Government of **Western Australia**
Department of **Water and Environmental Regulation**

Stormwater management manual for Western Australia

Chapter 10 Performance monitoring and evaluation

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Cover photo: Ecological Monitoring Lake Jandabup 2018, Jandabup WA (Source: Department of Water and Environmental Regulation)

Disclaimer

Preface

A growing public awareness of environmental issues in recent times has elevated water issues to the forefront of public debate in Australia.

Stormwater is water flowing over ground or built-up surfaces and in natural streams and drains, as a direct result of rainfall over a catchment (ARMCANZ and ANZECC, 2000). Stormwater consists of rainfall runoff and any material (soluble or insoluble) mobilised in its path of flow. Stormwater management examines how the runoff quantity, and these pollutants, can best be managed from source to the receiving water bodies using the range of management practices available.

In Western Australia (WA), where there is a superficial aquifer, drainage channels can commonly include both stormwater from surface runoff and groundwater that has been deliberately intercepted by drains installed to manage seasonal peak groundwater levels. Stormwater management is unique in WA as both stormwater and groundwater may need to be managed concurrently.

Rainwater has the potential to recharge the superficial aquifer, either prior to runoff commencing or throughout the runoff's journey in the catchment. Urban stormwater on the Swan Coastal Plain is an important source of recharge to shallow groundwater, which supports consumptive use and groundwater dependent ecosystems.

With urban, commercial or industrial development, the area of impervious surfaces within a catchment can increase dramatically. Densely developed inner urban areas are almost completely impervious, which means less infiltration, the potential for more local runoff and a greater risk of pollution. Loss of vegetation also reduces the amount of rainfall leaving the system through the evapo-transpiration process. Traditional drainage systems have been designed to minimise local flooding by providing quick conveyance for runoff to waterways or basins. However, this almost invariably has negative environmental effects.

This manual presents a new comprehensive approach to management of stormwater in WA, based on the principle that stormwater is a resource – with social, environmental and economic opportunities. The community's current environmental awareness and recent water restrictions are influencing a change from stormwater being seen as a waste product with a cost, to a resource with a value. Stormwater management aims to build on the traditional objective of local flood protection by having multiple outcomes, including improved water quality management, protecting ecosystems and providing livable and attractive communities.

This manual provides coordinated guidance to developers, environmental consultants, environmental/ community groups, industry, local government, water resource suppliers and state government departments and agencies on current best management principles for stormwater management.

Production of this manual is part of the State Government's response to the State Water Strategy for Western Australia (2003).

It is intended that the manual will undergo continuous development and review. As part of this process, any feedback on the series is welcomed and may be directed to the Urban Water Branch of the Department of Water and Environment Regulation at urbanwater@dwer.wa.gov.au

Western Australian stormwater management objectives

Water quality
To maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions.

Water quantity
To maintain the total water cycle balance within development areas relative to the pre-developmentconditions.

Water conservation
To maximise the reuse of stormwater.

Ecosystem health
To retain natural drainage systems and protect ecosystem health .

Economic viability
To implement stormwater management systems that are economically viable in the long term.

Public health
To minimise the public risk, including risk of injury or loss of life, to the community.

Protection of property
To protect the built environment from flooding and waterlogging.

Social values
To ensure that social, aesthetic and cultural values are recognised and maintained when managingstormwater.

Development
To ensure the delivery of best practice stormwater management through planning and development ofhigh-quality developed areas in accordance with sustainability and precautionary principles.

Western Australian stormwater management principles

- Incorporate water resource issues as early as possible in the land use planning process.
- Address water resource issues at the catchment and sub-catchment level.
- Ensure stormwater management is part of total water cycle and natural resource management.
- Define stormwater quality management objectives in relation to the sustainability of the receiving environment.
- Determine stormwater management objectives through adequate and appropriate community consultation and involvement.
- Ensure stormwater management planning is precautionary, recognises inter-generational equity,
conservation of biodiversity and ecological integrity.
- Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.
- Recognise the need for site specific solutions and implement appropriate non-structural and structural

Contents

Summary

Effective stormwater management requires:

- a good process to track the progress of activities
- an understanding of why the activities have succeeded or failed
- an understanding of what can be done to improve their success in the future.

This chapter outlines a generic process for developing stormwater monitoring and evaluation programs that can be applied at all levels of stormwater management. It is important that a monitoring and evaluation program is prepared at the beginning of the project and this chapter should be read as a project preparation document. The generic process has the following stages:

A. Purpose
B. Objectives
C. Evaluation questions and indicators
D. Planning
E. Implementation
F. Analysis and interpretation
G. Report and recommendations

Specific details relevant to determine the success of non-structural and structural best management practices have been discussed in separate sections. Structural best management practices (BMPs) act to alter water quality through physical, chemical and biological processes. To evaluate the success of structural BMPs, water quality monitoring both prior to and after the measures have been implemented, is required. Summaries of parameters regarding water flow, quality and quantity have been included to assist stormwater managers to select appropriate monitoring techniques and to evaluate the performance of BMPs.

Non-structural BMPs are institutional and pollution prevention practices designed to prevent or minimise pollutants from entering stormwater or to reduce the volume of stormwater requiring management. The success of non-structural BMPs depends on human behaviour.

When a new stormwater management technique is implemented, it is critical to understand its functionality and performance. Not only is monitoring and evaluation useful for determining success, it also helps in communicating outcomes to stakeholders and sharing lessons learnt.

Several approaches to evaluate BMPs are outlined in this chapter.

Please also refer to *Water monitoring guidelines for better urban water management strategies and plans (DoW 2012)* for monitoring requirements in land use planning and development process. This guideline describes what should be considered when determining pre- and post-urban development water monitoring requirements, and at what stage in the planning process various water monitoring is required.

1 Introduction

1.1 Aims of the performance monitoring and evaluation chapter

The aims of the performance monitoring and evaluation chapter are to:

- explain how to develop a stormwater monitoring and evaluation program, and ensure that the plan is integrated into the larger program of works
- describe the performance monitoring and evaluation process for structural and non-structural best management practice (BMP) performance monitoring
- provide an overview of performance monitoring and evaluation techniques, their selection, benefits and limitations, and provide links to key literature and resources for the details of the techniques.

1.2 Scope of the chapter

This chapter outlines a generic process for developing monitoring and evaluation programs. Performance monitoring and evaluation of structural and non-structural BMPs are discussed generally. References are provided for more detailed information.

Auditing of BMPs is usually undertaken by the organisation responsible for its implementation, such as a developer, local government or a catchment management group. Monitoring of the success of structural and non-structural BMPs is normally undertaken by expert consultants employed by stormwater managers such as local government authorities.

Maintaining or improving the condition of the receiving environment including waterways, wetlands and coastal waters is normally the ultimate objective of implementing a stormwater management project, whether it is a large program or an individual BMP. Regardless of the scale of the stormwater management project, stakeholders expect to see evidence of the success of the project and environmental change to the receiving environment as a result. Few organisations have the resources to do large scale monitoring over a large geographical area or for a long period of time. Resources have to be targeted to meet specific regional needs (ARMCANZ and ANZECC 2000).

There are often specific monitoring requirements placed on developers and landholders as part of the condition of development or licences to operate which are reported back and audited to the local government or state government.

1.3 Terminology and key definitions

Best Management Practices (BMP): Devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor & Wong 2002).

Contaminant: A substance that is not naturally present in the environment or is present in unnatural concentrations that can, in sufficient concentration, adversely alter an environment.

Effectiveness: The extent to which program outcomes are achieving project objectives (Bullen undated).

Efficiency: The extent to which project outputs are maximised for the given level of inputs. Efficiency is concerned with the processes (activities/strategies/operations) by which the project is delivered and which produce the outputs of the programs. BMP Efficiency: Measures of how well a BMP or BMP system removes or controls pollutants. Although ‘percent removal’ is the most common form of expressing BMP efficiency (when used alone) it is a poor measure compared with alternatives such as the ‘effluent probability method’ (e.g. US EPA 2002; Taylor & Wong 2003).

Evaluation: A periodic but comprehensive assessment of the overall progress and worth of a ‘project’ (Woodhill & Robins 1998). The term used for final assessment of whether the BMP has achieved its pre-defined objectives.

Goals or Aims: General descriptions of what a project will achieve (Woodhill & Robins 1998).

Indicators: The specific characteristics or phenomena that tell you about the project and what impact it is having on the problem or issue it was set up to tackle (Woodhill & Robins 1998).

Monitoring: The collection of data by various methods for the purpose of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures.

Nutrient: Any substance assimilated by living things that promotes growth. The term is generally applied to nitrogen and phosphorus in water, but is also applied to other essential and trace elements.

Objectives: Specific statements about what a project intends to achieve. Or concise, realistic, outcomes orientated statements of what a project aims to achieve.

Outcomes: The results of the activities or products of a project, i.e. the ultimate impact of a project (Woodhill & Robins 1998). All the impacts or consequences of the project beyond its outputs. Outcomes are often delayed or long-term and they may be intended or unanticipated (Bullen undated).

Outputs: The activities completed or products made during a project (Woodhill & Robins 1998). Outputs are within the direct control of the project.

Program: Development of monitoring and evaluation activities to determine the success or otherwise of measures put in place as part of stormwater management projects.

Project: The term is used to describe the development and implementation of stormwater management plans, BMPs and other catchment management initiatives.

Performance Indicator: A specific type of indicator that looks at outcomes to see if they are meeting the project’s objectives.

Performance Monitoring: Gathering of information to measure the success of strategies implemented when compared to objectives.

Receiving environment: Areas that receive stormwater runoff, including wetlands, waterways, coastal waters/dunes, groundwater and bushland areas.

Target: A numerical concentration limit or descriptive statement relating to an aspect of water management aspired to as part of a stormwater management project.

1.4 The target audiences

The target audience for this chapter is stormwater practitioners, mainly local government officers and industry consultants. It also provides information for the land development industry to a lesser extent; however, specific development condition monitoring requirements are outlined in the urban water management report. Other practitioners that will find this chapter of use are Department of Water and Environmental Regulation; Department of Biodiversity, Conservation and Attractions; Water Corporation; Main Roads WA; Public Transport Authority; catchment councils; and other catchment managers or service providers.

1.5 How to use this chapter

This chapter provides a generic process for performance monitoring and evaluation which can be applied at all levels of stormwater management. As outlined in Section 2, it is important that a monitoring and evaluation program is prepared at the beginning of a stormwater management project and therefore this chapter should be read as a stormwater management project preparation document.

Specific details relevant to determining the success of non-structural and structural BMPs are discussed in Sections 4 and 5. It is, however, important to note that most stormwater management projects have a combination of techniques and therefore both non-structural and structural monitoring and evaluation techniques will be employed.

The monitoring and evaluation of combined impacts of stormwater BMPs within a catchment by monitoring the condition of the receiving environment is discussed in the following section of this chapter. Monitoring of urban developments as part of the compliance requirements for a development is a separate land use planning process. However, there are parallels in the monitoring process and this document can be used as a reference.

2 What is stormwater performance monitoring and evaluation?

Effective stormwater management requires a good process to track the progress of activities; an understanding of why the activities implemented have succeeded or failed; and what can be done to improve their success in the future. The two tools of performance monitoring and evaluation are ways to measure the success of individual tasks to overall outcomes of a program. The two tools are simply defined below as:

- **performance monitoring** – the gathering of information to measure the success of implemented strategies against their objectives
- **evaluation** – refers to the process of determining the merit, worth or value of the stormwater management project. It can be a periodic but comprehensive assessment of the program's overall progress and worth (Woodhill & Robins 1998) or a final assessment of whether it achieved its pre- defined objectives.

Some reasons to undertake performance monitoring and evaluation are:

- to determine the success of meeting the stormwater management project goals and objectives
- to improve actions and procedures of a stormwater management project as it proceeds

- to find the best ways to add to a stormwater management project's strengths (adaptive management) and correct its weaknesses (risk management)
- to develop the skills and understanding of people involved in a stormwater management project
- to find new ways to understand the issues by engaging with your stakeholders
- to provide information for planning a new stormwater management project
- to demonstrate the worth of the group and organisation
- to be accountable to stakeholders including funding sources
- to contribute information to broader scale monitoring and evaluation
- to detect non-compliance with regulatory requirements
- to facilitate corporate performance monitoring (Woodhill & Robins 1998; DEC NSW 2004).

The performance monitoring and evaluation program should contribute to the improvement and effectiveness of particular aspects of the stormwater management project, whether it is the process, implementation, or the actual construction or functioning of specific BMPs.

It is important to design the performance monitoring and evaluation program at the beginning of the stormwater management project. Performance monitoring and evaluation is most effective when it is an integral part of the whole stormwater management project, and where there is a constant cycle of planning, acting and reviewing; utilised in this manner data and outcomes can contribute to addressing shortfalls in the stormwater management project (Woodhill & Robins 1998; DEC NSW 2004). Further advice on stormwater management planning and where performance monitoring and evaluation should fit in this cycle is discussed in Chapter 5.

