final report

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Bore Water Purification for Abattoir Use

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Executive Summary

Diamantina Meat Packers (Stanbroke) Grantham plant is a major meat processing facility in the region. The plant processes approximately 6-700 (5 days/week) head of cattle per day. The site employs up to 300 people from the local community.

Stanbroke spends over $1m pa on water supply. The water is high in hardness, silica, and general conductivity. This has the result of damaging expensive production equipment, costing significant money for fuel costs (gas, electricity), and producing high levels of waste water and emissions.

Stanbroke is aiming to employ Nalco to provide a 1.5MLD UF-RO plant to provide potable water to the plant and utilities. The source of the raw water is to be the bore water supply located on Stanbroke property. This plant provides the water quality required to reduce corrosion on plant, water supply costs, and provide pure water to the boiler plant. Pure boiler feed water means less blow down, and significant energy savings.

To validate the ability of the bore water to be processed, Nalco has conducted a 4 week trial using equipment comprised of a coagulation tank and pH reactor, multimedia filtration, carbon filtration, ultra filtration, and reverse osmosis.

The water was sourced from multiple bore heads, each origination from a common aquifer. The water from the aquifer showed significant variability in conductivity, Iron, and Manganese content. The plant was able to successfully treat the water to specification without membrane damage, or the requirement of excessive cleaning of membranes.

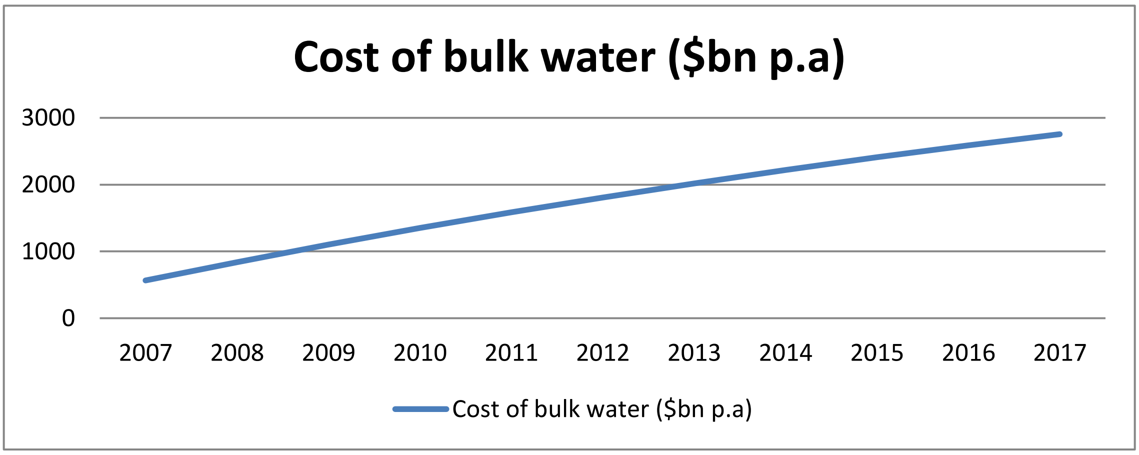
Consideration to the discharge of the brine to the Stanbroke site must be considered, and, its potential impact on the salt balance for the site. This area was outside the scope of this trial.

Abstract: Why do this project?

The manufacturing industry within Australia is under increasing cost pressure. The need to reduce costs, whilst exporting in to high growth markets is critical for long term business planning.

Water and energy are both rising costs. It is expected that by 2018, Queensland will be paying approx. $5/kL for the purchase of water for industry use.

Graph 1.1: The escalating cost of water[1].



Reduced Cost: To this end, Stanbroke sought a solution to control the escalating cost of water via the use of the bore water supply within the Stanbroke property borders.

This bore water presented challenges. The bore water is highly mineralised, containing high levels of chlorides, iron, manganese, silica, and calcium/magnesium. Direct use of this water would be very dangerous to equipment, and sustainability of business operation.

In the past, Stanbroke had attempted the use of green sand with potassium permanganate regeneration to clean up the iron and manganese out of the water. This process was not sustainable. It could note remove the Iron and Manganese to required levels, and utilised high level of regenerant. The process could not deal with the high chlorides which would do damage to stainless steel used in the plant.

Reduced risk of scale: Stanbroke have also recently experienced the destruction of one of their main boilers due to scale formation. This appears due to softener failure during off peak periods. Since the water coming in is very high in hardness (over 100ppm typically) destruction of a boiler is rapid.

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[1] Source: http://www.qwc.qld.gov.au/reform/pdf/bulk-water-prices-031210.pdf

Reduced Corrosion: The use of purified water has the additional benefits of reduction of carbonate alkalinity in the feed water to the boiler plant. This reduces carbon dioxide in the permeate and hence acidity of the condensate within the steam system. The impact of this is longer life of components in the steam systems, decreased corrosion rates, decreased returning iron levels in the condensate, and hence better protection of the boiler plant.

In the steam system the reduction in carbonate based corrosion (carbonic acid) is expected to protect the pipe work, boiler, and production equipment. This is achieved via the RO membrane rejecting the carbonate based alkalinity (which is the source of the CO2 which causes carbon dioxide related corrosion in the steam system).

Diagram 2: Carbonic Acid induced corrosion

The production of pure water for use in production reduces the risk of chloride based corrosion. Chloride based corrosion is particularly damaging to stainless steel at temperature. This crevice based corrosion can only be controlled by selection of suitable stainless alloys, temperature, or by removal of chloride materials in the water. Please see Diagram 3.

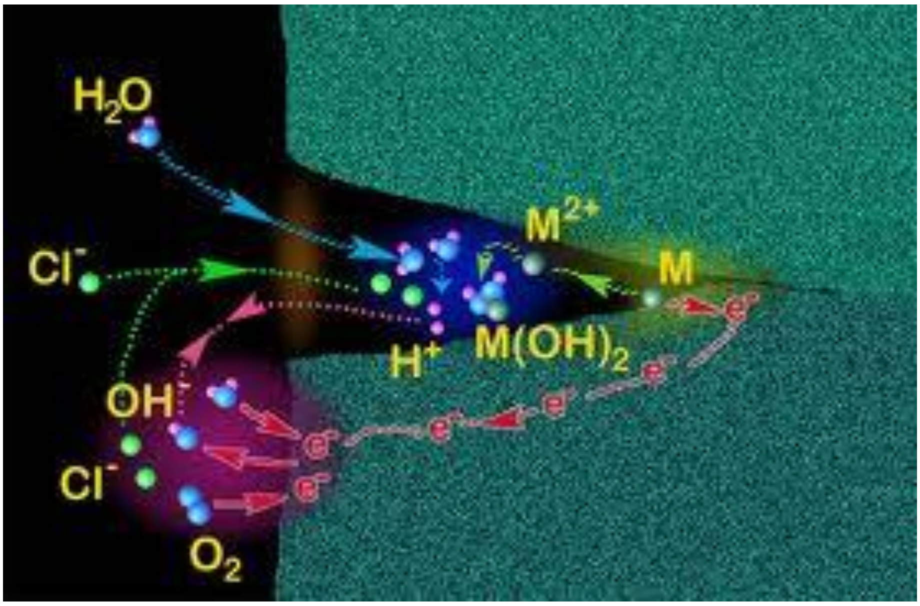
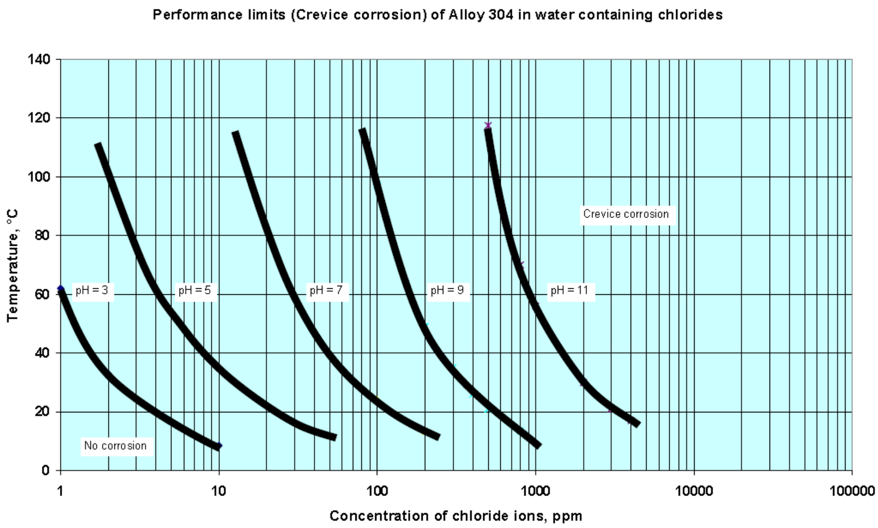


Diagram 3: Chloride Corrosion

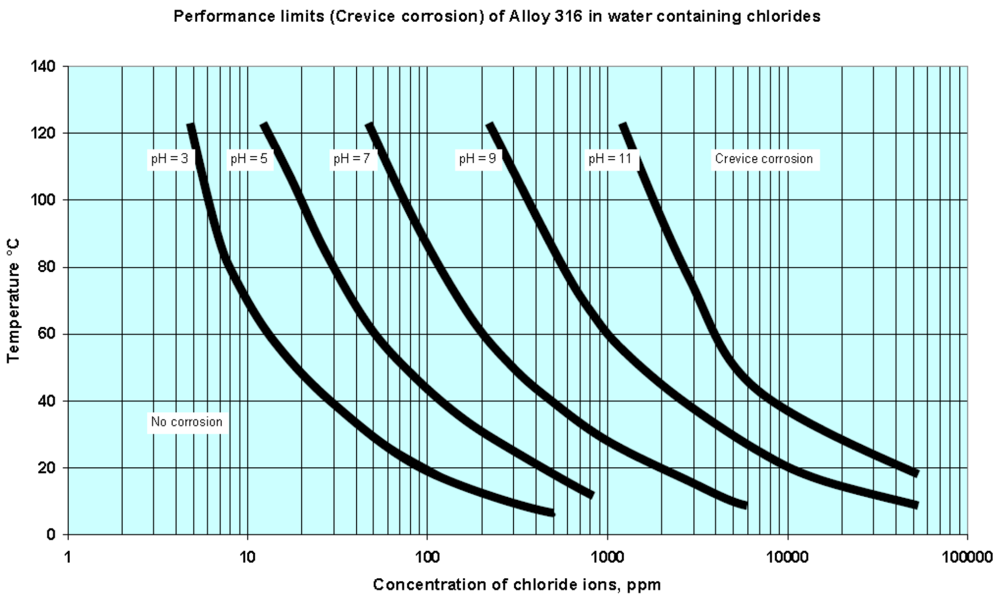
As stated previously, temperature and chloride content affect the corrosion performance of stainless steels whether 304 or 316. pH also has an effect on the corrosion performance. See the graphs below.

