COOPERATIVE RESEARCH CENTRE FOR **CATCHMENT HYDROLOGY**

NON-STRUCTURAL STORMWATER QUALITY BEST MANAGEMENT PRACTICES - A LITERATURE REVIEW OF THEIR VALUE AND LIFE-CYCLE COSTS

TECHNICAL REPORT
Report **02/13**
December 2002

André Taylor / Tony Wong

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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.
- A short-list of those non-structural BMPs deemed to be of most value in terms of effectiveness, efficiency, practicality, acceptance and potential for future use. This short-list used information from the literature and a survey of Australian and overseas stormwater quality managers.

- Recommended references relating to the design of non-structural BMPs.[1]
- 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 an **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 this 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 for Catchment Hydrology Working Document 02/6). The report presents guidelines and a new evaluation framework for measuring the value 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] Note that this research project did not intend to produce *design guidelines* for non-structural BMPs for stormwater quality improvement. An effort has been made however, to refer Australian stormwater managers to good sources of information that were identified during the project's literature review given the:
- paucity of such guidelines in Australia;
- low level of awareness of overseas guidelines; and
- need to improve the design of such measures.

List of Figures

List of Tables

1. Introduction

1.1 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.

Examples of non-structural BMPs for managing urban stormwater quality include:

- town planning controls (e.g. using town planning instruments to promote Water Sensitive Urban Design [WSUD] principles in new developments, such as decreasing the area of impervious surfaces);
- city-wide stormwater management planning (e.g. local authorities developing and implementing strategic management plans to improve stormwater quality throughout a catchment or city);
- controls involving construction and maintenance activities (e.g. maintenance activities such as regular inspection and clean-out of structural BMPs and manual litter collections);
- education and participation programs (e.g. focused campaigns that aim to change those aspects of behaviour that may be damaging the health of local waterways, such as over-applying lawn fertiliser);
- enforcement campaigns (e.g. the use of enforcement to improve erosion and sediment control on construction sites);
- economic controls (e.g. financial incentives to encourage the conversion of lawns and gardens that require large amounts of fertilisation and watering to more resource-sensitive alternatives);
- regulation and inspection activities involving industrial and commercial premises (e.g. auditing programs); and
- programs to identify and eliminate illicit discharges of pollutants to stormwater (e.g. programs to minimise illegal connections of sewerage to stormwater).

1.2 Types of Non-structural BMPs

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 to group non-structural BMPs in this report:

1. **Town planning controls** (e.g. statutory planning instruments requiring stormwater quality to be addressed in new developments through WSUD principles[2]).
2. **Strategic planning and institutional controls** (e.g. strategic, city-wide stormwater quality management plans and secure funding mechanisms to support the implementation of these plans).
3. **Pollution prevention procedures.** Such as:
   - practices undertaken by stormwater management authorities involving maintenance (e.g. maintenance of structural BMPs and 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 and the use of regulatory instruments such as environmental licences to help manage premises likely to contaminate stormwater.

2 Known as ‘Low Impact Development’ in overseas literature (see Lloyd, 2001 or Victorian Stormwater Committee, 1999 for further information).

2. Background

A detailed background on the nature of non-structural BMPs for urban stormwater quality improvement is presented in the overview report of this series, and will not be repeated in full here. The background section of the overview report contains information on:

- Terminology used in all four reports.
- Types of non-structural BMPs.
- Broad trends on the use of non-structural BMPs.
- The status of attempts to evaluate non-structural BMPs.
- Impediments to the evaluation of non-structural BMPs.
- Sources of information (i.e. web sites and on-line documents) that are recommended for the *design* of non-structural BMPs for urban stormwater quality improvement in Australia.

It is recommended that the overview report be read before the technical reports, where possible.

2.1 Terminology

The following definitions – modified from Strecker *et al.* (2001) and ASCE & US EPA (2002) – are used in this report:

- Best management practice (BMP) - 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*.
- BMP system - the BMP and any related stormwater the BMP is unable to manage.[3]
- Performance - a measure of how well a BMP meets its goals for the stormwater it is designed to improve.
- Effectiveness - a measure of how well a BMP system meets its goals for all stormwater flows reaching the area of coverage by the BMP.
- Efficiency - 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 US 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).

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 in this section); and
- ability to improve waterway health.

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

[3] See section 6 (Glossary) for additional information.

3. Methodology

The primary aim of this technical report is to summarise credible information on the value 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 has focused on *quantitative* information on BMP value (e.g. whether they provide *any* value, and if so, their efficiency) and cost.

To gather this information we:

- Surveyed 25 Australian stormwater managers and 11 stormwater managers from the US and NZ, to identify case studies where attempts had been made to monitor and evaluate the value and life-cycle costs of non-structural BMPs (see Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12, for details of this survey).
- Reviewed the literature using library and internet searches.
- Consulted with key individuals within Australia and overseas.
- Sought unpublished information through requests placed in industry newsletters and journals within Australia.

The collected data, much of which are presented in Section 4, 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. A discussion on the impediments to sound evaluation of non-structural BMPs is presented in the overview report of this series.

Although the lack of high-quality performance data for non-structural BMPs is not surprising, the high proportion of poorly designed and reported evaluation studies is of concern. For example, the majority of attempts to quantitatively describe a non-structural BMP's efficiency for pollutant removal do not clearly explain how 'efficiency' was defined.

Extending this example, a study may conclude (without explanation) that a particular non-structural BMP has a "50% removal efficiency" of total nitrogen (TN). Even if the assumption is made that this estimate is based on reliable data and has an acceptable level of confidence, uncertainty exists as to whether the 50% figure relates to a reduction in the annual average load of TN in stormwater, or a reduction in the concentration of TN in stormwater.

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. This approach provides 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.

For the five categories of non-structural BMP defined in this report (see Section 1.2), the following information is provided in Chapter 4:

- a brief section describing the nature of the management practices being evaluated by researchers[4];
- summarised information from the literature and case studies on the cost[5] and value of non-structural BMPs (e.g. their efficiency); and
- a summary section highlighting key findings garnered from the review.

Before reading the information summarised from the literature, it is recommended that the overview report of this series be read to gain an insight into attempts to evaluate non-structural BMPs. This information helps to explain why there is a paucity of high quality

4 For more information on the design of BMPs, including case studies, see the recommended references in the overview report of this series.

5 Note that where cost information is provided, it can be assumed that the currency relates to the year of the associated reference (i.e. they have not been adjusted for inflation) unless stated otherwise. Also, currency is in Australian dollars (AUD) unless otherwise stated.

data, and provides a context in which to interpret the results. For example, there is a risk associated with evaluating *some* non-structural BMPs in isolation from other BMPs that they support. As the US EPA (2001) stated, "Some individual practices may not be very effective alone but, in combination with others, may provide a key function in highly effective systems." (p. 2). This creates complexity for evaluation exercises as the usual reductionist strategy of monitoring a BMP in isolation may produce misleading results.

4. A Review of the Literature and Case Studies

4.1 Town Planning Controls

4.1.1 Description of BMPs

This Section presents information relating to two categories of town planning controls:

- city-wide town planning controls (e.g. elements of the municipal planning scheme that control development through measures such as zoning, development assessment, application of development conditions); and
- site-based planning controls, namely the application of WSUD principles to the design and construction of development in either a 'greenfield' or 'retrofit' context.

The reason for this categorisation, is that town planning controls can be viewed from two perspectives:

- as a powerful *framework* which controls the nature of development and within which structural and non-structural BMPs are applied at the estate, street and/or allotment scale through WSUD; and
- as specific site-based BMPs that can be used in WSUD (e.g. 'cluster development' principles, the minimisation of impervious area, use of vegetated buffer zones, soil amendment, etc.).

In Australia, State and/or local planning instruments[6] are potent mechanisms for managing urban stormwater quality at the construction and post-construction stage, and can be used to:

- control the type of development that occurs in a given area (e.g. through zoning and regional planning);
- require developers to plan, implement and monitor best practice erosion and sediment controls on construction/building sites; and
- require developers to design and build the developments in accordance with WSUD principles.

Planning instruments have such power because they typically:

- apply to large areas (e.g. city-wide) in a strategic manner;
- capture all major forms of development (including redevelopment);
- use an established, well-understood process to deliver their objectives (e.g. the development assessment process within local government); and
- are reinforced by a compliance assessment regime with penalties for non-compliance (e.g. prosecution for failure to comply with development approval conditions).

Four Australian examples given in Table 4.1 illustrate the use of town planning instruments in managing urban stormwater quality. These systems operate in different ways, but all aim to improve stormwater quality and, ultimately, waterway health.

4.1.2 Case Studies and Reported Data

Performance of City-wide Stormwater Planning Controls

The Victorian Stormwater Committee (VSC) (1999) has defined quantitative performance objectives for stormwater quality based on the anticipated outcomes of best practice urban stormwater management (e.g. through the use of 'end of pipe' structural BMPs on typical urban developments). These objectives are summarised in Table 4.2 and, for total suspended solids (TSS), are similar to those operating in parts of the US.

In Victoria, new development is required to meet the VSC objectives as a result of local town planning instruments (e.g. municipal strategic statements and local planning policies). In theory, the objectives represent an upper bound on the quality of stormwater expected to drain from newly developed areas in Melbourne. However, in reality, the performance of planning instruments for stormwater quality management is unlikely to meet the objectives on a *city-wide basis* for newly developed areas, as:

- Some sub-standard stormwater designs will inevitably slip through the planning framework.

[6] In this context, 'planning instruments' includes all State legislation and subordinate municipal planning schemes that guide and control development within urban areas.

Table 4.1 Four Examples of Australian Town Planning Controls for the Management of Urban Stormwater Quality

EXAMPLE	DESCRIPTION	HOW THE PLANNING CONTROL OPERATES
Blacktown City Council, Sydney, New South Wales – "Stormwater Quality Control Policy 2001" (Blacktown City Council, 2001)	• Applies to new development in the City that falls within certain categories (e.g. Industrial developments on allotments or industrial units of 1,000 m^2 or greater). • Applies via the town planning scheme and the State *Protection of the Environment Operations Act 1997*.	• Requires a Site-based Stormwater Management Plan to be submitted with the development application. • Requires the developer to demonstrate that at least 75% of the average annual stormwater runoff volume can be treated and/or stormwater pollutants contained within the run-off generated by 90% of the rain events in the catchment for an average year can be retained. • Defines "treatable flow rates" and "storage volumes" to retain a given depth of runoff for key pollutants. • Defines "priority pollutants", including those that must be treated. • Defines "retention criteria" for priority pollutants and structural BMPs (i.e. approximate percentage removal efficiencies). • Provides modelling/calculation guidelines and BMP design guidelines. • Defines qualitative "management objectives" for related aspects such as the reuse of stormwater.
Brisbane City Council, Queensland – "Stormwater Management Code" (Brisbane City Council, 2000a and 2000b)	• Applies to development in the City that has the potential to pollute stormwater (e.g. land disturbing activities, industrial activities, etc.). • Has power under the Cityís planning scheme (City Plan 2000) and supporting State planning legislation (i.e. the *Integrated Planning Act 1997*).	• The stormwater quality element of the code uses a series of thresholds (e.g. uncovered car parks with >100 spaces) to define "High" and "Low" risk development. • For low risk developments, applicants must demonstrate that their proposed development complies with referenced best practice guidelines (i.e. a qualitative approach). • For high risk developments, applicants must demonstrate that their proposed development will not threaten environmental values and water quality objectives for receiving waters. This is done through pollutant export modelling or simple calculations in accordance with referenced guidelines (i.e. a quantitative approach).

The Association of Bayside Municipalities, Melbourne, Victoria - *Proposed* Statutory Framework and Standards for Urban Stormwater Management (Stage 1)
 	
(ELM & EE, 2001)
	• Proposed model planning scheme provisions for stormwater quality management by local government authorities in the Bayside region of Melbourne. They include a model "Local Planning Policy" and standards.
	• The proposed policy applies to:
	  • all subdivision and building sites; and
	  • developments with an impermeable area >20%.
		• The proposed policy introduces a new concept called the "Equivalent Percentage Treated Area (EPTA)". The EPTA is the percentage of the site for which stormwater is treated using best practice techniques.
		• The proposed policy specifies minimum EPTAs that must be achieved *on-site* (dependent on the location and type of development), and proposes the purchasing of "treatment units" off-site to ensure all sites reach 100% EPTA when on-site <u>and</u> off-site stormwater treatment are combined.
		• The proposed policy requires developers to submit details on the EPTA with their planning permit application.
		• The EPTA is a mechanism to transfer city and State-wide best practice water quality performance objectives in Victoria (see below) to the site level within the municipal planning framework.
		• The approach is focused on improving the health of Port Phillip Bay in Melbourne.
		• Includes guidelines on how to calculate the EPTA.
		• Includes some qualitative performance standards (e.g. on-site solid waste management requirements).

Victorian *State Environment Protection Policy (Waters of Victoria)* and supporting "Urban Stormwater Best Practice Environmental Management Guidelines" (these guidelines are included in all Municipal Planning Schemes in Victoria as State Policy). (ELM & EE, 2001; VSC, 1999)	• The policy is a legally enforceable, statutory instrument. • Applied in planning instruments such as "Municipal Strategic Statements" and "Planning Permit Conditions".	• Sets numerical objectives for water quality that are to be applied in planning and licensing decisions. • Defines numerical "receiving water objectives" for various waterways (e.g. 90th %ile of TSS $\leq$ 80mg/l), and "current best practice performance objectives" for key pollutants (e.g. retention of the typical, untreated urban stormwater load of TSS) during the construction and post-construction phase of development. • Numerical objectives are defined for TSS, TN, TP, litter, stormwater flows and "toxic substances". • The "current best practice performance objectives" for key pollutants reflect what best practice, 'end of pipe', structural urban stormwater management practices could deliver in 1999 and are considered to be practicable.

Table 4.2 Stormwater Quality Performance Objectives for Stormwater Management in Victoria

POLLUTANT	BEST PRACTICE PERFORMANCE OBJECTIVES FOR STORMWATER (VSC, 1999)
Post-construction phase:	
Suspended solids (TSS)	≥ 80% retention of the typical (untreated) urban annual load.*
Total phosphorus (TP)	≥ 45% retention of the typical (untreated) urban annual load.
Total nitrogen (TN)	≥ 45% retention of the typical (untreated) urban annual load.
Litter	≥ 70% retention of the typical (untreated) urban annual load.
Construction phase:	
Suspended solids	Effective treatment of ≥ 90% of daily runoff events (e.g. less than 4 month Average Recurrence Interval). Effective treatment equates to a 50%ile suspended solids concentration of < 50 mg/l.
Litter (anthropogenic material larger than 5 mm)	Prevent litter from entering the stormwater system.
Other pollutants	Limit the application, generation and migration of toxic substances to the maximum extent practicable.

Note:
- * This objective is similar to the primary stormwater quality performance objective applied by the US EPA, namely that the average annual load of TSS shall be reduced by ≥80% or shall be no greater than pre-development loadings (US EPA, 1997).

Source: Victorian Stormwater Committee (1999).

- The stormwater treatment train and associated BMPs will not necessarily be built and/or maintained as designed and approved.
- Stormwater quality will be influenced by unusual activities (e.g. incidents and illicit connections to stormwater) even in newly developed regions.
- Redevelopment of urban areas is increasing in Australia's larger cities. In this retrofit context there are increased constraints on stormwater quality management, making compliance with water quality-related objectives more difficult.

Weber (2002) and Manners (2002) estimated approximately 60% of developments moving through Brisbane City Council's development assessment system are likely to actually deliver desired pollutant removal efficiencies such as those described in Table 4.2, over the life span of the developments.[7] This percentage effectively converts the ideal scenario of 100% compliance with city-wide planning requirements over the life span of developments into a realistic scenario reflecting what regulators can produce given the resources they have available. Brisbane City Council's experience in this area represents a leading perspective among local government in Australia, given its recent focus on improving stormwater quality management through the City's planning scheme.

A study by Houlihan (1990) examined the likely water quality impacts associated with proposed legislation for controlling non-point source pollution in the Rhode River Estuary in Chesapeake Bay, Maryland. A pollutant export modelling exercise found that if planning legislation were to limit the percentage of impervious area on developments/building sites to 15%, average annual nutrient loadings on the estuary could be reduced by approximately 33% when compared with similar development without this control.

Attempts have been made to predict the effects on stormwater quality from changes to land use brought about through planning instruments that alter the allowable development density (e.g. via land use zoning). For example, the NVPDC (1996) reported a

[7] This percentage reflects the following circumstances:
- not all approved developments are designed to fully meet the new water quality-related requirements of Brisbane's town planning scheme (although this percentage is expected to increase with time);
- not all developments are constructed as approved by Council; and
- not all developments adequately maintain their stormwater quality BMPs as required by their approval.

pollutant export modelling case study where the effects of down zoning on water quality was considered. Down zoning reduces development density and the proportion of impervious area. The study found that down zoning a 1,620 ha catchment that had high-medium density zoning with underdeveloped land parcels would result in approximately a 44% decrease in average annual loads of total phosphorus (TP) in stormwater.

Such studies are however, pollutant-specific and highly dependent on site-specific variables. For example, Davies (2001a and 2001b) collated information from a variety of sources to predict the TP load being *applied* to sandy soils on the Swan Coastal Plain around Perth, Western Australia, for different residential development densities[8]. Davies predicted that as residential development densities rise from two to 35 lots per gross hectare[9], TP inputs (kg/gross ha/year) would rise sharply to a peak - at around 10 - 15 lots per gross hectare - then fall again. In this scenario, TP inputs are primarily associated with fertiliser (being applied to lawns) and animal wastes, which appear to peak in medium density residential development in Perth[10]. Perth may be unusual in this respect, as large amounts of lawn and garden fertiliser are applied to sandy soils with a low ability to retain phosphorus.

Lehner *et al.* (1999) reported on a modelling study in Charleston, South Carolina, comparing the predicted pollutant loads associated with sprawl development to a traditional town development. The sprawl development was associated with increases of 43% in stormwater runoff volume and 300% in average annual suspended sediment load compared to a traditional town development, as well as an increase in nutrient loading and chemical oxygen demand.

Several studies have attempted to measure the performance of urban stormwater retrofit programs. These programs typically apply structural BMPs over large areas of existing urban land, to improve stormwater quality. Where estimated, cumulative pollutant removal efficiencies provide an indication of the possible performance of city-wide planning controls that impose stormwater quality management requirements on retrofit development (i.e. development that is often highly constrained in its ability to treat stormwater). Examples of such programs include:

- The Urban Retrofit Program in Alexandria, Virginia, which retrofitted structural BMPs to approximately 810 ha (more than 20% of the City's area) through government and privately-funded works. An indication of the performance of this program at reducing stormwater pollution can be gained from a study involving the Cameron Lake Regional Detention Facility. This facility is one of the major regional facilities built through the program and treats stormwater from 100ha (i.e. 12% of the area covered by the program). Lehner *et al.* (1999) reported this facility removes approximately 65% and 40% of the average annual stormwater loads of TP and TN, respectively.
- The Urban Watersheds Retrofit Program in Austin, Texas, which included the Central Park Wet Ponds Project. Lehner *et al.* (1999) reported that this project treats stormwater from approximately 70ha, removing an estimated 85%, 65% and 62% of the average annual stormwater loads of TSS, NO_x[11] and TP, respectively.

Costs Associated with City-wide Stormwater Quality Planning Controls

Table 4.3 presents approximate cost estimates for developing, implementing and maintaining two recently-developed stormwater management policies within Australian town planning schemes. Costs associated with developing such planning instruments should reduce with time, as a range of options are

8 For the purposes of this report, it is assumed that trends in the *input* of total phosphorus to pervious areas will, in the long term, be broadly reflected in the trends of total phosphorus in stormwater and shallow groundwater being *exported* from pervious areas.

9 A 'gross hectare' includes all urban land uses in the 10,000 m^2 area (i.e. the lots, roads, public open space, etc.).

10 This work considered the change in the percent impervious cover as densities increase but only evaluated the change in nutrient inputs from sources on pervious areas such as fertilisers, animal wastes and septic tanks. One could argue that this work represents only part of the picture for urban stormwater quality, as the load of nutrients in stormwater from all *impervious* areas may increase as densities increase, regardless of activities on pervious portions of the catchment. For example, as densities increase, traffic volumes are likely to increase, leading to greater atmospheric deposition of TN.

11 Nitrate (NO_3) and nitrite (NO_2).

Table 4.3 Indicative Cost of Australian Town Planning Controls for the Management of Urban Stormwater Quality

COST TO THE LOCAL AUTHORITY	EXAMPLES OF RECENTLY DEVELOPED TOWN PLANNING CONTROLS AND APPROXIMATE COSTS	
	Blacktown City Council, New South Wales — "Stormwater Quality Control Policy" 2002 (population = 240,000)	**Brisbane City Council, Queensland — "Stormwater Management Code" 2000 (population = 864,000)**
Development cost (i.e. work needed to develop the policy and supporting guidelines, training mechanisms, etc.)	AUD$23,000 (staff time over 1 year)	AUD$125,000 (AUD$65,000 in staff costs and AUD$60,000 in consultancy fees over 1 year)
Implementation cost (i.e. work needed to establish the policy and explain it to stakeholders)	AUD$15,000 (in progress during the review)	AUD$40,000 (AUD$20,000 in staff costs and AUD$20,000 in consultancy fees over 1 year)
Maintenance cost (i.e. work needed to refine the policy, resolve unforseen problems, service additional development assessment work, etc.)	AUD$80,000 per year (estimate)	AUD$120,000 (in staff costs per year – e.g. refining policy, additional development assessment, etc.)

Note:
- Assumed on-costs/overheads for staff = 100% of salaries.

Sources: Weber (Pers. Comm.) and Morison (Pers. Comm.)

tested, refined and shared within the stormwater management community.

The US EPA (2001) has estimated approximate unit costs for elements of sub-catchment planning. These costs relate to basic tasks needed to undertake planning controls such as zoning techniques. However, we have not repeated these estimates here, as more reliable estimates should be easy to derive from planners within a stormwater manager's own agency.

Planning controls, such as zoning, can be used to minimise adverse impacts on waterways from urban sprawl. This may result in reduced capital costs of municipal infrastructure. For example, the US EPA (1999) reported that concentrating development in established urban areas (rather than encouraging urban sprawl) through planning controls can significantly reduce the capital costs associated with development due to existing infrastructure and other public services. Such costs can be considerable. For example, in the US, the cost of servicing sprawling residential developments in conventional development patterns has been estimated to exceed the tax revenue from these developments by approximately 15% (Pelley, 1997). Frank (1989) reported the approximate capital cost of municipal infrastructure per single dwelling unit in a 'compact growth' pattern was approximately US$18,000 in 1997, compared to US$35,000 for 'low density growth', and US$48,000 for 'low density growth' 10 miles from existing development. These examples indicate that maintaining a compact growth pattern instead of encouraging urban sprawl can potentially save between 49% and 63% of capital costs associated with municipal services such as stormwater drainage.

Burchell and Listokin's (1995) research supports the US EPA's findings. They found that planned, compact development costs approximately 25% less for roads, 15% less for utilities (e.g. stormwater infrastructure) and 5% less for housing.

Performance and Cost of Site-based Stormwater Controls (Construction Phase)

For the purposes of this report, *temporary* erosion and sediment controls used *during the construction phase* are considered non-structural BMPs. Information is provided below on approximate costs and pollutant removal efficiencies of typical erosion and sediment controls.

The US EPA (1997) has reported a wide variety of pollutant removal efficiencies and life-cycle cost estimates for individual erosion and sediment controls. A condensed version is provided in Tables 4.4 and 4.5.

In addition, Schueler and Holland (2000) provided an overall estimate for the annual cost of erosion and sediment controls on large construction sites being US$800 - $1,500/cleared acre (approximately AUD$3,788 - $7,101/ha[12]).

The literature supports the view that appropriately designed, implemented and maintained erosion controls can be highly efficient. Schueler and Holland (2000) estimated the *average* suspended solids load removal efficiency for all erosion controls is approximately 85%. Lehner *et al.* (1999) interpreted a 1997 US national survey of erosion and sediment control practices as finding that *erosion prevention* practices such as site design, planning and phasing "are commonly capable of reducing 90% of suspended solids leaving construction sites" (p. 5-14)[13]. Lehner *et al.* (1999) also reported on a university-managed erosion control study in Geauga County, Ohio and St Joseph County, Indiana, that found intensive, widespread seeding and mulching on residential construction sites could reduce soil erosion by up to 86% and reduce phosphorus loadings by 80%.

Sediment fences and sediment basins are two of the most commonly used sediment controls on urban construction sites in Australia. The estimated suspended solids removal efficiency[14] for both these BMPs is approximately 70% (US EPA, 1997 and 2001). Thus, is reasonable to estimate that the *average* suspended solids load removal efficiency for well designed, implemented and maintained *sediment* controls on typical construction sites would be up to 70%. Schueler and Holland (2000) support this view, reviewing four studies into the efficiency of sediment controls and concluding that the suspended solids load removal efficiency of these controls is approximately 60% - 70%. The Wyoming Department of Environmental Quality (1999) proposed the same range of suspended solids removal efficiencies for sediment controls based on a review of five commonly used BMPs.

