30A:
Stormwater
Harvesting
1345–1400
Friday
8th May 2009
Stirling B Room

Royal Park Stormwater Wetland and Reuse Scheme

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City of Melbourne[1]

Introduction

Hidden at the "back" of Royal Park, yet only 4 km from Melbourne's CBD, the Royal Park wetland system is a project that demonstrates the "City as a catchment" model in action. Officially named *'Trin Warren Tam-Boore' (Bellbird Waterhole)* the project has a long history and required many year of dedicated planning and design works to be implemented. The project utilised the opportunities of under-utilised land, slope, large catchment a suitable demand and politics, to create a landmark stormwater treatment and reuse system. With a drier climate becoming a ever more permanent reality the Royal park system has been seen as an important water security asset that has been added to and heavily investigated for it flow and water quality performance, it's human and environmental risks it's Greenhouse gases impacts and costs. The Royal Park wetlands provide locals with a quite place to enjoy the pleasures of nature while also giving the City of Melbourne a valuable resource in this uncertain changing climate.

City as a Catchment

'City as a catchment' is a fundamental principle and approach supporting the creation of a 'water sensitive city'. It recognises the important role of the natural catchment but works primarily with the artificial city catchment (including its roads, roofs and other impermeable surfaces) to minimise mains water consumption, reduce wastewater generation and lessen the impact of stormwater discharges on receiving waters.

The 'city as a catchment' approach explores interactions between supply, the quality and quantity of stormwater and wastewater, land use, climate, social capital and the receiving waterways (rivers and bays). Furthermore, it is an adaptation strategy in response to climate change. It provides the basis for moving towards an informed 'city as an ecosystem' approach that encompasses greenhouse mitigation and habitat protection and stretches beyond single municipal boundaries. (Total Watermark – City as a catchment, City of Melbourne, 2008)

History

The 1984 Royal Park Master Plan proposed the development of a wetland at the Royal Park site to provide a range of benefits to the local community including increased biodiversity, visual amenity and recreation. Utilising the short stretch of existing creek (before it entered the main drain again) and the existing geological features, the development would provide a wildlife corridor and a major point of interest for this portion of the park. In 1998, the new master plan proposed a stormwater harvesting system to be established at the site as part of the wetland. It wasn't until 2002, that a preliminary feasibility study of establishing a stormwater harvesting system was undertaken, and then a conceptual system design was prepared the in 2004. At this stage the Commonwealth Games where coming to Melbourne and political implications went that money was to be spent on environmental initiatives. Given the development of the Athletes Village on a neighbouring parcel of land, the stars aligned for the project and the 22 years gestation period was nearing an end.

Master Planning

The Royal Park Master Plan Implementation Advisory Committee comprised of Council's Parks and Recreation staff, stakeholders and community representatives, and they met bi-monthly to discuss the key objectives of the Park's Master Plan of 1998. Planning for the Royal Park wetlands was developed with the involvement of this group, the Melbourne Zoo, the EPA, the Office of Commonwealth Games Coordination, Melbourne Water and extensive community consultation.

The project was managed by the City of Melbourne and the works were completed on time. From January to April 2006 the area was included in the secure recreation zone of the Athlete's Village. Consultation with the Wurundjeri Council resulted in the selection of 'Trin Warren Tam-boore' (bellbird waterhole) as the name for the Royal Park wetlands area.

Location and Catchment

The wetland scheme is located in the North West corner of Royal Park, in the suburb of Parkville in Melbourne. The 187 ha urban catchment is a mix of residential and commercial/industrial developments. Activities within an urban catchment are also highly variable resulting in a stormwater that contains pollutants with variable characteristics.

An initial conservative estimate of the impervious area was 41%. However, given the highly urbanized catchment, further investigation using observed and measured stormwater inflow where undertaken and a higher value of 65% impervious was used.

