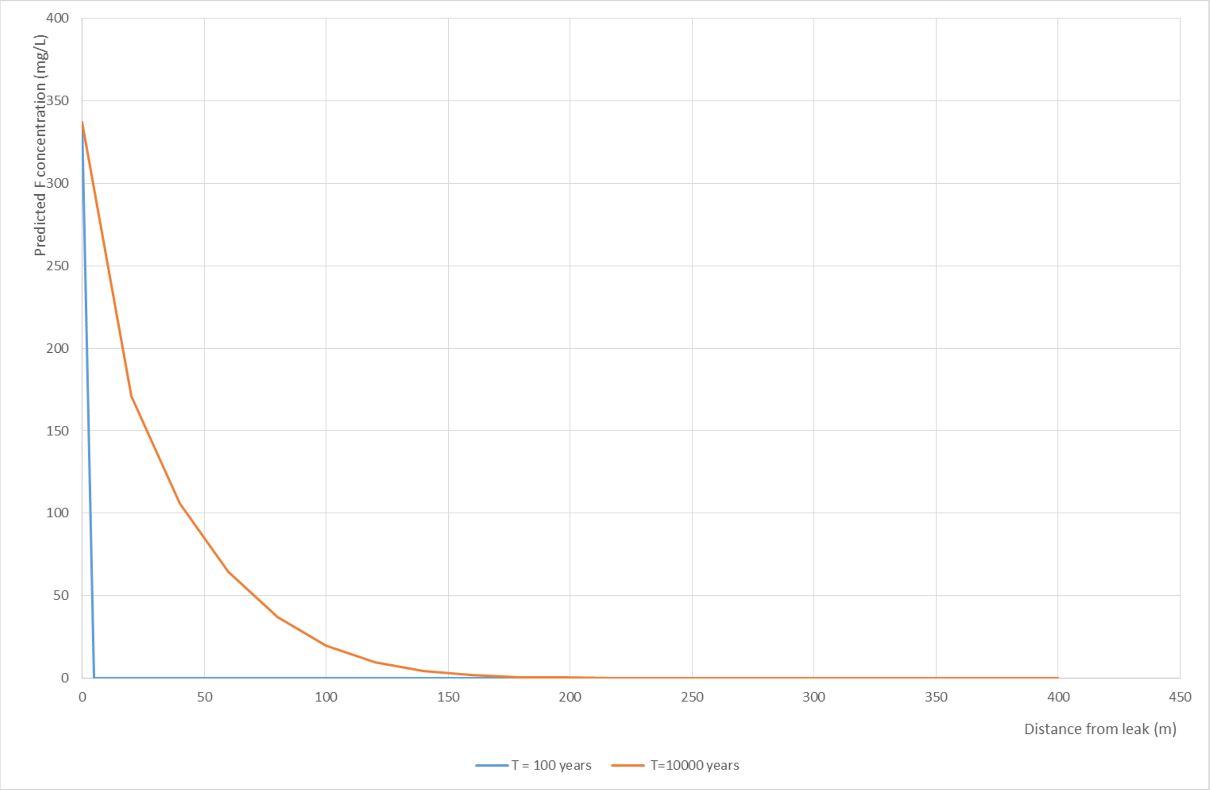


Figure 4-1 Reasonable case at T=100 years and T=10000 years

Figure 4-1 shows that leachate impacts are predicted to be limited to within 5m of the cell leak after a period of 100 years. Also that after 10,000 years the extent of impact is limited to less than 200m and has not reached the receptor, at a distance of 400m.

4.2 Concentration effects

Figure 4-2 shows the model predictions using the reasonable case parameters and varied initial concentrations. Concentrations modelled were:

- 1880 mg/L – the highest ever recorded concentration in leachate at the capped waste stockpile;
- 337 mg/L – the average concentration of TCLP F data for the capped waste stockpile samples;
- 150 mg/L – the target leachable concentration to which waste would be treated.

The predictions show the leachate impacts are limited to within 200m of the leak and there is no risk to the receptor from this concentration range within a 10,000 year timeframe under any concentration modelled.

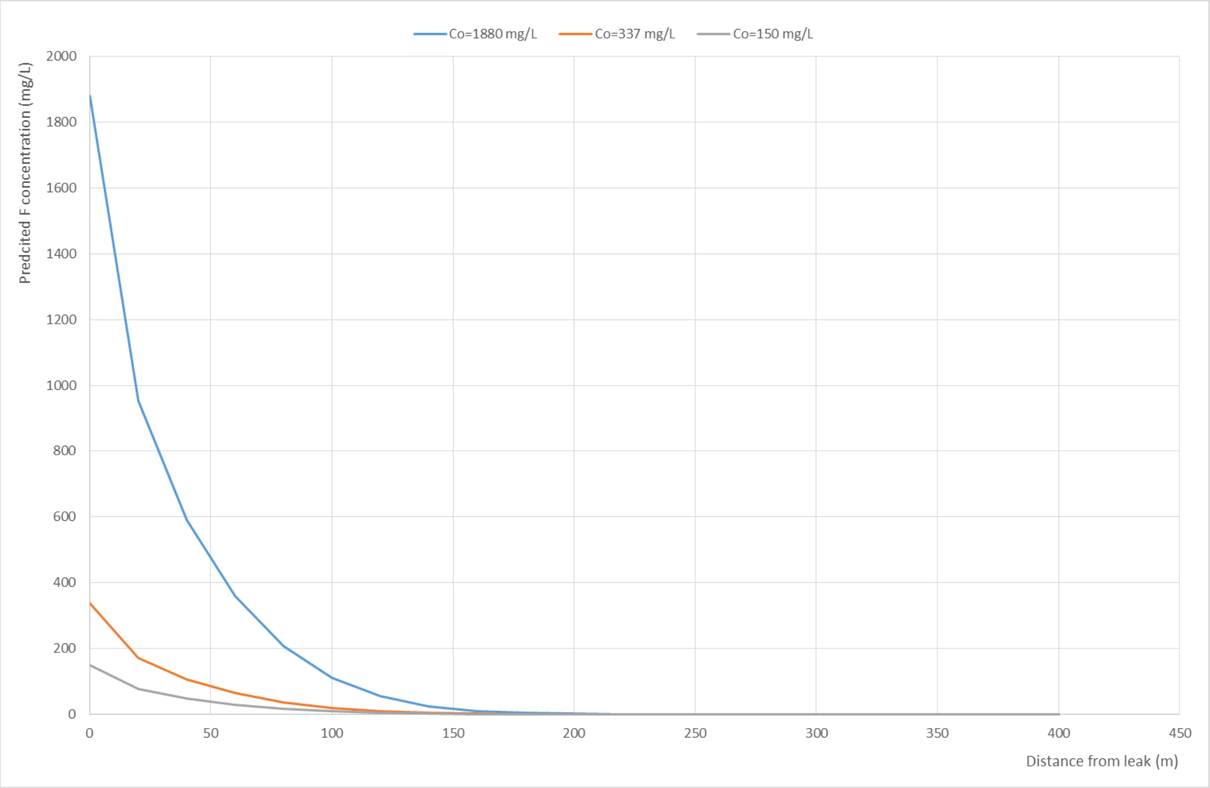


Figure 4-2 **Model Predictions using Varied input concentrations**

4.3 Sensitivity Testing Analysis

To test the sensitivity of key parameters, the Domenico time variant solution was used with the time set at 100 years, (the assumed containment cell life span).

Table 4.1, below presents the results of the analysis.

Table 4.1 **Model Sensitivity Analysis**

Parameter	Value used in Model	Sensitivity Analysis Value	Percentage Change from Original Receptor Concentration	Comment
Initial Concentration	337	1880	Nil	The plume does not reach the receptor
Plume Width	100	300	No change	Width of the plume is defined by geometry of the cell and Considered unlikely to be wider due to delineation evaluation completed and confinement with infilled channel.
Plume thickness	5	15	Nil	The plume does not reach the receptor
Aquifer thickness	10	8	No change	
Bulk Density	2.5	1.5	Increase in plume extent by 5m after 100 years.	Bulk density is considered to be likely to be greater than 2 based on common literature values for rock.

Parameter	Value used in Model	Sensitivity Analysis Value	Percentage Change from Original Receptor Concentration	Comment
Porosity	0.2	0.02	No change in plume length	Insignificant change
Hydraulic Gradient	0.02	0.05	Over 50 times greater conc. at 20m	Increase in gradient resulted in significant increase in conc at 20m however plume extended only to 60m
Hydraulic conductivity	0.00432	0.0432	Over 500 times greater conc. at 20m	Increase in hydraulic conductivity resulted in significant increase in conc at 20m - plume extended to maximum distance of 100m with exceedance of target concentration (1.5 mg/L) at less than 50m.
Soil Partition Coefficient	3	0.5 (0)	Approx. 300 times greater conc. at 20m	Increase in Soil Partition Coefficient resulted in significant increase in conc at 20m - plume extended to maximum distance of 60m with exceedance of target concentration (1.5 mg/L) at less than 50m. NB Complete removal of a soil water partition coefficient results in 500 times increase at 20m and a maximum plume extent of 200m, (exceedance of target concentration at 110m).

The analysis showed that the model is most sensitive to changes in hydraulic gradient, hydraulic conductivity and soil/water partition coefficient. However, although increases in plume concentrations near to the source, resulted from increases (or decreases) in these parameters, the length of plume extent (at any concentration) did not extend beyond 100m. In particular, plume concentration in excess of the target concentration (1.5 mg/L) did not extend beyond 50m.

The following provides comments more specifically on individual parameters:

- Soil partition coefficient is a sensitive parameter which is site specific and can be calculated from empirical testing using aquifer materials and site groundwater. The value of 3 L/kg is considered reasonable given the default value of 0.8 L/kg (from the model notes) and based on (Sullivan and Knight 1992).
- The hydraulic conductivity is based on preliminary aquifer testing and is considered a reasonable value consistent with literature values.
- The hydraulic gradient is measured from inferred groundwater contours from the 2014 investigation.