Time and resources are required to develop and undertake performance monitoring and evaluation; however, this investment will assist stormwater managers achieve better results. Preparing a monitoring and evaluation program beforehand will enable the appropriate data to be collected and evaluation opportunities to be identified.

3 Performance monitoring and evaluation – a generic process

This section provides a generic process for performance monitoring and evaluation of stormwater management projects. The monitoring and evaluation of stormwater management projects and individual BMPs is intrinsically linked to the objectives of the stormwater management project or BMP itself. This section details how to determine clear program objectives.

Regardless of the scale of the stormwater management project, a generic process can be followed to prepare the performance monitoring and evaluation program (see Figure 1).

A. Purpose

B. Objectives

C. Evaluation questions and indicators

D. Planning

E. Implementation

F. Analysis and interpretation

G. Report and recommendations

Figure 1. Generic process for the development of performance monitoring and evaluation plans.

A: Purpose

The purpose of the monitoring and evaluation program should reflect that of the overall stormwater management project, but be specific enough to determine whether it was successful or not according to the desired objectives and outcomes. This step is the time to consider:

- why the stormwater management project is being monitored and evaluated
- available resources including financial resources and time availability
- who to involve and in what way
- how objective based, open ended and comprehensive the evaluation will be
- identification of external or specialist help that might be needed
- timing and deadlines.

Stakeholders should agree on the purpose and scope of the monitoring and evaluation program through negotiation and consultative processes. Terms of reference and memorandums of understanding can be developed for larger multi-stakeholder stormwater management projects.

B: Objectives

The objectives for the performance monitoring and evaluation program relate directly back to the objectives for the stormwater management project. Vague objectives will be difficult to manage, to monitor and to evaluate. One way of checking whether stormwater management project objectives will be suitable to base a monitoring and evaluation program on is to see if they are SMART.

SMART objectives

Specific – what will be achieved is clearly defined.

Measurable – there is some way of measuring what will be achieved.

Achievable – the objective is realistic given the resources available.

Relevant – the objective is essential to the program vision and goals.

Time-framed – there is a time by which the objective will be met.

Examples of SMART stormwater management project objectives are:

- within four years of project commencement, 75% of local governments use a stormwater management plan to guide management decisions
- by June 2007, fence off and revegetate 10 km of Gully Brook
- by 2010 reduce Gully Brook stream total nitrogen (TN) nutrient status from high (2.0-3.0 mg/L) to moderate (1.0-2.0 mg/L) classification
- by December 2008, all households of Springfield have received training as part of the 'this drain is just for rain' Springfield Council stormwater management project.

Producing stormwater management project objectives such as the examples above may not be easy. A tool that may be used to clarify performance monitoring and evaluation program objectives is an outcomes hierarchy.

The outcomes hierarchy is one process of evaluation planning that describes what a stormwater management project is intended to do or achieve. The outcomes hierarchy can be used at any stage of a program's lifespan. If the program objectives are listed, they vary from the general to the quite specific. By identifying the outcomes that should result from the stormwater management project objectives and placing them in order from the most general to the most specific this will help set performance and monitoring objectives that are realistic. An objective may have several outcomes at various levels of the hierarchy. As an example, below is an outcomes hierarchy table prepared for evaluating environmental education stormwater management projects.

Table 1. Outcome Hierarchy Process (Modified from DEC NSW 2004)

Outcome hierarchy	**Definitions and examples**
Ultimate outcomes ↑	Describe the impact of the overall program and the ultimate program goals in biophysical, social, economic, organisational or communications terms. Often the ultimate outcome has several programs, possibly from different organisations contributing to them. *E.g. reduced stormwater pollutants at the source, and improved water quality of creek.*
Intermediate outcomes ↑	Describe changes in individual and group knowledge, skills, attitudes, aspirations, intentions, practices and behaviours. *E.g. positive change in knowledge and behaviour of community members.*
Immediate outcomes ↑	Describe levels and nature of participation and reactions to the activities to engage participants. *E.g. a community workshop held to raise awareness of daily activities that can impact on stormwater quality.*

The ‘outcomes’ include changes in awareness, knowledge, attitudes, skills behaviour, activities and decisions that result from the actions delivered. Outcomes from a stormwater management project can occur over any range of time, from weeks to months to years, and therefore they can be expressed as immediate, intermediate or ultimate outcomes.

‘Immediate outcomes’ describe the levels and the nature of participation, and the reactions to the activities used to engage participants in non-structural BMPs. For structural BMPs you may have immediate changes such as 3 kg of litter trapped in one gross pollutant trap (GPT). For non-structural BMPs outcomes might be a stakeholder workshop held on the value of source control in preventing stormwater runoff generation.

‘Intermediate outcomes’ describe the changes in individual or group knowledge, skills, attitudes, practices and behaviours for an education based stormwater management project. For structural BMPs, an intermediate outcome could be that 70% of all seedlings planted along a ‘living stream’ survived the first two summers. A non-structural outcome may be that participants have improved skills and understanding in river restoration techniques.

‘Ultimate outcomes’ describe the impact of the overall stormwater management project. When ultimate outcomes are reached, they result in change in environmental, social and/or economic conditions. They could be outcomes such as: the pre-development hydrograph is the same as the post-development hydrograph; or the TN and total phosphorus levels in Melaleuca Brook was reduced by 0.07 mg/L and 0.15 mg/L in two years. A non-structural outcome may be that residents behave in a way that protects the receiving waters due to improved education, skills and resources available to them.

A: Evaluation questions and indicators

It is important to devise evaluation questions or indicators that are suitable for the program. You may wish to determine your evaluation questions for the various outcomes according to the following template.

Table 2. Outcomes Hierarchy Framework Template (modified from Catherine Baudains, pers. comm. 2006 and DEC NSW 2004)

Outcomes hierarchy	Evaluation questions	Indicators	Instruments for collecting data/ information sources
Ultimate outcomes			
Intermediate outcomes			
Immediate outcomes			

Evaluation questions

Depending on purpose, evaluation relates to a variety of issues concerning appropriateness, effectiveness, efficiency and process. The evaluation questions could be considered under the following headings.

Table 3. Evaluation aspects and evaluation questions (Woodhill & Robins 1998)

Aspect	Evaluation questions
Appropriateness (Was the program a good idea?)	Did the stormwater management project address the right issues? Was there a need for it? Did the objectives address the need? Were the goals and objectives appropriate given the needs of the stakeholders, the funding and the circumstances in which the program was carried out?
Effectiveness (Did it work?)	Did the stormwater management project achieve the desired objectives/outcomes? What were the barriers? Was the stormwater management project effective in achieving its stated goals and objectives? Were all the planned actions carried out? Did these actions lead to the expected outcomes? Were there unexpected outcomes such as unintended social costs or benefits to the stormwater management project? What was the effect of unanticipated external forces on the stormwater management project – how might a period of drought or economic downturn have affected the progress? Flow on effects from the stormwater management project – did other stormwater managers learn from your experiences? People's perception of the stormwater management project – how did external stakeholders feel about the program? Ideas about how to make improvements – for the future.
Efficiency (Was it cost effective?)	Could there have been better use of the resources? Was the stormwater management project carried out in the best possible way?

A: Indicators

An important part of evaluation is deciding what criteria will be used to judge success and what will be monitored. This requires establishing indicators which show whether outcomes of a stormwater management project satisfy the project objectives.

While indicators are very important, they are not the only information that will be required for an evaluation. For example, discussions, interviews and workshops with people involved with or affected by the stormwater management project will often provide an improved understanding about the workings of the stormwater management project. This qualitative information can help explain why an indicator is giving a particular result (Woodhill & Robins 1998).

Indicators should be practical, and should relate to the appropriate geographical scale for the issue being considered. Indicators for site management will differ from local and regional scale indicators. It is also important to note that indicators for a project may be relatively simple or limited to a small number of important measures.

Ideally indicators are measurable; however, when dealing with social phenomena, e.g. when assessing the outcomes from education and awareness-raising projects, quantitative measurement may be difficult or meaningless. More valuable information will be the nature of people's perceptions and attitudes that cannot be reduced to a number. Indicators for social phenomena are often unsatisfactory due to the complex nature of human behaviour. This could be overcome by appropriate evaluation questions that provide a description of who, what and why behind the numbers are required.

Criteria to consider when deciding on indicators for a performance monitoring and evaluation program could:

- relate directly to stormwater management project objectives
- focus on outcomes, not inputs or outputs
- provide a measurable assessment of the stormwater management project outcomes
- be directly attributable to the impact of the stormwater management project and not overly influenced by external factors
- be quickly, easily and cheaply assessed
- have a reproducible methodology (e.g. regular monitoring at the same sites, using the same techniques)
- give results that are not prone to misinterpretation
- be capable of showing trends over time
- be able to permit assessment of cumulative impacts
- be capable of reporting outcomes clearly through appropriate technologies, e.g. GIS systems
- be consistent with accepted scientific concepts
- be readily understandable by the community or project stakeholders
- be consistent with an equivalent indicator used in other comparable plans, e.g. local government areas, state or federal levels (modified from Woodhill & Robins 1998).

B: Planning

Organising a system to monitor the indicators and record the performance monitoring and evaluation program activities will generate a list of stormwater management tasks up front and give some indication of how much time will be required. It is important to prepare a sampling design which includes the sample size, monitoring frequency and monitoring timeframe. A database of results documentation also needs to be prepared. It may be appropriate to trial the methodology being chosen to see if it is appropriate for answering evaluation questions or indicators (McKenzie-Mohr & Smith 1999). The types of activities may include:

- trial of monitoring and evaluation methodology
- regular monitoring of indicators
- summarising and graphing the results of indicators
- holding regular meetings to review progress
- undertaking surveys of stakeholders
- employing consultants to provide specialist information or independent reviews.

C: Implementation

The implementation stage involves gathering the information and monitoring the indicators. The types of activities may include:

- gathering background information
- monitoring the indicators
- undertaking reviews of data and methodology.

D: Analysis and interpretation

This stage involves analysing the data collected, drawing conclusions and making judgements about the performance, and determining the overall value of the program.

In arriving at conclusions, it is often useful to think in terms of issues, trends and themes as:

- an issue is something that people are concerned about. Issues emerge from people's perceptions or from factual information
- a trend is an observed change over time; it may be physical, biological, social or economic
- a theme is a pattern seen by looking at all the issues and trends
- themes give rise to discussion of desirable changes and priorities for action (Woodhill & Robins 1998).

It is important to review a number of sources of information. Where a number of sources of information have led to the same conclusion then there will be greater confidence in the conclusion. However, if there are contradictions, it may be appropriate to undertake further investigation.

E: Report and recommendations

The report and recommendations should be based on the outcomes of the monitoring and evaluation program and:

- explain intended and unintended results
- identify the desired and actual outcomes
- make recommendations to improve activities including appropriateness, effectiveness and efficiency
- plan a new phase of the current stormwater management project
- plan a new program if necessary
- share what you have learnt with others
- gain publicity and support
- contribute to larger scale evaluations
- account for funds to a funding agency (modified from Water and Rivers Commission 2002; Woodhill & Robins 1998).

4 Structural BMP performance monitoring

Structural BMPs alter water quality through physical, chemical and biological processes. Structural BMP performance monitoring and evaluation requires water quality to be assessed prior to the treatment and after the treatment measures have been implemented.

Structural BMP monitoring involves measurements of selected parameters before and after the inflowing stormwater has been exposed to/treated by the structural BMP. Due to the varied nature of structural BMPs, it is best to consider monitoring and evaluation in terms of measuring what is going in and what is going out of the structural BMP.

The varied nature of structural BMPs has implications for the style and method of monitoring. Much of this is discussed in the following sections. Another consideration is the receiving environment of the structural BMP, which is where the discharge or outflow from the BMP or drain is received. In many cases the discharge will flow to surface water channels – for this, standard guidelines for monitoring surface water referenced later in the document are appropriate and give a good indication of the parameters and processes involved.

Other structural BMPs work to infiltrate stormwater, making it more challenging to capture the post-treatment stormwater to assess the effectiveness of the structural BMP. Processes to monitor water movement and water quality improvements through the soil profile or filter media, as well as any discharge to groundwater, will most likely require monitoring mechanisms to be built into the initial structural BMP construction.

Monitoring of performance of structural BMPs using groundwater monitoring methods is subject to similar rules and considerations as surface water monitoring. As such, Section 4 is particularly relevant and many of the same questions must be asked when preparing the sampling and analysis plan (SAP).

Groundwater monitoring

The issue of groundwater monitoring is structural BMP specific and requires an understanding of the construction and function of the structural BMP. Groundwater levels and behaviour should also be understood prior to the design and installation of structural BMPs. Preliminary monitoring should indicate both quantity and water quality aspects of groundwater interactions at the site.

Groundwater separation from the base of structural BMPs can be critical to the capacity and function of the BMPs. This has the potential to contribute unknown or unaccounted for water quality to the structural BMP, impacting on the volumes treated, changed water quality or estimated effectiveness.

