Ensuring protection of Little Stringybark Creek

Evidence for a proposed design standard for new developments

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Technical Background Report

Melbourne Waterway Protection and Restoration Science-Practice Partnership

Department of Resource Management and Geography

THE UNIVERSITY OF MELBOURNE

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Summary

Streams draining urban catchments are generally in poor ecological condition, with erosion, pollution and a loss of biodiversity. The primary cause of this degradation in modern cities is urban stormwater runoff. To protect the biodiversity, community value and ecological function of streams in urban catchments, runoff from impervious areas such as roofs and roads needs to be captured for use, in order to reduce the volume and frequency of stormflows. At the same time, a proportion of it needs to be allowed to be slowly filtered through the ground via infiltration, to restore natural stream flows and recharge groundwater with high quality water.

This report describes a major pilot study (The Little Stringybark Creek Project) that is working to demonstrate that urban streams can be protected and returned to a healthy state through retention, treatment and use of stormwater within their catchments. The Little Stringybark Creek catchment drains half of Mt Evelyn on the eastern fringe of Melbourne. The project team is working with Yarra Ranges Council and the catchment community to install stormwater retention and harvesting systems on private and public land throughout the catchment. At the same time the project team is monitoring the hydrology, water quality and health of the creek, its tributaries and similar creeks in the area, so that improvements in the ecology of the creek can be clearly demonstrated.

During the study, substantial new development in the catchment has been observed —on private and public land—, resulting in increased stormwater runoff from newly created impervious areas discharging directly into the creek through stormwater pipes, thus undoing all the work which has been undertaken to protect and restore the environmental values of the Creek.

As a result, this report outlines the basis for establishing a new stormwater standard for the catchment, which aims to prevent stormwater from further degrading Little Stringybark Creek. The new standard, proposed to be implemented through and Environmental Significance Overlay, requires runoff from impervious areas such as roofs to be retained for use (e.g. toilet flushing and clothes washing), with the remainder infiltrated through techniques such as raingardens or infiltration trenches. The report outlines a *Stormwater Retention Score* (SRS), used to assess the performance of proposed stormwater retention systems for a given site. The ESO will require a minimum SRS of 6, with financial incentives available for those who wish to exceed this score (the maximum score is 10). A number of case studies are presented, showing how the SRS6 requirement can be met, and a Deemed to Satisfy (DTS) table is presented, for those wishing to adopt simple solutions without having to undertake their own design.

The ESO is designed to ensure that Little Stringybark Creek is protected and restored and remains an important environmental and community asset.

Glossary of terms

Baseflow: the flow in a waterway (e.g. creek) which occurs during dry weather and not as a result of a storm.

Catchment: the area of land that drains to a waterway, such as a creek or a river.

Directly connected imperviousness: see *Imperviousness* and *Impervious areas*.

Evapotransipiration: loss of water to the air through evaporation from surfaces and through uptake of water by plants and release through their leaves (transpiration).

Impervious surfaces: surfaces, such as roofs and roads that are impermeable to water

Impervious areas: hard surfaces, such as roads, roofs, footpaths or carparks, which do not allow rainfall to infiltrate through them, instead causing the rainfall to run off the surface.

Imperviousness: the proportion of an area of land (such as a catchment) covered by impervious surfaces. *Total imperviousness* includes all impervious areas. *Directly connected imperviousness* (also called *effective imperviousness*) includes only those impervious areas that are directly connected to the creek through a pipe or constructed drainage pathway, such that runoff from the impervious area, along with all its pollutants, are transported directly to the creek.

Infiltration: the passage of water through soils or through soil-like media in constructed infiltration systems. Infiltrated water ends up in groundwater and ultimately in the creek as filtered baseflow.

Nutrients: a class of contaminants that can be found in stormwater or in receiving waters and which encourage the growth of algae, potentially leading to toxic algal blooms (nitrogen and phosphorus are usually the two most important nutrients)

Runoff: runoff is the process where rainfall falls on the land surface and begins to flow across the surface (either because the surface is impervious or because the rainfall is greater than the infiltration rate of the soil). However, the term 'runoff' is often also used by hydrologists to describe streamflow, almost all of which is generated by flows filtering through soils in natural catchments. For example, the term "annual runoff coefficient" is used to describe the volume of streamflow as a proportion of rainfall within a year.

Sediments: Suspended sediments are fine particles floating in water, which, in excess, can have a range of negative effects on stream biota and can result in loss of capacity in downstream waterways, potentially leading to flooding. In general the term sediment refers to the material in the bottom of streams (ranging from clay, silt, and sand to cobbles and boulders) that form habitat for stream animals and plants

(Urban) stormwater: runoff from impervious surfaces, which occurs as a result of rainfall

Transpiration: see *Evapotranspiration*

Total imperviousness: see *Imperviousness* and *Impervious areas*.

Toxicants: a class of contaminants that can be found in stormwater or in receiving waters that causes direct toxic effects to animals or plants (metals and hydrocarbons are two types of toxicants found commonly in stormwater)

List of abbreviations

APD: Approved point of (stormwater) discharge (from a property).

DCI: directly connected imperviousness (proportion of a catchment covered by impervious surfaces with a direct, sealed connection to a stream or other receiving water)

DTS: Deemed to Satisfy. A decision on whether a standard has been met

LSC: Little Stringybark Creek

TI: total imperviousness (proportion of a catchment covered by impervious surfaces)

SRS: Stormwater retention score; the score which describes the degree to which stormwater runoff volume, frequency and the amount of infiltration are returned to their 'natural' (pre-development) levels.

1. Introduction

The aim of this report is to outline the development of a new stormwater design standard for developments in the Little Stringybark Creek catchment. The current "Best Practice Environmental Management Guidelines" for urban stormwater produced in 1999 by the Victorian Stormwater Committee does not adequately protect the stream, because it a) is aimed at protecting larger receiving waters (such as Port Phillip Bay) and so does not provide protection for small creeks like Little Stringybark Creek; and b) focuses on reducing pollutant loads, which overlooks the impact changes in creek hydrology has on the health of urban streams (or words to this effect). The proposed new site-scale standard is thus based on ecological protection objectives that have been developed specifically for the catchment. The new standard relates to new impervious surfaces and reflects a balance between protecting the stream as much as possible whilst not being too onerous on developers. The new standard is proposed to be incorporated into a new Environmental Significance Overlay over the catchment, which will protect the stream from incremental development that occurs in the catchment. The new standard will be accompanied by an incentive scheme (building on the existing Stormwater Fund which has been applied in the catchment since 2008). The incentive scheme will pay a bonus for developers who are able to go beyond the proposed minimum standard (and thus may be able to be used as an offset against at least some of the cost of meeting the standard).

The threat from stormwater

Disturbance to streams as a result of urbanisation has been well documented (see for example Booth & Jackson, 1997; Walsh et al., 2005; Wenger et al., 2009). Urban development reduces vegetation cover and increases the area of hard (impervious) surfaces (roads, roofs, carparks, etc) in a catchment. As a result, evapotranspiration and infiltration are both substantially reduced. Conventional piped drainage systems convey polluted runoff from these hard surfaces quickly and efficiently to the nearest stream (**Figure 1**). In such typical urban catchments, streams receive far greater total volumes of runoff, delivered much more frequently, causing erosion and channel enlargement. Being unfiltered, urban stormwater flows typically have high levels of nutrients, toxicants, and suspended sediments (Duncan, 1999; Fletcher et al., 2005). Hard surfaces also prevent infiltration, thus potentially starving streams of vital dry weather flows (often called 'baseflow').

Research on streams in the Dandenong Ranges region has found directly connected imperviousness (DCI) to be a strong predictor of stream health (Walsh et al., 2005). DCI is the proportion of a catchment's area covered by hard (impervious) surfaces that are connected to pipes (or other hydraulically-efficient drainage infrastructure) directly conveying stormwater runoff (and its pollutants) from the hard surface to a receiving water. The term *effective imperviousness* is also often used, with the same meaning. DCI has since been shown to be a good predictor of urban stream health (ecological condition) across many streams, both in Melbourne and interstate (e.g. Walsh, 2009). It is associated with the loss of many sensitive species of stream invertebrates, and increased abundance of pollution tolerant species (Walsh, 2004). Streams with even very low levels of DCI (as little as 1%) show multiple symptoms of ecological degradation (**Figure 2** and Walsh et al. 2005; Walsh & Kunapo, 2009). Symptoms include changes in structure of animal, plant and microbial communities (Newall & Walsh, 2005; Walsh, 2004; Perryman et al., 2011), degradation of water quality (Hatt et al., 2004), increased algal growth (Taylor et al., 2004), and increased leaf breakdown rates (Imberger et al., 2008).

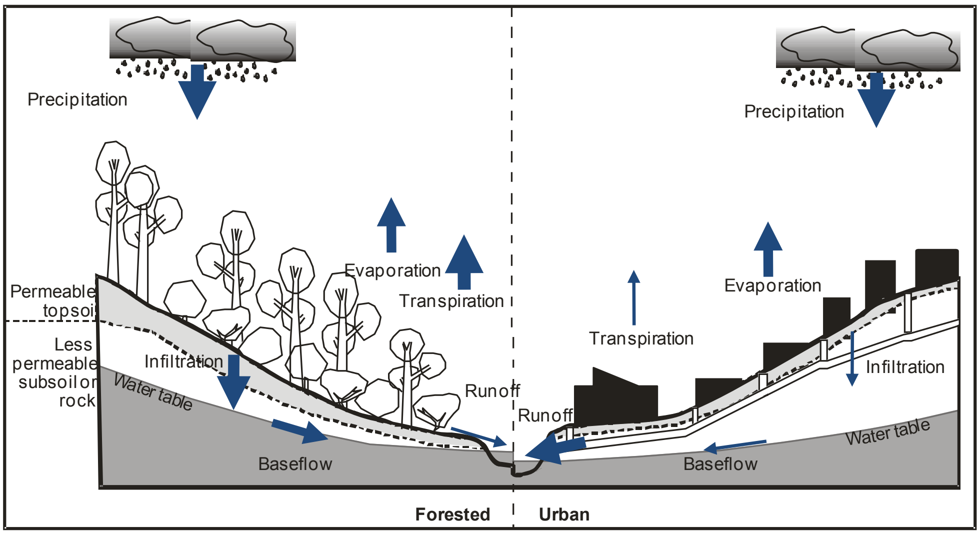

Figure 1 Changes in water cycle due to urbanization. Size of arrow indicates relative size of water flow. Transpiration and infiltration are greatly reduced by urbanization, whilst surface runoff increases both in frequency and magnitude. (Source: Walsh et al., 2004)

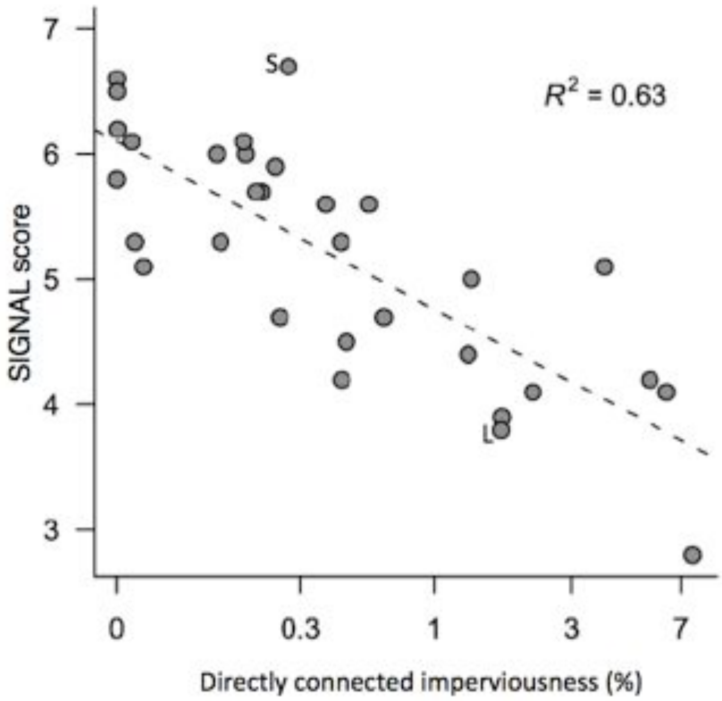

Figure 2 Condition of streams in the Dandenong Ranges region is well predicted by directly connected imperviousness, estimated here by weighting the area of each hard surface by how far it is from the nearest drain (or stream in the absence of drains). All streams with DCI > 0.5% were in poor condition. SIGNAL score is an indicator of stream condition based on the sensitivity of macroinvertebrate families present: 6-7 indicates good condition, <5, poor condition. S and L indicate data for Sassafras and Little Stringybark creeks, respectively (adapted from Walsh and Kunapo, 2009).

DCI is important because it is a much stronger predictor of stream condition than simple urban density (as measured by total imperviousness, TI): it indicates that the primary urban impact driving degradation is stormwater runoff (rather than urbanisation more generally). Importantly, *streams can remain in good condition even in substantially urban catchments as long as the hard surfaces in the catchment are not connected to the stream by pipes.* For example both Sassafras and Little Stringybark Creek (LSC) catchments have around 10% TI yet Sassafras remains in good condition while LSC is severely degraded (**Figure 3**). This can be explained by the fact that most of roads in the Sassafras Creek catchment are unsealed or drain to an earthen drain, most of its houses drain to gardens or rainwater tanks: where roads are drained by curb and channel, the pipe drains to the side of the hill several hundred metres above the stream. Consequently, DCI for the Sassafras Creek catchment is near zero whereas LSC DCI is ~2% (Figure 2[1]). Streams with near-zero levels of DCI will receive polluted and eroding runoff only rarely (during very large storms), while streams with more DCI will typically directly receive such damaging runoff ~100 times per year (Ladson et al., 2006).

To protect streams from degradation by urban stormwater, it is imperative that runoff from impervious areas be captured for use (either for human needs or for vegetation) and infiltrated, to allow the water to be slowly filtered and to recharge groundwater and restore baseflows.

Figure 3 A typical section of Sassafras Creek (left), appearing in good condition with intact riparian vegetation and minimal erosion, compared with a typical section of the Little Stringybark Creek (right), which has degraded riparian vegetation and is actively eroding.

2. The Little Stringybark Creek Catchment

The hydrology and water quality in the LSC catchment is currently being restored through a project led by the University of Melbourne and partnered by Monash University, Melbourne Water, the Shire of Yarra Ranges, Yarra Valley Water, the Department of Sustainability and Environment and the Port Phillip and Westernport Catchment Management Authority, through the Caring for Our Country Investment Fund.

