Reviewing the Feasibility for Raingardens in the Darebin Creek Catchment:

Engaging the Community to Manage Stormwater Runoff

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1. Introduction

Urbanisation has greatly increased the area of impervious surfaces in the Darebin Creek Catchment. This causes rainfall that would have otherwise slowly entered the catchment after seeping through the soil to instead flow from the catchment quickly and in greater volumes. The increase in the rate of water entering the creek has changed the hydrology of the Darebin Creek; flood events are now more severe and have an increased flow rate, causing erosion and damage to vegetation. Changes in the water flow also impact on sedimentation, macroinvertebrates and increase pollutant levels. The health of the Darebin Creek has been negatively affected by these changes and is in a poor condition (Melbourne Water, 2004).

Traditionally, measures to mitigate stormwater runoff have focused on centralized infrastructure such as wetlands, which are often costly and have not sufficiently alleviated water quality problems. Encouraging community-wide retention measures, using methods such as building raingardens, can effectively decentralize stormwater retention as well as increase community awareness of the negative impacts of stormwater runoff.

Every year Melbourians make about 100 million recreational visits to our rivers, creeks and streams (Melbourne Water, 2004). Melbourne waterways are highly valued by the local community and the conditions of the streams are viewed as an important indicator of environmental health. Darebin Creek is of high cultural and social significance to the community, allowing for scope in encouraging community-based mitigation of stormwater runoff. However, currently community awareness of the negative impacts of stormwater runoff is low and needs to be increased.

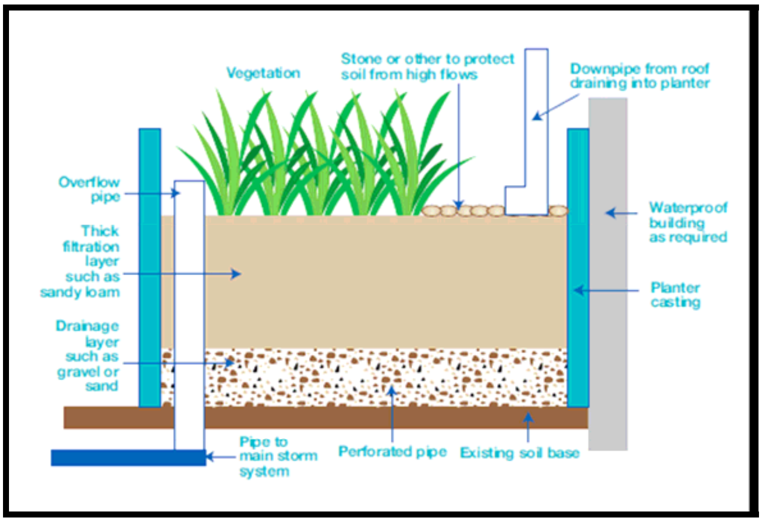
Raingardens are a simple way to do this. Easy to build raingardens can be constructed in domestic homes and can lower levels of pollutant runoff, as well as decrease the rate of stormwater runoff entering the Creek. A raingarden is a garden bed with sandy layers underneath designed to filter and slow the rate of water rushing from impervious surfaces into stormwater. These gardens are positioned to receive stormwater from hard surfaces such as roofs, paved areas or driveways and filter out accumulated litter, oil, and excess nutrients. This report reviews the feasibility of using raingardens in the Darebin Creek Catchment to see if the economic, ecological and social impacts are beneficial and outweigh the finnicial costs of building the raingardens.

2. What is a Raingarden?

A raingarden is a garden bed with sandy layers underneath designed to filter and slow the rate of water rushing from impervious surfaces into stormwater. These gardens are positioned to receive stormwater from hard surfaces such as roofs, paved areas or driveways and filter out accumulated litter, oil, and excess nutrients. Raingardens also capture and retain water, slowly releasing stormwater into waterways, reducing the occurrence of unnatural flood events.

Required design and characteristics of a successful raingarden

Raingardens can vary in complexity and size; however, every raingarden should include the same basic components.



(Inside a Raingarden. Nillumbik Shire Council 2010)

1. Site analysis

The area from which rain is going to run from into the raingarden should be carefully considered before building commences to ensure the continued effective operation of these systems. Raingardens should be positioned to easily collect water flowing from impervious surfaces, but can also be placed as a secondary catchment to overflow from watertanks. A raingarden may be positioned in a low spot that naturally collects water after heavy rain or close to an impervious surface to minimize additional plumbing. The site should be reviewed for specific outcomes i.e. water quality, flow management, area beautification or harvesting. They can be incorporated as part of an overall garden landscaping and can be complete gardens or just a simple planter box.

2. Size

The raingarden should be large enough to capture the amount of stormwater it will receive. Generally the size of the raingarden should be approximately 2% of the run-off area. For example a 100m^2 roof space (with all water draining to the same area) should have a rain garden approximately 2m2 in size ($2m^2$ x $1m^2$). The raingarden should be at least 1m deep.

3. Inflow

The inflow structure directs stormwater to the rain garden. The inflow can be a gutter downspout, a grassed or stone lined swale, or any other mechanism that can direct runoff to the rain garden without causing erosion. Problems generally arising from inflow include sediment and rubbish build up and scouring. This can be overcome by placing rocks or geotexiles to slow water entering the garden.

4. High-flow bypass

Raingardens are not designed to collect all rain that falls and during periods of high rainfall the high-flow bypass is an essential component ensuring raingardens do not flood. The high flow bypass should direct water to conventional stormwater or to another raingarden system.

5. Extended detention depth

The extended detention depth allows water to be temporarily pond while water is moving through the raingarden. Extended detention depths should be deep enough that they allow water to pond, but shallow enough to maximise plant viability and provide capacity for the system to self correct in the event of poor infiltration. It is important that the detention depth is designed to suit the expected flows into the system. A larger extended detention depth will result in a higher reduction in pollutants.

6. Drainage layer

This layer has the highest hydraulic conductivity to direct water to drainage. A 90-100mm ag or slotted pipe should be placed in the bottom layer of the drainage layer to direct water from the raingarden to stormwater. The pipe should then be covered with 150mm of washed fine gravel (4mm to 7mm) to direct water to drainage. Drainage into the soil is also possible if the soil is understood, no high water table is present and there is no need to harvest water.

Soil type	*Hydraulic conductivity*	*Minimum distance from footings*
Sandstone	Assumed to be negligible	Do not infiltrate
Sand	>180 mm/hr	1m
Sandy clay	180-36 mm/hr	2m
Medium clay	36-3.6 mm/hr	4m
Reactive clay	3.6- 0.36 mm/hr	5m

(The Institution of Engineers Australia, Australian Run-off Quality Guidelines.)

7. **Transition layer**

This layer separates the filter from the drainage layer, so this layer should be larger than the drainage layer. Draining at a faster rate than the filter layer, the transition layer should be well graded and washed sands, such as VicRoads A2 filter. This layer should be 100mm thick.

8. **Filter layer**

The main element of a raingardens, this layer provides treatment for pollutant removal and support vegetation. The layer should be 300- 500mm, lightly compacted and made from washed sandy material (AS 4419.)

9. **Mulch layer**

The mulch layers primary role is to reduce erosion, weed growth and retain moisture in the garden. It also importantly improves water distribution and dissipated flows in the top layer. Typically the layer is made from 10-20mm washed aggregates (small pebbles.) This layer should be 50mm.

10. **Vegetation**

In general, plants that grow well in raingarden like dry conditions but can tolerate temporary wet periods, are perennial rather than annual and have extensive fibrous root systems. Plants should also have a fats growth rate and high total root, leaf and shoot biomass. Approximately 6 plants should be planted in every $1m^2$. The nutrient removal efficiency of raingardens and bioretention tree pits is related to the root structure and density of the plants within the system. Dense fibrous roots provide the most efficient pollutant removal. Further, as plants mature and their roots penetrate the filter media they play a role in maintaining the hydraulic conductivity of the media. Root growth helps to maintain the surface porosity and the infiltration capacity of the filter media (FAWB, 2008).