Site constraints

Retrofitting the design of the treatment and reuse system into the existing landform and surrounding parkland was both a constraint and an opportunity. The opportunity was provided by the mature landscape that gave substance to the natural billabong feel of the design. To maintain this feel the design needed to minimise earthworks and disturbance to the surrounding landform and thus it required careful configuration of the hydraulic structures to attain calculated water level and flow relationships.

The design considered not only the cost associated with the volume of earthworks, but also the known existence of contaminated fill and a number of major services including underground power, a brick sewer and the underground section of the Royal Park Main Drain (which is a 2 metre diameter brick conduit). All these constraints where well managed and the wetland now sits within the landscape as if it had been there all the time.

Design process

A key reason for the success of this project, and where others often fall over, where the commitment to delivering a good product on the part of the clients, principally Melbourne Water and the City of Melbourne. The other was the consistent involvement of the principle design consultants, Ecological Engineering, throughout the project, from the preliminary feasibility study through to the sign-off stage and beyond.

The broad design objectives were to improve the quality of stormwater entering the Moonee Ponds Creek, increase biodiversity in the surrounding area, provide a focal point for visitors, provide educational opportunities for local schools, and to implement one of the key objectives of the Royal Park Master Plan. The later objective to reduce potable water usage within the City of Melbourne is now, in time of water restriction and drought, the feature that gets most of the attention.

Treatment description

The Royal Park wetland stormwater reuse scheme treats, harvests and reuses stormwater from an urban catchment collected by a conventional drainage system. The 'day lighting' of the stormwater at the site provided an easy opportunity for diversion. Lows flows are diverted to the constructed wetland and the storage pond. After UV disinfection water is pumped to a closed buffer tank and then used for irrigation.

Stormwater runoff is intercepted by the online diversion structure which also incorporates a sedimentation basin. This online silt trap is designed to remove coarse sediments (greater than 125 μm). The diversion structure directs low flows (up to 1 m^3/s) into the constructed wetland. This online set-up ensures that low flows always run through the wetland. When the wetland reaches capacity, a feedback mechanism is engaged and the high flow diversion is engaged. As the feedback mechanism dictates the water flow, the design of the wetland's riser plate was critical to the wetland operation and diversion structure. High flows are directed into the existing main drain via a weir. The weir is designed to also act as gross pollutant trap. Gross pollutants and litter are collected on the trash rack, requiring periodic maintenance for removal. The water then discharges into the Moonee Ponds Creek.

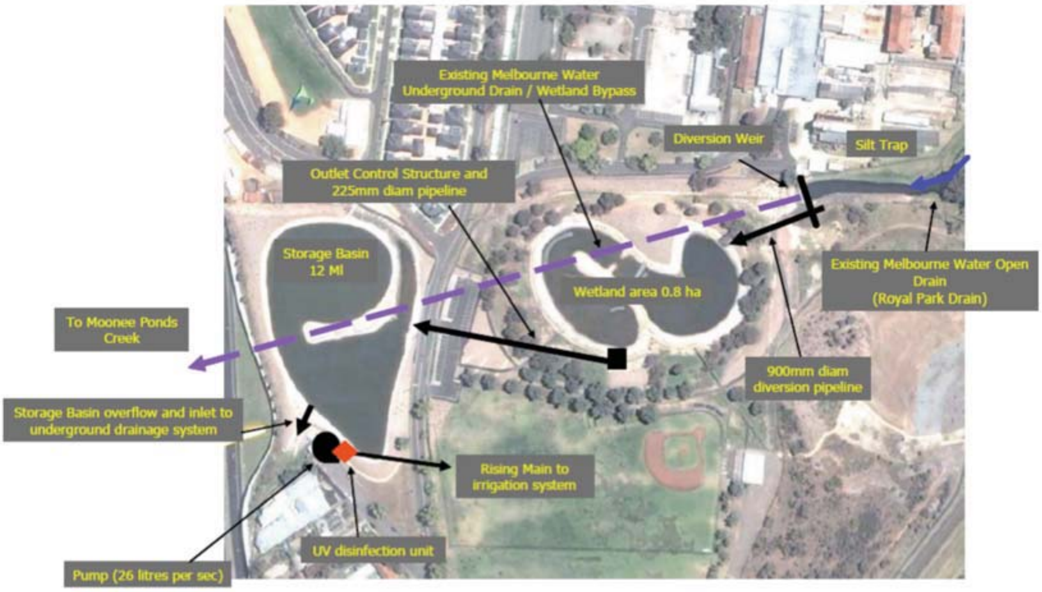


Figure 1. Layout of the main project elements of the original system (EE, 2006)

