



Urban Water Research Association of Australia

Domestic Greywater Reuse: Overseas Practice  
and its Applicability to Australia



Research Report No. 73

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Urban Water Research Association of Australia

**Domestic Greywater Reuse:  
Overseas Practice and  
its Applicability to Australia**

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Brisbane City Council

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## FOREWORD

This report is based on UWRAA Research Project No WR-33: 'Domestic Greywater Reuse, Stage 2' which was undertaken during the period June 1993 and December 1993. It supercedes an earlier report entitled 'Domestic Greywater Reuse: Preliminary Evaluation' which was published in July 1993 as UWRAA Research Report No 60.

Organisational responsibility for the project was as follows:

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## SYNOPSIS

This report is the second on a research project to determine the potential for domestic greywater re-use in Australia.

The first report, "*Domestic Greywater Re-use: Preliminary Evaluation (UWRAA Research Report No 60)*", was based on overseas correspondence, a literature search, and chemical and microbial analysis of some sullage systems. That report concluded that the western states of the USA and Japan are the world leaders in this type of onsite re-use and that greywater re-use poses environmental and health concerns but, with adequate guidelines, could achieve substantial water savings. This second report investigates overseas practices in greywater re-use and how these practises could apply to Australia.

Domestic wastewater can be segregated into two separate flows, namely:

- **Blackwater** - comprising water closet, bidet and bidette waste and having gross faecal contamination
- **Greywater** (also referred to as sullage) - comprising all remaining household wastewater; for example, bath, laundry.

*Although toilet wastes are excluded from greywater, greywater still contains human faecal indicator bacteria in concentrations high enough to indicate a health risk from the potential presence of pathogenic micro organisms. Overseas authorities have confirmed this conclusion.*

For safe re-use, either of the following must occur:

- greywater must be treated to remove or destroy these micro organisms
- human contact with greywater must be prevented.

Treatment of greywater to make it safe for human contact is expensive to achieve on an individual household basis. It is also difficult to ensure that treatment systems are maintained. Surveys in the USA, Australia and Brisbane have found that 60% to 80% of "onsite domestic wastewater treatment plants" are not maintained adequately. These treatment plants consistently do not produce an acceptable quality effluent.

Limited evidence from trials and existing greywater systems suggests that there are no adverse effects on lawns and ornamental gardens from chemicals occurring in greywater. However concerns are raised that chemicals in greywater could cause damage to clay soils and some native plants and increase the levels of nutrients in groundwater and waterways.

The twenty-two Western States of the USA allow the direct re-use of untreated domestic greywater by sub-surface watering of ornamental gardens and lawns. To prevent human contact with untreated greywater, sub-surface watering techniques, such as sub-surface drip emitters and leach fields, are specified.

Toilet flushing with greywater is not allowed because of the risk of human contact (from splashing and aerosols) and the unreliability of household treatment. *The preliminary evaluation given in the first report wrongly concluded that greywater re-use for toilet flushing did not require treatment other than disinfection and coarse screening.*

Japan does not re-use untreated greywater, except for hand washing water (without soap) being re-used to flush toilets. However, the Japanese carry out wastewater reclamation for toilet flushing, irrigation, and ornamental ponds/fountains, using expensive and sophisticated treatment processes. This happens in high rise buildings and at regional treatment plants and, because of Japan's severe water shortage, is economical.

The third and final part of the research will include testing and evaluation of existing sullage systems to determine guidelines for the application of domestic greywater re-use for Australia. Trials will also be carried out on hand basin cisterns which re-use hand washing water for toilet flushing.

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# 1 INTRODUCTION

## 1.1 Scope

This report is a consolidated summary of an investigation into domestic greywater re-use in the USA & Japan which was conducted to provide an insight into the potential application of overseas domestic greywater re-use practices to Australia. The information contained in this report should encourage water authorities to further evaluate this water saving measure.

## 1.2 Goals

This report is on the second part of a three part project. Its objective is to investigate and evaluate greywater re-use practices and systems used in the USA and Japan for suitability of use in Australia.

The project goal is to determine guidelines for using greywater systems suitable for Australia; that is, those systems which use domestic wastewater as their source. Domestic greywater is defined as that which is derived from a non-industrial source.

## 1.3 Background

The segregation of domestic wastewater at the source into two separate flows gives:

- *blackwater* - water closet, bidet and bidette waste; has gross faecal contamination
- *greywater* (also referred to as sullage) - all remaining household wastewater; for example, bath, laundry; (refer to Figure 1.1).

Numerous reports and articles on this topic have variations of the word "greywater". Most frequently used are:

"graywater"  
"gray water"  
"greywater"  
"grey water".

All are correct - but, for this report's purposes, "greywater" is the preferred spelling.

By re-using domestic greywater for toilet flushing, and lawn and garden watering, potable water usage can potentially be reduced.

Lawn and garden watering with greywater can be achieved in a number of ways, including:

- aboveground spraying or drip irrigation
- sub-surface drip or leach field watering.

Toilet flushing with greywater may involve:

- simple "hand basin" toilets, in which handwash water is re-used to flush toilet bowls
- toilet and urinal flushing systems that use treated greywater.

Greywater is wastewater that inevitably contains potentially harmful microbial and chemical constituents. Greywater may be re-used with or without first treating it to reduce or inactivate these harmful constituents. For this reports purposes the following terms will apply:

- *untreated greywater* - is greywater that has had no form of treatment apart from simple coarse screening.

- ***treated greywater*** - is greywater that has incurred some treatment process apart from simple coarse screening.

Inadequate methodologies in greywater re-use may pose a risk to community health and the environment. For this reason, this report has categorised greywater re-use systems as follows:

- ***hand basin toilets*** - these incorporate a hand basin in the top of the cistern with a tap for hand washing. The tap operates automatically when the toilet flushes, simultaneously refilling the cistern and allowing hand washing.
- ***primary greywater systems (PGS)*** - these directly re-use untreated domestic greywater from a single family home for sub-surface lawn and ornamental garden watering. These systems do not allow storage or treatment, apart from a coarse screen filter which removes lint, hair and coarse particles.
- ***secondary greywater systems (SGS)*** - these are any system which are not hand basin toilets or primary greywater systems. Secondary greywater systems may be used for multiple occupancy dwellings. They can also store, or re-use treated greywater for toilet/urinal flushing and lawn and garden watering (including surface watering methods).

# WATER USAGE IN THE HOME

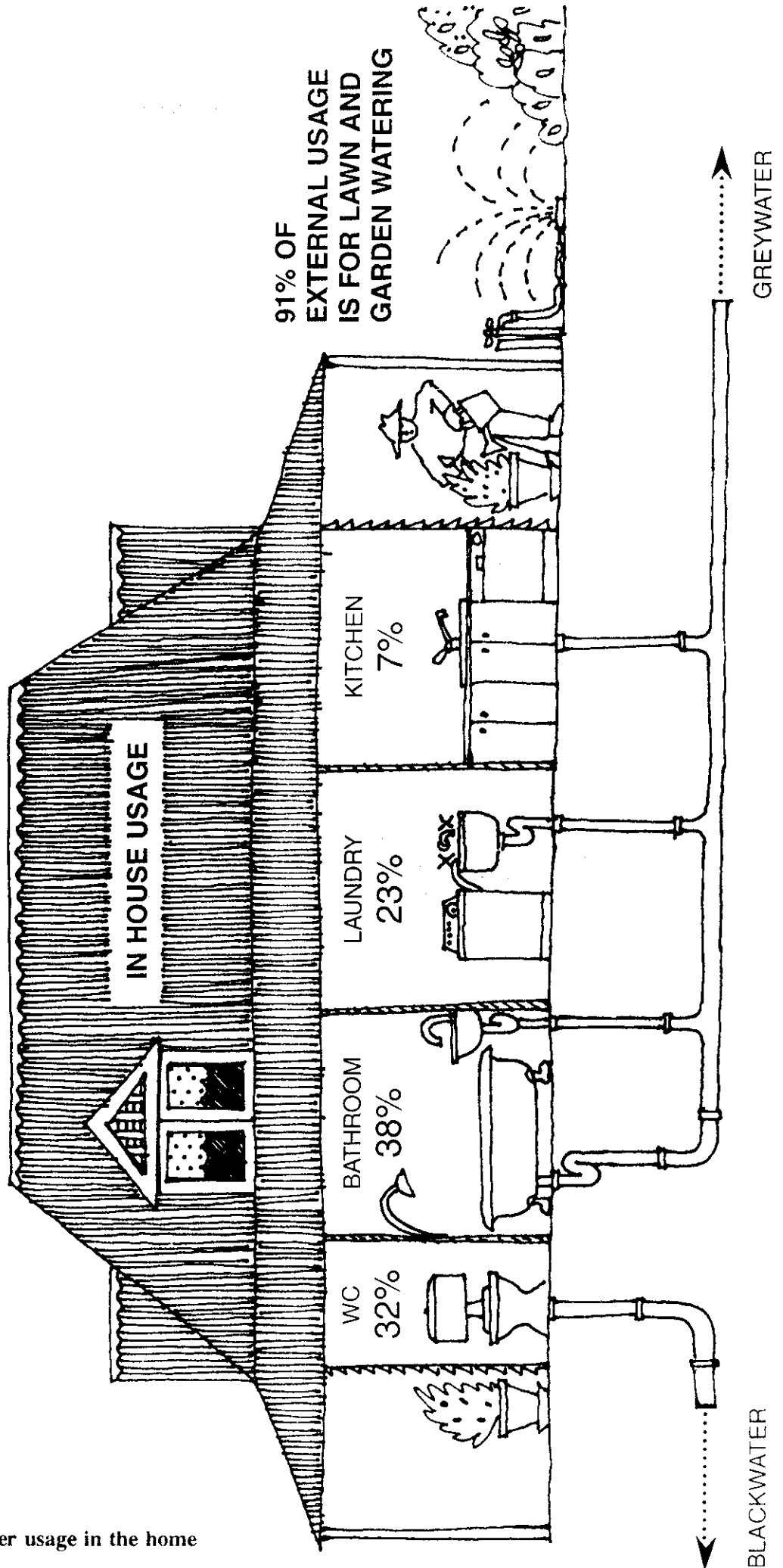


Figure 1.1 - Water usage in the home

## 2 GREYWATER RE-USE OVERSEAS

### 2.1 The United States of America

#### 2.1.1 Background

The USA has a long history of experimentation with greywater re-use. This may be partly due to the fact that approximately 60% of homes in the USA are not sewered, relying on onsite treatment of their household wastewater. Additionally, there is a general, but incorrect perception within the community that greywater is totally harmless in content. This could possibly be as a result of the 60's hippie movement which was strong in California. Environmental magazines regularly praised greywater's virtues by promoting plans and "do-it-yourself" kits, despite the illegality of the practice.

Scientific and research institutions have conducted numerous evaluation projects into most aspects of greywater re-use. Unfortunately, many of the conclusions are contradictory.

Regulatory authorities gave greywater re-use no credence until California had two very severe droughts in 1977-78 and 1987-92. Southern California has a very arid desert terrain, with no local permanent water sources. Most of the potable water needs for Los Angeles are transported hundreds of kilometres from the eastern slopes of the Sierras, the Colorado River, and Northern California.

Southern Arizona is also desert terrain, with long term overuse of ground water supplies causing concern. Tuscon is effectively mining its water supply at 2.5 times the rate of natural replenishment. The disappearance of water from the Santa Cruz River, which once carried paddle steamers, is a direct result of this. The river has not flowed regularly for 30 years.

USA water authorities are now seriously looking at all methods of economising present water usage and implementing alternative sources. Greywater re-use is one of the methods used by authorities in the western States of the USA. Figure 2.1 briefly outlines greywater development in the USA.

Other water-short states, such as Florida, do not consider widespread onsite domestic greywater re-use because of environmental and public health constraints (primarily ground water protection).

#### 2.1.2 The Role of State and Regulatory Authorities

The 22 western states of the USA, administer their plumbing to the Uniform Plumbing Code (UPC). In addition, each state has separate plumbing laws that the County and City regulatory authorities administer. State plumbing laws and the UPC did not include greywater before 14 July 1992. County and city health and building officials regulated greywater under their local health, building and plumbing codes.

A survey of plumbing authorities in 1977 found an unquantified number of illegal greywater systems installed in California. The survey concluded that there are probably thousands of these systems throughout the USA (Milne, 1979). One greywater system installer, Rewater, claimed responsibility for 240 systems alone.

DATE	HISTORY
1977	Survey of Californian County Health Officials confirms large numbers of unapproved systems operating in state. Estimates are in the tens of thousands for entire country.
1989	Santa Barbara County introduces first "Greywater Regulations".
July 1990	City of LA initiates research into greywater re-use.
1989-1992	Ten (10) other cities and counties follow Santa Barbara's lead.
May 1991	Ad-hoc greywater committee formed by Department Water Resources (CA) to investigate safe re-use. Recommends greywater "Appendix W" as a plumbing code.
September 1992	Uniform Plumbing Code (UPC) adopts "Appendix W". UPC is used by 22 Western States.
July 1992	Governor of California signs Assembly Bill 3518. The Bill directs the Department of Water Resources to establish State Greywater Plumbing Code.
November 1992	City of LA recommends greywater re-use under Appendix J.
March 1994	California Code (Appendix J) is due to be adopted by the Californian Building Standards Commission.

**Figure 2.1 - Milestones in the history of greywater re-use in the USA**

During a period of severe drought from 1977 to 1978, the State of California gave tax relief for the installers of greywater systems (Milne, 1979). This incentive recognised the water saving potential of greywater re-use.

In 1989, the Santa Barbara County Board in California became the first USA authority to make residential greywater re-use legal and a permitted option under the State Uniform Building Code. The following counties and cities followed Santa Barbara County's lead and made greywater re-use legal:

- counties:
  - San Luis Obispo (1990)
  - Los Angeles, Mariposa, San Bernardino, San Diego (1991)
  - Nevada (1992).
- cities:
  - Santa Barbara
  - San Luis Obispo
  - Lompoc
  - La Verne
  - Pasadena.

Most of these jurisdictions allowed sub-surface watering only. Some further restricted use to single family residential dwellings.

In May 1991, severe drought and public interest caused the formation of the Californian Ad-Hoc Greywater Committee. The committee's role was to investigate the safe re-use of greywater, and to develop safe guidelines that could be used by any jurisdiction permitting the re-use of greywater. The committee was composed of officials from State, County and City authorities representing the areas of Health, Building, Standards, Water and Plumbing. In addition there were representatives from the greywater industry, irrigation industry and landscape designers.

The completed guidelines were submitted to the International Association of Plumbing and Mechanical Officials (IAPMO) for inclusion in the UPC. On 29 September 1992, the greywater guidelines were included as Appendix W of this Code (refer to Appendix 2 of this report).

Governor Wilson for the State of California signed Assembly Bill 3518 on 14 July 1992. This bill directed the State Department of Water Resources to develop State plumbing code standards to permit installation of residential greywater systems, modelled on Appendix W (refer to Appendix 3). This standard is known as Appendix J and is expected to be approved in March 1994 (refer to Appendix 4).

### 2.1.3 Appendix W

Appendix W (refer Appendix 2) was developed around the following premises:

- Greywater can contain potentially harmful micro organisms and thus represents a health risk.
- Separating human contact from the source of the risk is the only reliably safe method of re-using greywater.

Consequently the code only allows for sub-surface re-use for garden and lawn watering. Other uses, which include urinal and toilet flushing, are prohibited as they are deemed to have an unacceptable risk of human contact with greywater.

Their research had also shown that the greywater volumes available for disposal in a single domestic dwelling generally did not meet the demand for lawn and garden watering. It was therefore argued that there was no need to consider the more "risky" alternatives such as toilet flushing, when all greywater could be used for irrigation.

The code is also restricted to "untreated domestic greywater from single family dwellings for direct re-use in sub-surface irrigation of lawns and gardens". This definition is designed to minimise the potential health risk. The terminology was chosen for the following reasons:

- *untreated* - studies have shown that 80% of owners will not provide adequate maintenance to their greywater system. On this premise, an unmaintained treatment system may potentially pose a worse hazard.
- *domestic* - the chemical constituents of domestic greywater are generally known and are acceptable for lawn and garden watering. This may not always apply with other wastewater sources.
- *single family dwelling* - this minimises any potential for sharing of pathogens between families. Members of a single household usually have an immunity to pathogens carried by other household members.
- *direct re-use* - by re-using greywater immediately, the potential for pathogens multiplying to unacceptable levels are reduced. Consequently the health risks are also reduced.
- *sub-surface irrigation* - by reusing greywater for sub-surface watering, it can be effectively separated from humans. Human contact is avoided and health risks are minimised. Greywater re-use for toilet and urinal flushing is not allowed.

## 2.2 Japan

The Japanese use the term "greywater" to define treated wastewater effluent. Little evidence of untreated onsite greywater re-use was found in Japan.

Due to the shortage of potable water in Japan, treated wastewater is used for toilet flushing, ornamental ponds and fountains and landscape watering in many high rise buildings. This wastewater is sourced from one of the following:

- a second reticulation system from a local wastewater treatment plant
- an onsite treatment plant using the building's own wastewater.

Generally, the onsite wastewater treatment plants are an aerobic process followed by membrane filtration and disinfection. Due to installation and operating expenses, they are only found in multiple occupancy dwellings or office blocks.

The administration for onsite re-use is the responsibility of the building owner; the government only sets effluent quality guidelines. Table 2.1 gives effluent quality standards recommended by the Tokyo Water Re-use Promotion Centre.

Greywater re-use in single family dwellings is generally limited to hand basin toilets and re-use of bathing water for clothes washing.

Hand basin toilets incorporate a hand basin in the top of the cistern with a tap for hand washing. The tap operates automatically when the toilet flushes to simultaneously refill the cistern and to allow hand washing (refer to Figure 2.2). Hand basin toilets are installed in most Japanese homes, as well as in commercial areas where potable water is still used for toilet flushing. There is also some limited use of these units in the USA, Canada and Europe.

Item	Landscaping	Dabbling
Coliform group count	< 1,000/100ml	< 50/100 ml
BOD	< 10mg/l	< 3mg/l
pH	5.8 ~ 8.6	5.8 ~ 8.6
Turbidity	< 10	< 5
Odour	Should not be unpleasant	
Colour Unit	< 40	< 10

**Table 2.1 - Japanese targets for the beneficial use of treated wastewater**

(Recommended by the Tokyo Water Re-use Promotion Centre)



Figure 2.2 - Hand basin toilet suite





### 3 THE GREYWATER SOURCE

#### 3.1 General

As previously mentioned, greywater is defined as the remainder of household wastewater left when blackwater is removed. Blackwater is water closet, bidet and bidette wastewater. Greywater by definition does not contain gross faecal contamination, though tests on greywater show that there are some faecal contaminants present, as discussed in Section 4.

Greywater can be simply separated from household wastewater by having separate household plumbing systems for greywater and blackwater. The blackwater plumbing system would discharge directly to the sewer (or septic in unsewered areas), and the greywater system could either be directed to the onsite greywater disposal system or to the sewer.

Potential greywater sources include the:

- kitchen sink and dishwasher
- bathroom shower, bath and basin
- laundry tubs and clothes washing machine
- spa and swimming pool backwash water.

The choice of what is an acceptable greywater source in the home depends on the type of greywater system and the degree and method of re-use. This is because each greywater source has different physical, microbial and chemical qualities. The choice of greywater source can be further limited to reduce the quantity of greywater for onsite disposal. If a site cannot take the full volume of greywater available because of limited area of disposal land, soil types etc., greywater sources can be limited to the higher quality sources, such as shower or even washing machine rinse wastewater.

#### 3.2 Greywater Source Volumes

The volumes of greywater available at any particular house vary depending on the water-use practices and number of occupants.

A number of metering studies have been conducted to determine average figures for domestic water use in certain cities of Australia, including:

- *"Domestic Water Use in Perth, Western Australia"* by the Metropolitan Water Authority (1985)
- *"Domestic Water Usage Patterns, Sydney"* by Lancaster and Dash (1993).

The reports showed that average in-house water usage figures did not vary significantly between these two cities. Estimates of average domestic water use were determined for Brisbane, as follows:

- assuming that Brisbane has similar in-house water usage to Sydney and Perth
- using water consumption and sewage volumes and population data for Brisbane.

These are shown in Table 3.1 and Figure 3.1.

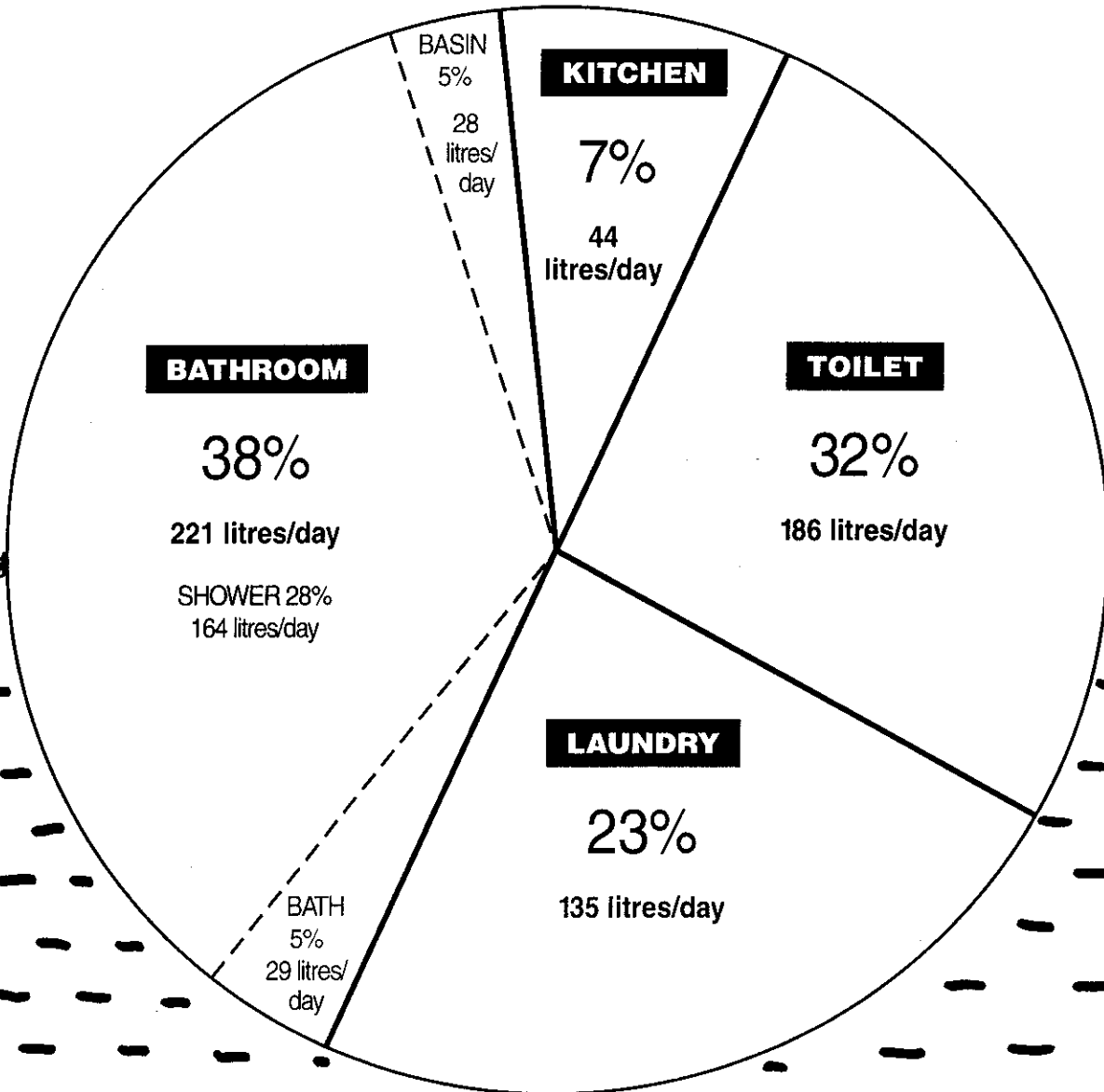
Table 3.2 gives volumes of greywater potentially available for re-use, based on these average figures. This shows that the total volume of greywater available at an average household is 400 litres per day. If kitchen wastewater is not included this figure is 356 litres per day. This represents 35% (31% excluding kitchen) of the total domestic usage, and 68% (61% excluding kitchen) of the in-house usage.

It should not be assumed that these volumes of greywater are available at every house, as they are based on averages. Some households will have more and some less greywater available than these figures indicate.

<b>Water Use</b>	<b>Average Volume Litres/day</b>	<b>% of Total Domestic Usage</b>	<b>% of In-house Usage</b>
Total Domestic	1232	100	-----
In-house	(586)	(48)	(100)
Shower	164	14	28
Bath	29	3	5
Basin	28	2	5
Kitchen	44	4	7
Laundry	135	12	23
Toilet	186	15	32
			<b>% of Ex-house Usage</b>
Ex-house	(646)	(52)	(100)
Landscape Irrigation	588	47	91
Other	58	5	9

**Table 3.1 - Brisbane average domestic water usage**

# BRISBANE INHOUSE WATER USAGE



**TOTAL IN-HOUSE WATER USAGE**

**586 LITRES/DAY**

Figure 3.1 - Brisbane average domestic in-house water usage

Greywater Source	Average Volume Litre/day	% of Total Domestic Usage	% of In-house Usage	% of Greywater Total
Shower	164	14	28	41
Bath	29	3	5	7
Kitchen	44	4	7	11
Laundry	135	12	23	34
Basin	28	2	5	7
- hand washing after toilet	7	0.5	1	2
- basin other	21	1.5	3	5
Total	400	35	68	100

Table 3.2 - Brisbane average greywater source volumes

### 3.3 The Kitchen

As shown in Table 3.2, kitchen greywater represents on average 11% of the total greywater available in a household. However, because kitchen greywater is potentially the poorest quality greywater available and the volume is relatively small, it is often precluded from onsite re-use and discharged to the sewer. As stated by Sherman (1991): "The kitchen sink produces wastes of sufficient strength to be considered blackwater".

Kitchen sink waste can be heavily contaminated with food particles, cooking oils and grease. As a greywater source it increases the necessity for maintenance on filters. It promotes the presence and growth of bacteria and other pathogens. Kitchen sink waste can potentially cause blockages in the irrigation system. Table 4.2 shows very high concentrations of faecal coliforms in kitchen greywater (for example  $2 \times 10^9/100$  ml).

Kitchen greywater can also contain detergents and cleaning agents that may be harmful to soils, plants and ground water, though biodegradable products can be chosen which will limit harmful effects (see Section 5.13). Some detergents and cleaning agents can promote alkaline pH in greywater, making it unsuitable for some acid loving plants. When these problems are balanced against the small volume of greywater available from this source, it may be considered more trouble than it is worth. For these reasons, California has specifically precluded the kitchen as a source of greywater.

Pima County, Arizona, has not taken this view and allows greywater systems using kitchen sourced greywater, with re-use to leach fields. Installation of in-line grease traps is not required. This method's reliability cannot be established as the total number of installations is small - with no longevity of operation.

Some researchers do not recommend dishwasher wastewater as a suitable source of greywater as:

- The wastewater temperature could dissolve the solidified grease collected in a grease trap, and allow it to transfer through the system
- The wastewater is too alkaline

- The wastewater contains food particles, oils and greases that could cause blockages in an irrigation system
- The wastewater temperature could damage the plants.

The last reason is unlikely to apply. The water temperature from any greywater source quickly stabilises to that of the drainage and greywater re-use system. Only if the hot water were directly discharged by surface disposal methods; for example, flooding, should there be concern.

Septic sullage systems in South East Queensland include kitchen waste via grease traps for surface disposal. Dishwasher wastewater is not precluded. In this case, no additional maintenance problems have been attributed to kitchen waste. Some of the local authorities in this region are recommending the use of larger capacity grease traps when dishwashers are installed. This is to reduce the effects of the hot water discharge on solidified grease.

*The kitchen sink should only be accepted as a greywater source where the disposal system is not adversely affected by the heavier contaminant load. Garbage disposal units are considered an unacceptable source, as the contaminant load is extremely heavy. In some applications, user education and the installation of a large capacity grease trap could reduce problems associated with kitchen sink waste.*

### 3.4 The Bathroom

The contribution of bathroom wastewater to the total greywater volume averages 55%, with the shower contributing 41%, the bath 7% and the basin 7%. This greywater is potentially the least chemically contaminated of the various sources, but may have poorer microbial quality than laundry water.

Rose et al. (1991) reported that "total coliform and faecal coliform numbers were approximately ten times greater in bathing water ... ( $10^5$  and  $6 \times 10^3$  colony forming units (cfu) per 100 ml, respectively)...than in laundry wash and rinse water". Although baths and showers generate the greatest volume of greywater they may also contribute the greatest load of micro organisms. These, they concluded, "present a public health hazard with re-use" without treatment. (This report recommends the investigation of separation of this hazard from human contact by using techniques such as sub-surface watering).

Concern has been expressed over the effects of chemicals (for example, those in shampoo, hair dye, toothpaste and cleaning solvents) entering the greywater system from bathroom sources and being concentrated at the point of application. These effects include damage to vegetation, soils and ground water. California's experience was that there is adequate dilution in the drainage pipes, surge tank and irrigation piping so that these effects are not experienced. Careful choice of appropriate shampoos, cleaners and other chemical-based products will further minimise these effects.

Concern is also often expressed regarding people urinating in showers or the bath, and thus increasing the health risk from the greywater system. Urine is generally sterile and if passed into the greywater system will not cause any health concerns. Some bladder infections can cause the host to pass micro organisms in urine, but the potential for these organisms to survive and infect a new host is considered negligible (Niven, 1993). The ammonia in urine may actually be beneficial to most plant growth.

It is sometimes recommended that greywater should not include basin wastewater as this can have a high concentration of contaminants. By rejecting this small volume (7% of total greywater), the resulting bathroom wastewater may have a much higher chemical quality. This may not always be feasible with both existing or new drainage systems.

Most soaps and shampoos do not have any biocidal qualities and cannot be relied upon to provide any disinfection. While biocidal soaps are available, the turbidity of greywater is so high, that these soaps would be virtually ineffective in improving microbial quality.

### 3.5 The Laundry

Laundry wastewater represents on average 34% of total available household greywater. It is potentially the highest microbial quality greywater, though chemical contamination can be extremely high.

Rose et al. (1991) reported that washing machine wash water and rinse water contained concentrations of:

- 199 and 56 cfu per 100 ml total coliforms, respectively
- 126 and 25 cfu per 100 ml faecal coliforms, respectively.

The one exception to these concentrations was a highly contaminated sample taken from a wash cycle containing a load of nappies.

Lint and hair can contaminate washing machine wastewater, as well as dirt residue which causes blockage and increased maintenance of the irrigation system and pumps. These problems can be avoided by installing a low maintenance in-line coarse screen at the surge tank. Screens should not be installed directly onto the end of the washing machine discharge hose; this increases the loading on the pump and may cause it to break down.

Wash cycle water can have high chemical concentrations - such as phosphate, ammonia, nitrogen, boron and suspended solids - as well as greatly increased turbidity and raised pH. Many of these pollutants can be classified as nutrients. If transferred to the water table or waterways they can lead to environmental damage. However, if this greywater is used for watering purposes, many of these contaminants will benefit vegetation growth (though native trees and shrubs are generally not tolerant to high levels of nutrients). The added advantage is that this re-use removes some of the load from wastewater treatment plants and the waterways to which they discharge their effluent. Chapter 7 discusses techniques which avoid greywater reaching the water table and encourage the uptake of nutrients by vegetation.

Laundry detergents, dish washing liquids and shampoos, particularly biodegradable and phosphate and boron free (or reduced) products, can be chosen to reduce some of these problems. The USA has banned the use of high phosphate detergents.

Powdered detergents contain fillers that may cause a residue build up, leading to watering system blockage. Liquid biodegradable detergents are recommended.

The disinfection ability of detergents (including bleach) can not be relied upon as a means of improving the microbial quality of greywater. This is due to the:

- ineffectiveness of disinfectants when turbidity is high
- variability in water quality and disinfectant dosage.

Some consideration has been given to using only washing machine rinse water for domestic greywater re-use, as this can be the highest chemical and microbial quality household wastewater. This concept would severely reduce the quantity of available greywater, and separation of wash water from rinse water is difficult. It also ignores the fact that rinse water still contains sufficient micro organisms and a high enough turbidity to pose a health risk.

Laundry tubs can be a source of harmful contaminants, where householders are in the habit of illegally using the tubs as a disposal system for chemical substances such as paints, solvents, or garden herbicides.

Families with infants are a direct source of faecal contamination of the greywater system through washing soiled nappies, which is generally done in the laundry tub. For these reasons the tub is often precluded as a grey water source but, with user education, these practices can be limited. One option is to incorporate a "diversion to sewer valve" at the washing machine. This would allow the user to select the method of disposal for each load.

Domestic pets should not be washed in laundry tubs as this can increase pathogens in the greywater, as well as introducing pet hair which leads to greater filter and pump maintenance.

*Householders need user guidelines to educate them to prevent discharge of illegal trade waste products and other unsuitable discharges into the greywater system.*

### **3.6 Spa and Swimming Pool Backwash Water**

Spa and swimming pool backwash water can be heavily contaminated with hair, lint, dirt and natural body oils. In most circumstances these contaminants are sufficiently concentrated to cause maintenance problems if discharged into a greywater system. The obvious concerns are that these pollutants block filters, pumps and drip irrigation emitters. Re-use to greywater leach fields may be successful.

### **3.7 Rainwater Supplement**

Rainwater is an acceptable source for supplementing a greywater system. However, rain often falls when greywater is not needed to water a rain wet landscape, and the greywater system should be diverted to the sewer at these times. Therefore, unless storage is provided for rainwater, it is of little use for watering.

The cost of providing storage vessels, with their limited capacity for other than drinking purposes, makes rainwater uneconomical when reticulated water is available. The exception may occur in regions where there is regular rainfall. For example, in Melbourne, rainwater re-used for toilet flushing could be a viable alternative to reticulated water.

A rainwater-supplemented greywater system must not provide any means or potential for cross-connection to the sewer. *Rainwater must never be discharged into the sanitary sewer system.*

Roofwater in urban situations is generally contaminated, especially with lead, and if re-used for toilet flushing could result in lead in sewage sludge. By installing a first flush diverter before the rainwater tank this problem is not diverted to the sewerage system.

### **3.8 Water Softeners**

Wastewater from a water softener fitted to the house water supply is not recommended to be included in a greywater system. The increased salt levels in this water can be harmful to plants. Water softeners replace calcium and magnesium in the water with sodium. Sodium can be toxic to some plants and can promote clogging of clay soils.

## 4 MICROBIAL AND CHEMICAL COMPOSITION OF GREYWATER

### 4.1 General

Greywater by definition is "used" water and, as a result of its use, is contaminated with various microbial and chemical constituents. If the wastewater is to be re-used it is important to understand:

- what these contaminants are
- what is their concentration
- the implications of their presence.

In this way greywater may be appropriately handled so that it may be beneficially re-used without excessively risking public health and the environment.

Numerous studies have been carried out which have examined the microbial and chemical composition of greywater. These include *Rose et. al* (1991); *Siegrist* (1977); *Brandes* (1978); *Boyle* (1982); *Sherman* (1991); *Hypes* (1974); *BCC* (1992); *NAPHCC* (1992). The results from these studies are as variable as the factors involved in producing greywater. Some of these variable factors are:

- the greywater source (such as kitchen, bath, laundry)
- socioeconomic factors
- personnel hygiene habits and activities (such as gardening or use of cloth nappies)
- types of cleaners and detergents used
- family composition
- climate.

