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WHAT DOES IT COST TO BUILD A WATER QUALITY TREATMENT SYSTEM?

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Abstract

Improving urban stormwater runoff water quality is a common catchment management objective across councils in Sydney. Many councils in Sydney are currently in the process of designing and constructing water quality treatment systems such as bioretention systems, wetlands, sand filters and swales to improve water quality discharging into waterways and receiving waters.

One of the major barriers to the widespread adoption of water quality treatment systems in existing developed areas is the cost of constructing retrofitted treatment systems. This barrier is exacerbated by the lack of good quality and easily accessible data on construction costs, particularly in Sydney. This paper seeks to address that gap by assessing construction cost data on more than 20 water quality devices through Sydney with a focus on the Ku-ring-gai, Hornsby and inner western Sydney local government areas.

This paper provides a breakdown of construction cost into its key components and compares construction costs in Sydney to construction costs reported elsewhere in Australia, particularly Melbourne and Brisbane.

Some of the key findings of this paper include:

- Larger variation in the construction of smaller streetscape biofiltration systems from \$500 to \$2000 per m^2
- A relatively stable cost of approximately \$500 to \$700 per m^2 for biofiltration systems larger than 100 m^2
- Earthworks and drainage are consistently large cost items.
- Disposal of spoil can be a large cost item and methods used to manage this cost have been discussed
- Costs are comparable to retrofits in other cities in Australia
- A relationship between MUSIC acquisition cost and acquisition costs for retrofits in Sydney

Introduction

It is becoming increasingly common for local councils in Sydney to adopt Water Sensitive Urban Design (WSUD) strategies. Improving urban stormwater runoff water quality is an integral part of such strategies and a common catchment management objective. These objectives are receiving support, both financial and institutional, from State and Federal Governments. To improve stormwater quality many local councils are in the process of retrofitting water quality devices into existing urban catchments to treat runoff before it discharges to local waterways.

Traditionally, water quality improvements have focused on primary treatment measures which remove coarse sediment and gross pollutants. In the last few years there has been an increasing trend to implement secondary treatment systems which also remove fine sediment and associated heavy metals, and nutrients including nitrogen and phosphorous (for example see Brown and Clarke (2007)). Councils have begun to retrofit into existing urban catchments water quality treatment devices such as bioretention systems (also known as biofiltration systems or raingardens), wetlands, sand filters and swales to improve water quality discharging into waterways and receiving waters.

One of the major barriers to the widespread adoption of water quality treatment systems in existing developed areas is the cost of constructing retrofitted treatment systems (for example see McManus and Morrison (2007)). This barrier is exacerbated by the lack of good quality and easily accessible data on construction costs, particularly in Sydney.

The main existing water quality costing tools, the life cycle costing module in the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) as developed by the Australian Cooperative Research Centre for Catchment Hydrology (CRCCH) will be assessed for its ability to determine construction costs in retrofit situations.

The major aim of this paper is to address this gap by assessing construction cost data for retrofit stormwater biofiltration systems in existing urban areas and:

- address capital costs as one of the major barriers to the uptake of WSUD
- increase information available on construction costs for catchment management planning purposes
- assess the existing construction data set for any patterns on how to reduce construction costs

Treatment Systems and Description

Costs have been compiled for 25 treatment systems that have recently been constructed (most within the last two years) in northern Sydney and inner western Sydney. All of the projects are retrofit systems built to treat stormwater from existing urban development. Table 1 shows a summary of the treatment systems, the type of treatment system, the cost to construct the system and the treatment system footprint. The table also includes a short description of the salient features of the system that have caused increased costs of construction for the particular system.

