Feasibility and cost of stormwater management for stream protection at property, street and precinct scales

Christopher J Walsh[1], Rhys L Eddy[2], Tim D Fletcher[1], Matthew Potter[3]

[1] Waterway Ecosystem Research Group, Department of Resource Management and Geography, The University of Melbourne, 500 Yarra Blvd, Burnley 3010, Victoria

[2] Envirostream Solutions Pty Ltd, Level 4, 349 Collins St, Melbourne Vic 3000, Victoria

[3] Melbourne Water, 990 La Trobe St, Docklands Vic 3008, Victoria

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The kernel of this report

- ***Introduction***. This report tests the feasibility and costs (at three different scales: allotment, streetscape and precinct) of stormwater management objectives that aim to protect flowing receiving waters such as urban streams. The proposed objectives a) limit how often untreated runoff flows directly to the stream, and b) restore lost baseflows with appropriate volumes of clean filtered water. The objectives thus focus on both water quality and the flow regime by which it is delivered.

- ***The importance and cost-effectiveness of harvesting.*** Across Victoria's range of climates and soils, systems that meet the proposed objectives are least costly if there is a large demand for harvested water: protecting streams from runoff of dense urban developments (that have a high demand) is therefore cheaper and easier than it is for low-density developments. Where there is insufficient demand, or where it is not possible to harvest road runoff, the infiltration rate of underlying soils becomes an important factor. The objectives are most difficult to meet in soils with low infiltration rates and in wetter climates. In all soil types, reliance on infiltration with insufficient harvesting will result in greater, less seasonal baseflow than ideal.

- ***Land-take.*** Systems with a high harvesting demand can protect streams while using <2% of the total development area. If harvesting is restricted to property-scale rainwater harvesting, street- and property scale systems designed for stream protection require more area, covering <2% (in soils with high infiltration rates) to 8% (in low-density developments in wet climates on soils with low infiltration rates). However, in all cases, most of the land required does not impact on other uses, being restricted to street verges and property gardens, in which infiltration systems can add amenity and function.

- ***Meeting both runoff frequency and baseflow restoration objectives.*** It is possible to meet the runoff frequency objective in soils with high infiltration rates, solely with street-scale infiltration systems, but property-scale harvesting combined with street-scale systems is more likely to also meet the baseflow objective (providing more certain stream protection—and at a lower cost, in denser developments). Precinct-only harvesting systems are capable of meeting both objectives in medium- and high-density developments, but the required treatment and distribution systems are likely to be costly. Meeting the objectives in low-density and rural-residential developments in wetter climates will require a combination of property-scale, street-scale, and possibly precinct scale systems to protect streams.

- ***A financial benefit even without considering the environmental benefit.*** Property-scale retention systems designed for stream protection provide a harvesting yield similar to that supplied by third-pipe wastewater recycling systems, but at substantially lower cost (saving of $10k present cost per property). The combined cost of property-scale and street-scale systems for stream protection is substantially lower than the total cost of recycled wastewater supply and stormwater infrastructure designed to meet 1999 Victorian 'best practice environmental practice' guidelines.

- ***Volume reduction is not a perfect surrogate for more ecological relevant objectives.*** The idea of finding a single, simple surrogate metric, such as volume reduction, for the ecologically relevant objectives used in this report could seem attractive. However, we show in this report that it is possible to meet strict volume reduction targets in ways that do not maintain the ecologically important aspects of the flow regime at a level likely to protect ecosystem health, even in tandem with a baseflow objective. The most effective way to ensure ecosystem protection is thus to use flow (and water quality) metrics that have direct mechanistic links to the health of receiving waters.

Summary

Research question and study method

In cities around the world, conventional urban stormwater drainage degrades stream and river ecosystems, resulting in the loss of many sensitive species of plants and animals and the loss of valuable ecosystem services. Stormwater management practices aimed at mitigating environmental impacts (primarily through reduction of peak flows and pollutant loads) have, to date, been ineffective at protecting urban stream channels and their ecological values. However, new approaches to stormwater management simultaneously reducing alteration to flow patterns and improving water quality from urban areas (and thereby reducing both physical and chemical disturbance) show greater promise for stream protection.

In this report, we assessed the feasibility and cost of implementing proposed 'flow-regime' objectives across the range of climatic and soil conditions (annual rainfalls 250–950 mm and infiltration rates 0.1–36 mm/h) and urban densities (rural residential to multistorey apartment developments) experienced in the state of Victoria, Australia.

We focussed on two objectives, hypothesised to be necessary for stream protection:

- minimization of the frequency of untreated runoff from impervious surfaces (to 1, 8 and 12 d/y, for 250, 650 and 950 mm/y climates respectively), and
- the restoration of filtered baseflows (lost as a result of reduced infiltration).

Implicit in both objectives is the filtration of most runoff released to the stream to ensure high water quality. Meeting these objectives will result in both the current and proposed Victorian "Best practice" environmental management standards for water quality being met or exceeded.