The interactions between the structural BMP and the groundwater are dependent on the function and design of the structural BMP. Systems that are not sealed at the base and function by infiltration aim to infiltrate surface water to the groundwater. The water, along with whatever contaminants it contains, will move through the soil profile ultimately reaching the groundwater. Alternatively, in seasons of high groundwater levels and low surface water, the groundwater may rise up through the base of an unlined system and contribute another source of water to the structural BMP.

Flow paths, flow rates and duration are not as easily determined for groundwater as in the case of surface water. These factors will be influenced by soil structure, vegetation type, site contamination (clogging) and hydraulic head. All these factors will vary across sites and even individual structural BMPs and all have the potential to impact on performance and monitoring aspects of structural BMPs. The area and depth over which interaction with the groundwater may be observed is also highly site dependent and harder to quantify than for surface water (see Appendix A and B for methods/tools to collect information on groundwater and groundwater quality).

Environmental health

Alteration of hydraulic regimes, pooling and management of surface water has the potential to alter or impact on the environment in ways that can affect public health or amenity. Consequently, these environmental health issues have the potential to impact on the longevity and public acceptance of structural BMPs. Information on the risk minimisation and management of public/environmental health issues associated with structural BMPs is presented in Chapter 9.

Further information on environmental health and public health monitoring techniques can be obtained by contacting the Western Australian Department of Health’s Environmental Health Directorate or through their website at ww2.health.wa.gov.au/Health-for/Environmental-Health-practitioners/Water

Climate change

‘Climate change’ or ‘drying climate’ have implications for the operation and therefore performance monitoring and evaluation of structural BMPs. Performance monitoring and evaluation must be focused, targeted and flexible enough to effectively monitor and evaluate the performance of the actual BMP. Climate change is having an adverse effect on the Perth Metropolitan Region and while the general trend is towards a drier climate, the intensity and frequency of extreme events are becoming greater (BOM 2020).

4.1 Purpose

The purpose of performance monitoring of structural BMPs is typically to evaluate the effectiveness of the structural BMP to determine:

- the efficiency and effectiveness of an implemented structural BMP
- if it is achieving the desired objectives of the structural BMP in situ
- if management actions are required to optimise the performance of the structural BMP
- how it performs with a view to implement elsewhere.

The purpose of the monitoring should be clearly stated at the start of the planning process. The objectives of the stormwater management project and the project partners will drive what performance monitoring is required, if any. Other factors to consider when determining the purpose of the monitoring program include:

- duration of the monitoring program (may vary from one year to five years or more)
- resources available to conduct monitoring (equipment available, personnel and experience time available to commit)
- budget available (staff salaries, vaccinations, protective equipment; capital costs for equipment, construction, maintenance and decommissioning; costs of chemical analysis, etc.)
- site constraints (access to site, occupational health and safety considerations).

More comprehensive monitoring programs may also aim to collect data for research purposes.

4.2 Objectives

As discussed in Section 3B – Objectives, the objectives for the stormwater management project will be derived from the purpose and need to be specific, measurable, achievable, relevant and time-framed, to enable monitoring and evaluation against the project objectives.

Examples of objectives for structural BMP projects include:

- after installation, the structural BMP will reduce the concentration of TN and total phosphorus in the water column by 20% in baseflow and first flush
- within four months after installation of the structural BMP, concentration of total phosphorus exported from the drain to the Swan River in baseflow conditions will meet the long-term target of mg/L of total phosphorus.

The evaluation questions for the monitoring will flow on from the purpose of the monitoring and the objectives of the structural BMP project.

4.3 Evaluation questions and indicators

When the purpose of the monitoring program has been determined and the objectives of the structural BMP project are defined, specific evaluation questions should be formulated to guide the development of the monitoring program. Like the objectives of the structural BMP project, the evaluation questions need to be carefully considered and defined so that the data collected is relevant and sufficient to answer the questions.

This list of questions is a prompt to consider aspects of the structural BMP that may be relevant to evaluate:

- to what degree does the structural BMP control the contaminant levels under typical operating conditions?
- how does the effectiveness vary from contaminant to contaminant?
- how does effectiveness vary with various input concentrations?
- how does effectiveness vary with storm characteristics such as rainfall amount, rainfall intensity and antecedent weather conditions?
- how do design variables affect performance?
- how does effectiveness vary with different operational and/or maintenance approaches?
- does effectiveness improve, decay or remain stable over time?

- how does the structural BMP's efficiency, performance and effectiveness compare to other structural BMPs?
- does the structural BMP reduce contaminants to acceptable levels?
- does the structural BMP cause an improvement or protect downstream receiving environments?
- does the structural BMP have potential downstream negative impacts?

Typical evaluation questions for structural BMPs might include:

- how effective is the structural BMP at reducing the concentration of nutrients discharged through the stormwater drain in baseflow conditions (other flow conditions or contaminants may also be considered)?
- to what extent has the structural BMP improved the effectiveness of the stormwater drain at reducing the concentration of contaminants discharged through the drain in baseflow conditions?
- how does the water quality downstream of the structural BMP compare to relevant water quality guidelines?
- are there any patterns in the effectiveness of the structural BMP that might be associated with seasonal variation or different flow regimes?

Answers to these evaluation questions will guide the extent of monitoring that is required. Several iterations may be required to ensure that the proposed monitoring will suit the available resources and budget, answer the evaluation questions, and meet the needs of the project partners and objectives.

4.4 Planning

Detailed planning of the monitoring is critical to ensure that the data collected will answer the evaluation questions in the most cost-effective way.

Before developing the monitoring program, collect any information about the site and likely seasonal changes. Investigate other monitoring programs to learn from their successes and failures. Make use of the local experience and knowledge of project partners when developing and conducting the monitoring program. Where possible or necessary, the structural BMP should be designed to suit the required monitoring. For example, construct flow control structures (e.g. weirs) where flow rate will be measured. The monitoring program must be planned prior to completion of the design and installation of the structural BMP to ensure that the structural BMP design can be adjusted to suit the proposed monitoring.

The interactions between groundwater and stormwater should be considered at the planning stage. If groundwater readily interacts with the surface water in the drainage system, it may be necessary to quantify the influence of the groundwater in terms of water quality and quantity. For more information about groundwater data collection methods, see Appendix B.

4.4.1 Variability in environmental systems

There is a high degree of variability in environmental systems. The location and frequency of sampling must be carefully selected to ensure that it is appropriate for the likely variability of the particular system and what you are trying to observe.

It is highly advisable to undertake a pilot study of the system to be monitored. This will provide information on the variability in the system (in time and space) and contaminants of concern, which will enable the ongoing water quality monitoring to be designed to suit the particular system. Using a pilot study will also provide justification for the scope of the ongoing monitoring program. It is important to consider if the results from the pilot study will be applicable for the duration of the sampling program. If the results from a pilot study undertaken in one season are extrapolated to design a monitoring program over several years, changes in hydrodynamics between seasons will need to be factored into the program design.

A pilot study will usually involve monitoring at a high frequency, with extensive spatial coverage, for a wide range of parameters. At least three sample events in time and space are necessary for statistical analysis of the variability. The frequency of the pilot study monitoring should be sufficient to understand the range of temporal variability in the system that is relevant to the monitoring objectives. For example, if the monitoring program is interested in changes in nutrient concentrations, the pilot study should take samples on a weekly basis and more frequently during storm events. Monitoring at a lower frequency (i.e. monthly) can miss important peaks in contaminant levels and give a deceptive picture of the water quality. Analysis of the pilot study results will indicate the appropriate frequency for ongoing monitoring.

Assessment of the spatial variability through a pilot study should confirm which sites will provide the information required to answer the evaluation questions. It is likely that the proposed monitoring sites will be the major upstream and downstream sites relative to the structural BMP (or inlets and outlets, for instance if the structural BMP is part of a compensating basin). The pilot study may involve sampling at all inlets and outlets, even minor ones, to see if they provide important information. In addition, the pilot study may be necessary to confirm that the proposed sites are representative of the intended 'water parcel' and are behaving as expected. If monitoring near an inlet but just inside the compensating basin, does the sample reflect the inlet water quality, or is it too mixed with the water already in the basin? Perhaps water only flows through the outlet when it is pumped from upstream – will this be a reliable site to sample? Are assumptions about the preferred flow path and extent of mixing valid?

A pilot study may also be used to investigate likely contaminant levels, with the view to narrowing down the list of parameters for ongoing analysis. However, care should be taken when eliminating key parameters based on a few samples taken at one particular time of the year.

Statistical analysis may be conducted to estimate how many events need to be monitored, to capture the expected change in water quality parameters caused by the structural BMP with the desired confidence in a conclusion (i.e. power analysis). This is an important 'reality check' to ensure that the objectives can be actually attained with the available resources.

Following analysis of the pilot study results, the ongoing monitoring can be designed. At this stage, it is critical to document the proposed monitoring in a SAP. The SAP will be a summary of:

- *why* the monitoring will be undertaken (the purpose of the monitoring, the objectives of the structural BMP project and the evaluation questions to be answered)?
- *what* monitoring will be undertaken (duration, frequency, sites, parameters)?
- *how* the monitoring will be undertaken (detailed methods)?
- *what* measures will be taken for quality assurance of the monitoring data?
- *what* measures are required to protect personnel from contaminants and other occupational safety and health (OSH) threats?
- *who* will be the custodian of the data collected – storage of data in a stable and accessible format?
- *what* will be done with the data collected (analysis and interpretation of the data, reporting and communication)?

4.4.2 Duration

The duration of the monitoring program will usually be more than one year, to capture seasonal variations. It is preferable to monitor for at least three years to allow statistical quantification of inter-annual variability. If the evaluation questions consider changes over time or variations in efficiency of the structural BMP depending on input conditions, it will be necessary to monitor for three years as a minimum.

4.4.3 Frequency

Frequency may be very intense to capture changes during storm events, or anything down to once per year (for instance, to measure accumulation of sediment). Clearly, more frequent monitoring will provide more comprehensive results but will be more expensive. To capture seasonal variation it is preferable to monitor at least monthly, preferably fortnightly. More information on frequency and how it relates to interpretation of data is provided in Chapter 3 of *Australian Guidelines for Water Quality Monitoring and Reporting* (ANZECC & ARMCANZ 2000).

If the evaluation questions concern changes in efficiency during different input conditions (e.g. different flow conditions or storm intensities) then it will be necessary to select the times for monitoring based on capturing a range of different input conditions. Regardless of how many different input conditions are defined, it is necessary to collect at least three samples for each of the different input conditions. This will provide a minimum level of data to allow assessment of statistical differences.

4.4.4 Site selection

Careful selection of sites will ensure that a scientific assessment of the structural BMP effectiveness can be made. A typical plan for measuring structural BMP effectiveness is to monitor upstream and downstream of the structural BMP, both before and after it is installed. The 'before' sampling (also called baseline sampling) establishes the initial efficiency of the site before installation of the structural BMP, and is used as a control. A control is subject to the same conditions as the test site, except for the structural BMP that you are testing. The 'after' sampling (also called evaluation sampling) is used to determine the effectiveness of the structural BMP and to determine how much difference it has made. If there is no control data, it is not possible to conclude that water quality treatment at the site is due to the structural BMP; the site may have already had a capacity for improving water quality (for example).

If the structural BMP is installed at a site that has multiple inlets or outlets, it may be necessary to monitor some or all of these. Typically, only major inlets and outlets convey water regularly. Minor inlets and outlets may not be monitored at all, or may be monitored less frequently when they are conveying water (e.g. immediately after storms).

For structural BMP types or applications where there is no clear 'upstream' then a control or reference area must be identified. In this case sampling either several control locations, or several sites within a control area, assists the interpretation of data by making it easier to account for other, potentially confounding, causes of variability in natural environments. Reference areas may also be considered if the structural BMP involves restoring native vegetation or ecological functions to a stream or wetland. In this case the reference sites will provide valuable information on species and key ecological processes and functions to be restored.

Site selection may also be limited by physical constraints or health and safety issues. For instance, if the upstream site is entirely piped, it may be difficult to get access to the water to take samples. Sites with steep sides or near busy roads should be sampled with care and not alone. Safe working procedures should be developed and implemented to overcome hazards.

It is important to ensure that the sites selected fulfil the criteria they are assumed to represent. For example, when sampling an inlet as it enters a water body, ensure that the water sampled is representative of the inflow water, not the mixed water in the water body.

4.4.5 Parameters

A wide range of parameters may be monitored, depending on the evaluation questions to be answered. Appendix A provides a summary of parameters that may be relevant to evaluation of structural BMPs, including what is measured, factors that may affect the parameter, and when it may be relevant to measure.

While the selection of parameters is issue, site and BMP specific, a list of common parameters for structural BMP monitoring is:

- physical parameters (conductivity, pH, temperature, dissolved oxygen)
- flow rate
- total suspended solids (TSS)
- nutrients (TN, TP, NO_X-N, NH_3-N/NH_4-N, DOrgN, SRP).