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[1] This figure calculated DCI using the weighting function used by Walsh and Kunapo (2009) from 2004 data: the standard measure of DCI used by Melbourne Water. Review of historical aerial photographs and on-ground 2011 assessment of construction age and drainage connection in the LSC catchment have found impervious surfaces with drainage connection to small tributaries not considered streams by the earlier study. The new estimates of DCI used in this report for the LSC site illustrated in Figure 1 are 7.2% in 2001, rising to 9.4% in 2009.

The creek is located 37 km from Melbourne and has a suburban catchment of ~300 ha in its headwaters, and a total catchment area at its confluence with Stringybark Creek of ~800 ha (**Figure 4**). The lower part of the catchment is primarily used for grazing. The upper part of the catchment, covering about half of the suburb of Mt. Evelyn, has three tributaries, each about 100 ha, and differing in urban density.

The three sub-catchments have a relief of about 120 m and are underlain by predominantly clay soils with low underlying permeability (0.01 mm/hr). Annual precipitation is typically 950 mm. Under today's developed conditions, in a year of average rainfall, the stream receives about 132 ML/yr more runoff to the creek than under forested conditions (an increase of 136% of the pre-development flow volume), as a result of stormwater pipe conveyance and reduced evapotranspiration.

The non-rural parts of the catchment are connected to the sewerage system that exports sewage from the catchment. About 20% of the residents have septic tanks, but these have been shown to have a negligible effect on stream health in this catchment, compared to the effects of stormwater runoff (Walsh 2004, Taylor et al. 2004, Hatt et al 2004, Newall and Walsh 2005). The upgrade of Wattle Valley Road (**Figure 4**) has recently connected uncontrolled grey-water discharges from several houses to the newly piped stormwater system. Whereas previously the grey-water had a chance to be filtered to some extent by the table drains, now this poor-quality water is directly discharged to the stream through sealed pipes and drains, contributing to ecological degradation of the stream.

There are 21.4 km of roads within the catchment, of which 11.6 km (54%) are currently directly connected to the stream via stormwater pipes. The remaining roads drain informally to the stream via table drains, 3.1 km of which remain unsealed.

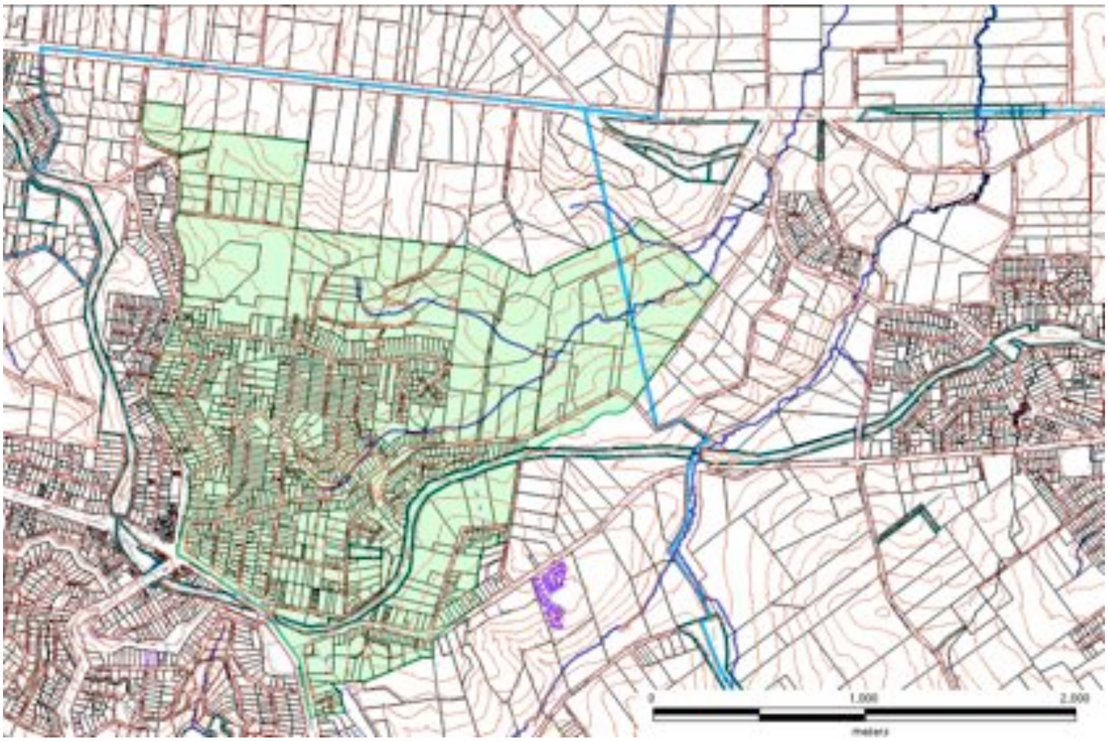

Figure 4 Little Stringybark Creek area, indicating property boundaries (black lines). The green shaded area shows the properties that are the subject of the proposed Environmental Significance Overlay (this area matches the LSC Restoration Project area in **Figure 5**).

3. The Little Stringybark Creek Restoration Project

The aim of the Little Stringybark Creek restoration project is to return the ecological function and health of the creek to a level more consistent with a natural stream, through better managing the quantity, timing and quality of stormwater runoff entering the creek. It is a world-first attempt to restore the health of a stream through implementing WSUD in an entire catchment. While it may not be possible to return the creek to a 'pristine' state, it should be possible to return a number of ecological functions such that it hosts a high level of biodiversity and provides an important natural asset for the local community.

The Little Stringybark Creek catchment was selected as a priority for restoration because while it is currently degraded, it could have important ecological function and environmental values restored at relatively low costs and within a realistic timeframe.

Works aimed at improving stormwater management within the catchment are being targeted at multiple scales: from allotments, to streets, to sub-catchments of large stormwater drains.

Residents in the catchment have been offered incentives to install stormwater treatment and retention measures. Grants were offered based on the benefit (hydrological and water quality) achieved (Fletcher et al., 2011). The project is now working with households that have been identified as being high priority, and directly funding and managing the installation of works using the funding level determined in earlier granting rounds (www.urbanstreams.unimelb.edu.au/allotments.htm).

To date 157 properties have been funded and 202 tanks and 101 raingardens have been installed. Raingarden infiltration systems along roadsides are also being constructed to treat and disconnect roads or roads plus upstream catchments. Major stormwater infiltration systems have been completed for Hereford Rd and Stringybark Boulevard. Two raingardens are under construction to treat runoff from O'Connor Ave and Wattle Valley Rd, and a large integrated raingarden and harvesting system is under construction in Morrisons Reserve (Figure 5). Further raingardens are proposed for Heath Avenue, Kemp Avenue, Newton Avenue and Old Hereford Rd.

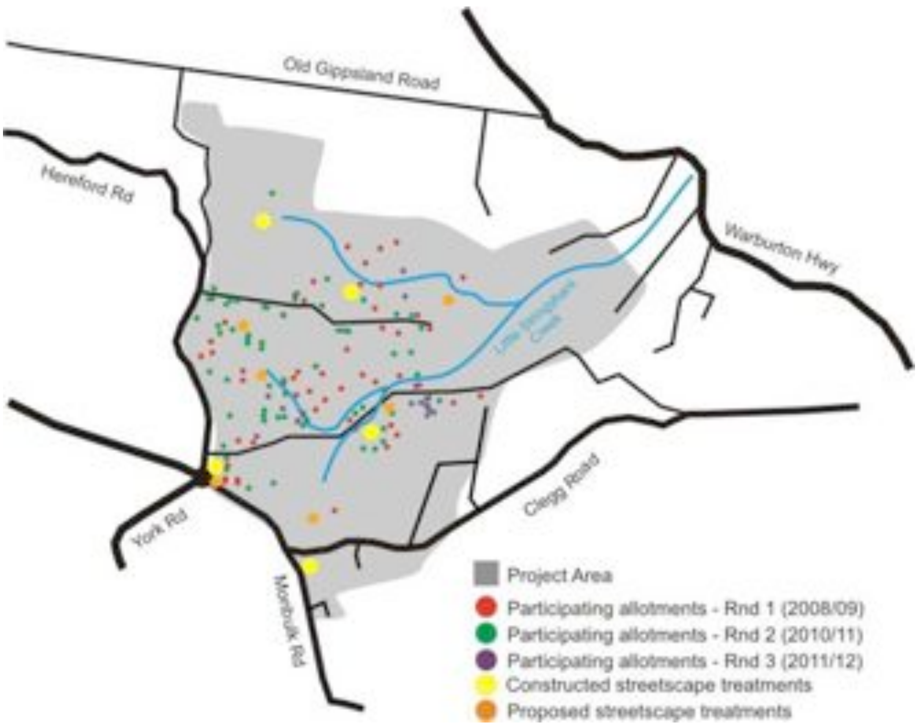

Figure 5 Locations of various allotment scale and streetscape scale treatment systems constructed and proposed as part of the LSC Restoration Project.

The funding program will continue through to at least the end of 2012, by which time it is anticipated that the DCI will have been reduced enough to detect improvement to the ecological condition of the creek.

Proof of success will be monitored in the main stem of Little Stringybark Creek, along with each of its three tributaries (the monitoring will continue until at least June 2014). There is a range of measures (including flow, water quality and biological) by which the project will be assessed. Along with continuous flow measurement in the creek and its tributaries, monthly water quality samples are taken. Water quality sampling also occurs during storms, in order to detect impacts from stormwater runoff. A range of ecological measures, including the diversity of macroinvertebrates and algae and algal biomass are being measured. All monitoring in LSC will be compared with three 'reference' streams (i.e. streams in good ecological condition) and three 'control' streams (streams with similar catchments to LSC, but without the major stormwater retention measures being put in place), to ensure that changes observed over time are due to the stormwater management measures being put in place, rather than some external influence (e.g. climatic variations between years). Monitoring will be also undertaken in smaller subcatchments to compare, for example, the stormwater quality and flow regime coming from adjacent streets, one with little stormwater retention in place and the other with significant 'disconnection' of impervious areas through retention, filtration and infiltration systems[2].

4. Current development in the catchment and the need for planning controls

We have quantified the change in impervious cover in the catchment over the last decade using aerial photographs from 2000, 2004 and 2010, and conducted extensive on-ground inspections and interviews with landholders, and analysis of building-permit data during the LSC project.

Development in the catchment is mainly infill (including some larger subdivisions with medium density housing) and extensions. On average, 12 developments a year have been built since 2000, an average increase in impervious area of 0.24 ha (2400 m^2) per year (**Figure 6**). About 80% of this increase resulted from new buildings, and ~20% from extensions to existing buildings. The largest development since 2000 has been the Mount Evelyn Primary School, an increase of 2,940m^2, while a single industrial development in Clancy Rd added 2,122 m^2

The area of impervious surfaces directly connected to the stream has increased to an even larger extent as a result of the upgrade of Wattle Valley Rd and O'Connor Ave (**Figure 6**). Together the road upgrade and infill developments have increased directly connected imperviousness of the creek at our downstream monitoring site (above Warburton Hwy) from 7.8% to 9.0%[3].

The many stormwater retention and harvesting projects commissioned by the LSC project from 2009 to 2011 have disconnected an area of impervious surfaces that is approximately equal to the new connected impervious areas that have been constructed since 2000. As a result there has to date been no net change in connected imperviousness in the catchment. Most of the new developments in the catchment have been built without stormwater retention measures. Such systems are substantially cheaper to install at the time of construction than when they are retrofitted after construction, as demonstrated by the one new development that has engaged with the project prior to construction (Box 1). If planning controls had been in place to require stormwater retention during this last decade, substantially greater

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[2] See http://www.urbanstreams.unimelb.edu.au/LSmonitoring.htm for further details on the monitoring and evaluation of the project.

[3] As above, these 2011 estimates of connected imperviousness are higher than the values used in Figure 2 and by Melbourne Water for its region-wide assessment of DCI.

progress towards restoration of the creek would have been made.

Large retention projects planned for 2012 as part of the LSC project will result in reductions in DCI that should be sufficient to see ecological improvements in the creek (Figure 7). Assuming infill development in the LSC catchment is likely to proceed at a similar pace as has been observed in the last decade, future developments will risk reversing these improvements and returning the creek to its current degraded state, unless appropriate stormwater management controls are placed on developments in the catchment.

There are several roads in the catchment that are currently effectively disconnected through the nature of their informal drainage (e.g. grassed swales which trap sediments and nutrients and which allow water to infiltrate into the soil). Upgrading these roads can threaten the health of the creek if not managed in an appropriate way.

At this stage, there are no future road-sealing projects planned in the catchment. However, this does not mean that such projects will not occur in coming years – there are still 3.1 km of unsealed roads in the catchment that could be upgraded (i.e. sealed), if local residents gather enough support for such projects and council has the funds to undertake the works. Unless appropriate stormwater filtration and retention systems are put in place to deal with such road upgrades, they represent a major threat to the creek, potentially adding large areas of directly connected imperviousness. A clear, effective mechanism for ensuring implementation of appropriate stormwater management systems as part of the design and construction of every road upgrade is required.

Furthermore, various drainage upgrade projects are likely to occur in the catchment. These projects typically include: the plastic lining of existing, damaged stormwater pipes and the formalisation (using stormwater pipes) of existing drainage lines. These projects usually occur in reaction to community complaint. For example, a significant drainage upgrade project that has been discussed is the extension of a drainage outfall in the Southern Tributary of the LSC Catchment. Fortunately, members of the LSC Team are currently working with Council to ensure that this drainage upgrade project occurs with no negative impact to the stream. That said, future drainage upgrade projects occurring in the catchment may not have input from the LSC Team and there is a risk that they could result in negative impacts to the stream. An Environmental Significance Overlay (ESO) over the catchment would help to protect the stream from further degradation and protect the major investment in returning the creek to a healthy condition for the community of Mount Evelyn.

An Environmental Significance Overly (ESO) over the catchment will not mean that urban development or road upgrades cannot occur; rather, such projects will simply need to be designed and constructed in a way that retains stormwater within the catchment for infiltration, evapotranspiration or harvesting, so that the creek is not degraded by further stormwater runoff.

