

Sustainable Water Management in Commercial Office Buildings

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EXECUTIVE SUMMARY

Water conservation, efficiency and reuse are becoming increasingly important as the planet faces reduced groundwater and surface water levels, drought and changing climate patterns. There are numerous programs in Australia targeting improved efficiency in residential water use, but less has been done to reduce water demand in the commercial sector. There are some examples, including the Millennium Dome in London, the Olympic Park at Homebush Bay in Sydney and the Water Garden in Santa Monica in California (Santa Monica City Council, 1990) where some aspects of sustainable water management have been incorporated in a commercial setting. However, there have been few examples, particularly in Australia, that have considered maximising water conservation through the integration of the whole suite of water conservation measures such as rainwater capture, installation of water efficient fixtures, effluent reuse and evaporation and productive reuse of treated effluent in roof gardens.

The first part of the paper examines the principles of the water quality cascade in relation to sustainable water management in commercial buildings, alternative water supply opportunities and the different water efficient technologies that can be used in commercial buildings. The second part reviews two studies of sustainable water management in commercial office buildings. Study One highlights the different aspects of water management in the 60L green building in Melbourne. The building is a refurbished 4-storey commercial building with construction completed in September 2002. The second study describes the research undertaken by the Institute for Sustainable Futures, for Sydney Water Corporation to determine the potential water savings from various water management options in a typical commercial high-rise building.

Both the studies show that reductions of up to approximately 80% of scheme water demand and 90% of sewage discharge can be achieved in a sustainable commercial building compared to a conventional building, through the integration of innovative water efficiency measures, rainfall capture and use, treated effluent reuse and evapotranspiration through roof gardens. A commercial building can be functionally efficient and at the same time provide enhanced amenity (e.g. through roof gardens and water features) and interpretive and experiential educational opportunities (e.g. for staff and through public tours highlighting the unique features of the raintanks, reuse systems and roof gardens). The integration of aspects of energy and water management is also important for enhanced overall benefits and reduced costs.

To encourage the design and development of sustainable water management in commercial buildings, it is important for regulatory authorities and Councils to incorporate the principles of sustainable water management into development controls and regulatory

guidelines to increase the take up of the technologies and practices for new commercial buildings. Support from water utilities is crucial, with a change in mindset from being water suppliers and wastewater managers to complete water service providers. Water industry professionals also have an important role to play in meeting the challenges and pushing the boundaries of what is possible and devising integrated approaches rather than single solutions to sustainable water management.

INTRODUCTION

Sustainable water management systems are based on the principle of the water quality cascade. This means that water sources should be matched with end uses in terms of the required water quality as shown in Table 1.

Table 1 Water Quality Cascade with End Uses

	Source	End Use	
Increasing perception of risk ↓	Scheme water OR Treated and disinfected rainwater	Drinking Kitchen Showers Basins	↑ Increasing quality requirement
	Treated and disinfected greywater	Cleaning Cooling tower make up Toilet flushing	
	Treated and disinfected cooling tower blowdown	Cleaning Toilet flushing	
	Treated and disinfected blackwater and blackwater blowdown	Roof garden irrigation	

The principles of sustainable water management help identify alternative sources of water that can be supplied to meet the water demand in ways that do not require potable water quality. It also puts emphasis on using the most water efficient appliances where possible.

While a lot is being done in the residential sector in terms of sustainable water management, it is less advanced in the commercial sector. However, there are some examples, including the Millennium Dome in London, the Olympic Park at Homebush Bay in Sydney and the Water Garden in Santa Monica in California (Santa Monica City Council, 1990) where some aspects of sustainable water management have been incorporated. However, there have been few examples, particularly in Australia, that have considered maximising water conservation through the integration of the whole suite of water conservation measures such as rainwater capture, installation of water efficient fixtures, effluent reuse and evaporation and productive reuse of treated effluent in roof gardens.

