Environmental & Remedial Technology Holdings

REPORT

Prepared for:

Coaltech

Application of EARTH ion exchange technology for conversion of RO brine from Tutuka/New Denmark into saleable products

11th June 2010

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1 Executive Summary

Tutuka Power Station treats a blend (24Mℓ/d) of acid mine drainage (AMD) from New Denmark Colliery (16Mℓ/d) and cooling water blow down (8Mℓ/d) using reverse osmosis (RO). This results in about 85% efficiency in extraction of potable water and the production of some 3Mℓ/d of brine with a TDS of about 16,000ppm. Tutuka Power Station is currently in the final stages of awarding a tender to implement a second RO stage to reduce the brine volume to 1Mℓ/d. The last remaining challenge to realize effluent free processing is to address the treatment of the brine produced.

The pilot trial reported here was conducted on the current single-stage RO brine (TDS = 14,700ppm). **Note that all projections in this report are based on a peak composition (TDS = 55,697ppm) for a 1Mℓ/d brine volume supplied by Keyplan**.

Currently the brine is used for dust suppression on the ash dump and the balance is sequestrated underground (0.86Mℓ/d). Both of these practices are deemed to be short-term measures to manage the brine however new methods are being sought to address the brine in a totally consumptive manner. ***The results of this pilot study demonstrate that the hurdle to effluent-free processing referred to above has been overcome and that brine can be converted entirely to saleable products*** *(see Figure 1).* Earth uses ion exchange (IX) to process the brine and produces fertilizer and explosives from the salts in the brine. We are also exploring other uses including thermal exchange media for concentrated solar power (CSP). A significant further fraction of the water that is *not* recovered by the RO process is also recovered. ***The Earth process is a zero liquid effluent discharge (ZLED) process and the need to dispose of brine is removed completely at acceptable cost.***

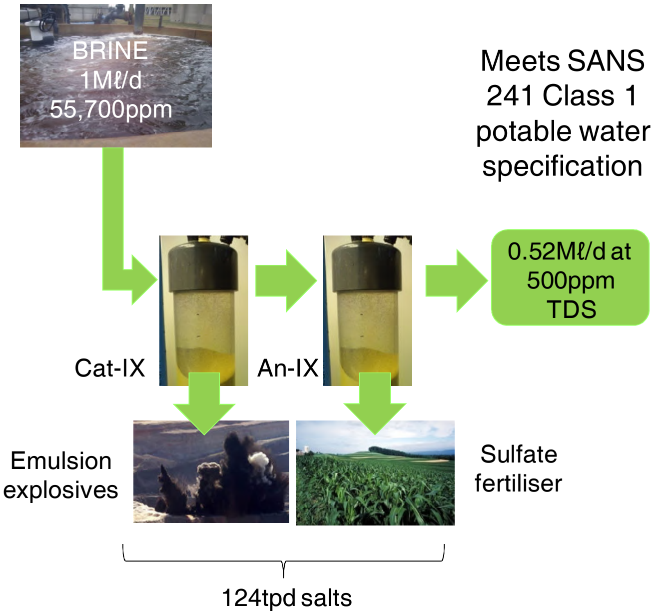

Figure 1. Schematic of Earth IX process

This study is the third of four pilot studies on different coal-based AMD liquors funded by Coaltech, the SA coal industry R&D association. The Coaltech project involves testing AMD from Exxaro Matla and from BECSA Kilbarchan and RO-generated brine from Tutuka/New Denmark and eWRP. The objective, beyond looking at specific solutions for these different sites (thus evaluating how broadly applicable the Earth solution is), is to look at the best *combination* of RO and IX to treat AMD.

Earth has a pilot plant in two 40 foot containers. These are based at its site in Boksburg Industrial East and liquors are transported to the site from the respective mines. One of the containers contains an 8 column fixed bed cation and anion exchange system that is manually operated on a 12 hour shift basis 24 hours a day. When new liquor is received, it takes some time to establish optimum operating conditions, working in an iterative mode with an external laboratory. Once the process is stabilised, it is run, at 5000 liters per day (of diluted feed), under steady state conditions to produce water and products (by eluting the ion exchange columns). The products, which are a mixed (alkaline) metal nitrate and ammonium sulfate (with a small fraction of ammonium chloride) that are concentrated to 50% and dried respectively and sent for testing (see Figure 2 – 50% concentrated mixed metal nitrate (MMN) on the left and dried ammonium sulfate on the right). Following laboratory testing, they are sent to anticipated end customers for testing and approval.

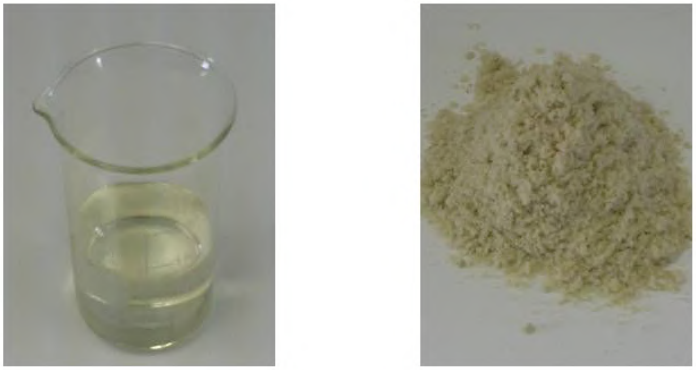

Figure 2. Photographs of MMN (left) and ammonium sulfate (right) products

The empirical work uses a flow-sheet which allows for significant variation in influent volume or salt-load. In short we are able to process anything from “raw” AMD with low salt loads of 2g/l to the high RO brine concentrations of up to 100g/l, directly to potable water in a single pass. Product specifications have been evaluated by Trailblazer Technologies, African Explosives Limited and Omnia/BME. All feedback to date shows that these products meet the requirements for direct sale into the markets as produced. In the case of the cationic products, stability and field testing are the next steps.

Earth’s business model involves ongoing exploration of product refinements which will expand the total available markets and establish better margins – in particular, testwork is being conducted by Hatch QED in Australia to separate chlorides from our ammonium sulfate and preliminary positive feedback has just been received and is being evaluated. We have already established that the economics of the additional process step look favorable and have started initial discussions with platinum refineries in South Africa about procuring the ammonium chloride produced as well as exploring other markets. Finally, we will provide feedback on *product shelf-life and stability* for the MMN as an oxidiser, which tests are being conducted by BME, at the end of the full 6 month Coaltech trial (expected in July or August 2010).

We have confirmed that there is adequate elasticity in the market to absorb the ammonium sulfate product and we have identified immediate markets in South Africa and surrounding countries for about half of the MMN product as oxidiser in emulsion explosives. We are confident that further beneficiation and/or exports will see a market for the balance and we are working on other applications, in particular as a precursor for production of potassium nitrate and as a precursor for salts used in concentrated solar power generation. ***These new applications will improve the economics and could even see the process as a profitable stand-alone process.***

We compare the economics of the proposed IX solution with construction of 25Ha brine ponds over a twenty year life of project (see Table 1). Scaling factors (supplied by Keyplan) have been used to estimate the IX capex. The conclusion is that ***the lifecycle costs to install Earth's IX solution are cheaper than brine ponds,*** even ignoring the improved economics of further process optimisation which we are confident of.

Table 1. Summary of lifecycle costs for Tutuka with brine ponds or with the Earth IX process for 1Mℓ/d brine stream at TDS = 55,700ppm (discount rate = 15%)

Solution	NPV to 2030
Brine ponds	-R262m
IX solution	**-R182m**

In summary for a brine stream at TDS = 55,700ppm at a flowrate of 1Mℓ/d:

- We recover 52.4% of the residual water in the brine;
- We recover >99% of the salts in the brine;
- The capital costs of this solution, being about R80m, will address the requirements of the DWA directive issued to New Denmark/Tutuka in late 2009 to cease the current non-compliant practices of brine disposal by October 2011;
- ***The Earth approach offers an NPV benefit of R80m; and***
- ***The proposed approach removes all brine pond-related liabilities for Eskom.***

Proposed next steps: There are a number of further process optimisation steps that will assist both the efficiency and economics of the Earth process. These include:

- Removal of reagent traces to achieve potable quality water;
- Further beneficiation of IX products to open up new and higher margin markets;
- Use of other possible regenerants to produce other products;
- Novel (patented) contactor geometries;

The primary recommendation is that the proposed IX process is demonstrated at a larger scale in the next phase of the project. Table 2 shows a high-level estimate of the costs associated with the construction and operation of a demonstration-scale plant designed to treat 1% of the Tutuka salt-load during a proposed 6-month trial.

Table 2. Cost estimate for a demonstration-scale IX plant treating 30kℓ/d of stage one RO brine at TDS = 20,000ppm

Item	[Rm]
Capex (1 year life)	5.0
Variable cost	1.0
Fixed cost	2.5
Lab studies (UCT & Hatch QED)	0.5
Sub-total	**9.0**
Feasibility study (±10%)	2.0
Total	**11.0**

The demonstration plant will produce around 55 tons of ammonium sulphate and 110 tons of the MMN product. BME and AEL have each requested at least one 5 ton batch of MMN for field trials.

We also suggest that we add a further (approximately) R500k for subcontracted product beneficiation work with Alison Lewis at UCT and with Hatch QED in Australia. This would take the total cost (ex VAT) to R9m for the demonstration plant. Products sales could be as much as R300k and would reduce this cost by 10%. A formal proposal would discuss these issues in more detail.

Finally, the client (Eskom and AATC) may wish for a reputable engineering company to provide an independent peer review of the project and provide 10% estimates for the commercial plant at an estimated cost of R2m.

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4 Background and objective

EARTH is a private South African company that develops solutions for the extraction of value from industrial and mining effluents, using ion exchange as a platform technology.

Earth carried out successful bench-trials on eight AMD-related liquors and brines for Anglo Coal in 2009 which led to a number of promising and insightful conclusions and projections for the potential improvement over current approaches (mostly RO based) in respect of net effluent footprint and economics. Following the trials above, Earth has been engaged by Coaltech to evaluate the ability of its proprietary ion exchange technology to treat a “representative” selection of four acid mine drainage liquors and/or brines derived from RO treatment thereof from the coal mines in South Africa. The *principle* behind the trials is to evaluate both:

- The ability to reduce or entirely to sequestrate the brine from RO plants built to treat the AMD; and
- The optimal combination of the *combined* use of IX and RO as part of a hybrid solution.

The third of the four liquors selected for treatment as part of this pilot program is the final concentrated brine produced by the RO process at Tutuka Power Station. This RO process treats a combined feed from New Denmark Colliery and cooling water blow-down from Tutuka of 24Mℓ/day to produce 21Mℓ/day of discharge quality water and 3Mℓ/day of brine at a TDS of around 21,000ppm. Analysis of the brine tested as part of the pilot trials has a TDS of around 15,000ppm – this may be due to seasonal variations and the areas from which AMD is abstracted from the mine for treatment during the rainy season. This brine is pH neutral and has high sodium content in combination with sulfates and relatively lower levels of chlorides that is fed to the IX process.

The basis of the Coaltech program is to try to process the brine and focus on extracting salts as saleable products rather than focus on producing potable water (which is effectively achieved with an RO process).

5 Technical trials

5.1 Collection, delivery and storage of samples

A single sample of 30,000 litres of RO3 brine was collected from Tutuka Power Station (see Figure 3) and delivered to the Earth pilot site in Boksburg (see Figure 4).

Figure 3. Collection of RO brine sample from Tutuka Power Station

These samples were stored in eight 4,200 liter plastic storage vessels in a bunded storage area (see Figure 5).

Figure 4. Off-loading of sample at the Earth Boksburg site

Figure 5. . Tank farm in bunded area at the Earth Boksburg site

5.2 Description of the IX pilot plant

A layout of the pilot plant is shown in Figure 6.

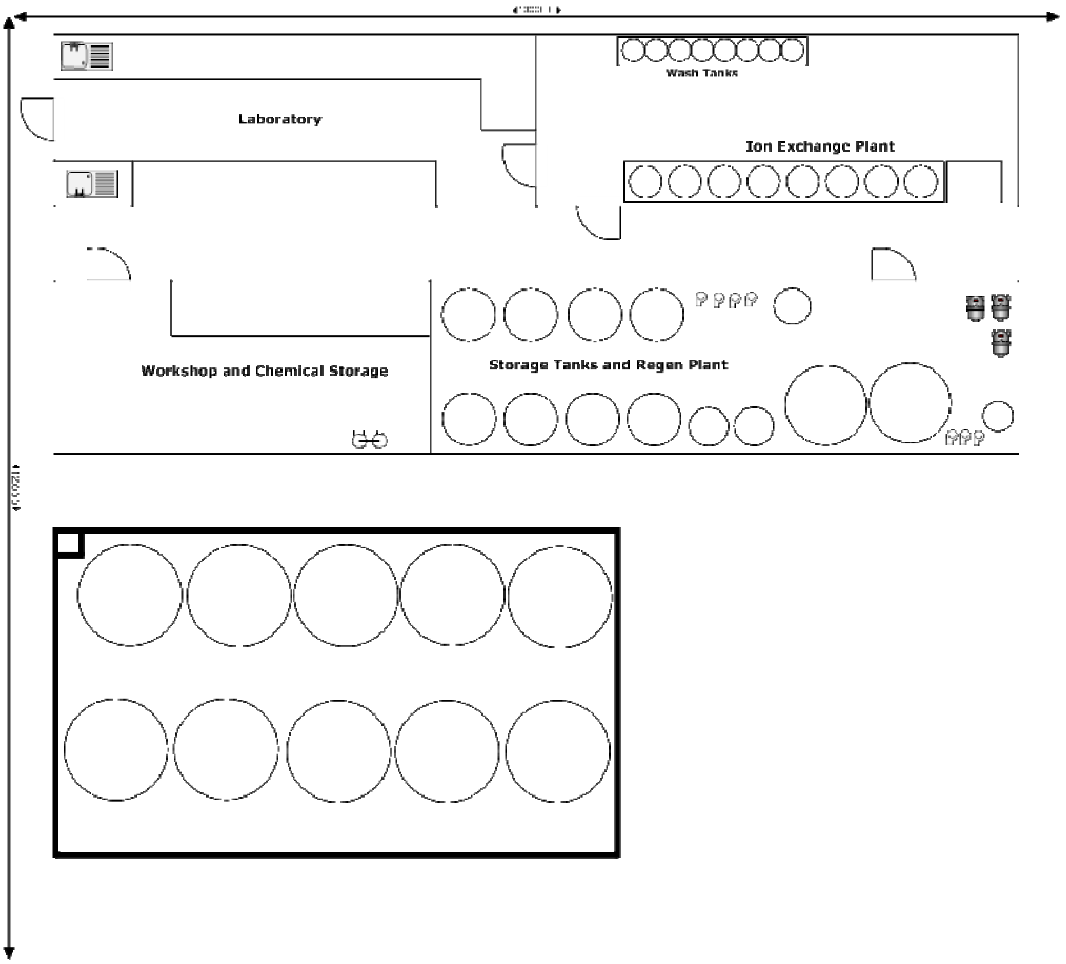


Figure 6. Layout of pilot plant

Four cationic columns are used, operated as independent carousels, where two columns are in the loading queue, one eluted column ready to enter loading and one saturated column in elution. Note the wash tanks opposite the ion exchange plant which are used to achieve both product water qualities as well as eliminate wash water as an effluent form the process.

A photograph of the cation and anion columns is shown in Figure 7.

Figure 7. Manifold for operation of the IX portion of the pilot plant

The cationic columns are filled with strong-acid resin. This removes metal cations from the influent at the incoming pH of around 7. The loading cycle of the sequence of two cationic columns in series is controlled as follows:

- Load two columns in series and feed effluent to the anion feed storage tanks.
- A pH cut-off point is selected to control cation breakthrough. When the breakthrough pH is reached the column is saturated and moved to the elution cycle for metal recovery with nitric acid.
- The polishing column is moved to the lead loading position and the last-eluted column to the polishing loading position.

The nitrate eluant is supplied from the nitric acid eluant buffer tank. The concentration peak in the eluate is routed to the cationic product tank and the “top and tail” of the elution is recycled to a recovery tank. At the end of the elution cycle the eluted column is emptied and washed using proprietary procedures to reduce transfer of the constituents in the eluate liquor into the product water when returned to the loading cycle.

Four anionic columns are used, operated as independent carousels, where two columns are in the loading queue, one eluted column ready to enter loading and one saturated column in elution. The anionic columns are filled with weak-base resin. This removes non-metal anions from the cationic effluent at an incoming pH of around 0.5. The loading cycle of the sequence of two anionic columns in series is controlled as follows:

- Load two columns in series and feed effluent to the clean water storage tank.

- A conductivity cut-off point is selected to control anion breakthrough. When breakthrough occurs the lead column is saturated and moved to the elution cycle for sulphate recovery with ammonium hydroxide.
- The polishing column is moved to the lead loading position and the last-eluted column into the polishing loading position.

The anionic eluant is supplied from the eluant feed recycle tank. The concentration peak in the eluate will be routed to the ammonium sulphate product tank and the balance of the elution will be recycled to an eluate feed tank in a closed loop system. At the end of the elution cycle the eluted column is emptied and washed using proprietary procedures to reduce transfer of the constituents in the eluate liquor into the product water when returned to the loading cycle.

The pilot plant is designed to operate at between 1,200 ℓ/day and 10,000ℓ/day (dependent on the influent TDS) which is at a scale where diseconomies of scale due to end and edge effects are minimised and from which engineering and commercial data can be reliably generated by extrapolation.

6 Results

6.1 IX treatment of single stage RO brine

Here we discuss the treatment of the current RO brine with dilution as depicted Figure 8. The RO brine is diluted using product water and is then contacted with the cation exchange resin, which removes more than 70% of the alkaline metals (sodium, potassium, calcium and magnesium) in the diluted brine. The cation effluent is then contacted onto an anion resin which removes more than 80% of the sulfates and chlorides in the stream.

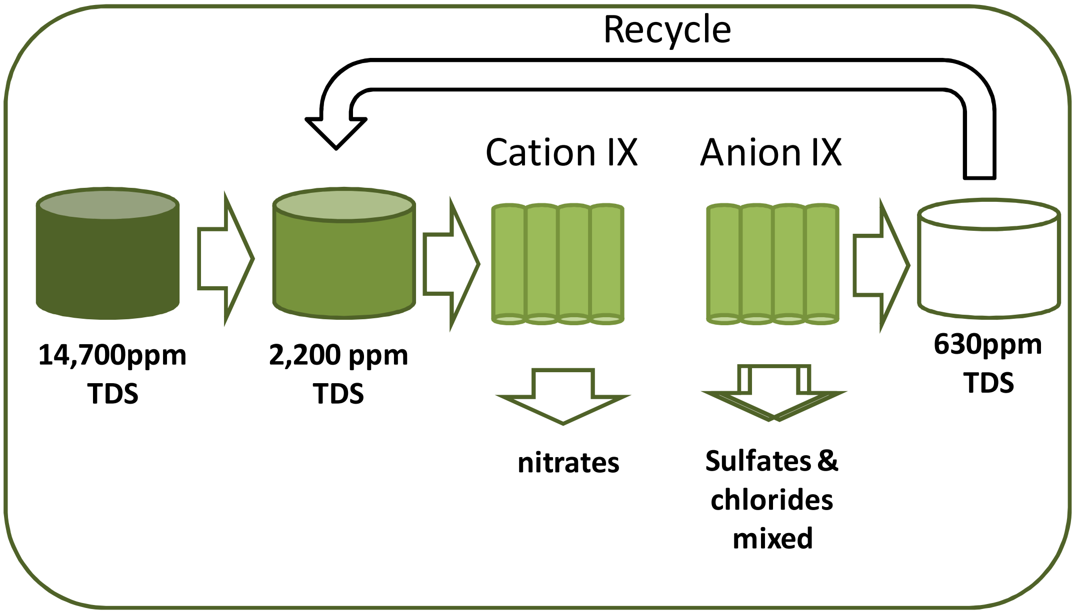


Figure 8. Schematic of performance of IX treatment of RO3 brine

Table 3 below shows the assayed results on influent and final “effluent” quality. The TDS achieved during the steady state pilot trials was about 630ppm (reduced from 14,709ppm) representing an ion removal efficiency of 95%. The effluent water volume is about 85% of the influent brine volume which is equivalent to 85% water recovery. It may be possible to recycle this product water back into the RO front end if a second barrier is required in the production of potable water for re-use.