From these estimates, one could assume that planning controls requiring erosion and sediment control on construction sites could reduce annual average sediment loads by 60% - 85% if fully implemented. However, total compliance with erosion and sediment control requirements on a city-wide scale is rarely, if ever, achieved. Various compliance rates have been reported by stormwater management agencies:

- Brisbane City Council (Queensland) has audited the performance of its erosion and sediment control program over 1999–2002. Overall compliance rates average about 50%[15]. Specifically, residential building sites average about 40%, developments (e.g. commercial developments and townhouses) average about 50%, subdivisions average about 70%, major construction projects undertaken by Council staff average around 80% and major construction projects undertaken by contractors average around 50% (Brisbane City Council, 2000b).
- The San Francisco Bay Regional Water Quality Control Board in California has reportedly used education and enforcement on construction sites to improve on a 30% - 40% compliance rate in the early 1990s to a 90% compliance rate in 1998 (Lehner *et al.,* 1999).

If one were to assume that:

- on average, across all sectors of the development industry in Australia, an ineffective or non-existent erosion and sediment control program would result in a baseline compliance rate of approximately 20% - 30% (based on information from Brisbane and western Sydney for development sectors that had previously been unregulated with respect to erosion and sediment control, as well as baseline compliance data from San Francisco);
- programs in Australia (like that in Brisbane) are producing, on average, across all sectors of the development industry, a compliance rate of approximately 50% after a couple of years of implementing a multi-dimensional program (i.e. effectively an increase in compliance of 20% - 30% from baseline levels);

12 Assumes an exchange rate of US$1 = AUD$0.522.
13 Assumed to be a reduction in the load of suspended solids.
14 Assumed to be a reduction in the load of suspended solids.
15 That is, 50% of sites that are audited are typically found to be complying with the City's erosion and sediment control requirements.

Table 4.4 Efficiency and Cost of Erosion Control BMPs

EROSION CONTROL BMP	PURPOSE	% REMOVAL OF TSS (efficiency)	USEFUL LIFE (years)[a]	CONSTRUCTION COSTS	ANNUAL MAINTENANCE COST (% of const. cost)	TOTAL ANNUAL COST
Turfing (sods)	To provide quick, high-quality erosion protection.	Average: 99% Observed range: 98% - 99%	2	Average: US$27,901 per ha.	Average: 5%	US$18,519 per ha.
Seed	To establish vegetation on a disturbed area.	After vegetation is established – Average: 90% Observed range: 50% - 100%	2	Average: US$998 per ha. Lehner *et al.* (1999) reported that intensive seeding on residential building sites can cost US$300/lot but the resulting lots increase in value to home-buyers by US$750.	Average: 20%	US$741 per ha.
Seed and mulch	To establish vegetation on a disturbed area.	After vegetation is established – Average: 90% Observed range: 50% - 100%	2	Average: US$3,704 per ha.	Average: N/A[b]	US$2,716 per ha.
Mulch	To temporarily stabilise a disturbed area.	Observed ranges: ***Sand*** wood fibre @ 1,680 kg/ha 20% slope: 50% - 60% 50% slope: 0% - 20% wood fibre @ 3,360 kg/ha 20% slope: 50% - 85% 50% slope: 50% - 70% straw @ 3,360 kg/ha 20% slope: 90% - 100% 50% slope: 95% ***Silt-loam*** wood fibre @ 1,680 kg/ha 20% slope: 20% - 60% 50% slope: 40% - 60% wood fibre @ 3,360 kg/ha 20% slope: 60% - 90% 50% slope: 60% - 70% straw @ 3,360 kg/ha 20% slope: 80% - 95% 50% slope: 70% - 90% ***Silt-clay-loam*** wood fibre @ 1,680 kg/ha 20% slope: 5% wood fibre @ 3,360 kg/ha 20% slope: 40% jute netting 20% slope: 30% - 60% 50% slope: 30% straw @ 3,360 kg/ha 20% slope: 40% - 70% 50% slope: 20% - 40% wood chips @ 11,120 kg/ha 20% slope: 60% - 80% 50% slope: 50% - 60% straw and jute 20% slope: 90% 50% slope: 90% US EPA (2001) reported "soil loss reduction" percentages associated with 14 different types of mulch. The range was from 53% - 100% and averaged 91%. Ten of the 14 much types were associated with a soil loss reduction ≥ 90%.	Straw mulch: 0.25 Wood fibre mulch: 0.33 Jute netting: 0.33 Straw and jute: 0.33	Straw mulch - average: US$4,198 per ha. Wood fibre mulch - average: US$2,469 per ha. Jute netting - average: US$9,136 per ha. Straw and jute - average: US$13,333 per ha.	Average: N/A[b]	Straw mulch: US$18,519 per ha. Wood fibre mulch: US$8,642 per ha. Jute netting: US$30,864 per ha. Straw and jute: US$44,444 per ha.
Terraces	To break up long or steep slopes.	Observed range: Land slope — Erosion reduction 1% - 12% — 70% 12% - 18% — 60% 18% - 24% — 55%	2	Average: US$16.40 per lineal metre.	Average: 20%	US$13.12 per lineal metre.
All erosion controls	To reduce the amount of sediment entering runoff.	Average: 85% Observed range: 85%	-	Varies, but typically low.	Varies, but typically low.	Varies, but typically low.

Notes:
- See US EPA (1997) for details of the origin of the above estimates.
- N/A - not available.
- [a] Useful life estimated to be ≤ the length of the construction project (assumed to be 2 years).
- [b] For total annual cost, assume annual maintenance cost = 2% of construction costs.
- TSS efficiency data are assumed to relate to TSS *loads* not concentrations.

Source: Summarised from US EPA (1997), except where otherwise referenced.

Table 4.5 Efficiency and Cost of Sediment Control BMPs

SEDIMENT CONTROL BMP	DESIGN/ PURPOSE	% REMOVAL OF TSS (efficiency)	USEFUL LIFE (years)[a]	CONSTRUCTION COST	ANNUAL MAINTENANCE COST (% of const. cost)	TOTAL ANNUAL COST
Sediment basin	Minimum drainage area = 2 ha. Maximum drainage area = 40.5 ha.	Average: 70% Observed range: 55% - 100%	2	Less than 1,416 m^3 in storage - Average: US$21.19 per m^3 storage (or US$2,716 per drainage ha[b]). Greater than 1,416 m^3 in storage - Average: US$10.59 per m^3 storage (or US$1,358 per drainage ha[b]).	Average: 25%	Less than 1,416 m^3 in storage - US$14.13 per m^3 storage (or US$1,728 per drainage ha[b]). Greater than 1,416 m^3 in storage - US$7.06 per m^3 storage (or US$2,222 per drainage ha[b]).
Sediment trap (a small excavated pit)	Maximum drainage area = 2 ha.	Average: 60% Observed range: (-7)% - 100%	1.5	Average: US$21.19 per m^3 storage (or US$2,716 per drainage ha[b]).	Average: 20%	US$24.72 per m^3 storage (or US$3,210 per drainage ha).
Filter fabric fence	Maximum drainage area = 0.666 ha per 100 m of fence. Not to be used for concentrated flows.	Average: 70% Observed range: 0% - 100% (sand: 80% - 99%, silt-loam: 50% - 80%, silt-clay-loam: 0% - 20%)	0.5	Average: US$9.84 per lineal m (or US$1,728 per drainage ha[c]).	Average: 100%	US$22.97 per lineal m (or US$2,099 per drainage ha).
Straw bales	Minimum drainage area = 0.332 ha per 100 m of barrier. Not to be used for concentrated flows.	Average: 70% Observed range: 70%	0.25	Average: US$13.12 per lineal m (or US$3,951 per drainage ha[d]). US EPA (2001) reported that unit costs are typically in the range of US$7.55 - $14.76 per lineal m, while installation costs are typically US$19.68 per lineal m.	Average: 100%	US$54.54 per lineal m (or US$16,790 per drainage ha).
Stormwater inlet protection	Protects stormwater drain inlet from coarse sediment.	Average: N/A	1	Average: US$100 per inlet.	Average: 60%	US$150 per inlet.
Construction entrance	Removes sediment from vehicle wheels.	Average: N/A	2	Average: US$2,000 per entrance.	Average: N/A[e]	US$1,500 per entrance. US EPA (2001) also reported that total life-cycle costs average US$3,000 (for entrances without a wash rack).
Vegetative filter strip (e.g. turf strips)	Removes sediment from stormwater if stormwater is travelling as sheet flow.	Average: 70%	2	Established from existing vegetation - Average: $0. Established from turf - Average: US$27,901 per ha.	Average: N/A	N/A

Notes:

- See US EPA (1997) for details of the origin of those estimates.
- N/A - not available.
- [a] Useful life estimated to be $\geq$ the length of the construction project (assumed to be 2 years).
- [b] Assumes volume = 1,800 ft^3/acre (0.5 inches runoff per acre) or 126m^3/ha.
- [c] Assumes drainage area of 0.5 acres/100 feet of fence (maximum allowed) or 0.664 ha/100 m of fence.
- [d] Assumes drainage area of 0.25 acres/100 feet of barrier (maximum allowed) or 0.332 ha/100 m of barrier.
- [e] For total annual cost, assume annual maintenance cost = 20% of construction costs.
- TSS efficiency data are assumed to relate to TSS *loads* not concentrations.

Source: Summarised from US EPA (1997) except where otherwise referenced.

- a 60% - 70% increase in compliance from baseline levels (i.e. from 20% - 30% to 90%) is *potentially* possible over a decade (based on information from San Francisco); and
- on average, on-site erosion and sediment controls on compliant sites could deliver at least a 60% reduction in the load of suspended solids in stormwater,

then an estimate of the overall pollutant removal efficiency for the reduction of suspended solids load leaving construction/building sites controlled by a regional or city-wide erosion and sediment control program (that incorporates planning, enforcement and educational BMPs) would be approximately 12% - 18% in the short term and 36% - 42% over a decade. These percentages represent the approximate reduction in TSS loads in stormwater drainage from typical developing areas during the period when land is disturbed.

Performance and Cost of Site-based Stormwater Controls (Post-construction Phase)

In this Section, we provide quantitative information on the performance and cost (primarily in terms of pollutant removal efficiencies) of:

- discrete non-structural BMPs (e.g. vegetated buffer areas that can be applied at the site-scale); and
- combinations of BMPs that can be applied on-site and include non-structural WSUD elements (e.g. site design based on 'cluster development' principles).

Distinguishing between the structural and the non-structural WSUD elements that can be applied on the site-scale is not straightforward and has led to the inclusion of constructed BMPs (e.g. constructed wetlands) in manuals and guidelines on *supposedly* non-structural controls (e.g. NVPDC, 1996). For the purposes of this report, site-scale BMPs will be considered to be non-structural if they:

- do not involve construction (e.g. preservation of existing vegetation as vegetated buffer areas); or
- involve constructing something *differently* without adding a new product or device (e.g. narrower road widths).

Under this definition, BMPs such as porous paving, grassed swales, turf filter strips, constructed wetlands, constructed ponds, infiltration systems, bioretention systems, roofwater tanks and alum injection are considered structural BMPs. For information on the cost and pollutant removal efficiencies of structural BMPs such as these, see the US BMP database (www.bmpdatabase.org), US EPA (2001), US EPA (1999), US EPA (1997) and CRC for Catchment Hydrology (1997).

Non-structural BMPs applicable at the site scale as part of new development include:

- minimising impervious areas (e.g. reduced street widths, alternative road turnaround designs);
- sensitive area protection (e.g. maintaining vegetated buffer areas around waterways, conservation easements, urban forestry);
- 'open space', 'cluster', or 'conservation' development[16] that cluster development and preserve open space (e.g. to minimise runoff, promote infiltration, to minimise disturbance, and minimise the need for road and drainage infrastructure);
- designing to allow for enhanced infiltration or bioretention (e.g. green parking lots, streets with linear bioretention systems); and
- soil amendments to bind key pollutants (e.g. phosphorus in areas with sandy soils).

Information on approximate pollutant removal efficiencies and costs for *specific types* of non-structural BMPs that can be used at the site scale is summarised in Table 4.6.

Finnemore (1982) compared two developments near Lake Tahoe in California. One - a water sensitive development - was well-planned and constructed, while the other was poorly planned without any stormwater quality BMPs. Table 4.7 summarises the characteristics of the sites in terms of stormwater-related costs, relative suspended sediment loads leaving the sites and the health of receiving waters (as measured through macroinvertebrate assemblages). The study is perhaps an extreme example, but showed water sensitive designs (if implemented correctly) can

16 All terms for the same concept, namely the concentration of dwelling units into a compact area (or areas) of the development site while providing open space and preserved natural areas elsewhere on the site.

Table 4.6 Pollutant Removal Efficiency and Cost Information for Non-structural, Site-based BMPs

BMP	POLLUTANT REMOVAL EFFICIENCY INFORMATION	COST INFORMATION
Vegetated buffer areas (consisting of existing vegetation, with or without restoration) - only effective at removing pollutants if stormwater is moving through the area as sheet flow (CRC for Catchment Hydrology, 1997; US EPA 1997).	Forested buffer areas/strips: • TP = 99%, TSS = 95%, TN = 95% (Barling and Moore, 1993, for forested buffer strips 4 m in width in an agricultural setting*). • Soluble P = 100%**, soluble N = 95%, where these percentages = median percent reduction of inflow concentrations (CRCCH, 1997). • TSS = 5% - 10% (suggested value by Urbonas, 1993). Buffer areas/strips (type of vegetation undefined): • TSS ≥ 50% (predicted pollutant removal efficiency for urban vegetated buffer areas by NVPDC, 1996). • TSS = 20% - 100%, TP = 0% - 60%, TN = 0% - 60%, Zn = 20% - 100%, Pb = 20% - 100%, BOD = 0% - 80% (Department of Environmental Resources and Planning Division, 2000). • TSS = 90% (average), 80% - 100% (probable range) (Wyoming Department of Environmental Quality, 1999). • TN = 4%, TP = 28.5%, TSS = 61% (NVPDC, 1996, for several studies with buffer strips 4.5m in width in an agricultural setting*). TN = 80.1%, TP = 77.2%, TSS = 97.4 (NVPDC, 1996, for several studies with buffer strips 27.9m in width in an agricultural setting*). Restored vegetated buffer areas: • NVPDC (1996) estimated the reduction in nutrient loads associated with the restoration of impaired riparian vegetation (i.e. TN = 71% and TP = 62%). These estimates only considered reductions in pollutant *generation* rates, and did not consider the probable increase in pollutant removal efficiencies associated with the through-flow of contaminated stormwater.	Construction cost = $0. Natural succession allowed to occur: • Average annual operation and maintenance cost = $247/ha (reported range = US$123 – $494/ha). • Total annual cost = US$247/ha. Natural succession not allowed to occur: • Average annual operation and maintenance cost = US$1,975/ha (reported range = US$1,728 – $2,222/ha). • Total annual cost = US$1,975/ha (US EPA, 1997; Wyoming Department of Environmental Quality, 1999).
Narrower residential streets	Pollutant removal efficiencies are not available. However, narrower residential streets typically produce 40% - 50% less impervious road cover, and 5% - 20% less total impervious cover over typical residential subdivisions (US EPA, 2001).	Savings of approximately US$21,875/km in road construction costs and costs associated with reduced downstream stormwater management infrastructure have been attributed to 1.22 m reductions in residential street width (US EPA, 2001).
Green parking lot design (e.g. minimising impervious area, maximising infiltration and bioretention)	The US EPA (2001) have suggested that green parking lots with bioretention areas should have pollutant removal efficiencies that are comparable to those of dry grassed swales, namely: • TSS = 91%. • TP = 67%. • TN = 92%. • Metals = 80% - 90% (from Claytor and Schueler, 1996).	Case studies (e.g. the Fort Bragg vehicle maintenance facility parking lot in North Carolina as reported in Lehner et al*.,* 1999 and US EPA, 2001) have demonstrated that green parking lot redesign can reduce construction costs by 20% compared to conventional designs. In addition they can reduce impervious cover by 40% and increase the number of parking lots by 24%.

Continued...

Table 4.6 Pollutant Removal Efficiency and Cost Information for Non-structural, Site-based BMPs (continued)

BMP	POLLUTANT REMOVAL EFFICIENCY INFORMATION	COST INFORMATION
Alternative turnaround designs (i.e. replace cul-de-sacs and reduce the amount of impervious cover created in residential developments)	Pollutant removal efficiencies are not available. However, alternative designs can produce a 75% reduction in the turnaround's impervious area. For example, a typical turnaround design with a 12 m radius has an impervious area of approximately 452 m^2 compared to a hammerhead design which has an impervious area of approximately 113 m^2 (US EPA, 2001).	Cost implications can be calculated based upon savings on road construction items (e.g. unit rates for asphalt in the US are approximately US\$5.38 – US\$10.76/m^2) and additional costs on items such as infiltration, bioretention (e.g. US\$68.89/m^2) and landscaping (US EPA, 2001).
Xeriscaping	Hipp et al. (1993) undertook experimental trials on 20 micro-watersheds in Dallas to examine the effect that resource efficient plants in a residential/commercial context could have on run-off volumes and the export of nutrients in stormwater. They found a significant reduction in runoff volume (e.g. after 6.35 centimetres of irrigated water was applied over one hour, traditional gardens with high maintenance regimes produced one centimetre of runoff compared to the xeriscaped ploats which essentially produced no runoff). Measuring runoff quality from a realistic irrigation regime, TP loads were significantly less (at the 0.05 probability level) in the xeriscaped plots compared to traditional gardens with high maintenance regimes. No statistically significant difference was identified for nitrate concentrations in stormwater runoff.	Lawn maintenance costs can be reduced by at least 50%, and watering costs can be reduced by at least 60% (US EPA, 1997).
Soil amendment (e.g. adding top soil with a high phosphorus retention capacity to sandy soils in residential settings)	An estimate of the potential reduction in TP loads can be obtained from the work of Kelsey (2001). In a pollutant export modelling exercise for a proposed development near Perth, Western Australia (a location where soil amendment is used to manage TP export), she used the following TP export rates based upon the best available information: Residential land use: • Lateritic soils TP = 0.15 kg/ha/yr. • Sandy soils TP = 1.2 kg/ha/yr. Rural land use: • Lateritic soils TP = 0.11 kg/ha/yr. • Sandy soils TP = 1 kg/ha/yr. From these rates, one could conclude that the use of lateritic top soils to amend sandy soils could have pollutant removal efficiencies of up to 87.5% and 89% for residential and rural land use, respectively.	Approximate cost of soil with a high phosphorous retention capacity in Perth (delivered to sites with the metropolitan region) = AUD\$25 - \$30 per m^3 (Brosnan, 2002).
Urban forestry (patches of forest and the trees that line streets)	N/A (considered to be minimal)	Approximate annual maintenance cost = US\$185/ha/year (NPS, 1995).
Conservation easements – natural open space	N/A	Approximate annual maintenance cost = US\$185/ha/year (CWP, 1998). This cost represents a minimal maintenance regime (e.g. just litter and debris collection).

Notes:

- * Research studies have indicated that urban vegetated buffer areas are likely to have significantly lower pollutant removal efficiencies compared to agricultural vegetated buffer areas (NVPDC, 1996). This is a consequence of the increased volume and velocity of stormwater in urban areas, as well as the propensity for concentrated flow (as opposed to sheet flow).
- ** A high pollutant removal efficiency for dissolved species of phosphorus conflicts with the findings of Gilliam (1994, reported in US EPA, 2001) who found that vegetated buffers/strips are reasonably effective at removing phosphorus if attached to sediment particles but are relatively ineffective in removing dissolved phosphorus.

Table 4.7 A Study of Two Residential Developments near Lake Tahoe, California

FEATURES OF THE DEVELOPMENT	A WELL-PLANNED, WATER SENSITIVE RESIDENTIAL DEVELOPMENT	A POORLY PLANNED AND CONTROLLED RESIDENTIAL DEVELOPMENT (NO BMPs)
Related costs	Stormwater related costs for the site were less than US$1,670/ha. Of these costs only 22% (US$367/ha) related to permanent erosion control measures.	Remedial action was needed to manage severe erosion after development. This remedial action cost US$93,000/ha of disturbed land. In addition, annual maintenance costs were approximately US$110/ha.
Water quality of streams receiving stormwater from the sites	After development, the sediment load in the receiving waters increased by a factor of 2.	After development (but before remedial action was taken), the sediment load in the receiving waters increased by a factor of 107.
Macro-invertebrate communities in receiving waters	After development, there was negligible impact to the macro-invertebrate community.	After development, there was a 34% decrease in the density of the macro-invertebrate community and a 54% decrease in the number of species.

Note:

- This case study is perhaps an extreme example of the benefits than can be achieved through WSUD, where the 'base case' is not typical of urban land use (i.e. it was subject to severe erosion after development).

Source: Finnemore (1982).

result in a 98% reduction in the loads of suspended sediment in stormwater compared to the loads from a poorly designed and constructed developments on sites with a high risk of erosion[17].

Aponte Clarke and Stoner (2000) and Lehner *et al.* (1999) reported on a less extreme example of water sensitive design at a residential development at Prairie Crossing in Grayslake, Illinois. The development incorporated structural and non-structural BMPs, including clustering the desired 317 residences on only 20% of the site (leaving the remainder as open space) and restoring vegetated buffer areas. Pollutant export modelling indicated that the development's WSUD elements would, in an average year, collectively remove approximately 85% of the load of nutrients, metals and suspended sediment from the development's stormwater. In addition, elimination of curb and channels (replaced with grassed swales) saved the developers approximately US$1.6 - $2.7M in construction costs, with the rate of sales comparing favourably to nearby conventional developments.

The US EPA (1999) reported on the cost savings associated with open space development (i.e. incorporating features such as reduced street widths, clustered residential housing, smaller parking lots and use of vegetated buffer areas) from three case studies from Delaware. Cost savings for the case studies were 52%, 63% and 39%. In all three designs, the road widths were reduced, lot sizes were reduced or configured to consume less public open space and on-site stormwater treatment was included. It is assumed these figures relate only to construction costs.

The WSUD principles of open space development, use of vegetated buffer areas and preservation of open space were also examined in a case study from Alameda County, California. It was estimated if 50% of a 40.5 ha parcel of land earmarked for future residential development was preserved as open space (incorporating buffers, clustered housing lots, etc.), the annual average loads of TSS and zinc entering the San Francisco Bay could be reduced by approximately 50% compared to if the whole site was developed (US EPA, 1997).

The US EPA (2001) summarised investigations into pollutant removal efficiencies associated with open space development/design. Desk-top studies by the Centre for Watershed Protection (1998), Maurer (1996), DE DNREC (1997), Dreher and Price (1994) and SCCCL (1995) have demonstrated the predicted average annual nutrient export loads can be reduced by 45% - 60% when conventional subdivision designs are converted to open space designs. In the open space design scenarios investigated, impervious cover declined by an average of 34%.

[17] Note that this case study involved a water *insensitive* development as a 'base case' that was unusual in that substantial restoration works were required after development to manage severe erosion.

The use of open space design techniques has been associated with considerable savings in construction costs. Eight examples of projects where projected construction savings have resulted from desk-top redesign studies are provided in Table 4.8. These savings range from 12% to 66% and average 47%.

The cost savings and pollutant removal efficiencies associated with open space design are demonstrated by the Remlik Farm case study undertaken by the Chesapeake Bay Foundation and reported in Schueler and Holland (2000). Two development scenarios were considered: a conventional residential design and an open space design. Both produced an equivalent lot yield to the developer. The site area was approximately 198 ha, 59% of which was developed under the conventional scenario but only 14% of which was developed under the open space design. For the open space design scenario, development costs decreased by 52% (representing a saving to the developer of more than US$0.6M) and predicted average annual loads of both TP and TN in stormwater decreased by approximately 42%.

Schueler and Holland (2000) also reported the results of a redesign study involving a low density residential development in Wicomico County, Maryland, known as Duck Crossing. Five development scenarios were modelled: pre-development conditions, conventional design (with no BMPs), conventional design (with BMPs), open space design (with no BMPs) and open space design (with BMPs). Open space design elements included a reduction in lot size, a narrower access road, shared driveways, redesign of a road turnaround, natural area protection, grassed swales and improved septic tank configurations. The predicted decrease in average annual loads of nutrients are presented in Table 4.9.

When the open space design (with BMPs) scenario is compared to the conventional design (with BMPs) scenario for Duck Crossing, Schueler and Holland (2000) reported a:

- 46% reduction in average annual TN loads;
- 50% reduction in average annual TP loads;

Table 4.8 Estimated Construction Cost Savings Associated with Open Space Designs from US Desk-top Redesign Studies

RESIDENTIAL DEVELOPMENT (SUBDIVISIONS)	ESTIMATED CONSTRUCTION SAVINGS	NOTES ON COSTS
Remlik Hall	52%	Includes costs for engineering, road construction, and obtaining water and sewer permits. Source = Maurer (1996).
Duck Crossing	12%	Includes roads, stormwater management, and reforestation. Source = Centre for Watershed Protection (1998).
Tharpe Knoll	56%	Includes roads and stormwater management. Source = DE DNREC (1997).
Chapel Run	64%	Includes roads, stormwater management, and reforestation. Source = DE DNREC (1997).
Pleasant Hill	43%	Includes roads, stormwater management, and reforestation. Source = DE DNREC (1997).
Stonehill Estates	20%	Includes roads, stormwater management, and reforestation. Source = Schueler and Holland (2000).
Buckingham Greene	63%	Includes roads and stormwater management. Source = DE DNREC (1997).
Canton	66%	Includes roads and stormwater management. Source = NAHB (1986).