The commercial sector typically comprises 10-20% of total water demand in an urban water supply system and provides ample opportunities for sustainable water management and potential savings in scheme water. This sector, unlike the industrial sector, is easy to target for water conservation measures, as a significant proportion of its indoor water use is similar to residential water use. Hence, commercial office buildings can make use of the technological advances made in the improved water efficiency of fixtures like toilets,

urinals, taps and showerheads and other systems such as cooling towers, reuse systems and rainwater capture and treatment systems.

ALTERNATIVE SUPPLY OPPORTUNITIES

The end-use break down for a typical office building, based on a Californian case study is:

Table 2 Breakdown of end use in a typical commercial building (CUWCC, 2001)

Indoor (domestic/restrooms)	31%
Cooling and heating	48%
Landscaping	18%
Other	3%

As can be seen from Table 1 and Table 2 over 50% of the total water demand in a commercial office building can be met by substituting potable water with rainwater or treated greywater and blackwater.

Rainwater can be harvested from the impervious surfaces (such as rooftops and other paved surfaces) of the commercial building premises. The quality of the rainwater from rooftops is higher than from any other paved surfaces. Consequently rainwater collected from rooftops would require less treatment when compared with the rainwater collected from any paved surfaces exposed to people and vehicular traffic. Rainwater used as make-up water for cooling towers could minimise blowdown, as it has lower levels of total dissolved solids compared to scheme water.

Greywater is collected from indoor sources other than toilets such as showers and hand basins and requires treatment such as screening, oil & grease removal (if kitchen wastewater is also included in the source), filtration and disinfection.

Blackwater is the discharge from the toilet and contains significant nutrient concentrations. The microbial contamination associated with blackwater means that it needs to be treated to a very high level, especially with respect to disinfection.

The decision about matching alternative sources of water to an appropriate end use takes into consideration two major factors:

- the minimum level of treatment required to ensure that the water from the alternative source is fit for the end use
- the quantity of the water supply from the alternative source.

The most preferred match is where the quantity of the supply from the alternative source is able to meet the demand of the end use with least cost of treatment.

Treated greywater can be utilized for one or more of the following:

- Toilet flushing,
- Landscape irrigation and
- Cooling tower make up water

Treated blackwater is most suited for sub-surface irrigation of landscape.

Combined sewage (greywater and blackwater), if treated to very high quality, for example by micro filtration and disinfection, can be used for toilet flushing and irrigation purposes.

WATER EFFICIENCY OPPORTUNITIES

Increasing the efficiency of fixtures leads to significant reductions in water demand from the end uses and also translates into considerable cost savings. This section describes the various water efficient fixtures that can be used in a commercial building.

Fixtures

Toilets

Toilets usually account for a significant portion of total water demand in an office building. Based on typical usage patterns, 6/3 L dual flush toilets have an average water demand of 4 L/flush. With higher drainage grades, flush toilets can operate at 5/2 L or lower, reducing average demand per flush to less than 3 L/flush. There are different types of water efficient toilets on the market and in production, ranging from low and ultra low flush toilets to composting toilets that use no water at all.

While vacuum toilets have had a wide application in aircraft and marine transportation, their use in commercial buildings and public restrooms is increasing. In these systems, the waste is evacuated from the toilet bowl through a vacuum that is generated by a vacuum pump. The waste is then macerated and can be directly discharged to sewer or transported to a holding tank or treatment system. The average amount of water used is between 1 and 1.5 L per flush (ISF, 2001).

Urine separating toilets separate the waste at the source, and as in composting toilets, they reduce the nutrient load on the wastewater treatment system, since approximately 90% of the nutrients in human waste are in the urine (ISF, 2001). These toilets are a fairly new concept in Australia, but are quite common in Scandinavia, and have water efficiency benefits as well as nutrient reduction.

