Collie-Wellington Basin

Water Source Options

Investigation

a

Supplementary Submission

By

Agritech Smartwater

11 December 2006

By invitation from the Policy Division

Department of Premier and Cabinet

Perth, Western Australia

A Supplementary Submission to the Steering Committee appointed to investigate Collie-Wellington Basin Source Options as initiated by the Policy Division, Department of Premier and Cabinet, Perth, Western Australia.

11 December 2006

Main Issues Addressed in this supplementary submission :

- Technical Feasibility of Gravity Fed Reverse Osmosis from Wellington Dam Scour Water
- Basic Description of Reverse Osmosis Systems
- Effects of Different Types of Feed Water on R.O. System Operation
- Conclusion

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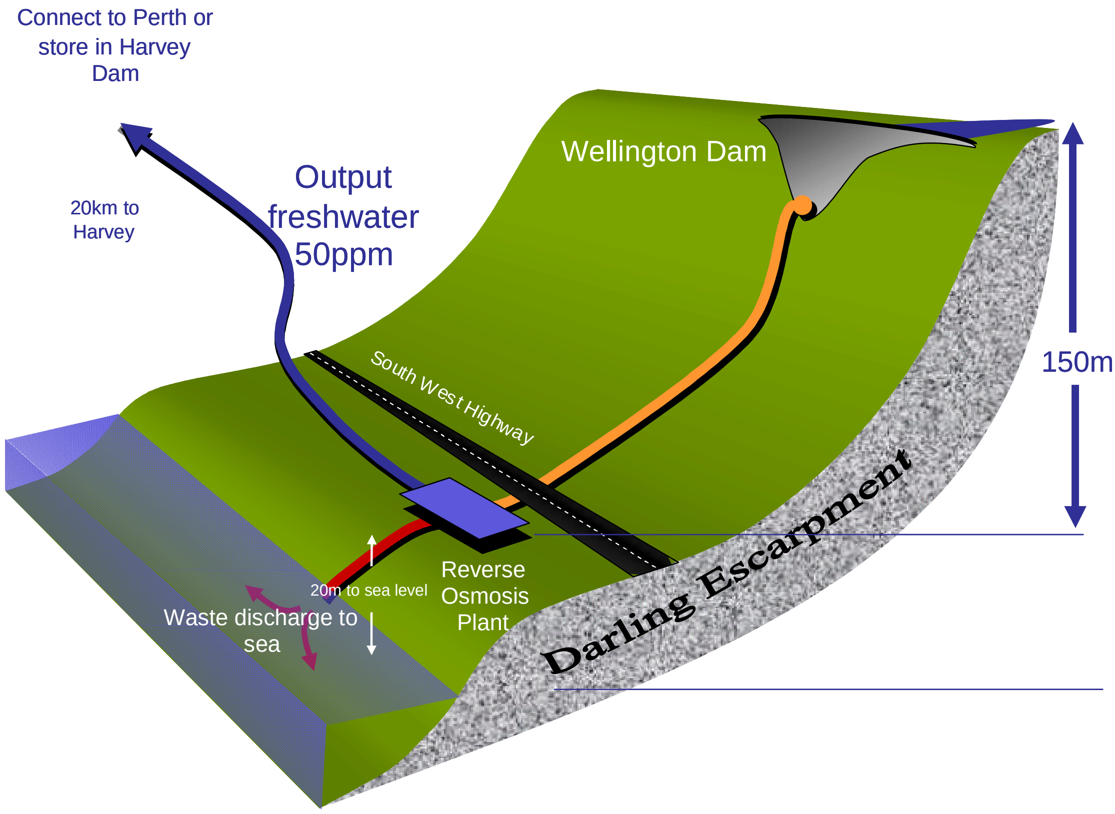
Technical Feasibility of Gravity Fed Reverse Osmosis

from

Wellington Dam Scour Water

This project will use a Reverse Osmosis (R.O.) process to desalinate the brackish scour water from Wellington dam into high grade potable water for domestic supply to Perth. It will use the pressure (hydraulic head) produced from the elevation difference (150m) between Wellington dam and a reverse osmosis desalination plant located at the foot of the Darling escarpment.

After a careful review of all factors, it is concluded that the above project is technically viable and the scheme is commercially viable without factoring in social and environmental benefits.