Note:
- Note that several regional studies have found that open space developments are also associated with increased property values. That is, residential properties in such developments often attract premiums of 5% - 32% more than those in comparable conventional subdivisions. In addition, they had been found to frequently sell or lease at an increased rate. See US EPA (2001) and/or Schueler and Holland (2000) for more details.

Sources: Table slightly modified from US EPA (2001) and Schueler and Holland (2000).

- 12% reduction in development (construction) costs; and
- 35% reduction in the site's total impervious area.

Schueler and Holland (2000) also modelled the effects of open space development on Stonehill Estates, a medium density residential subdivision near Fredericksburg, Virginia. They modelled the same five development scenarios as those for Duck Crossing. Open space design elements included a reduction in lot size, use of vegetated buffer areas along waterway corridors, narrower streets, shorter driveways, fewer sidewalks, alternatives to cul-de-sacs (e.g. loop roads), grassed swales, bioretention areas and detention ponds. The results in terms of predicted average annual loads of nutrients are presented in Table 4.9.

When the open space design (with BMPs) scenario is compared with the conventional design (with BMPs) scenario for Stonehill Estates, Schueler and Holland (2000) reported a:

- 45% reduction in average annual TN loads;
- 60% reduction in average annual TP loads;
- 20% reduction in development (construction) costs; and
- 24% reduction in the site's total impervious area.

Schueler and Holland (2000) also modelled the effects of open space design (also known as green parking lot design) on a corporate office car park in Maryland, using the same five development scenarios as for Duck Crossing and Stonehill Estates. Open space design elements included a reduction in the number of lots, reduction in the size of each parking lot, reduction in the width of drive aisles, bioretention areas, grassed swales and grid pavers. The results in terms of predicted average annual loads of nutrients are presented in Table 4.9.

When the open space design (with BMPs) scenario is compared with the conventional design (with BMPs) scenario for the corporate office car park, Schueler and Holland (2000) reported a:

- 45% reduction in average annual TN loads;
- 47% reduction in average annual TP loads;
- 3% reduction in development (construction) costs; and
- 22% reduction in the site's total impervious area.

From studies such as these, Schueler and Holland (2000) concluded that greenfield open space development that applies structural *and* non-structural design elements:

- can reduce the capital costs of subdivision developments by 10% to 33%, primarily as a result of reducing the length of infrastructure needed to serve the development; and
- can reduce site impervious cover from 10% - 50%, which reduces costs associated with the management of stormwater quality and quantity (e.g. the cost to manage stormwater quality and quantity from a single impervious hectare can range from US$4,938 to US$123,457).

Structural and non-structural BMPs can also be applied in a *retrofit* context on a site scale. Lehner *et al.* (1999) reported on the redevelopment of an eight-hectare industrial site in Portland, Oregon. Applying WSUD principles (e.g. parking lot re-design, grassed swales and mini linear wetlands) saved the developers US$78,000 in construction costs and is thought to have reduced average annual loads of suspended solids by 50%.

4.1.3 Summary of BMP Value and Cost

Based on the best available information gathered, we suggest the most valuable non-structural BMPs are planning instruments that ensure urban stormwater quality is satisfactorily addressed as part of local planning schemes in Australia (e.g. via zoning and land development approval processes). Well designed, implemented and enforced planning controls in developing areas can *potentially* deliver the following reductions in average annual pollutant loads over the post-construction development phase[18]:

- TSS (greenfield development) ≤33% - 98% (with 50% - 85% being common)[19].
- TSS (retrofit development) ≤50% - 85% (with 50% being common).
- TN (greenfield) ≤33% - 45% (with 45% being common).

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18 These reductions are an expression of how much average annual pollutant loads can be reduced below those loads typically associated with the same land use, but where there is no stormwater treatment or water sensitive urban design.

19 Note that the 98% figure represents an *extreme* example, where WSUD was able to minimise severe erosion.

Table 4.9 Predicted Stormwater Quality Improvements Associated with Water Sensitive Urban Design

DEVELOPMENT SCENARIO	PREDICTED ANNUAL TN EXPORT (kg/year)			PREDICTED ANNUAL TP EXPORT (kg/year)		
	Duck Crossing (low density residential)	**Stonehill Estates** (medium density residential)	**Corporate office car park** (commercial)	**Duck Crossing** (low density residential)	**Stonehill Estates** (medium density residential)	**Corporate office car park** (commercial)
1. Pre development conditions	59.9	12.2	6.8	16.3	1.8	0.9
2. Conventional design (no BMPs)	124.3	107.0	16.3	20.9	12.7	8.2
3. Conventional design (with BMPs)	119.7	86.6	50.8	20.0	10.9	5.0
4. Open space design (no BMPs)	70.3	84.4	51.7	10.4	10.0	6.4
5. Open space design (with BMPs)	65.3	47.6	28.1	10.0	4.5	2.7
Load reduction % of scenario #5 (compared to a base case of scenario #2) – calculated*	47%	56%	57%	52%	64%	67%
Load reduction % of scenario #5 (compared to a base case of scenario #3) – calculated*	45%	45%	45%	50%	58%	45%

Notes:

- 'Open space design/development' is also know as 'cluster development' and 'conservation development'.
- * Due to errors associated with 'rounding off', some of these calculated results are slightly different (± 2%) to those reported in the text of Schueler and Holland (2000).

Source: Schueler and Holland (2000).

- TN (retrofit) ≤40% - 65%.
- TP (greenfield) ≤33% - 60% (with 45% - 60% being common).
- TP (retrofit) ≤62% - 65%.
- Litter (greenfield) ≤70%.
- Heavy metals (greenfield) ≤50% - 85%.

These estimates in pollutant load reduction must be tempered by the knowledge that some developments will not always deliver the performance required by town planning controls. A compliance rate of approximately 60% is reasonable based on advice from officers from a leading Australian local authority. This represents the percent of developments passing through a local authority's development assessment system expected to actually deliver pollutant removal efficiencies such as those given above, over their life span.

Thus, the overall pollutant removal efficiencies (i.e. the reduction in annual average loads of pollutants) of city-wide post-construction phase stormwater quality control programs for *developing areas* that include town planning, enforcement and educational elements is approximately:

- TSS (greenfield development) ≤30% - 50%.
- TSS (retrofit development) ≤30%.
- TN (greenfield) ≤30%.
- TN (retrofit) ≤25% - 40%.

- TP (greenfield) ≤30% - 35%.
- TP (retrofit) ≤35% - 40%.
- Litter (greenfield) ≤40%.
- Heavy metals (greenfield) ≤30% - 50%.[20]

Local town planning instruments for stormwater quality management can cost large Australian local government authorities between AUD$23,000 and AUD$125,000 to develop, AUD$15,000 and AUD$40,000 to initially implement, and AUD$80,000 and AUD$120,000 per year to maintain. However, these development and implementation costs are expected to decrease as a range of *proven* planning instruments and supporting materials become more widely available.

Planning controls also have the potential to significantly reduce urban stormwater pollution during the *construction* phase of development, provided they are supported by complementary education and enforcement programs. Well planned, designed, implemented and maintained <u>erosion</u> controls on construction and building sites can be expected to reduce loads of TSS by ≤85% - 90% and TP by ≤80%. <u>Sediment</u> controls deliver a lower level of performance (≤60% - 70%). A typical best practice construction site with a combination of erosion and sediment controls has an estimated TSS removal efficiency of at least 60% (i.e. over their life span, the controls can be expected to trap 60% of the load of suspended sediment in stormwater).

Achieving and maintaining high levels of compliance with erosion and sediment control requirements, on a city-wide basis, is difficult. Based on Australian and overseas data, we estimate sound erosion and sediment control programs should be able to achieve a 20% - 30% increase in compliance levels in the first few years (based on a typical baseline compliance rate of 20% - 30%) and achieve a 60% - 70% increase from the baseline compliance rate over a decade. Thus, the overall TSS pollutant removal efficiency of city-wide construction phase stormwater quality control programs that include town planning, enforcement and educational elements is estimated to be approximately 12% - 18% in the short term (one to three years) and 36% - 42% over a decade. These percentages represent an approximate reduction in the average load of TSS in stormwater draining from developing areas over the life span of the construction phase.

Estimates of *individual* pollutant removal efficiencies and cost estimates are available for some temporary erosion control measures (e.g. turfing, seeding, mulching), temporary sediment control measures (e.g. sediment basins, sediment fences, straw bales) and permanent non-structural BMPs used on development sites (e.g. vegetated buffer areas, green parking lot design principles, soil amendment). Data on the performance of *individual* erosion and sediment control measures are associated with a greater degree of confidence than similar data for permanent non-structural BMPs that are used on development sites.

Despite this limitation, credible studies on construction cost and pollutant removal efficiencies associated with a <u>combination</u> of non-structural and structural stormwater quality management BMPs have consistently demonstrated significant benefits. Typically, water sensitive developments of differing density that incorporate non-structural BMPs (e.g. vegetated buffer areas, narrower road widths, alternative road turnaround designs, shorter and shared driveways) and structural BMPs (e.g. grassed swales, bioretention areas) have delivered reductions[21] of approximately:

- 50% - 85% in the average annual load of TSS.
- 45% in the average annual load of TN.
- 45% - 60% (average 50%) in the average annual load of TP.
- 3% - 63% (average 44%) in their capital costs.

20 These estimates conservatively assume that developments that have *not* been designed, built and/or maintained in accordance with a city's stormwater quality management requirements, provide no reduction in typical urban stormwater pollutant loads. These estimates have also used the most common ranges identified in the literature review (see above) and have been rounded to the nearest 5%.

21 These reductions are an expression of how much average annual pollutant loads can be reduced below those loads associated with comparable developments that have been designed with just 'end-of-pipe' structural BMPs for stormwater quality improvement.

4.2 Strategic Planning and Institutional Controls

4.2.1 Description of BMPs

This Section provides quantitative information on the overall cost and water quality benefits associated with city-wide urban stormwater management plans and programs.

In cities where urban stormwater management is a priority, leading government agencies typically manage the issue through strategic urban stormwater management plans (or programs) for the region. These are delivered within administrative frameworks characterised by features such as secure, long-term funding and staff with specialist skills.

Assessing the cumulative value of BMPs over a city or region accommodates the principle that non-structural BMPs often operate as highly interactive *systems*. For example, a review of 100 US stormwater management case studies by the Natural Resources Defence Council (Lehner, *et al.,* 1999) suggested the effectiveness of non-educational stormwater management BMPs (e.g. enforcement programs) was often tied to the effectiveness of associated public education campaigns. It is possible a stormwater-related awareness campaign may not directly affect short-term stormwater quality, but may lead to major and influential developments. Such developments include the establishment of a stable, dedicated funding mechanism for urban stormwater management, which in the longer term may deliver measurable benefits to stormwater quality.

Delivering a comprehensive urban stormwater management plan depends on a sound institutional and administrative framework. Finnemore and Lynard (1982) emphasised the importance of such frameworks, stating "the most promising non-structural control measures include institutional control agencies organised to adopt and enforce ordinances, conduct area wide control projects and levy stable and equitable sources of funding" (p. 1098). This view is supported by Lehner, *et al.* (1999), who nominated six keys to success based on their review of 100 US stormwater management case studies. Three of these were administrative in nature (i.e. a dedicated source of funding, strong leadership and effective administration).

4.2.2 Case Studies and Reported Data

Estimates of the Cost of City-wide Stormwater Management Programs

As part of this project, we surveyed stormwater management agencies in Australia, the US and NZ to identify urban stormwater management program funding profiles. Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12 provides details of the survey.

Table 4.10 summarises the approximate cost (per person per year) of urban stormwater *quality* management programs run by six Australian agencies and three overseas leading stormwater management agencies that participated in the survey.

The US EPA promotes city-wide, strategic urban stormwater management through its Phase II National Pollutant Discharge Elimination System (NPDES) stormwater program (known as the Phase II Rule for stormwater). The NPDES came into effect in late 1999 and generally requires small to medium-sized municipalities with urban stormwater drainage systems to implement six minimum control measures via a stormwater management program (or plan). These are:

1. Public education and outreach on stormwater impacts.
2. Public involvement/participation.
3. Illicit discharge detection and elimination.
4. Construction site stormwater runoff control.
5. Post-construction stormwater management in new development and redevelopment.
6. Pollution prevention/good housekeeping for municipal operations (US EPA, 2001).

The majority of these controls are non-structural, with only control number five (5) having a significant structural BMP component. Also, the management of stormwater *quantity* is included in this control measure.

Attempts have been made to quantify the cost of implementing urban stormwater management programs to comply with the Phase II Rule. Reese (2000) reported:

- When the regulations were drafted, the US EPA initially estimated the cost of compliance at between US$1.39 and US$7.83 per person per

Table 4.10 Approximate Expenditure on Urban Stormwater Quality Management by Nine Leading Urban Stormwater Management Agencies

AGENCY NAME	TYPE OF AGENCY	APPROXIMATE ANNUAL EXPENDITURE PER CAPITA (AUD$)
Australian agencies		
Melbourne Water, Victoria	Agency responsible for city-wide trunk/main urban stormwater drainage	$2.98
NSW EPA, New South Wales*	Agency responsible for State-wide stormwater quality policy	$3.62
Blacktown City Council, New South Wales	Medium sized local authority responsible for minor and trunk/main urban stormwater drainage in a city (except for one area of trunk drainage)	$3.13
Brisbane City Council, Queensland	Large local authority responsible for minor and trunk/main urban stormwater drainage in a city	$9.03
City of Salisbury, South Australia	Medium sized local authority responsible for minor and trunk/main urban stormwater drainage in a city	$26.83
Hornsby Shire Council, New South Wales	Medium-sized local authority responsible for minor and trunk/main urban stormwater drainage in a city	$32.34
Overseas agencies		
Auckland Regional Council, New Zealand	Large regional authority responsible for stormwater quality management initiatives (including regulation)	$4.53** (NZ$3.29)
City of Austin, Texas	Large agency responsible for minor and trunk/main urban stormwater drainage in a city	$51.06** (US$26.65)
City of Orlando, Florida	Medium sized agency responsible for minor and trunk/main urban stormwater drainage in a city	$88.51** (US$46.20)

Notes:

- See Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12 for details on the nature and funding profiles of these agencies (i.e. the approximate breakdown of total annual expenditure into eleven common stormwater management activities).
- These figures *only* relate to the management of *stormwater quality* (i.e. do not include expenditure on flood mitigation, relief drainage, etc.).
- * This estimate is based on figures from Phase 1 of the NSW EPA's Stormwater Trust funding.
- ** Currency exchange rates at 18 February 2002 were used to convert the US and NZ currency to Australian dollars (i.e. AUD$1 = US$0.522 or NZ$1.3755).

Source: Survey undertaken as part of this project (see Report No. 2 in this series).

year for the first five years of the program, and between US$1.28 and US$5.63 per person per year thereafter.

- Following the initial US EPA estimates, a 1999 survey of 121 US cities found only one city with an urban stormwater management program covering all six minimum control measures required by the Phase II Rule. This program was estimated to cost US$15.11 per person per year and involved a municipality with a population of 25,000.
- In the 1999 survey, 26 urban stormwater management programs had three or more of the six minimum control measures. Of these, the median annual cost was US$1.44 per person per year, while the mean cost was US$4.07 per person per year.
- In 1999, the US EPA revised its estimates of the cost of compliance with the Phase II Rule by producing the following formula:

Annual stormwater management cost to a municipality = US$1,525 + [(population/2.62) x US$8.93]

Where:

- US$1,525 is a fixed cost per municipality (associated with administration of the program).
- 2.62 is the average number of people per household in the US.

- US$8.93 is the cost per household for the program's annual operation.

  Using this formula, a town of 10,000 people would have an overall stormwater management cost of approximately US$3.56 per person per year, while a city of 50,000 people would have a cost of approximately US$3.44 per person per year.

- Reese (2000) reviewed the US EPA estimates and, based on his experience with more than 100 US communities, concluded that comprehensive stormwater management programs (including quality and quantity components) typically cost between US$7 and US$20 per person per year, where the *water quality* component is 20% - 30% of these estimates.
- Reese (2000) prepared two hypothetical stormwater management programs to meet the six minimum control measures in the Phase II Rule. One program was for a small town with 10,000 people, while the other related to a small city with 50,000 people. The annual per capita cost estimates are in Table 4.11 and indicate that costs over the first five year period range from US$1.33 - $10.96 per person per year, while costs over the subsequent years range from US$1.11 - $5.63 per person per year. No structural BMPs (e.g. large regional wetlands or gross pollutant traps) were included in Reese's hypothetical programs.

Additional cost estimates have been reported by US EPA (1999), including:

- In 1998, based on stormwater management related expenditure from 35 urban stormwater management programs, the US EPA estimated the average per capita cost to comply with the Phase II Rule at US$9.09. This estimate does not include municipal expenditure on post-construction stormwater controls (e.g. construction and maintenance of regional, structural BMPs).
- The US EPA also found a high percentage of total municipal compliance costs (approximately 63%) related to controlling stormwater quality on *construction sites* (i.e. erosion and sediment control activities). In 1998, they estimated the national average compliance cost for erosion and sediment control on different size construction sites. These are presented in Table 4.12 and represent the costs incurred by the operators of private and public sector construction sites.

Table 4.11 Estimated Cost of Comprehensive Urban Stormwater Management Programs that Focus on Stormwater Quality Management

MINIMUM CONTROL MEASURE	**ANNUAL PER CAPITA STORMWATER MANAGEMENT COST (US$) FOR TWO HYPOTHETICAL US MUNICIPALITIES**			
	TOWN WITH 10,000 PEOPLE		**CITY WITH 50,000 PEOPLE**	
	First five-year period	**Subsequent five-year periods**	**First five-year period**	**Subsequent five-year periods**
1. Public education	0.39	0.36	1.24	1.40
2. Public involvement	0.21	0.24	0.62	0.51
3. Illicit connections	0.24	0.10	1.77	1.16
4. Construction sites - stormwater management	0.20	0.18	0.96	1.10
5. Post construction - stormwater management	0.14	0.13	5.78	1.26
6. Housekeeping in municipal operations	0.15	0.10	0.59	0.20
TOTAL	**1.33**	**1.11**	**10.96**	**5.63**

Notes:
- Estimates do not include any publicly funded, regional, structural BMPs (e.g. wetlands).
- Minimum control measure number five (5) includes urban stormwater *quantity* management as well as quality management (as part of the implementation of water sensitive urban design/low impact development).

Source: Reese (2000).

Table 4.12 Estimated Average Cost of Complying with Erosion and Sediment Control Requirements on Construction Sites in the US

AREA OF CONSTRUCTION SITE	OPERATIONAL COMPLIANCE COST (1998 US$)	TOTAL COST* (1998 US$)
1 acre (or 0.405 ha)	1,206	-
3 acres (or 1.215 ha)	4,598	-
5 acres (or 2.025 ha)	8,709	-
1 – 2 acres (or 0.405 ha – 0.81 ha)	-	2,535
2 – 4 acres (or 0.81 ha – 1.62 ha)	-	5,927
4 – 5 acres (or 1.62 ha – 2.025 ha)	-	10,038

Notes:
- * Includes operational compliance and administration costs.
- Control of stormwater quality on construction sites (i.e. erosion and sediment control) is one of the six minimum control measures required under the US EPA's Phase II Stormwater Rule.
- These costs are incurred by those operating construction sites under the US EPA's Phase II Stormwater Rule, whether they be in the private or public sector.

Source: US EPA (1999).

US Estimates of the Value of City-wide Stormwater Management Programs

US EPA (1999) reported on a cost-benefit analysis to assess the economic impact of the Phase II Rule for stormwater management. It estimated:

- the cost of implementation (i.e. the total national compliance cost was estimated at US$807.2M per year in 1998 dollars);
- the potential value of waterway-related assets being protected (i.e. the US EPA estimated that the annual benefits associated with just the direct use of fresh water and the passive use of fresh water bodies was in the range of US$67.2M - $241.2M, through willingness to pay valuation methods); and
- the extent to which municipal urban stormwater programs would achieve their objectives (i.e. to improve stormwater quality and waterway health).

In relation to the last item, the US EPA expected "that municipal programs will achieve at least 80% effectiveness…" (US EPA, 1999, p. 6-42). The 80% figure represents an estimate of the overall performance of urban stormwater management programs. Put another way, the US EPA expected approximately 80% of the maximum possible value from healthy waterways would be delivered to the community via urban stormwater management programs. No explanation was given as to how this estimate was derived.

In an overview of stormwater monitoring needs in the US, Cave and Roesner (1994) estimated "City-wide pollutant loading reductions for typical NPDES [National Pollutant Discharge Elimination System] stormwater management programs developed to date are likely to be less than 25% for many pollutants under full implementation" (p. 8). This estimate is based purely on intuitive judgement (Roesner, 2002). ASCE & US EPA (2002) quoted Bannerman (2001) as suggesting the efficiency of such programs for reducing loads of typical urban stormwater pollutants was more likely around 40%.

Water Quality Improvement Associated with Mature, City-wide Stormwater Management Programs

The City of Orlando, Florida, is one of the most experienced cities in the arena of urban stormwater management. It established a stormwater management program in the early 1980s, which included a stormwater utility (a dedicated funding mechanism) and a program that included a variety of BMPs. In 1990 the City received the US EPA's national Stormwater Award for its achievements.

In its 2000 Lake Water Quality Report, the City of Orlando (2000) reported:

- The Florida Trophic State Index is the primary water quality indicator for the lakes' health. Changes in water quality over time are determined using regression analysis. Specifically, scientists examine how the Florida Trophic State Index changes over time.
- Coefficient of determination values (R^2) greater than 0.20 are considered a strong association by the State of Florida for surface water trends.
- Scientists from the City of Orlando assign a water quality trend status to each of the 94 lakes - "improving", "no trend" or "degrading" - based on the slope of the regression line (a negative slope indicates improvement) and the R^2 value. For example, a status of "improving" is assigned to lakes with R^2 values > 0.20 and decreasing trophic states (i.e. a negative regression line).
- Using this system, in combination with at least 11 years of quarterly water quality data, the City of Orlando reports 86 out of 94 (91.5%) of the City's lakes show either no trend in water quality or a trend towards improvement[22]. When one considers the region's relatively rapid annual population growth rate of approximately 1.4% for the City and 2.5% for Metro Orlando (City of Orlando, 2002), it is reasonable to conclude the City's overall urban stormwater management program is performing well.

The City of Tulsa, Oklahoma, has improved its stormwater quality as a result of a multi-dimensional stormwater quality management program. In the 1990s, the City's stormwater management strategy included a strong illegal discharge elimination program, litter collection campaigns, programs to minimise illegal dumping, hazardous waste collection programs, a variety of advertising campaigns and a stormwater drain stencilling program (Lehner *et al.,* 1999).

To measure the cumulative effect of this program, the City compared the quality of stormwater before and after implementation. Event mean concentrations (averaged over four-year intervals) of pollutants in stormwater were compared. Some of the results are presented in Table 4.13 and include a 13%, 17% and 18% reduction in event mean concentrations for TSS, TP and total kjeldahl nitrogen, respectively. Heavy metal concentrations were most greatly reduced, with event mean concentrations for copper, lead and zinc reduced by at least 55% (Lehner *et al.,* 1999).

4.2.3 Summary of BMP Value and Cost

Many non-structural BMPs operate synergistically (e.g. complimentary educational and enforcement campaigns) or work through structural BMPs (e.g. town planning instruments that influence the design of new development and deliver a wide range of structural BMPs). Accordingly, it may be misleading to evaluate some non-structural BMPs in isolation. An alternative approach is to look at the overall cost and performance of an integrated city-wide or regional urban stormwater quality management program.

Considerable work has been done in the US to estimate the cost per person per year of implementing a sound, stormwater quality-focused urban stormwater management strategy. Estimates vary greatly and significant differences exist between the government view and that of independent commentators. Based on available information, the most recent US EPA estimates for the cost of implementing a stormwater quality management program in a small to medium sized municipality is approximately US$3.50 per person per year. Independent, non-government estimates of the cost of such programs indicate small municipalities (around 10,000 people) may be able to design and deliver a program for as low as US$1 - $1.50 per person per year, while municipalities with 50,000 people may need to allocate US$5.50 - $11 per person per year.

Our data on funds allocated to stormwater quality management by large, leading US government agencies indicate that some agencies are spending significantly more than estimated in the literature. For example, two leading US urban stormwater management agencies that manage minor and trunk drainage spend approximately US$27 - $46 per person per year on stormwater quality management (approximately AUD$51 - $89[23]). Possible reasons for the difference include:

22 Of the City's 94 monitored lakes, 12 (12.8%) show an improving trend in water quality, while 74 (78.7%) show no trend.

23 Assumes an exchange rate of US$1 = AUD$0.522.

Table 4.13 Stormwater Quality Improvements in Tulsa, Oklahoma

PARAMETER	AVERAGE EMC* (PRE-PROGRAM) (mg/l)	AVERAGE EMC* (POST-PROGRAM 1994-95 to 1997-98) (mg/l)	% REDUCTION IN EMCs*
Total Suspended Solids	135	117.5	13
Total Phosphorus	0.325	0.270	17
Total Kjeldahl Nitrogen	1.660	1.354	18
Copper	0.03	0.013	56
Lead	0.170	0.027	84
Zinc	0.215	0.097	55
Biological Oxygen Demand	9.4	7.7	18
Chemical Oxygen Demand	70.2	66.5	5

Notes:

- * Four year average of event mean concentrations (EMCs) of pollutants in stormwater.
- At least 5 runoff events were sampled before the program (pre-1994) and twelve events during the 1994–95 to 1997–98 period.

