The Soil Doctor

SOIL & PLANT NUTRIENT ANALYSIS • MAPPING • DIAGNOSTICS

Preliminary Report

Project: **Lake Rehabilitaion Progress - Rotary Park Lakebed Sediment Analysis**

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SUMMARY

Up to 2004, Rotary Park lake was in poor condition and suffered from algal blooms and high turbidity, that were causing offensive odour emissions and fish deaths. In 2004, Mick Stronach approached the Rockingham City Council to commence experimental trials to improve lake health using Coal Fines as one of the key components.

Coal Fines were placed in a layer adjacent to the stormwater outlet pipes and along the drainage chanels into the lake. The aim was to force stormwater to seep through the Coal Fines, that would temporarily or permanently bind contaminants such as Nitrogen, Phosphorous and heavy metals removing them from lake system. No trial like this had been attempted before in Western Australia.

Since commencement of the trials, water quality in the Rotary Park lake has improved greatly; algal blooms have all but disappeared since 2005; fish life is present; offensive odours have been reduced and the water has cleared. However isolating specific mechanisms that helped it along are less clear. There are many aspects that need consideration besides the introduction of Coal Fines into the equation, such as monitoring lake biology and botany, types and abundance. Yet within the scope of this study, even at this preliminary stage, several aspects deserve attention

1. The Coal horizon contains the lowest alkalinity. One of the unusual properties of Coal Fines is that they tend to buffer both acidic and alkaline systems towards neutral, something like a universal buffer. This indicates that Coal Fines could be used in almost any Lacustrine environment regardless of pH conditions.

2. The seasonal wetting and drying cycle appears to be assisting leaching of nutrients such as Sodium, Magnesium and most Micronutrients into the Coal horizon where they are clearly accumulating.

3. Potassium has accumulated at very high levels in the Residual profile, yet is low within both Coal and Overburden horizons.

4. Although Sulphur normally accumulates in anaerobic conditions, especially adjacent to the ocean, the lower values for the Coal horizon suggests Sulphur is being fixed and/or consumed by biological activity.

Some of these mechanisms may become clearer once we have water records from Rotary Park to contrast with. Others will need further more detailed research that will require more study and data gathering. But something beneficial has occurred at the lake at Rotary Park and it was probably assisted through interaction of the Coal Fines.

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Chemical Abbreviations Used In This Report

Element	Symbol	Element	Symbol	Property	Symbol
Aluminium	Al	Molybdenum	Mo	Conductivity	Con
Boron	B	Nickel	Ni	Total Dissolved Solids	TDS
Calcium	Ca	Nitrogen	N	Soil Organic Carbon	SOC
Carbon	C	Nitrogen-Nitrate	NO_3	Effective Cation Exchange Capacity	ECEC
Chloride	Cl	Nitrogen-Ammonium	NH_4	Exchangeable Calcium%	Ca%
Cobalt	Co	Phosphorous	P	Exchangeable Magnesium%	Mg%
Copper	Cu	Potassium	K	Exchangeable Potassium%	K%
Hydrogen	H	Sodium	Na	Exchangeable Sodium%	Na%
Iron	Fe	Sulphur	S	Exchangeable Acid%	H%
Magnesium	Mg	Sulphur-Sulphate	SO_4	Total Exchangeable Acid	TEA
Manganese	Mn	Zinc	Zn	Total Exchangeable Bases	TEB

1 PROJECT BACKGROUND

2004 to Present

Up to 2004, Rotary Park lake was in poor condition and suffered from algal blooms and high turbidity, that were causing offensive odour emissions and fish deaths. In 2004, Mick Stronach approached the Rockingham City Council to commence experimental trials to improve lake health using Coal Fines as the key component.

Adjacent to the stormwater outlet pipes and along the drainage chanels into the lake, Coal Fines were placed in a horizon of 50-90cm thick, and packed and covered with beachsand up to a depth of 25cm. The reasoning behind the trial was to force stormwater to seep through the Coal Fines, that would react with contaminants such as Nitrogen, Phosphorous and heavy metals, binding them and removing them temporarily or permanently from lake water. Interaction with Coal Fines could also buffer water pH from either acidic or alkaline towards neutral, creating more favourable conditions for aquatic life. No trial like this had been attempted in Western Australia.