4.4 Discussion

4.4.1 Containment Cell Design

The containment cell design incorporates many levels of redundancy including liner design, multiple liner and leachate collection, geological setting and capping design, monitoring and leachate pump out. Importantly the waste is not leachate generating and therefore dry entombment minimises the volume of leachate in the longer term. The long term modelling predicts less than 400L/year of leachate will be generated within the cell from the minimal infiltration through the cap layer. To escape from the cell and reach the groundwater system both liners need to fail as well as the leachate collection systems and the underlying perched groundwater collection system. As this is unlikely to occur it reasonable to estimate that less than 0.01% of this leachate could potentially escape the lining and leachate collection system in the event of breach in the system, though this itself is considered unlikely. The leachate estimate is around 4L/year, and should this occur is an insignificant volume.

4.4.2 Modelling Results

The results of the modelling indicates:

- A reasonable conservative case and highly conservative case, using conservative input parameters, indicates that leachate migration will not reach any significant distance from the source due to the presence of clay and bedrock which acts to physically and chemically retard the leachate constituents.
- Based on the results, it is considered that there is no risk of migration of leachate from a potential breach of the proposed containment cell to the nearest environmental receptor under the adopted conceptual site model.
- There is no change in the risk profile to the receptor under the range of initial concentrations modelled.

These modelling results indicate that in the unlikely event that the containment cell was to leak at the highest (and overly conservative) concentration, leachate migration would take over 10,000 years to reach the nearest receptor. Modelling predicts that there is no reduced environmental risk as a consequence of treatment of the wastes prior to placement. Treatment of the waste prior to placement has been demonstrated to provide no environmental benefit.

4.4.3 Assumptions/Risks

The model makes several major assumptions which are considered below in terms of how their accuracy may affect the results:

4.4.3.1 Flow Path

The flow path is assumed to be infiltration from the base of the cell, through the underlying clays, into the aquifer within the bedrock and thence down-hydraulic gradient, discharging to the Creek or to the alluvial sediments surrounding the Creek. The hydraulic conductivities of these media are very low based on testing and observations made during investigations, (highly plastic, low permeability clay, rock profiles with minimal visible defects). If, however, a preferred pathway was available, any leakage from the cell would follow that pathway at potentially much higher flows following the topography (towards the plant site/receptor). Such pathways may exist at the interface between the overlying soil and weathered rock profile. Similarly, if a fracture system within the bedrock formed an interconnected secondary porosity, hydraulic conductivities would be significantly higher.

It is considered that although these scenarios may be possible, they would likely be present on a very local basis given the extent of the current investigations which have not identified widespread occurrence of these conditions. It is further considered that if local preferred paths were present on a localized basis, the sensitivity analysis undertaken would account for their increasing effect on hydraulic conductivity.

4.4.3.2 Soil/Water Partition Coefficient

A soil/water partition coefficient (Kd) has been assumed for the model, based on existing research in residual clays, however given that a significant proportion of the flow path is assumed through the bedrock aquifer the actual Kd may not apply. This was addressed in the sensitivity analysis where zero attenuation from soil partitioning was tested. The plume length was still restricted to 200m (with concentrations greater than the target concentration of 1.5 mg/L less than 110m from the source) at 10000 years post leak.

5. CONCLUSIONS

Ramboll Environ has undertaken preliminary groundwater modelling to assess a potential breach of the integrity of the proposed containment cell and migration of aluminium smelter wastes-derived leachate plume (containing elevated concentrations of fluoride) to the nearest environmental receptor. The cell is proposed for the former CBP site, a topographic high point to the west of the smelter and within Hydro land.

An analytical, one-dimensional, groundwater model of the site was constructed, based on a conceptual model of site geology and hydrogeology derived from previous and ongoing investigations at the site. The model was used to evaluate a predicted groundwater concentration of fluoride at a distance from the source where it may impact on the nearest surface water receptor, Black Waterholes Creek.

The model comprised a spreadsheet solution for contaminant transport flow, inputting parameters estimated for aquifer characteristics, aquifer geometry and contaminant characteristics. All parameters were based, where possible, on field measurements or relevant literature values.

These values were used to derive a preliminary result as a plot of concentration versus distance, extending to the predicted receptor impact distance. The model used a combination of conservative and reasonable assumptions to evaluate fluoride concentrations at the receptor impact distance.

The following conclusions were drawn from the results of the modelling:

- Should leachate escape from the system, the estimated volume is 4 L/year and is insignificant.
- However, in the event that leachate does enter the groundwater system, modelling of the potential for leachate migration on a receptor was undertaken. A reasonable conservative assessment and a highly conservative assessment using a time-variant solution set at 100 and 10,000 years, respectively, following entry of leachate into the groundwater indicates that no leachate migration would occur to any significant distance from the source and would not travel to the surface water receptor.
- The model demonstrates sensitivity to a number of input parameters including the soil partition coefficient, (Kd), however even with the application of very conservative values it is considered that there is no significant risk of migration of leachate from a potential breach of the proposed containment cell to the nearest environmental receptor under the adopted conceptual site model. This exposure scenario remains the case over the longer term as evidence by a modelling transport over a 10000 year.

The current conceptual design of the proposed containment cell incorporates a lined containment constructed using a liner system to minimise the possibility of leachate escape from the system including a combination of a compacted clay layer, a synthetic (plastic) membrane and/or a geo-synthetic clay liner, (GCL). A leachate drainage/collection and storage system will also be implemented to remove any accumulated leachate and a daily cover management and final capping strategy will minimize incident rainfall infiltration to the waste, (minimizing the potential for generation of leachate). The containment cell design incorporates many layers of redundancy and a breach from this system is considered of low likelihood. In the unlikely event that a breach occurs, the modelling predicts that the risk to the receptor is very low and that there is no change in this risk profile for treated or untreated wastes.

6. REFERENCES

Sulllivan, H.K. & Knight M.J. (1992) *Landfill of Aluminium Smelter Wastes at Wallaroo, NSW, Australia*. Australian Geomechanics, July 1992.

GHD (2016) *Hydro Aluminium Kurri Kurri Containment Cell Detailed Design and Associated Services Supplementary Geotechnical Investigation Factual Report*.

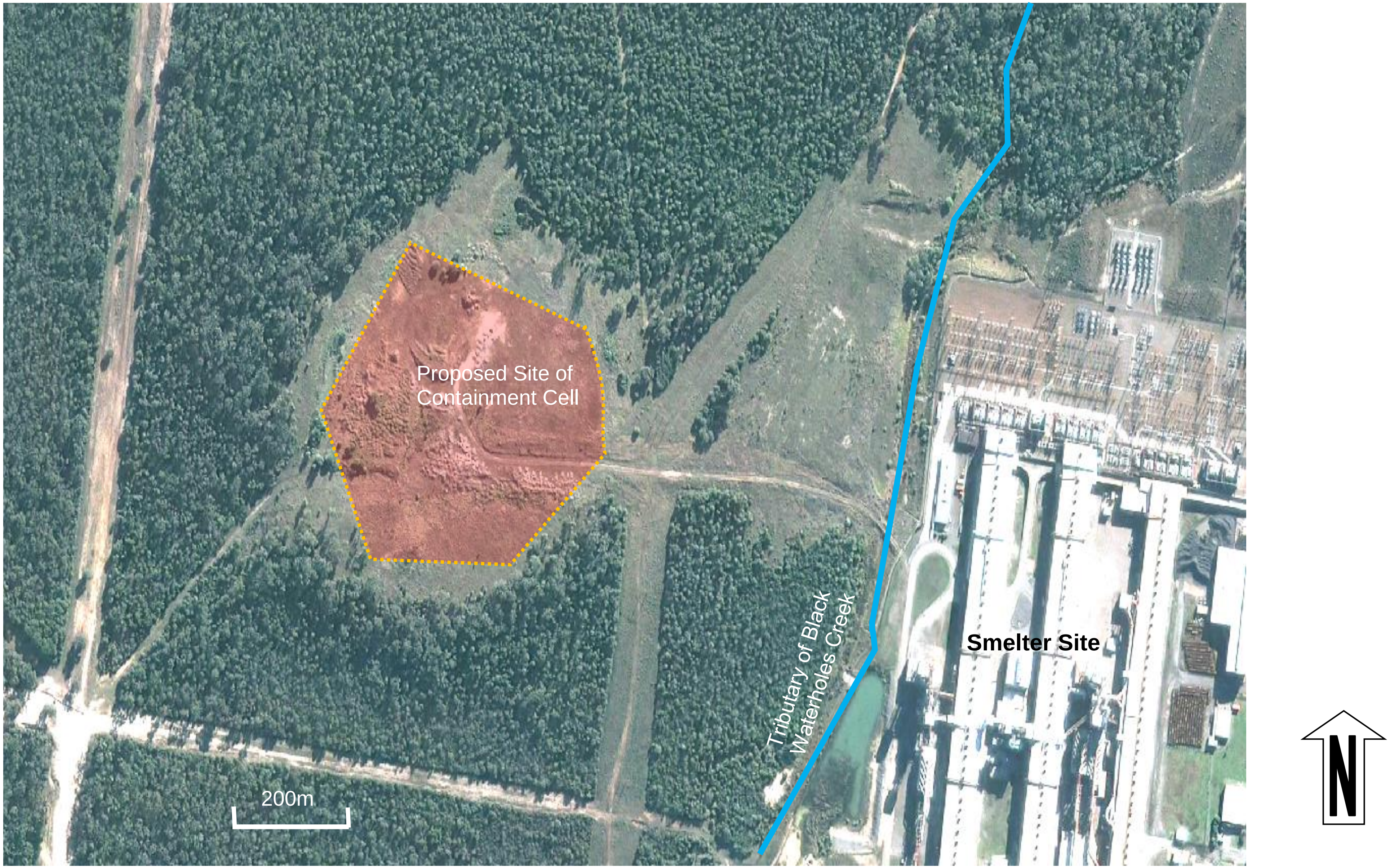
UK Environment Agency. *Remedial Targets Worksheet*.

Environ (2013) *Preliminary Containment Cell Study Hydro Aluminium Kurri Kurri NSW*.