Graph 1.1; Corrosion performance of 304 SS



The UF-RO plant is planned to reduce risk of chloride based corrosion, via rejection of chloride ions at the membrane surface. Hence purer water leads to reduced risk of crevice corrosion.

Graph 2.1: Corrosion performance of 316 SS



Nalcos has proposed the use of a Pre-treatment-UF-RO plant to provide all of sites water. This purifies the incoming water to required levels, removes hardness and conductivity for efficient clean boiler operation, and does not use high levels of messy regenerant.

The process of UF-RO is well accepted across the industry, and is sustainable in operation.

Reduce Water use: The project is aimed to reduce water use via increasing water efficiency in the boiler and condenser plants. This means less blowdown of the water systems. The projected daily savings exceed 50kL/day.

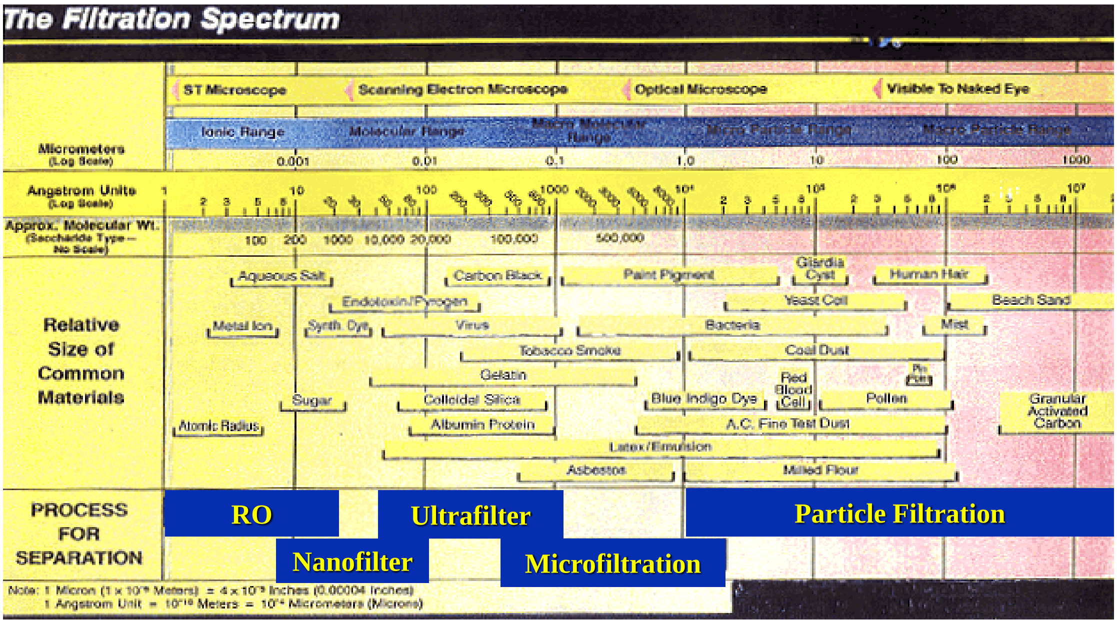
Additional savings in cleaning chemicals, process cleaning water use, and alike are all expected, but are not quantifiable at this stage.

Contents

Section 1.

1.1 Technology behind the trial.

The trial plant utilises a number of advanced filtration technologies which have specific functions. Please refer section 3 Table 1.1.



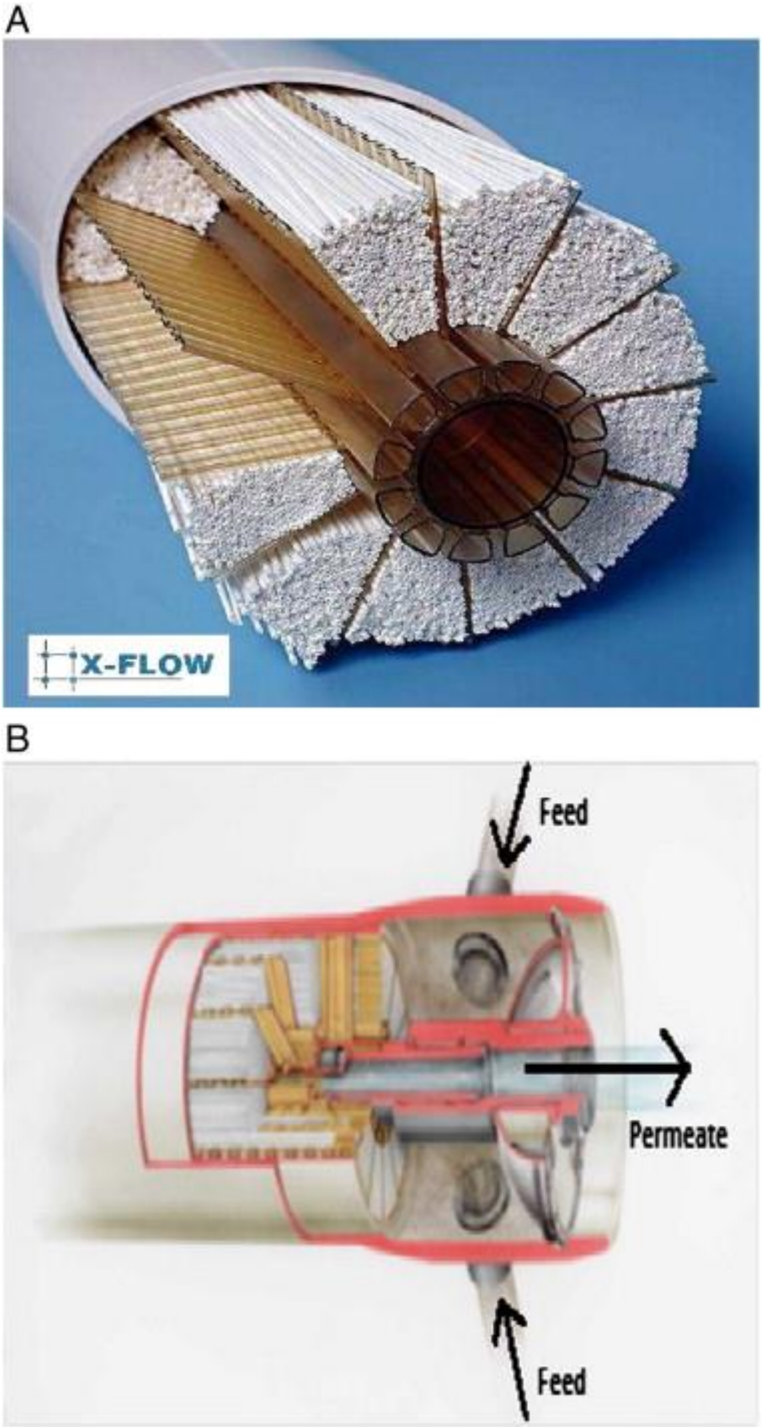
Multimedia filters are used to remove coagulated particles from solution. These particles are typically visible to the make eye and hence are on the very left of the spectrum

Carbon filtration is used to remove residual chlorine used to convert soluble iron and manganese into particulate material. This tends to filter coarser than the MMF hence also appears after the multimedia filter.

Ultrafiltration is used to filter 0.1-0.001um. This is extremely fine particulate, bacteria, and large molecular matter. The water typically exiting the UF is clear and clean. The ultra-filtration step assists in preventing the RO membrane fouling from particulate and bacterial deposition.

