

**NSW PARLIAMENTARY LIBRARY
RESEARCH SERVICE**



**Desalination, Waste Water,
and the Sydney
Metropolitan Water Plan**

by

Stewart Smith

Briefing Paper No 10/05

RELATED PUBLICATIONS

- The Future of Water Supply. NSW Parliamentary Library Briefing Paper No 4/2004.

ISSN 1325-4456

ISBN 0 7313 1785 8

August 2005

© 2005

Except to the extent of the uses permitted under the *Copyright Act 1968*, no part of this document may be reproduced or transmitted in any form or by any means including information storage and retrieval systems, without the prior written consent from the Librarian, New South Wales Parliamentary Library, other than by Members of the New South Wales Parliament in the course of their official duties.

**Desalination, Waste Water,
and the Sydney
Metropolitan Water Plan**

by

Stewart Smith

NSW PARLIAMENTARY LIBRARY RESEARCH SERVICE

David Clune (MA, PhD, Dip Lib), Manager (02) 9230 2484

Gareth Griffith (BSc (Econ) (Hons), LLB (Hons), PhD),
Senior Research Officer, Politics and Government / Law (02) 9230 2356

Talina Drabsch (BA, LLB (Hons)), Research Officer, Law (02) 9230 2768

Lenny Roth (BCom, LLB), Research Officer, Law (02) 9230 3085

Stewart Smith (BSc (Hons), MELGL), Research Officer, Environment ... (02) 9230 2798

John Wilkinson (MA, PhD), Research Officer, Economics (02) 9230 2006

Should Members or their staff require further information about this publication please contact the author.

Information about Research Publications can be found on the Internet at:

www.parliament.nsw.gov.au/WEB_FEED/PHWebContent.nsf/PHPages/LibraryPublications

Advice on legislation or legal policy issues contained in this paper is provided for use in parliamentary debate and for related parliamentary purposes. This paper is not professional legal opinion.

CONTENTS

EXECUTIVE SUMMARY	1
1.0 Introduction	1
Part One: Government Policy and Sydney Water Supply	1
2.0 The Metropolitan Water Plan	1
2.1 Proposals for a Sydney Desalination Plant.....	5
2.2 The Sydney Water Seawater Desalination Plant Proposal	6
2.3 The Desalination Planning Study	7
2.4 The Water Reuse Debate	9
Part Two: A Review of Desalination and Water Reuse Technologies.....	12
3.0 Desalination Worldwide	12
3.1 Desalting Technologies	14
3.2 Case Study – Israel	19
3.3 Desalination Case Study – Algeria.....	23
3.5 Desalination Case Study – Singapore.....	24
3.6 Desalination Case Study – London Thames Water Utility	25
3.7 Desalination Case Study – United Arab Emirates.....	26
4.1 Water Reuse Case Study – Water Factory 21 Orange County, California.....	30
4.2 Water Reuse Case Study - Singapore.....	33
5.0 A comparative analysis of desalination and waste water reuse.....	36
6.0 Conclusion.....	38

EXECUTIVE SUMMARY

This Briefing Paper is an update on the 2004 Briefing Paper *The Future of Water Supply*. The 2004 Paper highlighted the fact that at the time, Sydney was using 106 percent of the annual sustainable yield of its water supplies. This Paper is divided into two parts. Part One updates the development of Government policy in relation to Sydney water supply. Part Two is divided into three sections. Section one provides an overview of desalination plants and technology from around the world, including case studies. Section two reviews water recycling, whilst section three compares and contrasts the two water cycle approaches.

On 19th October 2004, *Meeting the challenges - Securing Sydney's water future* was released by the NSW Government. The plan - covering the next 25 years – outlines the Government's actions to secure the future water supply for Sydney. Actions proposed included: accessing water stored deep in dams; transferring water from the Shoalhaven River during high flow periods; large scale recycling programs for new land release areas; and investigating desalination.

In mid July 2005 the then Premier Bob Carr announced plans for a desalination plant at Kurnell. Whilst this plant was originally proposed as drought proofing measure, the new Premier Morris Iemma has stated that the plant will be built 'drought or no drought'. The proposed desalination plant attracted considerable debate. One of the major criticisms of the Metropolitan Water Plan was that it did not provide for the reuse of treated waste water into potable supplies. In response, the Government argued that there was no public support for this option, and that it was more expensive than desalination.

Worldwide over 23 million m³/day of desalinated water is produced. The majority of production is in the Middle East and North Africa. Whilst there are numerous techniques to produce desalinated water, reverse osmosis has the largest installed capacity. Reverse osmosis has wider applications than just removing salt from seawater for potable use. A wastewater treatment process including micro-filtration, reverse osmosis and ultraviolet disinfection can produce high quality water. Several countries now use this process to augment their water supplies, and case studies of both desalination and waste water reuse are presented.

1.0 INTRODUCTION

This Briefing Paper is an update on the 2004 Briefing Paper *The Future of Water Supply*. The 2004 Paper highlighted the fact that at the time, Sydney was using 106 percent of the annual sustainable yield of its water supplies, and that clearly this was not sustainable in the long term. The Paper noted the work towards developing a sustainable water strategy for Sydney, and a response to the continuing effects of drought.

This Paper is divided into two parts. Part One updates the development of Government policy in relation to Sydney water supply, and is a follow on from the 2004 Briefing Paper. Part Two is divided into three sections. Section one provides an overview of desalination plants and technology from around the world, including case studies. Section two reviews water recycling, whilst section three compares and contrasts the two water cycle approaches.

PART ONE: GOVERNMENT POLICY AND SYDNEY WATER SUPPLY

2.0 THE METROPOLITAN WATER PLAN

In March 2003 the NSW Government released its urban water policy *Changing the Way We Think About Water*. The policy reaffirmed the Government's commitment not to build any new dams, and required Sydney Water, amongst other actions, to continue to invest in demand management and provide opportunities to recycle treated wastewater.

On 19th October 2004, *Meeting the challenges - Securing Sydney's water future* was released by the NSW Government. The plan - covering the next 25 years – outlines the Government's actions to secure the future water supply for Sydney.

When the plan was released, Sydney was, and still is, experiencing the worst drought since the 1930s. Dam levels in October 2004 had fallen to 42.6% capacity (41.7% by early August 2005). Water restrictions were introduced on 1 October 2003, tightened to Level 2 restrictions on 1 June 2004, and tightened again to Level 3 on 1 June 2005. The Plan noted that if no further demand management strategies were introduced, and low runoff into the dams continued, Sydney would have approximately three and half years of water storage left before it ran out.

The plan stated that Sydney is faced with four significant factors in planning for future water management:

- population growth;
- drought;
- climate change;
- river health.

Sydney's population growth is expected to increase by one million people over the next 25 years or so. If consumption remains at current levels and nothing is done to reduce demand, an extra 200 billion litres of water will be needed each year within 25 years.

The plan links drought and climate change together, and states that the current drought (entered in the 1990s) being experienced by Sydney is being complicated by climate

change happening now. The plan states:

The Government has accepted international scientific opinion regarding the impact that global warming is already having on NSW. The effects in Sydney's water catchment appear to be warmer conditions and less rainfall, with the ongoing consequence that less water will be available for consumption each year on average. This situation has already been observed in south-west Western Australia and measures have been put in place to manage the impacts of climate change. Similar actions now needs to be put in place for Sydney.

This means that even when the current drought breaks, the long-term security of our future water supply is uncertain...unless changes are made.¹

The West Australian Government, faced with average dam stream inflows since 1997 some 64% less than in the period 1911-1974, has proposed to diversify their water supply through: desalination; wastewater recycling; better management of dam catchments; and water trading from irrigation cooperatives. In July 2004 the West Australian Government announced plans to construct the Perth Seawater Desalination Plant as part of the Integrated Water Supply Scheme. The Scheme supplies water to 1.5 million (of the 1.9 million) people living in Western Australia. The desalination plant is to provide 45 gegalitres² of water by the 2006/07 summer. The contract to build the plant was awarded in April 2005, and planning for a second 45 gegalitre/yr desalination plant has begun.³ A significant supply of water for the Integrated Water Supply Scheme is from groundwater. The Water Corporation (WA) has also commenced planning for aquifer storage and recovery, where treated wastewater is reused indirectly via aquifer replenishment. The Corporation believes that a significant aquifer storage and recovery scheme supplying some 20 gegalitres/yr could be implemented by 2014/15, and up to 60 gegalitres/year by 2040.⁴

Faced with Sydney running out of water in approximately three and half years, the NSW Government, through its *Meeting the challenges - Securing Sydney's water future* plan, announced the following five major projects:

- Access to water stored deep in dams. The Avon and Warragamba dams will be modified to that water at the bottom of the dams that is currently unavailable can be accessed. This will increase accessible dam water by up to 30 billion litres. Construction to be completed by 2006 at a cost of \$106 million;
- Transferring water from the Shoalhaven River. The Shoalhaven River flows into

¹ NSW Department of Infrastructure, Planning and Natural Resources, *Meeting the Challenges. Securing Sydney's water future. The Metropolitan Water Plan 2004*. 2004 at 4.

² 1 gegalitre is one billion litres.

³ Water Corporation (WA), *Integrated Water Supply Scheme Source Development Plan 2005-2050. An Overview*. April 2005.

⁴ Water Corporation (WA), *Integrated Water Supply Scheme Source Development Plan 2005-2050. Planning Horizon 2005-2050*. April 2005, at 28.

Tallowa Dam. When it overflows water is lost to the ocean. In the future, when river flows are high, this water will be pumped to Warragamba Dam. New pumps and pipes will need to be constructed. Stage 1 of the project will commence in 2007, cost an estimated \$250 million and provide the potential of between 50 – 80 billion litres of water when completed in 2009. Stage 2 of the project, at a cost of \$430 million, will increase the potential water increase up to 110 billion litres. Construction of stage 2 is expected to be completed by 2012, subject to assessment at the completion of stage 1;

- Construction of a desalination plant. The Government will commit \$4 million to investigate desalination infrastructure to supplement Sydney's water supply;
- Sinking of bores to augment existing dam supplies. At a cost of \$4 million, drilling into the ground near rivers or dams to access groundwater. Up to 13 billion litres of water could be accessed, which would be piped to nearby rivers systems for dam storage;
- Large scale recycling programs for new land release areas. The Government will undertake planning into the construction and operation of a Western Sydney recycling initiative, focussed on how recycled water supply can be built into the design and construction of new urban development areas in Sydney's west. Under the proposal, new release areas would be linked by pipe to existing wastewater treatment plants, and the treated waste would be pumped to the new release areas to be used for non-drinking purposes. Preliminary costs of this project are \$563 million, with a saving of approximately 24 billion litres of water per year.⁵ This scheme is similar to that of Rouse Hill in the north-west of Sydney, where 15,000 homes are provided with recycled water from the Rouse Hill Sewage Treatment Plant. On average, the scheme is saving 35% of drinking water per household.⁶

In addition, the Government announced new measures to conserve water. Referred to as *Conserving Water For Sydney's Future*, it was described by the Government as the second part of the Metropolitan Water Plan and complements the Infrastructure Plan as described above. Noting the water conservation programs implemented to date, (including the Building Sustainability Index – BASIX, where new houses are required to use 40% less water compared with an existing home), the Government's conservation plan focuses on five areas: business; Governments; incentives; households; and communities. The plans for each of these areas are outlined below:

Businesses

The Government will establish a Business Liaison Committee to consult with business on the development of a Business Water Conservation Plan. Under this scheme, the Minister for Utilities can designate categories of private sector water users (initially the top commercial and industrial water users) to develop Water Conservation Plans. These plans must be prepared by March 2006 and reviewed every four years. The Department of

⁵ NSW Department of Infrastructure, Planning and Natural Resources, *Securing the Future of our Water Supply. Part one of The Metropolitan Water Plan. The NSW Government's infrastructure plan to secure Sydney's water supply.* October 2004.

⁶ NSW Government, *Metropolitan Water Plan, Seawater Desalination Fact Sheet 5 – Seawater Desalination Compared to Recycling.*

Utilities, Energy and Sustainability will have the power to audit these plans. The plan does not outline what efficiencies those included in the program will be expected to achieve. However, it does say that as a minimum, water efficient devices such as tap and shower fittings will be required.

Government

All NSW Governments will be required to develop water conservation plans by 31 March 2006, and implement cost effective water efficiency improvements as directed by the Premier. The Department of Energy and Utilities will have the authority to audit these plans.

Sydney local councils will be required to prepare water conservation plans by 31 March 2006 and to review these every four years. Sydney councils will be required to implement a Water Conservation Plan by September 2007, and as a minimum install water efficiency measures as directed by the Department of Energy and Utilities, including water efficient taps, showers and toilet flushing systems in all of their buildings and public facilities.