Since commencement of the trials, water quality in the Rotary Park lake has improved greatly; algal blooms have all but disappeared since 2005; fish life is present; offensive odours have been reduced and the water has cleared. Although several factors have probably contributed to these improvements, the application of Coal Fines may be the key that could be used to improve other contaminated aquatic environments such as lakes and esturies.

Project Location and Area

Rotary Park is located adjacent to the Esplanade, about 1.5km west of the Rockingham town centre, approx, ~38km south-southwest of Perth. Co-ordinates - The centre of the lake is located at UTM 50H 378950mE, 6428150mN (±5m), GDA Datum. Size of the study area is approximately 2.6 ha for the park, 1.0ha for the lake and 0.1ha (~960m2) for the drainage area sampled.

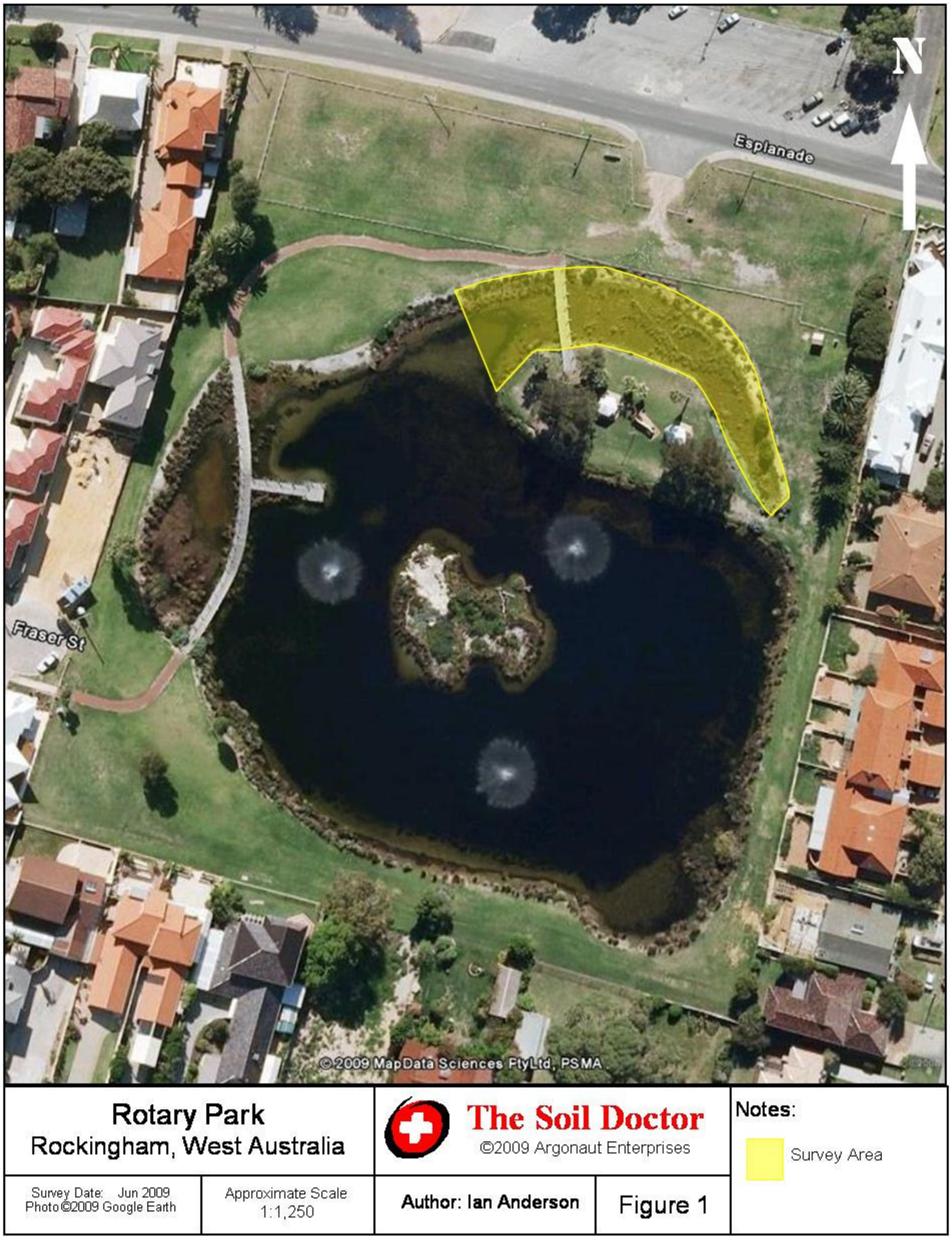
Project Scope

This project was undertaken to measure detectable changes in lake sediments within and above Coal-bearing horizons when compared to superficial residual lakebed sediments. Measurement of biological and botanical parameters (e.g. types, abundance, biological oxygen demand, etc.) whilst important, are beyond the scope of this project.