Table 3. Summary of influent (start) and effluent (end) water qualities

EARTH ID:	**SN 1304010**	**Average effluent quality**	**Sans 241 Class 1**
UIS ID:	**61355**		
Description	**T10**		
Species	**mg/ℓ**		
Al	0.052	0.004	<0.3
As	0.070	0.002	<0.010
Ca	102	0.5	<150
Cd	0.0003	<0.0001	<0.005
Co	0.026	0.001	<0.500
Cr	0.094	0.002	<0.100
Cu	1.071	0.006	<1
Fe	0.223	0.058	<0.2
Hg	0.0003	<0.0001	<0.001
K	120	2	<50
Mg	143	0.49	<70
Mn	0.346	0.001	<0.1
Na	5220	198	<200
Ni	0.401	0.002	<0.15
Sb	0.011	0.003	<0.01
Se	0.109	0.011	<0.02
V	0.427	0.008	<0.2
Zn	0.180	0.023	<5.0
NH4	<2.5	16	<1.0
NO3	71	136	<10
Cl	2000	223	<200
SO4	6993	23	<400
TDS	**14709**	**629**	

What is immediately apparent is that the concentrations of ammonium, nitrate and chloride ions are higher than the SANS 241 Class 1 potable drinking water standards. This is largely an artifact of the pilot scale trials. The chloride ion concentration can be reduced by tightening the end-of-cycle TDS set-point and the ammonium and nitrate concentrations will be lower with the increased number of wash tanks in the IX process (from 4 to 8) included in the final process design. In addition, as is discussed in the next section, it is possible to selectively remove the remaining ammonium and nitrate ions from the product water by making use of ion-selective IX resins.

6.2 Selective removal of ammonium and nitrate ions –preliminary results

In the event that potable water is required as the final effluent from IX treatment it is possible to polish the dilution circuit effluent with ion-selective resins targeting ammonium and nitrate ions respectively (see Figure 9). Preliminary results from the work performed at laboratory scale using these resins on Tutuka trial effluent are summarised in Table 4. It is clear from Table 4 that removal of ammonium and nitrate ions can be achieved selectively and it follows that it is possible to produce potable water quality from the dilution circuit. It should be noted that the nitrate ion selective resin is available commercially; however the ammonium ion selective resin is only available from Cwenga Technologies (Pty) Ltd.

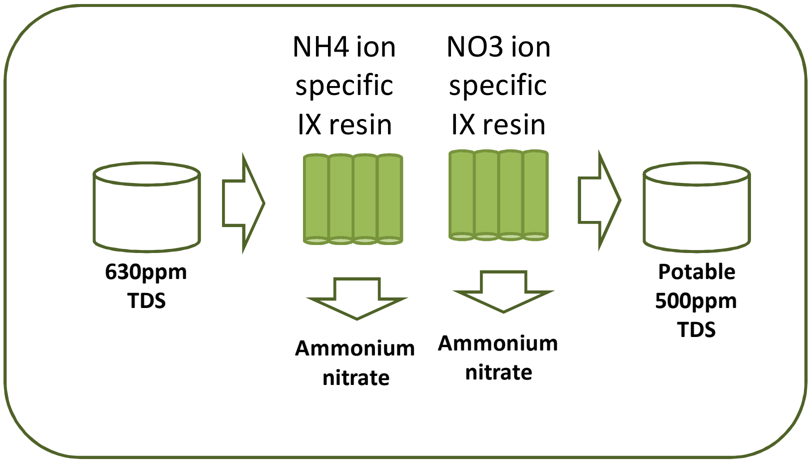


Figure 9. Summary of bench-scale tests using ion selective IX resins

We are currently testing the efficacy of nitric acid and ammonium hydroxide as regenerants for the resins mentioned above.

Table 4. Summary of bench-scale tests on ion selective resins

Earth ID		SN 0404001	SN 0404002	SN 0404003
Mod. Lab ID:		60626	60627	60628
Description		Feed, AET	NH4 Resin, effluent	NO3 Resin, Effluent
Element		mg/ℓ		
Ammonia	NH4	10	1	<1
Nitrate	NO3	102	102	<4

7 Product mix, customers and flexibility

7.1 Cation product

This section deals with the cationic product generated during the ion exchange trials. The data for the cation IX during the steady state trial is contained in Appendix 1 and Table 5 summarises the composition of the MMN product at various stages of its concentration and the final analysis of the product relative to the African Explosives Ltd specification.

Table 5. Cation eluate (MMN) product quality

EARTH ID:	SN 1604006	Calculated			Actual product		
UIS/Mod ID:	61369	Neutralised	50% soln	50% soln	62987	50% soln	AEL specification
Description	CPT				Final product		
Species	mg/ℓ			(m/v) %	mg/ℓ	(m/v) %	
Al	0.281	0.281	0.842	0.0001%	0.559	0.0000%	<0.0012%
As	0.002	0.002	0.005	0.00%	<0.698	0.00%	
B	1.79	1.79	5.37	0.00%	4.33	0.00%	
Ba	0.099	0.099	0.298	0.00%	n.d.	n.d.	
Ca	722	7501	22,493	2.25%	65,636	5.08%	
Cd	0.0002	0.0002	0.0005	0.00%	<0.070	0.00%	
Ce	0.001	0.001	0.003	0.00%	n.d.	n.d.	
Co	0.005	0.005	0.015	0.00%	<0.14	0.00%	
Cr	0.013	0.013	0.038	0.00%	0.279	0.00%	
Cs	0.003	0.003	0.008	0.00%	n.d.	n.d.	
Cu	0.579	0.579	1.736	0.00%	0.140	0.00%	
Fe	0.269	0.269	0.808	0.0001%	0.279	0.0000%	<0.0012%
K	803	803	2,408	0.24%	5,586	0.43%	
La	0.001	0.001	0.002	0.00%	n.d.	n.d.	
Li	0.452	0.452	1.355	0.00%	14.943	0.00%	
Mg	884	884	2,651	0.27%	1.117	0.00%	
Mn	0.111	0.111	0.334	0.0000%	0.008	0.0000%	<0.0012%
Mo	0.002	0.002	0.005	0.00%	1.117	0.00%	
Na	30500	30500	91,460	9.15%	97,755	7.57%	
Ni	0.120	0.120	0.361	0.00%	<0.698	0.00%	
Pb	0.003	0.003	0.008	0.00%	0.279	0.00%	
Rb	0.164	0.164	0.491	0.00%	n.d.	n.d.	
Sc	0.003	0.003	0.009	0.00%	n.d.	n.d.	
Se	0.019	0.019	0.056	0.00%	<1.40	0.00%	
Si	27.2	27.2	81.6	0.01%	n.d.	n.d.	
Sn	0.001	0.001	0.003	0.00%	n.d.	n.d.	
Sr	3.30	3.30	9.90	0.00%	175	0.01%	
U	0.0056	0.0056	0.017	0.00%	n.d.	n.d.	
V	0.015	0.015	0.045	0.00%	0.279	0.00%	
Y	0.001	0.001	0.003	0.00%	n.d.	n.d.	
Zn	0.152	0.152	0.454	0.00%	0.140	0.00%	
NH4	2210	2210	6,627	0.66%	n.d.	n.d.	
NO3	118171	118171	354,358	35.44%	474,810	36.75%	
Cl	6292	6292	18,868	1.89%	1,787.520	0.14%	
SO4	344	344	1,033	0.10%	251.370	0.02%	
Total	**159,960.80**	**166,739.61**	**500,000**	**50.0%**	**646,024**	**50.0%**	

Legend: n.d. = not detected

The cation eluate is a mixed metal nitrate, with the metals usually dominated by the alkaline metals (sodium, calcium and some potassium). Table 5 shows the measured results with predicted data for neutralised and concentrated products. Our pilot work produced product with a salt concentration of 18%. Explosives companies require product with a concentration of 50% and Modderfontein Laboratories has completed concentration of our product to this level (with associated assay results). There is a small increase in calcium in the mixed metal nitrate during the concentration stage due to the use of lime to neutralize the solution prior to and during evaporation.

The mixed metal nitrates such as these find application, variously, as:

- A stabilizer/oxidiser when mixed with ammonium nitrate in emulsion explosive applications (the immediate intended application). A distinct advantage of this approach is that the market is almost completely insensitive to the ratios of alkaline metals with one notable exception related to a lower solubility product for sodium nitrate versus calcium nitrate;
- A precursor to the production of potassium chloride; and
- As a heat-exchanger salt/liquid for concentrated solar power plants.

Samples of the MMN product have been delivered to both AEL (Andre Pienaar, Senior Technologist and Larry Wilson, Technical Manager UBS) and Omnia BME (Rainer Pille, Research & Development Specialist) for testing. A letter from AEL from our previous trials at Rand Uranium is provided in Appendix 2 – we expect to obtain similar letters from AEL and Omnia BME by the end of August for the current product. We expect initial reports from AEL and BME by the end of June when they have completed initial solubility and stability tests. The assumed price in our model below is based on information provided to us by AEL.

BME has confirmed the potential use of the Earth MMN product as an oxidizer in emulsion explosives and indicated that based on the sodium content that it may be admixed with ammonium nitrate to a level of between 10% and 20% (m/m) commensurate with the solubility of sodium nitrate. BME tests are underway including laboratory tests as follows:

- Oxidiser testwork/ characterization of components including the determination of the crystallization temperature of the MMN in the emulsion as a function of concentration in the emulsion (duration = 1 month from beginning of June);
- Emulsion testwork/Stability tests including measurement of viscosity/'pump-ability', shear resistance and 'gassing ability' (duration = 1 month from beginning of June)

The next steps will be to motivate for field trials (explosion tests) which would require support from the leadership of BME with permission from the relevant mine/s. A sample of between 5,000kg and 10,000kg (on a salt basis) would be required for such a trial and this should be an important input parameter to inform a Demonstration Plant for the Earth technology. AEL have indicated their willingness to conduct the aforementioned field trial/s upon receipt of the required sample and we are involved in similar discussions with BME.

As will be seen below, the MMN will saturate the emulsion explosive market in SA and there is a need either to export MMN or to convert at least part of it into products with other markets. Empirical work on this is beyond the scope of the current program however we are developing conceptual solutions to the problem. In particular, John Bewsey has patented a method to convert sodium nitrate to high-value potassium nitrate using low-cost potassium chloride as reagent. This process will produce sodium chloride as by-product and we will trial this technology as part of the proposed Demonstration Project.

7.2 Anion product

The data for the anion IX during the steady state trial is contained in Appendix 3. In the metallurgical industries ammonium sulfate has a market, provided the chloride levels are adequately low. Product data for our anion product which is substantially ammonium sulfate is shown in Table 6.

One of the primary *stated* objectives in the proposal provided to Coaltech was to separate the sulfate and chloride anions in this product. We were concerned previously that the anticipated ammonium sulfate product composition of around 10% chlorides may not be acceptable at all in the fertiliser industry. We have subsequently received confirmation that the fertiliser market will accept all of the ammonium sulfate we expect to produce from the Tutuka brine, even with the levels of chlorine shown (albeit at a lower market price). Both Trailblazer Technologies and Omnia are in receipt of samples and Trailblazer Technologies confirmed that the product quality is acceptable and suggested prices that we have incorporated into our model.

High purity ammonium sulfate commands a price of R2,400 per ton from industrial customers such as Vanchem (who reject product containing chlorides) while fertilizer-grade material fetches only R1900 per ton. Ammonium sulfate contaminated with around 10% chlorides will likely fetch around R1500 per ton (this value is used in determining the process economics – see Appendix 4 for communication from J Bewsey, Trailblazer Technologies, in this regard). Based on initial information it is likely that there is net economic benefit in the additional steps in the flow sheet required to split the anions. We propose to trial the Hatch QED technology as part of the recommended Demonstration Project.

Table 6. Anion eluate (ammonium sulfate) product quality

EARTH ID:	SN 1604010	Calculated		Actual product	
UIS/Mod ID:	61373	Neutralised eluate	Solid	63707	Omnia specification
Description	APT			Solid	
Species	mg/ℓ		(m/m) %		
Al	0.048	0.048	0.00005%	n.d.	
As	0.004	0.004	0.00000%	<0.001%	<0.002%
B	2.2	2.2	0.002%	n.d.	
Ba	0.003	0.003	0.00000%	n.d.	
Ca	7.76	7.76	0.007%	0.037%	
Cd	<0.0001	0.00	0.000%	0.000%	<0.002%
Co	0.001	0.001	0.00000%	n.d.	
Cr	0.013	0.013	0.00001%	0.000%	
Cu	0.019	0.019	0.00002%	0.006%	
Fe	0.165	0.165	0.00016%	0.000%	
K	1	1	0.00095%	0.00537%	
Li	0.004	0.004	0.00000%	n.d.	
Mg	3.79	3.79	0.00360%	0.00589%	
Mn	0.010	0.010	0.00001%	n.d.	
Mo	0.009	0.009	0.00001%	n.d.	
Na	92.8	92.8	0.088%	0.082%	
Ni	0.011	0.011	0.00001%	0.000%	
Rb	0.001	0.001	0.00000%	n.d.	
Sb	0.001	0.001	0.00000%	n.d.	
Sc	0.002	0.002	0.00000%	n.d.	
Se	0.011	0.011	0.00001%	<0.0002%	
Si	25.9	25.9	0.025%	n.d.	
Sr	0.013	0.013	0.000%	n.d.	
Ti	0.227	0.227	0.00022%	n.d.	
U	0.0006	0.0006	0.000%	n.d.	
V	0.097	0.097	0.00009%	n.d.	
W	0.001	0.001	0.00000%	n.d.	
Zn	0.008	0.008	0.00001%	0.0013%	
NH4	27,413	27,413	26.0%	25.7%	
NO3	35,429	35,429	33.6%	2.3%	
Cl	9,921	9,921	9.4%	11.6%	
SO4	29,076	32,505	30.8%	60.3%	
Total	**101,973**	**105,401**	**100.0%**	**100.0%**	

We have developed three approaches to separate the chlorides. The first is chromatography, the second involves the use of a well-developed Hatch (nanofiltration) technology (see Appendix 5) while the other is an electrochemical approach. We have sent samples to Hatch QED in Australia who have sent us the initial results of pilot work. This looks promising and we are evaluating the technical and commercial implications which will be presented in the final Coaltech Report Note that there are markets for ammonium chloride in battery manufacturing and the platinum industry in SA – the material is imported and distributed by Protea at volumes comparable to those we would produce.

7.3 Product Market Sizing

It is critical that products produced enter a market with adequate elasticity to absorb them. Table 7 indicates is that there is considerable elasticity in the ammonium sulfate market but that the market for MMN will be saturated in South Africa by a plant at Tutuka alone. We intend to separate sodium nitrate from calcium and magnesium (and potassium) nitrate and this will enable us to access the fertilizer markets which are much larger and produce potassium nitrate and sodium chloride for the chlor-alkali industries, and MMN (see Table 8). We also believe that there is an export market (there are several patents covering this material in China) and we are working to understand the implications for the economics of the process. Proof of these process steps and final determination of the economics will form part of recommended proposed Demonstration Project.

Table 7. Market size estimations for current product spectrum

Product	South African Market size	Main Suppliers		Main Customers		Fraction of market that Tutuka represents	Fraction of market that Tutuka, Matla and eWRP represent
Ammonium sulphate (Fertiliser Grade)	200ktpa	Sasol	52%	Sidi Parani and Co-Ops	87.5%	16.2ktpa = 8.1%	23.5ktpa = 11.8%
		Implats	28%	Omnia	12.5%		
		Imports	20%				
Mixed metal nitrate	20ktpa	Sasol	40%*	Captive market		28.5ktpa = 142.5%	37.7ktpa = 188.3%
		Omnia	30%*				
		AEL	30%*				

* The numbers provided are for ammonium nitrate for which mixed metal nitrate is a part substiture in explosives - MMN market is perhaps 10% of AN market at around 200ktpa

Table 8. Market size estimations for proposed product spectrum

Product	Southern African Market size	Main Suppliers		Main Customers		Fraction of market that Tutuka represents	Fraction of market that Tutuka, Matla and eWRP represent
Ammonium sulphate (Fertiliser Grade)	200ktpa	Sasol	52%	Sidi Parani and Co-Ops	87.5%	20.7ktpa = 10.4%	27.4ktpa = 13.7%
		Implats	28%	Omnia	12.5%		
		Imports	20%				
Mixed metal nitrate	60ktpa	Sasol	40%*	Captive market		5.6ktpa = 9.3%	8.0ktpa = 13.3%
		Omnia	30%*				
		AEL	30%*				
Potassium nitrate	50ktpa	?		Other	80.0%	27.1ktpa = 54.1%	35.2ktpa = 70.4%
				Omnia	20.0%		
Sodium chloride	417ktpa**	?		Chlor-alkali industry		15.3ktpa = 3.7%	19.8ktpa = 4.7%

* The numbers provided are for ammonium nitrate for which mixed metal nitrate is a part substiture in explosives - MMN market is perhaps 30% of AN market at around 60ktpa

** Estimate based on chlorine production in SA

8 Process economics

8.1 Assumptions

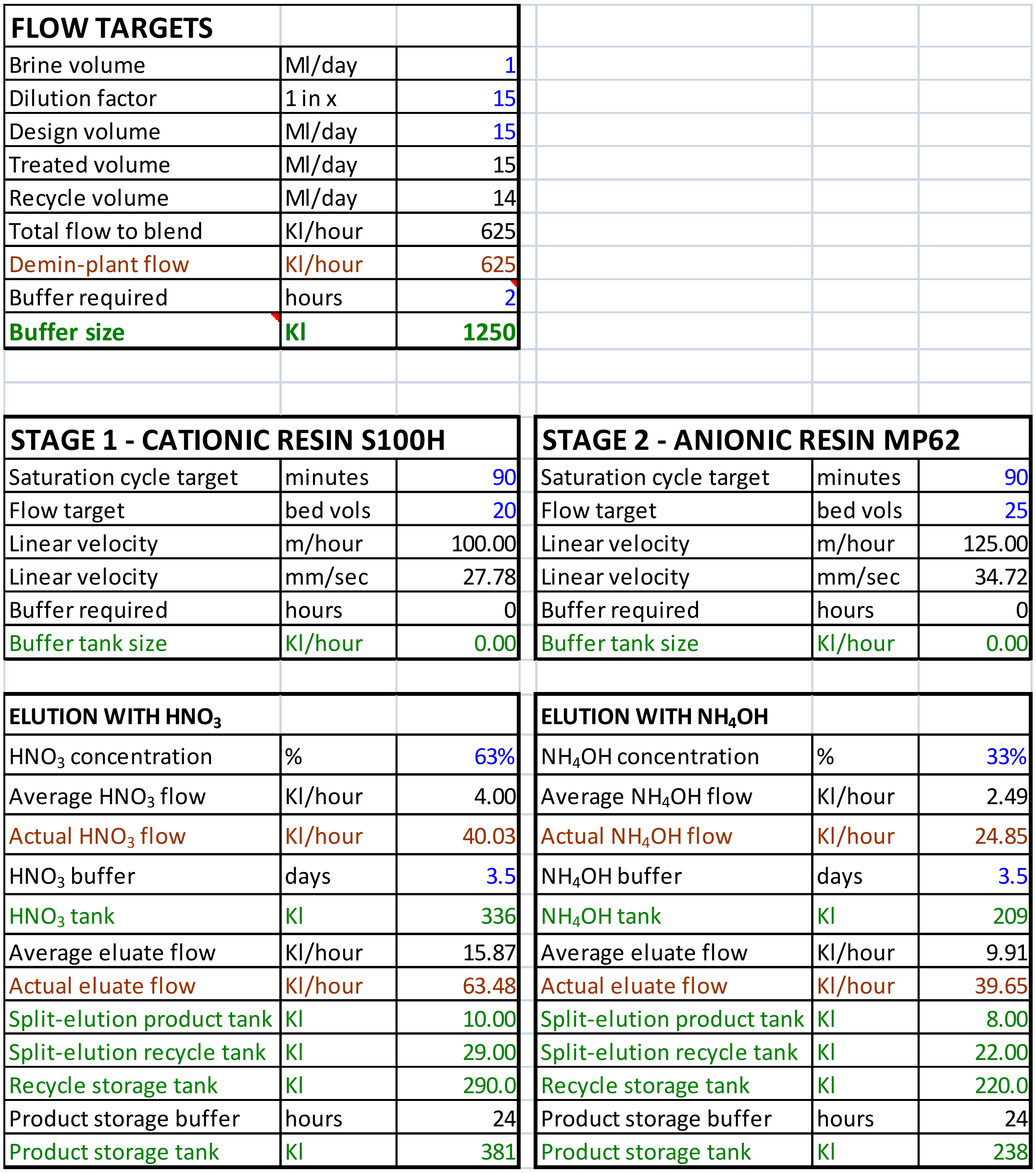
All of the IX process capex estimations and the opex model below are based on an assumption of a design basis of a feed of 1Mℓ/d (with TDS of 55,696ppm TDS – see Appendix 6 for projected quality of first and second stage RO rejects obtained from Keyplan). The economics are calculated on the basis of the mass balance (see Appendices 7 and 8 for details on the mass balance and Appendix 9 for a summary of NPV calculations).