Project Graphic

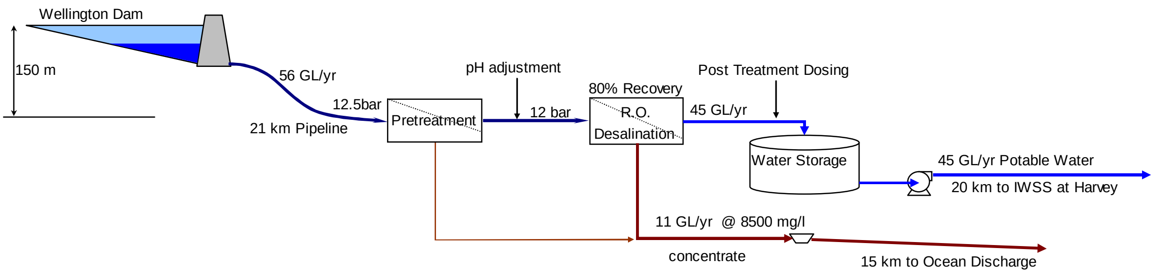
- Currently brackish scour water is discharged from Wellington dam during the winter months. The timing and duration of this scouring is then limited by the availability of the Collie river downstream of Wellington dam to transport this scour water to the Leschenault estuary but usually occurs between June and the end of October. The Collie River is unavailable at other times due to its use in transferring irrigation water from Wellington dam to Burekup weir. This rapid scouring rate has limitations in that it can cause breakthrough (vortex) where fresher water is drawn into the scour stream from the top strata's in the dam in preference to the saline layer on the bottom of the dam. This also causes mixing of the different strata's (layers) in the dam. A much slower and continuous withdrawal, as would be the situation if the scour water was withdrawn for desalination purposes, would be expected to produce better scouring of the saline layer from the dam because the breakthrough and mixing of the strata's would not occur. Additional sources of brackish water available at the top of the escarpment may also be able to be combined into this feed water stream to provide continuity of supply in the event of reduced quantities of scour water.

- Significant advances in reverse osmosis membrane technology are such that the quality of the water produced more than meets required Australian and World potable and drinking water standards and guidelines. In addition recreational and other activities on Wellington dam will not have to be curtailed and will have no effect on the final quality of the water produced by the reverse osmosis plant.

- The potable water produced would then be piped approx 20 km to Harvey to connect into the Integrated Water Supply Scheme (IWSS) connection point at Harvey. The energy required for this transfer could have 15 – 25% supplemented by energy recovered from the Desalination plant. Therefore total power requirements for this process will be low.

- The concentrate stream (waste discharge) from the R.O. plant will be less salty than seawater (20 – 25%) and can be discharged under gravity from the desalination plant to the ocean.

Based on detailed information provided by engineering groups and world reverse osmosis specialists it has been determined that it is possible and practical to desalinate the brackish scour water with a recovery rate of 80% using the hydraulic head available.



Basic Flow Schematic

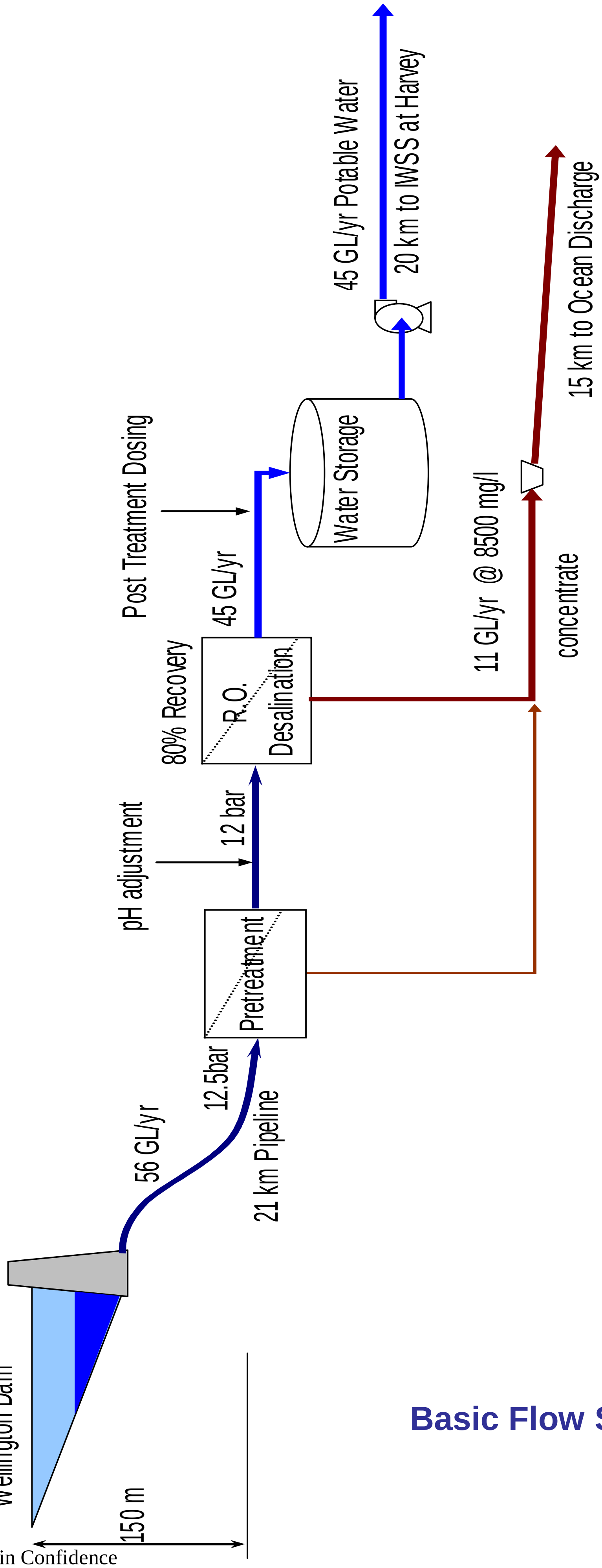
- The project would comprise a pipeline of approx 21 km in length to deliver the scour water from Wellington dam at the top of the escarpment, to the R.O. plant located at a suitable site near Brunswick. The pipeline is sized so that at full flow there will only be a small friction head loss.