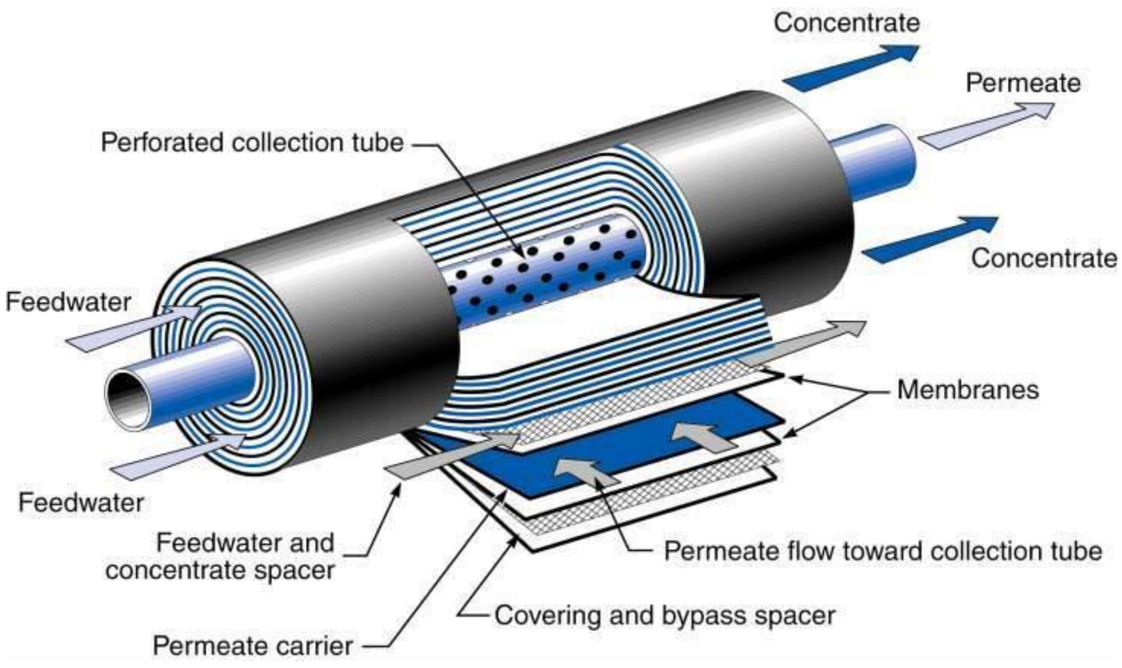
The Reverse Osmosis membrane removes materials ionised in water namely salts, dissolved organic molecules, and alike. A diagram of the function of the RO unit is as below

Diagram 2.1: An ultra-filtration plant



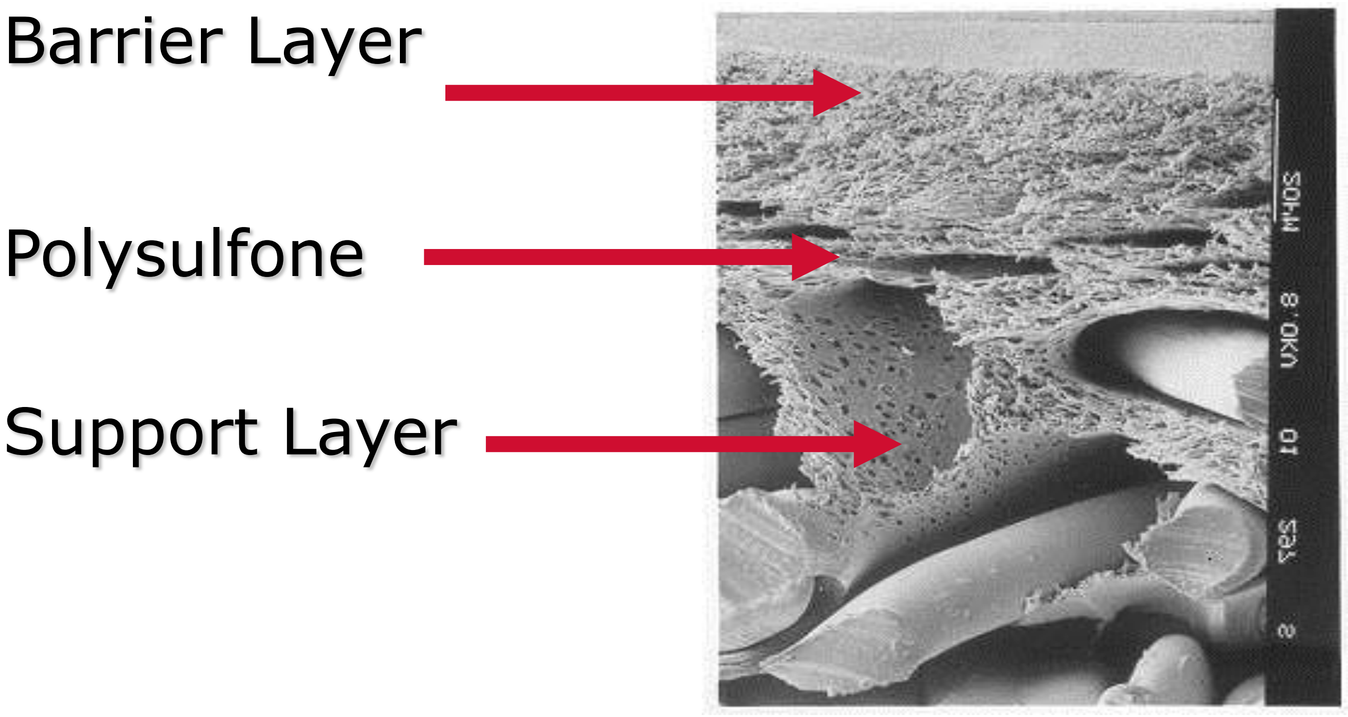
Using cross flow, the fouling of the UF can be limited. This cross flow is rapid flow across the surface of the UF membrane returning back to a feed tank for processing back through the UF.

Diagram 3.1: A Reverse Osmosis Membrane.



The heart of any RO plant is the membrane system. The membranes are expensive to purchase due to the technology involved in their manufacture. Please see diagram 4.1 for how a membrane is constructed,

Diagram 4.1: An electromicrograph of an RO membrane.

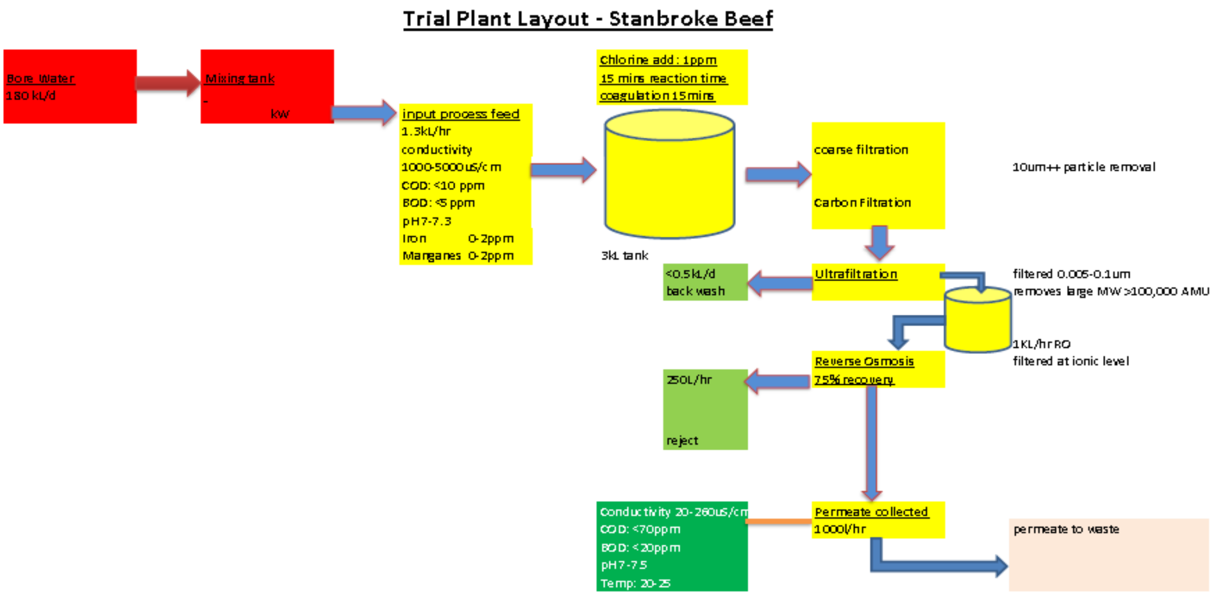


As can be seen from above, any particulate matter, oils, greases, or alike can easily foul the membrane surface and cause process upset. The effect of fouling is loss of quality of water, and most noticeably loss of flow or production rate. This is why pre-treatment of the water, removal of iron and Manganese fouling species, and filtration of particulate matter is so critical for performance maintenance.

Section 2:

1. 'Methodology and Procedure for Trial

A trial UF-RO plant was provided to Stanbroke Beef. This plant utilised the layout below for treatment.



MMF-CF-UF-RO

Trial plant at Stanbroke Beef. This was trialling the blended bore water at top of plant.

This area was trialled for two weeks processing 36kL of bore water.

Section 3:

Plant Components and Function.

The components involved were utilised for the specific functions below.

Table 1.1

Component	Function	Comment
Pre-reactor (3kL tank)	This system is the point where iron and manganese are reacted with chlorine to form the oxides of the metals, then coagulated and dropped as a sludge.	Main plant shall use a large reactor capable of allowing a minimum reaction time of 30 minutes. 15 minutes reaction time for chlorination then 15 minutes coagulation.
Coarse filtration	Remove large particles (>10um) and back wash to waste	Main plant design removes the need for this component
Carbon filtration	Removal of chlorine from pre-treatment water	Avoids “burning” of the RO membrane and hence premature failure.
Ultra filtration	Fine filtration prior to the reverse osmosis membrane. This treatment removes particles 0.005um and above. This includes large molecular weight polymers (>100,000amu).	System uses tubular “hollow fibre” poly amide based filters. Type used is an “out in”.
Reverse Osmosis	The plant uses LE440 type membranes using lower pressure and lower energy to effect removal of salts from the water.	With the higher input conductivity, some salt leakage was noted.