8.2 Opex

For the purpose of the modeled analysis we selected a recycle stream (dilution model as described above) at 15 times the flow of the second stage RO brine on the basis that we achieve acceptable IX cycle times (±60 minutes) and potable water as an effluent. In addition we have not as yet optimised the estimates for site specific issues such as the availability of excess heat, availability of better/cheaper resins, etc. These issues will be addressed as part of the recommended Demonstration Project.

We start with the underlying assumptions in terms of flows shown in Table 9.

Table 9. Summary of flow targets



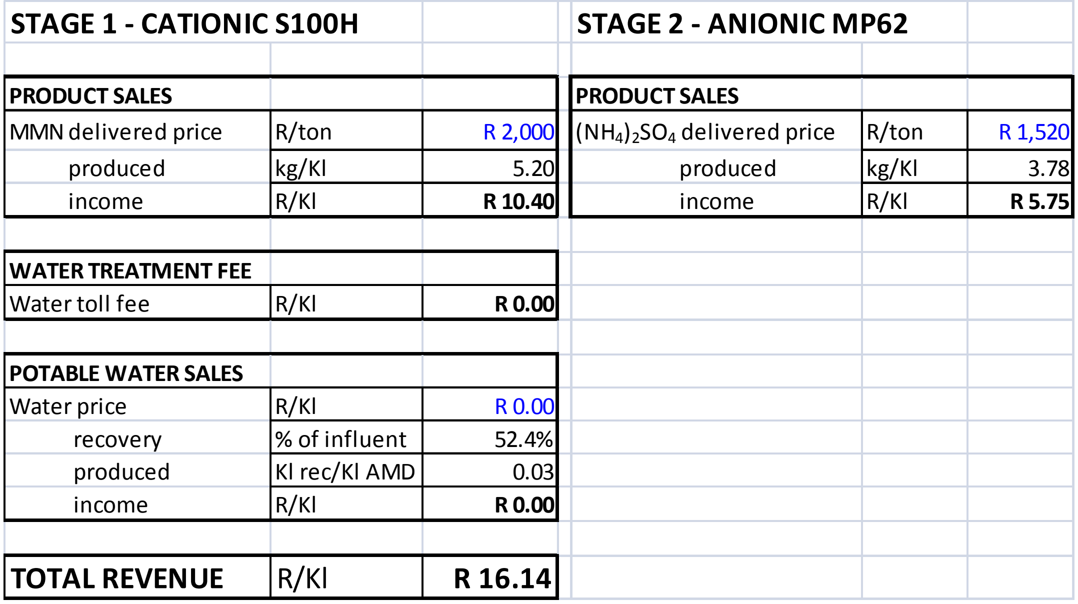
FLOW TARGETS		
Brine volume	Ml/day	1
Dilution factor	1 in x	15
Design volume	Ml/day	15
Treated volume	Ml/day	15
Recycle volume	Ml/day	14
Total flow to blend	Kl/hour	625
Demin-plant flow	Kl/hour	625
Buffer required	hours	2
Buffer size	**Kl**	**1250**

STAGE 1 - CATIONIC RESIN S100H			STAGE 2 - ANIONIC RESIN MP62		
Saturation cycle target	minutes	90	Saturation cycle target	minutes	90
Flow target	bed vols	20	Flow target	bed vols	25
Linear velocity	m/hour	100.00	Linear velocity	m/hour	125.00
Linear velocity	mm/sec	27.78	Linear velocity	mm/sec	34.72
Buffer required	hours	0	Buffer required	hours	0
Buffer tank size	Kl/hour	0.00	Buffer tank size	Kl/hour	0.00

ELUTION WITH HNO_3			ELUTION WITH NH_4OH		
HNO_3 concentration	%	63%	NH_4OH concentration	%	33%
Average HNO_3 flow	Kl/hour	4.00	Average NH_4OH flow	Kl/hour	2.49
Actual HNO_3 flow	Kl/hour	40.03	Actual NH_4OH flow	Kl/hour	24.85
HNO_3 buffer	days	3.5	NH_4OH buffer	days	3.5
HNO_3 tank	Kl	336	NH_4OH tank	Kl	209
Average eluate flow	Kl/hour	15.87	Average eluate flow	Kl/hour	9.91
Actual eluate flow	Kl/hour	63.48	Actual eluate flow	Kl/hour	39.65
Split-elution product tank	Kl	10.00	Split-elution product tank	Kl	8.00
Split-elution recycle tank	Kl	29.00	Split-elution recycle tank	Kl	22.00
Recycle storage tank	Kl	290.0	Recycle storage tank	Kl	220.0
Product storage buffer	hours	24	Product storage buffer	hours	24
Product storage tank	Kl	381	Product storage tank	Kl	238

Since we now have the flows, one can readily model the products and revenues summarised in Table 10. We note at this point that we have estimated the flows and costs *without* any contingency at this stage. We believe that this is appropriate for a pre-feasibility study where any uncertainties or adjustments for possible spillages, inefficiencies, commissions etc will be smaller than the ±30% accuracies of the current estimates.

Table 10. Summary of production rates and revenues



STAGE 1 - CATIONIC S100H		
PRODUCT SALES		
MMN delivered price	R/ton	R 2,000
produced	kg/Kl	5.20
income	R/Kl	**R 10.40**
WATER TREATMENT FEE		
Water toll fee	R/Kl	**R 0.00**
POTABLE WATER SALES		
Water price	R/Kl	R 0.00
recovery	% of influent	52.4%
produced	Kl rec/Kl AMD	0.03
income	R/Kl	**R 0.00**
TOTAL REVENUE	R/Kl	**R 16.14**

STAGE 2 - ANIONIC MP62		
PRODUCT SALES		
$(NH_4)_2SO_4$ delivered price	R/ton	R 1,520
produced	kg/Kl	3.78
income	R/Kl	**R 5.75**

Here we exclude revenues from water sales. Variable costs can also be calculated and the gross profit inferred from the variable costs and revenues as summarised in Table 11.

Table 11. Summary of variable costs for the diluted brine stream simulation

STAGE 1 - CATIONIC S100H			STAGE 2 - ANIONIC MP62		
REAGENTS COSTS			**REAGENTS COSTS**		
HNO_3 price	R/ton	R 2,610	NH_4OH price on NH_3 basis	R/ton	R 3,200
average dist	km	100	average dist	km	100
delivery	R/ton	R 159	delivery	R/ton	R 303
consumed	kg/Kl	3.65	consumed	kg/Kl	1.03
cost	R/Kl	**R -10.12**	cost	R/Kl	**R -3.60**
WATER COSTS			**REAGENTS COSTS**		
Water price	R/Kl	R 0.00	Water price	R/Kl	R 0.00
consumed	l/Kl	17.20	consumed	l/Kl	9.31
cost	R/Kl	**R 0.00**	cost	R/Kl	**FALSE**
NEUTRALISATION COSTS			**NEUTRALISATION COSTS**		
Lime stone price	R/ton	R 500	H_2SO_4 price	R/ton	R 1,600
average dist	km	100	average distance	km	100
delivery	R/ton	R 100	delivery	R/ton	R 102
consumed	kg/Kl	0.365	consumed	kg/Kl	0.348
cost	R/Kl	**R -0.22**	cost	R/Kl	**R -0.59**
EVAPORATION COSTS			**EVAPORATION COSTS**		
MMN dilute volume	l/Kl	23.00	NH_4SO_4 dilute volume	l/Kl	12.43
concentration	%TDS	20.0%	concentration	%TDS	20.0%
target conc	%TDS	50%	target conc	%TDS	100%
water lost	l/Kl	13.80	water lost	l/Kl	9.94
unit cost	R/m^3	R 45	unit cost	R/m^3	R 45
cost	R/Kl	**R -0.62**	cost	R/Kl	**R -0.45**
PRODUCT PACKAGING COSTS			**PRODUCT PACKAGING COSTS**		
Packaging unit cost	R/unit	R 0.00	Packaging unit cost	R/unit	R 60.00
weight	kg	0	weight	kg	1,000
cost	R/Kl	**R 0.00**	cost	R/Kl	**R -0.23**
PRODUCT TRANSPORT COSTS			**PRODUCT TRANSPORT COSTS**		
Delivery unit cost	R/km/ton	R 1.00	Delivery unit cost	R/km/ton	R 1.00
average dist	km	100	average dist	km	40
load	kg/Kl	10.40	load	kg/Kl	3.78
cost	R/Kl	**R -1.04**	cost	R/Kl	**R -0.15**
RESIN PROVISION			**RESIN PROVISION**		
Resin life	months	36	Resin life	months	36
Resin price	R/l	R 18	Resin price	R/l	R 54
Resin cost	R/Kl	**R -0.14**	Resin cost	R/Kl	**R -0.33**
COST PER STAGE	**R/Kl**	**R -12.13**	**TOTAL COST**	**R/Kl**	**R -5.35**
GP PER STAGE	**R/Kl**	**R -1.74**	**GP PER STAGE**	**R/Kl**	**R 0.40**
TOT VAR COST	**R/Kl**	**R -17.48**			

Finally, we include the fixed costs and can calculate the EBIT in Table 12. Note that a provision to replace the resin every 3 years is included in Table 11 above. It is important to note that this provision does not impact significantly on the total variable cost per kℓ of solution treated. At a resin life of 3 years this amounts to 2% of the total cost (variable and fixed) and at half the life (18 months) this increases to only 4% of the treatment cost. We expect a resin life in excess of 36 months for the mild operating conditions that would result from our proprietary IX-by-dilution treatment technology.

We have not made provision for any waste management costs that may arise during the operations of the proposed commercial IX plant for the following reasons:

1. We expect a relatively small quantity of solid waste to be generated when the sand filters are backwashed and these solids should be relatively innocuous and could be stored on existing solid waste facilities at Tutuka/New Denmark;
2. Once exhausted the organics captured on the granulated activated carbon (GAC) filters can be combusted with the GAC in the coal-fired zone of the evaporator system/s;
3. Disposal of spent resin is achieved by returning to the resin supplier.

The assumptions below take into account Earth’s experience in running similar plants and assume that Earth operates and maintains the proposed plant.

Table 12. Summary of EBIT calculation for the diluted brine stream simulation

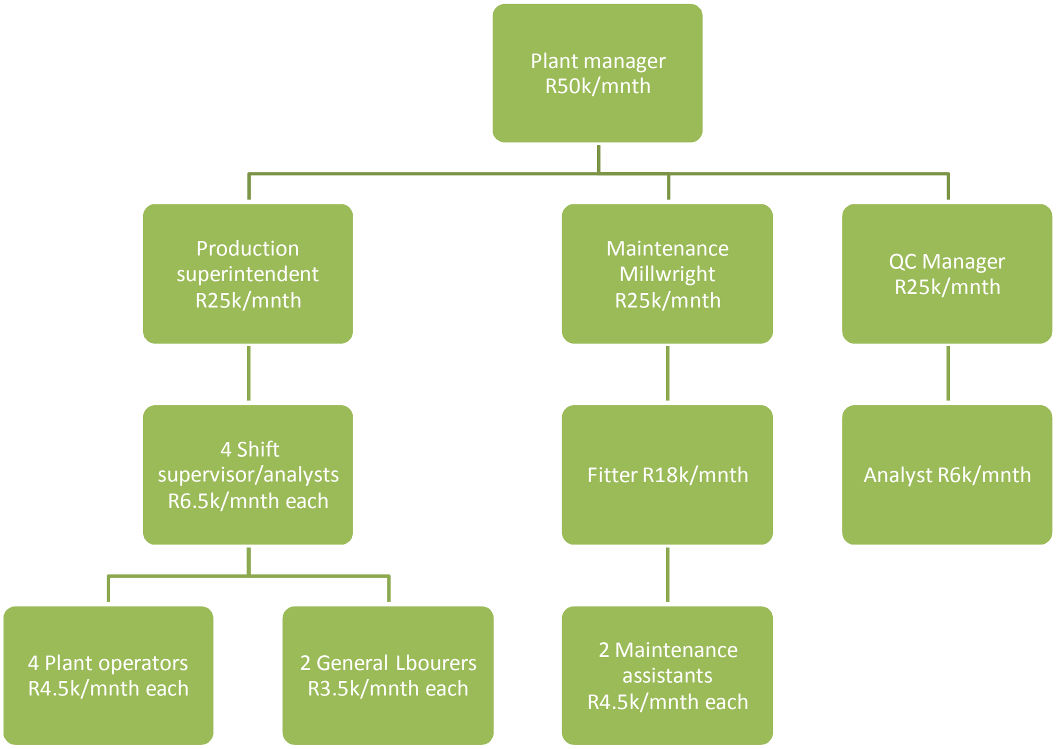
			Monthly
Admin and Accounting	R/Kl	R -0.03	R -15,000
Electricity	R/Kl	R -0.30	R -141,875
Fuel and Oil	R/Kl	R -0.10	R -55,625
Laboratory fees	R/Kl	R -0.07	R -30,000
Production Consumables	R/Kl	R -0.25	R -119,063
Repair and Maint	R/Kl	R -0.40	R -187,500
Statutory	R/Kl	R -0.01	R -6,000
Salary & Wages	R/Kl	R -0.44	R -200,000
Support fee	R/Kl	R -0.51	R -231,019
Travel and Accom	R/Kl	R -0.03	R -15,000
Water levy (DWAE)	R/Kl	R 0.00	R 0
TOTAL EXPENSES	**R/Kl**	**R -2.15**	**R -1,001,081**
EBIT per Kl through IX			
			Monthly
TOTAL EBIT	**R/Kl**	**R -3.48**	**R -1,589,844**
EBIT per Kl brine			
			Monthly
TOTAL EBIT	**R/Kl**	**R -52.27**	**R -1,589,844**
EBIT per Kl "raw" AMD			
			Monthly
TOTAL EBIT	**R/Kl**	**R -2.18**	**R -1,589,844**

Note that the above fixed costs are based on our practical experience obtained in designing, constructing and operating a stand-alone and similar-sized IX operation in the recent past. A high-level breakdown of these costs is provided below:

- **Admin and accounting** – a provision of R180k per annum is considered sufficient for both the regular monthly administration of the operation as well as the annual audit fees. This calculates to a monthly cost of R15k.
- **Electricity** – in part a factored variable cost based on the kW consumption per Kℓ treated against projected electricity costs. A small fixed overhead of R5k

(offices, laboratory and security) was added to finesse the calculated monthly cost.

- **Laboratory fees** – the monthly laboratory costs include R10k for the laboratory consumables and other chemical reagents required for operational control of the process. The balance of R20k is provided for access to external ICP analysis (Regen Waters, Witbank) to verify product qualities. The R30k does not include the cost of laboratory staff which is separately provided for under statutory, salary and wages. Our assumption is based on testing per 30 ton batch of product.
- **Production consumables** – provision is made all production-related consumables, e.g. filter cartridges replacement, spillage containment, cleaning and house-keeping, PPE, etc. A monthly budget of R15k per month was more than appropriate during 2007 and the R0.25 per kℓ used above was recently calibrated. A fixed overhead of R5k was added to the R0.25/kℓ variable component.
- **Repair and maintenance** – provision is made for plant maintenance on pumps, pneumatic valves and instrumentation (pH and conductivity probes). IX plants run with high mechanical availability (typical >99%) and are inexpensive to maintain. This is also a function of equipment selection and selected material to achieve optimal life cycles. A fixed overhead of R5k was added to the R0.40/ kℓ variable component.
- **Statutory, salary and wages** – these provisions are based on the following four-tiered organogram, with the monthly cost-to-company (CTC) shown with each position – ***note the exclusions below where these services are already covered.***
- **Support Fee** – this is effectively an operating margin to cover the overheads of Earth in providing support on O&M and is set at 30% of the fixed costs (for this specialist service).



The above structure is the minimum required to operate the plant as a stand-alone operation. This is highly dependent on the level of plant automation and the reliability of equipment from a maintenance support perspective.

All of the fixed costs reflected above for the Maintenance Millwright, QC Manager, Fitter and Analyst are assumed to be carried by the structures existing at Tutuka and ***are excluded from the Fixed Cost calculation***.

Also note that the EBIT number does not contain a license fee for Earth. Earth's preferred business model involves the mine or engineering partner covering all of the fixed and variable costs with industry-standard margins and an arrangement, *in* lieu of a license fee, where revenues from product sales are shared.