### 4.2 Microbial Quality

#### 4.2.1 The Suitability of Faecal Coliforms as an Indicator Organism

The microbial quality of greywater has historically been assessed by determining the presence (or absence) of total and faecal coliforms. Faecal coliforms - including *Escherichia coli* (E coli) - are used as indicators that water has faecal contamination and has potential for the presence of pathogenic micro organisms. As stated by *Rose et. al.* (1991);

"The presence of *Escherichia coli* and other enteric organisms in water indicates faecal contamination and the possible presence of intestinal pathogens such as *Salmonella* or enteric viruses. Faecal coliforms are a pollution indicator and may be used to assess the relative safety of greywater. Generally, a high faecal coliform count is undesirable and implies a greater chance for human illness to develop as a result of contact during greywater re-use."

Most authorities support this generally held view [including *City of Los Angeles* (1992); *Siegrist* (1977); *Karpisak* (1992); *Calif DHS* (1990); *Brandes* (1978)]; that faecal bacteria indicate faecal contamination. This in turn indicates the potential for pathogenic contamination. A couple of exceptions question this assertion.

Siegrist (1977) states that though "levels (of faecal coliforms) are sufficient to indicate a potential for faecal contamination..., which could in turn result in pathogenic contamination...", some faecal coliforms and streptococcal isolates "(were) probably from the natural environment or skin flora of man. However, the incidence of certain enterobacteriaceae did indicate possible faecal contamination". Table 4.1 gives results of tests carried out by Siegrist (1977) on household septic tank effluent. Siegrist compared these results with the analysis of greywater from three homes.

The results indicated "a very low incidence of (the pathogen) *Pseudomonas aeruginosa* (1 of 3 homes, 7 of 47 samples), and in those samples where it was isolated, the concentrations were always below 20/100 ml". Siegrist seems to suggest that, although greywater is faecally contaminated, actual pathogenic contamination is very low when the low incidence of commonly present pseudomonas in greywater is considered; and thus it is likely that all pathogens will have an equally low incidence. (Household septic tank effluent concentrations of pseudomonas - listed in Table 4.1 - give a mean of 8 600/100 ml and 95% confidence interval of 3 800 to 19 000/100ml).

Organism	Data Points	Mean <sup>2</sup> No./100 mL	95% Confidence Interval <sup>2</sup> No./100 mL
Faecal Streptococci	97	3 800	2 000 - 7 200
Faecal Coliform	94	420 000	290 000 - 620 000
Total Coliform	91	3 400 000	2 600 000 - 4 400 000
<i>Pseudomonas Aeruginosa</i>	33	8 600	3 800 - 19 000
Total Bacteria	88	34 x 10 <sup>7</sup>	25 x 10 <sup>7</sup> - 48 x 10 <sup>7</sup>

1 - The results are for samples from septic tank effluent at five (5) residences

2 - Log-normalised data

**Table 4.1 - Bacteriological Characteristics of Household Septic Tank Effluent (Siegrist, 1977)**

The City of Los Angeles carried out a greywater pilot project in 1992, part of which involved monitoring combined greywater quality in greywater surge tanks. Eight sites were trialled for 12 months; faecal coliform levels were measured in 92 samples over this period. These faecal coliform levels:

- averaged  $> 3 \times 10^4/100 \text{ mL}$
- were not detected in only 7 samples
- otherwise ranged from 17 to  $> 1.6 \times 10^5/100 \text{ mL}$ .

The presence of four "common" disease organisms (*Salmonella*, *Shigella*, *Entamoeba histolytica*, and *Ascaris lumbricoides*) was also tested at the same rate, with none detected in any greywater samples. The City of Los Angeles (1992) concluded that this may be because "(1) none of the residents in any of the test sites shed any of these organisms, or (2) disease organisms that may have been present were deactivated in the detergent-laden environment of the storage tank". On the basis of interviews with residents at all eight sites, who "indicated occasional reports of illness", it was concluded that "the possibility that a totally healthy population was contributing to the greywater systems is considered to be remote". This is considered inconclusive proof that pathogens are never present in greywater, or that there is no *potential* for greywater to contain pathogens because:

- the illnesses reported by residents were not necessarily a result of those disease organisms being tested

there is no proof that any of the residents in any of the eight sites carried any of the disease organisms being tested.

The City of Los Angeles (1992) finally concluded that "the results indicate that there may be minimal additional risk of exposure from use of greywater for irrigation of landscaping".

Millis (1993) draws attention to "pathogens which can occur in water where coliforms may not be a very sensitive indicator; for example, *Giardia*, *Acanthamoeba*, *Cryptosporidium*, *Naegleria*. In addition, there are a number of opportunistic pathogens such as *Pseudomonas*, *Aeromonas* and *Legionella* which are present in natural water without causing problems, provided their numbers are low... There are serious viral infections which can be carried in water (hepatitis A, rotavirus, poliovirus, enterovirus and adenovirus). Most are adequately indicated by faecal coliforms. Detecting and enumerating viruses directly is not practical as a routine, since the methods are lengthy, costly, insensitive and inaccurate".

Siegrist (1977) also draws attention to non-enteric organisms discharged in saliva or washed from the skin of someone suffering from a respiratory or epidermal infection; but concludes that "transmissions of non-enteric organisms in household greywater is not of major concern".

### Conclusion

*It appears that faecal coliforms may not be a perfect indicator of pathogenic contamination of greywater, but they may be the best available. As Millis (1993) states, "other indicators may have as many or more drawbacks. " The weight of argument appears to support the assertion that faecal coliforms indicate the potential for pathogenic contamination of greywater, but to what level of risk is as yet unanswered.*

#### 4.2.2 Microbial Levels Prior to Storage

Many authors report faecal coliform levels in greywater; Table 4.2 summarises these. It is important to note that levels given by Rose et al. (1991) are from grab samples, collected before the greywater passes through the fixture, water traps or household drainage.

Though varying widely, these figures all indicate the potential for pathogenic contamination from all greywater sources. It is interesting to compare these levels with those standards/guidelines for drinking water and recycled water in Table 4.3.

Table 4.4 gives contamination levels of faecal indicators in bath and laundry greywater. When compared with the figures for septic tank effluent in Table 4.1, it would seem that greywater is less contaminated than black water. Siegrist (1977) concludes that "while greywater is not innocuous, its potential contamination appears to be substantially lower than that of either the toilet wastes or combined household wastewater. " The figures in Table 4.4 are lower than some in Table 4.2, which questions the weight of Siegrist's conclusion.

### Conclusion

*The potential for greywater to contain pathogenic micro organisms is greater than that for drinking water and may be less than that for black water. A level of caution should be exercised with greywater re-use. The level of faecal coliforms indicates the potential for greywater to contain significant levels of pathogenic contamination. If an individual in a household is excreting enteric pathogens, these would also be found in greywater.*

FAECAL COLIFORMS/100 ml				
SOURCE	ROSE ET AL (1991)	CALIF. DHS. (1990)	BRANDES (1978)	KARPISAK ET AL (1992)
Bathing/Shower Water	6 x 10 <sup>3</sup> cfu <sup>1</sup>	4 x 10 <sup>5</sup> (MPN) <sup>2</sup>	<10 to 2 x 10 <sup>8</sup> c	
Laundry Wash Water	126 cfu	2 x 10 <sup>3</sup> to 10 <sup>7</sup> (MPN)		
Laundry Rinse Water	25 cfu			
Kitchen Wastewater			<10 to 4 x 10 <sup>6</sup> c 9 x 10 <sup>5</sup>	2 x 10 <sup>9</sup>
Combined Greywater	6 to 80 cfu <sup>A</sup> 1.5 x 10 <sup>3</sup> cfu <sup>B</sup> 1.8 x 10 <sup>4</sup> to 8 x 10 <sup>6</sup> cfu		8.8 x 10 <sup>5</sup> CD 13 x 10 <sup>6</sup> D	1.73 x 10 <sup>5</sup>

- A - families without children
- B - families with children
- C - Other study quoted
- D - Kitchen and bath only
- 1 - Colony forming units
- 2 - Most probable number

Table 4.2 - Faecal Coliform Concentrations in Greywater Prior to Storage

Purpose/Use of Water	Authority	Faecal Coliforms/100 ml
Drinking Water	NHMRC (1987) WHO (1984)	< 1 0
Recycled Water (for irrigation/industry - not drinking water)	NSWRWCC (1992) <sup>B</sup>  Brisbane City Council  NHMRC (1987) <sup>A</sup>  Arizona State (1984)  WHO (1989) <sup>B</sup>	< 1  1000 (geometric mean) 2000 (90th percentile)  1000 (geometric mean) < 4000 (4 out of 5 samples)  < 25 (geometric mean) ≤ 200 (geometric mean)

Note A: Not for public access during irrigation times.

Note B: Open access

**Table 4.3 - Guidelines/Standards for Faecal Coliform Levels in Drinking and Recycled Water**

EVENT	ORGANISM	SAMPLES	MEAN <sup>2</sup> No./100 ml	CONFIDENCE INTERVALS <sup>2</sup> No./100 ml	
				95%	99%
Clothes Washing <sup>3</sup>	Total Coliforms	41	215	65 - 700	45 - 1020
	Faecal Coliforms	41	107	39 - 295	28 - 405
	Faecal Streptococci	41	77	27 - 220	19 - 305
Bathing	Total Coliforms	32	1810	710 - 4600	530 - 6160
	Faecal Coliforms	32	1210	450 - 3240	330 - 4410
	Faecal Streptococci	32	326	100 - 1050	70 - 1510

- 1 - The results shown are from in-house event sampling at each of six residences.
- 2 - Log-normalised data
- 3 - Samples were obtained from the middle of the wash cycle. Samples taken from 15 rinse cycles were consistently lower than the corresponding wash cycle values.

**Table 4.4 - Bacteriological Characteristics of Bath and Laundry Wastewaters (Seigrist, 1977).**

### 4.2.3 The Effects of Storage on Microbial Quality

Surveys of greywater storage tanks (sullage tanks) by the Brisbane City Council (1993) found average faecal coliform levels in stored greywater to be  $1.4 \times 10^8/100$  ml. When compared with faecal coliform levels of pre-stored greywater (Table 4.2), it would seem that the microbial concentration of greywater increases with storage.

Rose et al. (1991) studied the persistence of microbial contaminants in greywater, and found that faecal coliforms (as well as total coliforms and standard plate count) increased by a factor of 10 to 100 in the first 48 hours and then declined slowly. Even after 12 days, numbers remained higher than those initially present. A number of other authors support these findings, implying that pathogenic micro organism numbers may not decline in greywater storage tanks, even though growth cannot be assumed.

The physical and chemical properties of greywater - such as high levels of phosphates, ammonia and turbidity - indicate that nutrients may be available which promote the growth of micro organisms. Brandes (1976) suggests that coliform regrowth occurs in greywater due to large amounts of material present which has undergone little biological degradation (compared with black water which undergoes considerable microbial and enzymatic breakdown in the human digestive tract).

To determine the fate of pathogens in greywater, Rose et al (1991) studied the survival of two pathogenic enteric bacteria, *Salmonella typhimurium* and *Shigella dysenteriae*, and Poliovirus in greywater. No regrowth was observed as was seen for the faecal coliforms. The shigella bacteria rapidly declined in numbers immediately, while the salmonella bacteria and the poliovirus numbers were found to remain stable for 2-4 days before decreasing. Significant levels of all pathogens were still present after 8 days.

#### *Conclusion*

*Though no regrowth was detected for the three pathogens tested by Rose et al (1991), there is no guarantee that this is the case for all possible pathogens in greywater. Generally, micro organisms are growing in stored greywater. As stated by Rose et al (1991), "Due to the low infectious dose of viruses, even low concentrations would be of concern".*

### 4.3 Chemical and Physical Quality

Table 4.5 gives the chemical and physical quality of greywater as reported by a number of authorities.

Traditionally, the parameters of concern when dealing with wastewater have been:

- biochemical oxygen demand (BOD)
- suspended solids
- nitrogen
- phosphorous.

Siegrist (1977) states that of the total household wastewater load, greywater contains:

- 63% of the BOD<sub>5</sub> load
- 39% of the suspended solids load
- 18% of the nitrogen
- 70% of the phosphorus
- 65% of the flow (agreeing with figures in Table 3.1).

These figures again highlight that greywater is wastewater and heavily contaminated with pollutants.

Removing greywater from the sewerage system could not only reduce wastewater flow, but could significantly reduce the biological and chemical load on wastewater treatment plants. The nutrients present in greywater may be a valuable fertiliser when greywater is used for lawn and ornamental garden watering. It would be important, however, to ensure that these nutrients are used within the biologically active upper soil layers. They must not be allowed to leach into the water table (and subsequently into surface waters).

Some of the chemicals found in greywater may be harmful to vegetation or soils if greywater is used for landscape watering. The chemicals of particular concern are boron, sodium, total salts, chlorine and alkaline chemicals. Boron is often used in powdered detergents. Salts, sodium, chlorine and alkaline chemicals are commonly found in detergents and cleansers. Products can be chosen which have none or a reduced amount of these chemicals. It is interesting to note that no boron was detected in the City of Los Angeles (1992) trial. Sections 5.13.4 and 7 have more information regarding greywater chemicals and landscape watering.

High turbidity is also of concern with greywater, as it provides a means of protection from disinfection to micro organisms. Both chlorine and ultraviolet (UV) light disinfection become less effective as the wastewater increases in turbidity. Table 4.6 gives turbidity (and ammonia) values for greywater from different family groups and sources. Laundry rinse water is of consistently higher quality than other sources, but still has potential for the presence of pathogens. If greywater is to be re-used with human contact, it would require treatment to reduce turbidity followed by disinfection (refer Section 6).

Limited human contact with chemical contaminants in greywater is not of concern, given the generally low concentrations of these chemicals. However, greywater is still not suitable for consumption.

### *Conclusion*

*On average, chemical contamination is low. However, serious risks exist when irresponsible actions lead to slug loads of chemicals entering the greywater system. For example, laundry sinks are often used illegally to dispose of solvents, herbicides and paints. Even kitchen sinks and vanity basins can be used to dispose of harmful solvents. These slug loads are of risk to the local environment, as well as human contact. This risk may be minimised by limiting the acceptable greywater sources or by education and increasing awareness of greywater system owners.*

Table 4.5 - Chemical and Physical Quality of Greywater

Parameter	Unit	Value												Tap Water						
		BCC (1991)		Rose et al (1991)		Brandes (1978)		Enderdi		Boyle <sup>b</sup>		Sherman <sup>b</sup>			Siegis (1977)		Karpiscak (1992)		City of L.A. (1992)	
		mean	range	mean	range	mean	range	range	range	range	range	mean	range		mean	range	mean	range	mean	range
BOD <sub>5</sub>	mg/L	175				149	35 - 245	40 - 620	125 - 291	33	260	229, 1489 <sup>c</sup>								
COD	mg/L					366	119 - 870	60 - 1610	242 - 622	52		539, 597 <sup>c</sup>								
TOC	mg/L					125	30 - 375													
Suspended Solids	mg/L	120				162	25 - 510	20 - 1500	36 - 160		155	90, 150 <sup>c</sup>								
Turbidity	NTU	80	76.3	20 - 140					42 - 67			56, 63 <sup>c</sup>								<1
Total Dissolved Solids	mg/L	350				528	284 - 854	420 - 1700	686 - 925				861	140-5960	1000					
pH	--	7.4	6.54	5 - 7		6.8	6.5 - 7.3		7.1 - 8.7				7.5	5.7 - 9.9	6.5 - 8.5					
Alkalinity	mg/L		158	149 - 198		148	125 - 169		382											131
Hardness	mg/L		144	112 - 152		39	26 - 54													142
Electrical Conductivity	µmho/cm	580				443	330 - 510													
Ammonia	mg/L	5.5	0.74	0.15 - 3.2		1.7	0.1 - 8.1		0.6 - 4.5											0
Total Kjeldahl N	mg/L	12	1.7	0.6 - 5.2		11.3	5.5 - 18	2 - 50	5.7 - 18.4	1.9	17	1.16, 6.68 <sup>c</sup>								
Nitrite Nitrogen	mg/L	<0.2				0.04	0.01 - 0.24													1.0
Nitrate Nitrogen	mg/L	0.3	0.98	0 - 4.9		0.12	<0.1 - 0.2		0.1 - 0.6											10
Sulphate	mg/L	30	22.8	12 - 40		11	4 - 19													28.3
Phosphorous	mg/L	8.0	9.3	4 - 35		1.4	0.8 - 3.2		0.3 - 11.9	3.4	23									3.1
Potassium	mg/L					8.9	4.5 - 13													

- A. Source Rose et al (1991).
- B. Source City of Los Angeles (1992) and B.C.C.
- C. Kitchen Sink Wastewater only.
- N.D. Not Detected.
- D. A compilation of measured values and various standards/guidelines

Table 4.5 - Chemical and Physical Quality of Greywater (continued)

Parameter	Unit	Value																	
		BCC (1991)		Rose et al (1991)		Brandes (1978)		Enferandi		Boyle <sup>b</sup>		Sherman <sup>a</sup>		Karpiscak (1992)		City of L.A. (1992)		Tap Water	
		mean	range	mean	range	mean	range	range	range	range	mean	range	mean	range	mean	range	mean	range	D
Total Dissolved Solids	mg/L																		
Aluminium	µg/L	670				120	20 - 270												200
Barium	µg/L	45																	1000
Boron	µg/L																N.D.	N.D.	5000
Cadmium	µg/L	<10																	5
Calcium	mg/L	30				9	4 - 18												
Chromium	µg/L	<10																	50
Chloride	mg/L			9.0	3.1 - 12	48	20 - 88												250
Copper	µg/L	150																	1000
Iron	µg/L	790				17500	11000 - 28000												300
Lead	µg/L	<50																	50
Magnesium	mg/L	15				4	1 - 6												
Manganese	µg/L	40																	
Nickel	µg/L	<15																	
Sodium	mg/L	70				76	59 - 90												200
Zinc	µg/L	380																	5000

A. Source Rose et al (1991).  
 B. Source City of Los Angeles (1992) and B.C.C.  
 C. Kitchen Sink Wastewater only.  
 N.D. Not Detected.  
 D. A compilation of measured values and various standards/guidelines

Housing situation	Ammonia nitrogen (mg/L)	Turbidity (NTU)
Young couples:		
- Bath/shower	0.342	96
- Laundry wash	0.1	296*
- Laundry rinse	0.06	29
Families with young children:		
- Bath/shower	0.37	28
- Laundry wash	3.47	54
- Laundry rinse	0.08	18
Family with young adults:		
- Bath/shower	0.11	43
- Laundry wash	0.44	39
- Laundry rinse	0.33	14

\* These couples engaged in more outdoor activities, which may explain the higher solids content of the laundry wash water.

**Table 4.6 - Ammonia and Turbidity Values from a Variety of Greywater Sources and Families (Rose et al, 1991)**

#### 4.4 Summary

*Domestic greywater inevitably contains faecal indicator micro-organisms - and poses a potential health risk through human contact. Micro organisms grow in greywater, so the risk of pathogenic contamination may be higher with stored greywater. Microbial levels can be minimised by direct re-use or by treatment, but this may not always be sufficient for an acceptable risk level.*

*Potential human contact with greywater (especially greywater with high turbidity levels combined with faecal indicator organisms) makes treatment and adequate disinfection necessary.*

*Greywater is wastewater, heavily contaminated with a variety of chemicals. Disposing of greywater onsite (by using landscape watering) can take a significant load off wastewater treatment plants and provide a valuable source of nutrients to the landscape. Care should be taken to ensure that chemical constituents do not leach into waterways and the water table, and do not damage vegetation and soils.*

## 5 HEALTH AND ENVIRONMENTAL CONCERNS WITH RE-USE

### 5.1 General

The re-use of greywater poses potential health and environmental risks due to the contamination it has acquired during its "first" use. (Section 4 discusses the microbial and chemical composition of greywater). When these contaminants come into contact with humans, or accumulate in the environment, they may cause unacceptable damage. Risk to health and the environment should be a major criterion when establishing guidelines for greywater re-use. This section discusses some of the health and environmental concerns associated with greywater re-use.

### 5.2 Health Risks from Pathogenic Micro Organisms found in Greywater

As discussed in Section 4.1, there is potential for greywater to contain significant levels of pathogenic contamination. Those of greatest concern cause gastrointestinal illness and are known as enteric viruses. If a person was excreting enteric pathogens, these would also be found in the greywater. Over 120 possible distinct pathogenic viruses alone may be found in wastewater because of human excretions. There is no evidence that HIV (AIDS) is transmitted by drinking water or disposal of sewage (Riggs, 1989; Slade, 1989). Even the cleanest sourced household greywater can potentially contain pathogenic micro organisms, as seen in Table 4.2. (Rose et al (1991) found washing machine rinse water to have a faecal coliform count of 25 per 100 ml and a turbidity of 29 ntu).

Human body secretions during bathing or from clothes washing are a possible source of pathogens in greywater (refer Table 5.3). Washing family pets in the bath or laundry tub is another source of contamination. Because greywater potentially contains these infectious micro organisms, human contact with this wastewater could lead to disease and public health risk.

Disease can be transmitted to humans:

- directly from person to person, through contact, ingestion or inhalation of infectious water droplets
- indirectly by contact with media previously contaminated.

The occurrence of illness is dependant on many factors, including:

- susceptibility of the host (some people are more susceptible than healthy adults;
  - young children
  - the elderly
  - people already in a poor state of health
  - people with reduced immunity conditions)
- the numbers of invading micro organisms
- the numbers of organisms necessary to initiate infection
- the organisms' ability to cause disease.

Studies have shown extreme variability in the infectious dose required to cause disease. Crook (1985) reported that 10 or fewer *Giardia lamblia* cysts or *Shigella dysenteriae 1* can cause illness, whereas it may require 1 000 *Vibrio cholerae* or 10 000 *Salmonella typhi* to produce the same result. Reports show that a very small number of viruses may be able to initiate disease in humans. California DHS (1990) reports that "infective doses of enteric viruses range down to less than 10 virus units (for example, hepatitis) and to one or two (for example, polio)".

The number of pathogens in wastewater has decline markedly over recent decades as a result of disease control with antibiotics, and improved sanitary conditions and practices (Crook, 1985). However, during a disease outbreak, the number of pathogens in wastewater dramatically increases.

This could lead to a similar pathogen increase in greywater. This may be an extremely rare occurrence in present times.

However, what is unknown is the effect of greywater re-use during such a disease outbreak, when to date practical experience with greywater re-use has involved a "healthy" population.

The level of immunity within the community - a highly variable factor - is also of concern. It is conceivable that pathogens have repeatedly contaminated existing greywater systems, but that previous exposure has made immune those in contact with the greywater.

This could represent a decidedly unstable situation rather than prove that uncontrolled greywater re-use is satisfactory. Pathogens could be introduced into the greywater system by an immigrant to the community, or from a seasonal outbreak for which people have no immunity.

Partially because of the low incidence of disease outbreak in developed countries and the lack of awareness which accompanies this, there have been trends away from immunising or for late immunising of children. Unfortunately this leaves these children with a much lower immunity to disease and facing serious health consequences. Specific religious groups in Holland who reject immunisation have repeatedly been shown to be susceptible to poliomyelitis (Forsyth, 1993).

The Queensland Government Health Department report on child immunisation ( Qld Health, 1993), quotes the United States along with Bolivia and Haiti as having the worst vaccination rates for children aged two years or younger in the western hemisphere. The report further states that:

"increasing incidence of vaccine preventable disease in the USA is occurring despite the requirement in almost all states for complete vaccination at school entry. Vaccination levels are estimated to be 97% to 98% at the time of enrolment in school, but as low as 50% among two year old children in some inner city populations."

Table 5.1 provides a detailed breakdown by age of child versus vaccination rates for Queensland; revealing that many vaccinations were administered much later than recommended. The report made particular note of the substantial delay in administration of the polio vaccine to children under 1 year old:

"One quarter of infants did not receive one or more of their 2, 4, and 6 month vaccinations until after their first birthday. While there have been no cases of polio in Australia since 1986, vaccination rates are now so low that there is concern about the possible resurgence of the disease."

	Under 1 year	1 year olds	2 year olds	3 year olds	4 year olds	5 year olds	6 year olds
Overall percentage of children who were age appropriately vaccinated	55.7	60.0	52.5	56.0	51.5	52.6	67.3
Percentage of children who were age appropriately vaccinated against diphtheria/tetanus	78.9	98.4	92.3	93.9	97.1	84.0	91.3
Percentage of children who were age appropriately vaccinated against polio	56.5	61.6	83.4	89.3	83.4	62.3	79.2

Source: Australian Bureau of Statistics, 1989-90  
National Health Survey

**Table 5.1 Age and Disease Specific Vaccination Rates for Queensland Children Aged 0 to 6 Years, 1989-90**  
(Queensland Health, 1993).

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUST
Percentage of total children who were either shown or claimed to be age appropriately vaccinated	51.6	51.0	56.1	53.1	56.4	48.9	46.3	64.2	52.9

Source: Australian Bureau of Statistics, 1989-90  
National Health Survey

**Table 5.2 Vaccination Status of Australian Children Aged 0 to 6 Years, 1989-90**  
(Queensland Health, 1993).

To give an indication of infection rates for Australia, Table 5.3 gives the incidence of disease from some of the dominant enteric pathogens for a few centres of population. It is interesting to note that the incidence of reported enteric infections in Melbourne was approximately half that for Perth and was far greater in the Kimberley region. Gibbs and Ho (1993) question the validity of this data, stating that variations between Melbourne and Perth were "more likely to have been due to differences in notification rates". *However, the Kimberley region is virtually unsewered, Perth is 70% sewered while Melbourne is nearly 100% sewered. It is possible that the disparity between the incidence of disease for these regions is directly related to the method of wastewater disposal.*

These figures do not include symptomless and unreported cases of infection, which could represent significant numbers, especially for viral infections. Viral disease is generally unreported for several reasons:

- the mild nature of most enteric virus infections precludes reporting by the patient or physician
- the variety of symptoms which can be produced by the same virus
- enteric viral infections are often not apparent
- damage caused by enteroviral infections may not become obvious for several months or years
- present methods of detecting viruses are not sensitive enough to isolate and identify the viral agent
- the low level dose of viruses required for infection.

[Crooke (1985) and Rose (1992).]

Pathogen	Incidence/100 000		
	Melbourne	Perth	Kimberley
Hepatitis A	14	NS	NS
<i>Campylobacter</i> species	58	103	448
<i>Giardia</i> species	20	46	1062
<i>Salmonella</i> species	23	34	712
<i>Shigella</i> species	2.0	4.4	418
<i>Echinococcus</i> species (hydatid disease)	0.03	0	0
Degree region is sewered	100%	70%	0%

**Table 5.3 - Incidence of Enteric Infectious Diseases per 100 000 Population (1991) (Gibbs and Ho, 1993)**

Table 5.4 lists some of the major pathogens that could be present in greywater, and the diseases that can be caused with infection.

MICRO-ORGANISMS	DISEASES CAUSED	SOURCE
<b>Virus</b>		
Enteroviruses (polio, echo, Coxsackie)	Gastrointestinal Symptoms, Meningitis, paralysis, cardiac systems, conjunctivitis, hand, feet and mouth diseases	Faeces
Rotavirus	Gastroenteritis, diarrhoea (especially in infants)	Faeces
Adenovirus	Respiratory disease, conjunctivitis, gastroenteritis	Faeces
Norwalk Virus	Gastroenteritis, winter vomiting disease	Faeces
Hepatitis A Virus	Infectious hepatitis	Faeces
<b>Bacteria</b>		
Salmonella	Gastroenteritis, diarrhoea, typhoid fever (S.typhi)	Faeces
Shigella	Bacterial dysentery	Faeces
Campylobacter	Gastroenteritis, diarrhoea	Faeces
Yersinia enterocolitica	Acute gastroenteritis, diarrhoea	Faeces
Pseudomonas aeruginosa	Skin and ear infections	Mucous membranes, skin lesions etc.
Clostridium perfringens	Gastroenteritis, gas gangrene	Faeces, soil
Clostridium tetani	Tetanus	Soil containing spores, possibly associated with vegetables
Aeromonas sp.	Gastroenteritis	Faeces
Escherichia coli	Gastroenteritis	Faeces, possibly soil
Vibrio cholerae	Cholera	Faeces
Leptospira	Leptospirosis	Faeces
<b>Protozoa</b>		
Giardia lamblia	Diarrhoea, nausea, vomiting, fever	Faeces
Cryptosporidium	Diarrhoea, nausea, vomiting, fever	Faeces
Entamoeba histolytica	Amebic dysentery	Faeces
<b>Helminths</b>		
Ascaris lumbricoides	Ascariasis (round worm)	Faeces, soil
Strongyloides stercoralis	Strongyloidiasis (thread worm)	Faeces, soil
Trichuris trichiura	Trichuriasis (whip worm)	Faeces, soil

Table 5.4 - Major Pathogens Potentially Present in Greywater  
(BCC, 1993, Gibbs and Ho, 1993, and Crooke, 1985)

## 5.3 Disease Transmission Through Greywater Re-use

### 5.3.1 General

For a person to become infected with pathogens from greywater, there must be some way for the person to come in contact with the greywater. This can happen in one of two ways:

- *directly* - by ingesting, inhaling or contacting infectious water droplets
- *indirectly* - by contacting media which has previously been contaminated, such as soil or edible fruit and vegetables.

Typical disease transmission scenarios, however unlikely, include:

- above ground irrigation droplets being inhaled by passersby
- above ground irrigation droplets deposited on edible plants are ingested by humans
- vegetable root crops being watered sub-surface with greywater are eaten raw
- child playing on greywater irrigated lawn ingests contaminated soil or droplets of greywater after licking hands or placing play objects in mouth
- person maintaining greywater system does not wear gloves/wash hands after working on system, then passes contaminants to mouth by:
  - smoking a cigarette
  - eating food
- children neighbouring a property, which spray irrigates with greywater, jump the fence to play under the sprinkler water
- person flushing a toilet or urinal utilising greywater is splashed with greywater droplet, causing a skin infection
- greywater used for watering is allowed to pond on the surface, and children play in and bath in the puddle
- child drinks from an above ground greywater irrigation pipe.

No illness due to contact with greywater has been reported, despite the widespread (yet sparse) practice of greywater re-use. However, for similar reasons as mentioned in the previous section (regarding viruses), this does not mean that no illness has occurred. In addition to suspected unreported cases of infection, greywater related disease incidences are likely to be low because of:

- the low number of greywater re-use systems in use
- the limited population that any single infected system would come in contact with (which would also reduce the likelihood of disease related to such a system being reported)
- the "healthy" population practicing greywater re-use, limiting pathogen shedding into the greywater system
- poor recording practice in establishing the cause of illness
- the mild nature of most enteric virus infections precludes reporting by the patient or physician.

Therefore, in the absence of any detailed risk analysis of the potential for disease transmission through greywater re-use, it must be concluded that this is a distinct possibility.

*Re-use methods must be such that human contact with contaminated greywater is prevented, or greywater must be treated to remove or deactivate pathogens before re-use. Avoiding human contact may be achieved by using sub-surface landscape watering techniques. Treatment to remove or deactivate pathogens would usually include filtration followed by some form of disinfection.*

### 5.3.2 Statistical Risk Analysis

The US Environmental Protection Agency (EPA) has stated that an infection rate in the community of 1 in 10 000 population is a socially acceptable risk. Risk assessment models by Rose and Gerba (1991) dealing with viruses and protozoa in re-used water in the USA assess the probability of infection from accidental ingestion of 100mL of reclaimed wastewater. (These give an equivalent risk of 2 in 10 000 when a virus/protozoan concentration of 10 infectious units/100mL is present in the reclaimed wastewater).

To date, there has been no attempt to quantify analytically the health risks associated with specific uses of greywater or greywater re-use systems. This is primarily because of the extreme variability and number of factors associated with any given risk analysis. The City of Los Angeles concluded that an statistical risk assessment would have little credibility as it would be based on too many assumptions, with the margin for error being compounded with each subsequent assumption (Sheik, 1993). *However any further research should include an evaluation of any statistical risk assessment of health risks associated with proposed greywater re-use practices. Quantification of the likelihood that assumptions will occur should lead to a more accurate measure of risk.*

### 5.4 Disease transmission by mosquitoes and vermin

Pathogens can be transmitted by birds, animals, mosquitoes and vermin; for example, rats, mice, cockroaches, flies. Screening vent cowls and air-tight access covers fitted to vessels will prevent access into the greywater system. Ponding from poor irrigation practices or methodology and inadequately maintained storage or surge tanks could provide further breeding habitats for mosquitoes (refer Section 5.13.7).

*The incidence of mosquito transmitted illness is increasing in Australia.* Mosquitoes are becoming resistant to insecticides sprayed on their breeding grounds. During the 1992/93 wet season, around Townsville, there was a serious outbreak of Dengue fever and Queensland's largest outbreak of

*Barmah Forest disease.* In 1992, Queensland had 4313 confirmed cases of Ross River fever. There are several species of mosquitoes that are of concern in either causing public nuisance through biting, as a vector of mosquito born disease, or both.

*Culex quinquefasciatus* is a common mosquito in Brisbane. The breeding habitat includes water which may contain a high level of organic pollutants. Known breeding locations include defective septic tanks and open drains. In Australia, *Culex quinquefasciatus* is relatively disease free. However in areas of the world with poor public sanitation, this is an important vector of *human filariasis* (diseases caused by filarial parasites). There are an estimated 200 million people infected with this disease. Pondered greywater would provide an ideal habitat for breeding of this species.

*Culex annulirostris* is a fresh water breeding mosquito which takes advantage of temporary and semi-permanent ponding. This mosquito is an important vector of *Ross River virus* and *Murray Valley Encephalitis virus*. It is common to Brisbane in times of high summer rains. Greywater disposal resulting in ponding itself or in conjunction with rain would support breeding of this mosquito under conditions of low organic contamination.

*Aedes aegypti* is a mosquito native to Africa and is common to tropical and sub tropical regions. As a container breeding mosquito it prefers relatively clean water and was once a problem in Brisbane with poorly maintained roof water tanks. This mosquito has been completely eradicated from the Brisbane region but can be found in other localities of Queensland. *Aedes aegypti* is the vector for *Dengue virus*. Pondered or stored greywater, with low levels of organic matter, could support breeding of this mosquito.

Depending on the quality of water contained within resulting ponds, there are several other species of mosquitoes that may breed in greywater.

## *Conclusion*

*Inadequately maintained greywater systems and poor irrigation methodology or practice could provide further breeding habitats for mosquitoes and inadvertently increase the incidences of mosquito related disease and public nuisance from biting. The Australian tourism industry is increasingly reliant on overseas tourists for success. Any increase in mosquito related disease can only be harmful.*

## **5.5 Disinfection**

### **5.5.1 General**

Chlorine residual from potable water is unlikely to be present or to provide any degree of disinfection once the water is used for domestic purposes. The high turbidity and the presence of solid matter would ensure any residual chlorine present is quickly inactivated and hence is ineffective.

Some parties have suggested that the residual detergents and bleach in washing machine greywater will provide adequate disinfection to remove pathogens. Studies - as detailed in Section 4.2.2 - clearly show this is not the case.

In general, the most important parameter when assessing the effectiveness of disinfection processes for greywater systems, is turbidity. All disinfection methods (chlorine, UV, ozone) will decrease in effectiveness as turbidity increases. Before disinfection some form of treatment should be included in the process to reduce turbidity. Chlorine is likely to be the most effective disinfectant which can be usefully applied to turbid waters. However, if turbidity is low or can be reduced to low levels, then UV would probably be more effective than chlorine as a disinfectant, due to its greater activity against viruses and cysts.

The cost of UV systems would be higher than a simple chlorination system, but may be justified if turbidity can be controlled economically in the greywater stream.