- The water under gravity pressure will then be pretreated using a pressurised microfiltration process designed with only a small pressure drop. The water may then need slight pH adjustment and/or dosing of an antiscalant to prevent scaling of the R.O. membranes. Since the water salinity is relatively low the level of any dosing will be quite small.

- The pressurised water from the pretreatment is then delivered into the multiple membrane arrays where the desalination occurs. Due to the high gravity pressure available the first stages of the membrane arrays must have the product stream throttled (reduced) to prevent excessive flux (flow) rates from some membranes.

- The product water will be accumulated in a buffer storage from where it is then pumped approx 20 km to connect to the existing IWSS at Harvey. This pumping will be the only major energy requirement of the system and can be supplemented by energy recovered from pressure throttling in the desalination process. The product water will be post treated to meet the requirements of the Australian Drinking Water Guidelines.

- The Concentrate stream will be much less saline than seawater and will be discharged under gravity from the R.O plant via pipeline to an ocean discharge point.



Basic Flow Schematic

Basic Specifications

for the

Wellington Dam Scour Water R.O Desalination Plant.

Feed water

Feed water	- 56 GL/yr (6422m3/hr) @ approx 1700 ppm TDS
Water temperature	- 14 ^{o}C min

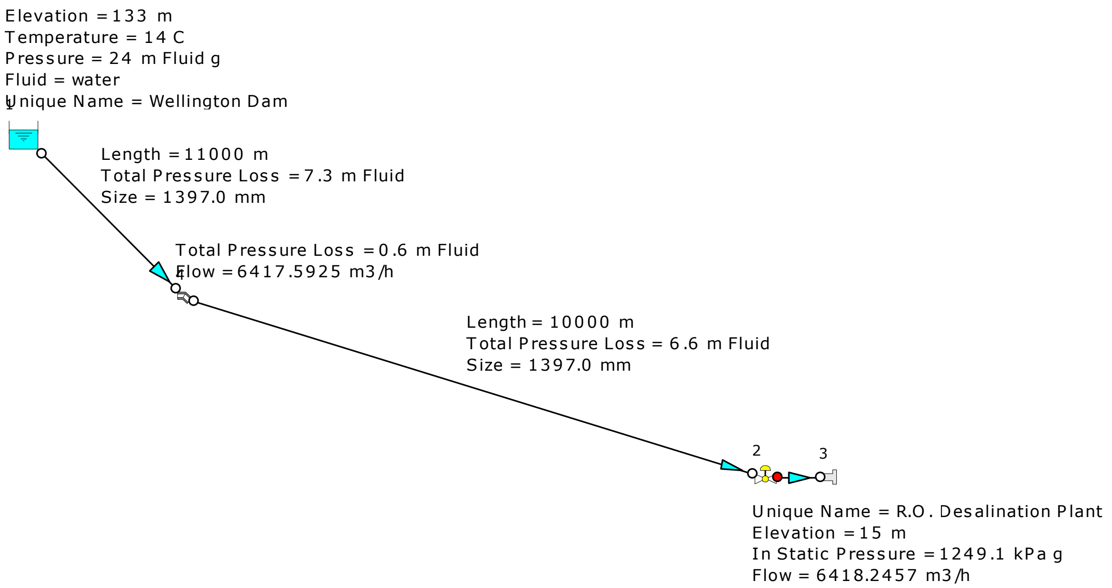
Wellington Dam

Full water level	- R.L. 167 AHD
Wall height	- 34 m

Feed water Pipeline

Dam Water Level	- min approx. 24 m - max 34m
Length	- approx. 21,000m
Diameter	- 1400mm
Discharge R.L	- approx. 15 m AHD
Friction Losses at full flow	- approx. 12.5 m
Discharge head at full flow	- approx. 125 m

