Appendix 1 – Craig Brown's NZLTC conference paper on water recycling

Recycled Water:
Risks, benefits, economics and regulation by system scale

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PLEASE NOTE:

In the conference proceedings, the payback period of the NZ greywater system is incorrect in Table 3 and the first paragraph of the discussion. It is correct in this copy of the paper.

Recycled water – risks, benefits, economics and regulation by system scale

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ABSTRACT

Wastewater recycling to any treatment standard is technically possible. The optimal level of treatment, avoiding unnecessary costs but maintaining public health, will vary according to the potential health risks, the sources of the water and the end uses. In turn these are primarily a factor of the scale of the recycling system, whether on-site, decentralised or reticulated. Smaller scale systems are inherently less risky as greater source control can be exercised and the population is small and already exposed to potential pathogens. A quasi-epidemiological study and literature review add weight to the scientific data that underpin this fact. Larger scale recycling needs very high treatment standards to mitigate against the greater risks, negating the economy of scale that pertains to the treatment process. The cost of the distribution network with large-scale systems is prohibitively expensive in many cases, whereas on-site systems are suited to a wider range of circumstances, having very short pipe runs. However, the cost advantage can be lost when additional costs are imposed by over-regulation, skewing the market towards less efficient alternatives for no appreciable benefit. It is argued that specific water quality standards are not required for on-site systems as adequate risk mitigation can be achieved by controlling (amongst other things) the water sources and end uses, as outlined in the Australian guidelines for water recycling.

KEYWORDS: Wastewater recycling, greywater recycling, costs/benefits, risks, scale, public health

INTRODUCTION

There has been increasing interest in recycling wastewater, especially in Australia, Japan, USA, Israel and Germany. Being a relatively new pursuit, there are many theories about the safest and most efficient way to achieve it. There is an influential view that centralised systems are cheaper and more efficient, giving economies of scale, whilst on-site systems carry greater risk due to a lack of expert control. An alternative viewpoint is that decentralised systems are more resilient, save on infrastructure costs and can utilise simpler technology, providing monetary, materials and energy savings.

Whilst this debate has been on-going, the public, especially in Australia, has been increasingly taking matters into its own hands and recycling its own greywater, quite outside of the regulations which have been hurriedly introduced in most cases. Over half of the Australian population now recycles greywater, very few with an ‘approved’ system. Meanwhile most Australian states are spending vast sums of money on reticulated water recycling schemes, as well as other water supply projects. It is suggested that most of this activity has been undertaken without a full understanding of the influence of system scale on safety and cost.

So what is the most cost effective scale and which is the safest? This paper has assumed that there are three scales of water recycling to supply domestic households, as follows:

1) **On-Site:** on-site, single domestic dwelling;
2) **Local:** on-site, multi-tenant (e.g. apartment block) *and*
decentralised/clustered (e.g. small subdivision);
3) **Central:** centralised/reticulated.

The two types of Local systems, though they may be technically different, are sufficiently similar in impact, likely risk and size of population to be considered as one. This paper investigates the potential health impacts and costs at these different system scales.

A key assumption is that where it is possible to separate out the waste streams, this is preferable because it leads to recycling which is easier, cheaper, less energy/resource intensive, more conservative of nutrients, etc. (Zeeman *et al.*, 2008). E.g. greywater requires less effort to recycle to a certain standard than a combined waste stream. Greywater (excluding the kitchen) represents over 60% of the water that would otherwise be in a combined waste stream and has less contamination with microorganims, organic matter, nutrients and chemicals (including pharmaceuticals). If separated, the other waste streams can also be treated more efficiently, either by dry composting of faeces and urine separation, or indeed by septic tank. It has been shown that septic tanks and trenches perform significantly better when the hydraulic load is reduced, both in terms of improved settling and decomposition inside the tank and in longer field life due to reduced clogging of trenches (Lismore City Council, 2001).

Thus simple, inexpensive, septic tanks, which have lower embodied energy, lower lifecycle costs and fewer components to maintain and replace, may again be considered viable where in recent times they have been 'superseded' by more technical systems. Equally, of course, retrofitting of a greywater recycling system has been shown to remediate failing on-site wastewater systems (Sorensen, 2003). This example is given to highlight the wide range of factors which could influence choice of recycling system, but for this paper to be of more general use, it is necessary to consider just two major factors: health impact and cost. Local conditions can then be overlaid on the findings as appropriate.

METHODS

A literature review was undertaken to find examples of problems with water recycling to households and to find the costs on a per-household basis. These are presented according to system scale.

No evidence was found for on-site greywater-related health impacts in the literature, although there were many instances of concern being expressed about the possibility of health impacts. Given the lack of evidence but high level of concern, a quasi-epidemiological study was undertaken, to determine if any trend could be discerned relating levels of greywater use (which was surveyed in 2007 in Australia and partially surveyed in 2008 in New Zealand) to levels of notifiable waterborne diseases in either country (in 2007).

Clearly a 'gold-standard' study designed to compare disease ratios between users of greywater and those that do not use it would need to survey these factors specifically, i.e. obtaining disease data and exposure to greywater data at the same time, rather than on a population basis only. By comparing between Australian states there are many confounding factors, such as socioeconomic status and climate. Nonetheless, a large portion of the population recycles greywater in Australia, so any trend of any significant magnitude, should be discernable as a positive correlation between greywater use and incidence of disease.

Separately from this, a cost-benefit analysis was undertaken using the methodology described in Brown (2007) and Brown (2007b), but using up-to-date data, including the current cost of the systems, current typical five year mortgage rate (6.50%) as the discount rate and the current cost of water (in Auckland City). It should be noted that the average number of occupants of a dwelling was taken to be 4, a number chosen to approximate the average occupancy rate in Auckland City once an adjustment had been made to exclude lower occupancy apartment buildings that are less suited to on-site systems. In the standard scenario, $1500 was added to the system cost for installation and consent fees. However an alternative scenario was generated in which the current preferential conditions for solar hot water systems were applied (i.e. no resource consent required, waived building consent fee, and a grant of $1000), on the basis that it may be considered beneficial to encourage greywater reuse in the future and that this is a reasonably equivalent item.