2 PROCEDURE AND ANALYSIS

Mapping Component	Reconnaissance
Soil Samples	**Nos.** 687586-588 = 3 Total
Depths	687586 = Composite of Coal-bearing horizons in cores 1-6 from ~20-95cm depth, containing 20-40% sand 687587 = Composite of Residual (Std) cores collected from beyond the treated area, from 0-60cm depth containing 100% sands, detritus and lakebed silts 687588 = Composite of horizons in cores 1-6 from above ~25cm depth, containing 95+% sand, detritus and lakebed silts
Sample Sites	See Figures 1 and 2 for Locations
Collection Method	Each core was augered to a depth of 100cm in order to penetrate the sand overburden and ideally reach the base of the Coal-bearing horizon.Samples were composited as equally as possible from the cores. Cores were located by GPS to an accuracy of ±5m.
Analysed By	Agric-Lab Laboratory, 12a Bowen Street Kardinya. Contact Neil George on 9331 5711.
Profile Composite Samples Tested For:	pH (1:5 CaCl2), Conductivity (Salinity), Total Dissolved Solids (TDS), Nitrogen Total, Nitrate (N-NO3) and Ammonium (N-NH4)), Total Phosphorous, Colwell Phosphorous (P), Available Potassium (K), Available Sodium (Na), Available Calcium (Ca), Available Magnesium (Mg), Sulphate (SO4), Copper (Cu), Zinc (Zn), Manganese (Mn), Iron (Fe), Boron (B), Chloride (Cl), Organic Carbon (OC), Lime Requirement to pH6.0, Phosphate Retention Index (PRI), Total Exchangeable Bases (TEB) and Exchangeable Acid, Effective Cation Exchange Capacity (ECEC), Exchangeable Cations (Ca%, Mg%, K%, Na%, Acid%) and Aluminium (Al), where required.
Water Samples	pH; Conductivity; TDS

Figures 1 and 2 – Location and Sampling Layout for Rotary Park



Rotary Park Rockingham, West Australia		The Soil Doctor ©2009 Argonaut Enterprises		Notes: ⊗ 1 Sediment Sample Points
Survey Date: Jun 2009 Photo ©2009 Google Earth	Approximate Scale 1:400	Author: Ian Anderson	Figure 2	

3 RESULTS AND DISCUSSION

3.1 Soil Types and Features

Only one type of soil was encountered apart from the Coal Fines within the survey area. This was essentially a fine off-white sub-rounded quartz beachsand containing 10-20% shell grit, limesand and/or crushed limestone fragments (essentially Quindilup beach sand). This soil-type normally drains freely, has low to moderate nutrient and moisture retention, is poorly structured and reacts with acidic or neutral fluids to buffer them to a slightly alkaline condition of pH 7.5-8.5. In addition, as the seashore of Cockburn Sound is only ~100m away from the lake, minor to moderate soil salinity is expected (~500-1,500ppm) due to the aerial deposition of salt and will vary according seasonal conditions such as rainfall and wind patterns.

3.2 Soil Profiles

A total of seven cores were collected along the spillway from the stormwater drain on the northen side of the lake (See Figures 2 and 3). This site was selected for its accessibility and length (the longest) and is considered most representative given the time frame and budget. At the time of sampling, all sites were saturated with 2-10cm of overlying water, indicating that the spillway is waterlogged for at least a third of the year, mainly over winter so that, saturated anaerobic conditions prevailed at the time of sampling, and this will affect results such as N-Nitrate and N-Ammonium values.

Six of the seven cores (#1 to #6) intersected the coal-bearing horizon and the seventh core collected just east of the footbridge shows the lateral limit of the coal-trial, about 50m from the drain. Figure 3 shows the depths at which each core encountered the coal horizon and varied from 20-45cm below the surface. Only one core (#2) penetrated below the coal-bearing horizon into coarse limestone gravel. Most cores contained 20-50% sand mixed in with the coal in the top 5-20cm and <20% sand below. This produced an average coal horizon of 50-60cm containing <20% sand, from which the coal composites were collected.

