# Monitoring the Effectiveness of Stormwater Control Measures

Little Stringybark & Dobsons Creek Projects
**Fact Sheet Series: 9**

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.

### About monitoring programs

There are many reasons to monitor the performance of individual SCMs or the collective impact of an SCM network: to ensure functional performance, to assess compliance with regulatory requirements, and to build knowledge that directly informs future design and installations. Doing this meaningfully requires the acquisition of data that are both appropriate to the research question and of suitable quality to confidently answer questions, which carries cost in terms of money, effort, and time. For example, it may be important to consider the temporal, spatial, analytical and quality assurance and quality control (QA/QC) characteristics to ensure the right variables, sufficient sampling frequency (including event-based capture where required), representative site coverage, appropriate analytical detection limits, and use of standardised procedures where available.

## Findings and insights

1. Identify what you want to know and how you want to use the data
2. Data accuracy requirements should be considered before monitoring sites are established
3. Consider the differences between low-cost vs high-cost sensors and loggers
4. Access to live (near-real-time, continuous) data can offer many benefits
5. Be willing to adapt your monitoring program
6. Ensure consistency of methods across all monitoring sites
7. Human resources are vital to good data collection
8. Comprehensive field notes are critical
9. Urban hydrology is complex, even at small scales
10. Timing and amount of rainfall varies significantly within and across study catchments
11. Collecting data is just the first step in monitoring
12. Regular processing of data is critical
13. Take steps so the data can be 'trusted' by all users

*See over for more details*

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This fact sheet is not intended to be a comprehensive guide to designing and operating a monitoring program. Rather, it is intended to share the experience and knowledge gained from our two decades of monitoring waterways and SCMs in the Greater Melbourne area. While many insights arise from the LSC and Dobsons Creek projects, this fact sheet also draws on more recent studies to give up-to-date perspectives and a wider range of experience and application. We provide recommended reading for comprehensive guidance on monitoring programs in the Further Information section.

**Project findings and insights**

## A. Planning and design

### 1. Identify what you want to know and how you want to use the data.

We find it helpful to first define the purpose of our monitoring program as a series of questions. For the LSC project, these included questions like: How well do SCMs perform with respect to hydrology, water quality and water harvesting potential? and does the actual SCM performance match the modelled performance? Such questions can form the basis of the performance objectives and evaluation criteria, which will inform the type of data that needs to be collected (as well as where and when).

Monitoring resources, skills and capacity typically constrain monitoring programs. As a result, the types of data collected often needs to be prioritised. For example, if it is difficult to accurately measure low and high flows concurrently, which element of the flow regime is more important? Answers to questions such as these will affect the choice of monitoring location, equipment and data frequency. These choices also have implications for considerations like cost (see Insight #3), power consumption, and security of equipment and data. For example, ongoing water quality analyses can be a significant expense (especially across multiple sites), meaning the monitoring program may need to prioritise which locations should be monitored. Finally, consider the duration of the project. For longer-term projects it can be worth investing more time and resources into site setup e.g. installation of secure storage cabinets for water sampling equipment or flow gauges.

### 2. Data accuracy requirements should be considered before monitoring sites are established.

Whenever possible, effort should be made to identify the required accuracy of data, informed by the monitoring objectives, experience from similar monitoring programs and/or consulting with experts. Often, the decision will be a balance between the size of the environmental response and the accuracy with which it needs to be measured, costs such as frequency of site visits, equipment, and the value of this information for decision making. At the beginning of a project, it can be difficult to appropriately instrument sites without knowing the sensitivity of the impact data (i.e., the range of observations or the size of the response to a management intervention). Flood monitoring, for example, might not require accurate monitoring of small variations in streamflow, as is necessary when evaluating the beneficial impact of WSUD assets. The LSC project initially relied heavily on natural flow controls (e.g. rock weirs) to monitor stream flows. This was justified because it was thought SCMs would have a larger impact on flows than they actually did and because of the high cost of installing accurate flow measurement equipment. However, the natural flow controls failed to provide the level of data accuracy required by the project, as they were affected by mobilisation of sand and silt, which frequently changed the flow rating curves. Eventually, these were replaced with V-notch weirs, which provided more accurate data for low- to-medium flows. The upfront cost of these upgrades was offset by the substantial reduction in site visits, gauging requirements, and post-processing of hydrological data.