The total variable and fixed costs with margin is therefore R19.63 per kℓ of diluted brine or R12.27 per kℓ of AMD influent. This is an NPV over 20 years (to 2030) of –R673m. If we sell products however we derive revenues R10.09/kℓ AMD so that the NPV is actually –R120m, ***representing a saving of R553m for the client due to product sales. Note that these projected revenues ignore sales of water.***

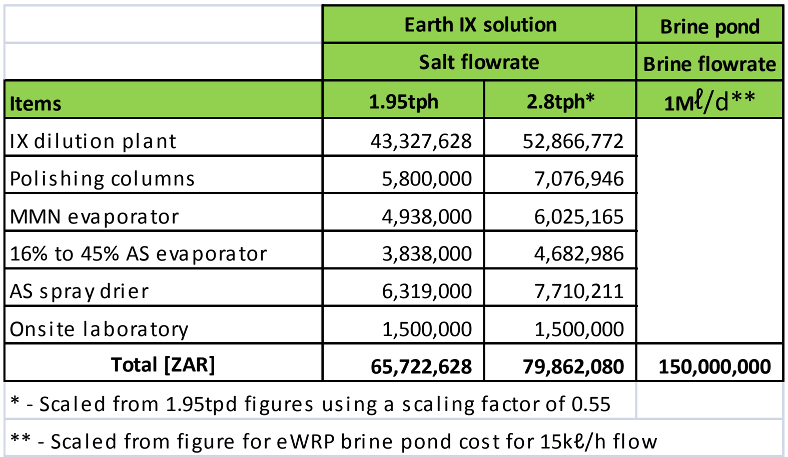
It is difficult accurately to obtain the economics for the process that includes a potassium nitrate step or assuming we supply product to CSP applications. However if we assume that we achieve just 20% more (net) for the cation product then the revenues increase to R11.39 per kℓ of AMD influent.

8.3 Capex

Keyplan has been contracted to develop capex estimates for a mooted plant. Appendices 10 and 11 contain copies of the PFD and P&IDs respectively.

The capital cost estimate is summarised in Table 13.

Table 13. Summary of capex estimate



	Earth IX solution		Brine pond
	Salt flowrate		Brine flowrate
Items	**1.95tph**	**2.8tph***	**1Mℓ/d****
IX dilution plant	43,327,628	52,866,772	
Polishing columns	5,800,000	7,076,946	
MMN evaporator	4,938,000	6,025,165	
16% to 45% AS evaporator	3,838,000	4,682,986	
AS spray drier	6,319,000	7,710,211	
Onsite laboratory	1,500,000	1,500,000	
Total [ZAR]	**65,722,628**	**79,862,080**	**150,000,000**

* - Scaled from 1.95tpd figures using a scaling factor of 0.55

** - Scaled from figure for eWRP brine pond cost for 15kℓ/h flow

The estimate above excludes the following costs:

The total capital costs are therefore expected to be (± 30%) R79.9m. The numbers for the evaporators and spray drier have been provided by John Bewsey at Trailblazer Technologies – Alan Sarkis from Keyplan has visited the company and reviewed the design. The onsite laboratory is similar to that found in the metallurgical industry and includes purchase of an ICP at a cost of R1,5m. However, if the brine composition is invariant this cost could be reduced to around R0.5m.

The estimated capex for a 25Ha brine pond is R150m and will have a lifespan at a brine flowrate of 1Mℓ/d of five years after which allowance has been made to cap the brine pond at 25% of the initial capex. It is assumed that each brine pond will be constructed five years after the preceding brine pond and that capital costs will be amortised over 12 years at an interest rate of 10% per annum. The proposed IX brine treatment solution at the peak TDS (55,700ppm) and flowrate of 1Mℓ/d is R79.9m producing SANS 241 Class 1 quality water. *It should be noted that the influent mass flow of salts (obtained from Keyplan) is around 2.8 tons per hour at both the current flowrate of 3Mℓ/d and the projected flowrate of 1Mℓ/d once the second stage RO plant is implemented.* Thus the capex from brine treatment is independent of whether the brine is further concentrated or not. The conclusion is that ***the lifecycle costs to install Earth's IX solution are cheaper than brine ponds*** (see Table 14)**,** even ignoring the improved economics of further process optimisation which we are confident of.

Table 14. Summary of lifecycle costs for Tutuka with brine ponds or with the Earth IX process for 1Mℓ/d brine stream at TDS = 55,700ppm (discount rate = 15%)

Solution	NPV to 2030
Brine ponds	-R262m
IX solution	**-R182m**

9 Further optimisation

We have made significant progress and confirmed substantially what the bench-work carried out last year had suggested in terms of our ability to process AMD brines from RO. Our market evaluation has also shown that we can sell our anion product without separating out the chloride content. The steady state trials that we have run have provided capital and operating costs supported by empirical data on the products and by Keyplan's inputs.

There are a range of other approaches that we believe have great promise, when optimized and applied together, to tip the balance to a net cash generative business model. These include but are not limited to the following:

- Split mixed-metal nitrates into mono and multi-valent salts in order to:
    1. Sell the "cal-mag nitrate" for R3,000 per ton
    2. Convert the sodium-potassium nitrate to potassium nitrate and sodium chloride; and
    3. Sell potassium nitrate for R9,000 per ton
- Split sulfate and chlorides in order to:
    1. Sell high grade ammonium sulfate for R2,400 per ton
    2. Produce potassium chloride as an input for the conversion of sodium nitrate to potassium nitrate
- More of the fixed costs used in our EBIT calculations will be carried by the existing cost-structures at Tutuka Power Station.

There are other potential areas for optimisation that would be enabled by longer-term testing including further concentration of products etc.

Finally, there is good reason to carry out longer-term trial work to minimize possible down-side risks. For example, we are now confident that the anti-scalant used in the RO process has no short-term effects on the ion exchange resin however possible long-term effects need to be established. We believe that the activated carbon filters included in our design will remove the anti-scalant effectively however this needs to be tested in long term testing. We propose to check organic carbon pre- and post GAC filters to verify this.

10 Options moving forward

The current study is effectively a pre-feasibility study. Usually, the intention of such a study is to set out a range of options with ±30% certainty and recommend a single way forward to progress to full feasibility studies based on demonstration scale operations.

The next decision involves the requirement for a Demonstration Project. We believe that the concerns related to resin degeneration etc have substantially been mitigated by the length of our pilot trials going back to April 2009.

11 Recommendations and next steps

The recommendations provided here are a summary, not of Earth's own views alone, but consist partly of the outputs of the Coaltech Surface Environmental Meeting held at Earth's premises on the 16th March 2010.

They include the following and reflect the positive results to date:

- That some further work be done on disposal of resins (i.e. the residual effluent);
- That Earth provide a proposal for a demonstration-scale plant;
- That there is ongoing work to establish markets for the proposed products.

12 Appendices

Appendix 1 – Data sheet for cation IX during steady state trial on Tutuka brine

Table 15. Data for cation IX during the steady state trial on brine

	Column 1			Column 2			Column 3			Column 4		
Time	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]
	Plant started on Tuesday, 13th March at 8:45											
8:45	6.43		4.2	4.63		4.1	0.62	0.89	9			
9:00				5.78		4.2	0.65		9	0.65	0.89	9
9:15				5.91		4.3	0.66		8.9	0.63	0.89	9
9:30				6.17		4.2	0.67		8.9	0.61	0.89	8.9
9:45				6.28		4.2	0.69		8.6	0.66	0.89	8.7
10:00				6.18		4.1	0.71		8.4	0.67	0.96	8.7
10:15				6.23		4.1	0.85		7	0.68	0.91	8.8
10:30				6.33		4.2	1.01		6	0.67	0.9	8.6
10:45				6.29		4.2	1.57		4.7	0.63	0.89	7.8
11:00				6.33		4.2	4.08		4.5	0.68	0.89	89.8
11:15	0.59	0.85	9				5.86		4.2	0.65		8.8
11:30	0.58	0.85	9.1				5.95		4.2	0.63		8.9
11:45	0.6	0.84	9				6.03		4.2	0.65		8.8
12:00	0.61	0.84	8.9				6.15		4.2	0.66		8.9
12:15	0.61	0.83	9				6.21		4.3	0.66		9.1
12:30	0.63	0.82	8.9				6.18		4.3	0.67		8.8
12:45	0.63	0.82	8.9				6.27		4.3	0.7		8.5
13:00	0.63	0.81	9.1				6.37		4.3	1.02		6.2
13:15	0.63	0.81	9				6.44		4.3	1.46		4.9

13:30	0.64	0.81	9.2				6.46		5.4	4.28		56.3
13:45	0.63		8.9	0.55	0.78	9.1				5.93		4.3
14:00	0.62		8.9	0.56	0.77	9.4				6.08		4.4
14:15	0.63		8.9	0.56	0.77	9.4				6.18		4.4
14:30	0.67		8.8	0.58	0.76	9.3				6.33		4.4
14:45	0.66		8.8	0.58	0.76	9.2				6.47		4.4
15:00	0.8		7.3	0.57	0.76	9.2				6.39		4.4
15:15	1.38		5.4	0.59	0.75	9.3				6.41		4.3
15:30	2.58		4.3	0.6	0.75	9.2				6.39		4.4
15:45	4.93		4.4	0.6	0.75	9.2				6.43		4.3
16:00	5.84		4.4	0.61		9	0.49	0.67	11.1			
16:15	5.98		4.4	0.53		9.3	0.52	0.73	9.3			
16:30	6.08		3.7	0.56		9.3	0.55	0.73	9.4			
16:45	6.04		3.6	0.66		7.8	0.62	0.81	0.9			
17:00	6.15		3.5	0.67		7.5	0.63	0.73	7.6			
17:15	6.18		3.4	0.7		7.1	0.66	0.84	7.1			
17:30	6.1		3.3	0.75		6.8	0.68	0.85	7.1			
17:45	6.11		3.3	0.9		5.4	0.7	0.88	6.6			
18:00	6.11		3.3	1.16		4.6	0.7	0.87	6.9			
18:15				1.5		4	0.71	0.87	6.6			
18:30				1.89		3.5	0.74		6.5	0.7	0.86	7
18:45				5.31		3.3	0.83		6.2	0.72	0.87	6.9
19:00				5.4		3.2	0.81		6.2	0.72	0.87	6.5
19:15				5.47		3.4	0.68		6.5	0.67	0.85	7.2
19:30				6.27		3.2	0.77		6.7	0.75	0.84	7.4
19:45				6.32		3.3	0.76		7	0.71	0.82	7.7
20:00				6.25		3.6	0.73		7.5	0.69	0.82	7.6

20:15				6.2		3.6	0.75		7.5	0.68	0.83	7.6
20:30				6.19		3.6	0.73		7.5	0.67	0.83	7.6
20:45				6.25		3.4	0.77		6.5	0.67	0.83	7.8
21:00				6.23		3.4	1.06		5.5	0.69	0.81	7.6
21:15				6.24		3.4	1.38		4.5	0.72	0.82	7.6
21:30				6.26		3.6	1.57		4.2	0.75	0.82	7.5
21:45	0.64	0.82	7.8				4.88		3.4	0.7		7.9
22:00	0.62	0.82	7.8				5.13		3.4	0.72		7.9
22:15	0.65	0.82	8.1				5.76		3.5	0.69		8
22:30	0.65	0.82	8.1				5.83		3.5	0.7		8
22:45	0.6	0.81	8.1				5.95		3.8	0.67		8.2
23:00	0.63	0.81	8.1				6.01		3.9	0.7		8.2
23:15	0.64	0.81	8				6.13		3.7	0.74		8.4
23:30	0.63	0.82	7.9				6.21		3.5	0.73		8.3
23:45	0.63	0.82	8.3				6.3		3.7	0.83		6.4
0:00	0.67	0.83	8.1				7.29		3.6	1.25		4.8
0:15	0.69	0.83	7.9				7.34		3.3	1.59		4
0:30	0.74		7.7	0.7	0.84	8.5				4.9		3.4
0:45	0.73		8.1	0.67	0.85	8.2				5.5		3.9
1:00	0.72		0.5	0.66	0.86	8.2				5.68		4
1:15	0.71		8	0.66	0.86	8.4				5.72		3.5
1:30	0.74		7.9	0.67	0.86	8.1				5.79		3.4
1:45	0.72		7.4	0.66	0.87	8.1				5.62		3.4
2:00	0.7		7.8	0.66	0.87	8.6				5.84		3.7
2:15	0.78		7.7	0.66	0.87	8.7				5.94		3.5
2:30	1.23		4.9	0.7	0.87	8.1				5.88		3.7
2:45	1.57		4.5	0.71	0.87	7.3				6.41		3.9

3:00	4.3		3.8	0.66		8.3	0.64	0.86	8.1			
3:15	5.19		3.8	0.7		7.6	0.64	0.87	8.3			
3:30	0.21		3.6	0.7		7.4	0.65	0.88	8.3			
3:45	5.79		3.7	0.67		7.5	0.63	0.89	8.4			
4:00	5.87		3.7	0.68		7.5	0.64	0.88	8.4			
4:15	5.99		3.6	0.69		7.9	0.64	0.878	8.6			
4:30	5.98		4.1	0.68		8.1	0.63	0.88	7.7			
4:45	5.84		3.8	0.88		6	0.63	0.88	8.3			
5:00	5.92		3.8	1.35		4.9	0.62	0.89	8.3			
5:15	5.95		3.8	1.59		4.2	0.64	0.89	8.3			
5:30				5.2		3.9	0.68		7.8	0.62	0.89	8.2
5:45				5.33		4	0.69		7.9	0.6	0.89	8.3
6:00				5.33		3.9	0.71		8.1	0.64	0.9	8.5
6:15				5.88		4	0.66		8.4	0.61	0.9	8.6
6:30				6.01		4.2	0.68		8.6	0.61	0.9	8.8
6:45				6.01		4	0.7		8.5	0.63	0.9	8.3
7:00				6.1		4	0.75		7.6	0.65	0.9	8.5
7:15				6.13		4.1	0.96		6.87	0.65	0.91	8.5
7:30	0.6	0.82	9.2				1.53		4.9	0.65		8.6
7:45	0.63	0.9	8.7				1.83		4.3	0.66		9.1
8:00	0.63	0.91	8.5				5.9		4.1	0.61		8.8
8:15	0.65	0.91	8.5				6.2		4.1	0.66		8.7
8:30	0.63	0.92	8.8				6.18		4.1	0.65		8.8
8:45	0.62	0.92	8.8				6.3		4.1	0.66		8.6
9:00	0.63	0.93	8.7				6.37		4.1	0.67		8.7
9:15	0.63	0.92	8.7				6.35		4.1	0.67		8.8
9:30	0.963	0.92	8.3				6.46			0.67		8.5

9:45	0.64	0.91	8.3				6.32		4.1	0.68		8
10:00	0.68	0.9	8.6				6.47		4.1	0.71		7.9
10:15	0.64		8.6	0.6	0.88	8.6				1.27		4.6
10:30	0.67		8.5	0.62	0.87	8.8				1.45		4.1
10:45	0.67		8.6	0.61	0.87	8.8				5.22		4.2
11:00	0.67		8.6	0.62	0.86	8.8				5.81		4.1
11:15	0.64		8.6	0.61	0.84	8.9				5.99		4
11:30	0.64		8.6	0.6	0.84	9				6.02		1
11:45	0.64		6.9	0.58	0.83	8.7				6.22		4.2
12:00	0.85		7.2	0.62	0.83	8.5				6.24		4.3
12:15	1.15		4.4	0.62	0.83	8.7				6.32		4.5
12:30	1.59		4.1	0.62	0.82	8.7				6.28		4.2
12:45	5.51		4.1	0.57		8.9	0.55	0.81	9	6.24		4.2
13:00	5.68		4.1	0.6		8.6	0.59	0.81	8.3	6.3		4.2
13:15	5.7		4.1	0.62		8.6	0.58	0.81	8.3			
13:30	5.8		4.1	0.61		8.8	0.57	0.8	8.7			
13:45	6.18		4.2	0.61		8.6	0.57	0.79	8.6			
14:00	6.21		4.3	0.62		8.6	0.58	0.78	8.7			
14:15	6.29		4.2	0.65		8.2	0.57	0.78	8.8			
14:30	6.31		4.2	0.98		6	0.59	0.78	8.8			
14:45	6.4		4.2	1.22		5.3	0.58	0.76	9			
15:00	6.39		4.3	1.6		4.8	0.58	0.77	9.1			
15:15				5.63		4.2	0.62		8.4	0.57	0.74	9
15:30				5.94		4.2	0.58		8.8	0.56	0.74	9.6
15:45				6.01		4.2	0.58		8.8	0.57	0.74	9.6
16:00				6.18		4.2	0.57		8.8	0.57	0.73	9.6
16:15				6.2		4.2	0.58		8.7	0.57	0.72	9.2

16:30				6.18		4.2	0.6		8.6	0.53	0.72	8.8
16:45				6.29		4.2	0.67		8.6	0.55	0.72	8.8
17:00				6.37		4.2	0.7		8.6	0.72	0.72	8.8
17:15				6.57		4	1.49		4.8	0.73	0.73	8.8
17:30	0.56	0.69	9.2				5.6		4.3	0.56		9.2
17:45	0.53	0.7	9.2				5.96		4.3	0.56		9.1
18:00	0.54	0.71	9.2				6.03		4.3	0.58		9.1
18:15	0.57	0.71	8.3				6.1		4.3	0.58		8.5
18:30	0.58	0.73	8.8				6.13		3.9	0.63		7.89
18:45	0.62	0.73	8.4				6.15		3.9	0.78		6.69
19:00	0.66	0.73	8.2				6.85		4.1	0.96		5.7
19:15	0.68	0.74	8.2				7.14		4	1.44		4.6
19:30	0.68	0.74	8				7.21		3.9	1.6		4.4
19:45	0.66		7.7	0.59	0.73	8.7				5.94		3.9
20:00	0.65		7.7	0.58	0.73	8.7				5.96		3.9
20:15	0.69		8.5	0.63	0.73	8.7				6.68		4
20:30	0.68		8.6	0.62	0.74	9				6.2		4.2
20:45	0.68		8.3	0.62	0.74	8.9				6.24		4
21:00	0.91		6	0.65	0.75	8				6.32		3.9
21:15	1.26		5.2	0.65	0.76	7.8				6.2		4
21:30	1.61		4.9	0.65	0.76	7.4				6.24		3.9
21:45	4.89		3.6	0.65		8	0.62	0.77	8.7			
22:00	5.2		3.6	0.65		8	0.6	0.79	8.7			
22:15	5.33		3.6	0.64		8	0.58	0.79	8.7			
22:30	5.5		3.7	0.64		7.8	0.59	0.79	8.8			
Plant stopped at 22:35, start at 23:04, Backwash valve broke												

