MurdochLINK

SUSTAINABILITY FRAMEWORK FOR ASSESSMENT OF RESIDENTIAL THIRD PIPE WATER SOURCES

FOR THE GOVERNMENT OF WESTERN AUSTRALIA DEPARTMENT OF WATER

Contact: Nicole Hodgson
Telephone 08 9360 2902
Email N.Hodgson@murdoch.edu.au

MurdochLINK Pty Ltd
Division of Research and Development
Murdoch University
South Street, Murdoch WA 6150

v13: September 2009

CONTENTS

List of figures

List of tables

Report prepared for MurdochLINK by
Nicole Hodgson, ISTP, Murdoch University
Martin Anda, School of Environmental Science, Murdoch University
Stewart Dallas, Environmental Technology Centre, Murdoch University
Scott Humphries, Boronia Corporation
Adam McHugh, School of Engineering and Energy, Murdoch University
Colin Walker, Geo & Hydro Environmental Management
www.boronia.com

1 INTRODUCTION

1.1 Background

1.1.1 Sustainability assessment

Sustainability assessment, put simply, is a process that directs planning and decision-making towards sustainability. It is an emerging field internationally, in use in UK through the Sustainability Appraisal of regional plans, and also in Australia, Canada and South Africa where the most prominent application of sustainability assessment has been at the project-level or in response to project proposals (Hacking and Guthrie 2008).

Applications of sustainability assessment vary between two broad and inter-related purposes:

- To improve the sustainability outcomes of planning and decision-making (often used internally by project proponents and organisations to inform their own decision-making); and
- To evaluate these sustainability outcomes against accepted sustainability benchmarks.

1.1.2 Sustainability assessment in the water industry

Internationally the Water Services Industry is increasingly using processes of sustainability assessment to make decisions about water services provision. The International Water Association has published *Sustainable Water Services: A procedural guide* (Ashley et al. 2004) the outcome of the SWARD project (Sustainable Water industry Asset Resource Decisions).

The Water Services Association of Australia has also published *Sustainability Framework of Urban Water Systems*, noting that the while traditionally economic and engineering considerations have dominated the project option evaluation process, the community now demands that all options under consideration are assessed in a broader context, to ensure they deliver a sustainable outcome (WSAA 2008). The WSAA Sustainability Framework is intended to assist the urban water industry to achieve sustainable use of scarce water resources, by developing a methodology for evaluating the sustainability of the various supply and demand options taking into account economic, environmental, human health, technical and social considerations.

Water Service Providers in Australia are increasingly using sustainability at both an overall operational level, as well as using sustainability assessment as a decision-making tool. For example, South East Water in Melbourne prioritise sustainability in a set of principles that help guide their decision-making principles, combined with a Sustainability Framework, Sustainability Multi-Criteria Analysis Tool, and a Stakeholder Engagement Tool.[1]

Yarra Valley Water applied a Sustainability Assessment Framework to evaluate water source options for a new development. The process considered eight options against 19 criteria, outlined in Section 2.2.3 (CSIRO 2005, Pamminger 2009).

The Water Corporation in Western Australia also used a Sustainability Assessment process to evaluate a large number of water options being considered in their 50 year plan *Water Forever*. This process and the results are discussed in further detail in section 1.1.3 below.

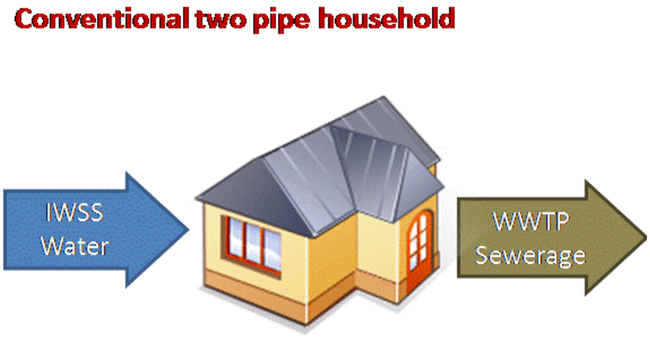


Figure 1: Household model - conventional

Figure 2: Household model - third pipe

---

[1] http://www.southeastwater.com.au/general/aboutus/longtermsolutions/Pages/Sustainabilityprinciples.aspx

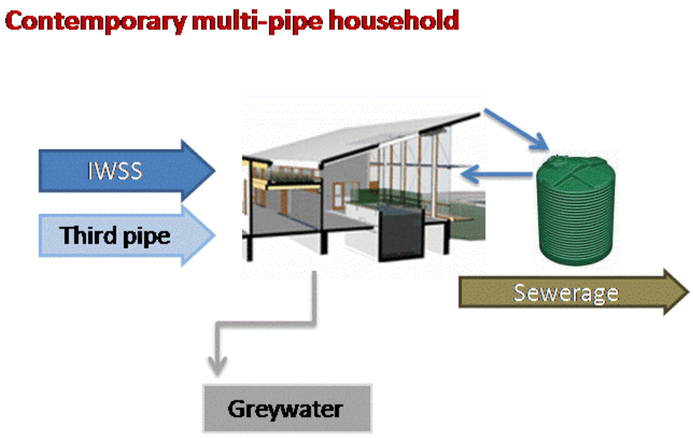


Figure 3: Household model - contemporary multi-pipe

1.1.3 Third pipe systems

Water restrictions, notoriously more severe than the two days per week sprinkler roster in Perth, are commonplace in the Eastern States. Prior to commencement of seawater desalination plants, Sydney, Brisbane and Melbourne had already begun to roll out dual reticulation or 'third pipe' systems (Figure 2) whereby treated wastewater, stormwater or groundwater is returned to the customer for non-drinking water uses such as toilet flushing and landscape watering. The third pipe supply was priced just below the price of 'first pipe' drinking water and its use was unrestricted. The outcome was typically a 40% reduction in scheme water use plus greener suburbs than those surrounding. Some land developers such as Austcorp in Queensland and VicUrban found these initiatives led to improved lot sales compared to adjacent subdivisions without third pipe. The establishment period in these new subdivisions was sometimes difficult with insufficient wastewater being generated initially and drinking water having to be supplied with land developers and utilities covering the losses. Overall these higher level treatment and additional reticulation systems were funded through developer contributions and subsequently the utilities' customer base after commissioning and handover. These systems were mandated for all new subdivisions in Melbourne in order to overcome the drought induced water shortage.

Dual water supply systems are a component of "water sensitive urban development" (WSUD) directed at optimising the substitution of non-drinking water for drinking water. Dual water supply systems are not new and have been used by Australia's non-urban communities for many years. However, in more recent times the concepts have been applied to urban developments in Australia such as at Rouse Hill in north western Sydney and Sydney Olympic Park at Homebush in inner western Sydney and in other developments which have commenced construction at Aurora Estate, Melbourne, Pimpama Coomera, Gold Coast, Mawson Lakes, Adelaide and other locations.

While some reduction in residential drinking water demands can be achieved without hydraulic redesign of the water supply system, a common element of many planned WSUD's is supply of both drinking water and non-drinking water with or without rainwater collection, storage and delivery (Douglas & Couchman 2005).

In Western Australia, a number of urban land developers, including Landcorp, ARA and MRA in the Perth metropolitan area, mining companies in regional areas, shire councils such as Augusta-Margaret River and country land developers such as Lester and Aspen Groups, have been planning for third pipe systems in their new residential developments. In the Water Corporation's own sustainability assessment the third pipe option has been found to be unviable compared to managed aquifer recharge and seawater desalination. This process is discussed further in section 1.1.5 below.

1.1.4 Perth metropolitan water system

The Perth metropolitan area, having a population of approximately 1.6 million, is served by the Integrated Water Supply Scheme (IWSS) that has been developed and managed by the Water Corporation of Western Australia.

Water sources. The IWSS sources its water from catchment dams in the nearby Darling Scarp (90 GLpa), groundwater from beneath the Swan Coastal Plain (145 GLpa) and most recently from the 2006 Kwinana seawater desalination plant (45 GLpa). The IWSS thus contributed a total of 280 GL in 2008. A second seawater desalination plant will soon be under construction at Binningup, south of Perth, that will have a capacity of 50 GLpa and able to be upgraded to 100 GLpa.

Wastewater treatment. Wastewater is collected by the Water Corporation at three main wastewater treatment plants (WWTP): Beenyup (having a capacity of 40 GLpa), Subiaco (20 GLpa) and Woodman Point (60 GLpa). Each of these discharge all of their secondary treated wastewater to ocean outfalls. A new WWTP is soon to be constructed at Alkimos (10-60 GLpa) to serve proposed new suburbs in the north of Perth. Another WWTP is proposed at East Rockingham (15-60 GLpa) that will serve new suburbs in the south of Perth such as Wungong.

Reclamation. Some of the wastewater leaving Woodman Point (6 GLpa), via the pipeline to Point Peron ocean outfall, is diverted and treated at the Kwinana Water Reclamation Plant by reverse osmosis to produce high quality water for adjacent industry. This was designed to replace scheme water consumption and also to overcome over-abstraction of the local groundwater resource.

Managed aquifer recharge. It is proposed that treated wastewater from the Beenyup and Alkimos WWTP will be used in a ‘managed aquifer recharge’ (MAR) process to recharge the declining Gnangara ‘mound’ groundwater resource. MAR is a generic term that covers a range of techniques and the technique being used for Gnangara can also be referred to as aquifer storage, transfer and recovery (ASTR) (Dillon, 2005). An MAR trial at Beenyup has recently commenced to more accurately assess the health and environmental impacts of this process over five years that will be followed by full-scale implementation.

Water Corporation approach. Climate change, climate variability and the concomitant rainfall decline led the Water Corporation to develop its ‘Security through Diversity’ approach whereby numerous water sources are used to support the IWSS. This approach essentially reduces down to a first pipe into a customer’s property, carrying high quality drinking water for all internal and external uses, and a second pipe leaving the property that carries raw wastewater. This approach can be represented graphically in Figure 4 at the scale of the IWSS and Figure 1 at the scale of the household. Figure 4 is the total IWSS as it looks now. Figure 5 is an estimated projection of the total system as it would look in 2060, based on Water Corporation data presented in the Water Forever process and limited achievement of water efficiency targets.

Seawater desalination and MAR have emerged as the Water Corporation’s preferred large-scale, long-term solutions for the security of the IWSS. The hydrogeological structure underlying Perth’s Swan Coastal Plain is ideally suited for the proposed large scale, long term MAR solution. If MAR is successful in both the short and long terms then, combined with nutrient recovery from the WWTP and with renewable energy and/or carbon offsets for all its operations, the Water Corporation has the possibility of ‘closing the cycle’ on water, nutrients and emissions and achieving full environmental sustainability in the IWSS. In the other major metropolitan areas of Australia the MAR option is not so readily available due to different hydrogeological structures.

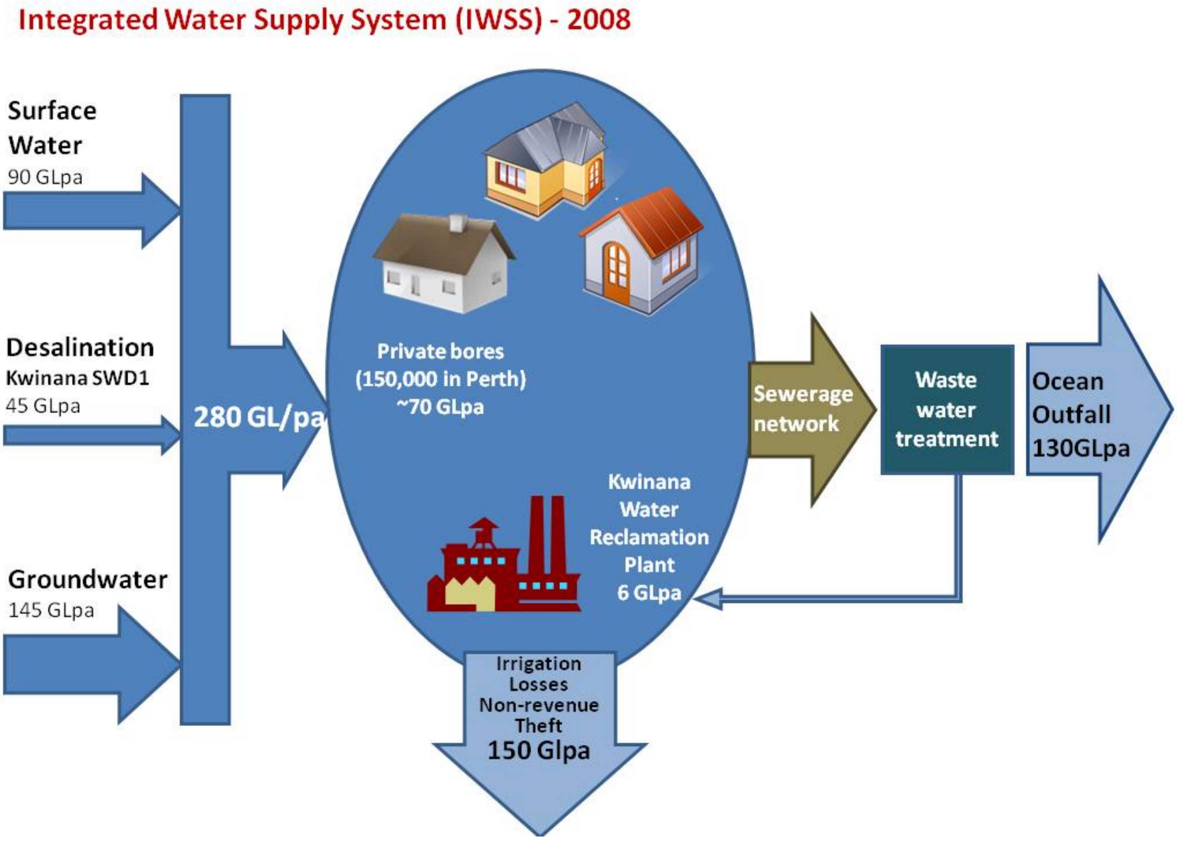


Figure 4: IWSS in 2008

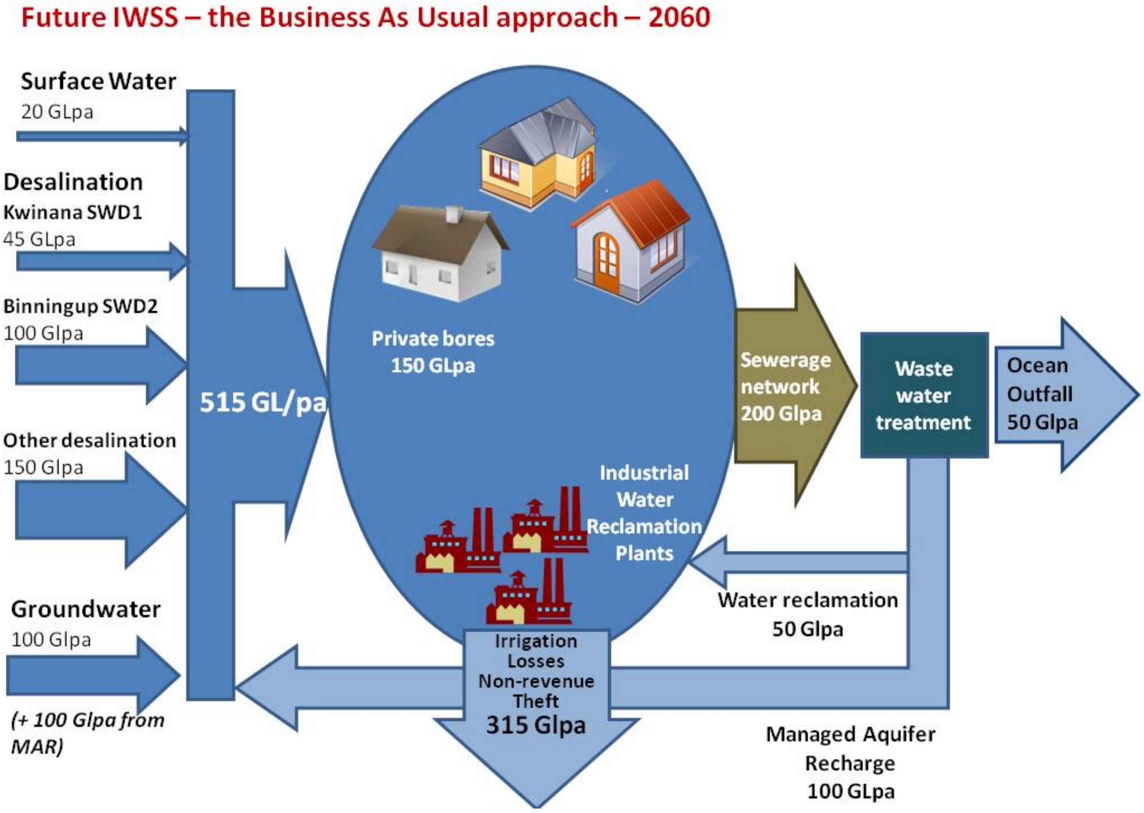


Figure 5: Projected IWSS in 2060 - Business as Usual approach

Systems analysis. By means of this input-output view one can see that the IWSS and household can be represented as a 'system' (Figure 6). This integrated systems approach enables a comparative 'system analysis' with other systems at different scales such as third pipe.

