Composting Toilet Demonstration

Feasibility Study

VOLUME 1: Report

Smart Water Fund

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GHD in association with Demaine Partnership, Bensons Property Group and Environment Equipment

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Executive Summary

Scope, Objectives and Outcome of this Feasibility Study

Waterless (or dry) composting toilets have the potential to reduce water use and divert pollutant loads from the sewerage system direct to agriculture.

This feasibility study has investigated:

- technical feasibility;
- costs;
- probable customer acceptance;
- regulatory constraints and
- environmental advantages

associated with the composting toilets with urine separation as an alternative to water-flush toilets. Emphasis has been on application in medium to high population density apartments in the urban Melbourne setting.

Whilst application of dry composting toilets is widespread in low density developments remote from sewerage schemes and whilst waterless urinals are being introduced in a variety of settings, the combination of both technologies in a high density urban environment has only been tried on a limited scale overseas. There is a need for demonstration of the technology in the medium to high population density urban setting because few decision makers with responsibility for sewerage planning have been exposed to composting toilets, composting toilets are rarely if ever considered in planning and there is limited information on rigorous assessment of their advantages and disadvantages.

The Funding Agreement between GHD and the Smart Water Fund for this feasibility study required reporting on:

- relevant government policy frameworks;
- key legal and regulatory risk issues associated with the project and the attitudes regulators may have in relation to the project;
- key technical risk issues associated with the project and how they can be managed;
- responses of potential end-owners of the properties equipped with composting toilets;
- regulatory constraints and contradictions and next steps required to progress the project.

In summary, the study has confirmed that there is an environmental and economic justification for further investigation, including a demonstration project.

Potential Advantages of Dry Composting Toilets with Urine Separation over Water-Flush Toilets

The potential advantages of widespread adoption of dry composting toilets with urine separation are:

- up to about 19% of an average household water usage (up to around 18 kL/c.yr saved out of 96 kL/c.yr currently used by the average Melbourne household) and up to about 28% of domestic sewage discharge would be avoided by eliminating toilet flushing. For the 12 apartments envisaged for the trial this translates to savings of up to 490 kL/yr;

- over 80% of the nutrients, nitrogen, phosphorus and potassium, around 55% of the total salts and 25% of the BOD discharged by a household to sewer can be recovered in a transportable, stabilised and reusable form with low pathogen content;
- even if adoption of composting toilets is limited, the potential 19% reduction in household water usage, 28% reduction in sewage volume, 80% reduction in nutrient discharge, 25% reduction in BOD and 55% reduction in total salts discharged by households to sewer could have a significant benefit in extending the life of water supply, wastewater collection and treatment systems as well as reducing loads discharge to receiving waters, reducing the salinity of recycled water and reducing the mass of biosolids generated at the sewage treatment plant;
- other technologies for reducing water use such as dual and low flush toilets, ultra-low water flush (vacuum) toilets, use of recycled grey water for toilet flushing or use of roof water for toilet flushing do not have the advantage of reducing pollutant, salt and nutrient loads to sewer. In the case of recycling of grey water for toilet flushing or low flush volumes, the concentrations of pollutants in wastewater, including concentrations of salts, are in fact increased which, in the case of salts, may impact on reuse potential;
- there is no odour in the toilet room;
- overall health risks to householders and sanitation workers are assessed as being no higher than with conventional sewerage;

Separation of urine is a key to improving composting and providing a liquid fertiliser with low health risk and urine separation on its own is receiving attention world-wide as a means of saving flushing water and recovering nutrients. Around 60% of urine can be separated using modern designs of compost toilet pedestals and these designs require minimal change to personal habits. In particular, designs are being developed to allow men to stand when urinating. Habit change to close the lid of a composting toilet after use is important for odour and ventilation control.

Based on review of the international literature, independent assessment of claims made by composting toilet suppliers and data on composting toilets and inspection of a number of composting toilets in Australia, these potential advantages have been confirmed. In addition, the feasibility study has shown that dry composting toilets with urine separation and a road-based transport system for compost and urine may have the potential to reduce energy use for wastewater transport and treatment, or at least not use significantly more energy, provided energy saved in fertiliser manufacture is taken into account and energy use for ventilation and heating associated with the composting toilet can be minimised.

Feasibility of a 12 Apartment Demonstration Site

Whilst this feasibility study concludes that composting toilets with urine separation potentially have advantages over conventional water-flush toilets, no one existing installation demonstrates all of these advantages for urban application, since most are in isolated locations in low population density settings and none have been subjected to rigorous monitoring. Therefore, a carefully designed and monitored demonstration project is considered essential as the next step.

Preliminary design and costing of a demonstration project on 12 two-storey apartments in Flemington has been undertaken in association with the developers, architects and a composting toilet equipment provider.

The developer, with GHD's assistance, has undertaken a customer survey, to which there were some 55 respondents, indicating that:

- 55% would consider purchasing an apartment with a composting toilet and 28% may consider purchasing such an apartment, a total of 83%;
- 76% would consider paying $5 000 more for a water-efficient apartment and a further 18 % may consider paying such an extra sum for a water-efficient apartment, a total of 94%; and
- respondents under 40 indicated a generally higher level of interest than older respondents but there was no significant difference in interest between genders.

Whilst a decision on whether to go ahead with this demonstration project will depend on further market analysis, design development and availability of funding assistance, and whilst potential purchasers may well change their minds when it comes to actually signing a contract, there is an encouraging indication that it would be possible to sell compost toilet-equipped apartments and that there is a demand to be satisfied.

The type of installation proposed for the demonstration will involve two modern toilet pedestals, one on each floor of each of the 12 apartments. The toilet pedestals are arranged in a way that most of the urine will be diverted to a holding tank shared by all 12 apartments. Solids will fall vertically down shafts to one multi-bin rotary composter in a sub-floor space for each of the 12 apartments. This rotary composter design has the advantage that filled compost bins are left to mature for some months after they become full which provides for a high degree of solids stabilisation, inactivation of pathogens and reduction in mass via an aerobic composting process before a person has to remove a finished bin from the composter. Leachate (liquid, including urine, that is not collected, but drains through the composting solids) will drain to a separate storage tank. Removal of a total estimated mass generated of around 11 tonnes/yr of urine and leachate and around 0.7 tonnes/yr of compost, will occur every three to six months by contract collection. Apartment owners will not have to handle the recovered materials although either the body corporate (or possibly and preferably the sewerage authority) will have to administer the removal contract.

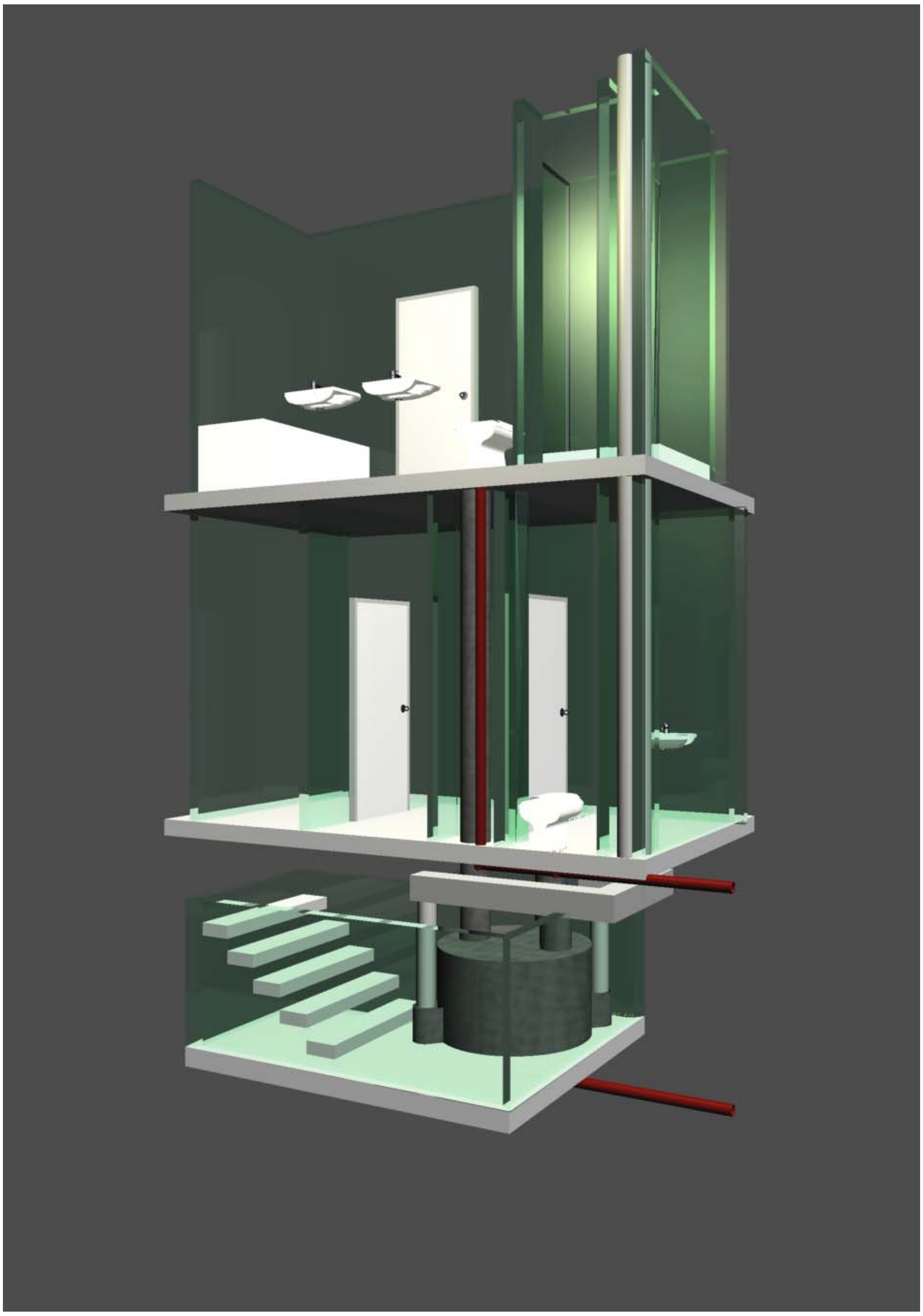
It is concluded that such a trial will involve additional capital costs (compared to standard water-flush toilets) of around $9 500 per apartment, or a total of $114 000 for the 12 apartments. Of this, some $6 500 per apartment or $78 000 for equipment has been specifically included for monitoring, data collection and flexibility in design and operation and would mostly not be required for normal commercial installations in the future. Thus the likely premium to pay for a two pedestal composting toilets in a two storey apartment is around $3 000 compared to standard water-flush toilets.

Consistent with other programs concerning lessening the ecological impact of housing (such as solar hot water installation), it would be appropriate to expect some contribution by Government and other interested parties to this additional cost per apartment in order to support the developer in installing the trial composting toilets. In addition, some reductions in headworks charges for the development would be justifiable. Thus, funding will be sought from various potential sources to offset the additional cost.

Operating costs for maintenance of the composting toilets, and for cartage and disposal of the compost, urine and leachate could be expected to be higher than standard sewerage rates given the small quantities of compost and liquid residues involved with the trial and the need for special transport arrangements. However, calculations indicate that overall operating costs will be similar provided that some reduction in sewerage rates is agreed with the water authority concerned. Significant expenditure on analysis and monitoring including monitoring of water use and grey water quality for the apartment development is proposed and would be part of the funding assistance sought rather than a cost to apartment owners.

Potential cartage contractors have indicated that they do not foresee any difficulties in collection and cartage of the material using a small truck with custom-built tray and containment.

The following figure gives an impression of the proposed arrangement of composting toilets in the apartments.



Proposed arrangement of composting toilets in one of the apartments

The compost chamber would be below the ground floor slab. One toilet pedestal would be located on each floor above the composting chamber. Plumbing to collect urine from each pedestal and leachate from the compost chamber is shown. Note that the access steps for maintenance and removal contractors to the sub-floor space would be shared between two apartments (the adjacent apartment and its composter which would be to the right are not shown).

Agricultural Reuse Trial for Residues

Just as a demonstration is necessary that composting toilets with urine separation are a real and acceptable option for apartments, a demonstration that the nutrient-rich residues can be safely and advantageously used in agriculture is necessary in order to provide a sound basis for decision-making on large scale application of this alternative sanitation approach.

A key benefit of composting toilets with urine separation is that the majority of nutrients in normal domestic sewage can be recovered in a form suitable for replacing manufactured fertiliser. This contrasts with conventional sewage systems where the majority of nutrients are either discharged to receiving waters or in the case of nitrogen, driven off into the atmosphere using electrical energy and, in the case of phosphorus, incorporated into biosolids at relatively low concentrations and low availability to crops.

It is proposed that the 12 tonnes of residue produced annually will be used as fertiliser in agricultural trials, probably on a site within Melbourne Water's Western Treatment Plant under an EPA Research, Development & Demonstration Approval. Melbourne Water has given agreement in principal to provide land. During the trial, alternative receiving sites would be identified for long term beneficial reuse of the residues.

The initial concept for this demonstration project envisaged an extensive and therefore expensive trial on both vegetable and grain crops with comprehensive investigation of crops, soil, groundwater and health issues. Advice from experts on the feasibility study Reference Panel including advice from Agriculture Victoria, led to the conclusion that a less ambitious agricultural trial on dry land grain crops or pasture would be appropriate. Part of the reason for this conclusion was that, even if safety of use on vegetable crops can be shown, farmers are unlikely, for the foreseeable future, to use the human excreta products on anything other than grains or pasture.

The proposed agricultural trial would be designed by Agriculture Victoria, with input from health specialists. Two hectares of land would be sufficient and it is estimated that set up and operation of the trial for two years with a final report would cost $300 000. The more comprehensive agricultural trial originally envisaged would have cost at around $700 000.

Key aspects of the agricultural trial would include:

- baseline monitoring of soils and groundwater and reporting at the end of the 2-year trial period on any changes in soil or groundwater due to application and possible long term impacts;
- investigation of total and available nutrients in the urine, leachate and compost and plant response;
- regular monitoring of bacterial levels, possibly indicators of faecal contamination such as cuprostanol and spiking trials using attenuated pathogen strains to obtain data on the likely fate of pathogens;
- possible investigation of the fate of endocrine disrupting chemicals;
- assessment of odour levels;
- assessment of storage, handling application approaches for compost, urine and leachate;
- a survey of potential users of the materials;

- field days to demonstrate the application methods and explain the risks, control methods and benefits in order to establish long term users;
- a report on the various aspects of the trial.

Sufficient information will be gathered to quantify health risks, operational aspects and benefits of reuse.

Duration and Estimated Cost of the Overall Demonstration Project

The proposed timing for the overall demonstration project and the estimated cost for establishment, operation and reporting over this period are as follows:

Approximate Timing	Stage	Expenditure
2004 to mid or late 2005	Design, approvals, marketing and construction of the apartments.	$265 000
Mid to late 2005	Establish contracts for maintenance and transport.	$30 000
Mid 2005 to mid 2006	Establishment of the agricultural reuse area and planning for the reuse trial.	$100 000
Mid 2005 to early 2006	Occupation of apartments.	–
Late 2005 to mid 2008	Operation, monitoring and maintenance at apartments	$85 000
Mid 2006 to late 2008	Execution of agricultural reuse trial.	$200 000
Late 2008	Report on demonstration project outcomes.	$50 000
2004 – 2008	**Demonstration Project**	**$730 000**

Overall, it is suggested that other parties, including, potentially, the Smart Water Fund should fund the following:

- all costs associated with transport and the proposed agricultural trial,
- all monitoring and project management and reporting costs.
- 50% of the design and supervision costs of the composting toilet installation.
- 75% of the difference between the cost of composting toilets (including associated heating and ventilation) and conventional sewerage,
- 100% of the cost of monitoring and automatic control equipment since it is provided for the purposes of investigation.

This would leave the developer (and ultimately the owner) to meet around 50% of the difference between composting toilets and conventional sanitation. None of the costs associated with extra monitoring, controls, trial facilities, maintenance and transport set up and operation would be borne by the developer. In all it is suggested that funding should be split between the developer (and in future the apartment purchasers) at no more than $230 000 (less any subsidy) and funding of research and development to benefit the wider community of $500 000 plus any subsidy agreed to make the apartments more attractive.

Policy and Regulations Relevant to the Demonstration Project and Barriers to Overcome

Composting toilets and waterless urinals have been installed in a relatively large number of public amenities, private houses and institutional buildings in Australia and there is an Australian Standard covering their design. Thus there are no particular policy or regulatory barriers to installation of composting toilets. The proposed apartment site is in the area of City West Water and negotiation on headworks charges and sewerage rates will be necessary. No particular barriers have been identified, and several councils and water authorities in Victoria have now approved or are considering applications for composting toilets within sewered areas.

Planning and building approval will be required and compliance with the Australian Standard should be sufficient to gain approval.

Composting toilets are generally associated with on-site disposal of waste, and the approval of on-site disposal of residues is the most challenging area. For this demonstration project, the reuse site will be distant from the apartments and will require EPA approval. It is anticipated that this approval will be obtained in the form of a Research, Development & Demonstration Approval.

The transport of the residue materials will not require special approvals. The status of urine, leachate and compost in terms of its waste classification and reuse in Victoria is not entirely clear. None of the residues fall under the Prescribed Waste Regulations and therefore transport can be by any means. General provisions of the Health and Environment Protection Acts will apply and it is likely that works approval would be required for any storage depot, particularly if further processing is involved.

The residues will probably be subjected to requirements for biosolids for which the EPA draft guidelines were released in November 2002. These guidelines are still in a draft stage and whilst they cover composted sewage sludge they do not cover the residues from composting toilets. Therefore there may be some scope for a subset of guidelines for compost and urine. This will need investigation during the demonstration program. Nevertheless, the biosolids guidelines do provide a framework for beneficial use of the residues.

The State Environment Protection Policy (Waters of Victoria) requires that premises be connected to sewer when they are located within a sewered area unless all wastes can be contained on site. This provision did not contemplate a composting toilet approach with off-site disposal of residues. However, such disposal regularly occurs with septage and with portable toilet facilities so no particular barrier is foreseen, other than clarification.

In summary, whilst some current policy and regulation did not anticipate large-scale transport of compost and urine to agricultural land, there are no particular barriers foreseen for establishment of the demonstration project. However, widespread application of the technology has significant implications and it is certain that new policy, regulation and guidelines will be and will need to be established before widespread use of composting toilets and widespread application of residues to agricultural land could be established.

The project has not looked at the implications of food-standards regulations on use of crops fertilised with residues. This would need review during the demonstration project.

Attitude of Regulators

Representatives of regulators and approvals bodies consulted (EPA, Human Services, Moonee Valley Council, City West Water) have indicated support for the demonstration project and it is reasonable to conclude that approvals bodies and regulators are interested in and will support for the demonstration project subject to it complying with statutory requirements.

Financial and Economic Evaluation of Large-Scale Application of Dry Composting Toilets and Residue Reuse

Financial evaluation and economic evaluations of two larger scale applications of dry composting toilets with urine separation and a grey water sewerage system have been undertaken, to a small fringe area or isolated town and to a new high density urban subdivision. These evaluations show that dry composting toilets and grey water sewerage, whilst somewhat more costly to the household to install (of the order of $2 500 to perhaps $3 000 depending on the configuration, additional building works and ventilation and heating systems), can provide sanitation at a similar overall cost to current conventional sewerage. It is likely that capital cost disadvantage would decrease with mass production of composting units and changed building design.

Several scenarios have been investigated for each type of development and conclusions drawn from these scenarios are:

- in the case where a sewerage system requires a significant capital upgrade to cater for a new subdivision where conventional sewerage is proposed, composting toilets with grey water sewerage offer a potentially less costly option, around $1 200 or 5.5% less per household in overall capital cost of the system (the house installation part of the overall capital cost would still be more costly than water-flush toilets) than conventional sewerage, the all-up cost per household of which is estimated as around $21 800;
- a similar conclusion holds in outlying areas distant from a sewer and treatment plant of adequate capacity such as many backlog areas where composting toilets with grey water sewerage have a clear financial advantage over conventional sewerage;
- where no upgrade of the sewerage system is required then composting toilets are will be about 8% more costly overall (by about $1 500/household over conventional sewerage which is estimated as $19 000/household) but are considered a more environmentally beneficial approach to sanitation;
- annual overall operating costs for a composting toilet/grey water sewerage system are likely to be of the order of $90 or 55% more per household than for conventional sewerage in a large urban subdivision but possibly $100 or 45% less than conventional sewerage for a backlog area or outlying town;
- the relative cost of energy does not have a significant impact on the relative cost advantages of conventional sewerage and composting toilets with grey water sewerage because energy costs are not a major factor in either system;
- increasing water costs in future could make composting toilets with grey water sewerage a less costly option than conventional sewerage.

The overall conclusion from the financial and economic evaluations undertaken is that composting toilets with a modified grey water sewerage system offers a potentially competitive option to conventional sewerage although, as for some other technologies that reduce environmental impact, capital cost is likely to be higher overall than for current approaches (but not in all cases).

Handling of Grey Water

This feasibility study has been based on providing a modified conventional sewerage system for grey water since, at high population density as proposed for this demonstration project, grey water cannot be sustainably used on site or on nearby parkland, particularly in winter. For a small low density town or low density suburb, dry composting toilets with urine separation and on-site grey water treatment is likely to be consistently less costly than conventional sewerage but sustainability will depend on population density. If density is more than around 20 persons per hectare then a grey water sewerage scheme will be essential in order to avoid significant long-term ground or surface water pollution by nutrients and possibly by salts. At population densities under around 20 persons/ha then sustainable reuse of grey water within the urban area may be possible but, without winter storage, it would be unwise to adopt such a scheme without careful assessment of long-term impacts.

Water Saving Potential of Dry Composting Toilets

Dry composting toilets do not use any water, therefore about 19% of an average household water usage (around 18 kL/c.yr saved out of 96 kL/c.yr currently used by the average Melbourne household) and 28% of domestic sewage discharge would be avoided by eliminating toilet flushing.

It is estimated that the long term vision of 20% adoption of composting toilets could lower overall urban water consumption in Melbourne by around 2.5% based on overall average water consumption for Melbourne of about 150 kL/c.yr (which includes non-domestic use not accounted for in the average household use of 96 L/c.yr above). For the 12 apartment trial this translates to an annual saving of 490 kL. .

The potential of composting toilets to reduce sewage flow and pollutant loads is quite significant.

For example, if around 20% of all houses and apartments were to adopt composting toilets in future, future wastewater flow from households in Melbourne could be reduced by around 5%. The impact on overall wastewater flow would be less, say around a 3% reduction because of non-household wastewater contributions.

The reduction in biosolids generation at sewage treatment plants and the avoidance of extension of treatment capacity would be more significant than water saving since composting toilets divert between 50% and over 80% of the sewage load. Thus a 20% adoption of composting toilets could potentially reduce pollutant loads by at least 5% and up to between 10% and 16% depending on the pollutant and the extent of non-domestic load in the treatment plant catchment. Residual sewage would be of lower salinity, which is an important advantage of composting toilets over grey water recycling for toilet flushing.

Energy Use for Composting Toilets Compared to Conventional Sewerage

The study has shown that conventional sewerage (which is not a high energy user compared to overall community energy use) may be more energy-efficient than dry composting toilet installations installed with mains-powered ventilation fans (which is the current practice in most installations).

Energy use is an important aspect and any system that uses more energy than a current system should be assessed in detail for overall benefit. Energy use will be monitored during the demonstration project.

The following table compares energy use of conventional sewerage with a composting toilet/grey water sewerage option. The range for conventional sewerage relates to whether the sewage treatment plant generates some of its own energy demand from biogas or not. The range for composting toilets results from different assumptions on supplemental heating and ventilation energy use.

Energy or Greenhouse Measure	Conventional Sewerage (WC waste and flushing water)	Composting Toilets and Grey Water Sewerage
TOTAL MJ/c.yr	248 - 540	171 - 529
Lifetime Emissions (50 years) tonnes CO_2-e	1.0 – 2.1	0.7 - 2.1

If mains-powered ventilation and supplementary heating is necessary (the high end of the range for composting toilets) to make the composting process and installation work effectively, composting toilet systems would use more energy than conventional sewerage with some energy generation from biogas at the sewage treatment plant. If ventilation fan energy is derived from solar power and if waste heat from the apartment or passive solar heat input is sufficient to keep the compost warm, then a sanitation system based on dry composting toilets with urine separation, trucking of residues up to 50 km (a 100 km round trip) and discharge of grey water to sewer will use less mains and non-renewable energy overall than a conventional system where the sewage treatment plant does not generate any of its own energy. This situation is typical of outlying areas with their own treatment plants.

The evaluation of energy use makes allowance for embodied energy in fertiliser saved by use of compost and urine on land.

Potential Fertiliser Replacement

The nutrients in urine and compost from composting toilets could replace a proportion of chemical fertilisers used in Australia. However, even if the entire Australian population converted to composting toilets, the residues produced would still only supply about 5% of current average Australian usage of fertilisers used to supply N, P and K to the soil. This small percentage reflects the extent of our export industry for agricultural products. Overseas studies on recycling of excreta have shown that fertiliser demand to grow food for a population come close to being met by the excreta from that population.

This substitution of chemical fertiliser is an important factor in relation to sustainability, especially when comparing composting toilet residues with sewage treatment biosolids. Biosolids from sewage treatment plants in Melbourne contain little of the nitrogen, phosphorus and potassium originally present in the sewage because these nutrients are either driven off by treatment or remain in the effluent discharged to the sea or inland waters.

Health Issues and Risk Management

Health risks associated with composting toilets are considered to be no higher for householders than conventional water-flush toilets, provided insect breeding is controlled and the systems are properly operated and maintained.

For transport workers, the risk is probably less than for sewerage system workers as the materials they may come into contact with are contained and already stabilised.

Health risk to agricultural workers using residues is probably no higher than risks to current sewage treatment plant workers but it is recognised that there will be a perceived and potential health risk associated with reuse of urine, leachate and compost.

Risk to consumers of crops grown using residues should be no higher than if sewage biosolids are used and some quantitative risk assessment in Europe has shown that risk levels are negligible provide urine and leachate is stored for at least six months before use and provided solids are properly composted. If, as is likely, the residues are used on dry-land grain crops or pasture health risk to consumers is negligible.

Technical, Financial and Health Risk Management for the Demonstration Project

The demonstration project cost estimates allow for comprehensive instruction to occupiers on correct use of composting toilets, contract maintenance and residue removal to simplify responsibilities of the body corporate, intensive monitoring of health risks and for backup and standby facilities should problems arise. Risks have been listed and assessed for likelihood and management actions have been identified to minimise risks. Because similar installations are already operating, it is certain that the demonstration project is technically feasible. Contingency allowances have been included in all cost estimates and allowance has been made for conversion of the apartments to conventional sanitation at any stage of the project. If the residue reuse trial proves problematic or too costly, the residues could readily be disposed of as for septic tank waste as the quantity (12 tonne/yr) is small. Thus technical, health and financial risks can be adequately managed.

Summary

In summary, the feasibility study has shown that dry composting toilets:

- have the potential to be either of similar cost or less costly than conventional sewerage for residential accommodation of varying densities;
- are likely to be more economical than conventional sewerage as the relative cost of water rises;
- have the potential to be more energy efficient overall;
- can provide up to 19% savings in domestic water use (18 kL/c.yr) and a up to 28% reduction in household sewage discharge volume;
- can reduce pollutant loads from a household by 25% for BOD, 55% for salts and over 80% for nutrients and in the process make nutrients available for agricultural use, reduce biosolids generation and reduce discharges to receiving waters.

By saving water, recovering nutrients, removing other pollutants from wastewater and reducing waste loads to receiving waters, dry composting toilets could reduce the impact of cities on the environment.

There is increasing application of composting toilets and urine separation in Australia and overseas. A demonstration project, as proposed, would help to prove the apparent advantages and, if successful, encourage uptake of this potentially more ecologically sustainable approach to management of excreta in the urban environment, thereby contributing toward societal change for a sustainable future

By demonstrating the technology in a medium to high-density development, the technology will be subjected to the most rigorous test.

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1. Why a Composting Toilets Demonstration Project?

Why propose a dry composting toilet demonstration project in Melbourne when we already have a properly functioning water-born sanitation system? This section sets out the reasons why it is important to undertake a project that may well demonstrate composting toilets are a more sustainable and superior sanitation option.

1.1 What are Composting Toilets?

Composting toilets, or specifically dry composting toilets for this study, are a sanitation system used to collect and compost human excreta that does not use water for flushing and convert or recover excreta in reusable, nutrient rich forms. They consist of a toilet pedestal arrangement similar to a conventional toilet (possibly incorporating a urine separating function in the toilet bowl) below which a straight chute directs solid excreta into a composting chamber. The urine and composted solid matter are high in nutrients and can potentially be reused beneficially in agricultural application as a fertiliser although realisation of this potential will require demonstration to farmers that the materials recovered can be used safely on existing crops.

Modern dry composting toilet designs ensure clean, odour free operation in a relatively familiar looking toilet setting. They are in use in a significant number of private houses, some institutions and in an increasing number of public toilet facilities in Australia.

1.2 Project Team

The principal author of this report, GHD Pty Ltd (a multi-discipline consulting group with long experience in sewerage and water supply), has an interest in sustainability and how alternative sanitation approaches may assist in moving towards sustainability.

The parties comprising the *Project Team,* lead by GHD, are listed below. All parties have contributed to the technical content of the study and report.

- GHD Pty Ltd (Environmental Consultants);
- Environment Equipment Pty Ltd (Compost Toilet Designer);
- Bensons Property Group (Property Developer);
- Demaine Partnership (Architect).