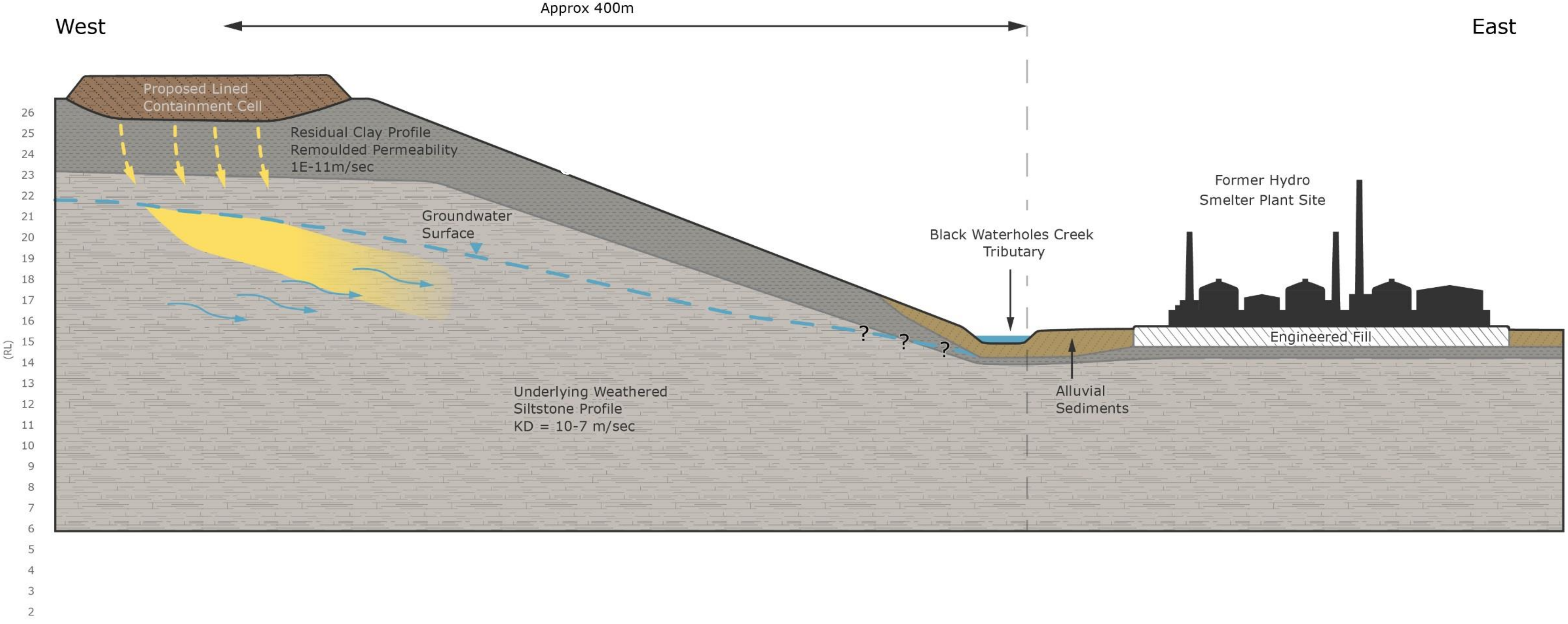
Environ (2015) *Preliminary Geotechnical Investigation Proposed Containment Cell Site Clay Borrow Pit*.

APPENDIX 1

1.FIGURES



Client: Hydro Aluminium Kurri Kurri Pty Ltd			Location of Containment Cell
RAMBOLL ENVIRON	JOB NO: AS130525	Date: September 2017	FIGURE 1



Client: Hydro Aluminium Kurri Kurri Pty Ltd

Conceptual Site Model

RAMBOLL ENVIRON

JOB NO: AS130525

Date: September 2017

FIGURE 2

APPENDIX 2
2.BORELOGS – PREVIOUS INVESTIGATIONS

BOREHOLE NUMBER CBP1

PAGE 1 OF 2

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd

PROJECT NAME Clay Borrow Pit Geotechnical Investigation

PROJECT NUMBER AS130389

PROJECT LOCATION Kurri Kurri

DATE STARTED 15/7/14 **COMPLETED** 15/7/14

R.L. SURFACE 21.819 **DATUM** m AHD

DRILLING CONTRACTOR TerraTest

SLOPE 90° **BEARING** ---

EQUIPMENT Commachio ADV

HOLE LOCATION Clay Borrow Pit Hydro Buffer Zone

HOLE SIZE

LOGGED BY SC **CHECKED BY** KG

NOTES

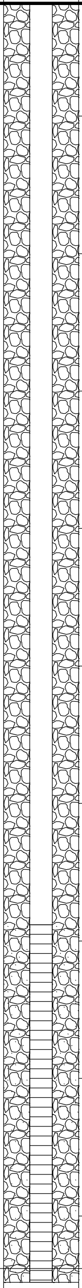
Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Auger	None Encountered					TOPSOIL; Silty SAND, brown						
						RESIDUAL CLAY; brown, high plasticity, moist, mc=pl						SPT n > 14
			21									
				1		RESIDUAL CLAY; red-brown to grey, medium plasticity						
												SPT n = 25
			20									
				2								
						Fragments of EW siltstone (iron-stain)						
			19									
				3		Silty CLAY; brown and grey, slightly moist/dry, low-medium plasticity						SPT n = 60
			18									
				4		Fragments of extremely weathered/highly weathered siltstone						
HQ Cored						Very hard, remnant siltsone/sandstone texture, trace calcite Continued as cored HQ hole						SPT refusal
			17									
				5		SILTSTONE; brown to grey, massive bedded Clay layer Grey	EW					
												Massively bedded, no visible defects
			16									
				6		Calcite inclusions						
							EW/HW					
						Calcite						
			15									
				7								
						Becoming coarser SANDSTONE						
Blade Bit						Coring Terminated at 7.65m. Borehole reamed to 20.2m						
			14									
				8								
			13									
				9								
			12									
				10								
			11									
				11								

BOREHOLE NUMBER CBP1

PAGE 2 OF 2

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 15/7/14 **COMPLETED** 15/7/14
R.L. SURFACE 21.819 **DATUM** m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90° **BEARING** ---
EQUIPMENT Commachio ADV
HOLE LOCATION Clay Borrow Pit Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC **CHECKED BY** KG
NOTES



Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Blade Bit					× ×	SILTSTONE; brown to grey, massive bedded *(continued)*						
			10	12	× ×							
			9	13	× ×							
			8	14	× ×							
			7	15	× ×							
			6	16	× ×	Circulation loss noted at 16m						
			5	17	× ×							
			4	18	× ×							
			3	19	× ×							
			2	20	× ×							
						CBP1 terminated at 20.2m						
			1	21								
			0	22								

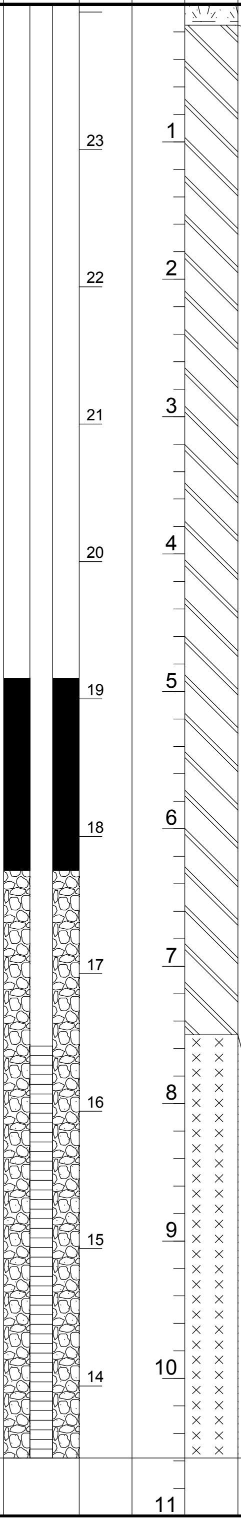
BOREHOLE NUMBER CBP2

PAGE 1 OF 1

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 16/7/14 **COMPLETED** 16/7/14
R.L. SURFACE 24.055 **DATUM** m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90° **BEARING** ---
EQUIPMENT Commachio ADV
HOLE LOCATION Clay Borrow Pit, Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC **CHECKED BY** KG
NOTES



Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	Is(50) MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Auger						TOPSOIL; silty SAND, brown, dry						
						RESIDUAL CLAY; red-brown, brown and grey, high plasticity, mc>PL						
			23	1								SPT - n = 15
						Becoming grey-cream (siltstone fragments)						
			22	2		Becoming extremely weathered SILTSTONE as silty CLAY; cream to red-brown						SPT - n = 22
						Harder						
			21	3								
						Relict sandstone/siltstone, structure with iron (red), cemented layers ~10mm, as silty sandy CLAY						SPT - n = 22
			20	4								
												SPT - n = 53
			19	5								
			18	6		Silty CLAY with some sand; brown and grey, low-medium plasticity, moist mc<PL						SPT - n = 45
			17	7								
	▼											
HQ Core						Extremely weathered SHALE; grey, laminated, horizontal bedded						SPT - refusal
						SILTSTONE; grey, massively bedded, with some medium-coarse grained sand, becoming laminated horizontal sandy SILTSTONE						
			16	8								
						Sandy, horizontal and sub-horizontal laminar bedding						
			15	9								
												75 degrees, joint, planer, rough
			14	10								
						CBP2 terminated at 10.58m						
				11								

BOREHOLE NUMBER CBP3

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 16/7/14 **COMPLETED** 16/7/14
R.L. SURFACE 20.714 **DATUM** m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90° **BEARING** ---
EQUIPMENT Commachio ADV
HOLE LOCATION Southern Clay Borrow Pit, Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC **CHECKED BY** KG
NOTES

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	Is(50) MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Auger						TOPSOIL						
						RESIDUAL CLAY; red-brown, brown and grey, medium-high plasticity, moist, mc>PL, trace sand and rock fragments						SPT - n = 17
			20									
				1								
			19			Pale cream and red/brown, medium-high plasticity						
				2								SPT - n = 23
			18									
				3		Relict sandy SILTSTONE structure as silty CLAY; grey, medium plasticity, moist mc~PL						SPT - n = 25
			17									
				4								SPT - n = 35
			16									
				5								
			15									
				6		Extremely weathered laminated SILTSTONE as silty CLAY, grey and brown, medium plasticity, moist<PL, trace sand and rock fragments Borehole continued as cored borehole log after SPT refusal at 6m						SPT - refusal Joints 35 degrees planar, sl-rough, Fe stained
HQ Core			14				HW/MW					
				7		SILTSTONE; grey, laminated, extremely weatherd bedding, horizontal to sub-horizontal.						65 degrees joint, rough, planar, Fe stained
			13			Becoming coarser, massive bedding, sandy SILTSTONE with some rounded pebbles (20mm) at 7.6m Clay zone (7.9-8.1m). Coring ceased at 8.82m. Borehole reamed to 20m.						
				8								
			12				MW					
Blade Bit				9								
			11									
				10								
			10									
				11								

