Appendix 4

Technical Memorandum – Narrabri Coal Project

Parsons Brinckerhoff (2007)

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TECHNICAL MEMORANDUM

9th March 2007

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Re: Narrabri Coal Mine Project

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1. Introduction and Background

Parsons Brinckerhoff (PB) has been engaged by Narrabri Coal Pty Ltd to provide guidance to the Company regarding the possible design and operation of a water conditioning plant to manage excess saline water pumped from the proposed Narrabri Coal Mine project.

Earlier in the project, GHD conducted a thorough review of local geology correlating hydraulic conductivity data from relevant strata of the Project Site. From this, GHD developed a groundwater model to predict the likely inflow of groundwater over time to the underground workings of the Narrabri Coal Project.

GHD groundwater modelling predicted that the volume of the mine inflow subsequent to the first fifteen years of operation is likely to exceed process requirements. Due to its saline nature, the groundwater needs to be stored on the surface and prevented from entering natural drainage systems. In order to accomplish this, it is proposed that the groundwater pumped to the surface from the underground workings would be discharged into a series of impermeable evaporation ponds.

This technical memorandum aims to investigate the suitability of and possible options for, groundwater management on site, which may include the option for a water conditioning system based on a process of integrated reverse osmosis with micro filtration. Such a system would be located in the Pit Top Area of the Project Site, adjacent to the evaporation ponds.

