COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - AN OVERVIEW OF THEIR USE, VALUE, COST AND EVALUATION

TECHNICAL REPORT
Report 02/11
December 2002

André Taylor / Tony Wong

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CATCHMENT HYDROLOGY

EPA VICTORIA

Taylor, Andre C, 1969-

Non-structural stormwater quality best management practices: an overview of their use, value, cost and evaluation.

Bibliography.
ISBN 1 876006 95 1.

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551.488

Keywords

Stormwater Management
Best Practice
Urban Areas
Water Quality Control
Water Pollution Control
Local Government
Planning Authority
Benchmarks
Finance
Efficiency
Design Data
Regulation
Education
Information Campaigns
Standards
Water Quality (Natural Waters)
Runoff (Urban)
Evaluation
Monitoring
Survey
Reviews

Non-structural Stormwater Quality Best Management Practices - an Overview of their Use, Value, Cost and Evaluation

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Preface

In 2001 the Cooperative Research Centre for Catchment Hydrology formed a partnership with the Victorian Environment Protection Authority to undertake research into the use, value, cost and evaluation of non-structural best management practices to improve urban stormwater quality (non-structural BMPs). Such BMPs include town planning controls, strategic planning and institutional controls, pollution prevention procedures, education and participation programs, and regulatory controls.

The primary aim of this research project was to produce monitoring protocols that could be used by local government authorities to measure the value and life-cycle cost of non-structural BMPs that improve urban stormwater quality.

Secondary objectives of this research project were to help local government authorities manage urban stormwater quality by providing:

- Quantitative information from the literature and case studies on the value of non-structural BMPs.
- Information on how structural and non-structural BMPs for urban stormwater quality improvement are being used (e.g. the extent to which 70 specific BMPs are being used around Australia, New Zealand and the United States of America).
- Funding profiles for several leading urban stormwater quality management authorities in Australia and overseas, that can be used as benchmarks when developing urban stormwater management programs.
- Information on the views of Australian and overseas urban stormwater quality managers on the effectiveness, efficiency and practicality of 41 non-structural BMPs.
- A short-list of non-structural BMPs deemed to be of most value in terms of effectiveness, efficiency, practicality, acceptance and potential for future use (based on the findings of a literature review and survey of Australian and overseas stormwater managers).
- Recommended references relating to the design of non-structural BMPs.

- A new evaluation framework that can be used for any type of non-structural BMP that aims to improve urban stormwater quality.

Four reports have been produced to communicate this work to stakeholders:

- CRC for Catchment Hydrology Report 02/11 (No. 1 in the series) is this **overview report** that describes the project's aims, background, methodology, and presents key findings in a condensed form.
- CRC for Catchment Hydrology Report 02/12 (No. 2 in the series) is a technical report on the findings of a detailed **survey** of 36 urban stormwater managers.
- CRC for Catchment Hydrology Report 02/13 (No. 3 in the series) is a technical report that presents the findings of a **literature review** on the value and life-cycle costs of non-structural BMPs to improve urban stormwater quality.
- The fourth report in the series investigates **monitoring and evaluating non-structural BMPs** for urban stormwater quality improvement. A draft version of this report has been released as a working document (CRC Working Document 02/6). The report presents guidelines and a new evaluation framework for measuring the effects and life-cycle costs of non-structural BMPs. This framework defines seven different styles of evaluation to suit the needs and budgets of a variety of stakeholders involved with stormwater management. In addition, monitoring protocols and data recording sheets have been developed to support each style of evaluation.

  This work will be published as a final CRC technical report during 2003.

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1. Introduction

This report presents an overview of a project that investigated the use, value, life-cycle costs and evaluation of non-structural best management practices (BMPs) for improved urban stormwater quality and waterway health.[1]

There are numerous types of non-structural BMPs for stormwater quality improvement, but common examples include town planning controls, education programs and enforcement programs. These BMPs are already widely - and increasingly - used in Australia. Urban stormwater managers are, however, investing in these strategies in a climate of uncertainty, as little information has been available on:

- the type and magnitude of change non-structural BMPs can produce, if any (e.g. behavioural changes, improved stormwater quality, improved waterway health);
- the performance, effectiveness and efficiency of non-structural BMPs (e.g. a BMP's efficiency at minimising loads or concentrations of stormwater pollutants); and
- life-cycle costs of non-structural BMPs.

1.1 Objectives of this project

The primary aim of this project was to produce monitoring protocols to assist local government authorities to measure the value and cost of non-structural BMPs that improve stormwater quality.

Secondary objectives were to help local government authorities and other stakeholders manage urban stormwater quality by providing:

- Information on how structural and non-structural BMPs for stormwater quality improvement are being used (e.g. the extent to which 70 specific BMPs are being used around Australia, New Zealand and the USA).
- Funding profiles for several leading stormwater quality management authorities in Australia and overseas. These may be used for simple benchmarking when developing management programs or plans.
- Information on the views of Australian and overseas stormwater quality managers on the effectiveness, efficiency and practicality of 41 non-structural BMPs.
- Quantitative information from the literature and international case studies on the value of non-structural BMPs (e.g. information on whether they provide any positive benefits and if so, their pollutant removal efficiencies).
- A short-list of non-structural BMPs deemed to be of most value in terms of effectiveness, efficiency, practicality, acceptance and potential for future use (based on the findings of the literature review and survey of Australian and overseas stormwater managers).
- Recommended references providing information on designing non-structural BMPs, as few guidance materials of this nature are widely known to stormwater managers in Australia.
- An evaluation framework for non-structural BMPs for stormwater quality improvement that allows for worthwhile assessment regardless of available resources.

1.2 What are non-structural stormwater quality best management practices?

Non-structural stormwater quality 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 (US EPA, 1999). 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.

[1] The term 'value' is used in this report as a collective description of the benefits of non-structural BMPs, encompassing attributes such as their:
- ability to raise people's awareness, change their attitudes and/or change their behaviour;
- performance, effectiveness and efficiency with respect to stormwater quality improvement; and
- ability to improve waterway health.

Various authors have attempted to categorise non-structural BMPs into homogeneous groups (e.g. Brown, 1999; NSW EPA, 1998; NVPDC, 1996; ASCE & US EPA, 2000; US EPA, 1999; LSRC, 2001; Aponte Clarke *et al*., 1999; Victorian Stormwater Committee, 1999; and ASCE & US EPA, 2002). Although these classification systems vary, five core categories of non-structural BMPs feature strongly and have been used by the CRC for Catchment Hydrology to group non-structural BMPs in our research:

1. **Town planning controls:** e.g. the use of town planning instruments to promote WSUD principles in new developments, such as decreasing the area of impervious surfaces.
2. **Strategic planning and institutional controls:** e.g. the use of strategic, city-wide urban stormwater quality management plans and secure funding mechanisms to support the implementation of these plans.
3. **Pollution prevention procedures:** e.g. practices undertaken by stormwater management authorities involving maintenance (e.g. maintenance of the stormwater drainage network) and elements of environmental management systems (e.g. procedures on material storage and staff training on stormwater management).
4. **Education and participation programs:** e.g. targeted media campaigns, training programs and stormwater drain stencilling programs.
5. **Regulatory controls:** e.g. enforcement of local laws to improve erosion and sediment control on building sites, the use of regulatory instruments such as environmental licences to help manage premises likely to contaminate stormwater, and programs to minimise illicit discharges to stormwater.

1.3 Project architecture

To achieve the objectives of this project the following three tasks were undertaken:

1. A detailed survey of 36 urban stormwater managers from around Australia, New Zealand and the USA.
2. A review of the available literature on the value and life-cycle cost of non-structural BMPs to improve urban stormwater quality.
3. A review of methods used to monitor and evaluate the effects and life-cycle costs of non-structural BMPs, followed by the development of monitoring and evaluation guidelines designed primarily for use by local government authorities.

Four reports have been produced to communicate this work to stakeholders. In addition to this overview report, a technical report has been produced for each of the three tasks listed above.

