

The Stormwater Metric “S”: A Tool for Predicting Stream Benefits from Stormwater Management

Little Stringybark & Dobsons Creek Projects
Fact Sheet Series: 8

The Little Stringybark Creek (LSC) and Dobsons Creek projects were long-term catchment-scale experiments designed to test if Stormwater Control Measures (SCMs)—primarily rainwater tanks, raingardens and infiltration systems—applied across an urban catchment, can help restore stream condition. Commencing in 2008, the projects were led by The University of Melbourne and Melbourne Water, in collaboration with local government, industry, and property owners. We monitored changes to stream water quality, hydrology, and ecology (Fact Sheet 10), and also assessed techniques for local government collaboration (Fact Sheets 3 & 4), community engagement (Fact Sheet 5), as well as SCM design, performance and maintenance (Fact Sheets 6 & 7).

About the fact sheets

These fact sheets summarise our scientific and practical findings and insights on catchment-scale stormwater management over the long-term LSC and Dobsons Creek Projects. We hope that they might inform and guide the planning and delivery of future waterways management projects for improved stream health.

Why we need to adjust Effective Imperviousness to account for stormwater management:

Effective Imperviousness (**EI**, also known as Directly Connected Imperviousness, DCI) is the proportion of a catchment covered by impervious surfaces—surfaces that water cannot soak through (e.g. roads, roofs, carparks)—that are connected to the stormwater drainage network. For example, an **EI** of 10% means one-tenth of the area of the catchment drains via stormwater pipes straight to the stream channel. Stream degradation is strongly correlated with increasing **EI**, with ecological indicators negatively impacted beyond ~2% EI. Because **EI** has a strong correlation with urban stream degradation, it is used both to anticipate the impacts of urban development (typically too much flow in wet weather and not enough flow in dry weather) and to track the benefits of improved stormwater management.

Conceptually, we hypothesise that the health of urban streams can be restored through the use of SCMs by reducing **EI** towards levels observed in healthy streams. In newly developing urban areas, the health of streams can be protected by limiting **EI** to the greatest extent possible. Impervious surfaces can be drained in ways that do not pipe stormwater runoff directly to streams. When SCMs intercept and treat runoff from an impervious area, they break the connection between impervious areas and streams.

Here we introduce a measure, **effective imperviousness with SCMs EIs**, that accounts for the mitigating effect of SCMs in a catchment. Values for **Eis** vary between 0 and 100% (or 0 and 1, if expressed as a decimal fraction). For example, if SCMs treated runoff from all impervious areas and operated perfectly in a catchment with 10% **EI**, the **EIs** for the catchment would be returned to 0%. Conversely, if the SCMs were completely ineffective then the **EIs** would remain at 10%. In reality, SCM performance will fall somewhere in between, and when we design or install SCMs, we want to estimate how much they mitigate **EI** based on modelled or observed SCM performance.

EIs provides a consistent, comparable metric for SCM performance across catchments and a stronger basis for predicting in-stream benefits. **EIs** can help planners set targets (pushing **EIs** toward the <2% value consistent with healthy streams), prioritise investments by benefit per treated unit of area, and accurately track progress over time (e.g. as SCMs are progressively added to a catchment).

How to Calculate EIs

Start by identifying every patch, **i**, of impervious area (**IA**) in the catchment and determine where its runoff flows to. Each patch is then given a score (**Si**) that reflects how much of its runoff reaches the stream (i.e. its impact on the stream). For a patch that is drained directly (via sealed pipe or impervious surface) to the stream, **Si** = 1 (full impact). Where a patch is fully disconnected (e.g. runoff is directed to a garden or other pervious surface distant from any stream), **Si** = 0 (no impact). For areas draining to a stormwater control measure (SCM), the score falls

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between 0 and 1, based on hydrologic modelling of SCM performance. For example, if the SCM reduces the impact of a patch by 50%, $S_i=0.50$.

To calculate EI_s , multiply each patch's area by its score, sum all of these "effective areas," and then divide by the total catchment area. The result, expressed as a fraction or percentage, is the **effective imperviousness with SCMs (EIs)**.

$$EI_s = \frac{\text{Sum of (Impervious Area x Score)}}{\text{Total Catchment Area}}$$

Equation 1

Example calculation

In a 100 ha catchment, 7 ha of impervious surface drains **directly** to the stream (giving it a score of $S_i = 1$, while 2 ha of impervious surface is **fully disconnected** (i.e. drains to green spaces), and so it has a score of $S_i = 0$.

$$EI_s = \frac{(7 \times 1) + (2 \times 0)}{100} = \frac{7}{100} = 0.07 = 7\%$$

Equation 2

Now, imagine that SCMs were installed, treating 3 ha of the impervious surfaces that previously drained directly to the stream. These SCMs operate at 50% efficiency (i.e. they reduce the impact of treated surfaces by 50%), meaning that 3 ha has a score of $S_i = 0.5$.

$$EI_s = \frac{(4 \times 1) + (3 \times 0.5) + (2 \times 0)}{100} = \frac{5.5}{100} = 0.055 = 5.5\%$$

