# THE BENEFITS OF INDOOR WATER EFFICIENCY FOR ON-SITE SYSTEM PERFORMANCE.

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## Abstract

The most common sewage treatment technology in unsewered parts of Australia is the septic system (septic tanks with absorption field effluent disposal). A combination of inappropriate design, poor management and inadequate planning controls has resulted in these systems manifesting high failure rates. Septic system failure is widespread in NSW, with many systems failing to meet chemical and microbiological standards for effluent discharge.

Reducing hydraulic loads to septic systems has the potential to alleviate or reduce the magnitude of system failures; or to extend the effective system life allowing time for alternative sanitation options to be explored. This paper reports on a water end-use analysis undertaken in the unsewered village of Clunes, New South Wales, Australia and draws conclusions about indoor water use. End-use analysis indicated that residential water efficiency could result in sizeable reductions in hydraulic load to septic systems. The potential for extending the effective life of absorption trenches through water efficiency is discussed, along with other financial benefits to householders. There are major opportunities for implementing water efficiency in the village and potential for significant septic system performance improvement through water efficiency.

**Keywords**
indoor water efficiency; greywater reuse, hydraulic load; septic systems; water consumption modelling; water end use analysis;

## 1 Introduction

### 1.1 Current on-site situation

Approximately 12% of Australia's population are not connected to a sewer network (Geary & Gardener, 1996) and rely on on-site sewage treatment systems to treat their domestic wastewater. The most common type of on-site system is the septic system, comprising a septic tank and absorption trench or field.

The current study focuses on Clunes on the north coast of New South Wales, an unsewered village with an approximate population of 500. The majority of households discharge their wastewater to septic systems (Geolink Group, 1996). The surface stratum in Clunes is predominantly red krasnozem with underlying Lismore Basalt. Precipitation exceeds evaporation during seven months of the year (January to July) and almost half of the area's average 2,300 mm annual rainfall occurs in the first three months of the year (Geolink Group, 1996).

### 1.2 Septic system failure

The failure of septic systems to meet chemical, microbiological and other treatment standards is well documented in Australia (Jeppesen & Solley, 1994; Geary & Gardener, 1996). The principal reasons for septic system failure are: inappropriate system design (including undersized systems and those unsuited to the site or application); poor management and maintenance of systems; and inadequate planning and regulatory controls.

A postal survey of on-site system performance in Clunes was conducted by Geolink in 1996. Based on the survey, Geolink concluded (and confirmed through post survey site inspections) that 70% of households experience saturated ground conditions and/or odour problems associated with their on-site systems (Geolink Group, 1996).

Lismore City Council is currently considering a proposal to provide Clunes with a reticulated gravity sewerage system. The proposed capital works would cost around $1.1m (Geolink Group, 1996). This cost would likely be borne by Lismore City Council, the NSW Government Country Towns Water Supply and Sewerage Program and the local community. Should this proposal go ahead, it is unlikely the sewage treatment plant would begin operating before 2004, based on the time required for community consultation, environmental impact assessment, construction and commissioning.

The 70% of septic systems which are failing in Clunes are undoubtedly impinging on the environment, and also pose a risk to public health. A recent example of health and financial impacts resulting from failing on-site systems in NSW has been documented in court proceedings (http://www.austlii.edu.au/au/cases/cth/federal_ct/1999/177.html). In light of this example, action is needed to remediate failing systems. Effective action should be taken in the short term, regardless of whether a reticulated sewer is installed, and should be low cost so as not to cause undue financial hardship to, or resistance from, residents.

## 1.3 Reduced hydraulic load

Modifying hydraulic loads may decrease the incidence or magnitude of failure in existing septic systems (Geary & van de Graff, 1991; Solomon *et al*, 1998) or extend the effective life of absorption trenches (Jenssen & Siegrist, 1990; Nelson, 1998). When hydraulic load is decreased, the following may be reduced or eliminated:

- Hydraulic load exceeding percolation rate, causing trench filling and surcharging;
- Low retention time in the septic tank leading to solids carry over and blocking of the infiltrative surface (Panswad & Komolmethee, 1997); and
- Saturated conditions within and surrounding the absorption trench leading to poor treatment of biological and inorganic contaminants (Geary & Gardener, 1996).

There are three main ways in which hydraulic loads can be reduced. Household wastewater can be diverted to alternative treatment (e.g. greywater system); indoor water consumption can be reduced through changed water use practices (e.g. behaviour change); or water efficient appliances and fittings can be installed (e.g. front loading washing machine, water efficient showerhead).

