WARRNAMBOOL'S REGIONAL ROOF WATER HARVESTING

A Toolkit has been developed to explore the potential for regional roof water harvesting in local towns

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Abstract

This paper outlines how harvesting of water from clustered house roofs in growth corridors is able to meet much, if not all, of the increased demand for water from growing towns and cities. The unique aspect of this principle is that water is harvested from all the roofs in a suburban subdivision via an independent pipe network that collects the water for further treatment as part of the town water supply. The regional roof water harvesting principle has been adopted for a growth corridor in Warrnambool, Victoria, providing a demonstration of how it can be successfully applied.

Given that the population growth areas are concentrated along the coastal strip of Australia that typically has an annual rainfall of greater than 700mm, there is significant opportunity to use this principle. A Toolkit has been developed for those responsible for water resource planning to explore the opportunity of regional roof water harvesting in their towns. This paper also outlines the structure of the Toolkit and its power to explore opportunities to utilise this source of water in growing communities.

Introduction

Wannon Water is an urban water supply corporation serving the south-west of Victoria, including the provincial centre of Warrnambool, a fast-growing city currently in excess of a population of 28,000 facing increasing water demand. Localised climate change predictions also suggest increasing pressure on future availability of the existing water supply source.

Growing towns and cities replace vacant land with roads, driveways, paved areas and roofs. From a water perspective, the net result is:

- A 10-fold increase in runoff into the local rivers and streams;
- Reduced volumes going to groundwater;
- Creation of a 'heat island' effect;
- An increased water demand;
- An increased sewerage service demand.

There is much discussion in the 'urban planning space' of how to make our cities more sustainable, with lower energy, water and ecological footprints while maintaining the living standards we have grown accustomed to. In many parts of Australia the harvesting of rainwater from the roofs of our growing urban areas can meet 100% of the annual demand of these new houses. Taking this component of water away from the 10-fold increase in runoff also reduces the adverse impact of development on the local rivers and streams.

Rural Australia utilises and relies on rainwater from roofs for its daily existence, but larger towns and cities have a low dependence on roof water. Backyard rainwater tanks are slowly finding their way throughout suburbia, but to date this has had little bearing on reticulated demand. Rainwater tanks are also limited by storage capacity, with much of the water overflowing from the tank and lost, even during small rainfall events, and there is reluctance in urban situations to use such water for potable purposes without some form of disinfection. More recent developments have incorporated "Water Sensitive Urban Design" to reduce the peak flows and improve water quality, but have not addressed the better use of this resource.

Regional roof water harvesting involves the construction of an independent roof water collection pipe network within the subdivision, in addition to the surface water (stormwater) network. The collected roof water can then be mixed with other raw water supplies before treatment, or be treated independently to meet drinking water standards. Either way, it contributes to the drinking water supply of the town or city.

The Warrnambool Roof Water Harvesting Project involves the roof water being conveyed to an untreated water storage via a dedicated pipe to mix with other untreated water resources. It is then treated through the existing water treatment plant to become part of Warrnambool's drinking water supply.

Numerous direct and indirect economic, environmental and social benefits to the local area have been identified, making this project a showcase of sustainability for the rest of the nation through the better use of available water resources and water-sensitive urban design.

Current discussion about alternative water supply systems appears polarised into centralised versus decentralised models. This project provides a working example of a hybrid model, utilising a new source of water derived from a decentralised catchment, but linked to existing centralised storage, treatment and distribution. This innovative approach eliminates many of the public health risks associated with decentralised systems, and provides for coordination of the water supply demand cycle for regional towns and cities.

Table 1: Water resource option comparison.

Option	Capital cost	NPC $/ML#	Ultimate yield per annum
Groundwater resource development	$7.81m	$1,958	1500ML
Regional roof water harvesting	$11.03m	$1,856	450ML
Individual 5kL tanks	$8.53m @	$5,482	210 ML*

Notes: # The NPC is calculated over 34 years and divided by the discounted volume of water over that period (34 years to build out the catchment).
@ If applied to all 3280 houses in the catchment.
*** Assumes all houses in the project's ultimate catchment (3280 houses) each have a tank that yields 70kL per year on average.**

Costs and Benefits

Wannon Water's Water Supply Demand Strategy 2007–2055, identified the need for new water resources within the 50-year planning period, beyond the current use of the Gellibrand River, to meet the projected increase in demand. The strategy identified a range of demand management options to reduce the growth in demand; however, additional water resources are still required. The bulk of this demand increase is a result of residential growth in Warrnambool.