Suitable plants include:

Anigozanthos sp. Kangaroo paw
Blechnum nudum Fishbone Water-fern
Calocephalus lacteus Milky Beauty-heads
Carex Appressa Tall Sedge
Carpobrotus modestus Pigface
Chrysocephalum apiculatum Common Everlasting
Derwentia perfoliata Digger's Speedwell
Dianella species
Ficinia nodosa Knobby Club-rush
Juncas amabilis Hollow Rush 20-50
Juncas flavidus Yellow Rush
Leucaphyta brownii Cushion Bush
Lomandra species
Melaleuca ericifolia Swamp paperback
Myoporum parvifolium Creeping Boobialla
Patersonia occidentalis Native iris
Pratia perdunculata Matter Pratia
Wahlenbergia communis Tufted Bluebell

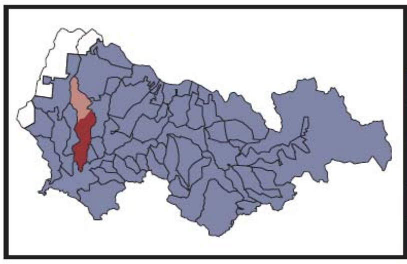
(Source: Melbourne Water 2010. Building a raingarden planter box)

(*Plants in the DCMC raingarden, all of which are indigenous species to the Darebin Creek area. Some species include Cut-leaf daisy Brachyscome mulifida, Golden Everlasting Chrrysocephalum Apiculatum and Long-leaf Purple Flag Patersonia Occidentalis)*

3. Urbanisation of Darebin Creek Catchment

The Darebin Creek catchment is located on the basalt plains to the north of Melbourne. In the upper, rural regions there are no significant tributaries in the rural reach and streamflow is intermittent. From Epping, Darebin Creek flows south draining into the Yarra River in Alphington. In the urban portion of the catchment, a permanent streamflow exists as a result of inflows from stormwater drains and groundwater intrusion (McGuckin, 2002). Melbourne Water (2004) ranks the health and streamflow of Darebin Creek as poor.

Urban Sections: Poor

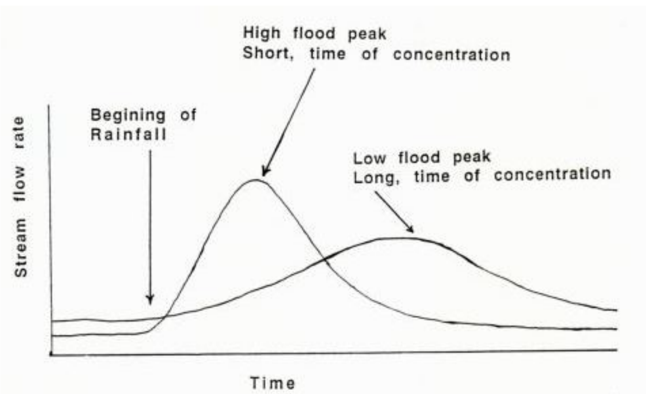


	Water quality	Aquatic life	Bed/bank stability	Vegetation	Flow
Excellent					
Good					
Moderate	●		●		
Poor		●			●
Very poor				●	

(Ranking of indicators of Darebin Creek. Melbourne Water 2004)

The impact of urbanisation on Darebin Creek's hydrology

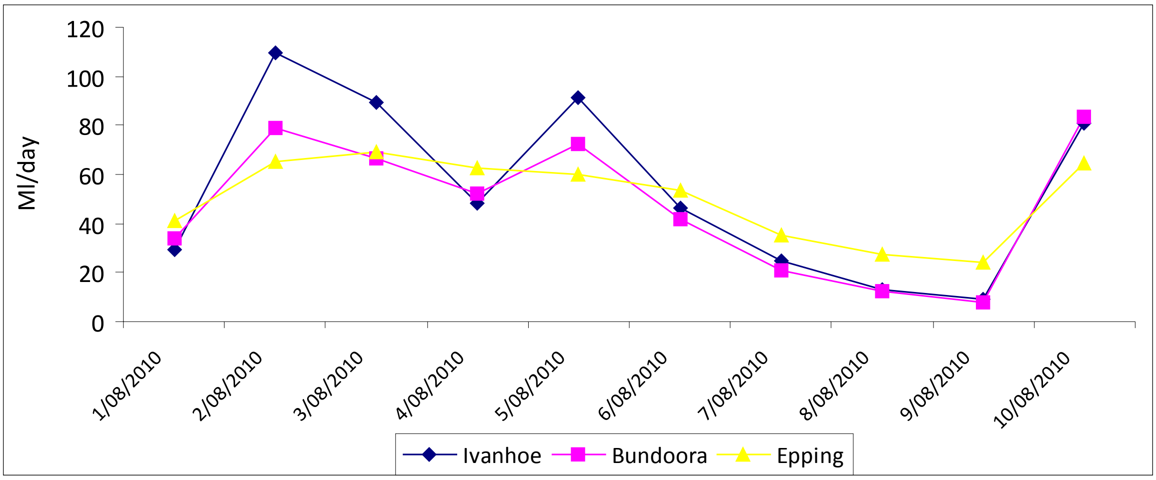
Urbanisation in the Darebin Creek Catchment has greatly increased the area of impervious surfaces, funnelling precipitation rapidly into Darebin Creek and changing the hydrology of Darebin Creek's flood peak from a low long flood, to a short high peak.



(Creek Care, 2010)

Urbanisation of Darebin Creek is generally concentrated three quarters of the way down the creek, with the upper regions characterized by farmland. The peak discharge generated from an urbanized catchment can be as much as 35 times that generated from a rural catchment, with the relative difference between rural and urban conditions being most pronounced for frequent storm events. This variation between rural and urban areas can be clearly observed. Melbourne Water monitors water conditions at three stages along the creek at

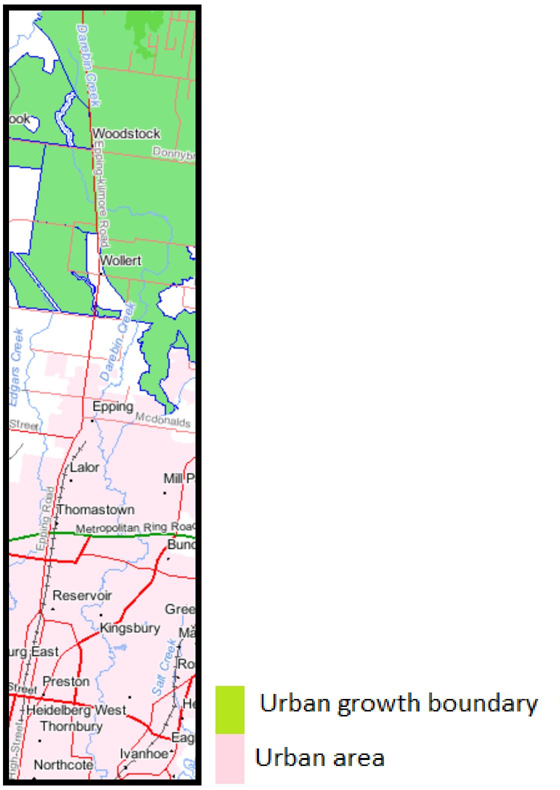
Epping (rural), Bundoora (periurban) and Ivanhoe (urban). Each monitoring site is likely to experience unique stormwater discharge. It is expected Epping would not experience as acute stormwater events due to a low percentage of impervious surface, allowing water to soak into the ground. The Ivanhoe monitoring station is expected to observe a far higher number of these storm events due to the very high percentage of surrounding impervious surface. The graph below gives an example of this over a ten-day period between the 01/08/2010 to the 10/08/2010, showing the obvious intense peaks of the Ivanhoe flow compared to the other sites.



(Source: Melbourne Water, 2010. Water flow comparison of intensity of water peaks at three sites along Darebin Creek)

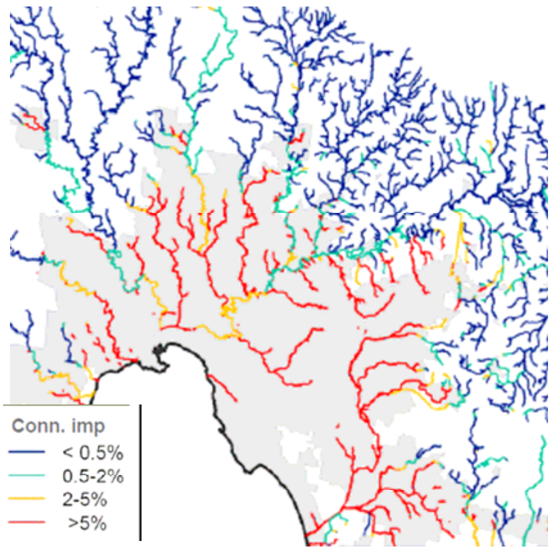
Growing urbanisation in the Darebin Creek Catchment

Urbanisation has greatly increased the area of impervious surfaces in the Darebin Creek Catchment. This causes rainfall that would otherwise normally slowly enter the catchment after seeping through the soil to instead fall onto impervious surface and flow from the catchment quickly and in greater volumes. The increase in the rate of water entering the creek has negatively impacted the hydrology of the creek. Of greater concern is the likely growth in urbanised area in the Darebin Catchment in the northern regions due to green field growth and expanding urban boundaries. This will add additional impervious runoff to the Darebin Creek, causing the creek to increasingly degrade in the upper regions.