Incentives

The Government proposes the establishment of a Demand Management Fund of \$120 million over four years. Businesses, Government departments and councils will be eligible to bid for funds. Criteria and guidelines for bidding for funds will be established.

Households

Sydney Water will accelerate its Retrofit scheme to target 120,000 households per annum (the Retrofit scheme enables households to have water efficient fittings installed throughout their home for a subsidised price of \$22, or free for pensioners). All existing homes sold after July 1 2007 will need to be certified as water efficient either through the BASIX program or the retrofit scheme. Sydney Water will extend its Rainwater Tank Rebate Scheme until July 2008, at a cost of \$6 million.

Community

Mandatory water efficiency labelling will be introduced for water appliances, and minimum performance standards will be introduced for toilets. The Government will prepare guidelines on water efficient garden design and extend training programs to improve agricultural water efficiency in the Sydney region.

The plan notes that the programs outlined above have the potential to save water of approximately 100 gigalitres per year.

The NSW Auditor General reviewed planning for Sydney's water needs, noting that adequacy of supplies is a significant public health, quality of life, conservation, and economic development issue. The Auditor General noted that State water agencies have made significant progress towards integrating all aspects of Sydney's water supply and the Metropolitan Water Plan is a comprehensive plan to close the gap between supply and demand. The Auditor General recommended that the (then named) Department of Infrastructure, Planning and Natural Resources, Sydney Water, Sydney Catchment Authority and related water agencies continue to develop and integrate all aspects of planning for Sydney's water in accordance with the principles agreed to by the Council of

Australian Government's National Water Initiative. This would incorporate: demand management measures and pricing; leakage reduction; surface waters; ground water; sewage effluent; grey water and stormwater. The Auditor General also recommended: better risk management processes; a review of legislative and organisational arrangements relating to Sydney's water supply/demand balance; and implementation of a greater level of public engagement in the development of demand management strategies, water supply reliability, water pricing and the appropriate balance between demand and supply side options.⁷

2.1 Proposals for a Sydney Desalination Plant

On 1 June 2005, the Government introduced Level 3 water restrictions for the Sydney Water supply region, noting that dam levels had fallen to 39.7%. At the time of announcing the tighter water restrictions, the Government reiterated that a desalination plant would be built if required to ensure a reliable water supply.⁸

In mid July 2005 the then Premier Bob Carr, visiting desalination plants in Dubai, United Arab Emirates, announced plans for a major desalination plant at Kurnell. Premier Carr was reported as saying: "Following a rigorous six month planning study, Kurnell has been identified as the best location for a plant to turn seawater into drinking water and provide up to a third of Sydney's daily water supply."⁹ Premier Carr stressed that the desalination proposal was still a contingency measure, and previously the Government had indicated that it may be implemented if dam levels fell below 30 percent.¹⁰ The Metropolitan Water Plan (released October 2004) stated: "An additional \$4 million has been earmarked for detailed planning and design to ensure that, if the drought continues beyond another two years, a desalination plant for Sydney could be built relatively quickly and efficiently."¹¹

Clearly desalination was originally proposed as a drought response. However, supporting documents released at the time of Premier Carr's announcement suggest that Sydney Water was looking to build a desalination plant for long term water supply. In regards to constructing a desalination plant, the supporting documents stated: "Plant sizes of 50-500ML/day have been considered. Should the drought persist, a 500ML/day plant could supply Sydney with a third of greater Sydney's daily water needs... If the drought breaks, smaller plant sizes may be considered to augment long-term water supply and address

⁷ The Audit Office of New South Wales, *New South Wales Auditor-General's Report. Performance Audit. Planning for Sydney's Water Needs*. May 2005.

⁸ Sydney Water, *Media Release: Level 3 Water Restrictions Introduced to Protect Water Supply*. 31 May 2005. See Sydney Water website: <http://www.sydneywater.com.au/WhoWeAre/MediaCentre/MediaView.cfm?ID=281>

⁹ "Dubai: that's where Bob revealed Kurnell will get a desalination plant." In *The Daily Telegraph*, 12 July 2005.

¹⁰ "Cold water on the salt solution." In *The Sydney Morning Herald*, 12 July 2005.

¹¹ NSW Department of Infrastructure, Planning and Natural Resources, *Meeting the Challenges. Securing Sydney's water future. The Metropolitan Water Plan 2004*. October 2004, at 12.

potential climate variability.”¹² Indeed, with the retirement of Premier Carr in late July 2005, the new Premier Morris Iemma MP has declared that a new desalination plant will be built at Kurnell. Premier Iemma was reported as saying: “... the Government will build a desalination plant for Sydney to secure our future drinking water...It’s clear we need an additional source of water, drought or no drought”.¹³ The Premier noted that the final size of the plant and time frame for construction were yet to be determined, but would be announced at the end of the year.

2.2 The Sydney Water Seawater Desalination Plant Proposal

Sydney Water has called for ‘Expressions of Interest’ to build at least a 100 ML/day reverse osmosis desalination plant and ancillary works. The closing date was August 4 2005, and the project brief is reproduced below.

Project Background

Sydney Water’s Vision for the Project

Sydney Water wishes to enter into a long-term collaborative arrangement with the successful participant under the Project to design, construct, operate and maintain a Desalination Plant and associated infrastructure supplying potable water with a capacity of 100 to 500 mega litres per day (100-500 ML/day) for connection into the Sydney Water distribution system.

The magnitude and complexity of the project is such that delivery will need to be by a collective grouping of leading companies who have proven capability, capacity and experience in delivering the specific major components of these works on other large scale reverse osmosis desalination plants and associated infrastructure.

Sydney Water prefers that in addition to proven experience in seawater reverse osmosis desalination the group that undertakes the process design and directs the detailed development of the plant, remains responsible for the successful operation and maintenance of the commissioned plant and associated infrastructure through the operation and maintenance contract. As such demonstrated, relevant operational experience and competence is an additional prerequisite to proven reverse osmosis desalination expertise.

Sydney Water has developed a staged approach to the delivery as follows:

- Stage 1 Phase 1 - Request for Expressions of Interest;
- Phase 2 - Request for Proposals;
- Stage 2 - Project Development;
- Stage 3 – Design and Construction; and
- Stage 4 - Operation and Maintenance.

Scope of Work

It is envisaged that the selected Participant may need to provide:

- Design and construction of:

¹² Sydney Water & GHD Fichtner, *Planning for Desalination*, July 2005, at 3. See Sydney Water website: <http://www.sydneywater.com.au/EnsuringTheFuture/Desalination/index.cfm#RelatedMaterial>, Accessed August 2005.

¹³ “Desalination plant to go ahead, drought or no drought.” In *The Sydney Morning Herald*, 20 August 2005.

- tunnels of between 3m and 4m diameter with a total length of 10km to 20km, and which may need to be constructed in up to 4 concurrent sections to meet the construction time frame;
 - smaller tunnels that may require micro tunnel and directional drilling ;
 - ocean inlet & outlet works and associated tunnels of between 3m and 4m diameter with lengths of 1km to 2km;
 - seawater reverse osmosis desalination plant that delivers potable water (the Desalination Plant) in the range of 100ML/d to 500ML/d;
 - pipeline(s) of up to 1.8m diameter with lengths of 5km to 10km;
 - pumping station(s);
 - 132 kV electrical substation and high voltage distribution;
 - connection(s) to the existing water supply network; and
 - buildings and other civil works associated with the plant and infrastructure.
- Operation and maintenance of the Desalination Plant and its associated infrastructure for up to 20 years.¹⁴

2.3 The Desalination Planning Study

As noted, when Premier Carr announced the location of the proposed desalination plant at Kurnell, a supporting document - the *Desalination Planning Study* was also released. The study supported the sequenced construction of a seawater desalination plant at Kurnell, using the process of reverse osmosis. The salient points are summarised below:

Chapter 3: Background and Context to this Report

- Consultants GHD and Fichtner were commissioned to work with Sydney Water on the feasibility study;
- Seawater desalination could increase the diversity of the water supply and reduce the risk of dependency on one supply;
- If the pattern of low rainfall continues in the coming years, then current planning for desalination would ensure that Sydney has a contingency plan;
- A staged approach that takes into account timing of construction of a plant and rate of dam depletion is an appropriate strategy;
- This study is Phase 1 in a two phase process. The next phase consists of further technical and environmental investigations, including environmental assessment and community engagement.

Chapter 5: Developing a Short List of Options

- The decision was made to adopt Sydney's current aesthetic water quality targets, as well as compliance with regulatory guidelines. This meant that desalinated water can be introduced directly into the distribution system without the need for blending;

¹⁴

See NSW Government E-Tender website:
https://tenders.nsw.gov.au/sydneywater/shared/rftdetail.cfm?p_id=6903&p_criteria=0310021621&p_advert=0. Accessed August 2005.

- In terms of plant location, a 500ML/day plant needs a site area of 25 hectares. 14 preliminary sites were identified, with three sites chosen for further investigation – Kurnell, Malabar and Port Kembla;
- Choice of desalination technologies – reverse osmosis or thermal processes, were canvassed;
- It was concluded that on financial grounds and other criteria such as greenhouse gas emissions the most suitable technology was reverse osmosis.

Chapter 6: Power and Greenhouse Gas Emissions

- Greenhouse gas emissions associated with desalination are a major consideration;
- A 500ML/day plant would result in an increase of the State's electricity demand of 1.2%, or 110 Megawatts;
- Three primary power supply options were considered: grid electricity (ie, mostly coal fired generation); gas-fired generation; and wind power;
- The cost of power for a 100ML/day plant is substantially higher from a base load gas power plant, being 80% more expensive than electricity from the grid, and the resultant cost of desalinated water is higher by approximately 10%;
- For a 500ML/day plant the cost of power from a gas power plant co-located with a desalination plant is marginally lower than for electricity from the grid. However, the social and environmental impacts of a co-located dedicated gas fired power plant were not considered acceptable;
- The only renewable energy option in Australia that is proven at a large scale is wind power. Rather than directly investing in renewable energy options for energy supply, it was considered more suitable to purchase renewable energy certificates;
- The greenhouse gas reduction strategy adopted will influence the final cost of water, based on the amount of mitigation required. The cost to fully mitigate greenhouse gas generation would be \$170-350 million over 20 years. This adds between \$0.10 and \$0.20/kilolitre to the cost of water. Offsets equivalent to those required of NSW energy retailers would be \$40 million over 20 years, adding \$0.02/kilolitre to the cost of water.

Chapter 7: The Short-listed Desalination Plant Options

- The three short listed sites – Kurnell, Malabar and Port Kembla were investigated in more detail. The northern beaches were eliminated as a potential site due to the increased length of seawater access tunnels needed to reach suitable source water, the limited capacity of the local distribution system and lack of suitable large sites;
- Only Malabar and Kurnell are suitable for staging a larger plant, so Port Kembla was eliminated;
- Three possible sites at Kurnell adjacent to the oil refinery were identified as being suitable. No electricity augmentation is required, and the sites are not in close proximity to schools or residences. Delivery of water greater than 50ML/day into the water distribution system would be via a pipeline or tunnel across Botany Bay to the Waterloo pumping station.
- Two sites at Malabar were identified. A 50ML/day plant could be constructed on the Sydney Water site. A larger plant up to 500ML/day could be constructed on the Malabar headland, and would occupy 22 hectares (of 110 hectares) of the Anzac Rifle Range. The site is in relatively close proximity to residential areas including

schools. The Rifle Range was formerly subject to uncontrolled filling with building and domestic waste, and possibly industrial waste. In the context of a drought response plant the potential for time delays due to the unknown nature of the contamination would be significant and a further six to 12 months may be necessary to undertake remedial work. As the Rifle Range is Commonwealth land, acquisition of a portion of the land would need to be agreed with the Commonwealth Government;

- As a drought response measure, Kurnell is the preferred location for a plant up to 500ML/day. Outside the context of drought, Port Kembla is suitable for a small baseload plant of 50ML/day.

Chapter 8: Financial Analyses

- To fast track a 500ML/day desalination plant at either Kurnell or Malabar is estimated to take a minimum of 26 months, with a total capital expenditure of \$1,750 million. Cost of water is \$1.44/kilolitre (\$2005);
- Construction of a 50ML/day plant at Port Kembla is estimated to cost \$330 million, take 24 months to build, and cost of water is \$2.30/kilolitre.