The constructed wetland is designed to remove pollutants through a combination of biological, chemical and physical removal mechanisms. During storm events sedimentation and filtration are the physical processes that dominate treatment. During dry periods, that is, between storm events when the wetland is sitting at Normal Top Water Level (NTWL), the physical processes are augmented by biological and chemical uptake mechanisms for pollutant reduction.

Further sedimentation within the 1.5 meter deep storage pond enables increased polishing of the water. Sedimentation is the dominant mechanism aided by bio-flocculation (flocculation induced by biological systems) of suspended solids. Biological uptake of soluble pollutants is facilitated predominately by phytoplankton which remains in the water column. Further pathogen reduction occurs by UV disinfection from sunlight.

The water level in the storage pond is allowed to fluctuate to provide sufficient storage for irrigation. The water is drawn down to a maximum of 1 meter to provide water for irrigation. It is pumped from the storage pond through a UV disinfection system before being pumped to buffer tanks. The buffer tanks are situated near the golf course and provide balancing for the irrigation demands and pumping capacity. When the storage pond has reached capacity, excess treated water is returned to Melbourne Water's main drain before entering the Moonee Ponds Creek. The outlet and inlet structures are positioned within the pond to ensure maximum water detention. There is also provision for peak flow events to be diverted by an overland flow path to Moonee Ponds Creek.

Maintaining the system

Management of the Royal Park wetland is a shared arrangement between the City of Melbourne and Melbourne Water. The components of the system can be broadly divided into aquatic and terrestrial components.

The main stormwater drain is owned and maintained by Melbourne Water. As such, the new works are considered an extension of this system and therefore Melbourne Water is considered the owners and has maintenance responsibilities for the diversion structure, the sedimentation basin and the constructed wetland and the storage pond up to the high or top water level.

The City of Melbourne is the owner and has responsibility for the terrestrial components surrounding the wetland and the irrigation infrastructure. This includes the UV disinfection, the buffer storage tanks, irrigation system and associated pumps.

Irrigation modelling

Ecological Engineering's conceptual design documentation reported that the annual average irrigation demand for the Royal Park Golf Course and the Western, Ryder, Ransford and McAlister ovals is an estimated 94 ML/y. During the concept design phase, modelling of different irrigation demand and supply scenarios enabled the size of the storage pond to be identified as the limiting factor in the overall capacity of the reuse scheme. Scheme elements were then optimised around the limited size of the storage pond.

Initial flows and uses

The supply reliability of the stormwater to meet the irrigation demand is a function of the rainfall pattern, seasonality and demand profile. Modelling using historical average rainfall patterns shows that this 187ha urban catchment would generate 438 ML/y of stormwater runoff. Given average storm patterns, the wetland would treat 383 ML/y of this stormwater and the rest would overtop the weir during peak storm events. Given the seasonal demand profile it was estimated that the system could supply 74 ML/y, which is approximately 79% of the annual irrigation demand.

The balancing stores have the ability to mix the stormwater with potable water if desired, or use potable water as a backup supply when there is a shortfall in the availability of stormwater in the storage pond. The water held in the balancing stores is then pumped into the purpose built recycled water reticulation system, delivering stormwater to the golf course tees and greens and the sports ovals for open space irrigation. A later addition where two hydrant stands in a street at the northern edge of Royal Park. These hydrants are used by water cartage trucks that take water all over the city to water street trees, parks without irrigation exemption and replenish water features such as heritage fountains and ponds.