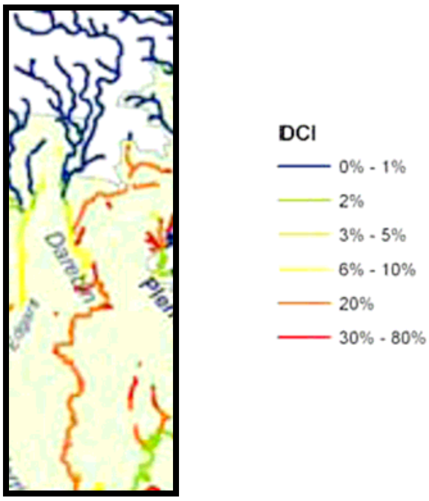
(Darebin Catchment; comparison of the urban growth boundary (incorporating rural areas) and urban areas Source: Water Resources data warehouse 2010)

Connected imperviousness



(Source: Chris Walsh, 2010. *Connected imperviousness in Melbourne's streams)*

Crucial to stream health is the concept of connected imperviousness (CI); the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes. The higher percentage of connected impervious area to the waterway, the greater likelihood of reduced river health such as elevated concentrations of nutrients and contaminants, altered channel-morphology and reduced biotic richness, with increased dominance of tolerant species (Paul and Meyer, 2001). Research undertaken using a model of urban stream health has suggested that stream health declines sharply with increases in CI from 0% to 5%, with studies in Melbourne suggesting a level less than 2% connected imperviousness is suitable to provide a healthy stream. Above the Henderson's Road Drain in Epping, only 1.7% of impervious surface is directly connected to the Creek. Whilst between the Drain and the Yarra confluence, 19.0% of impervious surface is directly connected (Danger and Walsh, 2008). Darebin Creek has a very high level of effective imperviousness, especially in the lower regions of the catchment.



(Source: Danger and Walsh, 2008. Darebin Creek estimated directly connected surfaces)

Connected imperviousness is directly linked to the health of the stream. As Darebin Creek has only a relatively small catchment area (129km^2) there is a great potential for the use of raingardens compared to a larger catchment area such as a river as a lower number of raingardens would be required to cover a larger proportion of the catchment area. However, Walsh (2010) stated that less than 2% of imperviousness should be directly connected to streams, which is unlikely in the Darebin Catchment without large-scale changes.

4. The Effects of Catchment Urbanisation

The response of streams to the impact of urbanisation can vary greatly depending on the physical characteristics of the creek, types ecosystems present, timeline of urban development and nature of riparian zones (Cottingham et al, 2004). Generally the following impacts are observed in all urbanized streams and the Darebin Creek:

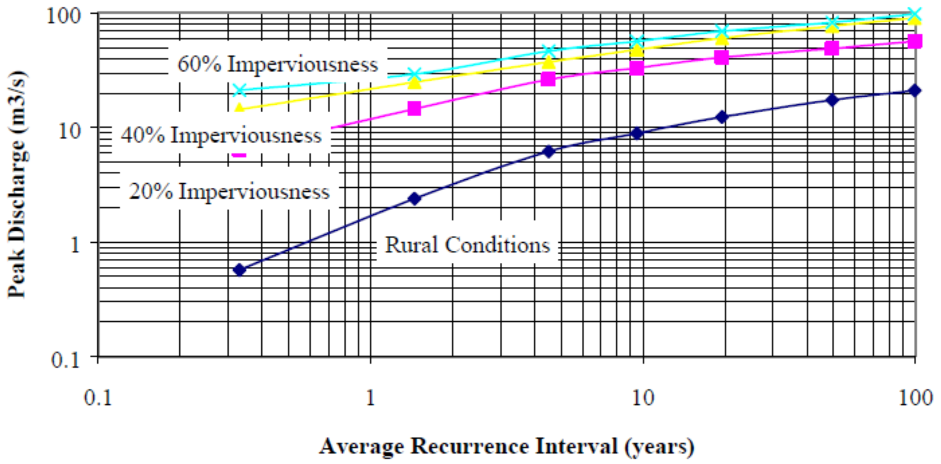
Increased imperviousness leads to:	Flooding	Habitat loss	Erosion	Channel widening	Stream bed alteration	Biodiversity decline
Increased volume	√	√	√	√	√	√
Increased peak flow	√	√	√	√	√	√
Increased water temperature		√				√
Decreased base flow		√				√
Sediment loading changes	√	√	√	√	√	√
Increased contaminant loads						√

1. **Flooding**

Flooding in urbanized areas occurs at a changed rate from pre-urbanised periods due to an increase in the volume of water entering the stream and the rate it enters. Less rain is now required to cause a flood in Darebin Creek.

Rainfall and likelihood of floods

Rainfall events and the floods that result in Darebin Creek are catergorised by the frequency at which floods of a given size are likely to occur: the *Average Recurrence Interval (ARI)* is a statistical estimate of the average number of years between events of a given size. For example a *100-year ARI* flood event will occur once ever 100 years. The *Average Exceedance Probability (AEP)* is the statistical likelihood of occurrence of a flood of a given size or larger, in any one given year. For example a *1% AEP* will occur once every 100 years or a *50% AEP* will occur once every 2 years (Bureau of Meteorology, 2010). These factors give no indication of when a flood event is next going to occur. Additionally, rainfall events vary in duration and intensity meaning there is no single types of rainfall events that will cause a flood in all areas in the creek. Generally very small, intense rainfall causes small scale flooding, while longer, lighter rain causes larger scale flooding. Catchment urbanisation has led to increased frequency of bankfull discharge from 5 years ARI to 0.5 years ARI. The graph below displays how a change in imperviousness affects the ARI.



(Effect on Flood Frequency Curves of Increasing Imperviousness. Source: Wong et al., 2000)

Rate of flow m^3/sec required to reach a certain ARI

*GS - Gauging Station m^3/s	Peak Flows **Proportioned Flows (Rough)**				
Flow Location	*2 Year ARI*	*18 Month ARI*	*1 Year ARI*	*6 Month ARI*	*3 Month ARI*
Darebin Crk, US of Findon Crk	10.6	9.5	7.9	5.2	3.2
Findon Crk, US Darebin Crk	9.1	8.2	6.8	4.5	2.7
Upper Darebin & Findon Creek	17.9	16.1	13.4	8.8	5.4
Darebin Crk at Epping GS*	18.0	16.1	13.4	8.9	5.4
Upper Darebin, US of Henderson Rd Drain	18.6	16.7	13.9	9.2	5.6
Hendersons Rd Drain RB	12.9	11.6	9.6	6.4	3.9
Hendersons Rd Drain RB	3.4	3.0	2.5	1.7	1.0
Hendersons Rd Drain	11.6	10.4	8.6	5.7	3.5
Darebin Ck and Hendersons Rd Drain (Childs Rd)	26.4	23.6	19.7	13.0	7.9
South Morang Drain	11.4	10.2	8.5	5.6	3.4
Darebin Crk at McKimmies Lane	31.0	27.8	23.1	15.3	9.3
Darebin Crk, DS of Bundoora Drain	36.4	32.6	27.2	17.9	10.9
Darebin Crk at Bundoora GS	36.4	32.6	27.1	17.9	10.9
Darebin Crk, DS of Dunne St	38.0	34.1	28.4	18.7	11.4
Darebin Creek at Plenty Rd	38.5	34.4	28.7	18.9	11.5
Darebin Crk at Ivanhoe GS	44.0	39.4	32.9	21.7	13.1