## 1.4 Water end use

Water end use analysis seeks to determine the quantity of water used, within a particular setting (e.g. a single residential dwelling), to provide water services (e.g. flushing of the toilet, cleaning of the dishes). By examining the end use that water is put to, we can determine the minimum quantity of water which can be used to satisfactorily provide the required water service.

The volume of water consumed during an end use is dependent on: the efficiency of the water-using appliance or fitting, how often or how long it is used, and how it is used. In residential dwellings, the array of indoor water using appliances or fittings, their efficiency, frequency of their use, number of occupants, and the water using behaviour of the occupants will determine the quantity of water used in the home and hence, the hydraulic load going to the sewer or on-site system.

Table 1 shows the amount of water consumed by indoor end uses in an average single residential dwelling in Sydney (2.8 occupants). Table 1 shows that the major indoor end uses are: showering; toilet flushing; and clothes washing. These are typically the major indoor residential end uses in homes throughout Australia (MWA, 1985).

Table 1 Water consumed by water using appliances and fixtures in the home (White, 1998)

| | End Use | Water Used (L/week) |
|---|---|---|
| Bathroom | Shower | 1096 |
| | Bath | 173 |
| | Basin | 135 |
| Toilet | Cistern Use | 865 |
| | Cistern Leak | 58 |
| Kitchen | Sink | 231 |
| | Dishwasher | 37 |
| | Insinkerator | 2 |
| Laundry | Washing Machine | 789 |
| | Laundry Tub | 154 |
| TOTAL | | 3540 |

### 1.5 Aims

This paper details water metering and surveys which were carried out in nine households in Clunes. Metering and survey results were used to model indoor water consumption and assess the potential for reducing hydraulic loads to the nine households' septic systems.
The aims of the study were:

- Modelling total indoor water consumption for each home;
- Surveying greywater reuse habits, maintenance and performance of each home's septic system, and gathering information about the absorption field;
- Calculating the daily hydraulic load to the septic system; and
- Modelling the decrease in indoor water consumption and decrease in septic system hydraulic load which would result from water efficiency upgrades in each of the nine homes.

## 2 Methods

### 2.1 Water metering

In December 1997 water meters were installed in eight Clunes homes. Meters logged the flow rate of water entering each property at ten second intervals for 24 hours per day. Metering continued for a period of at least seven days. A further four homes were metered in the same way in August 1998. Immediately following installation of meters, major water using appliances in each property were used, the data generated assisted in interpreting logged flow data.

Following metering, the quantity of water used by each major appliance during a typical use event was calculated by summing the metered flow for each event.

At least four water use events for each appliance in each home were identified. From these, the average volume of water used by each appliance during each water use event was calculated. In this way, the flow rate or amount of water used by each appliance, was quantified in conjunction with the behaviour of residents.

### 2.2 Appliances and habits survey

At the time that water meters were installed in participating homes, a preliminary survey was carried out to determine what water using appliances were present. Later, a follow up telephone survey was conducted to verify the earlier survey, and gain further information. Three of the original twelve households did not participate in the follow up survey and were subsequently excluded from further analysis. The survey assessed the number and types of toilets in the home (standard 11L, dual flush 9L/4.5L, dual flush 6L/3L) and whether the cistern contained a displacement device. Also: the number and types of showerheads in the home (standard or water efficient as defined by Standards Australia); type of washing machine; how often, if ever, washing machine wastewater was disposed of outside the septic system; and the presence of dishwashers, insinkerators and tap flow regulating devices. In addition, householders estimated how often they used the following appliances or fittings each week: showers, bath tub, washing machine, insinkerator, and dishwasher. The existence of greywater systems and/or alternative greywater disposal was reviewed and householders reported on the performance, any modifications to, and maintenance of their on-site systems. Results were collated for use in water consumption modelling.

### 2.3 Modelled water consumption

Water consumption models for each household were developed based on the average volume used during each water use event and the number of reported water use events each week. Due to the method of metering used, it was impossible to accurately identify the use of water from taps.

In this study, the following assumptions about tap end uses were made:

- Bathroom basin and kitchen tap end uses account for approximately 385 L/week (11%) of the total water consumed in a 2.8 person household;
- Water savings of 40% and 25% can be achieved for bathroom basin and kitchen taps respectively; through the use of tap flow regulators:
- No savings assumed for laundry tub or bath as these are volume dependant end uses; and
- Bath end use accounts for 60L of water consumption per use.

The quantity of weekly consumption attributed to these end uses was adjusted for the number of household occupants as there are economies of scale for indoor water use (MWA, 1985).