Unlike many towns and cities, Warrnambool has a new, relatively low-cost groundwater resource available. Table 1 compares the cost of this resource option with the centralised rainwater collection principle and individual tank option.

As can be seen from Table 1, the roof water harvesting approach has a significantly lower cost per ML than individual rainwater tanks and is also lower than the next major augmentation. There are a number of non-financial benefits of the roof water harvesting system:

Economic benefits

- Currently, water is pumped 80km from the Gellibrand River. Harvesting water locally results in reduced operating costs.
- It is a more consolidated and effective manner to harvest and use rainwater collectively than the *ad hoc* and scattered approach of individual landowners installing their own tanks, pumps and pipework on their land.
- It is able to be implemented progressively as development (and consequential demand) proceeds in the growth corridor.
- It reduces the works required for stormwater management for Council and developers – for example, size of stormwater detention basins and treatment systems.

Environmental benefits

- It reduces the energy use and associated greenhouse emissions for transporting water for use in Warrnambool.
- It diverts water to a beneficial use instead of it running to waste and causing downstream flooding and negative impact on local estuarine stream systems.
- It improves the environmental flows in the Gellibrand River.

Social benefits

- It reduces public health risks implicit in alternative recycled water or decentralised individual rainwater tank systems.
- Landowners will not be burdened with ongoing maintenance of an on-site harvesting and re-use system.
- It is innovative in approach to sustainable use of water resources, and promotes community consciousness of innovative outcomes that can be achieved in the water cycle.

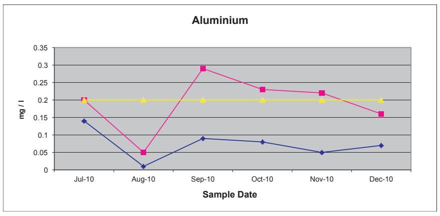

Figure 1: Aluminium comparison.

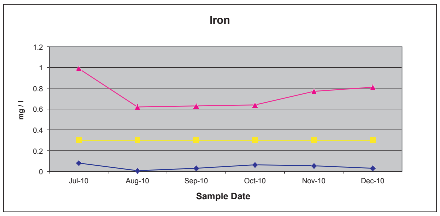

Figure 2: Iron comparison.

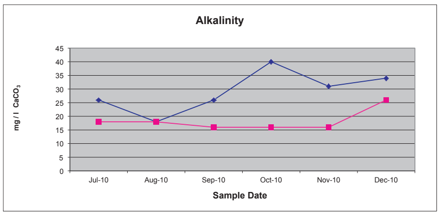

Figure 3: Total alkalinity comparison.

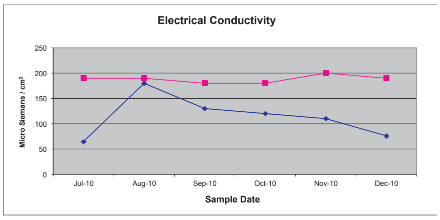

Figure 4: Total dissolved solids comparison.

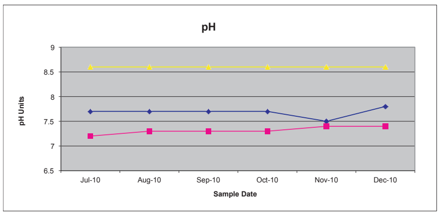

Figure 5: pH comparison.

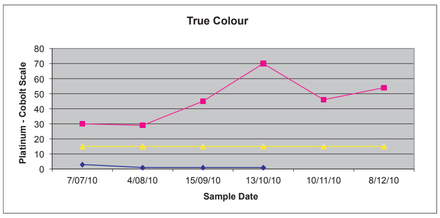

Figure 6: True colour comparison.

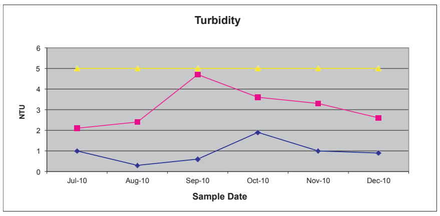

Figure 7: Turbidity comparison.

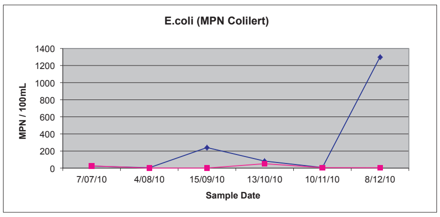

Figure 8: *E. coli* comparison.