23:15	5.61		3.9	0.85		7.1	0.62	0.8	8.8			
23:30	5.67		3.8	0.86		7.3	0.65	0.81	8.4			
23:45	5.86		4	1.07		5.6	0.64	0.82	8.3			
0:00	6.04		3.9	1.24		5.5	0.64	0.83	8.4			
0:15	6.21		3.7	1.65		4.9	0.67	0.84	8.1			
0:30				5.09		4.1	0.71		9	0.38	0.85	9.5
0:45				5.16		4.1	0.7		9	0.66	0.86	9.5
1:00				5.22		4.1	0.7		9.1	0.65	0.87	9.5
1:15				5.47		4	0.7		7.9	0.65	0.88	8.9
1:30				5.52		3.9	0.7		7.5	0.65	0.89	8.5
1:45				5.62		3.4	0.7		7.8	0.65	0.9	8.9
2:00				5.69		3.9	0.96		6	0.68	0.91	8.1
2:15				5.75		4	1.38		4.2	0.68	0.91	8.5
2:30				5.82		3.9	1.69		3.9	0.68	0.91	8.3
2:45	0.6	0.92	9.2				5.82		3.9	0.69		8.2
3:00	0.6	0.94	9				5.87		3.7	0.69		8
3:15	0.62	0.95	8.9				5.94		3.9	0.65		8
3:30	0.62	0.96	8.9				6.03		3.7	0.69		7.9
3:45	0.64	0.97	8.7				5.77		3.8	0.7		7.6
4:00	0.64	0.97	8.7				5.98		3.8	0.7		7.6
4:15	0.64	0.99	8.8				6.12		3.9	0.99		6.2
4:30	0.64	1	8.7				6.04		3.5	1.29		5
4:45	0.66	1.01	8.5				6.21		3.2	1.52		4.7
5:00	0.72		7.9	0.65	0.99	8.56				5.2		3.8
5:15	0.7		7.8	0.65	1	8.4				5.24		3.9
5:30	0.75		7.8	0.68	1	8.4				5.47		3.7
5:45	0.77		7.5	0.68	1.01	8.3				5.52		3.5

6:00	0.76		7.5	0.66	1.03	8.3				5.68		3.5
6:15	0.76		7.6	0.68	1.04	7.9				5.98		3.7
6:30	0.9		7.2	0.68	1.04	7.8				6.18		3.7
6:45	1.43		4.5	0.77	1.05	7.4				6.32		3.7
7:00	2.39		3.7	0.71		8	0.65	1	8.6			
7:15	5.76		3.7	0.73		7.8	0.68	1.04	7.9			
7:30	5.99		3.8	0.75		7.8	0.68	1.03	7.8			
7:45	6.08		3.9	0.69		8.1	0.69	1.03	8			
8:00	6.1		3.8	0.7		8.1	0.69	1.03	7.9			
8:15	6.29		63.8	0.72		8.1	0.68	1.02	8.1			
8:30	6.34		3.8	0.73		7.9	0.69	1.02	8			
8:45	6.33		3.9	0.76		7.4	0.68	1.02	7.9			
9:00	6.43		3.9	1		5.8	0.64	1	8.1			
9:15	6.39		3.9	1.5		4.3	0.65	0.98	8.1			
9:30				5.28		4	0.61		8.3	0.61	0.95	8.5
9:45				4.86		4.1	0.64		8.4	0.62	0.95	8.5
10:00				5.56		4	0.69		8.4	0.62	0.92	8.9
10:15				5.72		4	0.67		8.4	0.62	0.91	8.9
10:30				5.79		4	0.69		8.4	0.61	0.89	8.9
10:45				5.94		4.1	0.68		8.4	0.61	0.88	8.5
11:00				6.24		4.1	0.69		8.3	0.6	0.87	8.5
11:15				6.37		4	0.83		8.3	0.69	0.87	8.5
11:30				6.4		4	1.49		8.3	0.61	0.87	8.4
11:45	0.53	0.82	8.1				2.33		4.4	0.6		8.4
12:00	0.53	0.82	8.3				5.74		4	0.57		8.7
12:15	0.55	0.82	8.6				5.92		4.1	0.59		8.7
12:30	0.56	0.81	8.6				6.02		4.1	0.57		8.7

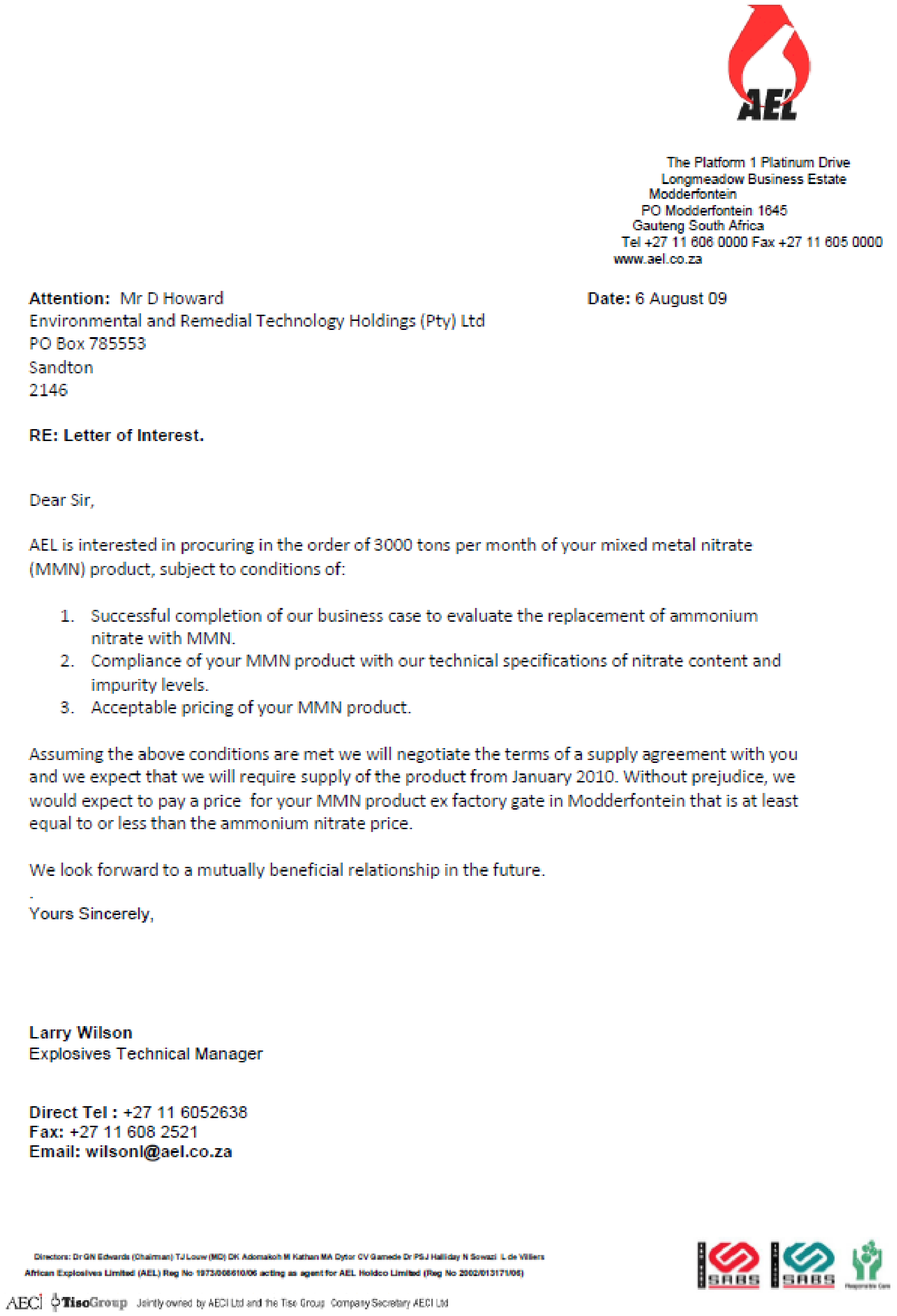
12:45	0.57	0.8	8.8				6.08		4.2	0.6		8.2
13:00	0.62	0.8	8.6				6.13		4.2	0.74		8.2
13:15	0.58	0.79	8.9				6.18		4.1	0.69		8.3
13:30	0.59	0.78	8.9				6.26		4.2	0.84		6.6
13:45	0.6	0.78	8.8				6.28		4.3	1.48		5
14:00	0.64		8.8	0.57	0.79	9.1				5.22		4.2
14:15	0.64		8.8	0.55	0.75	8.9				5.47		4.2
14:30	0.62		8.5	0.56	0.75	9.4				5.69		4.4
14:45	0.62		8.5	0.56	0.75	9				5.91		4.4
15:00	0.63		8.3	0.57	0.75	9.3				5.98		4.1
15:15	0.63		8.4	0.59	0.75	9.5				6.1		4.1
15:30	0.7		7.7	0.58	0.74	9				6.13		4.2
15:45	1		5	1	1	9				6		4
16:00	1.59		5.8	0.59	0.74	9				6.33		4
16:15	5.48		4.2	0.58		9	0.54	0.73	9			
16:30	5.53		4.4	0.63		9.1	0.56	0.73	9.1			
16:45	5.59		4.4	0.6		9.1	0.56	0.73	9.1			
17:00	5.65		4.3	0.6		8.8	0.54	0.73	9			
17:15	5.7		4.3	0.66		8.7	0.59	0.73	9			
17:30	5.81		4.2	0.65		8	0.56	0.73	8.9			
17:45	6.03		4.2	0.9		7.3	0.57	0.73	8.1			
18:00	6.04		4.2	1.52		4.7	0.64	7.1	8.1			
18:15				2.72		4.3	0.6		8.6	0.58	0.72	8.9
18:30				5.22		4.2	0.6		8.5	0.57	0.73	9.1
18:45				5.42		47.2	0.61		8	0.59	0.73	9
19:00				6.2		0.9	0.69		9	0.64	0.73	9.1
19:15				6.28		3.9	0.66		8.1	0.64	0.74	9

19:30				6.31		3.7	0.67		8	0.64	0.74	8.9
19:45				5.92		3.9	0.72		7.7	0.64	0.75	8.7
20:00				6.27		3.6	1.2		4.9	0.64	0.76	8.1
20:15				6.31		3.6	1.63		4.5	0.65	0.76	8
20:30	0.59	0.77	8.2				5.36		3.7	0.63		7.6
20:45	0.57	0.78	8.4				5.63		4	0.64		8
21:00	0.58	0.79	8.5				5.6		4.1	0.65		8.7
21:15	0.6	0.79	8.7				5.73		4.1	0.64		7.87
21:30	0.6	0.8	8.7				5.7		4.1	0.64		7.8
21:45	0.61	0.81	8.7				5.81		3.8	0.65		7.6
22:00	0.62	0.82	7.9				5.95		3.7	0.84		6.4
22:15	0.65	0.83	7.9				6.11		3.9	1.04		5.4
22:30	0.66	0.85	7.5				6.24		3.5	1.589		4.5
22:45	0.71		7	0.66	0.86	8.1				2.81		3.7
23:00	0.72		7.1	0.66	0.88	7.8				5.12		3.5
23:15	0.71		7.1	0.64	0.88	7.8				5.22		3.5
23:30	0.71		7	0.64	0.9	7.6				5.27		3.4
23:45	0.73		6.8	0.66	0.9	7				5.5		3.6
0:00	0.78		6.8	0.73	0.9	7.6				6.04		3.7
0:15	0.79		6.9	0.72	0.9	7.9				5.94		3.6
0:30	0.88		6	0.72	0.91	7.5				6.09		3.5
0:45	1.24		4.4	0.79	0.92	7.3				6.21		3.5
1:00	1.58		4.2	0.82	0.92	7				6.27		3.1
1:15	5.21		3.5	7.1		6.7	0.66	0.93	7.6			
1:30	5.37		3.5	7.3		6.4	0.66	0.93	7.7			
1:45	5.84		3.7	7		7	0.67	0.92	7.9			
2:00	5.91		3.7	7		7	0.67	0.91	8			

2:15	6.01		3.6	7.1		7.2	0.66	0.9	8			
2:30	5.94		3.8	7		7.5	0.66	0.9	8.2			
2:45	6.01		3.4	7.1		7.5	0.66	0.89	8.1			
3:00	5.68		3.9	1.2		4.8	0.67	0.88	7.9			
3:15	5.71		3.5	1.58		3.9	0.69	0.88	6.9			
3:30				5.27		4	0.68		8.1	0.63	0.88	8.5
3:45				5.34		3.9	0.69		7.8	0.63	0.89	8.4
4:00				5.43		3.8	0.7		78.7	0.63	0.89	8.3
4:15				5.57		3.9	0.69		7.7	0.63	0.89	8.3
4:30				5.7		3.9	0.69		8.3	0.63	0.89	8.6
4:45				5.81		3.9	0.69		8.1	0.63	0.89	8.4
5:00				5.87		3.9	0.93		7.6	0.65	0.89	8.2
5:15				5.79		3.9	1.25		6	0.64	0.89	7.9
5:30				5.82		3.7	1.55		5.1	0.66	0.89	7.4
5:45				6.1		3.5	5.17		4.7	0.66	0.89	7
6:00	0.58	0.85	9.1				5.25		4	0.67		8.6
6:15	0.59	0.86	9				5.29		4.2	0.61		8.5
6:30	0.58	0.86	9				5.4		4.2	0.6		8.5
6:45	0.64	0.87	7.8				5.98		4.2	0.63		8.5
7:00	0.6	0.88	8				6.13		4	0.65		8.7
7:15	0.61	0.88	8				6.28		4	0.65		8.8
7:30	0.62	0.91	8.8				6.34		4.2	0.8		6.8
7:45	0.62	0.93	8.8				6.3		4.2	0.99		6
8:00	0.64		8.2				6.3		4.2	1.62		6.4
8:15	0.67		8.2	0.63	0.89	8.3				4.99		4
8:30				0.6	0.88	8.7				5.81		4.1
8:45				0.6	0.88	8.6				5.9		4.1

Plant stopped at 08:45

Appendix 2 – Letter from African Explosives Limited



AEL

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Tel +27 11 606 0000 Fax +27 11 605 0000
www.ael.co.za

Attention: Mr D Howard
Environmental and Remedial Technology Holdings (Pty) Ltd
PO Box 785553
Sandton
2146

Date: 6 August 09

RE: Letter of Interest.

Dear Sir,

AEL is interested in procuring in the order of 3000 tons per month of your mixed metal nitrate (MMN) product, subject to conditions of:

1. Successful completion of our business case to evaluate the replacement of ammonium nitrate with MMN.
2. Compliance of your MMN product with our technical specifications of nitrate content and impurity levels.
3. Acceptable pricing of your MMN product.

Assuming the above conditions are met we will negotiate the terms of a supply agreement with you and we expect that we will require supply of the product from January 2010. Without prejudice, we would expect to pay a price for your MMN product ex factory gate in Modderfontein that is at least equal to or less than the ammonium nitrate price.

We look forward to a mutually beneficial relationship in the future.

Yours Sincerely,

Larry Wilson
Explosives Technical Manager

Direct Tel : +27 11 6052638
Fax: +27 11 608 2521
Email: wilsonl@ael.co.za

Directors: Dr GN Edwards (Chairman) TJ Louw (MD) DK Adomakoh M Kathan MA Dytor CV Gamede Dr PSJ Halliday N Sowazi L de Villiers
African Explosives Limited (AEL) Reg No 1973/008610/06 acting as agent for AEL Holdco Limited (Reg No 2002/013171/06)

AECI TisoGroup Jointly owned by AECI Ltd and the Tiso Group Company Secretary AECI Ltd

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Appendix 3 – Data sheet for anion IX during steady state trial on Tutuka brine

Table 16. Data for anion IX during the steady state trial on brine

		Column 1			Column 2			Column 3			Column 4		
Time	TDS INLINE METER	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]	pH	pH In-line meter	Conductivity [ms]
PLANT STARTED AT 08:45 MONDAY, 13th March 2010													
8:45	512				1.22	2400	0.4	6.25	480	1.7	6.75	480	1.7
9:00	512				1.07	3000	5.1	6.23	480	1.7	7.1	480	1.7
9:15	513				0.84	3500	6.3	6.57	480	1.7	6.85	480	1.7
9:30	513				0.71	5000	7.5	6.64	480	1.7	6.92	480	1.7
9:45	511				0.67	>5000	8.1	6.6	480	1.8	6.58	480	1.7
10:00	509				0.65	>5000	8.1	6.58	480	1.8	6.56	480	1.7
10:15	508				0.57	>5000	9	6.26	480	1.8	6.8	480	1.7
10:30	Plant stopped at 10:30 - 13:40, to increase anionic feed buffer												
10:45													
11:00													
11:15													
11:30													
11:45													
12:00													
12:15													
12:30													

12:45													
13:00													
13:15													
13:30													
13:45	525				0.49	>5000	9.7	5.16	800	2	6.31	490	1.8
14:00	618	7.62	800	1.8				5.22	800	1.8	5.63	800	1.8
14:15	547	6.98	800	1.8				5.21	800	1 .8	5.6	800	1.8
14:30	547	6.85	800	1.8				5.23	1100	1.8	5.62	800	1.8
14:45	546	6.78	800	1.8				1.43	1800	3.2	6.02	800	1.8
15:00	546	6.61	800	1.8				1.32	2800	3.8	6.14	800	1.8
15:15	546	5.84	800	1.8				0.81	4000	6.7	6.2	800	1.8
15:30	546	5.73	800	1.8				0.76	4200	6.8	6.18	800	1.8
15:45		6.75	800	1.8				0.65	>5000	8.3	6.13	800	1.8
16:00		6.69	900	1.8				0.55	>5000	8.6	6.04	1000	1.8
16:15	Blow Down to sink Columns quality problem												
16:30													
16:45													
17:00	545	6.11	800	1.8	7.73	800	1.8				5.98	800	1.8
17:15	Blow Down testing columns, quality problem												
17:30													
17:45	527	6.32	490	1.8	7.36	490	1.8				1.4	1700	3.12
18:00	527	6.31	490	1.8	7.24	480	1.8				1.13	2000	4.1
18:15	525	6.26	500	1.8	7.2	480	1.8				1.05	4100	6.9
18:30	528	6.23	500	1.8	7.16	490	1.8				0.79	5000	6.6
18:45	528	6.2	500	1.8	7.01	500	1.8				7.4	>5000	6.7
19:00	528	6.18	500	1.8	6.765	500	1.8				7.3	>5000	6.7
19:15	528	6.09	500	1.8	6.74	500	1.8				7	>5000	6.7

19:30	531	6	500	1.8	6.7	500	1.8				6.63	>5000	6.7
19:45	532	5.95	500	1.8	6.68	500	1.8				6.6	>5000	6.4
20:00	532	5.91	500	1.8	6.63	500	1.8				6.56	>5000	6.5
20:15	463	5.86	8500	1.8	6.6	430	1.8				6.53	>5000	8.4
20:30	473	5.8	1000	1.8	6.56	430	1.8				6.5	>5000	8.4
20:45	492	1.28	3900	4.1	6.44	430	1.6	7.66	430	1.6			
21:00	466	1.24	4500	4.1	6.41	430	1.6	7.64	430	1.6			
21:15	465	1.2	>5000	4.1	6.37	430	1.6	7.6	430	1.6			
21:30	466	1.06	>5000	6.3	6.32	430	1.8	7.56	430	1.6			
21:45	467	0.97	>5000	6.7	6.32	430	1.8	7.54	430	1.6			
22:00	465	0.94	>5000	6.7	6.3	430	1.8	7.51	430	1.7			
22:15	465	0.91	>5000	6.7	6.24	430	1.8	7.46	430	1.8			
22:30	460	0.87	>5000	6.7	6.21	430	1.8	7.42	430	1.8			
22:45	461	0.84	>5000	6.7	6.17	430	1.8	4.4	430	1.8			
23:00	461	0.82	>5000	8.4	6.09	430	1.8	7.26	430	1.8			
23:15	462	0.8	>5000	8.4	6.02	430	1.8	7.24	430	1.8			
23:30	515				1.35	1100	3.2	6.94	430	1.8	7.44	420	1.6
23:45	463				1.32	2100	4.7	6.91	430	1.6	7.41	430	1.6
0:00	464				1.3	3500	4.7	4.83	430	1.7	7.37	430	1.6
0:15	464				1.09	4700	6.7	40.78	430	1.7	7.3	430	1.6
0:30	468				0.98	>5000	6.7	4.73	430	1.7	7.25	430	1.6
0:45	468				0.96	>5000	6.7	4.7	430	1.7	7.2	430	1.6
1:00	468				0.93	>5000	6.3	4.66	430	1.7	7.14	430	1.6
1:15	467				0.9	>5000	6.3	5.28	430	1.7	7.06	430	1.7
1:30	466				0.86	>5000	6.3	5.22	430	1.8	7	430	1.7
1:45	456				0.83	>5000	6.4	5.2	430	1.8	6.76	430	1.7
2:00	458				0.54	>5000	8.4	5.17	1500	1.8	6.7	430	1.8