Source: Lehner *et al.* (1999) and Vanloo (2002).

- larger organisations may develop more comprehensive and relatively more expensive programs;
- leading organisations may be spending more on stormwater management per capita; and/or
- stormwater quality management may be an unusually high priority for these organisations.

By way of comparison, our data from Australian stormwater managers indicate that leading Australian local government authorities that manage minor and trunk drainage spend approximately AUD$3 - S$32 per person per year on stormwater quality management. These data *broadly* indicate that leading agencies in Australia are, on average, spending less on stormwater quality management compared with their US counterparts.

City-wide urban stormwater quality management programs are thought to range from roughly 25% to 40% in their cumulative pollutant removal efficiency. These estimates are *very* approximate and largely unsubstantiated, representing expert judgments on the cumulative performance of integrated stormwater management programs in reducing average annual loads of typical stormwater pollutants. It is suggested that these estimates are overly optimistic, given that cities such as Tulsa, Oklahoma (see below) were only able to demonstrate a 13% - 18% reduction in the event mean concentrations of TSS, TP and TKN in stormwater over eight years when their city-wide stormwater quality program included one of the most effective forms of city-wide non-structural BMPs - a substantial illicit discharge elimination program.

Reliable data on the quality of urban stormwater and receiving waters suggest well designed and implemented city-wide urban stormwater management programs can reduce levels of stormwater pollution and at least maintain the health of receiving waters in developing catchments.

Stormwater quality data from the City of Tulsa, Oklahoma, indicate a city-wide stormwater quality management program with strong non-structural elements is capable of reducing event mean concentrations of pollutants in stormwater[24] by:

- 13% for TSS.
- 17% for TP.
- 18% for total kjeldahl nitrogen.
- ≥55% for copper, lead and zinc.

[24] In this case, event mean concentrations were averaged over four year periods before and after the implementation of the stormwater quality management program. The percentages represent the difference between these four year averages (see Lehner *et al.,* 1999 for more details).

Water quality data from the City of Orlando, Florida, support the view that the City's stormwater quality management program maintained the health of most of the City's lakes receiving urban stormwater in 2000. The data indicate that 91.5% of the City's 94 lakes showed either a trend of improved water quality (12.8%) or no trend in water quality (78.7%), despite an annual population growth rate of 1.4% - 2.5% per year in the region and, therefore, the potential for increased urban stormwater pollution.

4.3 Pollution Prevention Procedures

4.3.1 Description of BMPs

Pollution prevention procedures are BMPs involving repetitive processes for preventing or minimising stormwater pollution. Most of the BMPs relate to maintenance activities (e.g. maintenance of the stormwater drainage network), but some relate to the process by which activities are planned (e.g. major construction works) and other elements of environmental management systems (e.g. staff training on stormwater management).

Pollution prevention procedures used by municipalities for operational activities are particularly important, as many are applied city-wide (e.g. litter collections, street sweeping, integrated pest management). They are considered so important in the US, they collectively comprise one of the six minimum control measures that operators of small, urban stormwater drainage systems must implement under the Phase II Stormwater Rule.

Detailed descriptions of specific pollution prevention procedures for stormwater quality management can be found in US EPA (2001) and Victorian Stormwater Committee (1999)[25]. Such procedures include:

- street sweeping and cleansing;
- integrated pest management techniques (e.g. reduced use of herbicides and insecticides);
- litter collection programs (e.g. clean-up days);
- recycling procedures and programs (e.g. hazardous waste collection days, used oil collection programs, product exchange programs, composting programs and the provision of recycling facilities);
- maintenance practices (e.g. maintenance of structural BMPs, stormwater drains, roads, footpaths, bridges, buildings, water mains, septic systems and sewerage infrastructure);
- good housekeeping of commercial and industrial premises (e.g. sound material handling and storage procedures);
- maintaining vehicles, plant and equipment (including car washing);
- maintaining public parks, road reserves, golf courses, nurseries, sports fields, swimming pools, etc.;
- planning construction and maintenance activities (e.g. developing environmental management plans);
- domestic waste collection;
- public litter bin design, placement and cleaning;
- graffiti removal;
- environmental incident and emergency response activities;
- pollution prevention plans and environmental management systems for operational premises or activities (e.g. incorporating elements such as risk assessments, standard operating procedures, training, auditing, etc.); and
- road de-icing procedures in cold climates.

Sources: LSRC (2001), Brown, (1999), Wyoming Department of Environmental Quality (1999), Victorian Stormwater Committee (1999), Schueler and Holland (2000) and US EPA (2001).

As demonstrated in Report No. 2 in this series (CRC for Catchment Hydrology Report 02/12), pollution prevention procedures such as street sweeping, catchbasin[26] cleaning, training of municipal employees and used oil collection programs are non-

[25] This guideline also includes a number of useful checklists for local authorities and businesses to assess their pollution prevention procedures.

[26] A 'catchbasin' is a US term for an "inlet to a storm or combined sewer equipped with a sediment sump and sometimes a hood, on its outlet pipe to the sewer. Catchbasins can collect some of the sediment and debris washing off the streets, and help to provide a water seal against the venting of sewer gases" (Lehner *et al.,* 1999, p. 13-2). Note however that not all catchbasins have a sump and trap sediment (e.g. those in Southern California). In Australia, stormwater gully pits (called drop inlets in the US) that immediately receive road runoff can provide a similar function (depending upon their design), trapping small qualities of coarse sediment and gross pollutants until the material is removed (usually by an eductor) or is flushed through the system by a high-energy rainfall event.

structural BMPs commonly used by US coastal municipal authorities. In addition, our survey highlighted their popularity in Australia. For example, the survey found that city-wide maintenance operations were, as a group, ranked in the top five of the most frequently used BMPs and in the top 10 non-structural or structural BMPs that were most widely increasing in use (see Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12, for survey results).

Of the pollution prevention procedures previously listed, only street sweeping has been studied with a high degree of rigour in terms of its performance as a BMP for stormwater quality improvement. Consequently, at the time of writing, street sweeping was the only non-structural BMP to have comprehensive monitoring data included in the US National BMP Database (see www.bmpdatabase.org/). The US EPA (1999) suggested the scarcity of data on the performance of maintenance practices in particular may be "due to the lack of appropriate evaluation methodologies and the difficulty associated with isolating water quality improvements attributable to these practices" (p. 5-50).

Unlike data on the effect of pollution prevention procedures on stormwater quality, costs associated with these activities are well known. Reliable and up-to-date cost information can usually be obtained from local authorities, which record unit costs associated with such activities (e.g. cost to remove and dispose of gross pollutants and sediments from a stormwater gully pit, cost to clean-out a certain gross pollutant trap, etc.).

4.3.2 Case Studies and Reported Data

Street Sweeping

In the early 1980s, the performance of street sweeping as a stormwater quality BMP was evaluated in several cities under the US National Urban Runoff Project (German and Svensson, 2001). These studies concluded that street sweeping, as practiced at that time, could be effective in removing litter and coarse fractions of sediment from the street surface, but produced no significant reduction in nutrient concentrations in stormwater runoff (US EPA, 1983). Accordingly, traditional street sweeping was seen as a limited BMP for city-wide stormwater management.

The CRC for Catchment Hydrology briefly reviewed the available literature on street sweeping in 1997. The conclusions supported those of the US National Urban Runoff Project, namely that "street sweeping appears to be fairly limited in performance, particularly when the frequency of sweeping is taken into account" (CRC for Catchment Hydrology, 1997, p. 35).

The minimal benefits of traditional street sweeping (i.e. infrequent use of mechanical sweepers) were thought to be related to its inability to capture a high proportion of fine sediments, to which most stormwater nutrients and toxicants are bound, even under test conditions. For example, it has been widely reported that traditional street sweeping techniques are inefficient at picking up fine particles smaller than 43 μm in diameter (NVPDC, 1996). Street sweeping data from a variety of catchments presented by the US EPA (1980) indicate while only 5.9% (by weight) of total solids were smaller than 43 μm (in diameter), 56.2% of the phosphate and 31.9% of the nitrate were associated with these small particles[27]. Table 4.14 further demonstrates how a street sweeping regime with a poor ability to collect fine particles can result in low pollutant removal efficiencies for stormwater pollutants such as phosphorus.

The CRC for Catchment Hydrology (1997) summarised the data on pollutant removal performance from five street sweeping studies; these are given in Table 4.15 as a guide only. Caution is needed when interpreting reported efficiency data for street sweeping such as that given in Table 4.15, as most studies report the percent reduction in surface loads of pollutants due to sweeping at a particular point in time (sometimes called removal efficiency or build-up removal), rather than reductions in stormwater pollutant concentrations or loads over a given period of time. Some studies have demonstrated reductions in surface loads of pollutants due to sweeping, but no reductions in mean concentrations of these pollutants in stormwater runoff (e.g. Bender and Terstriep, 1984).

[27] It is acknowledged that newer street sweeping technologies have improved their ability to collect finer particles of sediment, although their overall pollutant removal efficiency is still highly limited by issues such as the need for frequent sweeping and gaining access to pollutants under and around parked cars.

Table 4.14 Relationship Between Overall Mechanical Broom Street Sweeping Removal Efficiency, Particle Size Distribution and Street Sweeping Removal Efficiency for Selected Pollutants

PARTICLE SIZE RANGE (diameter in μm)	**SWEEPER REMOVAL EFFICIENCY** (% total removal)	**NITRATE** (% removal)	**PHOSPHATE** (% removal)	**HEAVY METALS** (% removal)	**BIOLOGICAL OXYGEN DEMAND** (% removal)
≥246 μm	67%	15%	5%	33%	29%
43 μm - 246 μm	34%	15%	12%	14%	11%
>43 μm	15%	5%	8%	-	4%
Overall	50%	36%	26%	47%	44%

Notes:
- Data relates to mechanical (broom) street sweepers.
- The above efficiencies are event and location specific (i.e. efficiencies relate to the amount of pollutants accumulated on the street surface at the time of sweeping). They are presented simply to aid understanding of the importance of particle size distribution in pollutant removal by street sweeping. For more information on this issue, see Walker and Wong (1999).

Source: NVPDC (1996).

Table 4.15 Pollutant Concentration Reductions Reported from Five Street Sweeping Studies

PARAMETER	**REDUCTIONS IN THE SURFACE CONTAMINANT LOAD (%)**	
	MEDIAN	**RANGE**
Total Suspended Solids*	41	37 - 50
Total Phosphorus	28	9 - 28
Soluble Phosphorus	45	-
Organic Nitrogen	27	12 - 45
Lead	32	5 - 48
Zinc	45	-
Copper	45	-
Cadmium	45	-
Iron	45	13 - 60
Chemical Oxygen Demand	35	34 - 45
Litter	98	95 - 100

Notes:
- * Strongly dependent upon particle size for the type of sweeping technology being evaluated by these studies.
- Frequent sweeping was assumed.
- Care should be taken in the interpretation of this data, as pollutant removal is dependent on many factors (e.g. particle size distribution, sweeping frequency, the load of pollution on the surface being swept, existence of parked cars, the type of surface being swept, sweeping technology, the inter-event period, etc.).

Source: CRC for Catchment Hydrology (1997).

Walker and Wong (1999) thoroughly reviewed the street sweeping literature and data from Australian field studies to evaluate the effectiveness of this BMP for stormwater quality improvement. Their principal findings and conclusions were:

- Literature from overseas studies indicate traditional street sweeping is relatively ineffective in reducing the load of particles smaller than 125 μm (in diameter) on the street surface.
- The typical range of suspended solid particle size in Australian urban stormwater is 1 - 400 μm (in diameter), with approximately 70% of the particles being smaller than 125 μm (in diameter).
- Analysis of particle size distributions indicates typical Australian road runoff particle size distribution is skewed towards the finer sizes compared with equivalent overseas road runoff. For example, while approximately 70% of particles in Australian stormwater are smaller than 125 μm in diameter, only 20% of particles in overseas stormwater are typically this small.
- For typical Australian conditions, street sweeping as it was practised in the late 1990s was unlikely to effectively reduce pollutants of concern (i.e. fine suspended particles with adsorbed heavy metals and nutrients).
- Australian field studies found significant loads of gross pollutants in stormwater draining from urban areas that had been subject to a daily street sweeping regime. Drawing on the findings of recent studies on the generation of gross pollutants in Melbourne, Walker and Wong (1999) suggested loads of gross pollutants in stormwater draining urban areas depend more on the nature of rainfall (i.e. the available *energy* to mobilise and transport gross pollutants) than reductions to the load of gross pollutants on the street surface (i.e. through street sweeping).
- While newer street sweeping technology[28] more effectively removes the finer fraction of suspended particles under experimental conditions (see Sutherland and Jelen, 1996), "the effectiveness of street sweeping programs depend more on factors such as land-use activities, the inter-event dry period, street sweeping frequency and timing, access to source areas and sweep operation than the actual street sweeping mechanism" (Walker and Wong, 1999, p. 4).

With respect to the last point listed above, the NVPDC (1996) also downplays the importance of new sweeping technology, stating that "despite advances in technology, sweeping frequency is the most problematic aspect of this non-structural BMP technique" (p. 5-53). In guidelines for local stormwater managers, the Northern Virginia Planning District Commission (NVPDC, 1996) recommends street sweeping frequencies of at least one sweep per week for residential areas and one to three sweeps per week for commercial and industrial areas, to maximise its effectiveness. These recommendations contrast with typical street sweeping frequencies conducted primarily for aesthetic and safety reasons (e.g. one sweep every six months for residential areas and one sweep every three months for industrial areas).

While street sweeping frequency is a variable that can influence pollutant removal efficiency, slightly increasing the frequency will not *necessarily* increase the efficiency of the BMP, due to other factors such as the nature of rainfall (e.g. its timing). For example, the influence of sweeping frequency on the load of litter entering stormwater from Californian highways was investigated in a US$2.8M Litter Management Pilot Study (Caltrans, 2000). The study found that increasing the frequency of mechanical sweeping from monthly to weekly did not statistically reduce ($\alpha = 0.05$) the count or weight of litter in stormwater (as measured at stormwater drain outlets) or the total load of litter in the stormwater system (Caltrans, 2000). The study concluded "weekly sweeping is not more effective than monthly sweeping in reducing litter in runoff from freeways with standard inlet grates" (p. ES-3). In addition, statistical analysis between treatment and control areas failed to show a reduced concentration of chemical constituents in stormwater that could be attributed to the increased sweeping frequency.

28 For example, the small-micron surface sweeper technology can reportedly remove particles as small as 4 μm (in diameter), and produce a total removal efficiency of approximately 70% for particles smaller than 63 μm (Sutherland and Jelen, 1997). Another technology is the regenerative air sweeper, that can reportedly produce a removal efficiency of approximately 32% for particles smaller than 63 μm (Sutherland and Jelen, 1997).

Another potential constraint to the performance of street sweeping is gaining access to pollutants in areas where cars are parked along the kerb (e.g. in residential areas). US studies have demonstrated almost 90% of contaminants on streets typically accumulate within 30 cm of the kerb (VSWCB, 1979). Like most limitations to street sweeping, this constraint can be managed if resources are available. A successful example is a City of Madison, Wisconsin, pilot study that aimed to test whether the surface pollutant removal efficiency of street sweeping could be improved by applying parking restrictions to areas where gaining access to the kerb was often difficult. The study included a public education, parking enforcement and a street sweeping component. As a result, the total quantity of pollutants collected by street sweeping increased in volume by 118% (i.e. 5.25 to 11.46 cubic metres per kerb kilometre swept). In addition, a public survey found 97% of respondents were aware of the new parking restrictions and the revenue gained from parking enforcement activities was such that the education and enforcement aspects of the program could be self-funding in the long term (Lehner *et al.,* 1999). No data were gathered on the effect on stormwater quality.

While street sweeping appears to have limited benefits as a stormwater quality BMP when applied on a city-wide scale, we suggest it has merit in specific circumstances. For example:

- The use of newer street sweeping technologies may be applicable for large industrial or commercial sites, where access to pollutants on impervious services can be easily controlled and resources are available for more frequent sweeping and sweeping at particular times.
- The use of traditional street sweeping technology in areas with deciduous trees during autumn. This BMP can potentially collect large volumes of leaf litter and minimise the loading of organic matter on sensitive waterways.
- The collection of absorbent material commonly used by incident response crews to contain liquids after traffic accidents in urban areas.
- To collect large volumes of gross pollutants deposited as a result of a specific event in a clearly defined and easily accessible area (e.g. after a ticker tape parade or major sporting event).

Street sweeping technology as a legitimate BMP for stormwater quality improvement in specific circumstances has been endorsed by the Massachusetts Department of Environmental Protection and Office of Coastal Zone Management (1997). Its Stormwater Technical Handbook (volume 2) acknowledges the TSS removal efficiency for commonly used street sweeping practices ranges from negligible (<5%) to moderately effective (50% - 80%). The Department allows a 10% credit towards the 80% TSS removal standard for new development[29] if a street or parking lot sweeping program is in place and consent is gained from the relevant development approval authority.

An approximate cost of street sweeping in Australia has been provided by Davies and Pierce (1998) as AUD$55 per kerb km. A survey of NSW local governments (McManus, Pers. Comm.) reported the following costs associated with MacDonald Johnson series 2000, 600 and 650 street sweepers:

- capital costs were approximately AUD$164,000, AUD$186,400 and AUD$237,000, respectively;
- annual maintenance costs were approximately AUD$30,000, AUD$19,700 and AUD$21,740, respectively; and
- annual operating costs were approximately AUD$30,000, AUD$19,700 and AUD$21,740, respectively.[30]

The US EPA (1997) reported an average cost of US$12.50 per kerb km, with a range of between US$6.25 and US$18.75 per kerb km. Capital and operational cost information for mechanical and vacuum assisted street sweeping has also been provided by US EPA (1999) and is presented in Table 4.16.

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29 Under this standard, proponents of new development must demonstrate that at least 80% of the average annual load of TSS will be removed by the proposed stormwater quality management program.

30 Note that street sweepers operated by local government authorities in Australia typically cover 100 km per eight hour day.

Table 4.16 US Street Sweeping Cost Information

FEATURES	SWEEPER TYPE	
	MECHANICAL	VACUUM ASSISTED
Life (years)	5	8
Purchase price (US$)	75,000	150,000
Operation and maintenance costs ($US/kerb km)	30	15
Annualised sweeper costs ($US/kerb km/year)		
Weekly (sweeping frequency)	1,680	946
Bi-weekly	840	473
Monthly	388	218
Four times per year	129	73
Twice per year	65	36
Annual	32	18

Sources: Finley (1996), SWRPC (1991), and Satterfield (1996). Summarised in US EPA (1999).

Manual Litter Collections

The Californian Department of Transportation undertook the three-year, US$2.8M Litter Management Pilot Study to assess the efficiency of various litter management practices on major highways (Caltrans, 2000). Specifically, the study examined the effects of increasing the frequency of manual litter collections.

It found that increasing the frequency of manual collections of litter along highways from monthly to weekly:

- decreased the quantity in stormwater of litter at all stormwater outfalls (a statistically significant finding with $\alpha = 0.05$); and
- decreased the average annual litter loading in stormwater by 30% (by weight), 41% (by volume) and 33% (by count) compared to control sites (Berger, 2001; and Caltrans, 2000).

The manual litter collections undertaken by the Californian Department of Transport involved only medium to large items (i.e. items greater in size than, but not including, cigarette butts) and cost approximately US$40 - $45 per km per collection (Berger, 2001).

Novotony (1984) reported litter control activities (e.g. bin placement and litter collections) can effectively control gross pollutants, especially in highly impervious areas. Citing Syrek (1981), Novotony claimed "it has been shown that litter control measures can reduce the amount of deposited litter by 50% – 70%" (p. 1242). It is *assumed* this figure relates to reductions in average annual surface loads.

A recent Australian manual litter collection program involved collecting gross pollutants from the Brisbane River and its banks in Queensland. The initiative was funded from stakeholder groups in the region and involved a litter collection boat to raise public awareness of the importance of healthy waterways. The program cost approximately AUD$130,000 in 2000-01, including litter handling, disposal and reporting. This level of funding enabled approximately 135,000 items of litter to be collected (Chandler, 2002).

Examples of major US litter collection campaigns to improve stormwater quality and/or waterway health include:

- Virginia's Adopt-a-Highway program that removed 27,488 cubic metres of gross pollutants in 1991-92 with volunteer hours valued at US$2M (US EPA, 1997).
- The International Coastal Cleanup, the largest coastal cleanup program in the US. In the 1991 campaign, 130,152 volunteers collected litter from 6,957 km of beaches and waterways, collecting approximately 1.3 million kg of litter (Younger and Hodge, 1992).

Public Litter Bins

Although litter bins in public places are *structural* BMPs, decisions such as placement, whether they should be accompanied by recycling bins, density of bins in a given area and bin design are non-structural aspects that potentially affect their performance.

The Beverage Industry Environment Council (BIEC, 1997a) undertook a review of literature concerning the possible effect of providing bins in public areas on littering behaviour, which showed simply increasing the number of bins did not always reduce littering. Of 12 research studies summarised by BIEC (1997a):

- six studies found providing bins reduced local littering;
- five studies found providing bins made no difference to local littering; and
- one study produced mixed results (i.e. litter decreased in the vicinity of bins with unusual designs but may have increased elsewhere).

In 1997, the Australian Beverage Industry Environment Council (BIEC, 1997b) undertook a national study to better understand littering behaviour, using observational and survey methods. The study found "a lack of bins was not a major factor in littering; most littering occurred within five metres of a bin" (p. 7).

The study also found approximately half the respondents to a public survey did not consider placing items next to an overflowing bin to be littering. BIEC (1997b) concluded that unless bins were regularly cleared, it may be better not to have any at all, as evidence suggests litter attracts more litter.

The BIEC evaluated the effect on littering of providing new bins in 1997-98 during a local research study in Sydney (BIEC, 1999). Using a combination of litter surveys, bin audits, structured observations and attitude surveys, the study generated mixed results. It ultimately concluded "the effectiveness of any new bins seems likely to depend on placement and design, as well as the nature of the site in which the bin is to be placed" (BIEC, 1999, p. 46). The Sydney study also examined the effect of installing *recycling* facilities/bins in public places on littering and found an associated increase in the percent of items binned and a slight decrease in the percent of items littered (28% to 24%). However, it also found "to some extent, the recycling bins prevented littering by encouraging use that led to contamination of the recycling bins" (BIEC, 1999, p. 50).

Reeve *et al.* (2000) summarised litter-related literature reviews by Huffman *et al.* (1995) and BIEC (1997a), concluding that the following strategies are thought to be usually effective in reducing local littering in public places:

- placing bins in locations that are convenient to the public;
- designing bins to catch the attention of the public;
- keeping observable litter to a minimum (e.g. through frequent collections);
- providing politely worded signage (although positive effects are generally short-lived);
- designing public open space to minimise areas that are hidden from public view; and
- involving the community in litter management initiatives.

Curnow *et al.* (2002) outlined eight principles for effecting change to reduce local littering in public places:

- Accessibility (e.g. provision of easily accessible litter and recycling bins).
- Clean equals clean (i.e. littering rates are reduced in areas that are regularly cleaned).
- Consistency (e.g. making the colours of litter and recycling bins consistent).
- Act on behaviour (e.g. with rewards and/or sanctions, as appropriate).
- Involvement (e.g. involve users of public areas in the design and placement of litter bin facilities).
- Responsibility (e.g. educate to encourage people to accept responsibility).
- Integration (e.g. anti-litter educational strategies should be accompanied by the provision of litter bin and recycling infrastructure and sound maintenance regimes).
- Demonstrate commitment (e.g. agencies promoting anti-litter messages must lead by example).

The view that these strategies and principles are generally effective is based on the findings of *local* observational studies involving littering. Some commentators caution against making the assumption that local anti-littering interventions (e.g. in a park or train station) would be just as effective if they were scaled up to the city-wide scale or greater. For example, Huffman *et al.* (1995) stated "the effectiveness of the interventions when used by large-scale organisations such as city, State or national government units remains unproven" (p. 197).

Highway and Bridge Maintenance

The US EPA (1997) and the Wyoming Department of Environmental Quality (1999) reported approximate cost and pollutant removal efficiency data for maintaining roadside and bridge vegetation with a stormwater treatment function. They estimated the average percent removal of stormwater pollutants by well-maintained vegetation to be approximately 60% (TSS), 40% (TP), 40% (TN), 50% (chemical oxygen demand), 50% (lead) and 50% (zinc)[31]. The average annual operation and maintenance costs for such vegetation were approximately:

- US$1,975/ha where natural succession of vegetation is prevented[32] (reported range = $1,728 – $2,222/ha); and
- US$247/ha where natural succession of vegetation is allowed to occur (reported range = $123 - $494/ha).

The Wyoming Department of Environmental Quality (1999) and the US EPA (1997) reported the probable pollutant removal efficiency for bridge maintenance techniques that seek to trap TSS was in the range of 50% - 100%.

Maintenance Regimes for Structural BMPs

Stormwater pollutant concentrations and loads are affected by the maintenance regime associated with structural BMPs for stormwater quality improvement (e.g. constructed wetlands, gross pollutant traps, porous paving, vegetated buffer strips). Unfortunately, quantification of this relationship in terms of pollutant loadings and cost must be undertaken on a site-specific basis, as many variables are involved.