Table 1 Construction Costs

Location	**Treatment System**	**Type**	**Footprint**	**Construction Cost**	**Construction Process**	**Site Notes**
Earlwood	Bioretention and swale	Streetscape	Swale: 30 m^2 Bio: 30 m^2	$87,000	Contractor	Sandstone wall required. Offline.
Strathfield South	Wetland	End of pipe	1100 m^2	$120,000	Contractor	Alligator weed removal required. Inline system
Greenacre	Bioretention system (two)	Streetscape	Total area: 150 m^2	$83,030	Council	Flat site constructed in centre median of local road. Simple diversion (offline) and spoil contained on site.
Arncliffe	Bioretention System	Streetscape	120 m^2	$62,000	Contractor	Spoil generation and off-site disposal of non-VNEM material increased cost. Offline.
Marrickville South	Bioretention system	Streetscape	20 m^2	$38,000	Contractor	Simple streetscape system with simple diversion and earthen batters. Offline.
Marrickville South	Bioretention system	End of pipe	30 m^2	$61,000	Contractor	Steep site, concrete block retaining walls required, rock-lined channel required to address local flooding
Inner Sydney	Bioretention system	Streetscape	20 m^2	$80,000	Council	Streetscape system as result of road closure, offline.
St Peters	Bioretention system	Park	400 m^2	$1,300,000	Contractor	Bioretention system built onto the edge of an existing pond and includes *significant* landscape components
Cheltenham	Bioretention system	End of pipe	320 m^2	$199,000	Council	Council reserve, relatively flat, significant rock excavation and sandstone wall required, 60m rock lined high flow by-pass. Saturated zone.
Mt Kuring-Gai	Bioretention system	End of pipe	150 m^2	$106,000	Council	Very steep site. Basin cut into rock. Sandstone wall required.
Hornsby Heights	Bioretention system	End of pipe	170 m^2	$118,000	Council	Flat, next to creek. Significant rock wall construction
Hornsby Heights	Bioretention system	End of pipe	250 m^2	$177,000	Council	Steep site, significant sandstone wall construction (>3m). In-line. Saturated zone.
Nth Epping	Bioretention system	End of pipe	320 m^2	$207,000	Council	Medium steep, significant sandstone wall construction, 90m rock lined channel. In-line.

Berowra	Bioretention system	Streetscape	40 m^2	$20,000	Council	6 raingardens built into traffic calming devices, part of local streets improvement program
Hornsby	Bioretention system	Tree pit	9 m^2	$24,000	Council	3 tree pits, part of local streets improvement program
Waitara	Bioretention system	Streetscape	45 m^2	$36,000	Council	2 raingardens built into traffic calming devices, part of local streets improvement program
Epping	Bioretention system	Tree pit	45 m^2	$120,000	Council	15 tree pits, part of local streets improvement program
Ku-ring-gai	Bioretention system	Streetscape	98 m^2 total (88 m^2 filter)	$111,749	Contractor, lump sum	System off-line. Concrete block walls and base, constructed in three separate beds in existing car park (easy access). Diverting runoff from stormwater pipe.
Ku-ring-gai	Bioretention system	Streetscape	43 m^2 total (15 m^2 filter)	$36,987 total ($25,179 for filter)	Contractor, lump sum	Small raingarden, taking local road runoff only. Later work included wood retaining walls and footpaths for aesthetic reasons. Easy access next to road, no rock.
Ku-ring-gai	Bioretention system	Streetscape	37m^2 total (14 m^2 filter)	$20,090	Contractor, lump sum	Small raingarden, taking local road runoff. Submerged zone, sand filter media w. water retaining crystals. Easy access in park next to road, no rock present.
Ku-ring-gai	Bioretention system	End of pipe	326 m^2 total (138 m^2 filter)	$ 76,932	Contractor, hourly rates, materials by Council.	System, in-line. Submerged zone, sand filter media w. water retaining crystals. Bush site, level, some problems with water intrusion (as in-line) during construction, need for de-watering.
Ku-ring-gai	Bioretention system	Streetscape	3 gardens total 45 m^2 (38 m^2 filter)	~$50,000	Council, as part of road upgrade	Three small biofiltration raingardens. Concrete walls and base. Taking local road runoff only. Easy access, no rock.
Ku-ring-gai	Bioretention system	Streetscape	5 gardens total 39 m^2(34 m^2 filter)	~$50,000	Council, part of road upgrade	Four small biofiltration raingardens. Concrete walls and base.

Ku-ring-gai	Bioretention system	Bioretention in parkland	430 m^2 total (278 m^2 filter)	$176,300	Contractor, lump sum	Biofiltration system, off-line. Some problems during construction where large volumes of sediment was washed into filter.
Ku-ring-gai	Bioretention system	Streetscape	70m^2 total (35 m^2 filter)	$152,600	Contractor, lump sum	Small vegetated sand filter, flow diverted via 75m of concrete pipes. Easy access. Included rock excavation (10% of cost). Includes excavation for tanks and concrete works and fencing, but not tanks themselves.

Analysis of construction costs – treatment area

An analysis of costs based on filter media size was undertaken. This relationship is shown in Figure 1. The scatter plot shows how costs generally decrease with treatment size. The figure shows that there is considerable variation in treatment costs for small size systems (systems smaller than 50 m^2). Small scale systems are typically streetscape systems or tree pits (all but one in Figure 1). These systems have a high ratio of edges to filter area and thus costs for these systems are heavily weighted to the design of the interface of the edge with its surrounds. The edges vary significantly from concrete walls for tree pits to earthen batters. Furthermore, streetscape systems are generally built to a higher standard of finish due to their location in the urban environment. This is reflected in higher construction costs.