2. Background

2.1 Terminology

Confusion exists in the literature with respect to the terminology surrounding non-structural BMPs because of:

- the existence of several broad terms such as 'source controls' and 'pollution prevention measures', which describe similar concepts (see Brown, 1999 and NSW EPA, 1998);
- the tendency of some authors to include vegetation-based structural BMPs such as vegetated filter strips, vegetated swales and constructed wetlands in descriptions of supposedly non-structural BMPs (e.g. NVPDC, 1996); and
- the tendency for some non-structural BMPs to provide a *framework* that results in discrete structural and non-structural BMPs at the estate or allotment scale (e.g. town planning controls are non-structural, but they produce new developments that incorporate both structural and non-structural BMPs).

This series of four reports uses the term 'non-structural stormwater quality best management practices' (non-structural BMPs), as defined in Section 1.2, to describe one set of source controls for the management of stormwater pollution. We define source controls as non-structural or structural measures to minimise the generation of excessive stormwater runoff and/or pollution of stormwater at or near the source (NSW EPA, 1998).

These reports include *temporary* erosion and sediment controls (e.g. mulching and sediment fences) in the definition of non-structural BMPs, as they do not involve the construction of fixed or permanent assets. It is acknowledged that this inclusion is debatable, however the inclusion of these BMPs in the literature review component of this project should assist the evaluation of related non-structural BMPs (e.g. multifaceted erosion and sediment control programs commonly run by government authorities).

The term 'value' is used widely in these reports as a collective description of the benefits of non-structural BMPs, encompassing attributes such as their:

- ability to raise people's awareness, change their attitudes and/or change their behaviour;
- performance, effectiveness and efficiency with respect to stormwater quality improvement; and
- ability to improve waterway health.

Definitions of additional terms and acronyms used in this report are provided in the Glossary (see Section 6).

2.2 Why non-structural BMPs are needed

In the past 20 years, Australian and overseas stormwater management agencies have become increasingly aware of the importance of urban stormwater runoff as a cause of environmental harm in waterways through pollutant discharge, altered hydrologic regime, and direct habitat destruction. For example:

- Urbanisation of the Moreton Bay catchment in Southeast Queensland from 2001 to 2020 is predicted to generate a 40% increase in the load of total nitrogen (TN) draining to the bay via stormwater unless controls are in place to manage stormwater quality (McAlister and Cavanagh, 2002). An increase in TN loads of this magnitude would produce significant degradation of ecological health, given that the bay is already under stress from elevated nitrogen loads (Dennison and Abal, 1999).
- In Melbourne, the ecological health of Port Phillip Bay is also under threat from nitrogen inputs (CSIRO, 1996). Accordingly, a target has been set to reduce the load of nitrogen entering the Port Phillip Bay from diffuse sources in the catchment (e.g. urban stormwater) by 500 tonnes per year (based on 1996 baseline levels) by 2006 (Chesterfield, 2002).
- In the USA, runoff from urban areas is now recognised as the second most prevalent cause of water quality degradation in the nation's estuaries, after discharges from industry (US EPA, 1998).

Part of the concern about this issue in Australia stems from our increasing tendency to live in the coastal zone and among major centres of urbanisation,

where rivers and estuaries are under growing pressure from urban stormwater runoff. Ninety percent of resident Australians live within 100km of the coastline (Shaw, 2002).

Another cause for concern is the economic impact of urban stormwater runoff. For example, in 1997 the US EPA conservatively estimated the total cost to the American economy from illness and loss of economic output due to urban stormwater pollution to be millions of dollars each year (US EPA, 1998). Impacts on estuaries are of particular concern, as they are vulnerable to stormwater pollution and are highly valued for the environmental services they provide, such as nutrient cycling, provision of habitat for fisheries, food production, cultural values and recreation. Costanza *et al*. (1997) estimated the average global value of the ecosystem services provided by estuaries to be US$22,832 per hectare per year (in 1994 dollars).

Within this context, funding for the management of urban stormwater quality in Australia's major urban centres has increased in recent years (Taylor, 2000). In particular, new funding mechanisms and programs have been established to help manage the problem. Examples include the Commonwealth Government's Natural Heritage Trust and Urban Stormwater Initiative, the New South Wales (NSW) Stormwater Trust, the Victorian Stormwater Action Program, the West Australian Swan-Canning Clean-up Program and Brisbane City Council's Environmental Levy.

Managers responsible for these funds typically undertake activities in accordance with catchment or city-wide stormwater management plans, which define water quality-related objectives, identify and prioritise local issues, and outline a mix of structural and non-structural BMPs to achieve their objectives. These managers have the challenging task of finding the optimal combination of BMPs to minimise stormwater pollution using limited funds (Schueler, 2000a; Taylor, 2000). To do this, reliable information is needed on the value (e.g. pollutant removal efficiency) and life-cycle cost of a wide range of BMPs. For non-structural BMPs, such information has been rare and difficult to access.

During the 1990s, most government expenditure on urban stormwater management in Australia was on large, regional, structural BMPs (e.g. gross pollutant traps, ponds and wetlands) (Taylor, 2000). Since the late 1990s, the funding has increasingly shifted toward source controls for managing urban stormwater quality and achieving a more balanced mix of structural and non-structural urban stormwater strategies, particularly in NSW (Taylor and McManus, 2002). Such controls include WSUD elements in new developments (e.g. the use of stormwater recycling and infiltration at the allotment or street-scape scale) and non-structural BMPs that can be applied on a city-wide scale (e.g. town planning controls, education and participation programs, and enforcement programs).

2.3 Potential benefits of using non-structural BMPs

Potential benefits from using non-structural BMPs for city-wide urban stormwater quality management include:

- **Cost:** Some non-structural BMPs are inexpensive for stormwater management agencies to run, particularly when compared with structural alternatives. For example, where major educational and enforcement campaigns aimed at erosion and sediment control have been conducted in Australia, the revenue gained from enforcement has often resourced the campaign's total operational expenses.
- **Coverage:** Some non-structural BMPs cover broad areas compared with structural alternatives (e.g. city-wide stormwater awareness campaigns or town planning controls).
- Can be used in a **retro-fit context**: Australia's larger cities are faced with space constraints in areas undergoing redevelopment, making installation of some types of structural BMPs difficult (e.g. the use of constructed wetlands for removal of fine sediment and nutrients from high density developments with very little garden area).
- Can target **specific pollutants** of concern: For example, in Perth's established residential areas, nutrients from lawns and gardens on sandy soils threaten the quality of stormwater and shallow groundwater. Such pollution is best

managed through non-structural means (e.g. encouraging the use of xeriscaping[2], slow-release fertiliser, improved fertilisation regimes and/or soil amendment).

- The polluter pays principle and **economic incentives/disincentives** can be applied through regulation and/or enforcement programs. Unlike large, regional, structural BMPs (e.g. constructed ponds and wetlands), where the bulk of the life-cycle costs are often borne by the wider community, regulation and/or enforcement campaigns allow the cost of pollution management to be borne by individuals or sectors of the community that are polluting (e.g. those found to be illegally discharging pollutants to stormwater).
- The high **potential effectiveness** of some measures: For example, the use of mandatory town planning controls to promote the widespread adoption of WSUD in new developments.
- **Community participation:** Interactive programs such as the successful Master Gardener training programs in the USA can encourage the community to accept responsibility for urban stormwater pollution and participate in a solution.
- **Flexibility:** Unlike structural BMPs, most non-structural BMPs can be quickly modified to take advantage of new opportunities or to respond to new priorities. For example, ongoing small business/ industry education programs can continually be modified to promote practices that incorporate new technology or knowledge (e.g. targeting problem areas that have been identified through annual compliance auditing).
- **Secondary benefits:** A strong argument for using some non-structural BMPs in a balanced city-wide stormwater quality management program is their secondary benefits, such as helping build a mandate for increased political support, funding and bolder initiatives. For example, the use of high profile stormwater awareness programs may help a stormwater management agency garner support for ongoing funding for stormwater quality management (e.g. a Stormwater Utility). North American researchers have surveyed communities and found the establishment of a dedicated funding mechanism and investment in educational activities are essential ingredients for success in urban stormwater quality management (Lehner *et al.,* 1999; Schueler, 2000b).

While these potential benefits appear promising, non-structural BMPs have their disadvantages. The most significant of these is uncertainty over the performance of many practices, particularly in terms of their ability to change people's behaviour, improve stormwater quality and improve the health of receiving waters.