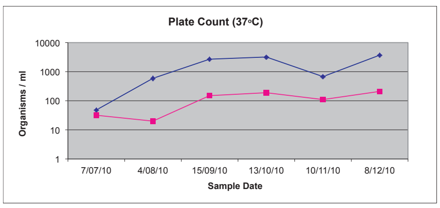

Figure 9: Plate count comparison.

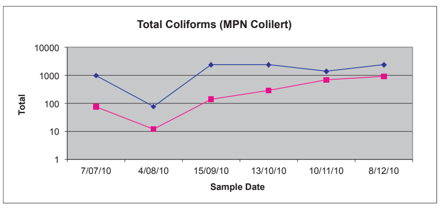

Figure 10: Total coliforms comparison.

Result Roof Water Harvesting
Brierly Basin Warrnambool
Limit

Legend for Figures 1-10

Inspecting the "inspection opening" on the trunk pipeline before laying.

Quality and Yield

The works associated with the demonstration of the roof water harvesting principle in Warrnambool have currently progressed to a stage where 11 houses are connected.

Water from the tiled roofs of these houses gravitates to a sump where it collects before being pumped over the bank into the storage (Brierly Basin). This has allowed water quality testing and the volumes collected to be measured. Preliminary data is provided in Figures 1 to 10.

As expected, the colour and turbidity are lower for the rainwater than the river water, as are aluminium, iron and TDS. Total alkalinity and pH are higher, probably due to the carbonates leaching out of the new concrete sump. Given the softness of the Gellibrand water, this will improve the water chemistry for subsequent treatment.

E. coli is of a similar magnitude for both (except for one sample), but the total plate count and total coliforms are significantly higher for the roof water samples than the storage. The samples are taken from within the sump where water can sit for some time if it has not been raining. Once pumped into the open storage it mixes with the rest of the raw water and is exposed to sunlight before being pumped to the water treatment plant. The variability on counts within the open storage is consistent with historic variability, indicating the roof water coming into the storage is not having a detrimental impact on the raw water quality.

A number of samples have been tested for a suite of trace metals and other less common parameters. Lead, copper, cadmium, chromium and antinomy are all at levels equivalent to the raw water. Zinc is a little higher than the raw water, but two orders of magnitude below the drinking water limits. In the two roof samples tested, fluoride was measured at 0.36mg/L and 0.05mg/L compared to 0.05mg/L in the storage, but still well below the 1.5mg/L limit.

Figure 11 shows the cumulative measured volumes harvested from the 11 roofs that were connected to the sump in June 2010 compared to the cumulative estimated demand of these properties based on 2009 meter reads. As expected, the harvested volume outstripped demand during the wetter/colder months of the year, but continued to do so during the current wetter than normal summer. The surplus is being utilised by other Warrnambool customers, resulting

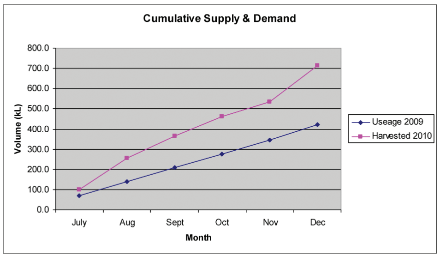

Figure 11: Supply and demand to date.

in less water supplied from the Gellibrand River.

Legislation and responsibility

Legislative responsibility for stormwater in Victoria rests with municipal councils, meaning that without the support of the Council, Wannon Water could not have pursued this water harvesting initiative. The Council will nominate the "legal point of discharge" for roof water as the roof water harvesting pipe connection point; and for surface water runoff, the kerb or stormwater connection point. Should a landowner want to install their own tank, they are still able to do so, but the overflow from the tank will need to be connected to the roof water harvesting connection point.

The *Victorian Safe Drinking Water Act* (2003) requires Wannon Water to have a Risk Management Plan for this new water source. No significant risks were identified that could not be addressed through the design of the system. As with other raw water supplies, Wannon Water will be monitoring the water quality of this source of water to quickly identify if the quality poses a risk to the supply. Cross-connection risk will be managed by Wannon Water inspecting the connection to the roof water harvesting system, the connection to the sewer and the connection to the stormwater system.

Wannon Water will also assume responsibility for the roof water harvesting network. Screening of leaves and other matter collected in gutters will be done at the Wannon Water storage, rather than expecting landowners to undertake any more maintenance of their gutters than they currently do. Flyers will be sent out regularly to remind landowners that water is being harvested from their roof and treated to form part of the drinking water supply for Warrnambool. By living in this area, they are part of a more sustainable city.

