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Barriers and drivers of new public-private infrastructure: Sewer Mining

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Editor: Mr Stephen McFallan

Authors: Stephen McFallan and Ian Logan

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Project Leader: Professor Kerry Brown

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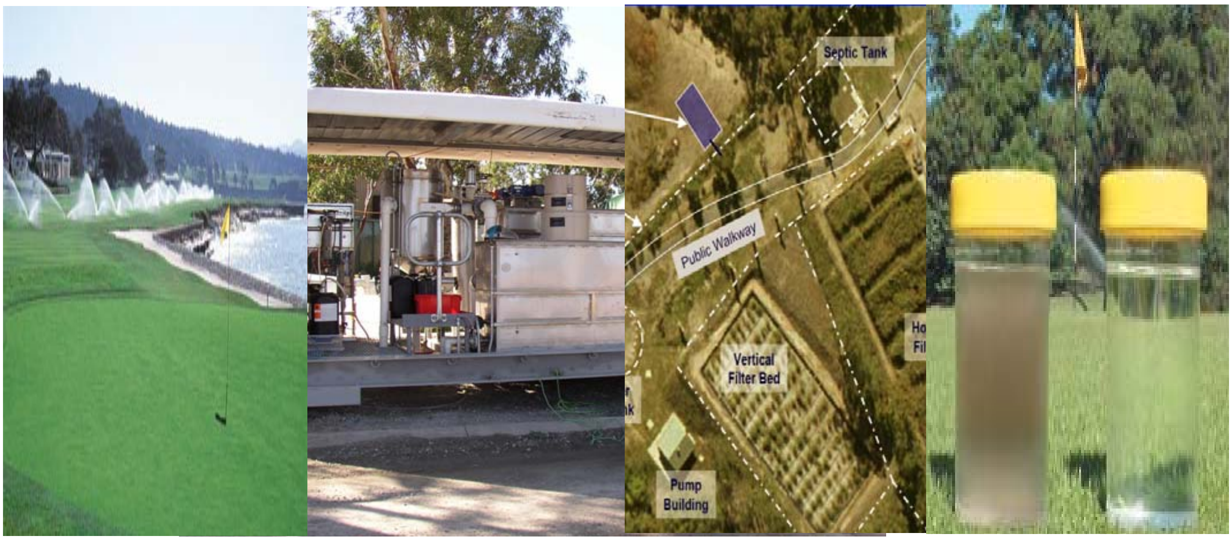

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Authors

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Please direct all enquiries to:

Chief Executive Officer
Cooperative Research Centre for Construction Innovation
9th Floor, L Block, QUT, 2 George St
Brisbane Qld 4000
AUSTRALIA
T: 61 7 3864 1393
F: 61 7 3864 9151
E: enquiries@construction-innovation.info
W: www.construction-innovation.info

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EXECUTIVE SUMMARY

The rate of water reform in Australia is gathering pace with Federal and State initiatives promoting a more integrated approach to water management. This approach encompasses a more competitive environment and a greater role for the private sector. There is a growing recognition of the importance of water recycling in these initiatives and the need to provide opportunities for its development. In March 2008 the Productivity Commission published its discussion paper on urban water reform. The paper cited inadequate institutional arrangements for the management of Australian urban water resources and noted the benefits to be gained from a comprehensive public review of urban water management. This development can be supported through the promotion of a sewer mining industry. This industry, offers flexible and innovative solutions to water recycling demands in a variety of situations and structures. In addition it has the capability of satisfying government competition and private sector policy initiatives.

Public policy in Australia, funding constraints, drought concerns and technological change are strong drivers declaring a need for new approaches to infrastructure delivery. Improved technology and the recognition of the need for integrated water management have raised questions about traditional water related infrastructure and the need for viable alternatives. There have been significant changes in funding models also. Public private partnerships (PPPs) in Australia and overseas have become a relatively popular method of delivering public infrastructure particularly in the areas of roads and tunnels and may have an important role in delivering recycled water to the Australian communities. The potential of PPP involvement in the recycled water industry has increased with changes in policies and with technological advancements. The development of the recycled water industry supports both government initiatives and provides opportunities to lower the burden on potable water use. It also improves the quality of the environment by enabling reclaimed water to be used to maintain parks and gardens.

However, despite technological advances and successful pilot operations, sewer mining lags in Australian implementation. Barriers to the adoption of sewer mining include public perceptions about the quality of the recycled water, a fragmented and inconsistent regulatory framework and a lack of robust and transparent financial evaluations of infrastructure investment options. The development of a sewer mining industry can play a key role in supporting recycling though it requires a national integrated and consistent approach to 3rd party access, a consistent regulatory framework and above all a robust and transparent pricing regime.

The aim of this paper was to review opportunities for the private sector to contribute to the implementation of government water policy initiatives. The paper focused on recycled water and the drivers and barriers to the development of one of its elements, the sewer mining industry, in Australia. Section 1 backgrounds the need for access to alternate water services while section 3 provides information on sewer mining including drivers and barriers. Section 4 discloses the steps to implementing a system. An outline of the current regulatory framework is discussed in section 5 with the study limitations and areas for future work provided in section 6. Conclusions are provided in section 7 which outlines a strategy for enabling the growth of a sewer mining industry.

What is needed is a national approach by key stakeholders including regulators, government policy owners, infrastructure owners, consumers and the private sector. Public policy in Australia continues to promote competition in the water industry and an expanded role for the private sector in that industry. PPPs offer a means of satisfying public policy objectives and providing innovative infrastructure delivery particularly in the area of sewer mining as shown in this paper. Other areas that require attention include:

- Concerns on public perceptions need to be addressed through education and marketing.

- Consistency in water pricing between potable and recycled water.
- There needs to be a closer coordination of policies and regulations governing water conservation and reuse.
- Industry stakeholders and regulators need to develop standards and performance indicators to keep pace with the rate of technological developments.
- There needs to be a cross fertilisation of engineering, behavioural, economic and environmental knowledge to provide an integrated approach to water management in general and water recycling in particular (Jeffrey and Temple 2008).
- A more critical approach to financial evaluations that take account of flexibility in decision making through the consideration of real options and the valuation of externalities.

Failure to develop recycling sources such as sewer mining leaves communities vulnerable to the ongoing vagaries of the environment and the maintenance of short-term ‘band-aid’ solutions.

1. INTRODUCTION

The ongoing drought in Australia and the increased pace of urbanization with its pressures on wastewater infrastructure are key elements in Australia's water reform initiatives. In contrast to other utilities in Australia, urban water and wastewater infrastructure is owned by the public sector either at the State or local government level (Marsden Jacob Associates 2005). However, there is a growing recognition of the need, at least at the political level, for a more comprehensive approach to infrastructure management in general and the potential for private sector contribution. Water reform initiatives at both the Federal and State levels in Australia have promoted the need for increased competition and an expanded role for the private sector (Marsden Jacob Associates 2006; NSW Government 2006; Queensland Water Commission 2007).

Recent developments have reinforced the direction of these initiatives. In January 2008, in a move designed to boost the economy's productive capacity and reduce infrastructure bottlenecks, the Australian Federal Cabinet approved the establishment of Infrastructure Australia. This new statutory advisory council will comprise members from the private and public sectors and will develop a strategic blueprint for Australia's infrastructure needs (including water). Infrastructure Australia will also provide advice to governments, investors and infrastructure owners on policy and regulatory reforms needed to improve infrastructure. Infrastructure Australia will report regularly to the Council of Australian Governments (Albanese 2008).

The New South Wales Parliament, in January 2008, released a discussion paper on local government private partnerships for asset development such as waste water treatment. The paper noted that many councils are constrained financially and yet are well placed with assets such as vacant land. According to the paper, two recent major inquiries (SCEFPA, 2003 and Local Government Inquiry, 2006) have raised issues about local government sustainability and their ability to fund infrastructure. The discussion paper is part of an inquiry into the role of private sector partnerships with local governments on asset redevelopment, including waste water treatment (New South Wales. Parliament. Standing Committee on Public Works 2008).

In March 2008 the Productivity Commission published its discussion paper on urban water reform (Productivity Commission, 2008). The paper cited inadequate institutional arrangements for the management of Australian urban water resources and noted the benefits to be gained from a comprehensive public review of urban water management. This will require consideration of the delivery of public infrastructure.

Public private partnerships (PPPs) in Australia and overseas have become a relatively popular method of delivering public infrastructure particularly in the areas of roads and tunnels. In the Australian context PPPs have been defined as: Government has a business relationship, it is long term with risk and benefits and private sector becomes involved in the financing, designing, constructing, owning or operating public facilities or services (Hodge 2004).

Some authors contest the effectiveness of PPPs (Renzetti and Dupont 2003; Cannadi and Dollery 2005; Greve 2006), primarily because conclusive evidence that PPPs offer a more attractive alternative to the traditional provision of community infrastructure by the public sector in all contexts, has still to be provided. Part of the difficulty in evaluating PPPs has been the fact that they are purpose built and are usually long term in nature, with 30 year lives not unusual (Greve 2003). Contracts may spell out PPP arrangements but risks and delivery parameters can change over time, for example, changes of government have frequently been followed by attempts to renegotiate PPP agreements (Quiggin 2005).

While the effectiveness of PPPs in every context is still a matter for debate, public policy initiatives and technical innovation are strong drivers for their adoption. Improved technology and the recognition of the need for integrated water management have raised questions about traditional water related infrastructure and the need for viable alternatives. The concept of large scale infrastructure replacement is considered by the water industry to be a costly, risky and possibly ineffective response (Jeffrey and Temple 2008). The funding of large scale infrastructure in the water industry though government grants has led to claims that this limits private sector investment and hampers competition (Young 2007).