To assist people who may wish to undertake such an analysis, information on typical operation and maintenance costs for a range of large, structural BMPs is provided in Table 4.17. This information draws on US literature as well as estimates from Brisbane and Melbourne.

Maintenance of the Stormwater Drainage Network

Most urban stormwater drainage networks have some capacity to capture and temporarily store pollutants (e.g. coarse sediment and litter). Such pollutants would be temporarily stored in drop inlets or gully pits[33], and ultimately removed by either large storm events or maintenance by the local drainage authority.

Mineart and Singh (2000) reported on a study in San Francisco, California, that investigated whether an increased cleaning frequency of stormwater drain inlets could result in increased removal of stormwater pollutants. They examined the mass of pollutants captured during monthly, quarterly, semi-annual and annual clean-outs of drop inlets. Monthly maintenance collected the greatest volume of pollutants in residential, commercial and industrial areas. They estimated monthly maintenance of drop inlet structures in the San Francisco region could reduce annual copper loads to waterways by at least 3% - 4%, and possibly higher (i.e. 11% - 12%) if the monthly maintenance captured pollutants from illegal dumping activities.

Pit (undated) and Lehner *et al.* (1999) reported that the annual maintenance of catchbasins within the City of Bellevue's stormwater drainage system in Washington was likely to produce the following reductions in average annual stormwater runoff:

- 10% - 25% reduction in the loads of lead and total solids in stormwater; and
- 5% - 10% reduction in the chemical oxygen demand and loads of TP, total kjeldahl nitrogen and zinc in stormwater.

An approximate cost for maintenance involving removing pollutants from many small pits in the stormwater drainage network has been obtained from

31 It is *assumed* these are reductions in average annual loads of stormwater pollutants.

32 Through maintenance practices such as mowing, revegetation and application of herbicides

33 'Drop inlets', 'gully pits', and 'catchbasins' are all terms for structures in the stormwater network that receive stormwater as it first enters the enclosed, public stormwater drainage system (e.g. from a road surface or commercial property). Designs vary depending upon the locality, but often, these structures have the ability to trap small amounts of coarse sediment and gross pollutants (albeit temporarily).

Table 4.17 Approximate Cost Information Associated with the Construction and Maintenance of Structural BMPs

BMP BEING MAINTAINED	CAPITAL COST ESTIMES	ANNUAL MAINTENANCE COST ESTIMATES	
	AUST DATA	AUST DATA	US DATA
Grassed swales/grass channels	Grassed swales (minimum costs): AUD$4.43/m^2 (\$9.38/m^2 with instant turf and \$5.55/m^2 with imported soil)	Grassed swales: AUD$2.50/m^2	5% - 7% of the construction cost
Filters strips	Turf buffer strips: AUD$3.50/m^2 Sedge/Mulch buffer strips: AUD$7.50/m^2	-	US$790/ha (of filter strip)
Bioretention systems/ vegetated swales	Vegetated swales (and wetlands): AUD$ = 343913Ln(surface area of vegetated BMP in ha) + 738607	Landscaping cost only (vegetated swales and wetlands): AUD$ = 9842.2(surface area of vegetated BMP in ha)$^{0.4304}$ Vegetated swales: Initially AUD$9/m^2, then decreasing over the first few years to AUD$1.50/m^2	5% - 7% of the construction cost
Infiltration trenches	-	-	5% – 20% of the construction cost
Infiltration basins	-	-	1% – 10% of the construction cost
Sand filters	-	-	11% – 13% of the construction cost
Sediment and litter traps	AUD$ = 13,703(catchment area in ha)$^{0.5904}$ AUD$50,000 (sediment traps with 50 ha treated area)	6% of the construction cost AUD$ = 311.67(annual volume of material removed in m^3)$^{0.8717}$ AUD$2,800 (sediment traps with 50 ha treated area)	-
Gully trap litter baskets	AUD$1,700 – 2,900/ha (of area treated)	$172/ha (of area treated)	-
Trash racks (with no sediment capture)	AUD$20,000 (100 ha catchment area)	30% of the construction cost AUD$1,400 (100 ha catchment area)	-
Trash racks (with sediment capture)	AUD$120,000 (15 ha catchment area)	6% of the construction cost AUD$1,500 (15 ha catchment area)	-
Floating litter traps	AUD$25,000 (150 ha catchment area) AUD$48,000 (1,700 ha catchment area)	7% of the construction cost AUD$1,300 (150 – 1,700 ha catchment area)	-
In-ground gross pollutant traps	AUD$200,000 (15 ha catchment area) AUD$900 – 18,400/ha (of area treated) AUD$ = [61,700Q] + 37,000 (where Q = the 1 in 3 month ARI flow in m^3/sec) Vortex type: AUD$100,000 per m^3/sec (when the flow is at its peak treatment)	10% of construction cost AUD$10,200 (15 ha catchment area)	-
Open gross pollutant traps	AUD$350,000 (300 ha catchment area) 1,700 – 14,200/ha (of area treated)	3% of the construction cost AUD$5,900 (300 ha catchment area)	-
Ponds	AUD$30,000/Ml (of pond volume) AUD$60,000/ha (of pond area - minimum cost)	-	3% – 6% of the construction cost
Dry ponds	-	-	1% of the construction cost
Wetlands (also, see figures above for vegetated swales)	AUD$500,000 (100 ha catchment area) AUD$3,400 – 17,900/ha (of area treated) AUD$730,000/ha (of wetland area) AUD$120,000 – 250,000/ha (of wetland area)	2% of the construction cost AUD$8,200 (100 ha catchment area)	2% of the construction cost
Sources:	Lloyd *et al.* (2002), Weber (2001 & 2002), Walsh (2001 & 2002)	Lloyd *et al.* (2002), Weber (2001 & 2002)	CWP (1998) and US EPA (2001)

Note:

- These figures are broad estimates and should only be used as a *guide* to typical costs. Costs of BMPs vary considerably due to site-specific variables. Note also that the CRC for Catchment Hydrology is currently undertaking research to better characterise life cycle cost of structural BMPs.

Sources: Lloyd *et al.* (2002), Weber (2001 & 2002), Walsh (2001 & 2002), CWP (1998) and US EPA (2001).

Brisbane City Council (Sivaananthan, 2002). In 2001-02, it cost approximately AUD$2.80 per inlet to remove pollutants from a stormwater gully trap pit full of sediment, litter and/or vegetative matter. This cost included pollutant removal, transport and authorised disposal.

Ferguson *et al.* (1997) reported an approximate cost range for the cleaning of enclosed stormwater drains of US$3.28 to US$6.56 per metre.

Industrial and Commercial House-keeping Practices (e.g. Material Storage)

Smith (2002a and 2002b) and Smith and Simmons (2002) reported *preliminary* results from a study of a stormwater management program involving an industrial estate in Manly, Sydney. This study is seeking to separately and collectively evaluate the effectiveness of industry education (including auditing), street sweeping, and a gross pollutant trap as BMPs to reduce stormwater pollution on a small (11.2 ha) industrial estate. A combination of pollutant export modelling and event-based stormwater quality monitoring is being used.

An educational program was run from March 2001 to March 2002 involving face-to-face discussions with operators of premises within the industrial estate, audits and promotion of improved house-keeping practices such as material handling and stockpiling. An Education Officer was appointed for 12 months to undertake this work. Consequently, substantial opportunities were taken by the occupants of the estate to improve the management of material storage. For example, in one of the estate's three sub-catchments, 1,260 m^2 (or 21% of the total area) was converted from an uncovered area used for stockpiling to a roofed area.

At the time of writing, the study was still examining the comparability of the rainfall and runoff events monitored before and after the implementation of the BMPs, in terms of rainfall intensity, build-up period, etc. Assuming the eight rainfall/runoff events monitored before the implementation of the BMPs are comparable in nature with the eight events monitored after the implementation of the BMPs, reductions in annual pollutant loads that can *potentially* be attributed to the combined effects of education, auditing and better industrial housekeeping are:

- 8% for TSS.
- 40% for TN.
- 49% for TP.
- 42% for copper.
- 72% for lead.
- 83% for zinc.[34]

In addition, when the *combined* effect of education, auditing, street sweeping, yard sweeping and a gross pollutant trap are considered, the total change in stormwater pollutant loads following implementation of the BMPs is approximately:

- 60% for TSS.
- 43% for TN.
- 56% for TP.
- 44% for copper.
- 79% for lead.
- 82% for zinc.[35]

Costs associated with the Manly project included:

- The small street sweeper cost approximately AUD$47,000 to purchase and cost AUD$44 (at AUD$22/hour) in labour each time the relevant areas of the estate were swept (maintenance costs were not available).
- The education and auditing tasks cost approximately AUD$70,000 over 12 months.
- The gross pollutant trap cost AUD$80,429 to purchase and AUD$2,640 per year in maintenance costs (Smith, 2002b; McManus, 2002).

Ferguson *et al.* (1997) estimated the cost of storing materials on a commercial or industrial site in a way

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34 These estimates are calculated by:
1) using event mean concentrations to estimate the difference in the loads of pollutants in runoff across the site before and after the BMPs were implemented;
2) subtracting the pollutant loads captured by street sweeping and by a gross pollutant trap on the site from the total load difference calculated in #1; and
3) converting the load reduction calculated in #2 (i.e. that is attributable to education, auditing and improved housekeeping) to a percent reduction of the pre-BMP stormwater loads. For more detail, see Smith (2002a).

35 This also assumes that pre- and post-BMP rainfall and runoff events are comparable in nature.

that minimises the risk of stormwater pollution (i.e. being contained in a covered building), based on typical construction costs for such buildings. They estimated pre-engineered buildings/sheds would cost approximately US$65 - $129/m^2, and a 15cm thick concrete slab floor would cost approximately US$37 - $54/m^2.

Collection Programs for Household Hazardous Chemicals and Used Engine Oil

Collection programs to recover substances that may otherwise be dumped to land or stormwater is a common BMP in major urban areas. The US EPA (1997) reported a rapid growth in the number of collection programs involving household hazardous chemicals during the 1990s. For example, only two programs were in place in the US in 1980, while 822 were in place by 1990.

Information on the effects such programs have on stormwater quality is not available. Some authors have inferred that quantities of material collected through such programs (e.g. used engine oil) approximate quantities of pollutants prevented from entering stormwater. This assumption would produce an over-estimate of the effectiveness of such programs.

In 1990 alone, US programs were collectively responsible for gathering approximately 61,700 litres of hazardous chemicals (US EPA, 1997, extrapolating estimates from Duxbury, 1990). Examples of successful US hazardous chemical collection programs reported by US EPA (1997) include:

- Seattle's Mobile Permanent Collection System, which collects household hazardous materials via a mobile collection vehicle. In the first six months of the program, approximately 251 tonnes of material were collected. The cost to run the program (including public education and staff costs) to King County was approximately US$1.5M over 28 months.
- University of Alabama's Project ROSE, which collected 47% of the State's used oil in 1990 (i.e. 36 million litres out of the 77 million litres of used oil generated that year). The annual budget of the program was US$80,000, 56% of which was spent on public education.
- The Sunnyvale Kerbside Used Oil Collection Program in California, which collected 341 - 545 litres of used oil per day from a region of only 28,000 homes.

An example of an Australian chemical collection program is the Statewide household chemical collection program run by EcoRecycle in Victoria. In a typical year, this program services 13 metropolitan and 11 regional locations at a cost of approximately AUD$700,000 (Cosson, 2002). In 2002, Cosson estimated that the program collected approximately 300 tonnes of household chemicals, most of which was paint (70%) and oil (15%).

The US EPA (1998) estimated the costs associated with the establishment and maintenance of a used oil collection recycling program in a typical urban area, based on data from the Galveston Bay National Estuary Program (US EPA, 1999). The capital cost was estimated at approximately US$30,000 and annual maintenance costs at approximately US$12,000.

Running costs can be substantially reduced if the collected materials are reused or recycled. For example, the City of Austin in Texas manages a public reuse centre where household chemicals are collected from residents and, if appropriate, offered back to residents for reuse (e.g. paint, cleaning products). In its first four months of operation, the centre reused approximately 6.6 tonnes of hazardous materials, saving the City US$3,207 in disposal costs (US EPA, 2001).

Car Washing

Brisbane City Council (1999) investigated the merits of management strategies to minimise stormwater pollution from charity car wash events. This information is relevant to car washing in other contexts (e.g. depots, commercial car yards). The study trialled three mitigation devices, finding:

- the quality of untreated car wash effluent was poor (i.e. mean concentrations [in mg/l] of TSS = 178, TN = 4.11, TP = 0.32, copper = 0.386, lead = 0.113, and zinc = 0.387);
- approximately 10 - 40 litres of effluent were produced per washed car;
- without treatment, approximately 90% - 95% of the effluent was discharged to the stormwater system and Brisbane's waterways;

- the most effective management option was a portable, heavy duty plastic catchment mat with bunded sides that collected all effluent and allowed the effluent to be pumped either to a permeable area (e.g. a vegetated area) or to sewer[36]; and
- the catchment mat cost approximately AUD$1,000 and had an anticipated life of 5 - 10 years with insignificant maintenance costs.

The pollutant removal efficiency of the preferred management option (i.e. the bunded catchment mat) could approximate the literature values provided for vegetated buffer areas (see Table 4.6), provided:

- the vegetated area was of a reasonable size;
- the application of effluent was evenly distributed; and
- conditions promoted sheet flow and infiltration of effluent.

If the car wash effluent was pumped to sewer (with a relevant trade waste permit), the *stormwater* pollutant removal efficiency would approach 100%, even though some pollutants would ultimately enter waterways via the city's sewerage network and sewage treatment plants.

Integrated Pest Management

Integrated Pest Management (IPM) strategies include the use of natural predators and pathogens, mechanical controls, native and pest-resistant plantings, removing pest habitat and localised use of appropriate chemicals as a last resort (Washington State Department of Ecology, 1992).[37]

IPM has been studied in Maryland, where it was used for managing street trees within a residential suburb. As a result, pesticide use was reduced by 79% - 87% due to spot application techniques and average annual costs reduced by 22% (US EPA, 1997).

The US EPA (1997) documented reports from a US lawn management company (the Natural Lawn Company) that it reduced its herbicide use by 85% - 90% by switching from blanket applications to spot application. Cost reductions of a similar magnitude were anticipated.

IPM was successfully applied at the 178 ha US National Arboretum in north-west Washington in the District of Columbia. As a result, pesticide use declined by 75%, resulting in an 80% reduction in costs (Lehner *et al.,* 1999). Similar figures have been reported by the City of Eugene, Oregon, where IPM has been applied to the City's public parks and recreational areas. The City's pesticide use dropped by an estimated 75% within the first few years of implementing IPM practices, with additional reductions achieved since that time (Lehner *et al.,* 1999).

The cumulative performance of IPM and associated non-fertilised buffer strips at the Rosewood Lakes golf course in Reno, Nevada, is measured by water quality monitoring in downstream wetlands. After eight years of water quality monitoring, pesticides have not been detected in the wetlands and nutrient concentrations do not show seasonal fluctuations, despite seasonal fertiliser application on the course (Lehner *et al.,* 1999).

Fertiliser Management

The US EPA (1997) reported significant reductions in phosphorus loadings in stormwater were anticipated in the Lake Barcroft district of Virginia. It estimated an 80% - 85% decrease in phosphorus loadings would occur during spring as a result of phosphate-free fertiliser use within a water management district. Increased costs associated with the use of such fertilisers were estimated to be US$1.00 to US$1.50 per household. It is unknown whether these predictions were realised.

Costs associated with switching from inorganic fertiliser to organic, slow-release fertilisers have been estimated to be US$0.11/$m^2$ per application, when commercial organic fertiliser is purchased (Cook, 1991).

4.3.3 Summary of BMP Value and Cost

Pollution prevention procedures include a wide range of common BMPs to minimise or prevent stormwater pollution. Most relate to the activities of local government authorities and their costs are reasonably

[36] It could be argued that such a mat is a *structural* BMP, however, the definition used in this report is that structural BMPs for stormwater quality management are fixed, permanent facilities. In this case, the catchment mat (like temporary erosion and sediment controls) is not fixed and is temporary, so it shall be considered non-structural for the purposes of this report.

[37] For detailed guidance on how to implement IPM, see NVPDC (1996).

well understood (e.g. street sweeping, stormwater drain maintenance). Their value in terms of improving stormwater quality and waterway health is poorly understood, with the exception of street sweeping, which has been investigated by numerous researchers since the early 1980s.

The literature on street sweeping was only briefly reviewed as part of this project, as the CRC for Catchment Hydrology undertook a thorough literature review three years ago (Walker and Wong, 1999). We concluded city-wide street sweeping, as currently practiced for aesthetic and safety reasons, provides little benefit to stormwater quality improvement due to limitations such as the frequency and timing of sweeping and gaining access to pollutants in urbanised areas. Automated sweeping is however still considered a potentially valuable BMP in *specific circumstances,* such as the use of newer sweeping technologies (that can capture a high percentage of fine particles) on commercial and industrial sites, where limitations in terms of sweeping frequency, sweeping timing and gaining access to pollutants can be overcome.

Manual litter collections can accumulate large quantities of gross pollutants with the *potential* to enter stormwater and waterways. One well-designed study involving the highways of California quantified the effects of different manual litter collection frequencies on pollutant loads of litter in stormwater. The study found that the average annual load of litter in stormwater draining highways could be reduced by 30% (by weight) if manual litter collection frequency was increased from monthly to weekly, at a cost of US$40 - $45/km.

The literature regarding the provision of public litter bins on littering behaviour (and by inference, stormwater quality) is inconclusive, despite a relatively high number of studies. One minor but relevant finding is that providing bins without a frequent cleaning regime is likely to be worse for stormwater quality than not providing bins at all. Based on the best available evidence, litter management researchers currently promote the following strategies to minimise littering in public places:

- place litter and recycling bins in locations that are accessible to the public;
- design bins to catch the attention of the public;
- keep observable litter to a minimum (e.g. through frequent collections);
- provide politely worded signage (although positive effects are generally short-lived);
- design public open space to minimise areas that are hidden from public view;
- involve the community in litter management initiatives (e.g. involve users of public areas in the design and placement of litter bin facilities);
- be consistent in terms of educational messages and the provision of infrastructure (e.g. make the colours of litter and recycling bins consistent);
- use rewards and/or sanctions to act on littering and binning behaviour;
- encourage people to accept responsibility through education;
- integrate anti-litter educational strategies with the provision of litter bin and recycling infrastructure and sound maintenance regimes; and
- demonstrate commitment (e.g. agencies promoting anti-litter messages must lead by example).

Some approximate pollutant removal efficiency and cost data were identified for highway and bridge maintenance activities. In particular, data were available for the potential value of roadside vegetation as a non-structural BMP for stormwater quality improvement.

Some *preliminary* results were identified from a study in Manly, Sydney, which indicate great potential for education and auditing to lead to improved industrial house-keeping practices (e.g. covering outdoor stockpiling and material handling areas) and substantial reductions in annual stormwater pollutant loads. At the time of writing the study was seeking to demonstrate the comparability of the rainfall runoff events monitored before and after the implementation of the BMPs. If this can be done, the study may conclude that the following reductions in annual pollutant loads are possible on small industrial estates where there are good opportunities for improved house-keeping practices: 8% for TSS; 40% for TN; 49% for TP; 42% for copper; 72% for lead; and 83% for zinc.

Several case studies have reported approximate pollutant removal efficiencies associated with the regular clean-out of nodes in the urban stormwater drainage network with the capacity to collect small quantities of coarse sediment and gross pollutants (e.g. catchbasins with sediment sumps, drop inlets and gully pits). Estimates of the potential reduction of average annual pollutant loads in stormwater range from 10% - 25% for total solids, 3% - 25% for heavy metals, and 5% - 10% for chemical oxygen demand, TP, total kjeldahl nitrogen and zinc.

Some temporary and portable BMPs for car washing have the potential to be highly effective at preventing related stormwater pollution (e.g. portable catchment mats that collect car wash effluent and allow it to be disposed to a vegetated area or sewer). If adopted, the pollutant removal efficiencies of these systems are effectively controlled by the nature of the vegetated area on which the effluent is being disposed. If correctly used, the pollutant removal efficiencies of these BMPs have the potential to at least equate with that of vegetated buffer areas (see Section 4.1.2).

Programs designed to collect unwanted household hazardous materials (e.g. paint, pesticides) and used engine oil are demonstrably effective in collecting large quantities of material. For example, approximately 300 tonnes of household chemicals are collected each year by EcoRecycle in Victoria at a cost of approximately AUD$700,000. Although we gathered information on quantities collected and costs to run such programs, no convincing studies were identified that translated the quantity of materials collected through such programs to a likely improvement in stormwater quality.

A number of case studies report on the successful implementation of integrated pest management (IPM) practices that have the potential to significantly reduce the use of pesticides and therefore the loads of pesticides in stormwater. Reported reductions in the use of herbicides and other pesticides range from 75% – 90%, with approximately 75% being common. Associated savings in the cost of pest management programs ranged from 22% – 90%, with 85% being common. Water quality data were also available from one golf course case study that indicates IPM, when combined with vegetated buffer zones, can prevent the migration of pesticides to downstream waterways.

Potential reductions of 80% - 85% in the load of phosphorus in stormwater during spring in Virginia were predicted from a program to implement the widespread use of phosphate-free fertilisers in a residential water management district. This estimate was made prior to the program's implementation and seems optimistic. The veracity of this estimate has not been subsequently substantiated in the reviewed literature.

The available and convincing literature on the value of pollution prevention procedures for stormwater quality improvement, albeit sparse, indicates the non-structural BMPs with most *potential* for use on a *city-wide basis* are:

- Manual litter collections.
- House-keeping practices in commercial and industrial areas (e.g. material storage and handling).
- Maintenance programs to regularly remove pollutants from nodes in the enclosed urban stormwater network that temporarily trap pollutants (e.g. catchbasins, drop inlets and gully pits).
- Collection programs for unwanted household hazardous chemicals and used engine oil.
- IPM practices (for residential and public areas).

4.4 Education and Participation Programs

4.4.1 Description of BMPs

Education and participation programs include elements of information provision, persuasion and/or involvement by the target audience. They aim to change the behaviour of sectors of the community whose activities are thought to impact on stormwater quality and waterway health.

Common examples of educational programs (or strategies within larger programs) include city-wide stormwater-related media campaigns and anti-littering signage. Examples of participation programs include stormwater drain stencilling by community groups and intensive lawn care training courses and workshops.

Ryan and Brown (2000) and Ryan and Rudland (2001) recommend an increased focus on public *participation* (e.g. individual activity, community stewardship and deliberative decision-making) as opposed to traditional community education approaches. Ryan and Brown (2000) describe traditional community educational approaches as top-down, delivered by experts from outside the site of intervention. Such education is described as consultative at best, rather than participatory. Public participation on the other hand is bottom-up, concerned with spreading control and ownership as widely as possible throughout the community and "developing a partnered or shared analysis of both the problem and the solution" (p. 10). These authors also promote broad public participation and consensus as "the key vehicles for improving the management of urban stormwater through social action" (p. 10).

The vast majority of attempts to measure the performance of education and participation programs adopt simplistic styles of evaluation (e.g. measuring participation rates, changes in knowledge or changes in self-reported behaviour). Few attempts have been made to link educational programs with actual changes in stormwater quality and/or pollutant loads (US EPA, 1997). For example, a literature review by Strecker and Quigley (1998) as part of the US National Stormwater BMP Database project could not identify any published studies containing quantitative information on the effectiveness of educational BMPs in terms of *water quality* improvement.

A number of other issues have plagued attempts to reliably quantify the performance of educational and participation programs as BMPs for stormwater quality improvement:

Firstly, it is commonly assumed in the design and evaluation of education programs for stormwater quality improvement that raising people's awareness or knowledge will automatically lead to changes in environmental beliefs and, eventually, behaviour. This assumption is not supported by the literature. For example:

- Commenting on the limited effect of voluntarism and the stewardship ethic in natural resource management, Barr (1999) concluded "there is a significant body of research that demonstrates that links between environmental beliefs and environmental behaviour are tenuous" (p. 134).
- Said (1998) summarised the findings of a large environmental research project involving a "usage, attitude and segmentation study" of 1,200 adults living in Adelaide, Brisbane, Melbourne and Sydney. He concluded "in short, the Environmental Marketing Unit report shows, however, that we cannot count on a linkage between environmental concern, knowledge, empowerment and behavioural change" (p. 98).
- Gardner and Stern (1996) in their text titled 'Environmental Problems and Human Behaviour' stated "…even in the presence of favourable attitudes, knowledge does not lead directly or automatically to pro environmental behaviour" (p. 85).
- In 1997 a nationwide study into Australian littering behaviour (BIEC, 1997b) found major differences between actual behaviour and attitudes. For example, 78% of people who had just been observed littering told researchers that littering was a "very important" or "extremely important" environmental issue.

Secondly, the magnitude of induced behavioural change is likely to vary greatly depending on the nature of the activity promoted and the target audience. For example an educational strategy in a low density residential area that encourages people to wash their cars on grassed areas is likely to be more effective than a similar one that encourages the same audience to travel and pay to have their cars washed in sewered wash bays.

Some researchers stress that activities that provide some *personal benefit* to the target audience (e.g. the adoption of xeriscaping to save on garden watering and fertilisation costs) are likely to have a faster rate and higher level of adoption. The importance of *self interest* on the rate and level of adoption of new practices and technology is well established in the agricultural adoption theory literature. As Lindner (1987) explained in a review of literature concerning the adoption and diffusion of technology in agriculture, "the finding that rate of adoption as well as ultimate adoption level are determined primarily by the actual benefits of adoption to the potential adopters is by far and away the most important result to be culled from the empirical literature on adoption and diffusion" (p. 150). This view is supported by Pannell (1997): "there is also strong evidence that even for innovations oriented towards resource conservation, economic considerations are the most important determinant of actual adoption decisions" (p. 2).