Chapter 9: The Next Steps

- Whilst construction costs for Malabar and Kurnell are similar, if the project is fast tracked to respond to drought, Kurnell is the preferred option.
- The proposed process is as follows:
 - Seek expressions of interest by the end of June 2005;
 - Be in a position within 22 weeks to engage contractors in a competitive process to complete pre-construction testing, design and costing;
 - Following a further 32 weeks be in a position to award a contract for construction, operations and maintenance if necessary.
- Actual progress will be dependant on climatic conditions, success of other supply and demand measures such as groundwater investigations and demand management initiatives.¹⁵

2.4 The Water Reuse Debate

The Government's announcement of the proposed desalination plant at Kurnell created some debate and was met with criticism from a wide variety of groups. The *Sydney Morning Herald* noted: "... the state opposition parties, environmentalists, academics, Sutherland Shire Council and John Howard all criticised the high energy consumption and greenhouse gases associated with a desalination plant. They also said it would discourage Sydney's residents from treating water as a scarce resource."¹⁶

Clean Up Australia Chairman Ian Kiernan, a member of the Government's Expert Water Panel, established to develop a water balance strategy for Sydney, noted the following:

¹⁵ Sydney Water & GHD Fichtner, *Planning for Desalination*, July 2005

¹⁶ "Cold water on the salt solution." In *The Sydney Morning Herald*, 12 July 2005.

As a member of the Expert Water Panel...our recommended strategy for water in our report 'A Sustainable Water Balance for Sydney' was to follow a path of reuse of industrial water followed by reuse of sewerage and stormwater. It is only once those strategies have been fully explored and in the eventuality of a calamitous drought period, desalination should be considered.....Desalination plants are only need for extreme situations when all other viable water sources have been exhausted.¹⁷

One of the major criticisms was that the Metropolitan Water Plan should provide for the reuse of treated waste water into potable supplies. The technology behind this and case studies from around the world are provided in Part Two of this paper. However, the then Minister for Utilities Hon Frank Sartor MP reported that a survey carried out for the Government showed that Sydneysiders were not prepared to drink recycled sewage. In the survey, 600 people were asked whether they were 'very comfortable, mildly comfortable, mildly uncomfortable, or very uncomfortable with drinking recycled sewage, including toilet water, that is treated to drinking water quality'. Only 12 percent said they were comfortable, 17 percent mildly comfortable, and 68 percent were uncomfortable. However, respondents were more open to drinking recycled water if it was mixed with rainwater in Warragamba Dam – 48 percent supported the 'shandyng' option, while only 44 percent opposed. Commenting on the results, Minister Sartor was reported as saying: "Recycling is a partial answer. We are doing it as much as we can, but we do not believe there is enough community acceptance to start piping water into the drinking water system." Minister Sartor also noted that the survey found 65 percent of people supported desalination.¹⁸

However, another survey of 200 Sydney residents carried out for Clean Up Australia showed support for recycled water. In this survey, four questions were asked:

- Would you accept treated water as a supplement for Sydney's future water needs?
- Are you in favour of pumping treated sewage water into Warragamba Dam?
- Would you be comfortable using treated water for household purposes?
- What is your preference between the Government investing in a desalination plant versus waste water re-use options?

Ian Kiernan, Chairman of Clean Up Australia noted the following results: "71 % of the Sydney-siders we spoke to are prepared to use quality treated water in their homes right now. Whats's more, 67.4% told us it's acceptable to use treated water from sewage plants to supplement our future water needs. Over two thirds of respondents said they are happy to use treated and recycled water as a future source of water, but more than half said they also support a desalination plant. The community is also divided about pumping treated sewage into Warragamba Dam with 46.4% in favour and 48.4% against." Ian Kiernan also noted that the results showed that there is a lot of confusion about water reuse in the community, and called on the government to conduct a community awareness and education campaign.¹⁹

¹⁷ Clean Up Australia, "Ian Kiernan says No to Desalination" *Media Release*, 12 July 2005. See Clean Up Australia website: <http://www.cleanup.com.au>, Accessed August 2005.

¹⁸ "Recycling water too distasteful, says Sartor." In *The Sydney Morning Herald*, 22 July 2005.

¹⁹ "Newspoll Survey Shows Sydney-siders are open to Water Reuse." *Media Release*, Clean Up Australia, 15 August 2005. See Clean Up Australia website <http://www.cleanup.com.au>,

The NSW Government notes that current demand for commercial use of recycled water is limited to less than 70 billion litres per year. For Sydney to achieve higher levels of wastewater recycling, it would have to be treated to drinking water standard and returned to Warragamba Dam. It was claimed that this would be very expensive due to the likely need to pump it 60 km from ocean treatment plants back to Warragamba Dam. The Government estimated the capital cost of recycled water from the ocean sewage treatment plants back to Warragamba Dam at \$2.845 billion, compared to the cost of desalination of \$2 billion. The recycled drinking water option was also projected to having running costs of \$140 million/year, compared to desalination of \$86 million/year. However, in regard to the recycled water plants, no information was provided on what these calculations were based on or how they were costed.²⁰

Two local councils have recently announced plans to reuse treated waste water for indirect potable reuse. On 30 June 2005 Goulburn Mulwaree Council made a submission to the Federal Government through its Water Smart Australia Program for funding of the Goulburn Mulwaree Council Sustainable Cities Project. This \$32 million project aims to increase the secure yield of Goulburn's water supply by reclaiming effluent and returning it to the Sooley Dam catchment for potable reuse. The project involves the construction of an advanced water reclamation plant to produce drinking quality water for transfer into the Sooley Dam via a chain of ponds and wetlands. The Goulburn Mulwaree Shire is currently experiencing level 5 water restrictions, and it is hoped the long-term water reclamation project will effectively drought proof the city.²¹

Similarly, in Queensland, the Toowoomba City Council, supplying water for 135,000 people, and experiencing level 4 water restrictions, has also applied for Federal funding for the Water Futures Toowoomba project. Costing approximately \$68 million, the project has several components, one of which seeks to purify 5000 megalitres/annum from the sewage treatment plant through a process of ultra-filtration, reverse osmosis and ultra violet disinfection and return it to Cooby Dam to supplement drinking water supplies.²²

Accessed August 2005.

²⁰ NSW Government, *Metropolitan Water Plan, Seawater Desalination Fact Sheet 5 – Seawater Desalination Compared to Recycling*.

²¹ Goulburn Mulwaree Shire Council, Sustainable Cities Project. See website: <http://www.goulburn.nsw.gov.au/roads/3014/3018.html>, Accessed August 2005.

²² Toowoomba City Council, *Water Futures – Toowoomba. Taking Control of Toowoomba's future. Briefing Paper*. 1 July 2005. See website: <http://www.toowoombawater.com.au>, Accessed August 2005.

Noting the above proposals, Darryl Day, Australian Water Association President, stated:

The Toowoomba and Goulburn initiatives are great examples of an integrated, sustainable approach for our smaller cities, and they reflect the significant investment required to secure the future of our rural and regional communities.... When all other options are exhausted and in order to balance our water budget into the future, indirect potable reuse is a viable option for recycled water but it does require extensive community consultation in order to gain broad-based support....Technology is no longer the barrier for indirect potable reuse; it is now community acceptance. Safe drinking water will remain the number 1 priority for our water suppliers.²³

PART TWO: A REVIEW OF DESALINATION AND WATER REUSE TECHNOLOGIES

Part two of this paper is divided into three chapters. Chapter 3 focuses on desalination, firstly by taking a global and regional perspective, a brief analysis of desalination technologies, and concludes with details of some individual plants. Chapter 4 discusses waste water reuse, whilst chapter 5 compares and contrasts the two technologies.

3.0 DESALINATION WORLDWIDE

Worldwide, over 23 million cubic metres (1 cubic metre (M³) is equivalent to 1000 litres) of desalinated water is produced per day. The majority of production is in the Middle East and North African region. Some of the reasons advanced to consider the ocean as a source for drinking water include:

- Limited surface fresh water availability;
- Over 50% of the world's population lives in urban centres bordering the ocean;
- Climate change – extended drought cycles of 10 yrs compared to a historical five year period;
- The ocean is a drought proof resource;
- Positive public perception.²⁴

The desalination of seawater for potable uses is on the rise. Currently, over 17,000 desalination plants in 120 countries are in operation, with US\$10 billion investment in new plants expected over the next five years. Total desalination capacity is expected to double by 2015, with reverse osmosis the dominating technology.²⁵

²³ Australian Water Association, *Media Release – indirect Potable Reuse, a viable option as part of Sustainable Water Management*. 2 August 2005. See AWA website: <http://www.awa.asn.au>, Accessed August 2005.

²⁴ Voutchkov, N. 'Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process.' Posieden Resources Corporation, USA. International Key Note Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

²⁵ Voutchkov, N. 'Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process.' Posieden

As shown below, 62% of the desalination capacity of the world is in the Middle East / North Africa (MENA) region. Countries in the Gulf region (the Gulf Cooperation Council countries – Bahrain, Kuwait, Qatar, Oman, Saudi Arabia, and the United Arab Emirates) alone account for 53% of worldwide desalination capacity.

The desalination capacity by region is as follows:

Region	Operational	Contracted
Worldwide	23,808,295	25,787,31
MENA	12,159,142	15,928,814 (62%)
GCC	10,355,436	13,754,536 (53%)
Non-GCC	1,803,706	2,174,278

Source: Drioli, E. and Di Profio, G. “Innovative Sustainable Desalination Systems Using Membrane Technology.” Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Region	Installed capacity (Billion Gall/day)
Saudi Arabia	1.6
United States	1.4
United Arab Emirates	1.2
Spain	0.53
Kuwait	0.53

Source: Drioli, E. and Di Profio, G. “Innovative Sustainable Desalination Systems Using Membrane Technology.” Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

3.1 Desalting Technologies

A desalting device essentially separates saline water into two streams: one with a low concentration of dissolved salts – the freshwater stream, and the other containing the remaining dissolved salts – the concentrate or brine stream. The desalting device requires energy to operate and there are a number of desalination technologies available. These can be grouped into:

- thermal energy: using heat to distill fresh water from sea water – three processes available include multi stage flash (MSF), multi effect distillation (MED) and thermal vapour compression (TVC);
- mechanical energy: reverse osmosis (RO) is a pressure driven process, with the pressure used for separation by allowing fresh water to move through a membrane, leaving the salts behind; and
- Electrical energy: the process used is electrodialysis - a voltage driven process which uses an electrical potential to move salts selectively through a membrane, leaving fresh water behind as a product.²⁶

Of all the desalination technologies, reverse osmosis has the largest installed capacity.

Installed World desalination capacity

Process	Installed capacity (Billion Gall/day)
Reverse Osmosis (RO)	3.7
Multi Stage Flash (MSF)	3.4
Electrodialysis (ED)	0.5
Vapour Compression (VC)	0.4
Nanofiltration (NF)	0.37
Multi Effect Distillation (MED)	0.32

Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Operational experiences at earlier seawater reverse osmosis installations have shown that upstream pretreatment of raw water is the most critical part to efficiently and effectively operating a reverse osmosis desalination plant. Ultrafiltration (UF) and/or nanofiltration of raw feed water is considered essential pretreatment, to enable the reverse osmosis membrane units to provide decades of reliable high quality product water.

²⁶ Buross, O.K. *The ABCs of Desalting*. International Desalination Association. Second Edition at 12.

For example, nanofiltration of seawater feed to a plant has the following benefits:

Nanofiltration step as feed pre-treatment for RO allows to:

- **Reduce hardness and TDS by removing more than 90% multivalent salts and 10-50% monovalent salts**
- **Decrease turbidity, micro organism and bacteria**
- **Enhance water recovery factors up to 50%**
- **Energy saving of 25-30%, by lowering osmotic pressure and energy requirements for the subsequently RO step**
- **Less chemical additive requested**

Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Reverse osmosis seawater desalination plants have become increasingly efficient over the last two decades. The efficiency of desalination processes is measured in a variety of ways, as indicated below. The recovery % is the amount of fresh water produced from one hundred units of seawater. Typically a seawater reverse osmosis plant produces 55-65 litres of fresh water for 100 litres of seawater. As noted, reverse osmosis requires the application of pressure / force, and plants built today have a greater operating pressure than in the 1980s. Product water quality is measured in total dissolved solids (TDS) milligram per litre (mg/l), and energy consumption is measured in kilowatt hours (kWh) per cubic metre (1000 litres) of fresh water produced.

Progress of RO Seawater Desalination Plants

	1980s	1990s	2000s
Recovery %	25	40 - 50	55 - 65
Operational pressure MPa	6.9	8.25	9.7
Product water quality TDS mg/L	500	300	< 200
Energy consumption kWh/m³	12	5.5	4.6

Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

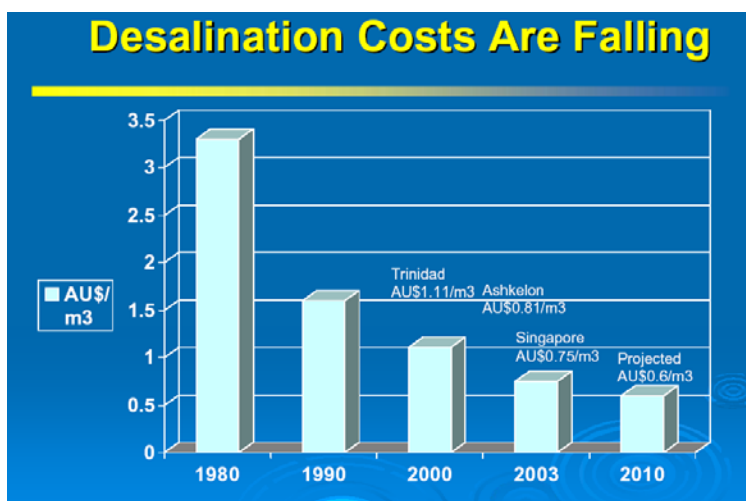
The cost of desalinated water using reverse osmosis depends on the capacity of the

desalination plant – the greater the capacity the lower the unit cost – as shown below in US\$.