1.3 Current Human Excreta Handling in Sewerage Systems

There are four primary reasons for providing systems for dealing with human excreta:

- aesthetic – nobody wants to see, smell or have to handle raw excreta regularly;
- health – faecal matter from a person suffering from a disease is infectious and blood can carry viruses, particularly those such as AIDS. (It is important to note that urine is not normally likely to be infectious and is in fact close to sterile when excreted);
- social – it is not regarded as acceptable in our society to either leave excreta handling to individuals or to require workers to handle excreta unless by mechanical means within containers;

- ecological - excreta is rich in organic carbon, salts and nutrients and can cause pollution of waterways by depleting oxygen and enriching with nutrients.

Approximately 30% of indoor household water use, or 50 L/c.d out of a typical use of 150 to 180 L/c.d, is used for flushing toilets (Jenssen, 2002, supported by Australian experience). Over 80% of the nutrients (nitrogen, phosphorous, potassium) in municipal sewage and around 40 to 50% of the biodegradable organic matter come from the toilet and much of the nutrient load is in human urine.

Western societies have long regarded excreta as a waste material and, for centuries, disposal to drains and waterways, has been a common practice. The establishment of piped sewerage systems in the late 1800's was a major contributing factor to making cities reasonably healthy places to live and at that time it was common to establish sewage farms that did at least make some use of the nutrient value of human excreta.

Melbourne's Western Treatment Plant (WTP), established in the 1890s, was a good example of such a system and continues to operate today using raw municipal sewage for irrigating pasture for raising beef cattle and sheep. Direct application of raw sewage to land is now being phased out because of odour problems, concern for impact on groundwater and the prevailing view that application of raw sewage to land is not an acceptable way to deal with sewage.

Thus Melbourne's WTP system is being converted to a more sophisticated, energy-intensive treatment process that will remove much of the nutrient and organic value in the wastewater and biosolids, and produce water that can be used for irrigation, plus a limited amount of biosolids. This strategy is still based on the premise that excreta is a waste. It uses water as the transport medium for this waste. This transport system, whilst proven, low cost and energy-efficient, does make it difficult to recover the materials within excreta in a useful form.

The latest upgrade at WTP, like most modern municipal sewage treatment plants, has adopted the process of *nitrification* and *denitrification* by *activated sludge,* which use electrical energy to drive nitrogen in sewage off as nitrogen gas to the atmosphere. This process will reduce the load of nitrogen on Port Phillip Bay since studies have shown that excessive nitrogen load to the Bay, from both the WTP discharge and stormwater runoff, is likely to increase *phytoplankton* growth (eutrophication), potentially including dinoflagelates (the cause of toxic red tides, which can make shellfish toxic). Melbourne's other major treatment plant, the Eastern Treatment Plant (ETP), converts nitrogenous material in wastewater to nitrate in order to reduce the concentration of ammonia in effluent discharged to Bass Strait.

Phosphorus is not removed at the WTP or ETP, as it is not regarded as the controlling nutrient in the Bay or the ocean. This is a common conclusion for marine waters. Thus phosphorus will continue to be discharged as waste, although, as beneficial reuse of treated effluent is established, some of this phosphorus will be returned to the land.

In most inland treatment plants in Australia, including several around Melbourne, where full irrigation of wastewater has not been possible, sophisticated treatment plants are progressively being established that also drive nitrogen off into the atmosphere. Most of these plants are now designed to fix the majority of the phosphorus load in the biosolids produced. This at least allows reuse of some phosphorus nutrient in excreta. All of the potassium remains dissolved in the effluent, which, unless recycled, is discharged to waterways and lost as a potential nutrient.

In conventional sewage treatment the organic matter in sewage is converted to either methane (which is sometimes burnt and may be used as an energy source), or carbon dioxide plus biosolids. Organics are recovered to a greater degree in conventional sewerage systems than nitrogen but are still treated as a waste to be transported in water and *treated* using electrical energy.

1.4 Alternatives for Excreta Handling

Many cultures in the world have long recognised the value of excreta in agriculture. Most of these cultures did not have the financial and energy resources to invest in civil engineering systems to transport excreta using water, nor to obtain agricultural nutrients from other manufactured sources. The most common manufactured fertilisers are superphosphate from processing bird guano and nitrogen fixed from the atmosphere by using energy from burning fossil fuels.

Direct and deliberate use of excreta on farmland is widely practiced in China and other less “developed” parts of the world. Even where it is not deliberately used, the absence of effective sewerage systems in many cities means that drain and river water used for irrigation and for aquaculture is in fact rich in excreta and the nutrients it contains.

Traditional methods of direct or indirect use of excreta in agriculture do have some health risks and these increase drastically when population density increases. For any cities, direct reuse of excreta (prior to some form of treatment), is not acceptable because of the risk of disease to those handling, transporting and using the excreta. Dry composting toilets provide a form of treatment and reduce risks by producing materials, in the home, that are much less likely than raw excreta to contain disease causing pathogens and parasites and by storing these materials until they can be reused.

1.5 Dry Composting Toilets – a Step Towards Sustainability?

Composting toilets are one of the technologies that grew out of a need for more sanitary means of dealing with excreta in situations where water, pipes or streams for transporting excreta are not viable. Savewater.com.au (sponsored by Yarra Valley Water and others) states “…the water conserving benefits of installing a composting toilet can be considerable… their potential application in domestic settings is worth seriously exploring”.

Dry composting toilets can reduce the load on a municipal sewerage system by around:

- 80% for nitrogen, phosphorus and potassium;
- 40% for Biochemical Oxygen Demand (BOD);
- up to 28% of water volume.

Figure 1.1 indicates the per capita contributions of water and pollutants to domestic sewage, from the toilet (black bars) sometimes called “black water” and from sinks, showers, baths and washing machines (grey bars) commonly called “grey water”. Contribution from urine is shown where appropriate as a lightly hatched side bar.

The numbers within the bars show the number of litres of water or the grams of pollutant per person per day from each source. The percentages of each contributed from the toilet are shown and it can be seen that these percentages are surprisingly high.

The lightly hatched side bars show the number of grams per capita per day of pollutants in urine and it can be seen that urine is the single greatest contributor of nitrogen and phosphorus.

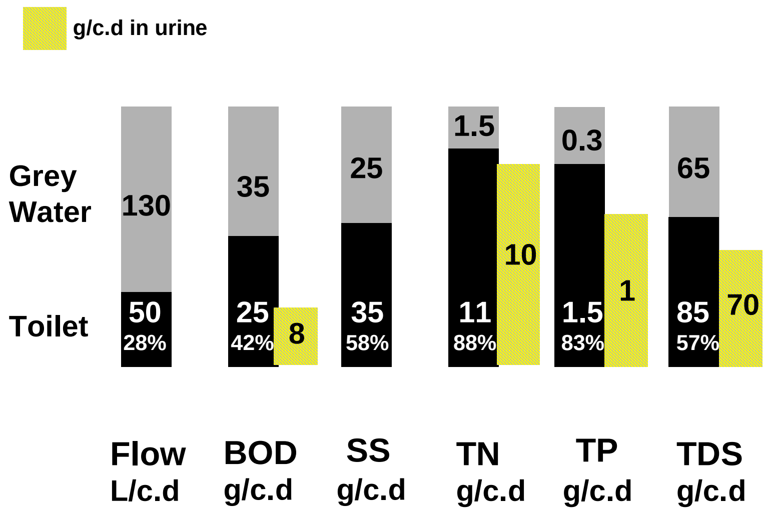

Figure 1.1 Load Components from Sewage & Grey Water

Table A1, Appendix A, summarises data on per capita pollutant loads, which was used to develop Figure 1.1. Appendix A is a review of some of the literature on composting toilets and associated issues and this review is summarised in Section 3 of this report.

Use of composting toilets that remove excreta from the sewerage system offers major potential reductions in loads on sewerage systems that could reduce future capital investment. Eliminating water for flushing will lower demand on water supplies. The nutrients recovered could be a benefit to agriculture by replacing a proportion of energy intensive and costly chemical fertiliser use.

There could therefore be a compelling argument for using composting toilets in new urban development and for retrofitting old housing stock if it can be shown that they:

- save a significant volume of water over conventional sewerage systems (potentially up to 50 L/c.d or 18 kL/c.yr);
- do not use more energy;
- enable nutrients and organic carbon produced to be safely and beneficially used in agriculture;
- are economically and financially viable;
- are socially acceptable;
- are safe and do not increase risk of disease in the community.

It is the objective of this feasibility study to explore these issues and demonstrate the benefits.

1.6 Issues Addressed in this Study

The Funding Agreement between GHD and the Smart Water Fund for this feasibility study required identification of and reporting on:

- government (Commonwealth, State and local) policy frameworks relevant to the Project (covered in Section 8);

- key legal and regulatory risk issues associated with the project, identifying risk management activities to allow the project to proceed and confirm the level of support, attitudes and concerns that regulators may have in relation to the project (covered in Section 8 and in other parts of the report and summarised in the conclusions in Section 12);
- key technical risk issues associated with the project and the risk management activities to allow the project to proceed, including identification of operational and compliance management arrangements for the recycling system once completed and in operation (covered in Section 4, 6, 8, 9 and 10 and summarised in the conclusions in Section 12);
- responses of potential end-owners of the properties equipped with composting toilets (covered in Section 7);
- regulatory constraints and contradictions, and next steps required to progress the project (covered in Section 8 and summarised in the conclusions in Section 12).

This feasibility study considers a demonstration of composting toilets in a new inner city medium to high density town house application, the “demonstration project”. This application, where there is too little space on the site for reuse of compost and urine and where collection systems for this material and for grey water are therefore required is seen as a severe and representative test of dry composting toilets. This dense urban setting is representative of much current urban residential development as well as having issues related to air discharges, compost and urine transport and user-acceptance that a low-density setting would not have. In addition, it provides a single source of compost and urine in sufficient quantities for trial of agricultural reuse.

Essentially this feasibility study is to assess the technical and financial feasibility of the demonstration project. The whole project, if it proceeds, aims to demonstrate and record data on the viable operation of dry composting toilets in the apartments, including maintenance, transportation of composted solid matter, urine and leachate, and the safe use of the human excreta products to replace traditional commercial fertilisers. Furthermore, the demonstration project, if it proceeds will provide a basis to confirm the feasibility of large-scale application composting toilet installations. Therefore the context of this study can be shown as:

Feasibility study **(this report)** ⇨ **Demonstration Project** **(12 apartments & reuse trials)** ⇨ **Project Feasibility** **(data interpretation, financial & technical reporting & conclusions)** ⇨ **Commercial & large scale application with significant water and energy savings**

Many issues have been addressed at this feasibility stage of the project. The study is not exhaustive but it addresses the social, technical, economic, administrative, logistical and legal aspects of the proposed project for the apartment source site, collection and transportation and the agricultural reuse trial site.

It looks at the various phases of the whole project from design through to decommissioning of a trial reuse site for the residue products.

Aspects of the proposed demonstration project specifically covered in the study include the following:

- the main drivers for why this project has been proposed by the project team (Section 1);
- a description and details of the specific project proposed for the 12 apartment units and associated reuse trial (Section 2);

- a summary of our literature review from international case studies and research on related applications including work done by the CSIRO in Australia as part of its Urban Water Project (Section 3);
- detailed overview of the technical components of the toilet design, installation requirements, toilet system, building features and the contracts required for system operation (Section 4);
- water saving estimates, energy usage comparisons and lifecycle analysis (Section 5);
- detailed overview of the proposed reuse trial, including the outcome of discussions with the Department of Primary Industries, Melbourne Water Corporation (MWC) and the Environment Protection Authority (EPA) (Section 6);
- the outcome of research into the marketability for inner city apartments equipped with composting toilets facilities and a proposed marketing plan for the current demonstration project (Section 7);
- investigations into applicable regulations, guidelines and approvals after preliminary discussions and meetings with EPA, City West Water (CWW), MWC, Mooney Valley City Council (MVCC) and the Department of Human Services (DHS) (Section 8);
- consideration of the various health risks and controls with input from experts in the field of microbiological health and risk aspects, including risks for the residents, transportation and disposal (Section 9);
- economic and financial evaluations of the potential application of composting toilets to both a large, high density urban subdivision and a small unsewered country town (Section 10);
- costing of the demonstration project, from inception to late 2008 when the trial reuse monitoring will be completed and the reuse site decommissioned (Section 10);
- a reporting structure as an integral part of this demonstration project is recommended (Section 11);
- conclusions on the findings of the study noting specific aspects that require further investigation (Section 12).

1.7 Data Collection on Water Use and Waste Generated

The literature reviewed indicates that no specific sampling or data collection on composting toilet systems has been carried out and it has been found that only a few users of composting toilets keep records that are sufficient to be of use. This study gathered data from a variety of literature sources and from the principal author's knowledge on both typical municipal sewage load and excreta loads. Section 3 sets out the data obtained (from literature) and used in this study.

Experience with operating composting toilet installation in Victoria was obtained by interviews, site visits and from the equipment supplier involved in this study. Experience has also been presented in a number of technical papers and books reviewed in Section 3.

1.8 First High Density Application in Australia

Although there are several examples of composting toilet systems being used in higher density residential and multi-level office systems overseas (Scandinavia, Canada), the only example found in Australia is at the Thurgoona (near Albury NSW) campus of Charles Sturt University. Use of composting toilets in Australia has otherwise been limited to remote locations (such as hiking tracks, rural sites or road side rest areas) or individual houses often in non-sewered areas (in the latter case largely initiated, installed and operated by the home-owner).

The team developer, Bensons Property Group, has indicated willingness to incorporate composting toilets into a new medium-density development as a demonstration project, subject to feasibility and funding support.

This development is intended to serve as a successfully operating example of composting toilets in a medium density residential setting. An additional and important component proposed is application of the human waste products (source-separated urine, leachate and composted faecal matter) to agricultural land. This situation will differ from many installations of composting toilets, where compost from a single house or larger multi-composting toilet facility is used or buried in the garden onsite or locally in community gardens or on open space.

1.9 Marketing, Public Perception & Acceptance Challenges

As yet no study has specifically aimed a survey at identifying attitude and preconceptions of the general public towards purchasing or occupying dwellings with composting toilets installed. As such, there is little detailed information available that documents general public perception of composting toilet systems prior to actually experiencing the systems. A questionnaire survey of previous clients and contacts of Bensons Property Group was distributed, and response evaluated as part of this feasibility study. The main aim of this survey was to assess the market acceptance of composting toilet systems in a medium density residential setting and to determine people's attitudes to, expectations and knowledge of composting toilet systems.

The other great challenge is whether farmers would accept compost, leachate and urine as replacements for fertilizers. If serious interest in using these alternative fertilisers can be generated during the demonstration project then one of the major reasons for large-scale adoption of composting toilets would be confirmed.

1.10 Addressing Health Concerns

This study describes and assesses the relative risk of various disease transmission risks related to use of composting toilets from the household through to the end use of residues. This work has been carried out by review of literature and by consultation with some of Australia's leading public health microbiologists and epidemiologists. Maintaining health standards in an urban environment is critical for any proposal to change current sanitation arrangements.

However, it must be recognised that disease transmission in modern Australian cities is predominantly by direct person-to-person contact, inappropriate food handling and transfer through air-born aerosols rather than from contact with toilets or sewage.

1.11 Acknowledgements & Technical Reference Panel

The GHD project team gratefully acknowledges the assistance and technical input of the following organisations and people. The content of this feasibility study is the work of GHD, Bensons Property Group, Demaine Partnership and Environment Equipment and it is not implied that the organisations and individuals listed agree with the conclusions reached.

Bensons Property Group	Kim Jaques, Elias Jreissati
City West Water	Bruce Freer
Cleanaway	Anthony McMahon, Phillip Lowry
Collex	Patrick Cannon

CSIRO	Clare Diaper
Demaine Partnership	Michael Jeffreson
Department of Human Services	Bob Eden
Department of Primary Industries	Sandra McDonald, Austin Brown, Siggy Engleitner & Guy Nicholson
Environment Equipment	Buzzby Burrows
EPA Victoria	Noelene O'Keefe, Suzie Sarkis, Don Williams, Sarath Katugampola
Melbourne Water Corporation	Michael Arbon, Terry Scott
Monash University	Martha Sinclair
Moonee Valley City Council	Hector Gaston
Smart Water Fund (representatives)	Richard Clarke (SEWL), Bruce Freer (City West Water)
University of NSW – School of Civil and Environmental Engineering	Professor Nicholas Ashbolt

In particular the team recognises the financial input and technical reviews provided by the Smart Water Fund and its members to facilitate this project so far.

Reference Panel Members

A technical Reference Panel was established early in the project and met once during this study. The contributions of these individuals are gratefully acknowledged. The members of the Reference Panel and their organisations are listed below.

Organisation	**Person**
City West Water	Bruce Freer
CSIRO	Clare Diaper
Demaine Partnership	Michael Jeffreson
DHS	Bob Eden
DHS	Natalie Blyth
Environment Equipment	Buzz Burrows
EPA	Noelene O'Keefe
Monash University	Martha Sinclair
MWC	Terry Scott
University of NSW	Professor Nicholas Ashbolt

2. The Proposed Composting Toilet Demonstration Project

The purpose of this section is to summarise the proposed composting toilet demonstration project so readers can appreciate what is being proposed and some of the issues that will have to be addressed. Further details of the project and the issues surrounding it are included in later sections.

2.1 Introduction

The composting toilet demonstration project is proposed for a high-density premium apartment development at a landmark site in Flemington. A separated block of 12 two-storey apartments is proposed for the trial with all, subject to feasibility, being equipped with composting toilets. The apartments units will be the premium apartments on the site, attractive to owner-occupiers, overlooking parklands. It is proposed that a range of environmentally friendly building products and systems will be used. Further apartment blocks will subsequently be developed on the same site subject to current negotiations with council.

Whilst a larger installation was envisaged, a combination of planning approval issues, project timing, financial risk to the developer and purchaser interest means that a larger trial is unlikely to be supported.

This section forms a summary of and describes specifically the proposed composting toilet demonstration project. More technical findings of our research and discussion on various options are contained later in this report and costs and technical details are included in Appendix B.

2.2 Design & Installation

A number of townhouses, facing onto a public park/reserve, have been set aside as appropriate for this demonstration project. The two storey configuration and ability to provide two external facades is beneficial, as is the availability of a car parking space near the townhouse entrances which doubles as an access point for the composting bins.

Building configuration issues are discussed further in Section 4. The concept of access galleries serving only the composting units, with dedicated goods lift access, was examined for use in high rise building configurations, however the floor space these lifts would require, the potential security and privacy aspects and the additional costs were of concern to the architect. This has led to the preference for application of the systems in a low-rise configuration.

Figure 2.1 shows a cut-away of the proposed layout of the apartment building and access provisions for the composting toilet system and Figure 2.2 shows the drainage plumbing. Preliminary Architectural plans for the proposed development are provided in Appendix C of this report.

2.3 Proposed Building Site

Benson's Property Group and a partner is currently negotiating with Moonee Valley City Council to rezone parts of a site in Flemington and the overall development of this site is subject to these negotiations. Until these negotiations are complete, expected to be in mid 2004, the site is confidential.

The part of the site proposed for the trial is already suitably zoned for the apartments to be built and therefore proceeding with the trial is dependent only on decisions to proceed with the apartment building, necessary planning and building approval and a decision to install composting toilets.

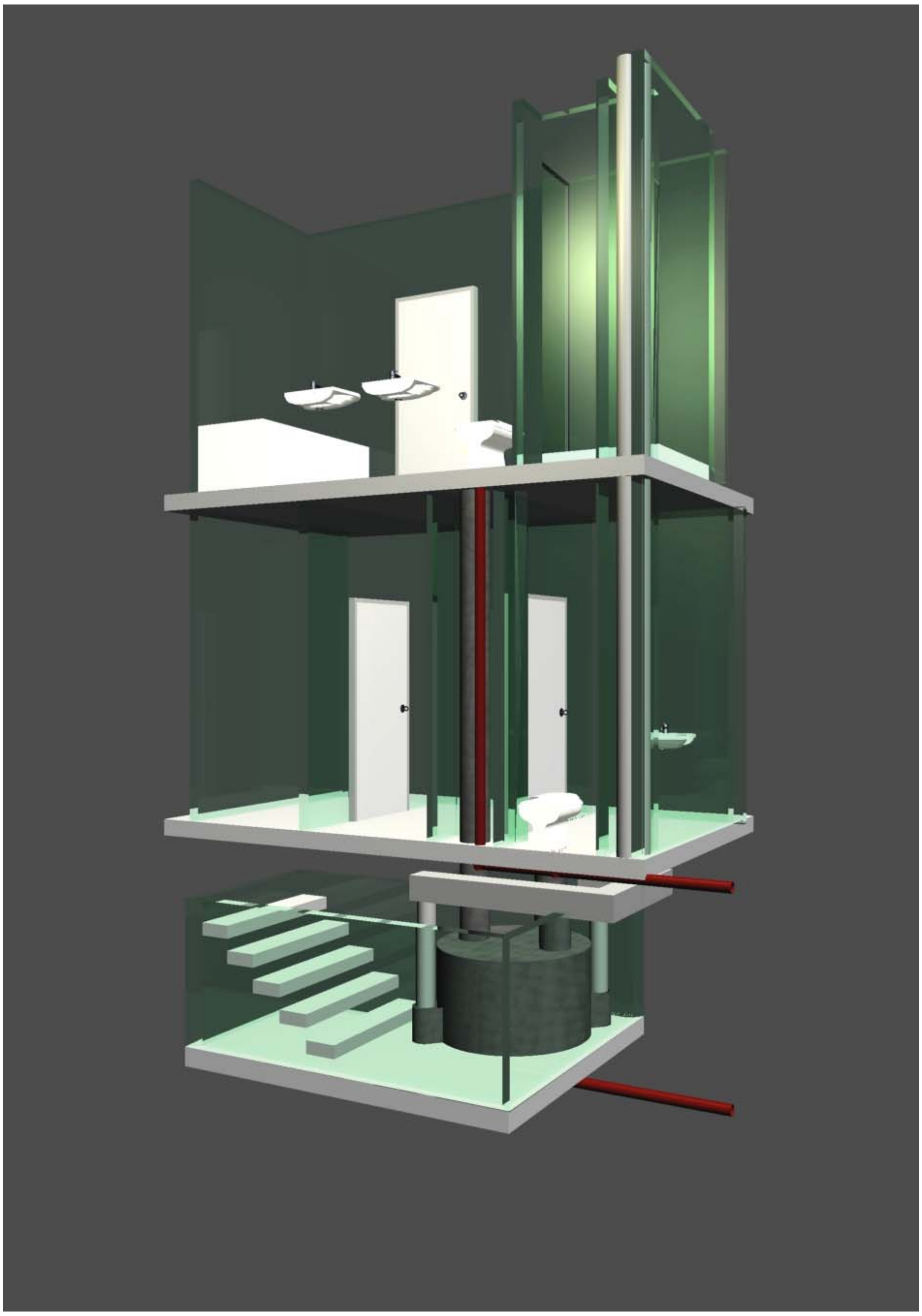

Figure 2.1– Cut-away Architectural Perspective of Composting Toilet System Installed in a 2-Storey Apartment

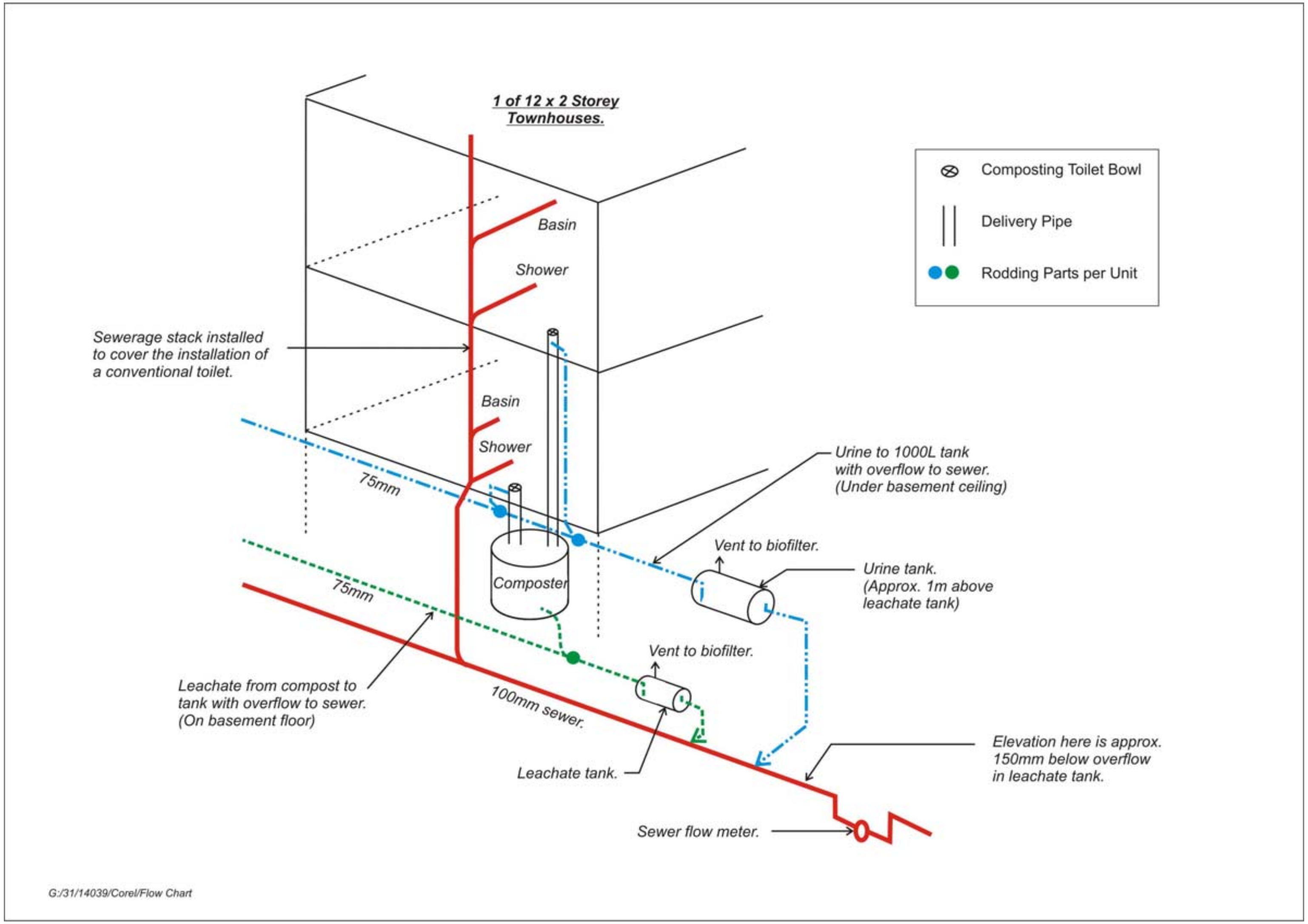

Figure 2.2 Drainage Plumbing for Composting Toilet in High Density Application

2.4 Urine, Leachate and Compost Reuse Trial

2.4.1 Disposal or Reuse?

Because of the planned high population density on the trial site and the limited open space around the apartment block, it is not possible to dispose of residues (urine, leachate and compost) on or adjacent to the site. This conclusion holds for all population densities higher than about four to five persons per hectare (compared with probably greater than 30 for the trial site) as discussed later in this report. To apply residues on too small an area of land will lead to contamination (by over-fertilisation) of soil, groundwater and surface runoff. Thus another aspect of this project is to demonstrate the feasibility of a collection system using trucks and to provide a suitable disposal or reuse solution.

Several options for disposal or reuse of the residues are noted, however some would require research and development before being adopted commercially. Options include:

- disposal to a sewage treatment plant;
- disposal to landfill;
- application direct to land, the option proposed for the demonstration project;
- blending with other fertiliser (blended for commercial use).

With significant benefits gained from removal of human excreta and the nutrients in it from the domestic wastewater stream it would be pointless to reintroduce these products back into the sewage treatment process. The high phosphorus, nitrogen and potassium nutrient content lends well to agricultural application as fertiliser and therefore this study has investigated some options for a trial application to a secure site, where a trial of nutrients and organic matter being beneficially used as replacement for chemical fertiliser can be undertaken. The trial is proposed to determine the actual health implications, benefits and practicalities of direct application to dry land crops. It is considered necessary to run a trial to demonstrate the viability.

The option of blending with other fertilisers will also be investigated during the trial.

2.4.2 Sustainable Trial for Reuse at Werribee

Preliminary discussions with Melbourne Water indicate that a site of approximately two hectares (required area determined in Section 6 of this report) can be obtained within the boundary of the Western Treatment Plant site and hopefully on high quality soils not previously used for wastewater or sludge disposal. Melbourne Water has given written agreement in principal to support this project subject to a more detailed proposal and risk assessment.

The demonstration project involves setting up this site to test application on grain crops versus using normal fertilisers on a control crop and to undertake sufficient soil, produce and groundwater chemical and biological testing to demonstrate that such application can be safe in terms of health and environmental impact. It is envisaged that this trial will run for about two years, dependant on detailed advice from the DPI, which has indicated an interest to run such a trial. A longer trial would be desirable to determine longer-term impacts on soils and groundwater but analysis during a shorter trial should be sufficient to provide an indication of long-term impacts.

2.4.3 After the Reuse Trial

During the reuse trial, investigation into the future reuse options for the compost, urine and leachate waste stream will be undertaken. In part the trial will provide a starting point for discussion on this matter. We envisage discussions with the fertiliser industry, EPA, Department of Primary Industries (DPI) and DHS regarding possible manufacture of a commercial fertiliser product and also with managers of open space areas such as golf courses, parks etc where burial for beneficial reuse could be implemented.