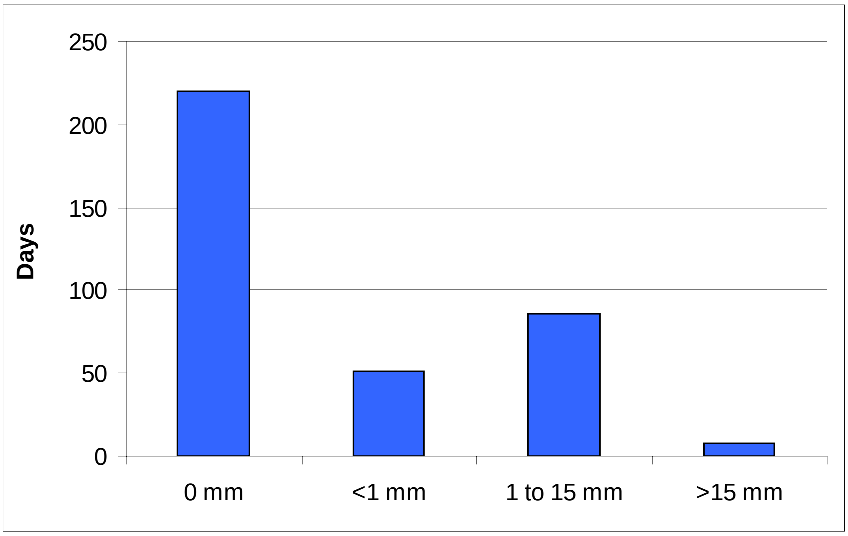
Darebin Crk, DS of Bell St	45.3	40.5	33.8	22.3	13.5
Darebin Crk at Abbotsford Grove	46.9	42.0	35.0	23.1	14.0
Darebin Crk at Yarra River Outfall	47.1	42.1	35.1	23.2	14.0

(Darebin Creek proportioned flows ARI in m^3/sec. Source: R. Bishop, Melbourne Water.)

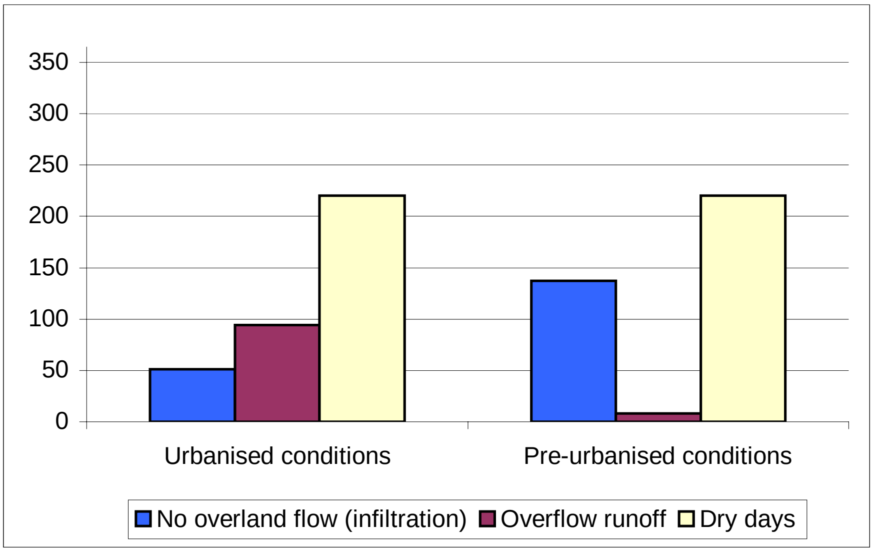
The peak flow is the flow at the given storm duration when the entire catchment is contributing flow to that location. In other words; the catchment has wetted up and soaked up its initial loss, and the furthest most point from the outlet is now contributing flow to the outlet, in addition to every thing in the catchment downstream.

Understanding how water entering the Darebin Creek has changed

Small to medium storms are rainfall that is large enough to produce runoff from impervious surfaces, but not so large that it would have produced overland flow from a block of land in the catchment before the land was developed. The lower limit for such a storm is sometimes called effective rainfall and is typically assumed to be 1mm/day, the upper level under forested conditions in Melbourne's East is about 15mm. Rainfall above this level would occur about 15 days a year and is deemed to be a 'large storm.' Now in urbanised areas, only about 1mm of rain is required to produce runoff, which will now occur but 120 days per year (The Cooperative Research Centre for Catchment Hydrology, 2010). Reducing volumes of water entering the creek in small to medium rainfall events can greatly improve the health of the streams. This data is subject to a variety of conditions and is likely be slightly different in the Darebin Catchment.



(mm/day of rainfall for a one-year period between the 30/09/2009 to the 29/09/2010 at Latrobe University. Source: Bureau of Meteorology, 2010)



(How impervious surfaces have changed runoff in the Darebin Creek Catchment. Comparison of current urbanised areas and previous pre-urbanised times and the outcome of rainfall between the 30/09/2009 to the 29/09/2010 near Latrobe University. Source: Bureau of Meteorology, 2010)

2. Changes in stream appearance

Darebin Creek is a naturally changing system, adjusting its width and depth in response to long-term changes in sediment supply and size and frequency of flow. Generally, during the early stages of stream development, depth decreases due to an increased sediment load being delivered to the stream. Once the amount of impervious cover has increased and there is an increase in the number of bank full flows and floods, an erosive process of channel widening begins. The channel cross sectional area may increase up to a factor of 10 in highly urbanized areas (Morisawa and Laflure, 1982) as it adjusts to long-term changes in sediment supply and flows. The creek is also likely to become increasingly uniform. Larger and more frequent discharges cause downstream channels to enlarge, whether by widening, downcutting or a combination of both. Frequent smaller floods in conventionally drained urban catchments are believed to be more important causes of channel incision than large infrequent events (MacRae & Rowney, 1992). Straightening a meandering channel generally increases stream energy and the potential for erosion.

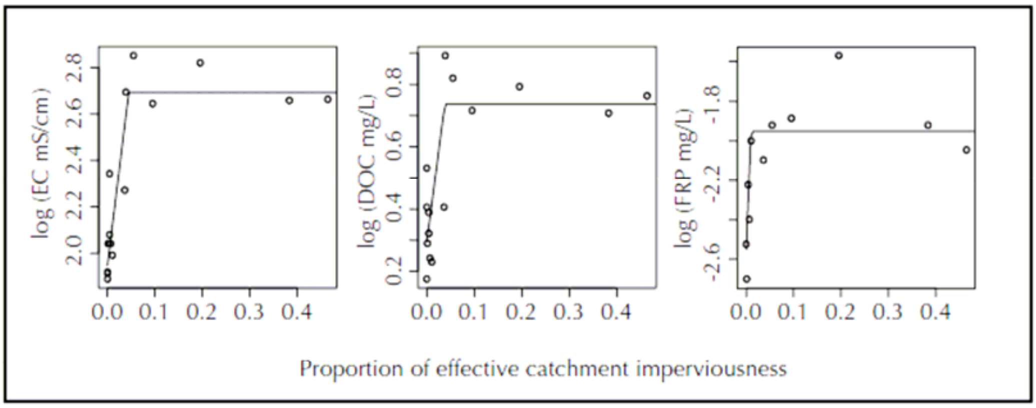
3. Increased erosion

Increased flooding in the Darebin Creek has caused increased levels of bank erosion. The large quantities of water flowing quickly through the creek cause the banks of the stream to erode, adding sediment and causing riparian vegetation loss. Nelson and Booth (2002) in a study of a 144km^2 urbanizing catchment found that the annual sediment yield had increased by nearly 50% due to urban development with stream bank erosion accounting for about 20%. One study estimated that channel erosion rates were three to six times higher in a moderately urbanized watershed (14% impervious cover) than in a comparable rural one, with less than 2%

impervious cover (Neller, 1998). Particles transported by the rapidly moving water can act as a sandblaster known as scouring. Scouring can undercut root systems and destroy aquatic vegetation and animals. Banks that have been lined with rocks or concrete to combat erosion end up channelling the water more quickly, increasing erosion downstream.

4. Changes in water quality

Changes in water flows and velocities can greatly affect the water quality of the creek. Stormwater delivers a wide variety of contaminants to streams, as well as causing changes to temperature, dissolved oxygen concentrations and pH. Up to 70% of the pollution in streams are carried there by stormwater (Raingardens of West Michigan, 2010). As smaller amounts of rain cause now run-off into the creek, smaller flood events include equal amounts of pollutants as larger flood events. Excess nutrients, washed from stormwater such as nitrogen can cause vigorous growth of algae, which leads to reduced oxygen levels in the water. Algal blooms threaten animals, plants and fish living in our waterways. The term total suspended solids (TSS) is a description of the organic and inorganic material suspended in water. The solids settle out and reduce dissolved oxygen levels in the water through chemical interactions in the water.