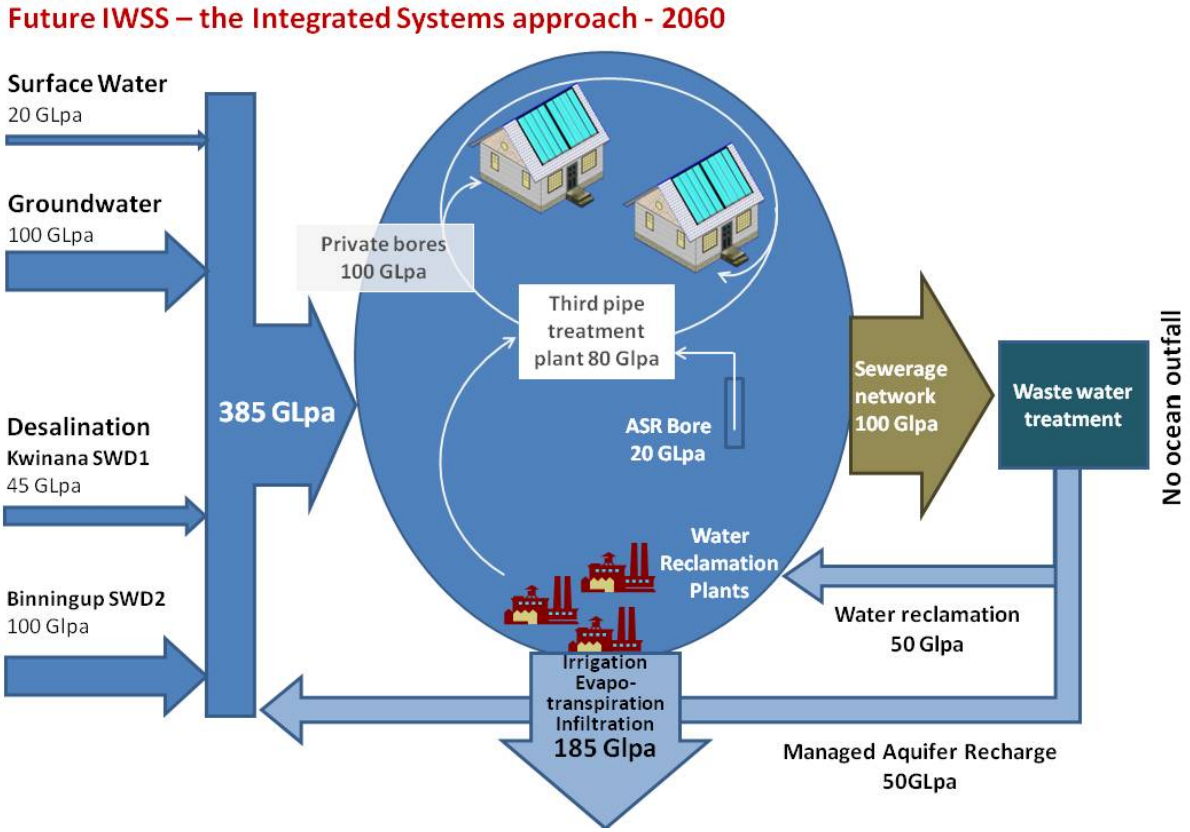


Figure 6: An integrated approach to the IWSS

State Water Recycling Strategy. Through the State Water Recycling Strategy, the WA Government is aiming to recycle 30% of treated wastewater by 2030. The Strategy expands upon the 2003 State Water Strategy (Government of Western Australia 2003) which identified large-scale, scheme-based reuse options as a priority above reuse at a household scale in view of environmental, economic and health considerations.

The Strategy also highlights the potential for recycling to provide water 'fit for purpose' for irrigated horticulture, green space irrigation and industry as well as the potential for managed aquifer recharge to increase water availability in groundwater systems and to maintain environmental values (Department of Water, Department of the Premier and Cabinet 2008).

Supply-demand gap. The Perth population is expected to double by around 2050 or 2060 and by this time the Water Corporation (in its Water Forever 2008 study) forecast a supply-demand gap of 285-365 GLpa if no reduction in use occurs. That is a rise in total IWSS water demand rising from 280 GLpa now to approx 500 GLpa. New water sources are proposed to supply 185-235 GLpa. By then projected wastewater flows from Perth are expected to be around 200 GLpa and the Water Corporation expects that more than 40% can be recycled (Options for Our Water Future, *Water Forever*, 2008, p19) by then. The State Water Recycling Target for 2030 it is 30%. Residential outdoor use in 2008 was 87 GL (*Water Forever*, p24), 97 GL indoors with approx 20-30% (20-30 GLpa) of that for non-potable uses.

Suitability of third pipe to address Perth's supply-demand gap. Therefore, 100-120 GLpa could be provided through an alternate water source via third pipe. Of course, it would not be cost-effective to renovate existing suburbs with third pipe systems but new subdivisions, urban renewal projects and new medium to high density green buildings, could be served over the coming years. By 2050-60 with no water reduction, total outdoor and indoor non-potable uses would amount to a doubling of the current 100-120 GLpa or approx 150-180 GLpa if the expected 25% water efficiency improvement was achieved. Assuming half of that was in new developments or urban renewal then in the order of 80 GLpa could be served by third pipes. Water Forever had identified potential wastewater recycling as 100 GLpa for groundwater replenishment (MAR) and industrial at 50 GLpa (Water Corporation 2008, p53) and seawater desalination at 250 GLpa. There was no proportion allocated to third pipe schemes. In other words 80 GLpa via third pipe could be an additional opportunity that could meet up to one third of new residential demand and up to one quarter of the forecast supply-demand gap by 2050-60.

Therefore, this option provides at least as much water as one of the two new Perth seawater desalination plans. Further consideration of this option, than was given in Water Forever, is worthwhile.

1.1.5 Water Forever sustainability assessment process

The Water Corporation (2008a) undertook a substantial sustainability assessment process as part of the Water Forever planning process. The overall aim of the process was to identify the most sustainable water options, taking into account a range of issues and impacts. A range of water source options were identified in consultation with the community, stakeholders and the Water Forever Science Panel. The sustainability assessment of each of the options was conducted in two phases. Firstly, a high level assessment was undertaken based on the three pillars of environment, economic and social to eliminate options that were clearly unviable for further analysis. A more comprehensive assessment was then undertaken of 33 water efficiency and source options, based on 15 detailed sustainability assessment criteria.

The Sustainability Assessment clearly demonstrated a hierarchy of preference for water efficiency, reuse and recycling options over the development of new sources (such as desalination), which was also supported by the outcomes community engagement process. However, the Water Corporation tempered this finding with:

> "It is important to note that we believe that a broad portfolio of water options is best placed to secure our water future – from more water efficiency to desalination."

Table 1 below is an extract from the Water Corporation's detailed scoring of water source options, comparing the results for desalination with the results for community greywater systems and sewer mining systems. This table clearly demonstrates that third pipe schemes performed very well on environmental and social criteria, but less well on the economic and technical criteria. However, despite desalination and community greywater systems both rating the same on the criterion of 'Economic' cost, when the outcomes of the Sustainability Assessment were utilised to outline *Directions for our Water Future* (Water Corporation 2009) these alternative water sources received less support. The Water Corporation's position appears to be that third pipe schemes are "typically very expensive due to the additional infrastructure to treat and transport relatively small quantities of water." Accordingly, Water Corporation suggests that "it is unlikely these schemes will play a major role in servicing growth corridors in Perth. Where they make sense however, they will be explored" (Water Corporation 2009).

Table 1: Extract from Water Corporation (2008a) Sustainability Assessment

Note that the Sustainability Assessment process involved a rating scale between 0 and 4, with the rating of 4 representing the most sustainable.

	Desalination	Community greywater systems	Sewer mining systems
Environmental			
Physical footprint	0	0	0
Energy intensity	1	2	1
Enhance environment	1	2	3
Water efficiency	0	2	2
Water allocation	4	4	4
Environment sub total	**6**	**10**	**10**
Social			
Community preference	2	3	2
Indigenous sites	3	3	4
Social amenity	2	3	3
Empower customers	0	2	3
Source risk	3	2	2
Social sub total	**10**	**13**	**13**
Economic			
Economic cost	2	2	0
Complexity	2	2	2
Reliability	3	2	2
Rainfall dependence	4	4	4
Flexibility	2	1	1
Economic subtotal	**13**	**11**	**9**
TOTAL Sustainability Rating	**29**	**34**	**33**

1.2 Aims of this report

The objectives for the study accepted by the Department of Water are to:

- Develop a Framework for an eventual comprehensive Sustainability Assessment;
- Against the Framework, map the range of issues that would need to be considered in a comprehensive Sustainability Assessment process;
- Identify the data that exists as well as those areas that would still require research in order to undertake a comprehensive sustainability assessment; and
- Based on the available data, conclude with some preliminary evaluations of how the third pipe model compares with the desalination model on sustainability criteria.

1.3 Limitations and assumptions

There are a number of limitations to this project, primarily due to the scope of the project being limited. Therefore, this report is not a comprehensive sustainability assessment. As is discussed further in section 2.1, this project's scope is limited to Phases 2, 3 and 4 of the WSAA Sustainability Framework as a guideline for developing a set of sustainability criteria and undertaking a preliminary screening of options.

There are also a number of assumptions inherent in the report, mainly:

- Consideration of third pipe systems assume implementation in a greenfields site or urban renewal development, as opposed to retrofitting existing suburbs; and
- Consideration of desalination assumes a seawater reverse osmosis process, in a coastal location and featuring an ocean brine outfall.

2 SUSTAINABILITY FRAMEWORK

2.1 Definition of a sustainability framework

In the Water Services Industry literature relating to sustainability assessment, a Sustainability Framework refers to the complete process used by decision-makers to conduct a sustainability assessment. Figure 7 below is an example of the Sustainability Framework proposed by WSAA.

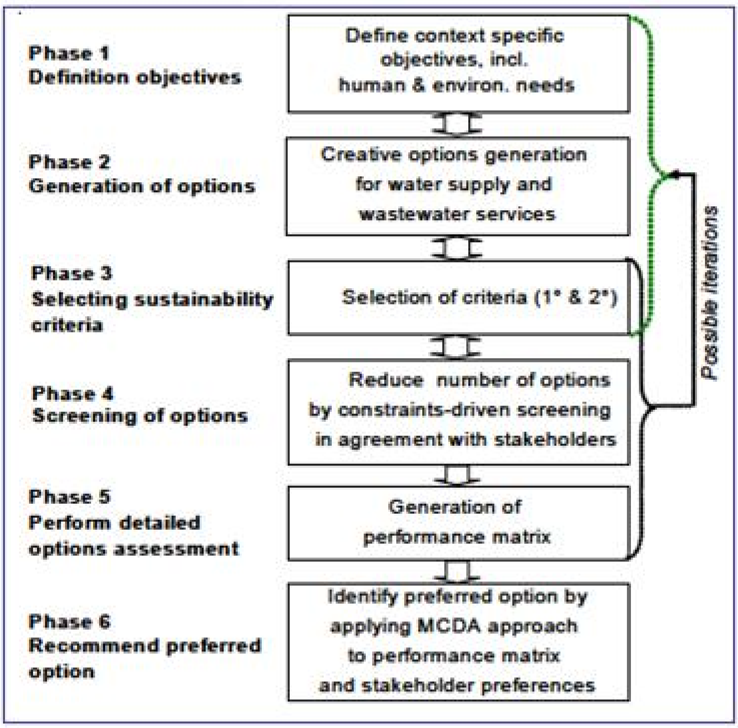


Figure 7: WSAA sustainability framework (2008)

Using this Sustainability Framework as a basis, this project has undertaken only some of these phases and generally in a more superficial way. For example:

- **Phase 1 – Definition objectives.** Objectives have not been defined, other than a broad objective of seeking a sustainable solution to Perth’s water future.
- **Phase 2 – Generation of Options.** As per the project brief, just two options are being compared: third pipe and seawater desalination.

- **Phase 3 – Selecting sustainability criteria.** Existing sustainability frameworks have been reviewed in order to establish a set of sustainability criteria that could effectively encompass third pipe and seawater desalination schemes. Most of the sustainability criteria are drawn from either the SWARD or WSAA work, however, a small number of the criteria have been developed specifically for this project.
- **Phase 4 – Screening of options.** This phase requires a quick and crude assessment of preliminary options, based on coarse data quality. However, the screening should still consider the objectives and fulfil the sustainability criteria. This screening phase is often based on qualitative and/or rough quantitative information.
- **Phase 5 – Perform detailed options assessment.** Due to the scope of this project a detailed options assessment was not possible. However, some preliminary analysis and comparison of the two options, against each of the criteria, has been conducted.
- **Phase 6 – Recommend preferred option.** Due to the scope of this project, it was not possible to recommend a preferred option.

In summary then, this project has focused predominantly on:

- **Phase 3 –** Identifying appropriate sustainability criteria for a comparison of the two options (the focus of the rest of Section 2); and
- **Phase 4 –** Undertaking a quick and crude assessment of preliminary options, based on coarse data quality (the focus of Section 3).

2.2 Existing sustainability criteria

2.2.1 International Water Association SWARD

The International Water Association published *Sustainable Water Services: A procedural guide,* which outlined the results of the SWARD project (Sustainable Water industry Asset Resource Decisions). This project developed a set of decision support processes that allow water service providers to assess the relative sustainability of water/wastewater system asset development decisions (Ashley et al. 2004).

Table 2: International Water Association Sustainable Water industry Asset Resource Decisions sustainability criteria

Primary Criteria	Secondary Criteria
Life cycle costs Stages include: Resource extraction costs Production costs End-use costs Remediation costs	Capital costs Operational costs Maintenance costs Decommissioning costs
Willingness to pay	For the product For environmental benefits For safety For health For other attributes
Affordability	% of household budget for lowest income households
Financial risk exposure	For capital investment For other investments
Resource utilisation	Water Resource use (withdrawal, river water quality, nutrients in water) Land use Energy use Chemical use Material use
Service provision	Water services Wastewater services Wastewater production
Environmental impact	Impact on water Impact on land (sludge re-use, recovery of nutrients, quality of sludge) Impact on air Impact on biological diversity
Impact on risks to human health	Availability of clean water Risk of infection Exposure to toxic compounds
Acceptability to stakeholders	Perceived health and safety impact Perceived environmental impact
Public awareness and understanding	Participation in sustainable behaviour Individual action Willingness to change behaviour
Participation and responsibility	Awareness of implications of behaviour Stakeholder information
Social inclusion	Social inclusion Voluntary activity

Primary Criteria	Secondary Criteria
	Community spirit Access to watercourse
Performance	Water quality (supply) Water quality (treatment)
Reliability	Water availability and distribution System failure
Durability	Design life
Flexibility of system	Level of accommodation in design Ability to add to or to remove from system

2.2.2 Water Services Association of Australia

The Water Services Association of Australia published *Sustainability Framework of Urban Water Systems*, noting that the while traditionally economic and engineering considerations have dominated the project option evaluation process, the community now demands that all options under consideration are assessed in a broader context, to ensure they deliver a sustainable outcome (WSAA 2008). The WSAA Sustainability Framework is intended to assist the urban water industry to achieve sustainable use of scarce water resources, by developing a methodology for evaluating the sustainability of the various supply and demand options taking into account economic, environmental, human health, technical and social considerations.

Table 3: Water Services Association of Australia sustainability criteria

Primary Criteria	Secondary Criteria
Life cycle costs	Including capital and operational expenditure
Human health	Risk of infection Exposure to harmful substances (e.g. toxic, carcinogenic etc)
Environmental	Extraction of freshwater and groundwater resources (GLpa) Land use and disturbance (ha pa) Resource input (t pa) Biodiversity Greenhouse gas emissions (tCO2e per year) Eutrophication (t phosphorous / year) Photochemical Oxidant formation Ecotoxicity including terrestrial, marine and freshwater aquatic
Technical	Performance potable water and wastewater quality Reliability Resilience/ vulnerability Flexibility
Social	Affordability Employment Acceptability to community Distribution of responsibility Organisational capacity and adaptability Public understanding and awareness

2.2.3 Yarra Water Sustainability Assessment

Yarra Valley Water applied a Sustainability Assessment Framework to evaluate options for a large new greenfields development (CSIRO 2005, Pamminger 2009).

Table 4: Yarra Valley Water sustainability criteria

Primary Criteria	Secondary Criteria
Economic	Annualised Operational Cost for all Stakeholders in the Project ($M pa) Annualised Capital Cost for all Stakeholders in the Project ($M)
Social	Innovative water service approaches are demonstrated Change in risk to public health Local amenity - Noise, look and smell Effect on sewerage capacity Reliability of supply
Environmental	CO_2 is emitted Volume of potable water saved Volume of waste water exported to the downstream system Volume of Nitrogen (N) discharged to the downstream system Volume of Phosphorus (P) discharged to the downstream system Volume of Sodum (Na) discharged to the downstream system Peak flow in a 1 in 2 year ARI storm event (Daily Flow 10% percentile) Peak flow in a 1 in 100 year ARI storm event (Daily Flow 1% percentile) Annual volume of stormwater runoff discharged downstream Nitrogen (N) discharged to the downstream system Phosphorus (P) discharged to the downstream system Total Suspended Solids (TSS) discharged to the downstream system

2.2.4 Water Corporation

The Water Corporation in Western Australia also used a Sustainability Assessment process to evaluate a large number of water options being considered in their 50 year plan *Water Forever*. This process and the results are discussed in further detail in 1.1.3 above.

Table 5: Water Corporation sustainability criteria

Primary Criteria	Secondary Criteria
Environment	Physical footprint Energy intensity Capacity to enhance the environment Water allocation Water efficiency
Social	Community preference Indigenous heritage (sites) Social amenity Empowers customers Source risk (health)
Economic	Net economic cost Reliability Capacity to adapt Rainfall dependence Complexity

2.2.5 Conclusions

These four frameworks have been reviewed and an appropriate set of sustainability criteria have been developed that combines elements of each of the frameworks. The set of criteria proposed for this project is outlined in Section 2.3 below.