The internal rate of return (IRR) was calculated, assuming a 20 year life (the expected life of the systems). The IRR was also calculated for a seven year period, reportedly being the average time that a home is held by one owner (personal communication with Eco Design Advisor for Auckland City).

The financial data in the literature were in many different formats and often incomplete, making comparison difficult. In the absence of quality cost-benefit analyses of Local and Central scale systems a crude estimation was made of purchase and operational costs for each household served at those levels, based on the data obtained. A calculation of net present values at each scale was also made, with the assumption that the Local scale has 2 residents per unit (being high density housing) and the Central scale has 2.5 residents per dwelling (being the average for Australia; ABS, 2008). The estimated purchase price and operational costs were used as the basis for the calculations. All other variables were kept the same as for the On-site scale.

RESULTS

Problems with recycled water / Potential health issues

Central

Prior to commissioning the system at Rouse Hill in Sydney (the largest urban recycled water scheme in Australia) a systematic approach was taken to verify main to meter, meter to house and internal house plumbing for every property prior to commissioning the scheme. About fifty direct cross-connections and several hundred significant plumbing errors were identified and rectified through this work (De Rooy and Engelbrecht, 2003). Despite this systematic approach to inspection, there have been four cross-connections discovered since in Rouse Hill, three pertaining to individual households and one affecting 82 homes (Storey *et al.*, 2007). Significant quantities of recycled water can be assumed to have been ingested in each case.

The current Australian standard allows for 1 in 1,000 properties to be cross-connected every year and the Rouse Hill development has achieved around 1 in 10,000, but this high likelihood of cross-connection means that all water must be treated to a more or less potable standard (microbiologically at least; chemicals and prions etc. may not be removed). There has also been a cross-connection in the Sydney Olympic Village water recycling scheme (Sydney Water, 2005) which affected two houses and wasn't detected until 2005, despite a complaint about water quality by one of the residents in 2002.

In addition to this, there are a large number of residents at Rouse Hill who are unaware of the fact that they are using recycled water and there have been anecdotal reports of accidental and even deliberate consumption of recycled water. Also, it has not been feasible to put a taste or colour into the water so cross-connections may be difficult to detect (Storey *et al.*, 2007).

Melbourne Water recently accidentally connected low grade recycled water to the drinking water tap in one of its administration buildings, leading to illness affecting at least 12 staff (Borensztajn, 2007).

At Utrecht in the Netherlands 4500 houses were provided with a supply of undisinfected river water for car washing, laundry, toilet flushing and garden watering. Two major cross-connections with the potable water system, including one that affected 950 houses, and numerous cross-connections within houses were subsequently detected, but not before an outbreak of gastrointestinal disease. The Netherlands government subsequently banned the use of dual supply systems for laundry reuse and external taps (AATSE, 2004). However it is still permissible for an individual household to recycle water for toilet flushing.

A business park in California, which included two food businesses, was accidentally supplied a mix of 20% recycled water and 80% potable water for two years (from opening) through the drinking water system. When the water utility expanded its recycled water programme it switched to 100% recycled water and the error was detected (Health Stream News, 2007).

Local

At the New Haven estate in Adelaide, 5% of the surveyed residents were unaware of the fact that they were using recycled water (for toilet flushing and garden watering) and all of them reported occasional problems, such as odour, murky colour, cutting off of water and clogging of irrigation equipment. Although sub-surface irrigation was stipulated, the public spaces and show homes were all spray irrigated (Marks *et al.*, 2003).

On-site

Examples were found of health authorities citing operator neglect (failing to perform maintenance) and the presence of indicator organisms in on-site greywater systems (e.g. Leonard and Kikkert, 2006) as causes for concern. However, no examples of actual illness being caused by on-site water recycling systems could be found in the literature. The fact that no cases have been reported does not mean there has been no illness, although the present author believes that the dire warnings about on-site greywater recycling do not match up to the reality of many years of practise for the following reasons:

- Unlike reticulated water systems which cover large populations, indicator organisms don't indicate the presence of pathogens as none may exist in the system
- Restricting the water sources (i.e. no blackwater) reduces potential pathogen input to the system by 99.9% (Ottosson, 2004). Avoiding kitchen wastewater will reduce this further

- Indicators over-estimate the likelihood of pathogen presence by a large factor (approximately 1,000 times) in greywater due to multiplication of indicators and die-off of pathogens (WHO, 2006)
- Restricting end uses of the greywater to low contact activities limits the opportunity for pathogens to exit the system in such a way as to infect others
- Many more direct pathways for infection exist within the population, which is not significantly more exposed when greywater is recycled within the individual lot

See Brown (2007) and Brown (2007b) for a more detailed discussion of these issues.

Comparison of greywater use and notifiable disease rates

The Australian Bureau of Statistics (2007) reported that "in 2007, greywater was the second most common source of water for households, after mains/town water. More than half (54.7%) of Australian households reported greywater as a source." (see *Fig 1*).

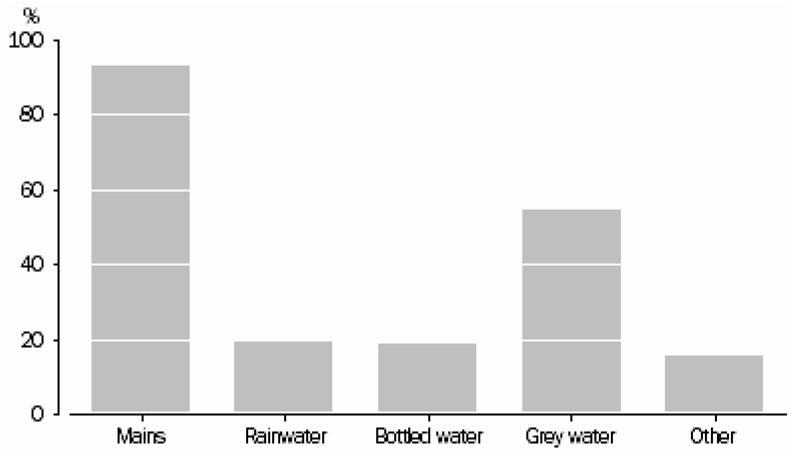

Fig 1. Sources of water for households in Australia.