We assessed the feasibility of meeting the objectives using technologies at 3 scales: the property, the street and the precinct (a 10 ha development: applying stormwater retention at any larger a scale would likely require the obliteration of a stream ecosystem). At each scale, we modelled the inflows, losses and outflows of many combinations and sizes of rainwater harvesting, bio-retention (rain-garden), or infiltration systems. We sought systems that met the objectives at least cost. We assessed cost across all scales by the land area required for stormwater retention, and for street- and property-scale systems, we estimated net present monetary cost accounting for the value of harvested water.

We compared the net present cost and harvesting yield of stormwater management systems for stream protection with comparable published estimates of the cost of third-pipe recycled wastewater systems that are commonly applied in new urban developments in Victoria. We also assessed the adequacy of volume-reduction targets (as proposed for new stormwater management guidelines in Victoria) as surrogates for the runoff frequency and baseflow objectives, which have more direct relevance to stream ecological structure and function. In particular we ask if meeting volumetric flow reduction targets ensure adequate reduction of runoff frequency or baseflow restoration, and we assess if the cost of meeting lesser objectives (proposed for lesser value streams) is necessarily lower than meeting objectives for achieving stream protection.

Findings

In all climates, harvesting demand was the primary determinant of the feasibility and cost of meeting stormwater management objectives. Achieving the objectives was most feasible

and cheapest for the highest density (and therefore highest demand per impervious area) developments at both the property scale (assuming harvesting of roof runoff for non-potable interior uses) and precinct scale (assuming harvesting of roof and road runoff for residential uses in the development). Achieving the objectives at the street scale was more difficult, particularly in low-infiltration soils, because road runoff is not harvested in such systems (as we modelled them).

Meeting the objectives was less feasible and more costly in lower density developments: the lack of demand in such developments resulted in systems that complied with the runoff-frequency objective relying more infiltration systems, resulting in baseflow volumes higher than the target. Exceeding the baseflow volume target was most likely to be unavoidable in the driest climate (Mildura), where streamflow volumes are naturally small and seasonal. Generally the baseflow objective was the more difficult objective to meet (i.e. it was difficult avoid baseflow that exceeded the pre-development level), because of the lack of demand to reduce overall volume of road runoff. All systems that met both objectives relied on large harvesting demands and little or no infiltration at the property scale, so that baseflow to the stream was provided predominantly from filtration of road runoff, thus compensating for the fact that harvesting of road runoff is difficult and less attractive.

If an increase in baseflow were to be permitted (which could potentially provide an acceptable ecological outcome in perennial streams), the runoff-frequency objective can be achieved in almost all climate-soil-density combinations, except for some developments in Croydon and Melbourne climates on low-infiltration soils. The net present cost of meeting the runoff-frequency objective at the street-scale was ≤$8,000 per property for all development densities in sandy soils in the wet Croydon climate and in most density-soil combinations in the Melbourne and Mildura climates, with increased costs for less dense developments in lower-infiltration soils. In soils with ≥1 mm/h infiltration in all climates, systems that almost met the runoff-frequency objective for ≤$10,000 were feasible on access roads, but runoff-frequency remained high from larger distributor roads with systems costing ≤$10,000.

Generally, precinct-scale harvesting systems require <2% of development area to achieve stream protection objectives, but the costs of such systems are likely to be similar to or greater than third-pipe recycled wastewater systems, which are likely to be substantially more expensive than systems installed at smaller scales. Protection of streams using more dispersed stormwater management requires larger areas for retention systems because harvesting is restricted to roof runoff, and paving and road runoff require infiltration without harvesting. As a result, street- and property-scale systems require from <2% of development area (in soils with high infiltration rates) to as much as 8% in low-density developments in wet climates on soils with low infiltration rates. However, in all cases, most of the land required for smaller scale systems does not impact on other uses, being restricted to street verges and property gardens, in which infiltration systems can add amenity and function.

The feasibility of complying street-scale stormwater retention was sensitive to assumptions on harvesting demand and the available green space in streetscapes. Increased harvesting demand and slight increases in available street (or precinct) green space would serve to increase feasibility and reduce net present cost of complying street-scale systems.

Proportional reduction in volume runoff has been proposed as a potential surrogate for the more ecologically relevant indicators of runoff frequency and baseflow contribution. Our analyses demonstrate that runoff reduction is not an adequate surrogate for runoff frequency, even when used in concert with baseflow contribution, because runoff frequency outcomes can vary greatly for a given level of volume reduction and baseflow contribution, depending on the configuration of the interventions. Meeting the runoff frequency and baseflow contribution objectives that we posit are required for stream protection is generally more expensive than meeting lesser objectives at the street scale (typically $1000-2500 per property, but substantially more expensive in soils with low infiltration rates and developments with low demand).

However, the present cost of systems that harvest roof runoff at the property scale is lower for systems that meet or exceed the runoff frequency targets than for systems that fail to meet the targets in developments with relatively high demand (medium- and high-density). That meeting stream protection objectives is cheaper than not meeting them in developments with high demands underlines our key finding that demand for stormwater is an important driver of both stream protection and its affordability.

If you would like a copy of the full report and its appendices, please email Chris Walsh at cwalsh@unimelb.edu.au