The feasibility of urine evaporation and blended fertiliser manufacture for agricultural use will be pursued as these are viewed as real commercial avenues. Further investigation is required. However, with the small volumes of output estimated from the 12 apartment units it is unlikely to be possible to run trials of more than one option. This aspect does not need resolution until the design and operation phases of the demonstration.

2.5 Proposed Marketing Plan Strategy

The developer will, as a matter of course, prepare a high quality brochure and eye catching newspaper advertisements when the time comes to commence the development.

The developer's usual practice is to make known in its advertising, brochures and other communications to potential purchasers information on the environmentally friendly nature of developments with which they are involved in.

The acceptance of the composting toilets (and other energy and environmentally friendly design features) was assessed through feedback received from a survey sent out to around 3000 investors, prospective purchasers and others interested in property on the mailing list of Bensons Property Group. The results from this survey are discussed in Section 7.

The planning for the specific content of marketing material for the apartments has not commenced at this stage but is likely to include both qualitative and some quantitative information on the features of the apartments aimed at minimising the owner's overall ecological footprint.

Typical marketing tools would include but not necessarily be limited to:

- mail outs;
- sign boards;
- press advertising;
- magazine advertising;
- marketing to agents;
- brochures.

Because normal practice seems to be that the sale of this type of development is conducted off the plan and generally prior to the commencement of construction it results in the average purchaser being an investor.

Investors generally are not prone to pioneering and accepting radical change. As a result, the risk associated with marketing of the units that are the subject of this feasibility study is greater.

However, the style of this apartment (medium density, good outlook and high quality presentation with environmentally friendly features) should be attractive to owner-occupiers who may be more willing to be pioneers with the technology and may even seek out such apartments. A strong ecologically sustainable emphasis to the marketing campaign will distinguish this development from others in the market. This will in turn have positive benefits for all parties involved, including the Smart Water Fund.

It is clear that the financial risk to the developer of designing the apartments to include composting toilets is significant due to the additional design cost and the risk of not attracting purchasers. Therefore, it is appropriate that the Smart Water Fund and other entities that stand to benefit if the demonstration project is successful, meet at least part of the additional costs of the project roughly in proportion to this benefit, thereby covering some of the developer's risk.

Section 10.6 discusses funding and funding options for the demonstration project.

2.6 Regulations and Approvals

An investigation into relevant guidelines, legislation and regulations was conducted to identify any legal requirements and constraints. The requirements fell into three broad areas:

- installation of composting toilets in the development itself;
- removal and transport of the human excreta from the development to the reuse trial site;
- application of the urine and composted matter to land at the trial site.

The project has not looked at the implications of food-standards regulations on use of crops fertilised with residues.

EPA Victoria reviews and approves composting toilet systems for use in Victoria, but is not involved in approving them for installation at individual sites. The relevant local council approves on-site wastewater treatment systems (including composting toilet systems) for individual sites, in accordance with EPA guidance.

Collection of the liquid and solid excreta from the apartments and transporting it to the reuse trial site is unlikely to require specific approval since septic tank pump out does not require specific approval or licensing of contractors. However, the cartage and disposal of significant quantities would be covered by general provisions of the Environment Protection Act and the Health Act concerning pollution and nuisance. This issue is discussed further in Section 8.

Containment of the compost, urine and leachate during transport will be necessary to minimise the risk of pollution or nuisance, and all containers should be sealed with minimal risk of escape during normal transport and possibly also for road accident situations. (In discussion with Victorian EPA staff.)

Requirements for the trial reuse site have not yet been fully defined, however the likely approval required will be an EPA Research, Development & Demonstration Approval since this is a genuine demonstration project. Involvement of the Department of Human Services to review and monitor the health aspects of the trial is anticipated but no specific approval is required from DHS. Further investigations will be required for health regulations relating to re-use of the end products (urine, leachate and compost) as fertiliser for food crops. However since this is only a trial, the produce will be destroyed. Overseas studies have included trials of the use of urine on crops such as cereal, with success, however according to the ATA (Alternative Technology Association) in Australia, use of human waste products to fertilise food crops is not currently legal. The legality or otherwise of such use has not been entirely clarified. Certainly Australian Standard AS 1546.2:2001 requires burial of compost and direct use on food crops has been discouraged by regulating authorities.

Initial discussions with Moonee Valley City Council (MVCC), indicate that the following planning process or steps for a development with composting toilets in its municipality will be followed.

- planning application to Council;

- planning will refer the application to the Environment and Urban Design Unit and the Public Health Unit for guidance and approval from each;
- these groups will seek specialist assistance from the EPA;
- Council will check that the proposal meets the EPA guidelines and Standards;
- Council needs to be sure the proposal will not adversely impact on the amenity of neighbouring properties from a planning and health perspective. Any impacts will need to be minimised or eliminated and the permit will include a clause to this effect.

MVCC is promoting sustainability and sustainable options for land use and Council will be supportive of an application. It will be necessary to demonstrate that the proposal minimises any negative impact on neighbours for a planning permit to be issued. No significant difficulties are foreseen.

2.7 Health Issues

There are no known reported cases of disease arising from composting toilet installations but this is not surprising considering the relatively limited application of the technology in societies where disease reporting is practiced. Because excreta and urine are removed from the apartment to a dedicated sub-floor composting vessel and underground tank respectively, the health risk to residents is minimal. The only exposure to infection for householders relate to insects and incidental contact whilst cleaning the toilet and upper part of the drop shaft. The cleaning risk is no higher than for conventional toilets provided normal hygiene is practiced, therefore it is concluded that risk from cleaning is acceptable.

Insects and spiders will populate the compost bin, drop shaft and vents. Evidence shows that urine separation minimises the risk of house flies and blow flies but smaller midges can be common inside the composting unit. These will be contained almost exclusively to the composter as the ventilation prevents migration up the chute to the toilet. Users of existing compost toilets do not report insects as a problem, but good insect control by use of fabric mesh screens and possibly natural insecticides needs to be included in the detailed design and covered in operation manuals.

For transport and maintenance workers, the risk of contacting the urine or unstabilised faecal matter is substantially lower than the current exposure risks to plumbers and sewer workers. Transporters will treat the material as a septic waste and implement worker OH&S guidelines for protection. Furthermore because the materials are separated and contained and the solids are aerobically composted, health risks to these workers will be minimal.

Agricultural reuse of residues will expose users to the materials and, if inadequately composted, solids could present a risk that will need careful management. Use of source separated urine as a fertiliser has advantages in terms of hygiene over other sewage products (Jonsson 1997) due to its near-sterile nature, therefore it is considered to have a low health risk. Leachate (drainage from the compost that will contain faecal matter) is estimated to present the highest risk of the residues, but it is concluded risks from all residues can be minimised within a detailed management plan for safe handling, transfer, storage and distribution.

The risk of contracting disease from crops fertilised with residues can be minimised by careful management and crop selection.

Overall, health risk to workers on the reuse site and to a lesser degree risks of insect-born disease transmission at the composters are aspects requiring further investigation at detailed design stage and careful management during operation.

2.8 Contract Arrangements

Contracts will be required for the following aspects of the project:

1. maintenance contract for the physical components of the composting system;
2. removal and transportation of the compost, urine and leachate from the apartment site to the reuse trial site;
3. modifications to a typical body corporate contract, with appointment of a professional manager briefed on issues specific to the composting toilets and associated infrastructure.

The body corporate constitution and rules would need to include provisions to cover the shared equipment (tanks, etc), access, drainage and to cover procedures in the event of failures leading to odour or health risk. A professional body corporate manager would need to be appointed and briefed for this responsibility or, alternatively a separate sub-contractor (e.g. the maintenance contractor discussed below) could be contracted on-call to respond to any failures or emergencies.

2.9 Maintenance Contract

In a rural residential setting the home owner would perform all maintenance requirements for their composting system, however in a high density, apartment setting with multiple units installed on the site, residents may be interested in having an external organisation maintain the system, so they have little or no maintenance responsibility, particularly given that they will not be handling the residues nor using these own their own garden areas (due to lack of space in this inner city application).

Maintenance is critical and needs to be carried out on a regular basis, with checks approximately every six months. The maintenance contractor must be on-call to respond to queries, complaints and service calls by residents as required. This service will be carried out by a third party as a separate contract from the collection and removal contract, for example by the system provider.

It is envisaged that the contract would be drawn up by the study team and managed by a professional manager acting for the body corporate.

The maintenance contract would contain the following elements:

- inspect all units individually on a biannual site visit;
- clean long waste chutes and ventilation extraction vent pipes;
- identify any units with a degree of failure in the compost process;
- ensure bin rotation is occurring at correct intervals for volumes of solid waste being produced (to avoid under and overfilling;
- ensure ventilation and aeration is operating effectively;
- ensure the leachate and urine collection systems are functioning properly and that reporting is occurring if larger volumes require more regular collection;
- response to callouts by residents with immediate maintenance requirements;
- provision of training and instruction material to residents initially, modified as a result of experience;
- provide a maintenance report containing observations and recommendations from each visit.

Provision for the cost of a maintenance contract has been included in Section 10.6 and Appendix B, Table B6(c). Two days have been allowed for one person, including travel time, inspection, minor adjustments, cleaning, reporting and discussions with residents as required for the biannual visit. In addition four callouts in between visits (i.e. per half year) have been allowed for response to immediate requirements of the residents. This equates to a total of 12 days per year for the 12 apartments.

This allowance is likely to be conservative, making allowance for start up problems and accounting for the unknown aspects and difficulties arising given that residents themselves are not taking full responsibility for the operation, care and maintenance of the whole composting toilet system in this application.

2.10 Collection and Transportation Contract

Two cartage contractors were consulted during the study and invited to participate by providing a concept of how the collection and cartage could be managed, broad estimate costs for this service and an indication of the type of contract conditions that might be required for such a project.

The specific elements required to set up and carry out collection and removal of composted solid matter, sterile urine and leachate are noted below.

- set up a truck with a lift-off platform specifically designed to house and secure a liquid waste tank, pumping equipment, and empty compost carousels or containers. The liquid tank may be set up for use on a separate truck;
- custom built split vacuum tank for separate suction removal of leachate and urine from onsite tanks;
- empty compost bin carousels or containers (approximately 4) to bring empty replacement bins to the apartment site and to house the full compost bins collected from the apartments;
- dedicated hoses, with hose lock away facility to ensure that the urine remains uncontaminated;
- truck mounted hydraulic hoist to lift and place the entire unit from ground to truck deck and vice versa. This means the compost bins can be wheeled onto the platform and loaded directly into the carousels or containers, avoiding manual lifting. The truck will have a sole operator;
- servicing the apartments will take place on approximately a quarterly basis. This is estimated from both calculated volumes and reported anecdotal evidence of solid matter and liquid produced;
- a servicing round is expected to take anything up to 10 hours including transport to the agricultural trial site, unloading and return to depot.

The sequence of operation carried out by the contractor will be as follows:

- the operator will drive to the apartment site bringing clean empty bins on the truck within the bin carousels or containers, park adjacent to the entry points to the underground urine and leachate tanks and hoist the removable deck platform off the truck bed to ground;
- clean empty bins will be removed and wheeled by trolley to the access pits at each of the apartments;
- full compost bins will be removed from the carousel serving each apartment, replaced with clean bins and the carousel turned to a new bin position;

- the full bins will be covered with a lid and wheeled by stair-climbing trolley from each apartment and slotted into the truck platform carousel;
- the platform will then be hoisted back onto the truck bed and with the containers secured in place. Residues will then be transported to the designed reuse trial site for off loading;
- urine and leachate will be collected by suction into the truck tanks. Provision will be made for the vacuum pump discharge to be connected to the on-site odour-scrubbing biofilter to minimise any odour release from this operation;
- emptied compost bins and equipment can be either washed at the reuse trial site or taken back to the contractor's premises for cleaning.

Requirements of a formal collection and transportation contract will typically cover the following:

- there will need to be a sole entity with which the transportation contract is made and signed, including a contact person and contact details. A designated professional manager acting for the body corporate would be an appropriate responsible contact;
- setup costs will need to be addressed and calculated independent of the normal transportation operation costs;
- payment details and the payer need to be established. Terms for payment will need to be negotiated and most likely a regular payment will be made to match the routine visits;
- standard waste transport conditions include allowance for rate changes at any time, particularly if the volumes and weights increase. This should not be an issue for the demonstration project as the volumes and weights are not significant. Handling difficulties may cause delays, however the intention would be to allow for ample operating time until a routine is established and a set charge can be determined;
- the term and cancellation/alteration clauses will need to be addressed specifically including calculations for damages on premature cessation of the contract. For example, one standard waste transport contract reviewed had a contract rollover into a 36-month term;
- as the waste, under a typical cartage contract, remains the property and responsibility of the payer the ownership becomes an additional risk and responsibilities need to be clarified at the time of drafting the various contracts. The body corporate may wish to have a further clause in the contract with the maintenance contractor to ensure they do not have unwanted responsibility in this respect;
- insurance and indemnity issues will need to be properly addressed between parties, including public liability. This will cover accident situations, injury to personnel, damage to property etc. The standard terms and conditions reviewed require the payer to indemnify the contractor for these types of occurrences which may not be acceptable;
- the conditions reviewed did not include specifically for septic or other wastes under which the compost and liquid residues for this project could be classified, however initial discussions indicate that the transporters will be willing to be involved in this project. The 'Other Waste' category can incorporate these products.

2.11 Monitoring Plan

Several aspects of the composting toilet demonstration will be monitored, some in more detail than others.

A brief description of the type and intent of monitoring applicable to each aspect is provided here, with more detailed discussions and costs to follow in later sections.

The costs of this monitoring are part of the demonstration project budget estimate and would not be met by the apartment owners.

Installation / Apartments:

- electronic monitoring of total water flow to the 12 apartments;
- electronic metering of grey water flow to sewer from the 12 apartments using a magnetic flow meter in an inverted syphon;
- monitoring of electricity and gas usage of equipment associated with composting toilets (eg: fans, hot water gas booster) on two of the 12 apartments;
- voluntary resident participation in information gathering (this is more likely to be the permanent residents rather than renters). For example:
  - odour
  - toilet use frequency;
  - number of guests;
  - any sickness;
  - insect nuisance;
  - other household habits (eg: water usage, electricity);
- logging of breakdown and other operating problems.

Residue Reuse Trial Site:

- sampling and testing of compost (according to AS/NZS 1547:2001) and urine to determine if the end-product is suitable for use as a fertiliser on food crops;
- soil sampling and appropriate analysis to determine impact of end-product application to soils;
- groundwater sampling and appropriate analysis to determine impact (if any) of product application at ground surface;
- testing of crops for evidence of pathogen, virus or bacterial uptake from urine and compost fertiliser usage by monitoring indicator bacteria and spiking with attenuated strains of bacterial, parasitic and viral pathogens;
- possible monitoring for selected endocrine disruptors.

2.12 Reporting

Section 11 describes the proposed reporting for the demonstration project in detail. As well as regular progress reporting to the funding entities, other participants and a technical advisory committee there will be a number of technical reports when design is complete, on commissioning to record as-built details and at the end of the agricultural reuse trial to capture all monitoring data, results, anecdotal information collected and knowledge gained.

One year following decommissioning of the reuse trial, reporting will cease and any further publications regarding the project will be at the discretion of individuals or other interested parties, with permission from the project managers.

Reporting will continue, to a steering committee to be determined by the funding bodies. The Smart Water Fund is understood to cease in mid 2005, prior to completion of the demonstration project reuse trial period. Thus funding from other sources will be needed for the agricultural reuse trial and for ongoing monitoring of the apartments.

2.13 Costs, Funding & Water Savings

Costs and funding for the demonstration project are detailed in Section 10, with full calculations in spreadsheets contained in Appendix B, Tables B6(a) and Table B7. Tables B6(b), B6(c) and B6(d) are also included as these costs were developed for a more comprehensive agricultural reuse trial. Following advice from Agriculture Victoria, the less ambitions dry land cropping agricultural trial costed in Table B7 was developed.

The total cost of the demonstration project is estimated at $730 000. If composting toilets were installed in the same apartments under normal conditions without provision for research and development and if there was no agricultural reuse trial, the cost over the same period is estimated as $230 000. Therefore the additional cost of $500 000 over the period is the cost of the demonstration project for which the project team will be seeking funding. In addition, some subsidy would be appropriate to encourage the developer (an apartment purchasers) to go ahead with the trial.

The benefits of the project in terms of estimated water savings are 18 kL per person each year, or around 19% of household water use. Around 28% of household wastewater to sewer is saved, there is a reduction in pollutant loads on sewage treatment plants and supply of a nutrient source to agriculture. The water saving and other benefits of composting toilet system technology are outlined later in Section 5.

2.14 Program

The proposed program timings and milestones for the demonstration project are shown below. Certain critical path aspects are very dependant on negotiations between the developer and the local authority for rezoning, and while this is not specific to the composting toilet aspect of the development, it may affect the project timing.

◗ July 03 - end of 2008	-	Project management and monthly reporting to the Smart Water Fund other funding agencies & Steering Committee (to be established)
◗ November 03	-	Feasibility Study report complete
◗ September 03 – early 2004	-	Negotiations and preliminary planning discussions with Council
◗ Early 2004 – mid 2004	-	Planning approval application, planning approval and preliminary pre-publicity release
◗ Mid 2004 – late 2004	-	Detailed design and pre-construction selling
◗ Late 2004 – mid 2005	-	Selling, project construction & installation phase
◗ Early 2005 – late 2005	-	Trial agricultural reuse site planning, site selection, construction and preparation
◗ Early 2006	-	Establish contracts for maintenance and residue transport
◗ Mid 2006 – late 2006	-	Apartments occupied
◗ Mid 2005 – early 2006	-	Begin operation monitoring and reporting at the apartment site
◗ Mid to late 2006	-	Reuse trial begins operation, monitoring and reporting
◗ Early 2007	-	Reuse trial at full capacity
◗ Mid 2008	-	Reuse trials cease but soil and groundwater monitoring continues
◗ Late 2008	-	Reuse trial site decommissioned and rehabilitated and final project report completed

2.15 Demonstration Project Publicity

GHD provided initial publicity for the proposed demonstration project by including a page on its website (www.ghd.com.au/compostloo), to showcase and raise awareness of the project. Bensons Property Group included a news item and questionnaire survey (for return post) in its September newsletter with a circulation of 3000. Both Bensons Property Group and Environment Equipment have an article promoting the project and these are being used on their website or in other marketing material. GHD also submitted an abstract for a paper to the AWA for the Enviro 2004 conference and this has been provisionally accepted as a platform presentation.

The project team will continue to feature the project in their company newsletters and websites as work progresses. They have a combined circulation approaching 10 000 covering many property and building companies, all water authorities in Australia and many overseas water authorities.

GHD, subject to Smart Water Fund approval, proposes to make regular press releases to the public press on the project. Just prior to finalisation of this report GHD staff met with a technical freelance journalist who specialises in water related subjects for the World Water magazine (published for the International Water Association) to discuss the composting toilet demonstration project and its merits.

Technical papers will be prepared for appropriate journals and conferences on appropriate occasions. These papers and the project report summary will be made available via GHD's website. Several organisations have expressed an interest in the demonstration project and this report or the executive summary will be circulated to those parties subject to Smart Water Fund Approval.

Some of the project team members will offer to present at technical and community meetings conjunction with various professional societies and government agencies to broaden awareness around the opportunities and benefits of composting toilet technologies. One such presentation has been made during this feasibility study to a community group in Central Victoria and information on the project has been provided to a Council in NSW which is attempting to deal with overload on one of its sewerage systems.

It is also assumed the Smart Water Fund and its contributors will provide some of the publicity for the results.

3. Literature Review for Composting Systems

This section reviews published information on dry composting toilet technology, urine separation, trials of the technology elsewhere and on health issues and risk management.

3.1 Introduction

A review of published information on composting toilets, sanitation alternatives generally and related topics was undertaken with emphasis on the following:

- nutrient loads, compositions and volumes of human excreta;
- use of composting toilets in Australia and overseas;
- design, operation and configuration of composting toilet systems;
- potential for re-using both urine and compost as fertiliser materials;
- energy usage comparisons between traditional centralised sewerage treatment systems and composting toilet systems.

A summary of the findings is presented here; for the full literature review, refer to Appendix A.

3.2 Estimation of Excreta Loads

A number of studies relating to compositions of traditional sewage and wastewater have been reviewed alongside studies specifically considering residues produced by composting toilets. From this review a comprehensive range of load data suitable for use in the feasibility and design phases of this project has been assembled. The per-capita daily loads adopted for use in this feasibility study are shown below (the full data table, with references, is included in Appendix A of this report).

A significant proportion of the total nutrient load (BOD, COD, TN, TP, K) of excreta is present in the liquid component (urine), and this is the basis for development of urine-separating toilets and waterless urinals.

3.3 Composting Toilets – Use and Attitudes in Australia and Overseas

Although composting toilets are widely used in remote areas in Australia both for private houses and public facilities and as a sanitation solution in developing countries, the majority of examples of their use in more densely populated residential areas come from Scandinavia, the US and Canada. There is growing interest and use in the urban setting in Australia and several water authorities and councils have permitted use of composting toilets within urban areas in recent years.

Crockett, 2000, assessed the feasibility of using composting toilets in a dense urban environment with grey water discharged to sewer and concluded that, for an unsewered city, there is a potential economic advantage over conventional sewerage as well as environmental benefits, particularly where nutrient had to be removed from sewerage prior to discharge.

Maher and Lustig, 2002, looked at decentralised water supply and sewerage systems and concluded that systems using composting toilets had merit for the urban setting.

Table 3.1 Adopted Loads (g/c.day unless stated)

Component	Urine	Faeces	Paper	Total
Total Volume (L/c.day)	1.2	0.18	0.02	1.4
BOD_5	7.5	11	1	25
COD	15	33	-	50
TN	10	1.2	-	11
TP	1	0.5	-	1.5
K	1.5	0.7	-	2.2
Na	3	-	-	3
Ca	0.3	1.1	-	1.4
Mg	0.2	0.15	-	0.3
Cl^-	6	-	-	6
SO_4^{2-}	1.2	-	-	1.2
NH_3.N	0.7	-	-	0.7
Fats	0.0	4.5	-	4.5
Organic Carbon	6.6	21	-	27
Organic TS	40	40	-	80
TS	70	44	9.966	120
SS	-	-	9.06	-

A large installation of 25 composters and 47 pedestals at the Thurgoona Campus of Charles Sturt University is the largest identified application of composting toilets in Australia. Details of this system and experience with it are included in Appendix G.

Mitchell (2002) reported CSIRO investigations of alternative approaches to providing sustainable water services for a 226 ha residential and industrial development near Brisbane. This work was part of CSIRO's work on investigation of options for urban water supply, stormwater and sanitation (The "Urban Water Project". The study included investigation of three scenarios involving different methods of supplying water and sanitation and dealing with storm water, including a scenario where the development was disconnected from the sewerage and water supply system. The latter scenario included evaluation of the alternative or composting toilets as an alternative to black water sewerage. The conclusions from this study were that more work was necessary but that disconnection from sewerage and water supply had the best overall environmental rating. No specific conclusions were reported on the composting toilet alternative. It was also concluded that more conventional approaches would be more likely because of developer and customer resistance although the basis for this conclusion was not stated.

3.4 Composting Toilets – Operational Aspects

The most important factors in the success of a composting toilet system are the maintenance of an aerobic environment through suitable ventilation (US EPA, 1999) and maintaining the temperature at greater than 20 degrees Celsius (Burrows, 2003).

Australian experience has been largely with single units in remote locations, including many of the "Clivus Multrum" design which was developed in the early 1900s and also commonly of the rotating chamber type. Burrows (2003) indicates that where urine separating pedestals are used, addition of bulking agents (such as bark chips and sawdust) is not generally necessary.

The design and installation parameters of the Rota-Loo® waterless composting toilet system proposed for this demonstration project and described in Section 4 (Environment Equipment, Australia) have been developed to ensure that the organic waste from the human body is processed and stored to facilitate natural degradation through an odourless, aerobic process.

The innovative design of the urine separating toilet pedestal allows the urine, which is high in nitrogen and phosphorus, to be separated from the faecal material. This has a significant implication not only in the composting process but also in the functionality of a domestic waterless toilet.

Faecal material is also high in nitrogen and when mixed with the carbonaceous material of the toilet paper (and where necessary) other bulking materials, the Carbon to Nitrogen (C:N) balance is a great deal closer without urine to optimum for composting.

Too much liquid in the composting pile can create an anaerobic environment, which is a major source of odour. Separating the urine can significantly reduce or eliminate odour.

Following the process of decomposition, human excreta become inert except for its properties to rejuvenate soils and close the nutrient cycle.

The Rota-Loo® system has been in use and development for a number of years and experience with this system is summarised below:

- source separation within the pedestal or by letting urine freely drain through the composting faecal matter and paper is important to aid in aerobic composting;
- separation of urine had in the past required men to sit while urinating, however recent redesign of the toilet pedestal allows conventional use while still capturing and redirecting uncontaminated liquid;
- there are a number of methods for evaporation of urine (to reduce or eliminate the volume of urine to be removed and transported from the system), including an open evaporation pan or a wicking method;
- compost volume is generally about 33% of the initial volume (and probably close to 33% of the total wet mass) of faecal matter and urine;
- a full bin in the Rota-Loo® system can weigh in the order of 30 kg;
- the composting process functions well in the range 20-25 °C, however an optimum temperature range is 28-30 degrees.

3.5 Compost & Urine as Fertilisers and Urine Source Separation

Apart from the obvious advantage that composting toilets provide a way to significantly reduce household water usage, one of the values of composting toilet systems is that a major proportion of the nutrient load currently handled by the sewage treatment facilities of major cities can be removed from the system.

However, without the development of options for reusing end products (compost, leachate and urine) from composting toilet systems, this value cannot be fully realised, as the products would have to be disposed of to more traditional treatment plants. Compared to other organic fertilisers, there is a higher proportion of directly plant-available nitrogen in source-separated urine (Jonsson, 1997). The use of source-separated urine as a fertiliser also has advantages in terms of hygiene, because very few pathogens are present in urine, and due to rapid die-off of pathogens in the collection tanks.

Johanssen (2001) reported on a major collaborative research project conducted in Sweden in 1996 on the use of urine separating toilets in two residential estates, both a few kilometres south of central Stockholm), Understenshöjden (44 apartments) and Palsternackan (51 rented apartments). Both used toilet bowls with a front urine collection section (which came onto the market around 1993), water trap and storage tank for separated urine. Faecal matter and grey water was discharged in one case to an on-site septic tank based system and in the other case, to sewer. Urine was tankered from on-site storage tanks to plastic tanks at an agricultural site near Lake Bornsjön in Salem.

In the abovementioned study, urine application rates were tested and associated crop yields measured. Application to the agricultural land was by surface spreading from an array of trailed hoses. Various application rates were tried and crop yields measured. The result was that the crop yield was concluded to be around 80% to 90% of that achieved with chemical fertiliser. About 10% of nitrogen in the urine was lost as ammonia and odour was noticeable during spreading, but not to any significant distance. Odour on the application sites disappeared within 24 hours.

Lienert et al. (2003) conducted a mail survey of 467 Swiss farmers. Conclusions from the study were that farmers having a real need to purchase additional fertilisers would be most likely to accept a urine-based product. This meant the market chances would be especially high among “integrated production” and vegetable farmers, although expectations were that the product would have to be cheap, odourless, of the desired type (grainy ammonium nitrate) and free of micro-pollutants.

Evaporation of urine to produce a granular fertiliser has been investigated and shown to consume less energy than production of chemical fertiliser having similar composition.

3.6 Health risks

Composting of faecal matter is effective in inactivating or reducing the viability of most pathogens except ova of helminths which tend to be resistant. Compost is generally regarded as relatively safe to handle provided care is taken and normal hygienic practices are observed. Most quantitative work on health risk and pathogen survival has been undertaken to assess the risks from faecal matter contaminating source-separated urine.

The health risks associated with re-use of urine as a fertiliser are largely due to contamination of the urine with faecal matter. Human urine does not generally contain pathogens that can be transmitted through the environment. Factors affecting the persistence of micro-organisms in source-separated human urine include temperature, pH, dilution and the presence of ammonia. Hoglund (2001) conducted a study into the persistence of pathogens in source-separated human urine, and an assessment of the risks. Conclusions were that risks associated with re-use of human urine as a fertiliser were generally low. Hoglund and Ashbolt (2002) also concluded that associated risks were low. More detailed discussions of these two papers are provided in Appendix A.

3.7 Literature Review Conclusions

It is concluded from the review of literature that urine separating toilets and composting toilets are established technologies but large-scale agricultural use of compost and urine, whilst it has been investigated, is yet to become established. Farmers in Europe have indicated interest in use of urine from urine separating toilets but use will only grow with continuing demonstrations of the type undertaken by Stockholm Water. This situation is not dissimilar from the situation in relation to biosolids and effluent reuse in agriculture that currently exists in Australia.

It is also evident that the concept driving this feasibility study, that composting toilets offer a waterless, lower energy, more ecologically sustainable means of sanitation than water flush toilets, is being pursued in several countries and in 2002 was the subject of an international conference.

Whilst more development work is needed on the beneficial reuse of residues and on the optimisation of design of composting toilets, urine-separating composting toilets are an established and proven technology offering advantages of low odour in the home and reduced household water use. The barriers to their adoption are lack of knowledge, false perceptions and resistance to change both in the general community and amongst the technical and decision-making community. A demonstration project can be a useful tool in overcoming these barriers towards an ecologically sustainable solution.

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4. Development of the Prototype Design & Installation

The purpose of this section is to present information developed during preliminary design of the demonstration project. It describes the issues and possible design solutions for a dry composting toilet installation in the high density residential development, which is the proposed site of the demonstration.