The potential of PPP involvement in the recycled water industry has increased with changes in policies and with technological advancements. The primary driver for water recycling has changed from meeting effluent discharge standards to using the recycled water to save drinking water and to contributing indirectly to drinking water supply (Radcliffe, 2007).

In the area of wastewater management, traditionally urban waste water treatment plants have been centralized due to concerns over health and reliability and the small capacity of alternative systems. However, improved technology offers scope for small scale development and private sector involvement (Tjandraatmadja, Burn et al. 2005).in the provision of water infrastructure and water supply. This is particularly relevant to the recycled water sector and the treatment of what has often been regarded as a liability, sewerage.

In Australia, water is predominately used for agricultural purposes including livestock pastures (70%) however the domestic consumption is approximately 16% (National Water Commission). The annual effluent load, the volume of discharge from Australia's water utility sewerage treatment plants in 2002 was 1824 GL with only 9.1% (166 GL) reused. Below is an estimate of water reuse in 2001-02.

Figure 1-1 Estimates reuse from STP's in Australia 2001-2002, (Hatton MacDonald et al 2005)

Region	Wastewater GL/yr	Reuse GL/yr	Percentage
Queensland	339	38	11.2
New South Wales	694	61.5	8.9
Australian Capital Territory	30	1.7	5.6
Victoria	448	30.1	6.7
Tasmania	65	6.2	9.5
South Australia	101	15.2	15.1
Western Australia	126	12.7	10.0
Northern Territory	21	1.1	5.2
Australia	1824	166.5	9.1

Source: Radcliffe (2003b)

The reuse proportion for the capital cities ranges from 0.1% to 3.3 with only Brisbane (6%) and Adelaide (11%) with a higher recycled proportion (Radcliffe 2004). Identified targets are detailed in the table below.

Figure 1-2 Water reuse for capital cities 2001-02 (Radcliffe, 2004)

State Capital	% recycled water use
SYDNEY	2.3
MELBOURNE	2.0
BRISBANE	6.0
ADELAIDE	11.1
PERTH	3.3
HOBART	0.1

Typical reuse water applications include the following:

- Amenity areas - parks, gardens, ovals, golf courses;
- Commercial agriculture - viticulture, floriculture, turf grass, pastures, hay cropping and vegetable production;
- Forestry - plantation forestry;
- Industrial applications; and
- Residential use as part of third pipe developments.

The development of the recycled water industry supports government initiatives and provides opportunities to lower the burden on potable water use. It also improves the quality of the environment by applying reclaimed water for example to parks and gardens. Experience in Melbourne shows that a high percentage (60%) of respondents were prepared to use greywater for toilet flushing, car washing and garden watering but only around 5% had installed systems (Diaper, Tjandraatmadja et al. 2007).

2. RESEARCH QUESTIONS

The aim of this paper is to review opportunities for the private sector to contribute to the implementation of government water policy initiatives. The paper focuses on recycled water and the drivers and barriers to the development of one of its elements, the sewer mining industry, in Australia.

The paper addresses the issue of why sewer mining has not been adopted to a greater extent in Australia and looks at the drivers and barriers to development of the industry.

This case study was predominately completed through desktop reviews of industry and government literature. A small number of site visits were carried out to develop a greater understanding of the complexity of the technologies and their application.

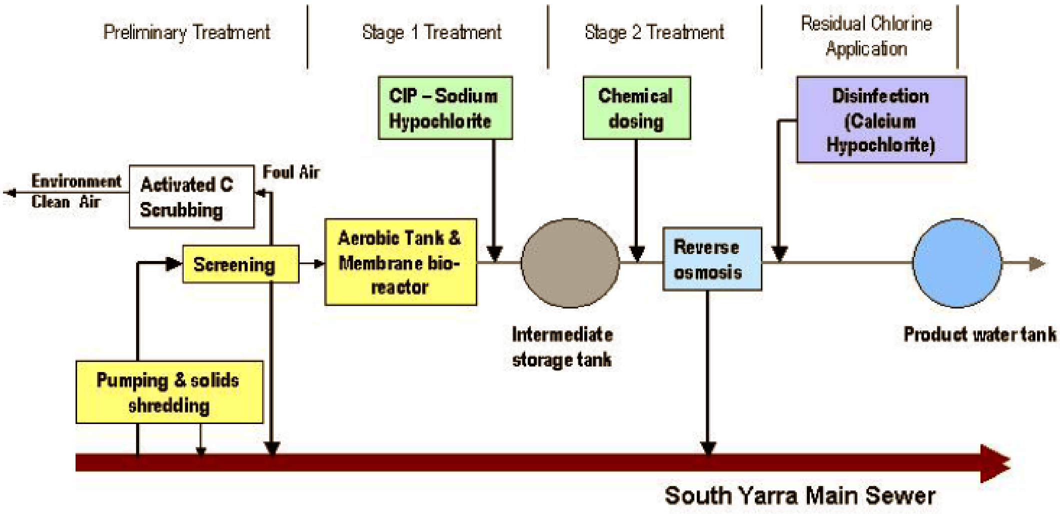
3. SEWER MINING

Sewer mining has been described as the ‘process of tapping into a sewer (either before or after the sewage treatment plant) and extracting sewage which is then treated as recycled water. Some sewer mining by-products may be acceptable for return to the sewerage system (Sydney Water 2006).

Sewerage treatment has three major steps, primary, secondary and tertiary. The primary step results in the removal of some suspended solids and organic matter though it is often preceded by a preliminary step where large elements such as sticks, rags and such are removed and can be followed by an advanced primary treatment using chemical additives or finer filtration to improve the primary removal. Secondary treatment results in the removal of much of the balance of the suspended solids and biodegradable organic matter. Disinfection is carried out at this stage of the process. The disinfection is usually carried out by UV exposure however filtration technologies are also available. In some systems the secondary treatment includes nutrient removal. Tertiary treatment results in the balance of suspended solids being removed and the treatment includes further disinfection of the treated product. This step includes removal of nutrients. At times this final step is followed by an advanced step to remove dissolved and suspended materials depending on the end-use of the recycled product. The extent of the treatment process is determined by the requirements of the water quality of the end-use. It is important to select the treatment level appropriate to provide the quality required for the purpose.

The chart below from a potable system implemented in Melbourne (Radcliffe, 2004) best illustrates the process flow.

Figure 3-1 Sewer Mining process flow (Radcliffe, 2004)



Appendix B discusses in more details the types of technology used in sewer mining

Reuse of the resource requires removal of sediments and solids, bio-solids, trace metals and trace organics, nutrients, parasites as well as living organisms and pathogens including viruses and bacteria. Most of these contaminants are able to be successfully removed using various technologies and pose no ongoing risks when using the recycled product but risk elements are high for the pathogens, heavy metals and pharmacological. Appendix A sets out the types of pollutants contained in effluent that may impact on human health. (Hamlyn-Harris, 2001)

Residential use including flushing of toilets and gardening water require tertiary level treatment with pathogen reduction while public places and groundwater recharge often only require secondary treatment, in practice though tertiary level is generally used. For ground water recharge there are site specific requirement where nutrient reduction is to be carried out. As a rule the minimum level of treatment required is secondary with limited application such as irrigation for fodder food and fibre crops.

Use of treated wastewater in irrigation may lead to health issues for nearby residence and park users thus the importance of gaining and maintaining appropriate levels of water quality are paramount precluding the transmission of pathogens. Potentially these are the most difficult to remove thus a clear set of guidelines firstly for the deemed safe levels including sampling and testing protocols as well as clear guidelines for acceptable use for the various qualities achieved is required. These guidelines are developed or being developed by local authorities and are generally more stringent but based on the WHO (1989) guidelines for wastewater reuse (World Health Organization, 1989).

There are a number of issues to be considered when planning to implement a plant including the availability of resource, appropriate technology identification and selection, location including land use alternatives, costs including capital and operational costs, regulatory and legal constraints, demand both quantity and quality and of course acceptance. Despite these issues there are many examples of sewer mining plants in existence for example the irrigation of golf courses and residential dual reticulation. Examples are reviewed in section 1.3.

3.1 Sewer mining drivers

Sewer mining operations can and do provide a significant range of advantages to communities, companies and organisations. The drivers for and advantages of sewer mining include:

- reduced the demand for water and water infrastructure in an increasingly urbanized environment;
- a catastrophic breakdown of a local wastewater treatment plant would not cause the whole system to shut down;
- sewage can be treated to a standard of fit for purpose. In other words the treatment can be tailored to specific user requirements, there is no longer the need for a one size fits all product.
- minimal impact on the environment due to their small size, their self containment and lack of odours.
- more flexibility in responding to technological change due to their size.
- can be adapted to a wide range of community and industrial wastewater applications ranging from residential development projects to sports facilities and parks for a range of volumes.
- The operation can be relatively inexpensive, the cost of sewer mining plants vary with conditions and capacity but bare minimum costs range from $1.00/kl (kilolitres or 1000 litres) for a 100-1000 kl plant with a capital expenditure of $900,000 to $2.74/kl and capital expenditure of $1,000,000 (Mallapa 2006).
- the load on the end of the line treatment plant is reduced as is the cost of transporting the recycled water from the central treatment plant to the reuse site;
- reduction in discharges to oceans and bays;
- in an urban setting sewer mining turns a liability into an asset (Gagliardo 2007).

As a result PPPs can be constructed around specific projects and funded accordingly. The PPPs can take a variety of forms such as design and construct, build own and operate and long term contractual arrangements.