Figure 1 shows that small streetscape systems typically cost more than larger systems (greater than 100 m^2), whether end of pipe or streetscape systems. Larger systems show much less variation in cost ($500 to $750 per square metre of filter area). This is likely to be explained by the reduced effect that edge systems have on cost, as the perimeter to area ratio decreases considerably with larger systems (a small bioretention tree pit has an edge to area ratio of approximately 2 while a system of 250 m^2 has an edge to area ratio of less than 0.25).

Figure 1 also shows that there is no obvious variation from the predicted cost for systems which require rock excavation or which require the construction of walls (in this case sandstone walls or concrete walls). This suggests that while steep sites or difficult sites present challenges, it is possible to construct bioretention systems with reasonable cost effectiveness in these environments.

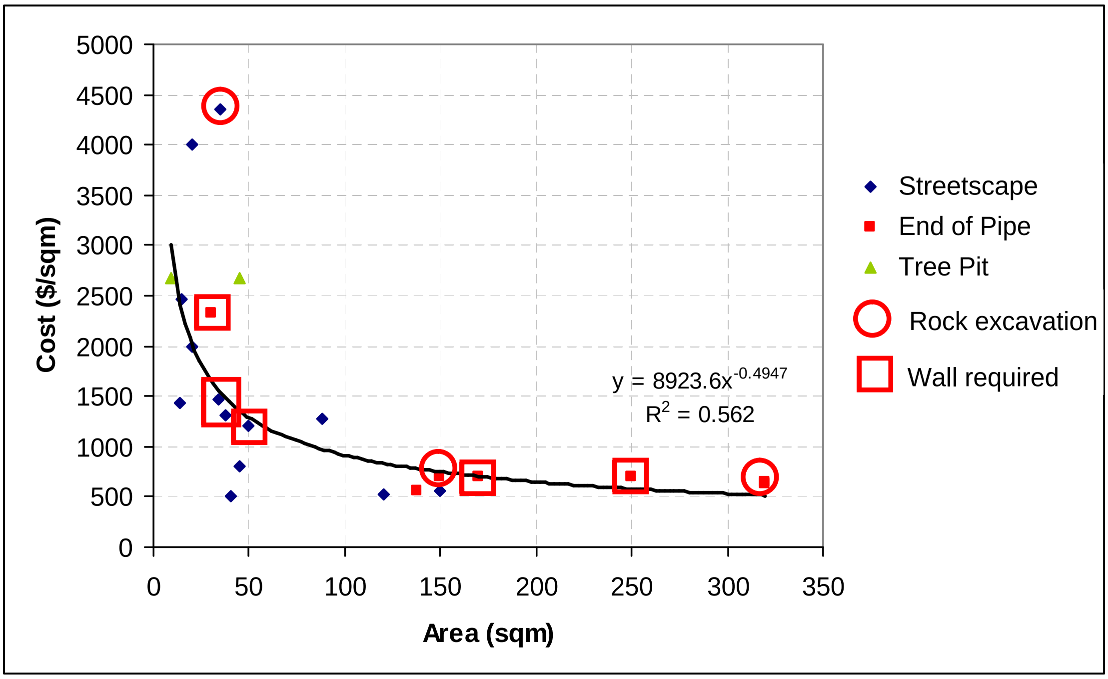

Figure 1 Sydney construction cost scatter plot (22 sites in total)

A trendline has been generated using Excel and using a power relationship. The relationship had an R^2 value of 0.56 which shows that while the relationship has a useful predictive ability there is still significant variation that is not explained by this relationship. This reflects, in particular, the large variation in costs of smaller systems.

Analysis of construction costs – by key components

An analysis of costs based on components (for e.g. excavation, drainage, landscaping, etc) was undertaken for those systems that had data (11 in total). These relationships are shown in Figure 2 for streetscape systems and Figure 3 for end of pipe systems.

The figures show that key components of costs for most systems, whether streetscape or end of pipe are:

- drainage (typically 15 to 25% of all costs)
- earthworks (10 to 30%)
- placing of filter media (typically less than 10% of costs)
- planting (typically less than 10% although in one case up to 20%) and
- landscaping (typically 5 to 10% of costs).

Some other key observations on costs for treatment systems:

- Where walls are required in larger end of pipe systems on steep sites these components are typically 10 to 15% of the total costs.
- Design, while not included in these figures, has been shown typically to be 10 to 15% of the total cost.
- Rockworks and roadworks, if required, can be substantial cost components (in a number of cases up to 20% of cost).