4.1 Introduction

There are at least eight different commercial composting toilet manufacturers in Australia, with some 23 different models.

Within these there are a number of systems of operation, from worm farming to dry composting, and including kitchen waste collection and treatment.

This section describes the composting toilet type and installation proposed for the demonstration project and the reasons for each equipment and design element selected.

4.2 Composting Toilet design

The proposed type of composting toilet is the Victorian-designed Rota-Loo®. Figure 4.1 shows the general arrangement of this type of rotary unit and Figure 4.2 shows a sketch of one Rota-loo® configuration. The Rota-Loo® design includes additional detailed features related to ventilation and bin design not shown in Figure 4.1. The key elements are the carousel on which compost bins are located and the urine-separating pedestal. Within the front of the pedestal is a compartment for collecting the majority of urine, draining to a urine collection tank.

The toilet lid is kept closed when not in use. When the toilet is used, a continuously-running fan creates a downdraft. This prevents odour emission into the indoor room, a distinct advantage over a conventional water-flush toilet. Faecal matter and toilet paper collect in one of several perforated compost containers on a turntable within the compost chamber. Urine and other liquids that are not collected in the compartment in the front of the bowl drain through the compost and either evaporate or are collected separately. No mixing of the compost is necessary with this design. Insect breeding and escape is controlled by a combination of ventilation and insect screening.

The main gas generated is carbon dioxide. Some limited amounts of oxides of nitrogen, hydrogen sulfide, ammonia, amines, and other odour-causing gasses will be released. The proposed demonstration project will investigate composition of the gasses and the effectiveness of a compost bed filter for odour removal.

The porcelain pedestal will be of a new design with a high quality lid. Because of the limited numbers produced only white will be available which restricts the bathroom colour scheme.

GHD

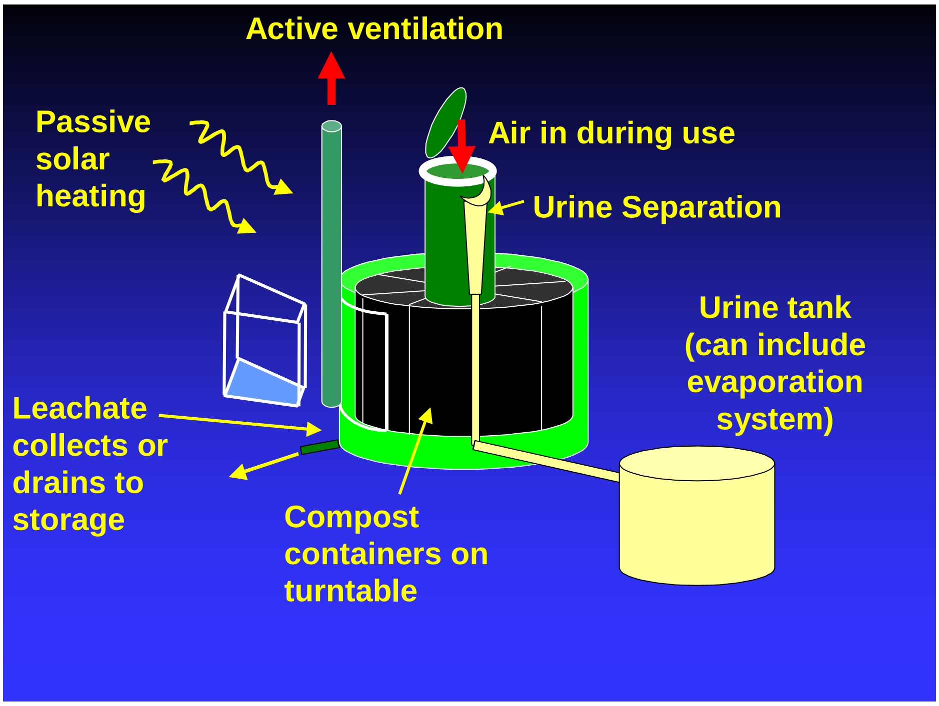

Figure 4.1 Proposed Composting Toilet (Rotary Type)

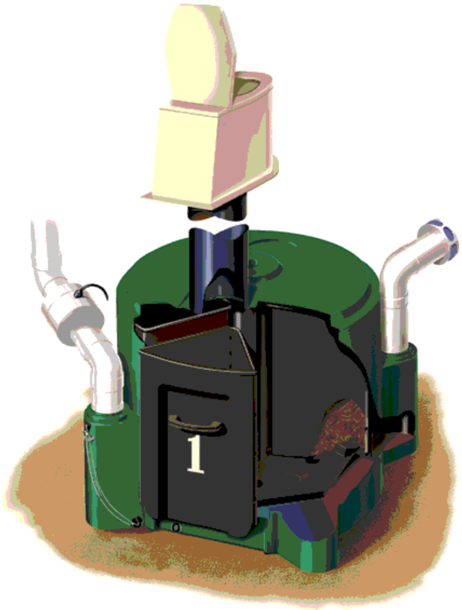

Figure 4.2 Diagram of a Rota-loo® Configuration

4.3 Urine Separation

Source-separation of urine has several advantages, relating to different aspects of the project. These are discussed below:

Maintaining aerobic composting conditions:	◗ by diverting as much urine as possible away from the composting bins and into urine storage tanks, it is easier to maintain a drier compost pile; ◗ if no liquid builds up in the bin then aerobic conditions will be more easily maintained, thereby minimising the risk of foul odours (from anaerobic conditions) being experienced by residents, and lowering the number of 'failed' compost bins. Aerobic composting also maximises pathogen inactivation;
Sterile urine (separated at source):	◗ urine leaves the human body as an essentially sterile liquid; ◗ research overseas has shown that urine has very low pathogen levels if it is uncontaminated with faecal matter; ◗ by diverting the urine fraction before it comes into contact with the faecal matter, the urine will remain low in bacteriological, parasite and viral risk to handlers.
Lower central wastewater treatment costs and longer treatment facility life:	◗ approximately 80% of nitrogen, 40% of phosphorous and 50% of potassium in domestic wastewater come from the urine fraction (Johanssen, 2001); ◗ by removing these valuable nutrients from the sewer system, long-term benefits for the wastewater treatment system could be achieved, i.e. extended life and lower operating costs;
Replacement for traditional mineral fertilisers:	◗ nutrient levels in source- separated human urine are comparable to those found in commercially available mineral fertilisers; ◗ by reclaiming the nutrients from urine and faecal matter and utilising these products for growing crops, we can replace a proportion of industrially produced fertiliser and lower the greenhouse emissions associated with their production.

The urine separation arrangement proposed may be of two types, the more conventional design with a separate small bowl in the front of the pedestal and a new design where urine running down the front of the bowl clings to the surface and then enters a diversion pipe. This newer design allows men to stand when urinating.

4.4 Loads of Compost and Urine

Table 4.1 summarises the expected quantities of solid and liquid excreta before and after composting for the 12 apartments with an occupancy of 2.25 persons per apartment (say 27 people). Details are included in Table D1, Appendix D.

Table 4.1 Calculation of Loads for 12 Apartments and 27 People

Component	Raw g/d		Losses %		Yearly Loads kg/yr			
	Faecal+ Paper	Urine	Faecal + Paper	Urine	Compost	Clean Urine (assume 60% collected)	Leachate[1]	Total
Total Nitrogen	32	270	10%	10%	21	53	25	99
Total Phosphorus	14	27	0%	0%	6	5.9	2.8	15
Potasium	19	41	0%	0%	9	8.9	4.1	22
Organic Carbon	567	178	25%	5%	163	37	17	217
Total Salts	567	1 701	0	2%	280	365	170	815
Calcium	30	8	0%	0%	11	1.8	0.8	14
Magnesium	4	5	0%	0%	2	1	1	3
Sodium[2]	8	73	0%	0%	6	16	7.5	30
Total Solids	1 457	1 890	30%	2%	453	406	189	1 048
Water	3 888	32 400	93%	2%	211	6 954	3 245	10 409

1 Assumes 70% of all urine not collected as clean urine ends up as leachate and 10% ends up in the compost (and 90% of water then evaporates).

2 Assumes 10% of the totoal sodium is in faecal matter.

It can be seen that around 0.6 tonnes/yr of compost (453 kg plus 211 kg of water), about 7 kL per year of urine and about 3 kL/ yr of leachate are expected from the fully occupied development, a total of about 11.5, say 12 tonne/yr. A urine tank of around 10 kL and a leachate tank of around 5 kL are proposed both with overflows to sewer and vents to the biofilter. Inlets will be in the bottom of the tanks. Compost will be stored within the individual bins in the carousels.

4.5 Ventilation and Odour Control

There are two main requirements for ventilation of a composting toilet system:

- ventilation for control of odours; and
- ventilation for maintenance of the aerobic composting process.

AS/NZS 1546.2:2001 requires that the composting toilet ventilation for odour control be separate from other building ventilation. For odour control to be effective the composting toilet should be directly ventilated to outdoors with make-up air supply from the apartment space entering via the toilet pedestal. The Rota-Loo® design also has also has a separate air intake.

4.5.1 Ventilation for aeration

AS/NZS 1546.2:2001 gives a recommended value of 200-300 L/c.d of airflow to provide sufficient oxygen for the composting process of a “full” compost pile. Assuming three persons per apartment this equates to 300 x 3=900 L/day, which is a very small flow rate.

The airflow for aeration should pass through the compost pile i.e. it should not bypass directly from the pedestal to the exhaust vent.

4.5.2 Ventilation for odour control

AS/NZS 1546 stipulates: "*There shall be continuous extraction from the toilet pedestals so that no odour associated with the composting toilet is detected by the user.*"

Rota-Loo® designers recommend a fan to draw air through the composter, which also provides a negative pressure under the pedestal to prevent odours entering the building. This is considered to be an acceptable approach and it has been adopted as the basis for the feasibility study and for estimating the ventilation airflow and energy requirements.

The determination of airflow for ventilation purposes was based on minimum capture velocity at the toilet pedestal to prevent odours escaping to the room. A capture velocity of 0.25-0.5 m/sec at the pedestal was considered acceptable. Assuming a 190 diameter pedestal opening and 0.5 m/sec velocity an airflow of approximately 15 L/sec is required at a toilet pedestal. This airflow would coincide with the toilet seat up (no restriction to airflow entering the pedestal). The airflow entering the toilet pedestal when the seat is down will be significantly less. The actual airflow in this case would be determined by size and number of air gaps when the toilet seat is down.

Each apartment will be fitted with two toilets serviced by one composting and ventilation system.

A bypass air balance inlet would be necessary to provide constant aeration when the lid is closed and to cater for varying airflows through the toilet pedestals, (i.e seat up or down), whilst reducing variance in airflow rate at the fan.

It is proposed a bypass airflow of 15-20 L/sec be adopted when both toilet seats are up (2x15 L/sec) giving a total airflow capacity of 50 L/sec. This should allow balancing of the system using a damper in the bypass inlet. Under this arrangement the total airflow exhausted by the fan would vary slightly when toilets are used, with the balance of airflow being provided via the bypass inlet air. This is a conservatively safe air flow since proper ventilation is vital and failure to provide it has been the principal problem encountered with composting toilets. It could well be that substantially lower ventilation rates will be sufficient so some flexibility will be built in to the design.

The precise configuration of the air extraction outlet will need careful attention at detailed design stage to ensure that:

- preferential airflow is through the toilet and chute before the bypass inlet;
- both upstairs and downstairs toilets are adequately and equally ventilated; and
- air passes through the composting pile, including all six bin segments before leaving the carousel.

4.5.3 Fan Monitoring for Energy Consumption

It is proposed to fit at least two apartments with variable speed fans, power metering and pitot tube insertion points for airflow velocity and temperature monitoring. These would be used to investigate minimum airflow required and power requirements by running trials.

The possible annual energy consumption of a fan for one apartment is estimated to be around 262 kW.hr/yr based on the 30 W rating of the fan proposed. This is a significant additional household energy use. With a conventional toilet and all excreta discharged to the sewer the likely energy use per household for wastewater transport and treatment (WC water only) would be around 43 kW.hr/yr. Environment Equipment's experience on single-storey installations is that a four W fan is normally sufficient. This would correspond to 35 kW.hr/yr per apartment. The difference between the 4 W and the estimate in this study of 30 W is due to the conservative selection of air flow rates since there will be difficult to vary the installation once it is installed. Provision to vary air flow and hence power drawn by the fan but at this stage the best estimate is that fan power will not be less than 4 W per apartment and not more than 30 W.

Energy consumption of the fans is a significant issue that will need investigation.

4.5.4 Odour Scrubbing

No reference has been found in the literature to the level of odour in exhaust air from vents and from the site visits it appears that odour emissions from vents are at a low level and usually easily dispersed before reaching the ground or ventilation intakes. Nevertheless, in a high-density environment with surrounding buildings and structures, the risk of odour from roof-top vents must considered, therefore and hence installation of a biofilter (soil) odour scrubber is currently proposed. It is not yet decided whether this will be within the garden at ground level with provision for a single vent stack discharging above the building or roof-mounted. Rooftop sitting has the advantage of not impinging on valuable outdoor space around the apartments, unless there is roof access by residents then undesirable. The currently proposed building design plan would need to be modified to incorporate additional structural strength to carry the added weight of the biofilter and would limit the potential for solar hot water and solar-voltaic collectors (which are being considered). The location will be determined during detailed design.

For costing, a ground level installation has been assumed, as this will be more easily maintained. The compost bed filter will be equipped with moisture sensing in the compost bed and fine irrigation sprays using mains water to keep the compost moist. It would be constructed in a plastic-lined excavation blending in with the landscaping. The exhausted air would be collected in a space above the compost and discharged to a roof top vent. Sampling ports will be included for airflow measurements and sampling. Trial of ground-level discharge may also be undertaken if odour levels are sufficiently low. Review of the literature shows that such compost beds will achieve some ammonia reduction.

The proposed design allows for a combined air ventilation rate of 240 L/s (20 L/s per apartment) since it is unlikely that all composting toilets will be open at one time and since the probable ventilation rate will be substantially lower than that allowed for in the design for individual apartments.

A preliminary sizing for the biofilter soil bed is 10-15 m^3 or around 10 to 20 m^2 in area.

None of the composting toilet sites inspected had any odour scrubbing. However, interview of the owners at one site indicated that there is periodic odour from the roof vents and that under still cool conditions this can cause odour at ground level. An alternative method to biofilters would be a vent stack direct from the ventilation exhaust to a suitable height above the apartment roofline, estimated at 4-6m. This option may also be considered at detailed design stage.

4.5.5 Control of Insects

Observations of three installations during this feasibility study indicate that houseflies and blowflies are not difficult to control by use of flywire on vents and by closing the lid between uses. However, two of the installations either suffered or had suffered infestation by small midges. One of the installations had controlled these by using nylon stockings over the vents. It is clear that a fine mesh screen will be necessary.

If midges are not controlled, spiders are attracted and cobwebs can cause reduced ventilation airflow.

One installation that had earthworms added appeared not to have a problem with flies or midges.

The facility visited that used added wood shavings attracted slater beetles.

None of the facilities visited reported problems with crawling insects entering the toilet room.

It is proposed that the demonstration installation include fine mesh screening, no addition of wood shavings, a design that inhibits crawling insects entering the toilet room and provision for easy access to all ventilation ducts for clearing of spider webs.

4.6 Heating

The dry composting system proposed by Rota-Loo® for application in this project requires the compost pile to be maintained at a minimum temperature of 20 deg C, and preferably over 30 deg C.

To avoid heat loss and maintain heat in the compost pile the following features are recommended:

- insulate the composting unit housing
- heat the bypass air drawn into the composting unit. (It is assumed that air drawn into the toilet pedestal from the toilet room would be nominally 20 deg C.)

Furthermore drafts must be eliminated from the space containing the composting unit.

The trial will incorporate supplementary heating of the composting material by means of hot water heating coils in the inlet air that is drawn direct into the composting chamber via the bypass inlet. Whilst most composting toilet installations do not incorporate this supplementary heating, the composters in the trial development will be on the south side of the building away from any possible passive solar input. This location is a requirement set by the development designer because the development faces parkland to the north and the value of the apartments will be maximised by having both maximum window area for the view and direct ground level access out into open space to the north of the building. Two further reasons for incorporating supplementary heating include the need to minimise the possibility of slow or no composting due to temperature of the composting mass dropping below 20 ^{o}C and the value of being able to investigate performance versus temperature.

Several options were considered for providing supplementary heating including air/air exchange with apartment ventilation air, passive solar heating of induct air in a collector on the roof and the adopted process involving use of hot water in a heat exchanger on the induct air vent to the composter. In addition, consideration was given to passing sink, shower and washing machine drainage through finned sections of pipe within the composter space.

The least costly and most practical method for the trial was concluded to be a hot water heat exchanger in the induct air operated by thermosyphon from a roof-mounted solar hot water service with gas boosting. It is assumed that the apartment hot water service will provide this duty.

Calculations show that a circulation velocity via a 20 mm insulated copper pipe with a 2^{o}C temperature differential and a flow rate of 0.12 L/s per apartment could provide sufficient energy to heat 15 L/s of induct air from 10 ^{o}C to 30 ^{o}C. The actual ventilation rate necessary may well be substantially less than this. Calculations in Appendix B also indicate that, assuming heating is only required for 40 days per year, gas usage could be of the order of 0.3 GJ/yr per apartment assuming that on these days only 30% of the hot water demand can be met by solar energy. Further detailed work would be necessary in the design stage.

Because of the need to minimise energy use with the installation, it is proposed to install both air flow and water flow temperature and flow monitors as well as temperature monitoring of the composter in two apartments so that the system can be optimised and different operating temperatures and heating strategies can be tried. A small programmable electronic controller and water solenoid valves would be provided to automate the supplementary heating.

4.7 Building layout

From an architectural point of view the evaluation of waterless, composting toilet systems in a medium or high-density building configuration poses particular challenges.

High-density housing is inevitably developed as a commercial operation by companies specialising in this field. In competing for land suitable for this form of development the price paid is generally determined by evaluating the land cost per unit. This requires that the developer estimate the number of units that can be built, allowing for planning regulations and the level of amenity to be achieved. More units allow a higher land price to be paid, and this drives development towards denser solutions. Such solutions also generally seek to achieve construction and planning efficiencies of a high order. In general, an efficient apartment design provides the maximum enclosed area with the minimum façade or external wall. The limiting factor is the number of individual rooms that can be provided deriving good natural light admission from windows in the external wall. The consequence of this is that an efficient plan will place the non-habitable rooms (bathrooms and service areas) to the interior of the plan away from the external walls, as they do not, by regulation, require natural light.

In contrast, a waterless composting toilet installation will ideally be placed on a north facing external wall, where solar gain can be used to provide warmed air, assisting the composting process. In addition, a composting toilet requires a direct drop to a sizable composting unit that can, in most cases, only handle two pedestals. Therefore bathrooms and in particular toilets must be grouped horizontally and vertically.

Where grouped one above another in a two-storey configuration the 300 mm diameter chute pipe for the upper pan will pass vertically through the lower level using a sizable duct or service enclosure. This must be configured to also carry a pipe carrying separated urine and vent pipes from the composting unit below. The limitation on pan position and the number of significantly larger chute, vent and urine separation pipes is a critical difference between water borne and waterless toilet technologies with a notable impact on high-density building design. Preliminary architectural plans showing the location of the composting toilet system and other features in relation to the unit layout are provided in Appendix C. Figure 4.3 shows the conceptual site plan and the architectural perspective and drainage and plumbing installation figures in Section 2 (Figures 2.1 and 2.2) further illustrate the proposed design.

The access to the composting unit itself is also critical. A chamber extending at least 1.2 metres below the last served toilet is required. This chamber must be accessible from the side for removal of the composting bins. The bins can weigh up to 30 kg, and space for lifting and maneuvering of the bins is required. These factors dictate a significant space provision. Ideally, this area should be capable of being accessed discretely and away from the general circulation and access passages of the building but must be designed in such a way that bins can be removed safely and that it is not classified as a confined space.

From a commercial point of the view, the cost of provision of space both in riser shafts and to accommodate the composting bins and access areas for those bins is significant. This space provision reduces development yield and reduces the efficiency of land utilization, issues that are not as critical in relation to a freestanding individual home. However like thermal performance requirements (such as the soon to be mandatory 5 star energy rating scheme) a regulatory requirement mandated by community pressure to save water and better manage resources could neutralize these commercial pressures. However, it will add to the average price of the housing product. It may also be somewhat more challenging and potentially expensive to apply measures such as waterless composting toilet technology to high rise developments since, in residential buildings exceeding say two to three storeys, a waterless system relying on gravity drop cutes only may not be practicable or viable at this stage. This limitation could be overcome by using a goods lift system servicing composters on several levels but this would take up valuable floor space and add to cost.

Other design parameters include the management and design of the bathroom ventilation system and systems to introduce, warm and distribute the requisite ventilation air. Consideration also needs to be given to the range and style of pedestals available, as the style and quality of sanitary ware often has a bearing on buyer perceptions of apartment products. Similarly, the matching of the finish and colour of the pedestal to complementary sanitary ware in the bathroom is of significance from a commercial standpoint whereas, at present, pedestals are only available in white.

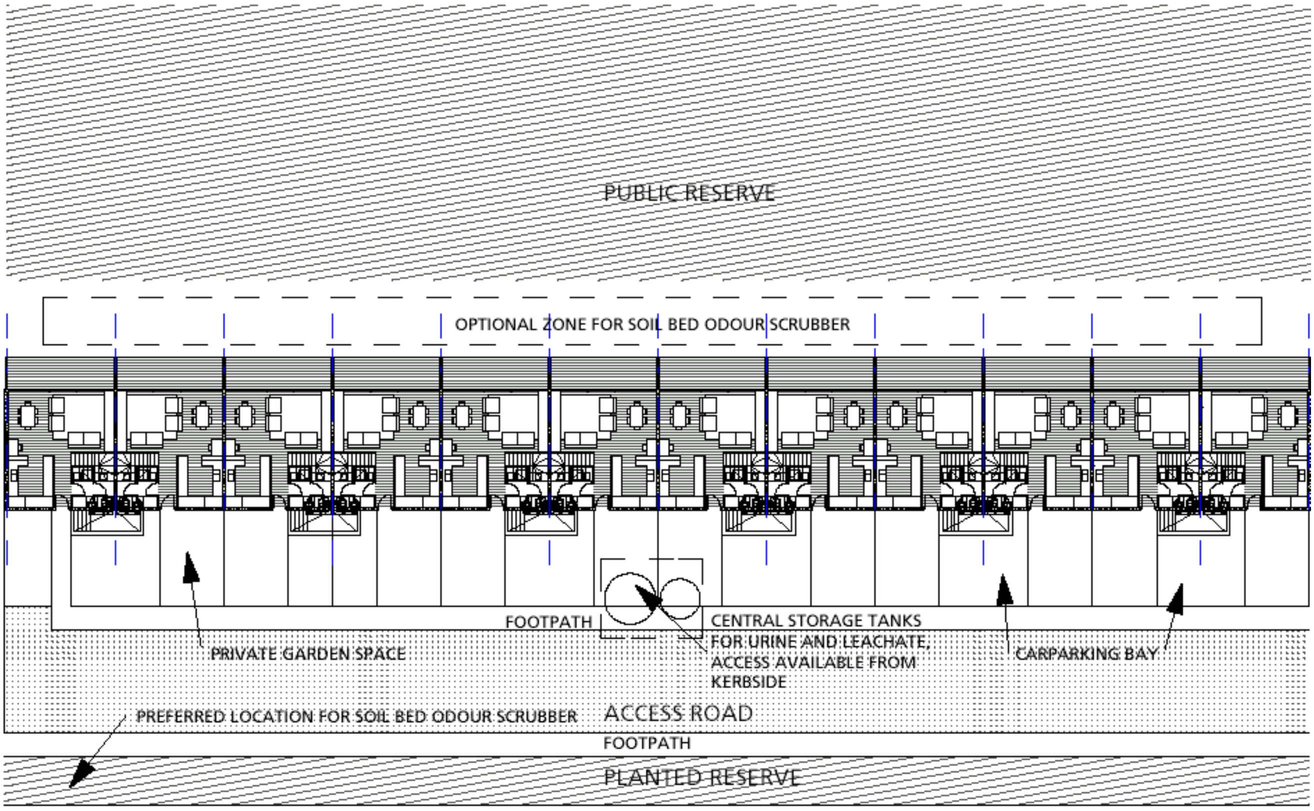

Figure 4.3 Conceptual Site Plan – Ground Floor

4.8 Monitoring of Water Use and Sewage flows

It is proposed that the overall water usage and sewage (grey water) flow from the apartment block be monitored by means of electronic water and sewage flow meters and that provision to periodically install a flow-paced portable composite sampler be made. In conjunction with the household logs described in Appendix E, this information will be used to derive accurate wastewater load and water saving information which will be of a suitable accuracy for use in future designs. Depending on timing of construction of this apartment block and other proposed apartments on the same site, similar monitoring may be installed in apartments with conventional sanitation to provide similar data for conventional systems in this high-density urban environment.

4.9 Other Sustainable Design Building Features

Subject to further feasibility assessment, the following environmental systems are under consideration for incorporation in the apartments:

Further water savings:

The following additional water saving appliances and features will reduce significantly the consumption of potable water use for the whole development (not just for the 12 apartments with dry composting toilets):

- water conserving appliances and fittings (saving from 30-90% of potable water use for different appliances, overall about 70 L/c.d or 25.5 kL/c.yr);
- evaluation of systems to reduce water loss when hot water taps are turned on;
- use of new generation water-conserving washbasins;
- provision of stormwater retention systems for garden irrigation and possible irrigation of the adjoining reserve area (volume depends on storage capacity and usage);
- possibly consideration will be give to grey water treatment and recycling for garden irrigation;

Energy savings:

- energy conserving appliances and light fittings. Evaluation of alternative designs in high-energy use appliances, particularly fridges;
- provision of systems to allow for natural drying of laundry (often not possible in medium and high density developments);
- use of active solar systems including solar hot water and photovoltaic cells;
- selection of construction materials for low embodied energy, using recognised materials ratings systems;
- high performance building envelope optimizing use of insulated thermal mass to stabilize internal temperatures in both summer and winter. Use of construction systems that allow for incorporation of environmental systems, for instance thermo-mass exterior wall construction, super-insulated roof constructions and floor slabs;
- use of new generation window technology to control heat loss and gain and provide a range of options for both manual and automatic operation of ventilation hoppers and trickle ventilation systems, based on computerized analysis of external climatic conditions;
- use of passive solar design to reduce heating and cooling requirements;
- use of new generation flexible soft wiring systems that allow for more sophisticated control and energy regulation protocols, including provision of sensor activation of lighting and use of automatic dimming systems responsive to the availability of natural light;

Waste minimisation:

- provision of systems to aid separation and management of waste;

- use of flexible, modular interior fit out systems including kitchens, wall units, storage unit etc. that can be readily reconfigured, rearranged and reused, reducing waste in the churn of the interior fit out over the lifecycle of the building;
- use of recyclable and reusable wiring systems that allow new power and lighting outlets to be added and rearranged without complex intervention in the building structure or partitioning;
- selection of construction materials for recyclability, using recognised materials ratings systems;

Grey water treatment or reuse:

Grey water can be sent to sewer, treated in wetlands on site or subjected to more energy-intensive treatment and recycled. Grey water recycling opportunities are limited in high density urban developments, particularly if composting toilets are used, since there is insufficient land for disposal of the nutrient and organic matter and since storage is needed over winter when there is no outside demand. There may be limited possibilities for grey water reuse in the demonstration project but they have not yet been considered in detail.

Healthy Living Environment:

- use of cross ventilation and fostering of natural airflows through the building interior;
- use of materials with low allergic risk, low fume generation and low toxicity.

4.10 Collection and Maintenance Contracts

The specific details for maintenance and collection contracts for an inner city compost toilet application were discussed earlier in Section 2.8, as relates specifically to this demonstration project.

Additional aspects to consider for broader scale application are:

- both contractors contacted during this study concluded that a truck specially fitted for the job would be the most effective, particularly in the longer term;
- containment of residues during transportation will be required. The organic compost and liquid residues would most likely be treated as for a septic tank waste. Cartage contractors indicated that they would need to notify the EPA, but that transportation of the residues, if confirmed as being in the same category as septic tank waste which seems likely, would not require a special permit and transportation certificates as for prescribed waste;
- securing the compost, urine and leachate during transportation is important. It will be essential to devise an effective system for containment of the compost, particularly on a large-scale application;
- short distances to reuse will also be important to reduce transportation travel times costs and costs;
- transport cost and time will be minimised if composting toilets are concentrated in particular areas rather than being scattered over a wide area in individual houses.

Medium to large-scale application or at least a long-term contract is necessary to achieve economy of scale and to allow economic transportation. This will offset the initial high set-up costs for specialised equipment and truck fit out.

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5. Water and Energy Saving Potential of Dry Composting Toilet Technology

This section estimates the potential for and value of water saving of composting toilets versus conventional sewerage, discusses the energy use implications of composting toilets compared to conventional sewerage, and discusses the value of residues produced compared to biosolids and water from conventional sewage treatment plants.

5.1 Water Saving Potential of Dry Composting Toilets

By eliminating the need for flushing, dry composting toilets can reduce per capita water use by up to around 19% or 50 L/c.d (up to 18 kL/c.yr) of an average household water usage of 96 kL/c.yr in Melbourne. Whilst a similar reduction in water use can be achieved by using grey water or roof water for flushing, this requires a tank, grey water treatment and a pressure pump and does not reduce overall sewage load from a household.