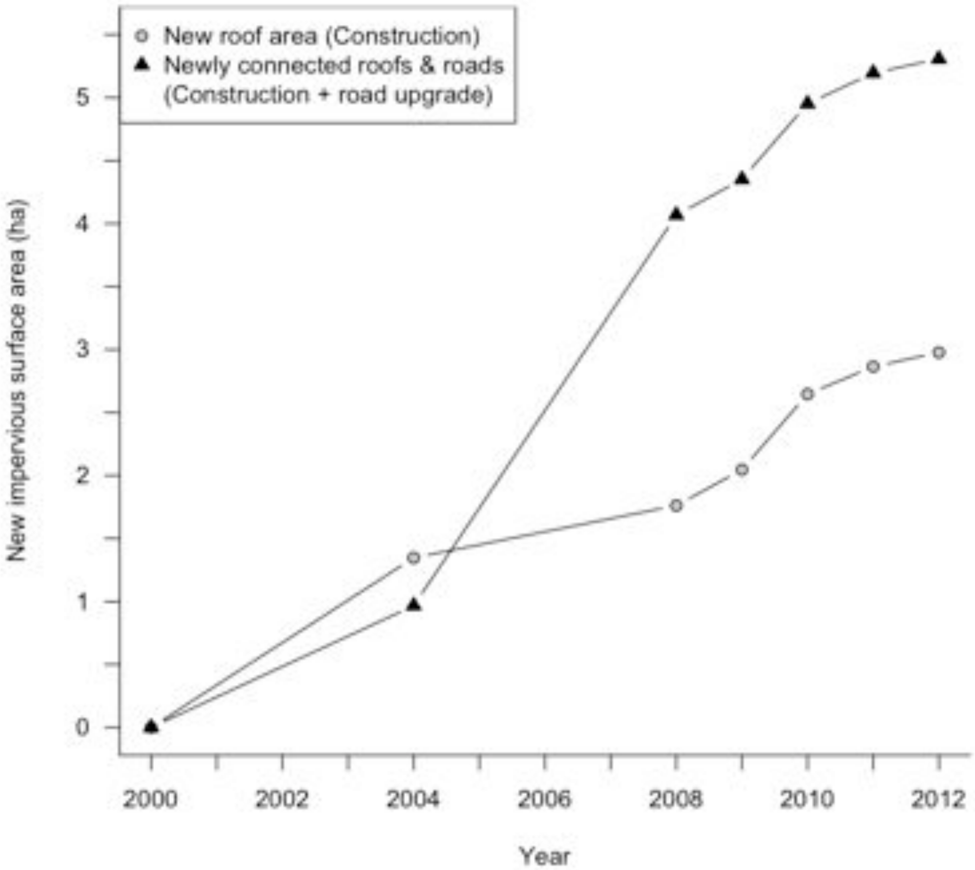

Figure 6 Growth in impervious area in the Little Stringybark Creek catchment since 2000. Approximately 0.24 ha of new roof area has been constructed annually over the last decade. The area of impervious surfaces with direct connection to the stream has increased at a greater rate as a result of road upgrades (e.g. Wattle Valley Road) in 2005.

Box 1. Interim process for treating new developments

It was recognised that incremental development in the catchment was hindering restoration efforts. A short-term immediate strategy for managing development was developed by the LSC team in 2010. Without the ability to require developments to retain and treat stormwater leaving the site, it was decided to utilise funds from the Little Stringybark Creek Project to provide incentives to developers.

The process was developed in partnership with the Yarra Ranges Council and involved firstly flagging developments through council's approved point of discharge (APD) process. The APD process is where developers are required to obtain information from council about the location and accessibility of a drainage outfall for the site i.e. *does the site have a point of discharge to the street drainage system and what are the requirements for connecting to it?*

Once identified, the site's developers are sent information with their APD report explaining the incentive program along with a follow-up letter from the LSC project team.

The amount of incentive developers are offered is determined by the area of impervious area they treating and the efficiency (in terms of environmental outcome) of that treatment.. While a minimum standard is not enforced, the indicators and metrics used to assess the performance of the treatment systems are the same as those proposed below.

To date, two such developments have been funded by the LSC project to treat and disconnect stormwater from the site. Letters to several other developers have been sent offering financial incentives. Unfortunately there has been little response from the developers despite incentives being offered. This further highlights the need to implement a more formal process which can flag and control developments in the catchment.

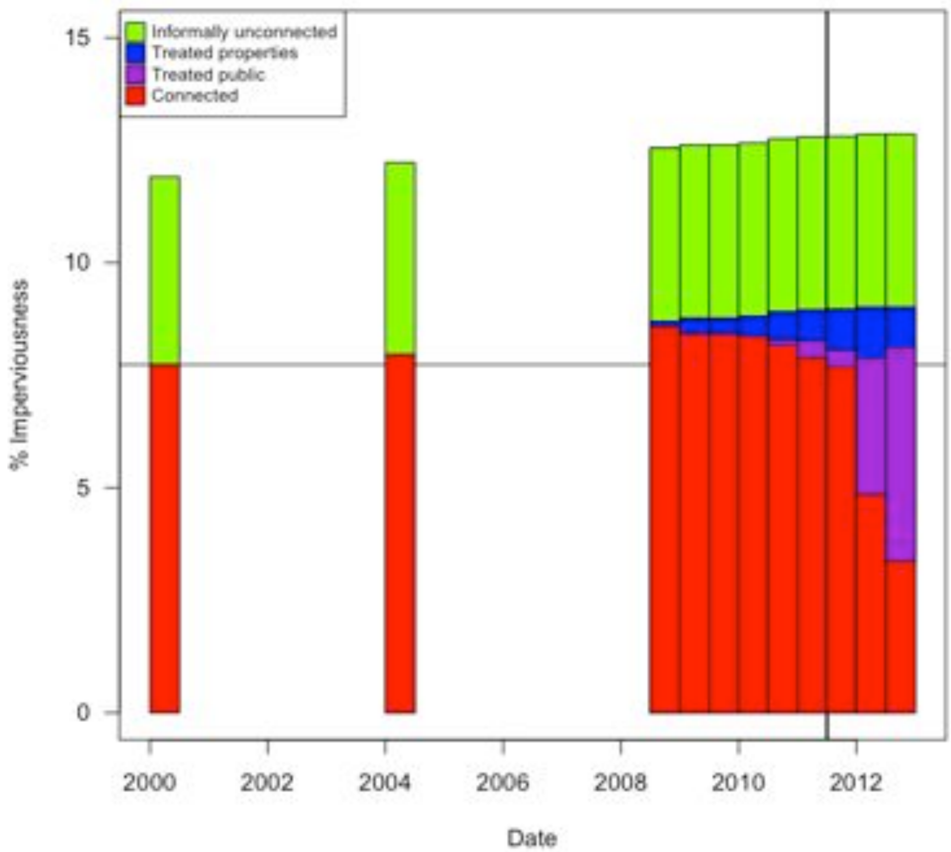

Figure 7 Increasing connected imperviousness (red) resulting from new constructions and road upgrades since 2000 has countered treatment works installed by the LSC project since 2009 (blue and purple), so that by late 2011 (solid vertical line) stormwater impacts to the creek remained at about the same level as they were in 2000. Planned works will reduce connected imperviousness to a level at which improvement in stream condition will be achieved. If stormwater runoff from future constructions is not adequately retained, stream health will worsen back towards its current degraded state.

5. Developing a new stormwater standard for Little Stringybark Creek

Why the current standard is inadequate for the LSC catchment

The "Best Practice Environmental Management Guidelines" (BPEM Guidelines) for urban stormwater produced in 1999 by the Victorian Stormwater Committee (driven by Melbourne Water and the EPA) (Victorian Stormwater Committee, 1999) have been instrumental in improving stormwater management over the last 15 years. Originally developed with a primary focus of protecting Port Phillip Bay from excessive nutrient loads from stormwater, the guidelines are significantly outdated and due for review. The current performance objectives are outlined in **Table 1**.

Table 1 Current performance objectives for urban stormwater listed under the BPEM Guidelines.

Pollutant	Receiving water objective	Current best practice performance objective
Total Suspended Solids (TSS)	Comply with SEPP	80% retention of the typical urban load
Total Phosphorus (TP)	Comply with SEPP	45% retention of the typical urban load
Total Nitrogen (TN)	Comply with SEPP	45% retention of the typical urban load
Flow	Maintain flows at pre-urbanization levels	Maintain discharges for the 1.5 yr average recurrent interval (ARI) at predevelopment levels

The pollutant load reduction objectives for TSS, TP and TN were based on expected improvements to achieve State Environment Protection Policies (SEPP) as well as what could be practically achieved with treatment technologies available when the guidelines were developed (around 1996-7). Treatment technologies at the time were mainly large-scale regional wetlands designed to reduce loads to large receiving water environments e.g. Port Phillip Bay, rather than to protect local receiving waters/ streams. Such systems were typically applied at the 'bottom' of catchments, by diverting water out of streams or large drains for treatment, meaning that the upstream portions of the creek remained unprotected. Since this time, technologies, modelling capabilities and performance data have substantially improved. It is now recognised that pollutant concentrations (as are used in SEPP) are likely to be a more appropriate performance objective and studies have shown that achieving appropriate water quality concentrations to protect streams requires significantly stronger targets (Fletcher, 2007).

Significant advances have also been made in relation to understanding the impact of urban drainage systems on flow regimes and the consequent impacts on streams. Whilst the receiving water objective to "maintain flows at pre-urbanization levels" is a desired outcome, the current performance standard is very limited and tends to be difficult to apply (and is thus ignored) in current practice. It relates only to controlling peak flow rates (the 1.5 yr ARI), without the need to manage other important elements of the flow regime, such as volumes, baseflows and frequencies, which have recently been found to be critical for urban stream health (Burns *et al.,* 2012b). This is once again partly a result of the technologies (and the understanding) which were available at the time these objectives were released. At the time flood retarding basins and wetlands were the main technologies in use and understanding of how to design systems to return the full range of flows[4] towards a more natural level was limited.

There is now much greater understanding of the need to manage not only peak flows, but to try to restore the baseflows which are so often lost through urbanisation, and result in streams being starved of flow during dry weather (Fletcher et al., 2007; Walsh et al., 2010, Burns et al., 2012b).

There are many hydrological indicators which can adequately describe the hydrology of a stream (see Appendix B) and explain the impacts of urbanization, including:

- Increased frequency of high flow events leading to increased disturbance to streams (Walsh et al. 2005 and Roy et al. 2009)
- Increased magnitude of events which increases the likelihood of physical

[4] With the exception of very large flows (e.g. events with an annual exceedence probability of 20% or less)

habitat disturbance (Konrad, et al., 2002)

- Decreased baseflows (summer and winter) which reduces available habitat area (Poff et al 2010), although these can sometimes be offset by anthropogenic inputs such as leaking water and wastewater infrastructure, or reductions in transpiration due to vegetation clearance.
- Increased rate of change and timing of events has changes dramatically, such that sensitive biota have less time to find suitable refugia (Lancaster 1999)

However, decisions about how to manage stormwater start *at the site, rather than at the catchment* scale. Until recently, there were few indicators that had been developed for scales at which stormwater or water management decisions are being made (e.g. allotment and streetscape). Such indicators are critical to be able to develop clear, measurable and practical design objectives for managing stormwater from a given site.

Ecological Protection Objectives for Little Stringybark Creek

Drawing upon extensive research into the impacts of stormwater on hydrology, water quality and stream ecology undertaken in Australia (e.g. Bunn & Arthington, 2002; Imberger et al., 2008; Hatt et al., 2004; Walsh et al., 2004, 2005, 2010) and overseas (Poff et al., 2010 Roy et al., 2009; Wenger et al., 2009), a suite of objectives for hydrology and water quality at the catchment scale have been developed, along with specific indicators for application at the site scale (Table 2). These site-scale metrics provide a practical means of assessing the performance of a proposed development in protecting Little Stringybark Creek from catchment inputs.

Table 2 Catchment scale flow and water quality objectives for Little Stringybark Creek, along with site-scale performance index which can be applied *to impervious areas* at the site scale.

Indicator	Objective	Site scale performance index
Flow Frequency	To maintain the natural frequency of surface runoff from a given impervious surface (where natural is how the catchment would have behaved when it was forested)	Estimates the number of days of runoff (above the natural baseflow rate of the catchment) from a site and compares it to what would have been the number of days on which surface runoff would have come from the site when it was a forest
Flow Volume	To maintain natural (forested) annual volumes of stormwater	Estimates the annual volume of stormwater leaving a site and compares it to natural levels
Baseflow	To maintain baseflow rates and volumes at or near the natural levels.	Estimates the annual volume of filtered flow, released at a rate not exceeding the natural catchment baseflow rate and compares it to pre-developed baseflow volumes
Water Quality	Maintain natural concentrations of key water quality parameter	Estimates the median concentrations of P, N and TSS from a site and compares them with the State Environment Protection policy (Waters of Victoria) targets.

The indicators apply only to impervious areas within the site (e.g. for a house block, this would apply to the roof area plus adjacent paved areas such as the driveway). It is assumed that the non-impervious areas, even if cleared of the natural forest cover, will have relatively minor impacts on the stream ecosystem (because most rainfall landing on these pervious areas will infiltrate into the soil). All modelling therefore of the indicators is carried out only for the impervious surfaces – with the main aim being to assess how well various stormwater retention and treatment systems can return the various indicators to a more natural state. Each indicator is scaled to a 100 m^2 impervious surface.

Each of the four indicators has been chosen because it measures an aspect of the flow regime or water quality which has been shown to be important to the ecological condition of streams. The rationale for each indicator is described below. Each indicator can be modelled using models such as MUSIC (www.ewatercrc.com.au) or using the EBcalculator, a free tool available at www.urbanstreams.unimelb.edu.au.

Flow Frequency index

The runoff frequency is a measure of the frequency of disturbance to streams. It represents the number of days (in a typical year) in which stormwater runoff directly reaches the stream. In undeveloped (forested) catchments, direct surface runoff to the creek would happen on only a few days a year (2-15), with most rainfall events simply intercepted by plants and infiltrated into soils. Runoff from impervious surfaces directly connected via pipes and drains to waterways, however, reaches the stream virtually every time it rains. In the Little Stringybark Creek, the pre-developed runoff frequency is estimated at 12 days per year (on average) and the post development runoff frequency is 120 days per year (on average), based on MUSIC modelling using local rainfall data (Fletcher et al., 2011). The ideal target for runoff frequency is thus 12 days per year.