Table 1 shows this data by state (Australian Bureau of Statistics, 2007). The highest percentage was in Victoria, with 71.7% of households reporting greywater as a source and the lowest was in the Northern Territory at 32.2%.

In New Zealand, the Ministry for the Environment's sustainability benchmarking survey (Research NZ, 2008) found that 10% of the population regularly reused the water from their washing machine, which was the only greywater-related question asked. The Australian survey was wider and asked about water from the shower/bath, laundry or kitchen, that households collected for reuse. Thus the NZ data will underestimate the percentage of the population reusing greywater and a direct comparison cannot be made. On Waiheke Island, an Auckland Regional Council (2008) survey found 36.7% of the population reusing greywater, which is likely to be higher than the national average due to high levels of local interest.

Table 2 shows the rates of notifiable disease for Australia as a whole (average) and for New Zealand as well. Clearly there are factors which result in substantially differing rates of waterborne disease in different areas, but there does not appear to be a trend towards increased rates of disease as rates of on-site greywater recycling increase.

Table 1. Incidence (per 100,000) for a range of potentially greywater-borne diseases by state. Use of greywater as a percentage of population also shown. All data are for 2007. Note: Campylobacteriosis is not notifiable for NSW. (Department of Health and Aging, 2009).

Disease	NT	TAS	WA	NSW	QLD	SA	ACT	VIC
Campylobacteriosis	136.3	144.5	99.7	--	106.1	169.4	123	80.9
Cryptosporidiosis	52.1	7.5	28.9	7.9	10.3	28.3	2.6	13.4
Salmonellosis	246.1	45.4	46.9	37.1	56.6	55.5	32.4	45.4
Typhoid	1.4	0.6	0.4	0.5	0.1	0.4	0.4	0
Cholera	0	0	0	0	0	0.1	0	0
Shigellosis	81	0.6	4.9	1	2.1	4.2	0	2.9
Legionellosis	0.4	0.6	3.9	1.5	1.2	1.1	1.2	1.5
STEC, VTEC	1.4	0	0.1	0.3	0.6	2.6	0.3	0.5
Hepatitis A	2.3	0.6	1	0.9	0.7	0.3	0.6	0.8
Hepatitis E	0	0	0	0.1	0.1	0	0.3	0.1
Percentage of population collecting greywater	**32.3%**	**37.0%**	**43.2%**	**46.7%**	**54.1%**	**54.3%**	**63.1%**	**71.7%**

Table 2. Incidence of diseases for Australia vs New Zealand (2007). Note: there was only one cholera case in NZ and Hepatitis E is not notifiable in NZ. (Department of Health and Aging, 2009; ESR, 2008).

Disease	Australia	New Zealand
Campylobacteriosis	80.9	317.2
Cryptosporidiosis	13.4	22.9
Salmonellosis	45.4	31.6
Typhoid	0.4	1.2
Cholera	0	--
Shigellosis	2.9	3.1
Legionellosis	1.5	1.7
STEC, VTEC	0.5	2.5
Hepatitis A	0.8	1
Hepatitis E	0.1	--
Percentage of population collecting greywater	**54.5%**	**10% *to* 36.7%**

Any trend associating higher greywater use with higher incidence of disease would be characterised by an increase in incidence from left to right on the graph (see *Fig 2*). Certainly any trend that might exist is dwarfed by other factors.

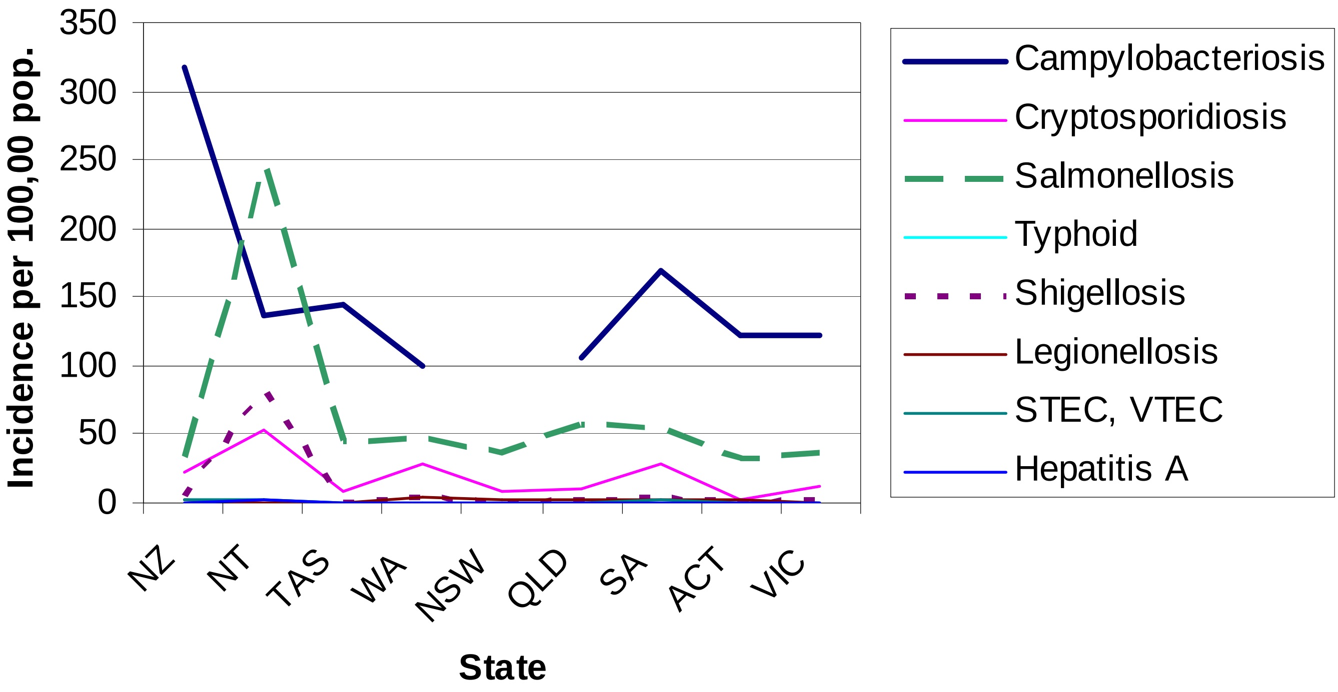

Fig 2. Disease rates by Australian state and NZ.