Simple Model – Pipeline from Wellington Dam to R.O. Plant

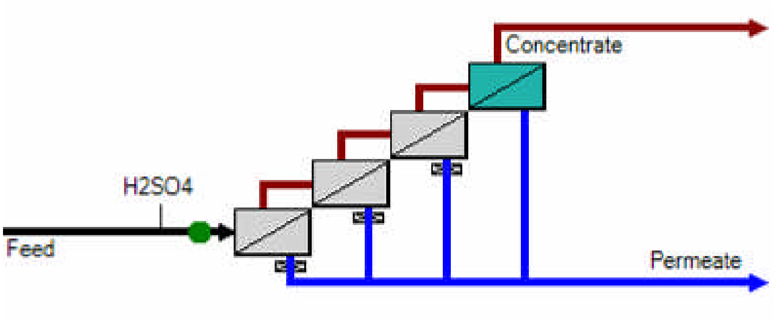


Pretreatment

Type	- Microfiltration
Location	- R.O Plant
Pressure Loss	- 4 - 5m head
Chemical dosing	- pH adjustment and/or Antiscalant chemical

R.O. Desalination Plant

RL	- approx. 15m AHD
Operating pressure	- nom. 12 bar
Recovery	- approx. 80%
Typical Membrane setup,	
No. of membrane arrays	- approx. 65
Each membrane array	- nom. 4 stage
Membranes type	- low energy BW 40m2 - 90/array



Concentrate Disposal

Driving pressure	- gravity head 15m
Energy recovery	- approx. 180 – 190 kW
Concentrate salinity	- approx. 8,500 ppm
Concentrate volume	- approx. 11 GL/yr, (1284 m3/hr)

Product Delivery

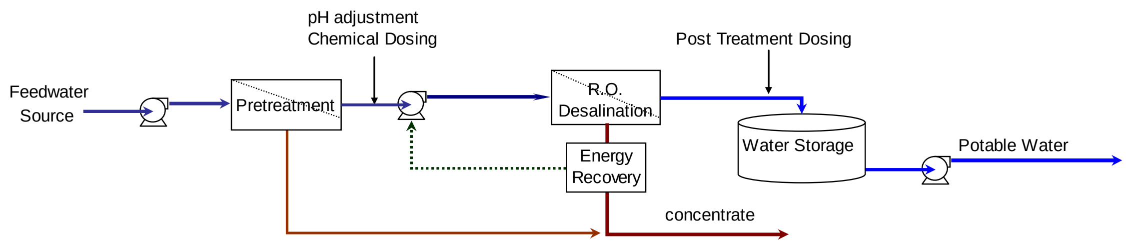
Pipeline	- Dia. - nom. 1200 mm
	- Length - approx. 21 km.
Static Head	- nom. 30 m
Friction Losses	- approx. 23 m
Driving Pressure	- mechanical pumping
Supplemented energy recovered from process	- Approx 15 – 25%

Reverse Osmosis Systems

Basic Description of Reverse Osmosis Desalination Systems

The principle of operation of all Reverse Osmosis (R.O.) desalination plants is similar, however the operating parameters can vary significantly, depending on the quality of the feed water. R.O. desalination plants with feed water having higher salinity and greater suspended solids loading will invariably have significantly greater operating costs than those operating on a clean low salinity feed.

The typical R.O. desalination plant will consist of the following sections:-



Pretreatment and Preconditioning Systems

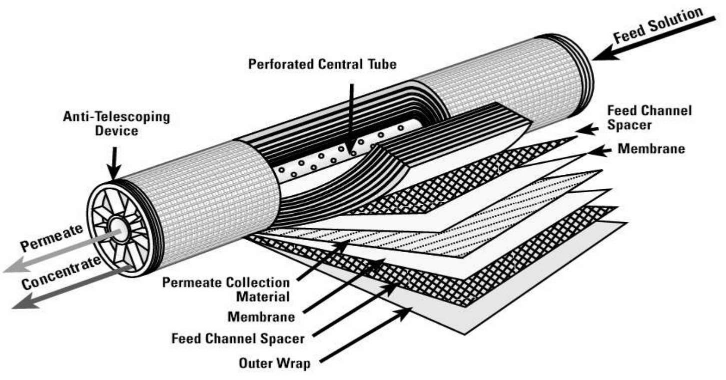
The function of the pretreatment section is to remove suspended solids and precondition the feed water. Generally the suspended solids are removed by a particulate filtration process. This is to prevent fouling within the membrane system. The preconditioning of the feed water is achieved by chemical dosing and is used to help reduce the propensity for dissolved salts to reach levels of saturation within the concentrate side of the membranes. This then prevents scaling of the membrane surface.