Core Samples—Rotary Park Rockingham, West Australia	Figure 3 Survey Date: Jun 2009	The Soil Doctor ©2009 Argonaut Enterprises

Coal-bearing samples (687586) contained slightly to almost entirely weathered coal fines (<10mm in size) and indicates that some of the coal has reacted, althoughh significant amounts (~50-60%) remain intact and available for further breakdown.

The Overburden composite sample (687588) was collected from the upper 20-40cm of cores #1-#6. The overburden was collected to assess if there were any vertical changes that may be influenced by the coal and to also assess more recent changes in water influx and it's effects on the upper horizon.

The "Residual" composite sample (687587) was collected from three cores west of the footbridge all of which resempled core #7 in Figure 3. The Residual was collected to contrast the Coal and Overburden horizons with a relatively undisturbed sand profile to assess any significant changes in nutrient levels.

3.3 Soil Nutrient Levels (RESULTS: Appendix 1)

Please note that these are preliminary results and interpretations only. Full and final results and interpretation will be available in the final report.

3.3.1 Acidity/Alkalinity and Conductivity

All three samples produced moderately alkaline pH values (8.30-8.70), although the coal sample contained the lowest (8.30). Lower pH for the Coal sample may be due to the presence of more reactive surfaces to adsorb hydroxyl (OH^-) ions, which is part of its natural buffering property

Conductivity and Total Dissolved Solids (TDS) are similar for the Coal (0.44mS/cm and 1,395ppm) and Residual (0.45mS/cm and 1,424ppm) samples, but significantly higher for the Overburden sample (0.71mS/cm and 2,266ppm), and may be due to recent heavy aerial salt deposition that has neither percolated downwards, or due to weeds impeding flow-rates, moved laterally and diluted.

3.3.2 Organic Carbon

The coal horizon contains the highest (as expected) at 9.1% OC, the Residual contains 3.4% and the Overburden contains 1.86%. This may indicate that deposition of OC under normal conditions is fairly slow as the disturbed Overburden has yet to reach the residual levels of relatively undisturbed sediments that comprise the Residual. Also, vertical redistribution from the Coal horizon appears slow to non-existant from these results. In addition, the Coal sample should produce much higher levels of OC, however, as a standard method of soil analysis, all components greater than 2mm are screened and removed. It should be noted that the Coal sample contained 43.5% gravel, of which almost all would have been unreacted or partially reacted coal.

3.3.3 Macronutrients (N, P, K, S, Ca, Mg, Na)

Nitrate and Ammonium Nitrogen levels were very low for all samples. **Total Nitrogen (N)** levels were similar for Coal and Residual horizons at 0.18% and 0.20% respectively but nearly half for the Overburden, 0.10%. This may be an artifact of sampling as deeper N reserves over longer intervals are being detected (~50cm for Coal and Residual vs. 20-30cm for Overburden). Yet it may also indiicate that N is not accumulating in the upper horizon at the same rate.

Total and available (Colwell) **Phosphorous (P)** levels are low in all three samples. Slightly higher results for the Coal horizon are present, possibly due to the small amounts contained in coal.

Available **Potassium (K)** levels are very high for the Residual (2,893ppm) yet low for Coal and Overburden (47ppm and 39ppm respectively). Potassium is a fairly mobile element in solution. Coal and the sand of the overburden probably contained very little Potassium initially, and some may have leached due to disturbance. However, the K-levels in the residual Residual still appear dramatically higher than expected. Further research is required at this point to resolve this matter.

Available **Sulphur (S)** levels are moderate for Coal (45ppm) and high for the Overburden and Residual samples (101ppm for both). Although S normally accumulates in anaerobic conditions, especially adjacent to the ocean, the lower values for the Coal horizon suggests S is being fixed and/or consumed due to biological demand.

Available **Calcium (Ca)** levels are high for all, which is typical for alkaline coastal sands. Values are similar for Overburden (5,556ppm) and Residual (5,330ppm) but slightly higher for Coal (6,312ppm) and may reflect a slightly different composition of sand with a higher Calcium Carbonate content used to stabilise the Coal Fines.

