Australian Conservation Foundation/Surrowee Pty Ltd

Green Building:
Sustainable Water Consultancy

Prepared for
ACF/Surrowee
by

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GLOSSARY

Greywater: Domestic wastewater from basins, showers and washing machines, but excluding black water and toilet waste.

Blackwater: Human excreta or water grossly contaminated with human excreta.

Effluent: Water mixed with waste matter (same as wastewater).

EXECUTIVE SUMMARY

The aim of this report is to present the results of water and wastewater modelling undertaken as part of a sustainable water consultancy for the ACF/Surrowee Green Building Project. The Institute for Sustainable Futures was engaged to develop a series of options, and to undertake modelling of the hydraulic, technical, economic and other aspects of these options and their implementation, in cooperation with the Design Team and other stakeholders.

For a building of this type to achieve the goal of world's best practice environmental performance in a commercially viable office building, it is imperative that scheme water demand be reduced as much as possible. The practical limits of demand reduction were tested by detailed end-use modelling of various sustainable water management 'options' incorporating water efficiency, reuse and dry sanitation technologies.

The options modelled and corresponding results for scheme water demand are summarised in Table 1.

Option number	Option name	Total water demand (kL/a)	Scheme water demand (kL/a)	Recommended priority
1	Business as usual	2,159	2,159	Not recommended
2	First level water efficiency	1,360	1,360	Not recommended
3	Second level water efficiency	626	626	Absolute minimum requirement
4	3 + effluent reuse in toilets	240	240	4
5	3 + composting toilets & small roofgarden, rain tank supply	240	13	1
6	3 + partial rainwater tank supply	240	136	3
7	3 + small roofgarden, rain tank supply	240	13	2
8	3 + large roofgarden for zero discharge, rain tank supply	240	13	5

TABLE 1 Options modelled, scheme water demand and recommended priority.

The results of modelling and the cost benefit analysis indicate that many of the options would provide net financial gains if the potential benefits from running tours and also from sale of produce from the roofgarden were included (Figure 1). Of the options modelled only Option 2 and Option 3 had net financial benefits on the basis of water and sewer charges avoided as shown in Figure 1.

The recommended option, (Option 5) which incorporated composting toilets was selected on the basis that it best satisfied a majority of the environmental objectives, such as exceeding 96% self supply, reduction of stormwater and elimination of sewage. This option replaces all flush toilets with dry composting toilets and waterless urinals. Option 5 also involves source separation of urine for storage and use as a fertiliser. Some greywater is generated and reused productively in a rooftop garden. The only 'waste' discharges resulting from this option would be when the rainwater tanks overtopped to the stormwater system. Urine and composted faecal matter could

be used productively in the rooftop garden or off-site. Option 5 is superior in terms of meeting other sustainability goals such as nutrient management for effective nutrient recycling. It also provides a good educational resource and importantly challenges perceptions about conventional 'flush-and-dispose' wet sanitation. Benefits from building visits are included. This option has the potential to provide a net financial benefit within 5 years meeting the requirement of commercial viability. All technology is off-the-shelf.

It is recognised that there are design implications of adopting this option such as the requirement to place composting chambers directly under all of the toilets in the building. For this reason, other more flexible (and more complex) 'wet sanitation' options are also recommended.

The next recommended option is Option 7, the 'small roofgarden' option. This incorporates the same technology as the composting toilet option except it has water efficient flush toilets and a small package sewage treatment plant, for treating and disinfecting sewage and greywater to a quality suitable for reuse in toilets and in the roofgarden. Subsequent recommended options involve smaller rainwater tanks for part supply (Option 6) and Option 4 same as Option 7 minus the roofgarden (Figure 1).

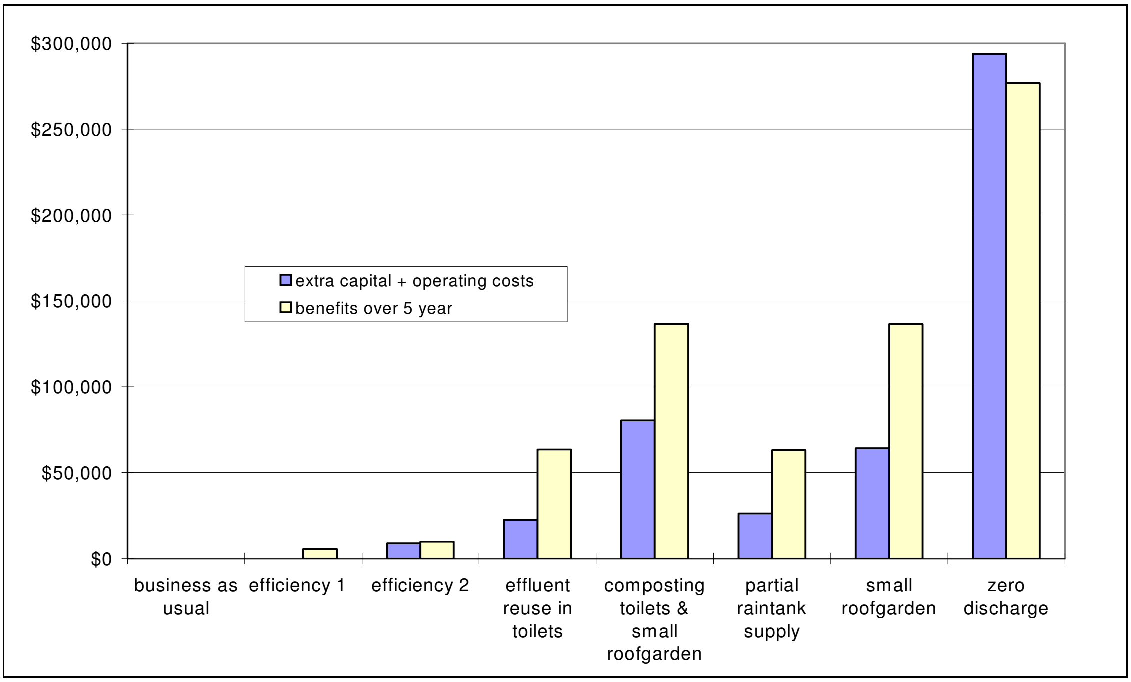

FIGURE 1 Costs and benefits of water system options over a 5 year time period relative to the business as usual case. Benefits include those estimated to come from sale of roofgarden produce and from building visitors.

The options considered in this report seek to help improve problems of river and ocean pollution by reducing or eliminating stormwater and sewage discharges to the environment using readily available 'off-the-shelf' technologies and to provide a working and replicable demonstration model of sustainable water and sanitation practice.

1. INTRODUCTION

The aim of the Australian Conservation Foundation (ACF)/Surrowee Green Building project is to examine how an environmentally performing building of attractive design could be built for a cost that can be fully justified in commercial terms. The building purchased by ACF for the Green Building project is at 60 Leicester St. Carlton, in Melbourne, Victoria. The building has three floors and is East-West facing. It will be retrofitted to make best use of existing infrastructure and materials. The building will have approximately 3,500m^2 of commercial space available to prospective tenants. The building has a roof area suitable for rainwater capture of 1,080 m^2 out of a total site footprint of 1,350 m^2.

The general principles developed by the ACF to be adopted during the development, planning, design, construction, operation and de-construction of the project include the following Environmental Objectives.

- Minimise resource consumption
- Maximise resource reuse
- Use renewable or recyclable resources
- Protect the natural environment (materials sourcing, manufacture & installation)
- Create a healthy non-toxic construction & work environment
- Pursue quality in creating the built environment
- Requirement for residual materials (waste) management plans from all parties
- Adoption of behavioural patterns & practices (including equipment & systems) to conform with stated environmental goals
- Ecological restoration - Acknowledgement of the desirability of at least balancing the ecological impact of the development (related to non-renewable resource uptake for materials and energy) with an ongoing contribution to broad ecological restoration programs

Specific water and wastewater objectives adopted by the ACF include the following:

- Use collected rainwater to replace 100% of normal mains water consumption unless health considerations dictate otherwise
- 100% on-site treatment and reuse of greywater streams
- 100% on-site treatment and reuse of blackwater (sewage) streams
- Establish a new benchmark for low water consumption in commercial buildings
- Stormwater - Reduction of residual matter (organic & inorganic) in site discharges to meet EPA Victoria requirements
- Use residual rainwater and treated water for landscape and building control systems
- Sewage - Reduction of residual organic matter in site discharges to meet EPA Victoria requirements for sewage treatment plant discharges to the environment

Part of the aim of this report is to provide a reasonable conclusion as to the worth of the environmental objectives and their relative importance.

There are inevitably trade-offs associated with deciding on the relative importance of the various environmental objectives. Some of the water and wastewater objectives have the potential to conflict in particular with the goal of overall commercial viability. It was also stated in the environmental objectives however, that where commercial restraints prohibit full implementation of environmental objectives, "*consideration to be given to demonstration & educational projects*". This is important as it recognises the long-term strategic value of implementing technologies and measures in a green building to provide working examples for others to follow.

Additional objectives considered as part of this project were:
- closing the nutrient cycle with the productive reuse of nutrients for agriculture;
- the productive use of effluent for the roof garden; and
- modelling options (technical, social and institutional) which form part of a long-term sustainable urban water future.

The basic structure of this report is as follows. Section 2 describes the water use and other parameters that were assumed for the building. Section 3 is concerned with the modelling methodology specifically how the combined end-use, rainfall, and evaporation tank model works. Sections 4, 5, & 6 provide some detail pertaining to the water sanitation and wastewater components that make up the recommended options. Section 7 details the components of the options as they were modelled. Section 8 presents the results of modelling including the cost benefit analysis of the options. Section 9 has some discussion regarding possible variations that can be made around modelled options. Other issues that must be considered are raised and discussed. Section 10 describes the conclusions and recommendations.

2. THE BUILDING

2.1 Background and setting

The building purchased by ACF for the Green Building project is at 60 Leicester St. Carlton, in Melbourne. The building has three floors and is East-West facing. It will be retrofitted to make best use of existing infrastructure and materials. The building will have approximately 3,500m^2 of commercial space available to prospective tenants and a roof area suitable for rainwater capture of 1,080 m^2 out of a total site footprint of 1,350 m^2.

The ACF Surrowee Green Building is adjacent to other buildings there is a multi-unit residential development to the south, a commercial building to the north, and an electricity sub-station to the east. The area is zoned mixed light commercial/residential.

2.2 Design assumptions

Modelling was undertaken using the following basic assumptions:

- Site footprint = 1,350 m^2
- Roof area for rainwater capture = 1,080 m^2
- 100% office space with approximately 250 tenants (does not include visitors on tours).
- The potential area on the roof available for evaporation is, at maximum, 250 m^2.
- Storage tanks for rainwater and treated effluent are required for various options. Tank sizes ranging from 1,000 – 200,000 litres for the effluent tank and 1,000 – 150,000 litres for the rain tank were modelled.

3. MODELLING METHODOLOGY

Water demand end uses, and wastewater and stormwater outputs were modelled for different scenarios using a purpose built spreadsheet model. The Bureau of Meteorology supplied daily historical climate data for Melbourne. Water demand data was based on results from recent residential end use modelling undertaken by the Institute for Sustainable Futures.

3.1 Demand modelling

The key input to the model was the total daily demand for water resulting from water using activities undertaken by building occupants (e.g. showering, flushing, hand washing). The model utilised assumptions about building occupancy on weekdays and weekends and allowed for different shower usage depending on the daily rainfall. Demand was modelled on a daily basis in preference to a weekly or monthly basis to ensure peak demands would not be masked. To simulate peak demands, it was assumed that a function, party or significant additional occupancy, occurred one Friday each month.