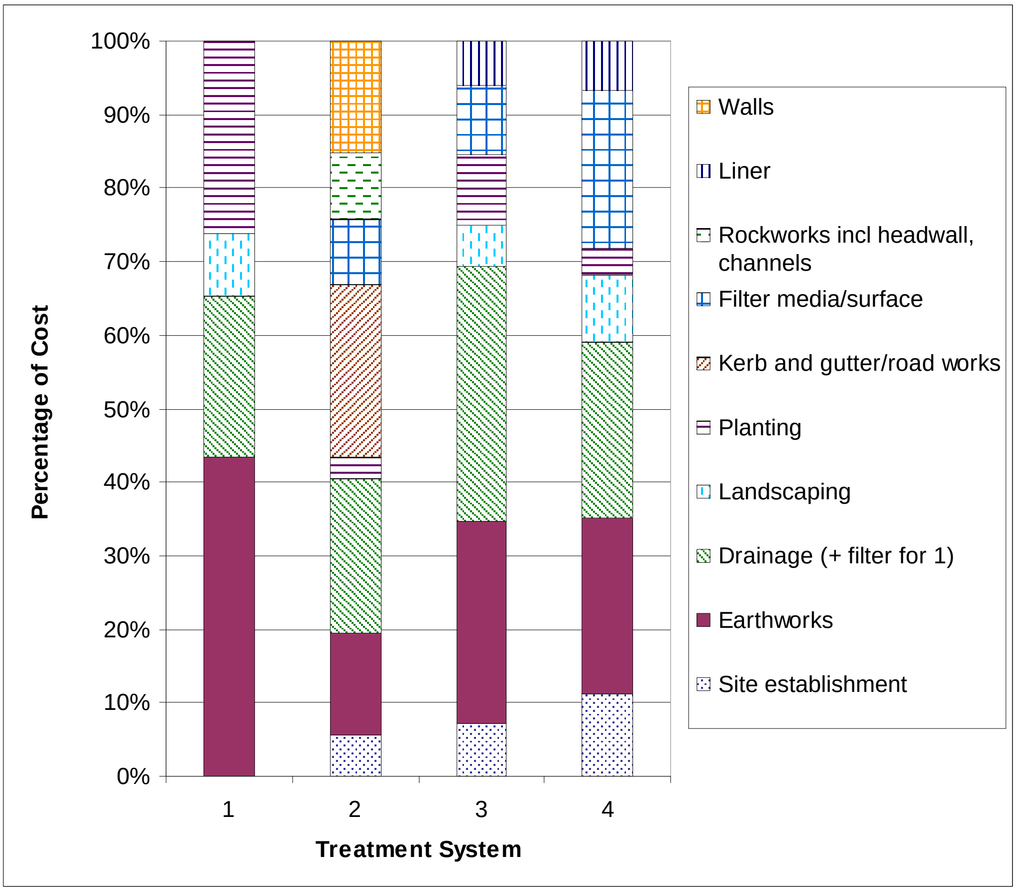

Figure 2 Components of streetscape system costs (4 sites in total)