It is anticipated that effective disinfection of greywater will ensure pathogens (and their faecal indicators) are at "acceptable levels" for human contact. If disinfection is not included in a treatment process, then it is unlikely that pathogen levels could be effectively controlled at all times. This is due to the ineffectiveness and unreliability of other treatment processes and the variability in levels of pathogen shedding by household members.

### *Conclusion*

*If a greywater treatment system employs no physical processes designed to reduce turbidity, any disinfection process will probably not effectively reduce microbial populations in greywater to acceptable levels.*

#### 5.5.2 Natural UV as a Disinfectant

Sunlight exerts a lethal effect on all micro organisms located on the very surface of soil (Frankenberger, 1992). This effect may be due to desiccation or UV radiation. Studies quoted by Frankenberger (1992) compared the survival of two Salmonellae species. One was exposed to direct sunlight; the other was shaded. The survival of salmonellae was prolonged in the shaded areas; other micro organisms (including *S. bovismorbificans*, *E. coli*, *S. faecalis*, *Leptospira*, *Brucella*, and *Mycobacterium*) had higher die-off rates when exposed to direct sunlight as opposed to shaded areas. The deactivation of pathogens in this way may have implications for greywater re-used for landscape watering. It may provide a mechanism for reducing the risk of contact with pathogens near the surface of a greywater irrigated landscape.

#### 5.6 The Reliability of Owner Maintained Systems

The City of Los Angeles (1992) Pilot Project on Greywater Re-use found that 80% of the greywater systems trialled were not adequately maintained by their owners. What is of significance is that the participants in this trial were all volunteers who were aware that their systems' performances were being monitored. These poorly maintained systems incorporated minimal treatment (screen filtering only - what this report defines as a "primary greywater system"). Most system failures recorded occurred as a result of inadequate filter cleaning. These failures resulted in water not reaching watering systems. While potentially damaging to vegetation in the long term, the failures were not considered to be of any public health significance (as greywater discharged to the sewerage system via a safety overflow).

What is of concern is the potential poor maintenance of greywater systems which incorporate a higher level of treatment (such as a higher degree of filtering and disinfection - what this report defines as a "secondary greywater system"). The poor performance of these systems may result in unsatisfactory quality effluent (which is thought to have been adequately treated) coming in contact with people and causing a health risk.

The Brisbane City Council's evaluation of onsite domestic sewerage treatment systems also found that the effluent quality of 65% of the sampled sites did not comply with the Queensland Water Resources Commission requirements. This study attributed this poor result mainly to inadequate maintenance.

*Based on this evidence, owners will probably not adequately maintain greywater systems. Because of this assumption, the Californian Ad Hoc Greywater Committee in Appendix W specified that greywater be re-used untreated and via sub-surface irrigation. There would be no reliance on greywater being treated to a standard that allowed contact with humans (see Section 2.1.3). In this way, these "primary" greywater systems can malfunction due to lack of maintenance without causing a risk to public health, as in the City of Los Angeles trial (1992).*

As suggested in the USA, a way to remind greywater system owners that maintenance was needed was to periodically mail out a simple check list to each "greywater household". As part of a permit system, the owner would check a list of maintenance requirements and then sign a declaration at the bottom of the list stating that his system was adequately maintained. The list would then be mailed back to the regulatory authority (refer Section 5.9).

### 5.7 Risks of Application to Multiple Users

Appendix W of the USA Uniform Plumbing Code (see Section 2.1.3) restricts greywater re-use to within a single family dwelling. This regulation's purpose is to minimise any potential health risk by confining any pathogens present to contact with their carriers. This regulation specifically precludes the application to multi-occupancy dwellings, commercial buildings, restaurants, and public accessed lawns and gardens.

The health risks associated with inadequate owner maintenance are being quoted as being substantially increased when greywater re-use is applied in multiple occupancy dwellings. The reason for this is that no-one claims responsibility for the system when there are many individual household units sharing the one system. In practice, the opposite often seems to occur, with a single person (often a complex maintenance person) assuming responsibility for the greywater system. The City of Los Angeles (1992) found that the only primary greywater system adequately maintained during its trial was installed in an apartment building, with one individual responsible for its maintenance.

Authorities responsible for implementing these regulations were unable to quantify the health risks associated with greywater coming in contact with separate unrelated households (refer Section 5.3.2). This regulation has merit, but it does not allow for minimising the risk level by treating greywater or by separating it from human contact. The Californian Ad Hoc Greywater Committee may be wise in providing multiple-barriers to the risk of pathogenic infection. These are both limiting greywater re-use to *single family dwellings* and *sub-surface irrigation*. This is because there is still some minor concern that sub-surface irrigation will not separate greywater from human contact in all circumstances. Treatment was considered an unreliable option due to the concerns of inadequate maintenance, as detailed in Section 5.6.

*For systems to be installed in multiple user situations, maintenance must be performed under an administrative procedure with independent auditing that will ensure acceptable effluent quality.*

### 5.8 Health Risks to the Owner During Maintenance

Most of the lawn and garden watering greywater re-use systems operating in California are simple generic systems that need regular maintenance. This may be as simple as replacing or cleaning filters at the inlet to a surge tank or irrigation system, periodically desludging the tank, and flushing the irrigation lines. However, anyone doing this work is at greater risk of coming in contact with greywater than any other party.

This health risk may be adequately minimised by educating the owner/maintainer of these systems to the danger and potential health risks of contact with greywater. Wearing gloves while working on the system, washing hands afterwards, or taking care not to splash greywater around the face may help to reduce this increased risk of exposure.

*Any permit to operate and maintain such a system should include education of the owner/maintainer to the associated health risks and basic hygiene practices needed for safe operation of the system.*

### 5.9 Inheriting a Greywater System

Inheritance of a greywater system may be through buying a premise where a greywater system is installed. *An administrative system is needed in the conveyance process to ensure that the new owner is both familiar with the characteristics of the greywater system and is competent to operate it.*

As mentioned in Section 5.6, a simple mail-out check list could be forwarded to the property at the time of permit renewal (annually). For permit renewal, the owner would have to return a signed, completed check list to show compliance. This type of process places the liability for greywater systems performance with the owner, but it does not ensure that the system is adequately maintained. New owners may not fully understand the function, operation and health and environmental risks of the greywater system they now own.

#### **5.10 Cross connection with the potable water supply**

With the incorporation of plumbing for non potable purposes into the home there is a potential for accidental cross connection of the pipework with the potable water supply. This serious health risk is of particular concern inside the home with greywater toilets, where dual plumbing may be required. Outside the home, accidental cross connecting of greywater and potable water irrigation systems could occur.

Solutions include the following;

- colour coding and labelling of pipework to identify the contents (as per AS 1345 - "Identification of the Contents of Piping, Conduits and Ducts").
- installation of anti backflow devices on the potable water service to the property and on all potable water taps and hose points within the property as per AS 3500 National Plumbing and Drainage Code
- maintaining the operating pressures for greywater plumbing at pressures less than the potable water service.
- use of non compatible pipes and fittings
- where potable water is used as a supplement in greywater vessels, air gaps should be provided (as per AS 3500 - "National Plumbing and Drainage Code"). An overflow should be incorporated into greywater vessels to ensure the integrity of the air gap.

The design of hand basin toilets should ensure that there is an air gap provided in the cistern between the potable service and the greywater, to prevent cross connection.

#### **5.11 The Effects of Flow Reduction on the Sanitary Sewer System**

Re-using greywater for any domestic purpose will effectively reduce the volume of wastewater being discharged to the sanitary sewer system. This is expected to have both an effect on the flow in sewerage pipelines, and on the facilities that treat the wastewater.

As discussed in Chapter 14, on average, dry weather sewage volumes could be reduced by 356 Litres/household/day through implementing greywater re-use. This represents a 61% decrease in sewage discharged from a household. Both BOD and suspended solids are also reduced by approximately 100 grams/kL of greywater removed (compare with Table 4.5). The BOD and suspended solids of the wastewater to be treated will increase in concentration, but the total load will decrease. The treatment process should benefit from the loads and flows reduced by removing greywater from the sewerage system.

Some authorities have suggested that wide spread acceptance of greywater re-use systems could result in savings through reduced sizing of the sewer system. This is an incorrect conclusion. Sanitary sewer capacities are designed by multiplying the estimated total dry weather flow by a design factor. The design factor is a safety margin that allows for increased wet weather flows through inflow and infiltration as well as dry weather catchment changes. During rain and for some period immediately after, the full capacity of the sewer will be required, as all the greywater is being diverted from the re-use system to the sewer. In addition, not all premises will be suitable for greywater systems nor will all property owners desire a system.

Concerns have been expressed that reducing sewer flows may cause problems with the transport of solid matter in wastewater along both private drains and sanitary sewer pipelines. This may lead to blockages and septic waste build-up. The Brisbane City Council (1988) conducted performance trials on low flush toilet volumes in sewer systems. Stage 1 of that research involved monitoring the passage of solid matter through a 100mm transparent sewer line, laid at minimum grade. The transparent sewer was purpose built and was connected only to the test site's toilets. Stage 2 of the project involved monitoring 6/3 litre dual flush toilets installed in private homes. The sewer in this instance was a 150mm diameter, mortar joint, glazed earthenware sewer, laid in 1926. The sewer again was constructed at minimum grade and was subject to wet weather surcharge. This research concluded that;

- Low capacity dual flush toilets provide a sufficient transport medium for toilet waste matter.
- This flow reduction has had no detrimental effects on the private drain or the sanitary sewer.

In January 1993, Brisbane City Council introduced plumbing by-laws making 6/3 dual flush toilets or the single flush equivalent mandatory for new installations.

### *Conclusion*

*The introduction of greywater re-use will not substantially reduce the loading on existing sanitary sewers. There may be some benefit in decreases in both sewage volumes and oxygen demand at the treatment plant. Specifically designed sewerage schemes incorporating greywater systems may reduce the design parameters of the sewerage system.*

*Extrapolating the Brisbane City Council research on low capacity toilets to greywater re-use, it is safe to conclude that reduced greywater volumes resulting from the retro-fitting greywater systems will not be detrimental to either private drains or the sanitary sewer (Krumins, 1993).*

### **5.12 Health Risks Associated with Storage of Greywater**

As discussed in Section 4.2, micro organisms will grow in stored greywater. This includes pathogen indicator micro organisms and may include pathogenic micro organisms. *Re-use of stored greywater must be associated with a higher risk to health than greywater re-used directly, because the higher the number of pathogen indicator organisms the greater the likelihood of transmission of infection.*

The Ad Hoc Greywater Committee in Appendix W specified that greywater was only to be used for direct re-use. This limits the potential for pathogens to multiply to unacceptable levels.

Some greywater is inevitably captured and stored in the water traps of plumbing fixtures, and on the surface of drain pipes. These areas will provide ideal environments for micro organisms to survive and breed. Subsequent use of fixtures will flush these organisms into the greywater flow. Storage volumes (and numbers of micro organisms) are expected to be small. With the dilution the greywater stream would provide this is not expected to be a problem with non contact re-use methods.

Care in the design of greywater systems may minimise storage volumes, and it is recommended that surge tanks be allowed to drain dry after every usage. Design considerations may include a sump incorporated into surge tanks, and pumps to be fitted with non-return valves so that water does not flow back into the surge tank.

It should also be noted that stored greywater can develop a very strong odour. The City of Los Angeles (1992) noted that the removal of greywater tank lids often lead to an "overwhelming" odour, and that "the odour was strongest and least tolerable if greywater had been allowed to reside in the tank for an extended period of time". This problem may have been accentuated through poor venting practice.

*Treatment of greywater may improve the quality of the water to such an extent that greywater may be able to be stored for some time without causing the above problems. Treatment should include at least filtration and high level disinfection to prevent regrowth.*

### **Conclusion**

*Storage of greywater promotes the growth of micro organisms, including faecal coliforms which are an indicator for the potential presence of pathogens. Direct re-use without storage will minimise this microorganism growth and hence reduce the health risk.*

*Storage of greywater should only occur if treatment and disinfection produce an effluent with an acceptable microbial level.*

## **5.13 Concerns with Application to Lawn and Garden Watering**

### **5.13.1 The Effects on Microbial Levels in the Soil**

In 1992, the Office of Water Reclamation for the City of Los Angeles, California, reported on the recently completed "Greywater Re-use Pilot Project". In this project eight greywater re-use trial sites were established and greywater landscape watering was practised for 12 months. Subsurface drip watering was adopted for all sites, with dedicated areas at each site receiving either greywater or potable water. Seven of the greywater systems were "primary" systems, and the other was a "secondary" system (see Section 6.3).

This project compared the microbial and chemical constituents of the soils and water in areas receiving greywater and those using tap water. The study found the following:

- The data showed a significant difference in total coliform levels between greywater and tap water irrigated sites. Indicator bacteria in the soil increased with greywater application, possibly because greywater has organic matter which can support the growth of soil micro organisms.
- For faecal coliforms or for enterococci bacteria levels, the data did not show any significant difference between sites or between areas irrigated with greywater or potable water. For both of these organisms, levels in the soils for all sites fluctuated widely and inconsistently between  $<20$  to  $>1.6 \times 10^6$  col/gram of soil.
- Backyard soils are already heavily contaminated with animal faecal matter.
- Tests for the presence of salmonella, shigella and entamoeba histolytica ("common" disease organisms) on all sites were negative. These organisms were not detected in the stored greywater. This may indicate an entirely healthy test population or a mechanism for deactivation of these pathogens.

The City of Los Angeles (1992) report concluded "that there may be minimal additional risk of exposure from use of greywater for irrigation of landscaping" because:

- there were already indicator organisms for faecal contamination in backyard soils prior to greywater irrigation
- three "commonly present" disease organisms, normally capable of surviving in the soil for a few days, were neither detected in greywater irrigated areas nor in stored greywater.

This conclusion may well be correct. However, there is no evidence that any resident at any of the eight sites was shedding these particular disease organisms at testing time. Not detecting these pathogens may only be indicative of a healthy test population. The risk to health from a greywater system must be assessed, taking into account the likelihood of the population remaining healthy, and the effects that a "disease outbreak" may have on this general good health.

The report also noted that one site which was virtually free of all domestic and wild animals had a consistently lower level of total and faecal coliforms in the control soils than in the greywater irrigated soils. This indicates one of the following:

- animal faecal contaminants effectively mask the contribution of greywater normally. *Human* faecal contamination does in fact contaminate greywater irrigated soils, even though concentrations are low when compared with the background faecal contamination naturally occurring in soils
- greywater promotes the growth of faecal indicator organisms already in the soil.

The most probable scenario is the second option, but if the first option is correct then what is unknown is whether human faecal contamination is a more serious health risk than animal faecal contamination. If this is the case, then the City of Los Angeles may be incorrect in concluding that greywater irrigation carries a "minimal additional risk".

### *Conclusion*

*There seem to be already high levels of indicator organisms for faecal contamination in backyard soils. With a healthy population, sub-surface watering confined to the parameters of the USA's Appendix W does not seem to cause health concerns. The important parameter here is a "healthy population".*

### 5.13.2 The Survival of Pathogens in the Soil

Pathogenic organisms can survive in soil, water or on vegetation from a few hours to months. The following are a list of the factors that can affect their survival:

- Type of organism
- Number of organisms
- pH
- Rainfall
- Humidity
- Degree of exposure to sunlight
- Competition with other microbial flora
- Type of soil
- Soil moisture content
- Temperature.

Table 5.5 shows a summary of survival rates for some pathogens in soils as reported by Gerba, et. al. (1975) and WHO (1989).

ORGANISM	SURVIVAL TIME (days)
Coliforms	38
Streptococci	35 to 63
Faecal streptococci	26 to 77
Salmonella	15 to > 280
Salmonella typhi	1 to 120
Tubercle bacilli	> 180
Leptospira	15 to 43
Entamoeba histolytica cysts	6 to 8
Enteroviruses	8 to 175
Ascaris ova	up to 7 years
Hookworm larvae	< 90 but usually < 30
Brucella abortus	30 to 125
Q-fever organisms	148
Vibrio cholerae	< 20 but usually < 10

**Table 5.5 - Survival of Pathogens in Soils**  
(Gerba, et. al., 1975 and WHO, 1989)

Tables 5.6 and 5.7 summarise the factors that affect the survival of enteric bacteria and viruses in the soil.

OPPOSE REMOVAL	PROMOTE REMOVAL
Increased soil moisture content.	Extremely acidic or alkaline soil conditions.
Cooler temperatures.	Exposure to sunlight.
Higher organic matter content.	Presence of antagonistic microflora.

**Table 5.6 - Factors Affecting the Removal of Enteric Bacteria in Soil**  
(Frankenburger, 1992)

Landscape watering with greywater will increase the moisture content and the organic matter in soils. Both these conditions promote the survival of enteric bacteria and viruses.

Pathogens in soils could survive long enough to potentially pass to a person who comes in contact with that soil. Frankenburger (1992) stated that when applied at the surface " continuous application of wastewater could result in accumulation of pathogens at the soil surface". Theoretically it would be possible for soils continuously watered with greywater to contain infectious doses of pathogens.

Factors	Remarks
pH	Low pH favours virus adsorption; however, high pH favours virus inactivation.
Temperature	High temperature favours virus inactivation.
Virucidal chemicals	Chemicals such as ammonia promote virus inactivation.
Cations	Cations neutralise or reduce the repulsive electrostatic potential (negative charge) of virus particles and soil components, favouring adsorption. The presence of chloride salts promotes virus inactivation.
Clay	Enhance virus adsorption.
Organic matter content	Enhance virus adsorption.
Cation exchange capacity	High cation exchange capacity promotes virus adsorption.
Flow rate	Low flow rates ( 0.6 m/day) favour virus removal.
Suspended organic solids	Soluble organic matter competes with viruses for adsorption sites on soil colloids and hinders viral inactivation in wastewater.
Rainwater	Promotes desorption of viruses.

**Table 5.7 - Factors Affecting Virus Removal by Soil**

(Frankenberger, 1992)

### 5.13.3 The Movement of Pathogens through the Soil Profile

Frankenberger (1992) summarised the following in his research into the fate of wastewater pathogens in soil and groundwater:

- The literature indicates excellent removal of viruses through soil columns and adsorption in batch studies. It is evident that viruses differ quite markedly in their survival and removal during percolation through the soil.
- Most studies show that bacteria are confined to the upper few centimetres of soil when wastewater is applied at the surface, and never reach ground water unless the soil has large cracks or channels.
- The main factors that govern the transport of bacteria, ova of intestinal worms, and cysts of protozoan through the soil matrix are straining, sedimentation, and adsorption. Adsorption is the primary mechanism for viral retention in soil.

Table 5.8 shows the movement of bacteria through soils as a result of wastewater application. Distances greater than 3 metres and up to 187 metres were recorded, though no information is given on the application rate of the wastewater. This would affect the distance travelled, with high flow rates promoting the movement of bacteria.

Frankenberger (1992) concluded that "wastewater application to soil appears to be very effective in pathogen immobilisation and inactivation".

Capillary action in some soils may be responsible for greywater (containing pathogens) emitted subsurface, reaching the surface (Kiado, 1993). Both Farwell (1993) and Sheik (1993) disagree with this opinion. Frankenberger (1992), noted that pathogens have the potential to accumulate at the soils surface using surface application methods. With appropriate application rates and soil types, pathogens may remain and deactivate close to the emitter, despite capillary action in the soils. Kiado (1993) quotes advice from the Californian State University (Centre for Irrigation Technology) that to prevent surfacing of greywater, subsurface drip emitters be located at the following depths:

- 200mm in sand
- 300mm in loam
- 400mm in clay.

### *Conclusion*

Further research is required to determine the potential for pathogens to move through the soil profile; particularly from sub-surface emitters to the soil surface. Still to be determined for Australian conditions are greywater application rates and depths for sub-surface drip emitters, that prevent greywater from reaching the ground surface.

Nature of Fluid	Organisms	Media	Maximum Distance Travelled (M)	Time of Travel
Tertiary treated wastewater.	Coliforms	Fine to medium sand	6.1	--
Secondary sewage effluent on percolation beds.	Faecal coliforms	Fine loamy sand to gravel	9.1	--
Primary sewage in infiltration beds.	Faecal streptococci	Silty sand and gravel	183	--
Inoculation water and diluted sewage injected sub-surface.	Bacillus stearothermophilis	crystalline bedrock	28.7	24 -30 Hrs
Sewage in buried latrine intersecting groundwater.	Bacillus coli	Sand & sandy clay	10.7	8 weeks
Canal water in infiltration basins.	Escherichia coli	Sand dunes	3.1	--

a. Adapted from Gerba (1975) & Hagedorn (1981) by Frankenberger (1992).

**Table 5.8 - Movement of Bacteria through Soils in relation to Wastewater Application**

#### 5.13.4 The Effects of Chemicals on the Soil

The City of Los Angeles (1992) also measured the pH, sodium, chloride, calcium, magnesium and total salts in greywater and in the soils. This determined if any of the agronomic characteristics of the soil might be affected by greywater irrigation. The sodium absorption ratio was computed for each sample. They found that the sodium and sodium absorption ratio were both significantly higher in greywater irrigated soils. They explained this as being partly due to the salt content of most detergents and the presence of other laundry additives.

Sodium applied excessively to clay soils will damage the soil structure by reducing the air space, giving it a grease texture and poor drainage capability. Ponding on the surface is an undesirable symptom of excessive sodium, because of the health concerns (refer to Section 5.13.7). This condition can be repaired by the application of gypsum, repeated leaching and time. Excessive application of sodium can be harmful to plants (refer Section 7.2).

Boron was not detected in the greywater, though many detergents contain boron. (Boron can be harmful to plants, refer section 7.2). None of the other parameters exhibited a statistically significant difference.

Discussions held with the project supervisor Dr Baheim Sheik during overseas research concluded that the long term application of greywater posed no foreseeable detrimental affects to the soil. The permeation of rainwater through the soil will remove any accumulated salts from the vicinity of drip irrigation emitters. Other authorities have disagreed with this opinion, stating that the application of greywater with its salt and suspended solids content will inevitably lead to clogging of the soil.

Nutrients (nitrogen and phosphorous) present in greywater would be of benefit to most plants if retained in the biological active layer of the soil. Leaching of nutrients and salts into ground water and waterways is an environmental concern (refer section 5.13.5).

Detergent products are available which are low in sodium and alkalinity and have no boron content. The use of these products would benefit a greywater watering system and should be recommended to owners.

*There is only a limited history on the Los Angeles research; a true representation may not be known for several years. Higher rainfall benefits the coastal fringe of Australia, which will reduce the affects of sodium and accumulation of salt. Los Angeles has primarily sandy soils compared to Brisbane's clay soils and shallow top soil layer. The excessive application of sodium is detrimental to the structure of clays. Further research is required to determine the effects on soils from prolonged application of greywater, for Australian conditions.*

#### 5.13.5 Effects of Wet Weather

##### Surface Runoff

Surface runoff after heavy rain or from excessive irrigation does pose concerns for the health and environmental impact that nutrients, other chemicals and pathogens could have if washed into waterways. Australia already has problems with algae blooms that thrive on nutrients.

The University of Sydney's Department of Geography is presently conducting extensive research into the effects of "Runoff in Sydney's unsewered urban areas".

*Sub-surface irrigation and the application of adequate site selection criteria may be a solution to confining these contaminants to the irrigation area. Bunds constructed around the irrigation area could prevent surface runoff, but the resulting ponding may cause equally serious concerns (refer section 5.13.7).*

## Contamination of the Water Table

Leaching of greywater irrigated soils by either rainwater or excessive irrigation may lead to nutrients, other chemicals and pathogens entering groundwater. This is of concern primarily if the groundwater is used for drinking water supplies; but also if the polluted greywater reaches fresh surface-waters.

Nutrients applied in the biologically active soil layer may be taken up by vegetation. This may prevent these nutrients being leached to groundwater. Some authorities argue that excess nutrients applied to soil will eventually be leached from the soil unless biomass is removed from the site; that is, vegetation must be harvested and "disposed" of elsewhere. Otherwise, they claim, a particular site's capacity to store nutrients in vegetation and the soil will be reached, and decomposing vegetation will release excess nutrients that will be leached into groundwater.

To oppose this argument, it has been claimed that there are other mechanisms in soil structures for immobilising nutrients (and other chemicals), such as bonding to soil particles and precipitation. Detergents and cleaners containing reduced quantities of nutrients and harmful chemicals are also available, which may help reduce these effects.

Mechanisms exist for the removal of pathogens in soils, which are likely to prevent them reaching groundwater (refer to Sections 5.13.2 and 5.13.3). Design criteria (for example greywater application rates, depths of emitters and soil types) are yet to be determined to maximise pathogen removal.

### Diversion to Sewer

In wet weather the greywater system for lawn and garden watering purposes must provide for flow diversion to the sewer. Diversion would occur during rainfall and for a period afterwards until the soil moisture content drops to a suitable level. This is to avoid surface runoff and leaching from waterlogged irrigation areas and to prevent root zone rotting and fungal attack to the vegetation.

It has been demonstrated that greywater system owners will not provide adequate maintenance to their systems (refer to Section 5.6). There is justifiable concern that the owner will be equally careless in manually diverting his system to the sewer in wet weather.

Most history on greywater systems is confined to the arid localities of California and Arizona in the USA. No problems have been attributed to this concern to date - nor are they likely to. There is no case history for comparison to the higher rainfall areas of the coastal fringe of Australia.

Automation of the diversion valve using moisture sensors is a future option. The Californian experience is that presently available moisture sensors are unreliable. A recommended option is a diversion valve that is active to sewer and passive to the landscape. The operator would have to manually divert the greywater to the landscape, after a predetermined period the valve would automatically redivert flow to the sewer.

*Further research is required to determine the affects of wet weather on greywater systems.*

### 5.13.6 Aerosols

Aerosols are defined as particles ranging from 0.01 to 50 $\mu$ m in diameter that are suspended in air. Viruses and most pathogenic bacteria are of respirable size. Inhalation represents a direct means of human infection. Indirect infection could occur by transmission of aerosols that have deposited on an intermediate surface; for example, food, clothes, tables. Inhalation may require a lower infection dose than the gastrointestinal tract.

Bacteria and viruses will survive longer and travel further under the following conditions:

- increased wind velocity
- increased relative humidity
- lower temperatures
- darkness.

Studies have shown that under optimum conditions high concentrations of coliform bacteria travelled 90 - 130 metres with a wind velocity of 1.5 m/s (Crook, 1985).

The draft Australian standard AS 1547, (Disposal of Sullage and Septic Tank Effluent from Domestic Premises), allows for surface irrigation of effluent *from approved treatment systems*. Sprinklers must be coarse droplet-producing with a maximum throw and plume of 2m and 600mm respectively. The effluent must comply with the following:

- Biochemical Oxygen Demand (5 days) not greater than 20 mg per litre
- Suspended Solids not greater than 30 mg per litre
- Faecal coliforms not more than 10 colonies per 100 mL
- Free residual chlorine level of not less than 0.5 mg per litre after 30 minutes contact.

This is measured at the first irrigation outlet by a field test method approved by the relevant regulatory authority.

However, for sub-surface disposal of effluent the draft does not require compliance with the third and fourth effluent quality parameters.

Clearly "untreated" greywater does not comply with any of the above parameters. *Surface spray disposal methods can produce aerosols or droplets that cannot be confined to a dedicated area. This poses a potential health risk. Surface lawn and garden watering using untreated greywater is not recommended.*

#### 5.13.7 Ponding

Ponding occurs with irrigation due to either poor watering practices or poor permeability soils. Ponding is an undesirable result because:

- it can promote the breeding of mosquitoes
- it may represent a health risk
- it could result in odours and is aesthetically displeasing.

Sub-surface watering may also lead to surface ponding of greywater. Factors which would contribute to surface ponding include:

- depth emitter is buried
- slope of the land to be watered
- application rate of the greywater
- clogging of soils through application of sodium and suspended solids
- soil type.

*Some irrigation methods are more likely to promote ponding and should be precluded as an acceptable method; for example, surface flood irrigation. Further research is required to determine design criteria for sub-surface irrigation to ensure ponding or surfacing of the greywater does not occur.*

#### 5.13.8 The Application to Habitable Areas

Lawn and garden watering can be accomplished by either sub-surface or surface disposal methods. Surface spray and flood irrigation with greywater has been a common practice in non sewerred areas of Australia for many years, but is used by only a relatively small sample of the population. No health concerns have been attributed to this practice but this may be due to poor reporting practice. Application to sewerred areas is likely to increase the proportion of high density areas practicing greywater re-use, and hence the potential for contact with greywater.

Because of the many health, environmental and public nuisance concerns (as detailed in this report), untreated greywater re-use by surface disposal methods is not suitable for habitable areas. Treated greywater would also be unacceptable for surface disposal unless its quality can be assured. *Sub-surface irrigation can be used for lawn and garden watering to habitable areas if the microbial health risk can be contained below the surface.*

#### 5.13.9 Horticultural Concerns

Greywater can be both nutrient rich and alkaline, and garden application may not suit all plants. Some Australian natives in particular do not like these conditions. As indicated, greywater can also be a source of salt. Californian authorities have indicated that the levels are sufficiently low and when dispersed with rainfall will not be detrimental to plants (refer Section 5.13.4).

##### Microbial

Generally, greywater used for garden watering should not come in contact with the edible portion of fruit and vegetables. Some researchers also recommend that edible root crops should not be watered with greywater.

##### Conclusion

*Caution dictates that edible root crops should not be watered with greywater. Hygienic food preparation practices should be used for edible plant crops grown in the vicinity of greywater re-use areas.*

##### Chemical

Greywater contains chemical pollutants that primarily come from household detergents. Detergents can be a source of sodium, boron, phosphate, chlorine and other chemicals. Generally, greywater has an alkaline pH.

Sodium applied excessively to clay soils will damage the soil structure resulting in reduced drainage capabilities. Sodium also alters the osmotic concentration relationship between the plant and the soil, reducing the plant's ability to take up water. It may be necessary to apply gypsum to supplement the magnesium and calcium in the soil, which prevents the effects of excessive sodium.

Chlorine is a plant poison, while boron can be tolerated only in minute quantities. Phosphate is a plant fertiliser but can be detrimental to some of the low nutrient tolerant native plant species. A build up of alkali salts is harmful to most plants. Californian authorities have indicated that the levels in greywater-irrigated soils is low. Any residue in the vicinity of the drip irrigation system will be dispersed with rainfall and is not detrimental to plants (refer section 5.13.4).

## Conclusion

*The suitability of existing plants and the soil condition are necessary when accessing a site for application of greywater. With application limited to ornamental gardens and lawns, it is unlikely that prolonged use will cause any adverse affects. Further research is required to establish this assumption. Greywater system operators should consider the choice of detergents and their chemical constituents; these should also be part of an owner's operation guide.*

### 5.13.10 The Effects of Excessive Watering

If greywater is continuously applied to the soil the nutrients may support growth of the natural microflora to an extent that could result in biological clogging of the soil's pore configuration. Additionally, accumulation of pathogens at the soil surface and ponding of greywater could occur (refer section 5.13.7).

The chemical constituents in greywater could also damage the soil structure, as Sections 5.13.4 and 5.13.9 of this report describe. Healthy plant growth is not promoted by over-watering as Section 7.5 of this report describes.

*Adequate criteria are necessary to ensure that excessive application does not occur. This should include greywater volumes produced, sizing of the irrigation area, soil composition and permeability. An additional consideration is providing multiple irrigation zones for each site. This allows for irrigation areas to alternate between watering with greywater and potable water.*

### 5.14 Concerns with Application to Toilet and Urinal Flushing

Greywater could be applied to the purpose of flushing toilets and urinals. There are two distinct types of systems as detailed below.

#### 5.14.1 Toilet and Urinal Flushing Systems

Toilet and urinal flushing systems are commonly designed to be flushed with captured bathroom and or laundry wastewater. This water generally is heavily contaminated (refer Chapter 4). Greywater used for toilet or urinal flushing cannot be totally separated from human contact. Health risks do exist with the potential for splashing of flush water. The term "splashing" means that, during defecation, droplets of liquid from the toilet pan splash as far as the level of the upper surface of the seat (in the down position); or, alternatively, come in contact with the user's thighs, buttocks or genitalia. This is of particular concern for women using the toilet, as micro organisms such as *Pseudomonas aeruginosa* and *trichomoniasas* could be transmitted in this manner. Gerba et al (1975) investigated the microbial hazards in toilet water droplets and aerosols and concluded the following:

"Droplets produced by syphonic pan flushing toilets were found to harbour both bacteria and viruses which had been heavily seeded into the toilets prior to flushing. The detection of bacteria and viruses falling out onto surfaces in the bathroom after flushing indicate that they remain airborne long enough to settle out on the surfaces in the bathroom and do not take into account the organisms present in smaller droplets which may be airborne for considerable lengths of time. Thus, there is a possibility that a person may acquire an infection from an aerosol produced by a toilet."

This study was done using syphonic pans - which, by design, produce fewer aerosols than the wash down configuration used in Australia. This conclusion is further reinforced by Mendes and Lynch (1975), who observed that faecal bacteria occur in large numbers on surfaces in washrooms and toilets.

The use of greywater as a flushing medium must not alter the present microbial health risk for aerosols and splashing produced in toilet flushing using potable water. Although the toilet pan water seal inevitably contains faecal contamination (and potentially pathogens), it has been claimed that aerosols produced with greywater as the flushing medium are more likely to contain pathogens because of the presence of fine suspended solids (Karpisack, 1993).

Greywater may pose no greater hazard than the micro organisms that could be retained on the porcelain surface or in the water seal of existing toilets flushed with potable water.

The measured microbial content of the water seal in a toilet pan, sourced by potable water, can range from zero colonies up to that of raw sewage. The level depends on numerous factors, including degree of use, frequency and quality of cleaning and the presence of faecal residue within the trap. Greywater used as a flushing medium must be treated and disinfected so that it poses no increased health risk above that of potable water.

By its very nature, greywater has varying supply frequency, volume and quality that must meet the variable demand requirements for toilet flushing. The variability in all of these essential elements means that passing greywater over pool chlorine tablets or dosing with set rates of liquid disinfectant is unlikely to provide flush water, free of pathogens. Dosing with high concentrations of disinfectant is considered uneconomical and is unlikely to be acceptable to the user due to odours. Further, the splashing of concentrated disinfectant presents further safety issues.

Treatment to reduce turbidity prior to disinfection is essential, but this has to be balanced against inadequate maintenance levels (refer Section 5.6). Greywater stored for even short periods of time does promote the growth of micro organisms and could increase any potential health risk (refer Section 4.2.3). Inadequate treatment and disinfection could result in micro organisms growing in the greywater toilets' storage tank, cistern and the toilet pans' water seal. Further research is required, but simple solutions appear unlikely.

Young children can have an unhealthy fascination with the toilet that parental supervision may not always circumvent. It is not known whether there would be any increased health risk from greywater to young children, who are more susceptible to disease.

*The application of greywater to toilet flushing may represent no additional risk over existing toilet flushing practice, but caution dictates that use of greywater for the owner-maintained domestic toilet is not a suitable option. Further research is required, but simple solutions appear unlikely. Alternatively, a system capable of treating greywater to an acceptable quality, maintained strictly to the conditions of licensing and audited by the regulatory authority, could be an acceptable option - however improbable in practice.*

#### 5.14.2 Hand Basin Toilets

Hand basin toilets are installed in most Japanese homes. There is also limited use of these types of units in the USA, Canada and Europe. It is expected that they pose virtually no microbial health concerns for general domestic application. It is assumed that the pollutants that could be transferred to a cistern after hand washing are minimal. Further research is required to confirm this assumption. The effects of soap and other contaminants on cistern operation must be evaluated prior to implementation.