In Section 10 the sensitivity of operating costs and savings to water price is investigated and it is shown that the saving in water achieved has a significant impact on operating cost, especially if water cost increases in future.

To put this potential water saving in context, for the proposed demonstration project occupied by around 27 persons, the projected water use with and without composting toilets is summarised in Table 5.1.

Table 5.1: Water Savings in the Demonstration Apartments

Case for 12 Apartments	Annual Water Use[1]	Annual Water Cost at $1.50/kL
Conventional water-flush toilets (based on 66 kL/c.yr)	1 774 kL	$ 2 661
Dry composting toilets (based on 48 kL/c.yr)	1 281 kL	$ 1 922
Saving	**493 kL**	**$ 739**

[1] Excludes outdoor water use which will be small for these apartments

Whilst the dollar saving is minor, the water saving of 27% just from the toilet is enormously significant, enough to supply water to another ten persons in the apartments.

The potential water saving if dry composting toilets were adopted more widely would be significant but is not in itself the only justification for the proposed demonstration. 100% adoption in a given area could reduce indoor water use and wastewater flow by around 25% to 28%. However, across Melbourne there will only ever be a partial adoption in the foreseeable future since retrofitting to many properties would be difficult and because there will be considerable resistance to change (at least in the short to medium term).

For example, if around 20% of all houses and apartments were to adopt composting toilets in future, future wastewater flow from households in Melbourne could be around 5% lower than it would otherwise be. If 40% adoption was achieved household wastewater flow may be 11% lower than it would otherwise be. The impact on overall wastewater flow would, be less, around a 3% and 7% reduction respectively for 20% and 40% adoption because of non-household wastewater contributions.

Overall water consumption in the city would be reduced to a lesser degree because of outdoor and garden usage, industry usage and irrigation of parks and playing fields. It is estimated that a 20% adoption of composting toilets may lower overall household water consumption by around 2.4% and a 40% adoption by around 4.9% based on overall average water consumption of about 150 kL/person.yr including all non-domestic use.

It is concluded that the potential contribution of composting toilets to reducing wastewater flow and overall water use is significant. A similar conclusion would probably be reached about use of recycled grey water collection for toilet flushing, although in the case of roof water use it would not reduce wastewater flow.

5.2 Reduced Pollutant Concentrations and Loads in Household Wastewater

The largest single benefit of dry composting toilets is reduction in pollutant loads in the wastewater system, which would flow on to reduced treatment capacity requirement and treatment cost, probably reduced loads to the environment and reduced biosolids yield.

For example, Table 5.2 summarises the likely change in domestic wastewater strengths with 20% and 100% adoption of composting toilets.

Table 5.2: Effect of Composting Toilet Use on Wastewater Loads in the Urban Environment

		Wastewater Concentration and Percentage Reduction				
Component	**Unit**	**Current Flow and Concentration**	**20% Adoption of Composting Toilets**	**% Reduction at 20% Adoption**	**100% Adoption of Composting Toilets**	**% Reduction at 100% Adoption***
Flow	L/c.d & %	180	170	6%	130	28%
BOD	mg/L & %	333	324	3%	206	38%
SS	mg/L & %	333	312	6%	147	56%
TN	mg/L & %	69	61	13%	8.8	87%
TP	mg/L & %	10	8.8	12%	1.8	82%
TDS	mg/L & %	833	782	6%	382	54%

* i.e. percentages as for the 12 apartment units with 100% composting toilets

It can be seen that some significant reductions in strengths (and consequently loads) can be achieved, with a 20% adoption of composting toilets. For example, a 13% reduction in nitrogen load would be achieved. With full adoption, the reductions in total nitrogen and total phosphorus loads of over 80% are very significant and the reductions in TDS, BOD and SS of 40% to 50% are major. Total dissolved salts could be reduced by 54% at 100% adoption, a major benefit for reuse of grey water. The significant reduction in nutrients by removal of urine from sewage is the reason urine separating toilets have been adopted in parts of Europe in combination with conventionally sewered homes. Composting toilets go a step further in nutrient recovery and include significant water savings.

The greatest benefit of the technology would be if it were applied to new outer-urban subdivisions where local wastewater treatment and reuse is proposed. The wastewater stream would be much simpler and cheaper to treat and salinity and nutrient loadings on the reuse area significantly reduced.

5.3 Energy

It is vital that any alternative sanitation system reduces use of energy derived from fossil fuel, or at the very least does not increase fossil fuel use significantly. Several authors have looked at this issue and the overall conclusion is that composting toilets with urine separation can reduce overall energy use for sanitation, but only if savings in energy input to manufacture of chemical fertiliser (that is energy savings due to substitution of manufactured fertilisers by urine and compost) are considered. Other investigations have generally neglected to include the energy use by ventilation fans since many compost toilet installations use natural draft ventilation or solar-powered electric fans. This section considers energy inputs for the type of high-density urban apartment composting toilet system proposed.

Because, in an established urban area, there will usually be a sewerage system, the embodied energy in this system has not been considered quantitatively. Likewise, the embodied energy in the road system required for collection of compost and urine has not been quantified. It is reasonable to conclude that the embodied energy components attributable to either a conventional or composting system will be insignificant.

For an un-sewered town or area, adoption of composting toilets will reduce the size and grading requirements of sewers and the size of the treatment and disposal or reuse infrastructure as this infrastructure will only be required to handle grey water. Hence embodied energy will be significantly reduced. By contrast, as use of roads for collection of compost and urine will be a minor part of overall road use it is reasonable to conclude that composting toilets will have an embodied energy advantage and therefore embodied energy has not been estimated. Generally, where it has been considered, the conclusion is that embodied energy makes up only a relatively small fraction of a system's total lifecycle energy use and rarely influences the conclusions of an energy analysis.

In the case of building works, there is no doubt that composting toilets will require more materials for the building and for the compost unit itself. However, this will be dependent on the type of building and will be a small fraction of overall building embodied energy. It has been omitted from this calculation.

Operating energy use makes up the bulk of the lifecycle energy of a system. Table 5.3 summarises estimates of operating energy and greenhouse emissions for both conventional and composting systems in a large city the size of Melbourne (about 3.5 M people) where the areas for reuse of compost and urine will be distant. A round trip of 100 km to get compost and urine to the reuse site has been assumed. Two cases have been incorporated within Table 5.3:

- where the sewage treatment plant generates 70% of its own electricity and electricity and gas are used for ventilation and heating the composting toilets;
- where the sewage treatment plant generates none of its own electricity and the ventilation and heating for compost toilet installations is solar-powered.

It can be seen that the total energy use and greenhouse emissions are very dependent on energy use at the composting toilet installations and on the degree of self-sufficiency in energy generation at the sewage treatment plant.

If the transport distance was reduced, such as in a small town or fringe area, energy use for a composting toilet system with grey water to sewerage will reduce substantially.

This case assumes a ventilation fan consumption of 4 W per household. If this is increased to 20 W which is still below the design allowance proposed in Section 4 of up to 30 W, the 358 MJ/c.yr for ventilation and heating increases to 1 255 MJ/c.yr and total energy use for the dry composting toilet system becomes 1 426 MJ/c.yr, which is substantially greater than for a conventional sewerage system. However, a composting toilet system with road transport does have potential to be significantly lower in operating energy use than conventional sewerage provided energy use for heating and ventilation of the composting system is minimised. A total average pumping lift in the sewerage system of 50 m has been assumed for the sewerage energy calculations.

The transport energy use in Table 5.3 is based on a five tonne truck carrying only 2.5 tonne of material. If larger trucks were used then the relative energy use for trucking would decrease substantially. However, if uptake of dry composting toilets is dispersed over a wide area then the transport distances and utilisation of load capacity of the vehicles would be reduced.

Table 5.3 Estimated Energy Use per Capita Per Year for collection, Treatment and Land Application of Excreta

Energy-using operation	Conventional Sewerage (WC waste and flushing water)	Composting Toilets
Ventilation and supplementary heating MJ/c.yr	0	0 - 358
Transport MJ/c.yr	105	202
Treatment and Reuse of Residues MJ/c.yr	142 – 434	39
Embodied energy in fertiliser saved MJ/c.yr (negative = saving)	Negligible	- 70
TOTAL MJ/c.yr	**248 - 540**	**171 - 529**
Equivalent diesel fuel use (L/c.yr)	6 - 14	4 - 14
Approximate GHG Emissions CO_2-e kg/c.yr	19 – 42	13 - 41
Lifetime Emissions (50 years) tonnes CO_2-e	**1.0 – 2.1**	**0.7 - 2.1**

Assumptions:

Sewerage system involves pumping against a 50 m head.

Compost toilet system uses 4 W for ventilation (this could be reduced with solar-powered fans)

An allowance has been included for supplemental heating of the compost chamber in winter.

Compost and urine collection by truck running a 100 km round trip at 50% of full load

Energy use is expressed as fuel burnt at the power station or in the transport vehicle

Wastewater sludge cartage by truck running a 50 km round trip

Note 1 MJ is equivalent to the energy available from combustion of about 26 mL of diesel fuel

Clearly there is potential for a sanitation system based on dry composting toilets to use more or less energy depending on a variety of factors and these factors need to be investigated during the demonstration project. In particular, energy use for ventilation and heating must be minimised for composting toilets to be energy-efficient compared to an efficient conventional sewerage system. A conventional toilet could be penalised by assuming there is a ventilation fan in the toilet. However, as such a fan would not run all the time, its energy use may be less than with a composting toilet, and this has not been considered in the calculations.

The numbers above support conclusions on urine transport reached by Jonsson (2001). Jonsson found, in a combined study of information from five different installations of urine separating toilets, that 24 MJ per person per year was required for transporting and spreading the separated urine at a farm site 33 km away from the installation. When taking into account the decreased nutrient load on the sewage system, 31 MJ per person per year was saved. Also, by taking into account the replacement value of the source separated urine, a further 75 MJ per person per year was saved by not producing the mineral fertilisers. These data are of a similar order to the figures derived in this feasibility study but suggest that the 70 MJ/person.yr of embodied energy in fertilisers saved may be conservative and illustrates that energy use for transport can be substantially less if distance to the reuse site is reduced and/or scales of economy improved.

5.4 Value of Residues as a Fertiliser Replacement

The total annual nutrient consumption (as fertiliser) of nitrogen, phosphorus and potassium (NPK) in Australia was investigated in order to quantify the proportion of fertiliser that could potentially be sourced from human excreta. Total use of NPK in Australia as ranging from 1 656 kt per year (ABARE, 2002) to 2 140 kt per year (NHT, 2001). A value obtained for Australia and New Zealand combined was 3 200 kt per year (IFA, 2002). Calculations are provided in Appendix B, Table B2 of this report.

Based on adoption of composting toilets over the entire population, between 4.9 and 6.4% of total fertiliser use in Australia could be potentially recovered from human excreta. Although this figure appears small, it should be noted that a large proportion of food grown in Australia is for export purposes, and in terms of supplying nutrients to feed Australia's population, the proportion able to be supplied from human excreta is likely to be far larger, with significant energy savings.

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6. Trial Reuse Development

This section describes the purpose of and preliminary design for the proposed trial of agricultural use of the urine, leachate and compost generated in the demonstration apartments. The estimated cost of the trial is established.

6.1 The Need for a Reuse Trial

A trial to reuse the nutrient-rich compost, urine and leachate produced from the composting toilets in medium-high density installations is an opportunity to investigate a holistic and potentially more sustainable solution to management of human excreta. Other options for disposal of residues as noted in Section 2.4 (with discussion) are:

- disposal to a sewage treatment plant (this would make composting toilets pointless as the overall energy use would be high and the nutrient value of residues would not be utilised);
- disposal to landfill (this would generate methane which, whilst some could be recovered, is undesirable and the nutrient value of residues would not be utilised);
- application direct to land to replace fertiliser;
- blending with commercial fertilisers or manufacture of a residue derived fertiliser.

Beneficial reuse of urine, leachate and compost, preferably without further stabilisation or processing, in agriculture is a key requirement for the feasibility of composting toilets in an urban area. In this section the feasibility of beneficial reuse is investigated and initial plans for a trial intended to demonstrate feasibility are set out.

Determining crop growth, crop health and survival of any pathogens associated with the reuse of compost and urine as fertiliser on edible crops is a primary aspect of the reuse trial.

6.2 Proposed Reuse Site

Negotiations toward an agreement with Melbourne Water (MW) to lease some land at the Western Treatment Plant (WTP) in Werribee are in progress and MWC has given written agreement in principle to support the project subject to clarification of risks and other conditions. WTP is selected primarily for its land classification status, controlled access, soil type, proximity to agricultural and laboratory expertise and WTP current operations, which make it a highly suitable location for reuse trials with human excreta. The following requirements for the site were acknowledged by MW staff in initial discussions:

- the preferred site is located preferably on the rich Werribee Delta soils not previously used for wastewater or sludge disposal;
- the site will have reasonable access to power and potable water (within 200 m) and road or track;
- access to water for irrigation if required;
- peppercorn lease rate.

Agreement with MW and its Land Use Strategy Committee for WTP will need to be reached before the location and details of the site can be confirmed.

6.3 Transport

Distance and residue volumes for transportation to a reuse site are critical factors in terms of the energy balance for composting versus conventional sewerage. WTP is approximately 45 km by road from the proposed development site in Flemington. One study concluded that the urine could be transported up to 220 km (by truck and trailer) before the adoption of urine separation used as much energy as a conventional system (Jonsson, 2001). This feasibility study indicates that a round trip of around 100 to 150 km is close to the limit for equivalent energy use to Melbourne's sewerage system.

The reuse site will cater for storage of organics and liquids via a series of plastic tanks for urine and leachate, and covered bays or wheelie bins for compost (given the small volume of compost being managed). The waste transporter will off-load the residues on a quarterly basis at the trial reuse site. The urine and leachate will then be distributed by a tractor-towed hose and distributor across the crops as appropriate. Compost would be spread by front end loader and rotary hoed into the soil.

The site will have a dual access for transportation and other operations, with a gravel site road.

6.4 Proposed Reuse Trial

6.4.1 Matching Available Nutrients to Crop Demand

Table 6.1 sets out the available nutrients in the urine, leachate and compost streams from the development based on the loads from 12 residential units estimated in Section 4.3, the likely nutrient uptake rates for N, P and K for a variety of crops and hence the area of crop that could be sustained on a trial agricultural area. Details of the calculations are included in Tables D1 and D2, Appendix D.

Table 6.1 Estimation of Areas for Nutrient Utilisation Trials, 12 Apartments and 27 Persons

Annual Nitrogen Available kg/yr	Crop Type	Typical Application of Nitrogen kg/ha.yr	Area of Crop Using Typical Application ha
99	Irrigated Pasture	180	0.55
	Dryland Grain	80	1.24
	Market Vegetables	130 or higher	0.76 or less

It can be seen that the estimated quantity of material produced could be sufficient to fertilise of the order of one hectare, depending on crop type and whether or not irrigation is applied.

6.4.2 Proposed Trial Crops & Compost/Urine Application Method

The focus of the project is sustainability and pasture for animal grazing is not seen as a preferred use. Given that in the medium-term it is unlikely that a practice of irrigation & fertilisation of vegetable crops with composted solid matter, leachate and urine will be commercialised, this study proposes that dry land (broad acre) cropping of grains will be most appropriate for the trial. Proposed grain crops could be barely, corn or canola. Corn has a high nutrient demand, while canola is a known accumulator of metals.

It has been assumed for the purpose of estimating costs of the trial that several plots will be established to allow appropriate replication and to compare to crops fertilised with normal fertiliser.

Residues would be applied to the soil via tractor-mounted distribution attachments. It is envisaged that the friable compost material would be dug into the soil and the urine irrigated (with some water mixing to ensure an even distribution given the small volumes and high concentration).

6.4.3 Preliminary Design of the Reuse Site & Trial

A preliminary design for the reuse site layout was developed (refer development ideas in Appendix C), and underwent a detailed review from the DPI's Agriculture Victoria Services Pty Ltd. This review and further discussion with the DPI brought to light the need for simpler and less costly trial to demonstrate and monitor some agricultural practices that are more likely to be accepted commercially in the short to medium term. Dryland grain cropping is considered practical, rather than market garden vegetable crops. There is significant agriculture of this kind west of Melbourne and it is considered to be the most likely and most practical agricultural end use for the material produced if composting toilets are widely adopted.

A detailed design for the trial will need to be prepared during the design phase of the demonstration project and the DPI has indicated an interest to be involved in design and operation of this trial. A trial can be designed to meet an appropriate budget depending on what outcomes are expected or required. From the investigations to date this feasibility study concludes that a budget in the order of $300 000 will be appropriate for a basic agricultural trial of dryland cropping for two summer seasons, which demonstrates a practical application for adoption commercially in the shorter term.

6.4.4 Operation of the Trial Site

It is anticipated that the apartments in which the composting toilets are to be installed will be completed mid 2006 subject to planning approval and construction progress. The first loads of compost, urine and leachate would therefore be available around late 2006.

The trial should run for at least two summer seasons, with cropping to be completed by mid 2008 (provided that a summer cropping season in 2006/2007 is achieved) and over this period there would be at least two grain crops.

6.4.5 Monitoring Program

The monitoring program for the trial site will be designed to include the following monitoring and recording element:

- compost and urine compositions, volumes and masses delivered to site;
- application rates to grain crops (including commercial fertiliser for the control crops);
- crop yield and quality;
- presence and fate of pathogens and indicator microorganisms and fate of spiked pathogens;
- possibly some investigation of endocrine disruptors;
- monitoring of soil and groundwater;

- odour and other aesthetic aspects;
- health of transport and trial site staff;
- anecdotal experiences relating to handling of compost, storage and spreading of urine, performance of equipment and other observations.

Preliminary discussion on development of an approach to monitoring of the trial is included in Appendices D and E.

6.4.6 After the reuse trial

Once the trials are completed the trial reuse site will be decommissioned, rehabilitated to its original state and returned to MWC.

Options for continued beneficial disposal of the compost, leachate and urine residues will be identified and investigated during the trial as discussed earlier in Section 2.4.3.

6.4.7 Cost Estimate for the Agricultural Reuse Trial

GHD's initial cost estimate for the reuse trial was based on plots for irrigated root and leafy vegetables, pasture and dry land grain crops. Allowance was made for set up, monitoring and management and reporting over a 2 year period. The overall cost estimate, set out in Tables B6a to B6d in Appendix D came to $723 000 including the cost of transport of the residues to the site. It included allowance for substantial site amenities and monitoring equipment, an irrigation system, and maintenance equipment.

Around $215 000 was for set up and around $284 000 was for ongoing monitoring and maintenance. A substantial contingency was also added.

Following the review by Agriculture Victoria Services and inputs from other reviewers it became apparent that a trial of application to dry land grain crops would be more realistic. This could be achieved at a lower cost.

Revised costs adopted for the agricultural trial component of the demonstration project of $165 000 for set up and $135 000 for ongoing monitoring and maintenance are set out in Table 10.7 with further detail in Table B7 in Appendix B.

7. Marketability and Project Financial Risk

This section summarises the results of a market survey of potential purchasers of high-density residential apartments and describes the issues that the developer perceives in marketing apartments equipped with dry composting toilets. It draws conclusions on the likely marketability of the demonstration project and considers commercial risks and risk management.

7.1 Market Survey

In order to gauge the likely level of market interest, understanding and acceptance of composting toilets in a residential setting, a market survey was developed by GHD and Bensons with input from Environment Equipment. The survey results were collated and analysed with the assistance of GHD's Community Consultation Group.

7.1.1 Survey Design

Survey questions were introduced in three stages (the full survey is included in Appendix F):

- *General Questions* – relating to interest in participating in energy and water savings activities including grey water recycling, water saving devises, and alternative sanitation;
- *Composting Toilet Questions* – to establish background perceptions of composting toilet systems and acceptance (or otherwise) of the system as a sanitation solution;
- *Operational Composting Toilet Questions* – specific questions to gauge willingness to change regular practices and habits that may be necessary for residents of a composting toilet equipped apartment.

All of the questions were designed to give respondents the chance to rate their opinion or feelings on an issue from 'strongly agree' to 'strongly disagree'. Opportunity was also given to provide comments, some demographic details and optional contact details to provide or receive more information.

The survey was distributed in hard copy to approximately 3 000 former, current and prospective clients of Bensons Property Group, and also to the public via an information page for the project on the GHD website (www.ghd.com.au/compostloo). Results from returned surveys have been collated and analysed using a statistical program for inclusion in this feasibility report.

7.1.2 Survey Results

A total of 54 responses were received. A few respondents did not provide an answer to every question. Survey results and selected graphs are included in Appendix F of this feasibility report.

Responses to Section 1 – *General Questions* showed that the majority of people surveyed already do engage in water saving activities in their home or 'would consider' doing so. 81% of people indicated that they already engage in personal action to reduce water consumption. Responses to the question relating to investing in alternative sanitation were fairly evenly spread (refer Chart 1 in Appendix F), with 33% of people stating they 'would consider' investing in alternative sanitation, 39% of people responded 'may consider', and 26% stated that would be unlikely to consider it. A total of 76% of respondents indicated that they would consider spending up to $5 000 extra on an apartment if it offered energy and water efficiency features (Chart 2), although comments showed that more quantitative information relating to annual savings for the homeowner would have been useful. Only 6% of people stated they would be unlikely to consider investing in a more costly, energy efficient apartment. Chart 3 shows how willing people would be to purchase an apartment equipped with dry composting toilets. 55% of respondents would consider purchasing such an apartment, 28% may consider it, and 17% were unlikely to consider.

The Composting Toilet Questions showed a reasonable level of support for the idea that composting toilets would be an acceptable solution for a modern house. Isolated comments were strongly opposed to composting toilets (one respondent said that the systems seemed 'archaic'), but comments also added indicated that customers were supportive of Bensons Property Group investigating and considering ecologically sustainable options for developments. 80% of respondents had never used a composting toilet. Of those that had, it appears that experience has largely been with older models in remote areas (eg: walking tracks). 59% of people either strongly agreed or agreed that there would be no smell associated with a modern composting toilet system, however 37% of people also indicated that they would expect there to be 'some smell' associated with the system. 70% of respondents were interested in finding out more about composting toilet systems, and 66% of people provided their contact details to receive further information.

The *Operational Questions* showed a considerable spread of results, with a high proportion of answers being 'need more information'. This was to be expected, as the questions were more specific and related to change of personal habits and use of the systems. On the whole, responses were more positive than negative. The answers given here highlight the need to develop an appropriate range of educational material for potential users and purchaser of composting toilet systems. Identification of areas where more information should be given to users was an aim of the survey.

The respondent demographic was as follows:

- 57% male, 43% female;
- 0% aged under 25, 52% aged 25-40, 42% aged 41-65, 6% aged over 65;
- 55% next property purchase for investment, 45% owner/occupier.

Analysis of answers by grouping indicated no significant difference in willingness to consider composting toilets or willingness to spend more between genders. There was a slightly greater willingness in the 25 to 40 age group on these questions than in the over 40 age group.

7.1.3 Implications of Survey Results

The preliminary results indicate that there is genuine initial interest in composting toilets as a viable, ecologically sustainable sanitation system. Clearly the respondents to this survey have little background knowledge of the system and how it functions. The survey was intended to establish the current level of information, not to educate potential users. Where respondents did have more background knowledge of composting toilets, it appears that results were more favourable. It should also be noted that the survey did not include information communicating the intention to maintain and operate the system through service contractors and operators. It is expected that this would have made the system more attractive to residents, as it would be clear that they were not expected to handle compost or urine.

Specific attention will need to be devoted to consumer education and awareness of composting toilet systems, in order to develop a definite support base for the development and for composting toilets as an option in inner city apartments.

Indications are that, on the whole, there is support in the community for ecologically sustainable features in urban developments. It is likely that support for composting toilets in particular would rise with increased consumer knowledge of the process.

7.2 Experience Elsewhere – Marketability

Composting toilets have been installed in a variety of situations, both overseas and in Australia. The success of the installation generally depends on the commitment level of the residents or users, and the commitment to maintenance and operation of the systems.

Attitudes to alternative sanitation solutions are usually dependent on information and understanding of the systems, and acceptance of these systems is normally linked to an awareness of environmental issues and desire to have an impact on a personal level, or to householders in non-sewered areas, who are obliged to seek out alternative waste collection and treatment methods.

The drive behind alternative sanitation and composting toilets in Sweden was an interest in recycling of nutrients, and to a lesser extent, minimisation of water used for flushing toilets (Hedberg, 1999). Composting toilets have been installed in several eco-villages, and urine separating micro-flush toilets in apartment buildings.

A Swedish example is the eco-village Toarp, which was constructed to house 150 inhabitants in 37 houses, and trialled three varieties of composting toilets (Fittschen, 1997). The three varieties included a batch system, a rotating batch system and a continuous single chamber system (refer to literature review, Appendix A). All three types were equipped with heating elements to evaporate liquid and maintain a favourable temperature. A survey of residents highlighted some important issues, as summarised below.

- the most successful system was the rotating chamber system. This reported the least number of incidences of odours outside, and had no odour issues inside. It also achieved an end-product that looked like earth;
- residents were generally more satisfied with source-separation toilets. The use of source separation generally eliminated flies.

The eco-village situation differs fundamentally from the development proposed by this feasibility study, in that the residents of single storey houses operated each unit themselves.

In Canada, composting toilets were installed in a multi-level office building at the University of British Columbia – the C.K. Choi Building. Although the type of toilet used in this development (Clivus Multrum) is different to those proposed here (Rota-loo®), the overall situation is more similar. Several toilet pedestals feed into each composting unit, and a building maintenance officer operates and maintains the system (similar to the maintenance contract proposed in this project). A post-occupancy survey was conducted of users of the building, with the following conclusions relating to composting toilets:

- users were generally satisfied with the toilets, although regular users were more accustomed to them;
- the maintenance officer found it necessary to clean the toilet bowls reasonably often (especially during a conference or similar event) to remove visible faecal matter;
- maintenance of the compost bins was aided by addition of woodchips and sawdust, as well as regular watering (1 minute per day) to keep the pile moist (it is not clear why this action was necessary, as the toilets used were not urine separating).

7.3 Marketing Strategies

The marketing and promotion of the waterless toilet in isolation, within a conventional apartment or townhouse product, is not considered to be appropriate. The system needs to be seen in the context of a broader delivery of an energy-efficient, environmentally responsive, innovative, technologically advanced and flexible residential design. In this sense it becomes a package that will attract a market interested in environmental issues and willing to pay more to pursue these ideals (although not the additional cost of monitoring, trials and initial transport set up costs given the poor scale of economy for the proposed demonstration project with 12 apartments). By identifying and quantifying the environmental benefits delivered by the building as a whole the toilets become one component of a very positive overall story, rather than the sole focus of attention.

From the developer's point of view, the additional expenditure on both the waterless technology and other environmental systems for a limited number of units is a potentially worthwhile investment in testing an emerging market. It also provides a community benefit in establishing a testing ground for technology that either needs to be tested in new settings, or is in prototype and initial development stages. In this case the legitimate branding of a limited number of apartments as amongst the most advanced in the Australia, or even the world, in terms of sustainability, benefit the market positioning of the development as a whole, and distinguishes it from competing residential products.

7.4 Site Inspections

The study team members made three site inspections and notes and photographs from these are included in Appendix G. The overall impression was very favourable in that there was no odour noted inside the compost toilet rooms. A number of matters were noted from these visits as set out in Appendix G and these have been addressed in developing the proposed demonstration project and assessing its feasibility.

One facility was an inner-urban environmental park in Brunswick where several manufactured and site-constructed composting toilets have been used for about four years. Urine separation was being tried with good success in that it appeared to aid composting. The composters were not heated and appeared to work well. Worms had been added to the system. There was no odour in the toilet rooms, which are used by the public visiting the park. Leachate and urine were discharged to wetlands and compost was buried on site.

One facility was a private house using a Rota-Loo®. There has been no problem with odour in the house. The owner has found that the location of the composter under the house without warmth from good solar exposure has limited the composting rate. The owner also found that midges were an initial problem but were easily controlled by stretching nylon stockings over the vents. The 4 W ventilation fan has been very reliable (7 year life) and is powered from the household solar panel system. Leachate from this system was discharged to a septic tank with grey water. Compost was buried on site.

The third site was the campus of Charles Sturt University at Thurgoona near Albury. This campus of around 300 staff and students (including some 40 residential students) has 47 pedestals connected to 25 Clivus Multrum composters. Leachate, together with urine from one waterless urinal is discharged to a wetland system. Compost is buried on site. The toilet rooms were odour-free and bowls were very clean.

Both an older staff member and a young student commented that since they have been using the composting toilets they find defecating into clean water in a flush toilet repugnant. This is an interesting reaction and the reverse of expectations of many people not familiar with properly designed compost toilet systems.

Odour problems have only occurred at this installation when fans have broken down or have been undersized. The campus includes some composters with up to four pedestals spread over two floors. The maintenance staff at the campus were enthusiastic about the composting toilets and did not find the tasks they undertook (and demonstrated to the authors) of raking the top of the compost pile, removal of compost and cleaning of the chutes and vents objectionable.

7.5 Commercial Risk and Risk Management

Table 7.1 summarises the commercial risks with the demonstration project and the risk management strategies proposed. It is conclude that the risk of either not selling the apartments or of having to convert them to conventional sanitation is significant. Therefore, funding support to the developer will be necessary to offset this risk if the demonstration is to go ahead.