Dissolved organic carbon (DOC) or biochemical oxygen demand (BOD) also provide useful information on the ecological processes relating to carbon cycling. If funds are available, consideration should be given to measuring one of these analytes also. Parameters that are more expensive but still of interest may be monitored less frequently (e.g. BOD, heavy metals). A useful guide to selection of parameters is *A Guideline for the Development of Surface Water Quality Monitoring Programs* (Department of Water 2009a). This document outlines parameters that may be relevant depending on local land use practices, and also discusses other aspects of the design of water quality monitoring programs.

4.4.6 Methods for water quality monitoring

There are a range of methods at different scales for monitoring structural BMPs. The method chosen will depend on available budget, capacity to procure and install infrastructure and the comprehensiveness of data required.

Table 5. Water quality sampling method characteristics

	Sampling method	**Description**
Decreasing cost, infrastructure required, and thoroughness of data collection ↓	Water quality transducers and data loggers	Probes installed at a fixed location, which measure parameters continuously or at fixed frequent intervals (e.g. every 5 mins, 60 mins). Limited by what the probes can measure – usually physical parameters, such as water depth, flow velocity, conductivity, temperature, dissolved oxygen, chlorophyll, etc. The data measured are stored in the logger on-site, and it is becoming more common to broadcast the data to a central computer via modem.
	Automated sampling	A sampler installed at a site and programmed to collect samples in particular conditions (e.g. during storm events). Consists of a pump system, a controller and an array of sample bottles within a housing. Parameters that will change significantly between the time of collection and when the sample is retrieved and analysed are not appropriate to measure with automated samplers (e.g. pH, nutrient fractions (NO_X-N, NH_3-N, etc).
	Integrated sampling	Samplers that integrate water samples over a fixed time period or volume. For example, materials that quantitatively adsorb organic contaminants or metals can be placed in a water body over an extended time, and will measure contaminants that are at low concentrations or infrequently present in the water column (passive samplers). Typically used for metals or organic contaminants.
	Manual sampling throughout storm events and different flow regimes	Water quality can vary considerably during different flow regimes. If the infrastructure required for automated sampling is too demanding, manual sampling during different flow regimes may capture some of the water quality variability. For example, collecting a series of manual samples throughout the course of a storm event. However, this requires a quick response to storm events, and may require sampling at odd hours and in hazardous conditions. It is also necessary to quantify the flow rate during each sampling event. Parameters that may not be appropriate to measure by automated sampling can be measured by manual sampling.

	Sampling method	Description
Decreasing cost, infrastructure required, and thoroughness of data collection ↓	Regularly spaced manual sampling	Manual sampling at a regular frequency will provide a general overview of the water quality. The sampling must be frequent enough so that changes in water quality are observable on the timescale that is relevant to the monitoring goals. A pilot study is recommended to determine the required frequency of sampling.
	Composite samples	Samples may be composited in time (e.g. integrated samples as discussed above, manual samples collected from one site but five minutes apart, etc.) or in space (e.g. samples from different depths, all inlets to a water body, etc.). Composite samples will account for more of the environmental variability without having to pay for analysis of many different samples. However, variability between the different sub-samples in the composite sample will be lost.
	Infrequent samples	Sampling infrequently or irregularly will provide data that is of limited use for evaluation purposes. However, it may be appropriate when investigating possible pollutants or to get a snapshot of the water quality.

4.4.7 Flow data

The flow rate puts all other parameters in context. The importance of the water quality from a particular source will depend on the volume of water that is conveyed from that source, as much as the concentration of contaminants in the water. Contaminant concentration is also influenced by rain events – if there is a high flow rate due to a recent storm, the contaminants may be diluted. In contrast, contaminant concentration is usually higher at the start of storms, when contaminants are washed from urban catchments. Discussing water quality in terms of concentration only, without describing flow conditions, can be inaccurate and misleading.

The influence of flow rate can be captured by expressing the contaminant in terms of load. Load is the total amount of a substance that is transported past a particular point, and is the product of concentration and flow rate. Flow events are usually the major influence on nutrient loading. Sampling at fixed intervals may misrepresent the load, as peaks and variations that occur during flow events are not fully captured. Using automated samplers and gauging flows is the best way to capture variability during flow events. However, this may be prohibitively expensive in many situations. Moreover, automated samplers can only be used to sample certain parameters – for example they are not suitable for dissolved nutrients.

Another way to present water quality data and account for flow events is using the event mean concentration. The event mean concentration is the total contaminant load divided by the total runoff volume. Like loads, event mean concentrations are not directly measured but calculated, and also require the flow rate to be measured.

Like water quality, flow rate can be measured in a variety of ways (see Appendix C for some suitable tools and methods). The particular technique chosen will vary depending on the situation. Flow rate can only effectively be measured when the water passes over a stable and confining cross-section of the channel that can be well defined. This usually occurs when water passes over a weir or similar structure.

A summary of flow measurement approaches is presented below.

Table 6. Flow sampling method characteristics

	Sampling method	**Description**
Decreasing cost, infrastructure required, and thoroughness of data collection ↓	Continuous quantitative	Probe that measures parameters continuously or at fixed frequent intervals (e.g. every 5 minutes). Flow rate is often measured by water pressure or water depth over a known cross-section where the relationship between water level and flow rate is stable. The flow monitoring site must be gauged by experienced personnel to establish a relationship between static water measurements and flow rate during different flow regimes. The relationship is called a rating curve. The data measured may be stored in the logger on-site, or broadcast to a central computer via modem.
	Non-continuous quantitative	A quantitative method for measuring flow at regular intervals or whenever samples are taken. For example, a water level indicator that can be read manually on-site to indicate the water level, and thereby calculate the flow rate from a derived relationship between water level and flow rate, known as a rating curve. As for continuous quantitative measurements, the site must be gauged to establish the water level to flow rate relationship.
	Non-continuous limited qualitative	Flow rate is described each time a sample is taken (e.g. fast flow rate, flow rate increasing, flow at peak, flow in recession, rained at this site today, no discernible flow, etc.). This will give an indication of the flow regime that may help when interpreting data.

4.4.8 Maintenance information

Most structural BMPs require ongoing maintenance. The party responsible for undertaking performance monitoring and evaluation of the structural BMP must also source details of all maintenance activities for the duration of the monitoring program. Maintenance activities can explain variations from expected performance and/or unusual monitoring results. Assessment of the extent of maintenance required can also feed into a cost-benefit analysis of the structural BMP.

4.5 Implementation

Implementation is the stage of undertaking the monitoring that has been planned. Careful and consistent methodology must be followed to ensure that the samples collected are not compromised by sampling error.

The Department of Water and Environmental Regulation has prepared Field Sampling Guidelines for manual collection of water quality samples (Department of Water 2009). These guidelines are a good reference for standard sampling techniques. They can also be inserted into the SAP to describe how the data were collected. Specific methods for collection of samples for common parameters have also been prepared (Department of Water 2009).

It is important to ensure that the sampling plans are followed, and any major deviations from the planned monitoring are recorded. While putting hard work and resources into undertaking monitoring, it is critical to ensure that the data collected are stored appropriately and are of good quality.

4.5.1 Data management

Good data management allows project managers to make defensible decisions based on good science, using data of a known quality. It allows central availability so that the data can have multiple uses and it allows for querying and manipulation of data while preserving the raw data. Finally it provides long-term security of data in which considerable time and money has been invested, from collection through to analysis and reporting.

Good data management begins before samples are collected and should be applied throughout the process. It is based on standards, follows an established process and is a good investment as it results in data that are trustworthy and useable, and become more valuable over time.

On the other hand poor data management can result in data that are incomplete or lost completely, of dubious quality, not traceable to original collection sources or standards, isolated and not centrally available to those to whom it may be of use, without context, and difficult or impossible to query or manipulate. Poor data management is a waste of valuable time and resources in terms of the original sampling costs and effort, the need to gather the data again, and inadequate environmental management. In short, poor quality data is worse than no data.

The basic requirements for good data management are:

- use standardised sampling procedures (based on national standards – AS/NZS 5667.1:1998: Water quality – Sampling – Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples, National Water Quality Management Strategy guidelines)
- use reliable sample analysis methods. Laboratories should be National Association of Testing Authorities (NATA) accredited for both the analytes and matrices and independently audited
- use standard operating procedures during sample collection
- always record how and where data was collected and analysed. Be specific, so that someone could use your method to repeat the sampling
- use your method to repeat the sampling
- record where the samples were collected, and use the same sites consistently
- enter the data into a maintained database, for security and availability now and in the future
- ensure that all data entered into the database meets all the requirements outlined above.

4.5.2 Quality assurance and quality control

Quality assurance and quality control are often treated as the same thing, but actually they are not.

Quality control is the generation of data for the purpose of assessing and monitoring how good the sampling and analysis method is and how well it is operating. This is the process of collecting quality control samples, for instance to test for contamination when collecting or transporting samples. Further information on quality control is available in *A Guideline for the Development of Surface Water Quality Monitoring Programs* (Department of Water 2009).

Quality assurance, by contrast, comprises all the steps taken to assure those who are using the data that the data is real, meaningful and of a high quality. Quality assurance encompasses quality control but also includes many other aspects, including, but not limited to:

- having prepared a documented SAP
- conducting sampling in accordance with standardised and consistent procedures that are documented in the SAP including the use of 'chain of custody' forms
- ensuring that equipment is well maintained, cleaned and fully calibrated before use, by means of specific, fully documented procedures
- ensuring that individuals that carry out the sampling are competent and trained to do so
- having dedicated systems, such as the Water Information database that carefully process and store data via standardised procedures, and allow data retrieval at a later date.

4.6 Analysis and interpretation

Prior to analysis, the quality of the data should be confirmed by reviewing the quality control results and checking for data input errors. Following quality assurance, presentation and analysis of the data can commence.

The data must be presented in an appropriate format. For most purposes, a table or graph is an effective way to summarise the data. Decide whether the raw data will be presented, or if it will be summarised some way.

Firstly, present and describe the baseline data (monitoring undertaken before the structural BMP was installed):

1. What is the water quality at each site? Are there any patterns in the changes in water quality, and how can they be explained? Consider flow data and/or rainfall data.
2. Is the water quality the same for all sites? If not, what could be some of the reasons why the water quality varies (consider land uses for example)?
3. How do the results compare to national water quality guidelines (e.g. ANZECC & ARMCANZ 2000)?
4. What is the baseline removal efficiency for the parameters of interest at the site where the structural BMP is proposed? If there is sufficient data, calculate the removal efficiency for a range of flow conditions and storm events.
5. What other changes in water quality are observed between the inlet(s) and the outlet(s)? Consider parameters such as dissolved oxygen and TSS, which may be not stated in the project objectives but are relevant to ecosystem functioning.
6. Are there any patterns (seasonal, different flow regimes) in the baseline removal efficiency?

Secondly, present and describe the evaluation data (monitoring after the structural BMP was installed):

1. What is the water quality at each site? Are there any patterns in the changes in water quality, and how can they be explained? Consider flow data and/or rainfall data.
2. Is the water quality the same for all sites? If not, what could be some of the reasons why the water quality varies (consider land uses for example)?
3. How do the results compare to local guidelines, local reference sites and baseline data as well as national water quality guidelines (e.g. ANZECC & ARMCANZ 2000)?
4. What is the removal efficiency of the structural BMP for the parameters of interest? If there is sufficient data, calculate the removal efficiency for a range of flow conditions and storm events.

5. What other changes in water quality are observed between the inlet(s) and the outlet(s)? Consider parameters such as dissolved oxygen and TSS, which may be not stated in the project objectives but are relevant to ecosystem functioning.
6. Are there any patterns (seasonal, different flow regimes) in the removal efficiency?

Thirdly, compare the results from monitoring the site before and after installation of the structural BMP, to assess the effectiveness of the structural BMP:

1. Has the removal efficiency for the parameters of interest improved since the structural BMP was installed?
2. How has installation of the structural BMP affected other parameters, compared to before the structural BMP was installed?

Finally, answer each of the evaluation questions, making use of the results from previous analysis and discussion.

4.6.1 Efficiency

The efficiency of stormwater structural BMPs can be calculated in a number of ways. More thorough calculations require more data to be collected. When using simpler calculations, it is important to be aware of the limitations and assumptions involved. Being aware of the requirements of the calculation method will allow the monitoring program to be designed appropriately.

One method of calculating removal efficiency is presented below. This method can be adapted depending on what data is available. It is generally used to average different contributions throughout an event, to take into account natural variability and sampling artefacts. Further methods and limitations of assessing structural BMP efficiency are discussed in *Urban Stormwater BMP Performance Monitoring* (USEPA 2002).

Firstly, calculate the event mean concentration (EMC) for each site for the parameter you are interested in. The EMC is defined as the total constituent mass divided by the total runoff volume, and is calculated as:

$$EMC = \frac{\sum load}{\sum flow\_rate}$$

The load is the product of the flow rate and the concentration of the parameter. The sum of the loads is the sum of all data available during an ‘event’. Similarly, the sum of the flow rate is all flow rate data during an event. It is assumed that a number of samples, measuring both flow rate and concentration, are collected during each event. If this is not the case, then EMC will simply be equal to the concentration (or average concentration) of the parameter.