2:15	482	7.54	500	1.7				1.66	2600	4.2	6.87	420	1.6
2:30	482	7.52	470	1.7				1.52	2800	4.8	6.83	420	1.6
2:45	454	7.5	450	1.7				1.44	4500	4.8	6.8	420	1.6
3:00	456	7.48	420	1.8				1.37	>5000	4.8	6.76	420	1.6
3:15	453	7.42	420	1.8				1.22	>5000	4.8	6.73	420	1.6
3:30	452	7.36	420	1.8				1.16	>5000	4.8	6.7	420	1.6
3:45	463	7.3	420	1.8				1.08	>5000	4.8	6.66	420	1.7
4:00	463	7.39	420	1.8				1.1	>5000	4.9	6.67	420	1.7
4:15	470	7.44	420	1.8				1.11	>5000	4.6	6.74	1400	1.7
4:30	486	7.4	440	1.7	7.52	440	1.6				6.89	2000	1.7
4:45	469	7.34	440	1.7	7.5	440	1.6				6.77	3200	4.6
5:00	388	7.3	430	1.7	7.423	440	1.6				5.06	4000	4.6
5:15	480	7.24	440	1.7	7.4	440	1.6				1.32	4500	4.6
5:30	490	7.21	440	1.7	7.36	440	1.7				1.24	4000	3.3
5:45	491	7.44	440	1.7	7.31	440	1.7				1.2	4000	3.4
6:00	492	7.28	440	1.8	7.39	450	1.6				0.84	5000	6
6:15	489	6.78	450	1.7	7.26	450	1.6				0.75	>5000	6.6
6:30	492	6.62	450	1.7	7.18	450	1.6				0.69	>5000	8.8
6:45	496	6.38	450	1.7	7.05	450	1.7				0.66	>5000	9
7:00	482	6.24	440	1.6	7.02	440	1.6				0.65	>5000	9.3
7:15	478	6.18	440	1.6	6.97	440	1.6				0.62	>5000	9.3
7:30	477	6.13	440	1.6	6.75	440	1.6				0.59	>5000	9.8
7:45	472	6.07	440	1.6	6.67	440	1.6				0.56	>5000	9.9
8:00	506	5.97	460	1.8	6.67	460	1.8				0.54	>5000	9.9
8:15	506	5.62	470	1.8	6.62	470	1.8				0.52	>5000	9.9
8:30	504	3.56	1000	2.2	6.57	480	1.8				0.48	>5000	9.9
8:45	411	1.3	1700	3.6	6.2	460	1.7	7.52	470	1.7			

9:00	498	1.04	3000	4.9	6.28	470	1.8	7.28	470	1.8			
9:15	505	0.92	3500	5.2	6.17	470	1.8	7.22	440	1.7			
9:30	516	0.78	5000	7.5	5.84	470	1.7	5.89	470	1.6			
9:45	513	0.64	>5000	8.7	5.84	470	1.7	5.85	410	1.6			
10:00	501	0.6	>5000	8.9	5.79	470	1.7	5.82	410	1.6			
10:15	494	0.58	>5000	9.5	5.66	470	1.7	5.75	460	1.7			
10:30	492	0.67	>5000	8.7	5.4	470	1.7	5.7	460	1.7			
10:45	486	0.53	>5000	8.9	5.4	470	1.7	5.69	460	1.7			
11:00	484	0.48	>5000	9.6	5.38	460	1.7	5.65	460	1.7			
11:15	483	0.54	>5000	10.3	5.36	460	1.7	5.63	460	1.7			
11:30	487	0.51	>5000	10.5	5.33	1200	1.7	5.57	460	1.7			
11:45	482				1.42	1800	2.9	5.57	440	1.7	5.61	440	1.7
12:00	479				1.04	2500	4.5	5.57	450	1.7	5.62	450	1.7
12:15	479				0.96	3200	4.8	5.55	460	1.7	5.6	460	1.7
12:30	492				0.84	4000	7.9	5.53	450	1.7	5.58	450	1.7
12:45	502				0.62	5000	7.5	5.55	450	1.7	5.6	450	1.7
13:00	508				0.61	>5000	8.5	5.57	4560	1.7	5.64	450	1.7
13:15	511				0.58	>5000	8.8	6.09	450	1.7	5.58	450	1.7
13:30	510				0.55	>5000	9.5	5.99	450	1.7	5.78	460	1.8
13:45	501				0.52	>5000	9.9	5.92	450	1.7	5.62	450	1.8
14:00	497				0.459	>5000	9.8	5.87	450	1.7	5.56	440	1.8
14:15	489				0.47	>5000	9.8	5.85	450	1.7	5.48	440	1.7
14:30	489				0.43	>5000	10.2	5.79	500	1.7	5.42	450	1.7
14:45	4890	6	480	1.7				1.37	1500	2.1	5.58	460	1.6
15:00	480	6.25	480	1.7				1.04	2500	4.7	5.78	450	1.7
15:15	476	6.18	450	1.7				0.98	3800	5.2	50.62	450	1.7
15:30	477	6.28	450	1.7				0.68	3800	6.8	5.74	450	1.8

15:45	479	6.35	450	1.7				0.65	4800	6.8	5.7	450	1.7
16:00	479	6.32	450	1.7				0.6	5000	6.6	5.68	450	1.7
16:15	479	6.27	450	1.7				0.57	>5000	8.2	5.62	450	1.7
16:30	480	6.25	450	1.7				0.55	>5000	8.2	5.59	450	1.7
16:45	479	6.2	450	1.7				0.52	>5000	8.2	5.55	450	1.7
17:00	477	6.17	450	1.7				0.48	>5000	8.2	5.52	460	1.7
17:15	464	6.15	450	1.7				0.45	>5000	8.5	5.48	450	1.7
17:30	468	6.13	460	1.7				0.41	>5000	8.5	5.38	1000	2.1
17:45	546	6.26	450	1.7	7.28	450	1.7				3.52	1800	2.5
18:00	485	5.86	430	1.7	7.14	430	1.7				0.98	2200	4.4
18:15	485	5.82	430	1.7	6.99	430	1.7				0.94	3000	4.4
18:30	484	5.78	440	1.7	6.96	440	1.7				0.92	5000	4.6
18:45	495	5.73	440	1.7	6.91	440	1.7				0.9	>5000	4.6
19:00	494	5.7	440	1.7	6.88	440	1.7				0.86	>5000	4.7
19:15	488	5.67	440	1.7	6.84	440	1.7				0.82	>5000	4.7
19:30	488	5.62	440	1.7	6.81	440	1.7				0.8	>5000	4.7
19:45	487	5.6	440	1.7	6.76	440	1.7				0.76	>5000	4.7
20:00	487	5.55	440	1.7	6.7	440	1.7				0.72	>5000	4.7
20:15	488	5.5	1000	1.7	6.67	440	1.7				0.53	>5000	4.7
20:30	499	1.35	2500	3.6	6.63	440	1.7	7.48	450	1.6			
20:45	490	0.76	4700	3.7	6.6	440	1.7	7.44	450	1.6			
21:00	491	0.73	5000	6.3	6.24	450	2.2	6.34	450	1.7			
21:15	495	0.7	>5000	6.3	6.21	450	2.2	6.3	450	1.7			
21:30	481	0.67	>5000	6	6.189	440	2.3	6.27	440	1.7			
21:45	481	0.64	>5000	5.9	6.11	440	2.3	6.23	440	1.7			
22:00	489	0.63	>5000	5.8	6.09	440	2.3	6.62	440	1.7			
22:15	484	0.61	>5000	5.8	5.99	440	2.3	6.17	440	1.7			

22:30	499	0.61	>5000	5.7	5.96	440	2.7	6.11	440	1.7			
22:45	Plant stopped at 23:45-23:04 to change Ammonia Container												
23:00													
23:15	489	0.55	>5000	10.5	5.43	430	1.6	5.98	440	1.6			
23:30	494	0.5	>5000	10.06	5.4	1300	1.6	5.94	440	1.7			
23:45	494				5.21	3300	2.3	5.9	440	1.8	7.74	500	1.4
0:00	505				5.02	4500	4.6	5.86	440	1.8	7.7	440	1.6
0:15	511				4.25	5000	4.7	5.83	440	1.8	7.65	440	1.6
0:30	511				1.36	>5000	4.8	5.8	440	1.8	7.6	440	1.7
0:45	511				1.27	>5000	4.8	5.77	440	1.8	7.55	440	1.7
1:00	513				1.22	>5000	4.7	5.74	440	1.8	7.5	440	1.7
1:15	514				1.2	>5000	4.7	5.7	440	1.8	7.46	440	1.7
1:30	513				1.06	>5000	4.7	5.65	440	1.8	7.4	440	1.7
1:45	513				1.02	>5000	4.7	5.6	440	1.8	7.33	440	1.7
2:00	508				1.1	>5000	4.7	5.54	1000	1.8	7.3	440	1.7
2:15	525	7.38	440	1.7				1.29	2000	3.5	7.26	440	1.8
2:30	513	7.31	440	1.7				1.2	2000	3.5	7.52	440	1.8
2:45	499	7.26	440	1.7				1.13	2500	4.6	7.18	440	1.8
3:00	496	7.23	440	1.7				1.07	5000	4.3	7.21	440	1.8
3:15	526	7.27	440	1.7				1.09	>5000	4.2	7.27	4540	1.8
3:30	527	7.32	440	1.7				1.15	>5000	4.3	7.23	440	1.7
3:45	527	7.3	440	1.7				1.1	>5000	4.3	7.2	440	1.7
4:00	527	7.24	440	1.7				0.96	>5000	4.6	5.34	440	1.7
4:15	529	7.31	460	1.7				0.5	>5000	10.6	5.64	460	2.5
4:30	526	7.2	460	1.7				0.57	>5000	9.8	5.61	460	2.3
4:45	525	7.16	460	1.7				0.54	>5000	9.8	5.61	1000	2.3
5:00	544	6.74	460	1.7	6.99	460	1.7				1.33	2100	3.4

5:15	531	6.7	460	1.7	6.96	450	1.7				1.31	3700	3.6
5:30	530	6.66	460	1.7	6.92	460	1.7				1.25	5000	4.8
5:45	526	6.6	460	1.7	6.86	460	1.7				1.18	>5000	4.8
6:00	524	6.56	460	1.7	6.8	460	1.7				1.08	>5000	4.9
6:15	525	6.47	460	1.7	6.78	460	1.7				0.73	>5000	8.9
6:30	524	6.39	450	1.7	6.75	450	1.7				0.68	>5000	8.9
6:45	512	6.08	450	1.7	6.65	450	1.7				0.56	>5000	9.2
7:00	503	5.91	440	1.7	6.43	450	1.7				0.52	>5000	9.5
7:15	490	5.43	440	1.7	6.39	440	1.7				0.43	>5000	9.8
7:30	498	3.52	1100	2.2	6.28	440	1.7				0.38	>5000	10.2
7:45													
8:00	481	1.01	3300	4.7	6.22	440	1.7	7.28	440	1.6			
8:15	477	0.98	4100	4.7	6.19	440	1.7	7.16	440	1.6			
8:30	475	0.78	5000	6.9	5.84	440	1.6	6.88	450	1.6			
8:45	471	0.67	>5000	7.9	5.65	430	1.6	6.76	430	1.6			
9:00	460	0.61	>5000	8.2	5.62	430	1.6	6.66	430	1.6			
9:15	456	0.65	>5000	8.7	5.98	430	1.6	5.96	430	1.6			
9:30	453	0.6	>5000	8.7	5.83	430	1.6	5.85	440	1.6			
9:45	455	0.58	>5000	8.9	5.77	430	1.6	5.72	440	1.6			
10:00	455	0.52	>5000	9.2	5.68	430	1.6	5.61	430	1.6			
10:15	455	0.88	>5000	9.5	5.58	430	1.6	5.55	430	1.6			
10:30	458	0.38	>5000	9.8	3.48	800	2.2	5.5	430	1.6			
10:45	459				1.21	2100	3.5	6.01	440	1.6	7.18	440	1.6
11:00	456				1.03	3200	3.8	5.98	440	1.6	7.03	440	1.6
11:15	457				0.96	4300	4.5	5.79	440	1.6	6.92	430	1.6
11:30	458				0.83	>5000	5.5	5.62	430	1.6	6.85	430	1.6
11:45	456				0.63	>5000	5.8	5.57	430	1.6	6.78	430	1.6

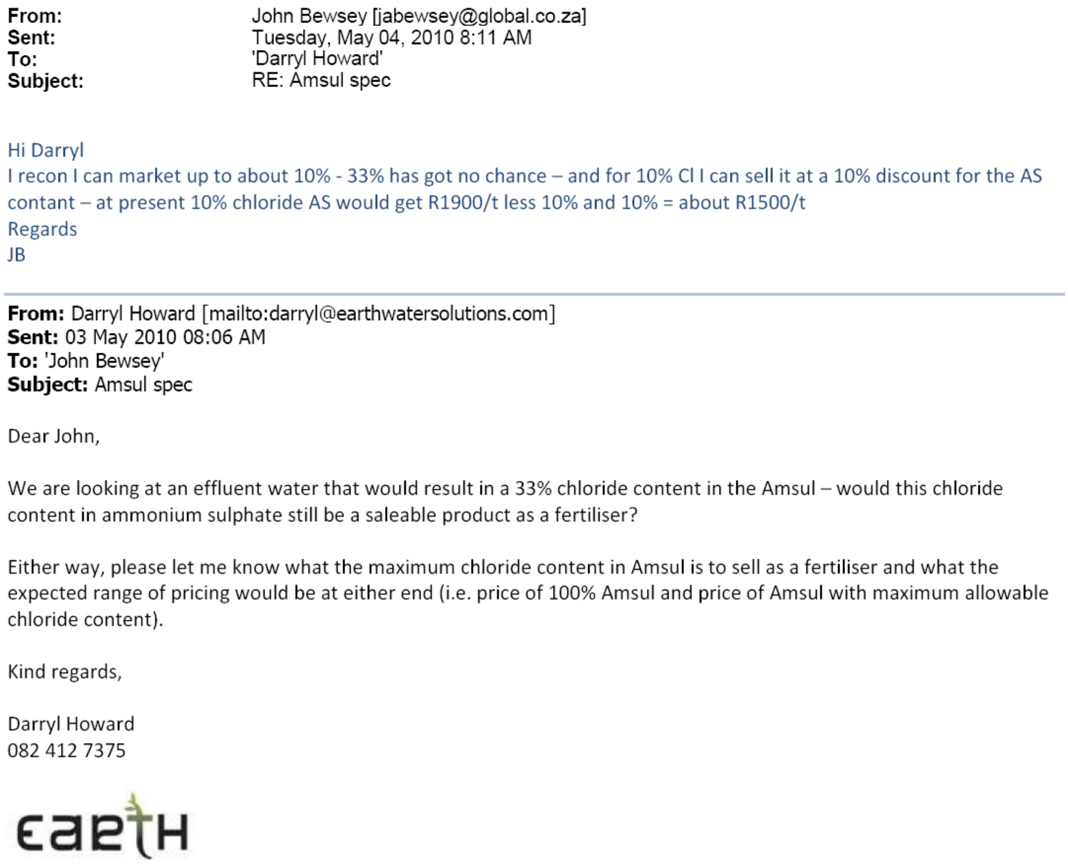
12:00	454				0.59	>5000	6.5	5.49	430	1.6	6.72	430	1.6
12:15	453				0.57	>5000	6.8	5.39	410	1.6	6.68	410	1.6
12:30	473				0.55	>5000	6.5	5.35	410	1.5	6.65	420	1.6
12:45	478				0.51	>5000	10.1	5.33	430	1.7	6.5	440	1.7
13:00	477				0.47	>5000	10.2	5.3	430	1.7	6.48	440	1.7
13:15	477				0.39	>5000	10.5	5.28	430	1.7	6.42	440	1.7
13:30					0.38	>5000	10.8	4.84	1100	2	6.4	440	1.6
13:45	Blow down												
14:00	487	6.37	440	1.7				1.53	3000	4.5	5.83	440	1.7
14:15	483	6.35	440	1.7				1.03	42300	5.2	5.11	440	1.7
14:30	480	6.3	440	1.7				0.98	>5000	5.5	5.68	440	1.7
14:45	480	6.28	440	1.7				0.78	>5000	5.8	5.53	450	1.7
15:00	483	6.25	440	1.7				0.58	>5000	9.9	5.68	450	1.5
15:15	488	6.18	450	1.7				0.42	>5000	10.5	3.5	1100	2.2
15:30	502	5.98	470	1.8	6.8	470	1.8				1.23	2100	2.5
15:45	489	5.89	450	1.7	6.75	450	1.7				0.98	3800	2.8
16:00	491	5.52	450	1.7	6.7	450	1.7				0.85	4800	2.8
16:15	494	6.13	450	1.7	6.73	450	1.7				0.8	>5000	2.5
16:30	491	6.02	450	1.7	6.69	450	1.7				0.73	>5000	2.5
16:45	4983	5.97	450	1.7	6.58	450	1.7				0.65	>5000	3.2
17:00	493	5.83	450	1.7	6.52	450	1.7				0.53	>5000	4.8
17:15	490	5.83	450	1.7	6.48	450	1.7				0.47	>5000	4.8
17:30	490	5.67	450	1.7	6.35	450	1.7				0.389	>5000	5.5
17:45	491	5.59	440	1.7	6.28	40	1.7				0.32	>5000	6.5
18:00	493	5.53	440	1.7	6.24	450	1.7				0.27	>5000	6.5
18:15	501	5.5	440	1.7	6.2	450	1.7				0.22	>5000	6.5
18:30	492	5.43	900	1.7	6.17	450	1.7				0.14	>5000	6.5