2.3 Proposed sustainability criteria

As mentioned above, the water services industry is increasingly using sustainability assessment as a tool for assisting decision-making about water supply options. The International Water Association (IWA) and the Water Services Association of Australia (WSAA) have both developed sustainability assessment frameworks to provide guidance to the water services industry in decision-making processes. In Australia, the Water Corporation (WA) also developed a set of Sustainability Criteria to be used in decision-making about a range of potential water supply options for Western Australia as part of the Water Forever process. Most of the water utilities in the eastern states of Australia have either embedded sustainability into their organisational principles, or used some form of sustainability assessment in order to make decisions about water supply options. Yarra Valley Water is one example, where they undertook a Sustainability Assessment to assist decision-making about options in a new greenfields development.

These four sustainability assessment frameworks have been examined and compared for the purposes of developing a Sustainability Framework for this report that aims to adopt the best practices of each.

Table 6: Proposed sustainability criteria for the Department of Water

Primary Criteria	Secondary Criteria
Economic	Life cycle costs Social cost Social benefit and willingness to pay
Technical	Systems analysis and resilience Flexibility and scale Fit-for-purpose Reliability
Social	Health Risk Community acceptability Community understanding and involvement
Environmental	Water resource efficiency Material efficiency Energy and Greenhouse intensity Landuse and disturbance Nutrient impact
Governance	Responsibility and accountability Regulation and institutional capacity

Each of the criteria is discussed in more detail below.

2.3.1 Economic

Life cycle costs

All the sustainability assessment frameworks examined include a broad economic measure that covers capital and operating costs; however, often the calculation methodology and inclusions are not obvious. It important for an effective sustainability framework to include all capital, operating, maintenance and decommissioning cash flow components and that the primary economic measure is transparently calculated in a fashion that allows evaluation of projects across a range of scales.

Scope. Incremental economic cash flows to or from the community over the life of the asset. The community includes the producer, utility, developers, and end users.

Capital cash flows should include:

- Resource extraction costs
- Remediation costs
- Decommissioning costs
- Salvage value of infrastructure at end-of-life

Operating cash flows should include:

- Production, being energy, labour, or consumables
- End-use costs
- Maintenance costs

Discount rate. When evaluating projects, future cash flows are generally discounted to present values for comparability. In some contexts, a low discount rate may be appropriate in order to maximise intergenerational equity (in the context of climate policy, Quiggin (2007) points out that a discount rate of just 3% p.a. over 25 years halves utility for each subsequent generation. However, in the context of this assessment, a low discount rate will favour highly capital intensive projects in levelised cost terms (see below). It is therefore appropriate to use a discount rate consistent with the returns generated from natural resource infrastructure projects, which are not inherently risky or speculative and do not require high risk premiums but which may be paid a fixed rate of return as determined by the Economic Regulation Authority.

Levelised cost. Valuations should be denominated by volume supplied (or conserved) in order to equivalently compare supply or conservation options on varying scales. This levelised unit cost of supply, which some commentators refer to as Long Run Marginal Cost (Marsden Jacob Associates, 2004), is a superior measure to the annualised unit cost for large scale supply schemes as annualised cost does not account for unutilised capacity in large scale schemes, systematically under representing actual costs. Levelised cost is widely adopted by the industry and used, for example, by the Economic Regulation Authority (2005) in urban water pricing and Sydney Water (2008) in comparing conservation and recycling options.

Demand modelling under climate change. The denominator in levelised cost is the marginal demand, and the resulting unit cost is sensitive to changes in this demand. This means a rigorous estimate of water-system yield is required. Uncertainty surrounding rainfall forecasts under climate change could provide opportunity for pessimistic interpretation of future climate to justify larger and earlier investment in desalination technology. For example, using demand based on a 1975–2006 climate scenario, the levelised cost of the Kwinana desalination plant is just $0.78/kL, while the cost associated with the drier 2001–06 climate scenario adopted by the Water Corporation is $2.19/kL (Brennan, 2008).

Carbon accounting. Costs of expected or anticipated carbon trading or tariffs should be included in operating cash flows. As carbon embodied in infrastructure is unlikely to be subject to tariffs it is not included here but rather in the environment pillar.

Social cost

The "true" social cost of a public infrastructure system includes that share of the total costs of production that is not borne by developers or utilities but is shifted to third parties, future generations or society at large. They are usually not internalised because of inherent challenges in determining true monetary values and are therefore normally considered in the other pillars of a triple bottom line or sustainability assessment such as this one.

Social benefit and willingness to pay

The WSAA and Water Corporation sustainability assessment frameworks both limit the economic criteria to 'life cycle costs'. However, the SWARD framework included a criterion of Willingness to Pay - for the product, for environmental benefits, and for safety and health.

This criterion is included here, for its particular relevance for consideration of third-pipe systems, where the willingness to pay by developers and consumers for a greater diversity of water source, particularly those that may not be subject to the same water restrictions as potable water from the Integrated Water Supply System, may be influential in a decision-making process.

2.3.2 Technical

Systems analysis and resilience

An open system is a system which continuously interacts with its environment. The interaction can take the form of information, energy, or material transfers into or out of the system boundary and makes use of processes within the boundary to enable throughputs. In the present study we are concerned with water, wastewater, their contaminants and the associated energy and emissions.

Systems theory is an interdisciplinary theory about the nature of complex systems in nature, society, and science. More specifically, it is a framework by which one can investigate and/or describe any group of objects that work in concert to produce some result.

As an extension of this theory, **systems analysis** is the interdisciplinary part of science, dealing with analysis of sets of interacting entities, the systems, and the interactions within those systems. It is also an explicit formal inquiry carried out to help someone, referred to as the decision maker, identify a better course of action and make a better decision than might have otherwise been made.

A further extension is **ecosystem ecology** that examines physical and biological structures and examines how these ecosystem characteristics interact with each other. Ultimately, this helps us understand how to maintain high quality water and economically viable commodity production. A major focus of ecosystem ecology is on functional processes, ecological mechanisms that maintain the structure and services produced by ecosystems. Therefore even the extension into ecosystems is a relevant form of analysis in this present study as it can help understand the relationship of a seawater desalination plant to the marine environment and a third pipe scheme to the local terrestrial environment.

A systems analysis is required to compare the sustainability of different source, recycling and disposal options under consideration. For example, seawater desalination and third pipe have different inputs and outputs at different parts of the total urban water cycle. Their system boundaries can also be located differently in time and space. This criterion does not currently exist in any of the sustainability frameworks reviewed, yet became important in attempting to compare third pipe and desalination.

Flexibility and Scale

Consideration of scale in the analysis of the two options of desalination and third-pipe is required to account for the very different scale at which these options operate. The scale at which systems are designed also has implications for the flexibility within that system.

The issue of scale needs to be examined for certain options because they may be operating in different quantity/ quality ranges. Similar to systems analysis, this criterion does not currently exist in any of the sustainability frameworks reviewed, yet became important in attempting to compare third pipe and desalination, because of the fundamental differences between the two options.

Definitions of scale are various as follows:

- ‘Centralised’ systems are sometimes considered to be those serving > 10,000 houses or 100,000 people.
- ‘Decentralised’ systems on the other hand are considered to be community, cluster, or neighbourhood scale water systems typically serving up to 300 homes, but also encompassing developments up to 2000 homes (by the AWA Integrated & Decentralised Water Systems Special Interest Group).
- ‘Small’ water systems are considered to be < 100,000 L/d or ~ 100 houses (by the IWA Specialist Group for Small Water and Wastewater Systems)
- Cluster scale = 4 to 100 houses
- Household scale is also referred to as lot scale or unit scale.

For Water Corporation the criterion that relates to flexibility is called Capacity to Adapt and is comprised of:

- Multi-use - the capacity can be used in different ways;
- Staged construction – option can be developed in stages;
- Ability to be moved, turned off/on, reversed, collapsed and recycled;
- Susceptibility to incompatible land and marine uses – this includes both water quality and quantity issues;
- Accommodate changes in inputs such as chemicals/ membranes, materials availability, energy and skilled labour; and
- Ability to adapt to changes in technology.

Fit-for-purpose

A key concept when considering opportunities for recycled water is ‘fit for purpose’ which matches the quality required by the end use of the water with an appropriate water source.

Currently in Perth, high quality drinking water is predominately used for all water-using activities in and around the home. Applying the concept of fit for purpose would avoid using high quality drinking water for uses where lower quality recycled water would suffice. For example, while drinking quality water is required for drinking, cooking, bathing and dishwashing, for other uses of water such as toilet flushing, clothes washing and garden watering, wastewater treated to a lesser quality can be used. Obviously the quality of the water is dependent upon the end use and seeks to ensure that there is no compromise to human health given the level of contact and exposure that is likely to that water.

The Water Corporation has identified a range of alternative water sources in line with the ‘fit-for-purpose’ concept that can be harvested from the urban environment:

- **Roof runoff (rainwater)** – rainwater collected from roofs and stored either in a tank on a lot or at a common point in a development;

- **Superficial groundwater** – this is typically the water tapped by backyard bores. Water quality and availability depends on geographical location;
- **Drainage water** – stormwater collected from hard surfaces including water conveyed by drains. This water tends to be collected seasonally and its quality can vary;
- **Domestic greywater** – water collected from showers, baths, bathroom basins and laundry. This water is typically high in organic content and requires considerable treatment;
- **Sewer mining** – water extracted from the wastewater system (before it reaches wastewater treatment facilities) and treated locally prior to use; and
- **Treated wastewater** – wastewater that has passed through the advanced treatment processes at a wastewater treatment plant (Water Corporation 2008c).

The criterion of 'fit-for-purpose' is included in this sustainability assessment framework as provides the basis of comparing the application of water from very different options such as seawater desalination to drinking water standard for all purposes and third pipe for non-drinking purposes only.

Reliability of the hardware

This is a common criterion across the IWA/SWARD, WSAA and Water Corporation sustainability frameworks and therefore is included here.

For SWARD the key aspects are:

- Water availability and distribution; and
- System failure.

For the Water Corporation the criterion is characterised as "the reliability of an option to deliver on the expected water volumes, or in the case of water efficiency initiatives the expected water savings."

Reliability can be considered in terms of operational run-time reliability and mechanical reliability. Operational reliability concerns the external environmental and governance decisions that determine its run times. Mechanical reliability concerns the response effectiveness of the repairs and maintenance program and the extent to which this causes shutdown time.

All plants will have varying mechanical reliability.

2.3.3 Social

Health Risk

All frameworks incorporate a criterion on human health risk. For SWARD and WSAA, the criteria are specific, incorporating:

- Availability of clean water (SWARD);
- Risk of infection (SWARD and WSAA); and
- Exposure to toxic compounds (SWARD and WSAA).

The Water Corporation frame the criterion slightly differently, evaluating the public health risk by reference to water quality. They identify the most desirable and lowest risk sources as dams with protected catchments and deep groundwater. Conversely, the least desirable and highest risk sources are the water recycling options and sources with degraded catchment areas. Yarra Water take an interesting approach by including ‘Change in risk to public health’ as the relevant criterion for this area.

In terms of actual infection risk, there are several infective organisms that are important here, and public awareness of outbreaks of *Cryptosporidium* and *Giardia* through public water supplies typify the impacts experienced. Further infections of (or derived toxicity from) microorganisms are known across the water quality industry. These include organisms such as *Burkholderia pseudomallei* , *Microcystis* and similar cyanobacteria, *Nodularia spumigena*, *Anabaena circinalis* and similar neurotoxin sources, and *Cylindrospermopsis raciborskii* and similar hepatotoxin sources.

The indicators used in the health risk area cannot easily cope with this wide spectrum of potential antagonists. The use of coliform bacteria and residual chlorine assays across a wide range of water service areas is a front line of monitoring for the water industry management. These could be nominated as potential indicators of a Health Risk in a sustainability framework. The Australian Drinking Water Guidelines (ANZECC, 1996) effectively mandates this and much more, indicating monitoring of treatment residuals such as copper, aluminium, and chloramine. Direct inspection for the presence of aquatic blooms of many microorganisms in surface water storage facilities is also indicated as an early warning indicator.

A broad criterion of ‘Health Risk’ is included in this sustainability assessment framework because of the perception of health issues that still remains in the potential use of recycled water.

Community Acceptability

The SWARD ‘acceptability to stakeholders’ criterion includes perceived health and safety impact and perceived environmental impact. WSAA includes the ‘timely and open engagement of the community is essential to maximise acceptability’.

The Water Corporation criterion differs slightly with the inclusion of ‘community preference’. However, this judgement of community preference was determined through the community engagement process undertaken by the Water Corporation for the Water Forever project (Water Corporation 2008) which may or may not accurately represent the views of the broader community. Some aspects of the community engagement strategy undertaken by the Water Corporation involved quite small numbers, e.g. the Water Forever website received 31 comments, there were 16 written submissions and 42 email or telephone submissions in response to the Options Paper. The Shopping Centre Displays involved more people with 404 providing written comment, and 187 people completed the Water Forever survey. With these relatively small numbers involved in the community engagement process, it is difficult to see how ‘community preference’ can be accurately gauged.

Instead, our criterion for this area is ‘Community Acceptability’ which is not as prescriptive as ‘community preference’.

Community understanding and involvement

For SWARD the relevant criteria are “Public awareness and understanding” incorporating:

- Participation in sustainable behaviour;
- Individual action; and
- Willingness to change behaviour.

As well as “Participation and responsibility” incorporating:

- Awareness of implications of behaviour; and
- Stakeholder information.

The WSAA sustainability framework incorporates “Public understanding and awareness” emphasising the timely and open provision of information to the community as essential to maximising the acceptability of proposals.

The Water Corporation takes a slightly different approach including a criterion of “Empower customers” which covers the ability of the customer to manage their own supply of water and the choice of how and when to use it – ranging from the full control of the source (rainwater tanks, water use efficiency behavioural change programs) to no control over the source (drinking water scheme based sources subject to restrictions).

For this sustainability framework the emphasis is on community understanding and involvement in decision-making on future water supply sources.

2.3.4 Environmental

The SWARD framework has a combined criterion of Resource Utilisation, incorporating:

- Water resource use;
- Land use;
- Energy use (for water supply and for wastewater treatment);
- Chemical use; and
- Material use.

The WSAA and Water Corporation sustainability assessment frameworks disaggregate different sorts of resource use and efficiency, and therefore our sustainability assessment framework will also cover disaggregated dimensions of resource use and utilisation.

Water Resource Efficiency

The WSAA framework includes the criterion ‘Extraction of freshwater and groundwater resources’ the implication being to ensure that ‘environmental flow requirements (or for groundwater minimum water level requirements) are met’.

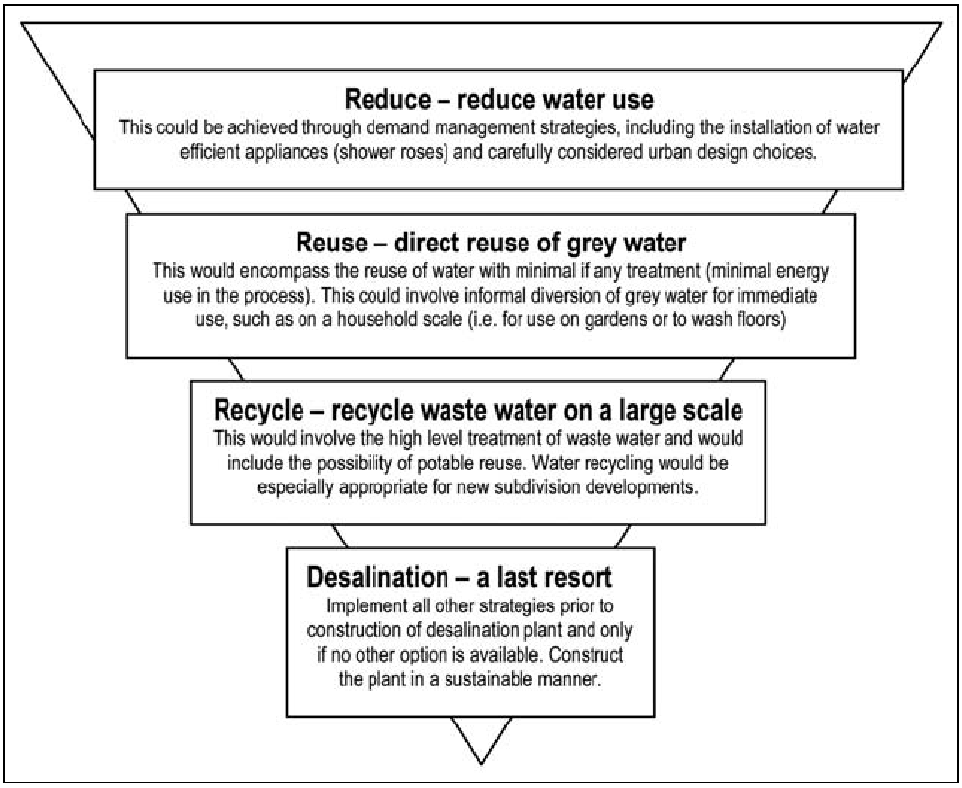
The Water Corporation sustainability assessment framework outlines a preferential hierarchy for the management of waste and applies that to the use of water resources:

- Avoidance;
- Reuse;
- Recycling;
- Recovery of energy;
- Treatment;
- Containment; and
- Disposal.

Similarly, Hurlimann (2007) suggests the use of a Water Source Hierarchy (Figure 8) to guide decision-making about new water source options. The intention is not to discount desalination as an option, but rather to view it as an option of last resort, after other water source options such as water efficiencies (reduce), greywater reuse (reuse) and large scale recycling such as third pipe (recycle) have been exhausted.

Water Resource Efficiency is included in this sustainability assessment framework as a way of comparing the extent to which the alternatives (third pipe vs desalination) make use of the water resources of the region with the goal of optimising environmental outcomes.