It is well established that indoor water consumption does not vary greatly from season to season (MWA, 1985; White, 1998). During periods of low outdoor water use, actual residential water consumption data can be used to approximately quantify indoor water use. Based on this, modelling results were compared with actual water consumption data obtained from Lismore City Council. This comparison verified that in most cases, modelled consumption was similar to actual consumption during periods of likely low outdoor water use (e.g. wet season).

### 2.4 Modelled impact of water efficiency

The impact of installing best practice water efficient appliances and fittings, was modelled for each of the nine homes. Modelling quantified the reduction in water consumption and hydraulic load to septic systems (taking into account the current wastewater/greywater treatment regime used by each household). Models were constructed from information obtained in the *Appliances and Habits Survey* and the best practice water use volumes shown in Table 2. A water efficiency upgrade is estimated to cost $570. This includes: installation of a water efficient showerhead and tap flow regulators; replacing toilets with 6/3L dual flush cisterns and appropriate pans; and a $200 rebate on the purchase price of a new front loading washing machine.

Table 2 Best practice water efficiency for selected water appliances or fittings (White, 1998).

| Appliance or fitting | Flow rate or volume per use |
|---|---|
| Showerhead | Rated flow 9L/min (AAA) or 6 L/min when in use. |
| Washing machine | For front loading machines, 60 - 100 L/load. |
| Toilet | Average is 3.8L/flush (6L/full flush and 3L/half flush). |
| Flow regulated taps | For hand basins 6L/minute (can be as low as 2.5L/min) and 6-9L/min for kitchen taps. |

## 3 Results and Discussion

### 3.1 Water metering and major water using appliances

Table 3 indicates that homes with water efficient showerheads generally consume less water than homes using standard showerheads. House 8 did not fit this pattern with metering in house 8 showing the showerhead was delivering around 6L/min. This could be due to an internal flow restrictor, showerhead blockage or residents restricting the flow rate. Also, residents in house 8 favoured short showers (5 min).

Table 3 Average volume used per shower, showerhead type, and frequency of shower and bath use in nine Clunes homes.

| House | Showerhead Type | L/Shower | Showers/ Week | Baths/Week |
|---|---|---|---|---|
| 1 | Efficient (AAA) | 21 | 35 | 1.5 |
| 2 | Efficient (AAA) | 27 | 27 | 7 |
| 3 | Standard | 59 | 25 | 9 |
| 4 | Standard | 59 | 14 | 0 |
| 5 | Standard | 90 | 7 | 0 |
| 7 | Standard | 41 | 21 | 0.5 |
| 8 | Standard | 31 | 14 | 0 |
| 9 | Efficient (AAA) | 39 | 18 | 2 |
| 10 | Standard | 107 | 14 | 7 |

Table 4 shows some households in the study had older style 9/4.5L water efficient toilets. In houses with 11L toilet cisterns, the average volume per flush was less than 11 litres. This may have been due to: alteration of the flush mechanism (e.g. bending the float valve); installation of a displacement device (house 8 had a brick in the cistern); or behaviour of residents (a resident in house 2 reported not fully depressing the toilet button resulting in reduced flush volume).

Table 4 Types of toilet and volume per flush in nine Clunes homes.

| House | Occupants | Toilet Type | Average L/Full Flush | Average L/Half Flush |
|---|---|---|---|---|
| 1 | 6 | 9L/4.5L | 9.0 | 5.5 |
| 2 | 2 | Standard (11L) | 9.5 | - |
| 3 | 6 | 9L/4.5L | 7.4 | 4.8 |
| 4 | 2 | Standard (11L) | 7.9 | - |
| 5 | 1 | Standard (11L) | 8.9 | - |
| 7 | 3 | 9L/4.5L | 8.8 | 5.3 |
| 8 | 2 | Standard (11L) | 7.6 | - |
| 9 | 3 | Standard (11L) | 11.8 | - |
| 10 | 4 | 11L/6L | 11.4 | 6.5 |

Table 5 shows that there was a large variation in the volume of water used to wash a load of clothing. The two households with front loading washing machines were on the lower end of the water use range compared with households using top loaders. However, the small number of front loaders involved in this study make it difficult to generalise. As no participating house reported using suds return, and washing machines were all large (5 to 7 kg load capacity), it appears that some households washed in smaller loads and adjusted water volume according to the size of load.

### 3.2 Modelled water consumption

The results of indoor water consumption modelling for each house are shown in Table 7.