Costs

Central
(figures in Australian Dollars)

The Rouse Hill recycling scheme in Sydney cost around $4/kL in operating costs. As a comparison, the cost of potable water to the consumer was 98c/kL and the cost of production would be less than that, to allow for profit. It was estimated that total costs would be more than double the unit costs. Notwithstanding this, the recycled water was sold to the consumer at a cost of just 27.5c/kL (PMSEIC, 2003), though this has risen to $1.61 and is now fixed at 80% of the potable water price.

The State of Victoria's Department of Sustainability and Environment (DSE, 2003) estimated that it would cost around $15 billion to retrofit Melbourne with a 'third-pipe' system for delivering recycled water (which was about $11,310 per dwelling, not adjusted to today's value). The report also stated that there would be significant operational costs and increased energy consumption from pumping and treatment, leading to increased greenhouse gas emissions (energy demands can be in the order of 4,000kWh/ML; White and Turner, 2003). If 'third-pipe' developments were only applied to greenfield developments close to WWTPs the (unadjusted) cost per lot would be between $3,400 and $5,500, plus increased operational costs and energy use.

Mawson Lakes (a greenfield development in Adelaide) has a water recycling system which cost $16 million (Hill, 2005) to install, a cost of around $4,000 per household. This relatively low cost is achieved by utilising an existing aquifer for the storage of treated wastewater, and stormwater from a nearby wetland.

Southern Adelaide has recently announced that $62.6 million will be spent to recycle wastewater to 8,000 new homes (Wong *et al.*, 2009). The cost would thus be $7,825 per household. It should be said that some sources state that up to 20,000 homes could eventually be served, but no details of additional costs or likelihood are supplied.

Fukuoka City, Japan, has supplied a 7.7km^2 area with recycled water (of a relatively low quality and with no checks on cross-connections, which are assumed not to occur) since 1980. The water costs $3.13/kL to produce, compared with $2.93/kL for drinking water and its use is mandated for large buildings (Ogoshi *et al.*, 2001).

Local

(figures in Australian Dollars)

A combined stormwater and greywater recycling system in St. Kilda, Melbourne (the Inkerman Oasis project) cost $654,428 to install in 2002/3, comprising a grant of $267,214, which was matched by the developer, and a $120,000 contribution from the water company (Port Phillip Online, 2008). The system services 236 apartments, at a capital cost of $2,773 per apartment. The system provides irrigation water and toilet flushing water for the development. It only collects greywater from 140 of the apartments.

An Israeli study (Friedler and Hadari, 2006) found that with Israeli water prices a greywater system became feasible in an apartment block of 27 or more flats. At US water prices it would require 76 flats and at German water prices it would require 15 flats. Auckland City prices are marginally higher than the German prices once the wastewater component, which is charged on a usage basis, is included (i.e. $4.14/kL).

On-site

(figures in New Zealand Dollars)

Fig 3 shows the Net Present Value of the system that conforms with current NZ regulations ('NZ') and that which conforms with current New South Wales regulations ('Aus'), plotted against years of operation (systems with the benefits accorded solar hot water systems are also plotted, marked as 'sol').

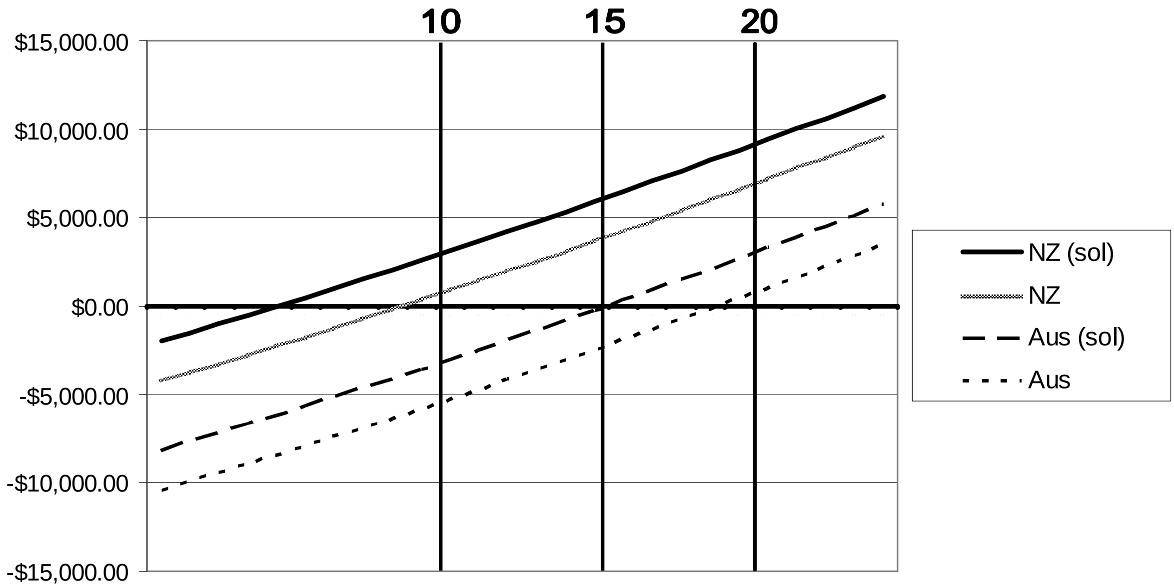

Fig. 3. NPV curve for NZ and AUS greywater systems.

Table 3. Net present values, payback periods and internal rate of return assuming 20 or 7 years of use (rates in brackets are losses).

	NZ	Australian	NZ (as per solar)	Australian (as solar)
NPV	$6,568.04	$430.04	$8,818.04	$2,680.04
Payback	<9 years	<20 years	<5 years	<16 years
IRR 20 yrs	17.86%	6.90%	33.16%	9.45%
IRR 7 yrs	1.74%	(16.20%)	23.77%	(11.90%)

Costs Summary

(figures in New Zealand Dollars)

A summary of the findings relating to cost can be found in *Table 4.*

Table 4. Cost of greywater system per household/unit (includes consent and installation costs). Numbers in brackets represent a loss.