Figure 8: Water Source Hierarchy (Hurlimann 2007)



Reduce – reduce water use
This could be achieved through demand management strategies, including the installation of water efficient appliances (shower roses) and carefully considered urban design choices.

Reuse – direct reuse of grey water
This would encompass the reuse of water with minimal if any treatment (minimal energy use in the process). This could involve informal diversion of grey water for immediate use, such as on a household scale (i.e. for use on gardens or to wash floors)

Recycle – recycle waste water on a large scale
This would involve the high level treatment of waste water and would include the possibility of potable reuse. Water recycling would be especially appropriate for new subdivision developments.

Desalination – a last resort
Implement all other strategies prior to construction of desalination plant and only if no other option is available. Construct the plant in a sustainable manner.

Material Efficiency

WSAA include a criterion of Resource input (tonnes per annum) which implies the requirement to purchase products with the highest resource-use efficiencies and with ‘cradle-to-grave’ recycling guarantees by their manufacturers.

In the context of this sustainability assessment framework, the other implications of material efficiency would be the material investment required to support different water sources. The indicator for this criteria could be tonnes per annum of operating materials but it could also by tonnes of materials/GLpa water produced.

The criterion of material efficiency (expressed as tonnes of resource per annum for example as suggested by WSAA) requires analysis of the type of materials used and their suitability for recycling/reuse, and the gross amount of materials used for both the infrastructure and consumables.

However, this criteria would need to consider the issue of whether a large centralised plant on a GLpa/materials quantity basis ends up out-performing a smaller local system.

Energy and greenhouse intensity

The WSAA framework isolates Greenhouse Gas Emissions as a criterion, specifying low carbon intensity sources of power or renewable energy and/or carbon sequestration to offset emissions.

The Water Corporation’s equivalent criterion is Energy Intensity and invokes a “pyramid of energy use, avoidance and efficiency, followed by use of renewable energy and then off sets (particularly off sets that provide multiple business benefits).”

This is obviously an important criterion to include in this sustainability assessment framework because of current and possible future regulatory requirements to measure and account for greenhouse gas emissions. For example, the Energy Efficiency Opportunities Act 2006, has an emissions reporting trigger of 0.5 PJ and the National Greenhouse Emissions Reporting Scheme with a trigger of 25kt at facility level or 125kt at corporation level.

Land-use and disturbance

All four of the sustainability assessment frameworks reviewed included criteria that cover impacts on water, land and biological diversity. Land-use and disturbance has been included here.

Nutrient impact

Because of the nature of the two options (third pipe and desalination) being considered in this project, nutrient impact is an important criterion to include. There are potential nutrient impacts from third pipe systems, as well as the release of salty brine to the marine environment association with operation of reverse osmosis water production.

2.3.5 Governance

Effective stewardship of the community's water infrastructure requires equally effective governance of those assets and resources. The owners and, in particular, the regulators of community water infrastructure should seek to maximise the value of these assets for current and future generations.

In terms of a sustainability framework, governance is seen as a means to steer the process of sustainable development. Any development should fit easily and clearly into existing governance processes or systems and should not impact adversely on the proper governance of the water system by its owners being the regulator or the service provider.

Responsibility and Accountability

The ASX's Eight Essential Corporate Governance Principles (revised 2007) provide a well-regarded framework for assessing corporate governance that can also be applied to infrastructure developments. These Principles, and their application to water infrastructure projects, are:

- Lay a solid foundation for management and oversight: Establishing clear roles and responsibilities for regulator, utility, developers, and operators;
- Structure the board to add value: Ensure a wide representation of stakeholders, a balance of skills and experience, and independence in decision making;
- Promote ethical and responsible decision making: Promotion of integrity, compliance, ethics, and stakeholder interests;
- Safeguard integrity in financial reporting: Accountability to promote participation;
- Make timely and balanced disclosure: Transparency in decision making by the network owner to meet the information needs of stakeholders;
- Respect the rights of stakeholders: Recognising the rights and interests of diverse stakeholders and the public as the ultimate network owner;
- Recognise and manage risk: Clear standards and policies should be in place to promote sustainable development of quality infrastructure;
- Remunerate fairly and responsibly: Rewards must be appropriately shared between developers, operators, and utilities according to the risks held.

Regulation

The regulation criteria represents the calling on the Department of Water to effectively lead the stewardship of the community's water assets. The potential for alternative water sources to be incorporated into a centralised system such as the IWSS in Western Australia depends on the existence of appropriate structures and roles and the institutional capacity for leveraging the incorporation of alternative water sources in the water sector.

Transparency

Openness about the costs and benefits of infrastructure options, including sustainability assessments, and levelised economic costs incorporating the maximum range of externalities, respects the rights of stakeholders and the public as the ultimate network owner.

3 MAPPING ISSUES AGAINST THE FRAMEWORK

This section represents a version of Phase 4 of the WSAA Sustainability Framework (Figure 7) where a quick and crude assessment of preliminary options is undertaken on the basis of the options fulfilling the identified sustainability criteria.

Specifically, the major issues relevant for each of the criteria have been identified and a preliminary assessment of those issues based on readily-available secondary research. A full sustainability assessment as per WSAA Phase 5 would require a much more substantial project, incorporating some capacity for primary research.

3.1 Economic

As a preliminary analysis and commentary, a summary of issues relevant to each economic factor are included in the table below. Clearly positive factors are shaded green and clearly negative factors are shaded red. A full sustainability assessment would be required for an accurate, quantitative rating of each factor.

Table 7: Summary of third pipe and desalination issues relevant to economic factors

Factor	Third pipe	Desalination
Levelised cost	Slightly higher overall cost due to smaller scale	Cheaper with current technology
Social cost	Nothing significant	Atmospheric pollution (not a social cost once internalised) External cost risk of marine impacts
Social benefit and willingness to pay	Amenity of greener gardens Associated increased property value Attenuates rural cross-subsidisation	Water is incorporated into IWSS therefore willingness to pay is not relevant here

3.1.1 Life Cycle Costs

Third pipe

The variation seen in third pipe implementations and the uniqueness of each situation makes a generalised assessment of third pipe economic value challenging. Proper economic assessment can only be undertaken for a particular third pipe scenario, while considering specific headworks and distribution capital costs, the benefits of reduced central potable water production and wastewater treatment, and deferred source development.

Capital costs. The level of capital costs required will vary considerably and depend upon:

- The condition and location of the development site and availability and location of land for third pipe headworks;
- The choice of sewer mining, groundwater, or aquifer storage and recovery;
- Ready availability of suitable wastewater, stormwater, groundwater, or aquifer storage; and
- The ease of augmenting reticulated services with a third pipe distribution network.

Capital costs for third pipe headworks and distribution networks are generally contributed in the most part by the land developer who passes on costs to end purchasers of lots. For the eventual network owner, the acquisition of third pipe assets usually occurs at little to no direct cost as the assets are handed over to the network operator by the developer.

Potable water and wastewater treatment saved. The provision of third pipe recycled water directly saves drinking water and, if sourced from wastewater, also saves the cost of transporting the wastewater to the central treatment plant.

Source development deferral. Taking a water system view, third pipe supplies reduce potable water consumption and therefore defer development of new potable water sources

Pricing. Third pipe water is typically priced at 75–85% of the first tier or second tier potable water charges. Non-drinking water is sold as an imperfect substitute for drinking water and the price has to be set in comparison to the regulated water price with the following considerations:

- A discount to potable water to reflect the reduced quality of the non-drinking water;
- A premium based on it not being subject to water restrictions; and
- Sufficiently close in pricing to potable water to discourage the drinking of third pipe water.

Typical unit costs. A survey of leading Australian third pipe implementations is shown in Table 8. As can be seen, many cost details are unknown or undisclosed.

Table 8: Third pipe lot and unit costs[2]

	Commissioned	Lots served when completed units	Potable water saved %	Total project savings *MLpa*	Capital cost *$M*	Headworks *$/lot*	Distribution cost *$/lot*	Connection *$/lot*	Operating cost *$/kL*	Levelised cost *$/kL*
Mawson Lakes, SA	2005-10	4,500	50%	800	16		1,300			
Rouse Hill, NSW	2001	18,000	40%	1,900		5,500		500		
Cranbourne, VIC	2006-	40,000	33%	6,000			2,000			
Aurora, VIC Class A recycled household		8,000			11	2,000	1,000			
Pimpama Coomera, QLD Class A+ recycled household	2008-	1,800	64%			2,650	3,000			
Currumbin, QLD		144								
New Haven, SA			30%							
Brighton, WA Groundwater		1,500	56%	215	2.2	2,000		500		
Wungong, WA Wastewater	2009-23	16,000		5,200	64	4,033	1,462	500	0.34	2.86

Desalination

Recent widespread interest and implementation of desalination plants has been driven by significant reductions in capital and operation/maintenance costs over the past 30 years. The unit cost of water from typical seawater reverse osmosis (SWRO) has decreased from close to $6.00/kL in the late 1970s to less than $1.00/kL in 2004 (Greenlee, 2009). The world's largest SWRO plant in Ashkelon, Israel, commissioned in 2005, produces 330 ML/day for just $0.67/kL (Sauvet-Goichon, 2007).

Greenlee (2009) outlines key factors affecting capital costs and/or operating costs for SWRO plants, which include:

- Energy efficiency, primarily attributable to the chosen membrane materials and technologies (due to flux, salt rejection, hydrostatic pressure required, and materials cost), pumping efficiency, and optimal design choices in target recovery;
- Energy cost, due to the chosen energy source;
- Economies of scale achieved through the size of the plant;
- The use of pressure recovery devices;
- Pretreatment required due to the source of the feed water;
- Membrane replacement due to scaling and fouling;
- Chemical costs for cleaning; and
- The method of concentrate disposal.

Of course, local energy costs and labour costs play a part. For SWRO plants, the power costs can account for up to 50% of the total plant operating and maintenance costs (Younos, 2003). The second largest cost is typically fixed costs (approximately 37%), including capital investment amortisation and insurance (Miller, 2003; Younos, 2003). Other costs include maintenance and

---

[2] Cost data from Economic Research Associates (2009).

parts (7%), membrane replacement (5%), labour (4%), and consumable chemicals (3%) (Miller, 2003).

Capital costs. The typical investment cost per unit of production capacity of seawater reverse osmosis plants ranges between $0.7–1.0 million per ML/day of capacity (Reddy and Ghaffour, 2007). Because of scale efficiencies, large plants yield lower unit water costs than small plants (Karagiannis and Soldatos, 2008). For a specific size plant, a design factor in the choice of target recovery can greatly affect the cost of the plant as higher recovery allows all associated equipment (i.e., piping, pumps, storage tanks, pretreatment equipment, chemical dosing systems, concentrate outfall) to be sized smaller (Wilf and Klinko, 2001). Another consideration is the process used – reverse osmosis or thermal – however recent improvements in membrane technologies have allowed RO to overtake thermal processes in energy efficiency (Greenlee 2009).

Operating costs. The level of operating cost depends greatly on the nature of the feed water, the plant size, and the energy source (Karagiannis and Soldatos, 2008). Other factors include the location (with implications for transportation), labour, financing and concentrate disposal.

Impact of operating below capacity. Knights (2008) reports the levelised cost of the 250 ML/day Kurnell desalination plant in Sydney at $1.55/kL (including a $2.5 billion capital cost) if the plant provides water as base-load, at 100% of capacity. Knights' analysis shows desalination cost could be as high as $6.80/kL if the plant is only used when required to top up Sydney water storages.

Emerging technologies reduce energy requirements. Emerging membrane technologies for seawater desalination will continue to reduce energy requirements, the largest factor in operating costs. The Affordable Desalination Collaboration in California has demonstrated energy consumption for seawater desalination at levels under 3 kWh/kL at a projected total cost under $0.97/kL (MacHarg, 2008). In comparison, Kwinana requires 4–6 kWh/kL.

Typical unit costs. A survey of typical SWRO desalination unit costs shows the capital and operating costs of the Kwinana, Binningup, Kurnell, NSW (under construction) and Askelon, Israel plants.

Table 9: Salt water reverse osmosis desalination unit costs

				Operating cost *$/kL*				
	Commissioned	**Capacity** *GLpa*	**Capital cost** *$/Kl*	**Power**	**Labour**	**Consumables**	**Maintenance & Other**	**Levelised cost** *$/kL*
Binningup[3]	2011	50	1.29	0.34	0.09	0.06	0.12	2.11
Kwinana[4]	2006	45	0.67	*0.22*	*0.07*	*0.07*	*0.17*	*1.21*
Kurnell, NSW[5]	2010	70	*1.46*	*0.53*	*0.09*	*0.06*	*0.12*	*2.26*
Ashkelon, Israel[6]	2005	90	0.40	0.17	*0.02*	0.07	*0.02*	0.67

---

[3] Bell, 2009a. Binningup's total gate price including renewable power.

[4] Bell, 2009b. Annual operating expenditure and proportions. Amounts estimated through regression analysis (based on Binningup proportions) are shown in italics.

[5] Moore, 2009. Including renewable power. Amounts estimated through regression analysis (based on Binningup proportions) are shown in italics.

[6] Reddy and Ghaffour, 2007. Amounts estimated through regression analysis are shown in italics.

Comments

On the basis of levelised cost, the third pipe option has a slightly higher overall cost (estimated at $2.86 per kilolitre for Wungong) than desalination (estimated at $2.11 per kilolitre for Binningup).

However, there are some aspects of the seawater desalination process that mean that this price represents the best case scenario, and may not always be accurate. Costs of desalinated water may increase significantly depending on how often the plant is not in operation.

It must also be realised that cost comprises only one half of the price discovery mechanism, with economy-wide demand for desalination technology also affecting contract terms. High demand for desalination construction may be driven by the private sector in times of rapid economic growth or by the public sector via nation building type stimulus expenditures in times of low economic growth.

3.1.2 Social cost

Third pipe

There are several social costs (or benefits) of third pipe systems that may not be internalised into the levelised cost and therefore should be considered qualitatively in a full sustainability assessment. These include:

- Clarity about who pays and the value received. Where in most third pipe developments the developer contributes most of the capital cost, some costs may be passed onto consumers either directly or indirectly (notwithstanding that direct third pipe consumers are willing to pay to drought proof their suburbs); and
- Benefits of reduced nutrient discharges to centralised wastewater systems.

Desalination

Similarly, there are several social costs (or benefits) of desalination systems that may not be internalised into the levelised cost and therefore should be considered qualitatively in a full sustainability assessment. These include:

- Greenhouse and atmospheric pollution (not a social cost once internalised via emissions trading);
- Credible claims of offsetting renewable energy associated with desalination must be associated with renewable generation additional to what would have happened otherwise (Knights et al. 2007);
- The cost risk of marine impacts and the costs involved in monitoring the disposal of brine.

Comments

A full sustainability assessment would require all identifiable costs to be monetised into the levelised cost of supply. Those unable to be directly monetised would be assessed qualitatively as a social cost or could be quantified by assigning probability densities and economic costs associated with each possible outcome.

3.1.3 Social benefit/willingness to pay

Third pipe

There have been numerous studies conducted in Australia about the willingness to pay of Australian households for reductions in water restrictions. For example:

- Hensher et al. (2006) studied the willingness to pay of Canberra households for different water restrictions days, duration and ban risk. Households were willing to pay AU$239 more per annum to go from stage 3 restrictions to no restrictions.
- Tapsuwan et al (2007) discovered that Perth households were willing to pay 22% more on water usage bills to increase sprinkler use from 1 to 3 days per week.

Survey based research has also been undertaken into the willingness to pay for different supply sources, for example Tapsuwan et al (2007) determined the willingness to pay for desalination, groundwater from SW Yaragadee or Reverse Osmosis Managed Aquifer Recharge (ROMAR). There was significant variation amongst respondents in considering different water sources. Overall, MAR systems must be treated as an option 'in development' and that awareness of it as a viable water storage and processing approach is likely to change in the future so that respondent opinion is likely to settle with a better level of information. Indeed, this is likely to follow well publicised trials and a period of subsequent recovery and use of MAR waters.

Developers in the Eastern States (Anda & Beyer 2009) that have implemented third pipe systems report there is a willingness to pay premiums for lots in these developments. While in most of these States, the initial driver for the scheme may have been through a State Government mandate for water recycling, the developers have found that developments with third pipe systems have a generally improved marketability, in that the lots sold preferentially and more quickly than similar lots in developments without third pipe. Developers found that this offset the additional costs per lot and the increased developer contributions due to:

- The broader sustainability message of the development;
- The community acceptability of green suburbs in times of drought;
- The opportunity for the community to avoid water restrictions by "drought-proofing" suburbs.

In addition Anda & Beyer (2009) found that the third pipe systems provide:

- Unrestricted and lower cost water for irrigation and non-potable uses;
- 30 to 50% reduction in scheme drinking water use.

Unfortunately the economic benefits of the third pipe systems have not been quantified in any of the five cases studied by Anda & Beyer (2009) given the difficulty in isolating the value of this point of difference from other beneficial marketing features of the development.

Where water delivery to rural areas occurs at a greater operational cost of conduits in the networks, it is common to find that the rural residential user enjoys a subsidised cost of their water. Such rural communities may have substantial water demand -because of aridity- if they attempt to maintain conventional lawns and garden beds. Such townsites commonly use the collected sewage water as an option for irrigation of sportsfields and similar public greenspace, but also maintain dams in nearby catchments and use collected rainwater preferentially for irrigation. The township residents therefore make use of scheme water for their residential garden needs and have the use of this water in the same subsidised cost.

Desalination

Water from seawater desalination plants is incorporated into the IWSS, and therefore the concept of 'willingness to pay' of consumers is not relevant beyond that already expressed in water tariffs.