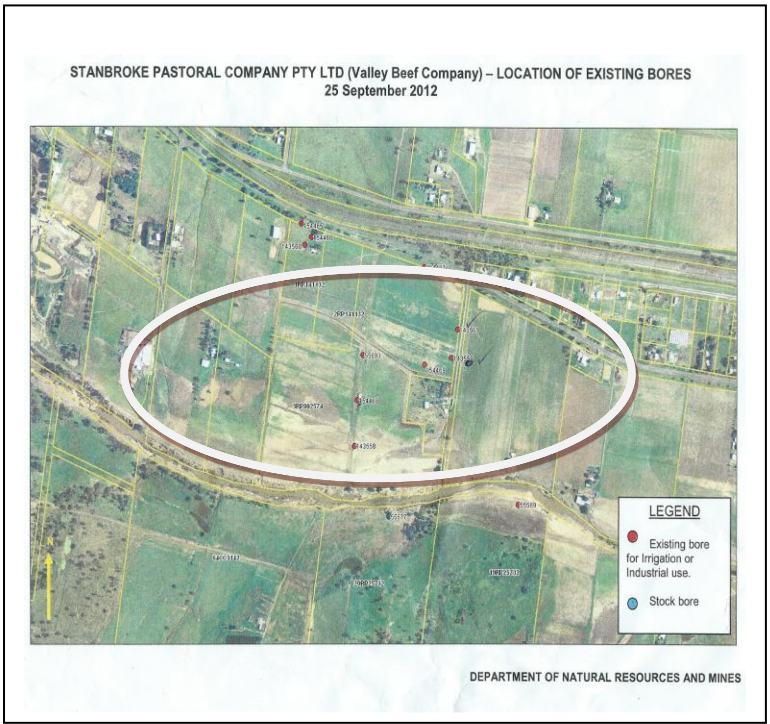
Section 4: Experimental Design

The trial was split into two components:

1. Testing of each bore for properties, stability in properties, challenges with the bore, etc. Particular attention was paid to iron and manganese levels, conductivity, and ph. This was conducted over a two week period.

2. Testing of continuous supply of the water using the pilot plant. This was utilised to determine fluctuation in supply, potential blocking of the membranes, fouling properties etc. This was conducted over a 2 week period.

Bore layout used. Diagram 1.1



<u>Bore allocation for Stanbroke Beef</u>.

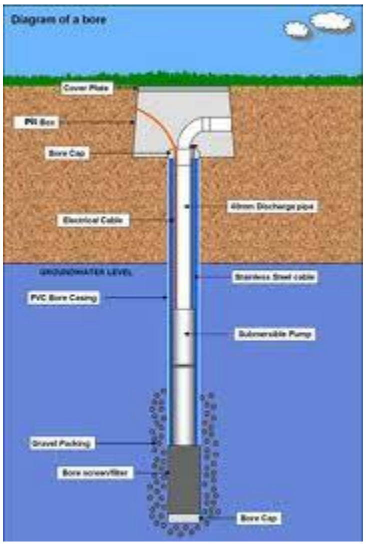
Small red dots represent bore locations.

Note “clumping” of bores.

Acquifer location suspected to be within the allocated ring areas.

Bore take off points used bore heads similar to below. These were purged only briefly and showed significant silt build up especially when left for an extended period.

Picture 1.1: Bore head



Procedure for the trial

The trial of the bore sites was conducted over a 4 week period using the equipment described. The equipment utilised one 2kL tank. This tank was used as the reactor, whereby chlorine (sodium hypo chlorite) was added and pH raised to 7.5-8.5. This procedure helped to precipitated Iron and Manganese salts via conversion to the insoluble hydroxide and oxide form.

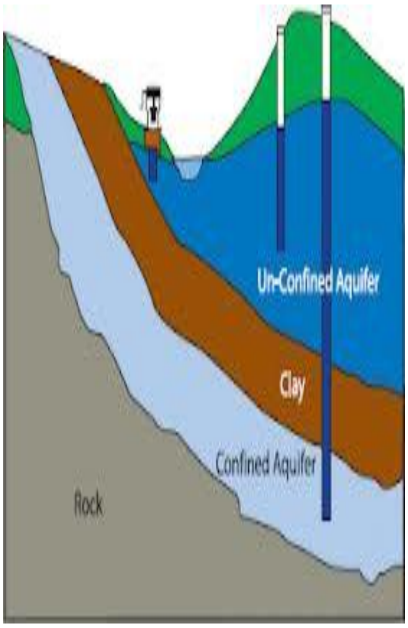
Chlorine (liquid solution 10%) was added and reacted for 10 minutes. Poly Aluminium Chlorohydrate (20%) was added (25ppm) and 5 minutes allowed for reaction. pH was corrected using caustic (30%).

Reaction for Iron as below:

In the presence of oxidant

$Fe^{2+} \longrightarrow Fe^{3+}$ e-

$Fe^{3+} + 4OH^- \longrightarrow FeO(OH)_3 + H^+$



The Chlorine reaction is:

$HOCL + H^+ + e^- \longrightarrow Cl_2 + H2O$

$CL_2 + 2e^- \longrightarrow 2Cl^-$

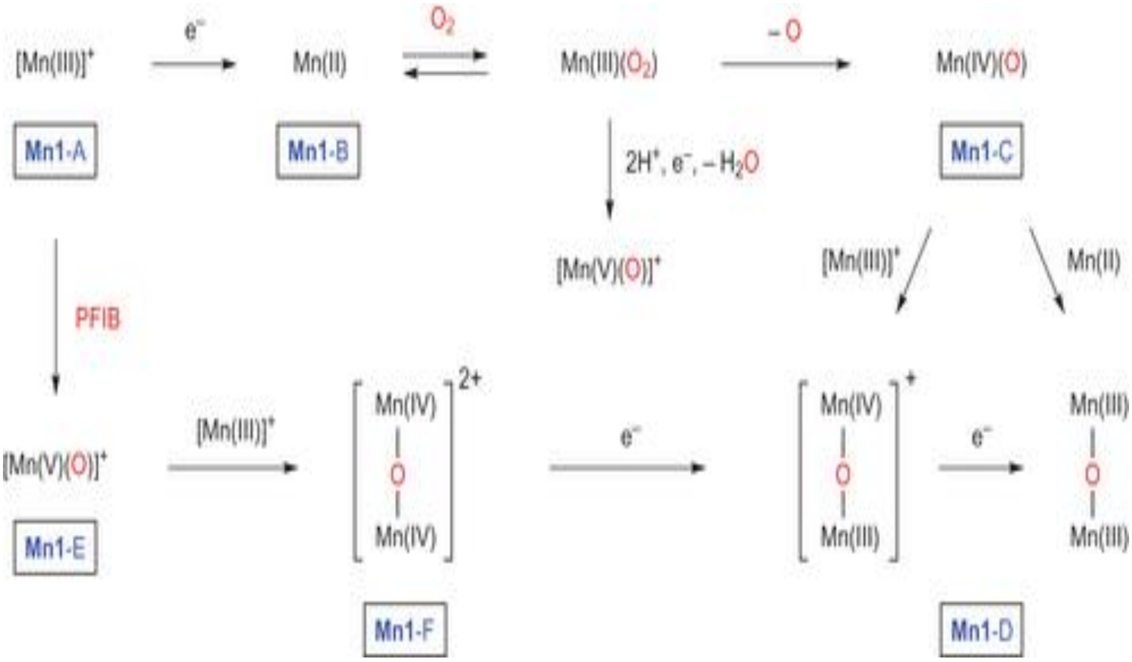
Overall reaction with Iron and Chlorine

$2Fe^{2+} + CL_2 \longrightarrow 2Fe^{3+} + 2CL^-$

Reaction for Manganese

$Mn^{2+} + 2H2O \xrightarrow{O2} MnO_2 + 4H^+ + 2e^-$

Manganese exists in multiple oxidation states – See Picture 2.1



The treated water was then batched and ran through the plant and processed. Samples were analysed for Iron, Manganese, conductivity etc.

Results are presented in Section 5.

Section 5:
Trial results collected

Plant operational data is presented graphically as below. The overall plant performance was to specification, with the system maintaining less than a 15% flow fall from the RO, thus avoiding the need for CIP whilst trial occurring.

Sludge was noticed to accumulate in the reaction vessel was a heavy, dark orange colour. In addition a light grey nature was observed. This material was likely to be degraded organic matter or alike.

The turbidity spike on start-up of the bores was significant. All bores excluding the Big Bore system are not routinely used. It is thus likely that the turbidity spikes will decrease with continuous operation of the bore systems. Stanbroke Beef personnel made the comment that flushing the bore for approximately 20 minutes typically resulted in clear water. This will depend on the bore condition, recharge rate, depth and general bore condition.

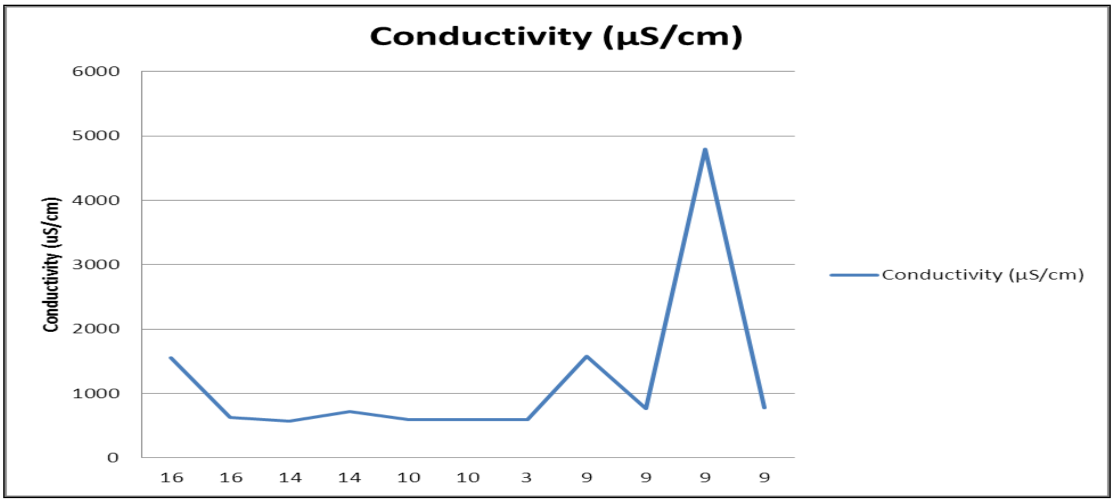
The trial plant processed in excess of 25 batches of bore water over the 4-5 week trial period. The batches trialled at the individual bores were in 1kL portions and trialled twice. Samples were collected and sport testing conducted on input and UF permeate water. Analytical samples were collected and results are shown below.