*There is extensive case history on the successful application of greywater hand basin toilets in Japan. Cultural differences require that the effects of soaps on the cistern mechanism be investigated.*

## 5.15 Summary

Domestic greywater inevitably contains micro-organisms and poses a potential health risk through human contact. The microbial levels can be minimised by direct re-use or by treatment, but this may not always be sufficient to achieve an acceptable level of risk. Arguably the safest method is to separate people from the re-use of greywater. For lawn and garden watering, separation of greywater from human contact may be achieved by the following:

- sub-surface irrigation (greywater is not to reach the ground surface)
- surface irrigation confined to non habitable dedicated areas.

Toilet and urinal flushing water cannot be totally separated from human contact. Health risks do exist with the potential for splashing of flush water onto the genitals. This is of particular concern for women using the toilet. Apart from simple screening and contact disinfection, treatment is necessary to achieve pathogen free flushing water. Further research is required, but simple solutions appear unlikely.

Greywater may contain micro organisms and chemicals that must not be passed into the water table or into water ways via surface runoff and leaching. These concerns must be addressed by having adequate design criteria for sub-surface watering systems utilising greywater.

*We live in a society that has a relatively healthy population. The sanitary sewer can be partly credited with this present status and the low incidence of water borne disease.*

*Infectious disease epidemics occur once the disease is introduced to the population and has a mode of transmission. Any decision to change the present sanitary practices should not be taken lightly.*

## 6 METHODS OF GREYWATER RE-USE

### 6.1 General

Once greywater has been separated from the remainder of household wastewater at its various sources, it can be beneficially re-used through what can be broadly called a greywater re-use system. These greywater systems vary widely in their use, and the degree (if any) of treatment and storage.

Domestic greywater may potentially be re-used onsite for:

- ornamental garden and lawn watering
- toilet and urinal flushing.

The configuration of the re-use system depends on the intended application. Parameters for consideration are:

- Re-use method
- Treatment required
- Methods of risk minimisation
- Suitability of storage.

### 6.2 Untreated Greywater Versus Treatment of Greywater

#### 6.2.1 Untreated Greywater Systems

For untreated greywater to be used safely it can only be used in methods that:

- minimise the risks
- do not have direct or indirect human contact
- retain the chemical constituents within the re-use site.

This allows only for systems that meet the same criteria as in the USA's Appendix W. These are as follows:

- *untreated* - studies show that 80% of owners will not adequately maintain their greywater systems. On this premise an unmaintained treatment system may pose a potentially worse hazard.
- *domestic* - on the premise that the chemical constituents of greywater are generally known and are acceptable for lawn and garden watering. This may not always apply with other sources of water.
- *single family dwelling* - this minimises any potential for sharing of pathogens between families.
- *direct re-use (no storage allowed)* - by reusing the greywater immediately, the potential for unacceptable levels of micro organisms to occur is reduced. Consequently the microbial health risk is also reduced.

- *sub-surface irrigation only* - this is a risk minimisation requirement. By reusing the greywater sub-surface, human contact, either directly or indirectly, is avoided.

*For application to Australia this report has categorised these requirements as Primary Greywater Systems (PGS) (refer to Section 6.3). Primary Greywater Systems are untreated domestic greywater systems from single family dwellings that directly re-use greywater for lawn and garden watering by sub-surface watering.*

### 6.2.2 Treatment Systems

Untreated greywater contains constituents that pose both health and environmental concerns. Treatment of greywater, on first assessment, may appear to be the obvious solution - but it also has problems that preclude open acceptance. Section 5.6 stated that onsite domestic wastewater treatment plants are not adequately owner-maintained. Probably 60-80% of systems do not meet their effluent quality requirements.

With regard to maintenance, any greywater system's performance depends on the reliability of the method, competency of the operator, and the degree and frequency of maintenance needed. Since it has clearly been demonstrated that maintenance can not be left to the owner, be it for toilet and urinal flushing or lawn and garden watering, the following two requirements will minimise the risk:

- Assess the performance; licence according to that performance and the intended re-use. Restrict all treatment systems to applications where regular maintenance is assured and audits can be done by the regulatory authority.
- Minimise the risk by allowing re-use methods that prevent human contact with greywater; for example, sub-surface irrigation or surface disposal to dedicated areas.

The degree of treatment required must also be considered with regard to the intended use. For example, a sub-surface lawn and garden watering system that treats greywater to facilitate extended storage would not need to produce effluent of the quality needed for toilet flushing.

There are numerous treatment methods that can be used to improve greywater to a quality suitable for its intended purpose of reuse. These include the following:

- *Media filtration* systems pass greywater through a filter media (silica sand, rock etc) to provide both physical and biological treatment.
- *Biological treatment* systems usually combine settling, aeration and clarification processes. Settable solids are removed first. Aeration then promotes the growth of aerobic micro organisms which reduce soluble solids. The clarification process then settles out the biologically active sludge, which is removed or returned to the aeration chamber (in activated sludge systems). These systems often include disinfection after clarification.
- *Wet lands* are a hydroponics system where greywater is passed through purpose built ponds or tubs filled with coarse sand and gravels. Organic matter is filtered out and subjected to biological treatment. Water plants grown in the ponds or tubs remove nutrients.
- *Chemical/Physical* use chemical coagulants and activated carbon to improve the greywater quality.
- *Reverse osmosis* systems filter greywater by pumping it through membranes.

Where greywater is to be stored or where reuse may involve human contact disinfection after treatment is used to ensure water quality. Disinfection methods used included:

- Chlorine
- Ultraviolet Irradiation
- Ozone
- Hydrogen peroxide

### **6.3 Classifications of Domestic Greywater Re-use Systems**

#### **6.3.1 General**

Once greywater is separated from household wastewater, some type of system is required to reuse greywater for its respective purposes. These greywater systems principally vary in the way they treat, store and re-use greywater, and can be divided into the following types:

- hand basin toilets
- primary greywater system
- secondary greywater system

#### **6.3.2 Hand Basin Toilets**

Hand basin toilets incorporate a hand basin in the top of the cistern with a tap for hand washing. The tap operates automatically with the flushing of the toilet for the purpose of refilling the cistern and facilitating hand washing at the same time (refer to Figure 6.1).

# HAND BASIN TOILET

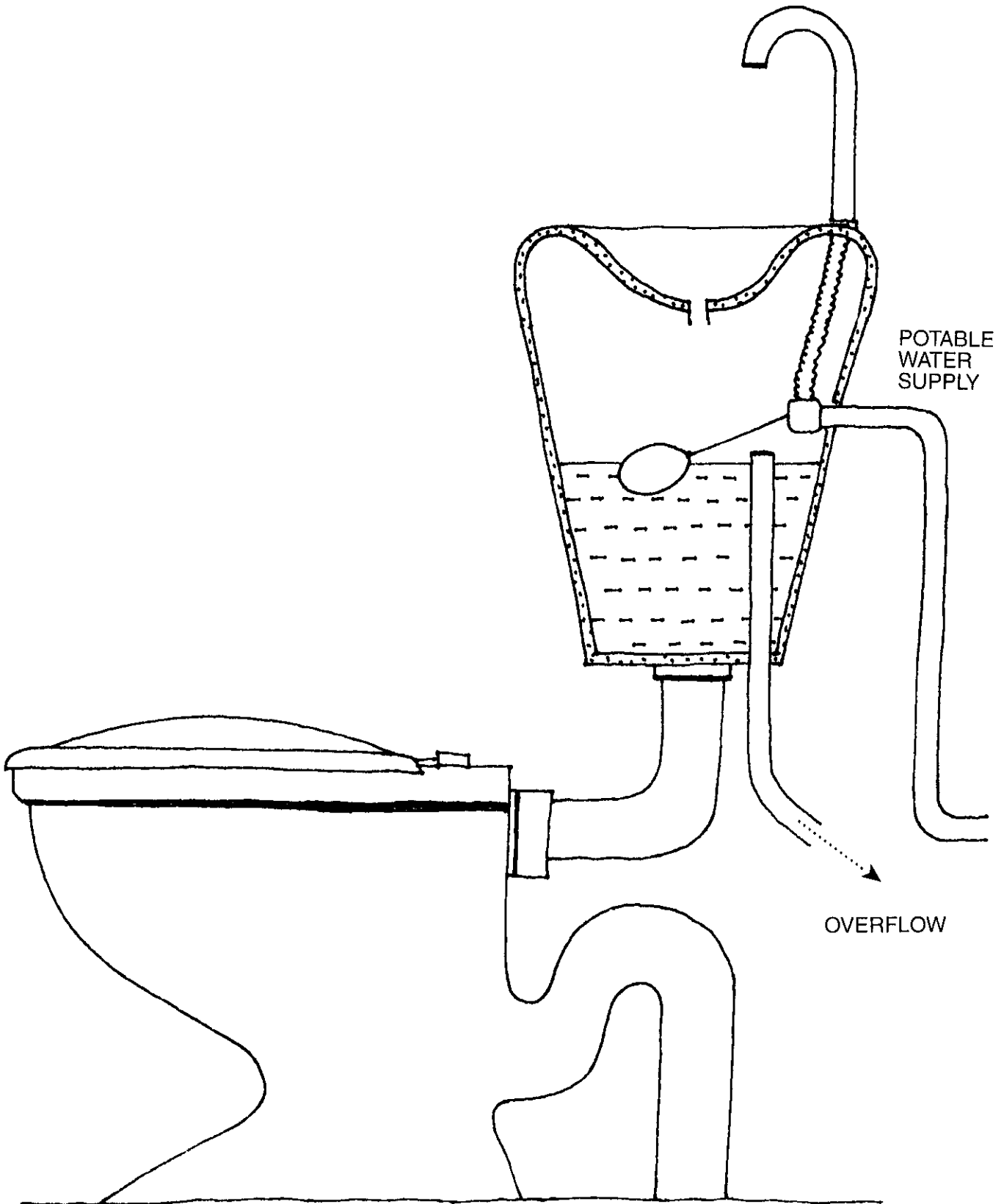


Figure 6.1 - Cross-section of a Hand Basin Toilet

### 6.3.3 Primary Greywater Systems

The Primary Greywater System collects the greywater and immediately redistributes it directly to the landscape for sub-surface lawn and garden watering (refer to Figures 6.2 and 6.3). No storage is allowed. A surge tank can be incorporated for coping with sudden influxes of flow and for housing a distribution pump. A filter, which can be a primitive screen, may be required to protect the distribution pump from blockages caused by hair and lint. For fine orifice irrigation systems the filter may also be required to prevent blockages by removing any small particles present.

The only regular maintenance required for this type of system is on the filter and periodic flushing of the surge tank and irrigation system.

The Primary Greywater System is to be designed according to the following criteria:

- single family dwelling only
- direct re-use only
- minimum maintenance requirements
- in-built safety checks for operation
- meet relevant health and plumbing standards
- maximise the efficient application to landscape
- sub-surface irrigation only.

# A TYPICAL PRIMARY GREYWATER SYSTEM TO DRIP IRRIGATION

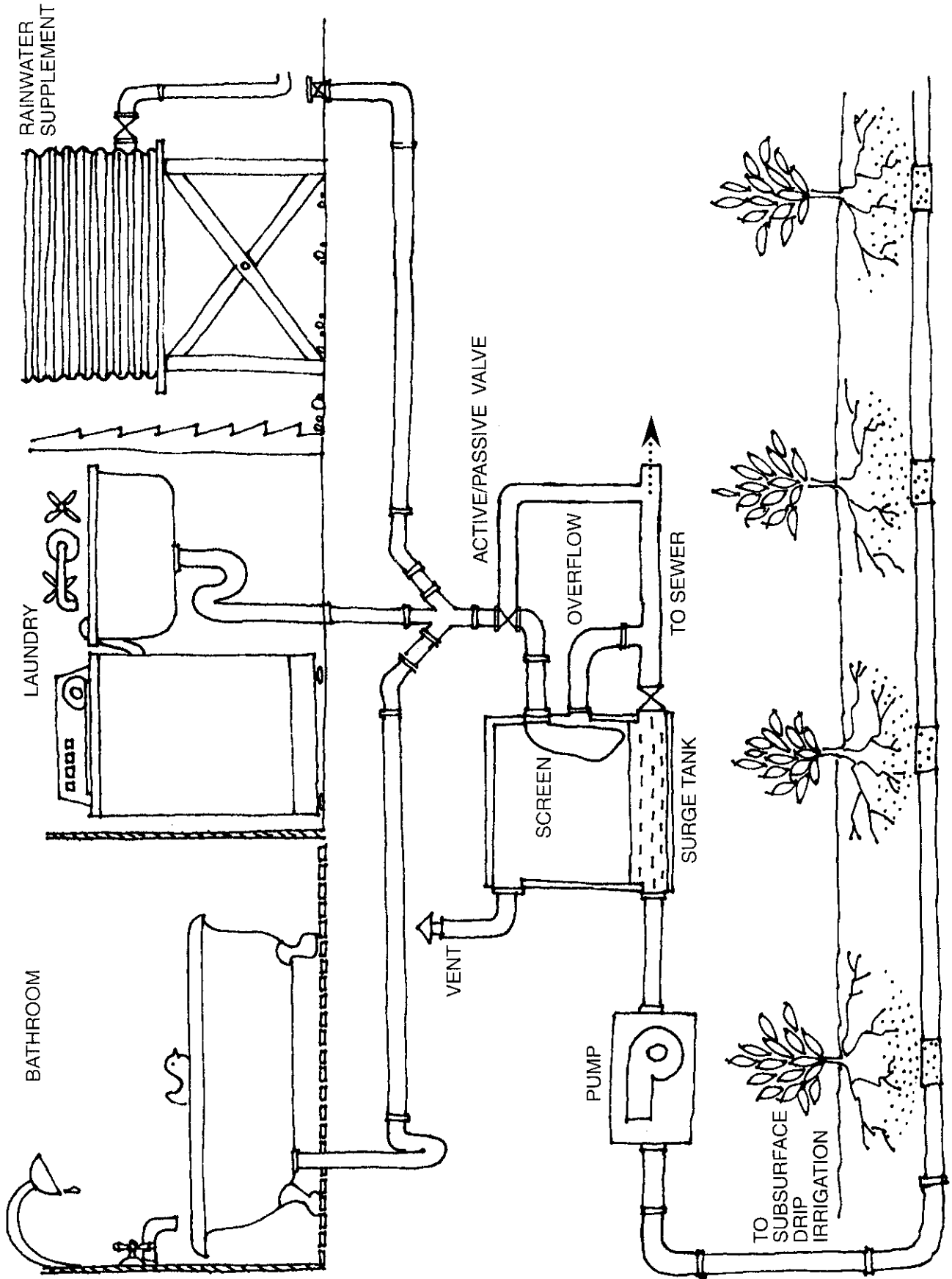


Figure 6.2 - Schematic of a Primary Greywater System with Re-use by Sub-surface Drip Watering

# A TYPICAL PRIMARY GREYWATER SYSTEM TO LEACH FIELD

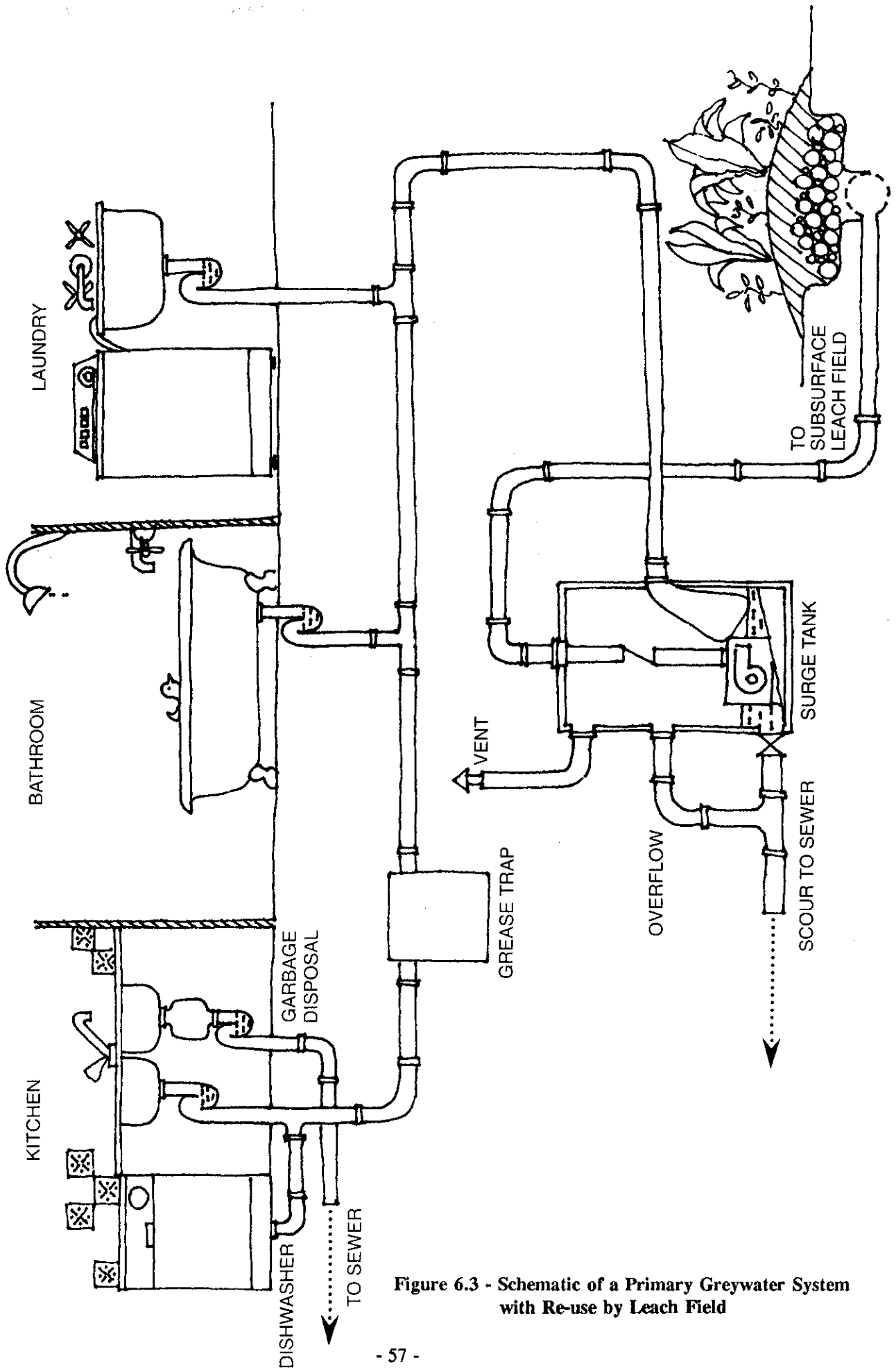


Figure 6.3 - Schematic of a Primary Greywater System with Re-use by Leach Field

#### 6.3.4 Secondary Greywater Systems

The Secondary Greywater System (refer to Figure 6.4) is any system that incorporates any of the following:

- Any form of storage other than a surge tank. For toilet flushing systems the cistern is deemed to be a storage tank.
- The design, operation and or maintenance requirements do not comply with that of a Primary Greywater System.
- The purpose of the re-use is for toilet and/or urinal flushing.
- Surface disposal (if this is an acceptable option to the regulatory authority).
- Any building incorporating a domestic greywater sourced system that is not a single family dwelling.
- Any system that incorporates processes for treatment, disinfection, sand filtration, reverse osmosis, auto backwash of filters, membrane filtration, wet lands.

# A SCHEMATIC OF A SECONDARY GREYWATER SYSTEM

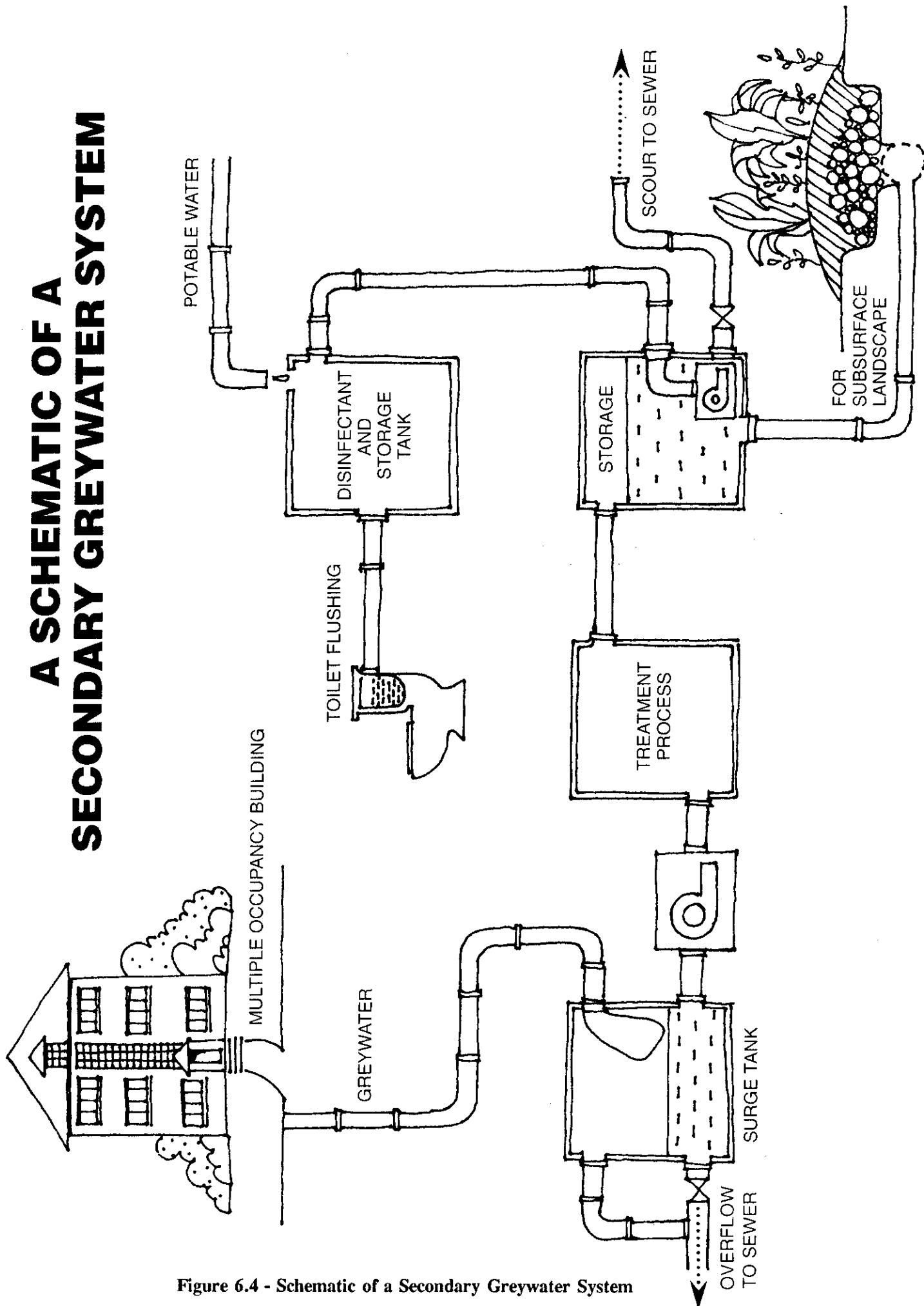


Figure 6.4 - Schematic of a Secondary Greywater System

## 6.4 Greywater Demand Potential

The demand for greywater varies from household to household depending on the water-use practices and number of occupants, and the type and size of dwelling/land.

Using the information given in Table 3.1, average daily greywater demand volumes can be determined, and these are listed below in Table 6.1. This shows that the potential demand for greywater at the average household is 774 litres per day. Toilet flushing needs 186 litres per day and landscape watering needs 588 litres per day. Table 3.2 shows that the total available greywater at an average household is 400 litres per day, and therefore there is easily enough demand for this total volume of greywater. With sub-surface irrigation, Farwell (1993) and Kourik (1993) stated that irrigation would be 60% more efficient than conventional above surface methods. The lawn and garden watering demand would drop to 353 litres per day, but the total greywater supply can be used almost entirely to satisfy this demand.

Greywater Demand	Average Volume Litre/day
Landscape Irrigation	588
Water Efficient Landscape Irrigation	353
Toilet	186

**Table 6.1 - Brisbane Average Greywater Demand Volumes**

*It would be incorrect to assume that the demand for greywater would be the same at every house, as these figures are based on averages. Some households will have greater and some less demand for greywater than these figures indicate.*

## 6.5 Summary

Greywater can be re-used for toilet and urinal flushing and for watering gardens and lawns. *Flushing systems cannot provide total separation of the flush water from human contact. Unless treatment can ensure microbial quality, it cannot be recommended as a safe method of re-use. Disinfection alone will not achieve this.*

*Hand basin toilets are expected to pose no distinct health risks, but all other re-use methods need further research.* Lawn and garden watering can be accomplished by either sub-surface or surface disposal methods. Surface disposal also has health concerns due to the difficulty of confining the greywater to dedicated areas. This is of particular concern with spray aerosols and surface runoff.

With sub-surface watering the microbial health risk can be contained below the surface, allowing lawn and garden watering to non-dedicated areas.

Surface re-use is not recommended unless criteria can be established that ensures health and environmental risks are maintained in a dedicated area.

The emphasis for greywater systems should be on maximising the application in lawn and garden watering, rather than as a means of disposal. The following chapter discusses this application.

## 7 RE-USE OF GREYWATER FOR ORNAMENTAL GARDEN AND LAWN WATERING

### 7.1 General

Greywater does contain contaminants that are beneficial to most plants. Re-use for this purpose requires a methodology that prevents human contact, poses no environmental concerns and promotes efficient water application to plants. The following is a summary of these criteria.

### 7.2 The benefits of Greywater as a Plant Fertiliser

Most plants require three principal nutrients for healthy growth: nitrogen, phosphorus and potassium.

- *Nitrogen* regulates a plant's ability to make proteins, controlling the rate and quantity of growth. Nitrogen is only taken up by plants as a nitrate compound and is easily leached from the soil.
- *Phosphorus* is needed for the production of sugars and energy in plants. It also plays a vital role in seed production, root development and flower formation. Very little phosphorus is lost by leaching.
- *Potassium* is only available to plants through the compound potassium oxide ( $K_2O$ ) which is also referred to as potash. Potassium contributes to the manufacture of sugars, starches and cellulose. Clay soils and heavy loams generally contain sufficient quantities whereas sandy soils and high organic soils may be deficient.

Secondary nutrients essential to plants are calcium, magnesium and sulphur. They are so named only because they are required by plants in smaller quantities than the three principal nutrients.

- *Calcium* aids in the manufacture and growth of the root system and plant cells.
- *Magnesium* is an important component of chlorophyll, necessary in photosynthesis.
- *Sulphur* like nitrogen contributes to the formation of proteins.

Other essential nutrients required by plants are boron, chloride, copper, iron, manganese, molybdenum and zinc. Plant growth naturally depletes these major nutrients from the soil. To sustain healthy growth, replenishment eventually is needed. Greywater can contain all of these nutrients and could be considered as a liquid fertiliser.

### 7.3 The Microbial Active Zone in Soils

It is expected that most pathogens are less likely to survive if greywater is applied in the top 300mm of soil (Farwell, 1993). The upper levels of the soil are the most aerobic and the natural antagonistic microbial activity more prominent (refer to Figure 7.1).

Kourik (1992) compared the top 75mm of the soil with a zone of soil 200mm to 250mm below the surface. He concluded that the top 75mm of soil contains;

- 4.5 times more bacteria
- 8.5 times more actinomycetes
- 2 times more fungi
- 5 times the algae.

These aerobic micro organisms play an integral part in plant growth by decomposing organic matter and in the converting of mineralised nutrients into a soluble form that is available for plants to absorb. Both these features are desirable when plant watering using greywater.

These micro organisms are best promoted in moist soils. Dry soil or over watered soil (to the point of saturation), inhibits their survival and thus plant growth (Kourik, 1992).

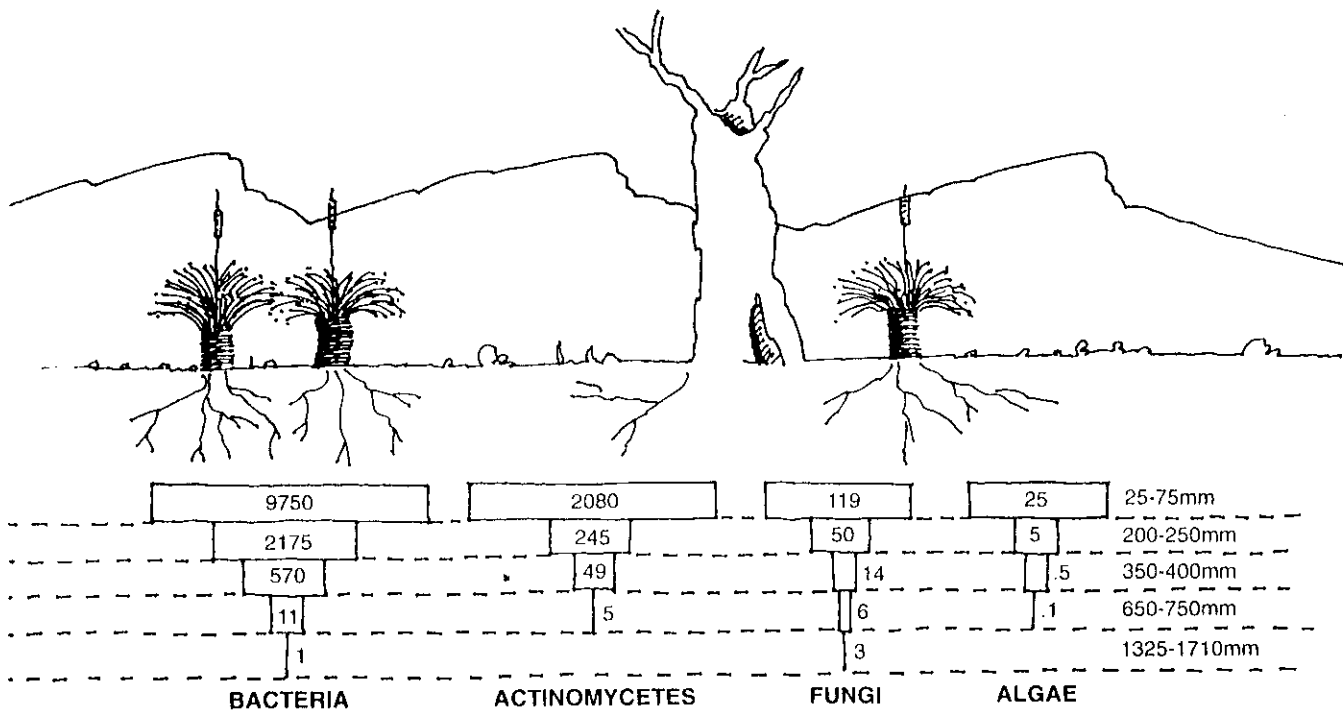
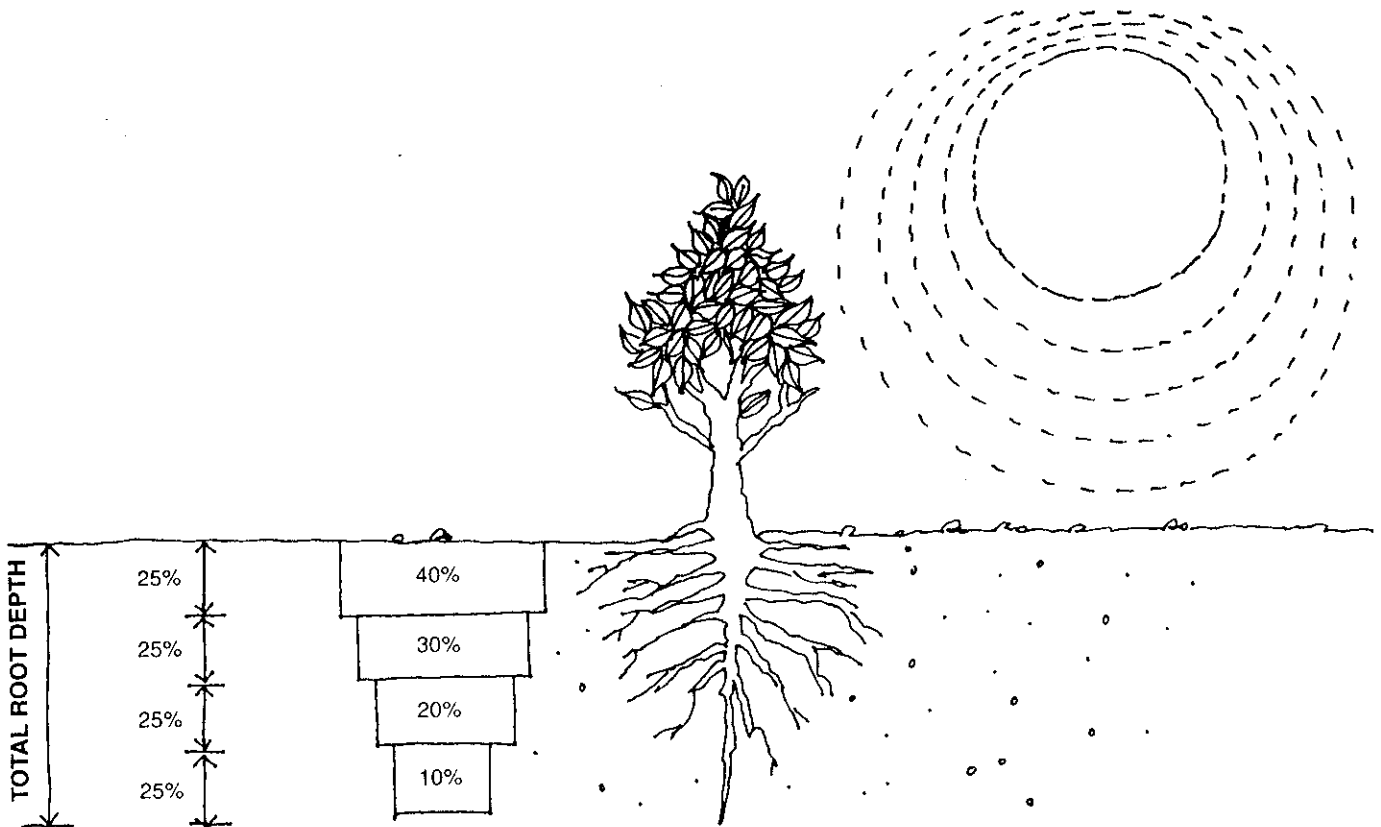


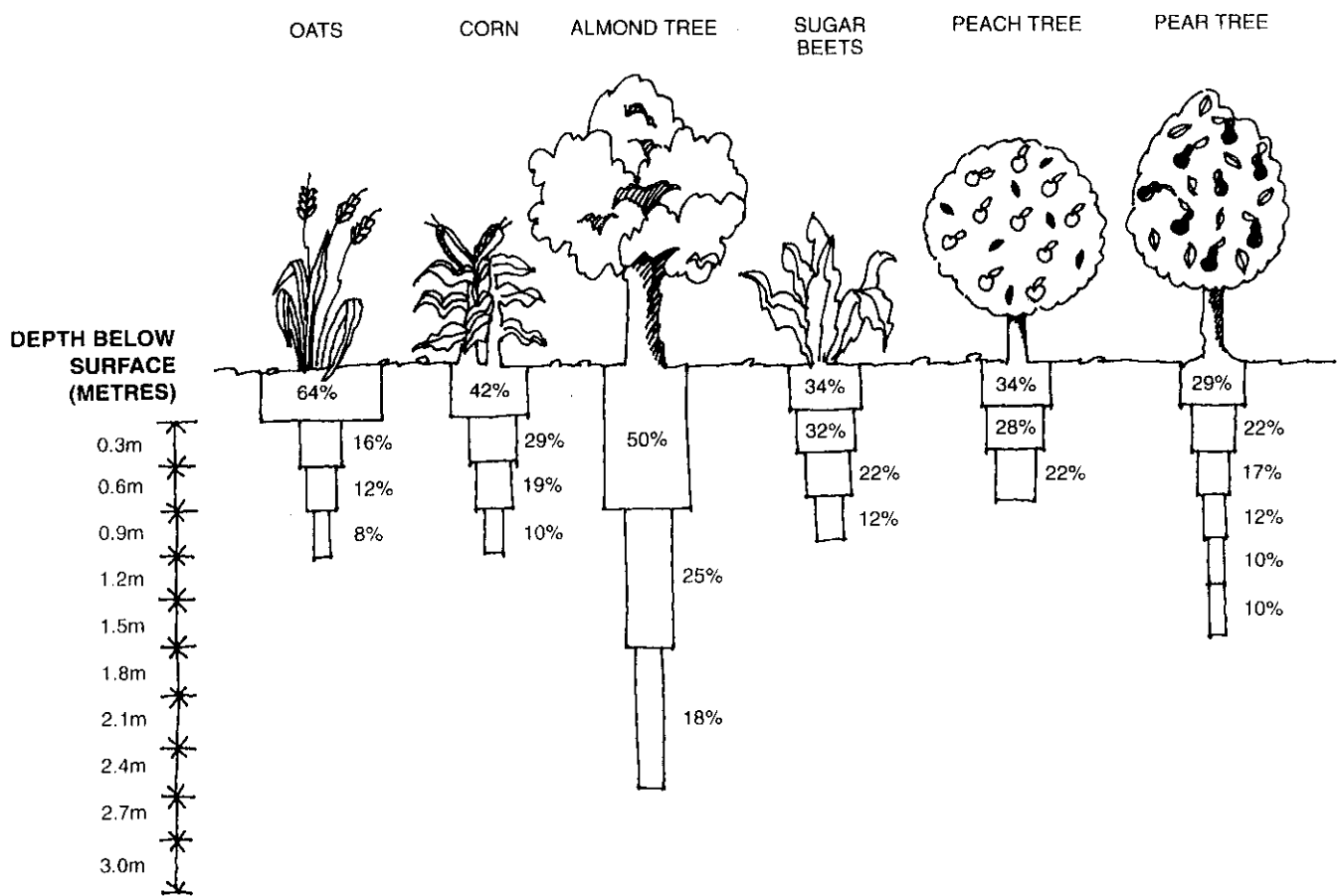
Figure 7.1 - Soil Biota Populations as a Function of Soil Depth  
 Reproduced courtesy of Mr Robert Kourik  
 "Drip Irrigation for Every Landscape and all Climates"

## 7.4 Application to the Plant Root Zone

There are numerous studies on irrigation methods that conclude that sub-surface drip irrigation can be up to 60% more efficient than conventional surface spray. This is because 70% of a plant's water and nutrition intake occurs in the upper 50% of the root zone, (refer to Figure 7.2), and water losses due to surface runoff, wind and evaporation are minimised. For most plants this is in the top 300 to 600mm of soil (refer to Figure 7.3). A sub-surface drip system can apply the nutrient rich greywater directly to this root zone. The balance of a plant's root structure is generally to provide stability.