Available **Sodium (Na)** levels are high for Coal and Overburden (453ppm and 570ppm respectively) and moderate for the Residual (251ppm). These differences may reflect accumulation of Sodium (salt); in the overburden due to poor water circulation/dilution, and; adsorption of salt onto coal surfaces in the lower horizon as it leaches downwards in summer months.

Available **Magnesium (Mg)** values are higher for Coal (673ppm) and Overburden (458ppm) than the Residual (368ppm) and this may also be caused by poor water circulation/dilution, and; adsorption of Mg onto coal surfaces, along with higher Calcium/Magnesium content of the sand used to stabilse the Coal.

3.3.4 Micronutrients (Al, B, Cu, Fe, Mn, Zn)

Although Coal does contain trace amounts of micronutrients, only Iron and Aluminium contents are high enough to have any measurable effect, and both are highly immobile under alkaline conditions. As a consequence, available Micronutrient levels will be a result of inputs and aqueous geochemical conditions rather than residual levels.

The Residual sample contained the lowest values for all Micronutrients (Cu 0.15ppm; Zn 0.43ppm; Fe 14ppm; Mn 0.5ppm, and; B 1.4ppm), the Coal contained slightly to significantly higher values (Cu 0.22ppm; Zn 1.63ppm; Fe 17ppm; Mn 0.8ppm, and; B 4.2ppm) whereas the Overburden contained significantly higher values for almost all (Cu 0.57ppm; Zn 2.56ppm; Fe 36ppm; Mn 1.2ppm, and; B 3.5ppm). The higher values in the Overburden indicates Micronutrients are accumulating due to stormwater influx. As they're also accumulating in the Coal horizon, the effects of periodic wetting and drying due seasonal change may be leaching micronutrients downwards.

Note that Aluminium is generally not tested in alkaline soils as it's mobility is close to zero.

3.3.5 Other Parameters

Phosphate Retention Index (PRI) is an indication of a soil's ability to retain Phosphorous. It's often linked with Organic Carbon and silt/clay values – the higher they are, the higher the PRI is. The Residual sample contains the lowest PRI of 9.6, whilst the Coal has 13.4 and Overburden has 15.2. Although it was expected that the Coal would have a higher PRI due to higher OC (see Section 3.3.2), it remains unclear why the Overburden is even higher at this stage.

4 CONCLUSIONS

4.1 General Soil Condition and Discussion

It's clear that the lake at Rotary park has improved greatly compared to its condition in 2004, however isolating specific mechanisms that helped it along are less clear. There are many aspects that need consideration besides the introduction of Coal Fines into the equation, such as monitoring lake biology and botany, types and abundance. Yet within the scope of this study, even at this preliminary stage, several aspects deserve attention

1. The Coal horizon contains the lowest alkalinity. One of the unusual properties of Coal Fines is that they tend to buffer both acidic and alkaline systems towards neutral, something like a universal buffer. This indicates that Coal Fines could be used in almost any Lacustrine environment regardless of pH conditions.

2. The seasonal wetting and drying cycle appears to be assisting leaching of nutrients such as Sodium, Magnesium and most Micronutrients into the Coal horizon where they are clearly accumulating. An additional mechanism could also occur over summer, as water levels decline, any drainage would percolate through the overburden and flow through the Coal horizon towards the open lake.

3. Potassium has accumulated at very high levels in the Residual profile, yet is low within both Coal and Overburden horizons. Although the mechanism is unclear, such a high result suggests some aspect is unbalanced but may have been corrected within the coal and overburden. More research is suggested.

4. Although Sulphur normally accumulates in anaerobic conditions, especially adjacent to the ocean, the lower values for the Coal horizon suggests Sulphur is being fixed and/or consumed by biological activity especially as it's a key component to many enzymes and protein synthesis.

Some of these mechanisms may become clearer once we have water records from Rotary Park to contrast with. Others will need further more detailed research that will require more study and data gathering. But something beneficial has occurred at the lake at Rotary Park and it was probably assisted by the interaction of the Coal Fines with the contaminated water and wind-blown salt.

4.2 Further Work

Water Analysis

The Rockingham City Council has been approached for their water monitoring records over the last five years. Although I'm assured they exist, this study cannot be completed without them. Department of Water has kindly offered some baseline data and further studies on lacustrine environments undertaken by Murdoch University is being searched for.