Wannon Water is working with the Warrnambool City Council to make the installation of the roof water collection network a requirement of all development within this catchment – similar to recycled water systems (3rd pipe networks) in other towns. It is supported by Section 56.07 of the Victorian Planning Schemes – Integrated Water Management.

The Toolkit

With the aid of Federal funding from the "Water for the Future Program", a Toolkit has been developed to assist in assessing the financial viability of roof water harvesting systems within Australia and allow quick comparisons with other potential water supply sources. The term 'roof water harvesting system' refers to the infrastructure required to collect rainwater from individual rooftops, typically within a new residential subdivision, and then transfer, store and/or treat this water before it is added to the town's drinking water supply.

The Toolkit allows a roof water harvesting system to be defined in terms of the collection system, transfer pipelines, storage basins and a treatment plant through entering a number of key parameters. Estimates of the capital and operating costs associated with the construction and operation of the roof water harvesting system are then calculated and a time-series simulation is run to estimate the volume of water harvested by the system annually.

710mm polyethylene pipeline ready for laying to convey water (under pressure) from the subdivision to the storage basin.

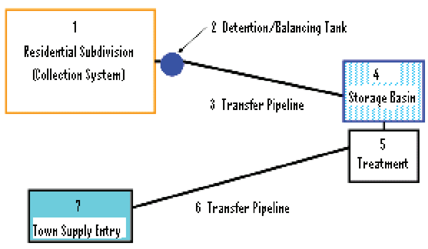

Figure 12: Schematic of typical system.

The Toolkit's cost estimates are primarily based on the extrapolation of data obtained from the roof water harvesting system implemented in Warrnambool. It allows for construction cost variation across Australia by applying appropriate cost factors and rainfall variation using different temporal rainfall patterns and spatial annual rainfall data from the Bureau of Meteorology.

The Toolkit is for preliminary screening of options on a relative cost basis and should not be used as a design or cost estimation tool. Calculations rely on a number of assumptions and relationships derived from limited data sets. Results are suitable for preliminary screening only and should not replace a more detailed assessment by an appropriately qualified and experienced person.

The Toolkit is available on a CD from Wannon Water (visit wannonwater.com.au to order a copy), and the program may be downloaded onto a PC using Microsoft operating systems. It has a self-contained help menu to guide users through its use.

Using the Toolkit

The flexible setup of the Toolkit allows a range of roof water harvesting systems to be defined with different arrangements for the transfer pipelines, storages and treatment plant. In Warrnambool's case, the storage basin, treatment plant and transfer pipelines already existed, so no capital cost was associated with these elements, but the operating cost is accounted for. Selecting which elements exist, or are not required, for a particular scenario is as simple as ticking a 'check box'. The transfer pipelines are able to be configured as gravity or pumped pipelines.

Data Input

Collection system

Location of the development, scale and other collection network design parameters are input using four data input screens.

Storages

The capacity and configuration of storages are input on a single screen to define the inlet and outlet levels and surface area if it is uncovered. This allows evaporative losses to be calculated and included in the water balance.

Pipelines

The single input page allows for a gravity or pumped pipeline to be selected. The gravity system assumes the pipeline is a fully sealed system able to operate under pressure with its capacity determined by the upstream and downstream elevations. The pumped system selects the required pump size to deliver the nominated flow along the nominated pipe size.

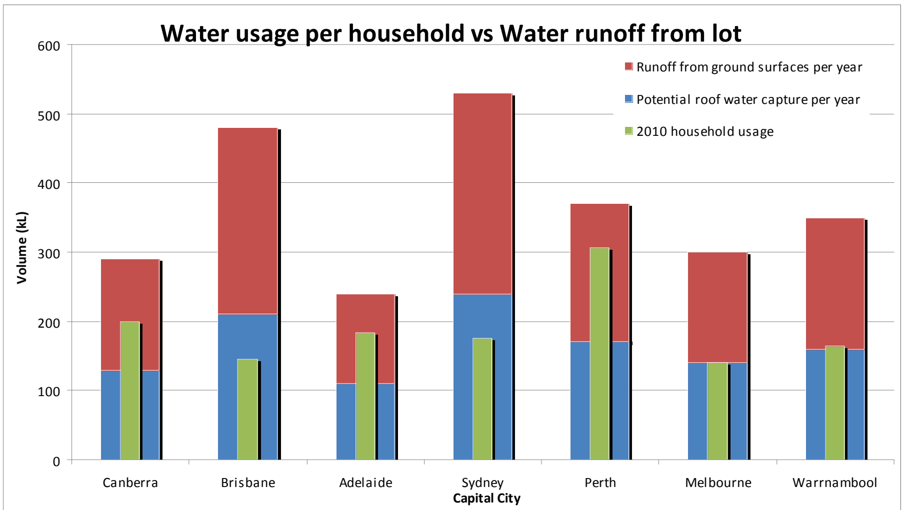

Figure 13: Comparison of available roof water to residential demand.