Composting toilets are not widely used in multi-storey commercial buildings in Australia, however, it is possible to install and use them in office buildings and there are examples in Sweden and Germany of their use in multi-storey residential buildings, and one example in Australia in a two-storey building (the Thurgoona Campus of Charles Sturt University in Albury). The main advantages of composting toilets are that they require little or no water for flushing, thus reducing water demand, they reduce the quantity and strength of the wastewater to be treated or disposed and return nutrients to the environment (US EPA, 1999a).

Urinals

While standard urinals in Australia use an average of 6 L of water per flush, water efficient urinals use 2.8 L per flush. Waterless urinals that use no water are being used in commercial buildings, hotels and government institutions. They are currently installed in a number of buildings in Australia and more widely around Europe, New Zealand and in the USA. Most of these urinals operate through the use of an oil barrier between the urine and the atmosphere, preventing odours from escaping. The potential water savings from a waterless urinal compared to a 2.8 L per flush urinal in a commercial building is approximately 1.5 ML/a based on typical usage of four flushes per day.

Taps

Adjusting the flow rate of taps while maintaining spray pattern through the installation of flow regulating tap aerators can significantly reduce tap water use in hand basins and kitchen sinks. Typical flow rates for non-efficient taps are usually 10-12 L/minute, which can be reduced to 2.5 L/minute with the installation of appropriate flow regulators. Infrared

tap controllers reduce the duration of the flow of water, by only operating when the sensor is activated. These taps require energy to operate, and are more expensive. A combination of flow regulated and infrared taps can achieve significant savings in water demand.

Showerheads

While showering may be the largest source of residential water demand, shower demand is not as high in commercial buildings. Typical non-efficient showerheads have a flow rate of approximately 11 L/minute in use. AAA-rated showerheads have flow rates between 7 and 9 L/minute and highly efficient showerheads can have flow rates of 5 L/minute or less. Showers can also be fitted with digital readout meters that show the user the amount of water being consumed and the duration of the shower. This can encourage the user in an office building situation to reduce water demand for showers.

Cooling Towers

Cooling towers use make-up water to replace water lost in evaporation as well as for blow down. The water use efficiency in the cooling tower can be maximized by ensuring that blow down is controlled to a set maximum total dissolved solids (TDS) concentration with the help of a TDS monitoring device. Evaporation losses are reduced by operating the cooling system more efficiently and reducing the heat load on the building through improved energy efficiency.

There have been recent developments in cooling system technology. The increased use of in-ground heat source pump (IGHSP) cooling systems is an example. The IGHSP cooling system utilizes the earth below the ground surface as the heat source and sink. As a result, the water consumption is significantly reduced without the usual decrease in energy efficiency that can result from air cooling systems. Although the initial cost of installing the system is higher than the water based cooling system, the operating cost in relation to water and energy use, is significantly lower (Rafferty, 1997). The hydro-geological features of the site are important in determining the feasibility of the system.

Roof gardens

Roof gardens or green roofs in commercial buildings can play a part not only in water and wastewater management but also in improving the energy performance of the building. There are two types of green roofs – extensive and intensive. Extensive green roofs have a thin growing medium, have lower plant diversity and are relatively inexpensive. Intensive green roofs have a deeper soil substrate, have a greater diversity of plants and habitats, potentially have greater energy efficiency and stormwater retention capabilities and a longer membrane life. Roof gardens can reduce the ‘urban heat island effect’, the overheating of urban areas due to an increase in paved and concreted areas in relation to ‘green’ areas. This reduction may lead to substantial energy savings. Other important benefits include prolonging roof life, filtering of airborne particles, sound insulation, creation of aesthetically pleasing landscapes and stormwater retention (Peck & Kuhn, 2001). Life cycle costing calculations undertaken by the National University of Singapore on rooftop gardens have found that extensive green roofs cost no more than conventional roofs when the energy savings are considered (NUS, 2002).

In a commercial building, roof gardens can be used either for stormwater retention or to evapotranspire the effluent generated from wastewater treatment plants. In the latter case it is important to ensure that the roof gardens are protected from rain, in order to maximise their evaporation capacity. The type of plants to be used and the location of the roof garden need to be carefully chosen to maximize evapotranspiration of effluent.