Soil and Profile Analysis

Some of the limitations of this study have been the limited number of soil samples that could be collected. It would be of great benefit to sample every 10-20cm to gain a clearer picture of nutrient movement down the profile. More samples would ensure the study's figures are more statistically valid. Sampling again in January/February would help create a fuller picture of seasonal variations and may help understand how some nutrients are moving down the profile whereas others do not. Further parameters could also be added such as the examination of soil-life, types and abundance

Additional Sites

With observed improvements at Rotary Park, further sites could be treated with Coal fines, with greater testing before, during and for many years after treatment to gain a better understanding of the processes at work, as well as trialling different rates of Coal, possibly mixed with other materials such as clay.

Contact me for further discussion

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5 REFERENCES

List to be completed in the final report.

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Appendix 1 – Soil Geochemical Data (Preliminary)

Sample No. Paddock/Block Name	687586 Coal Horizon	687587 Residual (Std)	687588 Overburden	
Current Use	Lake Sediment	Lake Sediment	Lake Sediment	
Depth (cm)	20-95	0-50	0-20	
Soil Type	Black LS	PYB LS	PYB LS	Unit
GPS Location - Zone 50 H	378990	378960	378990	mE
	6428210	6428210	6428210	mN
Gravel (+2.0 mm)	43.4	20.8	1.3	%w/v
pH H2O 1:5	8.3	8.6	8.7	
pH CaCl2 1:5	7.3	7.7	7.8	
Aluminium (Ca) 1:5	0.0	0.0	0.0	ppm
EC 1:5 w/v mS/cm	0.44	0.45	0.71	mS/cm
TDS	1395	1424	2266	ppm
Chloride (Scan)	NA	NA	NA	ppm
Est Free Lime	18%	23%	25%	%
Lime Requirement to pHw 6.0	-0.1	-0.1	-0.1	t/ha
Calcium Available (Ca)	6,312	5,330	5,556	ppm
Magnesium Available (Mg)	673	368	458	ppm
Potassium Available (K)	47	2893	39	ppm
Sodium Available (Na)	453	251	570	ppm
TEB (Total Exchange Bases)	39.2	38.2	34.1	meq
TEA (Total Exchange Acidity)	0.0	0.0	0.0	meq
ECEC (Effect Cation Exc Cap)	39.2	38.2	34.1	meq
Ca% ECEC	80.6%	69.8%	81.4%	%
Mg% ECEC	14.1%	7.9%	11.0%	%
K% ECEC	0.3%	19.4%	0.3%	%
Na% ECEC	5.0%	2.9%	7.3%	%
Exchange Acidity% ECEC	0.0%	0.0%	0.0%	%
Colwell Phosphorous	7	5	5	ppm
PRI Phosphate Retention Index	13.4	9.6	15.2	mL/g
Organic Carbon %	9.09	3.40	1.86	%
Total N	0.180	0.020	0.010	%
Total P	0.0366	0.0322	0.0334	%
Sulphate S	45	101	101	ppm
Nitrate N	1.0	1.0	1.0	ppm
Ammonium N	1.0	1.0	1.0	ppm
Copper DTPA (Cu)	0.22	0.15	0.57	ppm
Zinc DTPA (Zn)	1.63	0.43	2.56	ppm
Iron DTPA (Fe)	17	14	36	ppm
Manganese DTPA (Mn)	0.8	0.5	1.2	ppm
Boron (B)	4.20	1.40	3.50	ppm

Appendix 2 – Coal Fines Bulk and Ash Analysis

Component	Symbol	% Total	kg/t Coal
Fixed Carbon	C	45%	450
Nitrogen	N	1.0%	10
Sulphur	S	0.7%	7
Oxygen	O	21%	210
Moisture content	H2O	26%	260
Ash**	Complex	6.3%	63

**Ash contains the following:		% of Ash	g/t Coal
Silicon	SiO2	53.3%	3358
Aluminium	Al2O3	24.9%	1570
Iron	Fe2O3	12.9%	810
Calcium	CaO	1.47%	93
Magnesium	MgO	1.09%	69
Sodium	Na2O	0.38%	24
Potassium	K2O	0.58%	37
Sulphur	SO3	0.37%	23
Phosphorous	P2O5	1.33%	84
Manganese	MnO	0.80%	50
Zinc	ZnO	0.70%	44
		ppm in Ash	
Boron	B	12	0.8
Chloride	Cl	82	5.2
Copper	Cu	46	2.9

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