The Flow Frequency metric, scaled to 100m^2 is calculated as:

Equation 1 $$FF = \left(\frac{1 - R_g - R_n}{R_u - R_n}\right) \times \frac{A}{100}$$

Where:

R_g = number of days of runoff per year from *A* following treatment

R_n = frequency of runoff from *A* in pre-urban state (12 days per year)

R_u = frequency of runoff from *A* before treatment (121 days per year)

A = Impervious area m^2

Volume index

Typically around 5-20% of rain that falls on a catchment reaches the stream, and in most years the vast majority, around 90% of this is filtered via sub-surface flow before reaching the stream. The 80-95% which does not reach the stream at all is either intercepted by tree canopies and evaporated, taken up by plants and transpired or infiltrated into deeper ground water stores, not connected with the local stream.

The replacement of vegetation with an impervious surface results in 80-95% of rainfall falling on the ground over a year reaching the stream. Importantly, this water also carries pollutants from impervious surfaces, as it is not filtered through soils. The Little Stringybark Creek catchment generates on average 136% more streamflow per year more than it did in its per-urban state. Each typical 200m^2 roof generates around 130 kL more water per year than an equivalent forested area.

The volume indicator compares this *excess volume* to that which can be removed from a stormwater retention system (e.g either by household water use from tanks or the evaporation and transpiration losses of infiltration systems). The volume is calculated as the sum of all surface runoff (overflow) and infiltration from the stormwater retention system

Given that the volume indicator is based on mimicking the pre-development streamflow volume, the ideal range for this indicator is for the annual volume discharged from the site to be between 5 and 20% of the annual rainfall.

The volume metric scaled to $100m^2$ is calculated as:

Equation 2 $V = 1 - \frac{V_e - V_c}{V_e} \times A/100$

Where:

V_e = the excess volume of water generated by impervious surface *A* (i.e the difference between the volume of streamflow (assumed to be 15% of annual rainfall) from an area of forest equivalent to *A* and the volume of runoff from the impervious surface (including all surface runoff and any infiltrated flows, net of evapotranspiration)

V_c = the volume of water consumed from the treatment system e.g. tank (or lost from a raingarden through evapotranspiration)

A = Impervious area m^2

<u>Infiltration (Filtered Flow) index</u>

Baseflows are critical for the health of perennial streams (streams which would not normally dry up regularly) and are sustained by subsurface flows from the catchment. Hence infiltrating water into the ground is critical for a healthy baseflow. As shown above, around 5-20% of rainfall falling on a catchment infiltrates into the soil and reaches the stream. It can take weeks or months for these flows to reach the stream, during which time the water is slowly filtered through soils. In some catchments water can also enter deeper groundwater stores and not reach the stream. Infiltration rates can vary greatly across catchments; heavier soils will result in much more 'even' baseflows throughout the year, while sandy soils, which have rapid infiltration, will show a greater flow response in the days following a storm. Soils in the LSC catchment are largely heavy clay with inherently low infiltration rates. While the upper soil layers (topsoil) may have rates of up to 200 mm/hr, the deeper clays may infiltrate as slowly as 0.05 mm/hr.

The infiltration index assesses the volume of filtered water flowing out of a treatment system, both through an outlet pipe (if present), and through exfiltration to the surrounding soils. Following the logic above for volume reduction, we assume the ideal volume of filtered flow corresponds to the volume of stream flow generated from a forested (natural) landscape in the area. However, we assume that good ecological health would still be feasible if stream flow volumes approached the volumes generated by grassed catchments (which have higher streamflow coefficients, because of the lower evapotranspiration rate of grass). This flexibility allows a greater range of design options for stormwater retention systems. We therefore award systems a perfect score for the filtered volume index if the filtered volume is between the runoff volume from a forest and that from pasture. These limits are derived from the study of Zhang et al (2001) (Figure 8).

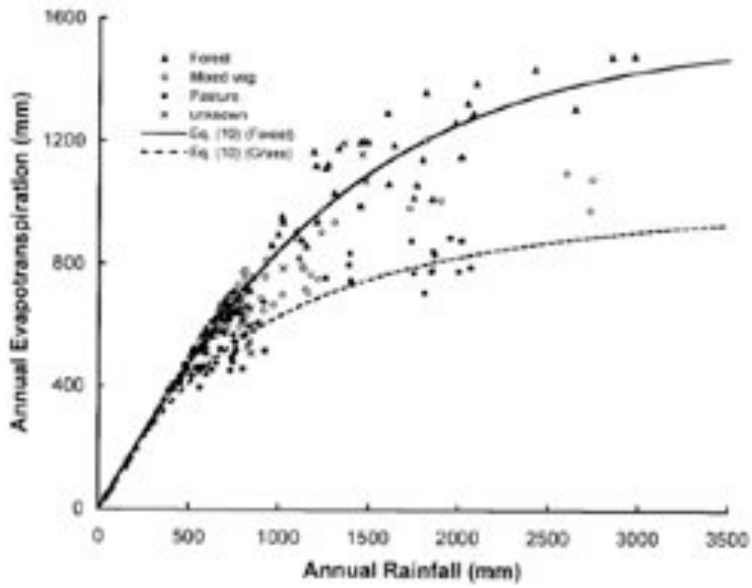

Figure 8 Relationship between annual rainfall and evapotranspiration (source: Zhang et al., 2001). For a given rainfall, the annual streamflow can be calculated simply as Annual Rainfall – Annual Evapotranspiration. This figure thus allows the appropriate baseflow range to be calculated.

The infiltration index (filtered flow volume index), FV is calculated as:

Equation 3

if $FV_g < FV_{forest}$,

$$FV = \left(\frac{FV_g}{FV_{forest}}\right) \times A/100$$

if $FV_g > FV_{pasture}$,

$$FV = \max\left(0, 1 - \frac{FV_g - FV_{pasture}}{FV_{forest}}\right) \times A/100$$

Else,

$$FV = 1 \times \mathrm{A}/100$$

Where:

FV_g = the volume of filtered water flowing out of the system, both through the outlet pipe (if present), and through exfiltration to the surrounding soils.

FV_{forest} and $FV_{pasture}$ represent the bounds of ideal filtered flow volume. They are derived from the model of Zhang et al. (2001) that predict evapotranspiration and runoff from catchments with forest and pasture vegetation, as a function of annual rainfall.

A = Impervious area m^2

Water Quality index

Water quality is also a critical objective for stream health. Pollutant load targets provide the best indicator for the protection of large waterways such as Port Phillip Bay, because these are subject to the long-term accumulation of pollutants. However, smaller flowing streams such as Little Stringybark Creek are more sensitive to variations in concentration (Hatt et al., 2004).

A complete set of indicators would thus include the three flow-regime indicators along with a lumped indicator which measures the median concentrations of suspended sediment (TSS), total nitrogen (TN) and total phosphorus (TP). Whilst the LSC project uses this full set of indicators, it was decided that for simplicity, the water quality indicator would not be required as part of the site-scale metrics to be used in the planning control for the catchment. Considerable work has been undertaken to assess the relative difficulty of achieving the flow and water quality objectives and has concluded that meeting the flow objectives would almost always result in the water quality objective being achieved. There is thus a high degree of redundancy between the two components. Secondly, the modelling of the water quality component is somewhat more complex. However, it should not be interpreted that water quality is unimportant; it is simply that meeting the flow objectives results in the water quality objective being very likely to be met by default, without requiring additional modelling.

Limitations on current technologies and cost are the main reasons why achieving the 'ideal' ecological protection objectives (volume, frequency and filtered baseflow) would be a difficult standard for developments to meet. The section below describes the process used to determine a practically achievable standard for the catchment which can still provide adequate protection for the stream.

Stormwater Retention Score (SRS)

The standard proposes to include the 3 flow indicators (frequency, volume and filtered baseflow) presented above into the stormwater retention score. The three indices are proposed to be included as (i) they are all important elements of the flow regime (and provide an adequate surrogate for water quality), (ii) can all be readily modelled and (iii) there are available technologies to manage these flow indicators.

For some impervious surface types and treatment systems, meeting all of the three metrics may be difficult. All metrics are thus combined, with the requirement to meet a minimum overall score. This gives more flexibility, allowing developers to match the design of systems to the constraints of the site. Combining the metrics also allows a weighted average (based on impervious area) to be calculated rather than requiring each discrete impervious surface to meet a minimum score.

The equation for calculating the Site Retention Score (SRS) is provided below. It combines the 3 flow metrics equally and weights these across the various impervious surfaces on the site. A score of 0 represents no treatment and a score of 10 represents the ideal natural conditions.

Equation 4 $$SRS = \frac{\left(\sum FF_{Ai} + \sum V_{Ai} + \sum FV_{Ai}\right)}{\sum A_i} \times \frac{1}{3} \times 1000$$

Where:

FF = Flow Frequency metric (see Equation 1 above)
V = Flow volume metric (see Equation 2 above)
FV = Infiltration metric (see Equation 3 above)
A_i = area of imperviousness (m^2)

A **Stormwater Retention Score (SRS) of 6** is proposed as the minimum development standard for the Little Stringybark Creek catchment. See sections below for justification for this standard.

A number of factors were taken into account when developing a new 'best practice' standard for the catchment. These are outlined in more detail below and included:

- Protection of stream health - minimum WSUD required to protect stream health
- Currently available technologies – use of robust, achievable and practical technologies and appropriate design assumptions
- Cost – the potential economic impact on developers and what was considered reasonable
- Site constraints – e.g. space available in typical developments in the catchment to implement current WSUD technologies

6. Stormwater retention technologies and their modelling assumptions

A range of established treatment technologies were used to help determine the proposed development standard and which were ultimately used in developing the Deemed to Satisfy (DTS) lookup table to allow quick sizing of systems. The systems were chosen based on their robustness, their cost effectiveness and the ability to adequately model their performance (so that their sizing can be readily undertaken). There are of course additional technologies or design variations which could be utilised by a developer to comply with the proposed standard, but the listed technologies represent simple and readily-applicable systems.

An overall description of each treatment system is provided below, along with some basic modelling assumptions. Further modelling information can be obtained from the on-line EB calculator http://www.urbanstreams.unimelb.edu.au/EBcalctech.html.

Table 3 explains which systems have been included in the DTS lookup tables, along with additional systems which were used in a series of case studies. All of these systems can be used for meeting the minimum standard. Other systems may also be used where approved by the Relevant Authority.

Table 3 Treatment systems used for the DTS (Deemed to Satisfy) table and within the case studies.

System	DTS	Case studies
Rainwater tanks for internal demand	√	√
Passive irrigation tanks	X	√
Infiltration Raingarden	√	√
Lined (or partially lined) Raingarden	X	√
Shallow raingarden	√	√
Infiltration trench	√	√
Permeable paving	√	X
Diffuse runoff dispersion	√	√

Rainwater tanks for internal demand

Tanks are commonly installed at residential homes across Victoria. Whilst most homeowners appreciate the water and cost savings of harvesting water from their roofs, tanks are also a great way to reduce stormwater runoff to creeks. Tanks are most effective at reducing volumes of stormwater runoff when connected to regular internal uses such as toilet flushing and cold water washing, because the regular drawdown leaves them with room to receive and retain the next rainfall which occurs (Figure 9). Tanks do not need to be very large (around 3,000L) to provide adequate stormwater retention, if there is a significant regular demand drawing on the tank. A landholder or developer may of course wish to use a larger tank, to ensure there is enough water to reliably meet the needs for garden irrigation or other purposes. Tanks are particularly good at reducing the volume and frequency of small runoff events, and in doing so, reducing the loads of pollutants. The infiltration objective does not score well for tanks used solely for internal demands (because no water is infiltrated to soils), but where the overflow from the tank is directed to a raingarden or infiltration trench, all three performance indicators can be met effectively (and thus meet the minimum standard of SRS 6). Assumptions used in modelling tanks are provided in Table 4.

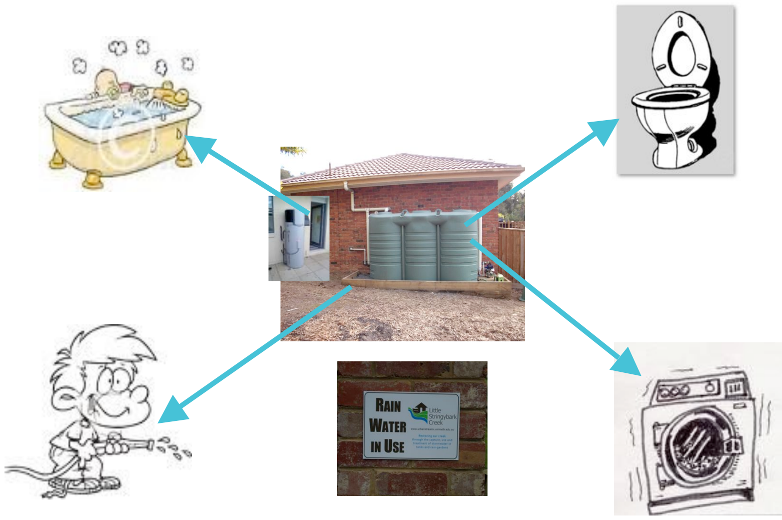

Figure 9 Potential residential uses of water from rainwater tanks

Table 4 Modelling assumptions for rainwater tanks

Assumptions	Source / Justification
Rainwater tanks modelled at 3kL	Given limitations on demands utilised in the modelling, tanks above 3kL did not significantly improve the SRS score. However, in a particular case, where there was greater demand, a proponent may wish to use larger tanks.
Entire roof area intercepted via single tank	New dwellings are able to configure roof to single outlet, for example using a 'charged' system.
Roof below 200m^2 modelled with two people water usage Roof 200m^2 and above modelled with three people usage	Reflect likely demographics – same assumptions as used by Melbourne Water & DSE in 6 star DTS tables
Toilet demand: 18.9L per person per day Cold water washing: 35.31L per/p/d, 23.54 for additional people 46.9L p/p/day hot water (Wilkenfield, 2006 estimate of 61L minus half of wash)	From Wilkenfeld (2006)
No garden demand	Too difficult at the development stage to estimate area that would be watered. In addition, monitoring of tanks in the catchment show that garden use is irregular and unpredictable (Burns et al. 2012a).
3 years of 6 minute rainfall data: Average year: 1965, 956 mm; Dry year: 1967, 661 mm; Wet year: 1970, 1085 mm.	Allows behaviour of tanks to be considered in a range of climatic conditions.
No first flush	Insignificant difference so left out of modelling – in reality first flush diverters would be utilised, but will neither significantly improve nor diminish performance.