Comments

Because of the lower cost of desalination (at least when calculated with conventional economic models: see Pamminger 2008) in comparison with water recycling, desalination is generally the favoured water supply source on a purely private cost economic basis. However, inclusion of social costs will move economic metrics, to some extent, towards the recycling option.

Moreover, evidence of households' willingness to pay for water sources that help them to avoid water restrictions (such as third pipe systems) should be incorporated into decision-making processes about water source options. Research is demonstrating that as community awareness of drying climate and scarcity of water resources increases, there is increased willingness to pay for alternative water sources, particularly for irrigation and other uses outside of the house.

In addition, supply of a third pipe option to rural township residents would allow the scheme-delivered water to do double duty and attenuate the extent of subsidisation.

3.2 Technical

As a preliminary analysis and commentary, a summary of issues relevant to each technical factor are included in the table below. Clearly positive factors are shaded green and clearly negative factors are shaded red. A full sustainability assessment would be required to quantitatively or accurately rate each factor.

Table 10: Summary of third pipe and desalination issues relevant to technical factors

Factor	Third pipe	Desalination
Systems analysis and resilience	Frees peak capacity in potable water supply Frees summer capacity in central wastewater system Associated deferred source and infrastructure development	An input to the system that can be easily integrated into the IWSS system High pumping costs and GHG emissions for consumers not close to the coast
Flexibility and scale	Economic at small scale Seasonally valuable supply Diversity of supply increases resilience	Economic at large scale Requires full-capacity operation to maximise scale benefits
Fit-for-purpose	Lower quality sources used for non-drinking purposes conserves drinking quality water in the IWSS	Blending into IWSS results in poor (unfit) match between high quality source and non-drinking uses
Reliability	Greater water utility because of double duty Increased water security for regional areas	Rainfall-independent water security for populated coastal regions Large proportional of overall water supply from one source

3.2.1 Systems analysis and resilience

A systems analysis of the two options of desalination and third-pipe is required to account for the very different role that each of these options can play in the urban water system, in this case the IWSS. A systems analysis also allows for the assessment of the overall resilience of the urban water system to be assessed.

Desalination

The Water Corporation system (the IWSS) is currently based on a single pipe in, single pipe out model – a centralised system. Seawater desalination is a freshwater production process both within and as an input across the IWSS system boundary supplying the 'first' pipe.

Third pipe

A third pipe scheme can be characterised as a system by itself with the inputs being either: sewer mining, a stand-alone WWTP or a groundwater source, and the output being non-potable water. Third pipe schemes can also be seen as a process component contributing to the throughput of the entire IWSS where these inputs/outputs are occurring within the system boundary as indicated in Figure 6**.**

In the first case above the third pipe scheme can be analysed with the system boundary around the subdivision it serves. In the case of a subdivision far inland from the coast, this localised system would see the seawater desalinated water supply as an input from outside with a relatively high energy cost attached to it due to the pumping from the coast.

A third pipe scheme does not supply the first pipe, rather it is a localised process within the system boundary, using the 'second' pipe (sewer mining) or groundwater or rainwater as its source to supply a new pipe internal to the system, the third pipe. Thus, it cannot be fairly compared directly to seawater desalination at the scale used by Water Corporation.

Comments

A conventional analysis of a seawater desalination plant would set the system boundary around the total IWSS. With the seawater desalination plant running full time in this system the levelised costs can appear favourable. The third pipe scheme may appear to have a higher levelised cost in a conventional analysis compared with seawater desalination. However, a systems analysis can point to other factors below not normally included.

Third pipes systems:

- Frees peak capacity in potable water supply;
- Frees summer capacity in central wastewater system (and winter capacity to a lesser extent, ie from toilet flushing);
- Infrastructure development only required for local schemes;
- Associated deferred source and infrastructure development;
- Can be an alternative source of nutrients for plant growth.

Desalination:

- New sources require integration into distribution and wastewater treatment systems;
- Can be integrated into the IWSS at strategic points along the coast as required or as land and environmental constraints permits;
- There are high pumping costs and greenhouse gas emissions for consumers not close to the coast.

Resilience. As Brown et al. (2009) highlight a city's resilience to changing conditions is at its strongest when water sources are accessed through a diversity of infrastructures at different scales including decentralised, precinct and centralised water supply schemes.

The Water Corporation has recognised this in their slogan 'Security through Diversity'. However the current model of the IWSS, with its linear approach to a single pipe in and single pipe out, and the addition of another large scale solution such as desalination, does not dramatically increase diversity. This is particularly the case in long term forecasts by the Water Corporation where other sources (surface water and groundwater) are forecast to dwindle in the future. Therefore the future increasingly looks dependent on seawater desalination, rather than a more resilient diversity of sources.

The IWSS can be strengthened by further consideration of all of the options that Water Corporation has explored in Water Forever process, however this will require a willingness to abandon the linear model of water provision, and a high level of sophistication from Government to manage this system.

There is an 'opportunity cost' in the preference for constructing large centralised water infrastructure, such as desalination plants, that may prevent other more sustainable water supply options being developed. "Once significant investment has been sunk into capital-intensive infrastructure it reduces investment in demand management, and rainwater, stormwater and wastewater recycling, and will continue to do so for 10 to 20 years into the future. Thus, decisions to construct desalination plants will dictate the urban water supply sustainability agenda for many years" (Knights & Wong 2008). Hurlimann (2007) identifies that 'supply-side' solutions such as desalination delay the onset of the water efficiency revolution so urgently needed.

From this very brief and preliminary analysis of a systems and resilience analysis of the urban water system it is clear that there are a multitude of issues that need further development and research in order to undertake a more comprehensive sustainability assessment.

3.2.2 Flexibility and scale

Consideration of scale in the analysis of the two options of desalination and third-pipe is required to account for the very different scale at which these options operate. The scale at which systems are designed also has implications for the flexibility within that system.

Third pipe

In general, third pipe schemes are considered to be small scale and decentralised. Theoretically, a third pipe scheme can be built across all of Perth as a large scale centralised scheme, however, the costs of trenching through existing suburbs would currently render this unviable. Installing a third pipe at the smaller scale of a new subdivision or an urban renewal project where trenches are being opened for other services would be more viable. This scheme could be centralised at the scale of the village but decentralised relative to the IWSS.

The flexibility of third pipe schemes can be expressed in terms of adaptability to the locally available water source. For example, in areas far from the coast where pumping desalinated seawater adds to the expense, where groundwater is already over-allocated, but where local sewers are loaded or stormwater ASR can be established then conditions could be ideal for third pipe.

Small scale systems, such as third pipe, may have the flexibility of being able to be turned off as required without having a major impact on operating or depreciation costs. However, membrane systems may require minimum run times and biological systems may require minimum feed levels in order to keep micro-organisms alive.

In Western Australia, the Gracetown and Hopetoun small town urban renewal projects by Landcorp have demonstrated that local third pipe schemes are viable. In the Hopetoun situation this was demonstrated through thorough economic analysis that resulted in a very different outcome to the Water Corporation base case of a heavily engineered single pipe in and single pipe out system. With the collapse of Ravensthorpe BHP Nickel mine there were no further requirements to develop housing in Hopetoun, and therefore the project did not proceed to implementation. Gracetown will proceed to implementation albeit at a smaller scale than originally proposed due to the economic downtown.

Desalination

A seawater desalination system connected to the IWSS is considered to be large scale. The IWSS is considered to be a centralised scheme in terms of regulation, management and technology. Once installed at a large scale there is limited flexibility as in order to achieve the lowest levelised costs the systems may need to be run full time.

The current Kwinana and proposed Southern (Binningup) seawater desalination plants by Water Corporation for the Perth-Mandurah IWSS are large scale facilities at 45 GLpa and 50 GLpa respectively each contributing approx 15-20% of the freshwater to the IWSS. At this scale the plants must operate close to full-time in order to provide cost-competitive water.

However, they will be vulnerable to rising energy prices and imminent carbon price implementation while being largely dependent on fossil energy. Smaller scale systems are currently in the test phase that could produce 0.2 GLpa freshwater from RO desalination and wave energy (for example, the CETO technology currently under development by Carnegie Corporation). Therefore, at this scale these systems are ideally suited for small coastal towns and small coastal villages along the metropolitan coast, and without the energy and greenhouse implications of the Kwinana and Binningup desalination plants.

Comments

Seawater desalination is appropriate as a large scale solution on the coast, and has less flexibility in requiring operation at full capacity to maximise the benefits of scale. Third pipe, on the other hand, can operate readily as a large or small scale solution anywhere in the total system.

3.2.3 Fit-for-purpose

Third pipe

Third pipe systems are inherently designed around the fit-for-purpose concept, in the reuse of wastewater for non-potable applications. The intention of fit-for-purpose is that the use of potable water is displaced by the use of water of a lesser quality.

The fit-for-purpose concept is applicable both for the source of water and for the demand side. One example of where the appropriateness of the source water was in the proposed third pipe scheme for Landcorp's Cockburn Central development. In the early stages of this project a decision was made to use the superficial aquifer as the source water before detailed analysis of water quality and treatment requirements was undertaken. As it turned out the poor water quality necessitated the use of expensive treatment technology, thereby undermining the economic viability of this project to the extent it was decided not to proceed. However, use of greywater in this development may have been appropriate and economically viable. This case study confirms why a fit-for-purpose analysis needs to be conducted early in the project planning cycle. This is currently the approach being taken by Armadale Redevelopment Authority and Midland Redevelopment Authority for their proposed third pipe schemes.

Desalination

Desalination represents a situation where fit-for-purpose is not being applied, with a high quality water source being used for purposes such as garden watering where a water of lower quality could have been applied. This is particularly relevant in situations where this source may have to be pumped large distances inland from the coast where other locally available sources may be available for non-drinking uses as is the case in the ARA area.

Comments

A large survey of urban water practitioners strongly supported the concept of fit-for-purpose use, with receptivity to non-traditional sources decreasing with increasing opportunities for personal contact (Brown et al. 2009).

The continued use of high quality potable water for all purposes around the home and garden is not an example of putting the 'fit for purpose' concept into practice. The use of seawater desalination to incorporate water treated to potable standards into the IWSS, exacerbates this situation.

3.2.4 Reliability

Third pipe

Where third pipe is providing only irrigation water then it may only be required to operate in summer and periods of no or low rainfall. As in the case of seawater desalination this would have a negative impact on the levelised costs of its water. However, where third pipe can also provide indoor non-potable water (for example for flushing toilets) this is a year round demand and its run-time can be full-time.

The reliability of a third pipe scheme is also dependent on its source water: stormwater ASR, recycled wastewater, shallow aquifer or others. Clearly, if this source is not adequately assessed during the planning phase and an unreliable feed water is chosen then in turn the whole scheme itself will be unreliable.

Desalination

The operational reliability of a system can have an impact on the cost comparisons as highlighted and therefore requires consideration. Knights & Wong (2008) found that because the NSW Government would only operate their seawater desalination plant as required to top-up storages the levelised cost of water becomes significantly higher compared to 24/7 full-time operation. When seawater desalination was only operated part-time the costs rose as high as $6.80/kl. This is significant to consider for the WA context where the Kwinana seawater plant has been ordered to shut down in events of high marine temperatures in Cockburn Sound in order for the concentrated reject stream not to exacerbate dissolved oxygen levels.

Comments

In general, there are no significant reliability issues with both third pipe and desalination systems. There are obviously some operational maintenance issues that will apply to all mechanical systems. There may be some difference in the impact of a complete system failure for each of the two options, with the impact on a large scale system that is providing potable water (i.e. desalination) being more significant than for a third pipe system.

In developing the third pipe system for the Wungong Master Plan, the Armadale Redevelopment Authority, in conjunction with the Department of Health and the Water Corporation has established that system failures for third pipe schemes are not as critical as system failures for potable water schemes. For example, where the recycled water is used to flush toilets, in the event of a third pipe system failure, toilets can still be flushed through bucketed water from potable water taps. Third pipe systems repair times are therefore less stringent than potable systems.

Anecdotally, there is a perception that third pipe systems are not as reliable as other options. However, there is a role for the Department of Water and the Economic Regulatory Authority to regulate the service providers of alternative water sources to ensure their reliability.

3.3 Social

As a preliminary analysis and commentary, a summary of issues relevant to each social factor are included in the table below. Clearly positive factors are shaded green and clearly negative factors are shaded red. A full sustainability assessment would be required to quantitatively or accurately rate each factor.

Table 11: Summary of third pipe and desalination issues relevant to social factors

Factor	Third pipe	Desalination
Health Risk	Given no potable use, indirect transfers from inherent cyclic process provide potential infection pathway, except where a barrier treatment technology is used such as MBR	Substantial chemical use in RO membrane maintenance may represent minor health risks
Community acceptability	Wide range of acceptability for indirect uses and increasing acceptability over time as adoption widens Strong perception of high social amenity derived from experience in regional areas	Indistinguishable product from scheme water therefore broad community acceptability Some localised objections to greenhouse emissions and marine salinity impacts
Community understanding and involvement	Limited understanding in Perth of third pipe schemes but are well established in eastern Australia Sense of ownership for community schemes and greater control over garden watering Requires community to refrain from ‘adventurous’ use	No driver for greater community understanding

3.3.1 Health Risk

Third pipe

The purification of water for recycling adds cost but there are also monitorable indicators of the health risk through such water. One possible approach in a third pipe system is to use in-ground filtration of ASR as a part of the filtration process. Although probably more cost effective than MBR (discussed later) this may represent the most difficult risk control of the third pipe options. Conventional technologies such as fabric or sand filtration, activated carbon filtration, ultra-violet irradiation and oxygenation may be needed in sustainable operation of the combination of ASR and third pipe processes. Given that a range of such technologies would be needed, indicators would arise in these operations that reflect correct operation and protection of health risk. In-line measurement of dissolved oxygen in the injection stream appears to be the most widely applicable of these.

For on-surface third pipe schemes, there is the potential for transfers of human pathogens due to the inherent cyclical process providing a potential infection pathway. However, such third pipe systems would incorporate a barrier treatment technology such as MBR. In general, water from the third pipe option is not intended for potable use, and the subsequent health risks are therefore low.

Perceptions of health risk are important in the community acceptability of third pipe and other water recycling options, and this area has been studied extensively. Dolnicar and Shafer (2009) found that 55% of their survey respondents had health related concerns about the use of recycled water. However, in comparing respondents knowledge with perceptions, they discovered that "Australians are mainly concerned about health issues that may be related to using water from alternative sources in their households while at the same time having only a low level of factual knowledge about the true health risks associated with desalinated and recycled water." Community acceptability and community understanding are both discussed in more detail in the following sections.

The lack of established regulatory and approval processes to manage the human health aspects of water recycling schemes is one of the present barriers to the widespread adoption of third pipe in Western Australia. Chapman, Leslie & Law (2001) mention draft reuse water guidelines in Queensland, Victoria and New South Wales, with viral standards unilaterally set at a stringent <2 virus per 50L. This represents an oppressive stance to the innovation and environmental benefits of such water use.

Desalination

There are limited human health risks in Western Australia's present utilisation of desalinated water, because the water is incorporated directly into the IWSS.

There are a large number of chemicals used in the desalination process that may pose a hazard in the unlikely event that the system breaks down.

Comments

The human health risks from desalination are also low. Substantial chemical use in reverse osmosis membrane maintenance may represent a minor health risk.

There are some potential pathways for infection in an inherently cyclical process such as water recycling through a third pipe system. However, using the MBR treatment technology in water reuse in a third pipe system provides good control over infection. MBR is expected to perform well even with strict regulatory levels (Chapman, Leslie & Law, 2001), and operational costs are projected to fall with newer technologies. Knowledge from many successful installations of MBR needs to diffuse into regulatory agencies to allow the regulatory safeguards to be formulated and put in place. In overview, the risks to human health from the use of MBR water from third pipe systems is low. Given that the third pipe option is intended only for non-potable use, this further limits the health risks.

While comprehensive health risks should of course be assessed, it should be within a context of the other health risks currently willingly taken and managed by householders in relation to water, such as greywater recycling systems and swimming pools. A study of swimming pool refilling by Perth householders by Syme found that a significant proportion would use their residential bore water for this purpose. Their presumed subsequent chlorine treatment and recirculation through sand filtration of the pool water was the safe-guard against infection from such a source. Despite this widely possible prospect, and knowledge of groundwater plume movements, there has been no Health agency intervention with operational directions to pool owners, even after Syme's study in the mid-1990's. Such risk-taking therefore remains.

This lack of clear policy development (ideally following risk assessment methods) then compounds the reluctance of practitioners to support the adoption of onsite and third-pipe technologies. This reluctance is due in part to the perceived risks associated with public health – not surprising as the provision of centralised public health protection has been instrumental to the Australian urban water hydro-social contract since mid-1800s – challenging this deeply embedded practice will be complicated (Brown et al. 2009).

3.3.2 Community Acceptability

Third pipe

The community acceptability of water recycling has received a lot of attention, particularly with high profile community opposition to water recycling schemes in communities such as Toowoomba in Queensland. However, the research demonstrates that the community acceptability of recycled water is far more nuanced than an outright rejection.

A national survey on the acceptability of water recycling options was conducted in 2005, with 2504 people surveyed (Marks et al. 2006). The results supported previous research conducted in Australian cities about the use of recycled water, in that the acceptability of recycled water decreases as the use moves closer to human contact. For example:

- 94% were in favour of using recycled water for flushing toilets in public buildings;
- 86% were in favour of using recycled water for irrigating school yards and playing fields;
- 68% were in favour of using recycled water to irrigate vegetables and fruit crops.