Table 5 Washing machine type, volume of water used per load and number of loads per week for nine Clunes homes.

| House | Washing Machine Type | L/Load | Loads/Week |
|---|---|---|---|
| 1 | Front loading | 37 | 16.0 |
| 2 | Top loading | 67 | 2.5 |
| 3 | Top loading | 151 | 12.0 |
| 4 | Top loading | 99 | 6.0 |
| 5 | Top loading | 63 | 2.0 |
| 7 | Top loading | 130 | 10.0 |
| 8 | Top loading | 110 | 4.0 |
| 9 | Front loading | 94 | 5.0 |
| 10 | Top loading | 138 | 7.0 |

### 3.3 Greywater and on-site survey

Table 6 summarises greywater disposal regimes, and maintenance of or modification to participating households' on-site systems. Most households in the study practise some form of greywater reuse or alternative to septic disposal. It is clear that an analysis of participating households' septic system performance, in light of current water using habits, would be of little value. This is due to: the small number of participants (9); variations in greywater disposal regimes; variations in absorption trench set-up; modifications to trenches; lack of configuration details; and variation in years since desludging of septic tanks. However, there is a great deal of scope for applying the methodologies developed in this study, to a larger study group.

Table 6 Greywater disposal regimes and on-site system maintenance for nine houses in Clunes.

| Hs | Alternative to Septic Greywater Disposal | Trench Length | Greywater Set-up and Modifications to Absorption Trenches | Years Since Septic Desludge |
|---|---|---|---|---|
| 1 | Yes (100% shower, bath and laundry water to gutter) | 20m | Trench remediated in 1982. In 1983 trench clogged again leading to septic overflow. | 1.5 |
| 2 | Yes (25% laundry water to garden) | 50m | Trench lengthened from 10m to 50m 6 years ago. | 6 |
| 3 | Yes (100% laundry water to garden) | NK | The trench has an overflow at the end. | 3 |
| 4 | Yes (75% laundry water to garden) | 20m | In 1990, extended trench to 20m and changed fill. Planted lilies either side of the trench. | 7 |
| 5 | No | NK | Have two trenches. | 8 |
| 7 | Yes (50% laundry water to garden) | NK | Had to put in more drainage 3-4 years ago. Now have two trenches. | 4 |
| 8 | Yes (100% laundry water to garden) | NK | | 5 |
| 9 | Yes (100% shower, bath, laundry water) | NK | All greywater to subsurface drainage system in yard (agricultural pipe). | 4 |
| 10 | Yes (100% shower, bath, laundry water) | NK | Seepage trench for water from bathroom, kitchen and laundry. | 2 |

NK = not known by householder

## 3.4 Modelled impact of water efficiency

Table 7 lists the results of modelling the impact on indoor water consumption of the installation of best practice water efficient appliances or fittings in each of the nine homes. The results of water consumption modelling are also presented.

Table 7 Modelled indoor water demand, and modelled demand with best practice water efficiency in nine Clunes homes (L/week).

| House | Modelled Current | Modelled Efficient | Decrease in Consumption |
|---|---|---|---|
| 1 | 3097 | 2574 | 523 |
| 2 | 2166 | 1694 | 371 |
| 3 | 5323 | 3298 | 2025 |
| 4 | 2099 | 1355 | 744 |
| 5 | 1136 | 645 | 491 |
| 7 | 3087 | 2056 | 811 |
| 8 | 1594 | 1109 | 397 |
| 9 | 2642 | 1744 | 788 |
| 10 | 4206 | 2212 | 1994 |

While the main focus of this paper is examining the potential to reduce hydraulic loads to septic systems, it is important to recognise that reduced water consumption from water efficiency would represent cost saving both to the householder and the local water authority, Rous County Council. The water tariff in Clunes is 85c/kL and the water savings presented in Table 7 would save householders between $16/annum (house 2) and $90/annum (house 3). Savings due to energy conservation (reduced hot water consumption in the shower) would range from approximately $24/annum (house 4) and $94/annum (house 10), based on $2/kL of shower water saved with average electricity price 7c/kWhr. Water efficiency upgrades in the nine homes in Clunes would result in a total water savings of 0.4ML/annum. This represents a saving of $1,400 to Rous County Council due to deferment of capital expenditure on new water supply infrastructure (White, 1997). This is a one-off saving expressed in present value terms.

The average volume of wastewater flowing to each home's septic system was modelled (Table 8). The modelling took into account alternative greywater use or treatment used in each home. Wastewater flows to septic systems was modelled under two scenarios: under the current water using configuration and based on best practice water efficiency for each home.