Passive Irrigation Tanks

Allowing a tank to slowly trickle to a garden bed all year round is another effective treatment measure, helping both to improve the stormwater retention performance of the tank, but also providing infiltration. The tank is drawn down slowly using a soaker or drip hose, providing space in the tank to capture the next rainfall event, effectively reducing volumes, frequent flow events and also allowing water to infiltrate back into the ground to recharge stream baseflows. Water quality is effectively treated through the filtering process of the soil. The passive irrigation tank can take a variety of forms (Figure 10) such as:

- A completely separate tank that takes the overflow from a tank that is already used to supply the indoor uses (such as the toilet)
- The top portion of a larger tank, where the water only leaks out from the top part leaving the water in the base of the tank for reuse
- An isolated tank that captures all or a portion of the roof that can't be connected to a rainwater harvesting tank

It is important that the trickled stormwater is managed and controlled to ensure it doesn't affect adjacent properties or cause erosion. Given that this treatment approach is relatively new, a conservative approach has been used to prevent these issues. The systems should be designed such that the garden area receiving the trickle cannot receive more than the annual rainfall volume through the trickle (in other words, such that the total water applied to the garden is no more than twice the 'normal' rainfall, including both the 'real' rainfall and the trickled water). Table 5 below outlines the modelling assumptions used when assessing this treatment system. This system has not been included in the DTS look up table as the amount of garden area available is too site-specific to make a general assumption. However, developers who wish to use this technique could undertake the modelling necessary to satisfy the Relevant Authority.

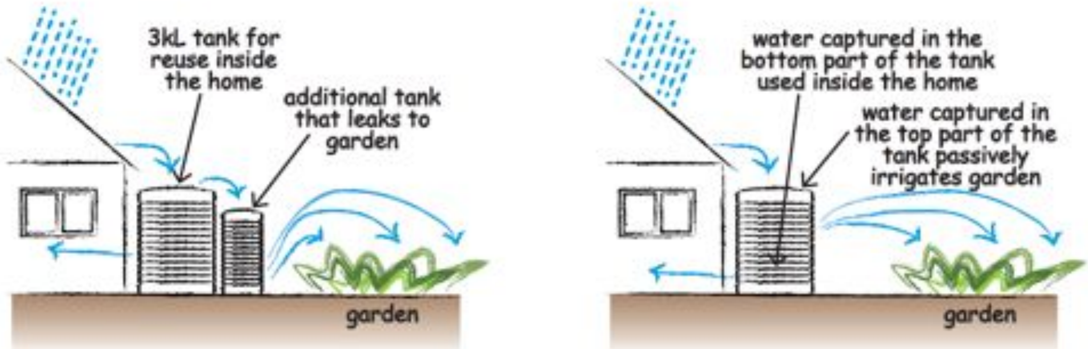

Figure 10 Options for setting up a passive irrigation tank treatment system

Table 5 Modelling assumptions for passive Irrigation tanks

Assumptions	Source / Justification
Modelled as a separate tank	Tank can be combined with another tank used for internal demands. In practice the passive irrigation component could be provided Differences in modelling results will be small.
Leak rate is $0.1L/hr/m^2$	Simulates volume contributing to baseflow rates.
Annual volume applied to pervious area from the tank is capped at the annual rainfall volume (956 mm Croydon rainfall station)	The garden area capable of absorbing up to twice the annual rainfall, without causing waterlogging problems.
Tank is modelled to leak all year	Maximises stormwater retention. Garden area needs to be sufficient to absorb the water.
Passive irrigation trickle outlet at bottom of tank	Since passive irrigation tank is modelled separate to rainwater tank

Raingardens

Raingardens are typically designed to promote infiltration and evapotranspiration although one or more sides may need to be lined if close to a boundary or buildings (Figure 11). Designs can be very flexible, varying with width, length and depth and with various types of plants (Figure 12). Raingardens in the DTS table are based on a typical design with modelling assumptions outlined in Table 6 below. In order to meet the minimum development standard SRS 6 the surface area of a raingarden needs to be about 4% of the impervious area (i.e. 4 m^2 for each 100 m^2 of impervious area). This area reduces to about 1% if the raingarden has a rainwater tank for internal use upstream (as this reduces the flow volume going into the raingarden).

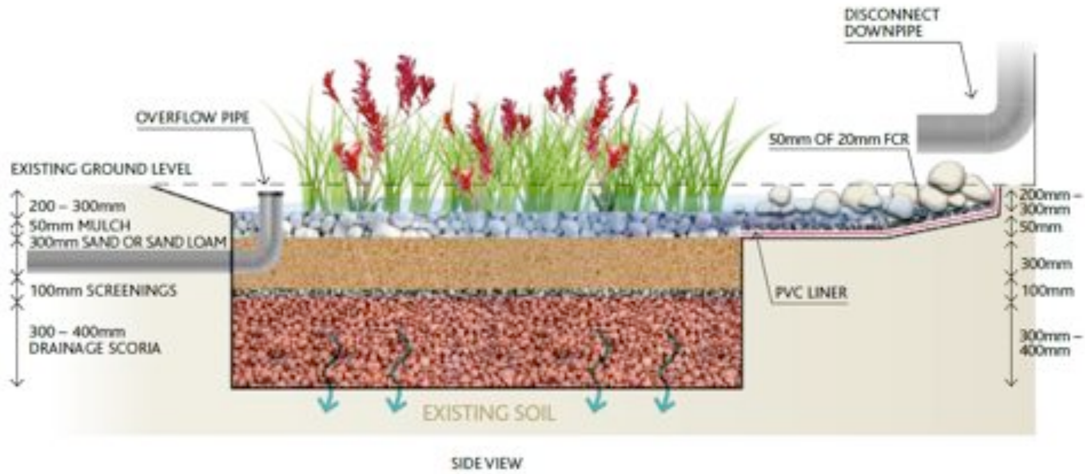

Figure 11 Typical design of an infiltration raingarden. (Source – 10k raingarden brochure www.melbournewater.com.au)

Figure 12 Images of typical raingardens from the Little Stringybark Creek catchment showing variation in design and settings

Table 6 Assumptions used in modelling raingardens

Assumptions	**Source / Justification**
Length always twice the width Hence, perimeter = 6x√(area/2)	- Same assumption as EB calculator, perimeter affects infiltration and hence important to keep length and width ratios consistent - This does not preclude alternative configurations in reality
1m depth filter media (500mm filter media and 500mm scoria)	Deeper than traditional raingardens. 600mm scoria used to maximise stormwater retention through evaporation and infiltration (thus allowing a smaller area to be used) Maximum depth before an excavation permit is required
Raingardens are vegetated	Maximises evapotranspiration (helps to reduce stormwater volume) and maintains soil porosity (ie. reduces risk of clogging). Also enhances garden landscape.
All sides unlined (for the DTS, with some lining in the case studies) ex/infiltration rate 0-300mm depth = 150mm/hr >300mm depth = 0.005mm/hr	Typical for Mt Evelyn as per geotechnical investigations conducted throughout the area.
Extended detention depth 0.3m	Maximum before special safety requirements needed and potential for permit
Filter profile default for Mt Evelyn • Filter media thickness= 500mm , porosity=0.4, infiltration=150mm/hr, exfiltration= 0.005mm/hr • Scoria thickness= 500mm, porosity=0.6, exfiltration=0.005mm/hr.	Typical soil filter profile used in stormwater retention raingardens (and already applied and demonstrated to work in many monitored raingardens in Mt Evelyn)
The model assumes ET loss from a wet, vegetated raingarden of x sq m is equivalent to the Potential ET loss from x sq m (ie. makes the assumption that ET is not limited by soil moisture)	(using Bureau of Meteorology potential evapotranspiration (PET) figures for the region)
3 years of 6 minute rainfall data: Average year: 1965, 956 mm; Dry year: 1967, 661 mm; Wet year: 1970, 1085 mm.	Allows performance in a range of climatic conditions to be considered.

Shallow raingardens

An alternative to the deeper-style raingarden described above is the shallow raingarden. This style of raingarden does not require multiple filter layers. Instead, the system uses typical topsoil (local or purchased) for its upper layer. Stormwater runoff is directed into a vegetated depression, which has about 300mm of extended detention (Figure 13 and Figure 14). Evaporation, transpiration and some infiltration are the main forms of stormwater treatment and retention. In order to perform as effectively as an infiltration raingarden (as described above) the surface area of the system needs to be twice the size of an infiltration raingarden (there is thus a tradeoff between easier (and cheaper) construction versus increased area required. These types of raingardens are cheaper and faster to build than a traditional infiltration raingarden, but require significantly more area in order to work effectively. Assumptions used to model this type of raingarden for the case studies are outlined in Table 7 below.

Figure 13 Image of a shallow raingarden constructed in the Little Stringybark Creek catchment

Table 7 Assumptions used in modelling shallow raingardens

Assumptions	Source / Justification
Length always twice the width Hence, perimeter = 6x√(area/2)	- Same assumption as EB calculator, perimeter affects infiltration and hence important to keep length and width ratios consistent - This does not preclude alternative configurations in reality
0.1m filter media with 150mm/hr infiltration rate	Assumes the top layer of soil has a higher infiltration rate.
300mm extended detention	Standard design
vegetated	Maximises evaporation and transpiration
Exfiltration to surrounding soil i.e. below 100mm = 0.005 mm/hr	Consistent with modelling other infiltration systems
3 years of 6 minute rainfall data: Average year: 1965, 956 mm; Dry year: 1967, 661 mm; Wet year: 1970, 1085 mm.	Adequate for modelling selected treatment systems

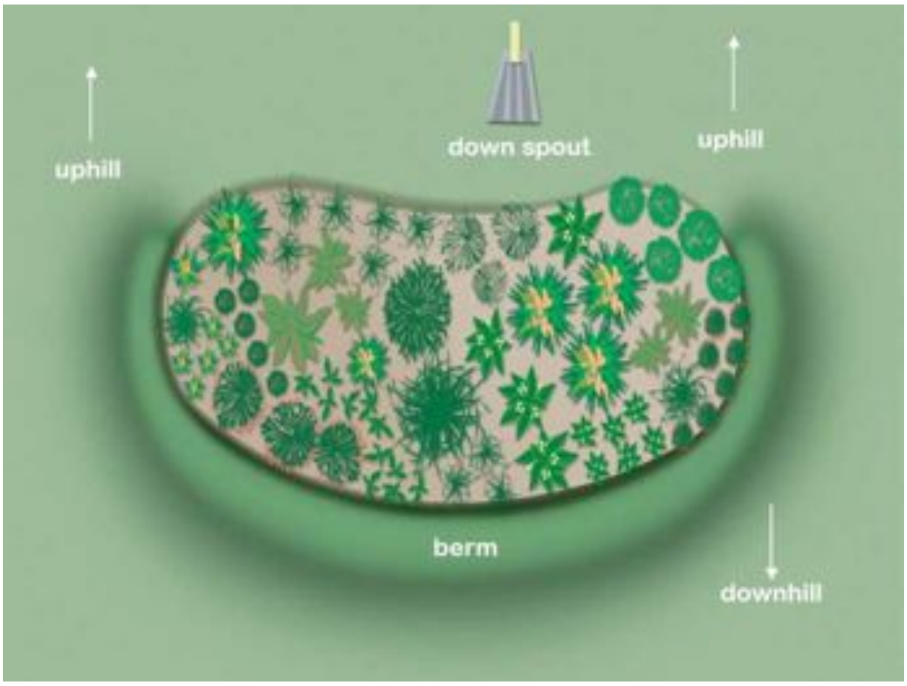

Figure 14 Schematic of shallow raingarden adapted from Raingarden Manual for Home owners - Geauga Soil and Water Conservation District

Infiltration trenches
An infiltration trench is a gravel-filled trench (**Figure 15** and **16**) below the ground surface, designed to receive stormwater. The trench can receive stormwater from a disconnected downpipe or from surrounding hard surfaces such as a driveway or paving collected in the drainage system. It incorporates a trench of gravel or scoria wrapped (top and sides) in a geotextile that is then covered typically with around 10-30 cm of topsoil and then grass, although such a system could be positioned under a driveway, provided that adequate reinforcement is provided. Infiltration trenches typically need to be sized to about 12% of impervious area to meet a SRS of 6, or about 3% if a rainwater tank connected to internal demands retains some of the stormwater and the trench just receives the overflow from the tank. The benefit of infiltration trenches is that because they are underground, they effectively do not take up any garden area.

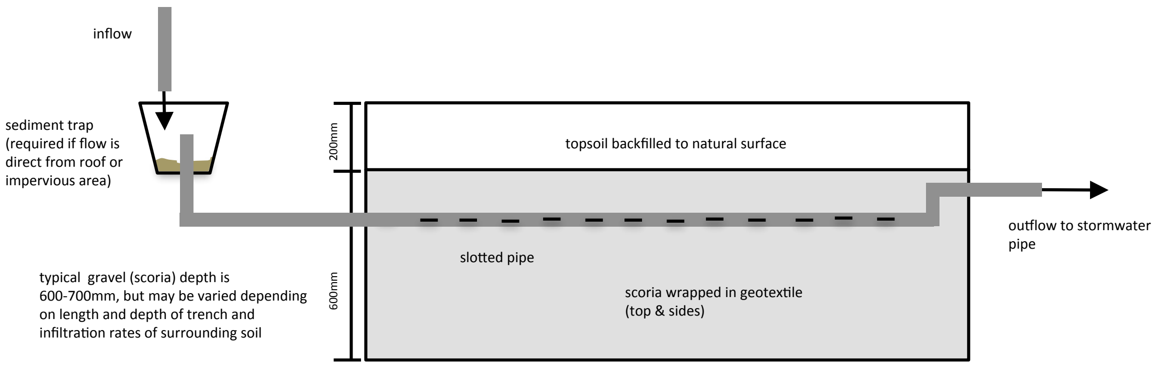

Figure 15 Cross section of typical infiltration trench. Note that a sediment trapping pit is shown; these are required wherever there is no upstream tank or other pre-treatment system to prevent clogging with leaves and debris. Backfill topsoil depth may vary depending on type of vegetation to be planted (if any).

Figure 16 Photo of an infiltration trench under construction (note geotextile used to prevent soil migrating into gravel layer below, as a minimum geotextile should be used on the top and sides of the gravel layer)**.**

Table 8 Assumptions used in modelling infiltration trenches.