In terms of uses around the home:

- 96.5% were willing to use recycled water for toilet flushing;
- 73.3% were willing to use recycled water for the washing machine; and
- 67.4% were willing to use recycled water for hand washing.

Given that water from third pipe options is intended only for non-potable use, it would suggest that levels of community acceptability of third pipe water would be high. There is also a long experience in regional areas of Western Australia where recycled water is commonly used for irrigating public open space.

As discussed in Section 3.1.3 above, a number of greenfield developments incorporating third pipe, in South Australian and Victoria in particular, have experienced a high demand for housing lots, with those lots attracting higher than average prices, partly because of the amenity associated with having water for outdoor use through the third pipe.

Desalination

The Kwinana Desalination Plant was approved and built in Perth with apparently little community opposition. In contrast, the proposed desalination plant for Sydney, proposed in 2005, was met with stiff community opposition and a high level of media attention (Hurlimann 2007). While in 2006 the plans for a desalination plant were temporarily axed, a desalination plant is currently under construction in the Sydney area.

A scan of the literature suggests that little research has been done on the community acceptability of desalination. However, some studies have explored community attitudes to a range of water supply options. Syme and Nancarrow (2008) suggest that communities are increasingly taking a much broader view of the water system, with attitudes moving away from a purely utilitarian view of tap-water to one in which the wider footprint of water supply is being more carefully considered.

Comments

Dolnicar and Shafer (2009) found that the Australian population discriminates between recycled and desalinated water, with respondents understanding that recycled water is the more environmentally friendly option, whereas desalinated water is perceived as less risky from a public health view. They also found that Australians 'discriminate according to water use'.

Po et al. (2005) undertook a three year investigation which aimed to develop a measurement of prediction of community intended behaviour in relation to the reuse of different wastewaters for different uses.

> "It has been apparent that communities support the concept of water reuse as a means of responsible water resources management. However, many technically sound schemes internationally have failed because communities have rejected them. Little has been known of how people make their decisions to accept or reject schemes. Public acceptance, therefore, has been viewed as an "obstacle" to implementing reuse schemes and so the emphasis has been principally on persuasion."

Writing five years later, Dolnicar and Schafer (2009) suggest that after nearly five years of serious drought, severe water restrictions across most of the country, and media attention on water scarcity, Australians now show more acceptance of desalinated water for close-to-body uses, and less resistance to recycled water for garden watering and cleaning uses. This differs from previous perceptions of desalinated water as environmentally unfriendly and recycled water a public health hazard.

In summary then, for third pipe, there is now a wide range of acceptability for indirect uses of recycled water, and there is likely to be increasing acceptability over time as adoption widens. There is a strong perception of high social amenity derived from experience in Greenfield developments in the eastern states, as well as experience in regional areas of Western Australia where recycled water is commonly used for irrigating public open space, and McGilvray Oval in Mt Claremont.

For desalination, because the product is indistinguishable from scheme water, there is clearly broad community acceptability of this option on the basis of health risk and potable use. However, in a broader sense, there have been community objections to the use of desalination based on the energy intensity and greenhouse emissions from the desalination process, as well as the marine salinity impacts.

3.3.3 Community understanding and involvement

Closely tied to the criterion of community acceptability is the level of community understanding of alternative water sources, and involvement in making decisions about those alternatives.

Third pipe

Russell et al. (2009) suggest that there has been little organised and informed dialogue about water recycling as part of overall water management strategies – a dialogue they see as a prerequisite for consultation about specific recycling proposals. They see it as particularly important to enhance community knowledge and understanding, without falling into a public consultation model of 'persuasion', where consultation and engagement is left until too late in the decision-making process, or is "more concerned with getting endorsement of a proposal, or heading off opposition, than genuinely seeking input from local communities" (Russell et al. 2009).

At a household level, there is also a requirement for increased community understanding in order to ensure appropriate use of third pipe systems. The pricing of water from third pipes is also important, with concerns that if water is priced too cheaply this may encourage households to use the water for uses it was not intended for (such as closer to the body uses).

Desalination

Much of the opposition in Sydney to the desalination plant in 2005 was based on the lack of community consultation and involvement in the decision-making process (Hurlimann 2007).

In general however, because water sourced from seawater desalination is incorporated into the IWSS, there is little requirement or few drivers for community understanding and involvement. The Water Corporation, in their Sustainability Assessment process, term a similar criterion 'Empower Customers', for which desalination received the lowest score.

However, more recent research, such as Syme and Nancarrow (2008) suggest that communities are increasingly taking a much broader view of urban water systems, and judging their acceptability on perceptions of risk, trust and perceptions of fairness and equity, as well as in regard to their specific characteristics such as price.

Comments

In ongoing research about community attitudes and the acceptability of different water sources, it has been noted that for most of the community in Australia, the number of people with direct personal experience of alternative water sources (such as water recycling or desalination) is very low and therefore perceptions of alternatives were essentially a 'brand image' problem (Dolnicar and Shafer 2009).

In Perth in particular, there is likely to be limited understanding of third pipe schemes, given how few water reuse and recycling projects are currently operating. In other jurisdictions where community scale recycling schemes are in operation, there is evidence of greater sense of ownership for community schemes.

3.4 Environmental

As a preliminary analysis and commentary, a summary of issues relevant to each environmental factor are included in the table below. Clearly positive factors are shaded green and clearly negative factors are shaded red. A full sustainability assessment would be required to quantitatively or accurately rate each factor.

Table 12: Summary of third pipe and desalination issues relevant to environmental factors

Factor	Third pipe	Desalination
Water resource efficiency	Water does double duty	Hard work being put into producing a new resource Minor deprivations of ocean resource
Material efficiency	Water in third pipe is locally derived so the material required for its employment is small Reduction in system infrastructure elsewhere in IWSS	Perception of greater efficiency Leverages existing infrastructure subject to distance from IWSS
Energy and greenhouse intensity	Displaced potable water at lower specific energy required	Wrong direction in greenhouse emissions
Land-use and disturbance	In hand with greenfield suburb developments, in basements for urban renewal projects	Significant shoreline land allocation, where land is often of high environmental, social and economic value
Nutrient impact	Reduced nutrients to ocean outfalls	Nutrients as pollutants persist

3.4.1 Water Resource Efficiency

Water Resource Efficiency is included in this sustainability assessment framework as a way of comparing the extent to which the alternatives make use of the water resources of the region. Thus, while use of desalinated seawater *avoids* the use of any landscape derived water -and consequently should rank highly for this - *reuse* of water through a third pipe option is also highly preferred in the Water Corporation hierarchy outlined in Section 2.3.4. Further consideration might be given to additional subdivisions of the hierarchy such as reuse with no treatment and no solid waste disposal, or reuse with significant nutrient recovery, and so forth.

A series of progressive steps are required to change policy in order to eliminate the subsidies supporting inefficient water usage. Third pipe systems can be seen as a step along such a policy revision process. Subsidising of water costs by governments has remained a driver of disconnection of supply-demand relationships, and consequential failure of private capital supply: why invest in resources where price competition is lead by a taxpayer-subsidised price shelf. It would appear that progress to change policy lies beyond demonstrating the value in reused water.

Third pipe

Anda & Beyer (2009) found that the third pipe systems in the eastern states displace between of 30 to 50% of scheme water in those developments.

Desalination

Use of desalinated seawater clearly avoids the use of any landscape derived water - and therefore is at best neutral on the basis of this criterion. However, it does need to be viewed in conjunction with other criteria of material efficiency and energy and greenhouse intensity.

Comments

In summary, third pipe systems rank highly for water resource efficiency, while desalination is at best neutral.

Third pipe systems, in reusing and recycling wastewater, are effectively ensuring that water performs ‘double duty’. Desalination, in using seawater, is clearly considered to be tapping into a virtually unlimited resource, however, the broader ecological impacts of injecting brine back into that water resource are important here.

3.4.2 Material Efficiency

Third pipe

Smaller scale systems such as treatment plants coupled with localised third pipe schemes could make use of locally manufactured tanks, pipes and motors and replacement parts.

Desalination

Large scale centralised solutions such as large seawater desalination plants rely on significant overseas technology, membranes and chemicals for their implementation and ongoing operation, therefore having a significant materials impact.

Comments

In a quick comparison of sewer mining and desalination on the basis of material efficiency:

- Both require substantial headworks infrastructure (concrete foundations, steel or concrete tanks, valves and pumps, steel pipework, electrical cabling);
- Both require membranes as the principal consumable, in addition to chemical additives (and excluding fuel consumption);
- The disposal of RO and MBR membranes is largely undocumented in the literature but research done in Spain suggests that it is problematic and reuse of the membranes for lower order filtration was being investigated (Veza and Rodriguez-Gonzalez 2003)[7].

It is possible that the infrastructure components are comparable between sewer mining and desalination on a per kL basis but this would need confirmation.

Table 13: Material efficiency of desalination and third pipe

Issue	Third pipe	Desalination
Water quality	Class A+ (at best toilets, washing machine)	Potable
Infrastructure: headworks	Medium	Medium
Infrastructure: piping	Third pipe required from source to house	Depends on distance from coast to demand BUT no third pipe required

---

[7] See for example Skyjuice Foundation, who are implementing the Millennium Development Goals for water and sanitation in developing nations http://www.skyjuice.com.au

A more comprehensive analysis of the material efficiency impacts of third pipe and desalination would require the following considerations:

- The source of water and the type of treatment required for the third pipe scheme e.g. groundwater or sewer mining;
- The distance of the source from the demand – for example a coastal desalination plant supplying water to meet an inland demand may have a material use, such as steel pipe, at orders of magnitude greater than a sewer mining plant in or nearby to the same demand. And by contrast desalination (producing potable water into the IWSS) can claim that no additional pipe is required, apart from the pipe required to transport water from the desalination plant to the IWSS.

On the basis of this preliminary analysis, there is not a significant difference between third pipe and desalination systems.

3.4.3 Energy and greenhouse intensity

Third pipe

The Membrane bioreactor (MBR) treatment process of wastewater, an increasingly common approach for sewer mining schemes in particular due to the relatively high quality of water achievable, has an energy consumption in the range of 0.80 - 1.5kWhr/kL. It can be concluded therefore that a recycled water of a suitable quality (fit for purpose) which could displace the use of potable water would have an energy consumption one quarter that of desalination (assume 1kWhr/kL for MBR and 4kWhr/kL for desalination).

Desalination

Energy consumption for desalination in a Western Australian context is known and is of the order of 4-4.5kWhr/kL (Churchill 2008). Again it is essential to consider the distance of the source from the demand as this has the potential to significantly impact the equation. For example, a coastal desalination plant supplying water to meet an inland demand may have an energy use due to pumping at orders of magnitude greater than a sewer mining plant in or nearby to the same demand.

The greenhouse gas emissions impact of the ongoing adoption of reverse osmosis technology to expand production of potable water appears to be moving the Water Corporation away from its target of zero GHG emissions. While a trajectory towards carbon neutrality is a commitment among water industry operators (Fig. 9), actual trend lines are upward, exacerbated with selection of reverse osmosis (Fig 10). An interim target of over 40% reduction against baseline emissions by 2016 appears to be the first potentially missed milestone, by 280,000 tCO_2-e (Humphries 2007).

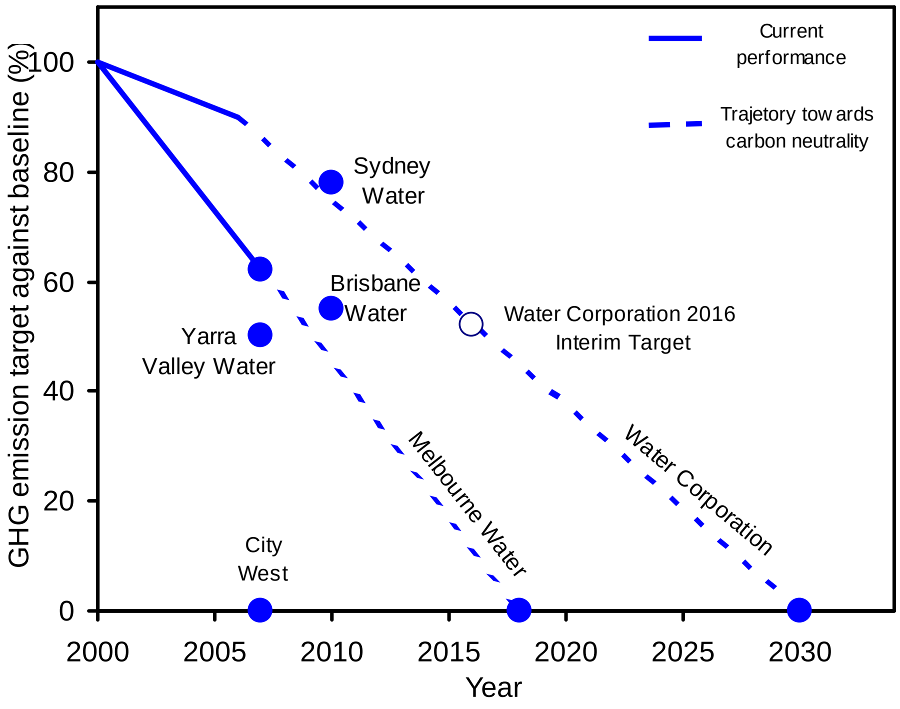


Figure 9: Water utilities' carbon neutral targets

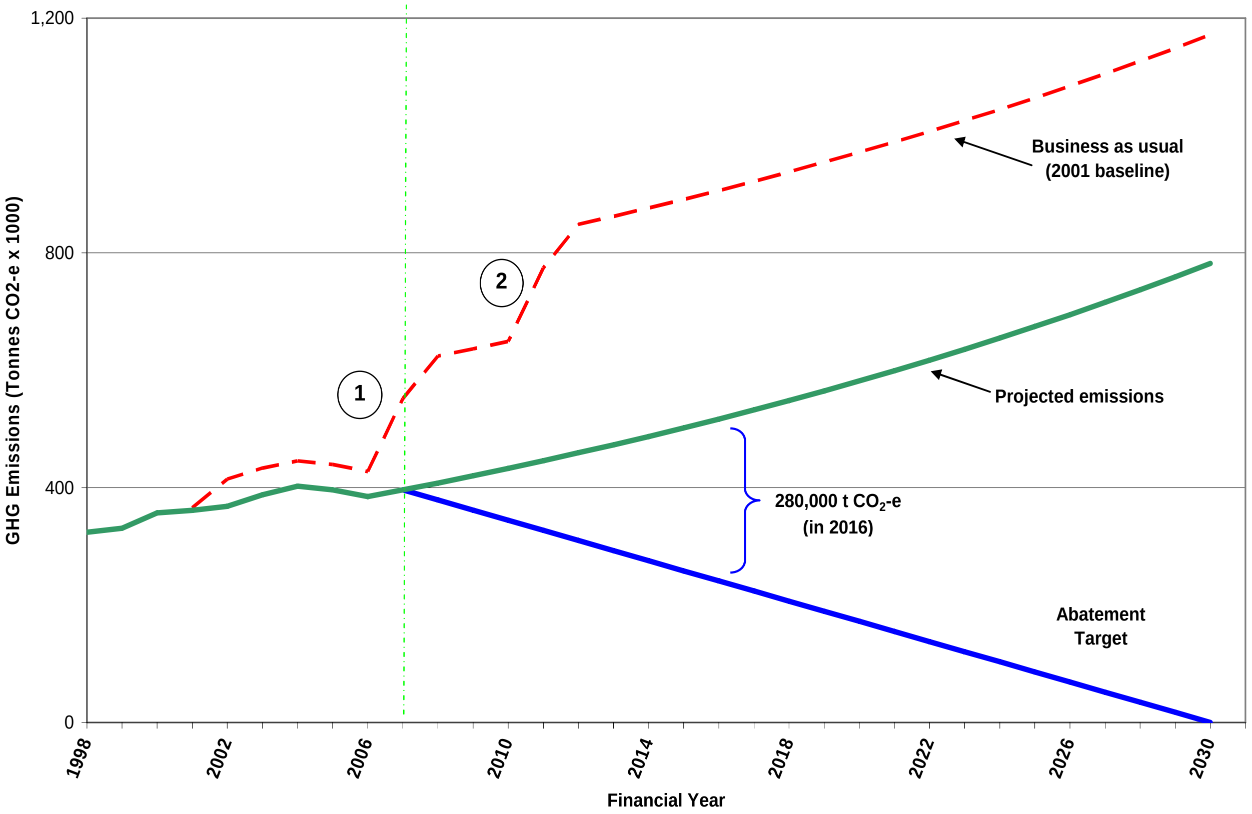


Figure 10: Water Corporation GHG Emissions

The greenhouse intensity of the desalination process has been recognised by water service providers, with the greenhouse emissions of the desalination process being ‘offset’ by the purchase of accredited renewable energy. However, this process of offsetting is more complex than it initially appears. As Knights et al. (2007) have pointed out “for any new installation to meaningfully claim it will be powered by renewable energy, *additional* renewable energy must be generated". In particular, because of the challenges of offsetting emissions from the environmental markets currently established in Australia, a renewable energy project would ideally need to be constructed in tandem with the construction of the desalination plant, with all Renewable Energy Certificates retired as opposed to surrendered. Any claim of reducing or eliminating the emissions from a grid connected desalination plant will be subject to the *Trade Practices Act 1974* and if deemed misleading by the Australian Competition and Consumer Commission may result in substantial penalties (ACCC, 2008) and other reputational damage.

Knights et al. (2007) highlight more significant limitations in the ability of emissions offsetting approaches to allow us to continue to build energy intensive infrastructure.

> "Even if the most rigorous carbon offsetting approach is adopted it is not possible to escape the issue that in a future carbon constrained world, choices about what we use energy for will become ever more critical. Desalination therefore represents another significant increment in electricity demand that makes the task of developing a sustainable energy system that much harder."