CASE STUDY 1 – 60 L GREEN BUILDING, MELBOURNE

The 60L Green Building is located at 60-66 Leicester Street in Carlton, Victoria and is a refurbished four-storey office building. The building covers a total area of 3,375 m². Construction of the building started in March 2001 and was completed in September 2002. The building is expected to be fully functional by October 2002.

The 60L Green Building aims to be a leading example of a green commercial building incorporating the principles of environmental sustainability in all aspects of its design, construction, operation and maintenance (Green Building Partnership, undated) and is governed by the following principles:

- Commercial viability
- Minimum resource use
- Protection of the natural environment (through appropriate selection and use of materials)
- Minimum energy use and greenhouse gas emissions
- Minimum scheme water use and maximum use of recycled and treated wastewater
- Adoption of environmentally sound and healthy work practices, during construction and occupancy.

Water management system

The design of the water management system is based on the principles stated above. The Institute for Sustainable Futures was involved in the development of concepts for the sustainable water management in the 60L building, including:

- Use of water efficient fixtures and fittings including waterless urinals
- The capture of rainwater for all indoor potable water use like drinking, showering and in basin taps
- Treatment of greywater and blackwater for toilet flushing, landscape features and roof garden irrigation (ISF, 2000)

The only requirement for scheme water supply is estimated to be for the weekly testing of the fire fighting system, which is a legal requirement (Pears, 2002).

The rainwater captured from the roof will be treated to a high degree by filtration and UV disinfection and stored in two 10,000 litre polypropylene tanks on the ground floor of the four-storey building. The water quality is continuously monitored and chemical processes of treatment will be used if required. There is a connection to scheme water supply downstream of the system (after treatment of rainwater) to eliminate unnecessary treatment of scheme water supply. An automatic system switches the connection on if there is a power failure or if the water levels in the tanks are low. The switch can also be manually operated during testing of the system (Pears, 2002).

The wastewater treatment system involves the collection and settling of greywater from sinks, basins and showers and blackwater from toilets in an underground tank. The treatment processes include treatment in a biological trickle filter and clarifier, filtration, UV treatment and if required, chemical treatment. This treated water is then used for toilet flushing and irrigation. The excess of reclaimed effluent is also expected to be used in a water feature in the atrium, and any further excess will be discharged to sewer. The wastewater treatment system will also be continuously monitored for water quality and as with the drinking water supply, a connection to scheme water has been installed downstream of the treatment system (Pears, 2002).

In order to achieve best practice environmental performance, the design and systems in the building have taken into account the need for energy efficiency and reduction in greenhouse gas emissions for example, by operating the treatment pumps on a needs basis and not continuous operation, use of low flow resistance cartridge filters instead of sand filters, use of high efficiency variable speed motors and pumps and provision of electricity to the building by rooftop photovoltaic arrays or certified Green Power. Other features include the use of metals, glass reinforced concrete, polyethylene tanks and ABS plastic pipes to reduce chemicals.

CASE STUDY 2 – SUSTAINABLE WATER MANAGEMENT OPTIONS FOR COMMERCIAL HIGH RISE BUILDINGS

Sydney Water Corporation commissioned the Institute for Sustainable Futures to undertake a study to determine the potential water savings from a typical commercial high rise building from various water management options.