Assumptions	**Source / Justification**
1m depth scoria filter media[1]	Maximum safety depth before excavation permits required
0.45m wide trench	Standard configuration
0.2m topsoil depth (150 mm/hr infiltration rate within this depth)	Standard configuration – optimal amount for treatment
All sides and base unlined	Maximises infiltration

[1] note that in practice an 800mm scoria layer should be built with 200mm of top soil to ensure the total depth of trench does not exceed 1m (the trigger for an excavation permit). The lookup tables while modelled using the above assumptions will be allowed to be built to 1m and not 1.2m and still meet the required standard. The discrepancy with modelling results is considered minimal.

Diffuse runoff dispersion

One of the simplest and cheapest options to manage runoff from impervious areas is to direct or divert this water to a lawn or garden. By grading a driveway to fall towards the lawn or adjacent garden bed, water which runs off the surface will infiltrate into the garden and not enter the stormwater system. This helps retain water on the property, and also provides the added benefit of passively watering the lawn or garden area.

Sizing these treatment systems is very simple: you need at least an equivalent amount of pervious area to treat the impervious area. For example, if the new paving area is going to be $25m^2$, then at least $25m^2$ of lawn or garden is needed to absorb the additional runoff. This option should only be used where the lawn or garden has a slope of 4% or less (on steeper slopes, runoff and erosion are likely).

Table 9 Assumptions used for simple shedding of runoff approaches

Assumptions	Source / Justification
Equivalent pervious area to impervious area required to adequately absorb and treat impervious runoff.	The pervious area should not receive in total more water than 2x the annual rainfall; ie. Rainfall onto the pervious + equivalent to 1 x rainfall volume from the impervious surface.
All metrics get perfect score – no modelling required	EB calculator does cannot currently model the flow metrics for this technique.
Slope: assumed to be no more than 4%	Slopes above this may result in runoff and erosion.

Permeable paving

Permeable paving allows water to flow through the paver, and infiltrate into the soil. It is also known as 'porous paving' or 'pervious paving'. In areas with clay soils such as Mt Evelyn, the pavers need to be laid on a base of sand, with an optimal sub-base of crushed aggregate. This increases the infiltration and storage capacity of the paved area. There are two basic types of permeable pavement: (i) porous concrete / asphalt (where the concrete or asphalt is made with pores, to allow water to infiltrate), (ii) paving block types, where water infiltrates either through the blocks or between the blocks (which are deliberately designed to allow a gap between each block for infiltration).

Permeable paving is required to occupy at least 26% of the impervious area in order to adequately treat the area to the minimum standard (see **Table 11**).

Table 10 Assumptions used for permeable paving

Assumptions	Source / Justification
Infiltration performance of the pavement (including gravel/sand substrate) is at least 360 mm/hr.	Permeable pavement typically has a much higher infiltration rate (several thousand mm/hr), but the underlying sand/gravel will limit the infiltration rate, as will build-up of sediment and debris over time.
Water below permeable pavement drains to underlying soil at 0.005 mm/hr	Based on geotechnical investigation of LSC catchment.
	There is no impermeable liner under the permeable pavement.
Pavers are underlain by at least 300 mm of sand and/or gravel.	Actual specification will depend on manufacturers' specifications.
The impervious pavement drains towards the pervious pavement.	This is essential to ensure that the pervious pavement can infiltrate runoff from the remaining impervious area.

7. Application of the new stormwater standard

Proposed Minimum Stormwater Retention Score

A **Stormwater Retention Score (SRS) of 6** is proposed as the minimum development standard for the Little Stringybark Creek catchment.

A number of factors were taken into account to determine an appropriate minimum SRS – the proposed minimum standard for new developments in the catchment, to be implemented through an ESO planning control. These factors are outlined in more detail below and largely included:

- Protection of stream health – the minimum level of stormwater retention required to protect stream health, in order to protect the Little Stringybark Creek for the community
- Availability of appropriate technologies – the standard should not require more than can already be achieved using currently available robust technologies and appropriate design assumptions,
- Cost – the potential economic impact on developers, ensuring that these were maintained at a reasonable level, and that incentives provided opportunity to offset at least part of these impacts
- Site constraints – e.g. space available in typical developments in the catchment to implement the proposed solutions

The suitability of the SRS6 required also included an assessment of several typical developments ('case studies'; see Section 8) in the catchment. The case study modelling shows an exponential increase in treatment size (and hence cost) to achieve scores greater than 6 (see **Figure 17**). The current "best practice" requirements (Victorian Stormwater Committee, 1999) for pollutant loads require around 1-3% of the impervious catchment area for adequate treatment, however some systems require significantly higher areas – which can also be the case for achieving an SRS score of greater than 6 in some properties. Keeping the treatment area to less than 5% of the impervious area was considered reasonable. The graph (**Figure 17**) clearly shows that the size requirement increases rapidly beyond 5% for very little improvement in SRS. The other key reason for selecting SRS6 was that it was practically and cost effectively achievable in a number of typical developments across the catchment. *The case studies outlined below demonstrate that SRS6 is practically achievable.*

Deemed to Satisfy (DTS) Lookup table

Setting a minimum SRS of 6 allowed the development of a series of Deemed to Satisfy solutions. The DTS table contains seven basic options:

- Option 1: 3kl rainwater tank (toilet use), with overflow to raingarden
- Option 2: 3kl rainwater tank (toilet + washing machine) with overflow to raingarden
- Option 3: 3kl rainwater tank (toilet use), with overflow to infiltration trench
- Option 4: 3kl rainwater tank (toilet + washing machine) with overflow to infiltration trench
- Option 5: raingarden only
- Option 6: infiltration trench only

- Option 7: permeable pavement (for driveways, etc)

Table 11 provides 'default sizing' of several types of the treatment systems in order to meet the minimum standard. This table is designed to be a simple lookup table for developers to size systems quickly without further modelling. All design and modelling assumptions are provided in the preceding tables.

Table 11 SRS6 Deemed To Satisfy (DTS) table for standard treatment systems modelled using the assumptions documented in Section 6. The DTS lookup table provides 'default sizing' of several types of the treatment systems in order to meet the minimum standard. This table is designed to be a simple lookup table for developers to size systems quickly without further modelling. All design and modelling assumptions are provided in the preceding tables.

Impervious area (m^2)	**Option 1** 3kl tank to toilet overflow to raingarden*	**Option 2** 3kl tank to toilet & washing overflow to raingarden*	**Option 3** 3kl tank to toilet overflow to trench	**Option 4** 3kl tank to toilet & washing overflow to trench	**Option 5** Rain-garden only *(m^2)	**Option 6** Infiltration trench only (m)	**Option 7** Permeable pavement (m^2)
	Raingarden* (m^2)		Infiltration trench (m)				
10	1	1	1	1	1	1	3
50	1	1	2	1	2	3.5	3
100	1	1	4	2	4	7	6
150	2	1	9	3	5	11	7
200	3	1	13	5	5	15	9
250	4	2	17	7	6	19	12
300	5	2	22	9	7	21	15
350	6	3	29	13	9	25	18
400	7	4	35	19	11	29	21
450	8	5	41	25	13	33	24

* Assumes normal raingarden. Where shallow raingarden is to be used instead, the area required will be twice that of the normal raingarden.

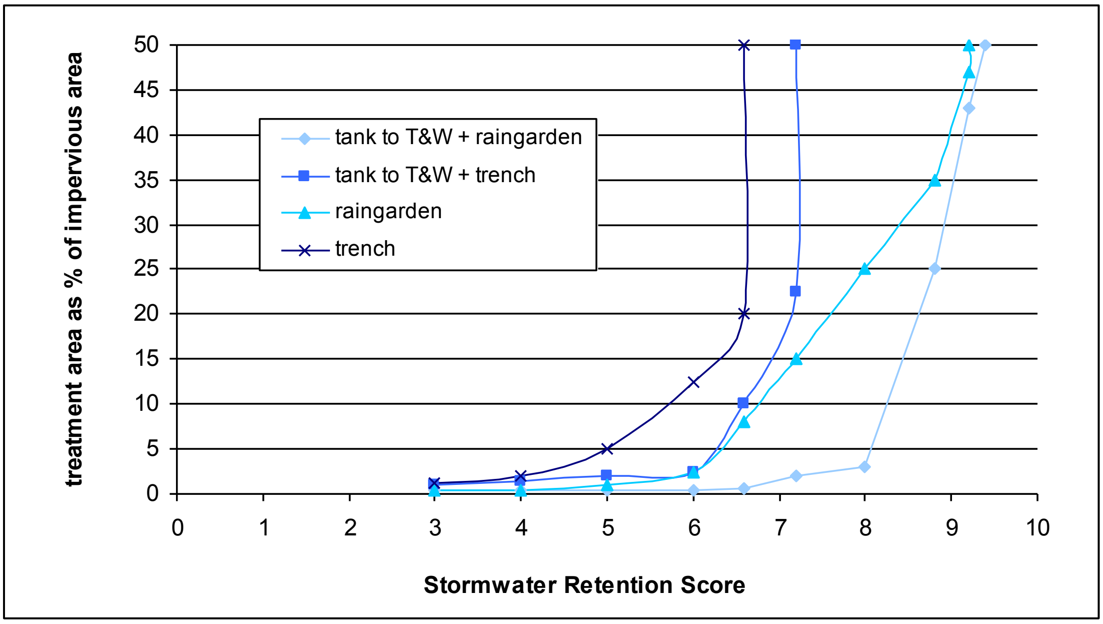

Figure 17 Treatment size (ie. surface area of raingardens or trench) as a % of the catchment area against Stormwater Retention Scores – for an impervious area of 200m^2.

Proposed Incentive Scheme

An incentive scheme is proposed to be implemented as part of the new stormwater control, to support and encourage developments to exceed the minimum standard. Some of the case studies in Section 8 demonstrate how easy it may be to go beyond SRS6 and to receive a financial incentive which exceeds the additional cost of the works. This may also help developers to partially offset the overall cost of the works.

The incentive scheme (see **Table 12**) proposes to offer $1000 per SRS beyond SRS6, paying $100 per 0.1 SRS (e.g. a development which achieved an SRS of 8.5 would be eligible for $2,500). The approach is simple and treats all developments equally regardless of size.

The incentive will be funded by Melbourne Water for the 3 year period that the pilot stormwater control will initially be in place, which is intended to last 3 years.

Table 12 Proposed incentive scheme for works which exceed the minimum standard of SRS6.

SRS	Incentive
6	0
7	$1,000
8	$2,000
9	$3,000
10	$4,000

8. Case Studies

Infill development in the form of extensions, dual occupancies and multi-units are the main type of developments in the Little Stringybark Creek catchment. Case studies were developed for a number of these typical developments, randomly selected from real examples in the catchment. Relevant information including drainage and landscape plans was obtained from council planning permit records. A series of workshops with representatives from council, Melbourne Water, the University of Melbourne and STORM consultancy were conducted to assess how each development could incorporate the above typical treatment measures and achieve the proposed minimum standard – SRS6. The aim was to test whether the standard could be practically achieved at a reasonable cost.

A number of rules and assumptions were agreed upon and applied to each case study. While many of these are documented in the modelling assumption tables provided in section, the following list summarises additional assumptions:

- The developments were typically built in the last 5 years and no attempt was made to 'theoretically' alter the layout of the development in order to make it easier to achieve the standard.
- Infiltration systems were lined where appropriate e.g. if within 5m of property boundaries or buildings.
- Treatments were positioned to treat runoff within a property boundary and not conveyed or discharged to another property within the same development (unless it was common properly).
- Nature strips were not utilised as treatment opportunities.

- Private open space requirements were taken into account and treatments avoided in these areas.
- Disturbance to existing vegetation, particularly mature trees, was avoided.
- All attempts were made to select the most cost effective systems.
- Treatment systems were limited to:
  - Rainwater tanks restricted to toilet and cold water washing demands
  - Passive irrigation tanks
  - Raingardens (unlined, lined and US style)
  - Infiltration trenches
  - Diffuse runoff dispersion
- All modelling was carried out using scripts based on the on-line EB calculator http://www.urbanstreams.unimelb.edu.au/e_benefit.htm
- Costs were consistently estimated for each case study – see method below

Costs were estimated in detail for each case study. Detailed cost assumptions are outlined in **Appendix A**. Local cost estimates for stormwater retention systems are are available from the current Little Stringybark Creek retrofit program (which has installed 200 tanks and 100 raingardens / infiltration trenches within the catchment since 2008; see www.urbanstreams.unimelb.edu.au); however these reflect a retrofit situation where costs are likely to be significantly higher than those incurred when a site is being developed. The retrofit costs were used as a potential 'high' end cost and a basis from which reductions on various unit costs were made – to attempt to factor in 'absorbed' development costs. It was also considered reasonable to subtract, where relevant, potential 6 star related costs, as it was observed in several of the case studies that tanks were incorporated as a result of this regulation. Building Regulations currently require either a solar hot water system or a 2 kl tank connected to 50m^2 of roof and connected to all internal toilets. For a developer, the most cost-effective option would be to use the tank option (upgraded to 3 kl) to simultaneously meet both the 6 star standard and the SRS6.

Case Study 1 (Dual Occupancy)

This development includes the addition of a second house (236m^2) and driveway (42m^2) on a 580 m^2 block (**Figure 18**), which makes the site 47% impervious. The block slopes to the south-east towards the driveway and road which is where the Approved Point of Discharge is located. Extensive excavation has occurred to flatten the site and a retaining wall is located along the east boundary. The extensive cut on the site makes the soil even more impermeable, a constraint on infiltration systems, which would require even further excavation.

Table 13 Summary of SRS treatments, score and costs for Case Study 1.

Proposed Treatment	**Treatment Cost** (see Table 14)	**SRS Score** (see Table 15)	**Incentive Scheme Payment**	**Net Cost to Developer**
Tank for toilet and passive irrigation	$730	6.6	$600	$130

The best solution for treating the 236m^2 roof was thought to be a 3kl tank connected to toilet and cold water washing with an additional 2kl of tank storage to be used for passive irrigation to around 35m^2 of garden area. This area represents about 1/3 of the backyard, which was proposed to be landscaped in some way. Due to the slope of the driveway only about 2/3rds could be easily treated with either an infiltration trench or a raingarden. However, treating the driveway was not needed to meet the minimum standard of SRS6. The cost for this system could be as low as $730, assuming that a tank was likely to be installed as part of the 6 star building regulations.