It was assumed that shower usage in the office area was relatively high, based on an assumption that a greater than usual number of occupants (20%) would be cycle commuting with half of these people showering daily except on 'raindays'. This assumption provides a likely overestimate of demand, based on current cycle commuting levels although allows for a significant expansion of cycle commuting in future years in line with cycle friendly workplace and sustainable urban transport policies.

3.2 Rainfall modelling

The modelling of rainfall involved the construction of a hydraulic model using daily rainfall, evaporation and temperature data. Daily rainfall data exists from 1855 although evaporation and temperature data was only available from the last 44 years (Figure 2). Melbourne Post Office rainfall gauging station was the closest to the Green Building and recorded an average of 660 mm/a over the last 141 years. This means that on average, 1000 m^2 of roof area can supply 660m^3 or 660,000 L of water per year given sufficient storage.

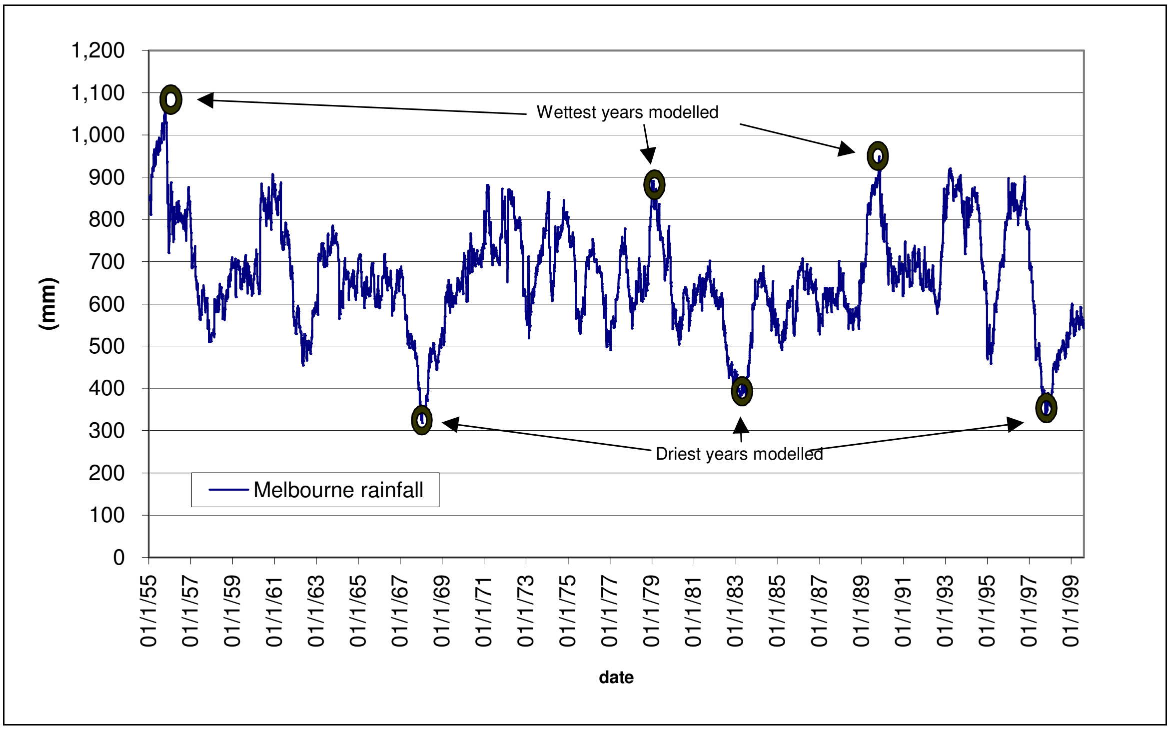

FIGURE 2 Melbourne average annual rainfall.

The 365-day running total for rainfall was plotted on a graph for the all years and the three driest and three wettest years selected from the last 44 years of data. These years were combined into a continuous record. This should provide a rainfall and climate record that would exceed any weather extreme likely to happen in the near future. The three wettest years were plotted first followed by the three driest years and used as the basis for the modelling runs to simulate weather extremes.

The model provided daily tank volumes for the rainwater and effluent tanks, information about the number of days that the tanks would either be empty or overtopping, and the deficit or surplus volumes.

3.3 Evaporation modelling

Evaporation was modelled according to the actual pan evaporation for the day multiplied by the evaporation area and a 'crop coefficient' for particular crops assumed to be growing in a roof garden. A crop coefficient is an expression of the amount of water that a specific crop can evapotranspire compared with a reference crop. The crop coefficient assumed was 0.75, which is a conservative figure considering that coefficients in excess of 1.0 are common for some crops. It must also be emphasised that changing the cropping coefficient has a very large effect on the amount of water than can be evaporated daily. A plot of Melbourne's 365 day potential pan evaporation (over 44 years) is shown in Figure 3.

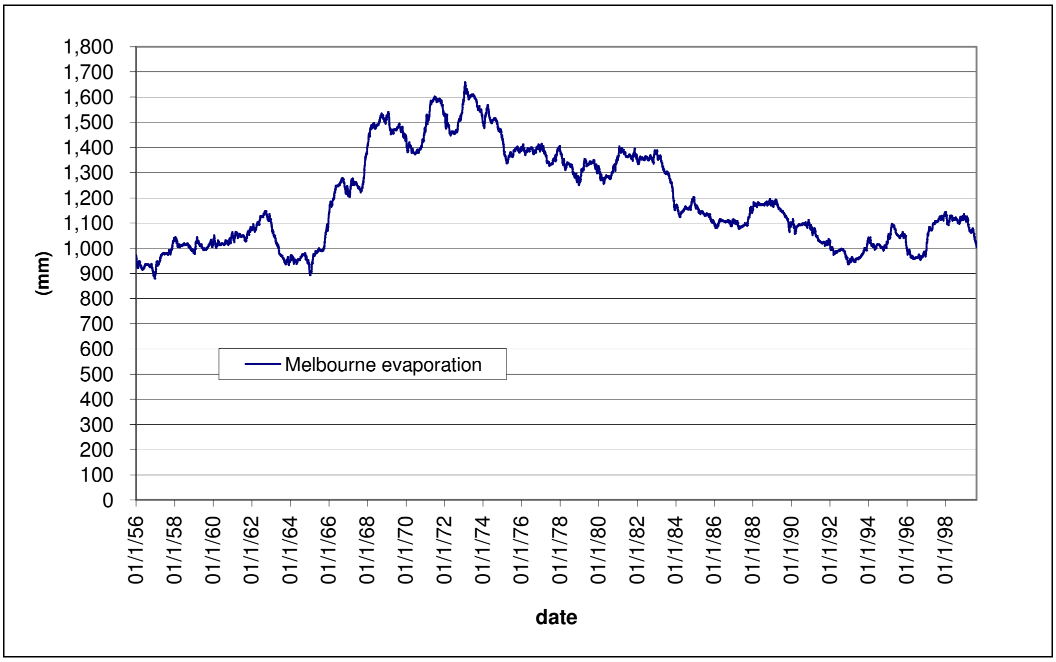

FIGURE 3 Melbourne's potential pan evaporation for the preceding 365 days.

4. OPTION COMPONENTS – POTABLE WATER

This section describes in brief the various components that make up the options that have been modelled.

4.1 Rainwater tanks and drinking water

For rainwater to be suitable for drinking and other uses the surfaces where it is caught, stored and transported must be free of materials that are toxic or release toxic substances. The following are potential sources of contamination:

- roof materials and paints;
- rainwater tank materials;
- guttering; and
- the mechanism for diverting the first flush of roof water to sewer or greywater.

As well as the rainwater tank issues identified above - activated carbon filtration is recommended for all kitchen taps (and possibly showers) to ensure high quality drinking water. There are many different models of filter available. A top of the range example would be an Austech under bench mounted two-stage ceramic and activated carbon filter for $1,041 per unit (one unit required per kitchen with a 4L/minute flow rate). A chiller is an optional extra. Alternatively a bench top Ultra Pure filter suitable for kitchen use costs under $250. An issue with supplying high quality filtered water is that some people fill up bottles to take home on a daily basis (Austech pers. comm.) thus impacting on water demand.

4.2 Feedback mechanisms

An important method of influencing water demand is by reinforcing for people the direct effects of their actions through feedback mechanisms. The simplest way to do this is by having some kind of meter that alerts people as to the current status of the tanks. Such a system could be on-line, and read-outs could be positioned in the kitchen or bathroom areas or even in all three locations. Monitoring and reporting of tank volumes would be an automated process.

Another potentially useful technology are shower timers that report to people via a digital readout or similar how long they have been in the shower. This would help people keep showers down to five minutes. This kind of technology could be run on an 'honour' system rather than automatically shutting off to avoid infringing people's privacy.

4.3 Showers

In most households, showers represent the biggest indoor water end-use. This pattern is not the same for commercial buildings where it was assumed that only a maximum of 5-10% of people would shower at work daily. It is important to ensure water efficient showerheads are fitted and that users are informed about their importance.

For an average shower (seven minutes) changing over from an 11 litre/minute showerhead to an efficient five litre/minute showerhead would result in a saving of approximately 40 litres per shower. The reduction in hot water demand also reduces energy demand (ISF 1998) and has consequent benefits for reducing greenhouse gas emissions. Reducing showering time from seven minutes to five minutes could further decrease water demand. This would save an additional 10 litres per shower. A method of encouraging shorter showers would be through a digital feedback timer in every shower that displays shower duration and a tank volume gauge so people know when water is running low.

Assumptions made in estimating water demand for showers are presented in Table 2:

Flow rates:	
standard flow rate (assumes flow rate throttled back by 1/3):	11 Litre/minute
Efficient flow rate (assumes flow rate throttled back by 1/3):	5 Litre/minute
Average shower duration:	7 Minutes
Shorter shower duration with user feedback timers installed:	5 Minutes
Daily usage: dry day	10% Occupants
Daily usage: rain day	2% Occupants
Daily usage: weekend	0% Occupants

TABLE 2 Assumptions made in estimating shower water demand.

4.4 Infrared automated taps

Bench-mounted, electronic hands-free taps are a useful technology to reduce water wastage. The single spout delivers a stream of water premixed to a set temperature and the person placing their hand under the outlet (in front of the sensor) activates the tap. The water turns off automatically two seconds after the hands are taken away. To prevent water wastage caused by an object blocking the sensor the water will run for a maximum of 45 seconds before the sensor needs resetting. The system requires a small amount of energy to operate (8 watts operating and 7.5 watts dormant). The sensors and switching mechanism can be used with a wide range of spout types and are suitable for kitchen and bathroom applications.

5. OPTION COMPONENTS – TOILETS

Sanitation options are considered in terms of performance in three main areas, (1) minimising water demand and effluent discharge, (2) nutrient management for effective nutrient recycling and (3) cost. In a perfect world we would reduce freshwater use as much as possible, reuse all of our effluent as many times as possible and recycle all our nutrients completely back to the soil. Doing all this would also be the most cost-effective option available.

Technically, it is possible to largely separate nutrients and water using tertiary treatment. However this is an energy intensive and costly approach so the solution has generally been to dump effluent in the ocean after primary or secondary treatment. In resource efficiency terms it makes more sense to separate excrement and urine at source thus avoiding costly pumping, treatment and pollution problems and also freeing up valuable resources.

Nutrients are not an unlimited resource. The current system of agriculture as practised in Australia is based to a large extent on inputs of nutrient fertilisers. Today approximately 90% of mined rock phosphorous is used as a fertiliser and about 70-80% of the phosphorous exported from the agricultural sector in meat and vegetables is passing through sewerage systems [Hellstrom, 1998 p1]. In addition nitrogen-based fertilisers such as nitrate and ammonium are also widely used in agriculture and their production involves large amounts of energy. A great deal of this energy is being expended needlessly to produce nutrient fertilisers while useful nutrients are being dumped in the oceans where they cause eutrophication problems [Hellstrom, 1998 p1]. The current wasteful trend of nutrient management has significant long-term sustainability implications.