BOREHOLE NUMBER CBP3

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 16/7/14 **COMPLETED** 16/7/14
R.L. SURFACE 20.714 **DATUM** m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90° **BEARING** ---
EQUIPMENT Commachio ADV
HOLE LOCATION Southern Clay Borrow Pit, Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC **CHECKED BY** KG
NOTES

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	$Is_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Blade Bit			9 8 7 6 5 4 3 2 1	12 13 14 15 16 17 18 19 20		SILTSTONE; grey, laminated, extremely weatherd bedding, horizontal to sub-horizontal. *(continued)*						
			0 -1	21 22		CBP3 terminated at 20m						

BOREHOLE NUMBER CBP4

PAGE 1 OF 2

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd

PROJECT NAME Clay Borrow Pit Geotechnical Investigation

PROJECT NUMBER AS130389

PROJECT LOCATION Kurri Kurri

DATE STARTED 17/7/14

COMPLETED 17/7/14

R.L. SURFACE 19.092

DATUM m AHD

DRILLING CONTRACTOR TerraTest

SLOPE 90°

BEARING ---

EQUIPMENT Commachio ADV

HOLE LOCATION South East Clay Borrow Pit, Hydro Buffer Zone

HOLE SIZE

LOGGED BY SC

CHECKED BY KG

NOTES

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	Is$_{(50)}$ MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Auger			19			TOPSOIL						
						RESIDUAL CLAY; red-brown, medium-high plasticity, mc>PL, trace of fine sand and extremely weathered siltstone fragments						SPT - n = 14
			18	1								
			17	2								SPT - n = 18
			16	3		Harder, silty sandy CLAY; grey and brown, low-medium plasticity mc<PL, very fine sand						SPT - n = 42
						Extremely weathered SILTSTONE; grey ~3.5, laminated, horizontal bedding						
			15	4			EW					
Cored						SILTSTONE; grey, laminated, with horizontal/sub horizontal bedding, brown, iron stained clay bands 4.5-4.8m						SPT refusal
			14	5			EW					
			13	6			EW/HW					No visible defects
			12	7								
Blade Bit						Coring stopped at 7.22m. Drilling continued to ream borehole down to 20m.						
			11	8								
			10	9								
			9	10								
				11								

BOREHOLE NUMBER CBP4

PAGE 2 OF 2

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd

PROJECT NAME Clay Borrow Pit Geotechnical Investigation

PROJECT NUMBER AS130389

PROJECT LOCATION Kurri Kurri

DATE STARTED 17/7/14 **COMPLETED** 17/7/14

R.L. SURFACE 19.092 **DATUM** m AHD

DRILLING CONTRACTOR TerraTest

SLOPE 90° **BEARING** ---

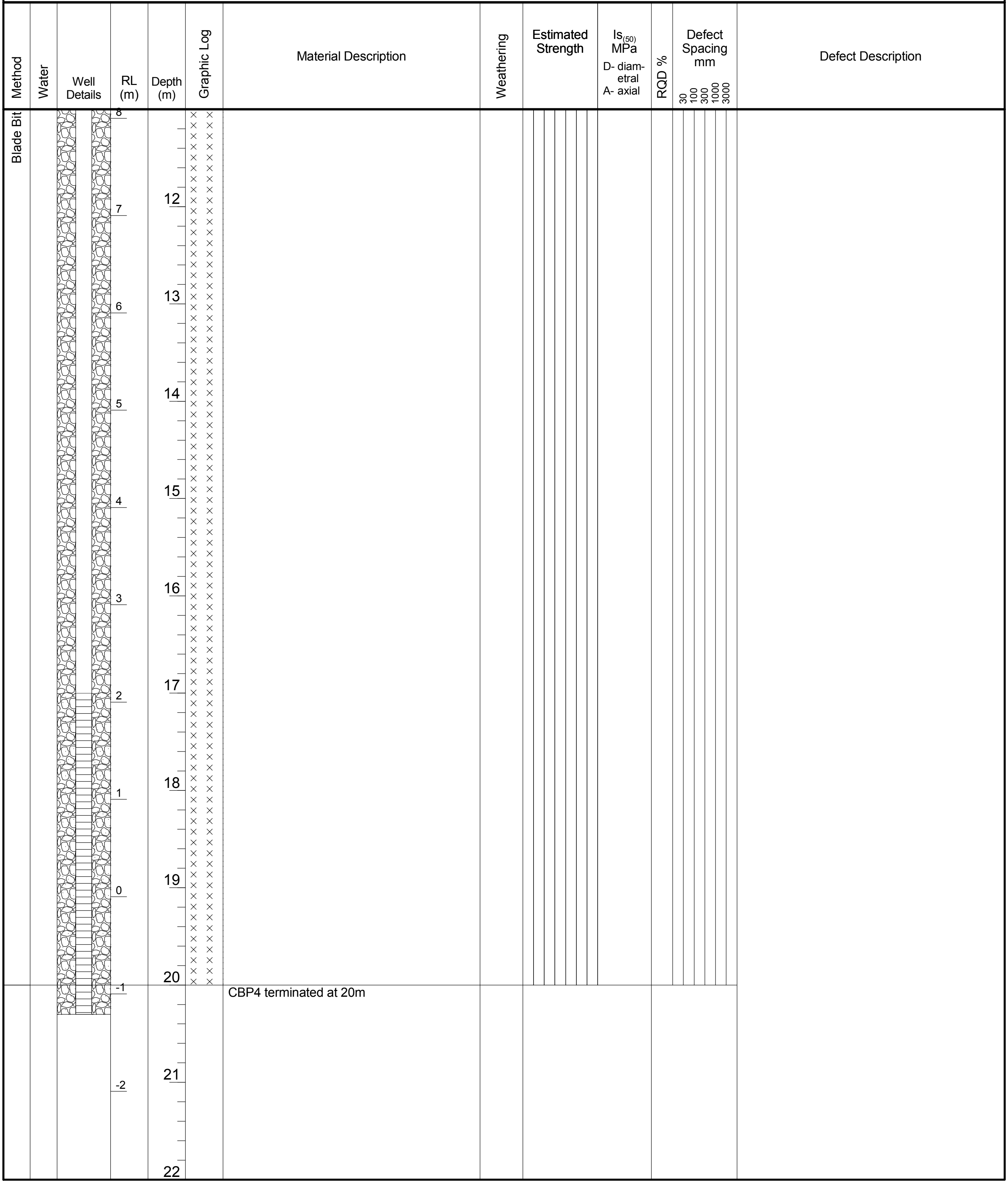
EQUIPMENT Commachio ADV

HOLE LOCATION South East Clay Borrow Pit, Hydro Buffer Zone

HOLE SIZE

LOGGED BY SC **CHECKED BY** KG

NOTES



CORED BOREHOLE AS130389 CLAY BORROW PIT GEOTECH.GPJ GINT STD AUSTRALIA.GDT 1/10/14

BOREHOLE NUMBER CBP5

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 15/7/14 **COMPLETED** 15/7/14
R.L. SURFACE 25.648 **DATUM** m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90° **BEARING** ---
EQUIPMENT Commachio ADV
HOLE LOCATION Clay Borrow Pit, Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC **CHECKED BY** KG
NOTES

Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	Is(50) MPa D- diam-etral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Auger						TOPSOIL; Silty SAND						
			25			RESIDUAL CLAY; brown and red-brown, medium-high plasticity, moist						SPT - n = 7
			24	1		Red-brown and grey, rootlets, angular fragments of extremely weathered Siltstone						SPT - n = 11
			23	2								
			22	3		Red-brown and light grey clay, high plasticity, LL>mc>PL, trace fragments of angular rock						SPT - n = 15
			21	4		Becoming extremely weathered Siltstone as silty CLAY; red brown, low plasticity, moist, mc<PL, fragments of iron stained siltstone, trace white calcite						SPT - n = 32
			20	5								
	►		19	6		Very slight water at base ~6m, hard brown silty CLAY (extremely weathered siltstone)						SPT - n = 46
			18	7		Silty CLAY and extremely weathered SILTSTONE, brown and red-brown, low-medium plasticity, mc<PL	EW					SPT - refusal
Cored			17	8		SANDSTONE; grey, medium grained, extremeley weathered, massively bedded (0.5-0.6 clay layer), very weak - crumbles under touch Coarse grained	EW					
			16	9								
			15	10		Sandstone cobble clast						
				11								

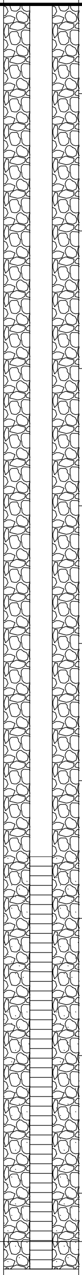
BOREHOLE NUMBER CBP5

PAGE 2 OF 2

ENVIRON

CLIENT Hydro Aluminium Kurri Kurri Pty Ltd
PROJECT NAME Clay Borrow Pit Geotechnical Investigation
PROJECT NUMBER AS130389
PROJECT LOCATION Kurri Kurri

DATE STARTED 15/7/14
COMPLETED 15/7/14
R.L. SURFACE 25.648
DATUM m AHD
DRILLING CONTRACTOR TerraTest
SLOPE 90°
BEARING ---
EQUIPMENT Commachio ADV
HOLE LOCATION Clay Borrow Pit, Hydro Buffer Zone
HOLE SIZE
LOGGED BY SC
CHECKED BY KG
NOTES



Method	Water	Well Details	RL (m)	Depth (m)	Graphic Log	Material Description	Weathering	Estimated Strength	Is(50) MPa D- diametral A- axial	RQD %	Defect Spacing mm 30 100 300 1000 3000	Defect Description
Cored			14	12		SANDSTONE; grey, medium grained, extremeley weathered, massively bedded (0.5-0.6 clay layer), very weak - crumbles under touch *(continued)* Coarse grained						
Overbored			13 12 11 10 9 8 7 6	13 14 15 16 17 18 19 20								
			5 4	21 22		CBP5 terminated at 20m						

GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH01

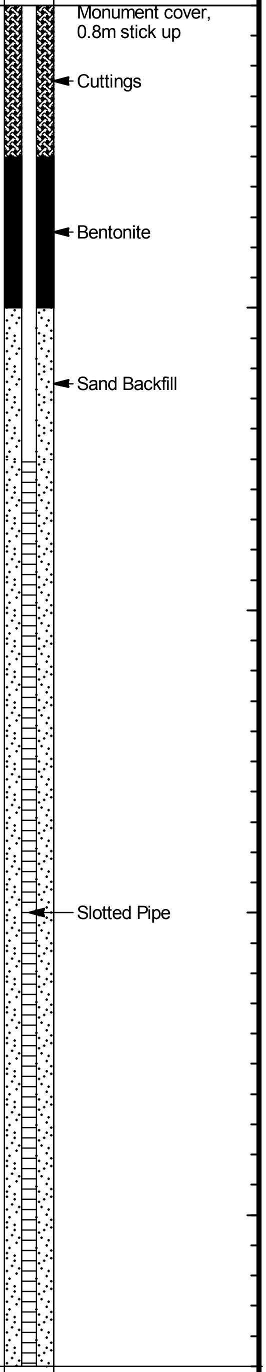
SHEET 1 OF 1

Position : 357079.0 E 6371322.3 N MGA94		**Surface RL:** 19.5m		**Angle from Horiz. :** 90°	**Processed :** VW
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd		**Driller :** Ryan Whyte	**Checked :** SA
Date Started : 9/3/2016		**Date Completed :** 9/3/2016		**Logged by :** VW	**Date:** 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations
0	TC-bit auger 200Ø	Nil			0.15 (19.35)	SC	Clayey SAND, pale grey, fine grained, low plasticity, trace fine, sub-rounded gravel (topsoil).	D	-	
						CH	CLAY, red brown, mottled pale grey and minor orange, high plasticity (MC>=PL), trace fine to medium, sub-angular, iron indurated gravel (residual).	M	St	
						CI	From 0.5m, grading to pale grey, minor red and orange mottling, medium plasticity (MC<=PL), trace silt.	SM		0.5-1.5m, Bulk sample taken
1	TC-bit auger 150Ø			B						
				SPT 2/6/9 N=15						
2										1.7-2.1m, increased resistance to drilling from possible minor bands of weak cementation/gravels
					2.40 (17.10)	CI	CLAY, pale grey minor orange mottling, medium plasticity (MC<PL), trace sand, trace iron cementation, relic rock fabric visible (residual).	SM	VSt	
				SPT 6/13/16 N=29						
3							From 3.3m, bands of orange brown, weakly cemented, completely weathererd to extremely weathered sandstone.			3.3m, poor recovery on auger 3.41m, groundwater level recorded ~4 weeks following completion of drilling. Note, no groundwater was observed during drilling.
			∇ (4/4/16)	D						
4							From 4.0m, sand content increasing.			
				SPT 10/19/26 for 130mm N=ref	4.20 (15.30)	-	SANDSTONE, orange brown minor pale grey, fine grained, extremely to completely weathered, very low to low strength.			4.2m, remoulds to medium to low plasticity sandy CLAY.
					4.50 (15.00)		End of borehole at 4.5 metres. Target Depth.			
5										

BOREHOLE



See standard sheets for details of abbreviations & basis of descriptions

Job No.
22-18015-03-02

GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH01A

SHEET 1 OF 3

Position : 357079.5 E 6371321.3 N MGA94 **Surface RL:** 19.5m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 9/3/2016 **Date Completed :** 9/3/2016 **Logged by :** VW **Date:** 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

DRILLING

SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests
0 – 1.5	TC-bit auger 200Ø	Nil		B (0.20 – 1.10)
1.5 – 5	TC-bit auger 150Ø			

MATERIAL

Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations
	SC	Clayey SAND, pale grey, fine grained, low plasticity, trace rootlets (topsoil).	D	-	
0.20 (19.30)	CH	CLAY, red brown mottled pale grey and orange, high plasticity (MC>=PL), trace fine, sub-angular, iron indurated, gravel (residual). From 0.4m, grading to pale grey mottled red brown and orange.	M	St	
		From 1.0m, moisture decreasing.	SM		
					2.4m, band of higher resitance, possibly cementation/gravels
					From 3.0m, poor recovery on auger
3.30 (16.20)	CI	CLAY, pale brown/brown, medium plasticity (MC>=PL), trace sand, bands of pale grey clay (residual).	SM-M	St	
4.00 (15.50)	-	SANDSTONE, brown, extremely to completely weathered, very low to low strength.	-	-	4.0m, increased resistance to penetration 4.0m, remoulds to medium to low plasticity sandy CLAY.

BOREHOLE

BOREHOLE Log	Components
0	Monument cover, 0.8m stick up
4	Cuttings

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No.
22-18015-03-02

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH01A

SHEET 2 OF 3

Position : 357079.5 E 6371321.3 N MGA94		**Surface RL:** 19.5m	**Angle from Horiz. :** 90°		**Processed :** VW
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Ryan Whyte		**Checked :** SA
Date Started : 9/3/2016		**Date Completed :** 9/3/2016	**Logged by :** VW		**Date:** 15/04/2016

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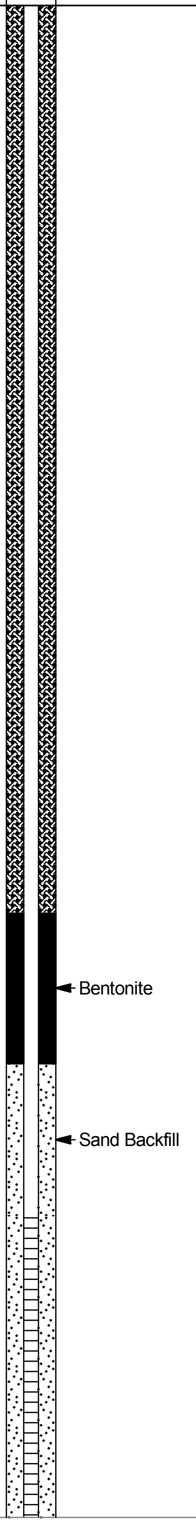
DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
	TC-bit auger 150Ø	Nil						SANDSTONE, as previous.	-	-			
					5.50 (14.00)		-	SILTSTONE, grey, extremely to highly weathered, very low strength. 5.8-6.0m, brown bands, possibly sandstone as above.	-	-	5.50m, remoulds to low to medium plasticity clay with silt.		
6													
			▽ (4/4/16)								6.80m, groundwater level recorded ~4 weeks following completion of drilling. Note, no groundwater was observed during drilling. 7.0m, water added approximately every 1-1.5m to aid in cutting returns		
7													
8													Bentonite
													Sand Backfill
9													
10													



See standard sheets for details of abbreviations & basis of descriptions

Job No.
22-18015-03-02

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH01A

SHEET 3 OF 3

Position : 357079.5 E 6371321.3 N MGA94 **Surface RL:** 19.5m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 9/3/2016 **Date Completed :** 9/3/2016 **Logged by :** VW **Date:** 15/04/2016

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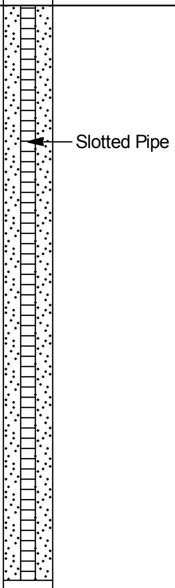

DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
	TC-bit auger 150Ø	Nil						SILTSTONE, as previous.	-	-			Slotted Pipe
11								From 11.2m, grading to dark grey, highly weathered.			11.2m, remoulds to medium plasticity clay.		
											Auger dry at base of hole		
12					12.00 (7.50)			End of borehole at 12 metres. Target Depth.					
13													
14													
15													

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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH02

SHEET 1 OF 2

Position : 356898.9 E 6371351.4 N MGA94		**Surface RL:** 22.3m		**Angle from Horiz. :** 90°	**Processed :** VW
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd		**Driller :** Ryan Whyte	**Checked :** SA
Date Started : 9/3/2016		**Date Completed :** 9/3/2016		**Logged by :** VW	**Date:** 15/04/2016

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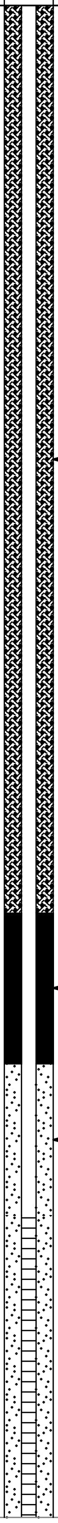
DRILLING — Drilling Method: TC-bit auger 150Ø; Hole Support \ Casing: Nil; Water: (4/4/16)

SCALE (m)	Samples & Tests	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations
0	D D		SC	Clayey SAND, grey/pale grey, fine grained, low plasticity, with fine, sub-rounded gravels (fill).	D	-	Appears moderatly to well compacted.
		0.40 (21.90)	CH	CLAY, yellow brown and grey, high plasticity (MC>=PL), trace fine, sub-rounded gravel (residual).	M	St	
1	SPT 2/5/18 N=23	1.20 (21.10)	CH	CLAY, pale grey mottled red and minor orange, high plasticity (MC<=PL), trace fine iron indurated, weakly cemented gravel (residual).	SM	VSt	At 1.1m, sandy clay completely weathered sandstone layer (100mm)
2	D						
	SPT 8/11/19 N=30			From 2.5m, grading to pale grey minor red and orange, increasing relic rock fabric visible.			
3	D						
4	SPT 5/11/14 N=25			From 4.0m, trace iron indurated, fine, sub-angular gravel, trace sand, relic rock fabric becoming more apparent.	M-SM		
5							4.93m, groundwater

BOREHOLE



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BOREHOLE LOG SHEET

HOLE No. BH02

SHEET 2 OF 2

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW
Position : 356898.9 E 6371351.4 N MGA94 **Surface RL:** 22.3m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 9/3/2016 **Date Completed :** 9/3/2016 **Logged by :** VW **Date:** 15/04/2016

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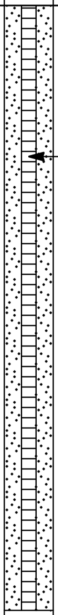
DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations	BOREHOLE Log	Components
	TC-bit auger 150Ø	Nil		D (possible mixed sample from cuttings)			CH	CLAY, as previous.	SM	VSt	level recorded ~4 weeks following completion of drilling. Note, no groundwater was observed during drilling.		Slotted Pipe
6				SPT 10/15/22 N=37	5.60 (16.70)		CH	CLAY, pale grey mottled orange brown, medium to high plasticity (MC<=PL), relic rock fragment visible, minor zones of weak cementation (residual).	SM	H			
7				SPT 16 25 for 90mm N=ref	7.00 (15.30)		-	SILTSTONE, grey/dark grey, extremely to highly weathered, very low to low strength. From 7.2m, highly weathered, low strength.					
8 9 10					7.24 (15.06)			End of borehole at 7.24 metres. Target Depth.					