Hydraulic Driving Force

The feed water must be delivered into the R.O. membrane array. with sufficient pressure to overcome the natural osmotic pressure of the feed water, plus additional driving pressure to create the required product flux (flow) rate from the membranes. This pressure is usually produced by mechanical pumping but can in some situations be produced by gravity generated hydraulic head.

R.O Membrane Systems

The R.O. membrane arrays consist of a number of spiral wound semi permeable membrane elements connected in series and housed in long cylindrical pressure vessels.



These membrane vessels are then arranged in parallel and series arrays. The arrangement of which is determined by careful design based on a number of factors, predominantly influenced by the quality of the feed water. The pressurised feed water is piped into one end of the array and the concentrate stream is throttled (restricted) at the other end to maintain the necessary operating conditions of pressure and product rate. There are a number of different types of membranes that are used for different feed water conditions, each with different characteristics of salt rejection and flux rates.

Product Water Stream

This desalinated water (permeate) stream still contains a small portion of the salt from the feed water. The quantity of this salt is determined by the salinity of the feed water, the salt rejection level of the membrane and the overall recovery rate of the array.

Concentrate stream

This stream of water contains all the salts from all of the feed water, minus the small percentage that end up in the product stream. This stream is at full operating pressure as it leaves the membrane array and must be reduced down to a much lower discharge pressure for disposal.

Energy Recovery Systems

There can be considerable energy that may be recovered at the point of pressure reduction of the concentrate stream after it has passed through the membranes. The energy recovered is generally in the form of mechanical energy that can be used to either generate electricity or used to directly drive pumping equipment. The lower the recovery rate of product from the feed water, the higher the proportion of input energy that can potentially be recovered.

Cleaning Systems

Each R.O. plant is generally set up and equipped to easily perform periodic cleaning of the membranes. The cleaning process circulates a chemical solution around the feed/concentrate side of the membranes to wash any particulates away and to dissolve any scale from within the membranes. The frequency of this cleaning is determined by a number of factors relating to the quality of the pretreated feed water.

Effects of Different Types of Feed Water

On

R.O. System Operation

This section provides a brief outline of the major differences in R.O systems designed for operation on different types of feed water. It should then become obvious as to why low salinity brackish water feeds are significantly cheaper to desalinate than high salinity seawater feeds and why some R.O systems with low salinity feeds can operate on gravity feeds whilst high salinity seawater requires significant energy input to produce high operating pressures.

Feed Water Pretreatment

Pretreatment of the feed water to any R.O. membrane system is of paramount importance to help reduce fouling and scaling of the R.O. membranes. Reducing fouling and scaling will reduce the amount of regular maintenance (chemical cleaning) and increase the life of the membranes. Fouling and scaling of the membranes reduce the product flux rate or require higher operating pressures.

The level and type of pretreatment required is dependent on the quality of the feed water. This falls into two categories;-

1. Particulate matter or Suspended Solids - which can be removed by either/or, flocculation, and different stages of filtration,