Table 7.1: Commercial Risk and Risk Management

Aspect	*Commercial Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
Cost of installation	Cost is higher than estimated.	This feasibility study has looked at costs in substantial detail and has made allowance for all foreseeable items plus an appropriate contingency. At the detailed design stage these costs can be confirmed before the apartments are built. The equipment is proven for composting. Urine separation is less proven. Thus some pilot trial of the pedestal and drainage system and further inspection and interview of owners/operators in Australia and overseas of operating systems with urine separation should be undertaken.	Low risk, particularly once detailed design is complete.
	Cost makes apartments unattractive to purchasers	Subsidy from the Smart Water Fund and other participants will be sought in order to make the price attractive.	If funding assistance is available this is a low risk.
		The apartments will be marketed as environmentally friendly and there appears to be a willingness in the community to pay a premium for such features. If they do not have to pay more in this case, sale should be relatively assured.	
Market reaction	Unfavourable reaction and no or few purchasers	The survey of prospective customers so far shows a good level of interest. A further more targeted survey would be desirable during the design phase before committing to construction.	The market survey, subsidy sought and ability to convert back to conventional toilets will reduce this risk to an acceptable level.
		Apartment design will allow for retrofitting of water flush toilets.	
		If funding support is provided, some of the financial cost of slow or limited sale will be offset.	

Aspect	***Commercial Risk***	***Risk Management***	***Qualitative Assessment of Residual Risk***
		The apartments will be attractive to owner-occupiers more so than investors which will maximise the possibility of market demand.	
Operational issues and complaints	Purchasers are dissatisfied.	Provide training and information; contract the maintenance and residue removal and address complaints quickly.	Some risk of uncertain outcomes but a system will be provided to deal with issues. Provision of responsive contract maintenance and collection service, user information and ability to retrofit water flush toilets will minimise this risk.
		Provision to retrofit water flush toilets at minimum cost has been allowed for.	
	Visitor complaints.	The above actions, signage plus providing owners with information to convey to visitors.	
	Third party complaints	Contract maintenance and transport system, on-site odour control and contingency plans.	
	Operating costs higher than anticipated.	Adequate allowance plus a contingency has been made in the estimates that indicate an operating cost advantage. These will be reviewed during detailed design. The installation will investigate costs for supplementary heating and costs for ventilation power. If these are too high the design could be modified. If they remain too high, water flush toilets can be installed. Some reduction in water and sewerage rates is anticipated to offset other operating costs.	

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8. Policy Settings, Regulations, Guidelines and Approvals for Composting Toilets

This section summarises the policy and regulatory framework related to dry composting toilet use and the use of residues on agricultural crops. Potential barriers are identified and ways to overcome the barriers are suggested.

8.1 Current Australian Policy Settings and Influence on Alternative Sanitation

No specific review of federal government policy in relation to composting toilets and reuse of residues has been undertaken. However, there have been recent Senate subcommittees looking into urban water management and ocean disposal of wastewater. The Federal Government also has adopted principles of ecologically sustainable development and is actively engaged in water conservation and support of agriculture. It is reasonable to conclude that Federal Government policy is more likely to be supportive of the demonstration project and wider adoption of a new sanitation technology provided financial, ecological benefits can be demonstrated.

At the State level, a number of current State Government initiatives have been taken in relation to sustainability, water conservation, recycling, waste minimisation and agriculture. All State Environment Protection Policies established or revised since 1997 and the Environment Protection Act itself as amended by the Livable Neighbourhoods Bill, include ten principles of ecologically sustainable development in their preambles. Of particular relevance to the proposed demonstration project are the following principles:

- waste avoidance and reuse and recycling must take precedence over treatment and disposal;
- integrated environmental management to achieve the best overall environmental outcome;
- improved valuation, pricing and incentives to ensure environmental factors are valued and that the full cost of impacts on the environment are included in costs of goods and services;
- integration of economic, social and environmental factors in decision-making;
- the precautionary principal which requires that lack of full scientific evidence of impact on the environment should not be used to postpone measures to adopt alternative approaches;
- conservation of biological diversity;
- intergenerational equity – leaving the environment in the same or better state for future generations.

It is reasonable to conclude that State Policy is supportive of taking actions that will reduce resource use and therefore of a demonstration project with this sole aim.

Whilst only a few years ago, most urban water authorities had policies that required people living in sewered areas to connect all waste to sewer, most have recently varied this policy to allow alternative sanitation approaches provided they meet the requirement under the State Environment Protection Policy, Waters of Victoria, for wastes to be handled on site. Specific policies on composting toilet use are yet to develop but a number of urban water authorities have recently permitted composting toilets within their sewerage districts.

The State Environment Protection Policy, Waters of Victoria has particular relevance to sewerage and alternative approaches to sewerage. Clause 18 specifically requires water authorities to work with the

Department of Sustainability and Environment to minimise the impact of wastewater on beneficial uses of the environment. Clause 28 also requires action to, where possible, avoid wastewater discharges.

Clause 24 requires that properties connect to sewer where sewerage is available unless it can be shown that all wastewater can be managed on site without discharging to surface water or impacting on groundwater. This clause did not specifically contemplate use of composting toilets but composting toilets are being approved on larger allotments. In the case of this proposed high-density application, there will be no intention to contain the residues on site. Rather, they will be taken by road to a reuse site.

It is concluded that State Government Policy is supportive of the proposed demonstration project but will need interpretation in relation to not connecting toilets to sewer.

8.2 Health

The Health Act does not have specific relevance except that the project should not cause *nuisance* or *danger* to the public. The Department of Human Services has the power under the act to take action if there is a risk to health. The Department is a referral agency for approval and will comment on proposals if referred from Council or the EPA. Generally the Department is aware of the technology and has been instrumental in the past in approving and advising on several installations in public toilet facilities.

Discussions with waste cartage companies indicated that transportation of compost and the liquid residues would be treated as a septic tank waste under EPA guidelines but not a prescribed waste requiring transport certificates and disposal at specially licenced facilities. Securing and sealing of containers during transportation and avoiding contact, etc during handling and transfer are covered by the EPA guidance in this regard.

Regulations as they relate specifically to health have not been fully investigated for operation of the reuse trial but advice from DHS is that there should be no particular difficulty, at least for the demonstration project. A management plan will be developed as part of the design of the trial to protect health of workers within guidelines set by and in consultation with the DHS and EPA. The DPI noted in its review of the proposed reuse trial that health and safety precautions for handling of potentially pathogenic materials need consideration, which will be addressed in the management plan.

8.3 Building, Ventilation and Plumbing

Building ventilation design for a composting toilet system was discussed under Section 4. Design is required to meet AS/NZS 1546.2:2001, which addresses ventilation for odour control and compost aeration.

Under the current plumbing codes there is no restriction on operators or owners installing a composting toilet system, however under new regulations soon to become law installation can only be carried out by people certified under the ‘On-Site Accreditation Course’ (provided by Holmesglen TAFE from the end of 2003). There will be a 12-18 month moratorium on plumbers and other DIY installers before the regulations will be enforced. This rule will apply for siting, installation and maintenance of composting toilet systems. A two yearly inspection and report to council is required under the new regulation.

8.4 Environment Protection Act

There is nothing within the Environment Protection act and associated guidelines and regulations that would prevent the use of composting toilets within the apartments other than general requirements to not cause pollution or odour. The installation must be appropriately designed to prevent nuisance and pollution and for this reason odour scrubbing has been incorporated. Because of the potential to cause groundwater or surface water pollution if the urine and leachate tanks leak, it would be prudent to include leak detection systems and by use of double walled tanks and pipework placed in ducts.

EPA released a new Guidelines for Environmental Management titled Septic Tank Code of Practice in March 2003 (EPA publication 891). These place considerable onus on councils and owners to properly install and manage septic tank systems. They also require a land capability assessment before councils issue a permit for a new septic tank system. If anything, this new Code is likely to encourage interest in alternatives such as composting toilets in unsewered areas since composting toilets lower the potential nutrient load on a site by allowing storage and off-site transport.

8.5 Water Act

The Water Act has not been specifically reviewed in relation to the demonstration project. It does encourage water conservation and while it provides for the operation of water authorities in providing sewerage, it is unlikely that any specific provision of the act would prevent the proposed demonstration project.

8.6 Planning

Generally there appears to be enthusiasm at a municipal level to support environmental initiatives. The cooperation of councils and health authorities in allowing for alternative waste management practices has not yet been tested in detail, but isolated examples of permits for on-site waste containment, treatment and reuse in Melbourne do exist.

The site planning of developments involving composting toilets as a whole is impacted by the need for vehicular access to extend reasonably close to the building and the compost pick up points, and to allow the potentially large vehicles used by waste management contractors to maneuver within the site. Whilst a constraint, it should be recognised that trucks will only have to access a site once or twice a year and there is ample precedent for large trucks accessing dense urban development in the form of commercial grease trap cleanout.

A planning permit will be required as for any development and the council involved will consider the composting toilet aspect, seek assistance or guidance from the EPA and other authorities as necessary prior to issuing a permit. Before a permit is issued the council will need to establish that the proposal will not cause nuisance to neighbours, and that the disposal of residues will be properly managed.

8.7 Reuse of Compost and Urine

A works approval is only required for a sewage treatment facility if volumes produced exceed 5 000 L per compost unit per day. For the project the proposed composting units will produce some minor fraction of this value, in the order of 5 L per unit per day, even allowing a few litres for cleaning liquid and other cellulose material there is no risk of exceeding this value. For a large centralised composting system taking kitchen and other household wastes, grey water etc from several residences this limit may become critical although it applies to conventional sewage treatment.

For reuse of human excreta product at the trial site, an EPA Victoria Research, Development and Demonstration (RD&D) approval will be required, as understood from reviewing the EPA guidelines and discussion with EPA staff in the West Metro Region (responsible for the Werribee area proposed for the agricultural reuse trial). EPA personnel advised they would consider this project as a team input from various parties including EPA specialists who deal with biosolids and the DHS on health issues. This permit allows genuine research projects to operate outside the works approval system, but does not override any other permits or approvals that may be required. Consideration is given on a case-by-case basis, particularly for a project such as this.

Other than the RD&D permit, no specific regulations related the reuse trial. Comments from the DPI on its review of the ideas developed for the reuse trial included a suggestion that health implications need to be considered by a biometrician and by testing the residues in accordance with the Victorian EPA Biosolids Guidelines (currently in draft and expected to be passed this year)

Expert Technical Advisory Panel members have been consulted regarding risks associated with the reuse trial and they consider it can be undertaken. No specific comments were provided in regards to regulations and approvals.

8.8 Controls on Cartage of Compost, Urine and Leachate

Collection of the liquid and solid excreta from the apartments and transporting it to the reuse trial site is likely to be covered by the permits and approvals processes in place for removal and transport of septic tank contents so a brief review of the controls on septic tank pump out was undertaken.

The Environment Protection, Prescribed Waste Regulations as amended in 2000 indicate that, although “inert sludges or slurries” and domestic “grease interceptor” waste are classed as prescribed wastes requiring transport under EPA Waste Transport Certificates by an EPA-licenced waste transport contractor. Septic tank contents, like sewage sludge or biosolids are not classed as Prescribed Wastes even though they could be interpreted to come under the “inert sludges or slurries category”. The EPA Code of Practice for Septic Tanks issued in 2003 states that septic tank pump out removes “non-biological inert material” (which is not considered by the author to be an appropriate description) but is silent on: who should remove the material (other than a “pump out contractor”), under what controls or where it has to be taken.

Discussion with a septic tank pump out contractor confirmed by discussions with the EPA indicates that although grease trap waste is handled as a prescribed waste using EPA Waste Transport Certificates, neither sewage sludge nor septic tank pump-out are not classed as prescribed wastes and that no specific permits are required. It appears that controls on the pump-out, transport and disposal of septic tank pump out stem purely form general provisions of the Environment Protection and other acts making causing pollution or nuisance an offence. A consequence is that septic tank pump out is generally if not always carted to a sewage treatment plant for disposal as to dispose of it otherwise, may cause pollution.

It is concluded that controls on septic tank pump out are therefore non-specific and if similar controls are applied to compost and urine, no specific permits for transport and disposal would be required. However, it is clear that disposal of more than single household quantities will come under general provisions of at least the Environment Protection Act and probably other acts and it is possible that specific regulations would be developed.

8.9 Attitudes of and Support from Regulators

Discussions have been held with officers of the EPA, the Moonee Valley City Council, the Department of Human Services, City West Water and Melbourne Water about regulatory barriers to use of composting toilets with urine separation and about application to agricultural land.

Council planning officers are of the opinion that planning approval will be forthcoming. It is possible that there could be third party objections but these are unlikely to be sustained if the proposal goes to the Victorian Civil and Administrative Tribunal.

The Department of Human Services was supportive of the demonstration project and pointed out that a number of composting toilets have been successfully installed and operated over many years, albeit in individual dwellings and public amenities. No objection would be raised to the demonstration project by the Department and no formal approval would be required.

EPA appears to be supportive and has certified the Rota-Loo® as suitable for use. EPA agrees that a Research, Development and Demonstration approval would be appropriate for the reuse trial.

Melbourne Water has indicated in discussions and in writing that it will probably be able to lease two hectares of land for the agricultural trial subject to further detail being provided, full assessment of risk and identification of risk management actions.

City West Water is supportive of the trial and would be interested in the results. At this stage the potential for a reduced headworks charge for the development has not been discussed.

In summary, there has been a positive indication or support for the demonstration project from regulators and others who would be involved in approving the project.

8.10 Approvals Risk Management

Table 8.1 summarises the foreseeable risks in getting approval for the demonstration project and lists risk management approaches. It is concluded that, whilst a number of actions will be necessary, there are no major policy, regulatory or other barriers that cannot be overcome.

Table 8.1: Assessment and Management of Approvals Risk for the Demonstration Project

Aspect	***Regulatory Risk***	***Risk Management***	***Qualitative Assessment of Residual Risk***
Planning approval & lack of specific policies on composting toilet systems	Planning approval timing and unforseen issues arising due to Council's lack of technical experience/knowledge in this area. Impact on project timing & amount of work required to resolve issues.	Consult and meet with Council early through the preplanning phase of project. Provide council with background information and seek advice, comments and questions. Align the proposal with Council's environmental and sustainability policies and planning guidelines to assist the process. Check relevant state and federal policies to assist Council Provide a briefing document to Council with reference to EPA, DSE, SEPPs, state and federal policies and relevant examples installed under other authorities' permits. Meet with Moreland City Council to ascertain the process required for the '*Westwyk'* development in Brunswick which includes a composting toilet. Demonstrate clearly that the project will not cause pollution or odour nor cause nuisance or danger to public that is any greater than similar projects/operations and also that residues will be properly managed. Address the Health Act and seek input from DHS if necessary.	This risk is manageable.
Planning approval	Third party objections causing delays to planning approval and possible appeal to VCAT	Prepare useful, informative material to present to potential objectors. Ensure Council is well informed to assist mitigation of such objections. Meet with objectors and/or provide a cooperative discussion platform to address community concerns early.	This risk is manageable.

Aspect	*Regulatory Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
Connection to sewer	SEPP, Waters of Victoria requiring connection to sewer unless all wastewater is disposed of on site.	Clarify early with EPA and City West Water.	Unlikely to be an issue.
Waste management onsite/offsite & transportation	Delays/difficulties coordinating between Council – for planning approval, including for waste collection methods/routes, and the EPA for an RD&D permit for reuse of residues. These delays would impact on project timing and require additional input from Project Team	Coordinate combined planning meeting with both council and EPA and seek early resolution of overlapping issues to be addressed Meet with EPA regarding collection and transportation of the residues prior to developer finalising design of the development site layout, to assess siting for urine and leachate underground storage tanks and also truck position for the collection process. Advance preliminary methodology and custom design of the transport system to demonstrate containment of residues (eg lids for the bins and custom built truck tray). Demonstrate adequacy to the EPA. Draft a management plan for each aspect of the demonstration project operations and maintenance and use this to support the applications and address concerns from EPA and Council.	Can be managed.
Maintenance and inspection	Difficulty finding a contractor willing to perform these roles	Seek support for the project from the DRY COMPOSTING TOILET system provider (Environment Equipment has indicated it could carry out this role and it is currently supportive of the project – part of the project team)	Low.

Aspect	*Regulatory Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
Health Aspects	Hold-ups or stoppages to the project in relation to Health regulations not being satisfied	Specific risks related to health are addressed in Table 9.1 Consult with DHS and EPA to address all relevant health regulations and include provisions for meeting the guidance in the management plans for each aspect of the project (operation, maintenance, collection & transportation and the reuse trial. This should be prepared in the planning phase of the project. Incorporate health management aspects in the agricultural reuse trial detailed design as suggested by DPI (or other appropriate organisation).	Low.
Building permit	Possible difficulty in gaining building permit.	Comply with all standards. Meet with building surveyor early and provide full information. Make provision for upgrading the ventilation fans and reconfiguring the ventilation systems (providing access points in the building design to do this). Ensure independent checks and verification of the design.	Low
EPA RD&D approval for the agricultural reuse trial	Not getting or delays in getting an RD&D approval or permit. EPA requires full works approval rather than a Research, Development & Demonstration Approval leading to potential third party appeal	Address this risk with the DPI, EPA, DHS and land owner at planning phase. Seek comment from all parties to be addressed in design of the reuse trial (likely to be done by DPI). Prepare a briefing paper for the EPA on the proposed design for all aspects of the agricultural reuse trial, including construction, operation, monitoring, decommissioning and reporting. Have alternative options for residue disposal so as not to hold up other aspects of the demonstration project.	Unlike to be an issue but may cause delay.

Aspect	*Regulatory Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
Future use of residues in commercial application	Difficulty getting approval or finding a willing user. Subsequent costs to project and need to dispose of residues to sewer.	Explore long-term options during agricultural trial. Develop information package. Implement early trials on private farms if possible. Hold early discussions with EPA on applicability of the Biosolids Reuse Guidelines.	Needs early attention.

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9. Health Aspects

This section reviews what is known about health risks associated with use of dry composting toilets and with use of residues from them in agriculture. The relative risk compared to other sanitation approaches is assessed and safeguards for the demonstration project are summarised.

For the key outcomes and risks identified in this Section please refer to Section 9.8 and Table 9.1 below.

9.1 Indoor Air Quality

The positive ventilation provided will mean that indoor air quality in all respects should be satisfactory. In particular, odour levels should be lower than with conventional water-flush toilets.

It is proposed to monitor gas types and concentrations in the ventilation exhaust both upstream and downstream of the biofilter odour scrubber. Monitoring will include odour, ammonia, amines, hydrogen sulfide, methane and nitrous oxide as well as presence of indicator microorganisms and insects.

It is unlikely that, with a biofilter, there will be any outdoor air quality problems that could impact on indoor air in the development or for surrounding occupiers. The biofilter is an added feature not usually provided with composting toilet installations and impacts significantly on cost, hence the need to assess air quality entering it as well as leaving it.

The construction materials for the composting toilet system will be porcelain and high-density polyethylene. No indoor air issues should arise.

The biggest risk to indoor air quality is exhaust fan failure. This can be minimised by having a back-up fan and by design of the stack to achieve some natural ventilation. However, during a prolonged power failure there will be odour released when the toilet lid is open. The risk in Melbourne of prolonged power failure does not justify standby power but indicates a possible benefit of having on-site solar panels for powering the fans.

Toilet lids are required to be closed, which requires users, particularly males, to change practices.

9.2 Odour, Insect Vector and Nuisance

There is a risk of insect vectors (insects such as flies, mosquitos and crawling insects), which could transmit pathogens onto food or direct to humans, and odour affecting the indoor air quality and health of residents. These will be minimised by a properly functioning ventilation system. The design codes of practice require a negative air pressure to be maintained in the toilet pedestal shaft at all times, which should eliminate all odours, limit the tendency for insects to migrate up the shaft and minimise the infestation from insects (due to lack of odour to attract them because of both urine separation and the use of an odour scrubbing biofilter and fine fabric screens on the inlet and exhaust air).

Should insects become established and be a problem in the compost chamber there are simple methods for killing them involving insecticide use. The fineness of screening necessary, the level of insect development and the nuisance and risk factors do need investigation since composting toilets inspected were colonised by small midges and spiders.

Residents will have to change from using chemical-based air fresheners that operate under a flush toilet system to some other method, preferably a natural spray or similar. However, they will probably find this altogether unnecessary due to odours being vented down the waste chute.

9.3 Controls for Residents

Provided residents maintain a clean pedestal as per the specific simple cleaning requirements for a composting toilet system, and do not add excess liquid (causing the composting process to go anaerobic), chemicals or other inappropriate matter through the chute the health risks to residents of their composting system should be no different to that of a conventional toilet.

Some consideration has been given to the value of taking swab samples on inside surfaces for microbiological testing, however the likelihood of detecting anything different from that of a conventional toilet is low, and the likelihood of detection of microbiological pathogens normally present in human excreta near any toilet is actually quite high.

While rare, if insect vectors inhabit a compost bin these can be killed off as noted above.

9.4 Controls for Transport & Maintenance

The exposure to excreta and hence the health risks to transport and compost system maintenance operators is lower than the exposure for sewer or septic system workers, with the worst case being a compost bin that has failed to compost aerobically. Detailed instruction will be given to transport contractors to ensure that safe handling procedures are understood for this scenario. Maintenance operators will be required to have formal training and certification for their operations.

Urine is near sterile with very low to nil counts of pathogens and viruses, so handling of this liquid is relatively risk free. Properly composted faecal matter is expected to have very low counts of faecal bacteria and this will be monitored to assess the risks more adequately. The leachate may be more contaminated and will be treated as such until known otherwise.

Clearing of blockages in urine and leachate pipes is likely to be the highest health risk activity undertaken by maintenance workers. It should be possible to eliminate this problem by careful material selection, design and installation. If blockages occur it appears that removal is possible using caustic soda.

Transportation and prolonged storage of composted organics material may lead to a risk of dust and this could be inhaled while the bins are being emptied at the reuse trial site. Precautions will need to be taken with operators using simple P1 masks to ensure their safety. Keeping the compost moist will also minimise this risk.

A further risk to transporters is cuts and infection from foreign objects (including sharps) being disposed of into the compost bins. While this event would be rare, instructions for transport contractors need to include safety provisions for emptying bins.

9.5 Controls for Reuse Site Risks

The compost received at the reuse site will generally be well stabilised with low odour and testing has indicted that bacteria and virus are unlikely to be found in urine if it has been stored for more than six months at 20^{o}C (Hoglund 2003). Pathogen contamination in leachate is unknown and must therefore be considered as a potentially high risk, although storage will reduce viability. This aspect needs research as the quantitative information available is on separated urine with minor faecal contamination rather than on leachate from compost. Clearly, leachate will need careful handling. The volume will be small if urine separation works well and one strategy would be to discharge leachate to sewer. The design of the plumbing at the apartments will allow for this.

Die-off of pathogens in compost has been tested extensively and it is generally accepted and shown by this data that the risk to persons handling compost is low. The greatest risk will occur during emptying of bins into the site storage and during sample collection and compost spreading, especially if the material is dry enough to cause dust. On a large scale this could be automated but for the trial, the risk of contact will have to be minimised by handling methods, use of gloves and masks, moisture control and personal hygiene.

For batches of compost that have not been properly composted, a facility will be provided at the reuse site to dispose of this to sewer. On a large scale, an additional composting facility may well be necessary for the small quantity of failed composted material that may need to be managed.

A further risk to workers on the reuse site is cuts and infection from foreign objects, including sharps, present in the compost. While this occurrence would be rare, instructions and personnel safety equipment will be provided to mitigate this event.

It is considered that the health risk to workers on the reuse site will be less than that faced by current sewerage system workers and many agricultural workers who handle raw animal excreta. However, it is recognised that attitudes of end-users to the residues will be a key aspect to consider and the demonstration project will allow some investigation of attitudes as well as quantifiable health risks.

9.6 Food Crops Fertilised with Compost and Urine

It is unlikely that application to vegetables would be accepted in the medium term. The agricultural reuse trial initially envisaged would have tested for indicator bacteria and spiked pathogens applied to a variety of vegetable crops as well as to grain crops. It is considered more likely that farmers would only be willing to use urine, leachate and compost as fertiliser substitute on grain or oil-seed crops in a commercial system. Research in Scandinavia has shown a high level of safety and a low level of risk for application of stored urine. Hoglund (2003) reported results of a quantitative risk assessment for application of urine to crops, which indicated a probability of protozoan infection in persons eating the uncooked crop of 10^{-7} (that is, very low) if urine has been stored at 4^{o}C for six months or at 20^{o}C for one month. The risk of ingesting infectious bacteria was assessed as 10^{-15} (that is, negligible).

Similar quantitative work on the risk of ingesting pathogens from crops to which compost or leachate has been applied was not found during this study but qualitative reports indicate a low risk provided the residues are appropriately aged and applied. For cooked crops, the risk is reduced to practically zero.

Consideration has been given to the fate of pharmaceuticals and endocrine disrupting chemicals. Urine and compost will contain negligible levels of endocrine disrupting chemicals such as nonyl-phenol, PCBs and other synthetic chemicals but will contain pharmaceuticals and natural hormones. All of these have been found to be present in municipal sewage at trace levels (Chapman, 2003). However, whilst there is interest in these chemicals and their impact on human health and ecosystems, there is insufficient information to assess whether they are significant risk to those ingesting crops fertilised with compost, urine and leachate. Some assessment of this during the trial is warranted. It is noted that in an expert review of risks from reuse of sewage for potable purposes for the Federal Department of Health and Aged Care (GHD, 2001) reached a conclusion that insufficient was known about hormones and endocrine disrupting chemicals and their removal in sewage treatment and that further research was necessary to provide data relating to human health risk assessment and development of applicable treatment technologies. The context of this conclusion was for treated sewage being used as drinking water rather than a situation where such chemicals will be subjected to natural degradation by soil microbes and sunlight, adsorption and then having to pass through cell walls into plant material to even be present in crops, as is the case for the agricultural reuse trial.

9.7 Health Risk Comparison to Everyday Practices

In summary, it is considered that there is ample quantitative and qualitative evidence to conclude that the health risks to all who may come into contact with pathogens and chemicals in compost, leachate and urine would be lower for this trial and probably lower for a full scale application with lesser control than encountered in many typical everyday practices. The trial is intended to provide data for assessing the overall risks of such a practice as collecting and reusing composted human excreta on food crops. For example monitoring survival of pathogens and other indicator micro-organisms, possible investigation into endocrine disruptors and health of the crops (safety for human consumption).

9.8 Summary of Health Risks and Risk Management

Table 9.1 summarises the health risks identified for the apartment occupants and maintenance and transport contractors and for those undertaking the agricultural trial. Included is a preliminary assessment of the risks to consumers of food crops produced from soils to which compost, leachate and urine have been applied.

Table 9.1: Summary of Risks and Risk Management for the Trial and for Full-scale Application

Aspect	*Health Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
Occupation of Apartments Maintenance of composting and urine system.	Contact with faecal matter or urine on the pedestal during use or cleaning.	Occupiers responsible for regular cleaning with instruction provided.	Not a significantly greater risk than with water flush toilets if instructions are followed and hands are washed.
		Provide hand-washing basin in the compost toilet room.	
	Disease transmission to other occupiers (indoors or outdoors) due to flies, midges and other insect vectors. This is a potentially significant issue.	Control by fine (0.2 mm) screening of intake and outlet vents.	Experience appears to show that this is not a problem indoors. Significantly higher risk compared to water flush toilets indoors if controls are not maintained. Potential risk outdoors if controls are not maintained. Urine separation may limit attraction of blow flies. Maintaining controls will eliminate any significant risk. Monitor during trial.
		Ventilation to run all the time to inhibit insect movement up into the toilet room.	
		Lid to be kept down. Consider possibility of automatic closure of lid when toilet door closes.	
		Possible need for periodic use of insecticide sprays within compost chambers.	
		Include features to inhibit crawling insect access up ducting to the pedestal.	
		Observe and record the incidence of crawling insects during trial.	
	Contact with un-composted faecal matter or contaminated urine or leachate.	Instruction of maintenance staff and provision of signage on composting toilet equipment.	Risk probably lower than for maintenance of normal sewerage installations, especially if a specific washing location is provided for use by maintenance personnel.
		Wearing of gloves during maintenance.	
		Washing of hands after undertaking maintenance and provision of an appropriate hand-washing and equipment washing location for maintenance staff.	

Aspect	*Health Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
		Use of a rotary system for compost bins limits the risk of contact with pathogen-containing uncomposted faecal matter.	
		Design of urine and leachate pipework to have high integrity, be self-cleaning and easily accessed for maintenance.	
		The Australian Standard specifies the reliability requirement for internal parts.	
		Design of urine and leachate pipework to minimise blockage and allow chemical descaling.	
		Locking of compost and urine equipment to prevent unauthorised access.	
	Contact from insects during maintenance work.	Insect controls for occupiers.	This risk needs to be evaluated during the trial, as it may be significant compared to conventional sewerage. A mask may be prudent for the trial. Experience elsewhere appears to indicate no significant risk.
		Protective clothing such as a mask.	
Collection, Transport and Unloading of Compost	Contact with compost, urine or leachate	Faecal matter removed will normally be well composted with the rotary arrangement proposed and bins, plus the truck loading arrangement will mean that contact with faecal material can be avoided. Gloves to be used and washing facilities provided at loading and unloading point. Provide covers for each bin removed which may be a design modification.	Risk can be managed and will be no greater than for septic tank and mobile toilet handling which are established practices.
		Contact with urine and leachate will be avoided, as for septic tank pump-out, by use of vacuum tankers.	