18:45	492	5.4	2500	1.7	6.12	450	1.7				0.08	>5000	6.6
19:00	529	1.89	4500	4.7	6.08	450	1.7	7.36	450	1.7			
19:15	512	1.84	5000	4.8	6.03	450	1.7	7.33	450	1.7			
19:30	509	1.8	>5000	4.8	6.01	450	1.7	7.3	450	1.7			
19:45	508	1.73	>5000	4.8	5.96	450	1.7	7.25	450	1.7			
20:00	503	1.7	>5000	4.8	5.9	450	1.7	7.2	450	1.7			
20:15	500	1.66	>5000	4.8	5.86	450	1.7	7.2	430	1.7			
20:30	499	1.6	>5000	4.9	5.83	450	1.7	7.14	430	1.7			
20:45	500	1.34	>5000	4.9	5.8	440	1.7	7.1	430	1.7			
21:00	500	0.99	>5000	4.9	5.76	440	1.7	6.87	430	1.7			
21:15	500	0.86	>5000	4.9	5.7	1000	1.7	6.8	430	1.7			
21:30	500				1.86	3000	2.6	6.77	440	1.8	7.39	460	1.7
21:45	502				1.44	4600	2.7	6.76	440	1.8	7.36	460	1.7
22:00	502				0.98	5000	2.2	6.73	460	1.7	6.31	460	1.7
22:15	501				0.94	>5000	2.7	6.7	460	1.7	6.28	460	1.7
22:30	535				0.98	>5000	2.7	6.66	460	1.7	6	460	1.7
22:45	535				0.87	>5000	2.7	6.62	460	1.7	22	460	1.7
23:00	534				0.84	>5000	2.7	6.59	460	1.7	6.2	460	1.7
23:15	536				0.81	>5000	45.7	6.54	470	1.7	6.17	460	1.7
23:30	541				0.77	>5000	4.7	6.5	460	1.7	6.14	460	1.7
23:45	541				0.76	>5000	4.7	6.44	470	1.7	6.11	460	1.7
0:00	541				0.7	>5000	4.7	6.38	1000	1.7	6.08	460	1.7
0:15	674	7.7	470	1.6				6.33	1900	1.98	6.08	470	1.7
0:30	535	7.65	470	1.7				6.3	2300	3.3	6.02	470	1.7
0:45	535	7.6	470	1.7				6.26	3800	4.6	5.86	470	1.7
1:00	531	7.55	470	1.7				6.22	4200	4.6	5.82	470	1.7
1:15	526	7.55	470	1.7				1.39	5000	4.7	5.82	460	1.7

1:30	525	7.5	460	1.7				1.34	>5000	4.8	5.8	450	1.7
1:45	521	7.46	460	1.7				1.31	>5000	4.8	5.77	450	1.7
2:00	521	7.4	460	1.7				1.23	>5000	4.8	5.73	450	1.7
2:15	3522	7.38	460	1.7				1.09	>5000	4.8	5.7	450	1.7
2:30	510	7.3	460	1.7				1.84	>5000	4.8	5.66	450	1.7
2:45	510	7.26	460	1.7				0.8	>5000	4.8	5.6	450	1.7
3:00	510	7.24	460	1.7				0.75	>5000	4.8	5.53	450	1.7
3:15	504	7.2	450	1.7				0.74	>5000	4.8	5.48	450	1.7
3:30	504	7.13	450	1.7				0.7	>5000	4.8	4.69	900	1.7
3:45	523	6.69	450	1.7	6.99	450	1.7				1.27	2200	3.4
4:00	523	6.63	450	1.7	6.94	450	1.7				1.24	3000	3.6
4:15	518	6.6	4560	1.7	6.91	450	1.7				1.21	5000	4.7
4:30	518	6.57	450	1.7	69.86	450	1.7				1.14	>5000	4.8
4:45	520	6.62	450	1.7	6.83	450	1.7				1.09	>5000	4.8
5:00	519	6.5	450	1.7	6.77	4580	1.7				0.98	>5000	4.8
5:15	519	6.46	460	1.7	6.72	450	1.7				0.94	>5000	4.7
5:30	525	6.42	460	1.7	6.65	450	1.7				0.9	>5000	4.7
5:45	528	6.33	460	1.7	6.63	460	1.7				0.88	>5000	4.7
6:00	528	6.3	460	1.7	5.87	460	1.7				0.82	>5000	4.7
6:15	558	6.22	1200	1.6	5.8	470	1.7						
6:30	567	1.4	1500	3.2	5.75	470	1.8	5.47	460	1.7			
6:45	589	1.18	2500	3.8	5.72	490	1.8	6.45	480	1.8			
7:00	573	0.78	3400	5	5.56	480	1.8	6.24	490	1.8			
7:15	562	0.73	4000	85	5.47	490	1.8	6.2	480	1.8			
7:30	561	0.69	5000	5.5	6.37	490	1.7	6.22	490	1.7			
7:45	555	0.68	>5000	6.5	6.47	480	1.8	6.32	485	1.8			
8:00	548	0.57	>5000	8.8	6.55	480	1.8	6.41	480	1.8			

8:15	545	0.49	>5000	9	5.84	480	1.8	6.26	480	1.8			
8:30	546	0.46	>5000	9.9	5.77	480	1.8	6.18	480	1.8			
8:45	541	0.39	>5000	10.2	5.62	480	1.8	6.1	480	1.8			
9:00	Plant stopped from 8:45-9:10												
9:15	549	0.3	>5000	10	5.6	1100	1.2	6.09	480	1.7			

Appendix 4 – Communication with Mr. J Bewsey re Amsul product



From: John Bewsey [jabewsey@global.co.za]
Sent: Tuesday, May 04, 2010 8:11 AM
To: 'Darryl Howard'
Subject: RE: Amsul spec

Hi Darryl
I recon I can market up to about 10% - 33% has got no chance – and for 10% Cl I can sell it at a 10% discount for the AS contant – at present 10% chloride AS would get R1900/t less 10% and 10% = about R1500/t
Regards
JB

From: Darryl Howard [mailto:darryl@earthwatersolutions.com]
Sent: 03 May 2010 08:06 AM
To: 'John Bewsey'
Subject: Amsul spec

Dear John,

We are looking at an effluent water that would result in a 33% chloride content in the Amsul – would this chloride content in ammonium sulphate still be a saleable product as a fertiliser?

Either way, please let me know what the maximum chloride content in Amsul is to sell as a fertiliser and what the expected range of pricing would be at either end (i.e. price of 100% Amsul and price of Amsul with maximum allowable chloride content).

Kind regards,

Darryl Howard
082 412 7375

Appendix 5 – Hatch Technology to Split Sulfates and Chlorides

Reclamation of Contaminated Ground Waters by a Multiple Membrane Process

Macintosh, P.D.[1], Fane, A.G[2] and Papazoglou, D [3]
1. Occtech Ltd, Perth, Australia. 2. UNESCO Centre for Membrane Science & Technology, UNSW. 3. WMC Resources Ltd, Kwinana, Australia.

ABSTRACT

This paper describes the application of a multiple step membrane train for the processing of ground and surface waters contaminated with ammonium sulfate. The key to the process is the unique ability of Nanofiltration (NF) to separate mono and divalent ions such that the concentrated stream could be forwarded to an evaporator. The paper outlines the problems to be solved, the initial separation concept, the plant design, unique design features and the experience gained over a decade of operation. The process utilises Microfiltration, Nanofiltration and Reverse Osmosis.

KEY WORDS
Ammonium Sulfate, Nanofiltration, Reverse Osmosis, Donnan Effect

INTRODUCTION

WMC's Kwinana Nickel Refinery is the world's third largest producer of refined nickel. It is located at Kwinana, about 40 kilometres south of Perth in Western Australia. The refinery began operations in 1970 and produces 99.8% Nickel briquettes and powder.

Ammonium sulfate (amsul) is a by-product of the nickel refining process, and is sold in crystal form as a fertiliser supplement. A mixture of tailings material and amsul solution was stored in a lined tailings dam, however a failure of the lining caused around 55,000 tonnes of amsul to seep into the underlying ground water. Typical analysis of the contaminated ground water is shown in Table 1.

A cellulose acetate Reverse Osmosis (RO) Plant was installed in 1981 to recover amsul from the groundwater and tailings dam. The high pressure RO section was added in 1983 to enable a six fold concentration (equivalent to 83% recovery) of the feed waters. The concentrated amsul stream was treated through an existing multi-effect evaporator, and the permeate was used in place of raw water, or if the total dissolved solids were high but still suitable for vegetation watering, for reticulation of the surrounding land. The general arrangement is shown in Figure 1**Error! Reference source not found.**.

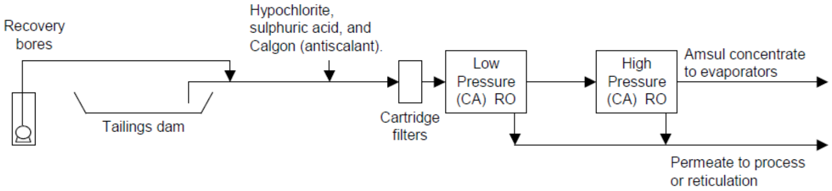


Figure 1. Original Ground Water Reclamation Process Arrangement using cellulose acetate RO membranes.

Appendix 6: Predicted composition of first and second stage RO rejects

Table 17. Predicted composition of first and second stage RO rejects

KEYPLAN A Division of epc THE AVENG GROUP		CALCULATION SHEET			Date		15-Mar-10
					Last Modified		15-Mar-10
		Client	**Eskom - Tutuka PS**		Made:	IK	Checked
Enq/Con No.	RECOVERY	Description	**Tutuka Brine**		Rev		Sheet
E1167	**60.0%**				A		
Description	Feed	Balanced Feed	Total Permeate	Total Reject			
Stream No	S_0	S_1	S_3	S_4			
Na (mg/l)	6 799.00	6 740.12	127.31	16 659.32			
Ca (mg/l)	329.00	329.00	2.10	819.35			
Mg (mg/l)	201.00	201.00	1.30	500.55			
K (mg/l)	272.00	272.00	7.08	669.38			
Cl (mg/l)	3 296.00	3 386.76	105.08	8 309.28			
HCO3 (mg/l)	508.74	508.74	18.11	1 244.69			
SO4 (mg/l)	10 990.00	10 990.00	137.71	27 268.43			
NO3 (mg/l)	15.80	15.80	0.86	38.21			
Acidity (mg/l)	0.62	0.62	0.00	1.54			
Sr (mg/l)	0.00	0.00	0.00	0.00			
F (mg/l)	1.31	1.31	0.07	3.17			
Fe (mg/l)	0.15	0.15	0.00	0.37			
Mn (mg/l)	0.12	0.12	0.00	0.30			
SiO2 (mg/l)	74.80	74.80	2.20	183.70			
SS (mg/l)	10.00	10.00	0.00	0.00			
Temp (ºC)	12.00	12.00	11.48	12.78			
pH	7.73	7.73	6.00	8.00			
Solids (t/h)	0.00	0.00	0.00	0.00			
TDS (mg/l)	22 497.92	22 519.79	22 519.79	55 696.76			
Flow (m3/h)	125.00	125.00	75.00	50.00			

Appendix 7 - Mass balance data

Table 18. Mass balance data – start of steady state trial

EARTH ID:	SN 1304001	SN 1304002	SN 1304003	SN 1304004	SN 1304005	SN 1304006	SN 1304007	SN 1304008	SN 1304009	SN 1304010	SN 1304011	SN 1304012	SN 1304013	SN 1304014	SN 1304015	SN 1304016	SN 1304017	SN 1304018
Description	CFT	CRT	CBT	CPT	ABT	APT	AET	Air Blow	STC	T10	CW1	CW2	CW3	CW4	AW1	AW2	AW3	AW4
	13 April 2010, start of mass balance																	
Species	mg/ℓ																	
Ag	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003
Al	0.015	0.464	0.429	0.550	0.021	0.003	0.004	0.795	0.402	0.052	0.016	0.044	0.160	0.401	0.024	0.014	0.014	0.014
As	0.008	0.004	0.004	0.003	0.001	0.008	0.002	0.075	0.030	0.070	0.002	0.002	0.004	0.007	0.002	0.003	0.005	0.006
Au	<0.001	<0.001	<0.001	<0.001	0.018	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	0.005	0.005
B	6.09	0.273	0.195	0.454	0.029	0.372	1.01	1.40	5.63	1.94	0.437	0.437	0.465	0.410	0.105	0.150	0.225	0.260
Ba	0.014	0.285	0.288	0.203	0.002	0.003	<0.001	0.042	0.015	0.174	0.003	0.013	0.059	0.205	0.045	0.034	0.035	0.035
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bi	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ca	17.2	1160	1110	755	14.4	7.45	0.46	46	5.89	102	2.77	27	97.4	245	19.7	38.7	48	40.7
Cd	<0.0001	0.0006	0.0006	0.0004	0.0001	0.0001	<0.0001	0.0014	0.0001	0.0003	<0.0001	0.0001	0.0003	0.0007	<0.0001	0.0001	0.0001	0.0002
Ce	<0.001	0.003	0.004	0.002	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Co	0.002	0.013	0.011	0.009	0.001	0.002	0.001	0.007	0.003	0.026	0.001	0.002	0.008	0.017	<0.001	0.001	0.001	0.001
Cr	0.011	0.034	0.042	0.020	0.006	0.019	0.002	0.042	0.021	0.094	0.004	0.008	0.023	0.058	0.004	0.009	0.013	0.015
Cs	<0.001	0.006	0.006	0.007	<0.001	<0.001	<0.001	0.002	0.001	0.004	0.001	0.002	0.004	0.009	<0.001	<0.001	<0.001	<0.001
Cu	0.078	0.781	1.020	1.215	0.007	0.130	0.005	0.334	0.175	1.071	0.067	0.312	1.136	2.098	0.007	0.001	0.003	0.005
Fe	0.106	0.542	0.612	0.454	< 0.01	0.336	0.034	7.37	1.77	0.223	0.261	0.239	0.356	1.06	0.052	0.041	0.083	0.136
Ga	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ge	0.004	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.001	0.003	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hf	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	<0.0001	0.0003	0.0005	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	0.0003	0.0002	0.0005	0.0007	0.0008	<0.0001	<0.0001	0.0001	0.0002
Ho	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
In	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ir	<0.001	<0.001	<0.001	<0.001	0.022	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001
K	14	815	718	706	0.6	0.8	1.8	38	6	120	18	65	129	223	0.3	1.4	1.1	1.6
La	<0.001	0.002	0.002	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Li	0.217	0.568	0.472	0.643	0.001	0.006	0.061	0.425	0.659	1.78	0.381	0.679	1.07	1.49	0.002	0.002	0.003	0.003
Mg	16.6	1140	1030	784	5.87	3.18	0.48	49.5	4.53	143	5.09	47.6	154	345	7.69	15.3	18.9	16.4
Mn	0.031	0.281	0.235	0.178	< 0.001	0.001	0.002	0.091	0.017	0.346	0.015	0.068	0.205	0.472	0.002	< 0.001	< 0.001	0.001
Mo	0.009	0.005	0.005	0.004	0.022	0.021	0.001	0.017	0.009	0.083	0.004	0.004	0.007	0.014	0.007	0.025	0.052	0.071
Na	600	25300	22600	29600	26.5	95.7	185	1620	384	5220	856	2860	5370	8980	11	23.6	32.2	31.1
Nb	<0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nd	<0.001	0.001	0.001	0.001	< 0.001	< 0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Ni	0.043	0.281	0.239	0.193	0.003	0.069	0.003	0.090	0.074	0.401	0.010	0.051	0.159	0.346	0.003	0.003	0.005	0.007
Pb	<0.001	0.012	0.012	0.007	< 0.001	0.002	<0.001	0.030	0.003	0.002	<0.001	<0.001	0.002	0.007	<0.001	<0.001	<0.001	<0.001
Pt	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001
Rb	0.046	0.334	0.310	0.287	< 0.001	0.001	0.006	0.075	0.028	0.438	0.060	0.117	0.263	0.551	0.002	0.002	0.002	0.002
Sb	0.005	<0.001	<0.001	<0.001	0.001	0.003	0.003	0.003	0.005	0.011	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.002
Sc	0.034	0.006	0.005	0.006	< 0.001	0.002	0.018	0.013	0.036	0.061	0.011	0.011	0.013	0.014	0.004	0.003	0.004	0.004
Se	0.020	0.035	0.027	0.031	0.004	0.015	0.010	0.013	0.021	0.109	0.020	0.017	0.024	0.034	0.009	0.008	0.009	0.009
Si	40.6	18.4	3.11	0.71	< 0.05	< 0.05	23.8	9.51	21.8	44.1	0.28	1.26	1.82	2.65	6.99	13.9	17.5	16.2
Sn	<0.001	0.004	0.004	0.002	0.001	0.001	<0.001	0.034	0.001	0.003	<0.001	0.001	0.003	0.007	0.001	<0.001	0.001	0.001
Sr	0.664	8.45	8.06	5.40	0.006	0.011	0.010	1.33	0.352	8.25	0.135	0.781	3.20	10.1	0.129	0.105	0.104	0.103
Ta	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Te	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001
Th	<0.0001	<0.0001	0.0001	0.0001	<0.0001	<0.0001	<0.0001	0.0009	0.0007	0.0003	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ti	0.074	<0.05	<0.05	<0.05	0.085	0.274	<0.05	0.057	0.068	0.650	<0.05	<0.05	<0.05	<0.05	<0.05	0.054	0.114	0.177
Tl	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	< 0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001
U	0.0006	0.0346	0.0362	0.0177	0.0025	0.0020	< 0.0001	0.0117	0.0034	0.0030	0.0020	0.0123	0.0414	0.0879	0.0001	0.0001	0.0002	0.0009
V	0.053	0.024	0.025	0.024	0.041	0.132	0.008	0.070	0.112	0.427	0.007	0.012	0.032	0.064	0.019	0.044	0.090	0.124
W	0.001	<0.001	<0.001	<0.001	0.003	0.002	<0.001	0.001	0.001	0.012	<0.001	0.001	0.001	0.001	0.001	0.002	0.005	0.007
Y	<0.001	0.003	0.003	0.002	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	0.001	0.003	<0.001	<0.001	<0.001	<0.001
Zn	0.044	0.390	0.331	0.247	<0.001	0.062	0.007	0.344	0.161	0.180	0.021	0.076	0.215	0.460	0.012	0.005	0.005	0.008
Zr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P																		
NH4	35	2100	2491	3167	30315	29157	8	610	170	<2.5	<2.5	217	436	717	1143	2557	3951	7288
NO3	168	135799	181150	115015	13286	28786	84	11293	886	71	6200	20371	36314	68200	1107	2214	3321	4207
Cl	404	40	40	120	9183	11058	236	455	456	2000	12	<0.25	144	151	381	817	1354	1822
SO4	709	198	201	422	26438	35695	25	937	689	6993	26	38	59	92	324	2286	5834	9554
Volume (ℓ)	925	70	315	20	200	40	950	275	-	2,900	10	10	10	10	15	15	15	15
Measured pH	8.19	-	-	-	9.97	8.92	8.09	-	1.07	8.30	-	-	-	-	9.09	9.34	9.53	9.66
Acidity(%)		5.08	10.38	1.79				0.88	0.08		0.46	1.29	2.21	3.54				
Alkalinity (%)	0.16				2.32	0.37	0.07			0.02					0.11	0.14	0.04	0.32