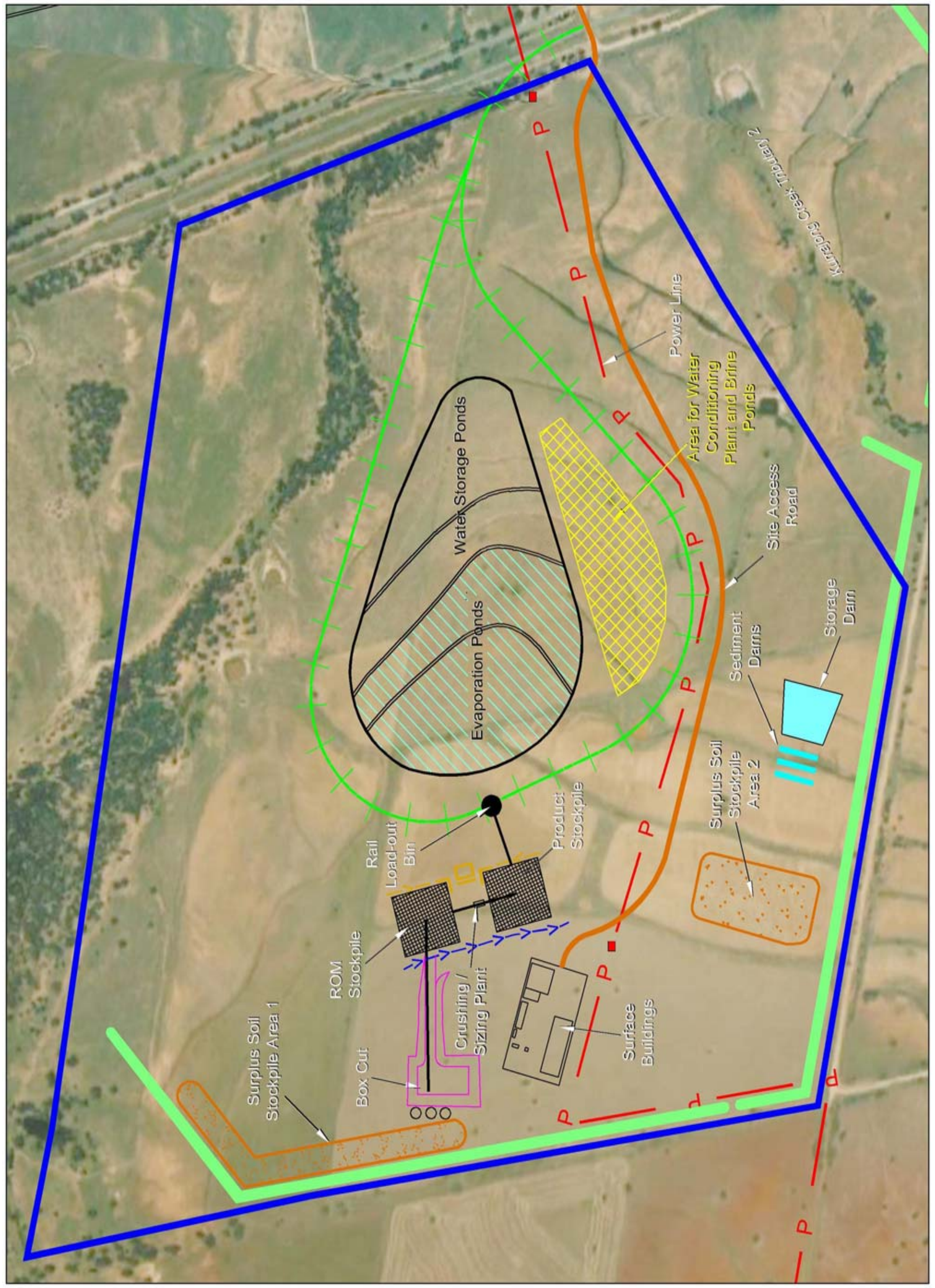


Figure 1 Site Layout – Pit Top Area

2. Water Balance

The water management regime on the Project Site, and more specifically in the Pit Top Area, has been designed to serve four primary functions, namely:

- Erosion and sediment control.
- Management of flood waters.
- Capture and storage of water for operational and environmental purposes.
- Storage, containment and conditioning if necessary, of saline water pumped from underground and possible usages such as irrigation.

Based on the model results undertaken by GHD, the estimated mine inflow of groundwater is as per *Table 1* below.

Year	Mine in flows (ML/Year)	Mine in flows (ML/day)
1	30	0.1
2	107	0.3
3	90	0.2
5	189	0.5
9	175	0.48
13	305	0.84
15	299	0.8
20	463	1.3
25	784	2.1

Table 1 Mine inflows

Table 1 is based on groundwater modelling undertaken by GHD using mean hydraulic conductivity values.

From the GHD modelling, it has been determined that the mine inflows peak at a rate of 784ML/year in year 25 of plant operation, following on from this the inflows decrease to a relatively steady inflow of approximately 1.9ML/day.

The proposed water management plan allows for mine inflows to be stored within the evaporation ponds and be available for dust suppression and other purposes as demonstrated in *Table 2* below.

Outputs	Rate (L/tonne)	Usage (ML/year)	Usage (ML/day)
Underground dust suppression	33	66	0.18
Surface dust suppression	17	34	0.09
Additional water application to coal stockpiles	25	50	0.14
Evaporation	N/A	150	0.41
Potable Water	N/A	7	0.02

Table 2 Water outputs via dust suppression and product watering

A water balance (figure 2) constructed for the Narrabri Mine based on inflows and outflows, as shown in Table 1 and 2, estimates annual surplus and/or deficits as indicated in Table 3.

Year	Usage ML/year	Usage ML/day
Year 1	-270	-0.74
Year 2	-193	-0.53
Year 3	-210	-0.58
Year 5	-111	-0.30
Year 15	-1	0.00
Year 20	163	0.45
Year 25	484	1.33

Table 3 Water Balance

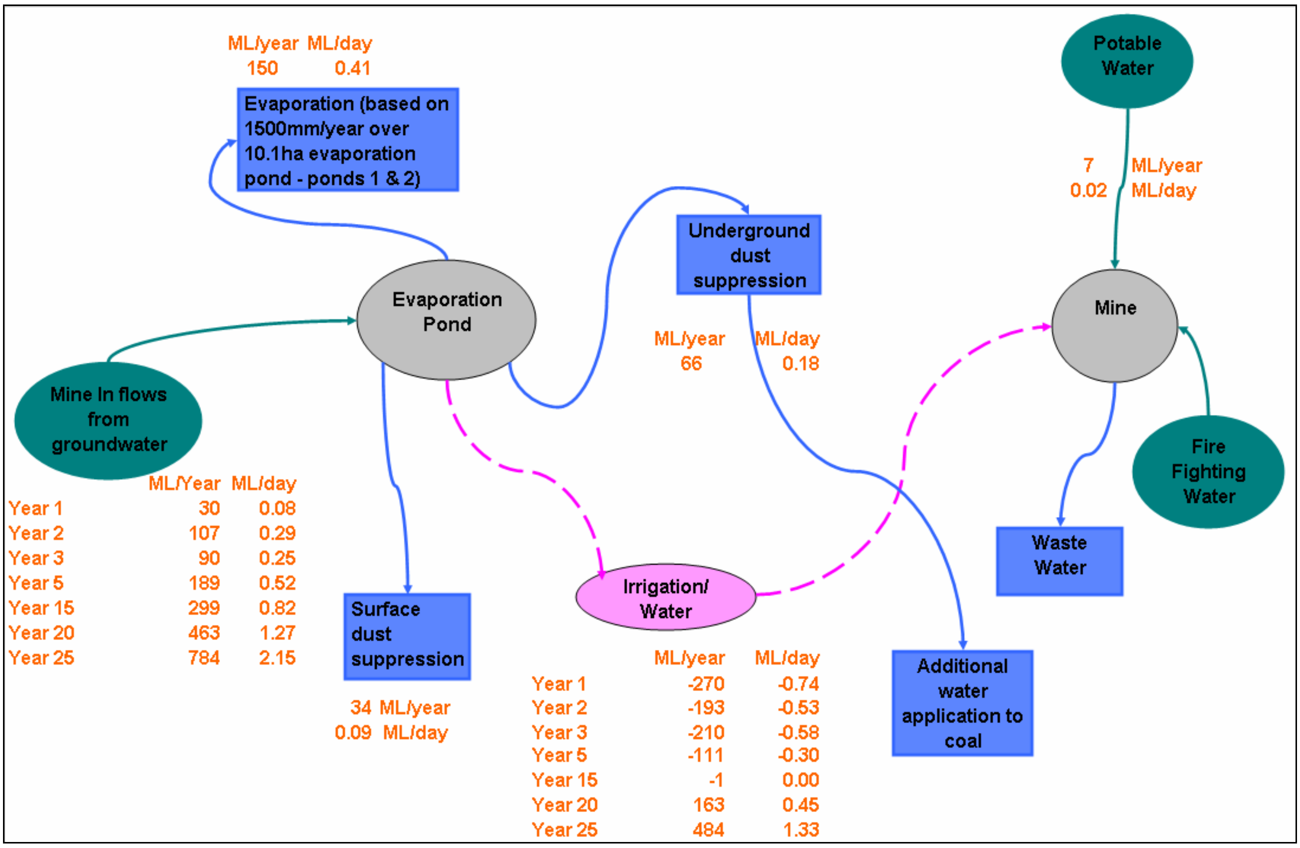
The deficit in the first 15 years of operation shall be offset by the 0.41 ML/day of evaporation. This would negate the requirements for the large evaporation ponds during this period of water shortage.