Aspect	***Health Risk***	***Risk Management***	***Qualitative Assessment of Residual Risk***
	Aerosol emissions.	Not regarded as a problem with grease trap and septic tank pump-out. Provide a connection to the on-site odour filter from the vacuum discharge.	Can be largely eliminated if the vacuum tanker does not have a free discharge to air.
	Spillage during loading, unloading and transport.	Provide a trolley for compost bins, a loading tailgate and contain the compost bins on the truck. Provide spill kit with disinfectant at apartments, on the truck and at receiving site.	A similar risk to that encountered with mobile toilet management.
	Cuts and infection from foreign objects (including sharps) in the compost bins	Instructions for transport contractors need to include safety provisions for emptying bins.	Low risk of occurrence, can be managed
Handling and storage on the receiving site and analytical laboratory.	Insect vectors expose workers.	The urine and leachate will be stored in tanks, which can be sealed to prevent insect access. The compost will be stored in covered containers to minimise insect access. May require an insect control program.	This is a significant risk area but can be managed with appropriate, equipment, management systems, training and monitoring. The risks should be less than to normal sewage workers since the materials are partly stabilised and will be handled with minimum exposure and aerosol formation.
	Contact during handling, spreading, sampling and analysis of compost and urine	Training, normal hygienic practices, gloves, protective clothing, probably use masks. The semi-stabilised nature of materials will limit exposure to or ingestion of viable pathogens. Provide a clean lunchroom.	
		Provide on-site washing facilities, signage, training in safe procedures and a service to clean protective clothing.	

Aspect	*Health Risk*	*Risk Management*	*Qualitative Assessment of Residual Risk*
		Provide spreading equipment for compost that limits generation of dust, flinging of particles and wash equipment after use. Provide an equipment and compost bin washing bay, materials handling equipment and a compost spreading system that minimises exposure to air-born particles. The small quantity produced in the trial will probably best be handled by manual tipping into a front end loader, spreading from this and rotary hoeing. Provide tractor with air-conditioned cab with appropriate filters and maintenance.	
	Exposure to un-composted faecal matter.	Provide for segregated storage in a warm building for composting material that is suspect. Appearance and odour will make such material easily detectable.	
	Aerosols from urine or leachate spreading.	The spreading method will probably be by tractor-drawn tank with a low-splash spreading bar. Urine and leachate will be analysed for presence of pathogens during trial.	
	Cuts and infection from foreign objects (including sharps) in the compost	Instructions and personnel safety equipment need to mitigate for this event. Compost distribution method to avoid direct handling.	Low risk occurrence, can be managed with adequate instruction and appropriate methodology.
Consumption of produce from the trial plot.	Direct ingestion of pathogens.	All produce produced will be buried on site or dispose to landfill from the laboratory. Staff will be instructed not to use produce.	No significant risk for trial. The trial will provide information on product safety. Note that, the agricultural reuse trial will only look at grain crop and possibly oil seed crop fertilisation because of likely community perceptions about use on other crops.
		The small population in the apartments will limit the probability of pathogens being present.	
	Ingestion of trace chemicals including pharmaceuticals.	Crops will be analysed for these.	

10. Financial & Economic Evaluation

This section summarises costs for the proposed demonstration project and compares the financial and economic feasibility of large-scale application of dry composting toilets in the urban environment. The future financial feasibility under various resource pricing scenarios is investigated and conclusions are reached on the longer term economic benefits of this approach to sanitation. Funding of the demonstration project is discussed.

10.1 Demonstration Project Costs

Table 10.1 summarises the estimated capital cost and annual operating costs for the various components of the proposed demonstration project. Further details are set out in Section 10.6 and Appendix B, Tables B5, B6 and B7.

Table 10.1 Costs for Demonstration Project with Agricultural Reuse Trial and Monitoring

	Capital ($k)	Annual ($k)
Composting Toilets, Associated Building Works and Monitoring Equipment	253	30
Transport & Agricultural Trial	198	75
Project Management	20	25
TOTALS	**471**	**130**

Table 10.2 summarises the cost of the demonstration project if the additional features, flexibility, management and monitoring that relates to the agricultural reuse trial are excluded. The cost of excluded items could weight the cost of the project and give an unfair impression of the cost of a composting toilet installation.

Table 10.2 Cost of a "Standard" Installation of Composting Toilets in 12 Apartments, with no Agricultural Reuse Trial

	Capital ($k)	Annual ($k)
Composting Toilets and Associated Building Works	150	13
Transport & Disposal	35	7
Project Management	5	-
TOTALS	**190**	**20**

From the table above, the total cost of the **two year** demonstration project is approximately $730 000 (that is $400 000 + $165 000 x 2).

The cost of installing and operating composting toilets in a “standard” installation without the monitoring equipment, heating, odour control and other flexibilities allowed for in the trial and without monitoring and reporting and without the agricultural reuse trial would be $230 000. Therefore the additional cost of $500 000 over the period is the cost of the demonstration project for which project participants would seek funding.

A 30% allowance has been allowed in all costs for contingencies, general design, engineering and administration and other unidentified costs.

The cost of installing conventional water-flush toilets in the apartment building is estimated as $115 000. Thus the additional cost of a “standard” composting toilet installation over water-flush toilets is around $35 000 or approximately $3 000 per apartment in this case.

10.2 Investigation of Financial Feasibility of Composting Toilets for a New Subdivision

The application of composting toilets to high to medium density urban development has the potential to save potable water and greatly reduce loads on existing sewerage systems and discharges to the waterways. A theoretical example of a new infill development of say 2000 lots varying for three storey townhouses to single storey medium density houses has been developed and costed. A total population of 4 500 persons has been assumed. The area of the development, including roads and open space is 143 hectares, which corresponds to a population density of 31.5 persons/ha. It is assumed in Option 1, the base case, that a trunk sewer is available nearby and that the regional treatment plant has capacity. The implications of an upgrade of both trunk sewers and treatment plant being necessary has been explored in the other options. The potential for grey water reuse is negligible because of small garden areas, limited public open space and the absence of toilet flushing.

Five options have been investigated:

- Option 1: Conventional sewerage;
- Option 2: Conventional sewerage where an upgrade of the trunk sewer and treatment plant is required to be funded as part of the subdivision headworks charge;
- Option 3: Urine-separating composting toilets with grey water to a modified sewerage system and agricultural use of all residues;
- Option 4: Conventional sewerage in a catchment where phosphorus removal is required;
- Option 5: Composting toilets and grey water sewerage where phosphorus removal is required.

Table 10.3 sets out the estimates of capital, annual operating cost and total annual cost. Total annual cost is calculated as operating cost plus 10% per year of capital cost to approximately recover interest and redemption. The available garden and public open space area within this 143 hectare development would only be around 28 hectares. Details of the estimates are included in Appendix B, Table B3.

The development would provide grey water sufficient to fertilise of the order of 78 hectares of garden area. Given the open space within the subdivision is only about 28 hectares, sustainable reuse of all grey water is not possible and a grey water sewerage system is essential. This conclusion will apply to any development having population densities above about 20 persons per ha and, unless winter storage is provided for grey water, probably applies to much lower population densities (Crockett, 2000).

Table 10.3: Summary of Costs of Sanitation Options for a Dense Urban Development of 2 000 Apartments or Townhouses

Option	Capital Cost [1]		Annual Operating Cost		Total Annual Cost	
	$M	$/household.yr	$M pa	$/household.yr	$M pa	$/household.yr
Without Phosphorus Removal						
Option 1: Conventional sewerage	37.9	18 972	0.32	162	4.1	2 059
Option 2: Conventional sewerage, if new capacity is required	43.5	21 755	0.32	162	4.7	2 338
Option 3: Composting/Grey Water Sewerage	41.1	20 528	0.51	253	4.6	2 306
With Phosphorus Removal						
Option 4: Conventional sewerage	37.9	18 972	0.34	169	4.1	2 067
Option 5: Composting/Grey Water Sewerage	41.1	20 528	0.51	254	4.6	2 307

1 Note capital costs include water and sewerage headworks, water reticulation costs and household plumbing costs

The estimates show that composting toilets would be more costly than conventional sewerage only if new capacity in the trunk sewers and treatment plant is not required, although the difference of around 12% in total annual cost is not particularly significant considering the limited accuracy of estimates of this nature.

Annual operating and maintenance cost for the composting toilet based system is estimated to be typically $100 more per household than for conventional sewerage because of the cost of electricity for ventilation fans and most particularly for gas to boost solar heating of the composters in winter which makes up about 60% of the estimated annual operating cost.

Operating costs are substantially offset by the value of flushing water saved, estimated at 82 ML/yr (18 kL/c.yr) for the 2000 unit development. This is substantial (in fact 23%) when compared to the estimated 356 ML/yr (79 kL/c.yr) that would be used with conventional toilets at the water usage rates (including limited garden watering) assumed for this development. The operating cost estimates include allowances for these savings.

If phosphorus removal is required, as is common in inland cities or where there are inland regional treatment plants in major cities, it is estimated that whilst the operating cost of a conventional system would increase more than for a composting toilet/grey water sewerage system, the annual cost for the latter will still be higher than for a conventional system.

If there is insufficient trunk sewer and treatment plant capacity for full sewerage but there is sufficient for a composting toilet/grey water sewerage system, it is estimated that the composting toilet/grey water sewerage option would have an equivalent to slightly lower annual cost than a conventional sewerage system.

These estimates confirm expectations, that composting toilets are likely to be a more capital-intensive approach to urban sanitation because of the household space and equipment required. However, the extra capital cost is estimated as no more than $1 560 per household and, if a major upgrade of the sewerage system is required to service the subdivision, overall capital cost could be around $1 200 per household less than for conventional sewerage.

If the ventilation fans for composting toilets are solar powered then the capital cost would increase but operating cost would decrease. This scenario is explored in Section 10.4. If, as well as solar-powered fans, the houses are designed such that gas boosted solar heating in winter is not necessary (which is the design philosophy for composting toilets), then the composting toilets start to become more attractive, because gas use accounts for about half of the estimated annual operating cost as can be seen from the detailed base case cost estimate in Appendix B, Table B3. These variations are explored in Section 10.4.

The comparisons are very sensitive to the calculated cost of composting toilets compared to the cost of conventional water-flush toilets. If, for example the cost of adding an exhaust fan in a conventional toilet room were included, the operating cost of a conventional toilet would increase substantially. If the capital cost of composting toilets decreases substantially due to volume of production, then again the estimated capital cost disadvantage may reduce or disappear.

It can be concluded that any current justification for use of composting toilets would have to be on other than financial grounds, except possibly where capacity for conventionally sewering a development is not available. Nevertheless, the additional costs over conventional sewerage are relatively small and due largely to the estimated additional capital cost within the house.

This comparison confirms the relative cost-effectiveness of water-born transport of excreta and of current wastewater treatment processes.

10.3 Investigation of Financial Feasibility for a Fringe or Backlog Area Remote from a Main Sewer

A possible application of the technology would be for fringe areas where there is a backlog in provision of sewerage. Similar issues arise in unsewered towns of which there are still several in Victoria where EPA, councils and the relevant catchment management authority would prefer to see some form of sewerage. Estimates have been prepared for a notional small fringe urban town of 2000 persons for four options:

- Option 1: A conventional sewerage scheme, extended aeration activated sludge treatment plant three km from the town and woodlot irrigation;
- Option 2: A conventional sewerage scheme and pumping 15 km to a main sewerage system;
- Option 3: Composting toilets with urine separation, residue re-use on agricultural land, a modified sewerage and lagoon treatment scheme just to handle grey water and with treated grey water storage over wet months and reticulation back to the town;
- Option 4: Composting toilets with urine separation, residue re-use on agricultural land, on-site grey water treatment in wetlands and transpiration beds but with ongoing discharge to stormwater in wet weather (that is a no-sewerage option).

Table 10.4 compares the capital, annual operating and maintenance costs and total annual costs for these four options. Total annual cost is calculated as operating cost plus 10% pa of capital cost to approximately recover interest and redemption.

Preliminary design calculation and cost estimates for these options are included in Appendix B, Table B4. Several features of each option are of particular importance for the purposes of this comparison. In all cases it is assumed that houses already have conventional toilets. For composting toilet options these are removed and replaced with composting toilet units.

Table 10.4: Options for Sanitation of a Fringe Area

Option	Capital Cost [1]		Annual Operating Cost		Annual Cost	
	Capital Cost $M	Capital Cost $/household	$M pa	Annual Operating Cost $/household.yr	$M pa	Total Annual Cost $/household.yr
1. **Conventional** Sewerage and Local Treatment and Irrigation	9.44	11 795	0.193	242	1.14	1 421
2. **Conventional** Sewerage and Pump 15 km to Main Sewer	9.26	11 579	0.166	207	1.09	1 365
3. **Composting** & Grey-water Sewerage with Local Lagoon Treatment and Recycling	8.20	10 254	0.107	134	0.93	1 159
4. **Composting** & On-site Urine and Grey Water Disposal	5.91	7 391	0.046	58	0.64	797

1 Note capital costs are not comparable to those in Table 10.3 as Table 10.4 does not include water & sewerage headworks costs, water reticulation costs and household plumbing costs

For the conventional sewerage schemes (Option 1 and Option 2) with local treatment and disposal, a typical sewage flow of 180 L/c.d has been assumed. For Option 1 – treatment in a local extended aeration activated sludge plant about three km from the urban area, winter storage and irrigation on trees has been assumed for the wastewater treatment and disposal option. This is a typical sort of off-stream treatment and disposal system. Water suitable for reuse could not be produced from this option without a significant increase in capital cost for treatment.

For the pumping to main sewerage option (Option 2) a distance of 15 km has been assumed which is probably optimistic for such areas. Both a headworks charge and an operating cost contribution to the regional treatment facility have been assumed.

For the composting toilet options (Options 3 and 4), it is assumed that grey water flow is 130 L/c.d and that urine is beneficially applied to agricultural land. Cartage costs (but not application costs) are included. It has also been assumed that composting toilets cost $4 000 per household more in this case than water-flush toilets. This is less than the $6 000 assumed for the dense urban development but is in keeping with the greater ease of installation in lower density development in low density areas. If a cost of $6 000 per household is assumed for the additional cost of composting toilets the costs of Options 1 and 3 become almost equivalent.

It is intended that the small amount of compost could be used beneficially on householders properties, and a grey water sewerage scheme with treatment in a facultative lagoon treatment plant and winter storage for grey water is to be provided. For Option 3 with a grey water sewerage system, lagoon treatment is appropriate since nitrogen will not have to be removed to allow sustainable irrigation. Treated grey water will be returned to a town distribution system for reuse rather than being reused on agricultural land or a tree plantation. The latter should be a less costly option so composting toilets have been somewhat penalised in this option. This reuse system is not a particularly economical scheme since the grey water would probably only be sufficient to irrigate around 72 hectares (28%) out of a total of 260 hectares of gardens and public open space available to be irrigated in this example. If such an area was irrigated it would receive a satisfactorily low (and probably sustainable) nutrient load from the recycled grey water (and some may have rainwater storage). It has been assumed that the grey water reticulation system would cover half of the town area to allow for the fact that not all property owners would make active and full use of the grey water. Centralised treatment of grey water with winter storage prior to reuse has the advantage that there would be no runoff of treated grey water from the town in winter and householders would not have to be concerned with waterlogging and management of an on-site system. It is noted that current unrestricted reuse regulations would require class A effluent that would include additional treatment in the form of coagulation and filtration or microfiltration and chlorination. However, it is considered that this additional treatment after prolonged storage would mean that this option would be unfairly disadvantaged for no real health or ecological benefit.

The calculations for composting toilets indicated that, even if separated urine is not carted away to agricultural land, the likely area available for grey water irrigation and compost in such a town would be more than enough to cater for the nutrient loads in urine, compost and grey water suggesting that such a town could manage its own wastewater on-site using composting toilets. In fact at a moderate nitrogen application of 20 kg/ha.yr, around 52% of the irrigable area would need to be used for disposal of urine and compost. However, this still assumes a relatively low density (around six persons per hectare or an average lot size of 0.3 hectares) and that some degree of garden harvesting or active tree growing and clearing takes place and neglects the fact that irrigation without runoff or accessions to groundwater is only feasible in dry periods. With composting toilets and urine separation, on-site storage of urine and compost by householders is feasible and would allow application to land during the growing season. However, it is difficult to envisage householders distributing stored urine and for this reason treatment of urine and grey water on site by a constructed wetland has been assumed. Previous work by the principal author (Crockett, AWA 2000) indicated that such a population density could be supported with on-site sanitation with all wastewater nutrients being applied on site in temperate climates. However, a more appropriate scenario is that urine would be tankered away because the population density as a result of sewerage would increase making on-site urine disposal less feasible.

The final option, Option 4, builds on the assessment that this fringe area with a low population density is sustainable with all nutrients and water able to be applied to land and takes into account that many people who are keen on applying alternative sanitation regard wetland treatment of grey water with some runoff and seepage to groundwater as being acceptable. The option still recovers urine and carts it for local agricultural use but assumes all grey water is treated on site by a wetland and that compost is used on site.

Note that operating costs have been discounted by an amount equivalent to the value of nitrogen in the urine.

It can be seen that composting toilets with on-site grey water management (Option 4) has the lowest capital and operating costs by a significant margin, which is not unexpected.

It can also be seen that the more ecologically sustainable option of a grey water sewerage scheme (Option 3) is less costly than either of the conventional sewerage approaches (annual cost being between 15% to 20% lower) and that this saving is potentially significant bearing in mind that such preliminary estimates do not have a high accuracy.

The conclusion reached for a dense urban development in section 10.2, that composting toilets are financially more costly than conventional sewerage, is reversed for this small unsewered town case. Thus, it is concluded that composting toilets potentially offer a competitive option for improving sanitation arrangements in small towns or in sewer backlog areas.

10.4 Economic Evaluation

A proper economic evaluation of composting toilets compared to conventional sewerage would require detailed investigation of all embodied taxes within the cost estimates, which have the effect of artificially influencing costs. With the advent of GST, wholesale sales taxes, import duties and other taxes have generally reduced and GST is probably applied to all inputs to housing and sewerage systems. Thus, it is likely that removal of taxes and duties from the cost estimates would not alter the relative differences between options. Therefore, it is considered valid to use the financial cost estimates as the basis for economic evaluation of the options.

It is typical to use present value of costs in such economic evaluations. A simpler approach of comparing annual costs calculated as being 10% of capital cost plus annual operating costs has been taken in this evaluation. The justification of this is that present value analysis downgrades the impact of ongoing operating costs. In the case of comparing composting toilets with conventional sewerage where the major issues are water use, energy use and resource use (and associated costs and savings), discounting ongoing costs would downgrade the importance of potentially important differences in resource and energy consumption.

It is probable that the cost of water and energy relative to other costs will increase significantly in future. Therefore, it is appropriate to recalculate the financial costs for different water and energy prices, including an estimate of any increase in cost of items that involve significant energy inputs in their manufacture or operation.

For the purposes of this study, two alternative future water and energy price scenarios have been used as set out in Table 10.5. The first assumes a doubling of water and energy cost with a corresponding increase in the cost of fertiliser. The second, an attempt to estimate the likely pricing of water and energy in an ecologically sustainable economic system, assumes a three-fold increase in the cost of water and energy relative to other costs. Justification of these order of magnitude increases is not attempted in this feasibility study but it is suggested that, in the case of water price, an ecologically sustainable price of $20/kL would not unreasonable (Crockett and Carrol, 2000). By comparison, $4.50 is conservative.

The mass of material and energy input to construction of either type of sanitation system will probably be of a similar order so no attempt has been made to increase the capital costs by a factor related to energy input. This increase may lead to a substantial increase in the capital cost of both options, but it is unlikely that the relative cost will change.

Table 10.5: Future Water and Energy Prices Used

Cost Item	Unit	Current	Scenario A (Double Cost)	Scenario B Ecologically Sustainable Pricing
Electricity	$/kW.hr	0.12	0.24	0.36
Diesel	$/L	1	2	3
Natural gas	$/GJ	10	20	30
Water	$/kL	1.5	3	4.5
Fertiliser Cost	$/tonne	600	800	1 000

Table 10.6 sets out the capital, annual operating costs and total annual costs per household for 12 scenarios based on the base case for 2000 new urban medium to high-density houses discussed in Section 10.2. The least cost option between composting toilets and conventional sewerage is highlighted in grey for each scenario. The Scenarios used are briefly summarised below:

- Scenarios 1 to 5 assume the use of mains-powered ventilation fans and gas-boosted solar hot water heaters to warm the compost chamber as allowed for in the demonstration project and in the base case in Section 10.2. Scenario 1 is the base case, Scenario 2 is the case where an upgrade in sewage transfer and treatment capacity is required (as in Section 10.2) but with added phosphorus removal and Scenarios 3 to 5 show the impact of doubling water and energy cost separately or together. It can be seen that conventional sewerage has the lowest annual cost in all but Scenario 2 where a sewerage system upgrade is required. Note that trebling water and energy cost would decrease the advantage of conventional sewerage but it would still be less costly if no major upgrade were required to cater for the development;
- Scenarios 6 to 8 show the effect under current and double energy and water costs of eliminating the need for electricity and gas with the composting toilet option by installing solar powered fans and all-solar heating. This is a realistic case as many composting toilet installations operate in this way. However, solar powered fans would add significantly to the capital cost (solar heating could be achieved by optimum building orientation in Melbourne). For scenario 7, where a sewerage system upgrade is required composting toilets become competitive. Scenario 8 compared to Scenario 5 shows that for a doubling of water and energy costs the cost disadvantage of composting toilets reduces but is not eliminated;
- Scenarios 9 and 10 build on Scenario 8 by assuming that the sewage treatment plant is a regional plant without any on-site energy generation from biogas and that an upgrade of the sewerage system and treatment plant is required. This is a likely scenario for a regional plant. This shows that composting toilets start to show a potentially significant cost advantage if water and energy costs double relative to other costs and this advantage increases with a trebling of water and energy costs;

Table 10.6: Cost Scenarios for a Medium Density Urban Residential Development Including Impact of Water and Energy Price

Scenario	Capital Cost $/household		Annual Operating Cost $ pa		Total Annual Cost $ pa		Percentage Difference in Annual Cost (-ve indicates Composting Toilets are Less Costly)
	Conventional Sewerage	Composting Toilets/Grey Water Sewerage	Conventional Sewerage	Composting Toilets/Grey Water Sewerage	Conventional Sewerage	Composting Toilets/Grey Water Sewerage	
With Electrically Operated Ventilation and Solar/Gas Heating of Composting Toilets, Sewage Treatment Plants 70% Energy Self-Sufficient							
1. Current Water and Energy Costs	18 972	20 528	162	253	2 059	2 306	12%
2. Upgrade of Reticulation, Treatment and P Removal	21 755	20 528	169	253	2 345	2 306	-2%
3. Double Water Cost	18 972	20 528	162	192	2 059	2 244	9%
4. Double Energy Cost	18 972	20 528	170	420	2 067	2 473	20%
5. Double Water and Energy Cost	18 972	20 528	170	359	2 067	2 412	17%
With Solar Operated Ventilation and Heating of Composting Toilets, No Odour Scrubbers, Sewage Treatment Plants 70% Energy Self-Sufficient							
6. Current Water and Energy Costs	18 972	23 028	162	98	2 059	2 401	17%
7. Upgrade of Reticulation, Treatment and P Removal	21 755	23 028	169	98	2 345	2 401	2%
8. Double Water and Energy Cost	18 972	23 028	170	48	2 067	2 351	14%
Upgrade of Sewerage System Required, Optimistic Capital Cost Estimate for Solar Ventilation and Heating of Composting Toilets, No Odour Scrubbers, Sewage Treatment Plants 100% Purchased Energy							
9. Double Water and Energy Cost	21 755	20 528	180	53	2 356	2 105	-11%
10. Tripple Water and Energy Cost	21 755	20 528	192	6	2 368	2 059	-13%
With Electrically Operated Ventilation and Solar/Gas Heating of Composting Toilets, Sewage Treatment Plants 100% Purchased Energy							
11. Current Water and Energy Costs	18 972	20 528	167	256	2 064	2 309	12%
12. Double Water and Energy Cost	18 972	20 528	180	425	2 077	2 478	19%

- The final 2 Scenarios, 11 and 12, show the impact of the sewage treatment plant having no on-site energy generation on the situation in Scenario 1. This shows that the percentage total annual cost advantage of conventional sewerage is not significantly changed by the absence of on-site energy generation but at double current energy and water costs the percentage advantage actually increases because there is an increase in treatment cost for grey water in the composting toilet case.

In relation to the cost of solar powering the ventilation fans and heating, an additional $2 000 capital cost has been included to cover the cost of solar powering of a 4 W ventilation fan and for all-solar heating. This power is based on advice from Environment Equipment. It is an important figure in the overall energy balance that needs to be confirmed since GHD's investigations indicate that 20 to 30 W may be required to guarantee no odour release inside the house and is close to the power used on many current installations where the significance of this power consumption has not been appreciated. However, the impact on costs of a 30 W fan is an additional $30 per household per year, which is not particularly significant. This issue was discussed in Section 5.

It is noted that none of the composting toilets visited during this study used other than passive solar heating and in two cases there was no passive solar heating and yet the composting toilet still worked well. Thus the inclusion of a cost for gas heating in winter is a pessimistic allowance. The amount of gas that would be needed is also highly uncertain.

The overall conclusions from this economic evaluation are as follows:

- the composting toilet/grey water sewerage option is likely to be more capital intensive than conventional sewerage for a dense urban development because of the additional cost of composting toilets and associated building works and the need to provide expensive solar-driven ventilation in order to avoid a total operating energy input that substantially exceeds the energy input necessary to operate a conventional sewerage system;
- if a significant capital works upgrade is necessary to service a new subdivision then composting toilets and a grey water sewerage system offer a potentially equal cost option to conventional sewerage. Composting toilets with grey water sewerage probably offer a significantly less costly option to a dual reticulation system that uses recycled sewage for toilet flushing;
- the cost advantage of composting toilets becomes greater (in the case where a sewerage system requires a significant capital upgrade) if water and energy prices increase in future. However, if a subdivision does not require a major capital upgrade of the sewerage system, the value of water savings achieved with composting toilets are not sufficient to cancel out the additional capital cost of composting toilets;
- whilst composting toilets with grey water sewerage can be made to be more energy efficient than conventional sewerage, this requires extra expenditure on solar generation of electricity for ventilation fans. This may be an unfair penalty against the technology since a composting toilet system with fan has a significant benefit of no odour in the toilet room compared to conventional water-flush toilets without fans.

In summary, the composting toilet/grey water sewerage option for a denser urban development is probably higher in capital cost than conventional sewerage but may have a total annual cost advantage in future. This potential advantage is due to the water savings it makes possible and is assisted by the value of the fertiliser-replacement materials recovered. Because energy use is similar to that for conventional sewerage, changing energy costs will have a minor effect on the relative economics of conventional sewerage compared to composting toilets and grey water sewerage.

These conclusions are based on limited evaluation and need further confirmation based on more reliable capital and operating cost data. However, they do provide economic justification for a demonstration project, particularly for an area where sewerage capacity is limited. Further refinement of the costing work must be part of the demonstration project to include such things as asset replacement costs at the end of their lifecycle and differing costs of capital to householders and water authorities.

10.5 Ecological Advantage of the Composting Toilet/Grey Water Sewerage Option

The forgoing evaluation takes no account of wider ecological advantages of the composting toilet/grey water sewerage option. There would be a notable saving in potable water use of approximately 18 kL/c.yr and of significant importance is the fact that the nutrient, BOD, pathogen and salt content of a community's wastewater would be greatly reduced and there would be some reduction in wastewater volume. Thus, even allowing for treatment to a similar effluent quality, the loads discharged to the receiving water would be reduced if there were a significant uptake of composting toilets. In addition, the burning of fossil fuel to manufacture fertiliser would be reduced by a measurable amount. It is beyond the scope of this feasibility study to try to determine the economic value of these advantages but it is important to bear in mind that:

- a composting toilet/grey water sewerage option appears to have a similar capital cost to conventional sewerage for dense urban developments;
- the cost is probably significantly lower for backlog areas or small towns;
- it is likely to have a lower annual operating cost and total annual cost if water prices increase. This additional advantage supports the desirability of a demonstration project to confirm the conclusions reached.

10.6 Demonstration Project Funding

The estimated cost of the demonstration project is set out in detail in Appendix B, Tables B5 and B6. Table 10.7 summarises the overall cost by component and includes a column of costs that would be incurred for a conventional development.

Table 10.7 shows that a substantial proportion of the cost of the proposed demonstration project is associated with the reuse trial and the experimental/study aspects. In addition, the cost of equipping the apartments with composting toilets is substantially greater than the cost of providing conventional sanitation.

The developer, if it decides to proceed with design, marketing, construction and hopefully early sale of compost-toilet equipped apartments, will be risking a substantial sum of money, around $113 000 of extra costs on the site for the additional building, plumbing, heating, ventilation work which may be wasted if the apartments are not sold until conventional toilets are retrofitted. It is likely construction will not start until sufficient apartments are sold off the plan, as this is one way to minimise risk.

Purchasers too, will be risking system problems that may not be quickly resolved as well as a reduced resale value.

Table 10.7: Funding required for the Demonstration Project (all figures include 30% contingency)

Component	Item	Capital Cost, Conventional Development $k	Capital Cost, Composting Toilet & 2 Year Trial $k	Operating Cost, Conventional Development $k	Operating Cost, Composting Toilet & 2 Year Trial $k
Apartments	Bathroom fit-out and Internal Plumbing	74.5	63	-	-
	External Plumbing and Tanks	16.6	32.4	-	-
	Additional Construction	-	41.8	-	-
	Heating and Ventilation	-	50.9	-	3.6
	Monitoring and Control	-	26	-	-
	Sewer and Water Headworks and Other Charges	23.4	14.3	5	4
	Maintenance & Operation	-	-	-	26.2
	Design, Management, Monitoring and Reporting	-	25	-	15
	Marketing	-	-	-	10
Transport System	Truck with custom-built platform	-	32.5	-	3.1
	Transportation	-	-	-	10.4
Reuse Trial	Trial – Implementation, operation, monitoring and reporting	-	165	-	135
Project Management	Project Management & Reporting to Steering Committee		20	-	50
	TOTALS	**114.5**	**470.9**	**5**	**257.3**
	ADDITIONAL COST OVER CONVENTIONAL SEWERAGE	**-**	**356.4**	**-**	**252.3**
				TOTAL COST OF 2 YEAR DEMONSTRATION PROJECT ($k)	**730**

Overall, it is suggested that other parties, including the Smart Water Fund should fund the following:

- all costs associated with transport and an agricultural trial;
- all monitoring and project management and reporting costs;
- 50% of the design and supervision costs of the composting toilet installation;
- 75% of the difference between the cost of composting toilets, heating and ventilation and conventional sewerage;
- 100% of the cost of monitoring and automatic control equipment since it is provided for the purposes of investigation.