At the conceptual stage City of Melbourne was content with the system being able to meet as much of the demand as possible – system reliability was not a critical factor in the systems development. Melbourne Water, based on this system yield estimate, granted the City of Melbourne with an annual diversion cap of 74 ML/y. Since stage 3 water restrictions come into force the city has depended heavily on this recycled water source.

During stage 3 restrictions, if the capacity of the system is reached, watering is generally rationed or ceases. This has occurred several times during the last two irrigation seasons and therefore options for additional water supply where investigated.

Additional storage

Modelling suggested that far more stormwater moved through the system then is utilised for irrigation. With the space for storage being the limiting factor, investigations where conducted into the feasibility of increase the storage capacity.

Key outcomes of this feasibility study were:

- Additional water can be extracted from Royal Park wetland for irrigation within Royal Park Precinct satisfying 88% of the 119 ML/y irrigation demand. This would simply require a renegotiated diversion licence cap.
- To extend irrigation beyond the Royal Park precinct:
  - Additional storage is required. Potentially a 5 ML underground storage will improve supply reliability and irrigation can be extended to surrounding streetscapes.
  - Irrigation demand for Princes Park precinct can be partially satisfied. Increasing the additional storage to 40ML will enable a 79% supply reliability from the harvested stormwater system.
  - Location for a large storage within the constrained urban area is difficult.
  - Reduction of irrigation demand, for example reducing irrigation to streetscapes, will increase water availability to a larger portion of the precincts.

Therefore a 5 ML storage volume was proposed to be situated underground. There is an existing pit approximately half way between the wetland and the storage providing an ideal opportunity for an off take to the new storage. The underground storage volume will rise and fall with the varying water levels within the open storage pond. The base level of the underground storage has been carefully selected to ensure water will drain to the pond for reuse. The top water level (RL8.85) within the underground storage is the same as the normal water level of the storage pond with the "roof" of the tank being higher then this to ensure the system is not pressurized.

Late in 2008 a 6ML underground storage consisting of domes covered with Scoria was constructed under the neighbouring Ross Straw sporting fields. It was calculated that the increased storage would allow an annual yield of 134ML/y for the whole system. Observations of the system function and background discussions with Melbourne Water eventually resulted in them granting a new diversion licence of 160ML/y.

Flow – predicted and actual

Monash University, through a SmartWater fund project, carried about detailed monitored of the Royal Park system from December 2006 to March 2008. Data was collected on flow, pollutants and viruses.

The observed water movement for a 369 day period from January 2007 to January 2008 is presented in figure 2.

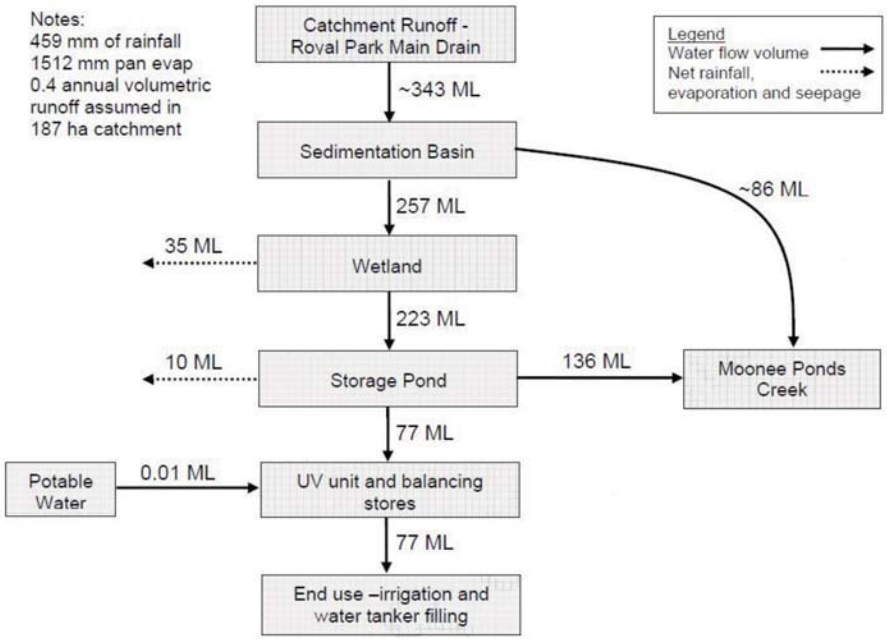


Figure 2. System water flux Jan '07 to Jan '08 (Monash, 2008)

257 ML of water was recorded entering the wetland which is considerably lower (–33%) then the predicted long term average of 383ML/yr. Given that the monitoring period was drier then the historical long term averages, with lower rainfall and higher evaporation, this is to be expected.