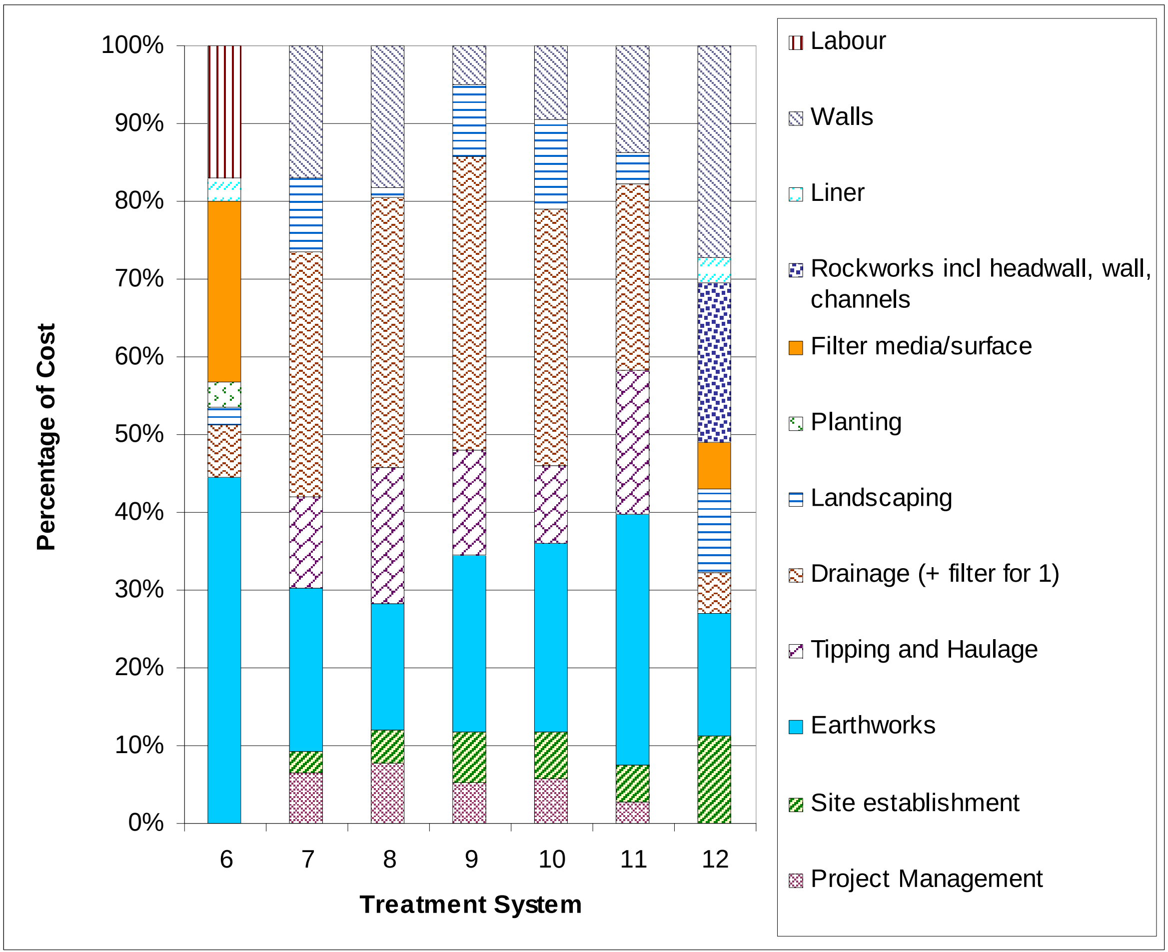

Figure 3 Components of end of pipe system costs (7 sites in total)

One observation based on the different component costs for these systems is the outer components of the system (external batters, drainage, rock, walls, landscaping elements etc) are a significant proportion of the total cost. This has significant implications for example in asset renewal costs. If asset renewal can be considered to be excavation of filter media, replacement of filter media and re-planting it is expected that this will be a maximum of 40% of the construction cost of the system. Considering that excavation of the bioretention media is likely to be much simpler than the original excavation for the entire system these costs could be as low as 20% of the original construction cost.

This however does not include the uncertainty over the cost of disposal of potentially contaminated material. Also, it does not consider the renewable costs if the structural integrity of the hard engineered components are compromised by poor initial construction or incorrect sizing and design.

Analysis of construction costs – by site factors

Topography

Site slope will determine the extent of cut and fill and the requirement for retaining walls, and steeper sites will require higher walls. From the data examined it has been hard to show a clear cost distinction between systems using walls and those that do not, however anecdotally the authors' experience is that walls can be a major cost. In some instances systems have been constructed where access to the site has been through steep areas. This has required more management from an environmental perspective (e.g. erosion and sediment control) but is normally not an issue in terms of constructability or cost increases.

In-situ soils and rock

Excavation costs depend on the ease of excavation of materials (e.g. sand, clay, rock of varying hardness). Construction in rock does not necessarily increase overall project cost when considering the alternatives. In some cases it may be cheaper to excavate in rock (especially in soft sandstone) than to build a wall to avoid excavation. The construction of sandstone rock walls also require a significant footprint, especially if they need to be water proofed, and may increase the overall system footprint.

The other significant variable is management of spoil, either on site or off site. Depending on the material classification (e.g. waste or virgin excavated natural material (VENM)) different sources of spoil can attract vastly different disposal costs. Some materials may potentially be reused for construction of the shell (e.g. rock and clay for bunding and retaining walls and for lining the system). Other material may potentially be used as filter media depending on characteristics. Remaining good quality spoil can potentially be relocated and disposed of on site. One potential issue with reusing soils on site is that it shifts costs from capital costs to maintenance costs, as greater time is required for weeding and plant establishment on areas surrounding the system. This is highly dependent on the quality of excavated material. One way to reduce maintenance cost is to use capping. Capping options include capping with crushed sandstone or imported top soil.

For excavated material which is clean, councils may also store the material (on council premises) for later reuse. This includes a cost for trucking material, but this is about half of what it would cost to dispose of material off-site.

Degraded soils (e.g. with weed propagules and contamination) will impact on disposal costs and potential reuse on site. These materials have a low potential for beneficial reuse and may need to go to landfill. The cost of disposing material can be significant, especially where material is contaminated (old stormwater outfalls etc.) or wet. Many contractors also avoid including this in lump sums and will charge this at a rate per tonne, which can be a hidden cost during the construction project if this is not factored into the project cost.