The prevailing view of leading Australian stormwater managers appears to be that an optimal balance needs to be found between the use of non-structural and structural BMPs for stormwater quality improvement, following a decade where structural BMPs have dominated. After reviewing 100 stormwater case studies from the USA, Lehner *et al.* (1999) stated: "…stormwater management efforts build synergistically off each other; the most successful municipal strategies cover all program elements effectively" (p. 5-16).

2.4 Evaluation of non-structural BMPs

2.4.1 The status of evaluation attempts

Several authors have highlighted the lack of reliable, data on the life-cycle cost and performance of non-structural BMPs as a major impediment to their adoption (NVPDC, 1996; Taylor, 2000; Brown, 1999; US EPA, 1997a). This point of view is perhaps best expressed by the Northern Virginia Planning District Commission (NVPDC, 1996): "… many of these non-structural measures are widely recognised by scientists and watershed managers to have clear utility in an integrated nonpoint source management program. However, the lack of credible data, site screening for applicability, and specific design parameters, may result in these measures being neglected, both in research and in jurisdictional nonpoint source program development, under federal, State, and local stormwater management initiatives" (p. 1-4).

In addition, the NVPDC states "reliance on conventional [structural] BMPs stems from the fact that such approaches facilitate the engineering calculations necessary to demonstrate compliance with numerical stormwater quality standards or criteria..." (p. 1-4). This

[1] Resource sensitive landscaping.

point is particularly relevant to Australian stormwater managers as:

- numerical descriptions of water quality-related objectives are increasingly used in town planning schemes and other legislative instruments to define the quality of stormwater needed from a particular development or catchment; and
- pollutant export modelling tools are being used more widely to quantitatively demonstrate a proposed suite of BMPs will collectively improve stormwater quality so that it complies with water quality-related objectives.

The need for research into the cost and value of non-structural BMPs has been recognised in the literature for more than two decades. For example, in 1980, attempts were made to evaluate the efficiency and cost of street sweeping and the addition of flocculants to stormwater to remove colloids (e.g. Biggers *et al*., 1980). Despite this history, modest progress has been made in quantifying the efficiency of non-structural BMPs other than street sweeping.

Perhaps the most instructive indicator of the stormwater industry's progress on measuring the life-cycle costs and pollutant removal efficiencies of non-structural BMPs for stormwater quality improvement comes from the US National Stormwater Best Management Practices Database (see http://www.bmpdatabase.org and Clary *et al*., 2000). Established in 1999, the database summarises data on stormwater BMPs in a standardised format that has been screened by experts. When reviewed as part of this project, it contained 113 sets of data on BMPs. Only eight concerned non-structural BMPs, and all of these involved street sweeping.

In 1999, the US EPA reviewed the availability of data on the efficiency of BMPs for urban stormwater management and concluded "… there is still a great need for focused research in certain areas, particularly for newer and innovative structural BMP types, as well as non-structural BMPs. However, due to the complexity involved in isolating the reaction of a complex and highly variable system such as a watershed to one isolated input, evaluations of non-structural BMPs are ambitious tasks. Still, where stormwater management is largely driven by the availability of scarce funding, data that indicate the cost effectiveness of various control strategies are badly needed" (US EPA, 1999, p. 5-85).

2.4.2 The main impediments to evaluation of non-structural BMPs

We suggest that five factors have significantly hindered the progress of non-structural BMP evaluation:

1. Monitoring BMPs that seek to change people's behaviour is inherently difficult (Livingston, 2001) because:
   - people's behaviour is extremely complex;
   - direct measurement of people's behaviour (i.e. through an 'observational approach') can be constrained by issues such as privacy, experimental influence on behaviour and the high cost of monitoring infrequent events (e.g. annual use of lawn fertiliser);
   - studies that measure observed behaviour often produce significantly different results from those that measure self-reported behaviour (Curnow, *et al.,* 1997; Williams, *et al.*, 1997);
   - studies have found major differences or incongruities between people's attitudes and their actual behaviour (e.g. littering behaviour as noted by Williams, *et al.*, 1997);
   - finding and managing suitable control sites for non-structural BMPs designed to operate over large areas and over long time-frames is difficult (e.g. on-going stormwater awareness campaigns); and
   - the tendency for the effects of non-structural BMPs to change with time (e.g. the effect of stormwater drain stencilling on public awareness of stormwater issues over time).
2. Over a given geographic area, the effect of non-structural BMPs on stormwater quality may be subtle and masked by the effects of other management measures and sources of pollution. These confounding factors are not easily controllable in an experimental sense during monitoring (ASCE & US EPA, 2002). This complexity has lead some authors to comment that when it comes to monitoring the effects on *stormwater quality*, "… some non-structural BMPs, such as public education programs … are virtually impossible to monitor or at best can be evaluated using trend analysis" (ASCE & US EPA, 2002, p. 46).

3. There is uncertainty over the transferability of the results obtained from some evaluation exercises, as the value of some BMPs depends on the *context* within which they are applied. For example, an education and enforcement program in a high density residential area may produce a reduction in the percentage of the population that wash their car on the street (rather than in a sewered wash bay) from 80% to 40%. An identical campaign may be run in another part of the city with similar land use, but if affordable wash bays were not as readily available, it is unlikely this magnitude of behavioural change would result.
4. Some BMPs operate synergistically (e.g. complementary education and enforcement campaigns). That is, "some individual practices may not be very effective alone but, in combination with others, may provide a key function in highly effective systems" (US EPA, 2001a, p. 2). This creates complexity for evaluation exercises as the usual reductionist strategy of monitoring a BMP in isolation may produce misleading results.
5. The determination of BMP efficiency and effectiveness suffers from comparability problems. That is, different evaluation methodologies have been used, making the results difficult to compare. Strecker *et al.* (2001) reported "… the differences in monitoring strategies and data evaluation alone contribute significantly to the range of BMP effectiveness that has been reported" (p. 144). To illustrate this point, Strecker *et al.* (2001) applied three commonly used data evaluation methods to the same structural BMP monitoring data set to derive an estimate of the pollutant removal efficiency percentage for one pollutant. The results ranged from 48% to 66%, with the range for non-structural measures expected to be significantly wider.

2.5 Sources of information on the design of best practice non-structural BMPs

This project focused on the use, value, cost and evaluation of non-structural BMPs and did not intend to produce design *guidelines* for non-structural BMPs for stormwater quality improvement. However, given the paucity of such guidelines in Australia, the low level of awareness of overseas guidelines and the need to improve the design of such measures, an effort was made to identify good sources of information during the project's literature review. Consequently, the following guidance documents are recommended.

Australian guidelines:

- 'Urban Stormwater Best Practice Environmental Management Guidelines' (Victorian Stormwater Committee, 1999).
- 'Managing Urban Stormwater - Source Controls' (Draft guidelines prepared for the State Stormwater Coordinating Committee, NSW EPA, 1998).

American documents (most are available from the internet, see the Reference Section for 'URLs'):

- 'National Menu of Best Management Practices for Storm Water Phase II' (US EPA, 2001a)*.
- 'Nonstructural Urban BMP Handbook - A Guide to Nonpoint Source Pollution Prevention and Control Through Nonstructural Measures' (Northern Virginia Planning District Commission, 1996)*.
- 'Stormwater Strategies: Community Responses to Runoff Pollution' (Numerous American case studies by the Natural Resource Defence Council, Lehner *et al.,* 1999)*.
- 'Guidance Specifying Management Measures for Sources of Nonpoint Source Pollution in Coastal Waters' (US EPA, 1997b)*.
- 'Preliminary Data Summary of Urban Stormwater Best Management Practices' (US EPA, 1999).
- 'Texas Nonpoint Source Book'. On-line BMP guideline and website (Statewide Storm Water Quality Task Force, 2002).
- 'The Practice of Watershed Protection' (Schueler and Holland, 2000).

* Note: Suggested as being the best references for non-structural BMP descriptions, design guidance, and case study information for local government authorities to use. All are freely accessible on the internet.