Table 2.1: All data presented in ppm. Conductivity in uS/cm.

Element	B9	Shed B	House B	AQ2BB	6ACR	RDHB	Big Bore
Calcium	37	200	42	240	69	39	230
magnesium	22	140	24	180	38	23	180
manganese	1.4	1.1	0.65	0.54	0.31	0.6	0.55
iron	1.8	1.8	6.9	2.8	3.9	0.3	0.55
silica	38	49	40	46	58	41	391
barium	0.07	0.2	0.05	0.3	0.06	0.05	0.3
potassium	5	4	3	5	2	3	4
strontium	0.33	2.1	0.36	3.4	0.46	0.32	3.5
sodium	57	370	61	490	75	57	500
hardness	180	1000	190	1200	310	190	1300

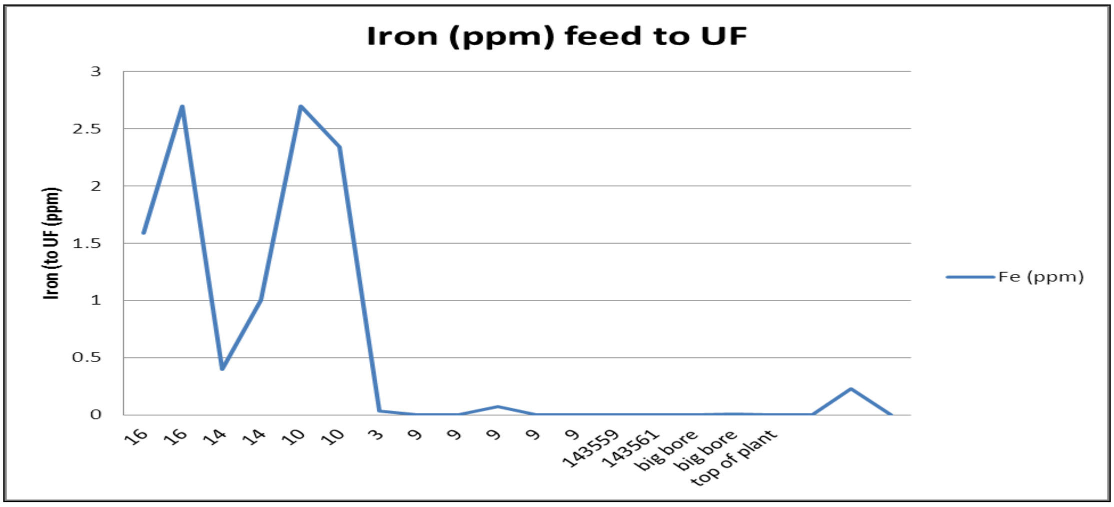
Plant Data	Value-Range	Comment
Water processed over trial period	72-120kL	2 weeks of mobile treatment travelling to various bore locations in bore area
Run time	Approx. 60 hours	Based on 4 weeks operation
Plant Rejection	75% typical	Set for recovery rate.
Plant inlet flow	35 L/minute	nominal
GAC pressure	0.18-0.24MPa	
UF operating pressure	0.18-0.22MPa	
RO inlet pressure	0.6-0.8MPa	As unit fouled, this crept to 1.1MPa. Variation in pressure also from varying osmotic pressure due to high salt concentration in feed (Big Bore)
Temperature	20-25c	
Conductivity inlet.	600-4000uS/cm	Variability from Creek to House bores.
Permeate outlet	40-150uS/cm	Variation expected due to inlet conductivity variability and membrane integrity.
Salt rejection (%)	95%	Nominal

Water Data gathered.



The conductivity results above indicate the various bores used versus bore location. Note the sample near the river. This indicates significant salinity ingress to the aquifer from the creek.

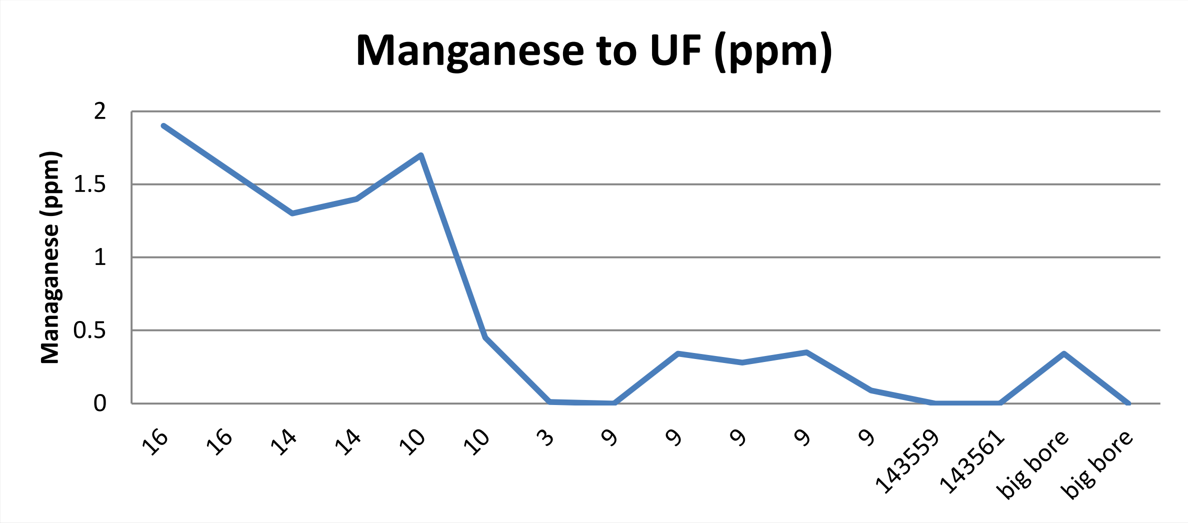
Conductivity loads the pressure up on the RO membrane (osmotic pressure) which can cause higher energy costs as the RO plant must operate at a higher pressure.



Iron results showed spikes upon start-up of bores, and elevated levels when near the furthest areas from the creek. This is consistent with conductivity – Iron will precipitate in the presence of high concentration of salts (similar to what happens at a river alluvial fan).

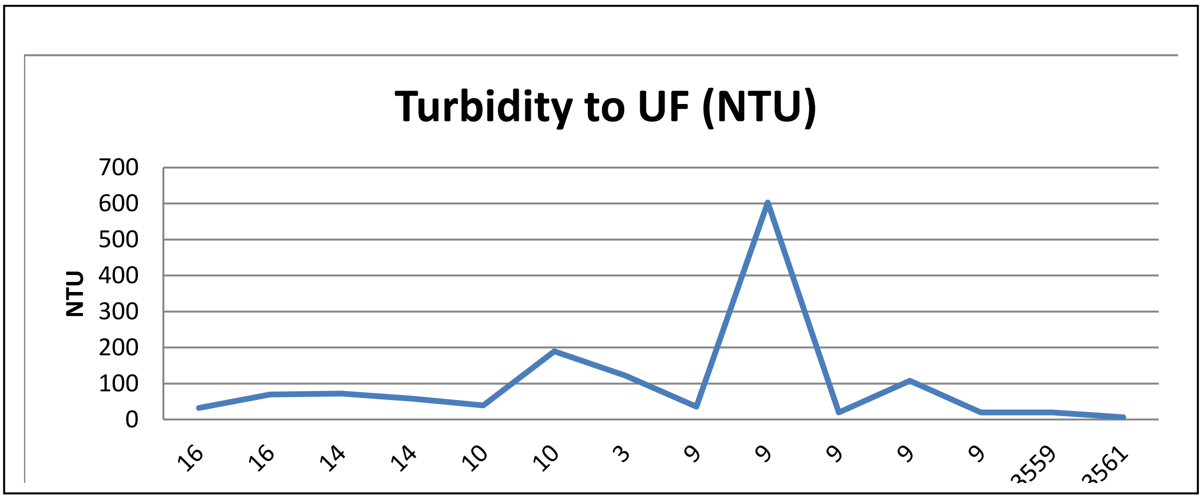
Too high levels of Iron can induce too much sludge formation and fouling of the UF and RO membrane surfaces.

Iron is removed using oxidation (chlorine) and coagulation. The MMF filters the particles out, and rejects them to waste.

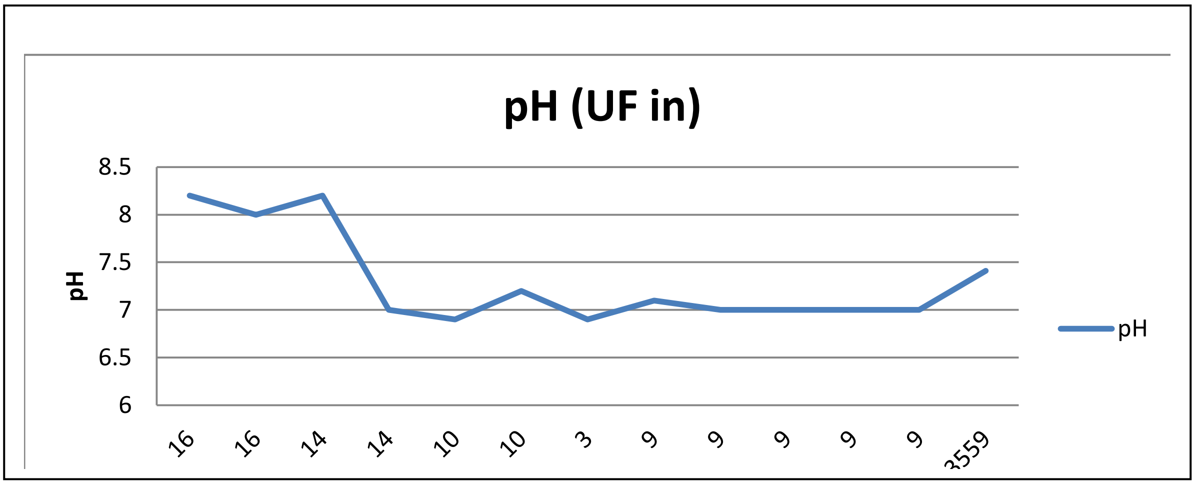


Manganese can induce excess sludge formation and fouling of the UF and RO membranes. To remove this, pH of 7-8 is used in conjunction with with chlorination and coagulation.