3.2 Sewer mining barriers

Sewer mining faces a number of barriers. Public perceptions and concerns, inadequate regulatory framework as well as a lack of robust financial evaluations lead the list. These barriers have the characteristics of a “wicked problem.” In a wicked problem, there are high dynamic and behavioural complexities, key decision makers hold different assumptions, values and beliefs and component problems cannot be solved in isolation from one another (Lane and Woodman 2008). Wicked problems are not solved in a linear fashion like their “tame” problem counterparts. Critical elements in solving wicked problems relate to social processes and developing processes that look for opportunities for breakthroughs, synergies, connections and allies (Conklin and Weil 2008).

3.2.1 Public perceptions

Public perceptions and acceptance of the risks associated with water recycling remain a key issue for promoting sewer mining. There is limited long term experience with recycling schemes in Australia; however, overseas experience suggests that health risks are not significant (Khan and Roser 2007). The Queensland Water Commission (Queensland Water Commission, 2007) noted that recycled water has been used to replenish drinking water supplies in many parts of the world for up to 40 years, including the USA, UK, Singapore and Belgium. There still remains though, the perception of the ‘yuk’ factor in dealing with recycled water (MacDonald and Dyack 2004). Factors influencing people’s decisions to use recycled water are still open to argument. Knowledge and pricing may not be as critical as is trust in the entity providing the recycled water (Po, Nancarrow et al. 2005).

There appears to be a strong public perception that recycled water should be priced at a discount to potable water. Despite many recycling schemes not being economically feasible water providers and regulators have tended to set the price of recycled water at a discount to potable water in response to public attitudes and the need to influence consumer behaviour (Hurlimann, McKay et al. 2005). The pricing of potable water itself in Australia is the matter of some debate and stakeholders argue that the pricing regimes limit opportunities for competition, new investment and innovation (Marsden Jacob Associates 2005). One of the key areas identified by the Productivity Commission (Productivity Commission 2008) was the need for further investigation into the cost and benefits of using pricing to signal water scarcity and resource allocation. Pricing regimes have not reflected water scarcity, instead governments have relied on water restrictions to manage demand in times of water shortage.

Consumer perceptions of prices and costs in the water sector need to be addressed in some detail through consultation and education programs. Given that the public has little knowledge of the water sector real costs (Hurlimann, McKay et al. 2005) it is important to consult widely with the community on pricing as well as health issues. There is a need to structure pricing to avoid perverse behaviours where consumers substitute potable water for recycled water because it is more economic to do so (Queensland Water Commission 2007).

3.2.2 Regulatory framework

The regulatory and legislative framework has failed to keep pace with the rate of technological change in the recycling industry and sewer mining in particular. There is also potential for a conflict of interest between the social and commercial objectives of governments and water providers (Essential Services Commission 2007). Innovative urban designs for water, wastewater and storm water service delivery may be far ahead of local planning policies, catchment plans and EPA guidelines. At the same time, there is a lack of coordination of both policies and regulations that govern water conservation and reuse. Local governments, regional authorities, States and Commonwealth all have roles to play, but currently with overlapping responsibilities and concerns (MacDonald and Dyack 2004). There needs to be clearer accountability (Victoria Government 2004)

As an example of the complexity of the legislative framework, recycling schemes in Queensland are governed by the following acts (Queensland Government Environmental Protection Agency 2005):

- Environmental Protection Act
- Integrated Planning Act
- Water Act
- Plumbing and Drainage Act.
- Health Act
- Food Act
- Workplace Health and Safety Act
- Local Laws
- Commonwealth Environment Protection and Biodiversity Conservation Act.
- Commonwealth Trade Practices Act

Water remains a highly regulated industry with prices oversight and access regimes in Australia administered by the states (Queensland Competition Authority 2000; Independent Pricing and Regulatory Tribunal 2006; Essential Services Commission 2007). However, with the increased calls by governments for greater competition and private sector participation the question of balancing regulation against competition needs to be addressed. Water is not necessarily a natural monopoly, “One of the major insights of the privatisation program in Britain has been that network utilities such as gas, electricity and water contain natural monopoly elements but also potentially competitive sectors.” (Robinson 2004). However, the fact that there is no substitute for water means that governments will always be sensitive to its pricing and availability. In reality there are some risks that cannot be transferred in the critical area of water supply (New South Wales. Parliament. Standing Committee on Public Works 2008) and government may well always be the supplier of last resort. Hence the argument for the need for a heavily regulated industry.

The argument that water is not a unique industry poses the question whether light-handed regulation is more appropriate. Is there a need for heavy-handed regulation? Robinson argues (Robinson 2004) that regulators may not necessarily improve the otherwise market outcome since the regulators suffer from a knowledge gap of what would actually drive prices and behaviours in a true market environment. Environmental issues do not necessarily require a "command and control" regulatory framework (Robinson 2004). Queensland has already promoted the idea of a more light-handed approach to the water industry by simplifying and increasing the certainty in the regulatory process and improving the timeliness of the regulator's decision making (Queensland Government 2007). But at the same time, State Government has also signalled that it anticipates introducing price monitoring of local government water suppliers from 1 July 2008 (Fraser 2008). There remain however, significant differences in the Australian States' approaches to price regulation. In New South Wales, Independent Pricing and Regulatory Tribunal (IPART) has a deterministic water-pricing role whereas in Queensland, the Queensland Competition Authority has a recommendatory role only.

3.2.3 Financial evaluations

One of the key elements in any decision to undertake a PPP is their financial evaluation process. However, given that PPPs are normally long term in nature, (30 year arrangements are not unusual (Greve 2003)), it is not always possible to understand the costs and benefits until some way through the PPP arrangement at which time risk and delivery parameters may well have changed (Quiggin 2005). Therefore, it is critical for both the public and private sector partners to incorporate flexibility and the wider social implications into their investment decision-making models. Investment decision models are normally based on traditional financial evaluations using Net Present Value (NPV) analysis where a project's cash flows are discounted for a certain project life. However, NPV fails to deal with project sensitivity (Ross, Westerfield et al. 1993) and overlooks management flexibility to alter the course of a project as market conditions change (Copeland and Kennan 1998). The concept of real options has developed in response to these NPV shortcomings. A real option has been described as the right but not the obligation to take an action (eg deferring, expanding, contracting or abandoning a project) at a predetermined cost, called the exercise price, for a predetermined period of time-the life of the option (Copeland and Antikarov 2001). Real option theory builds on the Black and Scholes option pricing models developed in the early 1970s.

Not all PPP situations lend themselves to the sophisticated mathematical modelling for option pricing nor is it always necessary. The value of real options is that they can provide a framework for qualitative consideration of alternatives where flexibility is required in the face of uncertainty (Howell, Stark et al. 2001). This could occur for example, where a water service provider is faced with alternate infrastructure investment decisions in the face of a drought of indeterminate length. It may be sufficient to assure the water provider that options do exist even though their value cannot be quantified with any degree of accuracy.

Economic valuations of water reuse projects have generally taken the form of cost benefit analyses (Hernandez, Urkiaga et al. 2005). Externality (i.e. non-market costs or benefits) pricing is an important element in the Cost Benefit Analysis (CBA). However, the traditional approach has been criticised on the grounds of failure to consider intergenerational effects of environmental externalities (Saez and Requena 2007) and public perceptions on what is a negative externality versus a positive externality (Steinacker 2006).

3.2.4 Product quality

The contaminants contained within the raw sewerage that render reuse difficult, are a further barrier. Raw sewerage volumes come from many sources at various concentrations including trade wastes from industrial, commercial, residential and building and construction wastes, i.e. concrete, motor vehicle industry, food industry etc. Residential wastes include organic solids from sinks, showers, basins and sink grinders as well as toilets. Sink grinders can add significantly to the Biochemical Oxygen Demand (BOD) which is a measure of the content of biologically degradable substances in sewage and suspended solid pollutant loads potentially restrict flow. These challenges require selection of appropriate technology to enable successful reuse. In some cases, depending on the reuse application, treatment may not be a financially feasible option in the traditional sense. However, real options analysis may support the investment on the grounds that it provides flexibility in providing micro solutions as an alternative to large-scale investment (see Productivity Commission 2008:93-94).

4. PLANNING AND IMPLEMENTING A SYSTEM

System planning and implementation are critical elements in sewer mining projects. The following section provides a general model for planning and implementation.

The initial phase in designing and implementing a sewer mining operation is a preliminary business feasibility study that examines the regulatory requirements, potential customers, business partnership opportunities and 3rd party access issues and pricing regimes.

After that there are six primary steps for implementation as follows:

1. Identify site

- identify development scale, type, location
- evaluate current centralised capacity
- evaluate potential upgrades to cater for development
- investigate offsetting investment in infrastructure upgrades with reuse treatment opportunities

2. Conduct a water balance

- align water uses with available water sources (including rainwater, stormwater, drinking water) on a fit-for-purpose basis
- assess water demands with an end-use analysis
- calculate water balance
- align demand profile with supply profile

3. Identify water reuse options, for example

- onsite
- localised treatment
- dual supply pipeline

4. Social and human health considerations

- adopt a risk-based approach to defining methods of delivery and corresponding water quality requirements
- define requirements for pre-commissioning monitoring and demonstration of compliance to current health standards for reused water
- identify community receptiveness to different applications of reused water

5. Evaluation of the impact on the natural environment

- receiving water quality impacts
- greenhouse gas emissions
- land suitability

6. Life cycle costing and economic considerations

- economies of scale
- capital, operational, replacement and decommissioning costs

The final step is the selection of an appropriate technology based on the above six steps, having completed an analysis of economic, environmental and social considerations in the context of site characteristics. Selection of the appropriate technology also requires consideration of the volume of effluent available and the volume of product required. There is a significant variation in the successful operating ranges for various technologies. Often there is a need for minimum flows to operate physical and chemical technologies successfully. While upper limits are clear for many technologies regardless of the treatment process type. There are also a range of sewer types to connect to including:

- reticulation sewers
- carrier sewers
- submain
- main sewers

When planning to extract raw sewerage one of the considerations will be the flow and diurnal patterns with mid-morning and early evening peaks and lower peaks on weekends however similar volumes.