In addition, the following web sites are recommended for people designing, implementing and evaluating non-structural BMPs:

Australian web site:

- The New South Wales Environmental Protection Authority's 'Urban Stormwater Program': http://www.epa.nsw.gov.au/stormwater/index.asp (Provides information aimed at local government authorities designing stormwater-related education/ media campaigns).

American web sites:

- The US Environmental Protection Agency's 'Storm Water Phase II Menu of Best Management Practices':

  http://www.epa.gov/npdes/menuofbmps/menu.htm (Currently the best single source of information on a wide variety of non-structural BMPs. Presented in a simple to use, fact-sheet format).
- The US Environmental Protection Agency's 'Non-point Source Program':

  http://www.epa.gov/OWOW/NPS/index.html (Also see their 'Publications and Information Resources' page for a wide range of useful American sites and on-line documents).
- The 'Stormwater Manager's Resource Center': http://www.stormwatercenter.net/ (Aimed at local government authorities developing strategic urban stormwater management plans and programs).
- The 'Texas Nonpoint Source Book':

  http://www.txnpsbook.org/ (A detailed on-line guideline for a wide variety of BMPs).
- The American 'National Stormwater Best Management Practices Database':

  http://www.bmpdatabase.org (Provides access to BMP performance data in a standardised format for over 190 BMP studies conducted over the past fifteen years. Currently however, structural BMPs dominate the database).

3. Methodology

3.1 BMP use and funding profiles of urban stormwater management agencies

To gather information on the use of, and funding allocated to, non-structural and structural BMPs, we designed a detailed three-part survey for urban stormwater managers, which included:

1. A section asking stormwater managers to indicate for 41 non-structural BMPs and 29 structural BMPs:
   - the degree to which the BMPs were being used in their regions (using a 1 - 5 rating system); and
   - whether the use of the BMPs was increasing, decreasing or remaining static.[3]
2. A section asking stormwater managers to consider 41 non-structural BMPs and then:
   - rank the BMPs in terms of their effectiveness, efficiency and practicality (using a 1 - 5 rating system);
   - indicate the most promising BMPs for future use in their region;
   - state whether the effects and life-cycle cost of the BMPs had been reliably monitored in their region and, if so, the nature of the monitoring indicators and whether monitoring protocols had been developed; and
   - provide contact details for further information on monitoring.
3. A section on public funding for urban stormwater quality management, asking stormwater managers to indicate:
   - the primary function of their organisation (six generic categories were provided); and
   - the approximate annual expenditure by their organisation in 11 categories of management activities (e.g. capital/construction costs for structural BMPs, planning and regulatory mechanisms, education programs, enforcement programs, etc.).

We contacted the Australian stormwater managers by telephone, forwarding the survey electronically to those who agreed to participate. We invited managers in 32 agencies from Queensland, New South Wales, the Australian Capital Territory, Victoria, South Australia and Western Australia, to participate. All agreed to be involved (100%) and 25 completed surveys were received by the deadline (a return rate of 78%).

For overseas stormwater managers, specific people and agencies were targeted based on their reputation as being leaders and/or highly experienced in the management of urban stormwater quality. Twenty-four (24) agencies were invited via email to participate, of which 15 agreed (63%), with 11 surveys being received by the deadline (a return rate of 73%).

For more information on the survey methodology, see Taylor and Wong (2002a) in this series.

3.2 Relative value of non-structural BMPs

To determine those non-structural BMPs most worthy of use in the short term and thorough evaluation, we assessed and ranked the relative value of 41 non-structural BMPs by using the following three assessment methods:

1. Using data from the survey of urban stormwater managers on *their perceptions* of each BMP's "effectiveness, efficiency and practicality", drawing upon an impressive resource of collective knowledge and experience in a wide variety of contexts.
2. Using a Value Utility Function that assigned a relative Value Score to each BMP, drawing on data collected via the survey of stormwater managers. The Value Utility Function incorporated four attributes (i.e. the current degree of BMP use, the trends in use, the degree of promise for future use, and perceptions of effectiveness, efficiency and practicality) and incorporated weightings for each attribute. Also, we performed a sensitivity analysis to ensure the final ranking of BMPs was not overly sensitive to the chosen set of weightings.

[3] The majority of these BMPs were named, listed and arranged in the same manner as the Victorian Urban Stormwater Best Practice Environmental Management Guidelines (Victorian Stormwater Committee, 1999).

3. Documenting the Author's opinion following a major international literature review on the beneficial effects and costs of non-structural BMPs for stormwater quality improvement. This opinion also draws on practical experience as a former stormwater quality manager for Australia's largest local government authority.

3.3 The literature review

The literature review summarised available information on the value and cost of non-structural BMPs that is reported in the literature (e.g. journal publications, conference proceedings, guidelines and manuals) or available from Australian and overseas case studies. In particular, this review focused on *quantitative* information on BMP value (e.g. whether they provide *any* value, and if so, their pollutant removal efficiency) and cost.

To gather this information we:

- Used the survey of urban stormwater managers to identify case studies where attempts had been made to monitor and evaluate the value and life-cycle costs of non-structural BMPs.
- Reviewed the literature using library and internet searches.
- Consulted with key individuals within Australia and overseas.
- Sought unpublished information through articles placed in industry newsletters and journals within Australia.

The collected data are presented in Taylor and Wong (2002b) in this series and were of varying quality. Very few high-quality, independent performance studies have been attempted for non-structural BMPs. Consequently, much of the information is in the form of estimates and results with unknown levels of confidence.

If we were to dismiss all data and conclusions relating to the value of non-structural BMPs derived from studies that lacked detail or produced results with a low level of confidence, we would be left with very little information. Our approach was to include findings based on quantitative information, with appropriate caveats and references, to provide stormwater managers with at least some information to help guide decisions until improved information on the value and cost of non-structural BMPs is available. Given that researchers and stormwater managers have been calling for a greater investment in research in this area for at least 20 years (see Finnemore and Lynard, 1982), it is reasonable to assume stormwater managers will need to continue to cautiously draw on imperfect and limited information for the foreseeable future.

3.4 The monitoring and evaluation tools

To develop monitoring and evaluation tools that can be used by local government authorities in Australia to evaluate all types of non-structural BMP, we gathered information on methods during the survey of urban stormwater managers and the literature review. Useful information typically occurred as:

- Generic guidelines on the evaluation of stormwater BMPs (e.g. ASCE & US EPA, 2002; US EPA, 1997c; US EPA, 2001b).
- Reports on specific monitoring and evaluation exercises (e.g. monitoring the impacts of litter reduction campaigns on people's littering behaviour). These typically included details of the monitoring methodology and tailored monitoring tools (e.g. project-specific telephone survey forms, erosion and sediment control audit checklists).

4. Key Results

4.1 The survey of stormwater managers

4.1.1 Australian BMP use

Data from the survey of 25 stormwater managers from Australian agencies within five States and one Territory indicated that:

- The majority of BMPs included in the survey were associated with an increasing trend in use, particularly the non-structural variety. For example, the majority of respondents (>50%) reported an increasing trend in use for:
  - 76% of the 41 non-structural BMPs included in the survey (e.g. the use of town planning schemes and school education programs); and
  - 34% of the 29 structural BMPs included in the survey (e.g. grassed swales and vegetated filter strips).
- Three of the top four most frequently used non-structural BMPs were related to planning (e.g. strategic, city-wide planning of stormwater management and the use of town planning controls).
- Nine out of the top 11 BMPs associated with the most widespread trend of increasing use in Australia were non-structural. In addition, seven of the top 11 BMPs were closely related to the philosophy of site-based WSUD.

4.1.2 Overseas BMP use

Data from the survey of 11 stormwater managers from agencies within New Zealand and the USA indicated that:

- Compared to Australian data on current degree of use, there appeared to be:
  - A more widespread trend of increasing use of stormwater BMPs, particularly the non-structural variety. For example, the majority of overseas respondents (>50%) reported an increasing trend in use for:
    - 90% of the 41 non-structural BMPs included in the survey (e.g. the use of strategic urban stormwater management plans and city-wide maintenance operations); and
    - 38% of the 29 structural BMPs included in the survey (e.g. hydrodynamic/vortex separators and porous pavements).
  - A much higher degree of use of non-structural BMPs in general. For example, even the tenth most commonly used non-structural BMP in New Zealand and the USA had a significantly higher degree of use than the most commonly used non-structural BMP in Australia.
  - An increased use of non-structural BMPs in New Zealand and the USA that related to regulation.
- Eleven (11) out of the top 13 BMPs associated with the most widespread trend of increasing use within New Zealand and the USA were non-structural. In addition:
  - Five of the top 13 BMPs were closely related to the philosophy of site-based WSUD.
  - Three of the top five BMPs related to operations carried out by local governments/ municipalities (e.g. city-wide maintenance operations and initiatives to minimise sewer overflows).