(Median baseflow measurements of electrical conductivity (EC), dissolved oxygen carbon (DOC) and filterable reactive phosphorus in 15 small streams in the east of Melbourne against effective imperviousness. Source: Walsh et al. 2004)

Water quality in Darebin Creek

The following graphs compare the conditions at four sites along Darebin Creek at three different periods of time. The sites are:

1. Downstream of drain outlet into creek, Preston/Heidelberg Heights
2. Upstream of Cave Clan Drain outlet, Preston/Bellfield
3. Dundas Street Drain, Thornbury/Ivanhoe
4. Dundas St footbridge, Thornbury/ Ivanhoe

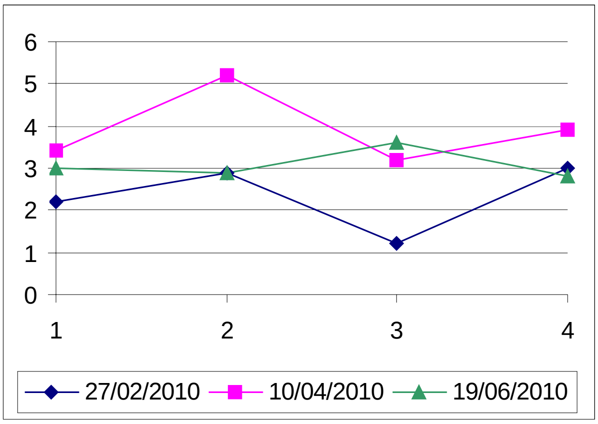
The sites are located close together and are likely to experience similar levels of connected imperviousness. Conditions will vary due to temperature changes and proximity to stormwater.

However, the three periods of time compare the creek after different rainfall periods:

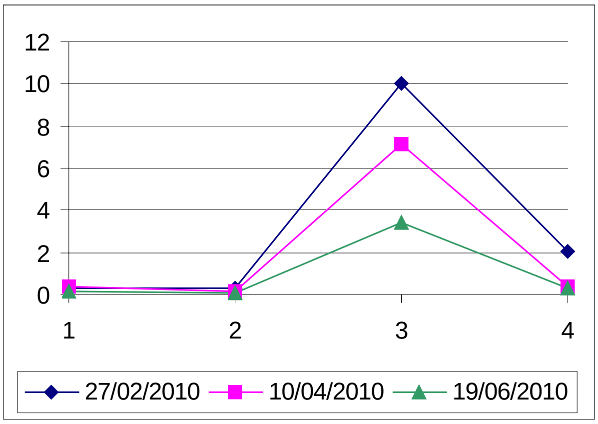
27/02/2010: No rainfall in the previous week

10/04/2010: 0.2mm the day previous. 10mm in the previous week.

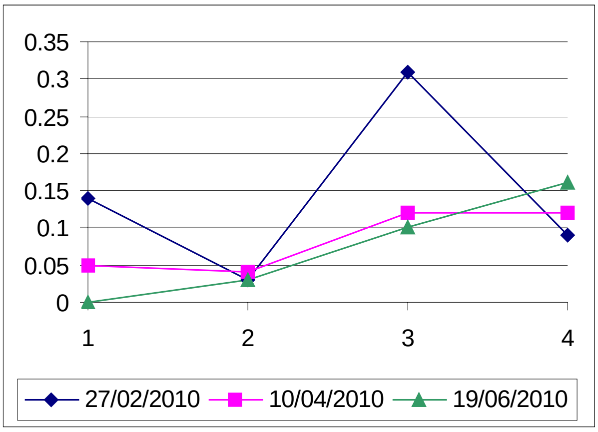
19/06/2010: 4.6mm on the day. 0.4mm the previous day. 26.4mm the previous week.



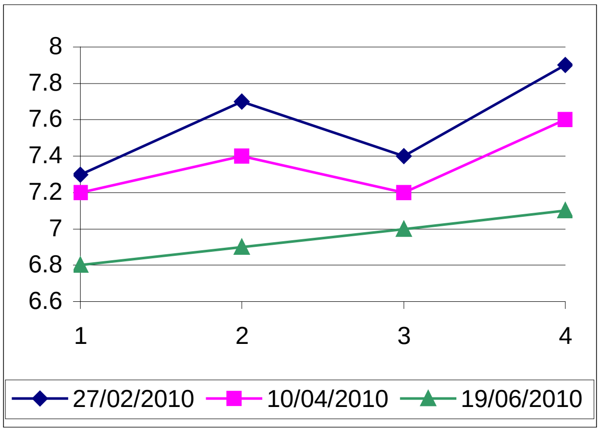
Dissolved oxygen



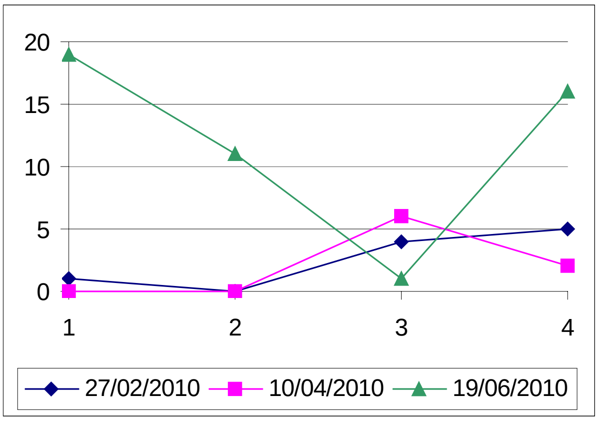
Ammonia levels



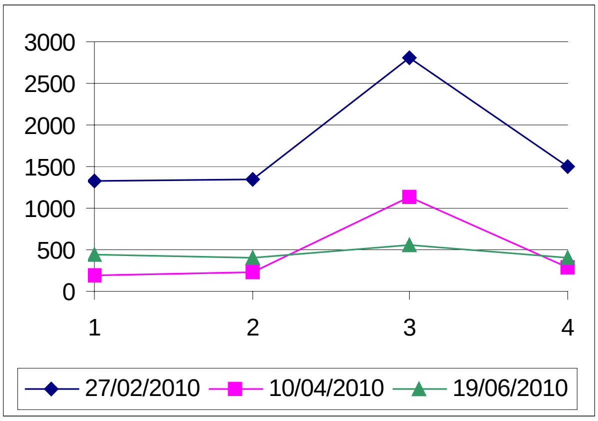
Soluble phosphate



pH



Turbidity FTU



Electrical conductivity

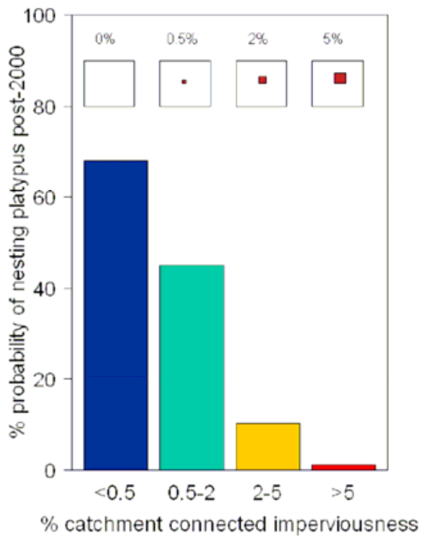
(Source: Julia Vanderoord, Darebin Council Waterwatch data, 2010)

Although not conclusive the differences from site to site after the various rainfall events can be observed. For example, the dissolved oxygen concentration varies at each site after the different rainfall. After high and medium rainfall events, the DO concentration is generally higher than in base flow periods. This may be due to the fact fast moving water holds more oxygen than still water, because the movement mixes the air into the water. The dissolved oxygen concentration at all observed sites was deemed to be low (below 6 mg/L). Unusually, the graphs show a very high build up of nutrients (phosphate and ammonia) and a high electrical conductivity at the Dundas Drain site after the low rainfall event. However, the ammonia levels were consistently highest after no rainfall across all sites. The particularly high reading at the Dundas Drain site may be due to the low turbidity at the site or continually high-polluted stormwater runoff. The pH of all fours sites is distinctively higher after no rainfall and lower after high rainfall. The turbidity was far higher on days of heavy rainfall (apart from the Dundas Drain site which may be indicative of water pooling). The electrical conductivity was also far higher during periods of low flow.