Initially a wide range of options were developed that ranged from simple ones that used water efficient fixtures to more complex ones that resulted in zero discharge. All the options were compared against the option of business as usual. These were further refined based on the results of demand modelling and raintank and evapotranspiration modelling. The final Options included the following:

Table 3 Options for improved sustainable water management

No.	Option name	Water Supply	Sewage Discharge	Stormwater Discharge	Fixtures	Wastewater Treatment	Fire Protection
1	Business-as-usual	Scheme water	To reticulated sewer	To stormwater system	11 L/minute showerheads; 6/3 L dual flush toilets, 6 L/flush urinals, 12 L/minute tap aerators	None	Scheme water
2	Level 1 Efficiency	Scheme water	To reticulated sewer	To stormwater system	AAA 9 L/minute showerheads; 6/3 L dual flush toilets, 2.8 L/flush urinals, 6 L/minute tap aerators	None	Scheme water
3	Level 2 Efficiency	Scheme water	To reticulated sewer	To stormwater system	5 L/minute showerheads with user feedback; 5/2 L dual flush toilets, waterless urinals, 2.5 L/minute flow regulated taps with infra-red sensors	None	Scheme water
4	Effluent Reuse in Toilets	Scheme water	Partial discharge to reticulated sewer	To stormwater system	5 L/minute showerheads with user feedback; 5/2 L dual flush toilets, waterless urinals, 2.5 L/minute flow regulated taps with infra-red sensors	Micro filtration and UV disinfection and effluent reused in toilet flushing	Scheme water
5	Rainwater supply + effluent reuse in toilets and rooftop garden	Treated Rainwater	Partial discharge to reticulated sewer or zero discharge	Treated and disinfected for use as replacement for scheme supply	5 L/minute showerheads with user feedback; 5/2 L dual flush toilets, waterless urinals, 2.5 L/minute flow regulated taps with infra-red sensors	Micro filtration and UV disinfection and effluent reused in toilet flushing and rooftop garden	Scheme water or treated effluent
6	Rainwater supply + composting toilets + rooftop garden	Treated Rainwater	Partial discharge to reticulated sewer or zero discharge	Treated and disinfected for use as replacement for scheme supply	5 L/minute showerheads with user feedback; composting toilets; waterless urinals, 2.5 L/minute flow regulated taps with infra-red sensors	Micro filtration and UV disinfection; urine separated and treated for use as fertilizer	Scheme water or treated effluent

A daily demand model was developed to determine the volumes of water required for each of the end uses. Various assumptions were made on the end uses and the number of occupants. Other assumptions considered in the model were a childcare centre, a coffee shop, a medium sized restaurant, a medical centre and a newsagency. The water demand assumptions were based on average water use as cited in Crites and Tchobanoglous (1998) and from the collection of actual metered water consumption data.

The results of the demand modelling showed that water savings of nearly 87% could be achieved through best practice water efficiency, rainfall capture and effluent reuse compared to a conventional commercial office building.

Table 4 Percentage of water savings of modelled options compared to a conventional office building

No.	Option	Water savings
1	Business-as-usual	0%
2	Level 1 Efficiency	>35%
3	Level 2 Efficiency	70%
4	Effluent reuse in toilets	>80%
5	Rainwater supply + effluent reuse in toilets and roof garden	>85%
6	Rainwater supply + composting toilets+ effluent reuse in toilets and roof garden	>85%

Raintank and evapotranspiration modelling were undertaken using daily models to determine the tank capacities required to store the rainwater and effluent respectively. Raintank modelling also determined the supply security of each of the options. For the evapotranspiration modelling, sensitivity analysis was undertaken for different volumes of wastewater generated, roof area available for evaporation and tank capacities.

The results of the modelling indicated that by using best practice water efficiency and effluent reuse, and with an appropriate tank capacity, it is possible to reduce by more than 50%, and in some instances eliminate the requirements for water supply from scheme water. Similarly, with a large enough roof area, it is possible to evaporate all the treated effluent through the roof garden. The treated effluent could also be used in cooling towers, which would reduce discharge volumes.

There is a potential to use the treated effluent in cooling towers as long as treatment levels are sufficient (guidelines do not currently exist for this use in NSW), the TDS is below 4,000 mg/L and appropriate treatment is used for prevention of corrosion and scale formation.