4.1 Examples of sewer mining operations

There is potential to use sewer mining in many applications including for example in over 200 golf clubs in Sydney that are sited directly over sewer mains and which use up to 4 ML of potable water per day to water their greens (Farmhand Foundation 2004). There is a large number of existing plants in operation including the following examples.

4.1.1 Sydney Olympic Park

Sewer mining forms part of the Sydney Olympic Park Authority Water Reclamation and Management Scheme (WRAMS) at Homebush Bay in Sydney where recycled water replaces 50% of the drinking water that would otherwise be used at Sydney Olympic Park and the Newington Estate (Sydney Water 2006). WRAMS is designed to save more than 850 million litres of potable water annually. About 40% of the recycled water is used for toilet flushing and 60% for irrigation and operational wash-down activities (Sydney Olympic Park 2006).

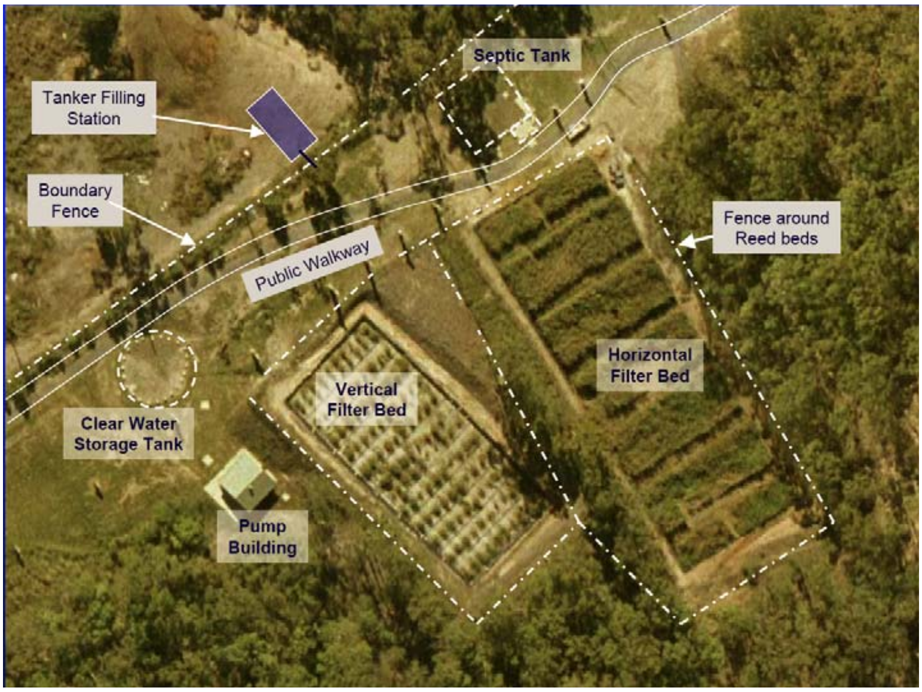
4.1.2 Beverley Park Golf Club

Kogarah Council is trialling sewer mining plant to irrigate Beverley Park Golf Club greens. It was reported that the trial would cost about $100,000 including the installation of an on-site treatment plant and a report on the trial. During the trial, up to 300 kl of sewage would be mined (Kogarah Council 2005). Other Councils are reported to be considering sewer mining projects (Ku-ring-gai Council 2006)

4.1.3 Riverside Rocks Park

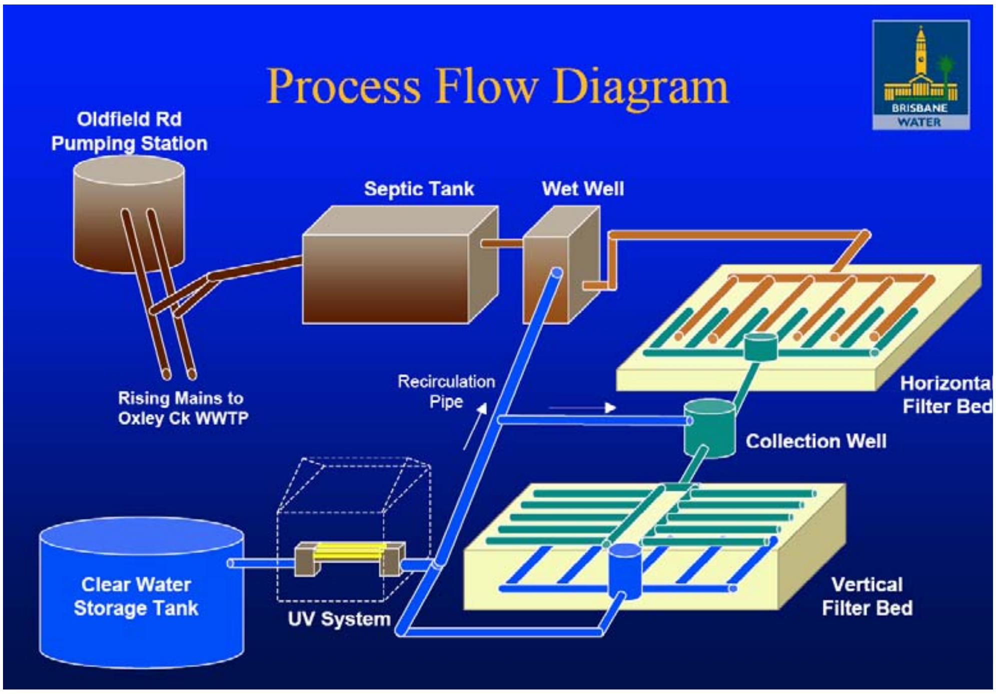
Brisbane City Council’s RRP project established to irrigate Riverside Rocks Park (26 hectares with 800 metres of prime river frontage) by mining waste water and treating it using constructed reed beds and ultraviolet disinfection. The project commenced as a research and development project with an investment of over $2 million. It is the largest of its type in Australia with the potential to save up to 130 ML of water pa and reduce the flow of nitrogen nutrients to the Brisbane River by 750 kg p.a. and saving 100 tonnes p.a. in greenhouse gas emissions (Brisbane City Council 2006). Development of the Rocks Riverside Park was intended to create a sustainable urban and nature park that would “stand up to intensive use so that future generations would enjoy it”. In its first year it was used by 500,000 people for many activities. The park has an irrigation Area of 5 ha and a water demand of 360 kL/d.

Figure 4-1 Riverside Rocks treatment facility - (Krumins and Towndrow, 2005)



Planning for the park included consideration of environmental, economic and community factors, used resources efficiently, and enriched community life. Sustainability principles were applied to infrastructure and ongoing management. Sewer mining technology chosen was reedbed process. (Krumins and Towndrow, 2005)

Figure 4-2 Riverside Rocks treatment facility process diagram (Krumins and Towndrow, 2005)



4.1.4 Ecovillage at Currumbin

The Ecovillage at Currumbin, Queensland has no water or wastewater connections to municipal supplies in what is believed to be a first for Australian residential development. Wastewater is collected via a low infiltration sewer reticulation system, treated to Class A+

(the highest standard) and recycled for site irrigation, household toilet flushing and household external uses (Tanner 2007).

4.1.5 Kings Domain gardens

Melbourne Water trialled a sewer mining system in the Kings Domain gardens in 2002, later at Albert Park Lake, and now transferred to Werribee, showed that membrane technologies could produce a Class A reclaimed water from Melbourne's sewers. The unit, mounted in a 12m shipping container had no significant environmental impacts, and was suitable for taking advantage of on-site water reclamation opportunities to irrigate Melbourne's parklands (Radcliffe, 2004) or top-up Albert Park Lake delivered 30,000 litres of high quality recycled water every day. The plant used 18kW of electricity at a cost of $1.80 per hour. (Farmhand, 2004).

4.1.6 Southwell Park

The Southwell Park sewer mining project in the Australian Capital Territory was designed to recycle up to 600kl per day. It was built at a cost of $2.4 million with annual operating costs of about $100,000 (Environmental Technologies 2006). Sydney Water has been pursuing localised water recycling schemes that include sewer mining but the take up rate appears to be low. In February 2008, Sydney Water highlighted only two examples of sewer mining initiatives in greater Sydney. These were the Sydney Olympic Park Authority's Water Reclamation and Management Scheme at Homebush Bay and the Kogarah Council initiatives (see above). However, Sydney Water did note that more sewer mining initiatives were on the way and that the NSW Government's Metropolitan Water Plan 2006, encourages innovative private solutions for water supply, particularly by recycling. Sydney Water was also able to point to larger scale recycling schemes involving sewage treatment plants. These include the proposed Hoxton Park project where recycled water will be provided to residents and businesses and also to the provision of recycled water to BluesScope's industrial plant in Wollongong (Sydney Water 2008).