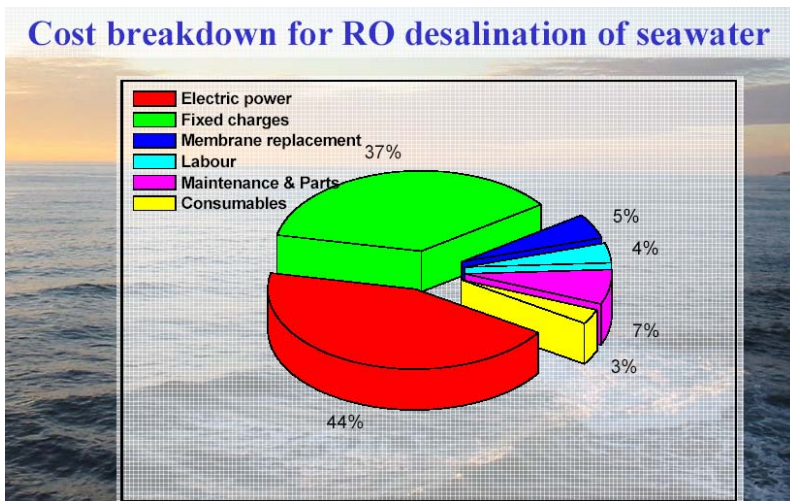
Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

However, as indicated below, desalination costs are falling, and are projected to reach A\$0.60 per cubic metre by 2010.



Source: Voutchkov, N. "Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process." Posieden Resources Corporation, USA. International Key Note Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Electricity is clearly the major cost input for a reverse osmosis desalination plant, accounting for 44% of costs as shown below.



Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

The following costs of various seawater reverse osmosis desalination plants are in US\$.

Water desalination costs and power required in some selected SWRO plants

Location	S/m ³	kWh/m ³
Israel (Ashkelon)	0,527	< 4
Singapore (Tuas)	0,78	-
Spain	0,45-0,71	3.1 - 4
USA (Tampa Bay)	0,659	-
Algeria	0,6994-0,7398	-
Cyprus (Larnaca)	0,79	3.4

Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005. NB: The price of Singapore water is considered to be in Singapore dollars, equivalent to US\$0.45/m³.

A major issue with any desalination plant is the disposal of the residual brine waste, which as shown below is twice the salinity of normal seawater.

Examples of feed water quality, water recovery, and residual quality

Source	Feed TDS (mg/L)	Water Recovery (%)	Residual TDS (mg/L)
Surface Water	200	85	1,330
Fresh Groundwater	400	85	2,660
Brackish Groundwater	2,000	75	8,000
Seawater	32,000	50	64,000

Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

In the United States, 41% of desalination plants dispose of their residual waste through surface water discharge. Sewer discharge and pumping back into the ground (well injection) account for 31 and 17% of disposal methods respectively

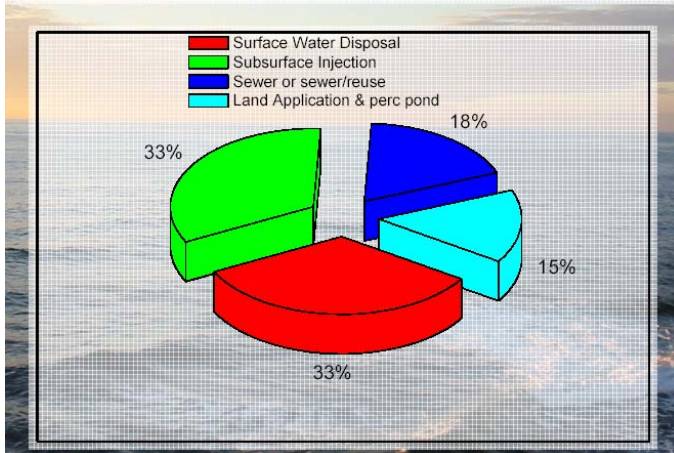
Concentrate Disposal – Current Status in the US (2004 Survey – Over 300 Plants)

Disposal Method	Percent of Plants Using This Method (%)
Surface Water Discharge	41
Sewer Discharge	31
Well Injection	17
Land Application	2
Evaporation Ponds	2
Reuse	2
Recycle	2
Other (Including Zero Discharge)	3

Voutchkov, N. "Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process." Posieden Resources Corporation, USA. International Key Note Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

In Florida, both surface water disposal and well injection share an equal 33% of concentrate disposal methods.

Concentrate disposal methods used in Florida



Source: Drioli, E. and Di Profio, G. "Innovative Sustainable Desalination Systems Using Membrane Technology." Research Institute on Membrane Technology, University of Calabria, Italy, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

However, it is apparent that blending 'fresh' wastewater discharge with concentrate of a very different salinity may cause marine organism toxicity – triggered by an ion imbalance. For example, in Santa Barbara, it has been demonstrated that sea urchins experience a negative effect on egg development when exposed to saline concentrate combined with wastewater treatment plant effluent, but no effect when exposed to concentrate and seawater alone.²⁷

3.2 Case Study – Israel

Israel's utilisation of its natural potable water sources is complete (almost 100%). Further increases on the supply side have to be through the development of non-conventional sources. In fact, utilisation of natural potable water sources over the past 15 years has exceeded natural replenishment, and this over-use has led to depletion of reserves and dangerously low aquifer levels. These aquifers must be rehabilitated to avoid further quality deterioration due to saline water intrusion and to assure meeting targeted supply reliability goals. 100-200 million m³/year of potable water, over ten years, have been allocated by the Israeli Water Commission for replenishing these aquifer reserves.

In Israel, wastewater reclamation is less of an option as agricultural use of potable water has been consistently reduced over the past five years and replaced by treated wastewater. This trend will continue as a matter of policy. The current level of irrigation with potable

²⁷ Voutchkov, N. 'Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process.' Posieden Resources Corporation, USA. International Key Note Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

water is approaching a critical minimum. It will be limited to highly sensitive areas where aquifer contamination is a clear danger and will not be able to serve as a reserve for periods of drought.

Hence the only practical source for large-scale additional potable water is seawater desalination. The Planning Division of the Israeli Water Commission has consequently developed and submitted to the Government a ten-year program (capacities, locations, time frame, budgets, etc.) for the desalination of a total of 500 million m³/year of seawater by 2015. This quantity will represent then about 25% of total potable water supply in Israel, and, together with the 80 million m³/year of desalinated brackish water that will also be added to the system, about 28%.

To improve the quality of municipal water supplies, with whom the desalinated water will be preferentially blended, and, indirectly, also the quality of the municipal wastewater, which will be reused mostly for irrigation (thereby reducing the threat of soil and groundwater salinisation), the ten-year plan dictates that all desalinated water in Israel must have a chloride concentration of only 10-80 ppm max. Boron concentration, which, likewise, threatens some sensitive important crops, is also limited in the plan to 0.4 ppm.

As of December 2004, the Government has approved the construction of seawater desalination plants with a total output of 315 million m³/year by year 2010. The Ashkelon 100 million m³/year plant, is the first step in implementing this program – as described in more detail at the end of this case study.²⁸

Israel's projected water demand is as follows:

Year	2005	2010	2015	2020
Agricultural				
Potable water	530	530	530	530
Brackish water	160	140	140	140
Treated wastewater	300	500	600	700
Total	990	1,170	1,270	1,370
Industrial				
Potable water	85	90	95	100
Brackish water	40	40	40	40
Treated wastewater	0	5	13	15
Total	125	135	148	155
Domestic				
Potable water	720	840	960	1,080
Nature Conservation	25	50	50	50
Aquifer Rehabilitation				
Potable water	100	200	0	0
Neighboring Entities	100	110	130	150
Total Demand	2,060	2,505	2,558	2,805

Source: Semiat, R. "Case studies & experiences with desalination delivery plants in Israel. Head of Grand Water Research Institute, Technion – Israel Institute of Technology. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

²⁸

Dreizin, Y. "Ashkelon Seawater Desalination Project – Off-taker's Self Costs, Supplied Water Costs, Total Costs and Benefits" Senior Manager, Israel Water Commission, in *International Conference on Desalination Costing. Program and Papers*. 6-8 December 2004, Lemesos, Cyprus.

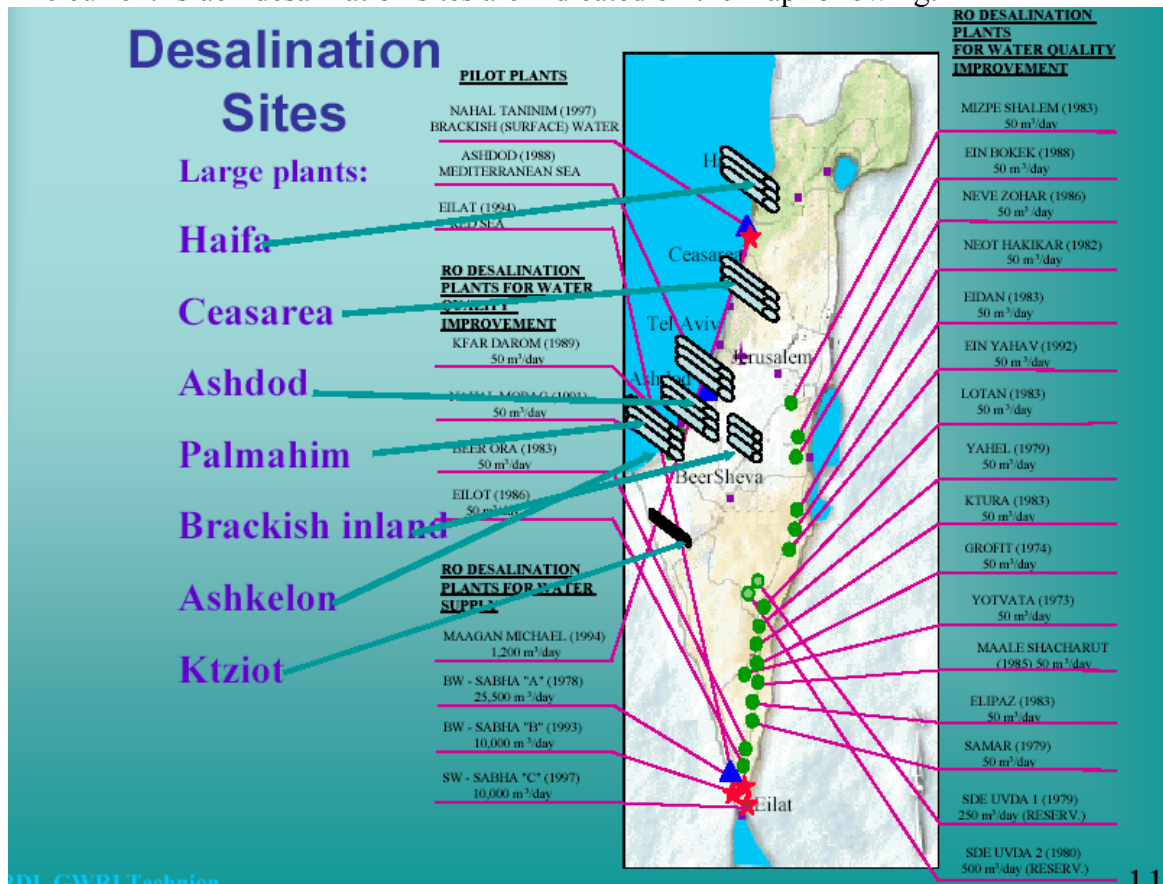
Currently, desalinated seawater comprises less than 5% of total Israeli supply, and is projected to increase to approximately 22% by 2020, as shown below.

Seawater desalination within Israel's projected sources of water supply– in million m³/year

Year	2005	2010	2015	2020
Potable water				
Natural sources	1,470	1,470	1,470	1,470
Desalinated brackish water	30	50	80	80
Desalinated seawater	100	315	500	650
Brackish water	160	140	140	140
Treated wastewater	300	450	520	600
Total	2,140	2,425	2,710	2,910

Source: Semiat,R. “Case studies & experiences with desalination delivery plants in Israel. Head of Grand Water Research Institute, Technion – Israel Institute of Technology. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

The current Israeli desalination sites are indicated on the map following:




Source: Semiat,R. “Case studies & experiences with desalination delivery plants in Israel. Head of Grand Water Research Institute, Technion – Israel Institute of Technology. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide

Feb 23-25, 2005.