**Figure 7.2 - Basic Moisture Extraction by Root Systems**  
Reproduced courtesy of Mr Robert Kourik  
"Drip Irrigation for Every Landscape and all Climates"



**Figure 7.3 - Water Re-use at Various Depths, in Percentage per Foot**  
 Reproduced courtesy of Mr Robert Kourik  
 "Drip Irrigation for Every Landscape and all Climates"

## 7.5 Good watering practice

Cycles of deep watering followed by dry intervals is no longer recommended as good watering practice. USA research indicates that plant growth is best promoted by maintaining an even and constant, but low, moisture level throughout the soil. The aerobic micro organisms necessary for healthy plant growth best survive in moist soils. The application rate for water, to maintain optimum moisture levels, should be linked to the sites evapotranspiration rates (ET). Periods, where the soil is either dry or saturated with water, inhibit the survival of these microorganisms. Root growth is healthier under irrigation systems that promote these conditions than with selective plant dedicated systems; for example, one emitter per plant. Sub-surface drip systems can provide an even distribution of the moisture throughout the soil. Under these conditions the roots are less likely to cause the emitter's orifices to block when seeking moisture. The intermittent but frequent supply of domestic greywater would promote this type of watering practice. Root intrusion can also be prevented by using irrigation lines impregnated with root inhibitors (Farwell and Kourik, 1993).

## 7.6 Sub surface drip irrigation

### 7.6.1 General

Sub-surface drip watering of greywater is arguably the safest, most efficient and effective method of lawn and garden watering when applied in a zone 200mm to 300mm below the surface. USA studies have established that sub-surface drip watering can be up to 60% more efficient than conventional surface spray methods (Farwell, 1993). This is partly due to the water being applied directly into the root zone of plants and no water loss from evaporation, mist, surface runoff and wind interference. Sub-surface drip irrigation has the added benefits of being:

- vandal proof
  - easily automated
  - does not restrict human access to irrigation areas during watering
  - does not promote surfacing, ponding or deep percolation
  - provides even water distribution on slopes.
- (Kourik, 1992)

Figure 7.4 shows a schematic layout of a typical sub-surface drip system.

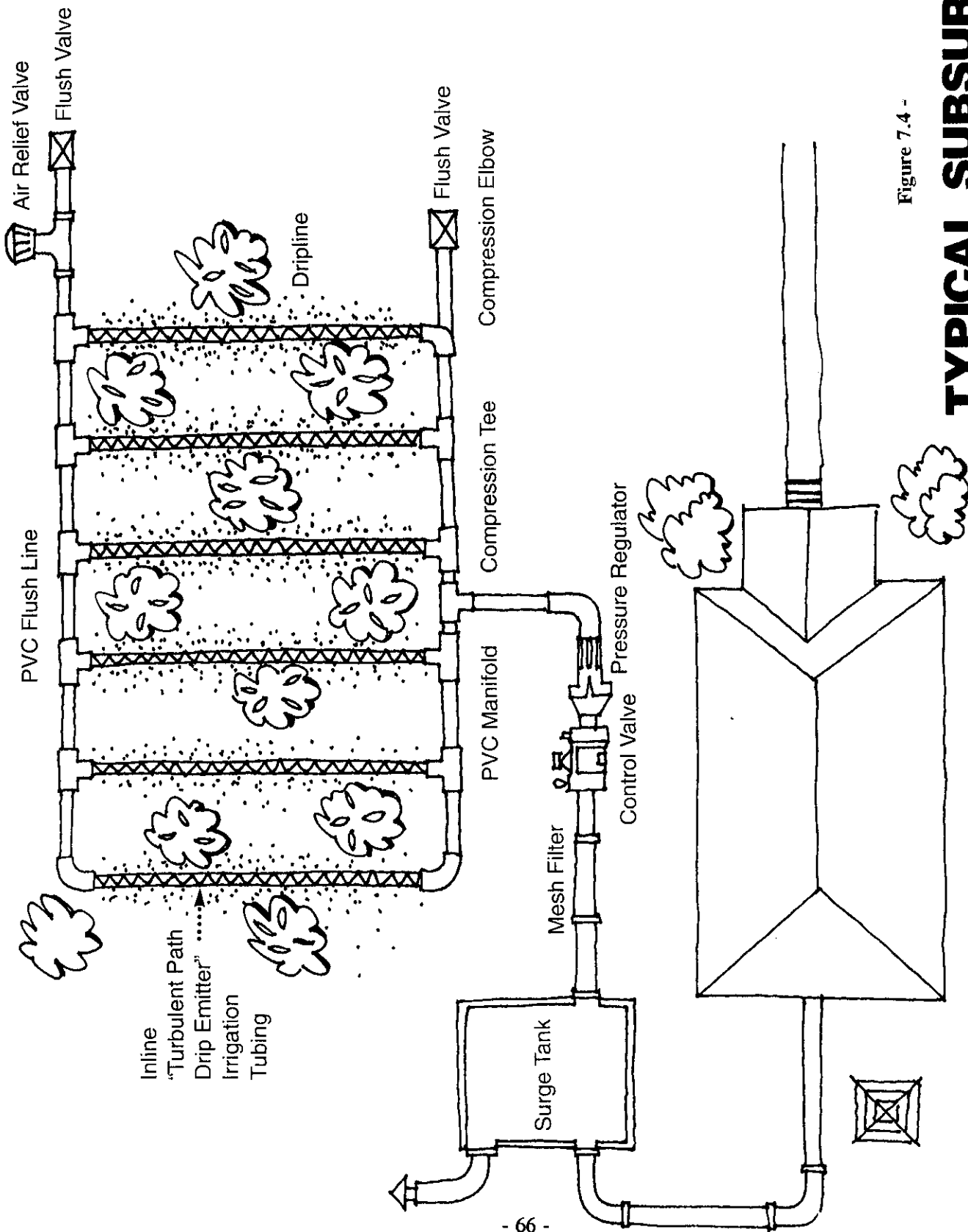


Figure 7.4 -

# TYPICAL SUBSURFACE DRIP IRRIGATION SYSTEM

### 7.6.2 Turbulent path emitters

Greywater contains non soluble pollutants, such as hair, lint, dirt and food particles. Coarse screening of greywater is essential to prevent blockages in pumps and the irrigation system orifices. 150 mesh size is generally recommended as it can filter out particles down to 106 microns. But, even after screening, some particles still tend to coagulate together and cause blockages. USA authorities have had remarkable success and recommend the use of "in-line turbulent path drip emitters" for untreated greywater in reducing this problem.

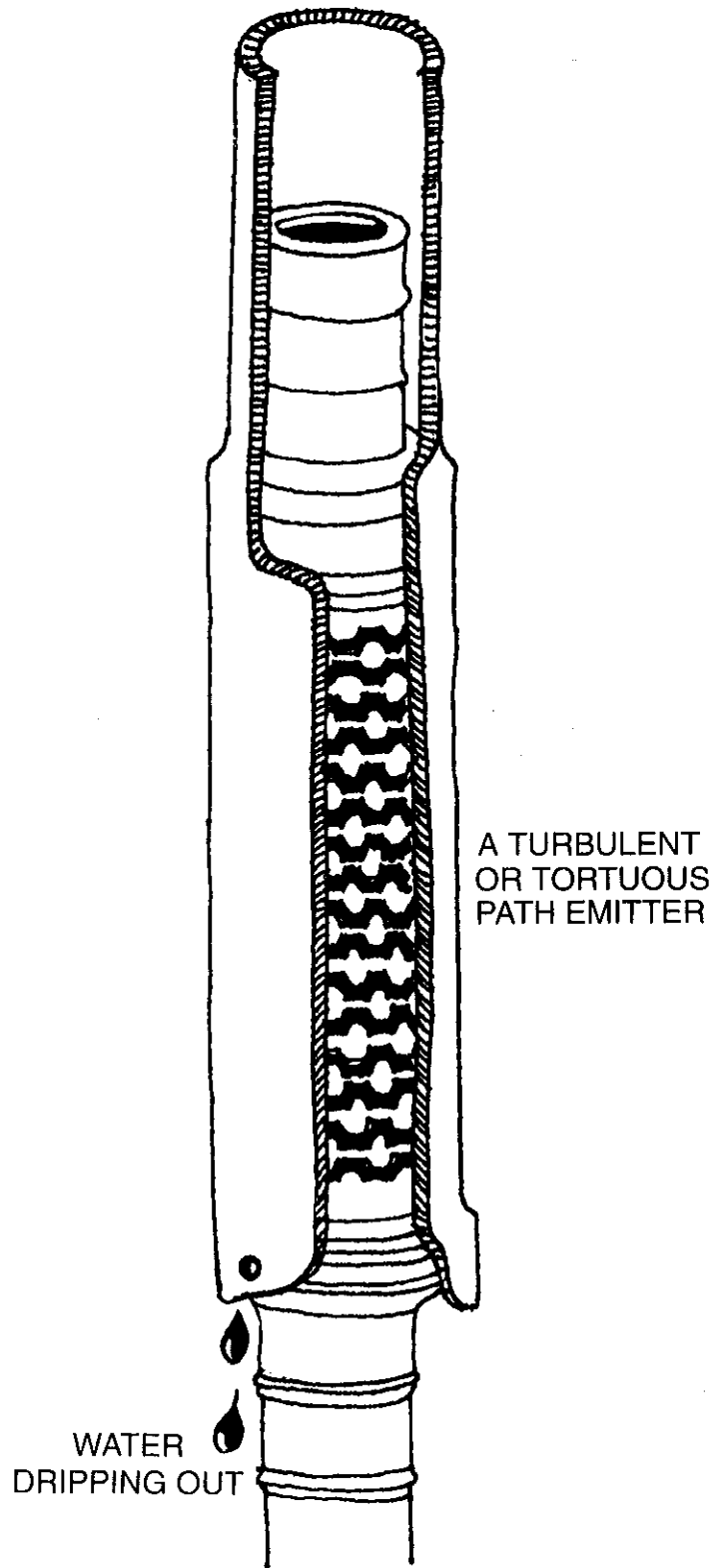
The emitter has a turbulent, complex (or tortuous) path of right angled channels for the water to follow. This maintains the fine particles in suspension until they are passed into the soil. The polyethylene irrigation tubing comes with the emitter preinstalled at regular designated intervals; for example, 300mm or 450mm. Figure 7.5 shows a sketch of an inline turbulent path drip irrigation emitter.

### 7.6.3 Porous Soakage Hoses

The Californian authorities do not recommend porous soakage hose for greywater reuse (Farwell, 1993 and Kourik, 1993). Their experience is that they clog over a short period of time. Trials on porous pipe products using potable water, conducted by the Centre for Irrigation Technology, California State University, concluded the following (Zoldoske, 1992):

- porous pipe products have not performed well
- uniformity of application along the line is low, averaging 70% compared to 97% for the discrete emitter products trialled
- to maintain high quality turf, extra water must be applied to compensate for this lack of uniformity, approximately 40% more than for equivalent discrete emitter systems
- all porous pipe products tested have suffered from a gradual reduction in flow
- the flow reduction is most severe in the downstream ends of the line
- 200 mesh filtration is not sufficient to prevent these products from slow plugging with fine silt particles in the water
- laboratory tests indicate that repeated high pressure flushing of these plugged lines can restore at least some of the original flow

However, Australian manufactures claim that they have proven success with the application of their product to land disposal of secondary treated municipal wastewater. Larger pore size with fewer openings has been stated as the reason for this success. These claims have yet to be investigated. Generally, greywater would have a higher level of suspended solids than effluent from an adequate secondary treatment process. The suitability of these hoses for use with greywater is still to be determined.



**Figure 7.5 - Sketch of In-line Turbulent Path Drip Irrigation Emitter**

#### 7.6.4 Conclusion

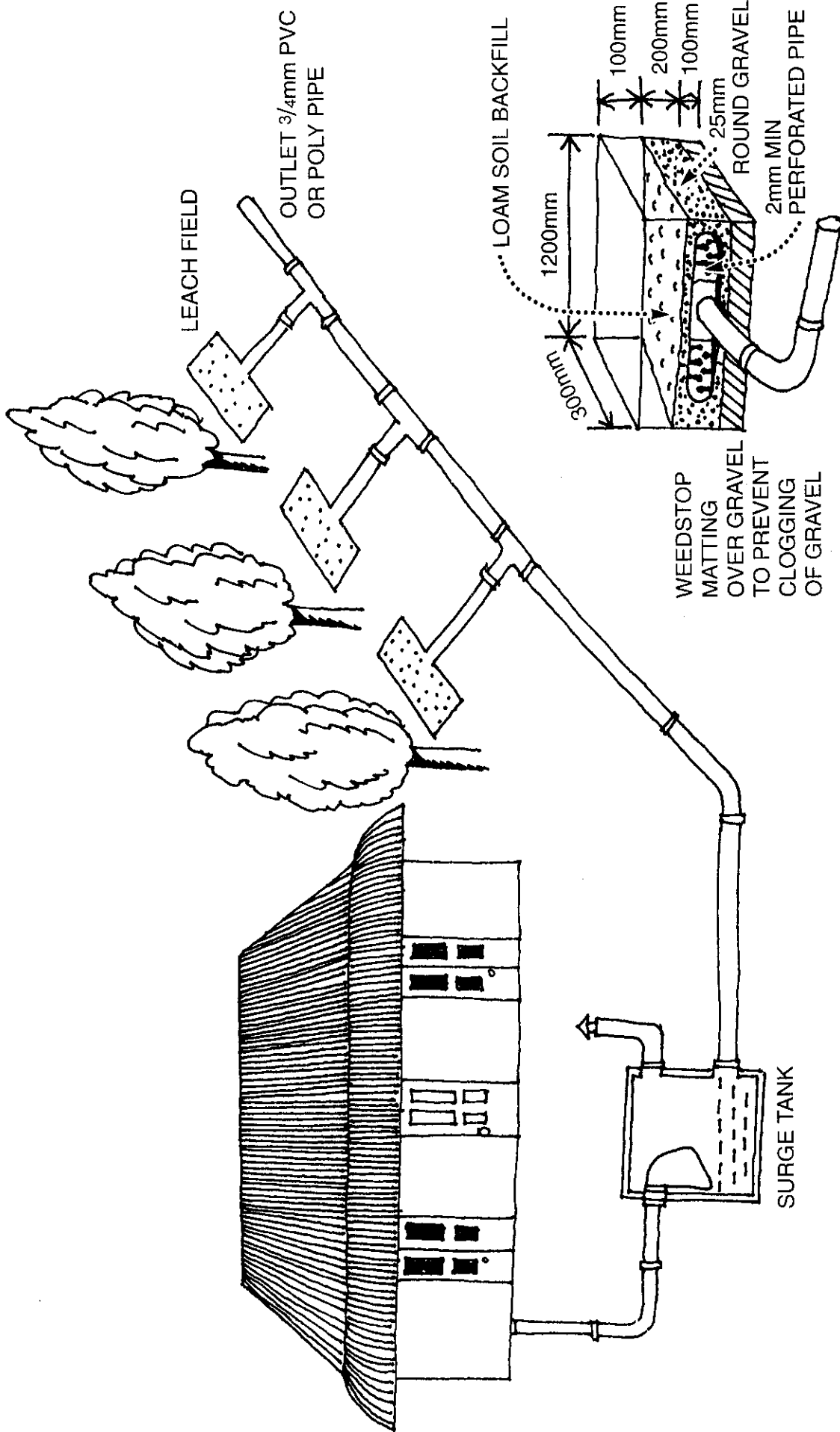
Sub-surface watering using turbulent path emitter, drip irrigation methods is the best and safest means of applying greywater to ornamental gardens and lawns. Blockage of the drip emitter is a concern when using greywater because of the contaminants that could be present, but good preventative maintenance practices are a solution. In addition, poor watering practice can cause blocking of the emitters by roots (refer to Section 7.5). Research in the USA indicates that drip irrigation using greywater works if it complies with the following:

- the kitchen is not an acceptable source
- regular flushing of the lines is performed
- a filter is installed in the surge tank to remove lint and hair
- an in line filter is incorporated in the drip system
- in-line turbulent path emitter irrigation is used
- adequate moisture levels in the soil are maintained.

#### 7.7 Sub-surface Leach Fields

Leach fields designed for the purpose of lawn and garden watering are an alternative to sub-surface drip and trickle systems. Unlike the standard evaporative transpiration trench, this design is for the purpose of plant watering and not as a means of wastewater disposal. Leach fields may be capable of using kitchen-sourced greywater. Arizona authorities expect the contaminants from the kitchen to decompose and not cause blockage of the soil. Unfortunately, there is limited case history.

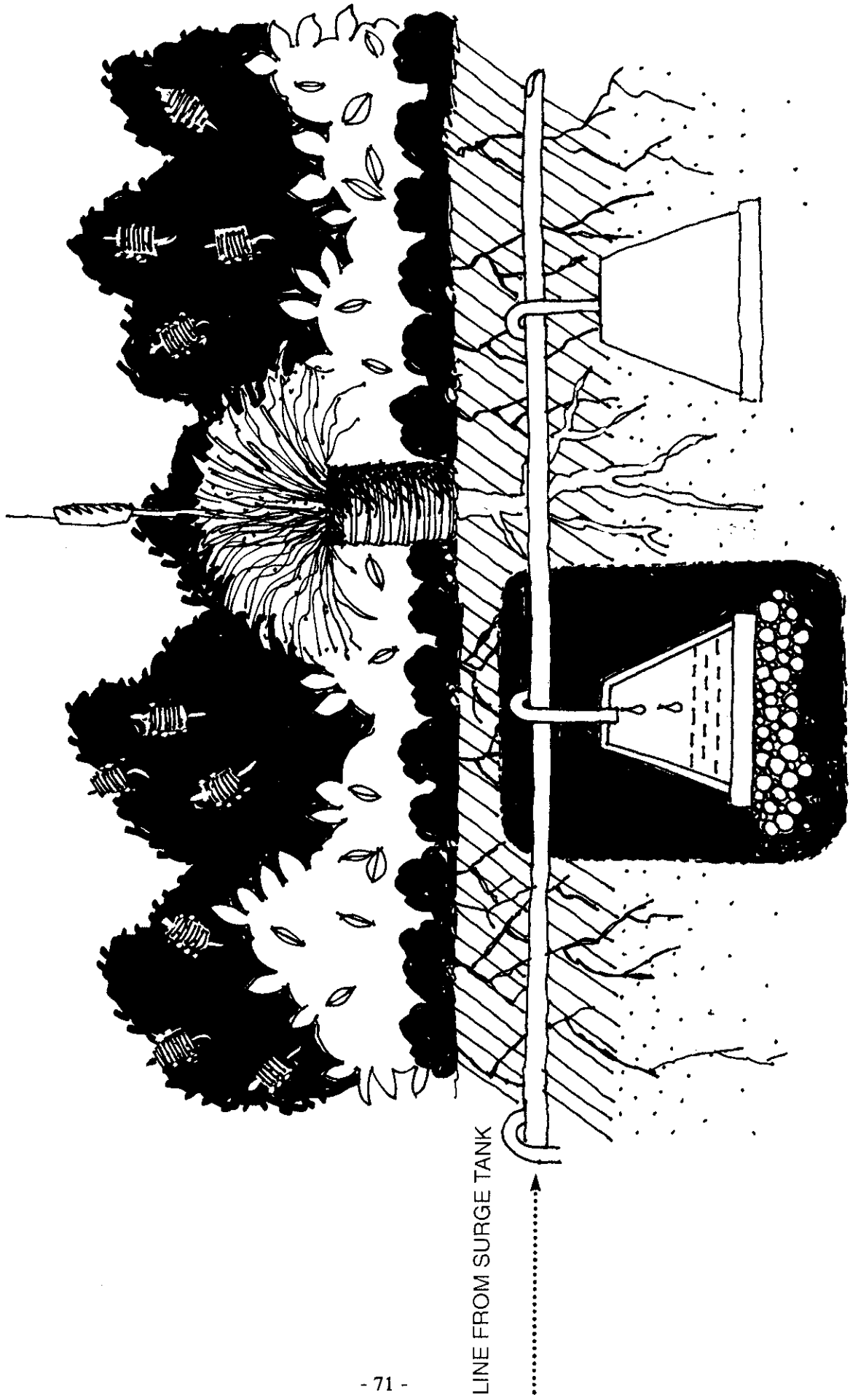
Another method of leach field garden watering is the mini-leach field system. This system involves the positioning of small coarse aggregate trenches at intervals along the distribution line. The greywater is pumped into this permeable material which acts as a reservoir, allowing slow dissipation of the water into the soil (refer to Figure 7.6). As with evaporation/transpiration trenches, the mini leachfield uses the aggregate to temporarily store the greywater. Figure 7.7 shows an alternate method of temporary storage using an inverted earthenware flower pot.



MINI LEACH FIELD FROM SURGE TANK

Figure 7.6 -

# PRIMARY GREYWATER SYSTEM reuse to mini leachfield



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LINE FROM SURGE TANK

# INVERTED FLOWER POT MINI LEACHFIELD

Figure 7.7 -

## 7.8 Surface disposal

### 7.8.1 General

In the USA there was some debate as to what is defined as the surface when assessing irrigation requirements. Does a 150mm layer of garden mulch constitute sub-surface or surface disposal? Clearly the purpose of sub-surface disposal is to provide a barrier between the hazard and human contact. The natural surface of the ground should be the appropriate dividing line and should be clearly stated as such in regulations.

### 7.8.2 Surface spray

*The new draft Australian Standard only allows surface spray disposal of sullage that is treated to a level complying with its water quality criteria (refer section 5.13.6). Even in these circumstances surface spray methods should be confined to dedicated areas.*

### 7.8.3 Surface flood

Surface flood irrigation is not an appropriate re-use method. This method promotes ponding and associated hazards as well as surface runoff.

Under no circumstances should regulatory authorities recommend or approve for use devices diverting any bathroom or laundry water directly onto the landscape surface. This form of re-use cannot meet the requirements for surface disposal of sullage in the draft Australian Standard AS 1547.

### 7.8.4 Surface drip

Surface drip irrigation for untreated greywater, if considered, must be confined to dedicated non-habitable areas. Even if the quality can be guaranteed, treated greywater should still be confined to dedicated areas. Surface drip watering can promote surface runoff of contaminants. Surface installation do have obvious advantages of accessibility for maintenance purposes that subsurface systems do not have.

### 7.8.5 Conclusion

Surface disposal has health and environmental concerns with the difficulty of confining the pollutants within dedicated non-habitable areas. The microbial and chemical contaminants in untreated greywater preclude surface irrigation re-use under the draft Australian Standard AS 1547 (Disposal of Sullage and Septic Tank Effluent from Domestic Premises).

## 7.9 Summary

The emphasis for greywater systems should be on maximising application to ornamental garden and lawn watering, rather than as disposal. Greywater is good for the lawn and garden. Greywater should be applied evenly throughout the soil and at a depth compatible with the plant's root zone. However, greywater should not surface. Pathogens are less likely to survive in the top aerobic layer of soil due to the predatory action of the soil's natural microflora.

Lawn and garden watering can be done by either sub-surface or surface disposal methods. The most efficient method of application is by sub-surface drip watering. With sub-surface watering the microbial health risk, if contained below the surface, will allow ornamental lawn and garden watering to non dedicated areas.

Surface disposal has health concerns due to the difficulty of confining the greywater to dedicated areas. This is of particular concern with spray aerosols and surface runoff. Surface disposal is not recommended unless criteria are established that ensure that the health and environmental risks are maintained in a dedicated area.

For treated greywater re-use, consideration should only be given to treatment systems that can:

- produce acceptable effluent quality
- operate and be maintained strictly to the conditions of licensing
- be audited by the regulatory authority.

For landscape watering effluent quality would have to comply with the parameters specified in AS 1547 (refer Section 5.13.6).

## 8 RE-USE OF GREYWATER FOR TOILET AND URINAL FLUSHING

### 8.1 General

The principal requirement for flush water as a medium in the operation of toilet or urinal, is to transport wastes. There is no logical requirement for flushing water to be of potable quality for this purpose. *However, a distinct requirement is that the flush water does not present an increased risk to public health from high microbial content.* Greywater sourced from the bathroom and laundry and reused for toilet or urinal flushing cannot be totally separated from human contact. Health risks exist as detailed in Section 5.14. Disinfection alone is not a simple solution due to the variables in water quality and flow rates and the questionable reliability of system maintenance. For pathogen-free flush water to be assured, it is essential that greywater be treated to so that turbidity is maintained at an acceptable level to allow effective disinfection. Other areas of concern are as follows:

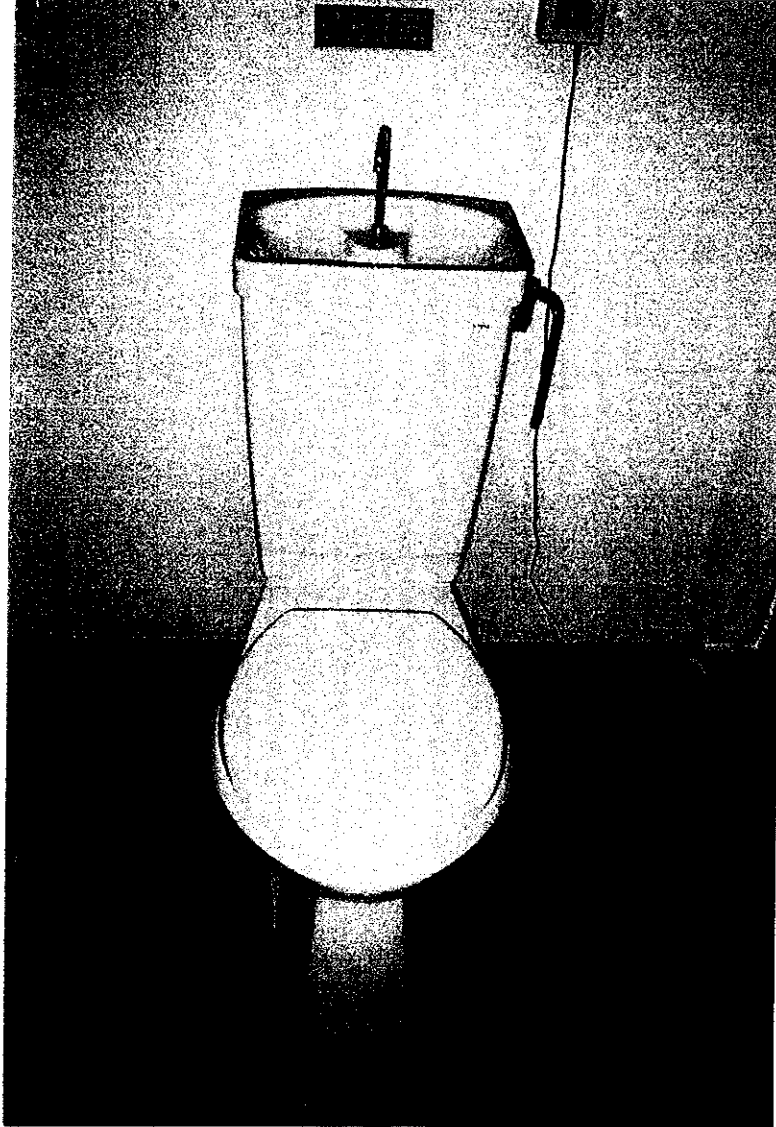
- cross connection prevention (refer Section 9.2)
- odours from greywater
- staining of the pan (refer Section 12.2)
- aesthetics of the flush water
- excessive foaming in the water seal which can reduce the flushing performance
- microbial activity promoted by storage (for example in the cistern, pan water seal).

Greywater systems for toilet and urinal flushing can be separated into two groups:

- hand basin toilets
- toilets and urinals flushed with treated or untreated greywater .

### 8.2 Hand Basin Toilets

Based on the extent of use for hand basin toilets in Japan, it is expected that they would pose no microbial health concerns (refer to Figures 8.1, 8.2 and 8.3). It is assumed that the pollutants transferred to a cistern after hand washing would be minimal and that, any health risks should be at socially acceptable levels. Further research is required to confirm this assumption. The effects of soap on the cistern's operation must be evaluated prior to implementation.

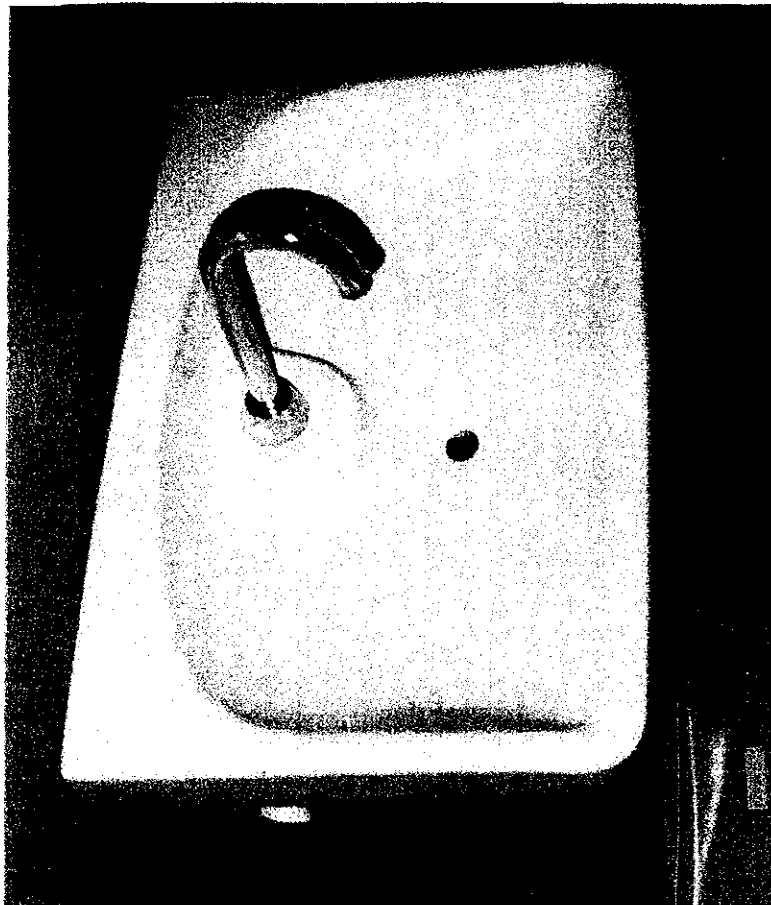


**Figure 8.1 - Hand Basin Toilet Suite**





**Figure 8.2 - Detail of Hand Basin Toilet Faucet**



**Figure 8.3 - Detail of Basin Configuration for a Hand Basin Toilet**



### 8.3 Toilet and urinal flushing

#### 8.3.1 General

Greywater re-use for toilet flushing is a generic concept that has been practiced in the USA, Germany and Australia since the 1970s (refer to Figure 8.4). The first such marketed system in Australia was the German made Reflux GMBH recycling system. A Brisbane based company - Five Star Australia Pty Ltd - marketed this type of system up until as recently as 1988. This system was fully automatic and incorporated an option for rainwater supplement.

Many of the generic systems marketed incorporate the following components:

- a coarse filter or screen for removal of hair and lint
- disinfection, usually with chlorine tables or a liquid disinfectant
- a storage reservoir to balance flushing demand and available greywater
- a pump to transfer greywater to the toilet cistern.

As stated in section 5.14 greywater reused for toilet and urinal flushing does pose serious health concerns. Treatment to reduce turbidity prior to disinfection is essential, but this has to be balanced with inadequate maintenance levels (refer section 5.6 and Figure 8.5). There is potential for human contact, both from aerosols during toilet flushing and splashing during defecation. Micro organisms do grow with storage and may further increase the health risks. Storage occurs in generic systems in the storage reservoir, the cistern and the pan's water trap. Prolonged periods of storage could result in anerobic conditions developing in the stored greywater. Generic type systems represent a very real health risk and can not be recommended.

#### 8.3.2 NASA Research

In the 1970s the NASA Langley Research Institute in the USA performed extensive studies into greywater re-use for toilet flushing. (Hypes et. al.,1975). After conducting experimental studies to characterise typical domestic bath and laundry greywater, NASA concluded that the chemical/physical and biological quality of the water needed to be improved before re-use. The processes selected for improving water quality were chosen on the criteria of low cost and operational simplicity. Diatomaceous earth filtration was chosen to improve physical quality and heat and chlorination trialled for improving microbial quality.