and

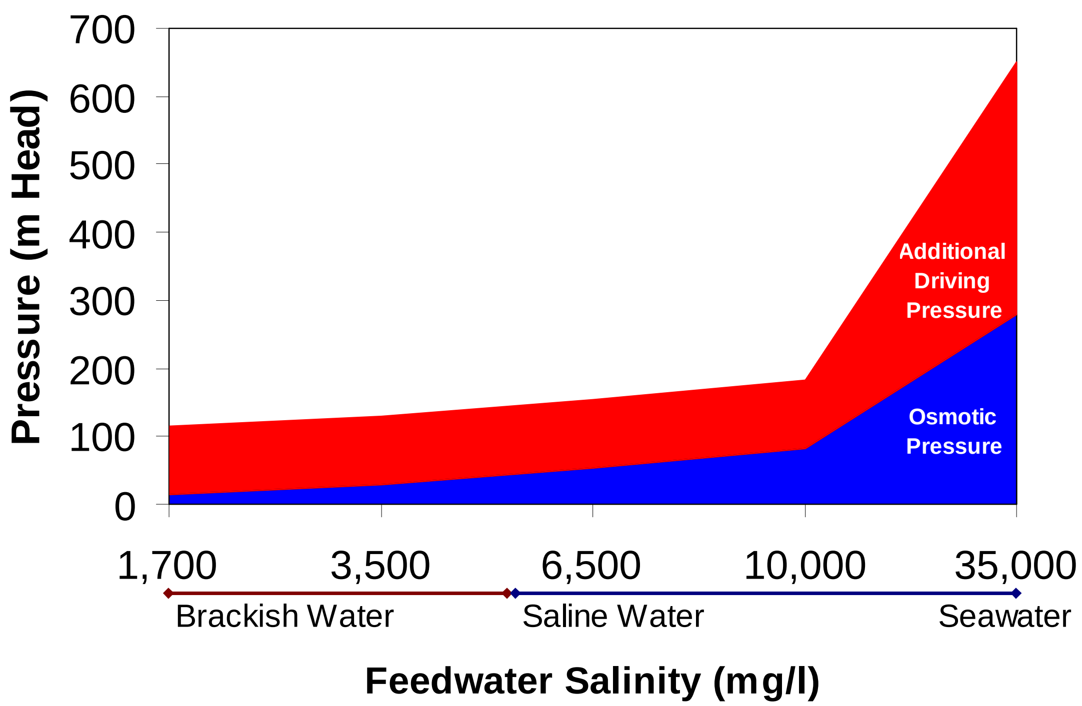
2. Dissolved solids that may precipitate out of solution when the feed water is concentrated through the R.O. membrane process. – These are treated generally by the addition of chemicals to modify the chemistry of the water so that precipitation is inhibited.

Note: Depending on the method of collection Seawater can be fairly high in suspended solids (0.6 – 5.5 mg/l) whilst some dam waters can be quiet low.

Reverse Osmosis Process

The natural osmotic process creates a driving force that causes a dilute solution to pass through a semi permeable membrane into a more concentrated solution. To reverse this process a pressure must be applied to the concentrated solution, firstly, to negate the natural osmotic pressure of the concentrated solution and then, a further driving pressure, to create a flow from the concentrated solution side of the semi permeable membrane to the dilute side. The greater the additional driving pressure the greater the flow rate of product (permeate) from the membrane. The driving pressure required for reverse osmosis desalination of brackish or saline water is roughly proportional to the level of salinity of the feed water. Therefore very much higher pressures and thus energy is required to desalinate seawater than low salinity brackish water.

R.O. System Operating Pressure



Water Salinity TDS (mg/l)	Osmotic Pressure (Bar)	Typical Additional Driving Pressure (Bar)	Typical Total Operating Pressure (Bar)
1,700	1.4	9 - 12	**10 - 14**
3,500	2.9	9 - 12	12 - 15
6,500	5.3	9 - 12	15 - 18
10,000	8.2	9 - 12	17 - 20
35,000	27 - 29	25 - 40	**50 - 70**

Note: The Osmotic pressure above is calculated for a NaCl solution and will vary marginally depending on the actual makeup of different salts in the water

Membrane Types

Membrane element manufacturers tend to have standardised for their largest size, on an 8” dia x 40” long unit that can be readily and safely handled by one or two persons. The semi permeable membrane itself is made available in a number of grades NF-Nanofiltration /BW-Brackish water/SW-Seawater. These can be generally described as being from a loose to a tight membrane. A loose membrane will have a much lower rejection of salt (ie more salt passes through the membrane into the product water) and require a lower driving pressure whilst providing a higher flux rate (Product rate/membrane). A tight membrane such as is used for seawater, will conversely, have a much higher rejection of salt and require higher pressures with lower flux rates. A seawater membrane must have a high salt rejection so that the product water is low enough in salt content to be of potable quality. Looser membranes can be used to produce drinking water from lower salinity feed waters.

Recovery rate

The recovery rate a reverse osmosis membrane system is operated at is dependent on a number of factors including the membrane configuration and the quality of the feed water. This will therefore affect the quantity of feed water required for any given quantity of product water. Thus a lower recovery rate will require a greater quantity of feed water, (ie larger pretreatment system and higher energy requirements) and a greater quantity of concentrate water for disposal. A higher recovery rate will produce a higher salinity concentrate stream and thus for a given membrane type will produce a higher salinity of the product water. The salinity of the concentrate stream is a simple mathematical relationship between the salinity of the feed water and the recovery rate. i.e. seawater (35,000 ppm) at 40% recovery will produce a concentrate stream of 58,000 ppm

Water Source	Feed Water Salinity (mg/l)	Recovery Rate	Concentrate Salinity (mg/l)
Brackish Water	1700	80%	8,500
Brackish Water	3,500	80%	17,000
Saline Water	6,500	65%	18,500
Saline Water	10,000	50%	20,000
Seawater	35,000	40%	**58,000**
Seawater	35,000	45%	**63,500**
Seawater	35,000	50%	**70,000**

There are many factors that will affect the configuration and array of membranes, recovery rate and operating pressure of a R.O. Desalination system. It is the experienced R.O. design engineer who must then take all these factors into account to provide the optimum configuration and design.