	On-site	Local	Central**
Purchase cost	$4,250	$3,550*	$7680
Operational cost (per annum)	$65	$108*	$269 (estimated)
Net Present Value	$6,568	$1,024	($3,438)

* - figure based on limited information

** - prices based on approx. average of existing schemes

DISCUSSION

The cost-benefit data for the on-site systems clearly show that a greywater system meeting the current New Zealand regulations is a good investment for a typical household, paying back in under 9 years (or under 5 if the same system of regulation and incentives was applied as is available to the solar hot water industry). If the New South Wales regulations were introduced, it would become less financially attractive unless the system was going to be owned for nearly 20 years or more or there is some appreciation in housing value as a result. According greywater systems the same conditions as solar hot water systems makes the total investment more attractive by reducing the capital cost and the length of time to pay back.

Care should be taken in interpreting the Local and Central scale data, due to the crudeness of the calculations, but if accurate, it shows that it can be affordable to install a greywater system at a Local scale as well, with a positive net present value for the scheme assessed. Centralised water recycling schemes however are unlikely to be a good investment except in very specific locations and circumstances. The average centralised scheme costs in excess of $10,000 more than the on-site system per household served over the course of its life.

Of course the above analysis has not costed any externalities such as health or environmental benefits or costs, or indeed deferred infrastructure investments or reduced operational costs at wastewater treatment plants. Some of these will be consistent across system scale and others will vary (for example higher energy costs for centralised systems).

A general point to note is that although there are economies of scale for the treatment system, there are diseconomies of scale for the distribution networks (Pinkham *et al.*, 2004). It should also be noted that reticulated (third pipe) recycled water schemes are rarely, if ever, considered viable retrofit options. The high costs found in this paper relate to greenfield developments which are the low hanging fruit in terms of possibilities for recycling on a municipal scale. Given this, it is not surprising that indirect potable reuse is being considered as an alternative as this achieves the economy of scale for the treatment system and avoids the high cost of the distribution system. A question remains as to whether such schemes are really safe, which is beyond the scope of this paper.

It can be said that centralised schemes based on ‘third pipe’ systems have had numerous cross-connection incidents, with effects varying in accordance with the quality of the water. Clearly such schemes need to treat water to a high level to mitigate the risks of cross-connection, which seem unavoidable at that scale (the treatment cost for indirect potable reuse would not be much greater than that already required).

As the population served by recycled water reduces, so do the health risks. Fane *et al.* (2002) stated that a precautionary approach to pathogen risk can be achieved by favouring decentralised reuse systems. If the sources of water for recycling can be selected (as they can at the smaller scale), the risks diminish also. And if the end uses are controlled, the risks are further reduced. Once the scale gets down to that of an individual dwelling, the risks are very small indeed.

Although not strong evidence on its own, the findings of the quasi-epidemiological study in this paper (that increased greywater use in single domestic dwellings does not lead to increased incidence of disease) would be the expected result if the risks are indeed small as the present author has argued. If high levels of indicator organisms in greywater were really related to significant risks one would have expected to have seen an effect on disease rates, given the large numbers of the Australian population that are recycling their greywater. (It should be noted that the vast majority of the recycling in question is either by hand bucketing, or using non-complying systems bought from the hardware store, not expensive greywater treatment units as would be required to comply with the regulations; NSW Health Department, 2005).

The Australian guidelines for water recycling (EPHC, 2006) do better at supporting a science-backed approach than the prescriptive state regulations. For example, they agree that emphasis should be on reducing sources and uses (p44), that a log reduction can be allowed for greywater as opposed to wastewater (p116) and that an – unspecified – decrease in log reduction requirements can be applied for on-site as opposed to larger scale recycling (p117).

Although not explicitly worked through in the guidelines, if low log reduction targets are set, due to the low exposure levels, and appropriate controls undertaken to achieve these; then reduced for greywater as indicated; then reduced for an on-site system; it’s likely that there would be no need for further treatment as the necessary log reduction would have been achieved. Filtration, settling and chlorination (as undertaken in the NZ system considered in the cost analysis) would add a level of redundancy to the risk reduction process and would assist in managing odours and appearance.

The EPHC (2006) guidelines also support the argument that systems serving larger populations, with a wider range of end uses and especially if taking a full wastewater stream, represent a greater risk and therefore need greater levels of control and treatment.

The overall findings of this paper can be characterised as per *Table 5*.

Table 5. Summary of findings.

	On-Site	Local	Central
Costs	Low	Medium	High
Risk	Low	Medium	High
Mitigation	Control source Control end-use Control installation Regular maintenance important	Control end-use Possibly control source High standard of treatment required Regular maintenance essential	Control end-use Very high standard of treatment required Continual monitoring essential Backflow detection techniques required
Applicability	All new and many existing single domestic dwellings	All new subdivisions, apartment and office buildings	Some new developments if close to WWTP

CONCLUSIONS

Standards for water recycling should be related to the scale of the system. Smaller scale systems have lower risks as they are less likely to be cross-connected and have a smaller population which might introduce pathogens into the system and a smaller population which might contact those pathogens. For single domestic dwellings standards should focus on ensuring no cross-connection with potable supplies and restricting the source (e.g. greywater only) and the use of the recycled water (e.g. toilet flushing and sub-surface garden watering only). The data and science do not support the introduction of stringent water quality standards.

For multi-tenanted buildings and small cluster developments, a higher standard of treatment is required, depending on the source (combined waste or just greywater) and the use. The NSW Health Department (2007) standards are probably about right for this scale of recycling, but there might be scope for reducing the standards to the equivalent of recreational water standards if the sources and uses of the water are restricted. Of course avoiding cross-connections is even more important as errors could affect more people.

The current Australian guidelines take a science-based approach (EPHC, 2006) but their interpretation into standards takes a conservative approach specifying water quality levels approaching drinking water standard, as well as controls on use, which dramatically affects the cost of on-site greywater recycling. Currently New Zealand permits the use of safe and economically attractive systems which provide significant environmental benefits with few environmental costs. It has been suggested that reticulated schemes should be the preferred option and that similarly restrictive controls should be introduced for on-site systems in New Zealand (Leonard and Kikkert, 2006) but this paper provides evidence to the contrary.