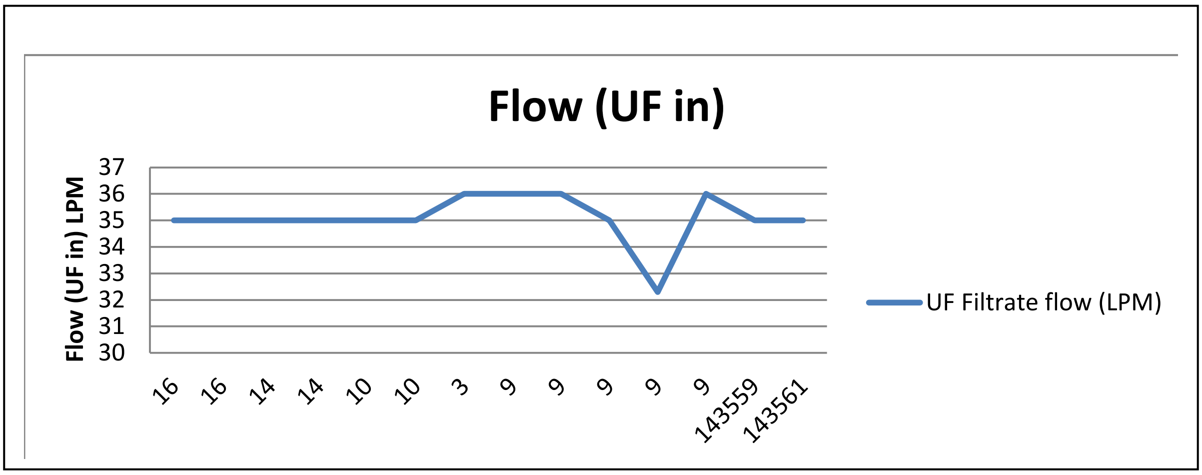
The sludge is removed using MMF and UF. Large particles can be removed in the main settling tank.



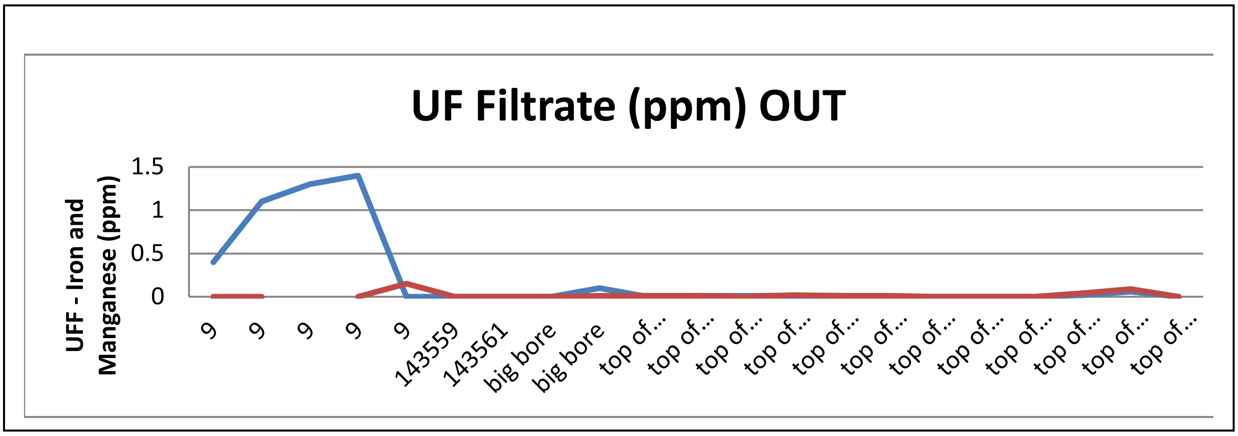
The UF feed turbidity is an indication of the effectiveness of the MMF units in removing particulate matter. These units saturate with iron and manganese particulate. This material must be rinsed away using back wash. The backwash water used should ideally be RO reject, or UF back wash collected.



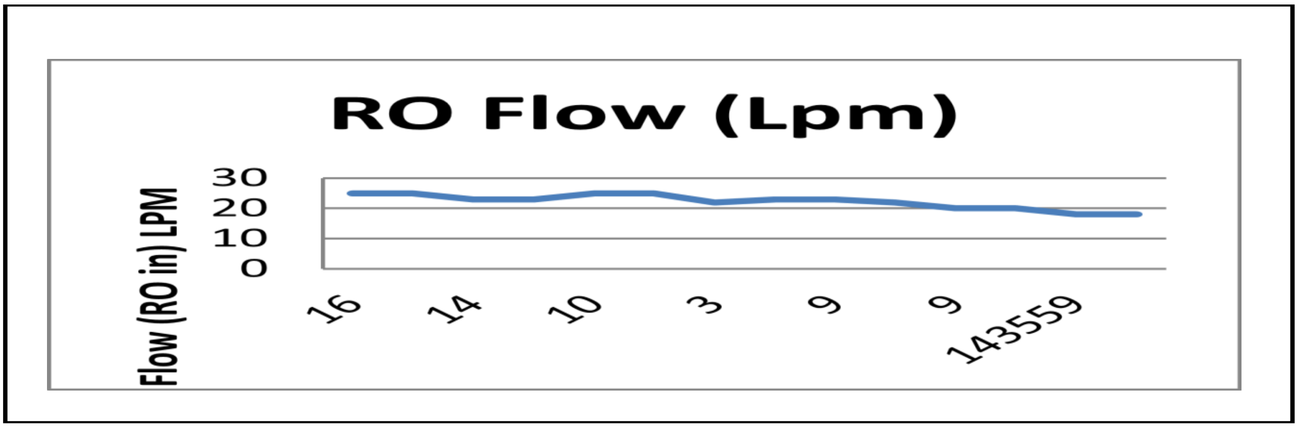
pH into the plant was critical due to the pH sensitivity of the Manganese oxidation reaction. This reaction is more rapid at pH 7-8.



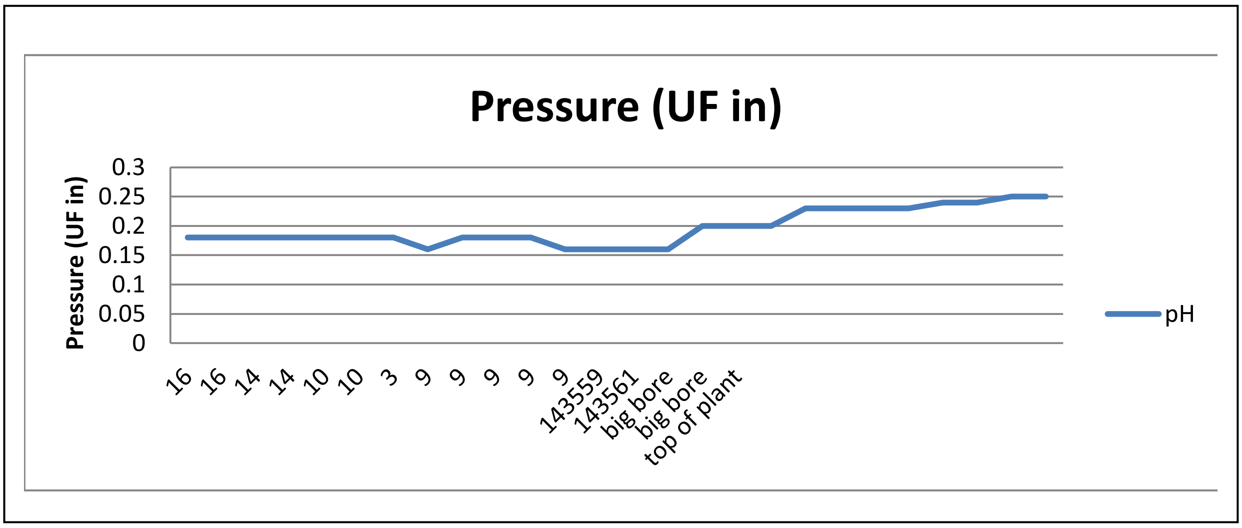
The input flow rate indicates any flow fall off from the MMF system. As can be seen, a flow fall off occurred as the MMF fouled. This flow was rapidly restored using back wash.



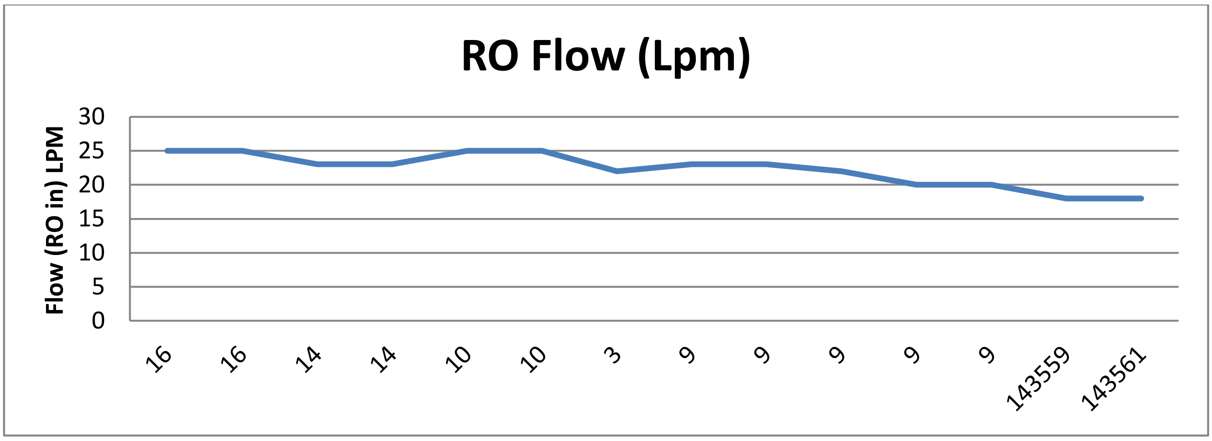
The UF permeate indicates consistent performance of the system, demonstrating that the UF did not foul heavily, and could be backwashed clean.