This would leave the developer (and ultimately the owner) to meet around 50% of the difference between composting toilets and conventional sanitation. None of the costs associated with extra monitoring, controls, trial facilities, maintenance and transport set up and operation would be borne by the developer.

10.7 Project Risk Management

The risks with the proposed demonstration project can be divided into the following categories:

- financial risk to the developer arising from not being able to sell the apartments quickly due to perceptions and having to redesign or modify the project;
- risk to the reputations of the developers, architects, engineers, Council, EPA, DHS and the Smart Water Fund if the project gets adverse publicity or if occupiers or third parties complain about any aspect;
- technical and financial risk that elements of the project do not work either for technical reasons or because of user behaviour and require substantial further investment or have to be abandoned;
- operational risks at the apartments;
- operational risks at the reuse site;
- health risk to occupiers, maintenance staff, transport operators or people working at the trial site;
- a transport accident leading to contamination or a health risk (particularly related to urine transport);
- risk that the project is unsuccessful or is not completed such that the project does not meet its objectives;
- risk of damage to soil or groundwater at the reuse site.

In developing the preliminary design of the installation and the trial reuse site, all of these risks areas have been addressed in some way and appropriate allowance made in the cost estimates for facilities, management input and monitoring.

Of the above risks, the first has the greatest probability of occurring as it could prevent what is considered to be a viable and useful project going ahead. It has been addressed to some extent at this stage by carrying out a survey of potential purchasers, by allowing for retrofitting of conventional sanitation and by involving a developer who considers the project has merit in this feasibility study. If the project progresses, there will be further opportunities to minimise the risk of financial loss by only committing to construction once there is real buyer interest and by meeting part of the cost of the installations from other sources.

Health risk area is assessed as a relatively low probability although a risk having potentially serious consequences both to individuals and to the future of the technology. The selection of the Rota-Loo® design, contracting the maintenance and collection of compost and urine, the overall design proposed, the approvals process and the provision for appropriate monitoring will minimise this risk. There is also good evidence that the risk is small based on successful less-supervised systems that are already in operation.

The other risks have been addressed in developing the proposed project by a combination of allowances in the budget based on preliminary design and investigation and selection of an experienced team.

It is also proposed that the early phases of the project include more detailed risk identification and assessment including the following steps:

- a HAZOP session during design;
- preparation of a documented detailed risk assessment to list appropriate risk management strategies for the significant risk areas;

- ongoing reporting of incidents and assessment of risks as the project progresses.

11. Reporting

The reporting component of the proposed composting toilet demonstration project is briefly described in this section.

Reporting for the demonstration project would include the standard progress reporting (nominally monthly) to the Smart Water Fund or other funding bodies, more detailed internal financial reporting within each of the project team participants' organisations and a consolidated team progress reporting system that would keep managers within the participant organisations informed.

A separate reporting system is also proposed to the technical advisory committee, which would be established with the Reference Panel established at this feasibility stage but expanded or adjusted for the demonstration project. This reporting would be to nominal quarterly meetings during design and construction and then six-monthly meetings. These reports would have summary financial information only, as the main emphasis would be on performance and technical issues.

Several project technical and financial reports would be produced during the project. The following reports are proposed:

- a planning report produced to accompany various approvals applications;
- a design report on completion of design
- marketing strategy, project program and risk management report once a decision has been taken by the developer to proceed;
- construction report to record the issues arising during construction and record the solutions and final project construction costs;
- a report on the proposed operation, maintenance and transport arrangements to explain the basis for the contracts entered into;
- a report setting out details for the agricultural trial;
- 6-monthly evaluation reports on the demonstration project as it progresses.

A final project report recording all of the information obtained, final project costs, conclusions reached and recommendations for necessary modifications for future installations or for necessary further investigations.

Many of these reports would include comprehensive technical and financial information of wide usefulness. They would be produced by team members who are independent of commercial interests. They would be produced to a high standard so that water authorities, developers and individuals could rely on the information.

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12. Conclusions and Further Investigation Required on Key Issues

This section sets out the conclusions from this feasibility study into a dry composting toilet demonstration project.

12.1 Why Consider Composting Toilets?

Composting toilets are worthy of consideration and demonstration as an alternative to the water-flush toilet for several reasons listed below.

1. In a municipality without major industrial wastewater load, human excreta discharged via water-flushed toilets contributes up to around 25% household wastewater or up to 18 kL/c.yr, over 80% of the nitrogen and phosphorus loads to sewer and around 25% of the BOD load to sewer as well as the major part of the pathogen load and a considerable proportion of the salt load. No other single and already proven technology has the potential to divert over 80% of nutrients and 25% of flow and BOD from the sewerage system, with significant energy, cost and environmental savings.
2. Composting toilets can save up to around 19% of household water use, or up to 18 kL/c.yr out of an average household water use of 96 kL/c.yr and up to 12% of total use of 150 kL/c.yr in Melbourne. If adopted widely, they would make a measurable contribution to Melbourne's water conservation efforts.
3. Urine-separation combined with composting toilets has the advantage of concentrating the majority of the nutrients into an easily handled liquid fertiliser as well as enhancing performance of the composting process for faecal matter and toilet paper.
4. Removal of this excreta load from the sewerage system would leave a grey water that is easier to transport, cheaper and easier to treat, lower in nutrients, salts and pathogens and probably easier to market for reuse, as well as reducing total pollutant loads on the receiving environment without upgrading sewage treatment plants. Few of these advantages are gained by alternatives such as use of grey water for toilet flushing which would increase sewage salinity.
5. The nitrogen, phosphorus and potassium from human excreta, recovered and stored via a composting toilet system, can provide a low embodied energy replacement for chemical fertilisers used in agriculture, potentially replacing up to 5 or 6% of fertiliser currently used in agriculture in Australia. This percentage is small because Australia is a major food and fibre exporter. In a country that does not export, the potential fertiliser replacement would be much higher.
6. Because a composting toilet system treats and stores the compost and urine products, they can be transported to land at appropriate times without the requirement for expensive communal treatment and storage facilities.
7. Composting toilets have been viewed by sewerage practitioners and by many others in the community as a fringe technology that is inappropriate to a modern city. However this attitude is changing as communities take up the challenge of achieving ecologically sustainable development. Urine separation is a new concept that is being picked up by mainstream building designers and becoming common in some other countries. A demonstration of both of these technologies in a controlled and

documented way will determine whether the claimed and estimated benefits are real and whether users would accept the change.

12.2 Policy Framework

The feasibility study concludes that policy at Federal Government, State Government, Council and Water Authority levels is generally supportive of demonstration of technologies such as composting toiles whilst not specifically encouraging their use in an existing sewered area. Two specific conclusions of particular relevance have been reached.

1. State Environment Protection Policies require action to avoid waste and minimisation of resource use. Therefore the proposed demonstration project is consistent with State Policy.
2. The requirement of Clause 34 of the State Environment Protection Policy (Waters of Victoria) that wastewater be discharged to a sewer where it exists unless it can be managed on site needs to be interpreted in the light of other requirements of the policy.

12.3 Legal and Regulatory Framework, Regulator Support and Possible Barriers to Overcome

The study team has reviewed applicable legislation, regulation and practice at national, state and local level. Various approvals will be involved and time will be required to gain these approvals. Nevertheless, discussions on the proposed project with representatives of the relevant approvals agencies lead to a number of positive conclusions and some conclusions on where clarification will be required or barriers will have to be overcome.

1. There is a sufficient level of support from all relevant agencies to make a demonstration project feasible.
2. A Research, Development & Demonstration approval under the environment protection act is likely to be the way in which the reuse trial site is approved.
3. Council planning approval will be required for the apartment installation.
4. There should be no specific building approval issues.
5. Compliance with the Australian Standard (AS 1546.2:2001) for composting toilets will be necessary at the apartments but some deviation from the requirements of the standard will be involved in operating the agricultural reuse trial site. Since it is a trial and since EPA does not specifically require conformance with the Standard this should not be an issue.
6. Recently developed guidance on use of biosolids is relevant and would probably prevent the proposed agricultural use of urine and compost. Whilst a Research, Development & Demonstration approval should allow the agricultural trial to go ahead, widespread adoption of use of compost and urine as fertiliser will require review of guidelines. This will be a major factor to be dealt with during the period of the trial and the information obtained on health risks to workers and consumers of products and impact on soils will be important in developing appropriate guidelines and standards.
7. The Department of Human Services is supportive and will have an advisory role to EPA and Council rather than a formal approval role.

12.4 Responses of Potential Users of Composting Toilets and Residues

A survey of potential apartment purchasers indicated a significant interest in purchasing apartments equipped with composting toilets and other water-saving technologies. In addition, users of composting toilets that have been well designed and managed report favourable reactions. Conclusions from discussions with the developer, site inspections of operating composting toilet installations, the experience of composting toilet suppliers and review of survey returns from potential apartment purchasers are set out below.

1. A significant majority of the 54 survey respondents (potential purchasers) who responded to the survey carried out, over 80%, stated they would or may consider purchasing an apartment with a composting toilet. Even if many changed their minds, it indicates a market does exist.
2. 88% of respondents indicated a willingness to pay more for an apartment with water and energy efficient features.
3. Respondents under 40 were slightly more likely to be supportive than older respondents.
4. Males and females indicated similar levels of support and interest.
5. Survey respondents who are unfamiliar with the technology consider composting toilets may produce odours.
6. Most survey respondents are interested to find out more.
7. Many (43%) of the survey respondents do not see major difficulties with changing their practices or explaining a composting toilet to guests, and a similar number of survey respondents (41%) indicated that they would like more information before responding.
8. A minority of survey respondents regard the concept as “archaic” and would not purchase an apartment with a composting toilet.
9. A minority of survey respondents have used poorly designed or operated composting toilets and are therefore suspicious of the technology. Of these some are still willing to consider the concept.
10. A majority of people who have used public composting toilets that are well designed and operated consider they are superior to water-flush toilets.
11. A majority of private purchases who have installed composting toilets consider they are superior to water-flush toilets (as per the next two points).
12. Users of well designed and maintained composting toilet systems freely comment that odour is absent, and that water-flush toilets are a source of objectionable odour.
13. Two users of composting toilets stated that they no longer like using water-flush toilets as they see it as wrong to pollute clean water.
14. Maintenance staff who maintain, clean and empty composting toilets do not appear to object to the tasks, both at the toilet pedestal and for removal and handling of the compost.
15. Non-users have a low level of awareness of the benefits and characteristics of composting toilets.
16. Male users are not likely to sit to urinate (note that this is not a specific requirement with modern designs of separating toilet pedestals).
17. Male users in particular tend to leave the lids up, which can lead to odour and insect problems.

The overall conclusion is that there is a potential market for apartments with composting toilets and that there is good evidence to suggest that an independent and successful demonstration project will rapidly generate further demand because of the high probability that people will see composting toilets as a superior solution (to a water based system) once they have used them.

12.5 Odour, Insects and Ventilation

The following conclusions can be drawn in relation to odour, insect nuisance and ventilation.

1. Experience with properly designed and operating composting toilets is that odour is absent within the toilet room provided the ventilation system works constantly and provided lids are normally left closed.
2. Composting toilet installations have a significant advantage over water-flush toilets in terms of the toilet room being odour free.
3. Electrically driven mechanical ventilation by fan is vital if odour is to be avoided. At this point insufficient work has been done to optimise the energy consumption of ventilation systems in a multi-storey high density application such as proposed for the demonstration project.
4. Odour external to buildings appears to be a low risk but most installations are at low-density developments with ample space around for dilution. It would be prudent in a high-density area to include odour scrubbing on vents.
5. Blowflies, houseflies, bush flies and mosquitos do not appear to be a significant problem although it is necessary to include screens on vents and fly screens on toilet windows and to keep the toilet lids closed.
6. Small midges, similar to those found in domestic compost bins, do breed in the compost and these attract spiders. Fine mesh screens on vents into and out of compost bins appear to provide effective control of midges and lower levels of midges removes a food source for spiders.
7. Slater beetles were found in an installation using significant quantities of wood shavings. Investigation of means to limit the access of crawling insects would be desirable even though the proposed composting toilets will not rely on use of wood shavings.
8. Spiders and flies do not appear to cause nuisance by exiting via the toilet in properly maintained systems (there may be odd incidents).
9. Some form of insect control by spraying or other method may be appropriate where people are concerned or if insects are likely to be a significant disease vector. This needs further investigation.

12.6 Water Savings and Energy Use

Composting toilets save water and have the potential to be a lower energy option than conventional sanitation. Specific conclusions reached are set our below.

1. A major benefit of composting toilets is that they can reduce household water use by up to around 19% or up to 18 kL/c.yr.
2. If water prices increase, composting toilets gain a significant operating cost advantage over conventional sewerage.

3. Most composting toilet systems operate effectively without supplementary heating. If heating is required then it needs to be as much as possible by means of solar energy and recovery of household waste heat if composting toilets are to be comparable in mains-powered energy consumption to conventional sewerage.
4. There is a small but significant energy saving with composting toilet systems in the form of embodied energy in fertiliser that compost and urine would replace. Including this energy in a life-cycle energy balance shows that composting toilets can be more energy efficient than many conventional sewerage systems, where treatment plants do not generate some of their own energy and provided that ventilation fan and supplementary heating energy is minimised and transport distance to the site where residues are reused is under about 50 km.
5. In an urban setting where compost and urine has to be carted more than about 50 km to the reuse site and with compost ventilation via a mains-powered electric fan, the operating energy use by a composting toilet system will exceed the operating energy use of a conventional sewerage system with a treatment plant that produces some of its own energy. This conclusion confirms the relative energy-efficiency of water born sanitation and that the energy use of modern wastewater treatment processes is not high compared to the alternative of on-site treatment by processes such as composting toilets.
6. Embodied energy in composting toilet systems with grey water sewerage and conventional sewerage systems are likely to be of a similar order. This conclusion is not based on calculations and may need confirmation. However, in most engineered systems that use energy in operation, it is the operating energy that dominates energy use by a large margin.
7. Increasing energy prices have no significant influence on the financial viability of composting toilets relative to conventional sewerage unless the system uses mains-driven ventilation fans, supplemental heating and involves long transport distances. Even then, because both composting toilets and conventional sewerage make only small demands on energy, the impact of rising energy costs on overall cost is not great.

12.7 Technical Design Issues and Implications for the Building

This feasibility study has attempted to develop a design that would be reliable and suitable for high quality inner urban apartments, a style of accommodation that is currently very popular and which makes a contribution to ecologically sustainable development by minimising land and resource use. The study has proposed some design solutions to known challenges with composting toilets but has also identified some uncertainties that will need further design, trial and possibly redesign during the proposed demonstration project. It is concluded that the following design features are the most appropriate for the reasons stated.

1. The developer has indicated willingness to consider installation of composting toilets as the only toilets in 12 two-storey apartments in a high quality development in Flemington. The equivalent population from these apartments, if fully occupied is 27 people. Whilst a larger installation was envisaged, a combination of planning approval issues, project timing, financial risk to the developer and purchaser interest means that a larger trial is unlikely to be supported. Support from the developer will be dependent on the level of funding support and ongoing assessment of purchaser interest.
2. Use of urine separation will maximise nutrient removal, minimise air emissions and improve composting.

3. A rotary semi-batch composting process will provide the greatest protection to maintenance workers and those applying compost to land as well as providing the best quality of compost.
4. Leachate from the compost should be collected and handled separately in the trial installation, as it presents the greatest risk of pathogen transfer.
5. The ventilation system should be designed to allow investigation of minimum ventilation rates, as mechanical ventilation will be a significant energy use. Further detailed design work on the ventilation system will be required.
6. Supplementary heating of the ventilation air by hermosiphon-circulated hot water from an apartment gas-boosted solar hot water service is the most practical way to maintain the compost at an appropriate temperature where the composters cannot be located in a sunny location. It will also allow trial of different composting temperatures. Further detailed design work on the supplementary heating system will be required together with investigation of heat recovery from building wastewater and ventilation air, since supplementary heating is a potentially high energy use.
7. Screening to minimise problems from insects needs to be by fine fabric filters rather than flywire because of the small size of insects.
8. The proposed linear two-storey apartment block with the ground floor at ground level presents a challenge for composter installation requiring below ground spaces under and to the side of the building as well as stair or ramp access. The additional structural costs will be high with this configuration and access by stairs to a space with removable covers is not ideal, as it will increase the time required for compost removal. The potential exists to significantly reduce these costs if elevated ground floors are possible.
9. Potential for additional cost reduction utilising north facing space for composters and clustering of apartments in such a way that more than two apartments could be serviced from one basement space. This is not available for the demonstration trial, however by using the less favourable configuration proposed it presents the opportunity for a more rigorous trial with conservative outcomes.
10. It will be prudent to install a biofilter-type odour scrubber on the trial installation. This is proposed to be at ground level however in other installations could be considered for the roof. This aspect needs further design development.
11. Lighting design in the toilet room will need attention as it is important for aesthetic reasons to minimise the visibility of composting material and skid marks on the chute when looking down into the chute.

12.8 Transport

Several conclusions can be drawn on the need for and means of providing transport to remove compost, urine and leachate from the composting toilets.

1. For an outlying area with low population density, around four to six persons per hectare, on-site disposal of compost and urine is feasible and sustainable. The ability to store residues over the winter for application to land in the growing season is an important advantage of composting toilets.
2. For population densities greater than about 10 persons per hectare, the available area of cultivated land becomes insufficient for sustainable application of the nutrient load in compost and urine and thus the materials, or at least the majority of the materials should be transported to agricultural land.

3. The proposed demonstration project will use a purpose-designed dual vacuum tank and compost bin module mounted on a custom built tray for the truck deck and either stored at the reuse trial site or the waste transport contractor's site. On a larger scale, more energy efficient larger transport vehicles dedicated to either urine or compost would be possible.
4. Transport energy is a significant part of the total energy use of this technology and is sensitive to the distance form the agricultural reuse site. Large-scale application of composting toilets will be best where suitable agricultural land for nutrient reuse is within 50 km. This suggests that this approach to sanitation could best be applied to developments on the city fringe. It also suggests that a city layout that incorporates intensive agriculture within green wedges is desirable.

12.9 Maintenance

It is concluded that maintenance requirements, within the house, for composting toilet systems, whilst greater than for water-flush systems are not particularly onerous. Specific conclusions are set out below.

1. The most critical mechanical item is the ventilation fan. On-site spares and easy access for replacement will be vital to ensure odour problems are avoided. It is suggested that a design enabling the owner to slot in and plug in a replacement fan would be the best arrangement.
2. Whilst some systems require supply and addition of wood shavings to the compost, this should not be necessary with the Rota-Loo® design proposed for the trial. However, it may be desirable to design the toilet rooms to allow space for a 20 L wood shavings bin and to provide storage of wood shavings in a central location for the apartments should they be needed.
3. Householders will need to clean the inside of the pedestals every few days, the only difference to cleaning of a water-flushed toilet being that this should be done with as little water as possible and without use of chemical cleaners that could inhibit the composting process. Warm water on an almost dry sponge, or a brush dipped in a weak vinegar solution, are possibilities. Some further investigation and preparation of instructions on this will be required.
4. Householders will also need to do some cleaning of the drop chutes, at least the first metre, in order to improve appearance and also to clear any cobweb build-up. Preferred methods for doing this will need development. It is likely that a combination of sponging and sweeping will be necessary. One approach has been to use a rolled-up newspaper, which is then simply dropped into the composter.
5. Spider web build up in the ventilation ducting will require regular sweeping and this necessitates easy access to all ducts. Fine screens limit midge growth, which limits the number of spiders. It is intended to arrange duct cleaning as part of the maintenance contract and to perform from outside the apartment.
6. Householders should not need to access the composting carousel at all. Thus it should be feasible to contract out all composting toilet maintenance and residue removal.

12.10 Reuse of Compost and Urine

1. Stockholm water has run significant trials on reuse of urine in Stockholm. Crop yields were up to 90% of those using mineral fertiliser, and no appreciable adverse effects were noted.

2. The use of urine, leachate and compost from composting toilets compared to use of biosolids and effluent from conventional sewage treatment has the potential to recover far more of the nutrient and organic matter available in a relatively uncontaminated form.
3. Australian experience with reuse of compost and urine is limited to a trial of urine application in Canberra and anecdotal information on use of compost from individual owners. Most urine and leachate in current installations in Australia ends up being discharged with grey water, often to wetlands.
4. The absence of information on the safety and benefits of use of these materials under Australian conditions in particular means that an agricultural reuse trial is appropriate.
5. Reuse on public parkland or urban market gardens or community gardens has not been considered, as a properly controlled trial is required to demonstrate benefits and safety.
6. Sufficient urine and leachate will be produced (about 10 kL/yr) to apply to a reasonable area of trial crops, an estimated 0.5 to one hectare, which should be large enough for meaningful research into the fate of indicator bacteria and the response of crops to this fertiliser. The quantity of compost will be only around one tonne/yr and its use may well be limited to a small trial area.
7. There is written agreement in principal from Melbourne Water, and interest from the Department of Primary Industries and health specialists to participate in a controlled agricultural use trial over two years on land owned by Melbourne Water at the Western Treatment Plant. Hopefully about two hectares in total can be made available on good soils that have not been used previously for wastewater irrigation.
8. Whilst the trial can provide information on the fate of indicator bacteria in urine, leachate and compost, it is unrealistic to expect much information will be obtained specifically on the fate of pathogens and pharmaceuticals with such a small population (around 27 equivalent persons) contributing.

12.11 Financial, Economic and Technical Advantages and Disadvantages of Composting Toilets in Full Scale Applications

Assessment of the financial feasibility and economic benefits of composting toilets with urine separation have been investigated for a for a 2000 household dense inner-urban development close to a sewerage system and for a smaller, low population density area or town distant from main sewerage. Conclusions on the financial and feasibility and economics of the concept are listed below.

1. A composting toilet/grey water sewerage option is likely to be more capital intensive than conventional sewerage for a dense urban development because of the additional cost of composting toilets and associated building works and the need to provide expensive solar-driven ventilation in order to avoid a total operating energy input that exceeds the energy input necessary to operate a conventional sewerage system.
2. where no upgrade of the sewerage system is required then composting toilets are will be about 8% more costly overall (by about $1 500/household over conventional sewerage estimated as $19 000/household) but are considered a more environmentally beneficial approach to sanitation.
3. In the case where a sewerage system requires a significant capital upgrade to cater for a new subdivision where conventional sewerage is proposed, composting toilets with grey water sewerage offer a potentially less costly option, around $1 200 or 5.5% less per household in overall capital cost

of the system (the house installation part of the overall capital cost would still be more costly than water-flush toilets) than conventional sewerage, the all-up cost per household of which is estimated as around $21 800.

4. In outlying areas or towns distant from sewerage where a major transfer main or local treatment plant would be required, composting toilets with grey water sewerage is likely to offer a significant cost advantage over connection to the distant sewerage scheme.
5. Annual overall operating costs for a composting toilet/grey water sewerage system are likely to be of the order of $90 or 55% more per household than for conventional sewerage in a large urban subdivision but possibly $100 or 45% less than conventional sewerage for a backlog area or outlying town.
6. The relative cost of energy does not have a significant impact on the relative cost advantages of conventional sewerage and composting toilets with grey water sewerage because energy costs are not a major factor in either system.
7. Increasing water costs in future could make composting toilets with grey water sewerage a less costly option than conventional sewerage.
8. Whilst composting toilets with grey water sewerage can be made to be more energy efficient than conventional sewerage, this requires extra expenditure on solar generation of electricity for ventilation fans. This may be an unfair penalty against the technology since a composting toilet system with fan has a significant benefit of no odour in the toilet room compared to conventional water-flush toilets without fans.
9. At urban densities of up to four to six persons per hectare, sustainable use of urine, leachate and compost within the urban area is possible but grey water disposal or reuse remains an issue in wet periods when there will be runoff.
10. If grey water is handled on site in a low-density fringe area or small country town, then composting toilets and on-site grey water treatment offer a lower cost approach to sanitation than sewerage. However, the impact of on-site grey water treatment in wet months is not considered to be as environmentally acceptable as centralised treatment, storage and reuse of grey water.
11. In dense urban environments of more than 30 person/ha, a grey water sewerage system is essential and compost, urine and leachate generated from composting toilets would have to be largely disposed of on agricultural land to avoid groundwater or surface water pollution (through elevated nutrient concentrations).
12. Financial viability of composting toilets with urine separation depends to some extent on reduced headworks charges for water supply and sewerage of new or infill subdivisions.
13. Composting toilets and urine separation are technically proven.
14. Composting toilets with urine separation offer a sanitation option that recovers nutrients and minimises water use and pollutant discharges to the environment. This system provides a practical tool to make cities more ecologically sustainable.

12.12 Costs and Financing for the Demonstration Project

The additional cost of installing composting toilets in the apartments compared to installing conventional sanitation is significant and is made more so by the desirability of including additional equipment to allow experimentation, provide a high level of certainty in performance and to enable adequate monitoring. The need to set up small-scale one-off transport arrangements and the need for a monitored reuse trial add significant cost that would not be incurred (or at least to this scale) in future application of the technology. Therefore, funding support will be essential to enable the developer to proceed with the demonstration project.

It is concluded that costs and funding support required for the project to will be as follows.

1. Composting toilets with urine separation will typically cost approximately $2 500 to $3 000 per house (or apartment) more to install than water-flushed toilets. The small scale of this trial and the need for additional equipment for flexibility, research, monitoring and to provide some redundancy in the design will increase this differential to around $ 9 000.
2. 75% or around $85 000 of the additional cost of the apartment installations of around $113 000 will need to be met by parties other than the developer (including the purchasers) since the remaining 25% or $30 000 (or $2 500 per apartment) is the estimated additional cost of composting toilets without the additional features and monitoring specifically proposed for the trial. This cost will be sought through funding from various parties in proportion to the benefits derived from the project.
3. Contract maintenance and part of the transport costs, say $400 per apartment per year, and other operating costs for ventilation and heating estimated at about $300 per apartment per year are reasonable costs for the householder to meet but if ventilation power and gas boosting of heating proves to cost more than this, some subsidy would be sought. This could be a further $300 per apartment per year, or $3 600 for the 12 apartments.
4. The cost of custom built equipment for collection and transportation from the households ($30 000) and for application to the trial site plus the cost of $300 000 for establishing and running the reuse trial over two years (including decommissioning of the site) should be born from external funding.
5. The total cost of the project over three years is estimated as $730 000. Of this $500 000 of funding by parties other than the developer and apartment owners will be required.

12.13 Risk Management for the Proposed Demonstration Project

The risks associated with each element of the demonstration project have been assessed and management actions to control risks have been identified. The key risks and proposed risk management actions approaches are summarised below.

1. Financial risk for the developer if apartments are not sold is a key risk. This can be minimised by careful market survey before proceeding and a subsidy to cover part of the additional cost of installing composting toilets. In addition, it is likely that many of the apartments would be sold off the plan prior to construction getting underway.
2. Health risk at the residue reuse site is a key risk. This can be managed by a combination of training and procedures.
3. Odour risk external to the building is a risk. This will be managed by use of odour scrubbing in a biofilter.
4. There is a risk of apartment owners being dissatisfied. This can be covered by initial education starting from the pre-selling stage and by allowing for conversion to water-flush toilets.

12.14 Management and Administration

Important requirements for management and administration of the demonstration project will be as follows.

1. Monthly reporting to a steering committee (as established by the Smart Water Fund or other funding body) will be an effective management tool both for the team and the funding bodies.
2. A high standard of project planning and management will be required to coordinate and oversee the demonstration project progression, particularly the set-up, operation and monitoring of the agricultural reuse trials to ensure that the process and data retrieved are adequately controlled.
3. Ensuring that monitoring, recording, surveys and discussion with all parties involved are proceeding as required will need to be part of the project managers duties.
4. Detailed reporting on the technical aspects of the demonstration project progressively during the project and at the end of the project will be vital in order to maximise the benefits.
5. Ensuring that the compost and liquid wastes are redirected to a suitable receiver once the reuse trials cease operation will be vital and establishing this reuse route will need to be worked on early in the project.

The party that will perform this role must have a sufficient technical background and interest in the successful implementation of the project.

12.15 Program

The proposed program timings and milestones for the Demonstration Project are noted below. Please refer to Section 2.14 for more details of dates and milestones.

1. Planning approval for the development that is the proposed site for composting toilet installation is expected in mid 2004.
2. Construction of the apartments could be completed by mid 2005 so design will need to get underway early in 2004. Thus applications for and decisions on funding support in early 2004 will be necessary in order to make necessary decisions on proceeding with the demonstration project as part of this development.
3. Establishment of the agricultural reuse trial site would need to occur before early to mid 2006 and by mid 2007 it would be expected to be receiving a full load from the apartments.
4. The whole demonstration project could be completed by mid 2008 with final reporting in late 2008.

For Appendices refer

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