Table 8 Modelled wastewater flow currently going to septic system and modelled volume to septic with best practice water efficiency in nine Clunes homes.

| House Number | Modelled Current (L/week) | Modelled Water Efficient (L/week) | Wastewater to Septic System Decrease |
|---|---|---|---|
| 1 | 1268 | 745 | 41% |
| 2 | 2124 | 1664 | 32% |
| 3 | 2853 | 2132 | 25% |
| 4 | 1655 | 1139 | 31% |
| 5 | 1136 | 645 | 43% |
| 7 | 2436 | 1816 | 25% |
| 8 | 1155 | 917 | 21% |
| 9 | 867 | 255 | 71% |
| 10 | 774 | 321 | 58% |

## 3.5 Absorption field longevity

Equation 1 (Nelson, 1998) is a first attempt at understanding the value of water efficiency in terms of absorption field longevity. For the purposes of analysis, it is assumed that effective absorption field life for a standard Clunes home is 25 years and that the relative effectiveness of water efficiency for extending absorption field longevity is equal to 50% of the hydraulic load reduction achieved.

$$L_{new} = L_{old} / (1 - F * S/Q) \qquad \textbf{Equation 1}$$

Where:
L new = extension to effective absorption field life with water efficient appliances and fittings
L old = effective absorption field life with standard appliances and fittings
F = factor to account for diminishing water efficiency benefit
S = LCD effluent to septic savings from installing water efficient appliances and fittings
Q = LCD (daily effluent to septic per person)

We found that effective absorption field life was extended by between 3 years (house 2) and 14 years (house 9). It is recognised that further research would be required to establish the true values of 'L old' and 'F', before this equation could be effectively applied in analysing the benefits of water efficiency for absorption field longevity in Clunes.

## 3.6 Absorption Field Size

The following is a calculation of the financial benefits of water efficiency for houses one and four, in the case of extensions to their absorption trenches. Each house currently has a single 20m trench. It was assumed that the cost of extending an existing absorption trench in Clunes is $250 per meter based on repair costs being higher than installation due to access and restoration issues (Lombard, 1998). Equation 2 (A. Rabbabah *pers. com.* based on AS1547 DRAFT, 1998) was used to calculate field size needed to treat current wastewater volumes produced by each house.

$$T = (P - ET) + W (D * A) \qquad \textbf{Equation 2}$$

Where:

T = required absorption trench length
P = average daily precipitation (L/m$^2$)
ET = average daily evapotranspiration (L/m$^2$)
W = wastewater sent to trench (L/day)
D = design loading rate (mm/day)
A = cross sectional area of trench (m$^2$)

Field size was calculated for modelled current and modelled water efficient wastewater volumes (Table 8). Table 9 shows the length of absorption trench required in each scenario (for the wettest month) and the cost to the householder of trench extensions. The design loading rate was assumed to be 6 mm/day and the trench cross sectional area 1m$^2$.

Table 9 Length of trench required to treat wastewater from houses 1 and 4 under two scenarios

| | | **Standard** | | **Water Efficient** | |
|---|---|---|---|---|---|
| House | Current Trench Length | Required Trench Length | Cost to Extend | Required Trench Length | Cost to Extend |
| 1 | 20 m | 32 m | $3,000 | 20 m | Nil |
| 4 | 20 m | 41 m | $5,250 | 29 m | $2,250 |

# 4 Conclusions

The study established:

- There is considerable potential for reducing the hydraulic load to septic systems by installing water efficient appliances and fittings in homes;
- Empirical and anecdotal evidence suggests that reducing the hydraulic load to septic systems can decrease the incidence or magnitude of system failure;
- There is potential for substantial cost savings associated with absorption trench length or trench longevity from water efficiency upgrades in homes with existing septic systems; and
- Installing water efficient appliances and fittings offers additional benefits including: reduced household water and energy bills; and reduction in investment in new water supply infrastructure.

In the case of Clunes, a $1.1m reticulated gravity sewerage system is under consideration. Should this system be approved, it is unlikely to be operational until 2004. Although water efficiency upgrades would not 'fix' all failing septic systems in Clunes, upgrades have the potential to reduce the incidence or magnitude of system failures. Therefore, upgrades should be undertaken in the short term, if the village is to be sewered, as a means of reducing the environmental and potential health impacts of failing septic systems.

If water efficiency upgrades could remediate a portion of the village's failing systems, the scope for developing alternatives to a reticulated gravity sewerage system would be increased. Comparing the low cost of water efficiency upgrades (approximately $570) with the approximate $6,500 per tenement which the reticulated sewerage option represents, it is clear that water efficiency should also be considered as a cost effective part of any alternative sanitation approach.

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