The recommended best practice design approaches include the following:

- Soil testing and site investigations (e.g. to determine the depth to rock): While incurring upfront costs can save money though guiding design and determining the extent of contaminated soil or cut and fill that can be undertaken. In some cases where costs are too high for a project due to site soils it may be better to look for an alternate location or in some cases an *alternate project* which will have a lower unit cost rate.
- Cut and fill balance: When reusing material, undertake a cut and fill balance and include designs of where the material is to be located on site showing the footprint, heights and batter slopes of reused material.

Site access and boundaries

Access should be considered during design and if access can not be provided or requires extreme measures the project should be re-evaluated and alternate projects should be considered. Access needs to be considered for on-ground machinery (e.g. excavator) and trucks to and around the site. Good access is essential when constructing retaining walls or filling the basin/shell. Where access is difficult a project is unlikely to be viable.

Consideration should be given to potential locations for stockpile areas for excavated material or materials to be used in construction (e.g. clay bunding).

Fringing vegetation, existing infrastructure and services may all need to be protected around and within the site. This is very important when considering streetscape or highly landscaped areas (e.g. public reserves and parks) so as to ensure construction and future performance of the device does not impact on adjoining areas or structures (e.g. water under road pavement). This is also important when considering the impact on trees and bushland of high importance.

Services

The location of services needs to be considered during the design phase, both through site investigations and by utilising the Dial Before You Dig service available in all states. So while services will have a major impact on the feasibility of systems in developed catchments, once a site has been identified as suitable this should ideally not cause major problems or impact on systems during construction. Construction contractors are required to be careful when working in proximity to services (e.g. sewer and water mains) but in the authors' experience, no major relocation of services has been required. If major relocation of services is required, re-evaluation of the project is strongly recommended at the concept design stage and alternate locations or alternate projects should be considered.

Offline vs. online

When online systems are constructed there is typically more downtime during wet weather. This has a cost involved, particularly if constructing with council/in-house staff or with contractors engaged on an hourly basis. For lump sum contracts there may not be a direct cost increase however morale and quality of work will suffer when the contractor experience problems that were not allowed for in the lump sum. An on-line system is also far more likely to fill up with sediment, litter etc. during a storm event and this can cause major cost implications. It is important, where possible and practical, to use a by-pass system if building on-line. This can limit the damage to works by high flows and also limit downtime associated with wet sites

Off-line systems are far less likely to experience any of these problems as long as they can be kept truly off-line even during very heavy storms.

Experience of construction team

A key consideration to minimise cost is ensuring that the site supervisor is skilled in the construction of similar structures, and fully understands all design elements. The site supervisor does not necessarily need to be experienced in the construction of biofiltration systems but needs to know his or her limitations and consult with the designer on a regular basis. As most of the work is civil in nature, the detailed knowledge (fitting of pipes, concrete pits etc.) is the same as for other projects and the difference is how these parts fit together. The supervisor needs to know either how the parts fit together and why, or know that they don't know and consult the designer.

This is extremely important when considering the structural integrity of hard engineered elements, especially those below the ground. A poorly finished wall penetration or inadequate placement of a liner may result in complete or partial system failure and very costly repairs. Hence, an understanding of how the system works and the potential for failure is essential.

Flexibility in design and construction

Flexibility in design and construction can be important. The design will need to be detailed enough not to leave anything up to interpretation, as this is likely to cause problems when people with a limited understanding of the system make assumptions during construction. However, if site conditions are found to be different than those anticipated during design, there needs to be some flexibility to adjust the design to suit these conditions. If you can have a flexible arrangement in place to address costly issues during construction, this can save costs. For example, if bedrock is discovered during construction when not expected, allowing for the flexibility to increase area and reduce the filter media depth to achieve similar performance outcomes can have considerable costs advantages.

It is however very important that any changes to the design are done in close collaboration with the designer, as it may not be obvious to everyone how the different parts of the system work together. The authors have experienced problems when people have made adjustments to the design based on their own understanding without consulting with the designer. This is closely related to the need to have a site supervisor that has a collaborative relationship with the designer.

Analysis of construction costs – construction arrangements

There are generally two traditional options for constructing retrofit treatment systems including constructing

- internally using Council construction teams
- externally using construction contractors

There have been differing experiences of bioretention systems constructed internally by Council organisations. Some Councils have been able to develop good working relationships with Council construction teams and have been able to implement well constructed bioretention systems at relatively low costs while others have not been able to construct systems of a sufficient quality or at a competitive price.