Over-regulation can distort the market to the extent that greywater recycling becomes unaffordable and thus the benefits it offers will not be achieved. These standards more than double the costs of installation and operation without offering any significant reduction in risk compared to standards which control the source and use of the greywater. This represents the difference between a system which can provide water at a lower cost than potable water and a system which has proven to be too expensive for all but enthusiasts to purchase in Australia (meanwhile more than half the population has found other, un-consented and unregulated ways to recycle their water).

It has been argued that no standards exist for greywater in New Zealand, but for on-site systems the Building Act already covers installation, including mandating the avoidance of cross-connection, the use of specific pipework and signage and requiring an inspection. Furthermore, regional councils already have powers under the Resource Management Act to dictate how and under what circumstances irrigation can occur. The only gap lies in preventing other uses, such as car washing (unless higher treatment standards, such as the Australian ones are achieved), although the Health Act could be said to cover this. There is however a notable gap in regulation for larger scale systems, which this paper has found to carry greater risk.

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Appendix 2 – Francis Pamminger’s case study on water infrastructure (Yarra Valley Water)

ADVANCING THE INFRASTRUCTURE SELECTION PROCESS –Case Study

Francis Pamminger: Manager Research & Innovation
Yarra Valley Water
August 2008

Introduction

This case study presents the work that Yarra Valley Water has undertaken to help it select more sustainable infrastructure options. The work aimed to address perceived barriers to adopting systems different from conventional servicing options. Prior to this work, debate existed as to whether alternative servicing options could deliver improvements. The perception was that such options would cost more, would require additional material and energy resulting in increased environmental burden, and would increase the business risks. Unaddressed, this uncertainty stopped any future exploration of alternative servicing options.

The case study is presented as part of the National Urban Water Governance Project. The NUWGP was established to understand how we can consciously encourage and support greater uptake of water sensitive technologies in Australia. It is well acknowledged that in transitioning to more sustainable urban water futures, the urban water sector has been limited by a range of institutional impediments including fragmented organisational responsibilities, disconnected regulatory and policy frameworks, and prohibitive capital and/or maintenance costs (Brown and Farrelly, 2007; Brown et al, 2007). Previous research with the Facility for Advancing Water Biofiltration (FAWB) highlighted that one of the key enabling context factors for providing resilience to the institutional network for change and learning was demonstration projects (Brown and Clarke, 2007). Additionally, during late 2006, a series of interviews were conducted by the NUWGP in Brisbane, Melbourne and Perth where respondents were asked to nominate a solution or 'way forward' to overcome the litany of barriers identified, to which again, a common response was demonstration projects.

Why Yarra Valley Water undertook this work

Yarra Valley Water is committed to environmental sustainability. It recognises that the well-being of the community and the strength of the economy is dependent on the health of the environment, and accordingly strives to provide water and sewerage services within the carrying capacity of nature.

Yarra Valley Water has a clear and bold commitment to achieve environmental sustainability. It is articulated in a business policy, endorsed by its Board, integrated into day to day business activities, and monitored monthly by the Executive through a Balanced Scorecard reporting process. Moreover, environmental sustainability is one of the four key strategic objectives that define Yarra Valley Water's existence. Along with targets for customer service, business culture, and efficiency, Yarra Valley Water aims to "provide services within the carrying capacity of nature and inspire others to do the same".

Getting to this stage was in itself quite a journey. Reflecting on the steps the organization had to take, four major challenges were identified and progressively tackled over a number of years. Organisational buy-in was required as was an agreed definition of sustainability, awareness of the challenges was necessary, and a means of moving from the philosophical to pragmatic was needed (Pamminger and Crawford, 2006).

It is a requirement of the Melbourne retail water companies to apply the "Sustainable Management Principles" in providing their services (Clause 26 in Statement of Obligations, 2008). These principles include water conservation, integration of short and long-term economic, environmental and social considerations, and conservation of biodiversity. The application of these principles is an important element in Yarra Valley Water's aim to deliver services in the best way possible.

It is with this background that Yarra Valley Water recognises that a number of environmental constraints are faced in providing infrastructure services to Melbourne. There is insufficient water to meet future growth. Port Phillip Bay, which already processes in the order of 3,500 tonnes of nitrogen a year discharged from Melbourne's sewage treatment plant, has reached its carrying capacity. Moreover, commonly adopted solutions to generate additional water and reduce nutrient discharge are energy intensive, leading to an increase in greenhouse gas emissions, which in turn exacerbates the very problems we are trying to solve.

Hence Yarra Valley Water considers it a core responsibility to find alternative means to provide infrastructure services in a more environmentally sustainable way.

Key challenges

Innovators seeking alternative servicing options face significant barriers. The barriers are inherently interwoven in the very processes that have delivered our significant societal improvements, which have come from separating water and sewage and adopting a centralised system. One could argue that this centralised service delivery is a central paradigm embedded in water industry culture. From this perspective, some water practitioners consider alternative decentralised options as a problem. They argue that that the environment will be worse off if we use more materials, that costs will increase, and that there will be greater risk to the community.

The site chosen for the research was a typical greenfield site, which in this instance was 3062ha and approximately 40 km north of Melbourne. Over the next 15 years, it is planned to house a population of 85,000. Yarra Valley Water engaged RMIT and CSIRO to find the best environmentally infrastructure solution for its new developments, which are split between Greenfield and infill sites, CSIRO and RMIT (2005). They were specifically asked to help identify ways to quantify environmental impacts, total community costs, and to compare risks between alternative serving options.

Process adopted to address challenges

The methods selected to quantify environmental impacts, community costs, and risk follows.

Environmental impacts

Prior to this study the general industry view was that selecting a third pipe system in this region would lead to an additional environmental burden. It was argued that the recycled water pipes and corresponding pumps would require additional material and energy to operate; hence any water savings would be offset by a larger environmental impact.

An LCA was used to quantify the actual environmental differences between alternative servicing configurations. LCA looks at the environmental impacts of a product or service throughout its entire life cycle. The traditional definition of LCA is "a cradle-to-grave environmental assessment that accounts for all resource use and releases related to the system being studied, and translates this information to the possible harm (or benefit) to the environment and human health" (Curran, 1999).