4.1.3 Funding profiles for several leading stormwater quality management agencies

We analysed the typical relative distribution of funding for various stormwater quality management activities. This analysis found that Australian stormwater management agencies responsible for minor and major/trunk drainage spend a far greater percentage of their total stormwater quality management budget on constructing structural BMPs than their American counterparts (i.e. approximately 31% compared to 14%).

Although the leading American stormwater management agencies surveyed appear to spend a smaller portion of their stormwater quality budget on

capital works than their Australian counterparts, they spend a larger portion on maintenance of structural BMPs (on average) and spend approximately the same percentage on city-wide non-structural BMPs.[4]

On average, leading Australian stormwater management agencies responsible for minor and major/trunk drainage spend approximately 57% of their total stormwater quality management budget on non-structural measures (i.e. AUD$10.41 of AUD$18.42 per person per year).

In terms of *absolute* funding allocated to stormwater quality management in agencies responsible for minor and major/trunk drainage, leading American agencies that were surveyed when compared to equivalent Australian agencies spend approximately:

- 3.8 times as much (per capita) on stormwater quality management in total; and
- 3.9 times as much (per capita) on the non-structural elements of their programs.

4.1.4 The relative value of non-structural BMPs

The survey and literature review information enabled us to develop a short-list of non-structural BMPs deemed most valuable. We developed this short-list because:

- Given the large number of non-structural BMPs, it is logical to develop monitoring tools and undertake evaluation trials on those BMPs likely to be of *most* value to urban stormwater managers.
- The desk-top evaluation of the relative value of non-structural BMPs is a useful outcome of this project in itself. This information can assist stormwater managers who are seeking an optimal mix of BMPs for their region in the absence of high-quality, locally derived data on their value. To the best of the Author's knowledge, this type of desk-top evaluation of relative non-structural BMP value has not been attempted before.

As explained in Section 3.2, three value assessment methods were used to determine the relative value of BMPs. Principal findings from these assessments were:

- The use of the three value assessment methods produced five ranked sets of non-structural BMPs (as survey data from Australian and overseas stormwater managers was kept separate). Six BMPs were represented in the top 10 rankings of all five sets. These were:
  1. Requiring stormwater quality management to be addressed in development proposals/ applications relating to stormwater quality.
  2. Development of urban stormwater management plans for the city, shire or catchment, for the improvement of urban stormwater quality and protection of urban aquatic ecosystems.
  3. Stormwater quality management addressed in construction activities *undertaken* by municipalities or State agencies.
  4. Stormwater quality addressed in a wide variety of maintenance operations.
  5. Implementing stormwater quality improvement policy in town/city planning schemes (closely related to BMP No. 1).
  6. Application of development approval/permit conditions (also closely related to BMP No. 1).
- Collectively, the overseas stormwater managers emphasised the value of non-structural BMPs involving enforcement, regulation and improved construction and maintenance practices, compared to their Australian counterparts.
- Collectively, the Australian stormwater managers emphasised the value of non-structural BMPs involving planning controls and site-based WSUD elements, compared to their overseas counterparts.

[4] For comments relating to funding profiles in this report, the 'non-structural budget' of stormwater quality management agencies does not include costs associated with construction or maintenance of structural BMPs. While manipulation of structural BMP maintenance regimes can be classed as a non-structural BMP, maintenance costs associated with structural BMPs have been excluded from the 'non-structural' budget' as they are an integral part of the life-cycle cost of structural BMPs.

4.2 The literature review

The literature review (Taylor and Wong, 2002b in this series) included approximately 200 references. This review encompassed a very wide variety of BMPs, from city-wide illicit discharge elimination programs, to the effect that the wording of signage has on people's littering behaviour.

For each of the five categories of non-structural BMPs defined in this report (see Section 1.2), the following information is provided in the literature review report:

- A brief section describing the nature of the management practices being evaluated by researchers.
- Summarised information from studies that have examined the ability of non-structural BMPs to influence people's awareness, attitudes, self-reported behaviour, actual behaviour, as well as stormwater quality and waterway health. Specifically, information is provided on the:
  - approximate costs associated with the design, implementation and maintenance of non-structural BMPs; and
  - value of non-structural BMPs (e.g. their pollutant removal efficiencies, where available).
- A summary section highlighting key findings garnered from the review. These sections will not be repeated here due to their length.

The overall finding from the literature and case studies is that non-structural BMPs can be highly valuable, and in some cases essential, for urban stormwater quality improvement. At a catchment or city-wide scale, a balanced and synergistic mix of structural and non-structural BMPs is preferable, with the non-structural BMPs having the most potential value being:

- Town planning controls involving the implementation of stormwater quality policy in town planning schemes, requiring stormwater quality to be addressed in development proposals, and applying development approval/permit conditions (such measures can result in wide-spread adoption of WSUD).
- Development of urban stormwater management plans for a city, shire, or catchment to improve urban stormwater quality and the protection of urban aquatic ecosystems.
- Illegal discharge elimination programs.
- Sustained erosion and sediment control programs that have strong enforcement elements and address both public and private sector works.
- Point source regulation of stormwater discharges (e.g. licensing and inspecting/auditing industry).
- Targeted, intensive and interactive community education and participation programs (e.g. the American Master Gardeners programs).
- The use of a wide variety of city-wide maintenance operations to improve stormwater quality, typically undertaken by local government authorities (e.g. maintenance of the stormwater drainage network and manual litter collections).
- Business/industry programs (e.g. targeted campaigns involving education, audits and/or enforcement to improve procedures and practices relating to stormwater management on commercial or industrial sites).

4.3 The monitoring and evaluation tools

After reviewing available information, we developed:

- A ***conceptual model*** of how non-structural BMPs may work to improve stormwater quality and ultimately, waterway health.
- A new ***evaluation framework*** for all non-structural BMPs that includes seven different styles of evaluation (see Appendix A). This framework accommodates the wide diversity of non-structural BMPs as well as the different characteristics of stormwater management agencies that may undertake the evaluation (e.g. their monitoring objectives and available resources).

  The seven styles of evaluation involve monitoring:

  1. BMP implementation (i.e. simple evaluation of whether the BMP has been fully implemented as designed).
  2. Changes in people's awareness and/or knowledge (i.e. evaluation of whether the BMP has increased levels of awareness and/or knowledge of a specific stormwater issue within a segment of the community).

3. Changes in people's *self-reported* attitude (i.e. 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).
4. Changes in people's *self-reported* behaviour (i.e. evaluation of whether the BMP has changed people's behaviour, as indicated through self-reporting.)
5. Changes in people's *actual behaviour* (i.e. evaluation of whether the BMP has changed people's behaviour, as indicated through direct measurement).
6. Changes in stormwater quality (i.e. evaluation of whether the BMP, or set of BMPs, has improved stormwater quality in terms of loads and/or concentrations of pollutants).
7. Changes in waterway health (i.e. evaluation of whether the BMP, or set of BMPs, has improved the health of receiving waters).

Several of these styles may be used to evaluate the performance of a given non-structural BMP. The choice of styles will depend on the aim of the evaluation, the type of BMP (as some evaluation styles intrinsically suit specific BMPs), and the resources available to the monitoring agency. Key advantages and disadvantages of each style are summarised in Appendix A.

As a general rule, the value to stormwater managers typically increases from evaluation style No. 1 to 7, as the higher levels of evaluation increasingly link the effects of BMPs to the ecological health of water bodies that receive urban stormwater. This increase in value is however, often associated with an increase in the evaluation's complexity and cost.