The water balance is based on the following data:

- Mining of coal at a maximum rate of 2.5 million tonnes per annum.
- Potable water requirements for approximately 100 staff using a typical rate of 0.2kL/day of water per person i.e. showers, drinking etc.

The water balance for the site is therefore depicted as follows in figure 2 below.

Figure 2 Water Balance for the Narrabri Coal Site



3. Water Quality

3.1 Raw Water

The groundwater that is to be encountered by the underground workings is saline in nature with a calculated total dissolved solids (TDS) concentration of approximately 25,000mg/L. This value was determined by calculating the average chemical composition from the water analysis done on a number of test wells on site; see *Table 3* of this report. Further test wells on site were analysed for electrical conductivity values, and the TDS based on these figures (calculated using an empirical conversion factor) were approximately a third of the calculated value of 25,000mg/L. In these preliminary stages, it is recommended to use the calculated value of 25,000 mg/L as this value is believed to be more accurate. The 25,000 mg/L TDS value is also considered to be the worst case scenario at this stage. Further testing is required prior to any detailed design stages.

Although no turbidity and suspended solids analyses were carried out, it was reported that TSS (total suspended solids) levels could be elevated and therefore turbidity would be high.

Based on the data provided taken from test wells on site, the groundwater, and hence the feed stream to the water conditioning system, would be made up of the components listed in *Table 4*.

pH	8.17
Electrical Conductivity (µS/cm@25°C)	20200.00
CATIONS	
Ammonium	0*
Potassium	112.57 mg/L
Sodium	7303.88 mg/L
Barium	0
Calcium	8.98 mg/L
Iron	0
Magnesium	5.99 mg/L
Manganese	0
Boron	0
ANIONS	
Bromide	0
Chloride	581.65 mg/L
Fluoride	0
Hydroxide	0
Nitrite	0
Nitrate	10.28 mg/L
Sulphide	0
Bicarbonate	16260.34 mg/L
Carbonate	1148.67 mg/L
Sulphite	0
Sulphate	5.85 mg/L
Theoretical Total Dissolved Salts	**25,438 mg/L**

Table 4 Ground water analysis

*Components in the feed stream with a value of 0mg/L were negligible or not present as per the laboratory testing results.

As the results of the analyses from various sample sites are similar, a simple arithmetic average was calculated for each of the above values.

3.2 Treated Water

If a water conditioning plant is to be installed, it is proposed to treat the water such that it meets the Australian Drinking Water Guidelines (ADWG). The palatability of drinking water has been rated in the ADWG based on TDS as outlined in *Table 5* below.

TDS Concentration (mg/L)	Quality
<80	Excellent
80 – 500	Good
500 – 800	Fair
800 – 1000	Poor
>1000	unacceptable

Table 5 Summary of water quality for TDS based on the ADWG

No health requirements are specified in the ADWG in relation to the TDS content in drinking water.