The Ashkelon Desalination Plant

The Ashkelon desalination plant has a production capacity of up to 110 million m³/year, and has been built as a Build, Own and Transfer (BOT) project.

Overview

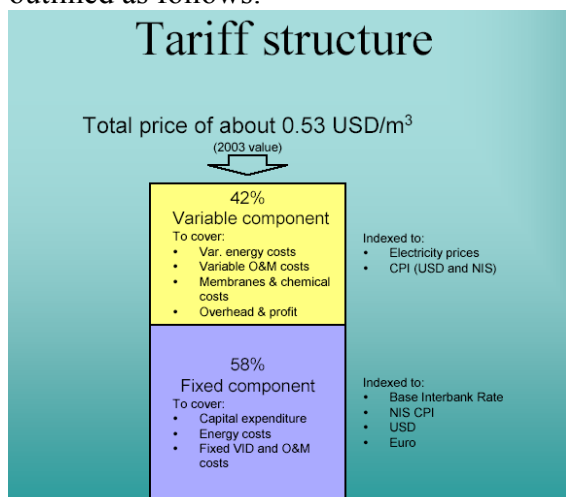


- Plant location at Ashkelon
- Production capacity up to 110 million m³/year guaranteed by BOT contract
- Commitment of Israel State in BOT contract to purchase 100 million m³/y.
- during 22.5 years
- The plant will supply drinking water to 1.4 million people in Israel & potentially in Gaza

18 Titre de la présentation 19/01/00

Source: Semiat,R. “Case studies & experiences with desalination delivery plants in Israel. Head of Grand Water Research Institute, Technion – Israel Institute of Technology. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

The Ashkelon pricing structure is composed of both a fixed component (to cover capital expenditure, fixed operation and management costs and part of the profit) as well as a variable component (to cover variable operation and management costs, membranes and chemical costs, and also part of the profit). The tariff structure of about US\$0.53/m³ is outlined as follows:



Source: Semiat,R. “Case studies & experiences with desalination delivery plants in Israel. Head of Grand Water Research Institute, Technion – Israel Institute of Technology. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

3.3 Desalination Case Study – Algeria

With an area of 2.4 million Km², Algeria is the second largest African country and the tenth largest country in the world. The water potentiality of Algeria is less than 500 m³ per head/year. According to World Bank guidelines that dictate a minimum of 1000 m³ per head/year, Algeria is classified in 14th place among countries poor in water resources. The average availability for domestic consumption is 55 litres per inhabitant/day and the water is usually cut off in almost all the cities. People normally use water stocked in tanks during water shortages, increasing the risk for disease.

Rainfall is the most important parameter used to evaluate water resources in Algeria and its average deficit, 30% in the last 25 years, has increased to more than 60% in the last 2 years. If this situation continues alongside population growth, in the year 2020 Algeria will only have 25 litres of water available per inhabitant/day, and the country will be ranked among the 6 poorest countries in water resources in the world.

This situation, together with the increased demand by different users and demographic growth, has given rise in the past few years to a new national water policy, whose budget is the third largest following Defense and Education. The Ministry for Water Resources was created to manage water resources. In 2001, the company ADE (Algerienne des Eaux) was created to develop this policy and to take charge of water distribution systems, replacing all pre-existing institutions. The National Agency of Dams was also created to improve the storage capacity of existing dams and to build another 50 dams before the year 2020. Their objective is to achieve a storage volume of 9 billion m³ that, together with the 7.5 billion m³ of subterranean resources, will provide a total storage volume of 16 billion m³.

The Algerian Government also decided in favor of private sector involvement in water management, with the incorporation of AEC (Algerian Energy Company) owned 50% by SONATRACH and 50% by SONELGAZ. AEC is the promoter of the desalination plants, while SONATRACH provides professional experience in the negotiation of international contracts and eventually will be incorporated as guarantor of the contracts. AEC and/or ADE will establish mixed public/private companies with private investors for the construction, financing and operation of these desalination plants.

Due to the shortage of natural water resources even in years with reasonable rainfall, to ensure an adequate supply of drinkable water independent of climatic changes, and in order to preserve subterranean resources for inshore city use and for agricultural purposes, sea water desalination seems to be the most logical and secure choice in the cities on the Algerian sea side, 1,200 km long, where the majority of the population resides. Accordingly, the Algerian Government has opted for a Program of Large Desalination Plants designed to reach a volume of 1,000,000 m³/day in the next 5 years, and a volume of 4,000,000 m³/day by the year 2020.

Project description

The Projects - "*Projet de Dessalement d'Eau de Mer de Beni Saf and Skikda*" - consists of the design, construction, financing, ownership and exploitation of a Water Desalination Plant producing 150,000 M³/d water per day using the Reverse Osmosis procedure for Beni Saf and 100,000 M³/d for Skikda.

The contracted price for the Beni Saf plant (150,000 M³/d capacity) was US\$0.6994 / M³,

and for Skikda (100,000 M³/d capacity) was US\$0.7398 / M³.

The Project will be financed through a Build, Operate and Own scheme (BOO). The buyer (ADE/SONATRACH) will purchase capacity and water output pursuant to a 25 year Take or Pay Water Purchase Agreement. AEC may purchase the Plant from the Project Company at the end of the 25 year period or this period may be extended by mutual agreement between the buyer and the producer. The construction period will be two years.²⁹

3.4 Desalination Case Study – Pretreatment of Water to Reverse Osmosis Desalination Plant, Tampa, Florida

Nearly two years ago the Tampa Bay, Florida seawater desalination facility began producing drinking water from seawater. As North America's largest seawater RO desalination plant, the 94 000 m³/day facility is intended to provide up to 10 percent of the drinking water required by Florida's Tampa Bay area and is part of the Master Plan to create an environmentally friendly, drought-proof supply of drinking water and reduce the need for groundwater pumping. Problems with the facility's pretreatment system, coupled with other operational difficulties have significantly reduced the plant's performance.

Currently the plant uses a two-stage dual sand pre-treatment system to remove turbidity, algae, organic material and other particulate matter from the incoming raw seawater. However, this screening is inadequate, the RO membranes foul too quickly and the plant cannot achieve peak drinking water production. The desalination plant faces frequent cleaning of the RO membranes, which significantly increases operating costs through higher energy consumption, increases chemical usage for cleaning and requires more frequent RO membrane replacement. Moreover, the plant only operates intermittently and produces less drinking water than it is designed to deliver.³⁰

According to the International Water Association, Tampa Bay Water has appointed American Water-Pridesa to remedy, operate and manage the city's desalination plant. Work is expected to be completed by October 2006, and once fully operational the cost of water will average \$2.54 per thousand gallons.

3.5 Desalination Case Study – Singapore

In January 2003, through a process of international tendering, the Singaporean Public Utilities Board (PUB) appointed SingSpring Pte Ltd to build, own and operate (BOO) a desalination plant for a contract period of 20 years. This 30 million metric gallons a day (mgd) or 136,380 m³/d seawater desalination plant when in commercial operation in December 2005, will be the largest desalination plant in Asia, and among the largest seawater reverse osmosis (RO) plants worldwide.

²⁹ Bravo,G. "Trends of Desalination Bids for RO plants in North Africa:The Case of Algeria." CEO, Befesa CTA (Abengoa), in *International Conference on Desalination Costing. Program and Papers*. 6-8 December 2004, Lemesos, Cyprus.

³⁰ Wolfi,P. and Siverns,S. "The New Generation for Reliable RO Pretreatment." Zenon Environmental Inc. *International Conference on Desalination Costing. Program and Papers*. 6-8 December 2004, Lemesos, Cyprus.

The Singapore desalination tariff of S\$0.78/m³ (US\$0.45/m³ at December 2004 exchange rates) is currently the lowest in the world for a reverse osmosis desalination plant.

The tariff structure comprises capacity payments and variable (output) payments for actual dispatch. The capacity payments provide for debt service, fixed costs and equity returns. The output payments provide for recovery of variable operating costs. Both capacity and output payments are indexed to inflation and foreign exchange rates to provide protection against fluctuations in these variables.

The total capital cost for the project is approximately S\$200 million (US\$116 million), which has been financed with 80% debt and 20% equity. The term for the loan is 18 years, the longest such project financing ever arranged in Singapore. Singapore's first-ever desalination plant, which when completed in end 2005, will meet some 10% of the island's water needs.³¹

3.6 Desalination Case Study – London Thames Water Utility

Thames Water proposed a reverse osmosis desalination water treatment plant to serve North East London. The Utility noted that:

- Per head of population London is drier than Madrid and Istanbul;
- Customer demand for water has gone up from 150 litres per head per day in the 1980s to 163 litres per head per day now - an approximate increase of 15% in 20 years;
- Lifestyle factors, such as increased single occupancy households, mean that demand for water is rising;
- By 2016, London is set to have more than 800,000 new residents - the equivalent of the population of Leeds moving to the capital;
- Climate change is a reality - hotter, drier summers are likely to become the norm.

Subject to planning permission, the Thames Gateway Water Treatment Plant will be constructed on the north bank of the Thames in the London Borough of Newham. The treatment plant will be the first desalination plant in London to take salty water from the Thames. The treated water from the plant will be pumped through a new pipeline to the existing reservoir in Woodford, Essex, ready for distribution to customers across North East London.

The plant is designed to serve 400,000 households, with a capacity of 150 million litres of water/day. Estimated construction cost is £200 million.³²

However, the Mayor of London Ken Livingstone has denied development consent for the project, on the grounds that it is too energy intensive and not enough work has been done to

³¹ Kiang, F.H and Yong,W.L. "Supply of Desalinated Water by the Public Sector 30 Mgd Seawater Desalination Plant" in *International Conference on Desalination Costing. Program and Papers*. 6-8 December 2004, Lemesos, Cyprus.

³² See Thames Water website: http://www.thameswateruk.co.uk/UK/region/en_gb/content/Section_Homepages/Section_Homepage_000516.jsp?SECT=Section_Homepage_000516, Accessed July 2005.

reduce water mains leakage. The Mayor's stated reason for refusal was:

The application does not deliver the sustainable and efficient management of water supplies in London and is contrary to policy 4A.11 of the London Plan "Water Supplies" which seeks to minimise the use of treated water and maximise rainwater harvesting opportunities and as such the proposed development is not in the interests of good strategic planning in London.³³

The London Plan 'Water Supplies' seeks to meet water supply needs in a sustainable manner through demand management and reducing mains leakage. A Liberal Democrat London Assembly Environment Spokesperson, Mike Tuffrey, said:

Before Thames Water embarks on such an ambitious project they need to reduce leakages and reduce demand for piped water or we are just storing up problems for the future. The desalination plant would require enormous amounts of energy to convert salt water to pure water and this could leave lasting damage on the environment. Simply increasing the supply of water, whether through flooding parts of the countryside for new reservoirs or through building energy intensive desalination plants, has significant environmental impacts.³⁴

3.7 Desalination Case Study – United Arab Emirates

The United Arab Emirates is a constitutional federation of seven emirates; Abu Dhabi, Dubai, Sharjah, Ajman, Umm al-Qaiwain, Ras al-Khaimah and Fujairah. The United Arab Emirates (UAE) occupies an area of 83,000 sq km along the south-eastern tip of the Arabian Peninsula. The capital and the largest city of the federation, Abu Dhabi, is located in the emirate of the same name. Four-fifths of the UAE is desert.

The United Arab Emirates is the third largest country in terms of seawater desalination capacity. However, there is a paucity of information available about desalination in the UAE. It is understood that each emirate has its own water authority, and each provides a different amount of information.

The United Arab Emirates has 55.5 m³ of natural renewable water resources per capita. In contrast, Australia has 25,185 m³ per capita.³⁵ The average annual precipitation in the largest city of the UAE, Abu Dhabi, is 89 mm. In contrast, Sydney has an average annual precipitation of 1333 mm.³⁶

³³ Mayor of London, Planning Decisions Meeting 14 April 2005. See website http://www.london.gov.uk/mayor/planning_decisions/strategic_dev/2005/apr1405/desalination_plant_final_decision.pdf. Accessed July 2005.

³⁴ "Mayor denies Thames desalination plant." In Environmental Data Interactive Exchange website, 29 April 2005. See website: http://www.edie.net/news/news_story.asp?id=9862&channel=4, Accessed July 2005.

³⁵ World Resources Institute, *Earthtrends – Water Resources and Freshwater Ecosystems. Data Tables 2003*. See WRI website: <http://earthtrends.wri.org/datatables/index.cfm?theme=2>. Accessed July 2005.