Table 19. Mass balance data – end of steady state trial

EARTH ID:	SN 1604001	SN 1604002	SN 1604003	SN 1604004	SN 1604005	SN 1604006	SN 1604007	SN 1604008	SN 1604009	SN 1604010	SN 1604011	SN 1604012	SN 1604013	SN 1604014	SN 1604015	SN 1604016	SN 1604017	SN 1604018	SN 1604019	SN 1604020	SN 1604021	SN 1604022	SN 1604023	SN 1604024	SN 1604025
Description	WP1	WP2	WP3	CRT	CBT	CPT	CFT	AET	ABT	APT	Air Blow	STC	STCat	STAn	CW1	CW2	CW3	CW4	AW1	AW2	AW3	AW4	CET	AFT	T5
	16 April 2010, End of mass balance																								
Species																									
Ag	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Al	0.004	0.003	0.006	0.221	0.261	0.281	0.002	0.001	0.012	0.048	1.19	0.147	0.401	0.016	0.015	0.024	0.107	0.240	0.015	0.011	0.011	0.036	0.013	0.015	0.013
As	0.002	0.002	0.002	0.002	0.002	0.002	0.001	<0.001	0.002	0.004	0.080	0.017	0.034	0.021	0.001	0.002	0.005	0.006	0.003	0.005	0.007	0.011	0.005	0.005	0.003
Au	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
B	1.49	1.49	1.5	1.3	1.23	1.79	2.29	2.22	1.87	2.2	1.61	1.37	1.37	1.38	0.420	0.584	0.682	0.630	0.194	0.318	0.435	0.664	1.37	1.37	2
Ba	<0.001	0.001	<0.001	0.135	0.128	0.099	0.001	0.001	0.003	0.003	0.051	0.006	0.059	0.005	0.001	0.007	0.039	0.135	0.043	0.039	0.037	0.039	<0.001	<0.001	<0.001
Be	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	< 0.001	< 0.001	< 0.001	<0.001	<0.001	< 0.001
Bi	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	< 0.001	< 0.001	< 0.001	<0.001	<0.001	<0.001
Ca	0.54	0.38	0.32	1060	1040	722	10.8	1.54	15.5	7.76	57.6	4.92	425	2.01	2.25	17.7	73.5	199	19.7	19.1	18.6	17.3	0.26	0.42	96.1
Cd	<0.0001	<0.0001	<0.0001	0.0003	0.0003	0.0002	<0.0001	<0.0001	0.0001	<0.0001	0.0015	<0.0001	0.0001	<0.0001	<0.0001	0.0001	0.0009	0.0006	<0.0001	0.0001	0.0002	0.0002	<0.0001	<0.0001	<0.0001
Ce	<0.001	<0.001	<0.001	0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Co	0.001	0.001	0.001	0.007	0.006	0.005	< 0.001	< 0.001	0.001	0.001	0.008	0.002	0.008	0.002	<0.001	0.002	0.008	0.014	<0.001	0.001	0.001	0.002	0.001	0.001	0.002
Cr	0.002	0.002	0.002	0.022	0.025	0.013	0.001	0.001	0.013	0.013	0.054	0.009	0.014	0.010	0.003	0.006	0.019	0.044	0.004	0.011	0.018	0.040	0.007	0.006	0.008
Cs	<0.001	<0.001	<0.001	0.002	0.003	0.003	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.009	<0.001	<0.001	0.001	0.003	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cu	0.006	0.006	0.006	0.363	0.432	0.579	0.011	0.002	0.007	0.019	0.477	0.100	0.142	0.088	0.036	0.126	0.436	1.591	0.011	0.002	0.003	0.007	0.009	0.009	0.084
Fe	0.053	0.068	0.079	0.301	0.378	0.269	0.064	0.065	0.087	0.165	9.73	0.507	0.915	0.632	0.254	0.327	0.462	0.575	0.096	0.123	0.152	0.974	0.190	0.190	0.198
Ga	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ge	0.002	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.003	0.002	< 0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.003	0.003	< 0.001
Hf	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hg	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0003	0.0005	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ho	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
In	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ir	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
K	2	2	2	819	699	803	14	2	0.7	1	51	6	18	3	17	53	113	200	1.5	1.6	1.7	2	3	3	110
La	<0.001	<0.001	<0.001	0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	< 0.001	0.001	< 0.001	< 0.001	< 0.001	< 0.001	<0.001	<0.001	<0.001
Li	0.048	0.053	0.056	0.412	0.365	0.452	0.013	0.006	0.001	0.004	0.544	0.439	1.96	0.062	0.224	0.654	1.10	1.43	0.002	0.003	0.004	0.008	0.080	0.085	0.112
Mg	0.49	0.48	0.45	1210	1130	884	15.8	0.83	7.01	3.79	75.3	5.08	1.9	1.21	4.99	37	138	323	8.32	8.2	7.99	7.49	0.4	0.62	148
Mn	0.001	0.001	0.002	0.160	0.147	0.111	0.002	0.001	<0.001	0.010	0.136	0.010	0.020	0.002	0.012	0.058	0.203	0.411	0.002	0.001	0.001	0.013	0.002	0.004	0.031
Mo	<0.001	0.001	0.001	0.002	0.002	0.002	<0.001	<0.001	0.034	0.009	0.016	0.005	0.006	0.009	0.002	0.004	0.011	0.012	0.009	0.032	0.060	0.083	0.005	0.005	0.004
Na	197	201	203	26800	23700	30500	744	213	25.4	92.8	2140	410	467	194	878	2530	4700	7880	13.3	12.9	14.1	15.8	206	220	5040
Nb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nd	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ni	0.002	0.002	0.002	0.163	0.147	0.120	0.003	<0.001	0.003	0.011	0.114	0.046	0.116	0.076	0.006	0.041	0.139	0.303	0.004	0.004	0.005	0.008	0.011	0.012	0.034
Pb	<0.001	<0.001	<0.001	0.003	0.004	0.003	<0.001	<0.001	<0.001	<0.001	0.030	0.001	0.003	0.001	< 0.001	<0.001	0.002	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Pt	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Rb	0.006	0.006	0.006	0.185	0.163	0.164	0.003	0.001	<0.001	0.001	0.107	0.014	0.112	0.007	0.033	0.103	0.241	0.465	0.002	0.002	0.002	0.002	0.007	0.007	0.028
Sb	0.003	0.003	0.003	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.001	0.002	0.003	0.003	0.003	< 0.001	<0.001	0.001	<0.001	0.001	0.001	0.002	0.003	0.003	0.003	0.001
Sc	0.023	0.024	0.024	0.002	0.002	0.003	0.003	0.003	< 0.001	0.002	0.019	0.031	0.041	0.032	0.009	0.011	0.014	0.015	0.005	0.005	0.005	0.003	0.038	0.035	0.006
Se	0.011	0.012	0.012	0.017	0.017	0.019	0.010	0.010	0.010	0.011	0.017	0.014	0.021	0.014	0.015	0.016	0.024	0.033	0.013	0.012	0.013	0.101	0.016	0.016	0.017
Si	28	29.1	28.4	38.2	25.3	27.2	37.9	33.4	15.9	25.9	10.8	27.6	28.5	27.5	4.05	4.69	5.46	5.72	3.84	3.99	4.28	4.91	29.7	30.1	42.8
Sn	<0.001	<0.001	<0.001	0.002	0.002	0.001	<0.001	<0.001	0.001	<0.001	0.036	0.001	0.001	<0.001	<0.001	0.001	0.005	0.005	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
Sr	0.009	0.008	0.008	4.89	4.43	3.30	0.055	0.002	0.009	0.013	2.06	0.171	5.29	0.025	0.073	0.601	2.87	8.71	0.132	0.123	0.114	0.122	0.009	0.013	0.581
Ta	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Te	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Th	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0006	0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Ti	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.200	0.227	0.074	0.053	0.186	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.109	0.216	0.510	0.073	0.071	0.082
Tl	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
U	< 0.0001	< 0.0001	< 0.0001	0.0092	0.0099	0.0056	< 0.0001	< 0.0001	0.0017	0.0006	0.0096	0.0005	0.0007	0.0001	0.0006	0.0046	0.0214	0.0527	< 0.0001	< 0.0001	0.0001	0.0005	0.0002	0.0002	0.0001
V	0.008	0.008	0.008	0.017	0.015	0.015	0.003	0.001	0.089	0.097	0.074	0.064	0.103	0.043	0.004	0.012	0.034	0.064	0.026	0.069	0.124	0.248	0.041	0.042	0.034
W	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.001	0.001	0.001	0.003	0.005	0.008	<0.001	<0.001	<0.001
Y	<0.001	<0.001	<0.001	0.002	0.002	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zn	0.022	0.024	0.034	0.209	0.193	0.152	0.006	0.001	0.003	0.008	0.421	0.092	0.073	0.177	0.017	0.058	0.188	0.368	0.006	0.005	0.004	0.007	0.320	0.570	0.024
Zr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
P																									
NH4	16	17	16	2068	2207	2210	21	10	29964	27413	586	117	118	267	52	153	259	539	566	2115	2887	3177	15	15	<2.5
NO3	137	133	133	139847	182198	118171	195	146	13286	35429	13286	886	1107	443	5979	16607	33214	58457	886	1771	3100	3543	310	235	89
Cl	225	218	223	40	30	6292	7181	210	7532	9921	756	472	431	451	10	381	428	1614	464	1037	1524	5446	420	410	2000
SO4	23	22	21	151	157	344	797	18	36241	29076	745	592	1827	592	17	29	41	40	452	1607	3356	6268	809	806	7649
Volume (ℓ)	1,000	345	40	242	126	353	860	1,000	335	338	400	600	140	140	10	10	10	10	15	15	15	15	400	300	500
Measured pH	7.23	7.17	7.56	-	-	-	7.37	7.08	9.91	8.85	-	1.04	0.86	8.85	-	-	-	-	8.67	8.97	9.16	9.25	0.74	0.73	8.28
Acidity(%)				5.08	10.25	2.13					0.79	0.17	0.08		0.46	1.17	2.04	3.13					0.13	0.17	
Alkalinity (%)	0.05	0.02	0.05				0.07	0.05	1.70	0.25				0.02					0.14	0.09	0.16	0.21			0.05

Appendix 8 – Method of calculation of the mass balance

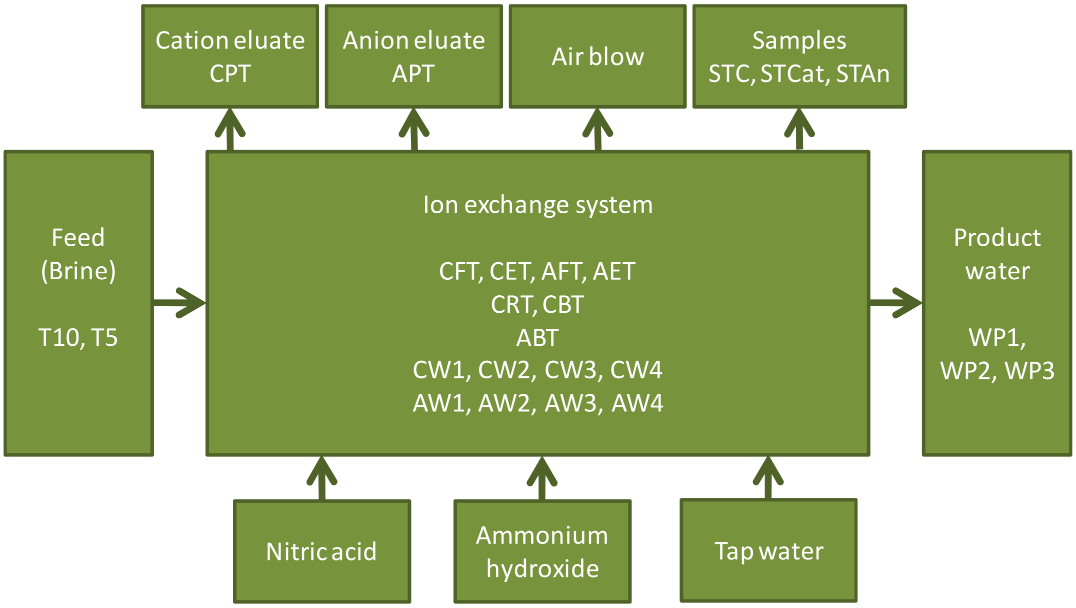


Figure 10. Schematic of flows for mass balance calculation

Table 20. Legend for mass balance

Acronym	Unit description
T10	Storage tank 10 in the tank farm
T5	Storage tank 5 in the tank farm
CFT	Cation IX feed tank
CET	Cation IX effluent tank
AFT	Anion IX feed tank
AET	Anion IX effluent tank
CRT	Cation IX eluate recovery tank
CBT	Cation IX eluant buffer tank
ABT	Anion IX eluant buffer tank
CW1 to 4	Cation IX wash tanks
AW1 to 4	Anion IX wash tanks
CPT	Cation IX eluate product tank
APT	Anion IX eluate product tank
STC	Tank for composite Cation IX and Anion IX samples
STCat	Tank for composite Cation IX samples
STAn	Tank for composite Anion IX samples
WP1 to 3	Product water storage tanks

Figure 10 indicates schematically the interrelationship between the influent and effluent flows to and from the ion exchange system. The total mass in the system at the beginning of the run was balanced with the total mass in the system at the end of the run according to the following formula:

Mass into the IX system – mass retained in the IX system = Mass out of the IX system

The system can be viewed as either in the 'loading cycle' as depicted in Figure 11 or in the 'elution cycle' as depicted in Figure 12.

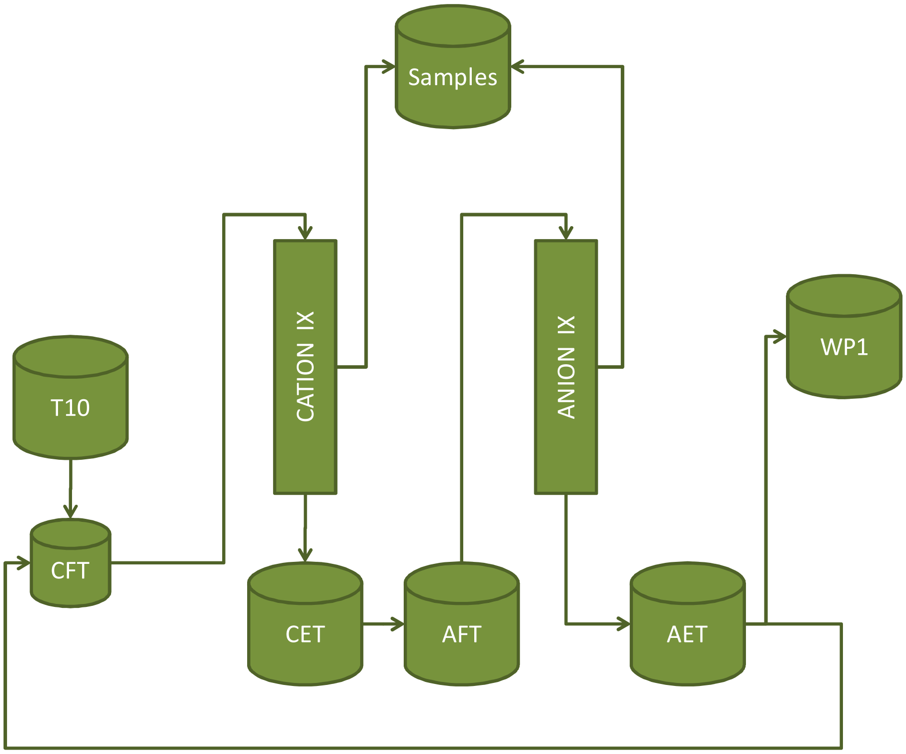


Figure 11. Schematic of pilot plant in the 'loading cycle'

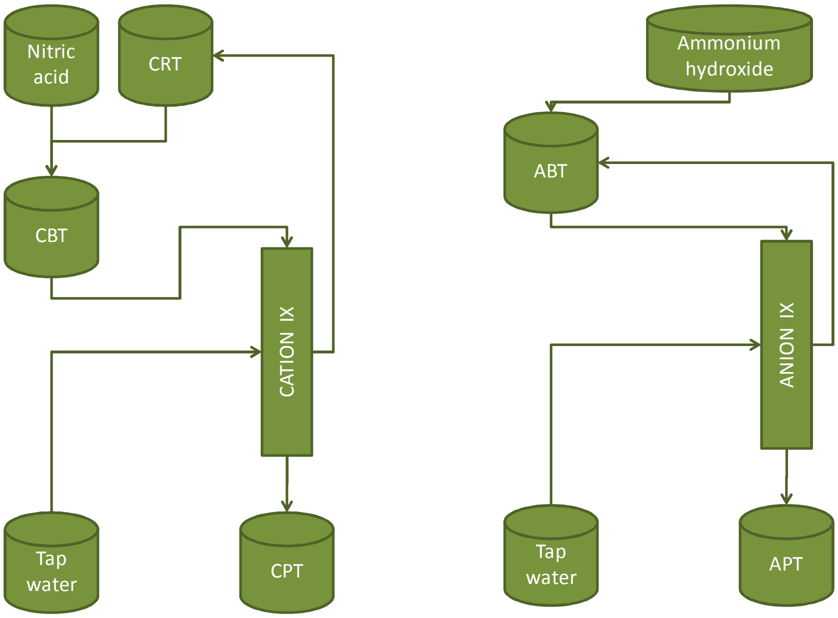


Figure 12. Schematic of the cation and anion IX in the 'elution cycle'

Table 21. Summary of mass balance calculation – major species

Species	IN	RETAINED	IN - RETAINED	MASS LOST TO SAMPLING & AIR BLOWS	OUT	Variance
	[kg]					[%]
Ca	0.25	(0.05)	0.30	0.07	0.24	-6.8%
K	0.29	0.00	0.29	0.02	0.27	0.5%
Mg	0.34	0.03	0.31	0.02	0.30	-2.5%
Na	12.62	0.73	11.89	0.75	10.47	5.6%
NH4	13.07	4.01	9.06	0.23	8.84	0.0%
NO3	45.04	(7.94)	52.98	2.58	50.40	0.0%
Cl	4.80	0.80	4.00	0.58	3.26	4.1%
SO4	16.45	6.88	9.57	0.73	8.54	3.1%
Total	**93.02**	**4.48**	**88.54**	**5.02**	**82.38**	**1.3%**

Appendix 9 – Summary of NPV calculations

Table 22. Summary of NPV calculations

	Year																			
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Capex - Brine ponds	(150,000,000)				(150,000,000)				(150,000,000)				(150,000,000)				(150,000,000)			
Annual loan repayment - brine pond 1	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)								
Annual loan repayment - brine pond 2					(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)	(21,511,409)				
Annual loan repayment - brine pond 3													(27,313,488)	(27,313,488)	(27,313,488)	(27,313,488)	(27,313,488)	(27,313,488)	(27,313,488)	(27,313,488)
Annual loan repayment - brine pond 4																	(45,652,644)	(45,652,644)	(45,652,644)	(45,652,644)
Capping					(37,500,000)				(37,500,000)				(37,500,000)				(37,500,000)			(37,500,000)
NCF	**(21,511,409)**	(21,511,409)	(21,511,409)	(21,511,409)	(80,522,817)	(43,022,817)	(43,022,817)	(43,022,817)	(80,522,817)	(43,022,817)	(43,022,817)	(43,022,817)	(86,324,897)	(48,824,897)	(48,824,897)	(48,824,897)	(110,466,132)	(72,966,132)	(72,966,132)	(110,466,132)
NPV (brine ponds)	**(261,285,901)**																			
Capex - IX plant	79,862,080																			
Annual loan repayment - IX plant	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)	(11,452,972)								
Revenue	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507	88,389,507
Opex	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)	(107,467,633)
NCF (excluding cost of capital)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)
NCF	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(30,531,098)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)	(19,078,126)
NPV (IX opex; no product sales)	**(672,675,538)**																			
NPV (IX net cost excl. cost of capital)	**(119,416,315)**																			
NPV (IX net cost)	**(181,498,514)**																			
Savings	**79,787,387**																			

Appendix 10 – PFD for the IX system (excluding polishing columns)

Appendix 11 – P&IDs for the IX system (excluding polishing columns)