Thirdly, it is not uncommon for stakeholder groups responsible for funding and/or managing educational programs to claim that such programs are successful despite poorly defined program objectives, a lack of sound evaluation and/or mixed or inconclusive findings.

Fourthly, the data analysis and reporting elements of attempts to monitor and evaluate the success of education and participation programs over several years are often poor. Even programs that have gone to great lengths to establish a sound monitoring and evaluation plan and show great promise (e.g. Drinkwin, 1995), often produce documented results of little value. Reasons for this may include a change of key personnel, lack of resourcing for evaluation, organisational cultures that discourage the reporting of unsuccessful projects, poor data management, difficulties in consistently applying BMPs over several years in a given catchment and little involvement by stakeholders that frequently publish their work (e.g. academics).

Finally, there is a heavy reliance on *self-reporting* as an indicator of behavioural change resulting from educational initiatives. The veracity of self-reported behaviour is rarely validated or even discussed in most evaluation exercises. Research indicates self-reporting of behavioural change can, *in some contexts,* be unreliable and misleading. For example:

- In 1997 a national study into Australian littering behaviour (BIEC, 1997b) found that only 45% of people who were observed littering within the previous five minutes told interviewers that they had littered in the last 24 hours.
- Heberlein (1971) conducted a follow-up questionnaire with people who had been observed littering and found only 50% of people recalled littering.
- Curnow *et al.* (1991) found "people often respond to perceived social expectations and express socially correct attitudes when asked for their views on environmental issues like recycling and littering" (BIEC, 1999, p. 12).

The following section provides information on the beneficial effects and cost of education and participation initiatives. However, evaluating the performance of these initiatives as *independent* BMPs only represents part of their potential role in stormwater management, as they may work synergistically with other BMPs (Lehner *et al.,* 1999; US EPA, 2001) and/or provide long-term, secondary benefits. For example, it is generally accepted that effective enforcement campaigns must be preceded and accompanied by appropriate educational campaigns. In addition, stormwater-related educational campaigns that raise the broader community's levels of awareness may not change people's behaviour immediately, but can lead to important, long-term developments such as the establishment of a specialist stormwater management agency with a secure source of funding (sometimes called a stormwater utility in the US). In this context, Schueler and Holland (2000) note "the experience of [US] communities that have successfully implemented stormwater utilities underscores the importance of public education and involvement" (p. 408).

4.4.2 Case Studies and Reported Data

Importance of Participation

Participatory programs promoting community involvement in defining problems and developing and implementing strategies are seen by most authors as more effective than traditional educational initiatives developed by experts and imposed on a target audience. Ryan and Brown (2000) believe the actual success of traditional educational campaigns for stormwater management in NSW "rely on the referred impacts of litter and some preventative health campaigns, with very little existing reliable empirical evidence of the success of community education in watershed management to support these endeavours" (p. 1). In addition, "a comprehensive review of the literature finds very little evidence of the success of traditional community education activities (Uneputty *et al.,* 1998; Robinson, 1999; Rundle, 1995; McIntyre, 1995; Nancarrow, 1997; Medway, 1999; and Young and Collier, 1999)" (p. 7).

Ryan and Brown (2000) conclude community education is limited in its ability to reduce stormwater pollution if deliberate participation strategies are not *also* used in urban stormwater management.

In a literature review on littering behaviours and intervention strategies Reeve *et al.* (2000) also stress the importance of a participatory approach, stating "there is ample evidence from the literature that community participation in the design and management of public space, together with the coupling of local litter education with community involvement strategies, is still one of the best ways of obtaining the sense of local ownership and relevance that enables social norms against littering to be effective" (p. 30).

Despite these comments, genuine participation programs for stormwater quality management are relatively rare in Australia, with the exception of stormwater drain stencilling. One of the likely reasons for this is the increased resources (especially time) that are generally required from agencies to shift the emphasis from traditional educational approaches to ones with a strong degree of community involvement. Participatory programs require partnerships between agencies and community stakeholder groups (Drucker, 1986) which take time to build and require a significant investment of people's energy, time and trust.

Providing Stormwater Information and Fostering Low-level Neighbourhood Participation

A major CSIRO study in the late 1990s investigated the feasibility of providing stormwater information to the Australian community and fostering neighbourhood action, as effective urban stormwater management measures (Nancarrow *et al.,* 1997 and 1998).

Stage one (Nancarrow *et al.,* 1997) found that certain attitudes (rather than knowledge) were predictors of self-reported stormwater management behaviour among citizens in Brisbane, Sydney, Melbourne and Perth. Nancarrow *et al.* (1997) concluded *attitudes* may drive stormwater management action while knowledge made only be indirectly involved.

Stage two of the study aimed to:

- promote among citizens attitudes thought to predict positive stormwater management behaviour, through a range of educational and participatory interventions (e.g. advertisements, providing participants with detailed stormwater management information, and fostering local activities such as stormwater drain stencilling);
- attenuate those attitudes down-playing the significance of the stormwater problem;
- increase people's knowledge of stormwater and its management; and
- determine if self-reported behaviour translated to actual behaviour.

The major findings of Stage two were:

- There was a general increase in stormwater awareness among people in the experimental catchments over the nine-month study, however participants did not improve their *specific and detailed* knowledge about stormwater.
- There was no evidence of any systematic attitudinal change that could be related to the intervention measures in Brisbane, Sydney, Melbourne or Perth, although major attitudes that were present continued to predict self-reported behaviour (as found in Stage one).
- No measurable behavioural change was detected by auditing physical conditions in the catchments or monitoring the actions of residents. The study concluded that "even though respondents reported that they were doing things to assist with stormwater management, there was little evidence to demonstrate that they were doing so" (Nancarrow *et al.,* 1998, p. 159).

Although the findings of this study do not appear encouraging because of the lack of attitudinal or actual behavioural change, Nancarrow *et al.* (1998) noted the experience of rural catchment management initiatives where longer timeframes are often needed for behaviours to change (i.e. 7 - 10 years). As discussed in Section 4.1 however, rural extension theory indicates adoption of land management behaviours in a rural context is far more dependent on the factor of self-interest than motivators such as altruism or environmental stewardship. Thus, if rural adoption theory was applied to this issue, we would anticipate high adoption levels and rates of desirable stormwater management behaviour *only* if the activities being promoted had significant personal benefits to the target audience. Unfortunately, this is rarely the case for the majority of citizens whose actions potentially pollute urban stormwater.

There is however some evidence from urban-based research to suggest that behavioural change can occur quickly following education as *long* as the infrastructure is provided so that adoption of new behaviour does not involve a significant expenditure of resources by the target audience (e.g. time, money). For example, provision of free compost bins with education can increase the involvement in composting, and litter bin placement and design in public places can quickly affect local littering behaviour (Curnow 2002; Spehr, 2002).

It would appear then, that if education in this context is to be the catalyst for substantial change, additional measures must be provided so that the desired change of behaviour:

- does not create an additional level of effort or expense to the target audience; and preferably
- creates an incentive based on people's self-interest (e.g. interests relating to a person's finances, self-image, free time, etc.).

Media Campaigns and Intensive Training on Stormwater Management

Schueler (2000) undertook a review of the effectiveness of US educational campaigns that were related to water quality improvement. Drawing primarily on *self-reported* information gathered through pre- and post-education surveys, he concluded that, of the wide range of educational strategies used (e.g. brochures, videos, web sites, posters, billboards, etc.), only two outreach techniques showed promise in actually changing behaviour: media campaigns and intensive training.

In this context, media campaigns is a term used for a mix of radio, television, direct mail and billboards to promote broad awareness messages to a large audience. Intensive training is a term used to describe the use of interactive workshops to communicate more complex messages about specific aspects of catchment management to well-defined target audiences (e.g. the US Master Gardener programs[38]).

Schueler (2000) concluded media campaigns and intensive training had the potential to produce 10% - 20% improvements in specific catchment management behaviours. By this he meant a number of studies have found media campaigns and intensive training can produce a 10% - 20% increase in the number of people in the target audience *who say* they have adopted new behaviours (e.g. reducing their use of lawn fertiliser). To support this case, Schueler (2000) summarised seven US studies, which are presented in Tables 4.18 and 4.19. The data presented in these tables appears to only relate to studies measuring *self-reported* behavioural change which has been shown in *some contexts* to be unreliable (e.g. littering studies reported in BIEC, 1997 and 1999).

Schueler (2000) suggested media campaigns were more effective at raising awareness of catchment management issues and communicating messages about undesirable behaviour, whereas intensive training (involving a higher degree of participation) was more effective at changing individual practices of residents in urban areas.

State-wide Stormwater Awareness/Education Campaigns

The NSW Environmental Protection Authority (EPA) leads Australia in terms of providing financial incentives for non-structural BMPs for stormwater quality improvement. The EPA manages the NSW Stormwater Grants Program, which allocated approximately 20% of its grants towards educational activities over its first three years (Smith, 2001). This equates to approximately AUD$10.2M of funding over three years from 1997 to an urban area with a population of approximately 4.88 million.

The EPA is responsible for the Statewide Urban Stormwater Education Program (USEP), which has funded a wide variety of educational campaigns over three years from 1997 at a cost of AUD$4M (Smith, 2001). From July 1998 to August 2001, the approximate breakdown of the USEP's expenditure was mainstream mass media (64%), mass media for people with non-English speaking backgrounds (9%), public relations (3%), community education on erosion and sediment control (7%), other forms of community education (4%), industry projects (6%), program management (3%) and research and evaluation (4%) (NSW EPA, 2001a).

The NSW EPA believes the USEP was successful over its first three years (see NSW EPA, 2001a),

[38] Master Gardener programs typically involve recruitment of volunteers, intensive training, demonstration lawns/gardens, mentoring, and one-to-one education of residents by trained volunteers.

Table 4.18 Changes to Awareness and Self-reported Behaviour after Four US Stormwater-related Media Campaigns

LOCATION AND NATURE OF TARGETED MEDIA CAMPAIGN	SELECTED QUANTITATIVE INFORMATION ON THE EFFECT OF THE CAMPAIGN ON CATCHMENT AWARENESS AND/OR SELF-REPORTED BEHAVIOUR*	SOURCE
San Francisco, California: Radio, television and bus advertising.	10% - 15% of the surveyed population exhibited increased awareness. 2% - 5% of surveyed homeowners reported that they had reduced their use of lawn chemicals.	BHI (1997)
Los Angeles, California: Radio and newspapers.	≥10% of the surveyed population reported changing practices that potentially pollute stormwater (e.g. littering, hosing off driveways into the street). 5% - 7% of the surveyed population reported changing car washing, engine oil changing, and car radiator draining practices that potentially pollute stormwater.	PRG (1998)
Oregon, Washington State: Television.	19% of the surveyed population reported changing practices that potentially pollute stormwater (e.g. being careful about what goes down the drain).	AMR (1997)
Oakland County, Michigan: Direct mail.	10% of the surveyed population reported changing some lawn care practices that potentially pollute stormwater (e.g. management of fertiliser and weeds), but no change in other lawn care practices. 44% of the surveyed population recalled the lawn care campaign.	PSC (1994)

Note:

- * Caution is needed when interpreting results from self reported surveys, particularly when there is a social stigma attached to the issue being evaluated. Some stormwater related studies have demonstrated what people say they do and what people actually do can be significantly different. For example (BIEC, 1999) found that only 33% of people who were interviewed in Sydney only moments after littering said they had littered in the previous 24 hours.

Source: Schueler (2000).

Table 4.19 Changes to Awareness and Self-reported Behaviours after Three US Stormwater-related Intensive Training Programs

LOCATION AND NATURE OF INTENSIVE TRAINING CAMPAIGN	SELECTED QUANTITATIVE INFORMATION ON THE EFFECT OF THE CAMPAIGN ON CATCHMENT AWARENESS AND/OR SELF-REPORTED BEHAVIOUR*	SOURCE
The Maryland Direct Homeowner Campaign	10% of the surveyed population reported changing their car washing practices (from self washing to commercial car washing). No change was measured in fertiliser application timing or rates.	Smith (1996)
The Florida Master Gardener Program	No change was measured in fertiliser application frequencies. 8% - 15% of the surveyed population reported reducing their rates of fertilisation and increasing their use of slow release fertiliser. 10% - 40% of the surveyed population reported reducing their use of pesticides.	Knox *et al.* (1995)
The Virginia Master Gardener Program	30% - 50% of the surveyed population reported changing their soil testing, fertiliser timing, and lawn aeration behaviour in accordance with the Master Gardener Program. 10% of the surveyed population reported changing their fertiliser application rates and management of lawn clippings in accordance with the Program.	Aveni (1998)

Note:

- * Caution is needed when interpreting results from self reported surveys (as opposed to the measurement of actual behavioural change).

Source: Schueler (2000).

primarily pointing to high rates of participation in educational events and results of surveys showing short-term improvements in *self-reported* behaviour and/or increases in stormwater awareness. Examples include:

- After the mass media element of the USEP in 1999, it was estimated that approximately 2.1M NSW residents changed some aspect of their behaviour to minimise stormwater pollution, based on self-reporting (Smith, 2001).
- The percentage of people reporting they ensured chemicals did not get into stormwater drains rose 10% from approximately 71% to 81% during the program (Smith, 2001).
- The percentage of people who believed that leaves, sediment and grass clippings were potential stormwater pollutants rose 8% from approximately 32% to 40% during the program (calculated from information provided by Smith, 2001).
- The proportion of the population that regarded stormwater pollution as "extremely" or "very important" rose 7% from approximately 68% to almost 75% during the program (calculated from information provided by NSW EPA, 2001b).
- The proportion of the population that regarded litter as a significant stormwater pollutant rose 5% from approximately 44% to 49% during the program (NSW EPA, 2001a).[39]

Another piece of evidence that has been used to suggest the USEP produced beneficial effects is the observation that loads of gross pollutants captured in large regional devices managed by Sydney Water declined in the late 1990s and early 2000s. For example, the total annual volume of sediment and gross pollutants removed from 13 of these devices declined by approximately 73% from 1999 to 2001 despite no differences in their maintenance regime (calculated from data supplied by Sim, 2002). A project jointly funded by the NSW EPA and Sydney Water is underway to see if this observation can be related to the effect of the USEP, rather than other factors which may have an impact on the data (McManus, 2002).

The Victorian Environmental Protection Authority (EPA) undertook a Statewide stormwater awareness advertising campaign in June 2001 that involved a combination of television, print and street advertisements (Span Communication and Quantum Market Research, 2002). The campaign cost approximately AUD$250,000, only ran once (for two to three weeks) and had a potential audience of approximately 3.4 to 4.8 million (Innes-Wardell, 2002; Span Communication and Quantum Market Research, 2002).

A telephone survey was undertaken after the campaign primarily to benchmark awareness levels and attitudes for future initiatives and to assist the development of the Victorian Stormwater Action Program's Communication Strategy. The survey also sought to evaluate people's awareness of the recent advertising campaign and its impact on their attitudes and behaviour. The survey involved 500 people, giving a sampling error of ± 3.5% at a 95% confidence level (Quantum Market Research, 2002).

The survey found that 23% of people were aware of recent advertising relating to urban stormwater without prompting. This figure rose to 62% after prompting. The survey also found that 32% of the descriptions given for television advertisements (by those who claimed to recall such advertisements) clearly related to the Victorian EPA campaign (Quantum Market Research, 2002). Of the surveyed people who gave an accurate description of the Victorian EPA campaign's television advertising:

[39] Information on the statistical power and degree of confidence associated with these survey results has not been presented with the findings in Smith (2001) or NSW EPA (2001a and b). This is common for reporting documentation associated with pre- and post-BMP surveys, probably because the reporting is aimed at a non-technical audience. Where it has been done for surveys it becomes apparent that a large number of samples are often needed. For example, in a stormwater quality-related telephone survey of Victorian residents, Quantum Market Research (2002) found that a sample of 500 was needed to reduce the sampling error to ± 3.5% at a 95% confidence level. The sampling error is the error attributable to actual variability in population units not accounted for by the sampling method (Gilbert, 1987). In the Victorian example, survey results would have to vary by more than 3.5% to conclude with 95% confidence that self-reported change occurred between the two sampling events.

- 49% agreed that the advertising had encouraged them to think differently about stormwater (i.e. to adopt more positive attitudes);
- 30% felt that the advertising encouraged them to behave differently in relation to stormwater[40]; and
- 34% felt that the advertising had no impact on their thoughts or behaviour in relation to stormwater.[41]

The Victorian EPA is also evaluating summer littering rates on 12 Port Phillip Bay beaches as a broad measure of how well litter-related education programs are working in the greater Melbourne region[42]. Based on available data (i.e. the litter survey data from 1999-2000 and 2000-01), the Victorian EPA concluded in December 2001 that the amount of litter found on these beaches had increased despite several city-wide awareness campaigns, local awareness campaigns, the Clean Up Your Beach Program and Beach Care days (VEPA, 1999 and 2000)[43]. Using the Disposal Behaviour Index (DBI) method of measuring littering behaviour through actual observations of littering, littering levels on Victorian beaches were also found to be higher than equivalent beaches in New South Wales and Queensland in 2002 (Curnow, 2002).

Regional and City-wide Stormwater Awareness/ Education Programs

Seventeen municipal agencies and districts within the Alameda County in California jointly developed the Alameda Countywide Clean Water Program and delivered a major stormwater awareness campaign (Lehner *et al.,* 1999). The campaign included stormwater drain stencilling, radio announcements, billboards, bus advertising, stormwater utility bill inserts, handouts, fliers and presentations. The approximate cost of the advertising campaign in the 1993/1994 financial year was US$300,000 (Cervantes, 2002). To put these costs in context, the Alameda County is approximately 1,889 km^2 in area and has a population of approximately 1.37 million.

During the first phase of the Alameda campaign (involving newspaper advertisements, billboards and stormwater drain stencilling), pre- and post-campaign surveys measured a 9% - 36% increase in the proportion of respondents who knew about key campaign messages (e.g. that pollutants can enter waterways through stormwater runoff).

After the second phase of the campaign (a four-month advertising campaign involving bus advertisements, billboards and newspapers), a post-campaign survey found:

- a 24% increase in the proportion of respondents aware of programs to educate the public about the disposal of wastes to stormwater drains (i.e. from 46% to 70%); and
- that 48% of the surveyed population reported that they had changed their behaviour in relation to stormwater management (Lehner *et al.,* 1999).

A group of municipal agencies in the Puget Sound region of Washington State formed a Water Quality Consortium to deliver a stormwater awareness campaign, using television and newspaper advertisements (Lehner *et al.,* 1999). The advertisements ran for approximately six months. Surveys of the public before and after the campaign indicated stormwater awareness levels rose over the advertising period. The survey demonstrated a 15% increase in the proportion of citizens who cited "water pollution" as the most important environmental issue in the region. The cost of the 1996 campaign and associated market research was approximately US$802,000 (Lehner *et al.,* 1999). The Puget Sound region covers an area approximately 5,847 km^2, with a population of approximately 2.5 million.

In 2000, a Community Consultation and Promotion Plan was prepared for the Upper Parramatta River Catchment region in western Sydney. The plan sought to raise general awareness of stormwater pollution, communicate benefits of stormwater pollution control,

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40 If 62% of surveyed people claimed to see the advertising, only 32% of these people actually remembered the Victorian EPA's advertising, and of these people, only 30% felt it encouraged them to alter their behaviour, then at best approximately 6% of people *may* have altered their behaviour as a result of their campaign.

41 If this Victorian EPA campaign had been a repeating campaign embedded in a strategic communication framework, rather than a 'once-off' event, it is likely that its impact would have been enhanced (Curnow, 2002; Spehr, 2002).

42 Litter and littering are currently the focus of Statewide stormwater quality education in Victoria. Accordingly, beach littering in the urban area of Melbourne is seen as a surrogate measure for how well these educational messages are influencing people's behaviour.

43 Care is needed when drawing conclusions from this litter count data, as:
- beach usage is highly weather dependent so that the amount of litter measured per year at beaches may be influenced by the weather as well as changes in people's behaviour; and
- counting littered items at a given location is not as reliable as measurement methods that involve observations of littering.

promote specific behaviours, overcome attitudinal barriers to behavioural change and maintain behavioural change (UPRCMT, 2000). The Plan includes itemised costs for various educational strategies/options. These cost estimates are presented in Table 4.20. To place these costs in context, the Upper Parramatta River Catchment is approximately 110 km^2 in area and has a population of approximately 230,000 people (Lees, 2001).

Unit cost information for elements of common education and participation programs (e.g. cost of running a public attitude survey) are also presented in Table 4.21.

An indicative annual cost for a city-wide stormwater-related public education and participation program has been provided by the US EPA (1999), based on actual expenditure in 1997 by the City of Seattle, Washington. For a population of approximately 535,000 people, the City spent US$481,500 on its public education and participation program. This included supplies for volunteers (~4%), communications (~4%), environmental education (~10%), field trips (~11%), teacher training (~1%), equipment (~8%), water interpretive services at two creeks (~19%) and support of youth conservation corps involved with creek rehabilitation (~44%).

Table 4.20 Itemised Costs Associated with Strategies Developed in the Parramatta Region of Sydney to Raise Awareness of Stormwater Pollution and Promote Behavioural Change

EDUCATIONAL ACTIVITY*	APPROXIMATE COST (AUD$)
Editorial services: Five pieces of editorial provided to local newspapers. Costs include research, drafting, liaison with the media, and include disbursements such as photography.	$3,000
Editorial services: One media release forwarded to community radio. Costs include sourcing and briefing a spokesperson and coordinating interviews.	$500
Personalised letters (e.g. to shopkeepers): Costs include the development of a generic letter ($500) and disbursements ($500) but not the time commitment by Council staff involved in the mail out (allow 2 full days).	$1,000
Providing information to shopkeepers: Drafting a generic 'Shopkeeper Kit' and overseeing its production.	$1,500
Providing information to shopkeepers: Drafting two specific supplements to the 'Shopkeeper Kit'	$1,000
Providing information to shopkeepers: Liaison with shopping centre managers.	$1,320
Providing information to shopkeepers: Designing and printing the information kits (200 A4 sized folders with a gloss, colour cover).	$2,800
Educational signage for shopkeepers to display on their premises: Costs include the design and printing of 300 A4 sized gloss board counter stands in four colours with supporting struts ($1,600), and drafting and management costs ($500).	$2,100
Public displays in shopping centres and malls: Costs include production of display materials, including posters and fliers/pamphlets, and the hire of equipment ($500) as well as management fees for coordinating display materials and staffing the display ($1,600). The display would occur in three locations for half a day in each location.	$2,100
Enhancing the exposure of the annual, nationwide 'Cleanup Australia Day' event through the provision of fliers to shopkeepers: Costs include drafting the flier and coordination of their production ($1,000) as well as production and distribution of the flier in limited locations ($300).	$1,300
Development of car 'bumper stickers' to promote improved automobile maintenance: Costs include the design and printing of 1,000 bumper stickers ($1,500), meeting with a local bus and coach association, and placing an editorial in their newsletter ($800).	$2,300
Liaison with community based environmental groups and the provision of campaign information.	$500
Workshops/presentations to specific businesses and premises: Costs include organising and delivering workshops (a total of 3 full days, making presentations to 12 separate businesses).	$6,500
Establishing a free, Stormwater Hotline on an existing phone line ($160 plus $10 monthly rental).	$280 (over the first year)

Notes:

- * These costed items were prepared as *options* for use by Councils in the Upper Parramatta River Catchment in 2000. This catchment is approximately 110 km^2 in area and has a population of approximately 230,000 people (Lees, 2001).
- Note that the campaign was aimed at both residents of the catchment and shopkeepers within commercial districts.

Source: UPRCT (2000).

Table 4.21 Itemised Costs Associated with Typical US Public Education Programs for Stormwater Quality Improvement

EDUCATIONAL ACTIVITY	APPROXIMATE COST	SOURCE
Stakeholder involvement program (includes 4 public and 4 community meetings, direct mail to 20,000 people, staff time and expenses included).	US$15,000	US EPA (2001)
Public attitude survey.	US$15,000 per survey (phone survey of 1,000 people, including questionnaire design and data analysis)	US EPA (2001)
Fliers.	US10¢ - 20¢ per flier	Ferguson *et al.* (1997)
Paint for stormwater drain stencilling.	US25¢ - 30¢ per stencil	Ferguson *et al.* (1997)
Safety vests for volunteers undertaking activities such as stormwater drain stencilling.	US$2.00 per vest	Ferguson *et al.* (1997)
Production of classroom education kits/packets.	US$100 - $200 each	US EPA (2001)
Production of permanent displays and physical models for classroom education.	US$1,000 - $5,000 each	US EPA (2001)
Posters for general community awareness.	US$2.50 each for 5,000	US EPA (2001)
Promotional T-shirts (500 large and 500 extra large, single colour on white, silk screen).	US$2.50 each for 1,000	US EPA (2001)
Promotional caps (one colour).	US$5.00 each for 6,000	US EPA (2001)
Promotional pens (ballpoint, one colour, capped).	US59¢ each for 5,000	US EPA (2001)
Promotional stickers (one colour, 75mm circle).	US7¢ each for 1,000	US EPA (2001)
Promotional magnets (two colour, business card size).	US23¢ each for 1,000	US EPA (2001)

Primary sources: US EPA (1999) & US EPA (2001).