³⁶ Nationmaster.com, *Geography: Precipitation*. See website: http://www.nationmaster.com/graph-T/geo_pre. Sourced from United Nations World

Dubai Desalination Capacity

Installed Capacity	2001	2002	2003	2004
Desalination Plant Million/gallons/day	148	168	188	188
Wells Million/gallons/day	12	12	41	41
Peak Demand	143	154	167	184

Source: Dubai Water and Electricity Authority, Statistics. See website (<http://dewa.gov.ae>)

Abu Dhabi Water Capacity and Production

Year	Capacity (million gallons/day)	Production (millions of gallons)
1998	212	66,772
1999	227	70,917
2000	258	76,015
2001	325	86,896
2002	449	105,560
2003	449	120,415
2004	641	138,297

Source: Abu Dhabi Water and Electrical Company, *Statistical Leaflet 2004*. See website <http://www.adwec.ae>

From the above table, it is evident that the Emirate of Abu Dhabi has significantly increased its desalination capacity, from 212 MG/day to 641 MG/day, in the six years from 1998.

3.8 Desalination Case Study – Spain

In June 2004, the Spanish government announced that up to 21 new seawater desalination plants would be built on the Mediterranean coast. The new facilities, with an overall capacity of 650 million m³/year treated water, more than doubles the present desalination capacity from over 900 desalination plants spread around the country. Spain has over 30 years of experience of desalination, with the use of reverse osmosis as the favoured technology.

Originally desalination was only for urban use. However, the reduction in costs has enabled desalinated water to be used for crop irrigation, with the south-eastern part of the country relying on desalination to develop a profitable out of season agriculture for export to other European countries. Now agriculture accounts for 22.4% of desalinated water use. The Carboneras desalination plant now being constructed, with a capacity of 145,000 m³/day, is designed purely for agricultural production.

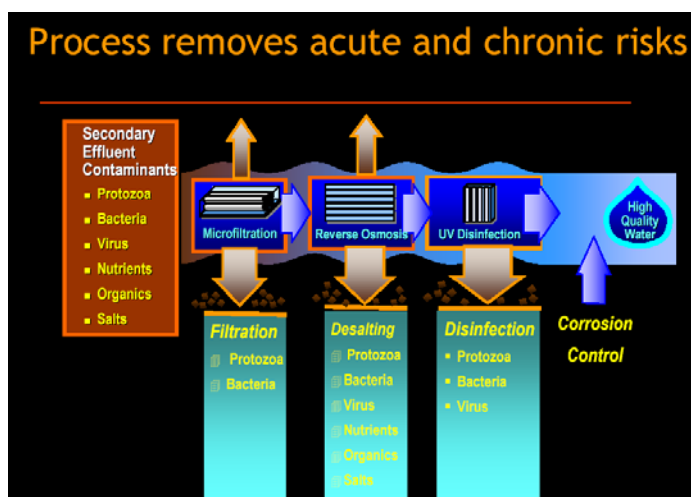
Other measures apart from desalination, including water reuse and savings in the water distribution systems – especially agricultural, will be able to supply 1,083 m³/year to the

coastal Mediterranean areas.³⁷

4.0 Water Reuse

Contaminants in waste water, such as that from a sewage treatment plant, contain both acute and chronic risks. Acute risks include pathogens such as viruses and bacteria, whilst chronic risks include synthetic and natural organic compounds. In any waste water reuse program, the treatment objective is to reduce these risks to below that of existing potable supplies.³⁸

Reverse osmosis has wider applications than just removing salt from seawater for potable use. A wastewater treatment process including microfiltration, reverse osmosis and ultraviolet disinfection can produce high quality water. The process is outlined as follows:



Source: Leslie, G. *et al* "Membrane Systems for Municipal Water Systems. A road map for the next generation of water recycling plants." University of New South Wales, UNESCO Centre for Membrane Science and Technology, & Amy Childress, University of Nevada, USA. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Using the above process, the cleanliness of the final treated wastewater is quite remarkable. As shown following, the risk of infection from drinking recycled water is significantly lower than the acceptable risk of drinking normal potable water.

³⁷ Jose Antonio Medina San Juan, "New Trends of Desalination in Spain." In *Watermark*, The News Letter of the Middle East Desalination Centre, Issue 24, September 2004.

³⁸ Leslie, G. *et al* "Membrane Systems for Municipal Water Systems. A road map for the next generation of water recycling plants." University of New South Wales, UNESCO Centre for Membrane Science and Technology, & Amy Childress, University of Nevada, USA. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

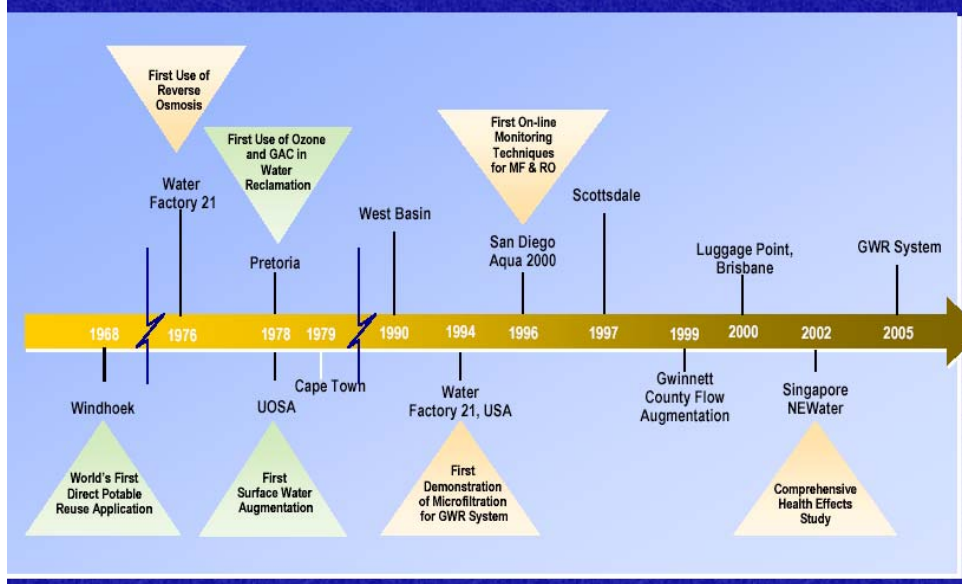
Estimate of acute risk in recycled water

	Virus	Bacteria	Protozoa
Effluent Conc. (organisms/L)	1×10^2	1×10^7	1×10^2
Process Efficiency (Log removal)	10	14	14
Product Conc. (organisms/L)	1×10^{-8}	1×10^{-7}	1×10^{-12}
Risk of infection (Recycled)	1.2×10^{-9}	4.7×10^{-10}	3.9×10^{-14}
Acceptable Risk (Drinking Water)	1×10^{-4}	1×10^{-4}	1×10^{-4}

Source: Leslie, G. *et al* "Membrane Systems for Municipal Water Systems. A road map for the next generation of water recycling plants." University of New South Wales, UNESCO Centre for Membrane Science and Technology, & Amy Childress, University of Nevada, USA. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

The first example of advanced water reuse was at Windhoek, Namibia in 1968. After an upgrade in 2000, reclaimed water now contributes 25% of the Windhoek water supply. The first use of reverse osmosis was in 1976 at the United States 'Water Factory 21' in California.

Advanced Reuse Milestones



Source: Law, I. "Membranes and the production of a Safe, Sustainable Water Supply." IBL Solutions, Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes*

and Desalination. Adelaide Feb 23-25, 2005.

Examples of reuse technologies include

Windhoek	Windhoek	UOSA	Singapore
1968	2000	1974	2002
Secondary Treatment followed by: <ul style="list-style-type: none"> • Algae flotation • Foam fractionation • Chem Clarification • Sand filtration • GAC • Chlorination 	Improved Sec Treat followed by: <ul style="list-style-type: none"> • Pre-ozonation (for Fe and Mn) • Dissolved air flotation • Sand filtration • Ozonation • GAC • Membrane filtration (UF) • Chlorination 	Secondary Treatment followed by: <ul style="list-style-type: none"> • High lime treatment • Clarification • Recarbonation • Sand filtration • GAC • Ion Exchange • Chlorination 	Secondary Treatment followed by: <ul style="list-style-type: none"> • Membrane filtration (MF or UF) • Reverse Osmosis • UV Disinfection • Stability control • Chlorination
Reclaimed Water Flow: 4.8 ML/d	Reclaimed Water Flow: 21 ML/d	Reclaimed Water Flow: 200 ML/d	Reclaimed Water Flow: 82 ML/d
Reclaimed water contribution: 4%	Reclaimed water contribution: 25%	Reclaimed water contribution: 10-45%	Reclaimed water contribution: 1% initially and increasing

Source: Law,I. “Membranes and the production of a Safe, Sustainable Water Supply.” IBL Solutions, Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

NB: UOSA: Upper Occusal Sewage Authority – Virginia USA.

4.1 Water Reuse Case Study – Water Factory 21 Orange County, California

Orange County, California, receives an average of only 13 to 15 inches of rainfall annually, yet sustains a population of approximately 2.5 million people. The Orange County Water District (OCWD) manages the massive groundwater basin that underlies the northwest half of the county, supplying about 75 percent of the District's total water demand. The remaining 25 percent is obtained through the Colorado River Aqueduct and the State Water Project via the Metropolitan Water District of Southern California.

As long ago as the mid-1960s, OCWD began a pilot-scale reclamation project that developed into the now-famous Water Factory 21. Located in Fountain Valley, California, the plant is well-known internationally, attracting more than 1,000 visitors annually from 30 countries.

By 1956, years of heavy pumping to sustain the region's agricultural economy had lowered the water table below sea level and saltwater from the Pacific Ocean had encroached as far as five miles inland. The first blended reclaimed water from Water Factory 21 was injected into the coastal barrier in October 1976. Several alternative sources of water were thoroughly evaluated for the seawater barrier injection program, including deep well water, imported water, reclaimed waste-water, and desalted seawater. The source of injection water finally adopted for Water Factory 21 is a blended combination of deep well water and recycled secondary effluent supplied by the Orange County Sanitation District (OCSA).

The recycled product water from Water Factory 21 meets drinking water standards through treatment using advanced processes. Recycled water was chosen for many reasons. Cost was a definite consideration, but even more important were the environmental advantages:

- Reduction of 15,000 acre-feet of wastewater discharged to the ocean annually;
- Reduction of dependency on State Water Project and Colorado River supplies;
- Constant availability of reclaimed water supply;
- Seawater intrusion barriers are last priority when imported supplies are diminished by drought or emergency interruption of importation systems.

Water Factory 21 product water is a blend of five million gallons per day (MGD) reverse osmosis-treated water, nine MGD carbon adsorption-treated water, and 8.6 MGD deep well water. This blend, with a total dissolved solids (TDS) content of 500 milligrams per liter (mg/L) or lower, meets all California Department of Health Services primary and secondary drinking water standards.

Water Factory 21 reclaims approximately 15 MGD, and, with the deep well water used for blending, produces 22.6 MGD. The blended injection water not only protects the basin from saltwater intrusion, but also replenishes aquifers from which 50 percent of the county's water is drawn.³⁹

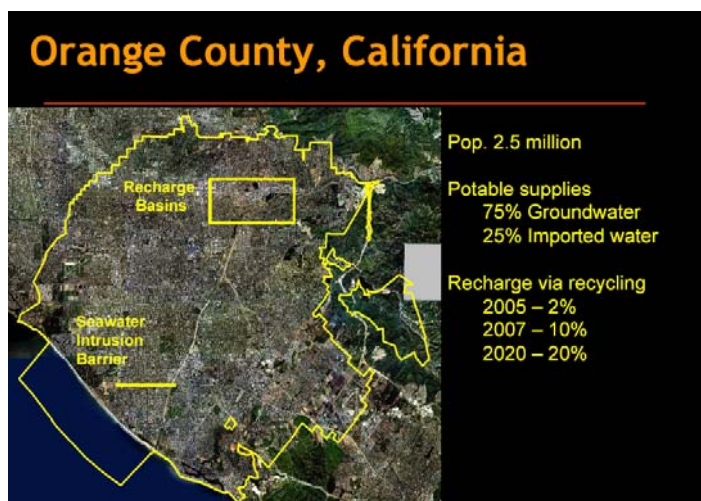
A new water purification system for Orange County, California was launched in October 2004, to provide drinking water for 144,000 families annually. The US\$487 million 'Groundwater Replenishment System' (GWR) takes highly treated sewer water that is currently released in to the ocean, and purifies it using a combination of microfiltration, reverse osmosis, and ultraviolet light with hydrogen peroxide treatment. The treated wastewater then percolates into the groundwater basin along the same natural filtering path as rainwater. More than half of the area's water supply for 23 northern and central Orange County communities is drawn from groundwater aquifers, with the remainder imported from the Colorado River and California. The treated water will also be injected along the coast to maintain a seawater intrusion barrier to keep the Pacific Ocean out of the groundwater supplies.