Assumptions:
Allotment size 750 square metres – 1/3rd roof area, 1/3rd paved, 1/3rd garden/lawn.
Runoff coefficients: roof 0.85, paved 0.8 and garden/lawn 0.2.
Water restrictions applied for some cities in 2010.
Warrnambool water consumption from 2009/10.
Using historical average rainfall and typical temporal patterns.

Treatment plant

Again this element can be included or excluded from the Toolkit calculations depending on whether treated or untreated water supply options are being investigated. Treatment plant costs can vary significantly depending on the nature of the treatment plant, so provision has been made to override both the capital and operating costs to suit the scenario being evaluated.

Data output

The Toolkit calculates the volume of water spilt from the storages, transferred along the various elements and yield from the system. The yield is compared to the annual demand for these properties (based on the data input) and the percentage of annual demand supplied from the roofs calculated.

It also determines the capital and operating costs of the various elements and the net present cost/ML of water harvested where the volume is also discounted using the same formula as costs. This cost is then able to be compared with other options being considered to determine if the roof water harvesting system should be considered further as an option. One of the advantages of the system is that it can be progressively built as development proceeds, resulting in a lower NPV/ML than up-front capital options. This is not reflected in the NPV calculation, meaning more detailed work is required to evaluate this effect.

One of the powers of the Toolkit is being able to trial different storage, pipeline and treatment plant sizes to optimise the cost/ML and/or the yield. Each 'run' takes a matter of seconds.

Toolkit Results for Australian Major Cities

The Toolkit was used to determine the yield from a regional roof water harvesting system (the same as that being demonstrated in Warrnambool) located in each of the Australian State capitals. The volume of water flowing from roofs and paved areas was calculated using the Toolkit and compared to the average annual household demand in those cities. Warrnambool data is shown for comparison in Figure 13.

In outer suburbs of Sydney and Brisbane the harvestable roof water significantly exceeds the water demand of these new houses, while in Melbourne and Warrnambool the water demand is matched. It should be noted that the residential consumption data used for this comparison is sourced from the

2010 annual reports of the relevant water agencies or directly from their staff. It should also be recognised that Melbourne and Brisbane have been subject to water restrictions during the 2010 year. Even if the percentage of annual usage is 50% or 60%, as in Perth, Adelaide or Canberra, this is still a significant reduction in reliance on the existing stressed water sources – worthy of consideration.

Conclusion

This paper outlines an innovative new approach to managing the increased water demand of growing urban communities by utilising water harvested from the roofs of these growing communities. It has been demonstrated to be the least-cost option in Warrnambool compared to individual rainwater tanks or developing a new groundwater resource. Adoption of this principle is able to reduce the impact of urban growth on the environment by utilising a resource that would otherwise go to waste, avoid transporting water long distances and lower peak flows to rivers and streams.

Initial water sampling indicates the water is better than the existing raw water used in Warrnambool for many of the parameters, but has higher microbiological counts, which is likely to be a result of the water being stored in a sump before pumping to the larger storage. The resulting raw water quality is still well within the historic variability of microbiological counts and accordingly is of no concern to the downstream treatment barrier. Higher levels of zinc were measured but these were still two orders of magnitude below the Australian Drinking Water Guidelines.

The measured volume of water harvested during the first six months of operation has exceeded the demand from the 11 houses already connected. This occurred during the higher rainfall and lower temperature months of July to September as expected, but has continued through to December due to the wetter than normal year.

The paper explains the operation of the Toolkit, data sets used and the input data required to allow it to calculate the volume harvested in an average year and the cost/ML of that water. The Toolkit has the flexibility to allow various system arrangements to be explored and optimisation of these through repeated runs of the package. The Toolkit is easy to use and allows water resource planners to quickly explore the opportunities for regional roof water harvesting in their region.

Footnote: This is an updated version of the paper presented at the Sustainable Infrastructure and Asset Management Conference, November 2010.

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Acknowledgement

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Resources

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Peter Wilson looking over the Brierly Raw Water Basin, receiving storage for harvested roof water. The tiled roofs seen in the background are connected to the system.