4.2 Costs and pricing

Capital and operating costs for sewer mining operations vary according to site location, technology and sewerage elements as the following tables show:

Table 4-1 Examples of costs for recycled water – (Radcliffe, 2004)

Location	Use	Class	Price /kL	Reference
Parafield, SA	GH Michell & Sons Australia Pty Ltd, woolscouring	Stormwater	30c (operating cost only)	Pitman, 2003
Springfield, Q	Amenity, schools, oval, residential	A	$1.45	Consultant – (Hall 2003)
Olympic Park/Newington, NSW	Public facilities and Residential supply for toilets, gardens, washing	A	$1.60 (operating cost only)	Listowski 2003
Melbourne	Integrated hydrological system, residential development	A	$2.50	Private sector development consultant, pers. comm.
Melbourne – Eastern STP	Integrated amenity and residential use	A	>$3.00	GHD 2002a
Rouse Hill NSW	Residential supply for toilets, home gardens, washing	A	$3-00 to $4-00 Initially, $7-00	de Rooy & Engelbrecht 2003, de Rooy 2003

A recent Melbourne Water study provides some useful insights however into the range of costs. A feasibility study commissioned by Melbourne Water last year looked into the option of sewer mining as an irrigation water source for a cluster of golf clubs. The clubs usually use between 0.5ML and 1ML per day in summer to keep their fairways green. A treatment plant to provide 0.8ML a day for a single golf club will mean a cost of approximately $1,800/ML for water supplied to the 'front gate'. Alternatively, a 2.5ML/day plant to supply a cluster of golf clubs will cost approximately $1,200/ML. This cost was in comparison to the option of reusing wastewater from the central treatment plant, which would cost between $650/ML and $700/ML. However, the capital costs of this system would be greater at $6 million to $6.5 million compared with the $2.4 million at the Southwell facility in the ACT. The current 'winter' price for water to the golf clubs in Melbourne through the normal system is $780/ML (Farmhand, 2004)

Table 4-2 Comparisons of costs for different technologies – (Radcliffe, 2004)

Treatment Alternative	Capital cost $	Amortised capital cost ($US/yr)	O&M cost ($US/yr)	Total cost ($US/yr)	Total cost. ($US/1000gal)	Total cost ($US/kL)
Zenon submerged membrane bioreactor	$5,068,627	$516,000	$267,000	$783,000	$2.15	$0.57
Oxidation ditch	$5,587,800	$569,000	$307,000	$878,000	$2.40	$0.63
Activated Sludge	$5,933 520	$606,000	$282,000	$867,000	$2.38	$0.63

The three systems compared here have different needs in terms of footprints an d influents. Submerged membrane bioreactor wastewater treatment process combines an aerobic biological treatment process with an immersed membrane system. It handles liquid/solids separation on a molecular scale. The combination of membrane separation with a suspended growth bioreactor is now widely used for municipal and industrial waste treatment (Judd, 2006). The technological advances combine with the added advantage of a small footprint making this a sought after technology. Compared to an activation sludge system where air is fed through treated sewage. This system is a biological treatment process where a mixture of sewage and activated sludge is agitated and aerated. The combination with organisms develops a biological floc which reduces the organic content of the sewage. The Oxidation Ditch is a modified form of the activated sludge system. Oxidation ditches are mechanical secondary treatment systems which tolerate variations in hydraulic and organic loads. They consist of an oval shaped channel equipped with mechanical aeration devices. ODs typically have long detention times and are capable of removing between 75% and 95% of the Biological Oxygen Demand (BOD).

Given the strongly regulated nature of the water industry in Australia, variability in pricing regimes and public perceptions that recycled water should be discounted against potable water it is not surprising that the provision of recycled water is seldom economically feasible and rarely meets full cost recovery (Hurlimann, McKay, & Geursen, 2005).

The table below illustrates the variability in potable water pricing in Australia where water prices contain 2 elements, a fixed access charge and a volume charge.

Table 4-3 Variability in water pricing in Australia (Hatton MacDonald et al 2005)

		Fixed Component		Variable Charge
Water Utility		Minimum $	Basis	cents per kL
ACTEW Corporation	Water	125	fixed	41 <200; 97 >200*
	Sewer	339.20	fixed	none
Barwon Water	Water	102.60	fixed	70
	Sewer	125.50	fixed	86
Brisbane City Council	Water	100	fixed	82
	Sewer	315	fixed	none
Central Gippsland Water	Water	69.90	fixed	55
	Sewer	209.65	fixed	88
Central Highlands Water	Water	56.21	fixed	32 to 76
	Sewer	205.60 to 313.34	per town	none
City West Water	Water	81.92	fixed	77
	Sewer	89.04	fixed	88
Coliban	Water	92.70	meter size	33 to 62
	Sewer	229.10	per town	none
Gold Coast	Water	173	fixed	65
	Sewer	393	fixed	none
Gosford City Council	Water	70	fixed	70
	Sewer	340.30	fixed	none
Goulburn Valley Water	Water	85.30	meter size	35 to 43
	Sewer	172.70 to 215.30	per town	none
Hunter Water Corporation	Water	26.55	meter size	94 <1000; 86>1000
	Sewer	222.96	property	41
Ipswich Water	Water	162	fixed	52 <100; 90 101-150 and 128 >150
	Sewer	410	fixed	none
Logan Water	Water	145	flow factor	79
	Sewer	324	fixed	none
Power and Water Corp	Water	103.11	meter size	68
	Sewer	322.06	fixed	none
SA Water	Water	130	fixed	40 <125; 97 >125
	Sewer	241	property	none
South East Water Limited	Water	34.80	fixed	79
	Sewer	126.60	fixed	84
Sydney Water	Water	75	fixed	94
	Sewer	328.36	fixed	none
Water Corporation	Water	144.20	fixed	40 <150; 65 151-350; 88 351-550;101 551-750, etc.
	Sewer	228.55	property	none
Yarra Valley	Water	57.36	fixed	75
	Sewer	122.76	fixed	87

* Abstraction charge 20c/KL Source: Assembled from WSAA (2003)

Costs to connect and use the infrastructure ranged from $34 to 173 for water connection with use charges highly variable while for sewer connections charges range from $89 to $410 with most authorities opting to levy no charges for use volumes.

The following table shows the discounted cost of recycled water compared to potable water.

Table 4-4 Comparison of recycled and potable water costs - (Radcliffe, 2004)

Location	Use	Class	Price, /kL	Reference
RECYCLED WATER				
Northern Adelaide Plains, SA*	Irrigated horticulture/vegetables	A	7-15c	Ringham (2003)
Sydney – Rouse Hill, NSW	Residential supply for toilets, home gardens, washing	A	28c	Sydney Water and IPART (2003)
Geelong, Victoria†	Various agricultural and horticultural irrigation uses	C	35-58c	Byrnes (2004)
Springfield, Qld.,	Residential supply for toilets, home gardens	A	43c	Hall (2003)
Southern Vales, SA*,	Vineyard irrigation	B/C	53c	Templeman (2003)
Olympic Park/Newington, NSW,	Public facilities and Residential supply for toilets, gardens, washing	A	83c	Listowski (2003), IPART (2003)
DRINKING WATER				
Sydney Water Corporation Drinking water	Human consumption (reticulated bulk supply)	-	98c	IPART (2003)
Ride citrus/mandarin sports water	Human consumption (in 500 mL bottles)	-	$6,600.00	*Choice*, Jan/Feb 2004, p27-29

* Marketed to users by pipeline company – water obtained without charge from water treatment agency. All other cases, water marketed by water treatment agency.
† Schemes use private infrastructure for transfer of recycled water.

5. REGULATORY AND POLICY FRAMEWORK

The water industry in Australia is heavily regulated in terms of water quality and pricing. Appendix C compares water quality, use and treatment across the states with the emphasis on maintaining health integrity. Section 1.4 above has already highlighted the regulatory pricing regimes in place in Australia. National water initiatives call for greater competition in the water sector and more scope for private sector involvement. However, given the non-substitutability of water it is likely that a fair degree of regulation of the water industry will always take place if nothing else but on health and equity grounds. At the end of the day Governments are in reality, the supplier of last resort for water. The challenge for regulatory and policy reform is to encourage alternative water structures and sources through a more light handed regulatory approach but still allocating risk to the parties most able to manage it. There needs to be a cross fertilisation of engineering, behavioural, economic and environmental knowledge to provide an integrated approach to water management in general and water recycling in particular (Jeffrey and Temple 2008). Queensland has already indicated its movement towards the light handed regulatory approach to pricing in its amendments to the Queensland Competition Authority Act (Queensland Government, 2007).

5.1 Roles and Responsibilities

It is clear that governments, whether at the local or state level play many roles such as regulator, infrastructure owner and contract party that can lead to conflicts of interest and failure to manage long term planning. As the productivity Commission points out "While institutions cannot make it rain, they are responsible for aligning long-term supply and demand and managing periodic scarcity" (Productivity Commission 2008:XV)

The responsibilities for water provision lay largely at the feet of Government as is detailed in the table below.

Figure 5-1 Roles and responsibilities

	Water regulator	Government	Infrastructure owner	Private sector operator/builder
Development impact		Y		
Environmental impact		Y		
Technology standards		Y		
Health standards		Y	Y	
Performance management	Y	Y	Y	
Supplier of last resort		Y	Y	
Risk management		Y	Y	Y
Pricing	Y	Y	Y	Y
Demand management	Y	Y		
Supply management	Y	Y	Y	Y
Financial evaluation			Y	Y
Value for money			Y	Y

This table identifies the main actors in the recycling process and the policy issues that face them. Infrastructure owner in the Queensland context is the local government.

5.2 Towards an Improved Policy / Regulatory Framework

The water initiatives at the state and federal levels have emphasised the need for a more comprehensive approach to integrated water management with a focus on increased competition and private sector participation. A key element in water management is recycled water. The development of a sewer mining industry can play a key role in supporting recycling however it requires a national integrated and consistent approach to 3rd party access, a consistent regulatory framework and above all a robust and transparent pricing regime.