Comments

Of note is the observation that the energy consumed in operating urban water systems appears to be significantly greater than the annualised energy embodied in the infrastructure (Kenway et al. 2008). A summary of the principal elements of embodied energy in common water assets is given in Kenway et al. (2008).

With respect to local conditions Perth has historically had a relatively consistent energy intensity of around 2000 GJ/GL for water supply which jumped dramatically to 3540GJ/GL with commissioning of the first desalination plant in 2006 (Kenway et al, 2008). Perth now has the highest water usage per capita of any Australian city (419L/cap/day) and the second highest total energy intensity (water supply and wastewater) of 846MJ/cap/annum. Of this 846MJ/cap/annum it is worth noting that: water supply pumping and treatment account for nearly two thirds of this amount; and sewage pumping and treatment approximately one quarter which aligns with the 1:4 ratio cited earlier.

Table 14: Energy intensity of desalination and third pipe

Issue	Third pipe	Desalination
Water quality	Class A+ (at best toilets, washing machine)	Potable
Energy consumption: process	Low-medium	High
Energy consumption: pumping	Relatively close to site	High subject to distance to demand

A more comprehensive analysis of the energy and greenhouse intensity impacts of third pipe and desalination would require the following considerations:

- The source of water e.g. groundwater, sewer mining etc;
- The type of treatment required for the third pipe scheme; and
- The distance over which water and wastewater is transported.

However, on the basis of this preliminary analysis, desalination is clearly a far more energy intensive water supply process than third pipe. In addition, the use of recycled water (using less energy to treat) is displacing the use of potable water, with much higher energy intensity, especially with the use of seawater desalination. The greenhouse gas emissions implications of this increase in energy intensity are not easily negated by offsetting in current Australian environmental markets and will become even more difficult if a nation-wide cap on emissions is mandated.

3.4.4 Land-use and disturbance

Third pipe

If third pipe systems are constructed in conjunction with greenfield or urban renewal developments, then the land use and disturbance required is minimal.

A third pipe treatment plant may also require additional land for processing the biosolids. This will potentially have a beneficial environmental value if the biosolids are composted or digested locally and reused for local soil improvement.

Desalination

Desalination projects require a significant shoreline land allocation, where land is often of high environmental, social and economic value.

If the marine impact area of the concentrated reject stream is also taken into account, the land use footprint becomes even larger. The land use footprint for desalination may also need to include a carbon sink offset land area.

Comments

On the basis of this preliminary analysis, there is clearly a significant difference the land-use and disturbance impacts of third pipe and desalination systems.

3.4.5 Pollution impact

The conventional disposal of water in the business as usual scenario can also be projected to have a greater environmental impact as we progress into the next century. Analysis of the wastewater processing and disposal ‘footprint’ of the Beenyup system (Figure 11, from Cooper 2007) can be summarised as:

- Increasing in approximate proportion to the Perth population growth over the next few decades;
- Increasing in magnitude of sludge as a problem disposal material;
- Increasing costs of treatment as capacity increases keep up with inflow; and
- Increasing in the total quantity going into an Ocean environment wherein concerns about the fisheries and marine life abounds.

Cooper (2007) goes on to summarise the overall set of key environmental impacts in a Business as Usual scenario for wastewater treatment:

- Land take: too much land reserved for treatment, pipelines;
- Operational (energy) costs: using 2.7million kWh/y amounting to 2,500 t CO2-e;
- Operability: a complex and extensive system that is not core to planning of Perth’s urbanisation, rather is being asked to grow to consume what develops as the flows;
- Community credibility, reputation: expectations to meet improved environmental performance while global outlook worsens;
- Reliability: failures and capacity top-outs risks having worse outcomes; and
- Greenhouse gases, as discussed above.

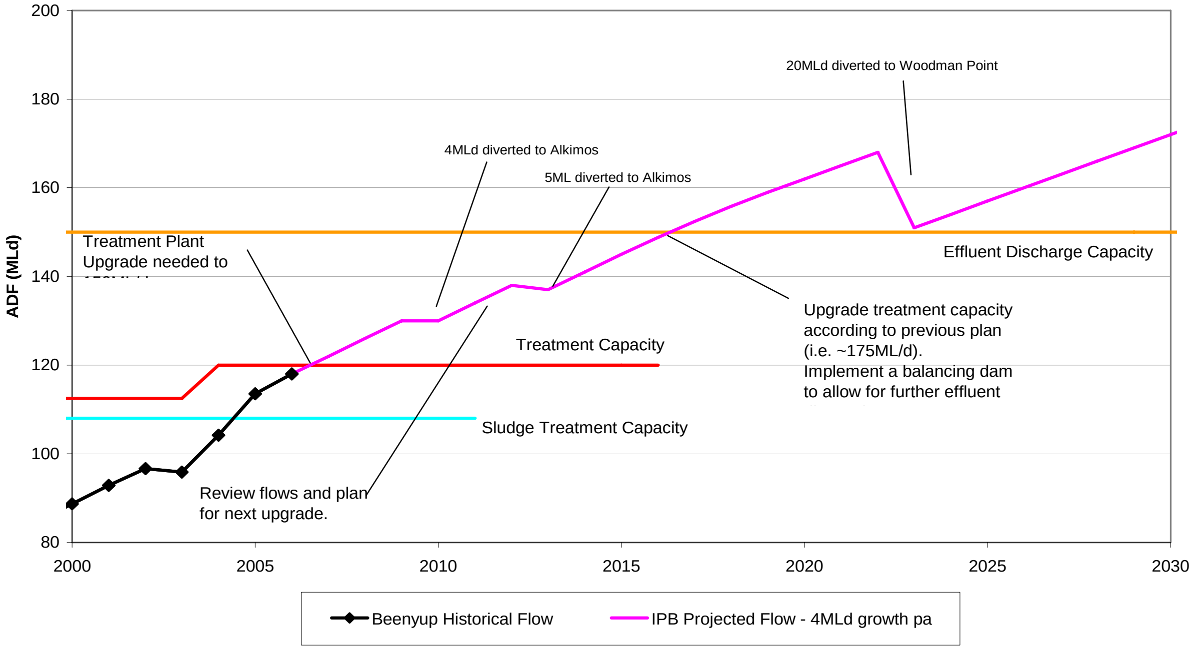


Figure 11: Beenyup system flow (Cooper 2007)

Third pipe

A significant benefit of third pipe systems is the displacement of a proportion of the treatment and disposal of wastewater.

There is also a benefit in displacing some use of chemical fertilisers by using treated wastewater that already contains some plant nutrients. The use of treated wastewater at McGillivray Oval is one such example, where there is no application of super-phosphate. There are standard issues around the nutrient load, which would be managed through a nutrient and irrigation management plan.

Desalination

The key issue for the desalination process is the disposal of brine into the ocean and the potential impacts on the marine environment.

The Environmental Protection Authority said in May 2009 “the significance of impacts to the marine environment from the discharge of brine by the Perth Metropolitan Desalination Plant is still uncertain and the marine environment of Cockburn Sound continues to be under stress” (EPA 2009).

Comments

With the displacement of some wastewater treatment that nutrient load, third pipe systems clearly have a positive pollution and nutrient impact. The impact of the disposal of brine from the Perth Seawater Desalination Plant, particularly into a sensitive environment such as Cockburn Sound

3.5 Governance

As a preliminary commentary and analysis, a summary of issues relevant to each governance factor are included in the table below. Clearly positive factors are shaded green and clearly negative factors are shaded red. A full sustainability assessment would be required to quantitatively or accurately rate each factor.

Table 15: Summary of third pipe and desalination issues relevant to governance factors

Factor	Third pipe	Desalination
Responsibility and accountability	Design standards for third pipe systems do not yet exist in WA Unclear responsibilities Weak direction in infrastructure innovation	Clear model for procurement, ownership, and operation
Regulation	Lack of co-ordinated approach in regulatory framework to meet State recycling target	Clear model for regulation
Transparency	There is a requirement for transparent cost reporting to the public	There is a requirement for transparent cost reporting to the public

3.5.1 Responsibility and Accountability

Third pipe

Various ownership models have been used in the development of third pipe systems. Although the roles and responsibilities should be fairly straightforward, in practice this is not the case due to several impediments.

Design standards for third pipe systems do not yet exist in WA. Prototype standards are currently under development by Wungong with collaboration from the Water Corporation and Department of Water. Based on a history of Gold Coast, VicWater, SA Water and other locations with operational third pipe schemes, we anticipate that draft guidelines for third pipe schemes will manage the development of this industry for a medium-term period after which it is expected that Western Australian standards will be developed. It is expected that interim standards for third pipe systems will be available by the end of 2009 for application at the Wungong Urban Water Project by ARA. It appears important that all stakeholders take an opportunity to participate in the development of these standards. These stakeholders would include the Water Services Association of Australia, the Australian Water Association, developers, local governments, health departments, water regulating agencies, water utilities, and community groups.

Unclear responsibilities. Currently, third pipe developers find barriers, lack of incentives, and delays in approvals leading in some cases to abandonment of projects and stranded assets due to unclear processes in overseeing third pipe developments. For example, the Cockburn Central project made significant engineering outlays into their land area and then abandoned these water service assets.

As a policy manager, the Department of Water (in collaboration with the Economic Regulatory Authority, the Department of Health, the Department of Environment, and any other appropriate departments) holds the central role in maintaining clear standards and policies on developments, technical specifications, handover, and operating agreements.

Asset handover should align interests. Currently the International Asset Management Manual is used in development of an asset management plan; we believe this is best practice. Asset management plans are handed to ERA with their acceptance leading to operations. It would appear that there have been no disputed asset conditions after periods of use of recycled water networks. On completion of the development, benefits of asset ownership (or licence) flow to the utility. It is imperative the operator’s interests are aligned with those of network owner to optimise the infrastructure life.

Weak direction in infrastructure innovation. All innovative national water projects are emerging from the vision of individual innovators and champions rather than standard policy positions. Instead, policy is developed on the back of innovators and champions (Brown et al. 2009). This is demonstrated by the historical eastern Australian developments with only weak mandates from regulators and local government, such as Rouse Hill, Pimpana Coomera, and Aurora are such schemes.

In WA, third pipe implementation is currently developer driven. For example, the Wungong third pipe scheme was strongly driven by the Armadale Redevelopment Authority as, despite both federal and state support, its requirement for best practice in water recycling came from the Department of Planning. Third pipe represents a benefit to government through the opportunity to raise funds from the private sector for infrastructure. However, to enable this, provision for third pipe needs to become a standard feature built into the subdivision process for new developments and the developer contributions scheme. Where third pipe systems in such a development contributes to a permanent annual reduction in scheme water demand, then the reduction in the standard headworks charges needs to be granted to the developer. This obviously needs to happen with the agreement of the local water service provider, which in Perth currently is the Water Corporation.

The regulatory systems that facilitate third pipe systems in other States vary. For example in Victoria, “the Government will not mandate dual pipe systems in all greenfield developments. However, in new developments near existing treatments plants, where dual pipe systems are likely to be economic, the Government may consider mandating through a planning scheme amendment or other mechanism” (Yarra Valley Water n.d.). South East Water have been able to mandate the supply of recycled water to all future residential developments in the Cranbourne and Pakenham growth corridors through changes to the Water Industry Act (1994) and the Planning and Environment Act (1987) (Environment and Natural Resources Committee 2009). The South Australian Government, through their Water for Good plan, is considering mandating a range of water sensitive urban design measures for new urban developments (Government of South Australia 2009).

Desalination

Keeping the community informed about cost and emissions appears to be the main governance issue for desalination.

Comments

The social and institutional barriers that prevent a diverse water source approach have been identified in a large survey of urban water practitioners. Over 60% of practitioners in Perth considered their institutional arrangements constrain a total water cycle, the largest proportion in each of the surveyed cities (Brown et al. 2009).

In summary, the results of the survey conducted by Brown et al. (2009) revealed urban water practitioners in Brisbane, Melbourne and Perth place high importance on the need for pursuing a diverse water supply approach in a fit-for-purpose context; particularly sewage, stormwater and greywater for non-consumptive purposes. However, the research demonstrated a lack of clear drivers for promoting diverse approaches, with environmental outcomes as the only obvious factor.

3.5.2 Regulation

The current arrangements for water systems in Western Australia, as in most industrial developed cities of the world, can be characterised essentially as a three-tiered hierarchy:

- Centralised regulation (State Government agencies);
- Centralised management (Water Corporation, a State Government enterprise);
- Centralised technology (the IWSS – and similar linear systems in sewered country towns).

The Water Corporation's 'security through diversity' approach represents a steady shift to more inputs into its linear single pipe in – single pipe out system. However, as large-scale technologies (seawater desalination plants, Yaragadgee borefields, MAR) they can still be categorised as centralised technology. If for example a third pipe scheme was established in Perth, within the IWSS, but managed by a local government (e.g. Brighton Green community bore by City of Wanneroo) or a private sector company (e.g. a new licensed service provider at Wungong) the above three-tiered hierarchy would become:

- Centralised regulation;
- Decentralised management;
- Decentralised technology.

The transition up the hierarchy to post-industrial 'smart' cities may only occur slowly as institutional capacity is built to manage decentralised systems such as third pipe schemes at subdivision scale.

The National Water Commission (2009) has characterised the regulation of drinking water management in Western Australia as follows:

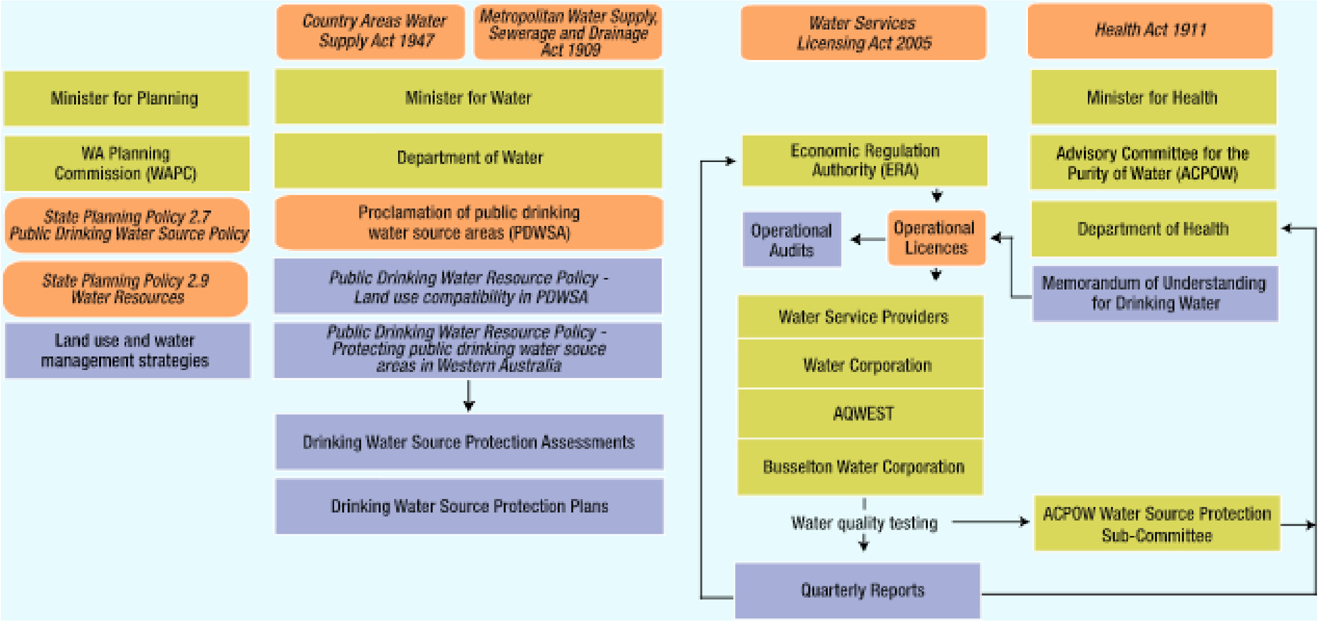


Figure 12: The regulation of water services in Western Australia (National Water Commission 2009)

The regulatory system for wastewater management is as follows:

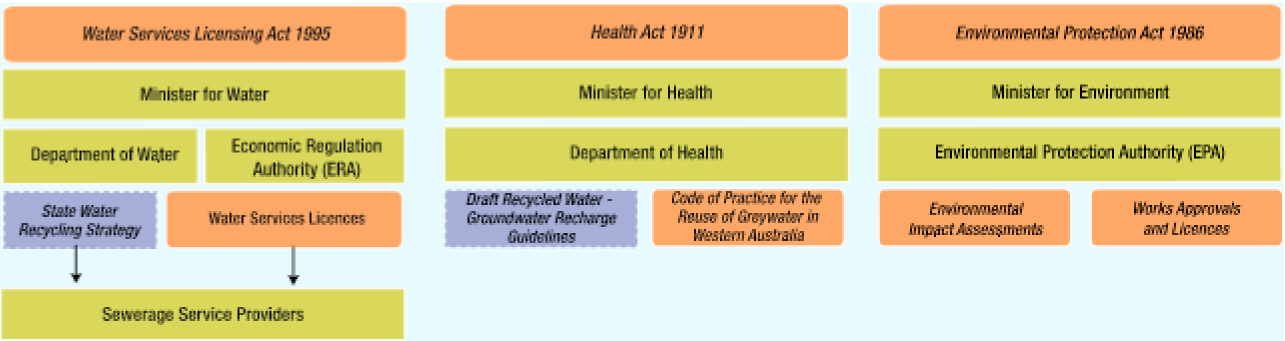


Figure 13: The regulation of wastewater management in Western Australia (National Water Commission 2009a)

However, in practice, for a proponent to secure a license to build and operate a water or wastewater service in Western Australia is more complex and can perhaps be represented as a dynamic interaction between agencies as represented graphically below:

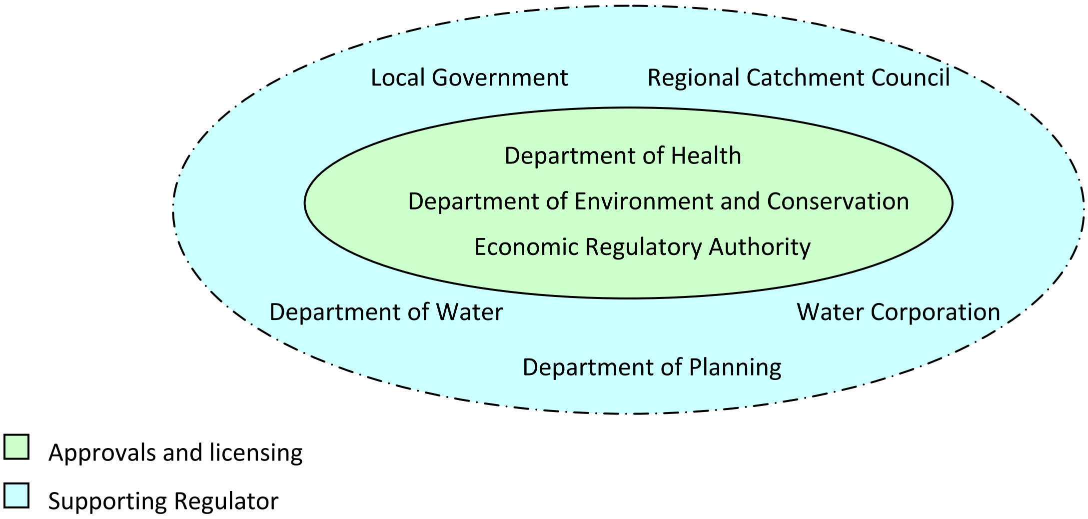


Figure 14: Agencies involved in approving, licensing, and regulating water services in Western Australia

It is clear that centralised regulation at a State level will be the norm for some years to come, but perhaps with some shift towards a national system of water regulation through COAG.