The EMC is calculated using all the data available for each ‘event’. An event is typically a storm event, but a similar principle may be applied to assess the removal efficiency during other flow conditions. For example, ‘baseflow during summer’ may be treated as one event, for the purposes of this calculation.

Secondly, the EMCs are used to calculate the removal efficiency of the structural BMP:

$$removal\_efficiency = \frac{average\_inlet\_EMC - average\_outlet\_EMC}{average\_inlet\_EMC}$$

The average_inlet_EMC is the mean of the EMCs for all the inlets (if there is more than one inlet). Likewise the average_outlet_EMC is the mean of the EMCs for the outlets. This will give a removal efficiency for each ‘event’, so that different flow conditions can be considered separately.

This method is most effective when there are a number of flow and concentration measurements taken at the inlets and outlets throughout one event. If there is only one sample taken, the lag time between the inlet(s) and the outlet(s) is not accounted for. It is assumed in the calculation that the sample taken at the inlet(s) is from the same slug of water that is sampled at the outlet(s). Unless this lag time is quantified (e.g. through tracer studies) and samples taken appropriately, the calculated removal efficiency may be inaccurate.

The USEPA recommends the use of the effluent probability method for quantifying structural BMP efficiency. Firstly, statistical tests are used to establish whether the inlet and outlet EMCs are statistically different – is the structural BMP providing treatment? When this has been established, a cumulative distribution function of standard parallel probability plot of the inlet and outlet quality is examined. The differences between the inlet and outlet graphs at different concentrations will indicate the level of treatment that the structural BMP is providing. This method can indicate differences in structural BMP effectiveness at different inlet contaminant concentrations. Details on undertaking this method of assessment are provided in Urban Stormwater BMP Performance Monitoring (USEPA 2002).

4.6.2 Effectiveness

The effectiveness of a structural BMP is measured by the extent to which it achieves the project objectives. For a structural BMP, the project objectives will typically be stated as a quantifiable improvement to water quality. The effectiveness would consider:

1. Does the calculated removal efficiency of the structural BMP achieve the anticipated improvements to water quality?
2. To what extent has the structural BMP improved the situation, compared to before it was installed?

4.6.3 Standards and guidelines

Baseline data and reference sites are useful in establishing suitable water quality guidelines; these figures are likely to be representative of local processes and conditions. Results from the monitoring may be compared to standards and guidelines to consider if the water or sediment quality is satisfactory for the receiving environment. Useful references include:

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra, ACT, Australia. Viewed September 2021, www.waterquality.gov.au.

4.7 Report and recommendations

It is advisable to prepare an interim report on the project. Annual analysis of the data will reduce the amount of work required when producing the final report, and will ensure that any problems with the data of the project are detected prior to the completion of the monitoring. At the conclusion of the monitoring program, a single comprehensive technical report should be prepared.This report will describe the project and evaluate it in terms of the project objectives. The report should be written with the target audience in mind.

Reports (interim and final) should cover the following broad areas:

1. Background – information about the site, why the project was implemented
2. Purpose and objectives – the objectives of the structural BMP project, why it was decided

to monitor and evaluate the structural BMP, evaluation questions to be answered by the monitoring program

3. Monitoring plan – summarise the monitoring sites, frequency and parameters, with reference to the SAP for further details

4. Methods – a reference to the SAP should be sufficient, unless unusual methodology is employed

5. Quality assurance (QA) assessment – review the laboratory QA data and any quality control samples taken. QA assessment should be done as soon as possible after each sampling occasion so this will hopefully be a summary of previous results

6. Results – present and describe the monitoring data, including broad patterns in the baseline and evaluation data. Tables or graphs are useful

7. Discussion – discuss patterns observed in the results and what they might indicate. This is where the efficiency and effectiveness are assessed. Address each of the evaluation questions in detail

8. Conclusions – summarise the results in terms of the purpose of monitoring and the evaluation questions

9. Recommendations – for future management or monitoring of the structural BMP, or for application of the structural BMP at other sites

10. References

11. Appendices.

4.7.1 Communication

The outcome from the structural BMP monitoring and evaluation should be communicated to key stakeholders. With a wide range of stakeholders, communications may need to be tailored to suit the intended audience. It may not be appropriate to distribute the entire evaluation report to all stakeholders indiscriminately.

However, distribution of information about the monitoring and evaluation of structural BMPs to other people or organisations involved in this area will increase knowledge and avoid repetition of mistakes and promote lessons learnt.

Example 1
A Swan River Trust (SRT) project, the Liege Street Wetland in Cannington, was designed to target the removal of nutrients in low flows, provide flood storage capacity for high flows, and increase habitat and amenity value. This is an example of how the generic process has been applied to monitor and evaluate a structural BMP. The Liege Street Wetland treats water from the Liege Street and Cockram Street main drains before they discharge into the Canning River upstream of the Kent Street Weir. Construction of the Liege Street Wetland was complete in July 2004, immediately followed by planting which continued into 2005.

The *purpose* of the Liege Street Wetland monitoring program was to evaluate the performance of the wetland at improving water quality, habitat and public health. It was appropriate to undertake extensive monitoring of the Liege Street Wetland, as this was a demonstration site which could be used to assess the effectiveness of constructed wetlands on the Swan Coastal Plain for stormwater treatment.

The *objectives* of the project were to:

- improve water quality being delivered into the Kent Street Weir Pool, with a particular focus on reducing the delivery of nutrients in summer and autumn, when the risk of algal blooms is high
- provide adequate storage and attenuation of peak flows
- improve wildlife habitat
- provide passive recreation and education opportunities
- provide information on wetland maintenance requirements and costs, both in establishment and long-term
- fill knowledge gaps in performance of wetlands at improving water quality and habitat.

These objectives appropriately describe the overall outcomes sought; however they are difficult to assess.

The *evaluation questions* to be answered to assess the performance of the Liege Street Wetland were:

- does the actual hydrology of the wetland match that of the design intent?
- what is the wetland treatment efficiency for a range of different parameters (nutrients, sediment, metals etc.) under different hydrological conditions (baseflow, rising limb, falling limb of various storm events)?
- how effective is each main element of the wetland (e.g. sumplands versus open water, flow path lengths)?
- what is the ability of the wetland to treat stormwater over time and with age?
- how does effectiveness vary with different operational and/or maintenance approaches?
- does the wetland cause an improvement in or protect biotic communities?
- can the operation and maintenance of the wetland be improved?

Again, these questions are appropriate in terms of the outcomes sought but are difficult to evaluate. For instance, question 4 asks 'what is the ability of the wetland to treat stormwater over time and with age?' However, this does not explain what aspects of treating stormwater will be considered – reducing nutrient concentrations. The question also does not describe how the 'ability' will be measured – percentage reduction, reduction of concentration, reduction of total loads?

For most projects, a precise definition of the project objectives and monitoring questions will enable the monitoring to be planned to answer the specific questions of interest within the available budget. This was not as critical for the Liege Street Wetland, as an extensive monitoring program was designed to collect as much information as possible to fill knowledge gaps.

Planning and implementation

The monitoring undertaken at Liege Street Wetland encompassed more than most other structural BMP monitoring programs would require. Aspects that were monitored included the surface water, groundwater, sediment, hydrology and biota. The surface water and hydrology (flow rate) sampling will be discussed here.

Limited *baseline data* was collected before construction of the wetland, as the project was initiated and constructed in a tight timeframe. Surface water was sampled on an ad hoc basis from 1999 and then from December 2003 to April 2004 on a monthly basis for nutrients (TN, TP, NO_X, NH_4-N, SRP), physical properties (dissolved oxygen, pH, conductivity, temperature), biochemical oxygen demand, total suspended solids and heavy metals. Ideally, at least one year of baseline data should have been collected, at the same frequency and with the same parameters as the planned evaluation sampling.

Evaluation sampling of the Liege Street Wetland was conducted from November 2004 on a monthly basis by taking manual samples for the following parameters:

- nutrients (TN, TP, NOX, NH4-N, DOrgN, SRP)
- total suspended solids (TSS)
- dissolved organic carbon (DOC)
- biochemical oxygen demand (BOD).

These parameters were selected to enable interpretation of nutrient cycling within the wetland, refine modelling of the catchment and understand organic matter fluctuations and oxygen demand. This suite of parameters will provide information on key aspects of the wetland ecology that contribute to algal blooms, by describing all the nutrient fractions, possible sediment loads of nutrients, organic carbon concentrations and demand for oxygen.

Manual samples were also taken on a quarterly basis at the same sites, and analysed for total heavy metals, chlorophyll and alkalinity. Sampling at a reduced frequency for these parameters is appropriate as they are not as critical to nutrient dynamics and algal growth.

Sampling at a monthly frequency is a common fallback method when undertaking monitoring and evaluation. This frequency is usually selected as a compromise between weekly or fortnightly sampling, and quarterly sampling. However, unless a pilot study is undertaken or high frequency historical data is available, it is not possible to understand what variability is missed by sampling at this frequency.

The sites were selected to be representative of a particular segment of the wetland, such as the inlets, open water bodies, and outlet. This is an appropriate site selection strategy. Again, with such a large area to investigate, the selection of sites ideally would be supported by a pilot study to understand the flow paths and how the different parts of the wetland interact.

Surface water samples were also collected by automated sampling, using a load measuring unit (LMU). This consists of a flow measurement device, a logger, an autosampler, a pump, and an array of bottles stored in a cool housing unit. The autosampler is programmed to collect samples in response to certain flow conditions. At Liege Street Wetland, the autosamplers took samples when the water velocity reached a certain speed – that is, during rain events. The parameters analysed from the LMU samples were TN, total phosphorus and TSS. As the samples are stored in the cool housing for up to a week at a time, it is not appropriate to analyse these samples for any parameters that might change (e.g. cannot analyse for nutrient fractions, as the relative amounts of each species may change after sitting in a bottle for a week). The LMUs at Liege Street Wetland were located at the two main inlets and the outlet from the wetland.

Flow rate was measured at Liege Street Wetland in a variety of ways. Firstly, at the same sites as the LMUs, Dopplers were installed. The Dopplers measure water velocity, hydrostatic pressure (to calculate water depth) and temperature. Information from the Dopplers is recorded on a data logger on-site and downloaded periodically. This is an example of continuous quantitative flow data.

In addition, staff gauges with peak level indicators (PLIs) and capacitance probes were installed in two of the ponds in Liege Street Wetland and at the outlet from the wetland. Capacitance probes measure and record the water level, another example of continuous quantitative flow data. PLIs indicate the highest water level until they are re-set, which is an example of non-continuous quantitative flow data.

Analysis, interpretation and reporting

An internal document, the Liege Street Constructed Wetland Annual Monitoring Report 2005, reported the first year of monitoring data for the Liege Street Wetland to the Swan River Trust. The main aims of the report were to:

- make recommendations to the SRT for updating the Liege Street Wetland monitoring program
- make recommendations to the SRT for improved management of Liege Street Wetland
- provide an initial evaluation of Liege Street Wetland performance (water quality treatment).

This was an interim monitoring report providing a review of available data collected in the first year of wetland monitoring. The wetland was not expected to achieve full treatment capability for a number of years after construction and planting. The surface water quality data was compared to the ANZECC and ARMCANZ (2000) trigger values for physical-chemical stressors and toxicant values.

The available data provided an initial indication of wetland performance. The efficiency and effectiveness of the wetland were not assessed in this report, largely because of delays in availability of the flow data. The performance of the wetland was qualitatively described, by summarising broad changes in nutrient species between the inlets and the outlets in different seasons.

5 Non-structural BMP performance monitoring

5.1 Context for non-structural BMP monitoring

Non-structural stormwater best management practices (non-structural BMPs) are institutional and pollution-prevention practices designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. They do not involve fixed, permanent facilities and they usually work by changing behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments (Taylor & Wong 2002). Chapter 7 defines non-structural BMPs for stormwater management into five principal categories: town planning controls; strategic planning and institutional controls; pollution prevention procedures; education and participation programs; and regulatory controls.

It is often perceived to be difficult to measure the degree of the success of non-structural BMPs and people tend to feel that they are less important than structural controls (NSW DEC 2004). However, they are essential in stormwater management as the key to improved stormwater quality and quantity heavily depends on behaviour change. Therefore, it is vital that the success of achieving change using non-structural BMPs is effectively evaluated through a properly designed and implemented performance monitoring and evaluation plan.

5.2 Non-structural BMP purposes and objectives

The outcomes of non-structural BMPs can be grouped as:

- the BMP has been fully implemented
- there has been a change in awareness and knowledge of specific stormwater issues within a segment of the community
- the BMP has changed people’s attitude (usually self-reported)

- the BMP has changed people's behaviour
- there have been actual changes in behaviour
- the BMP has improved stormwater quality and quantity
- there has been a change in the receiving environment quality.