The TDS in this conceptual design would be brought down to at least a level of under 500mg/L to provide a “good” quality water. This water may then be used on site as a source of potable water, negating the need to transport water to the site for that purpose. The treated water would also be suitable for irrigation.

Based on the preliminary concept plans completed, (see results below), the feed stream from a combined micro filtration and reverse osmosis conditioning system would yield water with a TDS quality of under 80mg/L which is classified as “excellent” as per the ADWG.

If excessive groundwater is still being encountered on site then the conditioning plant can be up-scaled and excess treated water sold as drinking water off site or provided as a community service in emergencies.

4. Water Conditioning Plant

4.1 General

A water conditioning plant capable of treating the excess saline groundwater would be based on combined micro filtration and reverse osmosis (RO) technologies, and could be installed as a self contained unit capable of handling a feed of 0.5ML/day. The number of units could then be increased if groundwater inflows increase over time. Each containerised unit would house a robust stainless steel box frame-mounted RO suitable for frequent transportation. It would incorporate pressure tubes loaded with RO membranes and have a built-in alarm and shut down system to ensure the system is fail safe. Each containerised unit would come with flange connections for feed, permeate and reject and could be integrated with feed and treated water pumps and level controls.

A schematic representation of the conditioning plant system is as follows.

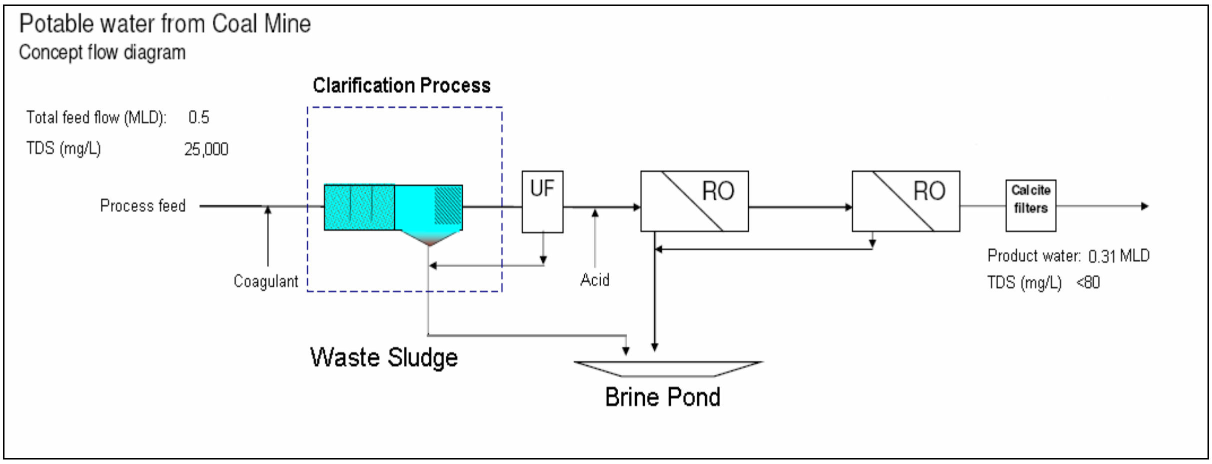


Figure 3 Schematic diagram of the conditioning plant system

The footprint of the system would be as follows.

- Micro filtration (MF) + main control panel and operator/monitoring interface = 1 x 20' container (length = 5.9m x width of 2.3m).
- Each RO pass, including high pressure pumps would be contained in 1 x 40' container (length = 12m x width of 2.3m).
- Break tanks between each stage are recommended. These can be poly/GRP/coated steel or other tanks. Sizes are flexible depending on available space.

The approximate footprint of the proposed water conditioning plant (which can be either installed in containers or a purpose built structure/building) would be 10m x 12m, or 120m^2 which would incorporate a loading area for chemicals and tanks.

An additional surface area of up to 10ha (2 x 5 ha) would need to be provided for the construction of ponds to contain the brine produced by the reverse osmosis process.

Preliminary estimated irrigation area for maximum surplus water is approximately 20 ha. A more detailed water budget is required to determine the exact area. This figure is based on 6 ML/ha per year and approximately 0.3 ML/day of available irrigation water.

4.2 Pre-Conditioning

The concept planning of the pre-conditioning depends on the physical, organic and biological parameters of the groundwater. Its main purpose is to eliminate or to limit the negative impact of suspended solids, colloidal matter, scale, micro-organisms and any special water constituents to which the RO membranes are sensitive.

The pre-conditioning system for the RO water conditioning plant will aim to correct the pH via a process of micro/ultra filtration. The MF/UF process would be capable of handling suspended solids and would be further specified in the detailed design phase.