Ocean disposal of nutrient rich effluent is ultimately unnecessary provided alternative methods of sanitation can be applied. Any water and sanitation system that aims to be ‘sustainable’ must work towards switching from the ‘flush-and-discharge’ mentality towards a ‘purify and recycle’ model with a final goal of eliminating ocean discharge altogether and closing the nutrient cycle by returning nutrients to the land. The most beneficial method of nutrient management is the one that involves source separation of human wastes and does not mix them together with water. Out of the options explored here only dry-composting toilets can do this.

Following is some information on dry composting toilets, waterless urinals and urine separating toilets.

5.1 Waterless urinals

Waterless urinals look similar to standard urinals except with no cistern, flush valves or other mechanical parts (Figure 4). They work just like conventional urinals but with a special trap cartridge (lasting 8,500 uses) that creates a liquid seal and prevents odours escaping from the plumbing system.

Waterless urinals have been included in all options greater than Efficiency 2 (Option 3) due to the fact that they do not use any water except for cleaning purposes and have an operating cost of less than $40 per annum per urinal (for trap cartridge replacement). Purchase and installation of waterless urinals costs little more than standard urinals and also leaves open the option of the urine being collected and stored for use as a fertiliser for plants. Waterless urinals are currently installed in a number of buildings in Australia and more widely around Europe, New Zealand and in the USA.

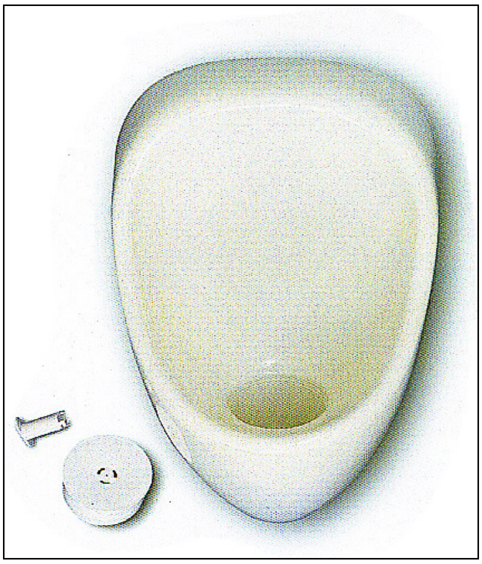

FIGURE 4 Waterless urinal and trap cartridge.

It is not essential to collect the urine and it can go into the general effluent stream or sewer, however urine separation and storage is a sensible option in terms of nutrient management as urine contains 90% of the nutrients found in effluent. Urine separation, collection and reuse is presently practised in a number of countries including Sweden, Norway, China, Vietnam, El Salvador, Yemen and Mexico (Winblad 1998). In these countries urine is generally used either on-site as a fertiliser or stored and transported to nearby agricultural users. At present no market exists for urine in Australia but this could be expected to develop.

5.2 Standard 6/3 L dual flush toilets

Six-three litre dual flush toilets have been widely available in Australia now since 1992. These toilets are a significant improvement on the earlier 11 or 13 litre single flush models and also far exceed the performance of the early 11/6 and 9/4.5 dual flush toilets introduced in the 1983 and 1989 respectively.

Six-three litre dual flush models can be adjusted to work at 5/2-litre capacity. These toilets have the advantages over other toilets that they are cheap, familiar and widely available. These toilets are part of the second level water efficiency option (Option 3) and are the absolute minimum standard recommended for the Green Building. These toilets are appropriate for use with treated effluent for flushing.

5.3 Dry composting toilets

With water reuse on-site and plenty of treated greywater available for flush toilets there is no water demand imperative to install composting toilets however there are other reasons to recommend them. The ACF/Surrowee Green Building aims to provide a model of world's best practice sustainability in action. The reasons why dry composting toilets should be considered include:

- source separation of 'waste' for effective nutrient management and nutrient recycling;
- less energy intensive than flush toilets and treatment;
- provides a useful resource (compost) rather than generating waste requiring treatment;
- provides a useful educational tool;
- eliminates blackwater thus lower level of treatment required for greywater and;
- potentially a cost-effective means of meeting the environmental objectives

Composting toilet technology is now well developed with many different types being available 'off the shelf' to suit Australian conditions. Indeed there are hundreds of designs world-wide to suit various climatic, cultural and environmental conditions (Winblad 1998).

The options described herein (Section 7), all involve a single type of toilet. It would also be possible that a 'mix and match' approach could be taken to increase options available to tenants. For example one or two composting toilets could be installed for use as an educational tool and to supplement flush toilets.

5.4 Urine separating toilets

These toilets are currently not widely available in Australia although they have been broadly adopted in Scandinavia and Europe. It is possible that they could be installed with provision for urine collection to occur when a market is developed. Alternatively they could be used as the basis of a research project into urine separation or the potential for using urine as a plant fertiliser under Australian conditions.

The main benefits of urine separation toilets is that they are good for managing nutrients and they are also water efficient. Ninety percent of the nutrients in human waste are in the urine and when collected and stored or disposed of separately nutrients are mostly eliminated from effluent.

WM-Ekologen is a Swedish company that manufactures dual flush urine separating toilets (as well as urine separating composting toilets). Urine is flushed with a single flush of approximately 0.1 litres while solids are flushed with 3-5 litres. Urine flows to a storage tank while solids go to a chamber for desiccation or composting. These toilets are made of porcelain and appear and flush like a conventional toilet. Toilets are sold in Sweden for approximately AU$600 and can be imported to Australia for approximately AU$700 per unit.

6. OPTION COMPONENTS - WASTEWATER TREATMENT

Different treatment options are required depending on the chosen configuration of the water system. It is desirable to keep greywater (showers, kitchen and bathroom basins) separate from blackwater (toilets) for optimum results. Mixing both streams which is the conventional approach, requires treating the whole stream to a tertiary level with disinfection before reuse can be performed.

In terms of the principal pollutants requiring treatment, greywater contains predominantly suspended solids with trace pathogens (bacteria, viruses and parasites) whilst blackwater contains significant quantities of pathogens as well as nitrogen, phosphorous, BOD (biological oxygen demand), potassium, calcium and magnesium. With separate waste streams, tertiary level treatment including disinfection is required for blackwater, whilst greywater requires only filtration as a prerequisite to subsurface irrigation and simple disinfection such as provided by ultra-violet light if spray irrigation or toilet flushing is desired. Treatment is less energy intensive when separation of wastes via dry composting or urine separation has been performed. This source separation step completely eliminates blackwater from the system cutting down on energy requirements.

A brief description of the some common alternative technologies is provided in the following sections.

6.1 Aerated Wastewater Treatment Systems (AWTS)

AWTS are basically large tanks with three chambers for various stages of treatment to occur. The treatment processes replicate the action of a large-scale sewage treatment plant in a smaller ‘package’ plant. AWTS comes in two types – suspended growth or attached growth systems.

Main processing stages:

- Settling or flotation in a primary chamber for removal of floatable and suspended solids
- Oxidation and consumption of organic matter through aerobic biological processes
- Clarification - secondary settling of solids
- Disinfection using chlorine, ozone, UV, or other approved means
- Does not significantly reduce nutrient levels

Maintenance issues:

- Requires energy to pump in air to aeration chamber
- Needs to run continuously with similar hydraulic loading
- Requires 3 monthly servicing
- Not good with disinfectants, bleaches, pesticides, antibiotics.
- Requires regular sludge removal

Dutek Wastewater Purification Pty Ltd have costed a small package treatment plant suitable for treating and disinfecting one kL/day of combined greywater and blackwater to a quality suitable for roofgarden and toilet flushing for approximately $12,000.

6.2 Microfiltration

Filters pre-screened greywater using membrane technology rather than chemicals or biological treatment. Removes particulates including faecal coliforms and other pathogens but cannot remove dissolved nutrients. Microfiltration can be used without disinfection to filter greywater but UV disinfection is a simple cheap measure to ensure the coliform count is kept at zero.

6.3 Sand filtration

Sand filtration removes suspended solids through a combination of biological and adsorption processes. It is suitable for treating effluent that has been primary or secondary treated. Alternatively it could be used for treating greywater prior to disinfection for reuse in a roof garden or for toilet flushing.

- Normal loading rate for a sand filter is 50 L/m2/day.
- Has a limited life span – 10-15 years before getting clogged and requiring cleaning [DPIE, 1988 p14]

6.4 Aerobic planted systems

An aerobic planted system is a system for biological treatment of wastewater and sewage. These systems are basically a series of tanks or ponds which process water using; plants, sunlight, bacteria, snails, fish and aeration to break down and digest organic pollutants. Depending on the climate, planted systems can be housed in a greenhouse, under shelter or in the open air. These kinds of systems have generally

been applied to larger scale treatment applications such as STPs and industrial treatment ranging in size from approximately 10 – 200 kL/day.
There are a wide variety of these kinds of systems available off-the-shelf. Commercially available systems include artificial wetlands, planted rock filters, Solar Aquatics, Living Machines (Figure 5) and Washwater Gardens.

An aerobic planted system has additional benefits in that it is a useful educational tool, and it can form an aesthetically pleasing and productive part of a rooftop garden. A quote received for a small (1 kL/day) Living Machine was $15,000, which is slightly more expensive than a conventional package treatment plant of this scale. The disadvantage of this kind of system is that it takes time to get a planted system up and running, and that they have to be purpose built and operation needs to be fine-tuned for each application. Planted systems are also not suitable where there are space constraints.

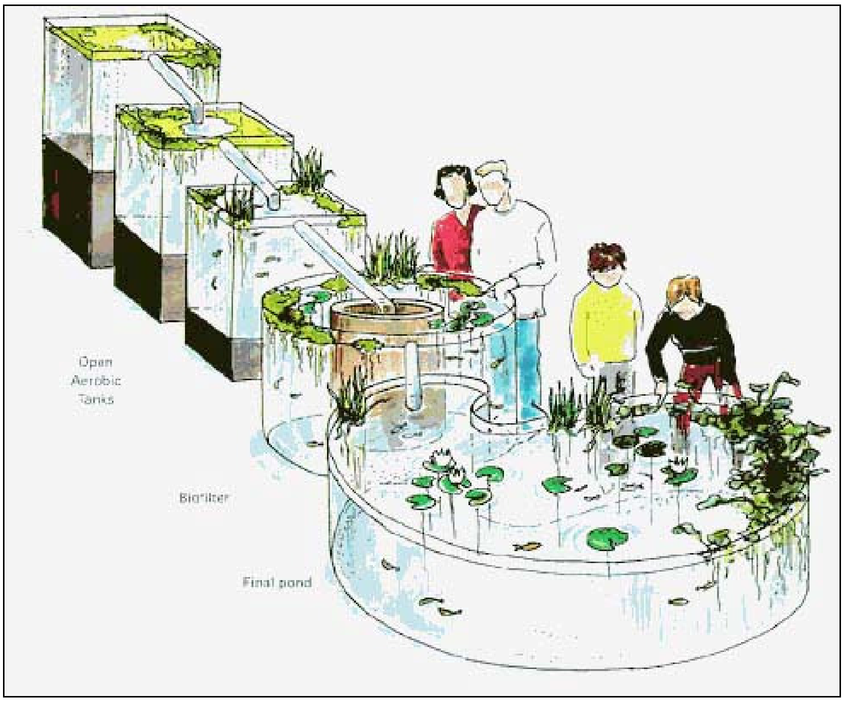

FIGURE 5 A 'Living Machine' aerobic planted wastewater treatment system.