5.3 Defining non-structural BMP success

What will qualify as a successful outcome for a non-structural BMP needs to be determined prior to implementation. By preparing an outcomes hierarchy for the non-structural BMP (Section 3), the levels of success can be determined. It is important to note that achieving one level of outcome for a project will not necessarily directly lead to achieving a higher level of outcome. For example, if there was a change in the behaviour of a community, then it may be incorrectly inferred that this would have some effect on quality or quantity of stormwater. If the quality or quantity of stormwater in the area improved, then it may be assumed that the behaviour change had some role in the change but showing a direct causal link may be expensive and difficult (McKenzie-Mohr and Smith 1999).

It is important to be aware that changes in a community's knowledge as the result of the implementation of a non-structural stormwater BMP does not necessarily lead to changes in behaviour as a result of that knowledge (Smyth 1996).

5.4 Variables that affect non-structural BMP success and things to consider

The success of non-structural BMPs is heavily dependent on human behaviour, significantly more than structural controls which once installed can make a difference to the receiving environment as long as they are well maintained. Existing knowledge, values, attitudes and beliefs will shape the behaviour and motivations of people (Smyth 1996; Garcia-Mira et al. 2003).

The success of town planning controls, pollution prevention procedures and regulations require that they have incorporated current best practice knowledge and practice in the regulations. Other variables that effect success for these tools include: that the application of the controls is correctly interpreted and applied; and how effectively these tools are enforced.

Institutional and strategic planning controls tend to have a range of implementation options such as licensing, legislation, regulation, administrative directions, reporting and taxation and service delivery. These controls may be unsuccessful because either the controls could not be implemented as designed, or the control was implemented as designed but did not achieve the desired objective.

Environmental education and participation programs aim to influence individuals to act in a manner that the benefits the environment. They will be successful if they have a holistic approach that includes appropriate and credible information, overcoming the barriers to action, choosing the right behaviours to promote, using effective educational tools and evaluating for success.

The following checklist provides a list of variables which influence success that could be considered when preparing a non-structural project implementation and monitoring and evaluation program. Performance monitoring and evaluation questions may ask whether these variables had an effect on the project.

Table 7. Check list of variables that influence non-structural BMP success

Understanding and agreement on project objectives and outcomes	Detailed specification of tasks to be completed
Communication and coordination	Compliance
Competence	Influence of external constraints
Agreement and support	Adequate time
Adequate resources	Suitable combination of resources
Valid theory and premise behind the designed project	Things change during the life of the project
Single implementation responsibility	

Given that the variables that will influence success are identified, baseline information needs to be gathered before the non-structural BMP is implemented (e.g. awareness levels before a stormwater awareness campaign). In addition, for some types of BMPs (e.g. educational campaigns), a pre-implementation monitoring exercise can be an extremely valuable input to help the design of the BMP (e.g. to clearly identify who is littering, where, when and why) (Taylor & Wong 2003).

Often, the timing of the 'monitoring and evaluation tasks' needs to be carefully synchronised with the 'BMP implementation tasks'. This is where the performance monitoring and evaluation program and a working group outlined in Section 3 is important as it highlights all the tasks for the program, who is responsible for their implementation and when they will be done.

5.4.1 Styles and techniques for non-structural BMP performance monitoring and evaluation

There are many approaches to evaluating the success of non-structural BMPs. When using the performance monitoring and evaluation generic process as outlined in Section 3, project managers will need to decide at stage A – Purpose, what monitoring and evaluation methodology is appropriate. This section discusses the approaches available. Once the non-structural control monitoring approach has been decided the rest of the generic performance monitoring and evaluation process can be followed.

Taylor and Wong (2003) classified seven styles of evaluation based on the desired outcomes of the programs implemented. The Department of Water and Environmental Regulation encourages the use of these styles of monitoring for non-structural BMPs. Widespread adoption of these styles of monitoring using uniform data recording templates will allow comparative monitoring between performance monitoring and evaluation programs, leading to an improved understanding of the non-structural BMP's effectiveness.

The monitoring protocols for the seven styles of evaluation and data reporting templates are covered in Taylor and Wong (2003) and a copy is provided in the eWater Website Archive ewater.org.au/archive/crcch/archive/pubs/pdfs/technical200314.pdf

5.4.2 Choosing the evaluation style for non-structural controls

This section outlines appropriate evaluation styles to help stormwater managers make a decision based on specific BMPs, knowledge of the likely costs, degree of difficulty, time-frames, and the resources commonly available to local government authorities. The following advice is based on Taylor and Wong's (2003) work.

It is recommended that expert advice be sought early when preparing a performance and monitoring and evaluation plan to help select a suitable evaluation style (or styles). Stormwater managers in Department of Water and Environmental Regulation, research bodies and expert consultants can assist with this process.

A range of evaluation styles are described in Table 8. This decision is a very important one, and should be made after consideration of the following factors:

1) The **objective(s)** of the BMP that will be evaluated.

For example, if the objective is simply to raise awareness of stormwater pollution within a target audience through an educational program then Style No. 2, monitoring changes in people's awareness or knowledge, would be appropriate. However, if the objective is to improve erosion and sediment control compliance 'on the ground', Style No. 5 would be the most appropriate as this would monitor changes in people's actual behaviour. For multiple objectives, several styles of evaluation may be needed.

It is recommended that evaluating the nature of BMP implementation (evaluation Style No. 1) always be attempted, as this provides a simple basis for more advanced forms of evaluation and often helps to explain the evaluation results (Taylor & Wong 2003). For example, if an enforcement program involving a new local law is found to be unsuccessful in changing people's behaviour, knowledge about the nature of enforcement activities (e.g. how many fines were issued, how many fines were successfully challenged in court, etc.) would be needed to help explain this outcome.

2) The **resources** available to the monitoring agency.

Generally the evaluation styles are ranked from the least resource intensive (evaluation Style No. 1) to the most costly (evaluation Styles No. 6 and 7). Typically the Styles No. 6 and 7 will be beyond the resources of most local government authorities in Australia (Taylor & Wong 2003).

3) The **timeframe** over which monitoring needs to occur.

For example, a monitoring and evaluation plan may be developed using Style No. 1, 5 and 7 which provides some evaluation results in the short term (e.g. whether the BMP has been fully implemented as planned), in the medium term (e.g. whether the BMP changes people's actual behaviour) and in the long-term (e.g. whether waterway health in the region has improved). Short and medium term reporting may be essential to keep stakeholders confident that the program is 'on track', particularly if the ultimate outcomes may not occur for years or even decades (Taylor & Wong 2003).

4) The **purpose** of the evaluation.

Consideration should be given to how the findings of the evaluation will be used, by whom, and their specific needs. This is covered in Section 3.

5) The **nature of the BMP**.

Some styles of evaluation are intrinsically suited to specific BMPs because of the nature of the BMP. For example, an industry education program could easily be evaluated by a pre- and post-campaign audit of industry practices (Style No. 5) to see if actual behaviour had changed. This style of evaluation would however be far more difficult if the BMP was an educational campaign promoting a change to fertilisation rates on residential lawns.

Table 8. Evaluation frameworks for non-structural BMPs that aim to improve stormwater quality and quantity management (source: Taylor & Wong 2003), includes management response evaluation and condition evaluation

Style of evaluation	Description	Who typically does it	Example of monitoring tools	Advantages	Disadvantages
1. BMP implementation	Evaluation of whether the BMP has been fully implemented.	Stormwater management agencies (e.g. local or State Government authorities) or community groups.	Auditing with checklists.	• Inexpensive. • Provides the basis for more advanced styles of evaluation (see below). • Simple to design and implement. • Useful for BMPs that have a relatively low risk of failure once implemented • Can usually also evaluate the quality of implementation (e.g. feedback on the relevance and quality of training materials as well as the quality of its delivery).	• Provides no information on whether the BMP has changed people's behaviour or water quality. • Desktop evaluation may not truly reflect what is happening 'on the ground'.
2. Changes in awareness and knowledge	Evaluation of whether the BMP has increased levels of awareness and/ or knowledge of a specific stormwater issue within a segment of the community.	Stormwater management agencies, often with the help of specialist community survey consultants.	Surveys that examine people's level of awareness and knowledge.	• Relatively inexpensive (depending on the level of confidence needed in the results). • Relatively fast. • Can directly examine levels of awareness and knowledge (i.e. this style of evaluation does not need to rely on self-reported changes to awareness and/or knowledge). • Can gather valuable information that helps to improve the design of the BMP (e.g. a baseline survey for an educational program may find that a high percentage of people mistakenly believe that stormwater is a minor risk to waterway health in the region). • Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).	• Changes in awareness and/or knowledge do not necessarily lead to a change in people's attitudes, behaviour or water quality.

Style of evaluation	Description	Who typically does it	Example of monitoring tools	Advantages	Disadvantages
3. Changes in attitude (self-reported)	Evaluation of whether the BMP has changed people's attitudes (either towards the goal of the BMP, or towards implementing the BMP itself) as indicated through self-reporting.	Stormwater management agencies often with the help of specialist community survey consultants.	Surveys that examine peoples self-reported attitudes.	• Relatively inexpensive (depending on the level of confidence needed in the results). • Relatively fast. • Can gather information that helps to improve the design of the BMP (e.g. people's attitudes may be based on incorrect assumptions that could be easily clarified). • Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).	• Changes in people's attitudes towards stormwater management do not necessarily lead to changes in behaviour. • The evaluation process and social norms may influence self-reported attitudes (e.g. some survey respondents may report a 'socially acceptable' attitude rather than their actual attitude). • Potential for confusion exists depending upon the attitude being monitored (e.g. some builders may have the unchanged attitude that new erosion and sediment control laws are unnecessary, but their attitude towards compliance may have changed simply because of the financial consequences).
4. Changes in behaviour (self-reported)	Evaluation of whether the BMP has changed people's behaviour as included through self-reporting.	Stormwater management agencies, often with the help of a specialist community survey consultant.	Surveys with survey forms that examine people's self-reported behaviour.	• Relatively inexpensive (depending on the level of confidence needed in the results). • Relatively fast. • Can examine types of behaviour that are very difficult and expensive to directly observe or monitor (e.g. infrequent application of lawn fertiliser, disposal of used engine oil). • Can usually monitor changes in people's awareness/knowledge, attitudes and/or self-reported behaviour with the same instrument (e.g. a survey).	• Self-reported behaviour can be a very poor indicator of actual behaviour in some contexts (e.g. littering in public places).

Style of evaluation	Description	Who typically does it	Example of monitoring tools	Advantages	Disadvantages
5. Changes in behaviour (actual)	Evaluation of whether the BMP has changed people's behaviour as indicated through direct measurement.	Specialists (e.g. research bodies, specialist consultants, trained staff from stormwater management agencies).	Observational studies or audits with checklists.	• Change in actual behaviour is a very good indicator for likely changes to stormwater quality and waterway health. • Data from such evaluations can be used to model predicted changes to stormwater quality and waterway health. • Such evaluations can provide valuable information that can be used for BMP design or improved evaluation strategies (e.g. highlighting errors associated with monitoring self-reported behaviour and identifying why certain forms of behaviour occur).	• Can be very difficult and costly to apply in some contexts due to issues such as invasion of people's privacy and the need to monitor a large number of infrequent events. • People's behaviour that influences stormwater quality is inherently complex, and is typically influenced by many variables (e.g. people's age, whether they are in groups, surrounding infrastructure, economic circumstances, etc.). Designing evaluation strategies to accommodate this complexity can be challenging.
6. Changes in stormwater quantity and quality (and quantities)	Evaluation of whether the BMP (or set of BMPs) has improved stormwater quality in terms of loads and/or concentrations of pollutants.	Specialists (e.g. research bodies or stormwater management agencies with a very high level of in-house expertise).	Stormwater quantity and quality monitoring programs or pollutant export modelling (immediate local scale of the BMP).	• Directly measures changes in stormwater quality (the primary aim of these non-structural BMPs). • The information collected may allow non-structural BMPs to be included in pollutant export modelling exercises when undertaking major stormwater quality management decisions (along with structural BMPs). • Can be used for individual non- structural BMPs or combinations of BMPs (e.g. monitoring the collective effect on stormwater quality over time of implementing a new city-wide urban stormwater management plan).	• Relatively expensive and time-consuming (depending upon the desired level of confidence in the results). • Usually requires a very high level of technical expertise to design the monitoring program and analyse the results. • Can be difficult to measure subtle changes in stormwater quality, given the very high spatial and temporal variability of urban stormwater quality. • Can be difficult to find and maintain suitable control sites or catchments. • Typically, a variety of pollution sources and other types of BMPs heavily influence stormwater quality in areas where non-structural BMPs are applied.