The pre-conditioning process is schematically represented in *Figure 4*.

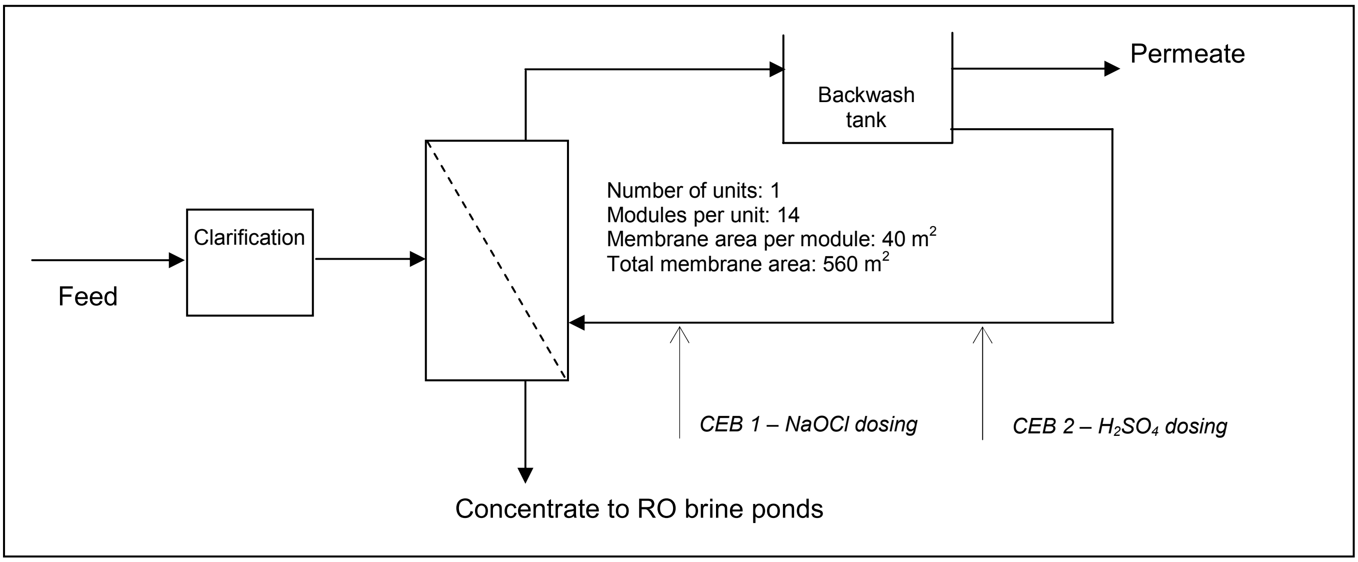


Figure 4 Schematic diagram of the filtration process

The initial clarification process serves to remove large solid particles from the ground water before it enters the MF/UF filtration unit.

The MF/UF filtration unit would typically consist of 14 membrane modules in the one unit that reduce suspended solids, colloidal material and bacteria. The 14 membranes have a total surface area of 560 m^2.

The MF/UF system was sized based on a feed of 0.5ML/day with a recovery of 78.1% and an efficiency of 72% The total suspended solids (TSS), which is the amount of solids in the water has been assumed to be high for the groundwater coming from the underground mine. However, after screening upstream of the MF/UF system, TSS would be reduced to <120mg/L.

The operation of the MF/UF filtration plant involves hydraulic cleaning (HC) and two lots of chemical enhanced backwashes (CEB's). Each backwash/cleaning is based at different intervals and generates different wastes. The CEB 1 is performed with sodium hypochlorite whilst the CEB 2 is performed with sulphuric acid at each cleaning interval. *Table* 6 provides estimates for plant cleaning requirements.

	Intervals	**Number of operations per day ***	**Backwash waste (L/day)**	**Forward flush waste (L/day)**	**Other waste (L/day)**
Hydraulic Clean	Every 15 minutes	80	970	470	N/A
CEB 1	Every 6.3 hours	3.2	970	470	CEB waste = 3900
CEB 2	Every 12.8 hours	1.5	970	470	CEB waste = 3900

Table 6 Operation of the pre-conditioning plant

*Based on 20 hour operation per day.

The estimated power consumption associated with the pre-conditioning MF/UF system is tabulated below.

Drive	Motor kW	Hrs/day	kWhrs/day
MF Filtrate Pumps - Filtration	18.5	21.3	176
MF Filtrate Pumps - Backwash		0.3	1
MF Filtrate Pumps - CIP	11	0.43	4
CIP Heater/s	10	0.41	13
Strainers	0.37	2	1
Air Compressor/s	Refer to Common Equip Data		0
B/W Disposal Pumps	0.75	24	0
Dosing	0.2	24	2
PLC's		24	5

Table 7 Power Consumption for Pre-conditioning system

Table 8 lists the chemicals and the quantities required to successfully run the pre-conditioning system.