- A set of five step-wise ***monitoring and evaluation protocols*** that can be used for all non-structural BMPs. The monitoring and evaluation protocols provide simple guidance on how to plan, deliver and report on a monitoring and evaluation exercise. These protocols have been written primarily for use by local government authorities as guidelines for their own work or as project briefs for specialist consultants. They have been deliberately kept short (compared to overseas equivalents), with references being made to more detailed guidelines where necessary. They also use a format that is consistent with equivalent protocols for structural BMPs developed by the CRC for Catchment Hydrology and those used in America (e.g. ASCE & US EPA, 2002).
- ***Data recording sheets*** for each monitoring and evaluation protocol to ensure that the salient details and results of the monitoring and evaluation exercise are collated in a manner that facilitates sound reporting, sharing of knowledge and continual improvement. The format of these sheets is also broadly consistent with overseas equivalents.
- ***Simple guidelines*** on how to use the monitoring and evaluation tools outlined above, and in particular, how to choose the best style(s) of evaluation to suit the objectives of the BMP and available resources. These guidelines also reference some examples of monitoring tools that could be tailored for use in typical non-structural BMP monitoring activities undertaken by local government authorities in Australia (e.g. specific survey sheets and audit checklists).

5. Conclusions and Recommendations

5.1 Conclusions

Based on the results of this project's survey of urban stormwater managers from Australia, New Zealand and the USA, we conclude that non-structural BMPs in Australia:

- are already playing a major role in urban stormwater quality improvement;
- are increasing in use; and
- will continue to increase in use if Australian programs mature in a similar way to those developed overseas.

Despite these trends, relatively little high-quality research was identified from the international literature and case studies on the ability of non-structural BMPs to improve stormwater quality. In general, the information reviewed from approximately 200 references was of a lower quality than that normally associated with equivalent studies involving *structural* BMPs for stormwater quality improvement (e.g. gross pollutant traps, constructed wetlands). This finding may reflect the relative maturity of the two areas of research and the difficulty in designing and executing sound monitoring and evaluation plans for many non-structural BMPs.

In this context, the philosophy we adopted in this project's literature review was to present the more reliable portion of the available information, despite some obvious limitations, to form a platform for future research involving improved evaluation.

The three technical reports generated from this project should assist Australian urban stormwater managers in the short and medium to long term.

In the short term, stormwater managers can now:

- Cautiously use the survey and literature review findings on the relative value and cost of non-structural BMPs to guide their decisions on the use of these BMPs until higher quality, locally-derived performance data are available.
- Use the survey and literature review findings on the relative value of non-structural BMPs to guide their decisions on which BMPs should be rigorously monitored and evaluated.
- Use the new evaluation framework, monitoring protocols and data recording sheets when assessing all types of non-structural BMPs for stormwater quality improvement to help raise the standard of monitoring and evaluation and provide valuable feedback to stakeholders on the merits and cost of these practices.
- Use information on funding profiles of leading Australian and overseas stormwater management agencies as benchmarks when developing or fine-tuning their urban stormwater quality management programs.

In the medium to long term, it is hoped that stormwater managers in Australia will able to use information on BMP value and cost that has been gathered from well-designed monitoring and evaluation programs using the newly-developed evaluation framework and monitoring tools. The accumulation of reliable, high-quality data sets on the value and cost of a wide range of non-structural BMPs will enable a greater degree of analysis when considering urban stormwater management options and produce greater confidence in the resulting strategies. It should also become more feasible to reliably predict the effect of non-structural BMPs on stormwater quality using pollutant export models such as the CRC for Catchment Hydrology's MUSIC.

5.2 Recommendations

1. Given the identified trends in the use of non-structural BMPs in Australia, the large number of non-structural BMPs and the paucity of high-quality data on their performance, more research is clearly needed. Some work is underway in Australia, particularly in New South Wales and Victoria. For example, the CRC for Catchment Hydrology is trialling the newly-developed evaluation framework, monitoring protocols and data recording sheets in Melbourne on two non-structural BMPs (i.e. a town planning control and an anti-litter educational campaign). This work is supported by funding from the Victorian State Government through the Environmental Protection Authority as part of the Victorian Stormwater Action Program.

2. Monitoring and evaluation exercises in Australia involving non-structural BMPs for stormwater quality improvement should:
   - focus on measuring the performance of those BMPs this project deemed to be of most potential value; and
   - seek to use evaluation styles No. 5 (i.e. measuring change in actual behavioural), No. 6 (i.e. measuring change in stormwater quality) and/or No. 7 (i.e. measuring change in waterway health), where resources allow. [5]

   BMPs that are seen to be a priority for evaluation include:
   - Town planning controls.
   - Strategic city-wide stormwater management plans.
   - Maintenance practices by local government authorities (e.g. the use of integrated pest management, anti-litter initiatives, the use of environmental management systems, maintenance of nodes in the stormwater network that collect pollutants, the use of manual litter collections, etc.).
   - The use of management systems to improve the quality of stormwater draining from government-managed construction sites.
   - Enforcement and education campaigns (e.g. erosion and sediment control programs).
   - Illicit discharge elimination programs.
   - Focused, intensive and interactive training programs, like the American Master Gardeners programs.
   - Licensing, auditing and education programs involving commercial and industrial premises.
3. In New South Wales and Victoria alone, considerable resources are being allocated to monitoring and evaluating a variety of non-structural BMPs, which is to be commended. However, it is recommended that greater cooperation and consistency occur between these States (and others) on how the evaluation data are reported, stored and communicated to stakeholders. We recommend that the data recording sheets produced by this project be used as standard reporting templates. These sheets are also broadly consistent with equivalent American systems, so that valuable data could also be shared internationally. We also recommend that a single Australian website be established to communicate evaluation results to stakeholders and direct them to relevant resources such as the products produced by this project.
4. In Australia, we now have detailed guidelines on how to monitor and evaluate non-structural BMPs for stormwater quality improvement as a result of this project, but we lack comprehensive guidelines on how these BMPs should be designed. Some information is available (e.g. Victorian Stormwater Committee, 1999; NSW EPA, 1998), but more is needed. More comprehensive American guidelines (e.g. US EPA, 2001a) could be tailored for use in Australia.
5. Ongoing training programs be developed to help urban stormwater managers access the best available information to select, design, implement, monitor and evaluate a wide variety of non-structural BMPs for stormwater quality improvement.

[5] See Appendix A for an explanation of these styles of evaluation.

6. Glossary of Key Terms and Acronyms

ASCE
American Society of Civil Engineers.

BACI
An acronym for an experimental design that has sampling Before and After sampling at a Control (no action) and Intervention (action) site. The intervention (or action) site is where the BMP has been implemented.

BMP
Best management practice - A device, practice or method for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters. Within the context of this report, BMPs primarily seek to manage stormwater quality to minimise impacts on waterway health.

BMP system
The BMP and any related stormwater the BMP is unable to manage. For example, a 'BMP system' may be a residential suburb over which a lawn fertilisation education program (BMP) is operating. The stormwater draining from this suburb may include some that is less polluted as a result of the BMP (e.g. runoff from lawns) and some that is not affected by the BMP (e.g. runoff from roads). A monitoring program may attempt to measure changes in stormwater quality as a result of the BMP. Such a program would be monitoring a 'BMP system'.

Control site
A sampling site which is as similar as possible to the intervention site (i.e. where the BMP is to be implemented) in every way, except that the BMP is not applied there.

CRC
Cooperative Research Centre for Catchment Hydrology (Australia).

Effectiveness
In the context of non-structural BMP monitoring, effectiveness is a measure of how well a BMP system meets its goals for all stormwater flows reaching the area of coverage by the BMP.

Efficiency
In the context of non-structural BMP monitoring, efficiency is a measure of how well a BMP or BMP system removes or controls pollutants. Although 'percent removal' is the most common form of expressing BMP efficiency, recent American work on structural BMP evaluation argues that 'percent removal' (when used alone) is a poor measure of BMP efficiency compared with alternatives such as the 'effluent probability method' (see ASCE & US EPA, 2002).

Evaluation
The final assessment of whether the non-structural BMP has achieved its pre-defined objectives and is usually based on some form of monitoring. However, unlike monitoring, evaluation involves an assessment of the project's success or failure.