7. SUSTAINABLE WATER AND SANITATION OPTIONS MODELLED

The options modelled include water efficiency measures and technologies that reduce both demand for water and the corresponding discharge of wastewater and stormwater and also manage nutrients for nutrient recycling to varying degrees. These options are summarised in Table 2. Simplified process diagrams are provided for (recommended) Options 4,5,6,7.

7.1 Option 1 - "Business as usual"

This option is being modelled as a comparison for the relative costs, benefits and impacts of all the other options being modelled. It assumes:

- Standard water supply connection to the scheme supply, and sewage discharge to the reticulated sewer and connection of roof water runoff to the existing stormwater system.
- Water using equipment is assumed to be that which would be installed under standard architect's and builder's specifications; including 6/3 litre dual flush toilets; 6 litre per flush urinals operated manually or using a demand-responsive detector flushing a bank of stalls; standard basin tap aerators (12 litres per minute); standard all-directional showerheads (11 litres per minute,) installed as part of a tap set.
- No use of rainwater or reuse of effluent.
- No on-site detention of stormwater.
- Fire protection provided via standard 150 mm main from the scheme supply.
- Conventional sewerage.

7.2 Option 2 – "First level water efficiency"

This option involves the use of basic, currently available efficient water using equipment, involving a minor marginal capital cost increase. It assumes:

- Standard water supply connection to the scheme supply, and sewage discharge to the reticulated sewer and connection of roof water runoff to the existing stormwater system.
- Water using equipment is assumed to be currently available efficient fixtures including 6/3 litre dual flush toilets; 2.8 litre per flush urinals operated using a demand-responsive detector flushing individual stalls; flow regulating tap aerators (6 litres per minute); AAA-rated water efficient showerheads (9 litres per minute, operating at 7-8 litres per minute)
- No use of rainwater or reuse of effluent.
- No on-site detention of stormwater.
- Fire protection is provided via standard 150 mm main from the scheme supply.
- Conventional sewerage.

7.3 Option 3 – "Second level water efficiency"

This option involves the use of more advanced, best available efficient water using equipment, involving a more substantial marginal capital cost increase. It assumes:

- Standard water supply connection to the scheme supply, and sewage discharge to the reticulated sewer and connection of roof water runoff to the existing stormwater system.
- Water using equipment is assumed to be best available efficient fixtures including 5/2 litres per flush toilets; waterless urinals with separate stalls; flow regulating tap aerators (2.5 litres per minute) with infrared detectors; 5 litre per minute water efficient showerheads with user feedback on shower duration and water and energy use.
- No use of rainwater or reuse of effluent or on-site detention of stormwater.
- Fire protection is provided via standard 150 mm main from the scheme supply.
- Conventional sewerage at reduced volume

7.4 Option 4 – "Effluent reuse in toilets"

This option is effectively the same as the previous option (Option 3) with an additional package wastewater treatment plant to treat and reuse greywater for flushing toilets. This reuse significantly lowers water demand. A process diagram for Option 4 is shown in Figure 6.

- Standard water supply connection to the scheme supply, and standard sewage discharge from toilets at reduced volume.
- Connection of roof water runoff to the existing stormwater system.
- Water using equipment is assumed to be best available efficient fixtures including 5/2 litre per flush toilets; waterless urinals with separate stalls; flow regulating tap aerators (2.5 litres per minute) with infrared detectors; 5 L/min water efficient showerheads with user feedback on shower duration and water and energy use.
- No use of rainwater and no on-site detention of stormwater.
- Fire protection is provided via standard 150 mm main from the scheme supply.

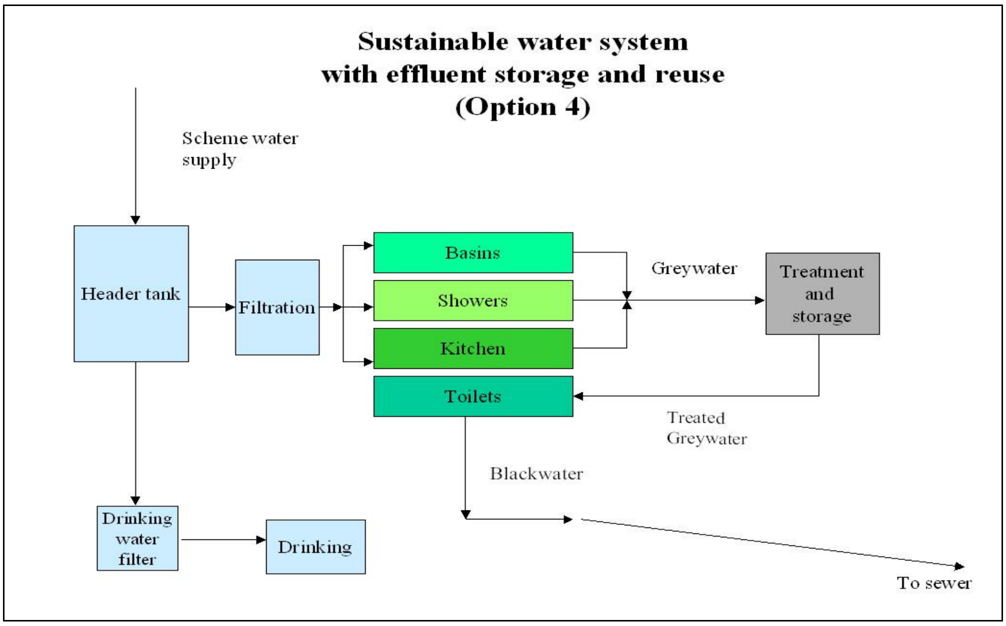

FIGURE 6 Process diagram for Option 4.

7.5 Option 5 – "Composting toilets and small roofgarden"

This option is another variation on Option 3. It is essentially the same except dry composting toilets are used to eliminate toilet water use and manage nutrients for recycling. A small roofgarden is included to make productive use of greywater. Composting toilets eliminate the need for blackwater treatment, blackwater reuse and bring demand down to the same level as that of the effluent reuse option using simpler technology. A simplified process diagram of Option 5 is presented as Figure 7.

- 20 kL rainwater tank topped up by small gauge connection to scheme supply, and greywater reused on roofgarden with excess discharge to the reticulated sewer.
- The composting toilets modelled were 15 urine separation pans or 'pedestals' connected to four (8 m^3) composting toilet chambers located in the basement. These chambers would need to be emptied out when full, although this would only be expected to be required on an annual basis. As the toilets were dry they would need to be located directly above the chambers. Urine would be separated using separating pedestals and diverted to a holding tank.
- Water using equipment is assumed to be best available efficient fixtures including; waterless urinals with separate stalls; flow regulating tap aerators (2.5 litres per minute) with infrared detectors; five litre per minute water efficient showerheads with user feedback on shower duration and water and energy use.
- 20 kL rainwater tank.
- 2 kL greywater tank.
- Small roofgarden with $33m^2$ evaporation area.
- Fire protection is provided via standard 150 mm main from the scheme supply.
- Discharge to sewer is proportion that is surplus to roofgarden requirements.

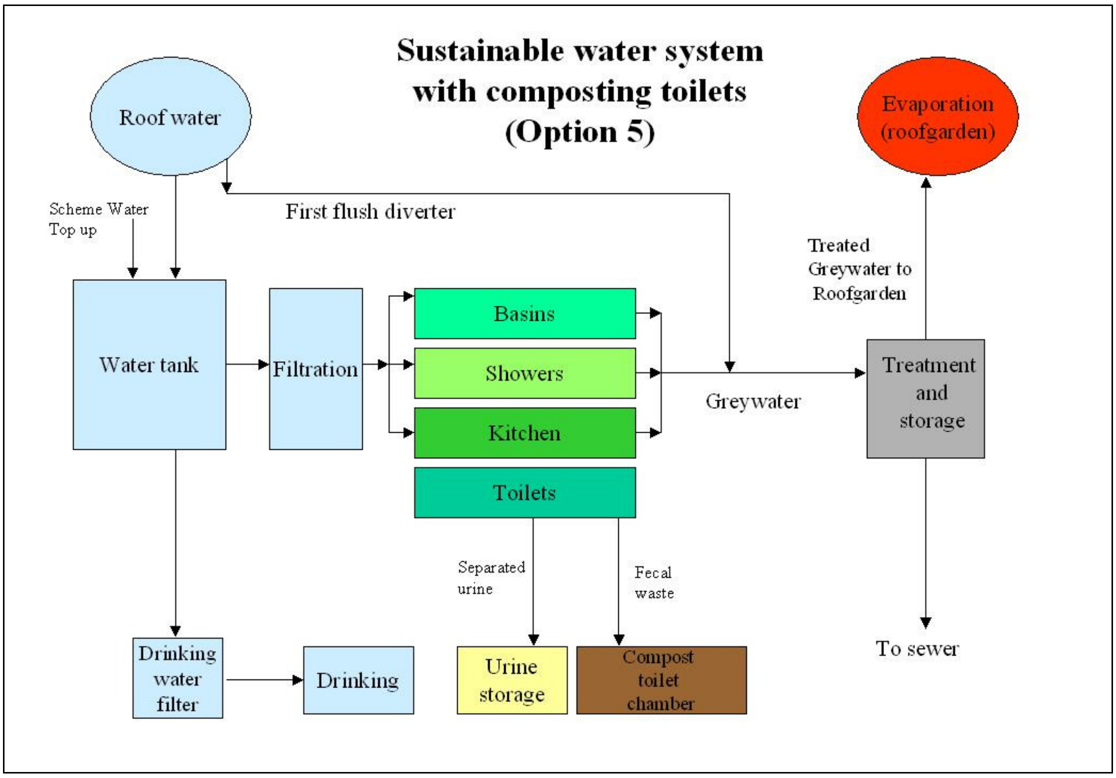

FIGURE 7 Process diagram for Option 5.

7.6 Option 6 – "Partial rainwater tank supply"

This option is the same as Option 3 but with partial rainwater tank supply and effluent reuse in toilets resulting in a reduction in scheme water demand. Supply security is 62% in worst case scenario years. A schematic of the option is presented as Figure 8.

- Sewage discharge (from toilets only) to the reticulated sewer and connection of roof water runoff to rainwater tank. Emergency top up from scheme water.
- Water using equipment is assumed to be best available efficient fixtures including 5/2 litre per flush toilets; waterless urinals; flow regulating tap aerators (2.5 litres per minute) with infrared detectors; 5 L/min water efficient showerheads with user feedback on shower duration, water and energy use.
- Fire protection is provided via standard 150 mm main from the scheme supply.
- A 2 kL rainwater tank and a 2 kL effluent tank were modelled with a package treatment plant to treat greywater to a standard required for toilet flushing.
- Use of entire available roof area (assumed to be 1,080 m^2) for runoff.
- first flush rainfall to be diverted to sewer or to the effluent reuse system .
- Filtration and UV disinfection of water for all purposes except drinking.
- Pumping of water to all use areas with gravity fed back up, or gravity feed to all areas from a header tank.
- Additional point of use filtration or treatment to appropriate levels for supply of drinking water in kitchens or work areas.
- The establishment of a system of water use restrictions, in which tenants are requested to reduce discretionary use of water at times of low storage levels in a way that does not compromise public health, and which provides accessible feedback on the success of these reductions.
- Fire protection provided via standard 150 mm main from the scheme supply, or from the rainwater storage if this can be undertaken within the requirements.
- A suitable operation, monitoring, maintenance and management arrangement that ensures that building occupants or owners are not required to take responsibility for operation of the systems.