Chemical Consumption		CIP Usage		Totals
Chemical	**Conc. wt%**	**Caustic kg (100%)**	**Acid /day**	**kg/day as Del.**
Sodium Hypochlorite	12.5%	0.55	0.00	4.40
Sulphuric Acid	98%	0.00	1.13	1.15
Memclean C	100%	0.00	0.00	0.00
Na-EDTA	40%	0.00	0.41	1.03
Hydrogen Peroxide	50%	0.00	0.00	0.00
Aluminium Chloro-hydrate	50%	-	-	24.91

Table 8 Chemical Consumption of the MF/UF plant

Chemicals would leave the system as backwash waste, which is generally of low pH and can be disposed of with brine to brine evaporation ponds or with other waste sludges, if available. The evaporation ponds would need to be appropriately sized so as to compensate this.

4.3 Reverse Osmosis

The water conditioning process is facilitated by a reverse osmosis (RO) system. Here, the dissolved solids content of the groundwater is reduced through the membranes, working on the principle of reverse osmosis. RO involves pumping water into a pressure vessel where it passes through the RO membrane rejecting the dissolved solids including salt.

The design of the reverse osmosis system including membrane selection depends on the physical and chemical parameters of the filtered groundwater, on the required water quality and quantity, and on the capability of the plant. However, even with careful pre-conditioning of the groundwater, fouling of the RO membranes in the course of the time cannot be excluded. The reason for this may be organic, inorganic or even biological substances. As such, membranes require periodic cleaning to remove fouling or scaling to prevent excess deterioration and reduction in productivity and salt rejection.

In order to produce drinkable water of high quality, a two pass RO system may be required plus post conditioning. The system would also consist of a pH adjustment, typically using a mixture of sulphuric acid and caustic, to suit exact water characteristics. To re-mineralise the water after RO, to limit pipe corrosion and to ensure appropriate taste, the water would be re-mineralised. A chlorine residual would be added to suit the distribution network and fluoride dosing could be added, if required.

The following table lists the chemicals and estimates the quantities required to successfully run the RO system.

Chemical Consumption				Totals
Chemical	Conc. wt%	CIP kg (100%)	Other /day	kg/day as Del.
Caustic Soda	49%	0.11	0.00	0.23
Sulphuric Acid	98%	0.00		0.00
Sodium Tripolyphosphate	100%	0.03		0.03
Na-EDTA	40%	0.01		0.01
		0.00		0.00
All purpose Antiscalant	100%		13.73	13.73

Table 9 Chemical Consumption for the RO process

Chemicals would leave the system similarly as to that described for micro-filtration above, i.e. as backwash waste to brine ponds.

The associated power usage for the RO system is summarised in *Table 10*.

Drive	**Motor kW**	**Hrs/day**	**kWhrs/day**
RO Feed Pumps	18.5	24.0	264
RO High Pressure Pumps - 1st Pass	55	24.0	1868
RO High Pressure Pumps - 2nd Pass	40	24.0	356
CIP Pump	11	0.10	1
CIP Heater	10	0.05	1
Anti-scalant Dosing	0.2	1	2
PLC's		24	5

Table 10 RO system power consumption

4.4 Post Conditioning

Chemicals used for conditioning are added to drinking water mainly to reduce or eliminate the incidence of waterborne disease, for other public health measures, and to improve the aesthetic quality of the water.

To produce water of a suitable quality for use in the mine as potable water, it would be necessary to dose the water with specific chemicals downstream of the RO stage.

Water from the RO plant to be used as potable water on the mine site would be typically dosed as follows to ensure the Australian Drinking Water Guidelines are met:

- carbon dioxide dosing
- lime dosing for alkalinity
- fluoridation through hydro fluoro silic acid dosing (optional)
- chloramination through sodium hypochlorite and ammonia dosing.

4.5 Other Infrastructure

Other infrastructure associated with the proposed water conditioning plant would include the following.

- Water storage tanks for clean water – this would typically be sized according to at least one day's production from the conditioning plant, say 300kL. This could be managed via 3 x 100kL above ground tanks.
- Pumps sized to handle 0.31ML/day capacity.
- Rising main.
- Reservoir sized for 1 days flow – say 0.3ML with hypochlorite dosing system
- Brine pumping station (if necessary).

5. Preliminary Concept Planning for a Water Conditioning Plant

5.1 Results

Preliminary level concept planning was undertaken on a combined MF/UF and reverse osmosis water conditioning plant.