*Water quality monitoring.*

3. Consider the differences between low-cost vs high-cost sensors and loggers. The choice of sensor(s) can be a critical decision for monitoring programs, which is made difficult by the wide range of sensor options available and the need to understand trade-offs such as: accuracy vs cost; cost vs maintenance time; ease of installation vs risk of losing equipment in large storms, and off-the-shelf vs custom-built infrastructure/equipment. We have used multiple sensor types for our monitoring programs and decisions about which sensor(s) to use for what program have been situational. In the early days of the LSC project, we found that the use of higher quality monitoring equipment yielded more accurate and reliable data. For example, the project team replaced several mid-range priced water level probes (accurate to 20mm) with a higher quality, more expensive product (pressure level sensor, accurate to 2 mm). Along with increased accuracy, the more expensive water level probes featured telemetry capability, which aided in data retrieval, interrogation, and timely identification of maintenance issues.

More recently, we have leaned towards cheaper, off-the-shelf sensors combined with custom loggers. These custom-built, low-cost systems include a potential trade-off of higher maintenance demands, but the benefit is flexibility and customization, especially for capturing 'live' data' (see Insight #4). High-end, off-the-shelf sensors are sometimes less flexible in terms of what data you can collect. However, advantages may include lower associated operational costs (e.g. time cleaning the data, see Insight #11) and high-quality reliable data. Custom built, low-cost sensors work for us because their flexibility gives us greater control over the data we collect.

*V-notch weir, measuring flow rate from water level data.*

4. Access to live (near-real-time, continuous) data can offer many benefits. Live data can reduce the requirement to send staff into the field. When combined with alerts, live data are invaluable for detecting problems early and for efficiently planning field work. For example, live data are helpful for checking flow and battery levels prior to a field trip or determining if it is a good time to collect water quality or ecological data. They are particularly helpful for capturing event-based water quality data, because they provide information that helps assess if the rainfall event triggered a streamflow response or if there is outflow from an SCM that can be sampled. Having a camera that can capture visual data on demand is also useful. For example, when something is wrong, being able take a photo remotely can help with diagnosing the problem before going to the site.

For many of our monitoring projects, we have adopted a model that accepts having less reliable live data when they are coupled with a high-reliability logger, storing data onsite which are regularly downloaded. Live data can be troubled by, for example, occasional breakdowns in communication (due to variable mobile or satellite reception). A high-reliability logger records everything and ensures no data loss due to such communication issues. In this scenario, the downloaded data are used for analysis and the live data are used for 'monitoring' the monitoring (e.g. alerts and surveillance). Prior to having access to live data, we found that obtaining good quality data required us to be out in the field more often and also resulted in some longer gaps in data as there was no way of knowing when a sensor was not operational other than through site visits.

5. Be willing to adapt your monitoring program. Experience from the LSC and Dobsons Creek projects demonstrates that, even with careful planning, gaps or practical issues are likely to arise once monitoring is underway. To avoid wasted effort and expense, plan for an adaptive approach e.g. test and validate methods with a pilot prior to implementing the full monitoring program, review and analyse data early and often, and be prepared to revise sampling frequency, instrumentation, or site selection.

## B. Collecting data

6. Ensure consistency of methods across all monitoring sites. It is important to maintain consistency of methods across all sites within a monitoring program, as variation can distort data compatibility and useability for desired analyses. In the LSC project, small differences in water quality samples that were collected manually versus automatically, in conjunction with the use of automatic samplers at some, but not all sites (and sporadically through time) meant the costly autosampler data were excluded from many analyses. For ecological monitoring, even a minor variation in methods can introduce variability or error into final analyses. This is particularly true for long-term projects, where changes to methods may arise due to staffing changes or changes to instream conditions that command methodological change. The former can be mediated by maintaining a written record of the methods (protocols) that are clear and sufficiently detailed such that the application of the method doesn't vary from person to person, along with adequate training of new staff. For the latter, it is vital to cross-calibrate old and new methods to ensure long-term comparability. We are currently using custom mobile phone apps to prompt field personnel on actions needed for specific projects. This helps to address many of the inconsistencies caused by different people visiting sites, and in particular helps with the challenge of the daylight savings timestamp.

7. Human resources are vital to good data collection. Acquiring reliable, accurate, fit-for-purpose data typically relies on a heavy investment in labour for the establishment, collection, processing, and quality assessment of data. For example, prior to having live data, the LSC used a team of 2 people, one day per week for maintenance and calibration (where they would visit 4-8 stream sites, some rain gauges, and a few SCMs). Although it can be labour-intensive, frequent site visits and inspections of equipment (especially weirs and levels), and performing regular equipment calibrations and equipment maintenance all resulted in better quality data, without which we would not have been able to confidently assess the project's objectives.