The research reached the following two main conclusions:

- Bath and laundry waters that have been processed by diatomaceous earth filtration and chlorine sterilisation are subjectively suitable for use as toilet flush water. An additional improvement in the acceptability of the processed water can be made by adding a charcoal filter to lower the concentration of organics and reduce turbidity. Diatomaceous earth filtration is effective in removing particulates above 1  $\mu\text{m}$  in size.
- Counts of coliform organisms in bath and laundry waters can be reduced to zero or near zero by heating the water to a temperature of 335.9 K (62.9°C) for 30 minutes or by chlorinating the waters to a chlorine concentration of 20 mg/l. If additional processing is accomplished after the initial chlorination, subsequent chlorination to a concentration level not greater than 10 mg/l may be sufficient.

During overseas research in the United States, discussions were held with the NASA Project's Principal Researchers, Mr Warren Hypes and Mr John Samios. The following points of interest were noted from these discussions:

- The chemical and physical quality of greywater requires filtration and disinfection for it to be suitable for re-use.
- Kitchen waste is not acceptable, due to pollutants.
- The bathroom vanity and the laundry basin were also precluded, due to the complexities of their waste versus the small volumes of water produced.
- Microbial disinfection was done using laundry bleach at a dose rate of 20 mg/l into the collection tank. This gave a retained residue of 0.5 mg/l in the system. Over and under chlorination created an odour nuisance.
- The project's main difficulty was in matching the chlorination dose to the variable grey water flows. An effective simple solution was not found.
- Disinfection of the cistern, using chlorine tablets, was recommended.

### 8.3.3 Conclusion

*Untreated greywater re-used for toilet or urinal flushing (even if disinfected) is not a safe and acceptable option. The NASA research did not consider the performance of owner maintained systems in evaluating their findings (refer section 5.6). Consideration should only be given to treatment systems that can produce assured and acceptable effluent quality, operated and maintained strictly to the conditions of licensing and audited by the regulatory authority.*

### 8.4 Summary

Untreated Greywater could be re-used for toilet and urinal flushing, but is not recommended as this form of re-use cannot provide total separation of the flush water from human contact.

Unless the microbial quality can be assured by treatment, this cannot be recommended as a safe method of re-use. Disinfection alone will not achieve this.

Hand basin toilets are expected to pose no distinct health risks, but all other methods need further research.

# SCHEMATIC OF UNACCEPTABLE TOILET FLUSHING SYSTEM PROCESS

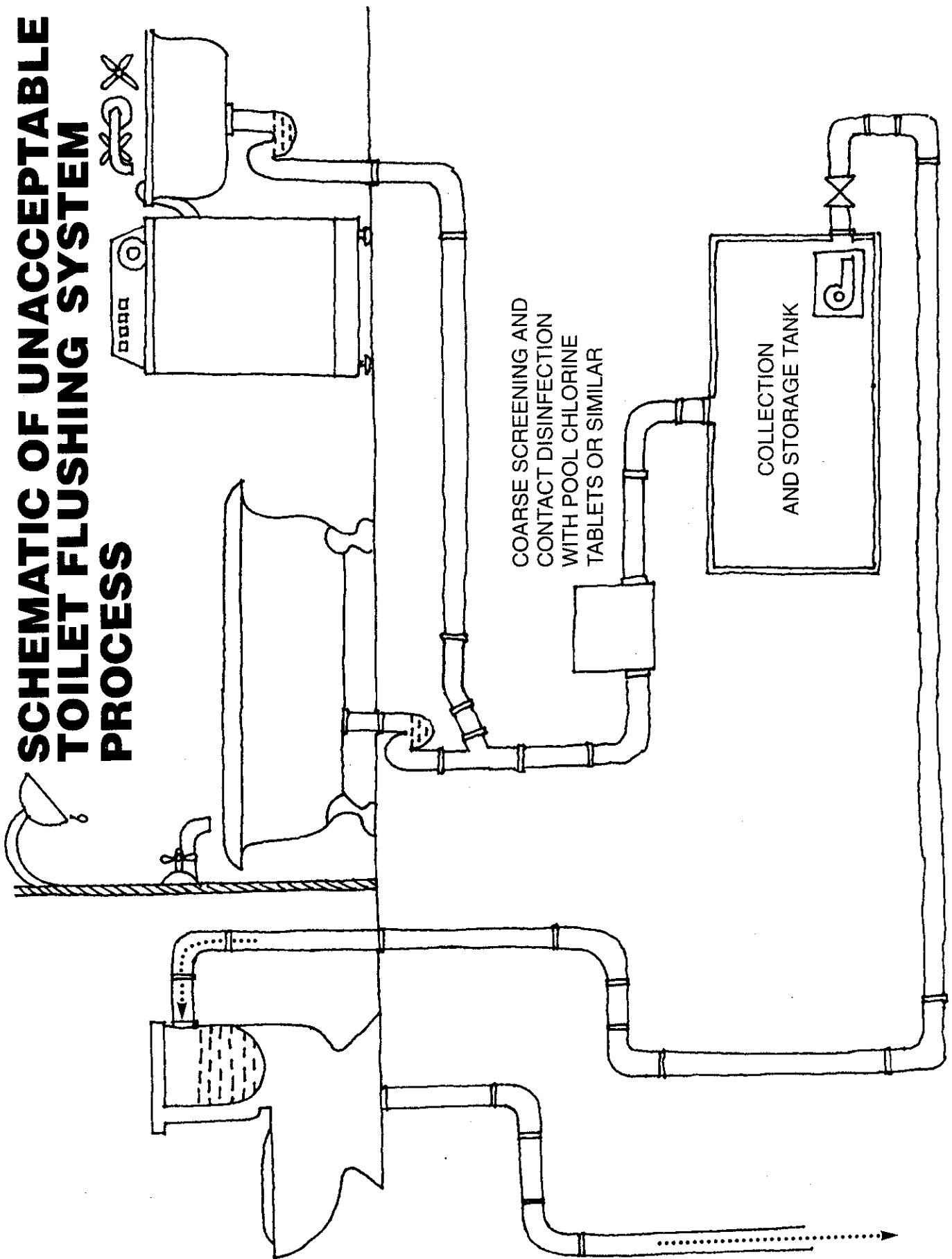


Figure 8.4 -

# SCHEMATIC OF ACCEPTABLE TOILET FLUSHING SYSTEM LAYOUT

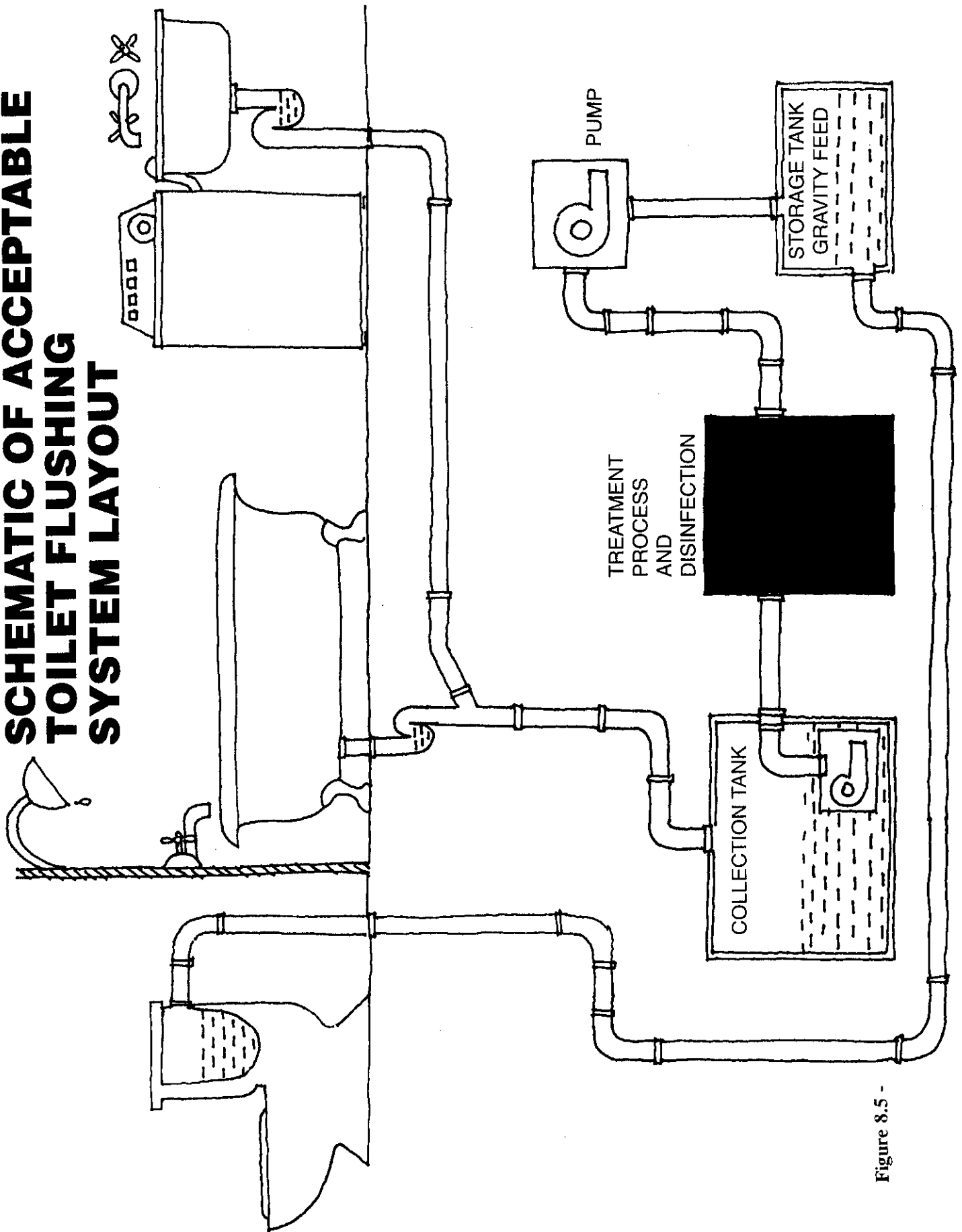


Figure 8.5 -

## 9 GENERAL DESIGN CONSIDERATIONS

### 9.1 General

The following Sections describe parameters and concerns which should be considered for incorporation into greywater guidelines and system designs.

### 9.2 Cross Connection Prevention

To prevent the risk of contamination by accidental cross connection of plumbing between greywater and potable water, the greywater pipe work must be suitably coloured and marked.

The Australian and the international Standard for dirty water is the colour purple. Some USA companies supply irrigation piping in this colour for dirty water irrigation systems. Australian manufactures can produce this coloured pipe; the only problem at present is lack of demand.

Ideally, greywater pipes and fittings should not be of compatible dimensions to potable water and should use automotive or other incompatible threads. However, the cost may dictate that this is not a viable option.

Irrigation outlets should be clearly and permanently marked that the supply is dirty water. This is to prevent drinking or other uses requiring potable water quality.

The potential for cross-contamination by intermixing irrigation plumbing and hoses must also be prevented by the mandatory fitting of backflow prevention devices on all properties installing a greywater system. The backflow prevention device should comply with AS 2845 and AS 3500

Operation of greywater pressure lines at a working pressure less than the potable water service is an advisable option in further reducing the potential for pollution of the potable water supply.

Where potable water is used as a supplement to greywater storage systems. Provision of appropriate air gaps is essential to prevent cross-contamination.

### 9.3 Coarse Screens

Hair, lint, food and dirt particles are just some of the non-soluble matter found in greywater. Customer surveys in Stage 1 of this project and discussions in the USA confirm that coarse screening is necessary to prevent blockage of pumps and irrigation system components.

For Primary Greywater Systems the coarse screen made of fine 75 micron nylon mesh bag or ladies stockings is recommended ( refer to Figures 9.1 and 9.2). The screen is affixed to the inlet pipe of the surge tank. Replacement frequency is entirely site specific, but is usually around 1 to 3 months.

The nylon bag type screens have a draw string for easy installation. They can be either cleaned and re-used or disposed of after use. Cost is around A\$7.00.

The nylon stocking is cheap and effective. The mesh will stretch as it becomes clogged with matter. This has the advantage of not closing off the supply drain and causing overflow. But this will then allow larger solids to pass and could result in blockages in the irrigation system.

### 9.4 Filters

Treatment systems may incorporate sand or membrane filters that periodically need backflushing. Sand filters generally use sizes 16 or 20 silica sand as the filter media. *Backflushing to the sewer could result in the unacceptable practice of filter sand being lost into the sewer* ( refer to Figures 9.3, 9.4 and 9.5)



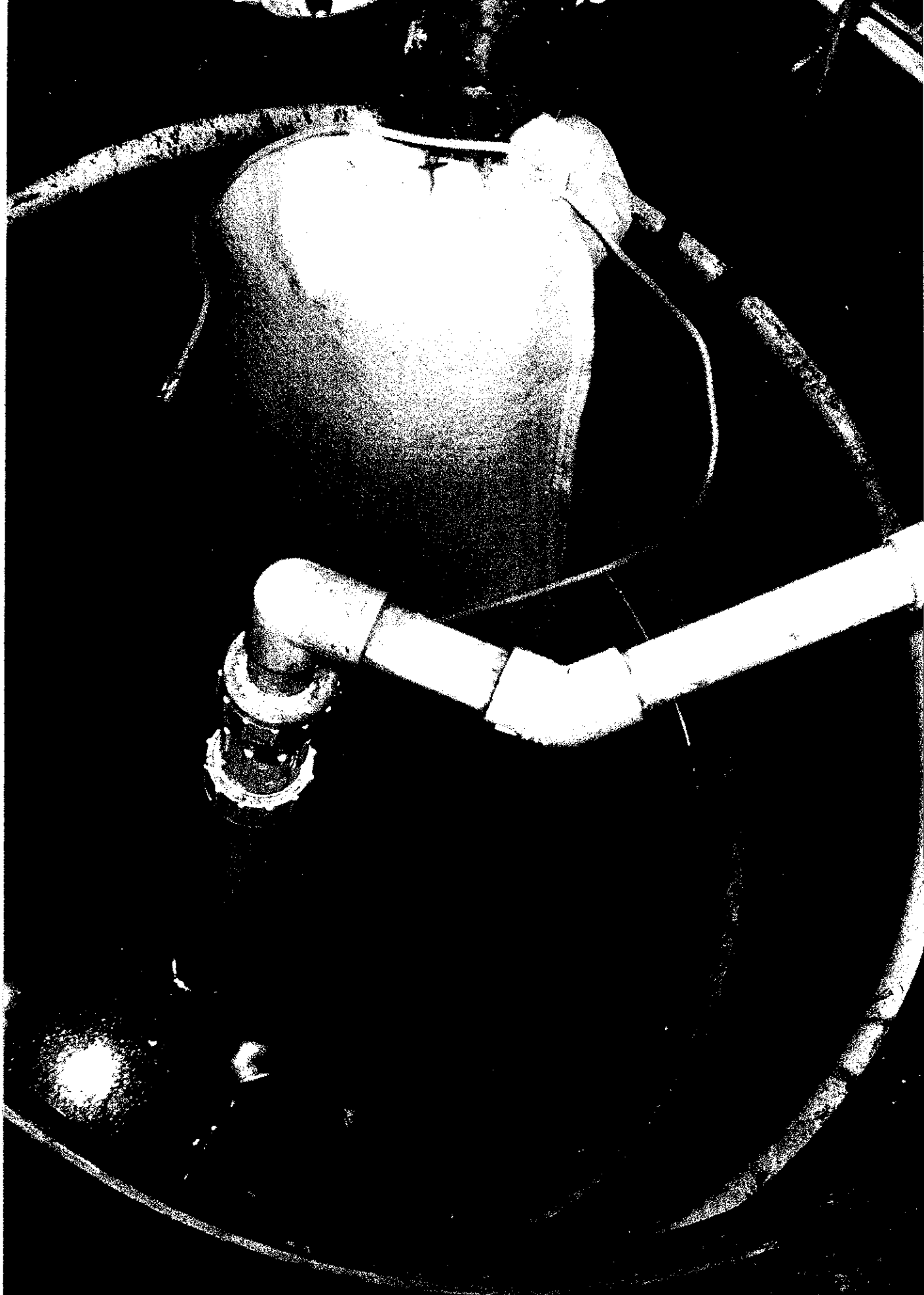


Figure 9.1 - Photo of Nylon Coarse Screen Bag



Figure 9.2 - Photo of a Lady's Stocking used as a Coarse Screen

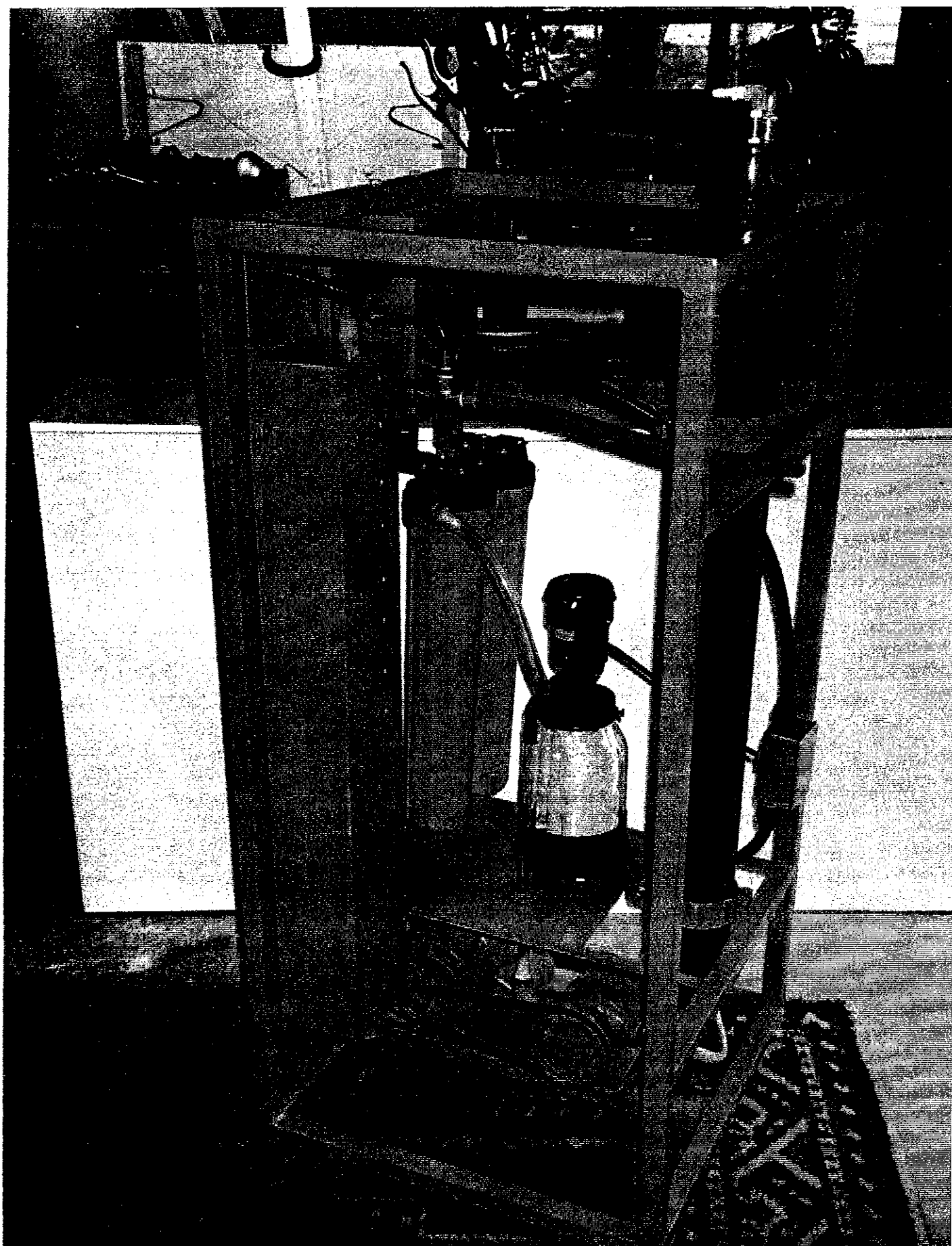






**Figures 9.3 and 9.4 - Photo of the "AGWA" brand Secondary Greywater System with Sand Filtration and Backflush to the Sewer**





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Figure 9.5 - Photo of a Membrane Filtration Secondary Greywater System "Water Recycler" brand



## 9.5 Grease Traps

To prevent irrigation blockages from kitchen waste, the exclusion of this source is recommended. A grease trap would only be recommended when kitchen waste is a source. Kitchen waste could be re-used in non sewerred areas by mini-leach field garden watering. In this instance, dishwashers are generally not recommended as the hot water discharge may result in accumulated grease in the grease trap dissolving and then later solidifying in the system. One solution is to use larger capacity grease traps which will dissipate the heat. Regular owner maintenance of the trap is essential but cannot be depended upon.

## 9.6 Accidental Ingestion Prevention

It is essential that the risk of accidental ingestion of greywater be minimised. Minimum requirements for public health protection are:

- colour coding and labelling of plumbing
- warning signs at hose points and irrigation areas
- non-compatible hose point couplings and threads to potable water fittings (may not be viable due to cost)
- backflow prevention devices fitted to the potable water service at the alignment.

The relevant Australian standards are:

- AS 1547 (Draft) - Disposal of sullage and septic tank effluent from domestic premises
- AS 1319 (1983) - Safety signs for the occupational environment
- AS 1345 (1982) - Identification of the contents of piping, conduits and ducts
- AS 2698 (1984) - Plastic pipes and fittings for irrigation and rural applications
- AS 2845 (1991) - Water Supply - Mechanical Backflow Prevention Devices
- AS 3500 (1990) - National Plumbing and Drainage Code.

## 9.7 Suitability of Site

Domestic greywater contains microbial and chemical contaminates. If applied incorrectly or to an unsuitable site, this could cause nuisance, health and environmental concerns. Parameters to be considered that are already covered in Australian Standard AS 1547 (Draft), "Disposal of sullage and septic tank effluent", are:

- land zoning
- topography
- suitability of soil
- location of site
- location of water table
- land available for a disposal area
- suitability of existing vegetation
- site stability
- climate
- water supply source
- local experience



In addition to the above assessment criteria, evaluations should also include whether the site is sewerred or non sewerred.

For sewerred sites, the sanitary sewer is the primary method of wastewater disposal. Greywater re-use is not an alternative to the sanitary sewer but should be considered as an option for irrigation. The chemical composition of greywater has advantages over potable water for enhancing lawns and gardens, with the added benefit of conserving water.

In non sewerred areas, greywater systems are already proven as a viable primary method of disposal. Sullage systems are already very common in Australia. Unfortunately the emphasis is on disposal rather than re-use. More efficient use of this water can be achieved by sub surface watering of ornamental gardens and lawns.

## **10 DESIGN CONSIDERATIONS FOR SURGE AND COLLECTION TANKS**

### **10.1 General**

Washing machines produce high volume flows when discharging. A means of temporarily capturing this flow is required that does not result in surcharge (overflow) of the greywater onto the ground surface. This can be accomplished by either including a surge vessel, providing adequate capacity in the drain line or by discharging the greywater through the disposal system at a rate equal to or faster than the inflow.

### **10.2 Surge Tanks**

The surge tank is a vessel designed to capture the high volume flows of greywater from the washing machine. It is also necessary for the occasions when the flow is originating from more than one source. Surge tanks in theory should not provide any storage. Greywater flowing into the tank must be immediately distributed for re-use by either gravity lines or by pump (refer to Figure 10.1). The use of submersible pumps will cause some greywater to remain in the surge tank at the end of the pump's run cycle.

Surge tanks should have the following features:

- venting
- overflow to house blackwater drain
- scour to house blackwater drain
- vermin proofing
- hopper floor sloped to the scour
- sealed access openings.

The surge tank has the added benefit of providing a housing for the coarse screen filter and distribution pump.

The hopper floor must be considered mandatory in collection vessels. The hopper floor directs all settleable solids towards the scour or pump suction point. It has the added advantage of reducing the volume of greywater retained at the end of the pump cycle; minimising the retained greywater volume in which micro organisms can breed between cycles.

One of the options for a hopper floor is to tilt the vessel permanently in the direction of the scour outlet (refer to Figure 10.2).

By incorporating a scour outlet to allow periodic draining of the tank sediment, sludge buildup is easily removed. The scour line should fall directly to the private house drain. During prolonged absence from the premises by the users, such as annual holidays, the system can be fully drained of residue to prevent microbial activity becoming anaerobic and causing nuisance and a potential health risk.

An alternative to surge tanks on a gravity distribution system or for non submersible pumps, is to have sufficient capacity in the drainage pipe that supplies the system.

The surge tank must incorporate venting to allow air flow through the gravity pipes and any retention facilities, to prevent accumulation of noxious gases and odours. The flow of air would decrease the potential for anaerobic conditions in the tank. Existing drainage codes within AS 3500 adequately cover the design and positioning of vent pipes, and in some cases the venting can be directed to existing house drain vents.



Figure 10.1 - Photo of a Typical Surge Tank in use in the USA



### **10.3 Storage Tanks**

Storage tanks are precluded in the California greywater laws because storage of untreated greywater promotes microbial activity. If an authority were to approve their use in Australia, it should only be after adequate treatment and disinfection have occurred. The vessel would then require the same minimum features as that of a surge tank:

- venting
- overflow to house blackwater drain
- scour to house blackwater drain
- vermin proofing
- hopper floor sloped to the scour
- sealed access openings.

### **10.4 Frequency of Desludging**

Greywater does contain settleable solids and, if allowed to stand, these solids will accumulate in surge and storage tanks. This sludge can cause operational problems with pumps and re-use systems. In addition, anaerobic digestion of the sludge could eventually occur. The provision of a scour operated periodically and draining back to the blackwater drain, removes any accumulated sludge.

The incorporation of a hopper floor in the surge/storage tank is necessary in reducing accumulation of sludge (refer to Section 10.2).

Brandes (1978), reported the sludge accumulation rate per person in a greywater septic tank to be 8.3 litres per year. The sludge accumulation rate per person for black water was 65.7 litres per year. This figure would be lower in a pump discharge system, but it does highlight that periodic desludging of capture vessels and flushing of pipe work is a necessary maintenance procedure.

### **10.5 Pumped Systems**

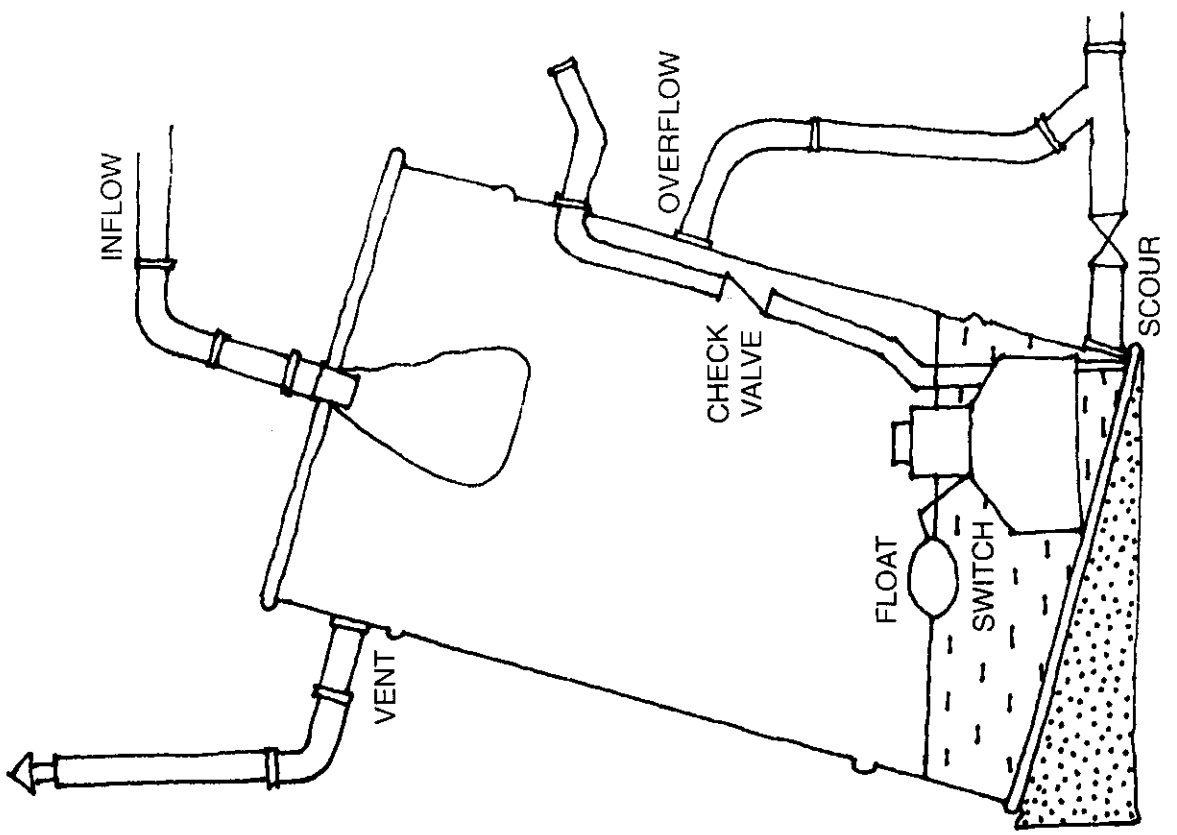
In most applications a pump is needed to distribute the greywater for re-use. This pump is required to operate immediately the greywater enters the collection tank. The pump should be activated by either electrodes or a float switch, and should be fitted with both audible and visual warning devices to indicate failure of the pumping system. The pump outlet should also be fitted with both an authorised non-return valve and an isolating valve.

### **10.6 Diversion to Sewer**

As discussed in section 5.13.5, due to concerns for lack of owner maintenance, it is expected that owners of greywater systems will be equally lax in diverting greywater to the sewer during wet weather. For this reason an active/passive valve arrangement is recommended (Krumins, 1993). To water the lawn and garden the valve must be manually operated, but after a set time the flow rediverts back to the house drain. Reliance upon the operator to manually activate this type of valve (each time greywater is produced), is likely to significantly reduce water savings.

The diversion valve should be accessible and visible. One United States manufacturer has the valve located in front of the washing machine. This allows the user to select the method of disposal for individual loads; for example nappy wash water can be diverted to the sewer.

# TYPICAL SURGE TANKS WITH HOPPER BASE



## 12 DESIGN CONSIDERATIONS FOR TOILET FLUSHING

### 12.1 General

Greywater re-used for toilet flushing needs treatment to ensure adequate disinfection occurs. Other parameters to consider are as follows.

### 12.2 Staining of the Pan

Staining of the pan is caused by the presence of manganese, iron and copper. The United States Department of the Interior recommends the following limits to prevent staining:

- Mn 0.5 mg/L
- Cu 1.0 mg/L
- Fe 1.0 mg/L
- Fe + Mn 1.0 mg/L

Cost and the practicality of treatment to reduce these components may not be feasible for an installation fitted to the single family dwelling. This problem was avoided by the Ontario Research Foundation's research into this topic through the choice of a black toilet pan. As the aesthetics of a black toilet may not appeal to the public, the solution may well be to:

- accept the minor problem
- choose appropriate consumer products (used in the home) that will not cause staining
- more frequent cleaning.

In Japan it is normal for toilets to be flushed on recycled effluent in commercial buildings. White is a seldom used colour for pans for this reason.

### 12.3 Greywater Quality Criteria for Toilet Flushing

<b>Public Health</b>	To be no risk of cross contamination with the potable water service. Flushing of the toilet is to retain aerosols within the confines of the pan. Microbial levels should be of a level that ensures no increased health risk above that of using potable water as the flushing medium.
<b>Odour</b>	The flush water is to have a minimal level of offensive odour.
<b>Staining</b>	The flush medium is not to cause excessive staining of the pan.
<b>Colour and Turbidity</b>	Customer acceptance of the aesthetics of greywater is dependent on education and/or cosmetic changes. Turbidity levels should not inhibit the disinfection process.
<b>Foaming</b>	Excessive foaming from detergents in greywater is to neither increase the need for cleaning nor reduce the flushing performance of the toilet with lightweight material; for example, toilet paper.
<b>Soap and Scum Residue</b>	Soap and scum residue is not to cause failure of the cistern mechanism.

## **13 DESIGN CONSIDERATIONS FOR HAND BASIN TOILETS**

### **13.1 General**

Hand basin toilets incorporate a hand basin in the top of the cistern with a tap for hand washing. The tap operates automatically with the toilet flushing to simultaneously refill the cistern and facilitate hand washing.

Hand basin toilets are expected to pose no microbial health concerns. There is considerable case history for their operation in Japan, where they are installed in most homes. It is anticipated that only minimal pollutants would be transferred to a cistern after hand washing. The effects of soap and other contaminants on the cistern's operation must be evaluated prior to implementation.

The development of the concept of hand basin toilets for 6/3 litre dual flush cisterns poses the following design problems for the manufacturer:

- positioning of internal mechanisms
- design of useable basin area
- ergonomics
- basin and spout design to avoid splashing
- redesign of inlet valve to divert water through flexible fittings to the outlet spout
- positioning of fittings in the confined tank area
- positioning of the water inlet from the basin
- noise reduction during the refilling process
- customer acceptance.

The potable water supply plumbing in the cistern must be positioned so that a permanent air gap is maintained above the top level of the flush water. This is a backflow prevention measure for the cistern's greywater contents.

Greywater Source	Average Volume Litre/day	% of Total Domestic Usage	% of Greywater Source Total
Shower	164	14	41
Bath	29	3	7
Kitchen	44	4	11
Laundry	135	12	34
Basin	28	2	7
- Hand washing after toilet	7	0.5	2
- basin other	21	1.5	5
<b>Total</b>	<b>400</b>	<b>35</b>	<b>100</b>
<b>Greywater Demand</b>			
Landscape Irrigation	588	48	
Water Efficient Landscape Irrigation	353	30	
Toilet	186	15	

**Table 14.1 - Brisbane Average Greywater Source and Demand Volumes Comparison**

### 14.3 Potable Water Savings

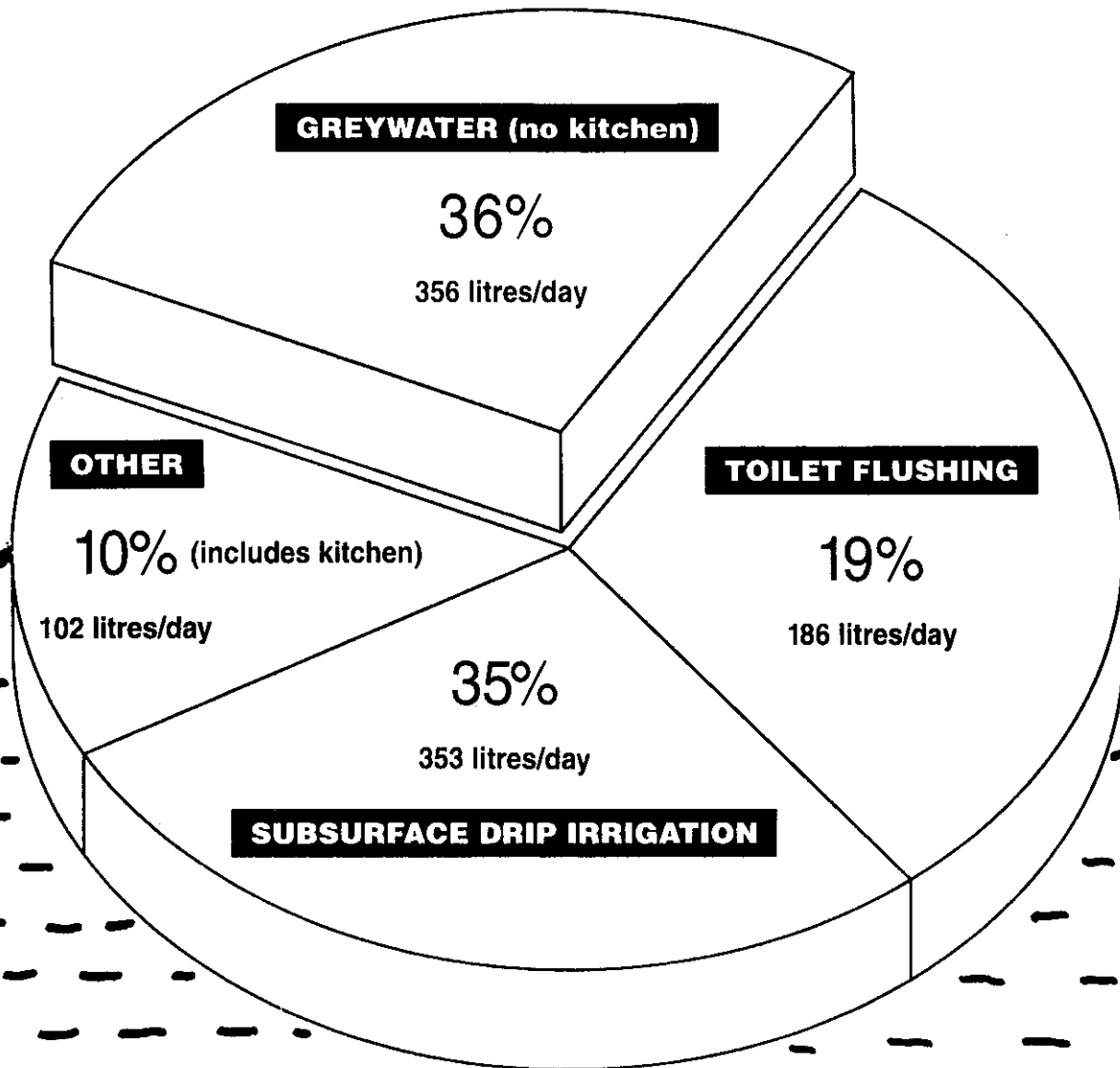
Using average water volume figures given in Table 14.1 to match greywater availability with demand, potential savings in potable water can be determined for an average household. Table 14.1 and Figure 14.1 show that 400 litres of greywater per day is available for re-use in an average household, though if kitchen wastewater is excluded this figure reduces to 356 litres per day.