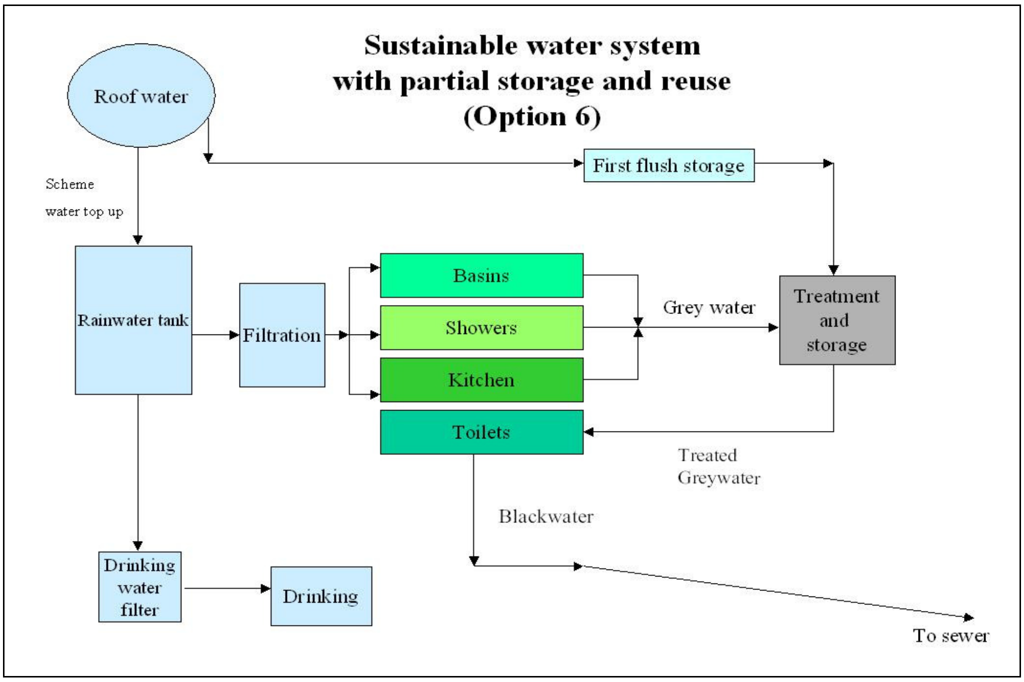

FIGURE 8 Process diagram for Option 6.

7.7 Option 7 – "Small roof garden and tank supply"

This option was modelled with reuse of treated greywater (from basins, showers) for toilet flushing to productive reuse of treated effluent (from either greywater or greywater plus toilet flush water) in a small (50 m^2) roof garden. The remaining greywater/blackwater would go down the sewer. A schematic is presented as Figure 9. This option assumes:

- 20 kL rainwater tank topped up by small gauge connection to scheme supply with treated blackwater used on the roofgarden and excess discharged to sewer.
- Use of a package wastewater treatment plant, with the treatment level and disinfection method determined by the mode of reuse, the requirement to protect public and occupational health and the requirements of the regulatory agencies.
- Use of the roof garden area for evaporation, using a glasshouse and growing beds or similar arrangement to maximise productive use of the treated effluent as well as roof garden area external to the greenhouse to double as a recreation area or meeting space in fine weather.
- Mechanical and passive venting of the glasshouse to remove water vapour in a controlled way, with monitoring and control systems for temperature, humidity, moisture levels in the growing medium, effluent flows, nutrient levels, salt levels.
- Possible separation, collection and storage of urine for productive reuse either in the roof garden or off-site. Reduces nutrient discharge to the sewer system.
- A suitable operation, monitoring, maintenance and management arrangement that ensures that building occupants or owners are not required to take responsibility for operation of the systems.
- Modelling of this option has also included the potential for transfer of rainwater from the rainwater storage tank to the treated effluent tank in times of high evaporation, and also the ability to vary the area of evaporation during these times to reduce the risk of running out of treated effluent.
- Fire protection provided via standard 150 mm main from the scheme supply.

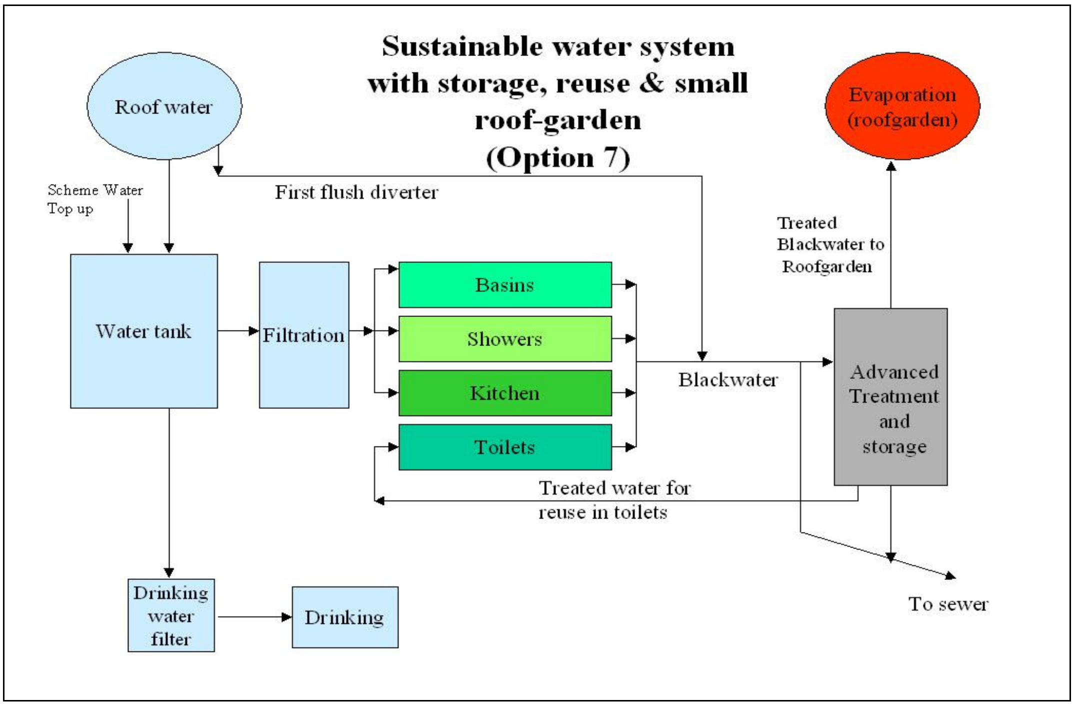

FIGURE 9 Process diagram for Option 7.

7.8 Option 8 – "Zero discharge"

This option was modelled with reuse of treated greywater (from basins, showers) for toilet flushing to productive reuse of treated effluent (from either greywater or greywater plus toilet flush water) in a larger (350m^2) roof garden. The aim was to see what the requirements were to achieve the goal of zero discharge of rainwater and effluent whilst maintaining 100% self supply. A schematic is presented as Figure 9A. It assumes:

- Use of a package wastewater treatment plant, with the treatment level and disinfection method determined by the mode of reuse, the requirement to protect public and occupational health and the requirements of the regulatory agencies.
- Use of the roof garden area for evapotranspiration, using growing beds or similar arrangement to maximise productive use of the treated effluent.
- Mechanical and passive venting of the glasshouse to remove water vapour in a controlled way, with monitoring and control systems for temperature, humidity, moisture levels in the growing medium, effluent flows, nutrient levels, salt levels.
- Storage of treated effluent in concrete storage tanks possibly beneath the building.
- Potential for separation, collection and storage of urine for productive reuse either in the roof garden or off-site, and to prevent the discharge of the nutrient load to the sewer system.
- A suitable operation, monitoring, maintenance and management arrangement that ensures that building occupants or owners are not required to take responsibility for operation of the systems.
- Modelling of this option has also included the potential for transfer of rainwater from the rainwater storage tank to the treated effluent tank in times of high evaporation, and also the ability to vary the area of evaporation during these times to reduce the risk of running out of treated effluent.
- Fire protection provided via standard 150 mm main supply, or from rainwater or treated effluent storage if this can be undertaken within the requirements.

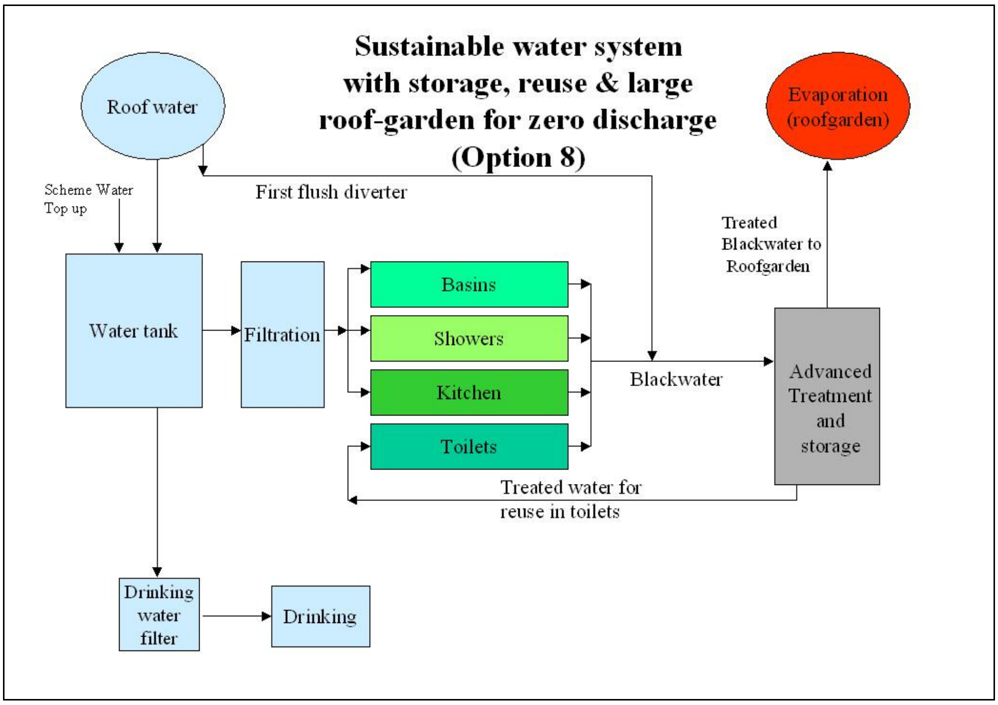

FIGURE 9A Process diagram for Option 8.

8. RESULTS

The water, wastewater and nutrient management strategies identified in Section 7 will provide a wide range of benefits over the life of the green building. The focus for this section is to provide details of the expected costs and benefits accruing to the owners and occupiers of the green building.

Financial benefits to the owners and occupiers of the green building include:
- operating cost reductions due to reduced demand for scheme water;
- reduced sewer usage charges from less water discharged due to water efficiency;
- productive reuse of effluent and nutrients in roofgarden rather than discharge direct to sewer;
- reduced energy costs due to less hot water being used.

Total water demand for the modelled options is presented in Figure 10.