5. Vegetation and biodiversity decline

The increased width and rate of flow of floods increases erosion along the banks of the creek, greatly impact on fringing vegetation. Riparian vegetation helps filter pollutants and debris, stabilizes stream banks and provides for wildlife habitat. The zones are vital to healthy streams, water quality and healthy ecosystems. Riparian zones regulate water temperatures by shading the stream, which increases the stream's ability to hold oxygen. Decrease in base flows also contributes to habitat destruction and causes stream temperatures to increase.

Changes in stream form can also greatly affect macroinvertebrates who are suited to a specific habitat, such as a shallow riffle or who are unable to adapt to changing water velocities. Melbourne streams have experienced reduced benthic macroinvertebrates species richness and an increased abundance of species that can tolerate increased physical disturbance (Cottingham 2003). In a study of 66 stream-dependent animal species found in Melbourne, only 7 were classed as urban tolerant (occurrence either not or positively correlated with Connected Imperviousness), while 10 were completely absent from streams with >1% Connected Imperviousness. Many species in the catchment have life cycles that area adapted to this disturbance cycle.



(Source: Hot Topic Series. Walsh, 2010.)

5. The cost of building a raingarden

The average cost of building a raingarden

The price of creating a raingarden can greatly vary depending on the size, simplicity and structure of the design. Simple, domestic raingardens can be built cheaply to capture small amounts of water flowing from impervious surfaces such as roof areas or paving, while streetscape raingardens are generally more expensive due to the large scales of the projects and the cost of civil works. There is no clear price for building a raingarden, as the variability of each project is likely to fluctuate the price substantially. Variables factors can include the price of plumbing and/or labor, size and type of raingarden and the types of plants used. Melbourne Water suggests that the cost of creating a $2m^2$ above ground raingarden will be between $400-$500, excluding labour and plumbing.

Cost of materials

The materials required vary greatly with the complexity and size of the raingardens. Below is a suggested list of materials from Melbourne Water required to build a $2m^2$ raingarden. However, it must be noted there is a great disparity in costs from factors such as box type, if a liner is required, the plumbing work required and labour costs.

Quantity	Material	Estimated Cost
1.5 l/m	90mm diameter slotted drainage pipe (Ag Pipe)	$15
2 l/m	90mm diameter uPVC pipe	$18
$0.4m^3$	7mm screenings	$30
$0.85m^3$	Sand (white washed)	$66
$0.15m^3$	Topsoil	$20
$0.1m^3$	Gravel mulch	$30
1	90mm PVC 90 degree bend or 2x 45 degree bends	$7
1	PVC grate 90mm finishing collar	$5
1	PVC 90mm diameter pipe grate	$5
1	PVC 90mm tee	$10
1	PVC 90mm cap	$5
$2m^2$	Colorbond water tank with base	$460
10	Specified plants	$50
Total		**$721**

l/m = lineal metres m^2 = square metres m^3 = cubic metres mm = millimeters

Design, Plumbing and Landscaping

There are three components of assistance required that add additional costs to building a raingarden. Firstly, ensuring the design is workable is crucial for the success of a raingarden. This may require external assistance to design the raingarden. Secondly, a certified plumber must be used for stormwater connections and modifications. This is likely to cost around $300 dollars excluding materials. Lastly, if the residents are also not willing to build the raingarden themselves, the costs of hiring a landscaper will also need to be added to the project.

Maintenance

Maintenance is primarily concerned with maintaining flow to, and through, the (bio-filter) garden, vegetation, preventing undesired vegetation from dominating the garden, removal of accumulated sediments and debris removal. Sediment will accumulate within the Rain Garden over time (depending upon the nature of the catchment draining to it and daily pollutant loads). Removal is likely to be the most costly maintenance requirement of this treatment system. When ponding (without additional inflow) exceeds 24 hours duration, the permeability of the Rain Garden soil is too low and maintenance is required in the form of sediment removal to return the garden to its performance requirement.

6. Cost and benefit analysis of raingardens

Every year, Melbourians make about 100 million recreational visits to our rivers, creeks and streams (Melbourne Water, 2004). Melbourne waterways are highly valued by the local community, and conditions of streams are viewed as an important indicator of environmental health. Consequently, as the connection between imperviousness and stream health becomes better acknowledged the responsibility of stormwater mitigation will become increasingly placed on communities. Traditionally, stormwater mitigation has been undertaken through centralized infrastructure such as wetlands, which can be expensive and often do not sufficiently alleviate water quality problems. Encouraging community-wide uptake of raingardens can decentralize stormwater detention, as well as increase awareness of the impact of stormwater run-off. The feasibility of using raingardens is dictated by their cost and benefit.

Environmental benefit

Environmental benefit is a measure of the benefits provided to the environment by raingardens or by any other measure introduced. A benefit is something that assists in restoring the health of the Darebin Creek back to its pre-urbanised state (i.e. restoration of macroinvertebrates or reduction in weeds). In the case of a raingarden or other water sensitive urban design, environmental benefit is a broad concept that generally measures how much stormwater and nutrients will be prevented from leaving the property. Numerically the benefit of a raingarden is the measure of the water volume reduction in the frequency of surface flow and entering stormwater (the connected impervious area and the size of the tank or raingarden) and reduction in pollution load.

This example is from the Little Stringbark Creek project (2009) quantifying environmental benefit from raingardens:

Environmental benefit	
A. Reduction in frequency of surface flow	propn reduction in days of runoff from imp. surfaces: 121 days/year from roofs or roads cf <12 days/year from forest
B. Volume reduction (through use or loss)	propn reduction from annual volume of runoff from imp. surfaces: 71 kilolitres/year from 100 sq m of roof or road
C. Reduction in nitrogen load, phosphorus and TSS	propn reduction from average load from imp. surfaces: 160 g/year from 100 sq m of roof or road

Environmental benefit unit= A + 0.5B + 0.5C, scaled to 100 sq m. So the maximum EBU for 100 sq m = 1

1. Environmental benefit: water absorbed by a raingarden

A raingarden should be sized approximately 2% of the total area of the impervious area it is capturing. A raingarden will not capture all water that enters the raingarden, but works best to capture small events that would not enter the creek as surface flow in pre-urbanised periods (<1mm). The amount of water a raingarden also will absorb depends on the ARI (e.g. the volume of rain in a period of time.) The role of the overflow pipe (and the high-flow bypass if present) is to divert heavy rainfall to stormwater. This creates a situation where small rainfall events will not immediately rush into the creek, but instead either be absorbed and transpired by the plants or slowly filter through the filter medium and enter the creek.

2. Environmental benefit: nutrients absorbed by a raingarden

Properly designed raingardens can effectively trap and retain up to 99 percent of common pollutants in urban storm runoff, potentially improving water quality and promoting the conversion of some pollutants into less harmful compounds (Clausen & Dietz 2006). Raingarden can significantly reduce concentrations of nitrates, ammonias, phosphorous and other pollutants reaching storm drains.

3. Environmental benefit: reduction in surface flow

The Little Stringybark Creek project, in an area of Melbourne with higher rainfall, states in pre-urbanised conditions surface flow would enter the creek on average 12 days a year. Now thanks to urbanizations water enters the creek 121 days a year. Raingardens ideally should only overflow 12 days a year- similar to conditions in pre-urbanised periods. Ideally, completely diverting your raingarden to your garden or watertank can greatly reduce your environmental impact. Each m^2 of roof area collects 1L for every mm of rain (savewater.com.au, 2010). The amount of stormwater available for diversion is the roof area x annual rainfall. An average shed is 25m2 x average rainfall 650mm = 16,250L. The Little Stringybark Creek Project (in a higher rainfall area) states that $100m^2$ of stormwater run off diverted can result in 71,000 litres/year of water diversion. Assuming this each connected m^2 of impervious surface can reduce stormwater by 710 litres/year.

Social benefit

Another less palpable benefit of a raingarden is the fostering of public understanding *that Darebin Creek is degraded because it is receiving too much water*. Currently public awareness focuses mostly on stormwater pollution; expanding this knowledge to understand the importance of stormwater flows on the health of waterways can be hugely beneficial to the Darebin Creek. In a survey conducted by the Little Stringybark Creek project on residents in the Mt. Evelyn area, 84% of residents had never heard of a raingarden. Reducing this proportion and increasing the level of awareness of the negative effects of stormwater on local creeks can be hugely beneficial.