There can be a number of advantages to constructing internally including

- Greater flexibility as constructing in-house is not constrained by contractual arrangements. As a result variations to design can be dealt with easily and without significant cost implications
- Delivering cost savings as services can be undertaken on a "do and charge" basis at very competitive rates without profit margins being an imperative
- Providing continuity as construction crews become familiar with the design objectives and construction methods and the development of specialized "wetlands/rain gardens crews"
- Increased Council ownership and retention of significant knowledge within Council

- Reduced construction time due to a reduction in time required for tendering and approved tenderer processes

However constructing internally in Council has provided a number of particular challenges in some Councils including:

- Reduced control of construction quality compared to an external contractor due to the more informal contractual arrangements and internal Council dynamics
- Council construction teams may take it upon themselves to make design changes without consultation based on their prior construction experience of standard drainage construction projects
- Increased requirement for site construction supervision by an experienced design engineer, especially with Council construction crews who are not experienced in constructing bioretention systems. In one particular example the limited experience of Council was overcome by almost constant site supervision by staff who had been involved in the design process and had an understanding of the key design parameters
- There may not be a strong internal commitment to constructing systems internally (due to current workloads, or organisational difficulties in constructing systems such as lack of appropriate equipment or qualified staff)
- In cases where Council's are unfamiliar with construction of bioretention systems the estimated construction costs can be inflated due to the lack of knowledge of construction techniques. This when combined with a low risk approach to pricing construction can mean that internal construction is not competitive with external contractors particularly when Councils are organised into business units, there can be a reduced financial incentive to use Council construction crews

An alternative to these two traditional construction contractual arrangements has been trialed recently with some financial success. The trial had the objective of reducing construction costs and providing improved construction quality. The method which was used in the trial involved the following:

- use of external construction contractors (such as excavation and drainage contractors)
- external construction contractors were engaged on an hourly rate
- materials were purchased internally through Council
- use of internal Council design staff for project management of the construction contractors

This process provides some of the flexibility of internal construction contractors, increased Council ownership and reductions in construction times but also avoids some of the issues when using internal construction crews has not been as successful due to the factors discussed above.

Comparison to other areas

A review of data from a range of *retrofit* projects in Melbourne was undertaken to assess the range of costs of retrofits undertaken in Melbourne.

Kingston City Council over a one year period retrofitted 30 residential streetscape raingardens. The cost reported for each raingarden was $6,800 per raingarden on average (Kingston City Council, 2009). Based on an estimate of size for the Kingston streetscape raingardens this is approximately $1,000 per square metre.

A number of documented recent retrofit projects in councils in Melbourne have reported the a range of costs from $260 per m^2 to over 6000 per m^2 as shown in the table below:

Treatment System	Capital Cost	Area m^2	Cost/Area	Reference
Bio swale	$122,000 -	475	$260 per m^2	Clearwater, 2009
Streetscape bioretention	$22,000	30	$733 per m^2	Clearwater, 2009
Bellair Street Raingardens	NA	NA	$1300 per m^2	City of Melbourne, 2009
3 small raingardens	$36,520	22 m^2 in total	$1660 per m^2	Port Phillip Council, 2009
10 tree pit raingardens	$50,000	8 m^2 in total	$6,250 per m^2	Clearwater, 2009

A review of the costs of bioretention systems was undertaken for Healthy Waterways Partnership (Ecological Engineering, 2007). This study found that the costs of retrofit treatment systems ranged from $111 to $2,170 per m^2 as shown below:

Treatment System	Area m^2	Cost/Area	Reference
Bioretention system Hoyland st	800 m^2	$111 per m^2	Ecological Engineering, 2007
Bioretention swale at Besline	1500 m^2	$640 per m^2	Ecological Engineering, 2007
Bioretention system at Streisand Dr	30 m^2	$2170 per m^2	Ecological Engineering, 2007
Bioretention system at Saturn Cres	30 m^2	$2050 per m^2	Ecological Engineering, 2007

A number of greenfield bioretention systems were also included in this report and are shown below:

Treatment System	Area m^2	Cost/Area	Reference
Bioretention system	450 m^2	$315 per m^2	Ecological Engineering, 2007
Bioretention system	900 m^2	$294 per m^2	Ecological Engineering, 2007
Bioretention swale	975 m^2	$240 per m^2	Ecological Engineering, 2007

These costs have been plotted on scatter plot in Figure 4. A power relationship has been derived from the data to predict cost based on treatment system area. The scatter plot and derived power relationship shows that there is a considerable variation in cost for small treatment systems while for larger systems the cost/per square meter of treatment system is relatively homogeneous and flattens out to a typical cost of $300 to 400 per square meter of filter media.