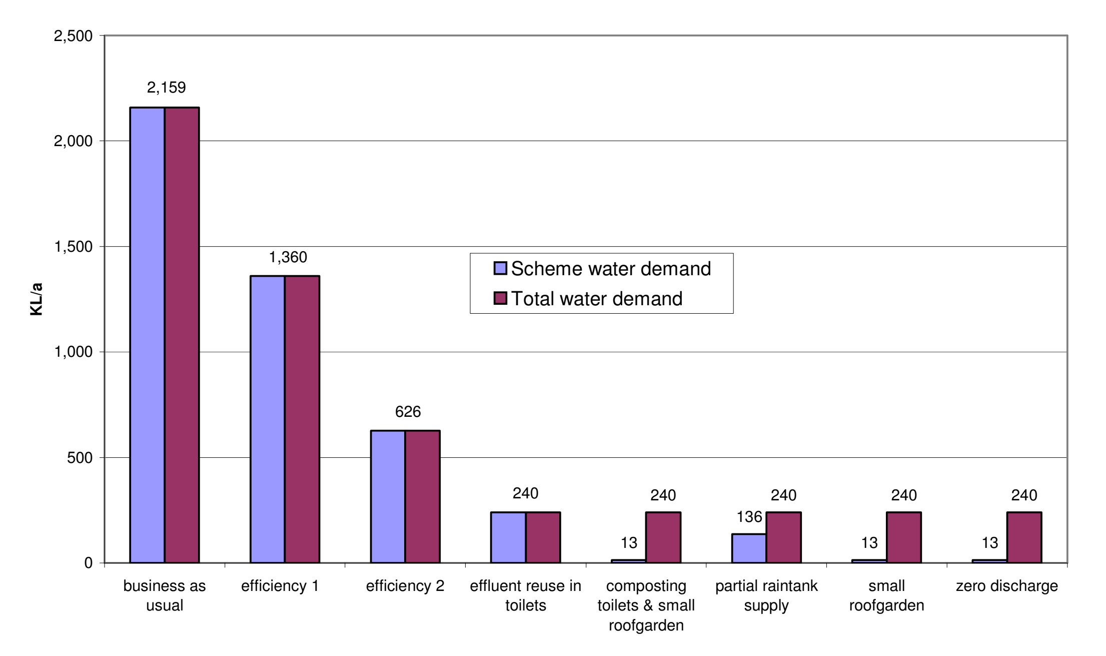

FIGURE 10 Total water demand (scheme and non-scheme) for modelled options.

With a project such as the Green Building there will be other benefits accruing to external stakeholders such as the water supply company, the environment and the community as a whole. These external benefits have not been costed and are presented in this report solely in point form. The Green Building project is also expected to result in strategic benefits that cannot be costed such as giving stimulus to the green building industry, encouraging others to incorporate green design elements in their buildings, providing a useful educational resource and contributing towards the overall sustainability of urban environments.

Benefits accruing to other stakeholders include:
- lower capital costs to water supply and sewage treatment company as less capacity is required and less upgrading of infrastructure;

- STP operating cost reductions due to reduced pumping and filtration associated with lower volume of water being supplied;
- capital cost reductions due to the ability to postpone or delay indefinitely system augmentation works due to reductions in water demand;
- capital cost reductions due to the ability to downsize, postpone or delay indefinitely system augmentation works as a consequence of reduced wastewater generation;
- reduced discharge of effluent to beaches and waterways;
- reduced greenhouse gas emissions due to reduced energy use for water and wastewater pumping and treatment.

8.1 Capital costs of options modelled

The capital costs of the various options include the costs of all fittings such as toilets, taps, showers, and treatment plants. Excluded from the costings were tanks, feedback mechanisms, and general installation costs. Estimated capital costs are presented in Figure 11 with a breakdown in Table 3.

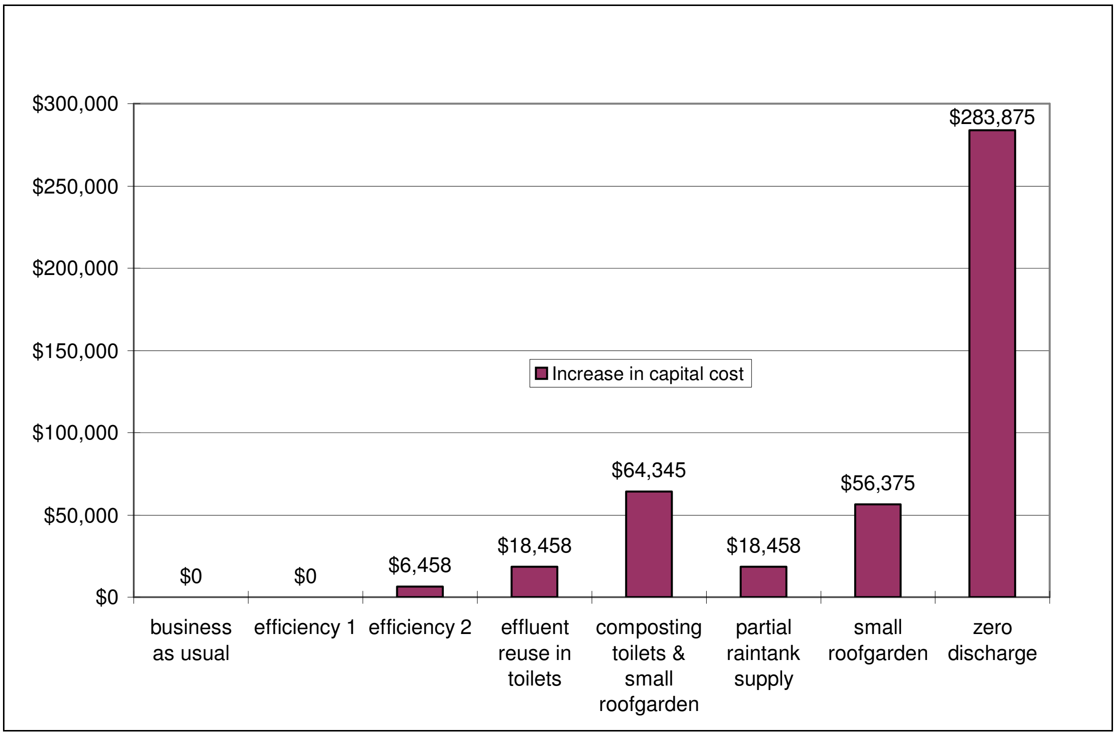

FIGURE 11 Capital cost increases in excess of the ‘business as usual’ option (Option 1).

	option 1	*option 2*	*option 3*	*option 4*	*option 5*	*option 6*	*Option 7*	*option 8*
Title	**business as usual**	**efficiency 1**	**efficiency 2**	**effluent reuse in toilets**	**composting toilets**	**partial raintank supply**	**Small roofgarden**	**zero discharge**
Major (additional) cost components								
Rooftop garden								
glass house component	$0	$0	$0	$0	$31,250	$0	$31,250	$218,750
garden component	$0	$0	$0	$0	$6,667	$0	$6,667	$46,667
Tanks and STP								
rainwater tank	$0	$0	$0	at cost	at cost	at cost	at cost	at cost
effluent tank	$0	$0	$0	at cost	at cost	at cost	at cost	at cost
treatment plant-capital cost	$0	$0	$0	$12,000	$0	$12,000	$12,000	$12,000
Fittings								
toilets and urinals	$0	$0	$1,400	$1,400	$21,370	$1,400	$1,400	$1,400
taps and showers	$0	$0	$5,058	$5,058	$5,058	$5,058	$5,058	$5,058
Estimated capital cost - above business as usual	**$0**	**$0**	**$6,458**	**$18,458**	**$64,345**	**$18,458**	**$56,375**	**$283,875**

TABLE 3 Capital cost increases in excess of the 'business as usual' option (Option 1) broken down into components.

Assumptions utilised in the capital costs are given in Table 4.

Item	**Capital cost assumptions**	**Cost**
Tanks	Listed as *'at cost'*. No costings performed for tanks due to uncertainty regarding location, size, materials and relative costs. Costing of tanks will have to be performed separately by the project cost estimators.	
Glasshouse	Price assumed for costing glasshouse Also assumed only 50% of glasshouse under glass	$1250/m^2
STP	Assumed no cost for locating STP – similar issues to tanks, can be located anywhere and costs will vary accordingly	
Fittings	Assumed price for retail availability in Australia – not costed for installation.	
Feedback mechanisms	Not costed	

TABLE 4 Capital cost assumptions.

8.2 Operating costs of the options modelled

The annual operating costs of the modelled options are presented in Table 5. The costs are based on how much it would cost to employ someone on a contract to service the relevant equipment. It might be possible to combine all of the service and maintenance roles into a single job or alternatively combine the roles and responsibilities with that of looking after the roofgarden and and/or building visitors.

	option 1	*option 2*	*option 3*	*option 4*	*option 5*	*option 6*	*option 7*	*option 8*
Title	**business as usual**	**efficiency 1**	**efficiency 2**	**effluent reuse in toilets**	**composting toilets**	**partial raintank supply**	**small roof-garden**	**zero discharge**
cost waterless urinals replacement cartridges	$39	$39	$39	$39	$39	$39	$39	$39
number required (replace every 4 months)	0	0	4	4	4	4	4	4
Rain tank treatment costs	$0	$0	$0	$200	$200	$200	$200	$200
STP operating costs (maintenance)	$0	$0	$0	$200	$0	$200	$200	$400
STP operating costs (energy/annum				$145	$0	$145	$145	$145
Composting toilet operating and maintenance cost	$0	$0	$0	$0	$2,000	$0	$0	$0
Rain tank system operating and maintenance cost	$0	$0	$0	$0	$750	$750	$750	$1,000
Total annual operating costs	**$0**	**$0**	**$468**	**$813**	**$3,218**	**$1,563**	**$1,563**	**$2,013**

TABLE 5 Annual operating costs of modelled options.

8.3 Water and sewer usage charges

There are costs associated with using water and sanitation services. In Melbourne this cost is approximately $1.40 kL. This figure is made up of a water usage charge and a sewer discharge charge. The combined costs of water use and sewer discharge for the various options modelled are presented in Figure 12.

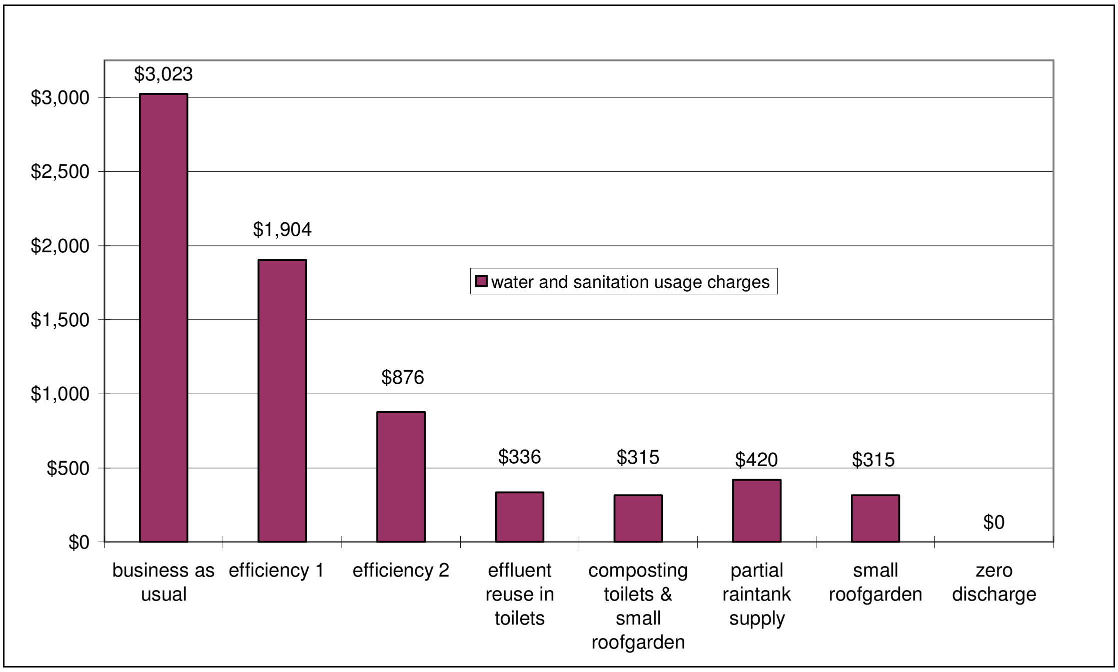

FIGURE 12 Water and sewerage usage charges.

8.4 Miscellaneous benefits for the options modelled

Miscellaneous financial benefits associated with the various options were estimated. These included benefits from sale of roofgarden produce, water and sewer usage charges avoided and tours of the Green Building. These benefits are shown in Figure 13.