However, due to the regular base flow of the catchment, the reduction in stormwater inflow did not lead to a shortfall in the amount of stormwater harvested. During this monitoring period, the harvested volume only once exceeded the storage pond inflow (Jan 08). Therefore the storage pond capacity was not reached. During the 2008–09 summer period we had a lengthy spell of no rain from Mid December to the start of March. During this period, despite the addition of the extra underground storage, the system reached its lower limit and harvesting had to cease.

Treatment – predicted and measured

Another interesting aspect of the Monash monitoring program is to compare the predicted MUSIC modelling pollution reduction estimates with the actual data. Monash sampled inflow and outflow from the wetland and outflow from the storage pond. Some of the key data is presented in Table 1.

The wetland and storage pond combined are treating the water to a very high level when only considering the waterway health parameters as MUSIC does. When comparing the results to irrigation standards, the system also performs well but there are three parameters that will need to be monitored in the longer term:

1. The remaining iron level within the storage pond intake is higher the long-term irrigation value. Iron concentrations higher than 0.3 mg/L give water a brownish colour and can cause staining of plants, paths, fences etc. Some plants with heavy iron staining may experience a reduction in photosynthesis and vigour. If irrigating with iron-rich groundwater, the system design should minimise spray onto paths, fences or buildings. Iron also precipitates more readily as the pH is raised above neutral.

2. The 95th percentile turbidity level is slightly high however, the UV disinfection performed well when monitored. Turbidity is not directly monitored at present but *E. coli*. pre and post UV treatment is sampled weekly
3. The salinity level is higher than desirable but for turf irrigation. To manage this soil samples are analysed on a 6 monthly bases.

Parameter	MUSIC	Mean Sample results			100 yrs irrigation value	20 yrs irrigation value
	Predicted % removal	Wetland inflow	Pond outflow	% removed		
pH		6.8	7.3	-	6-9	
Elec. Cond., μC/cm		277	723	-	Site specific	Site specific
TSS, mg/L	77	28.8	2.7	90	-	
TP, mg/L	60	0.2	0.03	85	0.05	0.8-12
TN, mg/L	45	1.6	0.5	69	5	25-125
Iron, mg/L		1.6	0.38	-	0.2	5
					Dual reticulation standard	Unrestricted access irrigation standard
Turbidity, NTU						
95th percentile			11		<10	<10
Maximum			20		<25	<25
Target					<2	<2
E. coli, median MNP, 100ml			5		<1	<10

Table 1. Comparison of MUSIC modelling (EE, 2006), actual sample results and irrigation guideline values (Monash, 2008)

Risk appraisal

Prior to commissioning the irrigation system, City of Melbourne undertook a risk management assessment. The resulting report produce by Ecological Engineering forms the bases of the following discussion.

Environmental risks

A land capability assessment revealed that elevated sodicity of the water is a potential risk to soil stability. To minimise the risk to plant species and the soil structure, periodic monitoring of the irrigation water electrical conductivity and soil ionic characteristics are essential.

Continual maintenance, particularly of the vegetation, and water quality measurements are essential to ensure good long term performance and appropriate water quality. This will thereby minimising the risk of irrigating the land with water of poor quality.

Human Health risk

The ageing water infrastructure of the catchment means that contamination of stormwater with human sewage is probable, in low flow conditions due to leaking sewers and due to rainfall induced sewer overflows during high storm events. Human sewage is the highest risk source and is a likely pathogen contributor at the site. Both the wetland and the storage ponds are also habitat for water birds, which undoubtedly contribute to the load of faecal indicator organisms. Therefore secondary contamination of the wetland and storage pond forms a potential health risk.