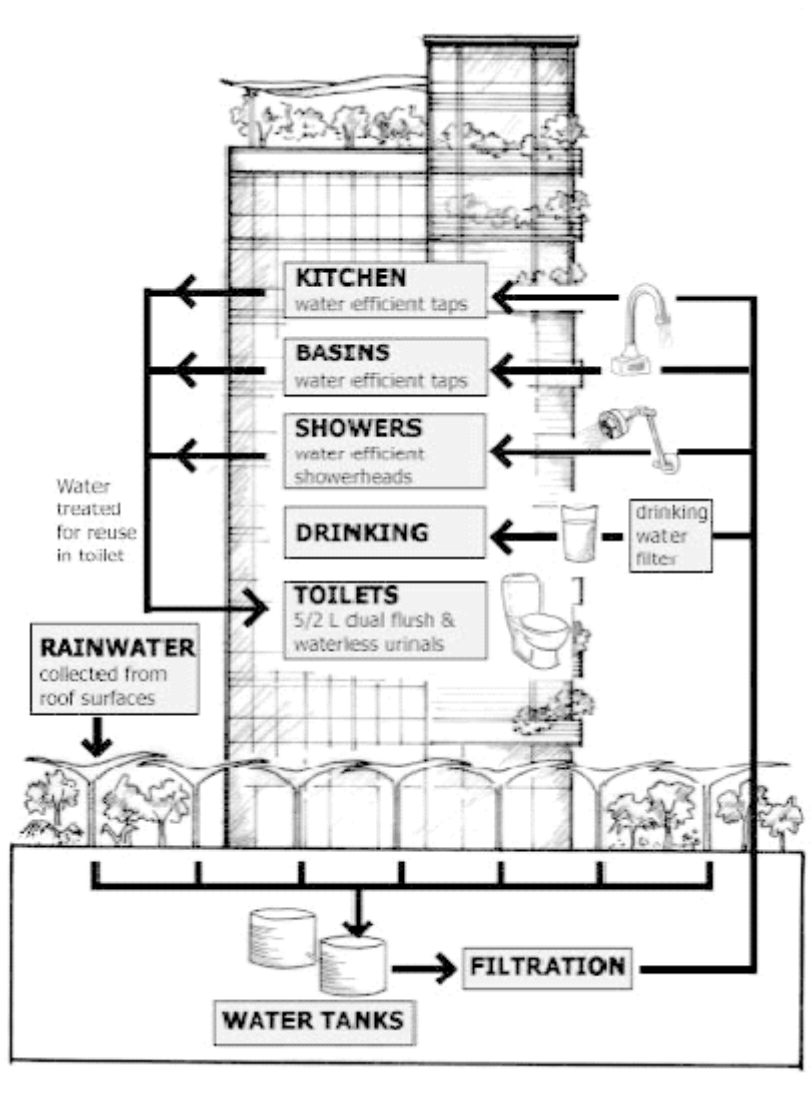


Figure 1 Water Management in a commercial building

CONCLUSION

The two studies have shown that in commercial buildings of typical size and configuration a reduction of 80% or more in scheme water demand and 90% reduction of sewage discharge can be achieved compared to a conventional building through the integration of innovative water efficiency measures, rainfall capture and use, treated effluent reuse and roof gardens. The building can be functionally efficient and at the same time provide enhanced amenity (e.g. through roof gardens and water features) and interpretive and experiential educational opportunities (e.g. for staff and through public tours highlighting the unique features of the raintanks and roof gardens).

There is also considerable potential for integrating aspects of energy management with the water management due to the overlap between these issues. This can be important for enhanced benefits and reduced costs.

Having these types of systems become reality will require regulatory authorities and Councils to incorporate the above principles into development controls and regulatory guidelines to increase and ensure the take up of the technologies and practices for new commercial buildings. There is also a need to set up demonstration projects that monitor and evaluate the savings and benefits from these buildings.

Water industry professionals have an important role to play in meeting the challenges and pushing the boundaries of what is possible and devising integrated approaches rather than single solutions to sustainable water management.

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