Life-cycle cost
The total cost of the design, implementation, operation and maintenance of the BMP over its life span.

LSRC
Land of Sky Regional Council (USA).

Monitoring
The gathering of information about a non-structural BMP over time and/or space. Monitoring may involve measuring or observing change and is often the raw material or data for evaluation.

Non-structural BMP
A range of institutional and pollution prevention practices that are designed to prevent or minimise pollutants from entering stormwater runoff and/or reduce the volume of stormwater requiring management. Unlike structural BMPs, they do not involve fixed, permanent facilities, and they usually work by changing people's behaviour through government regulation (e.g. planning and environmental laws), persuasion and/or economic instruments.

NSW EPA
New South Wales Environmental Protection Authority.

NVPDC
Northern Virginia Planning District Commission.

Performance
In the context of non-structural BMP monitoring, performance is a measure of how well a BMP meets its goals for the stormwater it is designed to improve.

Stormwater utility
A utility established to generate a dedicated source of funding for stormwater pollution prevention activities where users pay a fee based on the land use and contribution of runoff to the stormwater system.

Structural BMP
Engineered devices implemented to control, treat, or prevent stormwater runoff pollution.

TN
Total nitrogen.

USA
United States of America.

US BMP Database Project
A cooperative arrangement between the American Urban Water Resources Research Council of the American Society of Civil Engineers and the US EPA to promote technical design improvements for BMPs and to better match their selection and design to local stormwater problems. The project involves collecting and evaluating existing BMP performance data, designing and creating an on-line national BMP database (http://www.bmpdatabase.org) and developing BMP performance evaluation protocols. In 2001-02, the database focused on structural BMPs for stormwater quality improvement.

US EPA
United States Environment Protection Agency.

Value
The term 'value' is used in this report as a collective description of the benefits of non-structural BMPs, encompassing attributes such as their:

- ability to raise people's awareness, change their attitudes and/or change their behaviour;
- performance, effectiveness and efficiency with respect to stormwater quality improvement (as defined above); and
- ability to improve waterway health.

WSUD
Water sensitive urban design (also known as low impact development) - WSUD aims to minimise the impact of urbanisation on the natural water cycle. Its five key objectives for water management are:

- Protect natural systems.
- Integrate stormwater treatment into the landscape.
- Protect water quality.
- Reduce runoff and peak flows.
- Add value while minimising development costs.

Xeriscaping™
An alternative landscaping technique that focuses on the conservation of water and the minimisation of stormwater pollution through plant selection and site design. Also known as resource-sensitive landscaping.

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An Evaluation Framework for Non-structural BMPs that Aim to Improve Stormwater Quality

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 as designed.	Stormwater management agencies (e.g. local or State government authorities) or community groups.	Audits with audit checklists.	• Inexpensive. • Provides the basis for more advanced styles of evaluation (see below). • Simple to design and implement. • Useful for BMPs with 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 and 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 people's awareness and/or 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 (with survey forms) that examine people's level of awareness and/or 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 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.
3. Changes in people's 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.	As above.	Surveys (with survey forms) that examine people's 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 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).

Style of Evaluation	Description	Who Typically Does it	Example of Monitoring 'Tools'	Advantages	Disadvantages
4. Changes in people's behaviour (self-reported)	Evaluation of whether the BMP has changed people's behaviour, as indicated through self-reporting.	As above.	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).
5. Changes in people's behaviour (actual)	Evaluation of whether the BMP has changed people's behaviour, as indicated through direct measurement (e.g. an observational approach).	Specialists (e.g. research bodies, specialist consultants, trained staff from stormwater management agencies).	Observational studies (e.g. the 'Situational Litter Score' and the 'Disposal Behaviour Index' methods used for Australian littering studies) or audits with checklists (e.g. erosion and sediment control audits).	• Changes 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 occurs).	• 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, their location, etc.). Designing evaluation strategies to accommodate this complexity can be challenging.
6. Changes in stormwater quality	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 quality monitoring programs (e.g. 'BACI' design experiments[6]). Alternatively, pollutant export modelling can be used to translate known changes in behaviour into probable changes in stormwater quality.	• 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.
7. Changes in waterway health	Evaluation of whether the BMP (or set of BMPs) has improved the health of receiving waters.	Specialists (e.g. research bodies) or environmental protection agencies with a very high level of in-house expertise.	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).	• Directly measures changes in aspects of waterway health (the *ultimate* goal of most stormwater quality managers who 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 cause-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* affect 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.

[6] 'BACI' is an acronym for an experimental design that has sampling Before and After sampling at a Control (no action) and Intervention (action) site.

Appendix B - Acknowledgments

The following people are acknowledged for kindly assisting the CRC for Catchment Hydrology with aspects of this project:

- Adrian Tomlinson, Manager Swan-Canning Cleanup Program, Swan River Trust, Perth, Western Australia.
- Alison Saunders, Community Liaison Manager, Patawalonga Catchment Water Management Board, Wayville, South Australia.
- Anthony Collins, Catchment Remediation Program Manager, Hornsby Shire Council, Sydney, New South Wales.
- Bill Manners, Senior Development Assessment Officer, Brisbane City Council, Brisbane, Queensland.
- Bill Till, Program Manager, Stream and Stormwater Management, Water and Rivers Commission, Perth, Western Australia.
- Blair Nancarrow, Director, Australian Research Centre for Water in Society, CSIRO Land and Water, Perth, Western Australia.
- Brenton Curtis, Design Services Coordinator, City of Salisbury, Salisbury, South Australia.
- Bryce Routley, Senior Watershed Protection Officer (Wastewater and Stormwater), South Australian Environment Protection Agency, Stirling, South Australia.
- Byron Berger, Caltrans Stormwater Unit, Department of Transportation Environmental Program, Sacramento, California.
- Campbell Sturrock, Senior Pollution Control Officer, Auckland Regional Council, Auckland, New Zealand.
- Chris Chesterfield, Manager South-east Catchments Planning, Melbourne Water, Melbourne, Victoria.
- Chris Tually, Manager Urban Development and Infrastructure, City of Unley, Unley, South Australia.
- Clarissa Forster, Waste and Litter Education Officer, City of Port Phillip, Melbourne, Victoria.
- David Brown, Chief Development Officer, City of Unley, Unley, South Australia.
- David Pannell, Associate Professor, Agricultural and Resource Economics, University of Western Australia, Albany, Western Australia.
- David Perry, Program Leader, Communication and Adoption Program, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.
- Derin Warren, Senior Environmental Planner, Regional Stormwater Management Program, North Central Texas Council of Governments, Arlington, Texas.
- Diana Wolfe, Writer and Publicist, Wolfe Words, Melbourne, Victoria.
- Earl Shaver, Technical Specialist, Auckland Regional Council, Auckland, New Zealand.
- Edward M. Ritzer, Stormwater Management Planner, Pennsylvania Department of Environmental Protection, McMurray, Pennsylvania.
- Emily Low, Senior Environmental Planner, Gold Coast City Council, Gold Coast, Queensland.
- Eric Livingston, Chief of the Bureau of Watershed Management, Florida Department of Environmental Protection, Tallahassee, Florida.
- Fiona Chandler, Waterways Program Officer - Water Quality, Brisbane City Council, Brisbane, Queensland.
- Frank Piorko, Environmental Program Manager, Delaware Department of Natural Resources and Environmental Control, Dover, Delaware.
- Gary Walsh, Senior Engineer, Catchment Strategy, Melbourne Water, Melbourne, Victoria.
- Geoff Young, Manager Community Education Unit, New South Wales Environment Protection Authority, Sydney, New South Wales.
- Geoffrey Syme, Senior Principal Research Scientist, CSIRO Land and Water, Perth, Western Australia.
- Graham Rooney, Manager Water Environment Research, Melbourne Water, Melbourne, Victoria.
- Greg Rogers, Aquatic Scientist, Texas Natural Resource Conservation Commission, Austin, Texas.
- Greg Ryan, Senior Environmental Officer, Policy Development, Eastern Metropolitan Regional Council, Perth, Western Australia.