Other potential faecal material sources within the catchment include domestic animal, primarily dogs and cats, and urban dwelling birds, rodents and possums. And, while The Melbourne Zoo's separate onsite drainage is designed to eliminate runoff to the Royal Park system, overflow and failure events are possible and are therefore could be another potential source of pathogen contamination.

To manage these risks to human health preventive measures and multiple barriers are the key. The preventative measures incorporated in the scheme include:

- Treatment train approach
- Primary treatment through sedimentation basin
- Treatment through a constructed wetland
- Treatment through the storage pond
- Disinfection – UV disinfection prior to reuse
- Irrigation management
- Control of method and time of application – spray during night time
- Control of rate of application
- Signs
- Education programs targeting users of harvested stormwater:
- Backflow prevention and cross connection controls
- Correct installation of plumbing
- Best practice management of irrigation

The identification and planning of preventive measures ensures a robust, safe and reliable system. Multiple barriers ensure in-built system backup if there is failure of any particular treatment element.

Risk management in practise

Open storages that provide a habitat for waterfowl result in secondary faecal contamination and the potential for zoonotic transmission of infection. If the system receives water contaminated with human faecal material, then the likelihood of waterfowl becoming infected with a human infectious pathogen may increase. When such an infection occurs, pathogen numbers and subsequent health risks can rise rapidly leading to probability of infection. This scenario could lead to a higher incidence of human infection and the potential for an outbreak with far reaching disease burden implications.

Virus challenges

Analysis by the Monash team show that when human faecal contamination is present, viral risks dominate. Viruses these can persist in the environment and can be resistant to UV. Adenovirus, in particular is extremely resistant to UV disinfection.

When Monash University applied the Quantitative Microbial Risk Assessment it indicated that the health risks are highest when human faecal contamination is present, with human enteric viruses consistently yielding the highest infection. Zoonotic sources of infection cannot however be ruled out since animals including waterfowl can become infected with strains of pathogens that are also infectious in humans. However, considering the conservative assumptions regarding the concentration of pathogens, and the rare event that waterfowl are infected by human viruses, the UV disinfection appears to provide an adequate barrier.

Diversion licensing limitation

When the Monash study modelled the dynamics of the system over a longer term using the climate data for the decade 1998 to 2007, it found that the highly seasonal pattern of demand, storage capacity in the pond, and the 74 ML/y stormwater diversion cap all limit the water supply performance of the system. The study then looked at the varying the storage capacity and removal of the diversion licence limit. The harvestable amount increased by 15% if the storage was doubled and the diversion limit was removed. The yield increased by only 5% if either the diversion limit was removed or the storage was doubled. This result suggested that re-negotiating the upper cap to the diversion licence would give a more cost effective rise in the volume of stormwater harvested.