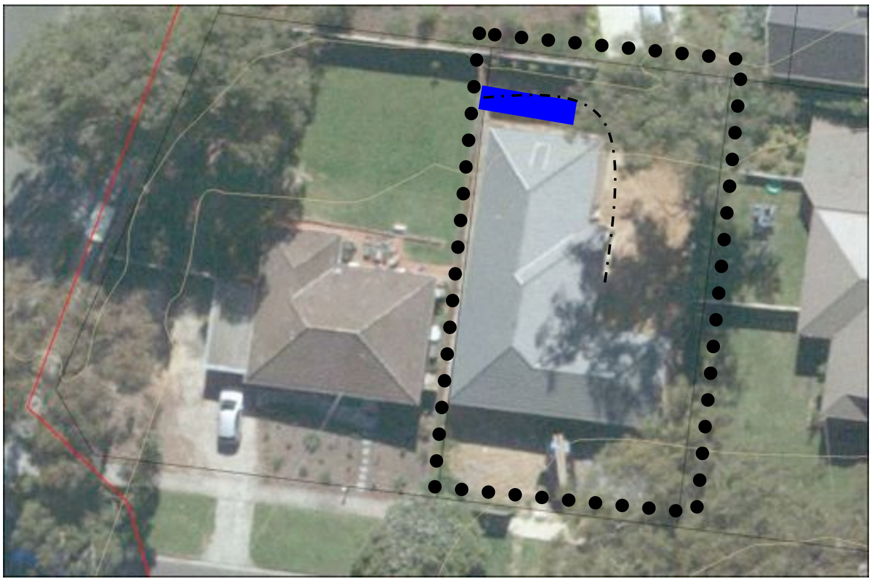

Figure 18 Aerial photo of the new building constructed as part of the dual occupancy development in Case Study 1.

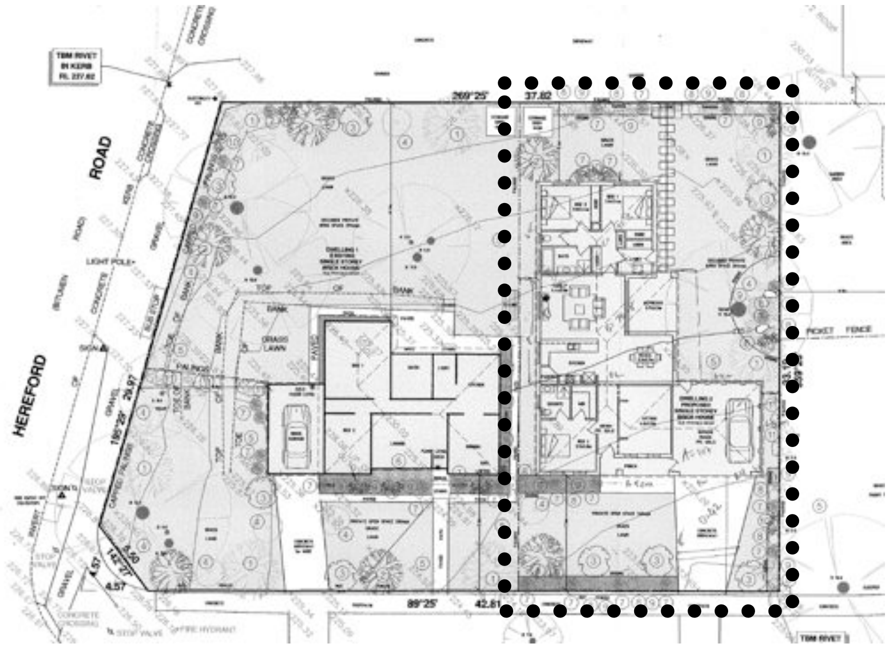

Figure 19 Approved plan of the new development for Case Study 1.

Table 14 Breakdown of costs for proposed treatment system (costs assumed based on rainwater tank already installed to meet 6 star) in Case Study 1. Other costs are derived from LSC retrofit project, with absorbed developed costs (e.g. call-out cost of plumber, since they will already be on site for other plumbing works as part of the development) assumed. Full details of cost assumptions are presented in Appendix A.

Cost elements	Estimated cost	Sources and explanation
Usage fitting costs (eg pipes and downpipes)	$300	Remove toilet costs ($150) as covered by 6 star
Toilet and washing		
Pump and electrics	0	Covered by 6 star
Tank 5kl	$100	Cost of a 5kl tank minus costs of a 2kl tank.
Labour	$330	Assumes an additional 3hours above that needed to install a tank to 6 star requirements.
Tank base	0	covered by 6 star
Electrician	0	covered by 6 star
Passive irrigation system	0	Costs considered negligible – LSB retrofit estimate
Total	**$730**	

Table 15 Summary table of SRS performance for Case Study 1.

Impervious area treated	Proposed system	FF index	V index	FV index	Av index	SRS
Roof (236m^2)	3kl tank connected to toilet and cold water washing with a 2kl passive irrigation tank to 35m^2 of garden	1.86	1.33	2.36	1.85	7.8
Driveway (42m^2)	Not treated	0	0	0	0	0
Weighted average SRS			(1.85+0)/2.78			**6.6**

Case Study 2 (Dual Occupancy)

This development is a typical dual occupancy where a common driveway is created to gain access to a new property at the rear of the block. It includes a new house (180m^2), a new driveway (215m^2) and a new garage (33m^2) for the existing house (236m^2). Together the properties are 700m^2 and the percentage of impervious cover for the whole site including the existing property is just over 60% (new impervious area totals 421m^2). The block slopes to the south-west, where there is a 1.8m drainage easement in the rear of the property. A 3kl tank is proposed for the new house – presumably to meet 6 star requirements.

Table 16 Summary of SRS treatments, score and costs for case study 2.

Proposed Treatment	**Treatment Cost** (see Table 17)	**SRS Score** (see Table 18)	**Incentive Scheme Payment**	**Net Cost to Developer**
Tanks for toilet, washing and passive irrigation and a rain-garden	$2,125	6	$0	$2,125

With the current layout this is a difficult site to achieve the SRS6 standard. The permeable areas are quite small and discrete and often quite close to the houses or property boundaries, and hence treatment systems would need to be lined. The best solution for this development was to offset some of the new driveway area by treating the existing house. The driveway is quite extensive and there is little room to effectively treat all of it. As can be seen in **Figure 20**, the best solution included a 3kl tank to toilet and cold water washing for the new house with an additional 2kl of storage which will slowly leak into a 7m^2 lined raingarden positioned on the south side of the driveway. This raingarden also treats about half of the driveway (128m^2). The existing house and the new garage are treated with a 3kl tank plumbed to toilet and cold water washing with an additional 2kl of storage that will 'leak' and passively irrigate about 20m^2 of garden in the front yard. This effectively offsets the remaining 80m^2 of untreatable driveway.

Figure 20 Aerial photograph of layout of dual occupancy development in Case Study 2.

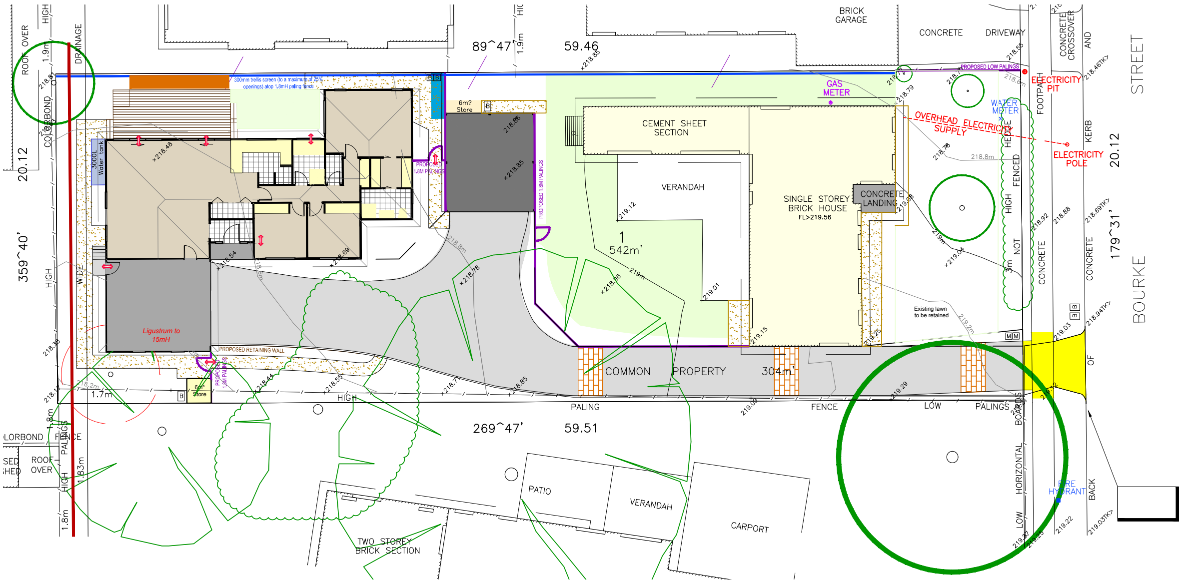

Figure 21 Approved plans for dual occupancy development of Case Study 2.

The costs for the proposed system for this case study amount to around $2,125 (**Table 17**).

Table 17 Breakdown of costs for proposed treatment systems in Case Study 2.

Item	Cost elements	Estimated cost	Sources and explanation # All costs derived from Little Stringybark Creek Project costs
2X5kl tank plumbed to toilet and cold water washing with leak to garden	Usage fitting costs (eg pipes and downpipes) Toilet and washing	$300 x 2	Remove toilet costs ($150) as covered by 6 star
	Pump and electrics	0	Covered by 6 star (LSB retrofit costs $X)
	Tank 5kl	$100 x 2	Cost of a 5kl tank minus costs of a 2kl tank. (ie $X-$X)
	Labour	$330 x 2	Assumes an additional 3hours above that needed to install a tank to 6 star requirements. ($X for a retrofit)
	Tank base	0	covered by 6 star (LSB retrofit costs $X)
	electrician	0	covered by 6 star (LSB retrofit costs $X)
	Total	**$730 X 2 = $1,460**	
7m2 lined Raingarden **Total**	Raingarden connection	0	A plumbers cost which should be negligible in a larger development. ($250 for a retrofit)
	Filter media	$50/m2	Costs for soil should be significantly reduced where other landscaping is incorporated. ($100/m2 for a retrofit)
	Pipes	$150	Cost of pipes should be significantly reduced in a larger development. ($300 for a retrofit)
	Plants	$15/m2	Costs for plants should be significantly reduced where other landscaping is incorporated. ($30/m2 for a retrofit)
	excavation	0	The amount of excavation required for a raingarden is likely to be small in comparison to other excavation on the site and hence costs should be minimal. ($100/m2 for a retrofit)
	Pit	$60	Cost of a installing a pit would be minimal alongside all other plumbing on the site. ($120/m2 for a retrofit)
	Total	**$665**	
Combined total		**$2,125**	

Table 18 Summary table for Case Study 2.

Impervious area treated	Proposed system	FF index	Vol index	FV index	Ave index	SRS
New house ($180m^2$) +$128m^2$ of driveway	New house into 3kl tank with 2kl 'leaky' tank overflow to $7m^2$ lined raingarden Driveway also directed to the $7m^2$ raingarden	0.28	3.08	0.68	1.36	3.5
New garage ($33m^2$) plus existing house ($236m^2$)	3kl tank with 2kl 'leaky' tank to $20m^2$ of garden	1.33	1.08	1.1	1.11	4.3
Untreated driveway area	$80m^2$	0	0	0	0	0
Total impervious area treated = $577m^2$	Weighted Average SRS		(1.36+1.11)/4.21			**6**

Case Study 3 (Multi-uinit)

This case study is typical of a multi-unit development in the catchment, in which an old house is demolished to make way for several new semi-detached dwellings – each on a separate title with a shared driveway. The $1,500m^2$ site has had 3 dwellings built, including carports. Most developments of this nature incur a set back requirement which in this case has restricted the density of the development and provided enough space ($220m^2$) for stormwater treatment. However, due to the presence of two mature trees, excavating raingardens or trenches was not considered the best option. The combined roof area is $503m^2$ and the paving area is $260m^2$ (total new impervious area = $763m^2$). The property slopes and drains to the southeast with an APD (approved point of discharge) at the street. There is minimal private open space around the back two dwellings. The driveway appears to have been designed to protect some existing vegetation and there are also two significant trees at the front of the block.

Table 19 Summary of SRS treatments, score and costs for Case Study 3.

Proposed Treatment	Treatment Cost (see Table 20)	SRS Score (see Table 21)	Incentive Scheme Payment	Net Cost to Developer
Tanks for toilet, washing and passive irrigation	$2,840	7.1	$1,100	$1,740

As depicted in **Figure 22**, the most cost effective solution for this site was for the rear two houses to each have 3kl tanks connected to toilet and cold water washing with additional 2kl storage tanks that passively irrigate (via a trickle outlet) the garden area to the south of the driveway. Each tank can effectively passively irrigate about $30m^2$ of garden. The overall size of this garden area is $100m^2$ and is also utilised to treat a portion of the driveway (D1 – $200m^2$ see **Figure 22**). Excavating a raingarden or trench was not possible due to existing vegetation and hence a simplified built-up raingarden was modelled (see shallow raingarden description in Section 6). Essentially it included creating a small embankment (approx 300mm) on the downslope side of the garden area to capture, store and infiltrate runoff from 140m^2 of driveway; essentially similar in design to a small retarding basin. The treatment area modelled was 40m^2, as the passive irrigation tanks were utilising the remaining garden area. Without the standard soil filtration layers of a typical raingarden, the system will not operate as effectively, however the relatively large ratio of pervious to impervious area (40m^2/140m^2 = 29%) helps to improve the performance. This leaves 60m^2 which is not treated for this section of driveway.

The system for the front unit includes a 3kl tank to toilet and cold water washing along with a 2kl storage tank which will leak to and irrigate about 20m^2 of the front garden. Runoff from the front section of driveway (D2 – 64m^2) can be readily directed to the front garden area. There is ample room for runoff from the 50m^2 of driveway to be dispersed to to 50m^2 of garden bed. This simple shedding of runoff approach is allowable given there is a 1:1 ratio of pervious to impervious and slopes are not great than 4%. This leaves 12m^2 of untreated driveway.