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BOREHOLE LOG SHEET

HOLE No. BH02A

SHEET 1 OF 3

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

Position : 356900.6 E 6371351.2 N MGA94	**Surface RL:** 22.2m	**Angle from Horiz. :** 90°	**Processed :** VW
Rig Type : Scout **Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Ryan Whyte	**Checked :** SA
Date Started : 10/3/2016	**Date Completed :** 10/3/2016	**Logged by :** VW	**Date:** 15/04/2016

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SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations	BOREHOLE Components
0	TC-bit auger 200Ø	Nil				SC	Clayey SAND, grey/pale grey, fine grained, low plasticity, with fine, sub-rounded gravels (fill).	D	-	Appears moderatly to well compacted.	Monument cover, 0.8m stick up
				B	0.30 (21.90)	CH	CLAY, dark grey, with minor red and orange mottling, high plasticity (MC>=PL), trace fine, sub-angular to sub-rounded gravel (residual).	M	St		
1							From 1.1-1.3m, Sandy CLAY layer, possibly completely weathered cemented sandstone.	SM			
					1.30 (20.90)	CH	CLAY, pale grey mottled red and minor orange, high plasticity (MC<=PL), trace fine, iron indurated gravel (residual).	M	VSt		
	TC-bit auger 150Ø										
2								SM			
3											
4											← Cuttings
			∇ (4/4/16)							4.5m, water added to aid with cutting recovery 4.61m, groundwater level recorded ~4 weeks following	
5											

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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH02A

SHEET 2 OF 3

Position : 356900.6 E 6371351.2 N MGA94		**Surface RL:** 22.2m		**Angle from Horiz. :** 90°	**Processed :** VW
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd		**Driller :** Ryan Whyte	**Checked :** SA
Date Started : 10/3/2016		**Date Completed :** 10/3/2016		**Logged by :** VW	**Date:** 15/04/2016

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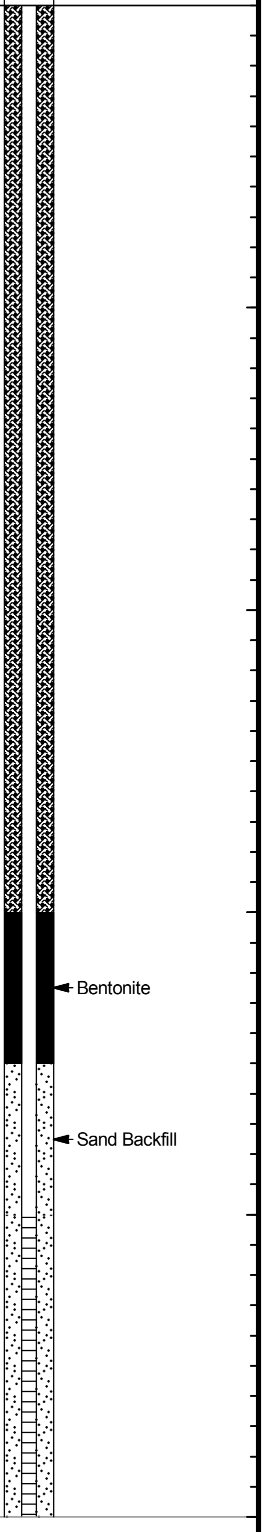
DRILLING					MATERIAL							BOREHOLE
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log / **Components**
	TC-bit auger 150Ø	Nil					CH	CLAY, as previous.	M	VSt	completion of drilling. Note, no groundwater was observed during drilling.	
					5.80 (16.40)		CH	CLAY, pale grey and orange brown, high plasticity (residual)	SM	H		
6												
7					7.00 (15.20)		-	SILTSTONE, grey/dark grey, extremely to highly weathered, very low to low strength.	-	-		
8								From 8.0m, highly weathered.				Bentonite
												Sand Backfill
9								From 9.0m, possible minor sand inclusion into matrix (~10%)				
								From 9.8m, grading to slightly weathered to fresh, medium strength.			From 9.8m, increased resistance to drilling	
10												



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GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH02A

SHEET 3 OF 3

Position : 356900.6 E 6371351.2 N MGA94 **Surface RL:** 22.2m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 10/3/2016 **Date Completed :** 10/3/2016 **Logged by :** VW **Date:** 15/04/2016

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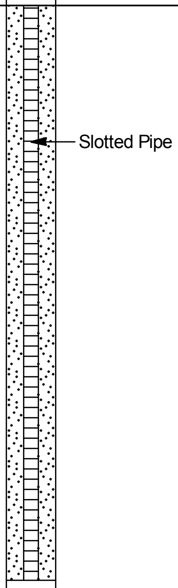
DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
11	TC-bit auger 150Ø	Nil						SILTSTONE, as previous.	-	-			
								From 11.5m, medium to high strength.			From 11.5, further increased resistance to drilling Difficulty clearing cuttings out of hole		
12					12.00 (10.20)			End of borehole at 12 metres. Target Depth.					
13													
14													
15													

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GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

Client :	Hydro Aluminium Kurri Kurri		**HOLE No. BH03**
Project :	Supplementary Geotechnical Investigation		
Location :	Kurri Kurri, NSW		**SHEET 1 OF 1**
Position :	357013.1 E 6371563.8 N MGA94	**Surface RL:** 23.0m	**Angle from Horiz. :** 90°
Rig Type :	Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd
Driller :	Ryan Whyte	**Processed :** VW	**Checked :** SA
Date Started :	10/3/2016	**Date Completed :** 10/3/2016	**Logged by :** VW
Date:	15/04/2016		

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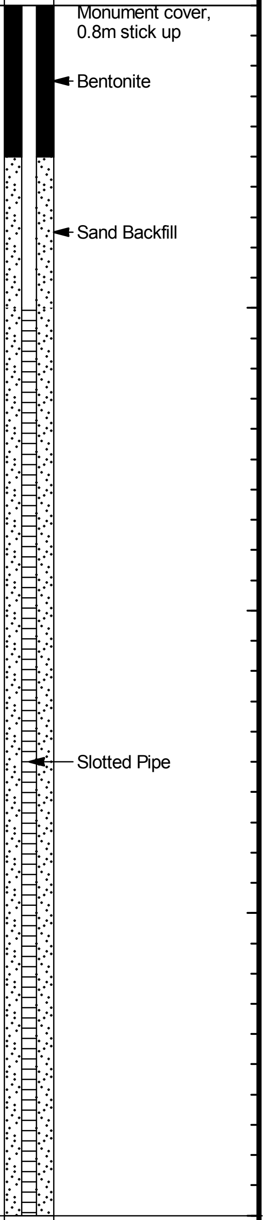
DRILLING				MATERIAL					
Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations
TC-bit auger 200Ø	Nil	GNE			SC	Clayey SAND, pale grey, fine grained, low plasticity, trace fine, sub-rounded gravel , trace rootlets (topsoil).	D	-	
			B	0.30 (22.70)	CH	CLAY, grey/dark grey minor brown, high plasticity, trace fine, sub-angular to sub-rounded gravels (residual).	M	St	
				1.10 (21.90)	CH-CI	CLAY, pale grey mottled red, minor brown, medium to high plasticity (MC<=PL), trace fine, sub-angular, iron indurated gravels (residual).	SM	VSt	
TC-bit auger 150Ø					CH	From 1.9m, grading to pale grey minor red, moisture increasing, high plasticity (MC>PL)	M	St	
					CH-CI	From 3.7m, pale grey mottled red and orange brown, medium to high plasticity (MC<=PL).	SM	VSt	
				4.00 (19.00)		End of borehole at 4 metres. Target Depth.			Borehole dry on completion

BOREHOLE



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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH03A

SHEET 1 OF 3

Position : 357014.0 E 6371563.2 N MGA94 **Surface RL:** 23.0m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 10/3/2016 **Date Completed :** 10/3/2016 **Logged by :** VW **Date:** 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

Drilling Method: TC-bit auger 150Ø
Hole Support \ Casing: Nil

Samples & Tests	Water	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations	Components
			SC	Clayey SAND, pale grey, fine grained, low plasticity, trace fine, sub-rounded gravel , trace rootlets (topsoil).	D	-		Monument cover, 0.8m stick up
		0.30 (22.70)	CH	CLAY, grey minor orange brown mottling, high plasticity (MC>=PL), trace rootlets (residual).	M	St		
SPT 2/4/8 N=12								
SPT 5/9/12 N=21		1.10 (21.90)	CI-CH	CLAY, pale grey mottled brown red and orange, medium to high plasticity (MC<=PL), trace fine, sub-angular, weakly cemented, iron indurated gravel, trace silt (residual).	SM	VSt		
D			CH	From 2.0m, grading to pale grey, minor red and orange, high plasticity (MC>PL), no gravel.	M	St	From 2.0m, increased moisture	
SPT 4/6/7 N=13								
D								
SPT 9/15/22 N=37				From 4.0m, grading to pale grey mottled orange and red.	SM	VSt		Cuttings
		4.30 (18.70)	-	SILTSTONE, grey, very low to low strength, moderately to slightly weathered.	-	-	Siltstone easily broken with fingers, remoulds to low plasticity silt with clay	
	▽ (4/4/16)						4.83m, groundwater level recorded ~4	

SCALE (m): 1, 2, 3, 4, 5

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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH03A

SHEET 2 OF 3

Position :	357014.0 E 6371563.2 N MGA94	**Surface RL:**	23.0m	**Angle from Horiz. :** 90°		**Processed :**	VW
Rig Type :	Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Ryan Whyte		**Checked :**	SA
Date Started :	10/3/2016	**Date Completed :**	10/3/2016	**Logged by :** VW		**Date:**	15/04/2016