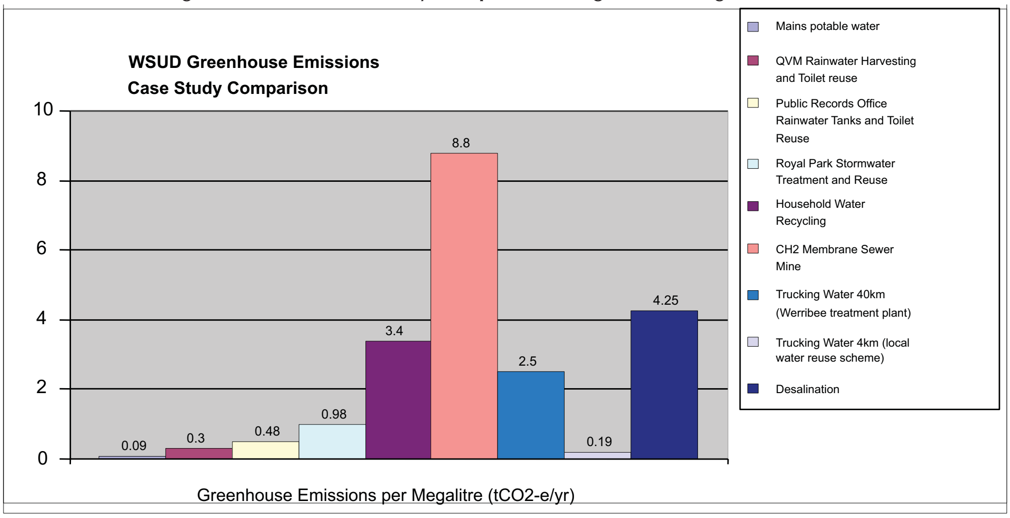
The Monash report prefaced this by stating "It is important that stormwater harvesting is not detrimental to the health of urban waterways. So it is suggested that the current simple maximum annual volume diversion conditions be replaced with a more flexible set of rules which responds to climate conditions, enabling increasing harvesting in wetter years, when the environmental impact of increasing harvesting would be negligible."

As state earlier, City of Melbourne actually increased the storage capacity by 50% from 12 to 18ML with construction of the underground storage. This project was underway before the Monash report was completed. Due to the additional storage and discussions with Melbourne Water regarding the impact of the diversion licence on the system, a higher diversion limit was set at 160ML/y.

Carbon analysis

As part of the revision of the Melbourne Water / Inner Melbourne Action Plan (IMAP) WSUD guidelines, a carbon emissions analysis case study was conducted on a number of water reuse projects existing within the city of Melbourne. The results are shown in figure 3.

Figure 3. WSUD case study comparisons of greenhouse gas emissions



This analysis indicts that although the Royal Park reuse scheme produces more greenhouse emissions then the mains, it stacks up favourably to equivalent larger scale alternative water schemes such as sewer mining and desalination. Studies to date also show that for a range of WSUD treatments embodied energy emissions contribute to less than 0.1% of total emissions over the life of the scheme.

Cost summary

The project provides economic benefits to Council and the community by replacing drinking quality water currently used for irrigation with low cost recycled water. It also provides economic benefit for Melbourne Water, who have capital works programs and performance targets for reducing nitrogen levels of stormwater reaching Port Phillip Bay. These benefits are maximized through a project design that minimizes operational and maintenance costs. Examples of such project design aspects are as follows:

- All aspects of the treatment and reuse scheme up to the point that stored water is supplied to the irrigation system is achieved simply through the use of gravity and without mechanical or chemical processes.
- When the treated water is used for irrigation, the disinfection via ultra violet irradiation involves a relatively low energy use and the new irrigation control system minimizes the use of pumps through optimal patterns and levels of watering.
- The sediment basin constructed upstream of the wetland is predicted to require cleanouts every 3 to 5 years. An area adjacent to the basin (out of public view) has been provided for the stockpiling of sediment while it dries; further minimizing the cost of disposal.

Wetland and storage pond construction cost	$5,000,000
Underground storage construction cost	$2,000,000

Potable water savings

- 2007–2009 74 ML per year @ $1.35/kL has a value of around $100,000/year
- 2009 onwards160 ML per year @ $2.70/kL (predicted cost of water by 2012 has a value of $432,000/ year.

Based on the cost of works constructed elsewhere in Melbourne for removing Total Nitrogen from stormwater, the pollutant removal capacity of the Royal Park Scheme (at a harvest volume of 74ML/yr) has a capital value of more than $450,000

Conclusion

The Royal Park stormwater wetland harvesting and reuse scheme truly is a benchmark project. It has provided valuable knowledge into the application of City as a catchment principles and the sustainable management of stormwater resources for the benefit of the environment and society alike. This project would not have been possible without the collaboration of a number of consultants responding to the designated outcomes for this project. The final result is a success for both; the ecology of the site, and the Royal Park drought proofing initiative. The tangible cost saving in the ongoing maintenance of the park has exceeded the expectations of all parties.

References

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