From our survey of 36 stormwater managers throughout Australia, NZ and the US (see Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12), we recorded relative expenditure on city-wide stormwater education. Typically, education and participation programs cost 0.4% - 4.2% of the annual operating budgets for stormwater quality management within leading stormwater agencies that were surveyed.

Education and Participation Programs Involving Lawn and Garden Care Practices

In parts of the US, significant effort has been spent on designing, implementing and evaluating programs to reduce non-point source pollution from residential lawns and gardens. Supporting earlier work by Schueler (2000), the US EPA (2001) reviewed available information on their effectiveness and concluded "from evaluations of several market surveys, it appears that media campaigns and intensive training can each produce up to a 10 to 20 percent improvement in selected watershed behaviours among their respective target populations. A combination of both outreach techniques is probably needed in most watersheds, as each complements the other" (p. 29). What the US EPA did not mention however, was that the 10% - 20% range primarily originates from studies that used *self-reporting* as an indicator of performance without validation of actual behavioural change.

The Chesapeake Bay Residential Watershed Water Quality Management Program (Virginia Cooperative Extension, 2001) was an intensive training program involving recruitment of residents from selected neighbourhoods, lawn care seminars by trained extension agents, home visits and data collection by trained Master Gardener volunteers and demonstration lawns. The program included pre- and post-participation surveys to assess changes in people's attitudes, knowledge and self-reported behaviour.

From 1990 to 2001 approximately 3,600 residents participated in the program in 18 counties and cities in Virginia, with an estimated area of lawn managed through the program in 2001 of 158 hectares.

Results reported by Virginia Cooperative Extension (2001) and Aveni (2002) included:

- Soil testing increased from 25% to almost 100% following participation in the program.
- Composting grass clippings increased from 22% - 54% to 50% - 71% following participation.
- The proportion of people who knew how much fertiliser they applied to their lawn each year increased from 25% to 66% following participation.
- The proportion of people fertilising their lawn during the autumn (as promoted) increased from 55% to 77% following participation.
- The proportion of people who aerated their lawns increased from 12% - 50% to 75% - 100% following participation.
- Estimates derived from self-reported behavioural change data indicated that the load of TN and TP *applied to residential lawns* were reduced by approximately 1 – 2 lb/1,000 square feet/year (49 – 98 kg/ha/year) as a result participation in the program.

The Prince William County Cooperative Extension has also reported results of intensive education and training on lawn care practices in Virginia (see NVPDC, 1996; Lehner *et al.,* 1999; US EPA, 2001). After the first five years of the Water Wise Gardener Program in Prince William County, key results included:

- Substantial changes to levels of knowledge (e.g. an increase in the proportion of participants who linked excessive nutrients with water quality problems from 60% to 86%).
- Substantial changes in attitudes (e.g. an increase in the proportion of participants who considered integrated pest management to be important from 45% to 62%).
- Substantial changes in self-reported behaviour (e.g. an increase in the proportion of participants who said they undertook lawn fertilisation in the recommended season from 50% to 82%).
- An estimated reduction in the average amount of nitrogen, pesticides and water *applied* to participants' lawns by 40%, 25% and 25%, respectively.

Lehner *et al.* (1999) and the US EPA (2001) also estimated that the Water Wise Gardener Program would reduce the load of nitrogen applied to lawns managed by the program's 700 graduates by approximately 20 tonnes over five years. The approximate area and population of the Prince William County is 865 km^2 and 254,000, respectively, and the cost to run the program was approximately US$30,000/year. The program requires approximately 1.5 full time equivalent employees.

The estimated cost to run an intensive lawn and garden care program such as that used in Virginia for an *existing* extension office is approximately US$8,000 - $10,000/year. This equates to approximately US$4.05 – $8.10/ha of managed lawn (Aveni, 2002).

Another example of a major education and participation project focusing on lawn and garden practices is the Lake Harriet Watershed Awareness Project in Minneapolis. This project ran in three phases from 1994 to 1999 (Brown, 2002), aiming to reduce loadings of pesticides and nutrients into Lake Harriet by educating urban homeowners on lawn and garden care practices. The catchment of Lake Harriet is only 461 ha and hosted approximately 6,000 homeowners during the project (Lehner *et al.,* 1999). The project cost approximately US$154,000 from 1994 to 1999 (Brown, 2002) and, unlike many similar campaigns, it had a strong commitment to monitoring and evaluation over several years.

A wide range of educational initiatives and products were implemented within the Lake Harriet catchment, including brochures, a video, a slideshow presentation, billboards, training of Master Gardener volunteers and a homeowner education folder (known as the Green Folder). Monitoring and evaluation activities included event-based stormwater quality monitoring, phone surveys, mail-out surveys, on-ground surveys of lawn care behaviour, telephone interviews, focus group discussions and water quality monitoring in Lake Harriet.

Results included:

- Phase I (1994 - 1995): 72% of homeowners surveyed by phone reported their knowledge had increased about lawn care practices as a result of the information supplied.

- Phase II (1995 - 1997): 29% of respondents to a mail-out survey reported changes to their lawn care practices as a result of the Green Folder educational package. (Note that the response rate to the survey was only 15.5%, and one would expect a proportionately higher response rate from people who were persuaded by the educational material).
- Phase II (1995 - 1997): Approximately 20% of people who participated in a phone interview reported positive changes to their lawn care behaviour.
- Phase III (1997 - 1999): A home owner lawn care survey qualitatively compared self-reported results from the Lake Harriet catchment (like those listed above) to four nearby control catchments. Although the findings were mixed, overall the results indicated better lawn care practices were occurring in the Lake Harriet catchment.
- Phase III (1997 - 1999): In this phase, stormwater runoff quality was analysed from data collected from 1992 to 1996. Reductions of 56% - 86% in event mean concentrations of four of the most common pesticides (lawn care herbicides) were observed between 1992 – 1995 (see Table 4.22). However, event mean concentrations of phosphorus in stormwater actually increased from 1994 to 1996 by approximately 27% (see Table 4.22). The increasing phosphorus runoff concentrations were explained as "due to factors beyond the homeowner lawn care BMPs and is outside the scope of this project" (Brown, 2002, p. 27 of the project's Final Report).

The Florida Yards and Neighbourhoods (FYN) Program is another major US education and participation program that has invested significant effort in evaluating and reporting its performance. The FYN Program is a component of Florida's State-wide Environmental Landscape Management Program (Lofland, 1999; Lehner *et al.,* 1999).

In 1997 the University of Florida compared the outcomes generated from three educational methods used throughout Florida by the FYN Program:

- Master Gardener training (i.e. intensive and interactive workshops for volunteers).
- One to six hour seminars.
- Publications only.

The results are presented in Table 4.23. The primarily conclusion was pre- and post-intervention self-reporting surveys indicate an increase in the average number of best practice lawn and garden management practices that participants say they use for all three program delivery methods over six months, while no significant change was measured in a group of non-participants (Lofland, 1999). As shown in Table 4.23, the highest level of adoption and the greatest increase in desirable behaviours (36%) occurred in participants involved in the intensive and interactive Master Gardener training.

Data on the performance of the FYN Program in 2001 were also available. In 2001 educational initiatives included a web site, educational presentations, involvement in Master Gardener training programs, educational display boards at community events, educational publications, articles in newspapers, demonstration landscapes and educational signage (Haynes, 2002).

In 2001, the FYN Program used homeowner research questionnaires to assess self-reported behaviour prior to, and following, at least four hours of instruction in nine best practice landscaping principles. The post-program survey was mailed to workshop participants six months after their involvement (Haynes, 2002). Reported results from the survey are presented in Table 4.24. In summary, for 20 different lawn and garden care behaviours that have the potential to affect stormwater quality, approximately 21% of the participants (on average) who responded to the survey reported increased use of these behaviours.

It is suggested that, like other surveys of this type, the monitoring results recorded by the FYN Program should be seen as *upper estimates* for the likely change in behaviour that intensive, participatory, and workshop-orientated programs can produce, given:

- It is possible that self-reporting by attendees in this context may be biased towards producing positive results (see Curnow *et al.,* 1991).

Table 4.22 Changes to Stormwater Quality Associated with a Major Lawn Care Educational Initiative in the Lake Harriet Catchment, Minneapolis

STORMWATER POLLUTANT	EVENT MEAN CONCENTRATIONS (µg/l)					% CHANGE
	1992	1993	1994	1995	1996	
Pesticides*						
Dicamba	0.5	0.4	0.2	0.2	-	Decreased by 59% (1992-95)
2,4 - D	1.5	1.6	0.6	0.6	-	Decreased by 58% (1992-95)
MCPP	1.1	1.2	0.8	0.5	-	Decreased by 56% (1992-95)
MCPA	2.4	1.4	0.7	0.3	-	Decreased by 86% (1992-95)
Phosphorus						
Spring phosphorus	-	-	N/A	972	N/A	-
Summer phosphorus	-	-	625	610	724	Increased by 16% (1994-96)
Fall/autumn phosphorus	-	-	401	845	684	Increased by 71% (1994-96)
Average total (phosphorus)	-	-	558	693	708	Increased by 27% (1994-96)

Notes:
- * These four pesticides are all herbicides used in lawn care activities. They were found in 80% of all of the stormwater samples taken (i.e. they are the most common out of the 30 pesticides that were monitored).
- "-" = not reported.

Source: Final Project Report on the Lake Harriet Watershed Awareness Project supplied by Brown (2002).

Table 4.23 The Effect of Different Educational Methods on the Adoption of Lawn and Garden Care Management Practices in Florida

TYPE OF EDUCATIONAL PROGRAM	MEAN NO. OF PRACTICES USED BEFORE THE PROGRAM	MEAN NO. OF PRACTICES ADOPTED (SIX MONTHS AFTER THE PROGRAM)	ADJUSTED NET NUMBER OF ADOPTED PRACTICES*	% INCREASE IN THE NUMBER OF ADOPTED PRACTICES**
Master Gardener program	19.4	7.3	6.9	36%
One to six hour seminars	17.9	4.5	4.3	24%
Publications only	17.1	2.8	2.6	15%
Comparison/control group – no education	13.3	0.1	0.0	0%

Notes:
- * Adjusted means were "generated by the analysis of variance for comparison using Fisher's least significance differences" (Lofland, 1999, p. 289). Lofland (1999) reported that Fisher's least significance difference method "indicated that each [educational] program type differed significantly from other groups in the number of practices adopted" (p. 288).
- ** Derived from the *adjusted* net number of adopted practices and the mean number of practices used before the program.

Source: Lofland (1999).

Table 4.24 Self-reported Behavioural Change Following Education on Lawn and Garden Care Management Practices in Florida

LAWN AND GARDEN CARE ACTIVITIES THAT MAY AFFECT STORMWATER QUALITY	PERCENT INCREASE* (%)
Stormwater runoff	
Directing downspouts (roofwater downpipes) where water can be used by plants/lawn.	24
Using porous/pervious surfaces in the landscape.	26
Using rain barrels (roofwater tanks) for irrigating plants.	12
Using swales to catch and filter stormwater.	20
Site analysis, planting, and landscape design	
Choosing plants based on site conditions.	24
Incorporating low maintenance landscape areas into the landscape.	32
Irrigation	
Watering plant beds and lawns separately.	18
Applying the correct amount of water for each application.	18
Adjusting watering frequency according to rainfall and season.	12
Pest management	
Routinely checking lawn/landscape for pest problems.	20
Applying pesticides only when a pest problem is confirmed.	32
Spot treating problem areas rather than broadcast treating.	22
Avoid practices that encourage pests.	28
Choosing the least harmful pesticides when it was deemed necessary to use them.	16
Fertilisation	
Using slow-release fertilisers.	24
Applying appropriate fertiliser rates.	22
Mowing, mulching and recycling	
Applying appropriate amounts of mulch.	20
Recycling yard waste on sites.	24
Using alternative mulches.	20
Leaving grass clippings on lawn.	14
Summary for all 20 selected lawn and garden care activities	Mean = 21% Range = 12% - 32%

Notes:

- * This column lists the percentage of respondents to a survey that reported that they had increased their use of this BMP.
- These results were measured by a pre-workshop survey and a post-workshop survey that was mailed out to participants six months after their involvement.
- The pre- and post-workshop survey results given above represent *matched* results from 50 questionnaires.
- The workshops involved a minimum of four hours of instruction in the nine environmentally friendly landscaping principles promoted by the Florida Yards and Neighbourhoods Program.
- The survey's response rate is unknown.
- Note that the majority of survey respondents reported that the above practices saved them time on their yard work (i.e. 88% of respondents), as well as money on their water bills (i.e. 76% of respondents), pesticides (i.e. 68% of respondents) and fertilisers (66% of respondents).

Source: Haynes (2002).

- The use of a post-program mail-out survey returned by only *some* of the participants may produce a bias towards positive results.
- Adoption rates of BMPs are likely to reduce over time unless substantial changes have been made to the framework within which the behaviour occurs. For example, BIEC (1999) found that the use of anti-littering signs produced a short term change in littering behaviour, however this effect was only sustained if changes to litter-management infrastructure also occurred (e.g. the provision of litter and recycling bins).

The Naturescaping for Clean Rivers Program in the Portland metropolitan area of Oregon also measured changes in self-reported behaviour (Lehner *et al.,* 1999). The program educated citizens about resource-sensitive gardening practices (e.g. the use of native plants and natural landscapes) and involved a demonstration site, workbooks, booklets, information brochures, presentations and interactive workshops.

In 1996, 220 residents attended the Clean Rivers Program's workshops. An independent survey of workshop participants conducted the following year found:

- On average, respondents reported changing their behaviour in 7.6 of the 19 subject areas (i.e. 40%) covered by the workshops.
- 75% of respondents said they had added native plants to their gardens following the workshops.
- 49% of respondents said they had reduced their area of lawn following the workshops.
- 33% of respondents said they had reduced their lawn coverage by ≥10% following the workshops.
- 53% of respondents said they had started or increased their use of composting following the workshops.
- 27% of respondents said they used less or no fertilisers following the workshops (Lehner *et al.,* 1999).

The Centre for Watershed Protection (1999) investigated the performance of communication strategies to reduce the quantity of nutrients draining from residential areas into Chesapeake Bay in Virginia and Maryland. Its work included identifying communication methods preferred by residents of the Chesapeake Bay catchment, used by 50 US stormwater managers from around the nation and deemed most effective by the same US stormwater managers. It also gathered some information on the cost of urban nutrient prevention programs using educational and participatory methods.

As part of their survey of residents in Chesapeake Bay, the Centre for Watershed Protection (1999) found only 36% of respondents indicated that they had obtained advice or information on lawn management issues such as fertilising (a major source of nutrients in the region). Of those who had received advice on lawn care, 48% reported making "some changes" to the way they cared for their lawn, while 13% of respondents reported "significant changes".

Table 4.25 presents the Centre for Watershed Protection's (1999) findings from a brief review of communication methods in eight US urban nutrient management programs. The Table indicate the methods most likely, in the view of the target audience, to influence their behaviour. The data indicate that typically, residents believe communication methods such as television and newspaper advertisements are more likely to be effective than methods such as brochures, meetings and videos.

Figure 4.1 presents the data gathered by the Chesapeake Bay survey on communication methods preferred by residents as a good means to attract their attention. Also plotted on this graph are data on communication methods found to be most used, and deemed to be most effective, by US stormwater managers. The data on use and perceived effectiveness were gathered from a survey of stormwater and catchment managers from 50 US nutrient management programs.

Figure 4.1 shows significant differences between communication methods preferred by Chesapeake Bay citizens and those used in 50 US nutrient reduction campaigns. For example, brochures and training workshops are the most widely used communication methods, but score a moderate to low rating in terms of the community's preference (i.e. a score ≤ 5 out of 10). Similarly, there are significant differences between methods most frequently used by stormwater managers and those deemed most

Table 4.25 The Relative Effectiveness of Methods to Communicate Catchment Management Messages (As Ranked by US Residents)

US SURVEYS AND SOURCES	COMMUNICATION METHODS RANKED BY DEGREE OF INFLUENCE MOST INFLUENCE ◄							► LEAST INFLUENCE
Chesapeake Bay, Maryland and Virginia (CWP, 1999)	TV	TV Ad	Newspaper	Local Paper	Video	Brochure	Local Cable TV	Meeting
Washington (Elgin, 1996)	TV Ad	TV	Newspaper	Radio Ad	Brochure	Radio News	Paper Ad	Billboard
Oregon (AMR, 1997)	Direct Mail	TV Ad	Newspaper	Radio	TV	Bill Insert	Newsletter	Local Paper
California (Assing, 1994)	TV Ad	Stencils	Billboard	Local Paper	Brochure	Radio Ad	Bus Sign	DirectMail
California (PRG, 1998)	TV	Newspaper	Radio	Magazine	Neighbours	School	Billboard	Brochure
Michigan (PSC, 1994)	TV	Newspaper	Cable TV	Local Paper	Newsletter	Video	Meeting	Brochure
Wisconsin (Simpson, 1994)	TV	Newspaper	Newsletter	Brochure	Site Visit	Video	Meeting	-
Minnesota (Morrisand Traxler, 1996)	Direct Mail	Direct Mail	TV	Neighbours	Extension Service	Radio	Meeting	Local Cable TV

Source: CWP (1999) and Schueler (2000).

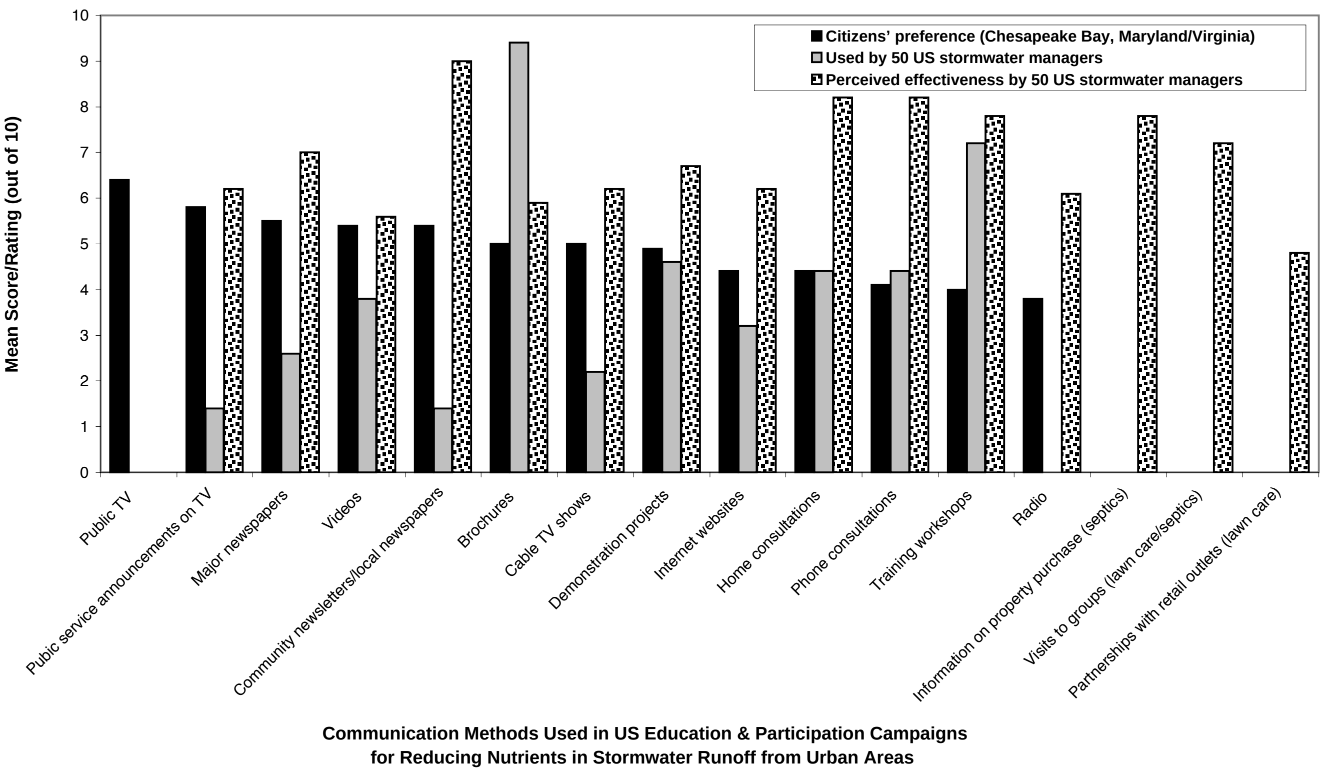

Figure 4.1 Communication Methods Preferred by Residents of Chesapeake Bay, Most Used by US Stormwater Managers, and Deemed to be Most Effective by the Same US Stormwater Managers (CWP, 1999)

effective by the same stormwater managers. For example, public service announcements on television, major newspapers and community newsletters have a low degree of use (i.e. a score < 3 out of 10) but a high degree of perceived effectiveness (i.e. a score > 6 out of 10).

The survey of stormwater and catchment managers also obtained some information on costing. The Centre for Watershed Protection (1999) found the annual budgets of most US urban nutrient education programs to be "quite small". That is, 58% of programs had an annual budget no greater than US$25,000.

Combined Stormwater Education Campaigns for Residential, Commercial and/or Industrial Areas

Sydney's Mosman Municipal Council launched an education campaign in 1999-2000 to improve stormwater awareness of residents and operators of retail food outlets in the Balmoral region. The campaign included an environmental audit program for local food businesses, an environmental management booklet, stormwater drain stencilling, fact sheets, local newspaper advertisements, display boards and media coverage associated with the installation of structural stormwater quality BMPs (Pickering, 2002). In addition, the NSW EPA ran a complementary media campaign (e.g. television and bus shelter advertisements) targeting stormwater pollution and littering in the time between the pre- and post-program surveys, which were used to evaluate the overall effectiveness of the campaign (TRC, 2000).

The potential audience for the local campaign was approximately 26,000 residents and 258 local food businesses. The educational elements of the program cost approximately AUD$18,925, while the evaluation cost approximately AUD$24,805 (Pickering, 2002).

Results from the residential survey (TRC, 2000) were generally positive, finding:

- A rise of 8% in the proportion of surveyed residents saying they were concerned "a great deal" or "a fair amount" about stormwater pollution (i.e. from 74% to 82%).
- A rise of 3% in the proportion of surveyed residents who could give a general definition of stormwater (i.e. from 91% to 94%).
- A decrease of 8% in the proportion of surveyed residents who said they did not know where stormwater goes (i.e. from 19% to 11%).
- A rise of 23% in the proportion of surveyed residents aware of the Mosman Municipal Council's activities to reduce stormwater pollution (i.e. from 34% to 57%).

Results from the retail food outlet survey (TRC, 2000) were mixed but generally disappointing, finding:

- A rise of 17% in the proportion of surveyed food outlet personnel saying they were "not at all" concerned about stormwater pollution (i.e. from 3% to 20%).[44]
- A rise of 25% in the proportion of food outlet personnel who said dropping cigarette butts should be punishable by law (i.e. from 70% to 95%).
- No change in the proportion of surveyed food outlet personnel who were aware of the Mosman Council's activities to reduce stormwater pollution.

In 1999-2000 a stormwater awareness campaign was implemented in the Girraween Industrial Estate and the St. Martins Mega-Centa (a commercial shopping centre with a high percentage of retail food outlets) in the Upper Parramatta River Catchment, western Sydney. Initiatives included a combined golf day and workshop, posters, pamphlets, newsletters, drain stormwater stencilling, billboards, educational site visits, an Internet site and award ceremonies (Matthews and Meynink, undated).

Changes in levels of self-reported awareness, beliefs and behaviour were measured by pre- and post-intervention surveys. The findings are presented in Table 4.26. Overall, the results indicate the campaign was associated with an increase in knowledge of some stormwater issues by 8% – 15%, and an increase in the proportion of respondents believing stormwater management saved them time and money by 0% -

[44] Care is needed in the interpretation of such results. For example, it is possible that the surveyed respondents were voicing displeasure with the auditing program or even the evaluation process. Where such negative results occur, they should quickly prompt a thorough investigation to determine the cause of the result and how the situation can be rectified (Curnow, 2002; Spehr, 2002).

Table 4.26 Measured Outcomes from an Educational Campaign in Western Sydney Involving an Industrial Estate and a Commercial Complex

OUTCOME BEING EVALUATED	QUANTITATIVE INFORMATION ON THE EFFECT OF THE CAMPAIGN ON STORMWATER AWARENESS AND/OR SELF-REPORTED BEHAVIOUR*	
	GIRRAWEEN INDUSTRIAL ESTATE	ST. MARTINS MEGA-CENTA (COMMERCIAL SHOPPING COMPLEX)
Awareness of local stormwater issues and stormwater management practices	91% of respondents said that the educational program had helped to heighten the awareness of proprietors at the estate (no baseline was recorded). There was a rise of 8% in the proportion of respondents who knew where stormwater drains to (i.e. from 63% to 71%).	80% of respondents said that the educational program had helped to heighten their awareness (no baseline was recorded). There was a rise of 15% in the proportion of respondents who knew where stormwater drains to (i.e. from 65% to 80%).
Belief in the educational message	There was a rise of 10% in the proportion of respondents who believed that stormwater management saved them time and money (i.e. from 55% to 65%).	There was no change in the proportion of respondents who believed that stormwater management saved them time and money (i.e. steady at 60%).
Feelings toward stormwater management	91% of respondents felt positively about stormwater management (no baseline was recorded).	80% of respondents felt positively about stormwater management, stating that stormwater management is an important consideration in their business (no baseline was recorded).
Adoption of stormwater management practices	63% of respondents reported that they had adopted stormwater management practices in their workplace to minimise spills and stormwater pollutants (no baseline was recorded).	60% of respondents reported that they had adopted stormwater management practices through spill and waste plans (no baseline was recorded).