The environmental benefit of a raingarden versus other environmental measures

Raingardens are not the only way to filter or divert water moving from impervious surfaces; other measures such as bioretention ponds or watertanks can also be used for dispersed water treatment. Watertanks are the most beneficial to be used instead of raingardens at a domestic level, as they are cheaper than raingardens per amount of water diverted and are more efficient capturing water. Watertanks however, do not filter and slowly allow water to drain back through the soil, restoring groundwater like raingardens do. The following table (from the Little Stringbark Creek Project, 2009) gives an indication of the ideal measure to capture water from certain impervious surfaces:

Building Type	Impervious Area Range (m^2)	Recommended Treatment to Achieve Minimum Requirement
Garden Shed	<25	Consider a rain-garden* only (2m^2 by 1m deep in size)
Carport/Garage	25-50	Consider a rain-garden only (4m^2 +/- 2m^2 in size)
Large Barn	50-150	Consider a rain-garden only (8 +/- 2m^2 in size)
Medium Size or Medium Density Dwelling	200	Consider a 2000L rainwater tank used for garden watering and toilet flushing with the overflow connected to a rain-garden (> 1m2)
Low Density Dwelling or Large House	375	Consider a 5000L rainwater tank used for garden watering and toilet flushing with the overflow connected to a rain-garden 8 +/- 2m^2 in size)

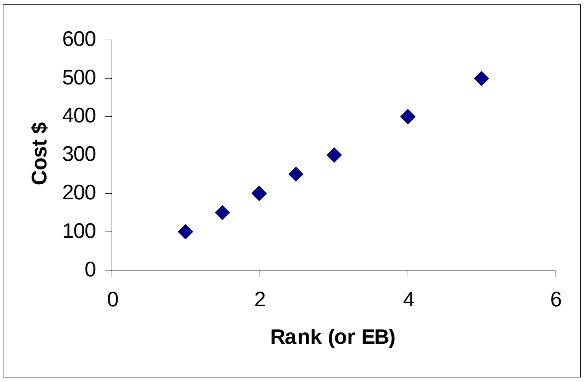
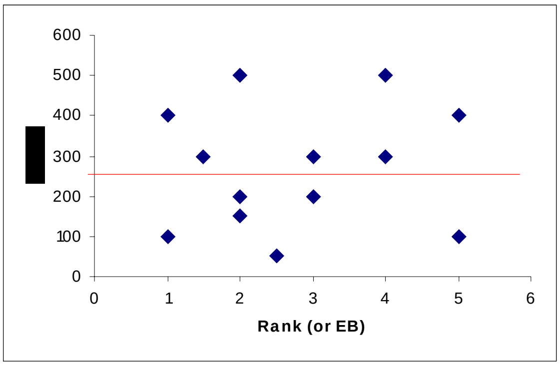
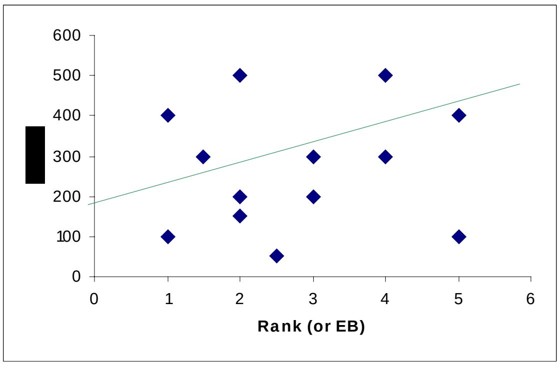
(Type of stormwater mitigation action. Source: Little Stringbark Creek, 2010)

Type	Cost/L absorption in 2009/2010 financial year	Pros	Cons
Watertank	$1500/618.9mm (all rainfall collected) for 5,000L tank =$2.42/mm	-Simple to install -Captures all water -Long lasting -Can be pumped for other uses	-Does not filter water -Often simply overflows and water is wasted -Does not increase awareness of problems with stormwater runoff
Raingarden	$600/355.8mm (rainfall less than 10mm/day). $1.68/mm	-Adds amenity -Increases awareness and understanding of problems effecting the creek -Filter and cleans water	-Can be difficult to correctly build -Does not capture water in high rainfall periods -Water is not often reused

7. Case Studies and Mechanisms to Deliver Incentive Programs

Types of funding mechanisms and incentives to encourage the creation of domestic raingardens

Currently, community awareness of the issues urban streams face is low and it is unlikely the community will be willing to undertake such measures without some understanding of the benefits of building a raingarden. Using market mechanisms has been generally observed to be the most successful way to encourage uptake of raingardens in domestic situations. Many types of mechanisms can be used to encourage uptake; auctions are viewed as the most superior to other means of allocating resources due to their efficiency, objectivity, transparency and flexibility (CSIRO, 2005). Reverse auctions can also be used as this allows for ease in community programs.

Type		
Fund per amount of environmental benefit	Environmental benefit scores can be used as a method to compare the cost/benefit of a raingarden. This ensures each project is supported on the good it will do and will ensure the efficiency of funding.	
Equal incentives for all projects	Having a block fund that is given to each project reduces the amount of administration required and allows each project to easily and simply understand what they are expected to gain from the project. However this can disproportionately fund projects with very low environmental benefit.	
Reverse auction	A non-uniform price auction is beneficial because of its theoretical "truth-revelation" properties, which should induce an optimal bidding strategy and will reflect the actual opportunity cost of stormwater management practice adoption (Cabezas, 2008).	

Case studies

Australian case studies of funding and incentive programs

Melbourne Water 10,000 Raingardens Program

Melbourne Water's Raingarden program aims to attract 10,000 registered raingardens in the Melbourne Region. Research found that incentives were not the driving factor for their target audience (likely to be those already environmental minded), so the program relies on education and increasing awareness of the benefits of raingardens. Because of this Melbourne Water have chosen not to offer incentives at this stage of their program. The program has supplied brochures and a website to encourage the creation of these programs. Melbourne Water is also waiting for soil reports and permeability maps across the key councils before further implementation of any new measures.

Little Stringbark Creek

Unlike Melbourne Water's program, the Little Stringbark Creek program attempted to reduce stormwater runoff by using market mechanisms. This included scoring the potential environmental benefit of a project, than auctioning the potential funding for the greatest environmental benefit.

	Submitted		Funded	
	Total*	Average*	Total	Average
Bids	102	-	56	-
Bid Amount ($)	$590,000	$5,786	$340,584	$5,160
Environmental Benefit	129.07	1.27	100.3	1.7
$ requested/Environmental Benefit	-	$8,054	-	-
Nitrogen capture (kg/year)	18.66	0.18	14.74	0.26
Water Savings (L)	8,480,000	83,140	5,871,000	104,000

Source: Little Stringybark Creek. Summary figures (total and average) for submissions to Stormwater Tender and the successful bids. Where a bidder submitted more than on bid, only the most cost effective bid was included.

Overseas case studies of funding and incentive programs

Organisation	Requirements	Mechanism
Raingarden Initiative	To be considered must meet minimum requirements: must test soil percolation, applicants must provide estimated cost. Scored on public visibility, ability to maintain, if will build it themselves, if they will use recommended plants, provide site map.	Will fund estimated total cost based on matrix that ranks most worthy applicants.
City of Fort Wayne	Applicants must attend workshop to receive funding and agree to maintain raingarden. Raingardens should be built from approved designs. Must provide size, raingarden design, sun and plumbing requirements.	Applicants will receive free plants (up to $250) and cash payment is $150 will be mailed to them once finished
Clement soil and water conservation district	Applicants must show how raingarden will improve quality and quantity of stormwater or directly disconnect downsprouts or other direct flows.	Applicants will receive $100 to offset cost of installing a raingarden. If approved, first come first served.
TAPP funding	Provide instruction manual. Applicants must provide where raingarden will be located, size, cost, fertilizer use. Required to fill out checklist.	Grants will not exceed $175. Reimburse plants, compost, and mulch. First come, first served.
Rice Creek Watershed District	Applicants fill out at form ranking subjects out of 10. Must get a score of at least 31 to be considered.	Will fund 50% of project up to $2500.

What should be required for applicants of a program?

In order for applicants to take ownership of their raingarden project, it is suggested that they construct the raingarden themselves (with the help of a plumber.) However, as this may discourage or inhibit many people from joining it is proposed that this not be a defining factor. Environmental benefit should also be rated highly in applicants, however, it is unlikely that any pilot program will make an evident impact on the creek this too should not be the most imperative factor.