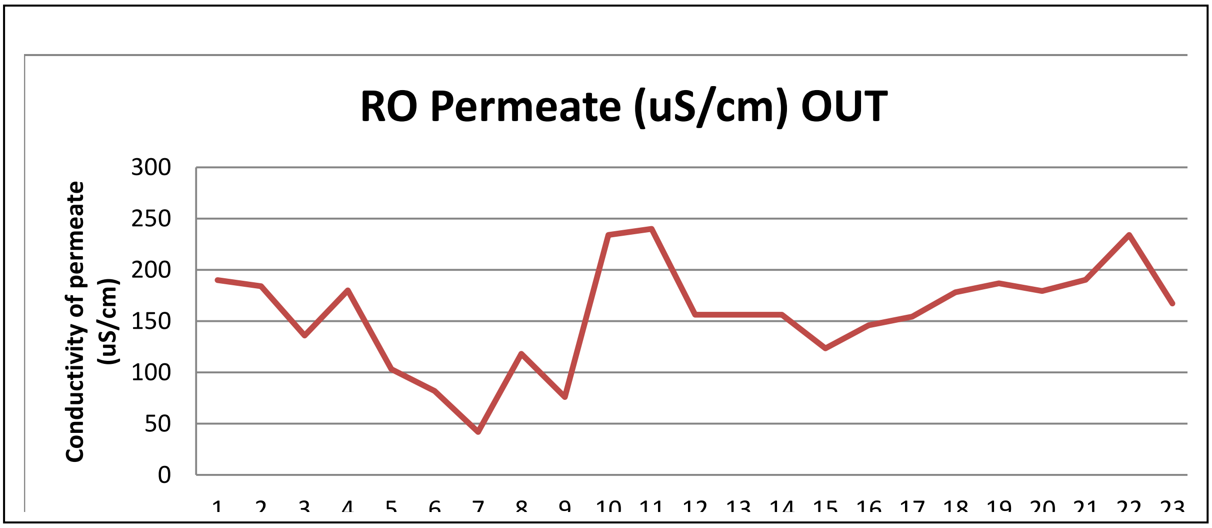
The RO permeate flow indicates consistent performance.



The pressure on the UF membrane indicates a small amount of fouling



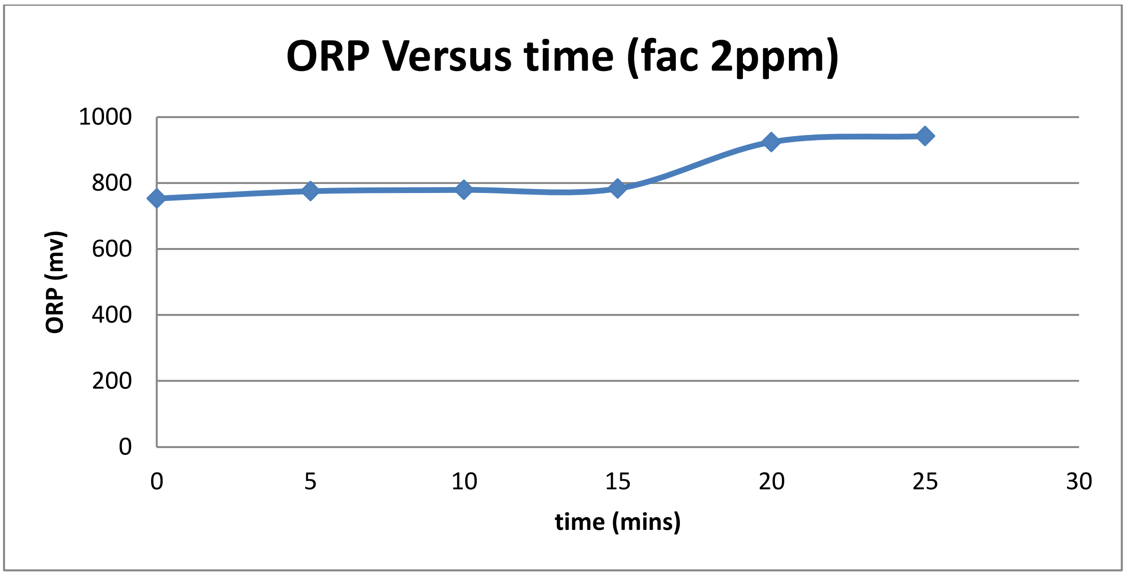
Flow fall off on the RO membrane indicates consistent performance with evidence of flow fall off.



RO conductivity indicates values of conductivity increasing with elevated input conductivity. This requires review of membrane type, and careful blending of the close to creek "big bore" water with the mid field and near road bores.

Effects of Coagulation/Oxidation

Studies were conducted to observe the importance of reaction dwell time on the manganese and iron content. Use of chlorine (hypo) and KMnO4 (potassium permanganate) were assessed and results graphed below.



Recommendations are made to utilise a 3D TRASAR for continuous monitoring and cycle all bores for feed. Recording time of start-up and shut down and correlating turbidity duration versus flow. This should demonstrate how quickly the turbidity remains in the system and how long to purge out. This will of course be flow dependent and time dependent.

Oxidation/ Reduction Potential (ORP)

ORP is a typical control method for chlorine and oxidising sterilising agents. This measure determines the potential difference between a platinum and reference and measuring cell this voltage (mV) is typically proportional to the concentration of species in the water, but is heavily interfered with by contamination, pH, temperature, and back ground from undesirable materials such as tannins and alike. The voltage measured is also interfered with by the metallic species such as manganese, Iron, and alike.

Plant Data Continued.

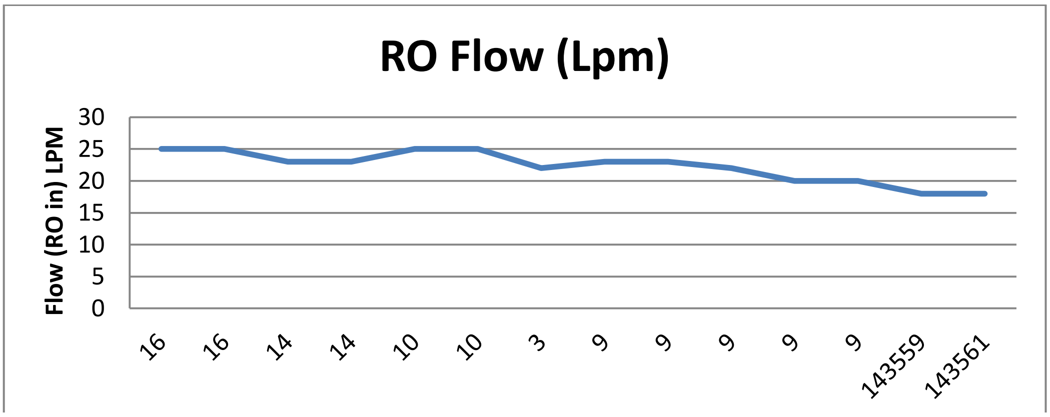
With the concentration of iron and manganese often exceeding 1ppm, ORP functionality is questioned.

The use of batch chlorination and coagulation may well require the use of colorimetry to control the chlorine dose. It is high likely that a free chlorine analyser will foul rapidly with iron and manganese materials and hence render poor control putting the plant as risk.

Spot testing conducted during the trial utilised hand held meters and colorimetry as means of measure. Recording of plant performance was made during operation was made and is recorded in the trial log.

Some bores processed very simply with the exception of the “big bore”. This bore was very low in iron and manganese and turbidity but had very high salinity. This salinity in turn resulted in elevated osmotic pressure and decreased throughput.

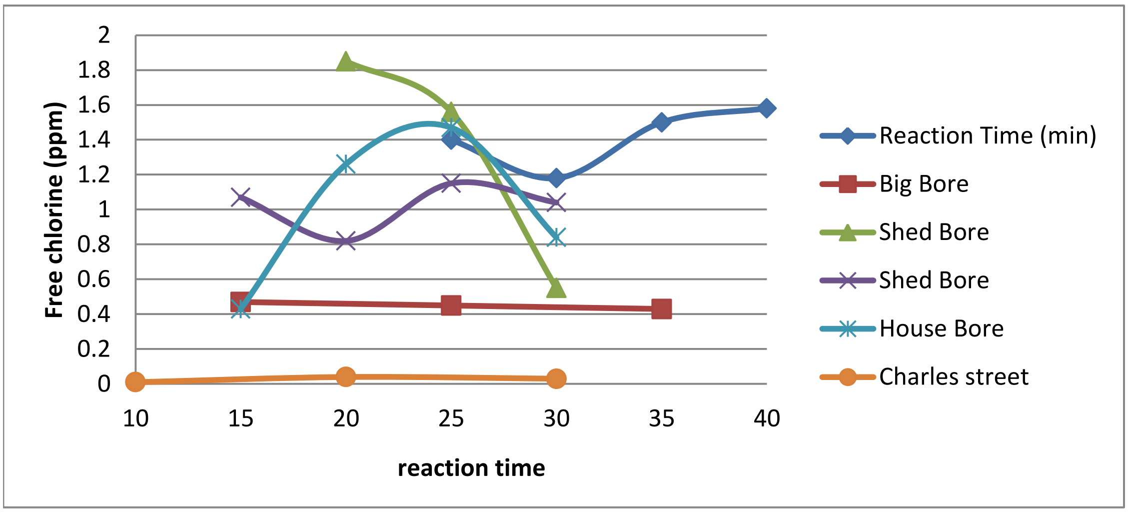
Fouling of the membranes was observed to worsen particularly when processing the big bore water supply. This demonstrated the need for an antiscalant designed and carefully controlled for the input water quality. Adjustment thereof will be critical as the mineral content of the component bores is significantly different.