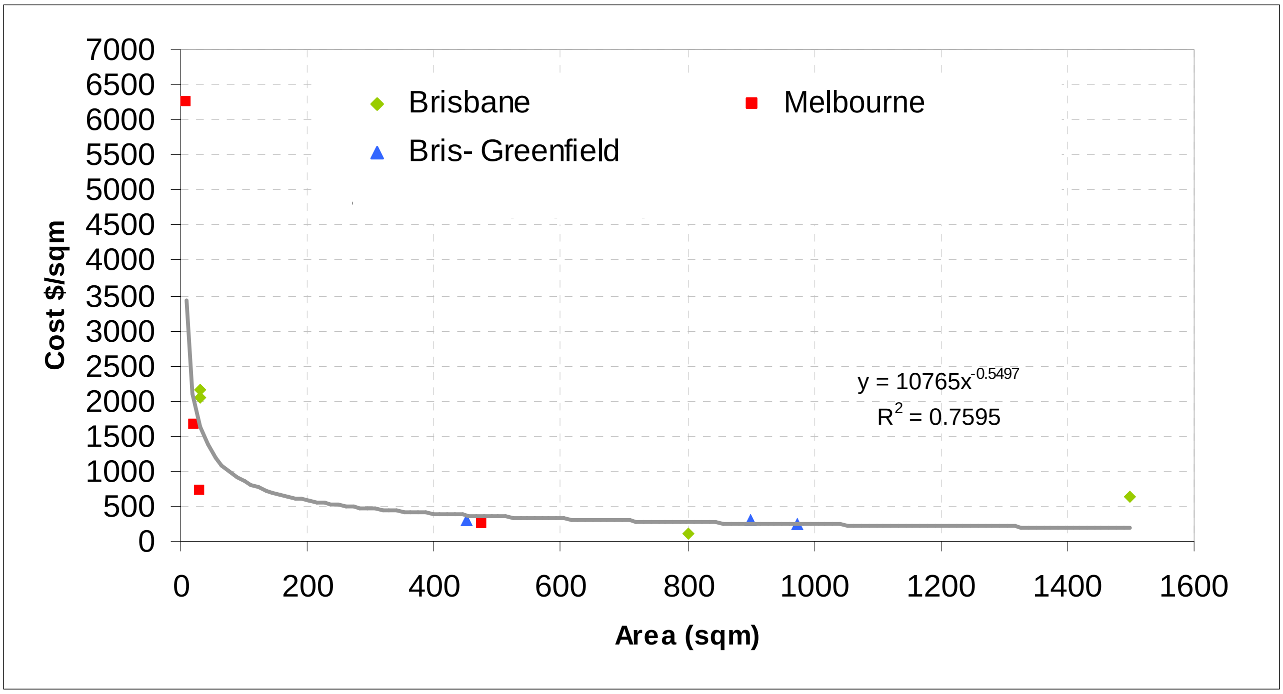

Figure 4 Melbourne and Brisbane Construction Cost Scatterplot (11 sites in total)

Comparison to MUSIC

The MUSIC life cycle costing module only collected data for Greenfield applications. Furthermore when the data was collected there was a lack of data for new and emerging treatment devices which have now become more widely adopted. For example the MUSIC v3 and v4 life cycle costing module only collected data for bioretention systems and swales as a *combined* group and it only collected data for 7 such bioretention systems or swales (CRCCH, 2005).

Table 2 compares costs estimated in the MUSIC life cycle costing module (both the "expected" and "upper" values) with costs estimated using the curves in Figure 1 and Figure 4. This shows that even the upper costs estimated in MUSIC are significantly lower than the costs found in this study. In the case of small bioretention systems, the MUSIC costs are only approximately 50% of those found in this study. It is noted in the MUSIC manual that the algorithm for bioretention system costs is based on a combined data set including both bioretention systems and vegetated swales, as there was insufficient data to analyse bioretention systems on their own (CRC for Catchment Hydrology, 2005, p.134).

Table 2 Comparison with MUSIC life cycle costs

Bioretention system area (m^2)	MUSIC cost (expected)	MUSIC cost (upper)	Cost based on Sydney curve (Figure 1)	Cost based on Melb+Bris curve (Figure 4)
50	$8,777	$32,512	$64,421	$62,670
100	$14,939	$46,870	$91,441	$85,628
200	$25,427	$69,476	$129,793	$116,995
500	$51,361	$124,716	$206,219	$176,750

Summary

This paper is the first major published review of costs for retrofit projects in developed areas and provides a database for costs of retrofitted bioretention systems in Sydney. These costs can be used as a benchmark by catchment managers to determine if their project is cost effective.

Some of the key findings of this paper include:

- Larger variation in the construction of smaller streetscape systems from $500 to $2,000 per m^2
- A relatively stable cost of approximately $500 to $700 per m^2 for treatment systems larger than 100 m^2
- Earthworks and drainage are consistently large cost items.
- Disposal can be a large cost item and methods used to manage this cost have been discussed
- Costs are comparable to retrofits in other cities in Australia
- The life cycle costing module in MUSIC is not a suitable tool for estimating retrofit costs however a simple relationship has been developed to develop ball park estimate for a retrofit project

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