Types of questions that should be asked:

1. Amount of impervious surface to be captured
2. Size, type and depth of raingarden
3. Accessible equipment (hand tools, shovels, piping, topsoil etc)
4. Estimated cost to build
5. Willingness to assist or if assistance is required (plumber, labor, design)
6. Where it will be located (front, side or backyard)
7. Will suggested plants be used?
8. Will the design be the same as the recommended design

8. Case Study: Darebin Creek Management Committee

The Darebin Creek Management Committee built its own demonstration raingarden at its Alphington office in the Darebin Parklands to promote to the local community the benefits of building a raingarden. The Darebin Parklands is visited by thousands of people each year, allowing the site to be in a very prominent position to promote raingardens to the public. Signage will eventually be constructed to describe how a raingarden works and its benefit to the creek.

Sourcing site and materials

The raingarden was planted in a 60cm x 102cm x 180cm galvanised iron planter box. The raingarden was placed next to a downpipe that collected water from a balcony roof sized approximately 8m^2. The ground was flattened and site prepared to ensure the raingarden sat straight and flat.

Connecting pipes to stormwater

The downpipe was cut off at the top and bottom. The bottom section of the stormwater outflow was then connected to the pipe that was stuck out of the raingarden.

Fitting in slotted pipe and overflow

A 90mm hole was drilled in the bottom of the raingarden to connect the slotted pipe and overflow to stormwater. Slotted pipe the length of the raingarden was placed along the bottom (see left photo) and connected to the overflow pipe and to a PVC tee with another pipe that was placed through

Putting in filter media

The bottom layer of the planter box was filled with 7mm screenings to cover the slotted pipe. 100mm of washed sand was placed on top of this and then 500mm of 4:1 sand to topsoil mix. This allowed space for 100mm for the overflow pipe and another 100mm for the retention depth.

Plants

Hardy plants were chosen that would be able to survive in dry conditions with periods of inundation. Plants were spread evenly throughout the raingarden. The overflow pipe was also covered to stop debris from getting into stormwater. A 10mm layer of river pebbles was placed around the plants to retain moisture and inhibit weeds from growing.

Actual Costs associated with the project

Galvanised Garden Bed Tank	600mm x 1800mm x 1020mm = 1.01m^3 www.tankworks.com.au	$550
Screenings	0.216m^3 of 7mm screenings washed fine gravel (4mm to 7mm)	$18 (1/4$m^3$)
Transition layer	0.108m^3 of Transition layer well graded and washed sands, and 0.432m^3 of Filter layer washed sandy material (AS 4419) or 4 parts sand 1 part topsoil (in total 0.3456m3 (minus topsoil) + 0.108m3 From Landscape supplier	$38 (0.5$m^3$)
River pebbles	0.054m^3 of Gravel mulch (2 types- smaller around plants- larger to slow water velocity) From Landscape Supplier	$16
Plants	Indigenous plants from Nursery (plus own from Darebin Creek Parklands)	$25
Piping	90mm diameter uPVC 90 degree bend or 2x 45 degree bends, 1 PVC grate 90mm finishing collar, 1 PVC 90mm diameter domed pipe grate, 1 PVC 90mm tee, 1 PVC 90mm cap, 2m x 90mm diameter slotted drainage pipe (Ag Pipe)	$50
Total cost		$697

9. Recommendations for raingarden pilot programs

1. Pilot program to encourage community uptake of raingardens in the catchment

It is recommended that as there is low community awareness of the benefits of raingardens, a community pilot program be created to encourage the uptake of raingardens. Although these raingardens are unlikely to make any significant impact on the volume of runoff onto Darebin Creek, building raingardens can greatly increase the awareness of the negative impact of stormwater on Darebin Creek and begin momentum towards an improvement in the knowledge of the importance of stormwater mitigation. The program should be spread as evenly as possible around the Darebin Creek Catchment.

2. As there is still low awareness of the benefits of raingardens, use financial incentives plus education to attract participants

Although other programs in Australia have not used financial incentives to encourage uptake of raingardens, using a financial incentive to attract participants is the easiest way to encourage uptake. Currently, very little is known about raingardens and it is unlikely people will act unless they are aware of the benefits they provide. Combing education with a financial incentive can greatly improve interest in the program. Although it is likely in the future once awareness of raingardens become better known, future programs will not have to pay entirely for the projects and will only have to pay for some elements of the program.

3. Participants can apply in a reverse auction format based on environmental benefit or a block amount of money can be given to all

In order to minimise administration and encourage participants to take part in the project it is recommended the domestic pilot program pays for the entire cost of the raingarden up to $700. Although this is not the most efficient way to pay out funding, it is the most convenient and as the main focus is not on environmental benefit but social benefit, the benefits are non-figurative. However, using a reverse auction format can encourage awareness by the participant of the environmental benefit of the raingarden and efficiently distribute funding.

4. Target not only domestic homes, but also businesses and schools

It is recommended the pilot program also allow for business and school applications. Businesses and schools are major contributors to the total impervious cover in the catchment and also have a large potential for high visibility and education programs. Education programs can also be matched in schools with the construction of raingardens.

5. Pilot programs should be advertised in local media, websites and letter-drops

Advertising of the program should be evenly spread throughout the catchment and should not focus on one specific area or demographic, but encourage everyone to apply to achieve fair and even coverage to all.

10. Conclusions

Currently, there is low community awareness of the fact urban streams are sick from receiving too much water. Improving this can greatly increase interest in decentralised mitigation of stormwater, which will be beneficial to the Darebin Creek

Raingardens are a way of achieving this. Although less efficient at catching water then raintanks, raingardens add amenity, create awareness of stormwater issues and filter water from pollutants. They are now becoming accepted as best practice in urban water sensitive design.

However, as Darebin Creek is highly urbanised and has a very large population a very large number of raingardens is required to reduce connected imperviousness in Darebin Creek Catchment to levels lower than 2%. This is unlikely to be achieved without a dramatic mindset change from the public.

There is scope to improve engage community and improve awareness in this area. A domestic raingarden pilot program will greatly engage the community and increase knowledge of raingardens in the Darebin Creek Catchment.

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12. Appendices

Example of Application to Receive Financial Assistance to Build a Raingarden in the Darebin Creek Catchment

Name				
Address				
Do you reside in the Darebin Creek Catchment?	Yes		No	
What is the area of impervious surface to be captured?	m^2			
Size of raingarden	Size	m^2	Depth	m
Type?	In ground		Planter box	
Where will it be located?	Front yard	Backyard	Side	Other:
Please circle what you have available to help build a raingarden	Shovel	Wheelbarrow	Drill	Topsoil
	Handtools	Please state:		
	Other	Please state:		
How would you prefer your raingarden to be built:	Myself		I need assistance for labour	
Do you require a plumber?	Yes		No	

Will the suggested plants be used?	Yes		No	
If no, what plants will you use:				
Will the design be the same as the recommended design?	Yes		No	
If no, please attach your own design:				

APPENDIX B

Example of Simple Way of Calculating Environmental Benefit

	A	B	C	D	E	F	G	H	I
1									
2		Name	John Smith						
3		Address							
4			122 Darebin Street, Darebin Catchemnt						
5		Do you reside in the Darebin Creek Catchment?	Yes				No		
6		What is the area of impervious surface to be captured?	m^2			20			
7		Size of raingarden	Size (m2)			2	Depth (m)		1
8		Type?	In ground					Planter box	
9		Where will it be located?	Front yard	Backyard		Side			Other:
10		Please circle what you have available to help build a raingarden	Shovel	Wheelbarrow		Drill			Topsoil
11			Handtools	Please state:					
12			Other	Please state:					
13		How would you prefer your raingarden to be built:		Myself		I need assistance for labour			
14		Do you require a plumber?	Yes				No		
15									
16		Will the suggested plants be used?	Yes				No		
17		If no, what plants will you use:							
18									
19		Will the design be the same as the recommended design?	Yes				No		
20		If no, please attach your own design:							
21			Pts						
22		Area to be captured (area divided by 10)	2						
23		Size of raingarden (Area in m3)	2						
24		Locations (2 points FY, 1 Pt for back or side)	2						
25		Assistance (0.5 point for each tool)	1						
26		Building (2 points myself, 0 points labour)	0						
27		Plumbing (2 points no plumber, 0 points need plumber)	0						
28		Plants (2 points suggested plants, 0 points other)	0						
29		Design (2 points recommended design, 0 points other)	2						
30		**TOTAL**	**9**						
31									