PB has undertaken this high level planning concept based on modelling potential layouts for the RO arrangement using an iterative approach to optimise the system and achieve acceptable recovery along with minimum TDS values. It is believed that the system could and would be further optimised during future technical stages of the project.

Assumptions used to model the system were as follows.

Operating temperature 25 degrees Celsius.

Well water classification.

Fouling factor of 0.85 for the system.

Feed flow of 0.5ML/day, i.e. 25m^3/hour based on the system operating 20 hours per day to allow for extra spare capacity in the system. This feed rate ignores considerable losses through the MF/UF system with its waste product (in the order of 22%) i.e. both the MF/UF and RO systems were designed for a 0.5 ML feed.

The aim of the concept plan was to increase the recovery of the system and decrease the TDS in a reasonable manner so as not to excessively increase the cost of the system, i.e. by adding more elements/pressure vessels etc to the system and by keeping the power required to run the system down to a minimum.

A number of scenarios were analysed using an iterative approach to determine the optimum relationship between TDS, the number of elements in the system, power requirements and recovery rates. In addition, different TDS feed concentrations of 25,000 vs. 12,000 were used to compare the complexity of the process. The following tables represent typical conditioning plant parameters for differing TDS concentration.

Pass	**1**	**2**
Stage	**1**	**1**
Pressure vessels per stage	4	2
Elements per pressure vessel	7	7
Total number of elements	28	14
Feed pressure	32 bar	10 bar
Final TDS	<80 mg/L	
System recovery	58%	
Energy consumption	1.79 kWh/m^3	0.49 kWh/m^3

Table 11 System design for a TDS value of 12,000 mg/L (two passes, one stage per pass)

The scenario shown in *Table 11* presents a conditioning plant with a feed TDS concentration of 12,000 mg/L. It has a total of 42 elements (for both passes) and a final TDS concentration of less than 80 mg/L, which is rated as "excellent" under the ADWG.

Pass	**1**		**2**	
Stage	**1**	**2**	**1**	**2**
Pressure vessels per stage	3	3	2	2
Elements per pressure vessel	8	8	7	7
Total number of elements	24	24	14	14
Feed pressure	46 bar	44 bar	7 bar	5 bar
Final TDS	<80 mg/L			
System recovery	61%			
Energy consumption	2.48 kWh/m^3		0.34 kWh/m^3	

Table 12 System design for a TDS value of 25,000 mg/L (two passes, two stages per pass)

The scenario shown in *Table 12* has a feed TDS concentration of 25,000 mg/L, uses a total of 76 elements and treats the water to a concentration of less than 80 mg/L which is rated as "excellent" under the ADWG.

The two scenarios have similar design outputs despite their differences in initial TDS concentration and both have suitable effluent TDS quality. Significant differences between the two systems are the number of elements and pressure requirements which are the key parameters for a cost effective plant. As the number of elements increases, the capital and operating costs of the process increases.

A system with a two pass (two stages per pass) RO process as depicted in *Figure 5* below was selected at this stage to treat the groundwater with an estimated 25,000 mg/L TDS.