Denis Bilodeau, president of Orange County Water District, in October 2004 said the system would serve as a model for water management professional throughout the world. "The GWR System is the first water purification system of its kind in the world and will be emulated by water suppliers in regions across the globe facing similar water supply, population and climate challenges."

Phase One of the Ground Water Replenishment System is currently operational and injecting five million gallons/day of purified water to the county's seawater intrusion barrier to prevent salination of the aquifer. Construction has now begun on the larger, 70 million gallons per day facility.

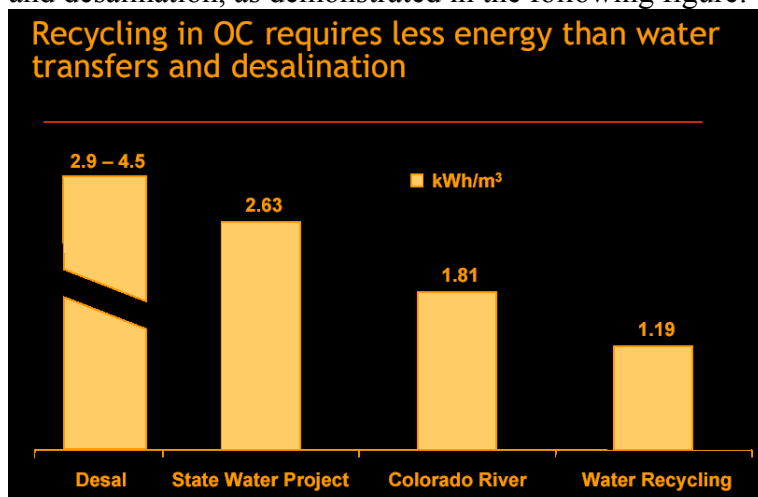
³⁹ Orange County Water District, *Water Factory 21 Overview*, see website <http://www.ocwd.com/html/wf21.htm>, Accessed July 2005.

Steve Anderson, Chair of the Orange County Sanitation District, said: "It's environmentally beneficial because it improves water quality and drought mitigation, saves energy over importing water from Northern California, delays the need for an additional ocean outfall, reduces the amount of wastewater to the ocean. And, because it reduces the need for imported water from Northern California, it lessens the strain on the ecosystem of the San Francisco - San Joaquin Bay Delta."⁴⁰



Source: Leslie, G. *et al* "Membrane Systems for Municipal Water Systems. A road map for the next generation of water recycling plants." University of New South Wales, UNESCO Centre for Membrane Science and Technology, & Amy Childress, University of Nevada, USA. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

Recycling of waste water in Orange County (OC) requires less energy than water transfers and desalination, as demonstrated in the following figure:



Source: Leslie, G. *et al* "Membrane Systems for Municipal Water Systems. A road map for the next generation of water recycling plants." University of New South Wales, UNESCO Centre for

⁴⁰ "The future is orange for groundwater replenishment system." 15 October 2004, In Environmental Data Interactive Exchange website http://www.edie.net/news/news_story.asp?id=9029&channel=4. Accessed July 2005.

Membrane Science and Technology, & Amy Childress, University of Nevada, USA. Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

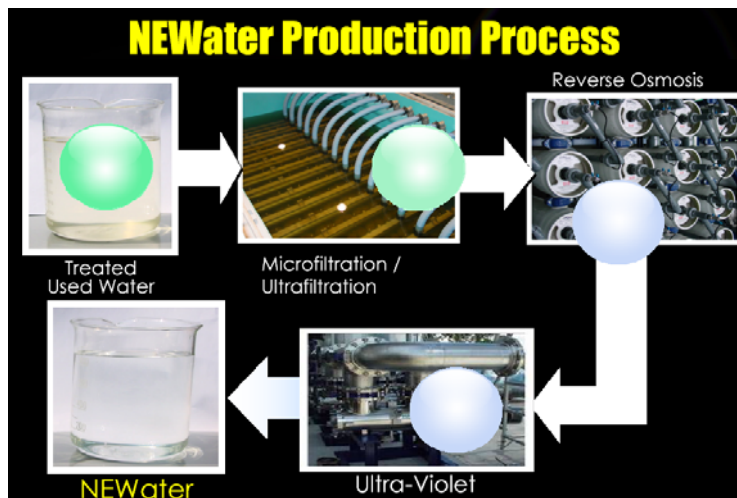
4.2 Water Reuse Case Study - Singapore

Drinking water in Singapore has traditionally been obtained through the treatment of river water and surface water. The Public Utilities Board (PUB) of Singapore has been exploring various methods of diversifying Singapore's water sources. The 'four taps' of water supply presently envisaged by PUB include:

- surface water sourced within Singapore;
- surface water purchased from Malaysia;
- NEWater, reclaimed from used water, is then either blended back into surface water reservoirs for potable treatment (referred to as indirect potable use), or used directly in commercial and industrial applications (direct non-potable use); and
- seawater desalination for direct potable use.

NEWater

The NEWater production process includes the micro/ultra filtration of treated waste water, reverse osmosis to remove contaminants, and disinfection with a final ultra-violet treatment. This process is shown below.



Source: Seah, H. "The NEWater Experience and Singapore's Four National Taps." Director, (Technology) Singapore Public Utilities Board, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalinisation*. Adelaide Feb 23-25, 2005.

A NEWater demonstration plant has been operational since May 2000, with a capacity of 10,000 m³/day. During the demonstration process, in total 190 physical, chemical and microbiological parameters were tested. A two year health effects study was also conducted. It was found that the quality of NEWater has been consistently better than stipulated by the World Health Organisation (WHO) and the United States Environment Protection Authority (USEPA), with no health effects.⁴¹

⁴¹ Seah, H. "The NEWater Experience and Singapore's Four National Taps." Director,

Water quality comparisons of NEWater, local reservoir (ie, untreated) water, PUB tap water and USEPA/WHO standards are shown below.

Water Quality Parameters	Local Reservoir Water	PUB Tap water	NEWater	USEPA / WHO Standards
Turbidity [NTU]	0.5 - 11	< 0.1	< 0.1	5
Total Dissolved Solids [mg/l]	117 - 154	149.5	48.5	500
Lead [mg/l]	< 0.013	0.002	< 0.0005 to 0.002	0.01
Mercury [mg/l]	<0.00003	<0.00003	<0.00003	0.001
Hormones (Synthetic & Natural) [µg/l]	ND	ND	ND	Not Specified
PCBs [µg/l]	ND	ND	ND	0.5
Dioxin [pg/l]	ND	ND	ND	30
Total Organic Carbon [mg/l]	2.6 – 6.2	1.9 – 3.5	<0.1	Not Specified
Total Coliform [cfu/100 ml]	3 - 967	ND	ND	ND
Enterovirus	ND	ND	ND	ND

Source: Seah,H. “The NEWater Experience and Singapore’s Four National Taps.” Director, (Technology) Singapore Public Utilities Board, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

The current demand for direct non-potable use is 15 million gallons/day, expected to increase to 55 million gallons/day by 2011. Direct non-potable use includes air conditioner cooling in commercial buildings, cooling and boiler feed and to the electronics industry.

For indirect potable use, 2 million gallons/day have been returned to reservoirs since February 2003 – less than 1% of total water consumption. This was increased to 3 million gallons/day in 2004, and is to progressively increase to 10 million gallons/day by 2011 – about 2.5% of the total volume of water forecasted to be consumed daily.⁴²

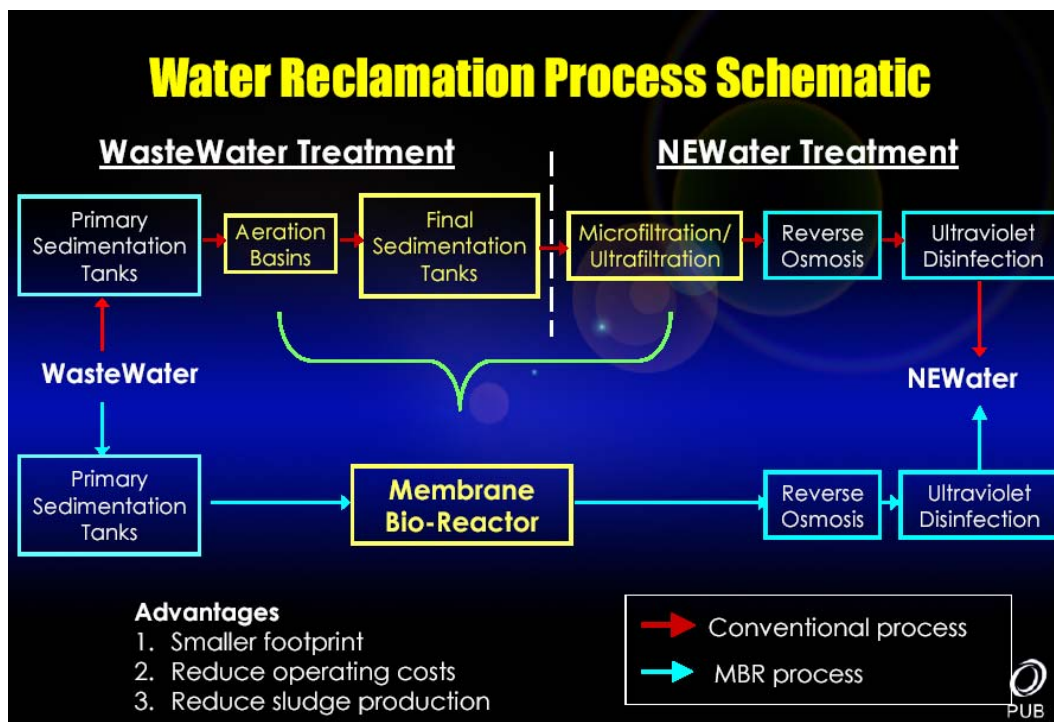
The next stage for Singapore wastewater reuse is the continual development of a membrane bioreactor. Membrane bioreactors (MBRs) combine the use of biological processes and membrane technology to treat wastewater. Within one process unit, a high standard of treatment is achieved, replacing the conventional arrangement of aeration tank, settling tank and filtration that generally produces what is termed as a tertiary standard effluent. The dependence on disinfection is also reduced, since the membranes with pore openings, generally in the 0.1-0.5mm range, trap a significant proportion of pathogenic organisms.

(Technology) Singapore Public Utilities Board, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

⁴² Seah,H. “The NEWater Experience and Singapore’s Four National Taps.” Director, (Technology) Singapore Public Utilities Board, International Key Note Speaker Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

The more common MBR configuration is to have the membrane immersed in the wastewater, although a side stream configuration is also possible, with the wastewater pumped through the membrane module and then returned to the bioreactor.⁴³

Currently in Singapore three pilot plants of 300 m³/day, incorporating both a membrane bioreactor and reverse osmosis process, are in operation. A five million gallons/day demonstration plant is targeted to be operational by 2006. The advantages of using a membrane bioreactor include reduced operating costs and reduced sludge production. The water reuse process using a membrane bioreactor, and the differences compared to the conventional process, are outlined below.



Source: Seah, H. "The NEWater Experience and Singapore's Four National Taps." Director, (Technology) Singapore Public Utilities Board, International Key Note Speaker Presentation at AWA (Australian Water Association) Speciality Conference: Membranes and Desalination. Adelaide Feb 23-25, 2005.

⁴³

Mallia, H. and Till, S. "Membrane Bioreactors: Wastewater Treatment Applications to Achieve High Quality Effluent." In *Water Industry Operators Association, 2001 Conference Papers*. See website: http://www.wioa.org.au/conf_papers/01/paper8.htm

5.0 A COMPARATIVE ANALYSIS OF DESALINATION AND WASTE WATER REUSE

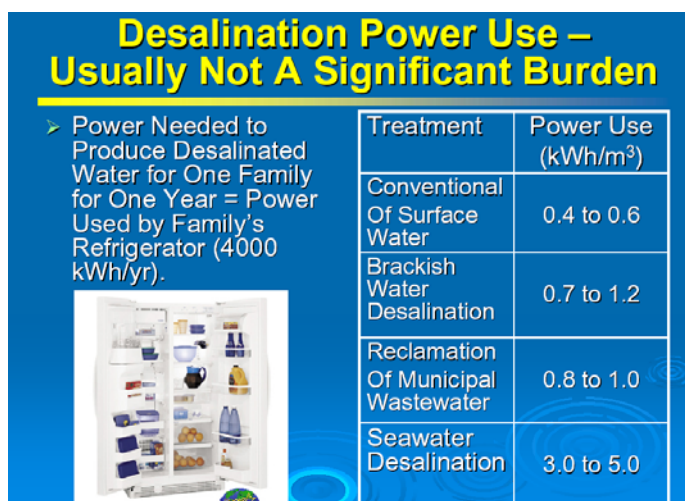
Fane notes that the ‘drivers’ of using reverse osmosis to treat waste water for reuse include:

- relatively low total dissolved solids in waste water, compared to seawater;
- higher recovery of water (80%) compared to the desalination of sea water (which has a recovery of 50% or less); and
- the costs of reuse is less than 50% of the costs of seawater desalination.⁴⁴

The Singapore Public Utilities Board – in response to the question of why not just build more desalination plants rather than expand NEWater, stated on their website:

Due to the presence of high salt contents in saltwater, it is more costly to desalinate seawater because desalination plants use more energy. However, the cost of desalination has been coming down as technology improves. So PUB has decided to diversify our water resources including supplying desalinated water. As NEWater is more cost competitive in the foreseeable future, PUB intends to maximise the use of NEWater.⁴⁵

The comparative power use of various water treatment processes is shown below – with seawater desalination requiring up to five times the power of municipal wastewater reclamation. The author, N. Voutchkov (from a desalination sales company), comments that the power needed to produce desalinated water for one family for one year is equivalent to the power used by that family’s refrigerator.