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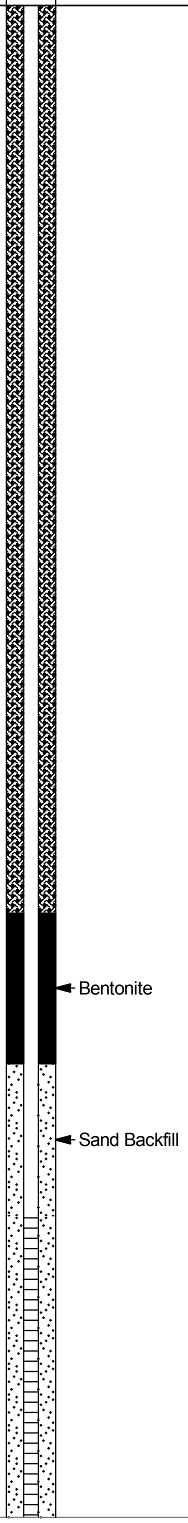

DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
	TC-bit auger 150Ø	Nil						SILTSTONE, as previous. From 5.1m, increased brown staining, highly weathered to moderately weathered.	-	-	weeks following completion of drilling. Note, no groundwater was observed during drilling.		
				SPT 14/25 for 120mm N=ref									
6													
7													
								From 7.5m, grading to grey, minor brown staining.					
8											8.0m, water added down hole to aid with clearing of cuttings		
													Bentonite
													Sand Backfill
9								From 9.0m, grading to grey, moderately weathered to slightly weathered, low strength.					
10													

See standard sheets for details of abbreviations & basis of descriptions

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GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH03A

SHEET 3 OF 3

Position : 357014.0 E 6371563.2 N MGA94
Surface RL: 23.0m
Angle from Horiz. : 90°
Processed : VW
Rig Type : Scout
Mounting: Truck
Contractor : Total Drilling Pty Ltd
Driller : Ryan Whyte
Checked : SA
Date Started : 10/3/2016
Date Completed : 10/3/2016
Logged by : VW
Date: 15/04/2016

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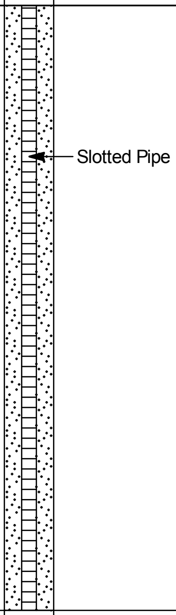
DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
11	TC-bit auger 150Ø	Nil						SILTSTONE, as previous. From 10.2m, medium strength.	-	-			
12					12.00 (11.00)			End of borehole at 12 metres. Target Depth.					
13													
14													
15													

See standard sheets for details of abbreviations & basis of descriptions

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CONSULTING GEOTECHNICAL ENGINEERS AND GEOLOGISTS

Job No.
22-18015-03-02

BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

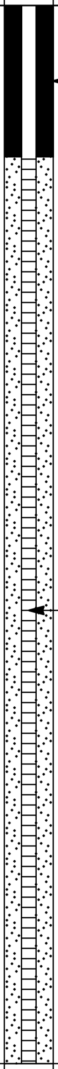
HOLE No. BH04

SHEET 1 OF 1

Position :	357134.1 E 6371538.0 N MGA94	**Surface RL:** 22.1m	**Angle from Horiz. :** 90°	**Processed :** VW	
Rig Type :	Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Ryan Whyte	**Checked :** SA
Date Started :	11/3/2016	**Date Completed :** 11/3/2016	**Logged by :** VW	**Date:** 15/04/2016	

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
	TC-bit auger 200Ø	Nil	GNE				CH	CLAY, pale red, minor pale grey, high plasticity (MC>=PL), with fine to medium grained sand, trace fine, angular to sub-angular gravel (residual). Between 0.2-0.3m, dark grey mottled orange and red.	M	St			Monument cover, 0.8m stick up Bentonite
1				B	0.30 (21.80)		CI	Sandy CLAY, pale grey, mottled red and orange brown, medium plasticity (MC<=PL), fine grained sand, trace fine sub-rounded, iron indurated sandstone gravel, trace weakly cemented, iorn indurated bands (residual).	SM	VSt			
								From 1.2m, grading to pale grey, minor red and orange brown staining, medium to high plasticity (MC>=PL), no gravel.	M				
2 3	TC-bit auger 150Ø												Slotted Pipe
4 5					3.50 (18.60)			End of borehole at 3.5 metres. Target Depth.			Borehole dry on completion		



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22-18015-03-02

GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

HOLE No. BH04A

SHEET 1 OF 3

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

Position : 357131.9 E 6371538.5 N MGA94		**Surface RL:** 22.0m	**Angle from Horiz. :** 90°	**Processed :** VW
Rig Type : Scout	**Mounting:** Truck	**Contractor :** Total Drilling Pty Ltd	**Driller :** Ryan Whyte	**Checked :** SA
Date Started : 11/3/2016		**Date Completed :** 11/3/2016	**Logged by :** VW	**Date:** 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						BOREHOLE
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations	Components
	TC-bit auger 150Ø	Nil	GNE	D		CH	CLAY, pale red, minor pale grey, high plasticity (MC>=PL), with fine to medium grained sand, trace fine, angular to sub-angular gravel (residual). Between 0.2-0.3m, dark grey mottled orange and red.	M	St		Monument cover, 0.78m stick up
					0.30 (21.70)	CI	Sandy CLAY, pale grey, mottled red and orange brown, medium plasticity (MC<=PL), fine grained sand, trace fine, sub-rounded, iron indurated sandstone gravel, trace weakly cemented, iron indurated bands (residual).	SM	VSt		
				SPT 3/7/10 N=17							
1				SPT 9/12/15 N=27			From 1.2m, grading to pale grey, minor red and orange brown staining, medium to high plasticity (MC>=PL), no gravel.	M			
2				D							
				SPT 6/9/12 N=21							
3											
				D	3.50 (18.50)	CI	CLAY, pale brown and grey, medium plasticity (MC>=PL), with fine grained sand (residual).	M	VSt		
					3.90 (18.10)	-	SILTSTONE, pale brown, minor red staining, extremly low to very low strength, extremely weathered, with sand in matrix.	-	-	3.9m, remoulds to medium plasticity clay.	← Cuttings
4				SPT 17/18/25 for 110mm HB N=ref							
5											

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Job No.
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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

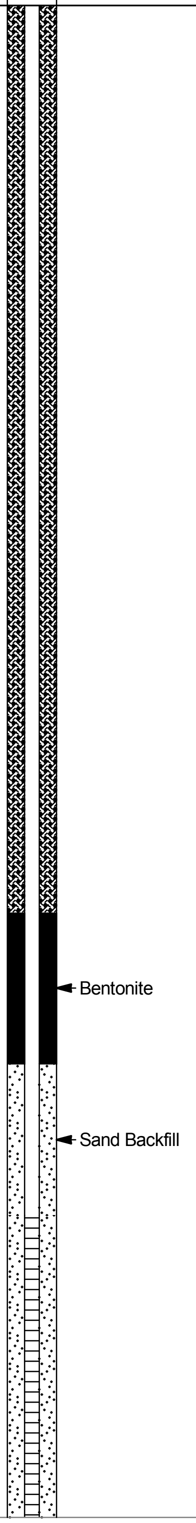
HOLE No. BH04A

SHEET 2 OF 3

Position : 357131.9 E 6371538.5 N MGA94 **Surface RL:** 22.0m **Angle from Horiz. :** 90° **Processed :** VW
Rig Type : Scout **Mounting:** Truck **Contractor :** Total Drilling Pty Ltd **Driller :** Ryan Whyte **Checked :** SA
Date Started : 11/3/2016 **Date Completed :** 11/3/2016 **Logged by :** VW **Date:** 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL							BOREHOLE	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
	TC-bit auger 150Ø	Nil						SILTSTONE, as previous.	-	-			
6								From 6.0m, medium strength, no sand in matrix.			From 6.0m, increased resistance to drilling		
								From 6.5m, grading to grey and brown, highly to moderately weathered.					
7													
8								From 8.0, grading to grey, slightly weathered.					
9													
10													



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GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

BOREHOLE LOG SHEET

GEO_BOREHOLE 22180150302_HYDRO ALUMINIUM KURRI KURRI.GPJ GHD_GEO_TEMPLATE.GDT 2/5/16

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH04A

SHEET 3 OF 3

Position :	357131.9 E 6371538.5 N MGA94	**Surface RL:**	22.0m		**Angle from Horiz. :** 90°		**Processed :** VW
Rig Type :	Scout	**Mounting:** Truck	**Contractor :**	Total Drilling Pty Ltd	**Driller :** Ryan Whyte		**Checked :** SA
Date Started :	11/3/2016		**Date Completed :**	11/3/2016	**Logged by :** VW		**Date:** 15/04/2016

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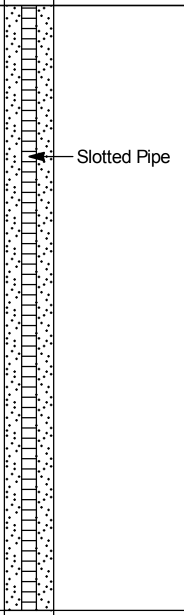
DRILLING					**MATERIAL**							**BOREHOLE**	
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	**Description** SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	**Comments/ Observations**	BOREHOLE Log	**Components**
11	TC-bit auger 150Ø	Nil						SILTSTONE, as previous.	-	-			Slotted Pipe
12					12.00 (10.00)			End of borehole at 12 metres. Target Depth.			Borehole dry on completion		
13													
14													
15													



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BOREHOLE LOG SHEET

Client : Hydro Aluminium Kurri Kurri
Project : Supplementary Geotechnical Investigation
Location : Kurri Kurri, NSW

HOLE No. BH05

SHEET 1 OF 1

Position : 357034.9 E 6371462.5 N MGA94
Surface RL: 24.1m
Angle from Horiz. : 90°
Processed : VW
Rig Type : Scout
Mounting: Truck
Contractor : Total Drilling Pty Ltd
Driller : Ryan Whyte
Checked : SA
Date Started : 10/3/2016
Date Completed : 10/3/2016
Logged by : VW
Date: 15/04/2016