Equation 3

How to Predict How Much Impact SCMs Remove:

To work out how well your SCMs treat impervious surfaces (i.e. the impact they remove, their resulting S_i), you must first identify what "impact" means. Stormwater impacts stream hydrology and water quality in multiple ways. Walsh et al. (2022) developed a composite index that averages four sub-metrics that collectively account for the multiple impacts:

- Runoff frequency, S_r , which assesses how closely the frequency of overflows from the SCM mimics the frequency of storm flow before the catchment was urbanised;

- Filtered flow, S_f , which assesses how closely the rate of treated water draining from the SCM to the stream matches pre-urban baseflow;
- Water quality, S_w , which assesses the degree to which outflow concentrations of important pollutants (total phosphorus, total nitrogen, and total suspended solids) from the SCM matches reference condition concentrations; and
- Runoff volume reduction, S_v , which assesses the degree to which the volume of water reaching the stream from the SCM matches pre-urban runoff volume.

Full details of how to calculate each of these sub-metrics can be found in Walsh et al (2022). Below, we show an example of how to calculate EI_s based on runoff volume reduction (S_v) alone.

Using the same rainfall record dataset, model¹ the annual runoff volume for three situations:

1. Pre-urban (natural), call it I_n ;
2. Urban with no SCMs, I_u ; and
3. Urban with the SCMs in place, I_m .

Now turn these into a single score which measures SCM performance. Do that by comparing the SCM case to the natural baseline, relative to the no-SCM urban case:

$$S_i = \frac{(I_m - I_n)}{(I_u - I_n)}$$

Equation 4

where S_i is the score for impervious patch i draining to an SCM. A value of 0 means the SCM brings you back to pre-urban natural conditions, while $S_i = 1$ means the SCM makes no difference compared to a conventional (i.e. pit and pipe) drainage system.

Let's assume the example from the previous section is located in the Little River area rainfall band¹. The modelled¹ annual runoff volume from the example area under pre-urban conditions, I_n , is 0.96 ML/year. Recall that the catchment had 7 ha of impervious surface (we don't need to consider the 2 ha of impervious surface that is already fully disconnected). Modelling the urban case with no SCMs, (I_u), yields an annual runoff volume of 25.8 ML/year. Now, let's say we retrofit a combination of SCMs across the 7 ha of impervious surface that enables us to achieve the

1. For example, using MUSICX and following the MUSIC Guideline 2024. For further information on stormwater harvesting and infiltration targets and how to model them, see the *Healthy Waterways Strategy Stormwater Targets: Practitioners Note* and *MUSIC Guideline 2024*, both available at: <https://www.melbournwater.com.au/building-and-works/developer-guides-and-resources/guidelines-drawings-and-checklists/guidelines>.

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stormwater harvesting and infiltration targets for this rainfall band (i.e. harvest 2.9 ML/ha/year and infiltrate 0.1 ML/ha/year). As mentioned above, in practice, ***I_m*** would be modelled¹ but for this illustration, ***I_m*** can be calculated as follows:

$$I_m = I_u - (V_h + V_i) = 25.8 - 7(2.9 + 0.1) = 4.8 \text{ ML/year}$$

Equation 5

where ***V_h*** is the volume harvested (or evapotranspired) and ***V_i*** is the volume infiltrated. We can then estimate how much stormwater runoff volume impact our retrofit SCMs remove, ***S_i***:

$$S_i = \frac{(4.8-0.96)}{(25.8-0.96)} = \frac{3.84}{24.84} = 0.15$$

Equation 6

Plugging this value in to estimate the **effective imperviousness with SCMs, *E_{is}***, for the 100 ha catchment, we get:

$$E_{I_s} = \frac{(7 \times 0.15) + (2 \times 0)}{100} = \frac{1.05}{100} = 0.0105 = 1.0\%$$

Equation 7

In other words, implementing the SCMs has enabled us to disconnect enough of the impervious surfaces in the catchment to reduce ***E_I*** from 7% to 1.0%. At this level of ***E_I***, we could reasonably expect to see improvements in the health of the stream (see Fact Sheet 10). Alternatively, if this was a new urban development, we expect the stream would remain in good ecological condition.

In most cases, achieving the necessary runoff volume reduction will also achieve the other three sub-metrics of

runoff frequency, filtered flow and water quality that are important for maintaining good ecological condition. Though it is also important to understand and account for relevant local conditions that may have a bearing on each of the other sub-metrics (e.g. point source pollution).

References:

Walsh, C. J., M. J. Burns, T. D. Fletcher, D. G. Bos, P. Poelsma, J. Kunapo and M. Imberger (2022). "Linking stormwater control performance to stream ecosystem outcomes: Incorporating a performance metric into effective imperviousness." PLOS Water 1(2): e0000004.

For more details on the outcomes of this project and guidance on the operation and maintenance of SCMs, please refer to:

- Walsh, C. J., D. G. Bos, M. J. Burns, M. Imberger and T. D. Fletcher (2023), "Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects", Technical report 23.2, Melbourne Waterway Research-Practice Partnership,
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