Style of evaluation	Description	Who typically does it	Example of monitoring tools	Advantages	Disadvantages
7. Changes in environmental quality (receiving environment quality)	Evaluation of whether the BMP (or set of BMPs) has improved the health of receiving waters.	Ecological health monitoring programs (e.g. trend analysis). Alternatively, receiving water quality modelling can be used to predict the ecological effect of known changes in stormwater quality (e.g. in estuary systems).	Ecological health monitoring programs or ecological effect of known changes in stormwater modelling.	• Directly measures changes in aspects of waterway health (the ultimate goal of stormwater quality measures which are implementing non-structural BMPs). • Can be an efficient form of evaluation where BMPs involve a specific stormwater pollutant with few sources (e.g. an education campaign to phase out the use of specific pesticide in an urban catchment) or where a case-effect relationship has already been established (e.g. the relationship between sewer overflows and ambient water quality in a river).	• Relatively expensive and time-consuming (depending upon the desired level of confidence in the results). • It is often very difficult to attribute subtle, long-term changes in waterway health to the use of any particular BMP. This style of evaluation is mainly used to evaluate the collective effect of all catchment management activities over time. • Usually requires a very high level of technical expertise to design the monitoring program and analyse the results.

Example 2
The following is a summary of the methodology of the monitoring and evaluation for the South East Regional Centre for Urban Landcare (SERCUL) Industrial Survey and Inspection Program (ISIP). The project facilitated direct engagement of light industrial small and medium enterprises (SMEs) by Local Government Association Environmental Health Officers (LGA EHOs) in a supportive and educational environment, to assess, record and educate SMEs regarding environmental management practices, particularly stormwater, chemical and waste management.

The study was conducted with 268 businesses in five local government areas including eight different industrial areas. These were all located within the SERCUL Natural Resource Management (NRM) region in southern Perth from September 2005 to May 2007. The process is described according to the generic process outlined in this chapter.

This approach can be described as promotion of structural and non-structural BMPs, focusing on pollution prevention using environmental risk management, education and participation and, to a lesser extent regulatory controls.

A. Purpose

To assess if light industrial SME environmental management is improved by LGA EHO engagement in a support and education approach.

The project evolved out of a literature review of related studies and personal contact with stakeholders in the area of interest, to establish that data regarding current practices and barriers to change had not been collected previously. The literature review provided significant guidance in the approach taken in the South East Regional Centre for Urban Landcare (SERCUL) study.

B. Objectives

The overarching objectives for the SERCUL study were:

- measure SME owner/manager awareness of stormwater contaminants and legal obligations
- establish SME barriers to environmental management and preferred information and communication sources
- measure changes in SME environmental risk management and identify contributing factors
- establish the cost of implementing the approach
- assess suitability of LGA EHOs as service provider.

Measuring non-structural BMPs success can be challenging. In the SERCUL study, measuring organisational change for environmental risk management was chosen over water quality monitoring, which was considered too difficult to control the range of variables for reliable results. Similarly change of awareness does not necessarily equal behaviour change or improved environmental outcomes, and was not considered after the initial survey suggested a relatively high SME awareness of stormwater contaminants and legal obligations.

C. Evaluation questions and indicators

Evaluation questions were determined using the outcomes hierarchy below.

Outcomes hierachy for evaluation of the SERCUL industrial survey and inspection project						
		Project aims	**Evaluation questions**	**Data sources**	**Instruments for collecting data**	**Comments**
Ultimate aims	**1**	Improvement in SME environmental management (stormwater protection)	Has SME environmental management improved as a result of LGA intervention?	SME EHO	Risk management survey Premise inspection	Assessed stage 2
	2	Assessment of appropriate CBSM tools for SME behaviour change	Have CBSM tools deployed contributed to improved environmental management?	SME	RM survey Premise inspection	Assessed stage 2
	3	Productive relationships developed between LGAs and SMEs	Have productive relationships been developed between LGAs and SMEs? Has this influenced environmental management?	LGA SME	SME evaluation survey LGA survey	Assessed stage 2
Intermediate aims	**4**	Identification of LGA barriers to SME regulation	What are the LGA barriers to SME regulation?	LGA	LGA survey	Stages 1 and 2
	5	Establish cost estimate of an LGA-SME engagement program	What is the cost of an LGA-SME regulation program based on this model?	SERCUL LGA	LGA survey SERCUL industrial survey and inspection pilots	Stages 1 and 2
	6	Profile businesses with high and low risk of contamination of stormwater	What are the relationships contributing to high and low stormwater contamination risk ratings?	SERCUL	Risk management surveys (SPSS analysis)	Stages 1 and 2
Immediate aims	**7**	Identification of SME barriers to environmental management	What are the SME barriers to environmental management?	SME	Risk management survey	Assessed stage 1
	8	Identification of preferred SME information and communication modes	What are the preferred SME information and communication modes?	SME	Risk management survey	Assesed stage 1
	9	Assessment of current SME environmental management	What is the current level of SME environmental management (stormwater management)?	SME EHO	Risk management survey Premise inspection	Assessed stage 1

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Key

SME	Small and medium enterprises
EHO	Environmental health officer
LGA	Local government association
CBSM	Community-based social marketing
BMP	Best management practices
UDR	Unauthorised Discharge Regulations 2004
SERCUL	South East Regional Centre for Urban Landcare
SPSS	Statistical Package for Social Scientists

It is appropriate to seek expert advice in the design of evaluation questions and indicators as the study design will determine the type of analysis that can be performed and the reliability of results. The SERCUL study used a range of evaluation styles as described by Taylor and Wong (2003) incorporating elements of styles 1 to 5. Multiple evaluation styles added value to the study, acknowledging the challenge in obtaining resources, access and funds to carry out this type of research.

The SERCUL survey used an interview style with open and closed questions; responses to some questions were measured by a Leichart scale to determine the strength of barriers and preferences. Other recordings in the survey were simple judgements about the acceptability of environmental management procedures and practices being used.

The performance indicator chosen to identify improvements in environmental legislative compliance was represented by the field ‘On-site activities discharge to stormwater’. A significant reduction in discharge to stormwater on repeat surveys represents the program operating successfully in achieving the protection of stormwater quality through implementation of environmental risk management.

Indicators for the development of rapport are established through questions such has ‘Do you consider LGA visits improve your environmental management?’ and ‘Has the approach used in this program contributed to a positive relationship with your LGA?’.

The combination of a measured reduction in the number of businesses discharging to stormwater and a positive response to LGA engagement indicates the program is performing as anticipated and would contribute to a positive evaluation of the overall program.

A Leichart scale was also used for SMEs to rate the usefulness of interventions implemented. The intention was to establish if the program was achieving improved SME environmental risk management and to establish the likely contributing factors.

D. Planning

A CBSM analysis was chosen to assess which interventions were likely to be effective. The SERCUL study used collated barriers and benefits data from previous Australian studies for the initial CBSM analysis and collected barriers data from survey participants to confirm or reject the assumptions of the initial analysis.

An assessment was made regarding the available resources, skills, time and access to the study group when considering which actions would be implemented from the CBSM analysis.

The intention was to perform field based research at SME premises, a group acknowledged as difficult to attract away from their place of business. Past literature suggested a face-to-face, individual and site specific approach. Previous studies indicated LGA EHOs had the required skills to perform the environmental management audits, credibility and access, and could possibly carry out the function over the long-term. It was therefore essential to attract LGA partnership in the study.

SERCUL chose to measure organisational environmental risk management due to the non-prescriptive structure of the relevant legislation, i.e. Environmental Protection (Unauthorised Discharge) Regulations 2004. A scored environmental risk assessment allowed the measurement of practical uptake and application of the environmental management education and advice being provided.

Each pilot was coordinated with the participating LGA distributing letters to SMEs regarding the survey, survey dates, printed materials, transport and report writing.

The electronic survey instrument was designed to collect data about current environmental management, barriers to improved management, preferences for communication and information and perceived improvement versus assessed achievement in environmental risk reduction.

Appropriate technology aids were identified and obtained. Data collected was imported into a database on Microsoft Excel and transferred to a Statistical Package for Social Scientists (SPSS) database for further analysis.

The intention was to focus on the development of rapport with SMEs and engagement in continuous improvement beyond regulatory compliance. A regulation and enforcement approach was considered to be unlikely to develop the necessary rapport and is an approach that cannot be used beyond basic legislative compliance.

E. Implementation

Interviews were used to collect data in stages one and two and were conducted at light industrial SME premises with owner/managers from pre-arranged appointments with businesses initially targeted by the following criteria:

- water used in processing on-site
- liquids or manufactured chemicals stored on-site.

A door-to-door cold canvas approach was used to initially establish whether the criteria applied. Official letters from the participating LGA were handed over explaining the purpose of the study. Participation was voluntary. Electronic recording (a laptop) was used to test effectiveness in the light industrial SME survey and audit application. Electronic recording made data storage, transfer and analysis much simpler.

The electronic survey was conducted by a Natural Resource Management Officer from SERCUL and the premise inspections by an Environmental Health Officer from the participating LGA.

Examples of interventions taken include a survey of environmental risk, a premise inspection and advice, distribution of information packs for SME environmental management, stencilling of stormwater drains, repeat LGA EHO visits, waste and recycle directories, environmental improvement plans and follow up industry specific information packs.

The first stage of surveys measured awareness of legal obligations (particularly for stormwater), barriers to environmental management, preferred communication and information sources and a scored environmental risk audit.

The second stage measured perceived improvement in environmental management, attitude to the effectiveness of the interventions taken and a repeat of the scored environmental risk audit to be compared with the initial results.

F. Analysis and interpretation

Mathematical statistical analysis asks appropriate logical questions and measures the limitations of answers; i.e. Data input quality (and/or appropriateness of test chosen) → Data output quality.

Statistical analysis usually adds significant value to the data and study as a whole. Statistical analysis may not be so important if you are simply trying to bring attention to an issue without the need for an immediate investigation.

SERCUL chose to collect qualitative and quantitative categorical data with a predicted normal (Gaussian) distribution. Chi squared and Bivariate analyses were chosen to test for strength and significance of relationships in the data. More rigorous statistical tests were not chosen because it was felt that it was difficult to control some variables in the study, and that the conditions could be met for the tests chosen and would provide adequate insight into the research questions from the data collected.

G. Report and recommendations

A report was produced for each LGA pilot providing the results as descriptive statistics and a description of the barriers and issues raised by SME participants. Recommendations were made regarding the achievement of environmental legislative compliance in an approach that encourages the development of rapport and engagement in beyond compliance environmental management and sustainability initiatives.

A final report for each stage of the project (consisting of five pilots) was compiled including conceptual models illustrated as diagrams to demonstrate the likely reasons for the project outcomes, to help evaluate success and provide guidance on how to adapt the approach to improve program efficiency.

Reports to other stakeholders have changed in format and style depending on the audience that is being targeted.

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Acronyms

ANZECC	Australian and New Zealand Environment and Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BMP	Best management practice
CBSM	Community-based social marketing
DBCA	Department of Biodiversity, Conservation and Attractions
DEC	Department of Environment and Conservation
DoW	Department of Water
DWER	Department of Water and Environmental Regulation
EHO	Environmental Health Officer
EMC	Event mean concentration
EWR	Ecological water requirement
GPT	Gross pollutant trap
ISIP	Industrial survey and inspection program
LGA	Local government authority
LMU	Load measuring unit
MAR	Managed aquifer recharge
NATA	National Association of Testing Authorities
NRM	Natural resource management
OSH	Occupation safety and health
QA	Quality assurance
RM	Risk management
SAP	Sampling and analysis plan
SERCUL	South East Regional Centre for Urban Landcare
SME	Small and medium enterprises
SPSS	Statistical package for social scientists
SRT	Swan River Trust
TDS	Total dissolved solids
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UDR	Unauthorised Discharge Regulations
WSUD	Water sensitive urban design

Appendix A – Summary of common water quality parameters

Parameter	Abbrev.	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Physical parameters						
Specific conductivity	SpCond	mS/cm (micro-siemens/ cm)	Water	How well water can pass an electric current. Indicates presence of inorganic dissolved solids. Standardised to 25°C.	Geology of the catchment, fertiliser runoff, acid mine drainage, salinity.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Dissolved oxygen	DO	mg/L %	Water	Concentration of oxygen dissolved in the water.	Water temperature, algae growing in water, water velocity, organisms respiring in water.	Dissolved oxygen is necessary to support aquatic life and is an important measure of physical water quality.
pH	pH	-	Water	Hydrogen concentration in water, on a logarithmic scale. pH 7 is neutral.	Carbon dioxide in water decreases pH (makes the water more acidic). Runoff from acid sulphate soils also decreases pH.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Salinity	Sal	ppt	Water	Dissolved salt content (salt being ions).	Influences from oceanic water, dry-land salinity, etc.	Simple physical parameter that most probes will measure. Provides general information about the water quality.
Temperature	Temp	°C	Water	Water temperature.	Atmospheric temperature, direct sunlight, water colour, inputs of warm or cold water.	Simple physical parameter that most probes will measure. Temperature regulates the rate of metabolic and reproductive activities in aquatic organisms, and strongly influences dissolved oxygen concentration.