Note: * indicates signatures on original issue of log or last revision of log

DRILLING					MATERIAL						
SCALE (m)	Drilling Method	Hole Support \ Casing	Water	Samples & Tests	Depth / (RL) metres	Graphic Log	USC Symbol	Description SOIL TYPE, colour, structure, minor components (origin), and ROCK TYPE, colour, grain size, structure, weathering, strength	Moisture Condition	Consistency / Density Index	Comments/ Observations
	TC-bit auger 200Ø	Nil	GNE	D			CH	CLAY, brown with grey and red, high plasticity (MC>=PL) (residual).	M	St	
1				SPT 4/7/9 N=16 SPT 4/6/9 N=15	0.40 (23.70)		CI	CLAY, pale grey mottled orange brown, medium plasticity (MC<=PL), with pockets of fine gained sand, trace silt (residual). From 0.8-2.0m, grading to pale grey mottled red and orange brown, with bands of weakly cemented iron induration. From 1.0m, moisture increasing.	SM SM-M	St	0.5-1.5m, BULK sample taken in addition to other tests
2 3	TC-bit auger 150Ø			D SPT 13/16/16 N=32 D				From 2.5m, bands of weakly cemented, sand rich, iron induration.			
4				D SPT 12/25 for 120mm HB N=ref	3.70 (20.40)		-	SILTSTONE, brown/pale brown, mottled pale grey, extremely low to low strength, extremely weathered to highly weathered, with sand in matrix (~20%).			
5					4.27 (19.83)			End of borehole at 4.27 metres. Target Depth.			Borehole dry on completion

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APPENDIX 3

3.PREVIOUS INVESTIGATIONS

Table E1 Summary of Testing Results

Sample Name	Sample Depth (mbgl)	Sample Depth (mAHD)	Pit/Bore Location (4)	Soil Description - Origin(5)	Clay Thickness metres (approx)	Moisture Content	Liquid Limit	Plastic Limit	Plasticity index	MDD (Standard) (1)	OMC (1)	permeability (w/leachate) (3)	permeability (2)	% passing 0.002mm	% passing 0.075mm	% passing 1.18 mm	Clay	Silt	Sand	Gravel	Description	USGS
RB17	*1.5-2*	*20.9-20.4*	Mid-eastern slope of CBP area	Silty Clay - residual	-(6)	27.6	43	11	32	1.66	20	5.00E-12	1.00E-11	50	71	97	50	21	26	3	Silty Sandy CLAY with trace gravel	CL
RB22	*1-1.5*	*21.2-20.7*	Mid-eastern slope of CBP area	Silty Clay - residual	-(6)	25.3	66	16	50					60	82	99	60	22	17	1	Sandy Silty CLAY with trace of Gravel	CH
RB22	*2.5-2.8*	*19.7-19.4*	Mid-eastern slope of CBP area	Silty Clay - residual	-(6)	19.8	48	26	22					40	85	100	40	45	15	0	Sandy Clayey SILT	CL
TP101	*1.2-1.8*	*24.5-23.9*	mid-CBP - topographic high point	Silty Clay - residual	3	18.2	43	14	29	1.68	18	8.00E-11	5.00E-10	37	75	93	37	38	18	7	Sandy Clayey SILT with some Gravel	CL
TP102	*0.9-1.5*	*21.7-21.1*	NW CBP	Silty Clay - residual	2	16.5	36	13	23					22	60	85	22	38	25	15	Gravelly Clayey Sandy SILT	CL
TP103	*0.2-0.6*	*24.5-24.1*	Western CBP	Silty Clay - residual	1.5	21.6	48	14	34	1.59	23		2.00E-11	60	86	98	60	26	12	2	Silty CLAY with some Sand and trace of Gravel	CL
TP104	*0.6-1*	*21.3-20.9*	South-western corner CBP (up track)	Silty Clay - residual	1.5	18.2	62	15	47					60	87	99	60	27	12	1	Silty CLAY with some Sand and trace of Gravel	CH
TP105	*1-1.5*	*20.6-20.1*	Southern CBP	Silty Clay - residual	2	20.3	53	20	33	1.64	21		4.00E-11	40	85	91	40	45	6	9	Clayey SILT with some Sand and Gravel	CH
TP106	*0.8-1.4*	*18.9-18.3*	South-eastern CBP	Silty Clay - residual	2	13.6	35	12	23					35	80	96	35	45	16	4	Sandy Clayey SILT with trace Gravel	CL
TP107	*0.5-1*	*16.9-16.4*	Eastern CBP (near base of slope)	Silty Clay - residual	1.5	22.3	45	13	32	1.66	19	3.00E-11		40	72	97	40	32	25	3	Sandy Silty CLAY with trace of Gravel	CL

Notes.

1. Moisture density testing (ASTM D698) - MDD - Maximum Dry Density, OMC Optimum Moisture Content, under Standard Compaction
2. Permeability (remoulded flexible wall) – ASTM D5804) with potable water
3. Permeability (remoulded flexible wall) – ASTM D5804) with supplied Leachate (fluoride, cyanide, sodium)
4. See Figure 2
5. See logs in Appendix A For detailed soil descriptions
6. RB17 and RB22 were part of an associated investigation which did not excavate full clay profiles.

5. Laboratory test results

The geotechnical laboratory results are summarised in the following tables, while the laboratory test report sheets presented in Appendix D.

Table 5-1 Moisture content and Atterberg Limits test results

Sample Location	Sample Depth (m)	Material	FMC (%)	Atterberg Limits			
				LL (%)	PL (%)	PI (%)	LS (%)
BH01	1.0-1.45	Clay	11.5	39	15	24	13.0
BH02	2.5-2.95	Clay	6.8	51	19	32	15.0
BH03A	5.5-5.92	Siltstone	16.3	44	19	25	10.5
BH04A	1.0-1.45	Sandy Clay	15.4	39	17	22	13.0
BH04A	4.0-4.45	Siltstone	13.5	39	17	22	10.5

Where: FMC = field moisture content LL = liquid limit
PL = plastic limit PI = plasticity index

The above moisture content and plasticity results confirm the logging of the tested soil as typically medium to high plasticity. Field moisture contents in the tested samples were generally dry of the plastic limit.

The above Atterberg Limits data, along with the previous results extracted during the gap analysis, is plotted on a plasticity chart in Figure 5-1 below.

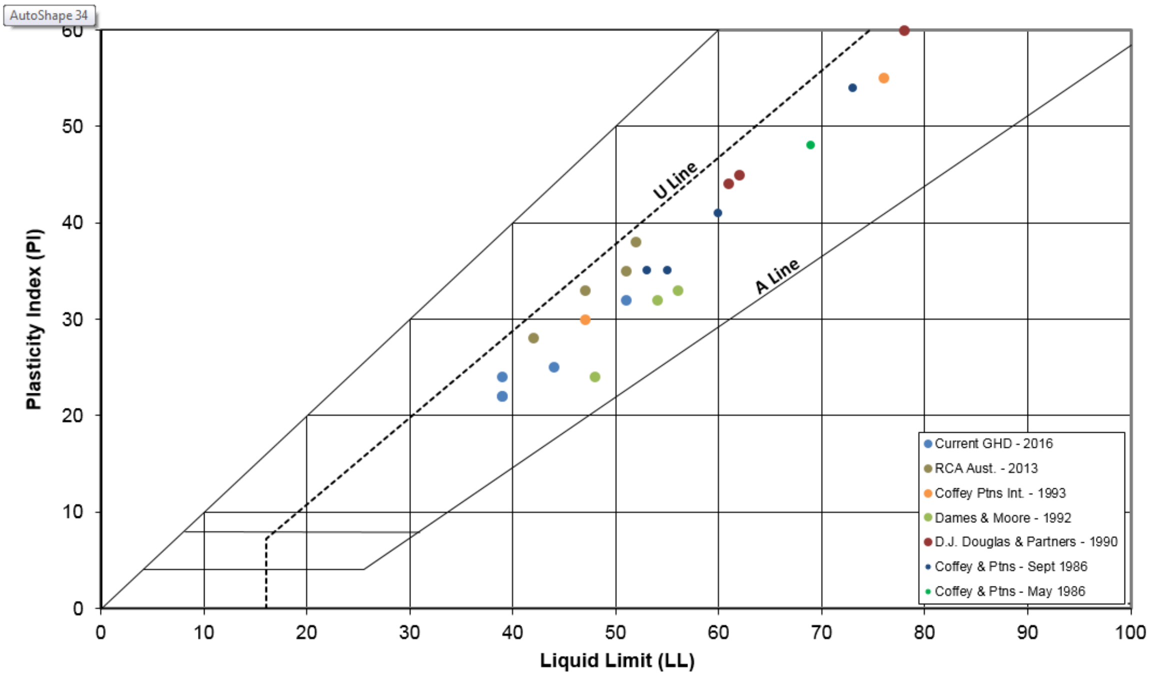

Figure 5-1 Plasticity Chart

Table 5-2 Particle size distribution test results

Sample Location	Sample Depth (m)	Material	% Fines (<0.075mm)	Sand (% 0.075mm to 2.36mm)	Gravel (% > 2.36mm)
BH03A	3.5-3.6	Clay	94	5	1
BH05	4.0-4.12	Siltstone	54	46	0

Table 5-3 Emerson class test results

Sample Location	Sample Depth (m)	Material	Emerson Class Number
BH01	2.5-2.95	Clay	1
BH02	0.5-0.6	Clay	3
BH02	7.0-7.24	Siltstone	1
BH03A	2.5-2.95	Clay	1
BH05	3.7-3.8	Siltstone	2

The above Emerson Class test results indicate that the tested soils are dispersive in nature (i.e. they will break down in contact with water and form a cloudy colloidal suspension).

Table 5-4 Standard compaction and California Bearing Ratio test results

Sample Location	Sample Depth (m)	Material	FMC (%)	MDD t/m3	OMC (%)	CBR (%)
BH01	0.5-1.5	Clay	16.4	1.75	17.3	3
BH04	0.3-1.5	Clay	22.1	1.72	18.2	4

Where: *FMC = field moisture content* *MDD = maximum dry density*
OMC = optimum moisture content *CBR = California bearing ratio*