Greywater demand is much higher than the volume of greywater available, with landscape watering demand 588 litres per day on average. Based on these figures it would appear that the total greywater volume could easily be used for landscape irrigation alone and still require a potable water supplement. Therefore, if the total greywater volume was re-used for landscape irrigation, potable water demand would be reduced on average by 356 litres per day; a 29% reduction from 1232 litres per day.

Farwell (1993) and Kourik (1993) stated that sub-surface watering was 60% more efficient than surface methods. Therefore, if sub-surface watering is a requirement for greywater re-use, then it can be expected that landscape irrigation demand will reduce to 353 litres per day. It can now be seen that, on average, landscape irrigation demand matches the greywater volume available. Table 14.2 shows the average water consumption for a household using greywater (excluding kitchen) for sub-surface landscape watering. Comparing this table with Table 3.1, it can be seen that this greywater re-use can reduce on average total potable water demand from 1232 litres/day to 644 litres/day.

# BRISBANE DOMESTIC WATER USAGE

## DISTRIBUTION WITH SUBSURFACE DRIP IRRIGATION



**TOTAL WATER USAGE**

**997 LITRES/DAY**

• NB Subsurface drip uses 60% of the water used with surface irrigation.

Figure 14.2 - Brisbane's Average Domestic Water Usage  
Distribution with Surface Irrigation of Potable Water

## 14.5 Cost Benefits

Potentially, major savings may be made in both potable water supply and sewerage system costs with the widespread implementation of domestic greywater re-use. However, householder savings are expected to be minimal due to the current low cost of potable water compared with the high cost of greywater systems and their maintenance and expected permit fees. Consideration may be given to the local water authority carrying the administration costs and/or offering rebates to households installing greywater systems, to reduce the cost to the customer and encourage the widespread implementation that would be required to realise the cost benefits quoted in the following sections.

It again should be noted that water saving figures used are averages and will give an inflated estimate of potential savings due to greywater implementation (refer Section 14.1).

### 14.5.1 Cost Benefits to the Customer

A householder who installs a greywater system used for landscape irrigation could potentially save 105 to 173 kilolitres of potable water per year, which using the Brisbane City Council's current pricing structure would save the customer between \$68.00 and \$91.00 per annum (if the customer was paying for water based on the amount used through a water meter) (see Appendix 9).

A primary greywater system, built and installed by the customer, could have a capital cost as low as \$500.00 with a minimum of \$5.00 per year operating/maintenance costs. Even with this small outlay, the greywater system would have a payback period of between 8 and 11 years (based on the above costs and an annual interest rate of 6%). Assuming that the life of a greywater system would be about 10 years, then the cost/benefit in installing a \$500 greywater system would be one. Any greywater system costing less than \$500 would have a cost/benefit greater than one; if costing more than \$500, the cost/benefit would be less than one.

A primary greywater system, built and installed by either a plumber or some type of greywater company, is expected to cost at least \$1 500.00, with similar operating/maintenance costs (minimum \$5.00 per year). This system would have a payback period of greater than 50 years.

A secondary greywater system is expected to cost at least \$3 000.00, with no payback.

Local water authorities may in the future charge each household for the volume of wastewater discharged to the sewer based on their potable water consumption. It is unlikely that LWA's would reduce the charge if a greywater system was installed, even though the system would potentially reduce the sewage volume discharged. The problem is that there would be no method of verifying that the greywater system was operating, short of installing an electromagnetic flowmeter (which would be extremely costly). Therefore, it is not anticipated that a customer would directly receive any savings from reduction of their sewage discharge.

Hand basin toilets would save, on average, 2.5 kilolitres of potable water per annum, saving the customer about \$1.60 a year in potable water charges. It is not anticipated that these toilets would cost any more than currently available models, and would only be installed in new and replacement installations as their would be no payback for retrofitting these toilets in existing locations.

### 14.5.2 Cost Benefits to the Local Water Authority

The cost benefits of greywater for Local Water Authorities have been calculated using the Brisbane City Council as the Datum.

<b>COST BENEFITS TO CUSTOMER - SAVINGS</b>	
<b>Potable Water</b> - irrigation - hand basin toilet  <b>Primary Greywater System</b> - self built and installed - plumber build and installed  <b>Secondary Greywater System</b>	\$68.00 to \$91.00 per annum \$1.60 per annum  8 to 11 year payback > 50 year paypack  No payback
<b>COST BENEFITS TO BCC - SAVINGS</b>	
<b>Greywater Irrigation</b> - potable water system   - sewerage system  - total saving  <b>Hand basin Toilets</b> - potable water system - sewerage system - total savings	\$68.00 to \$112.00 per annum/household \$19M to \$31M per annum  \$42.00 per annum/household \$11M per annum  \$30M to \$42M per annum  \$0.45M per annum \$0.2 M per annum \$0.65M per annum

**Table 14.3 - Cost Benefit Summary**

Watering Method	Year	Region		
	1993 (1015)	Maribyrnong (225)	Yarra (455)	South East (335)
Hand held hose	60%	55%	59%	65%
	627,400	127,600	275,300	224,500
Hose end sprinkler or soaker hose	27%	17%	32%	26%
	278,200	40,400	1,474	90,400
Bucket or watering can	20%	18%	18%	25%
	212,500	41,000	83,200	88,300
Fixed sprinkler system	20%	18%	22%	19%
	208,400	42,300	101,200	65,000
Drip watering system	6%	4%	6%	7%
	61,500	8,400	29,00	24,000
Recycled water	5%	5%	5%	5%
	49,900	11,500	22,000	16,400
<b>Total dwellings watered garden last summer</b>	<b>81%</b>	<b>74%</b>	<b>83%</b>	<b>83%</b>
	<b>848,000</b>	<b>171,900</b>	<b>388,300</b>	<b>287,800</b>

Note: The number in brackets is the number of people surveyed.

**Table 15.1 - Type of Watering Method (Melbourne Water, 1993)**

	Total	Watering Method					
		Bucket	Hose	Sprinkler/ Hose	Drip	Fixed Sprinkler	Recycled
Lawn	41%	47%	51%	69%	53%	55%	43%
Productive plants	39%	55%	50%	54%	49%	52%	64%
English style plants	66%	88%	82%	81%	78%	89%	88%
Native plants	33%	45%	42%	46%	50%	54%	37%
Trees	1%	2%	1%	1%	2%	1%	4%
Pot plants	7%	14%	9%	7%	9%	6%	14%
Other plants	3%	4%	3%	4%	8%	2%	11%
<b>Total watered garden</b>	<b>81%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>	<b>100%</b>
	<b>848,000</b>	<b>212,500</b>	<b>627,400</b>	<b>278,200</b>	<b>61,500</b>	<b>208,400</b>	<b>49,900</b>

**Table 15.2 - Type of Garden and Watering Method (Melbourne Water, 1993).**

The Queensland Sewerage and Water Supply Act 1949-1982, Division 8, Clause 33 " Compulsory and Permissible Discharges" states:

"The occupier of any sewered premises shall discharge into the sewers all faecal matters, urine, household slops, liquid wastes from sinks, baths, and all similar fixtures".

This means that greywater must be discharged to the sewer, precluding re-use for lawn and garden watering. The wording of the act does not appear to prevent re-use for toilet or urinal flushing.

Division 10, Clause 3, of this same Act requires all fittings, fixtures and pipes used in connection with the installation of any house drain, plumbing, sewer or septic tank and all materials and apparatus necessary for such connection be authorised for use by the Joint Committee. The Joint Committee is a body representing government and regulatory authorities and is defined within the Act.

As the law in Queensland presently stands:

- No Local or State Authority can give permission for the installation of any greywater system, including for the purposes of toilet and urinal flushing, without the system first being authorised for use by the Joint Committee.
- The Joint Committee cannot authorise greywater systems that do not discharge to the sewer; for example, lawn and garden watering re-use systems.

In Queensland the Joint Committee has given agreement in principle for some concepts submitted, but to date has not authorised any greywater systems for use.

For the legal application of domestic greywater re-use for lawn and garden watering to occur in sewered areas, state legislation must first be amended as has occurred in the western states of the USA.

Storage of greywater promotes the growth of micro-organisms, including faecal coliforms. Direct re-use without storage will minimise this micro-organism growth, and hence reduce the health risk. Storage of greywater may be possible if treatment can reduce the microbial activity in greywater to acceptably low levels. Not allowing storage of greywater will reduce the potential savings to be made from greywater re-use, as demand for greywater may not match supply at any one time. Excess greywater must then be diverted to the sewerage system.

Limited evidence from trials and existing greywater systems suggests that there are not adverse effects on lawn and gardens from chemicals occurring in greywater. Concerns often raised are that chemicals in greywater will cause damage to soil structures, salination, and increased levels of nutrients in groundwater and waterways due to leaching and runoff. These concerns are yet to be fully investigated. Care should also be taken to ensure that slug loads of chemicals do not enter a greywater system due to disposal of solvents, herbicides etc, down laundry tubs. This risk can be minimised by limiting the sources of greywater, or by education of greywater system owners.

Twenty-two of the Western states of the USA permit the direct re-use of untreated domestic greywater for sub-surface watering of ornamental gardens and lawns. To prevent human contact with untreated greywater, sub-surface watering techniques are specified. Toilet flushing and surface watering with greywater are not permitted because of the risk of human contact (from splashing and aerosols) and the unreliability of household treatment.

No evidence of untreated greywater re-use was found in Japan, except for hand washing water (without soap) being re-used to flush toilets. The Japanese carry out wastewater reclamation for toilet flushing, irrigation and ornamental ponds/fountains, using expensive and sophisticated treatment processes. This occurs in high rise buildings and at regional treatment plant, and is economical because of Japan's severe water shortage.

The widespread, yet sparse practice of domestic greywater re-use in both Australia and overseas has occurred while encountering few complaints or problems. This is encouraging given the substantial water savings that can be made by utilising this water re-use method. However, caution should be exercised when introducing greywater re-use because of the undefined increase in risk to health and the environment.

LIST OF REFERENCES

## APPENDIX 1 - LIST OF REFERENCES

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**UNIFORM PLUMBING CODE: APPENDIX W  
(PUBLISHED BY 'INTERNATIONAL ASSOCIATION OF  
PLUMBING AND MECHANICAL OFFICIALS'  
AND ADOPTED BY THE 22 WESTERN STATES  
OF THE U.S.A.)**

## APPENDIX 2 - UPC APPENDIX W

The California Ad-Hoc Graywater Committee Proposed Amendment to the UPC FEBRUARY 5, 1992:

### APPENDIX W - GRAYWATER SYSTEMS FOR SINGLE FAMILY RESIDENTIAL OCCUPANCIES

#### Section W-1 Graywater Systems (General)

- (a) The provisions of this Chapter shall apply to the construction, alteration and repair of graywater systems for underground landscape irrigation. Installations shall be allowed only in single family residential occupancies. The system shall have no connection to any potable water system and shall not result in any surfacing of the graywater. Except as otherwise provided for in this Appendix, the provisions of this Code shall be applicable to graywater installations.
- (b) The type of system shall be determined on the basis of location, soil type, and groundwater level and shall be designed to accept for plant usage all graywater connected to the system from the residential building. The system, except as otherwise approved, shall consist of holding tank(s) which discharge into subsurface irrigation/disposal fields.
- (c) No graywater system, or part thereof, shall be located on any lot other than the lot which is the site of the building or structure which discharges the graywater; nor shall any graywater system or part thereof be located at any point having less than the minimum distances indicated in Table W-1.
- (d) No permit for any graywater system shall be issued until a plot plan with appropriate data satisfactory to the Administrative Authority has been submitted and approved. When there is insufficient lot area or inappropriate soil conditions for adequate absorption of the graywater, as determined by the Administrative Authority, no graywater system shall be permitted.
- (e) No permit shall be issued for a graywater system on any property in a geologically sensitive area as determined by the Administrative Authority.
- (f) Private sewage disposal systems existing or to be constructed on the premises shall comply with Appendix I of this Code. In addition, appropriate clearances from the graywater systems shall be maintained as provided in Table W-1. The capacity of the private sewage disposal system, including required future areas, shall not be decreased or otherwise affected by the existence or proposed installation of a graywater system servicing the premises.

#### Section W-2 Definition

Graywater is untreated household waste water which has not come into contact with toilet waste. Graywater includes used water from bathtubs, showers, bathroom wash basins, and water from clothes washing machines and laundry tubs. It shall not include waste water from kitchen sinks or dishwashers.

#### Section W-3 Permit

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered any graywater system in a building or on a premises without first obtaining a permit to do such work from the Administrative Authority.

**Section W-6 Procedure for Estimating Graywater Discharge**

(a) The number of occupants of each dwelling unit shall be calculated as follows:

First Bedroom	2 occupants
Each Additional Bedroom	1 occupant

(b) The estimated graywater flows for each occupant shall be calculated as follows:

Showers, Bathtubs and Wash Basins	25 GPD/occupant
Laundry	15 GPD/occupant

(c) The total number of occupants shall be multiplied by the applicable estimated graywater discharge as provided above and the type of fixtures connected to the graywater system.

**EXAMPLE 1**

Single Family Dwelling, 3 bedrooms with showers, bathtubs, wash basins and laundry facilities all connected to the graywater system:

$$\begin{array}{rclclcl} \text{Total number of occupants} & = & 2 + 1 + 1 & = & 4 \\ \text{Estimated graywater flow} & = & 4 \times (25 + 15) & = & 160 \text{ GPD} \end{array}$$

**EXAMPLE 2**

Single Family Dwelling, 4 bedrooms with only the clothes washers connected to the graywater system:

$$\begin{array}{rclclcl} \text{Total number of occupants} & = & 2 + 1 + 1 + 1 & = & 5 \\ \text{Estimated graywater flow} & = & 5 \times 15 & = & 75 \text{ GPD} \end{array}$$

**Section W-7 Required Area of Subsurface Irrigation/Disposal Fields (Figure 5)**

Each valved zone shall have a minimum effective irrigation area in square feet as determined by Table W-2 for the type of soil found in the excavation, based upon a calculation of estimated graywater discharge pursuant to Section W-6 of this Appendix, or the size of the holding tank, whichever is larger. The area of the irrigation/disposal field shall be equal to the aggregate length of the perforated pipe sections within the valved zone times the width of the proposed irrigation/disposal field. Each proposed graywater system shall include at least three valved zones and each zone must be in compliance with the provisions of this Section. No excavation for an irrigation/disposal field shall extend within ten (10) vertical feet of highest known seasonal groundwater nor to a depth where graywater may contaminate the groundwater, except that such distance may be reduced to five (5) feet above groundwater that is ocean water as approved by the Administrative Authority. The applicant shall supply evidence of groundwater depth to the satisfaction of the Administrative Authority.

**Section W-8 Determination of Maximum Absorption Capacity**

- (a) Wherever practicable, irrigation/disposal field size shall be computed from Table W-2.
- (b) In order to determine the absorption quantities of questionable soils other than those listed in Table W-2, the proposed site may be subjected to the percolation tests acceptable to the Administrative Authority.
- (c) When a percolation test is required, no graywater system shall be permitted if the test shows the absorption capacity of the soil is less than 0.83 gallons per square feet or more than 5.12 gallons per square feet of leaching area per 24 hours.

Section W-11 Irrigation/Disposal Field Construction (Figure 5)

- (a) Perforated sections shall be a minimum 3 inch diameter and shall be constructed of perforated high density polyethylene pipe, perforated ABS pipe, perforated PVC pipe, or other approved materials, provided that sufficient openings are available for distribution of the graywater into the trench area. Material, construction and perforation of the piping shall be in compliance with the appropriate absorption fields drainage piping standards and shall be approved by the Administrative Authority.
- (b) Filter material, clean stone, gravel, slag or similar filter material acceptable to the Administrative Authority, varying in size between  $\frac{3}{4}$ " to  $2\frac{1}{2}$ " shall be placed in the trench to the depth and grade required by this Section. Perforated section shall be laid on the filter material in an approved manner. The filter material shall then be covered with untreated building paper, straw or similar porous material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter material cover until after inspections and acceptance.
- (c) Irrigation/Disposal fields shall be constructed as follows:

	Minimum	Maximum
Number of drain lines per valved zone	1	--
Length of each perforated line	--	100 feet
Bottom width of trench	12 inches	18 inches
Spacing of lines, centre to centre	4 feet	--
Depth of earth cover of lines	10 inches	--
Depth of gravel cover of lines	2 inches	--
Depth of gravel beneath lines	3 inches	--
Grade of perforated lines	level	3 inches/100 feet

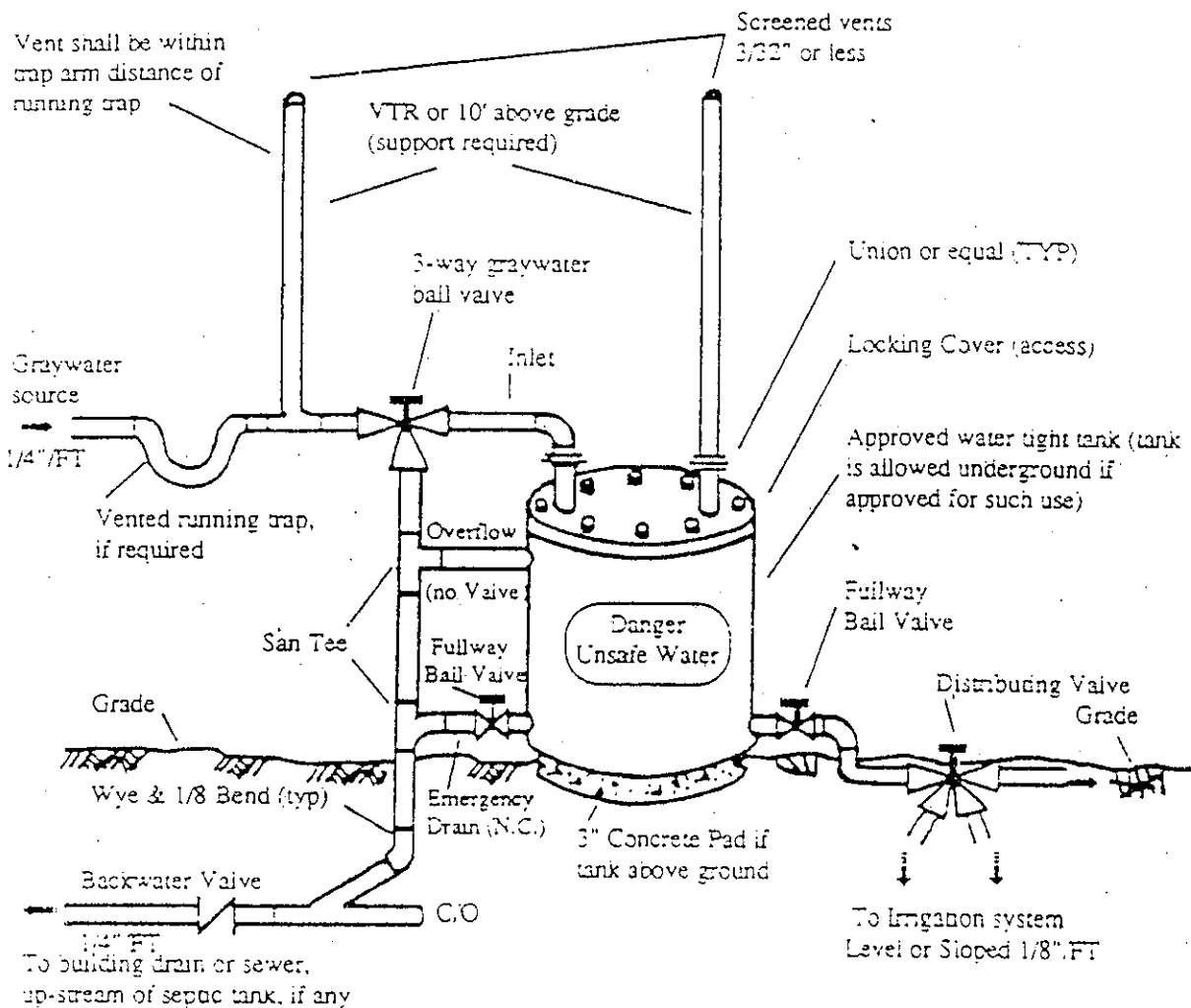
- (d) When necessary on sloping ground to prevent excessive line slopes, irrigation/disposal lines shall be stepped. The lines between each horizontal leach section shall be made with approved watertight joints and installed on natural or unfilled ground.

Section W-12 Special Provisions

Other collection and distribution systems may be approved by the local Administrative Authority as allowed by Section 201 of the UPC.

# GRAYWATER SYSTEM

## Single Tank - Gravity



ABBREVIATIONS

- C.O. Cleanout
- N.C. Normally Closed
- S.O.V. Shut-off Valve
- VTR Vent Thru Roof

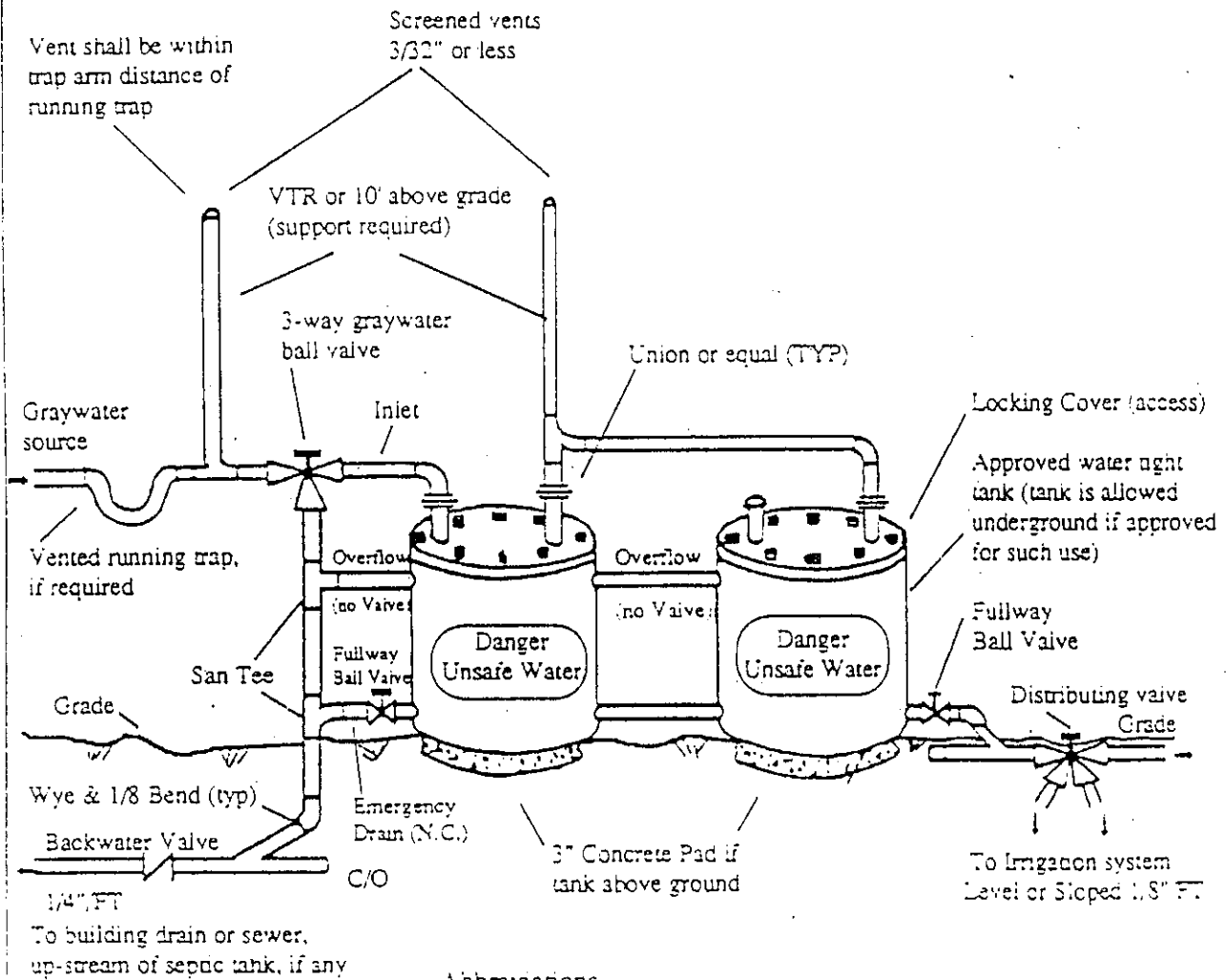
Uniform Plumbing Code  
Appendix W

Figure 1

Date: 12-91

Revised:

# GRAYWATER SYSTEM Multiple Tank Installation



Abbreviations

- C/O Cleanout
- N.C. Normally Closed
- S.O.V. Shut-off Valve
- VTR Vent Thru Roof

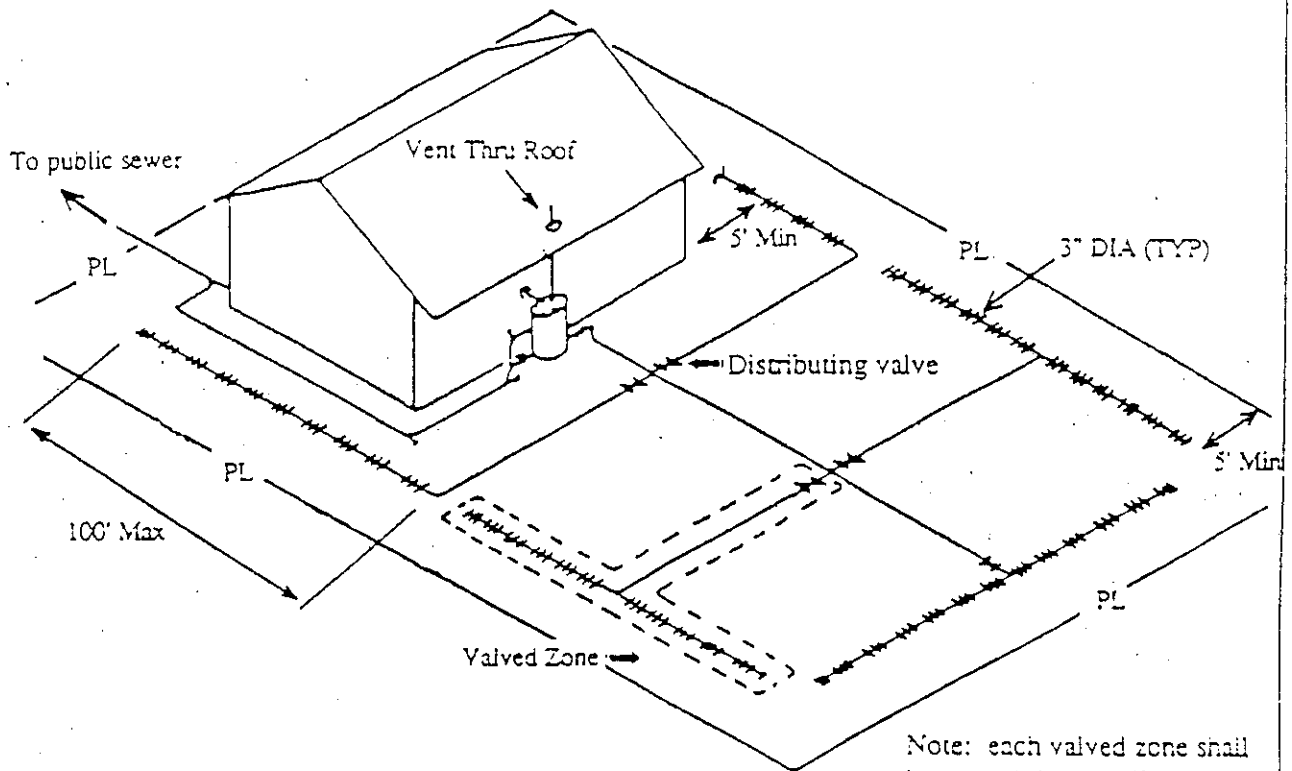
Uniform Plumbing Code  
Appendix W

Figure 3

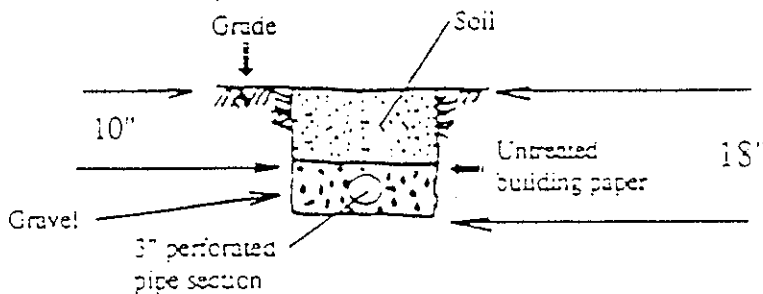
Date: 12-91

Revised:

# GRAYWATER SYSTEM Typical Irrigation Layout



Note: each valved zone shall have a minimum effective absorption/irrigation area in square feet predicated on the estimated graywater discharge in gallons per day and on the type of soil found in the area. Area of the field shall be equal to the aggregate length of perforated pipe sections within the valved zone times the width of the proposed field.



Uniform Plumbing Code  
Appendix W

Figure 5

Date: 12-91

Revised:

CALIFORNIA ASSEMBLY BILL 3518

(b) The department shall revise its graywater systems standards as needed.

14877.2 A graywater system may be installed in a residential building if the city or county having jurisdiction over the building determines that the system complies with standards adopted by the department.

14877.3 After a public hearing, a city or county may adopt, by ordinance, more stringent criteria for approval of graywater systems or may prohibit graywater systems.

APPENDIX 4

CALIFORNIA PLUMBING CODE: APPENDIX J

### Section J-3 Permit

It shall be unlawful for any person to construct, install or alter, or cause to be constructed, installed or altered any graywater system in a building or on a premises without first obtaining a permit to do such work from the Administrative Authority.

### Section J-4 Drawings and Specifications

The Administrative Authority may require any or all of the following information to be included with or in the plot plan before a permit is issued for a graywater system:

- (a) Plot plan drawn to scale completely dimensioned, showing lot lines and structures, direction and approximate slope of surface, location of all present or proposed retaining walls, drainage channels, water supply lines, wells, paved areas and structures on the plot, number of bedrooms and plumbing fixtures in each structure, location of private sewage disposal system and 100% expansion area or building sewer connecting to public sewer, and location of the proposed graywater system.
- (b) Details of construction necessary to ensure compliance with the requirements of this Appendix together with a full description of the complete installation including installation methods, construction and materials as required by the Administrative Authority.
- (c) A log of soil formations and ground water level as determined by test holes dug in close proximity to any proposed irrigation area, together with a statement of water absorption characteristics of the soil at the proposed site as determined by approved percolation tests. In lieu of percolation tests, the Administrative Authority may allow the use of Table J-2, an infiltration rate designated by the Administrative Authority, or an infiltration rate determined by a test approved by the Administrative Authority.

### Section J-5 Inspection and Testing

#### (a) Inspection

- 1. All applicable provisions of this Appendix and of Section 318 of the UPC shall be complied with.
- 2. System components shall be properly identified as to manufacturer.
- 3. Surge tanks shall be installed on dry, level, well-compacted soil if in a drywell, or on a level, 3" concrete slab or equivalent, if above ground.
- 4. Surge tanks shall be anchored against overturning.
- 5. If the irrigation design is predicated on soil tests, the irrigation fields shall be installed at the same location and depth as the tested area.
- 6. Installation shall conform with the equipment and installation methods identified in the approved plans.
- 7. Graywater stub-out plumbing may be allowed for future connection prior to the installation of irrigation lines and landscaping.

#### (b) Testing

- 1. Surge tanks shall be filled with water to the overflow line prior to and during inspection. All seams and joints shall be left exposed and the tank shall remain watertight.
- 2. A flow test shall be performed through the system to the point of graywater irrigation. All lines and components shall be watertight.

- (b) Surge tanks shall be constructed of solid, durable materials, not subject to excessive corrosion or decay and shall be watertight.
- (c) Surge tanks shall be vented as required by Chapter 5 of this Code and shall have a locking, gasketed access opening, or approved equivalent, to allow for inspection and cleaning.
- (d) Surge tanks shall have the rated capacity permanently marked on the unit. In addition, "GRAYWATER IRRIGATION SYSTEM, DANGER - UNSAFE WATER" shall be permanently marked on the surge tank.
- (e) Surge tanks installed above ground shall have a drain and overflow, separate from the line connecting the tank with the irrigation fields. The drain and overflow shall have a permanent connection to a sewer or to a septic tank, and shall be protected against sewer line backflow by a backwater valve. The overflow shall not be equipped with a shut-off valve.
- (f) The overflow and drain pipes shall not be less in diameter than the inlet pipe. The vent size shall be based on the total graywater fixture units, as outlined in UPC Table 4-3 or local equivalent. Unions or equally effective fittings shall be provided for all piping connected to the surge tank.
- (g) Surge tanks shall be structurally designed to withstand anticipated loads. Surge tank covers shall be capable of supporting an earth load not less than 300 pounds per square foot when the tank is designed for underground installation.
- (h) Surge tanks may be installed below ground in a dry well on compacted soil, or buried if the tank design is approved by the Administrative Authority. The system shall be designed so that the tank overflow will gravity drain to a sanitary sewer line or septic tank. The tank must be protected against sewer line backflow by a backwater valve.
- (i) **Materials**
  - 1. Surge tanks shall meet nationally recognised standards for non-potable water and shall be approved by the Administrative Authority.
  - 2. Steel surge tanks shall be protected from corrosion, both externally and internally, by an approved coating or by other acceptable means.