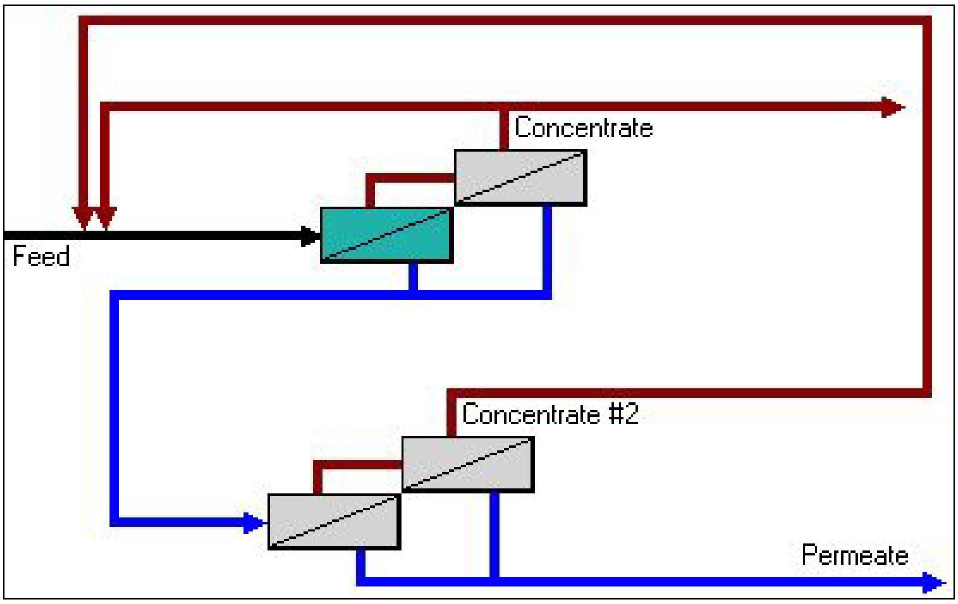


Figure 5 Selected RO system

The selected option would provide an overall recovery rate of 61% to the system. Therefore, based on a flow rate of 500kL (0.5ML) per day, this would produce 305kL/day of potable water with a TDS of less than 80mg/L. The concentrate streams would therefore produce 195kL of brine per day. This brine would need to be stored in brine ponds for further concentration of salts by evaporation. Based on an average net evaporation rate of 1500mm/year the brine ponds would need to have a surface area of approximately 5 ha. For contingency purposes to allow for reduced evaporation rates with concentrate and for operational flexibility, it is recommended to double the size of this evaporation pond to approximately 10 ha, i.e. pond size of 5 x 2 ha. The power associated with this RO system was estimated at 2.8 KWh/m^3.

The feed pressure to pass 1 was estimated at approximately 46 bar and the feed pressure required for the feed into pass 2 would be approximately 7 bar. The first pass would require a total of 6 pressure vessels and 48 elements, whilst the second pass would require a total 4 pressure vessels and 28 elements, therefore the total number of elements for the system would be 76. It is estimated at this stage that TDS variation would increase the capital cost by approximately 40%.

5.2 Discussion

The preferred option for the RO plant is based on the aim of reducing the TDS whilst balancing costs for the system through keeping the number of elements down and maximizing the recovery rate.

To reduce the size of the evaporation ponds and increase the recovery of the RO system to 90% there is an option to install a brine minimisation process. Typically this process is used on the RO reject from the first pass RO. The process is tailored to the water characteristics and for small volumes, such as for this application, would be considerably simpler. With a recovery of 90%, the evaporation ponds would need to have a surface area of approximately 2.5 ha (including the contingency). This is a reduction of 75% of the area.

If space on site was a critical factor at the Narrabri Coal site this would be a feasible option, however based on the low feed rate per day it would be more cost effective to operate without a brine minimisation process and dedicate 10 ha of land to evaporation ponds.

Following treatment in the RO, the TDS would be under 80mg/L, which is classified as an “excellent” drinking standard in accordance with Australian Drinking Water Guidelines. Therefore this water would be suitable to be used as potable water on site or sold as a high quality drinking water off site.

Currently there is a 20 hectare area reserved for evaporation/storage ponds in the Pit Top Area. In addition to this, the proposed water conditioning plant including brine ponds is estimated to have a foot print of at least 10 hectares which allows space for brine evaporation ponds. The current etched area (as shown in yellow on *Figure 1*) only allows for 6 ha space for the water conditioning plant, as such if the water conditioning plant was to go ahead it would need to do so at the expense of expanding the evaporation ponds area.

6. Conclusion

Based on GHD’s predicted groundwater inflows supplied for the site, PB predict that as the volume of annual mine inflows increases, there would ultimately be a surplus of water beyond which could be managed within the nominated evaporation / storage ponds. Between Year 15 and 20, the groundwater inflow would increase gradually to about 0.5ML/day. At this volume of inflow, PB does not consider it feasible to construct and operate a water conditioning system, rather, the construction of an additional evaporation pond of approximately 12 ha would be a preferable solution.

However, should mine inflows continue to increase (GHD predict groundwater inflows to peak around Year 25 and stabilize to an approximate inflow of 1-1.5ML/day), PB considers it a feasible option to construct and operate a water conditioning system, as detailed in this report (subject to water quality review and analysis). If groundwater inflows increase as predicted, then 0.5ML/day increment package conditioning plants can be supplemented on to the original system to give the desired aggregate treatment capacity per day at the appropriate time.

PB strongly emphasises the importance of using an accurate TDS value when determining if a water conditioning plant is a feasible option for the Narrabri Coal Mine Site. Based on PB’s preliminary modelling, it was concluded that the system is extremely sensitive to TDS values. Feed flows could be increased and overall costs of the system still reduced as a whole based on decreasing the TDS value. The higher the TDS, the more elements that is required in the conditioning system which dramatically increases the cost. Therefore, if high TDS values and low groundwater inflows are confirmed, then a water conditioning plant would not be justified based on the high cost of the conditioning system and the relatively low production of treated water (61% recovery). In this circumstance it would be more efficient to use the evaporation pond option. If, however, refined TDS values are significantly lower and/or ground water inflows are high over the years of operation, then it may be worth while to further investigate the option of installing a water conditioning plant as conceptually outlined in this report.

Additionally, cognisance must also be given to overall required water supply conditions when making decisions to condition water on site.