- Harvey Lane, Project Officer - Stormwater Management, Caboolture Shire Council, Caboolture, Queensland.
- Hugh Duncan, Research Fellow, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.
- Ian Innes-Wardell, Manager Victorian Stormwater Action Program, Victorian Environmental Protection Agency, Melbourne, Victoria.
- J. Douglas Fritz, Water Quality Coordinator, City of Chattanooga, Chattanooga, Tennessee.
- Jacquie White, Education and Promotion Coordinator, Moonee Ponds Creek - Keep It Clean Program, Melbourne, Victoria.
- Jade Ballantine, Environmental Project Officer, City of Port Adelaide Enfield, Port Adelaide, South Australia.
- Jane Clary, Regulation Specialist, Wright Waters Engineers Inc., Denver, Colorado.
- Janet Jessel, Team Leader, Municipal Stormwater Regulation Team, New Jersey Department of Environmental Protection, Trenton, New Jersey.
- Jannette Huston, Community Education Officer, Eastern Metropolitan Regional Council, Perth, Western Australia.
- Joanne Sinclair, Regional Education Officer, Least Waste, Mitcham, Victoria.
- Jody Haynes, Program Extension Agent, Florida Yards and Neighbourhoods Program, University of Florida, Homestead, Florida.
- John Brosnan, Senior Civil Engineer, PPK Environment and Infrastructure, Perth, Western Australia.
- John Neal, Senior Engineer, Department of Planning and Land Management, Canberra, Australian Capital Territory.
- Juanita Higgs, Regional Projects Manager, South Sydney Regional Organisation of Councils, Hurstville, New South Wales.
- Karen Cosson, Litter Champion, Victorian Litter Action Alliance, Melbourne, Victoria.
- Karen Spehr, Managing Director, Community Change Pty Ltd, Melbourne, Victoria.
- Karl Cloos, Manager Planning Policy and Coordination, Roads and Services Section, Department of Urban Services, Canberra.
- L. Kenneth Pensyl III, Program Manager, Point Source Program, Maryland Department of the Environment, Baltimore, Maryland.
- Larry Roesner, Professor, Colorado State University, Fort Collins, Colorado.
- Leon Rowlands, Environmental Planner, Gold Coast City Council, Gold Coast, Queensland.
- Leslie Tull, Manager, Water Quality Management Section, City of Austin, Texas.
- Louise Cervantes, Clean Water Division, Alameda County Public Works, Hayward, California.
- Lyndall Pickering, Environmental Officer Communications, Mosman Municipal Council, Sydney, New South Wales.
- Marc Aveni, Area Extension Agent, Environmental Sciences, Virginia Cooperative Extension, Manassas, Virginia.
- Mark Blosser, Water Resources Engineer, City of Olympia Public Works, Olympia, Washington.
- Mark Foord, Coordinator Design and Project Services, City of Port Phillip, Melbourne, Victoria.
- Mark Labaz, Coordinator Stormwater Pollution Prevention Projects, Environment Protection Agency, Adelaide, South Australia.
- Mark Taylor, Program Officer - Pollution Prevention, Brisbane City Council, Brisbane, Queensland.
- Max Pfitzner, Team Leader Environment and Planning, City of Kingston, Melbourne, Victoria.
- Mick McCarthy, Executive Manager Environmental Services, Eastern Metropolitan Regional Council, Perth, Western Australia.
- Nando Treppiedi, Business Unit Leader, Maintenance and Construction Services, City of Unley, Unley, South Australia.
- Natalie Brown, Water Quality Specialist, Minneapolis Park and Recreation Board, Minneapolis, Minnesota.
- Neville Pavan, New South Wales Department of Land and Water Conservation, Sydney, New South Wales.
- Nona Ruddell, Stormwater Technical Officer, Kogarah City Council, Kogarah, New South Wales.

- Patrick Dupont, Environment Officer - Water, City of Unley, Unley, South Australia.
- Paul Smith, Masters Student, Centre for Systemic Development, University of Western Sydney, Sydney, New South Wales.
- Peter Morison, Environmental Programs Officer, Upper Parramatta River Catchment Trust, Sydney, New South Wales.
- Peter Morrison, Principal Environmental Health Officer, City of Canning, Perth, Western Australia.
- Peter Reid, Drainage Manager, Waitakere City Council, Waitakere City, New Zealand.
- Peter Salier, Senior Stormwater Education Officer, New South Wales Environment Protection Authority, Sydney, New South Wales.
- Peter Scott, Senior Adviser - Stormwater, South Australian Environmental Protection Agency, Adelaide, South Australia.
- Phil Smith, Senior Education Officer - Stormwater, New South Wales Environment Protection Authority, Sydney, New South Wales.
- Philip Alviano, Stormwater Project Officer, Construction and Building Sites, City of Kingston, Melbourne, Victoria.
- Randy Greer, Environmental Engineer, Delaware Sediment and Stormwater Program, Department of Environment, Delaware.
- Ray Tickle, Urban Drainage Officer, Dubbo City Council, Dubbo, New South Wales.
- Richard McManus, Stormwater Officer, Stormwater Team, New South Wales Environmental Protection Authority, Sydney, New South Wales.
- Rob Curnow, Director, Community Change Pty Ltd, Melbourne, Victoria.
- Roberta Ryan, Associate Director, Elton Consulting, Sydney, New South Wales.
- Robyn Sim, Stormwater Manager, Sydney Water, Sydney, New South Wales.
- Roger Hawthorne, Stormwater Operations Manager, North Shore City Council, Auckland, New Zealand.
- Scott Van Loo, Environmental Compliance Specialist, Public Works Department, City of Tulsa, Oklahoma.
- Shane Barter, Senior Project Officer - Stormwater, New South Wales Environment Protection Authority, Sydney, New South Wales.
- Siva Sivaananthan, Waterways Program Officer - Stormwater, Brisbane City Council, Brisbane, Queensland.
- Stephen Lees, Executive Officer, Upper Parramatta River Catchment Trust, Parramatta, New South Wales.
- Tanja Mueller, Victorian Stormwater Action Program Coordinator, Victorian Environmental Protection Agency, Traralgon, Victoria.
- Tim Fletcher, Program Leader, Urban Stormwater Quality Program, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.
- Tony Weber, Senior Waterways Program Officer - Water Quality, Brisbane City Council, Brisbane, Queensland.
- Tony Wong, Associate Professor, Urban Stormwater Quality Program, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.
- Verena Mette, Waterways Program Assistant, Brisbane City Council, Brisbane, Queensland.
- William Chamberlain II, Bureau Chief, Streets, Drainage and Stormwater Utility Bureau, Public Works Department, City of Orlando, Florida.

In addition, the Victorian Government is acknowledged for providing the bulk of the funding for this project through the Environmental Protection Authority as part of the Victorian Stormwater Action Program.

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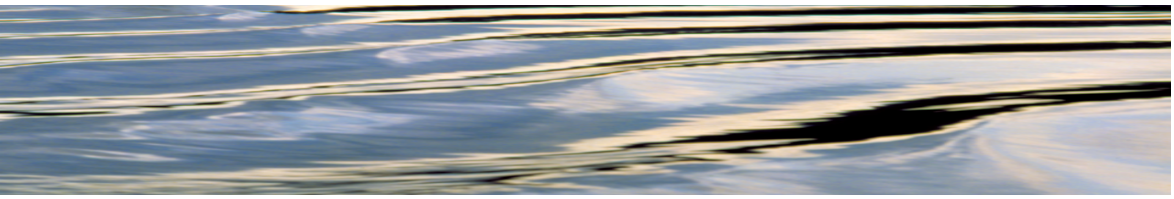

The Cooperative Research Centre for Catchment Hydrology is a cooperative venture formed under the Commonwealth CRC Program between:

- Brisbane City Council
- Bureau of Meteorology
- CSIRO Land and Water
- Department of Land and Water Conservation, NSW
- Department of Sustainability and Environment, Vic
- Goulburn-Murray Water
- Griffith University
- Melbourne Water
- Monash University
- Murray-Darling Basin Commission
- Natural Resources and Mines, Qld
- Southern Rural Water
- The University of Melbourne
- Wimmera Mallee Water

Associates:

- Water Corporation of Western Australia

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CRC AUSTRALIA

Established and supported under the Australian Government's Cooperative Research Centre Program