6. LIMITATIONS OF THE STUDY

Debate about water reforms and management in Australia continues amid considerations of the broader questions of infrastructure requirements. Ongoing technological developments and political policy initiatives create a moveable feast so that it is difficult to draw a line in the sand. Public perceptions continue to play an important role in water management particularly in terms of whether the drought has ended and this will in turn impact on future policy developments and regulatory frameworks.

Anecdotal evidence suggests that total water management with a focus on recycling will remain a key initiative for governments at all levels and that there is growing public acceptance of the need for this.

6.1 Future Research

Future research needs to focus on both the non-technical and technical aspects of sewer mining.

On the non-technical side research avenues include:

- there is significant scope to further research on public attitudes towards recycling in terms of demand management techniques and pricing methodologies.
- At the same time there needs to be a better understanding of the broader cost-benefit issues of sewer mining, how externalities are measured and how real option s can be factored into investment decision making. In addition, cost-benefit evaluations should consider human waste management schemes with and without reuse.
- The development of a consistent and coherent regulatory framework and its adoption by all levels of government.
- Development of a pro-forma PPP template for designing and evaluating PPPs for sewer mining.
- Whether the provision of a critical public utility such as water should be left left to contractual arrangements or whether the regulatory framework should be the ultimate supplier and arbiter.

On the technical side, a number of gaps in knowledge have been identified, Martin Strauss, Allison et al. (1998), Birley and Lock (1999) and Rose (1999) have identified gaps-in knowledge relating to human waste use in urban agriculture and are suggesting action and field research to fill them. Below is a non-exhaustive listing of identified gaps:

- Health impacts from chemical constituents contained in human wastes (heavy metals; persistent organics; pharmaceuticals): assessing the importance of the human waste – soil – crops – food –cycle.
- Strategies to avoid (e.g. through source separation) the mixing of toxic chemicals and domestic wastewater and faecal sludges.
- Development of appropriate, i.e. implementable and enforceable quality standards for treated human wastes applied in urban agriculture and aquaculture
- Technical, economic/financial, institutional, cultural and agronomic aspects of non-centralised human waste treatment-cum reuse (“integrated urban waste management” schemes based on domestic wastes mainly, e.g. through case studies of existing schemes or components thereof or through pilot projects with stakeholder involvement
- Carbon (organic matter) and nutrient needs in urban agriculture vs. C and nutrient generation in the city; estimating the theoretical C and nutrient demand potential of urban farms; use of material flow analysis (MFA) as an assessment and planning tool

7. CONCLUSION

Public policy in Australia continues to promote competition in the water industry and an expanded role for the private sector in that industry. Funding constraints, drought concerns and technological change are supporting new approaches to infrastructure delivery and a more integrated approach to water management with a stronger focus on recycled water.

PPPs offer a means of satisfying public policy objectives and providing innovative infrastructure delivery particularly in the area of sewer mining as shown in this paper. However, there are significant barriers to the full development of a sewer mining industry. Firstly, public perceptions and concerns need to be addressed. This can be achieved through a public education campaign on a national level with a strong emphasis on allaying public health concerns and influencing consumer behaviour. Public education and acceptance remains critical. Experience in Melbourne shows that a high percentage of respondents were prepared to use greywater. Consistency in water pricing between potable and recycled water and educating the public in the true cost of water is a critical element in changing public perceptions and behaviour.

Secondly, there needs to be a closer coordination of policies and regulations governing water conservation and reuse. Industry stakeholders and regulators need to develop standards and performance indicators to keep pace with the rate of technological developments. There needs to be a cross fertilisation of engineering, behavioural, economic and environmental knowledge to provide an integrated approach to water management in general and water recycling in particular.

Thirdly, there needs to be a more critical approach to financial evaluations that take account of flexibility in decision making through the consideration of real options and the valuation of externalities. The recent heavy rains in Eastern Australia may have eased concerns about the drought but they give no grounds for complacency in providing for alternative water sources. Failure to develop recycling sources such as sewer mining leaves communities vulnerable to the ongoing vagaries of the environment and the maintenance of short-term ‘band-aid’ solutions.

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9. GLOSSARY

Main Sewers	trunk mains which drain to the ocean, usually ocean outfall sewers such as SWSOOS or NOOS typically concrete boxed sections with internal linings to protect against corrosion
Sewer Sub-main	750mm or larger, receives flow from carriers can be circular or box section concrete sewers with internal linings
Carrier Sewers	usually sewers 375-1200mm can be circular, or oviform pipe materials VC, CONC, brick or HOBAS
Reticulation Sewers	typically circular size 150-300mm; pipe materials VC, CI, PVC & PE
Bio-Solids	Nutrient-rich organic materials resulting from the treatment of sewage sludge
Trace Metals	Metals almost at the molecular level still present they can be toxic in excess quantities.
Trace Organics	Include endocrine disrupting chemicals and as such monitoring is very important
Endocrine disrupting chemical	a class of chemicals with potentially harmful effects on ecosystems
Biochemical Oxygen Demand (BOD)	a chemical procedure for determining how fast biological organisms use up oxygen
Pharmacological	Interaction between drugs and biological systems
Diurnal	Daily pattern of flow in the system

Appendix A – Pollutants

Table 9-1 Pollutants that may impact on human health (Hamlyn-Harris, 2001)

Inorganics	Organic Compounds	Pesticides	Volatile Organics	Disinfection Byproducts	Algal Toxins	Pharmaceuticals	Endocrine Disruptors
Aluminium Ammonia Arsenic Asbestos Barium Beryllium Boron Bromate Cadmium Chloride Chlorine dioxide Chlorite Chlorate Chromium Copper Cyanide Fluoride Sulphide Iodine/iodide Iron Lead Manganese Mercury Molybdenum Monochloramine Nickel Nitrate/nitrite Phosphates Selenium Silver Sodium Sulphate Tin Zinc	Acrylamide Chlorobenzene Dichlorobenzenes Epichlorohydrin EDTA Hexachloro-butadiene Nitrotriacetic acid Alkyl tins Phthalates PAHs Styrene Trichloro-benzenes Vinyl chloride monomer Chlorinated dioxins PCBs	Aldrin/Dieldrin Atrazine Chlordane 2,4-D DDT and metabolites Heptachlor & epoxide Lindane Endosulfan Organo-phosphates Chlorpyrifos Carbamates Fungicides Pyrethroids Organic mercurials	Benzene Carbon tetrachloride Dichloroethanes Dichloroethenes Dichloro methane Ethylbenzene Tetrachloro-ethene Toluene 111-trichloroethane Trichloroethylene Xylenes	Halogenated furanones Haloacetic acids Haloaldehydes Haloketones Chlorophenols Chloropicrin Cyanogen chloride Formaldehyde Haloacetonitriles Chloral hydrate Trihalomethanes **Radionuclides** Radium- 226 and – 228 Radon – 222 Uranium generated (Cs 137, Sr-90 etc) See also radio-pharmaceuticals	Microcystins Cylindro-spermopsin Saxitoxins Nodularin **Treatment byproducts from Algal toxins** Mycrocystin byproducts Cylindro spermopsin byproducts Saxitoxon byproducts	Radiopharmaceuticals Synthetic oestrogens/ Progesterones (oral contraceptives) – levonogestrel and ethynylestradiol Cardiovascular drugs • Beta blockers • Atenolol • Anticholosterol • Simvastatin Antibiotics • Cephalexin • Cefactor • Amoxycillin Analgesics • Paracetamol Sedatives • Temazepam H_2 receptor agonists • Ranitidine **Hormones** 17β estradiol Estron Testosterone	*These are a diverse group of chemicals and have been included under pesticides, organics metals, pharmaceuticals and hormones.*

Appendix B – Types of Technologies

A range of treatment technologies is available to remove the contaminants with the choice made being largely dependent on the quality water sought. Local climate is also important in the selection of suitable technologies. Some of the processes are listed below for removal of pathogens.

- Primary sedimentation, plain or primary sedimentation, coagulated
- Activated sludge and secondary sedimentation
- Trickling filter and sedimentation
- Contact filtration of secondary effluent
- Waste stabilisation ponds
- Chlorination or ozonation
- Septic tank and anaerobic filter
- Upflow anaerobic sludge blanket clarifier

Other wastewater treatments systems include anaerobic filters, anaerobic sludge blanket (UASB) clarifiers; trickling filters; vertical-flow soil filters ("constructed wetlands") and duckweed ponds. The Guideline *Use of Reclaimed Water* sets out the quality required of reclaimed water and extent of monitoring that might be anticipated for secondary and tertiary treated effluents for various potential uses. These include indirect potable, urban (non-potable), agricultural, aquacultural, recreational impoundment, environmental and industrial uses. No guidance is provided on direct potable use. Guideline values are suggested for various use applications, primarily for how reclaimed/recycled waters may be incorporated into irrigation programs. Although there are references to turbidity (to some extent an aesthetic consideration), and to pH, the suggested parameters are primarily expressed in terms of thermotolerant coliforms (also known as faecal coliforms). The coliform values are given in 9-2 Thermotolerant coliform standards for various recycled water use applications (Ratcliffe, 2004).

Table 9-2 Thermotolerant coliform standards for recycled water use applications

2.6.2.1.1 Recycled Water use application	Thermotolerant coliforms per 100 ml (median)
Non-human food chain	<10 000
Low contact, eg. Irrigation of open spaces with controlled public access	<1 000
Medium contact, eg. drinking water for stock (except pigs)	<100
High contact, eg. urban residential garden watering	<10

There are in essence three treatment processes for the treatment of sewerage, physical, chemical and biological. Combinations of the processes are used to achieve the required output water quality. The technologies include:

- Physical removal – screens, filters, separation and flotation
- Chemical treatment – coagulation and flocculation
- Biological removal anaerobic and aerobic – transform pollutants to more manageable forms for separation eg suspended growth systems and fixed growth systems – such as Biolytix foot print of ~5m^2
- Natural systems – wetlands and vermiculture – such as rootzone

Each of the processes has a number of steps requiring a specific technology resulting in a grade of water quality which in turn leads to the next step for higher quality water. The potential for pollutant removal for each technology category is detailed below in 9-3 Overview of treatment technologies and their pollutant removal abilities from Holt 2006.