8. Comprehensive field notes are critical. Thorough field notes of site conditions, visual observations (e.g. water level, water colouration), anomalies, or changes to site locations through time are critical for explaining data variation. This is especially true for long-term monitoring projects where personnel can change over time. In our experience, field notes serve two primary functions: 1) to keep track of equipment issues and function to improve reliability and maintenance of the equipment, and 2) to record comments on the quality of data collected (e.g. flow control condition) to help with processing of the data. This should be done promptly and regularly (see Insight #13)

9. Urban hydrology is complex, even at small scales. The monitoring of pipe flows in the headwaters of the LSC catchment revealed the complexity of urban hydrology – specifically, the complex pathways urban runoff can take before entering the drainage system. The impact of this complexity varied across different catchment scales. At very small scales (1-2 allotments), uncertainty can be reduced by checking each pipe and their associated catchment area. Uncertainty is greatest at a scale of a few streets (10-50 allotments) – where there is a greater chance of hydrology being affected by confounding issues, such as blocked pipes, leaking infrastructure or the urban karst (a network of constructed, high-permability subsurface pathways) but ground-truthing is impractical.

The LSC project also showed the potential for pervious surfaces to generate runoff during quite small rainfall events (<10mm), which confounded modelling and analysis. Similarly, the hydrology of natural catchments can also be complicated. The LSC project found substantial differences in the flow between different reference catchments (nearby forested catchments free from urban impacts, against which we compared the LSC and Dobsons catchments), differences much larger than the differences observed in water quality and biological indicators. For example, flows in Lyrebird Creek were often half as much as that observed in Olinda Creek (two of the study's three reference

*Monitoring levels of rainwater tanks*

catchments), despite both streams having a similar catchment size. These findings highlight the importance of selecting suitable reference catchments; ideally catchments with similar physical properties (e.g. land-use, slope, geology) and, most importantly, flow regime. We acknowledge that the flow regime might not be known before a monitoring program commences, so having a long lead-in time might be necessary to allow collection of preliminary data to confirm that sites are comparable.

10. Timing and amount of rainfall varies significantly within and across study catchments. Several rainfall gauges across the LSC catchment (installed and maintained by the project team) often recorded different data, despite their close proximity (~1 km). In addition, there were often notable differences in the rainfall recorded by the team and that recorded in and near the study catchments by the Bureau of Meteorology (BOM) and Melbourne Water. For example, it was common to have days where the project gauges recorded <0.5mm of rain, but nearby guages recorded several millimetres of rain. These findings stress the importance of having multiple rain gauges in small, urban catchments, especially for those with high relief (where variability is increased due to the complex interaction between topography and atmospheric processes), if obtaining accurate rainfall is important.

## C. Using data

11. Collecting data is just the first step in monitoring. There is a significant amount of effort involved in organising, processing (e.g. quality checking, error detection, and handling) and storing data. This time-consuming task should be considered in the planning and design phase to allow for staff/funding planning and because it may also influence the design of the monitoring program (e.g. how much data are collected or the quality of the data collected or sensors used).

12. Regular processing of data is critical. Checking data continually (e.g. to detect sensor drift and need for re-calibration) is essential for understanding whether the data you are collecting are adequate for your defined purposes. This is a critical action regardless of whether the sensors/loggers are low- or high-cost, and whether the data are live or otherwise. Not examining the data until the end of the collection period is a recipe for failure. Additionally, it is also recommended to perform a preliminary analysis of the data, to check whether the assumptions are correct for proposed statistical analyses.

13. Take steps so the data can be 'trusted' by all users. Document the strengths and limitations of each dataset (which is only possible if you're regularly checking and working with the data). Retain an untouched copy of the raw data. Ideally, have a traceable, computationally reproducible data processing procedure, so it is possible to track (or understand) how the analyst obtained the final results from the raw data.

**For more details on the outcomes of this project, 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.
- Jean-Luc Bertrand-Krajewski, Francois Clemens-Meyer, and Mathieu Lepot (Eds) 2021 Metrology in Urban Drainage and Stormwater Management: Plug and Pray, IWA Publishing.
- McCarthy, D. T., K. Zhang, C. Westerlund, M. Viklander, J.-L. Bertrand-Krajewski, T. D. Fletcher and A. Deletic (2018). "Assessment of sampling strategies for estimation of site mean concentrations of stormwater pollutants." Water Research 129: 297-304.
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