Parameter	Abbrev.	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Turbidity		NTU (Nephelometric Turbidity Units)	Water	The cloudiness of the water, how much light is scattered by suspended particles (measured by turbidimeter). May also be measured by Secchi disk, in which case the measurement is metres below the surface that the disk can be seen.	Erosion, runoff from urban areas carrying particles, algae, decomposition of organic matter, suspended solids, high flow rate.	Turbidity can indicate high concentrations of suspended solids, algae growth or possible microbial growth.
Flow rate		m^3/s	Water	Measures the velocity of water flowing through a given cross-section.	Rainfall and runoff are main factors that influence flow rate. Groundwater flow or other inputs of water can contribute.	The flow rate puts all other parameters in context, e.g. high concentrations of contaminants in a trickle of water are not as concerning as high concentrations in a high flowing stream. It is desirable to measure flow rate, or at least qualitatively describe it, when any other measurements are taken.
Moisture content		%	Sediment	The percentage of water in sediment.	Soil type.	
Particle size distribution	PSD	%	Sediment	Percentage of soil in different size fractions.	Soil type, erosion, urban development.	

Common chemical parameters						
Parameter	**Abbrev**	**Units**	**Component**	**What this parameter measures**	**Factors that affect this parameter**	**When to use AND/OR effect of this parameter**
Total suspended solids	TSS	mg/L	Water	Solids in water that can be trapped by a filter.	Erosion, runoff from urban areas carrying particles, decomposition of organic matter, suspended solids, high flow rate.	High levels of TSS can block light to submerged vegetation, interfere with aquatic fauna (e.g. block fish gills) and often correlates with higher levels of pollutants (often attached to sediment particles). Common parameter to measure.
Total nitrogen	TN	mg/L	Water; sediment	All forms of nitrogen in the water (organic + inorganic, soluble + particulate).	Discharge from wastewater treatment of septic systems, animal excreta (e.g. cows, birdlife), fertiliser runoff.	An important parameter to measure, nitrogen is a key nutrient contributing to algal growth.
Total oxidised nitrogen	TON NO_x-N	mg/L	Water	Nitrate (NO_3^-) and nitrite (NO_2^-). Measured from a water sample that has been filtered.	Both highly soluble inorganic nitrogen species. Ammonium is converted to nitrite then nitrate by bacteria. Nitrate is taken up by plants.	An important parameter to measure, nitrate is the form of nitrogen most readily available to algae.
Ammonium/ ammonia	NH_3-N / NH_4-N	mg/L	Water	Ammonium (NH_4^+) and ammonia (NH_3). Measured from a water sample that has been filtered.	Highly soluble inorganic nitrogen species. In oxygenated waters, ammonium is quickly converted to nitrate.	An important parameter to measure to understand the contributions of different nitrogen species.
Dissolved organic nitrogen	DOrgN	mg/L	Water	Includes urea, amino acids, amines, polypeptides, etc. Measured from a water sample that has been filtered.	Organic sources.	An important parameter to measure to understand the contributions of different nitrogen species. DOrgN is not readily available to plants and algae, but is converted to available inorganic forms by bacteria and fungi.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Total Kjeldahl Nitrogen	TKN	mg/L	Water	NH_3-N / NH_4-N plus DOrgN plus particulate nitrogen.	As for the individual components.	This parameter is generally calculated by the labs, not directly measured. It is an outdated term carried over from when chemistry techniques did not allow separate identification of the separate nitrogen components. There is no need to specifically measure or describe this parameter.
Total phosphorus	TP	mg/L	Water; sediment	All forms of phosphorus in the water (soluble + particulate, inorganic + organic).	Discharge from wastewater treatment of septic systems, animal excreta (e.g. cows, birdlife), fertiliser runoff, detergents, urban sources.	An important parameter to measure, phosphorus is a key nutrient contributing to algal growth.
Soluble reactive phosphorus	SRP	mg/L	Water	Ortho-phosphate (PO_4^{3-}) (also called reactive phosphate). Measured from a water sample that has been filtered.	Produced by natural processes, also present in sewage.	An important parameter to measure. SRP is readily available to plants, and phosphorus is usually the limiting nutrient for plant/algae growth in freshwater systems.
Dissolved organic carbon	DOC	mg/L	Water	The component of organic carbon that is readily available to organisms, including polysaccharides, amino acids, peptides, other organic acids, and carbohydrates. Measured from a water sample that has been filtered.	Runoff from urban catchments, organic matter, sewage.	DOC is metabolised by bacteria, using oxygen in the process. High concentrations of DOC can draw a lot of oxygen from the water, causing anoxic conditions. The decomposition of DOC can also emit odours.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Total organic carbon	TOC	mg/L	Water; sediment	Highly sensitive, non-specific measurement of all organics present in a sample, including organic matter, hydrocarbons, etc.	Highly variable depending on type of organic compound.	Can indicate organic chemical discharge. An indicator of pollution but does not specify type of pollution.
Biological (or biochemical) oxygen demand	BOD	mg/L	Water	The amount of oxygen used in the metabolism of biodegradable organics.	Dead plant matter, algae, manure, sewage, grass clippings, food waste, etc. can all contribute to higher BOD.	Indicator of the degree of contamination by organic waste. High BOD indicates the potential for anoxic conditions, as the oxygen is used for decomposing the organic waste. An indirect measure, depending on the application it may be more useful to measure TOC or DOC.
Total heavy metals (suite may include Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn)		mg/L	Water; sediment	Metal species to be measured must be specified. Measures soluble and insoluble fractions.	Manufacturing processes, factories, release from acid sulphate soils, motor vehicles (fuel, exhaust), groundwater (e.g. iron). Solubility of metals is strongly influenced by pH and carbonates (CO_3^{2-}, HCO_3^-), which precipitate some metals; alkalinity should be measured whenever metals are measured.	Useful to get an indication of general pollutants, but not as critical to ecosystem function as parameters such as nitrogen and phosphorus. Total heavy metals are appropriate for investigative purposes.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Soluble heavy metals (suite may include Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, Se, Zn)		mg/L	Water	Metal species to be measured must be specified. Measures soluble fractions only. Measured from a water sample that has been filtered.	Solubility of metals is strongly influenced by pH and presence of carbonates (CO_3^{2-}, HCO_3^-), which precipitate some metals; alkalinity should be measured whenever metals are measured.	Soluble heavy metals indicate the portion of metals that are bioavailable. The effect of pH on solubility should be considered.
Total alkalinity as $CaCO_3$	Alk	mg $CaCO_3$/L	Water	The concentration of alkaline compounds in water (e.g.HCO_3^-).	Geology and soils, pH, cleaning agents.	Indicates the buffering capacity of the water, the capacity to neutralise acids. Also can reduce toxicity of metals by binding with metals and forming precipitates.
Other chemical parameters						
Parameter	**Abbrev**	**Units**	**Component**	**What this parameter measures**	**Factors that affect this parameter**	**When to use AND/OR effect of this parameter**
Polycyclic aromatic hydrocarbons	PAHs	µg/L	Water; sediment	A group of over 100 different hydrocarbon compounds that have multiple benzene rings in their chemical structure.	Can be formed during the incomplete burning of coal, oil garbage, etc. Typical component of asphalts, fuels, oils, and greases. Some PAHs are manufactured.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Polychlorinated biphenyls	PCBs	µg/L	Water; sediment	A family of man-made chemicals that contain 209 individual compounds with varying levels of toxicity, used for a variety of applications including heat transfer, lubricants, etc. Manufacture of PCBs is now prohibited.	PCBs have low solubility in water and do not degrade readily. Once in the air, PCBs can be carried long distances.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.
Organochlorine and organophosphorus pesticides	OC/OP pesticides	µg/L	Water; sediment	A pesticide is an all-encompassing term to refer to a substance or mixture of substances intended to preventing, destroying, repelling, mitigating pests or defoliating or desiccating plants.		
Phenoxy Acid Herbicides		µg/L	Water; sediment	A group of organic herbicides with high selectivity and ease of translocation.		
Anionic surfactants as methylene-blue active substances	MBAS	µg/L	Water; sediment	A compound comprising of a strongly hydrophobic group and a strongly hydrophilic group. The hydrophilic group in this case is anionic (has a negative charge). Anionic surfactant examples are alcohol ethoxylated sulphate; linear alkylbenzene sulphonates.	Surfactants often enter waters and waterways by discharge of aqueous wastes from household and industrial laundering and other cleansing operations.	

Parameter	**Abbrev**	**Units**	**Component**	**What this parameter measures**	**Factors that affect this parameter**	**When to use AND/OR effect of this parameter**
Benzene, toluene, ethylbenzene, xylenes. Total recoverable hydrocarbon fractions: TRH:C_6-C_9, TRH:C_{10}-C_{14}, TRH:C_{15}-C_{28}, TRH:C_{29}-C_{36}	BTEX TRH	µg/L	Water; sediment	Liquid geologically-extracted hydrocarbons. Benzene, toluene, ethylbenzene, and xylene isomers are analysed as they make up part of the C_6 to C_9 petroleum hydrocarbons (which are quite volatile).	Motor vehicles and other sources of petroleum.	Analysis for these parameters is expensive. They may be used for investigative purposes or to detect suspected pollutants.
Chromium reducible sulphur set			Sediment	Includes an analysis of the chromium reducible sulphur (S_{CR}), plus determination of the existing acidity and potential acidity, plus the acid-neutralising capacity.	Acid sulphate soil or potential acid sulphate soil.	
Biological parameters						
Parameter	**Abbrev**	**Units**	**Component**	**What this parameter measures**	**Factors that affect this parameter**	**When to use AND/OR Effect of this parameter**
Faecal (thermo-tolerant) coliforms (presumptive thermo coliforms) (count <10-1000,000 cfu/100 mL))		Presumptive thermo-tolerant coliforms CFU/100 mL	Water	Coliform bacteria of faecal origin are referred to as faecal coliforms and grow at higher temperatures (44.5 °C or higher).	Septic tank failure, poor pasture and animal keeping practices, pet waste, and urban runoff.	Can indicate pollution of water by faeces of humans or other warm-blooded animals. Used as an indicator of pathogenic bacteria.

Parameter	Abbrev	Units	Component	What this parameter measures	Factors that affect this parameter	When to use AND/OR effect of this parameter
Enterococci (confirmed enterococci (count <10-24,000 MPN/100 mL))		Confirmed enterococci MPN/100 mL	Water	Faecal streptococci are normal inhabitants of the intestinal tract of humans and other animals. The enterococci portion of the faecal streptococci group includes *S. faecalis, S. gallinarum* and *S. avium*.	Sewage, excreta of higher animals.	Enterococci are the best indicators of faecal contamination from warm-blooded animals in marine waters.
Phytoplankton species			Water	Phytoplankton is microscopic algae.		The particular algae species present may indicate where algae originated, proportions of nutrients in the water, etc., and can help in determining treatment options.
Chlorophyll	Chl	µg/L	Water	The concentration of chlorophyll in the water sample.	Chlorophyll is the green pigment in algae that is used in photosynthesis.	Indicates concentration of algae in the water, but may be influenced by algae species.

Appendix B - Groundwater data collection methods

Method	Data provided	Description	Use
Suction cup lysimeter	Collects water samples from various depths to allow analysis.	Porous ceramic cups set at specific depths to capture unsaturated leaching.	Allows targeted monitoring of leachate at different depths of unsaturated soil profile.
Piezometer	Provides information regarding the depth to groundwater.	Monitoring wells constructed to allow measurement of the hydraulic head in an aquifer.	Assists in developing an idea of groundwater behaviour in an area and possible interaction with surface water.
Groundwater bores	Allows access to extract groundwater samples.	Monitoring bores constructed for generalised characterisation of water quality within an aquifer.	Analysis of extracted groundwater gives an indication of groundwater quality in the area.
Neutron moisture meter	Moisture levels at different depths in the soil profile.	Reflection of emitted neutrons is measured at different depths of a lined casing, calibrated to indicate soil moisture.	Accurate measurement of soil moisture levels and depth.
Lysimeters	Provides access to water samples moving through saturated soil profile.	A system to capture saturated flow leachates (generally involving a large PVC pipe driven into the ground, removed, end-capped and fitted with tubing to allow sampling of leachate waters).	Allows water quality analysis of leachate from different depths in the soil column.

Appendix C - Flow data collection methodology

Method	Data provided	Preposition	Use
Peak level indicator (without rating)	Provides an indication of the peak water level since the last observation.	Device installed to register the peak level.	Useful for understanding the maximum water levels in parts of a system (e.g. drain, swale, or compensating basin).
Peak level indicator (with rating)	Provides an indication of the peak water level and peak flow rate since the last observation.	Device installed to register the peak level together with a known relationship between level and flow rate (rating curve). The rating curve may be obtained by the use of a weir or developed empirically.	Useful for understanding the maximum water levels in parts of a system (e.g. drain, swale, or compensating basin) and for understanding the maximum flow rates in drains.
Continuous logger with stable structure, i.e. weir	Provides an ongoing record of flow and stage heights.	Device installed to constantly measure stage height and obtain accurate flow measurements.	Used to accurately gauge flows through a well-maintained fixed point.