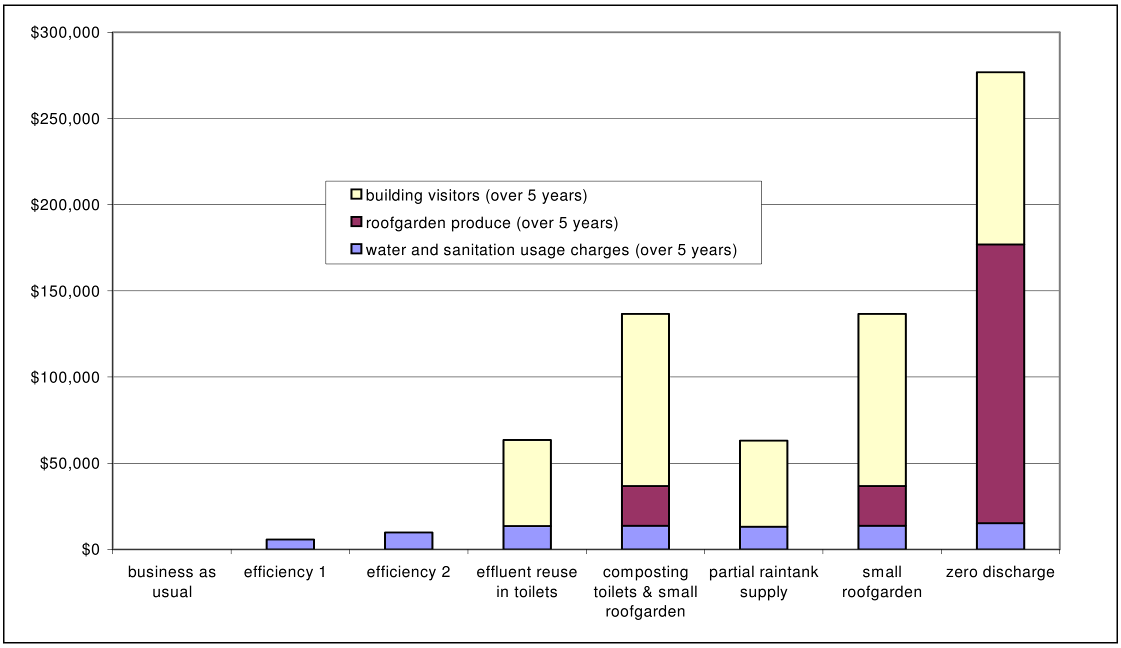

FIGURE 13 Breakdown of financial benefits from modelled options.

8.5 Cost benefit analysis

Results of the cost benefit analysis of the modelled options are presented in Figure 14. The breakdown between benefits from water and sanitation savings, building tours and produce from the roofgarden can be seen in the previous Figure 13.

Cost benefit analysis compared the cost of the options over five years incorporating capital cost greater than the business as usual case plus operating cost over the five years. This was compared with expected benefits in terms of sewer and water charges avoided plus prospective revenue gained from sale of roofgarden produce and tours of the building.

It seems reasonable that significant income could be generated from running tours. A model sustainable house in Sydney attracts an average of 33 people a week to tours with each person paying $15. This generates almost $25,000 in additional income per year and a larger scale green building with many innovative features as is proposed by ACF/Surrowee would be expected to easily match or exceed this amount.

Extremely conservative assumptions were used to estimate benefits from building tours. The 'lower' scenario (Table 6) was assumed for the options with some innovative features (Options 4 and 6). For the options that also had a small roofgarden (Options 5, 7) the 'small' scenario was assumed (Table 7). Option 8 was based on the 'large' roofgarden scenario (Table 7). No benefits from tours were attributed to the first three options, which could not be considered innovative enough to be of interest on their own.

	lower	low	medium	high
Number of visitors per week	50	100	200	400
Number of visitors per year	2,500	5,000	10,000	20,000
Average payment per visitor	$5	$5	$5	$8
Revenue from tours per year	$12,500	$25,000	$50,000	$160,000
Costs for tours per year (20%)	($2,500)	($5,000)	($10,000)	($32,000)
Net income from tours per year	$10,000	$20,000	$40,000	$128,000

TABLE 6 Assumptions used in the building tours section of the cost benefit analysis.

The assumptions used for estimating roofgarden produce are presented in Table 7. It is worth noting that the potential benefits from roofgarden produce are small in comparison with the potential benefits from tours.

	small	medium	large
Area of garden devoted to produce (m^2)	33	100	233
Number of produce items	2,860	8,667	20,193
Unit retail price of produce items	$2	$2	$2
Value of produce items	$5,720	$17,333	$40,387
Cost of management and inputs for produce production (20%)	($1,144)	($3,467)	($8,077)
Net income from produce items per year	$4,576	$13,867	$32,309

TABLE 7 Assumptions used roofgarden produce section of the cost benefit analysis.

The results of modelling and the cost benefit analysis indicate that many of the options would have net financial benefits if the potential benefits from running tours and also from sale of produce (e.g. flowers) from the roofgarden were factored in (Figure 14). All of the recommended options modelled did not show net financial benefits when considered purely on the basis of water and sewer charges avoided.

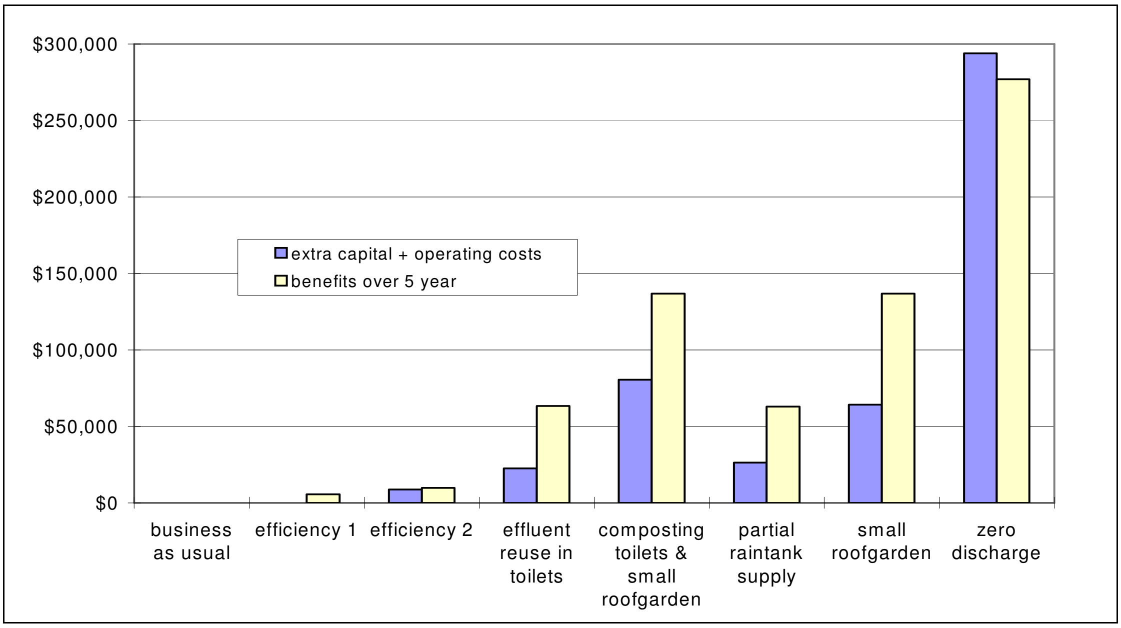

FIGURE 14 Cost benefit analysis of the modelled options over 5 years.

9. POSSIBLE VARIATIONS ON MODELLED OPTIONS

The choice of options modelled was designed to provide a representation of the key major alternatives available to the design team rather than an exhaustive survey of all possible options. There are some significant sub-option alternatives that should also be considered.

9.1 Toilet sub-options

One of these options is the potential to fit a mixture of different types of toilets and Table 8 provides an indication of the relative merits of some of the most common alternatives. Apart from men's urinals, there are 4 main types of toilets (flush, micro-flush, dry composting and urine separation), all of which have various advantages and disadvantages. A brief outline of these alternatives is provided.

Type	Cost per unit	Water conservation (litres/flush)	Country of manufacture & availability	Advantages	Diadvantages	Other comments
6/3 dual flush	$250	6 full 3 half - average 4.5L/flush	Australia	Easy availability familiar	Uses much more water than composting or micro-flush toilets	Not compatible with dry composting systems
5/2 dual flush	$250	5 full 2 half - average 3.5L/flush	Australia	Easy availability familiar	Uses much more water than composting or micro-flush toilets	Simply a modified 6/3, with improved plumbing system
Micro flush	approx. $800 per unit	0.5 - 1 litre	Europe Japan	Easier for people to accept micro flush than zero flush	Generates wastewater and can flood/slow down composting systems	Can be used with composting system however generates much more leachate
Composting	approx. $800 per unit	0 litres (no flush)	Australia	Water saving and produces compost for use on gardens/ agriculture. Much simpler technology than effluent reuse (less to go wrong)	Requires some maintenance - eg emptying compost when full and ensuring composting is working properly	
Urine separating	Approx $700 per unit	Suits either dry composting type or flush	Sweden – WM Ekologen	Diverts urine away from composter or sewer	Requires some behavioural change	Urine diverter placed in front of toilet bowl
Male urinals	$545	Approx. 1 litre	Australia	More efficient than flush toilets	Uses water unnecessarily	
Male waterless urinals	$895	0 litres (no flush)	New Zealand and Australia	Extremely water efficient and compatible with urine separation	needs separate plumbing for urine system and emptying of tanks when full	

TABLE 8 Toilet options (disadvantages and advantages).

9.2 Demand, rainwater tank size and supply security

Another sub-option consideration is the potential to fit a wide variety of different kinds/sizes of rainwater tanks. All these variations will have implications for the cost of the overall project and also for the supply security and degree of overtopping. An indication of the implications of the different tank sizes for the water demand levels modelled for the options are presented in Figure 15 and Table 10.

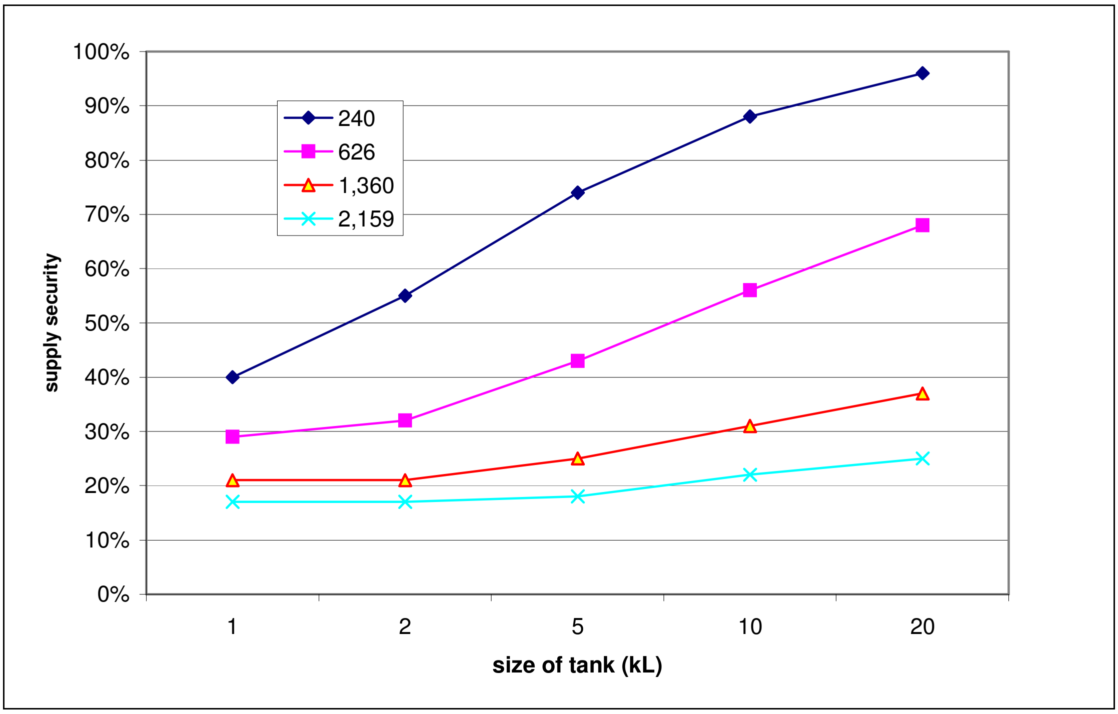

FIGURE 15 Supply security for different tank sizes at different levels of annual demand (kL/a).