Table 9-3 Treatment technologies and their pollutant removal abilities

	Suspended solids (TSS)	Biodegradable organics (BOD removal)	Nutrients: nitrogen	Nutrients: phosphorus[5]	Salts	Pathogens
Biological processes	Yes	Yes	Yes	Limited	No	Limited
Natural systems	Yes	Yes	Yes	Yes	No	Good
Recirculating media filter	Yes	Yes	Yes	Limited	No	Limited
Media filtration	Yes	Function of size	Limited	Limited	No	Limited
Membrane filtration	Yes	Function of size	Function of size	Function of size	Reverse osmosis only	Function of size
Membrane bioreactor	Yes	Yes	Function of size	Function of size	No	Function of size
Subsurface flow wetland	Yes	Yes	Yes	Yes	No	Good[6]
Disinfection	No	No	No	No	No	Yes

To further explore the broad groups of technologies available for water treatment, representative technology types are described. These technologies listed below provide an overview of the most common and applicable treatment systems available and include;

Activated sludge is a suspension of microorganisms in water which are activated by air that provides oxygen and hence the activated sludge process is an aerobic suspended-growth process. There is usually two phases; aeration followed by the settling.

Fixed growth treatment systems are primarily used to remove dissolved and colloidal organic matter from water. Fixed growth refers to systems where the microorganisms are attached to a surface that is exposed to the water.

Recirculating textile filters (RTF) and recirculating sand filters (RSF) are other biological treatment processes which remove organic material from the wastewater. Recirculating textile filters are similar to trickling filters, however the media used for the growth of biofilms are textiles rather than plastics or rocks. RTFs are available in small compact footprint package plants, suitable for decentralised treatment. These technologies consist of two major components, a biological chamber and low-pressure distribution system. The wastewater flows between and through the non-woven lightweight textile material in the RTF and through a bed of sand in the RSF.

Natural systems include subsurface flow wetland. In subsurface flow wetlands, all the flow is through the soil substrata. The soil typically has a high permeability and contains gravel and coarse sand. The bed is planted out with appropriate vegetation. As the flow percolates through the wetland, biological oxygen demand (BOD) and total suspended solids (TSS) are predominately reduced by biological decomposition.

Subsurface wetlands are typically applied in wastewater treatment systems where there is a relatively consistent influent flow rate. Subsurface flow wetlands provide a low cost, very low energy, natural treatment system.

Filtration is a tertiary treatment process that typically occurs after the secondary biological process. Filtration may be required to remove residual suspended solids and organic matter for more effective disinfection. Filters have been used for water treatment for more than 100 years. Sand (or other media) filters typically treat settled wastewater effluent.

Membrane filtration is a physical separation process to filter pollutants using a semi permeable media. There are four classes: microfiltration has the largest pore size, decreasing to ultrafiltration, nanofiltration and reverse osmosis. As water is passed through a membrane under pressure, it 'squeezes' through the structure and the membrane traps larger pollutants. Membrane filtration processes can remove particles, bacteria, other microorganisms, particulate matter, natural organic matter and salt (desalination), with removal determined by the membrane's pore size.

The smaller pore size requires greater pressure and greater energy requirements for effective treatment. Reverse osmosis (RO) is the finest membrane filtration process with the smallest pore size (about the size of a molecule) and the highest pressure requirements. RO removes most pollutants including pathogens, viruses and salts. It is typically used for sewer mining or desalination.

A membrane bioreactor (MBR) combines the process of a biological reactor and membrane filtration. The treatment process has a small footprint and produces high quality effluent with low TSS, BOD, and turbidity that meets almost all health criteria guidelines. There are two basic configurations for a MBR: a submerged integrated bioreactor that immerses the membrane within the activated sludge reactor and a bioreactor with an external membrane unit.

Disinfection destroys pathogenic microorganisms in water to ensure public health. Eradication of waterborne pathogens is the most important public health concern for water treatment. Disinfection ranges from boiling water to large-scale chemical treatment for water supplies. The three most common disinfection methods are ultraviolet radiation, chlorination and ozonation.

There is a large range of existing specific technologies which include:

- Activated sludge
- Aerobic granular reactor
- Anaerobic clarigester
- Anaerobic digestion
- Anaerobic lagoon
- Bioconversion of biomass to mixed alcohol fuels
- Biolytix
- Carbon filtering
- Cesspit
- Combined sewer
- Composting toilet
- Constructed wetland
- Dissolved Air Filtration Flotation
- Distillation
- Electrocoagulation
- Electrodeionization
- Electrolysis
- Expanded granular sludge bed digestion
- Floculation
- Flotation process
- Imhoff tank
- Iodine
- Ion exchange
- Living machines

- N-Viro
- Reverse osmosis
- Reed bed
- Septic tank
- Sequencing batch reactor
- Sewage treatment
- Ultraviolet disinfection
- Upflow anaerobic sludge blanket digestion
- Wet oxidation

Appendix C – Water Recycling Regulations

All following tables sourced from Radcliffe (2004)

Table 17A Comparison of Water Recycling regulations Class A recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class A (Highest Quality)				
QUALITY **Thermotolerant coliforms:<10 org/100ml (median)** Turbidity: ≤2 NTU (mean), 5 NTU (max) pH 6.5-8.5 (90 percentile) Cl_2 residual: 1mg/l after at least 30 minutes contact time or equivalent level of pathogen destruction Consider salinity controls	<10 *E. coli* org/100mL Turbidity < 2NTU (24 hr median), < 5 NTU (max) <10mg/L BOD <5mg/L Suspended Solids pH 6 – 9 (90 percentile) Cl_2 residual: >1mg/l after at least 30 minutes contact time where human contact, <1mg/L at point of use. <10 *E coli*/100mL, < 1 helminth/L, <1 protozoa / 50L, & <1 virus / 50 L	<10 *E. coli* org/100mL (median) Turbidity < 2NTU BOD < 20mg/L Specific removal of viruses, protozoa and helminths may be required. (Treat Class A reclaimed water to reduce the risk of infection of all types of human pathogens) Chemical content to match use.	**<10 median thermoltolerant coliforms / 100mL** pH 5.5 – 8.0 BOD < 10 mg/L Nutrient, toxicant and salinity controls	**Total coliforms <2.2 org/100mL (median over last 7 days)** <23 org/100mL (in any 30 days, maximum 1 exceedence) ≤ 240 org/100mL (at any time) Tubidity: if using conventional filter loaded no greater than 12m/hr, ≤ 2 NTU (24 hr median), ≤5 NTU (95% over 24 hr period), ≤ 10 NTU (at all times). Chemical dosing not required prior to filtration if influent:- ≤ 2 NTU (24 hr median), ≤5 NTU (no exceedences > 15 mins.) ≤ 10 NTU (at all times), and a back-up chemical dosing is available If using membrane filtration:- ≤ 2 NTU (24 hr median), ≤5 NTU (at all times)
PERMITTED USES Indirect potable groundwater recharge by spreading or injection Municipal with uncontrolled public access Residential non-potable Raw human food crops in direct contact with reclaimed water eg via sprays, irrigation of salad vegetables	Urban (non-potable) with uncontrolled public access Agricultural – *eg* human food crops eaten raw Industrial – open systems with worker exposure potential	Primary contact recreation; Residential non-potable – garden watering, toilet flushing, car washing, path/wall washing; Municipal use with public access/adjoining premises Dust suppression with unrestricted access Unrestricted crop irrigation	Indirect potable groundwater recharge by spreading or injection; Non-potable municipal irrigation (uncontrolled access); Urban non-potable (general household use); Fire and water protection systems; Agricultural – direct contact of reclaimed water with crops consumed raw; Stream augmentation and groundwater recharge; Urban use (garden watering and toilets); Aquaculture (human food chain); other uses subject to approval	Surface irrigation of food crops (including edible root crops) where the edible portion is in direct contact with reclaimed water; Surface irrigation of unrestricted golf courses, parks and playgrounds, school yards, residential landscaping; Recreational impoundment (unrestricted access); flushing toilets and urinals; Decorative fountains; artificial snow making; commercial car washes; structural fire fighting; unrestricted access industrial process water.
TYPICAL TREATMENT Tertiary with pathogen reduction. May need nutrient reduction for groundwater recharge.	**Tertiary treatment & pathogen reduction with sufficient log reductions to achieve above.** Where schemes pose a significant risk of direct off-site movement of reclaimed water, nutrient reductions to nominally 5mg/L total N and 0.5 mg/L total P will be required. Dept Health Services endorsement of plant	Full secondary + tertiary filtration + full disinfection. Coagulation may be required to meet water quality requirements	Coagulation, flocculation, advanced filtration and other best practice treatment processes to remove nutrients, sediments and other contaminants. Disinfection: MF, UV, ozonation and chlorination. Chlorination best practice if residual required to prevent bacterial regrowth	

* The Australian System (NWQMS 2000) does not use categories. The categorisation is expanded from SKM (2000).
† This summary is from SKM (2002).