The LCA methodology can be summarised into the following stages (ISO 14040, 2006):

- Goal and scope definition. Here, the purpose of the LCA is identified and the scope and boundaries of the study are set.
- Inventory analysis. This involves quantifying the environmental inputs and outputs at each stage of the life cycle.
- Impact assessment. The inputs and outputs from the previous step are translated into potential environmental impacts.
- Interpretation. The results hitherto are interpreted with regard to the study objectives.

An LCA of the servicing options identified that all of the alternative options analysed deliver an environmental benefit when compared against a traditional servicing configuration. Figure 1 shows the reduction in water consumption, greenhouse gas and nutrient impacts from each alternative option, compared to traditional servicing.

The options are respectively:

- **Conventional** – traditional centralised servicing with reticulated water and sewage pipes connected to an existing central network. Water efficient (3A) appliances.
- **Third pipe from STP** – third pipe recycling using treated water from local sewage treatment plant.
- **Third pipe from stormwater** – third pipe recycling using treated stormwater.
- **Onsite water supply and greywater** – water supply solely from rainwater tanks and greywater treatment at each property.

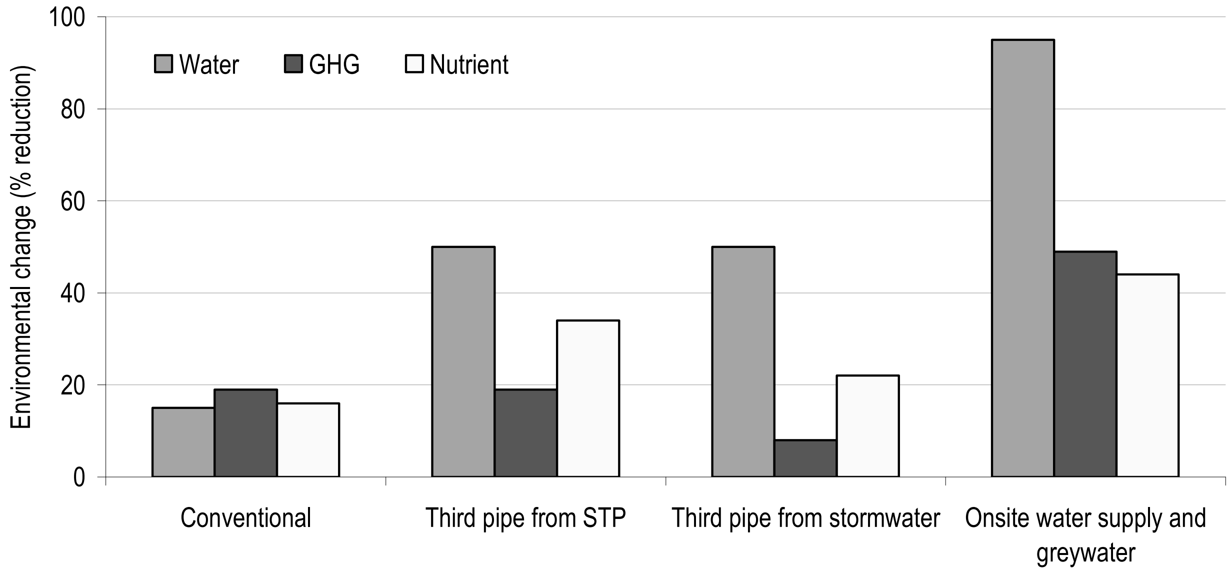

Figure 1 Life Cycle Assessment results

Community costs

Prior to this study, the general industry view was that selecting a third pipe system would cost more than a conventional water and sewerage system, due to increased capital and operating costs for the additional infrastructure.

Life cycle costing was used to quantify the total costs borne by all sections of the community. This is particularly important with the analysis of decentralised servicing options which can move infrastructure such as rainwater tanks and greywater systems onto the customer's property. To conduct a true comparison of costs, it is necessary to compare all costs independent of who will be paying for them.

All costs were monetised under this assessment. This included environmental costs such as water, greenhouse gas emissions and nutrient discharges in addition to the usual capital and operating costs. Water was costed at the market rate of water auctions. Greenhouse gas emissions were monetised at the market abatement rate. Lastly, nutrients were monetised at the rate charged by Melbourne Water in their water quality offsets program for all new developers.

Results from the Life Cycle Costing showed that when all environmental elements were costed, the decentralised options had a lower community cost. A summary of the results is shown in Figure 2.