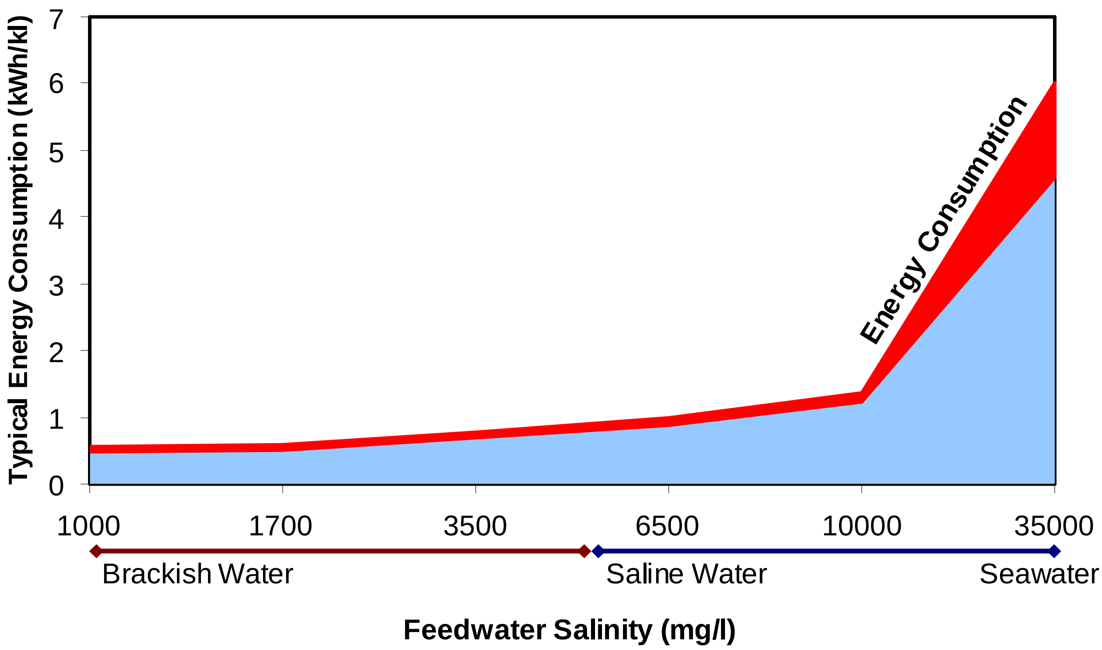
Energy Consumption

The majority of the energy consumed in a typical R.O. plant is used for pressurizing the water within the system, namely;

1. Feed water delivery system
2. Pretreatment filtration process
3. Membrane desalination process
4. Product water delivery.

The energy requirements for any R.O system are therefore dependent on the quality and salinity of the feed water.

Typical Energy Consumption for the Membrane Desalination Process



Water Source	Salinity (ppm)	Typical Power Requirement (kWh/kl)	Potential for Energy Recovery
Wellington dam Scour Water	1,700	0.52	yes
Brackish Water	3500	0.69	yes
Catchment desalinisation	6,500	0.88	yes
Saline Water	10,000	1.22	yes
Seawater	35,000	**4.6-5.6**	yes

Feed Water Chemistry

It is vitally important, for the efficient, long term, operation of any R.O. plant, to know and understand the chemistry of the feed water and to regularly monitor it for any changes. Operating parameters may need modifying if certain changes occur in the chemistry of the feed water. Even small quantities of some elements and compounds can be sufficient to cause significant problems for efficient membrane operation.

Membrane Fouling

Fine particulate or colloidal material that may have passed through any pretreatment filtration stage, or metal oxides that may form after the pretreatment process, will provide physical fouling of the membrane surfaces. This can cause impediment to feed water flow over the membrane surfaces as well as reducing the flow rate of product water through the membrane.