The ultra-filtration plant (UF) showed no signs of fouling as demonstrated by no performance fall off nor increase in pressure. This is believed to have been the direct result of effective pre-treatment in the pre-reactor with the coagulation and chlorination/oxidation process.

Iron and Manganese Removal.

The post UF results demonstrated very high levels of effective iron/manganese removal and turbidity rejection <0.1NTU as a typical result. The exception in removal efficiency was with the "House Bore" which continued to have elevated manganese in the UF permeate no matter what the reaction time duration that was used. Please see below.



From the graph (previous) the heavier laden bores (laden with iron and manganese) show the greater rate of consumption of the free chlorine as shown by the steeper curve. The "Big Bore" and "Charles street" have immediate demand which flattens in demand. This can be observed as the same chlorine content is added to each of the batches each time (1ppm chlorine).

From the reaction curve, the reaction on all bores has tapered off after 30 minutes.

Water quality and Efficiency indications from the plant data.

The purpose of the UF-RO plant is cost reduction, emission reduction, energy reduction, corrosion reduction, and boiler feed water purity improvement.

Presented below in Table 1 are the specified values for plant performance required by Stanbroke. In the far right column, is the average permeate quality achieved by the trial plant. As can be seen, the trial met specifications for water purity.

Table 3.1.

No	Parameters	Units	Value	Trial plant (ave values)
1	pH (post pH correction)		6.5-7.5	7
2	Total Dissolved Solids	mg/L	<150	100
3	Sulphate	mg/L	<5	<5
4	Calcium	mg/L	<5	<5
5	Magnesium	mg/L	<5	<5
6	Silica	mg/L	<5	<5
7	Chloride	mg/L	<20	<10
8	Alkalinity	mg/L	<7.0	<7
9	Total Hardness	mg/L	<5	5
10	TSS	mg/L	<0.1	0

The purity of water to the boiler feed water required is as below.

Table 4.1.

No	Parameters	Units	Value	Trial plant (ave values)
1	pH		6.0 -7	7
2	Conductivity	µS/cm	<50	100
3	Chloride	mg/L	<20	<10
4	Alkalinity	mg/L	<7.0	<7
5	Total Hardness	mg/L	<1	5
6	TSS	mg/L	<0.1	0

As can be seen from above, the single pass RO unit cannot achieve required water purity alone. Nalco has thus designed an additional RO pass to purify the water to boiler specification.

The analytical data from the trial plant indicates compliance with the requirements of table 1 and 2 above.

The predicted performance improvement of the boiler plant is listed in Diagram

Diagram 2.1: Boiler Savings Summary using UF-RO plant

NALCO

TOOL IS OUT OF DATE !

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ENERGY STAR PARTNER

Boiler Energy & Water Savings

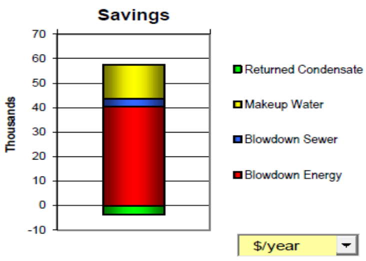
Company: **Stanbroke Beef** Date: **9-Jul-12**

Plant: **Boiler (main)** Prepared by: **M Collen**

City: **Grantham** NALCO Copy to:

Attention: **Customer Contact**

Copy: **Other Contact Names**



Input Values

Input		SI Units	Value
Sewer Cost		$/m³	0.50
Make Up Water Cost		$/m³	2.80
Makeup Water Temp.		°C	23.0
Return Condensate Temp.		°C	93.3
Fuel Cost	natural gas	$/GJ	8.06
Boiler Efficiency		%	80.0%
Operating Days per Year		Days	288

Boiler System Operation

		Current Operation Value	"What If" Analysis Value	Savings from Current
BD Heat Recovery	Yes or No	NO	NO	
Heat Recovery % Efficiency		80.0%	80.0%	
% Condensate Return	%	20.0%	20.0%	
Boiler Cycles	Cycles	6.0	50.0	
Steam Rate	kg/hr	5,000	5,000	
Steam Pressure	barg	8.0	8.0	
Steam Temperature	super heat °C	245	245	
Steam Enthalpy	kJ/kg	2,874	2,874	
Blowdown Enthalpy	kJ/kg	743	743	
Makeup Flow	kg/hr	4,800	4,082	718
Return Condensate Flow	kg/hr	1,200	1,020	180
Feedwater Flow	kg/hr	6,000	5,102	898
Blowdown Flow	kg/hr	1,000	102	898

Energy & Water Costs and Credits

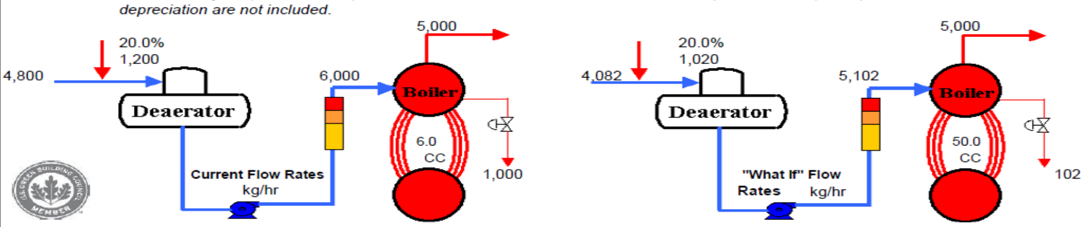
Blowdown Energy Cost	$/year	45,000	4,592	40,408
Blowdown Sewer Cost	$/year	3,458	353	3,105
Makeup Water Cost	$/year	92,957	79,045	13,912
Sub Total (Costs)	**$/year**	**141,416**	**83,990**	**57,426**
Returned Condensate Fuel (Credit)	$/year	-24,597	-20,916	-3,681
NET SAVINGS or (COSTS)	**$/year**	$/year		**53,745**
Calculated Cost of Steam*	$/1000 kg	31.35	29.79	1.56

NET CO_2 EMISSION SAVINGS (INCR) fuel is natural gas metric ton CO2 / yr **227**

Comments:

based on current meter readings 43kL of makeup is sent to boiler. (from softnenr)

**Includes only fuel, cost of water, and cost of blowdown sewer. Chemical treatment, maintenance, labor, and depreciation are not included.*



-963-Metric Energy&Water Savings Cal (11/08) v8.5 SI 11.25.08 Nalco Company 1601 W. Diehl Rd. Naperville, IL 60563-1198

The savings calculator indicates cost savings on gas and water of $53k. Savings on CO2 emissions are rated at 227T per year. Electrical consumption from the UF-RO plant is not factored into this calculation

The corrosion rate of the permeate generated is expected to lead to a mild steel corrosion rate of <1mpy based on modelling.

General comments on Water quality.

The water quality of the UF reject indicates it is not suitable (in isolation) for use on cattle wash, as it is heavily contaminated with iron, manganese, and solids. This also applies for the MMF back wash water.

The RO brine water is suitable for cattle wash, and, with approval from AQIS/AVA, be suitable for cattle drink. Since the salinity is elevated, the cattle drink greater volumes of water whilst on site and hence gain weight. This weight gains means greater carcass weight and hence greater sale value once processed.

The generation of solids from precipitation of iron and manganese must be managed. The levels seen in the trial may well require a clarifier, tube settler, or similar system to collected solids for disposal. Disposal of materials would likely be as an iron source fertiliser.

Section 7. Conclusion and Recommendations.

Overview

The trial has indicated that permeate quality can be achieved in compliance with the Stanbroke required limits. The bore water was shown to be able to be processed using the treatment design of chlorination, coagulation, precipitation, filtration, carbon filtration, ultra filtration, and reverse osmosis.

Significant impact was noted from the bore plant start-up namely, that a high level of iron rich sediment was received by the plant on commencement of processing. This must be taken into account when the system runs.

The properties of the brine reject indicate suitability for cattle wash and may well suit cattle drink. The high salinity levels are ideal for wet weight gain of the animals prior to processing.

The energy gains, water quality, and corrosivity modelling of the water indicate suitability of the solution. The savings agreed with projections.

Recommendations

Variation of water quality of bore samples close to the creek was noticed. The concentration of iron and manganese increased with distance from the creek (see bore sample versus location). Thus further sampling and subsequent blending of the waters for the upscaled plant should be considered.

Recommendation is made to finalise plant design of full scale system taking into account the information gathered by this trial. This includes the solids separated, high sediment load occurring at start up, chemical requirements, etc.

The use of the brine reject for cattle drink should be considered. Approval from the AVA/AQIS personnel should be sought if Stanbroke deem suitable to proceed. Not only does this have significant economic benefit, but the salt ingested by the cattle assist in salt reduction across site.

Disposal of the iron/manganese sludge must be sought and organised prior to plant start. This material should possess significant fertiliser benefits, but its properties should be verified.

A salt balance for the site with the new brine stream from the RO should be conducted. This allows any impact on the final discharge conductivity to be measured, and its impact clarified.

Appendix 1.1

Analytical Results