Source: Voutchkov, N. ‘Seawater Desalination. From Research to Environmental Permitting, Construction, Start-up and Operations – Managing the Project and the Process.’ Posieden

⁴⁴ Fane, T. “Harvesting Water from Compromised Sources. Membranes and the Water Cycle.” UNESCO Centre for Membrane Science and Technology, UNSW, Australia, Institute for Environmental Science and Engineering, NTU, Singapore. Presentation at AWA (Australian Water Association) Speciality Conference: Membranes and Desalination. Adelaide Feb 23-25, 2005.

⁴⁵ Singapore Public Utilities Board, *Frequently Asked Questions*, See website: <http://www.pub.gov.sg>. Accessed July 2005.

Resources Corporation, USA. International Key Note Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

The comparative costs of waste water reuse versus seawater desalination were investigated by Cote and Severns. The general assumptions used were as follows:

- treated sewage quality (after biological treatment and reverse osmosis) is suitable for industrial applications and indirect potable reuse;
- membrane filtration is the best available technology for reverse osmosis pre-treatment in water reuse;
- desalination was focussed on open seawater sources – where pre-treatment is needed;
- desalination pre-treatment requires either single or double stage media filtration depending on water quality.

Importantly, the sewage input used for treatment was assumed to be biologically treated before discharge, and hence only the incremental costs for reuse were considered. The costs (in US\$) of producing water from secondary effluent and seawater reverse osmosis desalination were as follows:

Costs of Producing Water from Secondary Effluent and from Seawater

Component	Units	A: from CAS effluent	B: from seawater	Ratio (B/A)
Capital costs				
Infrastructure & pretreatment	\$/m ³ /d	161	320	1.99
RO	\$/m ³ /d	321	624	1.94
Total	\$/m ³ /d	482	944	1.96
Total Life cycle costs				
Capital	\$/m ³	0.07	0.24	3.43
O&M	\$/m ³	0.21	0.38	1.81
Total	\$/m ³	0.28	0.62	2.21

Source: Cote,P and Siverns,S. “Cost Comparison of Membrane-based Solutions for Water Reclamation and Desalination.” Zenon Environmental Inc, Presentation at *AWA (Australian Water Association) Speciality Conference: Membranes and Desalination*. Adelaide Feb 23-25, 2005.

From this analysis, the cost of reclaiming water from a sewage treatment plant (US\$0.28 m³) is less than half that of desalinating seawater (US\$0.62 m³). Other considerations include the expense of piping reclaimed water back to a water source, compared to desalinated water which can be added direct to a water reticulation system.

However, the cost of desalination or wastewater reuse is only one consideration. Public understanding and acceptance of technologies is also an important factor.

In reviewing the use of membranes to clean water, Law makes the following conclusions:

- We cannot continue to use our fresh water supplies in an unsustainable fashion;
- Advanced reuse has a big role to play – we must make full use of what the membrane based technologies can offer;
- Desalination does have a role to play in diversifying our water sources but it does suffer from cost and environmental penalties;
- We have the technologies to produce safe water – we need the regulators, the water professionals and the community at large to accept water reuse as a responsible way forward for the future.⁴⁶

6.0 CONCLUSION

It is pertinent to ask what makes an urban water infrastructure system sustainable? The NSW Legislative Assembly Standing Committee on Public Works, in its Interim Report on Urban Water Infrastructure, canvassed this issue. The Committee made the following findings:

Finding 1: If sustainability is one of society's underpinning values, a new paradigm for urban water for the 21st century needs to be set in train. This paradigm will be based on infrastructure that ensures integration and closed water cycle.

Finding 3: The new paradigm will only come about if Government takes a strategic lead in creating the circumstances which ensure alternative systems become an integral part of urban water infrastructure solutions. This will require the identification or establishment of a lead agency to drive total water cycle policy.⁴⁷

Traditionally water supply was a 'once through system', which involves taking water from a dam, using it once, and then disposing of it. By contrast, the objective of the closed water cycle is to reduce the net total loss of water from the system. Similarly, the objective of the integrated urban water management approach is to take a holistic view of the system. The concepts of integrated water management and a closed loop system can be used together to provide a sustainable urban water system.⁴⁸ The Government's Metropolitan Water Plan goes some way towards 'closing the loop' and integrated water management.

⁴⁶ Law, I. "Membranes and the production of a Safe, Sustainable Water Supply." IBL Solutions, Presentation at AWA (Australian Water Association) Speciality Conference: *Membranes and Desalination*. Adelaide Feb 23-25, 2005.

⁴⁷ NSW Legislative Assembly Standing Committee on Public Works, *Interim Report on Urban Water Infrastructure*, Report No 52/11, December 2002, at 33.

⁴⁸ NSW Legislative Assembly Standing Committee on Public Works, *Interim Report on Urban Water Infrastructure*, Report No 52/11, December 2002, at 25. Evidence of Dr Andrew Speers, CSIRO, to the Committee.

Recent Research Service Publications



*To anticipate and fulfil the information needs of
Members of Parliament and the Parliamentary
Institution.*

[Library Mission Statement]

Note: For a complete listing of all Research Service Publications
contact the Research Service on 9230 2093. The complete list
is also on the Internet at:

<http://www.parliament.nsw.gov.au/prod/web/PHWebContent.nsf/PHPages/LibraryPublist>

(A) BACKGROUND PAPERS

<i>New South Wales State Electoral Districts Ranked by 2001 Census Characteristics</i> by Mark D'Arney	1/03
<i>New South Wales State Election 2003: Electorate Profiles</i> by Mark D'Arney	2/03
<i>Prospects for the 2003 Legislative Council Election</i> by Antony Green	3/03
<i>2003 New South Wales Elections – Preliminary Analysis</i> by Antony Green	4/03
<i>Alcohol Abuse</i> by Talina Drabsch	5/03
<i>2003 New South Wales Elections – Final Analysis</i> by Antony Green	6/03
<i>New South Wales Legislative Assembly Elections 2003:</i>	
<i>Two-Candidate preferred results by polling place</i> by Antony Green	7/03
<i>New South Wales Legislative Council Elections 2003</i> by Antony Green	8/03
<i>The Economic and Social Implications of Gambling</i> by Talina Drabsch	9/03
<i>Principles, Personalities, Politics: Parliamentary Privilege Cases in NSW</i> by Gareth Griffith	1/04
<i>Indigenous Issues in NSW</i> by Talina Drabsch	2/04
<i>Privatisation of Prisons</i> by Lenny Roth	3/04
<i>2004 NSW Redistribution: Analysis of Draft Boundaries</i> by Antony Green	4/04
<i>2004 NSW Redistribution: Analysis of Final Boundaries</i> by Antony Green	1/05
<i>Children's Rights in NSW</i> by Lenny Roth	2/05

(B) BRIEFING PAPERS

<i>Court Delays in NSW: Issues and Developments</i> by Rachel Callinan	1/02
<i>Sentencing Law: A Review of Developments in 1998-2001</i> by Rowena Johns	2/02
<i>Outworkers</i> by Roza Lozusic	3/02
<i>Censorship in Australia: Regulating the Internet and other Recent Developments</i> by Gareth Griffith	4/02
<i>Bushfires</i> by Stewart Smith	5/02
<i>Information Privacy and Health Records</i> by Gareth Griffith	6/02
<i>Public Liability</i> by Roza Lozusic	7/02
<i>Dealing with Graffiti in New South Wales</i> by Rachel Callinan	8/02
<i>Human Cloning and Stem Cell Research</i> by Stewart Smith	9/02
<i>Victims of Crime: Plea Bargains, Compensation, Victim Impact Statements and Support Services</i> by Rowena Johns	10/02
<i>Public Liability: An Update</i> by Roza Lozusic	11/02
<i>Water Reforms in New South Wales</i> by Stewart Smith	12/02
<i>Defamation Law Reform Revisited</i> by Gareth Griffith	13/02
<i>Drought</i> by Stewart Smith	14/02
<i>Bail Law and Practice: Recent Developments</i> by Rowena Johns	15/02
<i>Gangs in NSW</i> by Roza Lozusic	16/02
<i>Native Vegetation: Recent Developments</i> by Stewart Smith	1/03
<i>Arson</i> by Talina Drabsch	2/03
<i>Rural Sector: Agriculture to Agribusiness</i> by John Wilkinson	3/03
<i>A Suburb Too Far? Urban Consolidation in Sydney</i> by Jackie Ohlin	4/03
<i>Population Growth: Implications for Australia and Sydney</i> by Stewart Smith	5/03
<i>Law and Order Legislation in the Australian States and Territories, 1999-2002: a Comparative Survey</i> by Talina Drabsch	6/03
<i>Young Offenders and Diversionary Options</i> by Rowena Johns	7/03
<i>Fraud and Identity Theft</i> by Roza Lozusic	8/03

<i>Women in Parliament: the Current Situation</i> by Talina Drabsch	9/03
<i>Crimes Amendment (Sexual Offences) Bill 2003</i> by Talina Drabsch	10/03
<i>The Consumer, Trader and Tenancy Tribunal</i> by Rowena Johns	11/03
<i>Urban Regional Development</i> by Stewart Smith	12/03
<i>Regional Development Outside Sydney</i> by John Wilkinson	13/03
<i>The Control of Prostitution: An Update</i> by Stewart Smith	14/03
<i>“X” Rated Films and the Regulation of Sexually Explicit Material</i> by Gareth Griffith	15/03
<i>Double Jeopardy</i> by Rowena Johns	16/03
<i>Expulsion of Members of the NSW Parliament</i> by Gareth Griffith	17/03
<i>Cross-examination and Sexual Offence Complaints</i> by Talina Drabsch	18/03
<i>Genetically Modified Crops</i> by Stewart Smith	19/03
<i>Child Sexual Offences: An Update on Initiatives in the Criminal Justice System</i> by Rowena Johns	20/03
<i>Horizontal Fiscal Equalisation</i> by John Wilkinson	21/03
<i>Infrastructure</i> by Stewart Smith	1/04
<i>Medical Negligence: an update</i> by Talina Drabsch	2/04
<i>Firearms Restrictions: Recent Developments</i> by Rowena Johns	3/04
<i>The Future of Water Supply</i> by Stewart Smith	4/04
<i>Plastic Bags</i> by Stewart Smith	5/04
<i>Tourism in NSW: after September 11</i> by John Wilkinson	6/04
<i>Drug Offences: An Update on Crime Trends, Diversionary Programs and Drug Prisons</i> by Rowena Johns	7/04
<i>Local Development Assessment in NSW</i> by Stewart Smith	8/04
<i>Indigenous Australians and Land In NSW</i> by Talina Drabsch	9/04
<i>Medical Cannabis Programs: a review of selected jurisdictions</i> by Rowena Johns	10/04
<i>NSW Fishing Industry: changes and challenges in the twenty-first century</i> by John Wilkinson	11/04
<i>Ageing in Australia</i> by Talina Drabsch	12/04
<i>Workplace Surveillance</i> by Lenny Roth	13/04
<i>Current Issues in Transport Policy</i> by Stewart Smith	14/04
<i>Drink Driving and Drug Driving</i> by Rowena Johns	15/04
<i>Tobacco Control in NSW</i> by Talina Drabsch	1/05
<i>Energy Futures for NSW</i> by Stewart Smith	2/05
<i>Small Business in NSW</i> by John Wilkinson	3/05
<i>Trial by Jury: Recent Developments</i> by Rowena Johns	4/05
<i>Land Tax: an Update</i> by Stewart Smith	5/05
<i>No Fault Compensation</i> by Talina Drabsch	6/05
<i>Waste Management and Extended Producer Responsibility</i> by Stewart Smith	7/05
<i>Rural Assistance Schemes and Programs</i> by John Wilkinson	8/05
<i>Abortion and the law in New South Wales</i> by Talina Drabsch	9/05
<i>Desalination, Waste Water, and the Sydney Metropolitan Water Plan</i> by Stewart Smith	10/05