Table 17B Comparison of Water Recycling regulations Class B recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class B (or 2nd highest quality)				
QUALITY Thermotolerant coliforms < 100 org/100mL (median) PH: 6.5 – 8.5 (90 percentile)	<100 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile) Treatment includes Helminth reduction for cattle grazing use schemes	<100 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Specific removal of viruses, protozoa and helminths may be required. (Class B-D use depends on use – *eg* Helminth *Taenia saginata* represents risk to cattle (beef measles) and should not be in reclaimed water used to irrigate pasture or stock water for cattle) Chemical content to match use.	<1000 median thermotolerant coliforms/100mL (<100 thermotolerant coliforms/100mL in special cases – stock drinking standard – applies for pastures and fodder crops (dairy and non-dairy) without withholding period pH 5.5 - 8.0 BOD < 50mg/L Nutrient, toxicant and salinity controls	**Total coliforms <2.2 org/100mL (median over last 7 days)** <23 org/100mL (in any 30 days, maximum 1 exceedence)
PERMITTED USES Indirect potable (surface water) Crops to be consumed raw but not in direct contact with reclaimed water (edible product separated from contact with effluent *eg* By peel or use of trickle irrigation or crops sold to consumers cooked or processed Pasture and fodder for dairy animals without withholding period Drinking water for all stock except pigs	Agricultural eg Dairy Cattle grazing Industrial *eg* Washdown water	Secondary contact recreation; Ornamental ponds with public access; municipal use with restricted access; Restricted crop irrigation; Irrigation of pasture and fodder for grazing animals; Washdown and stockwater; Dust suppression with restricted access; Fire fighting	Crops for human consumption; Crops to be consumed raw but not in direct contact with reclaimed water (edible product separated from contact with effluent *eg* By peel or use of trickle irrigation or crops sold to consumers cooked or processed; Pasture and fodder (no pigs or poultry); for grazing animals withholding period applies – 5 days for dairy (unless <100 thermotolerant coliforms/100mL applied), 4 hour for non-dairy; Non-potable municipal irrigation with controlled access	Surface irrigation of food crops where the edible portion (above ground) is not in direct contact with the reclaimed water Recreational impoundment Fish hatcheries
TYPICAL TREATMENT Secondary with pathogen reduction. Indirect potable (surface water) should comply with raw drinking water standards	Secondary treatment and pathogen reduction	Full secondary + disinfection	High rate processes such as activated sludge, trickling filters. Lagoon treatment with separate polishing lagoons is acceptable for < 1000 thermotolerant coliforms /100mL Disinfection – chlorination, UV and ozonation. Detention lagoons will not be sufficient if a concentration of < 100 thermotolerant coliforms/100mL is required.	

Table 17C Comparison of Water Recycling regulations Class C recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class C (or 3rd highest quality)				
QUALITY Thermotolerant coliforms <1000 org/100mL (median) PH: 6.5 – 8.5 (90 percentile)	<1000 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile) Treatment includes Helminth reduction for cattle grazing use schemes	<1000 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Specific removal of viruses, protozoa and helminths may be required. (Class B-D use depends on use – *eg* Helminth *Taenia saginata* represents risk to cattle (beef measles) and should not be in reclaimed water used to irrigate pasture or stock water for cattle) Chemical content to match use.	<10000 median thermotolerant coliforms/100mL pH 5.5 - 8.0 BOD < 80mg/L Nutrient, toxicant and salinity controls	**Total coliforms <23 org/100mL (median over last 7 days)** <240 org/100mL (in any 30 days, maximum 1 exceedence)
PERMITTED Raw human food crops not in direct contact with reclaimed water, or crops sold to consumers peeled, cooked or processed Pasture and fodder for grazing animals (except pigs and dairy animals) with 4 hr. withholding period Pasture and fodder for dairy animals with 5 day withholding period Municipal with controlled public access (4 hr. withholding period) Ornamental water with no contact and restricted access Mines, dust suppression	Urban (non-potable): with controlled public access Agricultural: eg human food crops cooked/processed, grazing/fodder for livestock Industrial: systems with no potential worker exposure	Passive recreation, Municipal use with restricted access Restricted crop irrigation Irrigation of pastures and fodder for grazing animals	Agriculture (non-human food chain, *eg* forestry, cotton) Industrial processes (closed system) Non-human food chain aquaculture	Surface irrigation of ornamental nursery stock and sod farms with unrestricted public access Surface irrigation of pasture for grazing animals producing milk for human consumption. Surface irrigation of cemeteries, freeway landscaping and restricted access golf courses, Ornamental water with no decorative fountain, Non-structural fire fighting. Dust control Road/footpath cleaning Restricted access industry process water.
TYPICAL TREATMENT Secondary treatment and pathogen reduction	Secondary treatment and pathogen reduction	Primary sedimentation + lagooning or Full secondary (Disinfection if required to meet microbial criteria only)	Lagoon based systems No additional disinfection required	

Table 17D Comparison of Water Recycling regulations Class D recycled water

AUSTRALIAN NATIONAL RECYCLING GUIDELINES*†	VICTORIA (EPA 2003)	SOUTH AUSTRALIA (DHS 1999)	TASMANIA (Dettrick 2003)	CALIFORNIA - Title 22†
Class D (or lowest quality)				
QUALITY Thermotolerant coliforms <10000 org/100mL (median) pH: 6.5 – 8.5 (90 percentile) For aquaculture, salinity TDS < 1000mg/L, < 10% change in turbidity (seasonal mean conc.), May need dissolved oxygen controls for fish, zooplankton	<1000 *E. coli* org/100mL <20 mg/L BOD <30mg/L Suspended Solids pH 6 – 9 (90 percentile	<10000 *E. coli* org/100mL (median) BOD < 20mg/L Suspended Solids < 30mg/L Helminths need to be considered for pasture and fodder. Chemical content to match use	No Class D	Total coliforms: No limit specified Suspended Solids: None specified but assume ≤ 39mg/L BOD: None specified but assume ≤ 20mg/L
PERMITTED USES Silviculture, turf, cotton etc. with 4 hour withholding period Aquaculture – non-human food chain Stream augmentation	Agriculture: Non-food crops including instant turf, woodlots, flowers	Restricted crop irrigation, irrigation for turf production, silviculture, non food chain aquaculture		
TYPICAL TREATMENT Secondary treatment and pathogen reduction (Pathogen reduction is site-specific for streams as required)	Secondary treatment	Primary sedimentation + lagooning or Full secondary		

Table 28. State/territory based structures for plumbing (Technical Solutions) (Workman, Herbert and Tink 2003).

New South Wales	Victoria	Queensland	South Australia	Western Australia	Tasmania	ACT	Northern Territory
On site Regulations Sydney Water Act 1994, Hunter Water Corporation, Sydney Water Corporation, Aust. Inland Energy and Water, other water authorities and local councils, NSW Code of Practice Plumbing and Drainage, Different authorities call up different versions of AS/NZS3500 **Wastewater** (additional regulatory groups include NSW EPA, Sydney Health, local government.) **Occupation Licensing** NSW Dept of Fair Trading	**On site regulation** Plumbing Industry Commission (PIC), All work must comply with AS/NZS 3500 **Wastewater** (Additional regulatory bodies include Victorian EPA, Dept Health/Human Services, Local Government.) **Occupation Licensing** PIC with processes supported by the Australian and New Zealand Reciprocity Association Agreement	**On site regulation** Building Codes of Queensland Local Government Councils regulate plumbing works **Wastewater** (Additional regulatory groups include Qld. EPA, ecoaccess, local government.) **Occupation Licensing** Plumbers and Drainers Examination Licensing Board	**On site regulation** South Aust. Water Corporation administered by Development Services Branch **Wastewater** (Additional regulatory groups include Department of Human Services, local government.) **Occupation Licensing** Commissioner for Consumer Affairs	**On site regulation** Water Corporation of WA. Technical regulatory role with transfer of Plumbing Licensing Board and the Office of Water Regulation **Wastewater** (Additional regulatory groups include local government) **Occupation Licensing** Water Corporation will transfer to Plumbing Licensing Board	**On site regulation** Dept of Infrastructure, Energy and Resources (legislation and regulations), Local Government councils (issue permits and certification of completion of plumbing works.) **Wastewater** (Additional regulatory groups include local government.) **Occupation Licensing** Plumbers and Gasfitters Registration Board.	**On site regulation** Building, Electrical & Plumbing Control (BEPCON), ACT Dept. Urban Services **Wastewater** (Additional regulatory groups include Environment ACT and Urban Services.) **Occupation Licensing** Plumbers Drainers and Gasfitters Board	**On site regulation** The Building Advisory Services branch of Lands, Planning and Environment **Wastewater** (Additional regulatory groups include local government.) **Occupation Licensing** Plumbers and Drainers Licensing Board, administered by Dept of Industries and Business.

Source – Commonwealth Dept. Industry, Science and Resources (2000) "Future options for Plumbing and Drainage Regulation in NSW February 2002 – NSW Interagency Committee on Plumbing Regulation Reform

AUTHOR BIOGRAPHIES

Mr. Stephen McFallan

Stephen McFallan is a statistical and modeling researcher with the CSIRO Division of Sustainable Ecosystems. His research interests lay in the area of sustainable urban environments, particularly the lifecycle impacts of urban development. Some of his models have been adopted by Government agencies and have led to reduced expenditure on maintenance and enabled strategic allocation of funding for improved portfolio outcomes.

Stephen has contributed to research covering topics as diverse as innovation in the construction industry, service provision in remote desert communities, development of models to estimate the impact of climate change on water demand for current and future integrated water supply options, lifecycle models for forest and wood products and development of tools to aid decisions toward future sustainable urban development.

Mr. Ian Logan

Ian Logan is studying part time for a Masters in Business by research at Queensland University of Technology. He works full time for Brisbane City Council in the Corporate Finance area. The views expressed in this paper are personal and do not represent Brisbane City Council