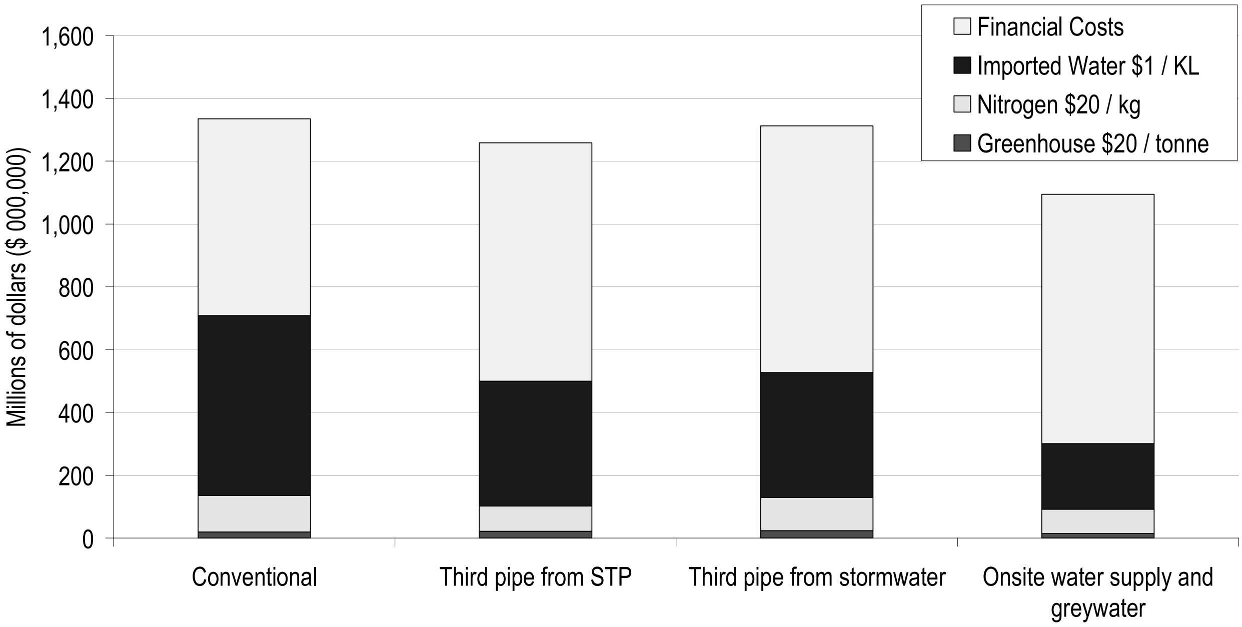

Figure 2 Community cost results

Risk assessment

Prior to this study, the general industry view was that selecting a third pipe system would bring additional risks above those occurring with a conventional water and sewerage system. The added complexity of third pipe systems was considered counterintuitive to the existing adopted industry paradigm to simplify and reduce risk. Third pipe systems were seen to increase potential for cross connections, and this in itself was considered a high enough risk to disregard them.

A means to quantify all risks as a cost was required, and a "Total Cost Assessment" methodology was adopted for this purpose. Total Cost Assessment can be defined as "the consideration of all environmental and health costs associated with a decision, including direct costs, risks and liabilities, and costs borne by others" (Earthshift Consulting, 2008). The procedure was developed in the early 1990s by the Tellus Institute for the US EPA and the New Jersey Department for Environmental Protection. Amongst other things, risk costs can include lawsuits, penalties due to non-compliance and intangible costs such as damage to worker morale, corporate image and community relations (Tellus Institute, 1998).

Yarra Valley Water selected the TCAce package to undertake a Total Cost Assessment. Data was populated using a group of industry experts who identified all potential risks. A probability density function was then fitted to each risk. This was done by identifying the lowest, median and maximum probability of an event taking place. A business cost for each of these was then added. The end result was the production of a risk-cost curve for each alternative servicing option, which is shown in Figure 3. The options shown are respectively:

- **Centralised** – conventional servicing using reticulated water and sewage pipes connected to an existing central network.
- **Dual reticulation** – third pipe recycling from a local sewage treatment plant.
- **Decentralised** – fully self contained, utilising rainwater tanks and package treatment plant (SBR) on each property.

More information on the TCAce package can be found at http://www.earthshift.com/tcace.htm.

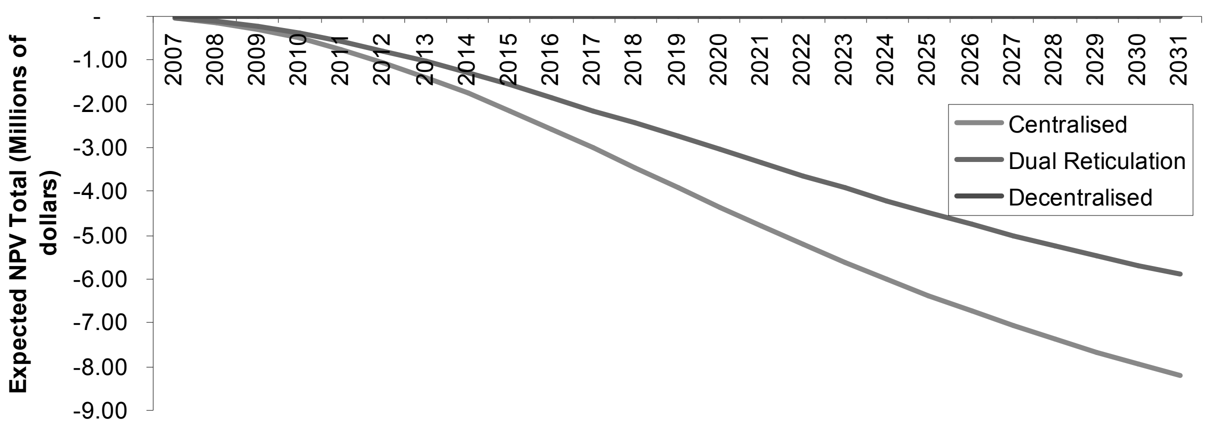

Figure 3 Total Cost Assessment results

When risks were costed for a dual reticulation system, decentralised option and centralised system, it was surprising to see that the centralised system had the highest risk-cost. In essence, this was due to the relatively high probability that drought, fire in the catchments or algal blooms could occur, and the large number of people that would subsequently be impacted. On the other hand, failures to decentralised systems would impact a relatively small number of people, hence the lower risk-cost.

Conclusion and Learnings

This project analysed a range of different servicing options for a large 3,062 ha development in Melbourne. They included both stormwater and sewage recycling, together with on-site options like rainwater tanks and greywater recycling.

Prior to this work, debate existed as to whether alternative servicing options could deliver improvements. The perception was that such options would require additional material and energy use resulting in an increased environmental burden, would cost more, and would increase the business risk. The use of robust, quantitative assessments has shown that this is not the case for all alternative options in this case study area.

- Life Cycle Assessment was used to quantify the environmental impacts and this revealed that alternative servicing options could deliver a solution with a lower environmental impact than traditional servicing.
- Life Cycle Costing was used to analyse the costs borne by all and found that while many options cost more to some individuals, they delivered an overall lower total community cost.
- Total Cost Assessment allowed a comparative risk assessment to be undertaken of options, and this highlighted that most of the alternative options investigated reduced risks.

The use of Life Cycle Assessment, Life Cycle Costing and Total Cost Assessment has accordingly contributed to changing strongly held views in the industry about the environmental impact of third pipe systems, community cost, and actual risk.

While it is important to recognise that specific infrastructure options recommended in this study are site specific, independent on option selection, this work has shown that infrastructure assessments can be made more robust by selecting quantitative methods for critical variables. Critical variables are those variables that most impact the final result.

Introducing scientific methods to an engineering industry, which bases its decisions on scientific principles, has been instrumental in bringing about the change. Barriers to adopting alternative services that previously existed have been removed, allowing a consensus to be reached that will now deliver more sustainable results.

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