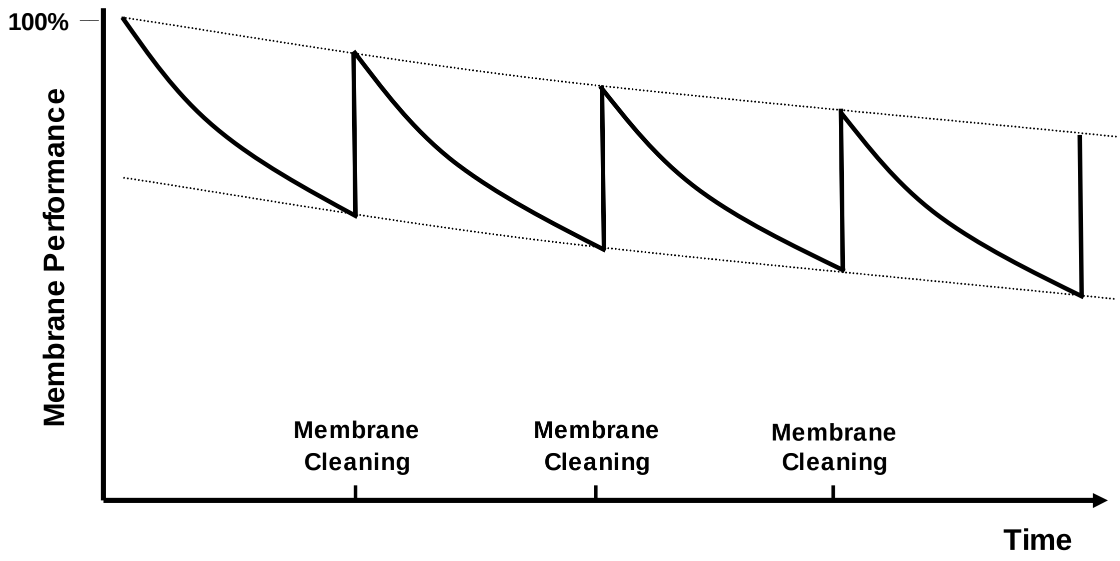
Membrane Scaling

The more the feed water is concentrated the more likely it is that the saturation point of certain chemical compounds may be reached. Therefore the greater the recovery rate of the R.O. system the greater is the likelihood that some compounds will reach saturation point and precipitate out as scale on the membrane surface. Scaling of the membrane surface will significantly affect the flux rate of the membranes. This scaling tends to be in the form of sulphates, carbonates or silicates. Modifying the pH of the feed water, or by the addition of certain antiscalant chemicals, the propensity for scaling to occur can be reduced or almost eliminated. The higher the salinity of the feed water and the higher the recovery rate of the system the greater the chemical usage. For example, a seawater feed water will require a much greater quantity of chemical dosing than a low salinity brackish water.

Membrane Fouling Factor

The flux rate from R.O. membranes will be reduced from their new value over the life of the membranes. Chemical cleaning of the membranes will not be able to fully restore them to the original flux rate each time it is undertaken. Within the calculations used in designing an R.O membrane array a fouling factor is selected to best represent the degraded performance of the membrane elements at an arbitrary end of life point. For properly maintained systems the degradation of performance of membrane elements generally tends to follow a slow decay pattern. The typical form of performance decay, showing chemical cleaning cycles is depicted on the following diagram.

Typical Membrane Performance over Time



Membrane Cleaning

The frequency of chemical cleaning of the membranes is usually related to the quality of the feed water, its pretreatment and preconditioning. There are a number of different cleaning chemicals that can be employed to help clean the membrane elements. Each type is used to target different foulants or forms of scaling.

Summary

The preceding text and graphics conclusively show that low salinity brackish water can be desalinated to potable water using R.O. technology, at significantly lower costs than high salinity seawater. The driving pressure in certain circumstances can even be provided by gravity hydraulic head.

Conclusion :

Water is the most critical issue of concern facing Australia today. It is our most precious resource and life is totally dependent upon it. Serious concern has been raised in recent times pointing out that climate change and global warming will make this dwindling resource even scarcer.

The emphasis must be on better water management which includes paying more attention to sustainability through water reuse options.

The Agritech Wellington Dam proposal has been in the public domain for the past 3 years. This project has been the only significant attempt to reuse and retreat the scour water from the dam. The dam scouring process has been occurring for the past 25 years resulting in the loss of hundreds of gigalitres of water.

The project provides this State with the ultimate triple bottom line :

- Environmental benefits unmatched by any competing proposal.
- Huge social dividends to water users and taxpayers of this State
- Reuse of a wasted resource, the ultimate in sustainability.

and, is in keeping with the intention of the national water initiative and the policy direction of the Minister for Water in his press release dated 18 October 2006.

Finally, the Agritech Smartwater proposal has the compelling additional benefits of safety to the government and the taxpaying public of Western Australia in that it does not have any technical or financial risk.

Agritech Smartwater commends this proposal for your consideration.