Third pipe

The current Water Corporation position appears to be that water reuse is only economic if the site is immediately adjacent to a Wastewater Treatment Plant (such as in the case of McGillivray Oval). Due to the extent of regulation for treating wastewater, the system in Perth is centralised, with most plants on the coast to have access to ocean outfall. Such a centralised wastewater treatment system severely limits the opportunities for water recycling.

Yet, the State Government has a target for 30% water recycling by 2030 which will require coordinated responses from Government and regulatory approvals.

The establishment of a third pipe scheme at Gracetown by Landcorp in partnership with a private sector service provider, e.g. United Utilities, may enable clarity and direction to be provided for imminent changes in the regulatory arrangements outlined in section 2.

A key issue is the institutional capacity development requirements necessary to become a licensed service provider to operate a third pipe scheme, for example, fed by treated wastewater. This currently provides a major barrier to new entrants seeking what may appear to be good opportunities for the future.

Desalination

There are limited regulatory barriers for the Water Corporation, as an existing licensed service provider, to establish new seawater desalination plants along the southwest coast, as evidenced by all approvals gained at a state and national level for the Kwinana and Binningup plants.

Comments

There are a number of changes imminent to the current regulatory arrangements and key issues flagged by ERA (Kelly, 2009 at AWA seminar August 27) include:

- Maintaining regulatory uniformity across industries (water, gas, electricity)
- Cost recovery
- New Water Services Bill
- Definition of a water service
- Not contrary to or in public interest (s.19 of the current Water Services Licensing Act)
- Licence exemptions (under s.19)
- Removal of controlled areas

The current limited number of licensed service providers in WA with Water Corporation predominant is a historical feature of policy development and stable economic and climatic conditions. With climate change and an ERA sometimes promoting more competition in the market place new decentralised management models along with the new decentralised technologies available for water and wastewater services may be able to add value and exist alongside the current centralised system of water services.

Third pipe wastewater reuse schemes, localised ASR forms of MAR and smaller scale wave-powered seawater desalination systems are examples of some new technologies for Western Australia that are being considered by Water Corporation but could also be economically viable and effectively operated by decentralised management models.

4 EVALUATION AND CONCLUSIONS

4.1 Summary

This table provides a summary of the preliminary analysis of major issues of each of the options against the sustainability criteria.

Table 16: Summary of third pipe and desalination issues relevant to each of the sustainability criteria

Factor	Third pipe	Desalination
Economic factors		
Levelised cost	Slightly higher overall cost due to smaller scale	Cheaper with current technology
Social cost	Nothing significant	Atmospheric pollution (not a social cost once internalised) Cost risk of marine impacts
Social benefit and willingness to pay	Amenity of greener gardens Associated increased property value Attenuates rural cross-subsidisation	Water is incorporated into IWSS therefore willingness to pay is not relevant here
Technical factors		
Systems analysis and resilience	Frees peak capacity in potable water supply Frees summer capacity in central wastewater system Associated deferred source and infrastructure development	An input to the system that can be easily integrated into the IWSS system High pumping costs and GHG emissions for consumers not close to the coast
Flexibility and scale	Economic at small scale Seasonally valuable supply Diversity of supply increases resilience	Economic at large scale Requires full-capacity operation to maximise scale benefits
Fit-for-purpose	Lower quality sources used for non-drinking purposes conserves drinking quality water in the IWSS	Blending into IWSS results in poor (unfit) match between high quality source and non-drinking uses
Reliability	Greater water utility because of double duty Increased water security for regional areas	Rainfall-independent water security for populated coastal regions Large proportional of overall water supply from one source

Factor	Third pipe	Desalination
Social factors		
Health Risk	Given no potable use, indirect transfers from inherent cyclic process provide potential infection pathway, except where a barrier treatment technology is used such as MBR	Substantial chemical use in RO membrane maintenance may represent minor health risks
Community acceptability	Wide range of acceptability for indirect uses and increasing acceptability over time as adoption widens Strong perception of high social amenity derived from experience in regional areas	Indistinguishable product from scheme water therefore broad community acceptability Some localised objections to greenhouse emissions and marine salinity impacts
Community understanding and involvement	Limited understanding in Perth of third pipe schemes but are well established in eastern Australia Sense of ownership for community schemes and greater control over garden watering Requires community to refrain from 'adventurous' use	No driver for greater community understanding
Environmental factors		
Water resource efficiency	Water does double duty	Hard work being put into producing a new resource Minor deprivations of ocean resource
Material efficiency	Water in third pipe is locally derived so the material required for its employment is small Reduction in system infrastructure elsewhere in IWSS	Perception of greater efficiency Leverages existing infrastructure subject to distance from IWSS
Energy and greenhouse intensity	Displaced potable water at lower specific energy required	Wrong direction in greenhouse emissions
Land-use and disturbance	In hand with greenfield suburb developments, in basements for urban renewal projects	Significant shoreline land allocation, where land is often of high environmental, social and economic value
Nutrient impact	Reduced nutrients to ocean outfalls	Nutrients as pollutants persist
Governance factors		
Responsibility and accountability	Design standards for third pipe systems do not yet exist in WA Unclear responsibilities Weak direction in infrastructure innovation	Clear model for procurement, ownership, and operation
Regulation	Lack of co-ordinated approach in regulatory framework to meet State recycling target	Clear model for regulation
Transparency	There is a requirement for transparent cost reporting to the public	There is a requirement for transparent cost reporting to the public

4.2 Conclusions and recommendations

As mentioned previously, due to the scope of this project, this report represents a scoping of some of the issues that would need to be considered in a more comprehensive sustainability assessment. However, on the basis of this preliminary comparison in Table 14, there is clearly a case for the further consideration of third pipe systems as sustainable water source options within the IWSS in the future. On the sustainability criteria established for this project and within the scope of the preliminary analysis undertaken, third pipe systems perform well against desalination as a sustainable water source option.

In the preliminary assessment of third pipe and desalination some of the key implications that emerged included:

- The requirement for new water source options to be more rigorously assessed against their fit into a sustainability or water resource efficiency hierarchy;
- The lack of a level playing field in terms of the regulatory and financial environment within the urban water system;
- The risk that without direction from the regulator and State Government, that innovation in water infrastructure will be lacking in the future. In a field with rapid adoption of new technologies and rewards of innovation, regulatory uncertainty may not serve the best interests of the community. Regulators need to watch and respond to the global innovations of the field.

In the process of identifying a sustainability framework that would enable the options of desalination and third pipe to be fairly and comprehensively assessed for their contribution to sustainability, a number of gaps in the existing water service industry frameworks were identified. We recommend in particular that further work is conducted on:

- Undertaking a systems and resilience analysis of water source options that allow options such as third pipe and desalination to be assessed for the extent of their fit into a system strategic framework;
- Monetising the external costs and benefits of different water source options;
- Considering governance issues and institutional capacity for incorporating different water source options.

Our recommendations for the future are:

- The sustainability framework developed in this project for the Department of Water be trialled in a full assessment of the Perth IWSS ;
- A more independent and full sustainability assessment of sustainability of water sources options, that is based on a deeper assessment of economic costs and benefits, is undertaken;
- Development of a pathway approach to progressively eliminate the market distortions that defeat cost recovery through appropriate pricing of water.

5 REFERENCES[8]

Australian Competition and Consumer Commission (2008) Carbon claims and the Trade Practices Act

Ashley, R., Blackwood, D., Butler, D. and Jowitt, P. (2004). *Sustainable Water Services: A procedural guide.* International Water Association Publishing

Bell, D (2009). Desal Costs. Email from Pricing & Evaluations Branch, Water Corporation, July 10.

Brennan, D (2008). Will we all be Rooned without a Desal Plant? Hanrahan's Lament and the Problem of Urban Water Planning under Climate Change. *Agenda* 15(3), ANU College of Business and Economics.

Brown, R., Farrelly, M. And Keath, N. (2009) “Practitioner Perceptions of Social and Institutional Barriers to Advancing a Diverse Water Source Approach in Australia”. *Water Resources Development*. 25:1.

Chapman, S., Leslie,G. and Law, I. (2001) Membrane Bioreactors (MBR) for Municipal Wastewater Treatment- an Australian Perspective.

Churchill, N. (2008) “Southern Seawater Desalination Project Update”. Presentation by Nick Churchill, Project Director, Major Water Sources, Water Corporation, 21 February 2008.

Cooper,S. (2007) “Sustainability into Design, Construction and Organisation. Challenges, Approaches and Reflections of a Major WA Alliance.” In *Sustainability of Groundwater Resources. Ann. Groundwater Seminar*, WA Int Assoc. Hydrogeologists. 6th July 2007, Citywest, Perth.

CSIRO (2005) *Sustainability of Alternative Water and Sewerage Servicing Options – YVW; Kalkallo and Box Hill PAC Developments*

Department of Water (2009) Recycling.

Dolnicar, S. and Schafer, A. I. (2009). “Desalinated versus recycled water – public perceptions and profiles of the accepters”. *Journal of Environmental Management* 90, 888–900

Douglas B & Couchman G (2005), *Dual Water Supply Systems*, First Edition Version 1.2, A Supplement to the Water Supply Code of Australia, WSA 03—202, Water Services Association of Australia Inc., Melbourne, p28.

Economic Regulatory Authority of Western Australia, 2005, *Final report: Inquiry into urban water and wastewater pricing*.

Economic Research Associates (2009) *Economic Evaluation of the Proposed Wungong Water Recycling Project (Draft)*. Armadale Redevelopment Authority.

---

[8] Access to online references was verified in September 2009.

Environment and Natural Resources Committee (2009) *Inquiry into Melbourne's Future Water Supply*. Parliament of Victoria. http://www.parliament.vic.gov.au/enrc/inquiries/Water/report/report.html (Accessed 15 November 2009)

Environmental Protection Authority (2009) EPA Report 1327 Perth Metropolitan Desalination Proposal - Water Quality Management, Change to Implementation Conditions.

Fane, S., Robinson, J., and White, S. (2002). The Use of Levelised Cost in Comparing Supply and Demand Side Options, *Water Supply* 3(3): 185–192.

Government of South Australia (2009) *Water for Good: A plan to ensure our water future to 2050.* http://www.waterforgood.sa.gov.au/wp-content/uploads/2009/06/complete-water-for-good-plan.pdf (Accessed 15 November 2009)

Greenlee, L.F., Lawler, D.F., Freeman, B.D., Marrot, B. and Moulin, P. (2009). Reverse osmosis desalination: Water sources, technology, and today's challenges, *Water Research* 43, 2317–2348.

Hensher, D., Shore, N. and Train, K.(2006). Water Supply Security and Willingness to Pay to Avoid Drought Restrictions. *The Economic Record*. 82(256), 56-66.

Humphries, R. (2007) "The concept of sustainability and groundwater – an oxymoron?" *In* Sustainability of Groundwater Resources. Ann. Groundwater Seminar, WA Int Assoc. Hydrogeologists. 6th July 2007, Citywest, Perth.

Hurlimann, A. (2007). Time for a Water Re-'Vision'. *Australasian Journal of Environmental Management* 14, 14-21.

Karagiannis, I.C. and Soldatos, P.G. (2008). Water desalination cost literature: review and assessment. *Desalination* 223 (1–3), 448–456.

Kenway, S.J., Priestley, A., Cook, S., Seo, S., Inman, M., Gregory, A. and Hall, M. (2008) *Energy use in the provision and consumption of urban water in Australia and New Zealand.* CSIRO: Water for a Healthy Country National Research Flagship.

Knights, D., MacGill, I. and Passey, R. (2007) *The sustainability of desalination plants in Australia: is renewable energy the answer?* Paper presented at OzWater Conference, 5th March 2007, Sydney.

Knights, D and Wong, T (2008). 'Drought proofing cities: Desalination versus rainwater tanks – a challenge to water supply managers', *Australian Journal of Water Resources* 12(2):101–109.

Leviston, Z., B.E. Nancarrow, D.I. Tucker, and N.B. Porter (2006) *Predicting Community Behaviour: Indirect Potable Reuse of Wastewater through Managed Aquifer Recharge*. CSIRO Land and Water Science Report 29/06. Perth: Australian Research Centre for Water in Society.

MacHarg, J., Seacord, T.F., and Sessions, B. (2008). ADC Baseline tests reveal trends in membrane performance, *Desalination & Water Reuse.* 18(2):30–39.

Marks, J.S., Martin, B. and Zadoroznyj, M. (2006) "Acceptance of Water Recycling in Australia: National Baseline Data". *Water.* March 2006.

Marsden Jacob Associates (2004). *Estimation of Long Run Marginal Cost (LRMC)*, Queensland Competition Authority.

Moore, M (2009). Full steam ahead for desalination plant. *Sydney Morning Herald*, June 29.

National Water Commission (2009) *Drinking Water Management .* http://www.nwc.gov.au/www/html/2266-drinking-water-management.asp?intSiteID=1 Accessed 12 September 2009

National Water Commission (2009a) *Recycled Water Management*. http://www.nwc.gov.au/www/html/2224-recycled-water-management.asp?intSiteID=1 Accessed 12 September 2009.

Pamminger, F. (2008) Advancing the Infrastructure Selection Process – Case Study. National Urban Water Governance Project.

Pamminger, F. (2009) “Water Industry Example of Applying a Sustainability Assessment Framework”. Presentation at *Creating Water Sensitive Cities in Australia*. Perth 9-10 February 2009.

Quiggin, J. (2007) Stern and his critics on discounting and climate change, Risk & Sustainable Management Group, Schools of Economics and Political Science, University of Queensland.

Radcliffe, J. C. (2008) “Australian water recycling today – the big issues”. Paper presented at *National Water Recycling and Reuse 2008 Conference*, 27 May 2008.

Reddy, K.V., Ghaffour, N. (2007) Overview of the cost of desalinated water and costing methodologies. *Desalination* 205, 340–353.

Russell, S., Lux, C. and Hampton, G. (2009) “Beyond ‘Information’: Integrating Consultation and Education for Water Recycling Initiatives”. *Society and Natural Resources*. 22: 56-65.

Sauvet-Goichon, B., 2007. Ashkelon desalination plant – a successful challenge. *Desalination* 203, 75–81.

Sydney Water (2008) *Water Conservation and Recycling Implementation Report 2007–08*.

Syme, G. and Nancarrow, B. (2008) “Changing Attitudes to Water Use and Consumption”. In Newton, P.W. ed. (2008) *Transitions: pathways towards sustainable urban development in Australia*. CSIRO publishing.

Tapsuwan, S., Brennan, D., Ingram, G. and Burton, M. (2007) “Household study of private gardens and lawns and the Willingness to Pay (WTP) to avoid drought water restrictions: A case study of Perth, Western Australia”. Presentation at CSIRO Public Seminar, 24 September 2007.

Veza, J.M. and Rodriguez-Gonzalez, J.J. (2003) “Second use for old reverse osmosis membranes: wastewater treatment”. *Desalination*. 157 (65-72).

Yarra Valley Water (n.d.) *Dual pipe water recycling*. Fact sheet. http://www.yvw.com.au/NR/rdonlyres/DEF1352C-7DAE-4EC0-8C75-3184915B9C48/0/DualPipeWaterRecycling.pdf (Accessed 15th November 2009)

Water Corporation (2008) *Water Forever: Reflections: Community Engagement Report*. August 2008.

Water Corporation (2008a) *Water Forever: Sustainability Assessment*. December 2008.

Water Corporation (2008c) *Water Forever: Alternative Water Supplies - Residential Developments*.

Water Services Association of Australia (2008). *Sustainability Framework*. WSAA Occasional Paper No. 27. February 2008.