#### Section J-10 Valves and Piping (Fig. 1, 2, 3 and 4)

Graywater piping discharging into a surge tank or having a direct connection to a sanitary drain or sewer piping shall be downstream of an approved waterseal type trap(s). If no such trap(s) exists, an approved vented running trap shall be installed upstream of the connection to protect the building from any possible waste or sewer gases. All graywater piping shall be marked or shall have a continuous tape marked with the words "DANGER - UNSAFE WATER". All valves, including the three-way valve, shall be readily accessible and shall be approved by the Administrative Authority. A backwater valve, installed pursuant to this Code, shall be provided on all surge tank drain connections to the sanitary drain or sewer piping.

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2. Clean stone, gravel, or similar filter material acceptable to the Administrative Authority, and varying in size between 3/4 inch to 2 1/2 inches shall be placed in the trench to the depth and grade required by this Section. Perforated sections shall be laid on the filter material in an approved manner. The perforated sections shall then be covered with filter material to the minimum depth required by this Section. The filter material shall then be covered with landscape filter fabric or similar porous material to prevent closure of voids with earth backfill. No earth backfill shall be placed over the filter material cover until after inspections and acceptance.
3. Irrigation fields shall be constructed as follows:

	Minimum	Maximum
Number of drain lines per irrigation zone	1	---
Length of each perforated line	---	100 feet
Bottom width of trench	6 inches	18 inches
Total depth of trench	12 inches	18 inches
Spacing of lines, centre to centre	4 feet	---
Depth of earth cover of lines	6 inches	---
Depth of filter material cover of lines	2 inches	---
Depth of filter material beneath lines	2 inches	---
Grade of perforated lines	level	3 inches/ 100 feet

#### Section J-12 Special Provisions

- (a) Other collection and distribution systems may be approved by the Administrative Authority as allowed by Section 201 of the UPC.
- (b) Nothing contained in this Appendix shall be construed to prevent the Administrative Authority from requiring compliance with stricter requirements than those contained herein, where such stricter requirements are essential in maintaining safe and sanitary conditions or from prohibiting graywater systems.

#### Section J-13 Health and Safety

- (a) Graywater may contain faecal matter as a result of bathing and/or washing of diapers and undergarments. Water containing faecal matter, if swallowed, can cause illness in a susceptible person.
- (b) Graywater shall not include laundry water from soiled diapers.
- (c) Graywater shall not be applied above the land surface or allowed to reach the land surface, and shall not be discharged directly into or reach any storm sewer system or any water of the United States.
- (d) Graywater shall be not be contacted by humans, except as required to maintain the graywater treatment and distribution system.
- (e) Graywater shall not be used for vegetable gardens.

November 1993

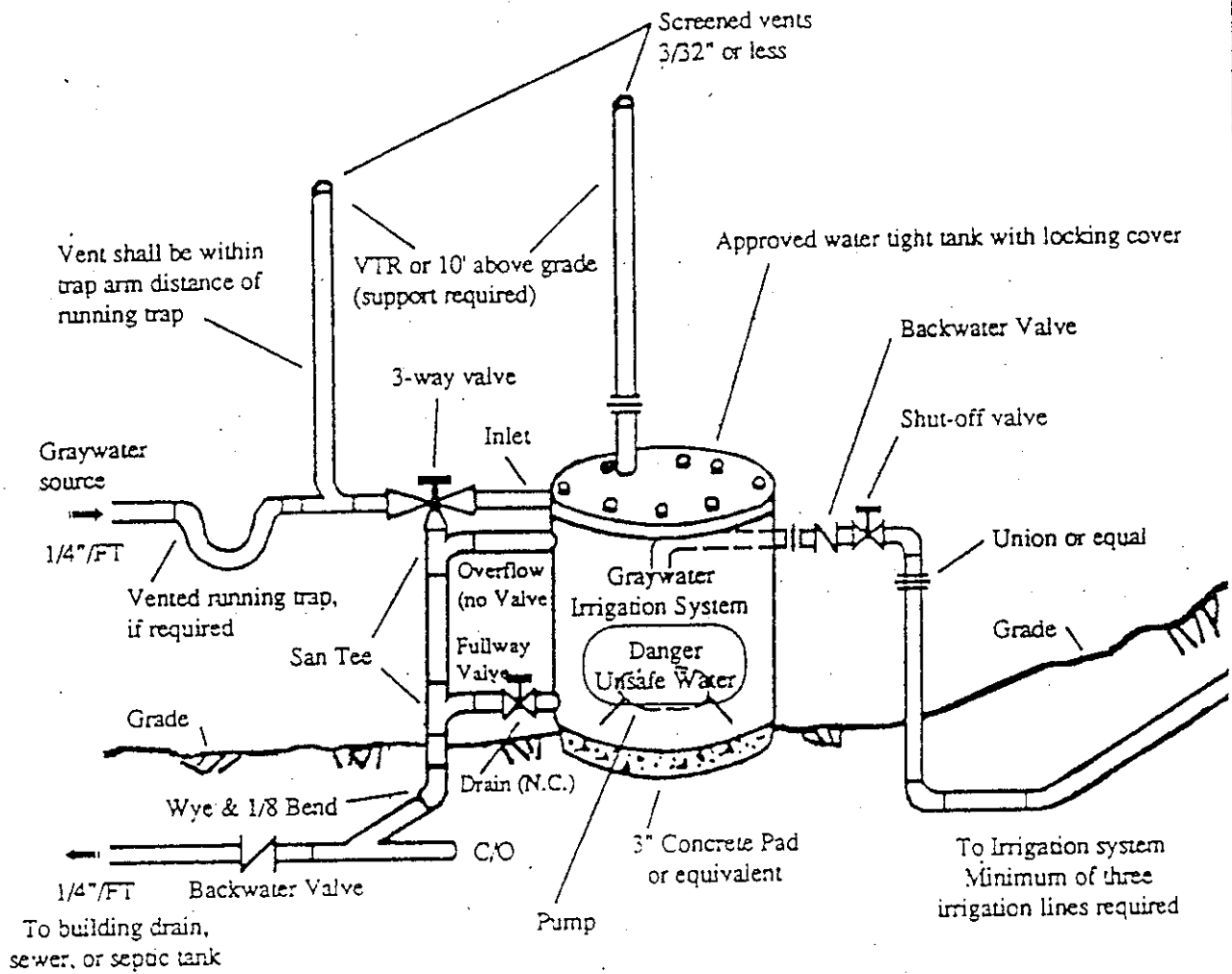
**Table J-3 Subsurface Drip Design Criteria of Six Typical Soils**

	<b>Minimum sq. ft. of irrigation area per 100 gallons of estimated graywater discharge per day</b>	<b>Maximum absorption capacity, minutes per inch, or irrigation area for a 24 hour period</b>
1. Sand	1.8	.6
2. Sandy loam	1.4	.7
3. Loam	1.2	.9
4. Clay loam	.9	1.1
5. Silty clay	.6	1.6
6. Clay	.5	2.0

Use the daily graywater flow calculated in Section J-6 to determine the number of emitters per line.

# GRAYWATER SYSTEM

## Single Tank - Pumped (conceptual)



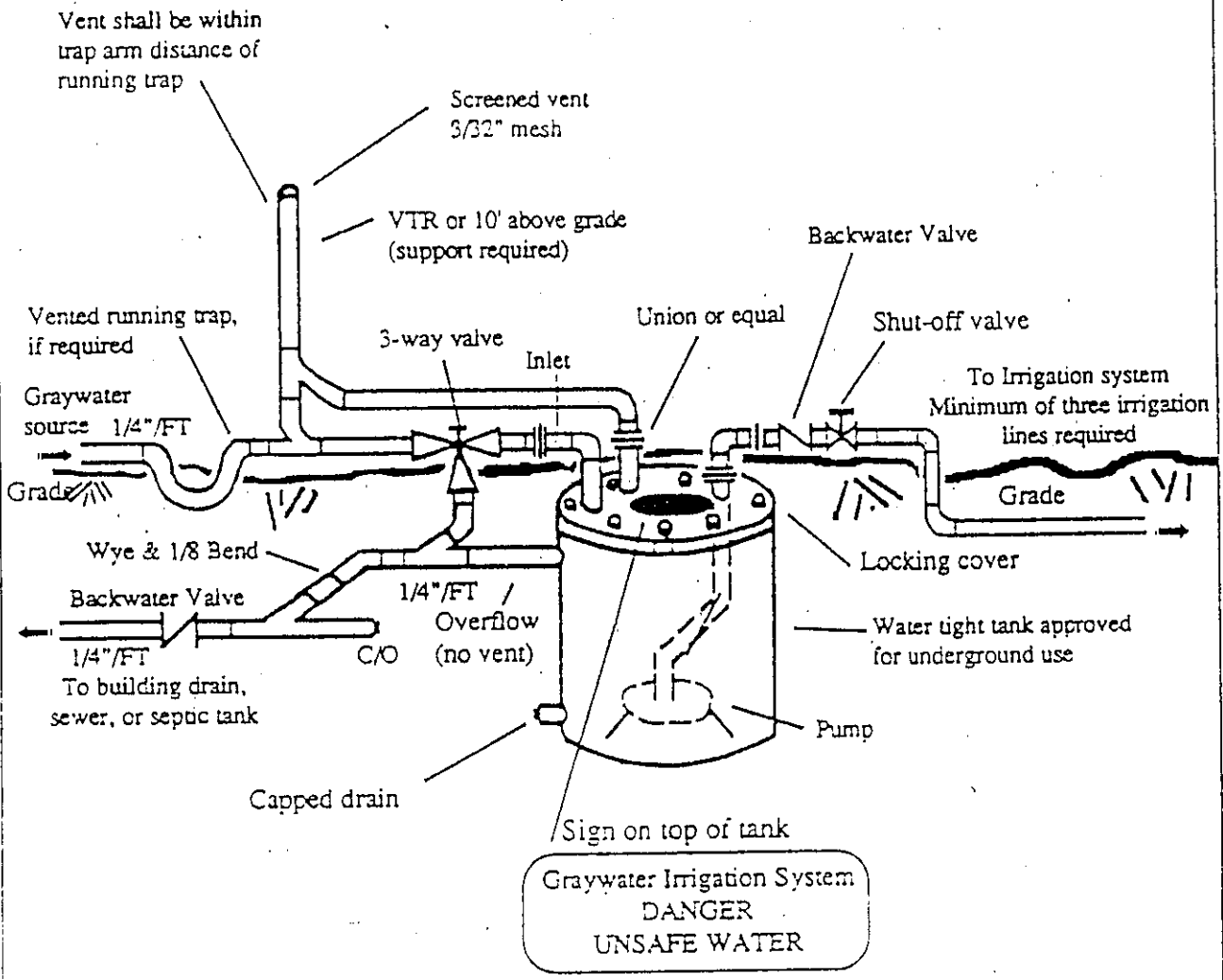
- Abbreviations
- C/O Cleanout
  - N.C. Normally Closed
  - VTR Vent Thru Roof

California Plumbing Code  
Appendix J

Figure 2

Date: 4-93  
Revised: DRAFT

# GRAYWATER SYSTEM Underground Tank (conceptual)



Abbreviations  
 C/O Cleanout  
 VTR Vent Thru Roof

California Plumbing Code  
 Appendix J

Figure 4  
 Date: 4-93  
 Revised: DRAFT

**LIST OF INTERVIEW QUESTIONS  
USED BY B JEPPESEN AND D SOLLEY  
IN OVERSEAS DISCUSSIONS**

## APPENDIX 5 - LIST OF INTERVIEW QUESTIONS

### 5.1 AUTHORITY

5.1.1. Does the authority allow greywater re-use?

If so, how is it administered? -

- Owner ownus
- No regulation
- Permit
- Fully regulated

5.1.2 Does the authority inspect installations on a regular basis?

If so, what does the inspection comprise?

5.1.3 If a nuisance occurs, does the authority have the capacity to withdraw permission to operate from the owners or forcibly rectify any problems?

5.1.4 What has been the primary driving force in establishing greywater re-use in your locality?

- Public demand
- Water conservation
- Overloaded public services
- Drought

5.1.5 Has the authority had any great difficulties in administering this type of project to date?

5.1.6 Was implementation preceded by scientific evaluation of research data or was it by natural progression?

5.1.7 Who within the authority has the primary responsibility for administering greywater re-use?

- Health
- Plumbing
- Building

5.1.8 Have the environmental concerns been addressed re:

- Overflow to waterways
- Saturation of the soils with salts
- Clogging of the soil
- Pollution of the water table

5.1.9 Has the authority evaluated the potential cost savings to the community if greywater was general accepted re:

- Dollar terms
- Water saving
- Future infrastructure deferment
- Maintenance of Infrastructure

5.1.10 What are the primary re-uses for greywater?

- Lawn and garden watering
- Toilet flushing
- Other

## 5.2 DESIGN

5.2.1 What is the average water usage per household per annum for your region?

5.2.2 Do you have a breakdown of inhouse water usage versus exhouse? Of this how much is used for lawn and garden watering?

5.2.3 What are the sources of greywater? KL/annum

(a) Kitchen

- Sink
- Dishwasher
- Garbage disposal

(b) Laundry

- Tubs
- Washing machine
- Floor wastes

(c) Bathroom

- Vanity
- Bath
- Shower
- Floor wastes

(d) Rainwater

(e) Swimming pool/spa backwash

(f) Other eg. air conditioner

5.2.4 If the kitchen is a source, is there

- (a) a grease arrester
- (b) special considerations for food particles
- (c) user guidelines.

5.2.5 If any of the above sources are not accepted, why? e.g.

- Nappies
- Washing of pets etc.
- water softeners

5.2.6 Does the authority require the owner to be supplied with user guidelines?

## **5.4 RE-USE**

### **5.4.1 How is the water re-used?**

- Subsurface
- Surface drip
- Surface spray
- Toilet flushing
- Other

### **5.4.2 What is the basic methodology for the above?**

### **5.4.3 Is the choice of plants affected by re-use?**

### **5.4.4 Does the chemical constituents of greywater cause any concerns with the soil or plants.**

### **5.4.5 Do site size, topography, geology and locality play a role in either permission to operate, design or the function of a greywater system?**

## **5.6 HEALTH**

5.6.1 Has any research into microbial content of greywater being done?

5.6.2 Are the bacterial levels affected by

- source
- duration of storage
- pump residue

5.6.3 Does the authority have concerns about these levels re pathogenic viruses?

5.6.4 Has the authority performed any risk assessment?

5.6.5 Do these levels constitute a necessity for non human contact or disinfection?

5.6.6 If disinfected, what are the acceptable microbial levels?

5.6.7 Is the microbial content a concern in toilet flushing?

5.6.8 If not treated or disinfected, how is the risk avoided?

- subsurface disposal
- natural UV
- other

5.6.9 Does the authority enforce stringent plumbing and signage codes to avoid cross connection?

e.g.

- colour coding pipes
- nonconforming plumbing fittings
- alternate plumbing materials

5.6.10 Have there been health surveys on the incident of water borne disease in the community prior to or after introduction of greywater?

5.6.11 Has there been any risk assessments done?

## 5.8 ECONOMICS

- 5.8.1 In dollar terms, what is the maximum water saving potential of greywater systems for a domestic household?
- 5.8.2 What is the cost of potable water per kilolitre?
- 5.8.3 What are the operating costs for greywater systems?
- running costs
    - electrical
    - maintenance
    - chemical
    - replaceable components
- 5.8.4 What is the purchase price of a greywater system?
- 5.8.5 What is the payback period to the consumer?

LIST OF CONTACTS ON GREYWATER REUSE

## APPENDIX 6 - LIST OF CONTACTS ON GREYWATER RE-USE

During the course of research, several greywater systems have been presented for comment. In addition the names of systems and companies have also come to my attention. The following is a summary of all these systems and companies. Some of these may no longer be in operation:

### AUSTRALIA

#### AQUASAVER (Australian brand)

Sweetglen Pty ltd  
c/o Glen Gaskon  
26 Wunnulla Street  
Thornside, QLD. Ph (07) 2075137.

The "Aquasaver" is a fully self contained greywater system that is designed to collect and re-use all of the households greywater. The system incorporates a fibreglass container, filters with an automatic backwash to sewer, option to disinfect, electronically operated valves and effluent pumps.

**Under the findings of this report this system would be classified as a secondary greywater system.**

Estimated cost \$1500.

#### CLIVUS ROUGHING FILTER

Clivus Multrum  
c/o 1/26 Argon Street  
Sumner Park QLD 4074

Estimated cost \$400.

The roughing filter removes grease's, hair, food, lint and other matter etc from the total household greywater flow allowing it to be diverted for re-use/recycling. Clivus also market a stretch filter greywater system.

**Under the findings of this report this system would be classified as a secondary greywater system.**

#### DRAIN DIVERTER

Mr Bill Temby  
c/o P.O. Box 33  
Oaklands Park SA 5046

Description - The Drain Diverter is a device that can be installed beneath fixtures. By rotating the fixtures outlet grate, the flow can be diverted either to the sewer or for re-use.

**Under the findings of this report this system would be required to be incorporated with a sub surface drip irrigation system so as to allow classification as a primary greywater system.**

Estimated cost. Less than \$100.

H<sub>2</sub>YDROSAVE

Wastewater Management Systems Pty Ltd  
C/- Ron Bishop (074) 911 422  
P O Box 231, Caloundra Qld 4551

The H<sub>2</sub>YDROSAVE is a fully automatic greywater system for flushing toilets. Cost - \$1,600.

**This system does not comply with the findings of this report.**

**Orange** Toto Kiwi USA Inc.  
Unit A, 415 West Taft Avenue  
Orange Ca  
Phone: 0011 1 (714) 282 8686  
Fax: 0015 1 (714) 282 1541  
Reference: Greywater Toilet Cistern

**Hermosa Beach** Mr Wayne Stanton  
Water Save  
914 Prospect Avenue  
Hermosa Beach Ca 90254  
Phone: 0011 1 (310) 379 3575  
Reference: Greywater System

**San Francisco** Mr Rodney Ruskin  
Geoflow Drip Irrigation  
236 W. Portal Ave, # 327  
San Francisco Ca 94127  
Phone: 0011 1 (415) 621 6008  
Reference: Drip Irrigation System

**San Luis Obispo** Mr Bob Davis  
Apple Farm Inn Restaurant  
2015 Monterey St.,  
San Luis Obispo, CA 93401  
Phone 0011 1 (805) 544 2040  
Reference: Toilet flushing with greywater.

**San Dimas** Fred Magnuson  
A&M Services  
POBox 216  
San Dimas, CA 91773  
Phone 0011 1 (714) 599 3905

**Van Nuys** Mr Mark DuBois  
DuBois Sprinkler Systems  
5642 Vaira Avenue  
Van Nuys Ca 91401  
Phone: 0011 1 (818) 784 6281  
Reference: Irrigation Systems

**Palo Alto** Mr Steve Bilson  
Re Water Systems  
438 Addison Avenue  
Palo Alto Ca 94301  
Phone: 0011 1 (415) 324 1307  
Reference: Greywater/Cones

**La Crescenta** Mr Steve Kiefer  
Outdoor Concepts  
PO Box 12539  
La Crescenta Ca 91224  
Phone: 0011 1 (818) 951 4519  
Reference: Greywater with ozonation

**Ann Arbor**

**Mr John Irwin**

Thetford Systems Inc.

PO Box 1285

Ann Arbor MI 48106

Phone: 0011 1 (800) 521 3032  
(313) 769 6000

Fax: 0015 1 (313) 761 7842

Reference: Cycle-Let Wastewater Treatment and Recycling  
Systems for Commercial Buildings and Apartments

**ARIZONA**

**Williams**

**Mr Anton Van Puffelan**

Cycle H2O

Homestead Utilities

HC62, Box 3812

Camp Verde, AZ 86322

Phone: 0011 1 (800) 292 5340

alternate address-

Star Route, Box 2

Williams AZ 86046

Phone: 0011 1 (800) 292 5342

Reference: Greywater toilet flushing system

**ALASKA**

**Fairbanks**

**Mr Clinton Elston**

AlasCan

3400 International

Fairbanks AK 99701

Phone: 0011 1 (907) 452 5257  
683 2698

Reference: Greywater Systems

alternate address.

P.O. Box 278

Healy, Alaska. 99743

Phone: 0011 1 (907) 683 2698

**PENNSYLVANNIA**

**Telford**

Bi-Cep Inc.

20 Indian Valley Ln

Telford PA 18969

Phone: 0011 1 (215) 723 3178

Reference: Greywater System Plans

**COLORADO**

**Berthoud**

**Mr Douglas Spence**

Water Maide

Desiderata Ranch

4617 County Road 2

Berthoud CO 80513

Phone: 0011 1 (303) 772 9611

Fax: 0015 1 (303) 776 3611

LIST OF TERMS

## APPENDIX 7 - LIST OF TERMS

**AUTHORISED** Applies to materials, products, fixtures, appliances and apparatus which are sanctioned for use in the area of jurisdiction of the authorising authority.

**BLACKWATER** Domestic wastewater from the water closet, bidet and bidette; has gross faecal contamination.

**CROSS-CONNECTION** Cross linking of the potable water supply with wastewater, risking contamination.

**DRAIN** A line of pipes above or below ground level within the property boundary, including all fittings and equipment, intended to convey under gravity, sewage or trade waste.

**FITTING** Anything placed in a pipeline for jointing, connecting or changing the direction or internal diameter of the pipeline.

**FIXTURE** A receptacle with necessary appurtenances designed for a specific purpose, the use or operation of which results in a discharge into the sanitary plumbing or sanitary drainage installation.

**FOOD WASTE DISPOSAL UNIT** An appliance being an electrically operated mechanical device for reducing kitchen food waste into fragments small enough to be flushed into the drainage system.

**FULLY VENTED SYSTEM** A system of sanitary plumbing with provision for the separate ventilation of every fixture trap connected (other than fixtures discharging to a floor waste gully) and of the trap of every floor-waste gully.

**GENERIC GREYWATER TOILET** A method of toilet flushing that uses greywater. Treatment consists of coarse screening to remove lint and hair followed by contact disinfection, then storage.

**GREYWATER** (also referred to as sullage). Domestic wastewater from bath, basins, shower, laundry, kitchen sink, dishwashers, swimming pool backwash and including floor wastes from these sources etc. It does not include water closet, bidet and bidette waste.

**GREYWATER SYSTEM** Shall mean any appliance, fitting or device that re-uses/recycles greywater from any single greywater source or a combination of sources.

**GREASE TRAP** (Grease arrestor installation) A drainage fitting used to separate oils and greases from the wastewater flow. Generally used with the kitchen sink when connected to septic/sullage systems.

**SCREEN (Coarse)** A device generally made from wire or nylon mesh or spaced bars to separate solid matter from a liquid.

**SCUM** A floating mass of sewage or sullage solids buoyed up by entrained gas, grease or other substances.

**SEWAGE** The wastewater from the community including all faecal matter, urine, household and commercial wastewater that contains human waste.

**SLUDGE** Semi-liquid solids settled from sewage in septic tanks, sedimentation tanks, and grease arresters.

**SULLAGE** For the purposes of this paper the definition will be as per Australian Standard AS3500-1990, part 0 glossary of terms. Domestic wastes from bath, basins, showers, laundries, and kitchens, including floor wastes from these sources. Sullage will differ from the definition for Greywater in that there is an intent to re-use\recycle greywater.

**SURGE TANK** A vessel designed to capture the high volume greywater flows for the purpose of direct reuse. Not used for storage.

**SURCHARGE** Overflow from a sewer, combined sewer, stormwater channel, or stormwater drain caused by overloading, or chokage. Usually used in reference to wet weather infiltration or inflow.

**SURFACE FLOOD IRRIGATION** An irrigation method where the irrigation water is applied by flowing over the ground surface.

**TREATED GREYWATER** Greywater that has incurred some treatment process apart from simple coarse screening.

**TURBULENT PATH EMITTER** A drip irrigation component. Contains a complex (or tortuous) path of right angled channels for the water to follow. This maintains the fine particles in suspension until they are passed from the emitter.

**VENT** A pipe provided to limit the pressure fluctuations within the discharge pipe system or to encourage the passage of gases.

**UNTREATED GREYWATER** Greywater that has had no form of treatment apart from simple coarse screening.

**WATER USAGE CALCULATIONS**

**(Refer to Sections 14.3 and 14.4  
of main report)**

## COST-BENEFIT CALCULATIONS

(Refer to Section 14.5 of main report)

## APPENDIX 9 - COST BENEFIT CALCULATIONS

### TO THE HOUSEHOLDER:

#### Sub-Surface Watering

Savings in potable water	=	105 to 175 kL/a
Present cost structure	(	\$0.30/kL for first 340 kL/a
	(	\$0.65/kL for > 340 kL/a
Daily usage	=	1232 L/d
	=	450 kL/a
		340 kL/a @ \$0.30/kL
		110 kL/a @ \$0.65/kL
So value of water	=	105 x \$0.65
		to 110 x \$0.65 + 65 x \$0.30
	=	\$68.00 to \$91.00/a/hh

#### Costs of Greywater Systems:

(i)	simple system self installed and built	≈	\$500
(ii)	simple system plumber installed	≈	\$1,500
(iii)	fully automatic system installed	≈	\$5,000
	Minimum annual maintenance costs	≈	\$5/a

Present Value = 0 = PV (Annual Savings - Maintenance, 6%, n years)

- Cost of system

n is the payback period

Solving for n

- (i) n = 8 to 11 years
- (ii) n = > 50 years
- (iii) n = ∞

#### Hand Basin Toilets:

Saving in Potable Water	=	2.5 kL/a @ \$0.65/kL
	=	\$1.62/a/hh

BRISBANE CITY COUNCIL  
POLICY FOR AEROBIC SEWAGE TREATMENT PLANTS

# CRITERIA FOR ONSITE DOMESTIC SEWAGE TREATMENT SYSTEMS IN THE CITY OF BRISBANE

## 1.0 Allowable Systems

### 1.1 - Sanitary Waste Treatment Systems

Only sanitary waste treatment or collections systems that have been licensed by the Queensland Water Resources Commission and/or the Queensland Department of Health are permitted within the area of the City of Brisbane.

### 1.2 - Effluent and sullage Treatment Systems

The following effluent or sullage disposal systems are permitted:

- 0 trenches, either transpiration or absorption
- 0 sub-surface irrigation to fixed landscape areas
- 0 surface irrigation (drip, trickle or flood) to fixed landscape areas
- 0 sand filters followed by surface irrigation (drip, trickle or flood) in fixed landscaped areas.

## 2.0 Restrictions

2.1 - Fixed landscaped areas used for drip, trickle or flood irrigation shall not be used for passive or active recreation purposes.

Paths, barbecues, play equipment and the like shall not be constructed or erected in such areas.

2.2 - Effluent from sanitary waste treatment systems or sullage wastes shall not be disposed of by spraying or any other method that produces aerial mists.

## 3.0 Guidelines

Plant or system installation, including effluent disposal, if appropriate, must comply with Brisbane City Council guidelines before final approval will be given.

### General

1. The owner shall be responsible to ensure that the installation complies with Queensland Water Resources Commission and Queensland Department of Health license conditions, with the Sewerage and Water Supply Act (1949) and these guidelines.
2. Only applications for treatment systems licensed for domestic applications will be considered.
3. Capacity of the treatment or collection system must be linked to the number of bedrooms in the dwelling. Systems capable of serving ten persons are required in all dwellings of three bedrooms or more. Smaller systems will only be considered for dwellings with less than three bedrooms.
4. The sanitary and sullage waste treatment system shall be chosen to suit the site's ability to contain and dispose of all effluent and other by-products within the property boundaries/ Relevant Standards, such as the draft Standard issued by the WS/13 Committee should be used for this assessment.

- d. Effluent and sullage disposal areas are to be completely prepared or landscaped and the irrigation system fully installed to the satisfaction of Council prior to commissioning of the treatment system.
- e. Within or adjacent to the surface irrigation area there shall be a sign advising that reclaimed effluent or sullage is being used for irrigation. The sign shall be on a white background with red lettering at least 20mm high. The sign shall state:

**RECLAIMED EFFLUENT OR SULLAGE WATER**  
**DO NOT DRINK AVOID CONTACT**

## **2.0 Permit Renewals**

2.1 - As the result of the reports received, audit procedures will be developed by the Council for each facility type and inspection frequency will depend on the facility type and the record of performance of each individual installation.

2.2 - An annual permit fee shall be set (its payment to be a condition of the permit) for each facility type and reflect the administration costs and the Audit Inspections costs incurred by the Council.

2.3 - As knowledge of the performance of different systems improves, conditions of the permit may be revised. These new conditions will be advised at the time of the annual permit review.

2.4 - When a property changes title a permit will be transferred to the new property owner.

## **APPENDIX 11 - GREYWATER SYSTEMS OBSERVED DURING OVERSEAS RESEARCH**

The following is an appraisal of the marketed greywater reuse systems observed during this overseas research and their application to Australia. They are listed in order of viewing.

### **SYSTEM NAME: AQUAMISER.**

**SYSTEM DESCRIPTION.** The Aquamiser is a Primary Greywater System designed for lawn and garden watering. The system is a 4 part module package with options for (a) Gravity distribution. (b) Pumped distribution. (c) Potable water supplement. (d) Fine filtration.

The system has options for full automation.

**APPLICATION.** Single family domestic dwellings.

**COST.** Prices start at \$179 US for the base unit.

**CONTACT DETAILS.** Mr Ray Tiradeau & Mr Ron Waers.  
Water Recycling Systems Inc. 4852 Avenida Vista Verde  
Palmdale, California 93551. 800-696-5365.

### **SYSTEM NAME: AUTOMATED GREY WATER APPARATUS (AGWA)**

**SYSTEM DESCRIPTION.** The AGWA system is a fully automated Secondary Greywater System designed for lawn and garden watering. The system incorporates potable water supplement, storage, sand filtration with auto backwash, timer and moisture control landscape watering. This system requires very little maintenance.

**APPLICATION.** Single family and multiple occupancy dwellings.

**COST.** \$3500 US

**CONTACT DETAILS.** Mr Garry Stewart.  
AGWA, 801 So. Flower St, Burbank, California 91502. 818-  
562-1449

### **SYSTEM NAME: CYCLE-LET GREYWATER SYSTEM**

**SYSTEM DESCRIPTION:** The Cycle-let system is an onsite wastewater treatment system for re-use in toilet and urinal flushing, landscape irrigation and ornamental ponds. The process includes biological treatment, membrane filtration, activated carbon treatment and UV disinfection.

**APPLICATION.** Commercial buildings and large apartment buildings.

**COST.** On application, site specific.

**CONTACT DETAILS.** Mr John Irwin.  
Thetford Systems Inc, P.O. Box 1285, Ann Harbor,  
Michigan 48106. 800-521-3032.

**SYSTEM NAME: WATER RECYCLER**

**SYSTEM DESCRIPTION.** This is a membrane filtration and UV disinfection system specifically designed for domestic greywater. The effluent quality that can be achieved may make it suitable for toilet and urinal flushing.

**APPLICATION.** Single and multi occupancy dwellings.

**COST.** \$3000 US.

**CONTACT DETAILS.** Mr Ken Leek.  
Water Recycler. 1973 Cordilleras Rd, Redwood City,  
California 94062. 415-369-7010.

**SYSTEM NAME: WATER MAIDE**

**SYSTEM DESCRIPTION.** This system is a fully self contained unit that has been marketed in the USA for over ten years for the purpose of toilet flushing in single family dwellings. For application to Australia the system can be readily adapted to the purpose of ornamental garden and lawn watering as a Secondary Greywater System.

**APPLICATION.** Single family dwellings.

**COST.** \$1000 US installed.

**CONTACT DETAILS.** Mr Douglas Spence & Mr Christopher Cross.  
Water Maide. Desiderata Ranch, 4617 County Road 2,  
Berthould, Colorado 80513. 303-772-9611.

# UWRAA RESEARCH REPORTS

Report Number	Title	Author	Report Number	Title	Author
1	Trickling filter – solids contact process: Pilot plant studies.	M. Laginestra	21	Management and display of dam surveillance data	D. M. Stirling G. L. Benwell A. B. Murnane
2	A model of water pricing for Melbourne, Sydney and Perth	P. B. Dixon P. M. Norman	22	Evaluation and demonstration facilities for primary sensors	J. A. Lanaway M. Cavey
3	Taste generation associated with chloramination	M. Kerslake	23	Modelling and design of reservoir aeration destratification systems	D. P. Lewis J. C. Patterson J. Imberger R. P. Wright S. G. Schadlow
4	Bacterial regrowth in water supplies	K. Power L. A. Nagy	24	Modelling optimum conditions for reservoir destratification using mechanical mixers	R. M. A. Velzeboer J. A. Cugley J. C. Patterson
5	Leakage management: Assessing the effect of pressure reduction on losses from water distribution systems	B. Horvath	25	Methods for detection of <i>Giardia</i> and <i>Cryptosporidium</i> in water: A preliminary assessment	C. A. Bee P. E. Christy B. E. Robinson
6	Improving communication with the public on water industry policy issues	B. E. Nancarrow G. J. Syme	26	Toxic cyanobacteria in water supplies: Analytical techniques	D. J. Flett B. C. Nicholson
7	Water use efficiency of domestic appliances	I. J. Beith D. J. Horton	27	Tracing toxic discharges to sewers by analysis of biofilms	D. Oliver T. Watson
8	Pilot plant study of fermentation units to increase degradable COD fraction in sewage.	P. J. Bliss D. Barnes P. R. Evans I. Law	28	Electronic meter reading: Link between water meter and house	P. J. Reid J. S. Renwick M. F. Prior
9	Artificial destratification of water storages in Australia.	T. F. McAuliffe R. S. Rosich	29	Identification of common noxious cyanobacteria: Part 1 – Nostocales	P. Baker
10	Taste thresholds of mono-chloramine and chlorine in water	R. O'Halloran C. Veres	30	Forecasting water demand using weather data	M. N. Viswanathan
11	Chromatographic analysis of chloramines using electro-chemical detection	R. O'Halloran, Hai Lin Ge P. Spizziri	31	Effects of controls on water consumption	M. N. Viswanathan
12	Glass reinforced plastic bore casing for large diameter and deep bores	R. Bowyer	32	Biological removal of iron from groundwater: Preliminary studies	M. N. Viswanathan
13	A guide to improving communication with the public on water industry policy issues	B. E. Nancarrow G. J. Syme	33	Statistical modelling of water main failures	E. Tsui G. Judd
14	Fouling and cleaning of fine bubble ceramic dome diffusers	K. J. Hartley	34	Stratification, mixing and water quality in Darwin water supply reservoirs	R. Lukatelich D. Robertson K. Boland J. Imberger J. Patterson
15	Chloramination of Water Supplies	P. M. Thomas (ed)	35	Performance auditing in the Australian urban water industry	S. O'Kane I. Parry D. Blunden D. Herring
16	The 1988 Australian Winter Storms Experiment: Report on aircraft observations	J. B. Jensen	36	Microbiological studies on enhanced removal of phosphates from sewage	R. C. Bayly J. W. May G. Vasiliadis G. N. Rees
17	Pipeline assets: Life cycle economic life	R. Vass management and M. Anderson R. Lewis D. Samson	37	Magnetite and microwaves in sewage effluent treatment	D. R. Dixon A. J. Ware
18	Development of empirical model for tradewaste discharges to small treatment plants	Camp Scott Furphy	38	Polymer based electrode for the selective detection of dichloramine	Y. Lin G. G. Wallace
19	PRELIM users guide (Amended): Australian Version	Camp Scott Furphy	39	Current cost asset valuation: Methodology	J. Dyke
20	Chemical regeneration of activated carbon: Preliminary studies	G. Newcombe			