Implications of the assumptions used for supply of rainwater assuming a roof area of 1080m^2 can be seen in Table 9.

Year	Annual rainfall (mm/a)	Annual water available (kL/a)
Wettest (1992)	829	895
Average (over 140 years)	660	713
Driest (1967)	332	359

TABLE 9 Total rainwater available

From these figures it is apparent that historically there has been a wide variation in annual rainfall for Melbourne. If each year was considered in isolation, supply security could only be 100% guaranteed in the driest year if total annual demand did not rise above 359 kL/a. In practice however (assuming sufficient storage capacity) there is the potential to carry over water savings from one year to the next. As such the average rainwater availability of 713 kL/a is a much more appropriate guide representing the absolute upper boundary of peak annual water demand for the Green Building.

It should also be noted that if the worst case scenario did occur and the tank ran out of water, then the rain water tank could always be topped up with scheme water. Alternatively it would also be technically possible to source additional rainwater from an adjoining building.

It was not possible to run the entire 45 years of daily data in the daily model to test supply security so it was modelled using the 'worst case scenario' time series, comprising the three wettest and three driest years of data. This was the preferred method to ensure a conservative result i.e. the supply securities modelled here would be the absolute lowest possible. The demand scenarios in Table 10 correspond with the options modelled.

	Annual demand (kL/a)			
Water tank size (kL)	**195 (Options 4,5,6,7)**	**509 (Option 3)**	**1,102 (Option 2)**	**1,751 (Option 1)**
1	40%	29%	21%	17%
2	55%	32%	21%	17%
5	74%	43%	25%	18%
10	88%	56%	31%	22%
20	96%	68%	37%	25%

TABLE 10 Supply security for different tank sizes and different levels of demand.

The results indicate that it is possible to reduce the size of the water tank at various demand levels, and still achieve good scheme water saving. All of the recommended options 4,5,6 & 7 represent an estimated annual demand of 240 kL/a.

9.3 Roofgarden size and potential evaporation

The size of the roofgarden would be expected to significantly effect the quantity of recycled effluent capable of being evaporated. Average volumes of effluent that could be evaporated for a range of roofgarden sizes were estimated and are presented in Table 10A. This table assumes an average cropping factor of 0.75 and an average daily pan evaporation of 3.16mm, which were the assumptions used in the evaporation modelling. It should be technically possible to minimise or maximise evaporation dependent on the design and day to day management of the roofgarden.

Total area of roofgarden (m2)	**Area of roofgarden dedicated to plants (m2)**	**Average potential evaporation per day (L/day)**	**Average potential evaporation per annum (kL/annum)**
25	8	20	7
50	17	39	14
100	33	79	29
200	67	158	58
300	100	237	86

TABLE 10A Estimated evaporation potential of different sizes of roofgarden. (Assumes 2/3 of roofgarden is utilised for cropping at any time, a cropping factor of 0.75 and an average daily pan evaporation of 3.16mm)

10. CONCLUSIONS AND RECOMMENDATIONS

The modelling of water demand for the ACF/Surrowee Green Building (assuming a commercial only occupancy), indicates that best practice water efficiency measures, including water efficient showerheads, infrared taps, waterless men's urinals and water efficient toilets can reduce the demand on scheme water and discharge to the sewerage system by approximately 70%. We consider this an absolute minimum requirement in terms of working towards the projects environmental objectives. These measures on their own are expected to provide significant net financial benefits as a result of avoided water and sewage usage charges and reduced hot water energy costs.

In addition to best-practice water efficiency, it is recommended that rainwater tank supply be used to reduce scheme water demand and stormwater runoff from the site. Modelling of rainwater availability and supply security has indicated that a small rainwater tank of 5 kL (5,000 L) would be sufficient to meet demand requirements of 240 kL/a 74% of the time for the worst case scenario years modelled. This is a substantial saving from such a small tank. At this level of demand 88% security is met by a tank of 10 kL and 96% from a tank of 20 kL.

In addition to 'best practice' water efficiency measures and rainwater tank supplies, it is also recommended that the design team implement either;

(a) composting toilets as a means of reducing total water demand and effluent production whilst also managing nutrients for recycling or;

(b) treated effluent reuse for toilet flushing as a means of reducing demand for water and effluent volumes.

Results from our end-use modelling indicate that either of these options will further reduce water demand from the second level water efficiency (Option 3) by 62 % to 240 kL/a (Options 4,5,6,7,8). That represents an 89% reduction in annual water demand compared with the business as usual option (Option 1).

Dry composting urine separating toilets are recommended as the best method of effectively dealing with nutrients, minimising energy demand for sanitation and treatment and also eliminating altogether the blackwater stream for simple and effective pathogen control. Dry toilets require that the composting chambers be sited directly below the toilet pedestals.

The effluent reuse options (Options 4, 6 and 7) are good in terms of reducing demand to the same level as the composting toilets option (Option 5), however this occurs at the expense of requiring more thorough and expensive treatment including disinfection to ensure reuse water meets health standards. A benefit of the reuse options is more flexibility in terms of siting of toilets.

It is also recommended that the design team consider installation of a small roofgarden. This would provide a number of benefits in terms of productive reuse of greywater effluent, evaporation of excess wastewater to reduce or eliminate discharges, and importantly with the added potential to provide a pleasant and useful recreation or meeting space in the building. It was also considered that such a space would increase the overall attractiveness of the building and improve considerably the benefits to be gained from running tours of the Green Building should these be desired. Based on our cost benefit analysis (including conservative assumptions regarding financial benefits from tours) it appears that the inclusion of a small roofgarden in the design of the Green Building would provide net financial benefits after a period of less than 5 years. An additional roofgarden benefit considered was the potential to generate revenue from sale of produce such as flowers grown on-site.

Because the dry composting toilet option effectively eliminates blackwater, appropriate treatment for greywater would be microfiltration (with optional UV disinfection) prior to supply to the small roofgarden. Depending on the size of the roofgarden treated greywater may need to be mixed with rainwater for watering plants. No reuse is required for toilet flushing. Even with the small roofgarden, this option is essentially zero effluent discharge, although depending on the available evaporation area, some discharge of rainwater to sewer or stormwater may be required.

If effluent reuse for toilet flushing were chosen then blackwater would require tertiary level treatment and disinfection to meet health department guidelines prior to use on the roofgarden. Additionally zero discharge of effluent and full nutrient recycling would only be possible with a large roofgarden able to meet the higher evaporation rates.

From the cost benefit analysis a prioritised list of the options modelled was developed. Cost benefit analysis did not consider beneficial nutrient management for nutrient recycling so a matrix was developed to take this into consideration. These options are not intended to be exhaustive and it is recognised that for a variety of reasons it may be necessary to combine or alter various aspects of the different options. The prioritised recommended options are presented in Table 11.

Option number	Option name	Water Efficient?	Nutrient recycling?	Financially viable?	Recommended priority
5	3 + composting toilets & small roofgarden	y	y	y	**1**
7	3 + small roofgarden	y		y	**2**
6	3 + reuse and partial rainwater tank supply	y		y	**3**
4	3 + effluent reuse in toilets	y		y	**4**
8	3 + large roofgarden for zero discharge	y		n	**5**
3	Second level water efficiency			y	Absolute minimum requirement
2	First level water efficiency			y	Not recommended
1	Business as usual			y	Not recommended

TABLE 11 Options modelled, scheme water demand and recommended priority.

11. REFERENCES

Del Porto, D. (1999). The Composting Toilet System Book. Concord, Massachusetts, The Centre for Ecological Pollution Prevention (CEPP).

DLG, DUAP, DLWC (1998). Environment & Health Protection Guidelines - On site Sewage Management for Single Households. Sydney, Department of Local Government.

DPIE. (1988). Low Cost Sewerage Options Study. Canberra, Australian Government Publishing Service.

Hellstrom, D. (1998). Nutrient Management in Sewerage Systems: Investigations of Components and Exergy Analysis. Department of Environmental Engineering, Division of Sanitary Engineering. Lulea, Lulea University of Technology**:** 145.

Hollo, N. (1995). Warm House Cool House, Sydney, Choice Books, Griffin Press.

Pearson, D, (1998). The New Natural House Book, Sydney, Harper Collins Publishers.

Schmitz-Gunther, T., Ed. (1998). Living Spaces - Sustainable Building and Design. Slovenia, Konemann.

Winblad, U., Ed. (1998). Ecological Sanitation. Stockholm, Swedish International Development Cooperation Agency.

12. APPENDICES

12.1 Appendix 1

Appendix 1 is a list of assumptions that were used in the water end-use model.

Melbourne ACF Green Building Modelling Assumptions					
modelled option -					
number of people in development	business as usual	efficiency 1	efficiency 2	reuse	composting toilets
offices only (non residential)	250	250	250	250	250
assumed average occupancy ratio for res component	2.3	2.3	2.3	2.3	2.3
number of residential units	0	0	0	0	0
residential plus office					
residential component	0	0	0	0	0
office component	200	200	200	200	200
total	200	200	200	200	200
percentage of workers who work on weekend	0.05	0.05	0.05	0.05	0.05
weekend workers	10	10	10	10	10
% of men to women	0.5	0.5	0.5	0.5	0.5
male non-res flush ratio -% of full to half flushes (1:4)	0.25	0.25	0.25	0.25	0.25
site area (m2)	1350	1350	1350	1350	1350
percentage of site that is roof	0.8	0.8	0.8	0.8	0.8
roof area (m2)	1080	1080	1080	1080	1080
taps - Bathroom - non res					
flow rate (litres/minute)	12	6	2.5	2.5	2.5
seconds wash duration	15	15	10	10	10
washes per day (normal day)	3	3	3	3	3
taps - Kitchen - non res					
flow rate (litres/minute)	12	6	2.5	2.5	2.5
seconds wash duration	15	15	15	15	15
washes per day (normal day)	1	1	1	1	1
toilets					
average flush volume (litres)	4	4	0	4	0
urinals average flush volume (litres)	6	2.8	0	0	0
non res number of flushes/day	3	3	3	3	3
showers					
flow volume (litres/minute)	12	7.5	5	5	5
proportion of people showering daily no rain (non res)	0.1	0.1	0.1	0.1	0.1
proportion of people showering daily when it rains (non res)	0.02	0.02	0.02	0.02	0.02
shower duration non residential (mins)	7	7	5	5	5
days per year					
working days	260	260	260	260	260
all days	365	365	365	365	365
party once a month on a Friday night	party	party	party	party	party
if a party assume:					
people	100	100	100	100	100
toilet uses	3	3	3	3	3
washing (bathroom)	3	3	3	3	3
washing (kitchen)	1	1	1	1	1
party (not incl toilets) creates additional demand of (L)	4500	1350	292	292	292
Holidays					
it was assumed that there were 12 days of public holidays	holidays	holidays	holidays	holidays	holidays
non res cleaning demand (toilets and offices)					
number of toilets (pans)	14	14	14	14	14
flushes per cleaning	1	1	1	1	1
floor mopping and general cleaning (L)	30	30	30	30	30
daily average water demand non res cleaning (L)	44	44	44	44	44
reuse?	no	no	no	reuse	no