With the above treatment solution a SRS of 7 was achieved.

Figure 22 Aerial photo of new multi-unit development showing treatments

Figure 23 Approved plan for development

The overall cost of the systems on this development would be $2,850.

Table 20 Breakdown of costs for proposed treatment systems for Case Study 3

Item	Cost elements	Estimated cost	Sources and explanation
			# All costs derived from Little Stringybark Creek projects
3X5kl tank plumbed to toilet and cold water washing with leak to garden	Usage fitting costs (eg pipes and downpipes) Toilet and washing	$300 x 3	Remove toilet costs ($150) as covered by 6 star
	Pump and electrics	0	Covered by 6 star (LSB retrofit costs $X)
	Tank 5kl	$100 x 3	Cost of a 5kl tank minus costs of a 2kl tank. (ie $X-$X)
	Labour	$330 x 3	Assumes an additional 3hours above that needed to install a tank to 6 star requirements. ($X for a retrofit)
	Tank base	0	covered by 6 star (LSB retrofit costs $X)
	Electrician	0	covered by 6 star (LSB retrofit costs $X)
	Total	**$730 x 3 = $2,190**	
Shallow raingarden	Area = 40m^2, ponding depth = 300 mm. Cost = 1 day labour + hire of mini-skidsteer for earthworks	$650	
Total		**$2,840**	

As the minimum standard was exceeded and a SRS7 achieved, a $1000 incentive is possible and would reduce the increased development costs for the site to $1,850.

Table 21 Summary table for Case Study 3

Impervious area treated	Proposed system	FF index	V index	FV index	Av index	SRS
R1 ($200m^2$)	3kl tank to toilet and cold water washing with 2kl storage slowing leaking to $30m^2$ of garden	2	2	0.95	1.65	8.25
R2 ($150m^2$)	3kl tank to toilet and cold water washing with 2kl storage slowing leaking to $30m^2$ of garden	1.5	1.5	0.67	1.22	8.2
D1 ($140m^2$)	$40m^2$ shallow raingarden	1.4	1.4	0.42	1.07	7.6
D1 ($60m^2$)	No treatment	0	0	0	0	0
R3 ($153m^2$)	3kl tank to toilet and cold water washing with 2kl storage slowing leaking to $20m^2$ of garden	1.11	0.86	1.14	1.03	6.7
D2 ($50m^2$)	Diffuse runoff dispersion to $50m^2$ front garden	0.5	0.5	0.5	0.5	10
D2 ($12m^2$)	No treatment	0	0	0	0	0
Total imp area ($763m^2$)	**Weighted SRS**	(1.65+1.22+1.07+0+1.03+0.5+0)/7.63				**7.1**

Case Study 4 (extension)

With relatively large blocks in the Mt Evelyn area it is quite easy to achieve the minimum standard for a simple house extension. This case study is an example of this type of development. **Figure 24** below shows the house with the added extension. The additional impervious area added to the site is $150m^2$ making the total impervious area $400m^2$. Even with the extension the property only has an impervious cover of 20%. While there is an APD on the street the block slopes to the rear.

Table 22 Summary of SRS treatments, score and costs for Case Study 4.

Proposed Treatment	Treatment Cost (see Table 23)	SRS Score (see Table 24)	Incentive Scheme Payment	Net Cost to Developer
Tank for toilet, washing and passive irrigation	\$3,270	8	\$2,000	\$1,270

There are many options for treating this site to achieve SRS6. Using the DTS table, the following systems would meet the standard:

- A 3kl tank to toilet overflow to $2m^2$ RG
- A 3kl tank to toilet and washing overflow to $1m^2$ RG
- A $5m^2$ RG
- A 20m trench

A cheaper solution however which cannot be determined from the DTS table is a 3kl tank connected to toilet and cold water washing combined with a 2kl passive irrigation tank. There is ample garden area available (500m^2 backyard) and even passively watering 50m^2 of this area with a 2kl storage tank can achieve a SRS of 8.

Figure 24 Aerial photo of the completed extension in Case Study 4

As the site is an extension, there would have been no 6 star requirements for a tank or a solar hot water system. Therefore the 'additional development costs' of the treatment system will be higher than a development which has this requirement. Hence 'some' absorbed development costs but no 6 star discounts (see **Table 23** below and **Appendix A** for detailed explanations of the assumptions used), the estimated additional cost on this development would be $3,270 (**Table 24**).

Table 23 Cost details for the proposed passive irrigation system in Case Study 4

Cost elements	**Estimated cost**	**Sources and explanation**
Usage fitting costs (eg pipes and downpipes)	$300	LSB retrofit estimates
Toilet and washing		
Pump and electrics	$1250	LSB retrofit estimates
Tank 5kl	$750	LSB retrofit estimates
Labour	$770	LSB retrofit estimates (minus 5 hours from total of 12 for absorbed development costs). Assumes a labour rate of Plumber $80/hr and Labourer $30/hr.
Tank base	$200	LSB retrofit estimates
Electrician	$0	Considered to be absorbed by the development
Irrigation system for leaky tank	$0	Costs considered negligible – LSB retrofit estimates
Total	**$3,270**	

Under the proposed incentive program of $1,000/SRS beyond 6, a subsidy toward the works of $2,000 would be offered. This would significantly reduce the additional development costs to $1,270.

Table 24 Summary table for Case Study 4

Impervious area treated	Proposed system	FF index	V index	FV index	Av index	SRS
New roof (150m^2)	3kl tank connected to toilet and cold water washing combined with a 2kl passive irrigation tank to 50m^2 of garden	1.29	1.07	1.24	1.2	***8***
Combined (150m^2)		1.2/150 = 0.8 (0.8*10)				**8**

Case Study 5 (dual occupancy)

In this case study, the developer agreed to incorporate some stormwater treatment as part of the current 'interim' funding arrangement for developments (see **Box 1** in Section 4). The development includes a new house (230m^2) and 2 new driveways (20m^2 and 25m^2) one for the new and one for the existing property (**Figure 25**).

The developer agreed to install a 3kl tank connected to toilet and cold water washing with a 2kl storage tank that will slowly leak to a 6m long trench in the front of the property. The trench will also receive any overflow from the tank. Given the voluntary nature of the program meeting the proposed SRS6 standard was not pushed and hence the driveways were not treated.

Table 25 Summary of SRS treatments, score and costs for Case Study 5.

Proposed Treatment	Treatment Cost (see Table 26)	SRS Score (see Table 27)	Incentive Scheme Payment	Net Cost to Developer
Tank for toilet, washing and passive irrigation and an infiltration trench	$1,520	7.5	$1,500	$20

However, subsequent modelling of the development has shown the ease with which an SRS of 6 or higher could be achieved. For example, the driveway for the new property could be directed into the proposed trench effectively treating this area and also offsetting the need to treat the new driveway for the existing property. Adopting this and treating the second driveway with a 2m^2 raingarden would result in an SRS of 7.5.

D1

D2

Tan

Figure 25 Proposed dual occupancy development for Case Study 5

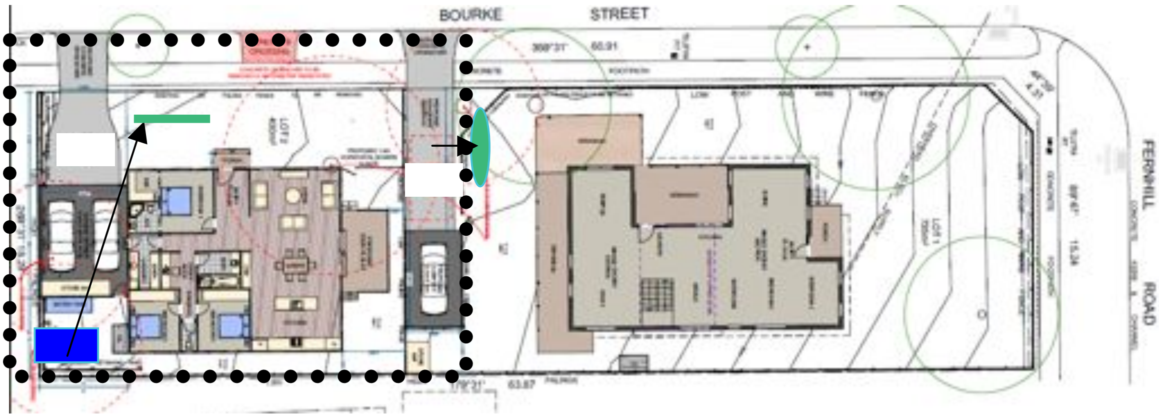

Figure 26 Details of proposed passive irrigation system and infiltration trench for Case Study 5

Costs for the proposed system outlined in **Figure 26** could be around $1,520. Given an SRS of 7.5 is achievable a $1,500 incentive is possible and would almost entirely offset the additional cost of the requirements.

Table 26 Detailed breakdown of costs for Case Study 5

Item	Cost elements	Estimated cost	Sources and explanation
3kl tank to toilet and washing plus a 2kl storage tank	Usage fitting costs (pipes, downpipes) Toilet & washing	$300	Remove toilet costs ($150) as covered by 6 star
	Pump & electrics	0	Covered by 6 star
	Tank 5kl	$100	Cost of a 5kl tank minus costs of a 2kl tank.
	Labour	$330	Assumes an additional 3 hours above that needed to install a tank to 6 star requirements.
	Tank base	0	Covered by 6 star
	Electrician	0	Covered by 6 star
	Passive irrigation	0	Costs considered negligible – LSB retrofit estimate
	Total	**$730**	
6 m trench	Connection	0	A plumber's cost which should be negligible in a larger development.
	Cost per linear length	$75/m x 6m	60% reduction in LSB retrofit estimates considered reasonable for a large development where other excavation and plumbing present.
	Total	**$450**	
2m^2 raingarden	Raingarden connection	0	A plumber's cost which should be negligible in a larger development. ($250 for a retrofit)
	Filter media	$50/m^2	Costs for soil should be significantly reduced where other landscaping is incorporated (compared to $100/m^2 for a retrofit)
	Pipes	$150	Cost of pipes should be significantly reduced in a larger development. ($300 for a retrofit)
	Plants	$15/m^2	Costs for plants should be significantly reduced where other landscaping is incorporated. ($30/m^2 for a retrofit)
	excavation	0	Excavation required for raingarden very small in comparison to other excavation on the site and hence costs should be minimal. ($100/m^2 for a retrofit)
	Pit	$60	Cost of a installing a pit would be minimal alongside all other plumbing on the site. ($120/m^2 for a retrofit)
	Total	**$340**	
Total cost			**$1,520**

Table 27 Summary table for Case Study 5

Impervious area treated	Proposed system	FF index	V index	FV index	Av index	SRS
New roof ($230m^2$) and $20m^2$ driveway	3kl tank to toilet and cold water washing with 2kl storage tank which leaks slowly to a 6m trench. Trench also receives overflow from the tank and runoff from the driveway	2.09	2.5	0.65	1.74	7.6
25 m2 driveway	$2m^2$ raingarden	0.2	0.2	0.03	0.14	7.2
Combined ($275m^2$)			(1.74+0.14)/2.75			**7.5**

9. How to assess performance

There are several tools available for assessing compliance with the proposed standard. The simplest method is to use the Deemed to Satisfy (DTS) table that has been developed. However, where proposed solutions or combinations of solutions are not covered by the DTS table, two modelling tools are available: the Environmental Benefit (EB) Calculator and the Model for Urban Stormwater Improvement Conceptualisation (MUSIC).

Deemed to Satisfy (DTS) – Lookup Tables

As described in Section 7 (**Table 11**), simple lookup tables have been developed for several treatment combinations. These include:

- Tanks for internal demand with overflow directed to a raingarden or a trench
- Just an Infiltration Raingarden
- Just an Infiltration trench
- Permeable paving
- Diffuse runoff dispersion

Modelling assumptions are outlined in Section 6 (Stormwater retention technologies and their modelling assumptions)

Increments of $50m^2$ are provided in the DTS table; where the impervious area differs from this, the next increment up can simply be selected (the difference in system sizing between $50m^2$ increments is generally small). For example a $225m^2$ roof area will need to refer to the $250m^2$ row in the DTS table.

The table does not allow impervious areas to be lumped – particularly for tank systems – because the assumptions about how much water will be used (the water demand) are related to the roof area. For example a $200m^2$ roof assumes a demand of two people. If 2 x $200m^2$ houses were lumped together and the $400m^2$ increment on the lookup table was selected it would recommend one 3kl tank to deal with both houses, assuming a water demand equivalent to that of a large house (with 3 residents). This demand will be different than 2 x 200m^2 houses (water demand per person tends to decrease as the number of residents in a house decrease, because of 'economies of scale' for activities such as clothes washing and dishwashing).

EB Calculator

A custom web-based model has been developed specifically for the Little Stringybark Creek catchment (http://www.urbanstreams.net/Rpad/EBcalc.html). The model requires a number of inputs relating to the size of the impervious area and design elements of treatment systems (mainly rainwater tanks and raingardens) and then gives the user the SRS for the specified system.

Pros and Cons of DTS versus EB calculator

The benefit of the DTS table is that it provides developers with a very simple and quick lookup table on how to size a system for a particular impervious area. The downside is that it does not allow more sophisticated systems to be designed and optimised to suit site conditions; the choice is thus one of flexibility vs simplicity.

As seen in the case studies (section 8), many different combinations were modelled using the EB calculator. The advantages of using the EB calculator are summarised below:

- Ability to model more complex treatment trains, matched to the site opportunities and constraints
- Ability to model more complex connections of multiple impervious surfaces to the one treatment device,
- Ability to take into account variations in design e.g partial lining of rain gardens when near infrastructure
- Calculation of a site weighted average e.g by over treating some areas and under treating others

The EB calculator can thus be used to develop the most cost effective solutions. While the calculator is simple enough to use it does require a reasonable understanding of treatment systems and some modelling expertise. It is envisaged that assistance would be available to developers to help utilise the model. Where a civil engineer has already been engaged as part of the development's design, they should be able to assist in the modelling of the proposed solutions.

MUSIC

MUSIC is the current industry standard urban stormwater modelling program (see www.toolkit.net.au/music). It is designed to simulate a wide range of urban stormwater systems, including the stormwater retention systems described in this document and in the DTS table. Using MUSIC to model the proposed design standard flow metrics is more complex than using the EB calculator. Until guidelines are developed to assist in modelling the required flow metrics, the EB calculator is the preferred tool.

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