Note:

- * Caution is needed when interpreting results from *self-reported* surveys (as opposed to the measurement of actual behavioural change).

Source: Matthews and Meynink (undated).

10%. However, care is needed in interpreting the awareness data, as during the surveys respondents were asked questions such as "do you believe the education program has helped to increase your awareness regarding stormwater management?" (Matthews and Meynink, undated, p. 10), rather than testing whether their knowledge had *actually* changed through specific questions (e.g. "what specifically can you do to stop stormwater pollution?").

As briefly outlined in Section 4.3.3, Smith (2002a and 2002b) and Smith and Simmons (2002) reported *preliminary* results from a study of a small (11.2 ha) industrial estate in Manly, Sydney, that included an evaluation of the effectiveness of industry education and auditing as non-structural BMPs to promote improved house-keeping practices and to reduce stormwater pollution.

An educational program was run from March 2001 to March 2002 involving face-to-face discussions with operators of premises within the industrial estate, audits and promotion of improved house-keeping practices such as material handling and stockpiling. An Education Officer was appointed for 12 months to undertake this work. Consequently, substantial opportunities were taken by the occupants of the estate to improve the management of material storage. For example, in one of the estate's three sub-catchments, 1,260 m^2 (or 21% of the total area) was converted from an uncovered area used for stockpiling to a roofed area. The approximately cost of education and auditing activities over 12 months was AUD$70,000 (McManus, 2002).

At the time of writing, the study was still examining the comparability of the rainfall and runoff events monitored before and after the implementation of the BMPs, in terms of rainfall intensity, build-up period, etc. Assuming the eight rainfall/runoff events monitored before the implementation of the BMPs are comparable in nature with the eight events monitored after the implementation of the BMPs, reductions in annual pollutant loads that can *potentially* be attributed to education, auditing and better industrial housekeeping are:

- 8% for TSS.
- 40% for TN.
- 49% for TP.
- 42% for copper.
- 72% for lead.
- 83% for zinc.

Another Australian industrial education project evaluating its impact on water quality is the Old Joe Flows On Project in Melbourne. This project involved 40 small to medium automotive businesses gathering every two months and undertaking two environmental audits between October 2001 and July 2002 (Sinclair, 2001). Waterway health monitoring in two downstream waterways was undertaken by Waterwatch, a community-based group. The waterway health monitoring program was very basic, involving the measurement of:

- electrical conductivity and ortho-phosphate concentrations at five sites, on four occasions and over one year (winter 2000 to winter 2001); and
- macroinvertebrates assemblages at five sites, on three occasions and over six months (summer 2001 to winter 2001).

The water quality monitoring results for 2000-01 (Sinclair, 2001) indicated:

- Electrical conductivity in Old Joe's Creek and Dandenong Creek (the receiving waters) generally became worse over the period of monitoring, but with no obvious trends being observed at the site on Old Joe's Creek immediately downstream of the industrial estate.
- Ortho-phosphate concentrations in Old Joe's Creek immediately downstream of the industrial estate rose steadily from approximately 0.03 mg/l in the winter of 2000 to approximately 0.175 mg/l in the winter of 2001.
- A Stream Pollution Index was used to present the collected macroinvertebrate data. This index was in the "poor" range of 0 - 4 for all sites and at all times during the monitoring program. The index scores for Old Joe's Creek immediately downstream of the industrial estate were approximately 2.4 (summer 2000-01), 0 (autumn 2001), and 1.3 (winter 2001). Hydrocarbon discharges were thought to be responsible for the absence of macroinvertebrates in the autumn of 2001 immediately downstream of the industrial estate.

Given the rudimentary nature of this monitoring program, only very large, short-term changes to water quality and/or waterway health would have been detected. Certainly no positive trends were observed, while there is some weak evidence to suggest water quality and waterway health may have declined during and shortly after the industry education program. The only firm conclusion that can be drawn from these data is that monitoring water quality and/or waterway health to reliably detect the effects of typically subtle changes in behaviour as a result of an educational project is fraught with difficulty. To undertake such monitoring typically requires considerable program design expertise and expense (see Report No. 4 in this series, CRC for Catchment Hydrology Working Document 02/6 for guidance on this issue).

Stormwater Education and Participation Campaigns Involving Commercial Shopping Centres

Morison and Hargans (2002) reported on a multi-faceted education and participation campaign to reduce stormwater pollution around a shopping mall in western Sydney, NSW (i.e. the 16 ha Mt. Druit Shopping Mall). Strategies included a media campaign (e.g. press releases), stormwater drain stencilling, in-store display panels, car bumper stickers, a colouring-in competition, an in-store treasure hunt, a promotional event involving a rain simulator and pollution prevention plans for retailers.

Overall, the non-structural BMPs cost approximately AUD$64,000, staff time and reporting approximately AUD$95,000, associated capital (structural) works approximately AUD$230,000 and monitoring, evaluation and project management approximately AUD$175,000, for a total cost of approximately AUD$0.5M (Morison, 2002).

Evaluation of the project involved pre- and post-program surveys and statistical analysis of the results (rarely done for this style of evaluation). Key findings reported by Morison (2002) and Morison and Hargans (2002) include:

- An increase of 5.4% of respondents reporting that litter ends up in waterways (i.e. from 20.5% to 25.9%). The association between participation in one or more educational strategies and believing that litter ends up in waterways was found to be statistically significant (Chi Squared Test: χ^2 = 14.24, p<0.05).[45]

- When the views of participants who saw or took part in at least one of the educational strategies were compared with the views of participants who did not, there was an increase of 9.7% in the proportion of surveyed shoppers who thought that stormwater runoff from residential areas was the biggest source of local water pollution (i.e. 26.5% compared to 16.8%). The association between taking part in one or more educational strategies and believing the stormwater runoff from residential areas was the biggest source of local water pollution was statistically significant (Chi Squared Test: χ^2 = 9.60, p<0.05).
- Participants who had heard of the stormwater project reported picking up someone else's litter more frequently during the last year (on average). Using a four point scale from 1 ("never") to 4 ("always"), the mean score for those that had heard of the project was 2.52, compared to the mean score for those that had not heard of the project which was 2.06. A one-way analysis of variance was used to confirm that the difference between these means was significant (ANOVA: F = 9.71 and p<0.01).
- Seeing the stormwater drain stencils was positively correlated with understanding the basic educational messages that were communicated during the campaign (Pearson's correlation: r = 0.21, p<0.05). These messages included what types of activities pollute stormwater, where it flows to, etc.
- Participants in the pirate treasure hunt[46] said they encouraged others not to litter on average more than those who did not participate. Using a four point scale from 1 ("never") to 4 ("always"), the mean score for those that participated in the pirate treasure hunt was 3.04, compared to the mean score for those that had not been involved which was 2.55. A one-way analysis of variance was used to confirm that the difference between these means was significant (ANOVA: F = 4.47 and p<0.05).
- No significant associations were found between those participating in the colouring-in competition and improved attitudes or self-reported behaviours towards littering and stormwater management.

The Mt. Druit Shopping Mall study concluded that overall "those in the post-education group who saw or took part in one or more strategies revealed better attitudes and [self-reported] behaviours towards the environment, littering and pollution than those from the pre-education group who did not see or take part in any of the strategies" (Morison and Hargans, 2002, p. 21). However, care needs to be taken not to mistake association with causation (e.g. people with pre-existing positive attitudes towards environmental management may be more strongly attracted to the participation events and therefore disproportionately represented in the 'participants group').

Education Campaigns Involving Non-residential Premises

Laris (2001) reported on the effects of the South Australian Be Stormwater Smart (BSS) Project. The primary goal of the project was to reduce stormwater pollution by raising awareness about stormwater issues particularly in the commercial, industrial and local government sectors. Pollution Prevention Project Officers within each of the host Councils visited non-residential premises (e.g. small to medium-sized businesses) to promote practices to minimise stormwater pollution. No enforcement activities were involved.

As of mid April 2001, 319 premises had been visited at least once, with sufficient funding to allow 20 - 30 sites to be visited each quarter (Laris, 2001). The annual running cost was approximately AUD$180,000, not including in-kind support from three host Councils (Labaz, 2002).

The effect of the project on the levels of awareness, self-reported behaviour and actual behaviour of participants was evaluated through telephone surveys, face-to-face and telephone interviews and site assessments. To the credit of those involved, the evaluation strategy included the validation of *self-reported* behavioural changes, involving a number of

45 See Morison and Hargans (2002) for details of the statistical analysis.

46 The aim of this activity was to establish a trail that school-aged children could follow through the Centre, learning about stormwater pollution as they progressed (Morison and Hargans, 2002)

site visits after the telephone survey. Major findings reported by Laris (2001) included:

- Fifty eight percent (58%) of all businesses responding to the survey reported making at least one change to their business practices to prevent stormwater pollution, with:
  - 40% of respondents reporting that they had made changes to the storage of materials.
  - 34% of respondents reporting that they had made changes to waste disposal practices.
  - 26% of respondents reporting that they had made changes to staff training.
  - 29% of respondents reporting that they had made changes to environmental management systems.
- Forty four percent (44%) of businesses demonstrating "satisfactory" results during previous site visits reported at least one change to their stormwater management practices during the telephone survey.
- Ninety three percent (93%) of businesses demonstrating "unsatisfactory" results during previous site visits reported at least one change to their stormwater management practices during the telephone survey. This significant finding has been broadly supported by post-project audits which found that the vast majority of businesses who reported making improvements, did so (see below).
- Thirty one (31) businesses demonstrating "unsatisfactory" results during previous site visits and reported making at least one change to their stormwater management practices were visited to confirm that improvement *actually* occurred. The visited sites were given a score of 1 to 5 (where 1 was non-compliance and 5 was total compliance). Fifty-two percent (52%) of the visited sites were found to be in total compliance, 6% were found to be non-compliant, and the average score out of 5 was 3.9. These results were interpreted by Laris (2001) as confirming the general validity of self-reported behavioural change measured through the project's telephone survey.[47]
- Five proprietors who demonstrated "unsatisfactory" results during previous site visits and reported making at least one change to their stormwater management practices were interviewed and visited after the educational campaign. The degree of compliance by these premises was scored from 1 to 10 (where 1 was non-compliance and 10 was total compliance). Forty percent (40%) of the visited sites were found to be in "total compliance, 80% were scored ≥5 out of 10, and the average score was 6.8 out of 10. Again, Laris (2001) broadly interpreted these results as confirming the general validity of self-reported behaviour measured during the telephone survey.

Overall, the project concluded that it was successful in changing behaviour and, in particular, "the great majority of businesses visited by the project and initially assessed as unsatisfactory do make significant changes towards compliance" (Laris, 2001, p. 7). The project is an important one, as it is one of very few projects in the literature that makes a sound attempt to validate self-reported behaviour and is able to convincingly demonstrate that positive behavioural change occurred.

City-wide Anti-littering Awareness/Education Campaigns

A city-wide stormwater awareness campaign in Brisbane, Queensland, focused on litter and littering. The If You Miss the Bin, You Hit the Bay Campaign ran for approximately six months from April 2001 and included a range of communication mechanisms (e.g. posters on bus shelters, press advertisements, street posters, articles in local newspapers and community service announcements on commercial

47 This result, albeit a generalised one, conflicts with other studies that have found self-reporting to be a very poor indicator of actual behaviour (e.g. BIEC, 1997b and 1999). It is suggested that the accuracy of self-reporting as a measurement tool is likely to be issue specific, as well as being dependent on the nature of respondents and the context of the evaluation. The importance of context is supported by Reeve *et al.* (2000) for littering research who stated "a widely acknowledged problem with studies using interviews is the willingness of the person being interviewed to express 'socially correct' rather than honest attitudes (see McGregor Marketing, 1994)" (p. 7). McGregor Marketing (1994) promote 'non-threatening' group discussions to minimise this effect. Unfortunately, as noted by Curnow (2002) and Spehr (2002) such discussions may still lead to misleading findings due to group dynamics influencing how some participants respond to questions (e.g. young, 'blue-collar' males, overemphasising their littering behaviour).

television). The campaign specifically targeted geographical litter hotspots and users of recreational areas, public transport and business zones (Brisbane City Council and Queensland Government, 2001).

The campaign cost approximately AUD$194,000, comprising project management (11%), creative design work (29%), placement of advertisements (59%) and market research (1%). The campaign's coverage was approximately one million people within the metropolitan Brisbane region (Chandler, 2002).

Three random telephone surveys of 302 - 402 adult residents were undertaken to determine the campaign's effect on awareness of littering and stormwater in general. The surveys were undertaken before, during and shortly after the campaign (AC Neilsen, 2002). Key findings were:

- Unprompted awareness of litter advertising dropped by 3% at the start, with 27% of respondents having seen or heard advertising relating to litter prior to the campaign, compared to only 24% during the campaign. No post-campaign results were gathered for this aspect.
- Prompted awareness of the litter advertising message increased by 14% at the end of the campaign, with 36% of respondents during the campaign believing they had seen the advertising, compared to 50% after the campaign. No pre-campaign results were gathered for this aspect.
- Shortly after the campaign, 83% of respondents who believed they had seen the advertisements (when prompted) thought they were now a "lot more conscious of disposing of litter properly so that does not end up in the River/Bay". No pre- or during-campaign results were gathered for this aspect.
- Shortly after the campaign, 88% of respondents who believed they had seen the advertisements (when prompted) thought that they were now "more aware of the effect littering can have on wildlife within the River/Bay". No pre- or during-campaign results were gathered for this aspect.

Caution is needed when interpreting these results, as all of the survey's positive results are associated with *prompted* questioning and untested, self-reporting of changes in awareness and knowledge.

Local Anti-littering Awareness/Education Campaigns

An example of a small, localised campaign to reduce litter on the beaches of Melbourne, Victoria, was the City of Port Phillip's beach litter patrols, which were part of its Summer-in-the-City campaign in 2000-01. To the credit of those involved, despite the small size of the program and limited success, it was well evaluated and reported.

This campaign aimed to reduce littering on the City of Port Phillip's beaches. Beach litter patrols were used as an education strategy along with a limited mass media campaign (Community Change, 2001). The Council officers involved in the beach patrols talked with beach users about the issue and promoted various anti-littering behaviours. No enforcement was involved. The beach litter patrols ran for approximately two months at a cost of approximately AUD$3,000 (Forster, 2002). Associated promotional activities cost approximately AUD$3,000 (Forster, 2002).

The performance of the campaign was measured by an observational approach. Specifically, the Disposal Behaviour Index (DBI) was used[48]. The DBI monitoring methodology is powerful, as it enables comparisons between what people say they do with what they actually do, with respect to littering, binning and recycling.

The evaluation strategy included measuring the DBI at the beach litter patrol locations and at control sites before, during and shortly after the campaign. The conclusion was that "while the research project contained a number of confounding variables, it did not find evidence of a positive impact of beach litter

48 The Disposal Behaviour Index (DBI) is an "objective, mathematical measure of all the environmentally desirable disposal behaviours found for a specified site and observation session" (BIEC, 2001, p. 80). The DBI, the Littering Behaviour Index (LBI) and the Clean Communities Assessment Tool (CCAT) are observational approaches used in Australia for measuring the effect of anti-littering BMPs. The LBI is defined as "a measure of the amount of littering in a specified site for an observation session; focused on negative behaviour and used as a proxy measure for the DBI" (BIEC, 2001, p. 80). The CCAT is a simplified and more widely accessible method that uses both observations and litter counts and has been designed to be used by trained stakeholders such as local government authorities (Curnow, 2002). The LBI and CCAT methods are however, not as robust as the DBI (Curnow, 2002).

patrols on people's behaviour. It appeared that simply talking to people on the beach did not adequately raise awareness of the importance of litter prevention to the extent expected" (Community Change, 2001, p. 34).

One of the reasons put forward for the failure of the beach litter patrols to significantly change littering behaviour was that the level of engagement of the community was not high. Referring to the findings of another Melbourne-based litter study conducted in the City of Banyule (i.e. the Conversations About Litter Program), Community Change (2001) concluded "the level of engagement of community members is critical to successful outcomes from interventions involving the community" (p. 34).

Stormwater Drain Stencilling

The marking of stormwater drain inlets in public places with educational symbols and messages (e.g. "Dump no waste – flows to creek") is a common educational strategy in Australia and overseas. Some studies have reported a positive correlation between seeing the stencils and levels of stormwater awareness/knowledge (e.g. Morison and Hargans, 2002), but no studies were identified that demonstrated stormwater drain stencilling raises people's awareness or induces behavioural change.

Cost estimates associated with stormwater drain stencilling programs include:

- Brisbane City Council in Queensland manages a program that allows community groups to access 10 stencilling kits for an urban area with a population of approximately 864,000. The initial program establishment cost was approximately AUD$1,310 (including staff time). The approximate cost per kit was AUD$95, with kits needing replacement every five years. The approximate annual maintenance cost of all the kits is AUD$600, not including cleaning costs, which depend on the degree to which the stencils are used (Mette, 2002).
- A grant of US$4,500 allowed the University of Nevada Cooperative Extension group and a local, non-profit river advocacy group to jointly establish and run a major stencilling project for two years in Reno, Nevada (Cobourn, 1994).
- The total cost of implementing a stencilling program in Puget Sound, Washington, was US$2,644, including materials and labour (US EPA, 1997).
- A comprehensive stencilling kit was estimated to cost US$36.90 (NVPDC, 1996 quoting information from Denver, Colorado).
- The Northern Virginia Soil and Water Conservation District reported the initial cost of making a stencil was US$300 but subsequent stencils cost only US$20 each to produce (NVPDC, 1996).
- The US EPA (2001) reported that permanent drain signs were a more expensive alternative to traditional stencilling techniques using paint. Ceramic tiles can cost US$5 - $6 each, while metal plaques cost at least US$100 each.

Stormwater Education Through Signage

The Beverage Industry Environment Council (BIEC, 1997a) reviewed literature concerning the effect of signage on littering behaviour and discovered conflicting findings. For example, some researchers found a wide variety of signage reduced littering (e.g. Durdan *et al.,* 1985), while others found reductions in littering around signage was a short-term phenomenon (e.g. Reiter and Samuel, 1980).

Researchers have examined the relationship between the wording of signage and littering behaviour (e.g. the relative effect of messages that were positive, polite, etc.). Of seven research studies summarised by BIEC (1997a), five found littering behaviour was affected by the nature of signage.

The effect of signage on littering in Australia was evaluated during a 1997-98 research study in Sydney (BIEC, 1999). Using a combination of litter surveys, bin audits, observations and attitude surveys, the study found signage was associated with an immediate reduction in littering. These effects were relatively short lived, unless other anti-littering strategies were adopted to support the effect of signage. Specifically, the BIEC (1999) study found that when signage was used as the only anti-littering strategy in a given area, the percentage of littered waste materials immediately dropped from approximately 44% (baseline) to 30%, but by the end of the 8-month project, this percentage had risen to approximately 43%.

Anti-littering signage, new street litter bins and recycling facilities were also applied in combination as part of the 1997-98 research study in Sydney (BIEC, 1999). Four months after implementation, below-baseline littering rates were observed. Littering rates were measured by the DBI. As mentioned previously, the DBI is an index that combines observed negative behaviours (e.g. littering) with positive behaviours (e.g. binning). On the DBI scale of 0 to 7 (where 7 is ideal), DBI scores increased at four intervention sites by 0.5 – 3 points over the course of the study. Consequently, the BIEC (1999) study concluded "a combination of strategies for reducing litter need to be implemented for the maintenance of gains" (p. 66).

Stormwater Education Through Theatre Productions

Victoria's City of Banyule undertook a community participation initiative in 2000-01 known as the Conversations About Litter program (BIEC, 2001). The program involved live performance, street theatre and interactive discussions. Using the DBI to measure the program's effect on littering, the Beverage Industry Environment Council (2001) concluded "overall, DBI results showed that there was a direct and immediate effect on people's disposal behaviour when they were engaged in awareness raising activities" (p. 74).

A stormwater education initiative using theatre as a communication mechanism was implemented in Dubbo, NSW, in 2000-01. The initiative involved a major theatrical production called Storm Warning, as well as impromptu street theatre elements (McLeod, 2002). The initiative ran over eight months at a total cost of AUD$50,200 (Tickle, 2002). More than 8,000 people saw the theatre performances during May 2001.

The primary aim was reportedly to change people's *attitudes* through education (McLeod, 2002). However, an attempt to evaluate the program was made through annual stormwater *awareness* surveys. Residents were asked to see if they could recall the Storm Warning program and, if so, its message (Tickle, 2002). Unfortunately, results of the awareness survey could not be used to determine whether community awareness was raised or not (Tickle, 2002). Despite this, some staff of the Dubbo City Council are confident, based on anecdotal evidence, that the program raised awareness.

Stormwater Education for Pet Owners

Encouraging pet owners to collect, contain and appropriately dispose of pets' waste to prevent stormwater pollution is a common educational activity in densely populated urban areas.

The NVPDC (1996) documented an attempt to calculate the potential reduction of non-point source pollution as a result of a hypothetical public educational campaign on the management of pet waste in public areas. It assumed that, initially, 15% of pet owners undertook sound management practices, while 20% of pet owners allowed their pets' waste to be discharged *directly* to the stormwater drain. A year later it was assumed that an educational program produced a 5% increase in the proportion of pet owners undertaking sound management practices and a 10% decrease in the proportion of pet owners allowing pets' waste to be discharged *directly* to the stormwater drain. The NVPDC calculated the hypothetical educational program would reduce the amount of faecal matter reaching local waterways by approximately 37% (see NVPDC, 1996 for calculations).

Stormwater Education and Participation Programs Involving Car Washing

Kitsap County in Washington manages the Sound Car Wash Program that aims to educate residents about avoiding stormwater pollution from car washing (US EPA, 2001). The program requires 10 to 15 hours a week of staff time over a 25-week period, as well as US$1,500 - $3,000 in equipment and expenses over the same period (US EPA, 2001).

The Clean Bay Car Wash Kits Program is run in Tacoma, Washington, where the use of car washwater collection devices is strongly promoted. It costs the Tacoma Stormwater Utility approximately US$2,000 in expenses and less than two weeks of staff time to manage the program each year (US EPA, 2001).

Stormwater Education and Participation Programs Involving Composting

The promotion of composting as a garden management practice in residential areas can help to minimise stormwater pollution (e.g. by minimising the need to apply soluble, inorganic fertilisers). The Texas Natural Resources Conservation Commission

(TNRCC) promoted residential composting through a Master Composter program involving training, mentoring, and informing individuals through workshops, presentations and demonstration sites. In 1995 the program trained 116 Master Composters in Texas, who provided at least 3,951 individuals with composting information (Lehner *et al.,* 1999).

A survey of attendees at the Master Composter courses found:

- Of those who did not compost prior to the training sessions, 88% reported doing so after the training.
- Of those who previously disposed of organic materials via the domestic waste collection service, 100% said that they stopped this practice after training.
- Of those who applied fertiliser on their lawns, 70% said they reduced the amount after training.

The TNRCC used a similar approach to educate officials from local governments in the region. Surveys after the composting training courses indicated that 30% of respondents reported using less fertiliser after training. In addition, of those municipalities without a centralised composting program prior to the training, 50% said they developed one after a representative had attended the training (Lehner *et al.,* 1999).

Stormwater Education Programs Involving the Maintenance of Septic Systems

Programs to educate homeowners about the proper operation and maintenance of septic systems is common in un-sewered urban areas with water quality concerns. The US EPA (2001) summarised costs associated with three educational programs for owners of septic systems:

- The City of Olympia in Washington managed a program that involved the use of brochures, training workshops and septic system monitoring. The cost of the program was US$40,000 per year and 0.5 full-time equivalent staff were required.
- Thurston County in Washington managed a program that involved the use of brochures, training workshops, and discount coupons for septic maintenance. The program cost US$35,000 per year and 0.5 full-time equivalent staff were required.
- The Minnesota Cooperative Extension managed a program involving a variety of publications, videos, training workshops, conferences for policy makers and a Train the Trainer program. The cost was US$18,000 per year and 0.25 full-time equivalent staff were required.

Stormwater Education Programs to Achieve Secondary, Long-term Benefits

Education campaigns often precede and help to trigger major developments such as the establishment of a self-sustaining funding mechanism for city-wide stormwater management, a specialist stormwater management agency or an enforcement program. Typically, such campaigns aim to raise awareness and support in the general community as well as educate local politicians.

An example of a successful stormwater awareness campaign that led to the establishment of a county-wide stormwater utility[49] occurred in Prince William County, Virginia. This County now has a US$2.2 million annual budget for stormwater management serving a population of approximately 254,000 across approximately 865 km^2 (Lehner *et al.,* 1999). Lehner *et al.* (1999) reported "this level of stormwater pollution funding is extraordinary in Virginia, and was obtained only after an effective education campaign" (p. 7-16).

Findings from Similar Research Involving Water Conservation Campaigns

Household water conservation is a closely-related area of the urban water cycle where education campaigns are widely used as a tactic to change behaviour. Syme *et al.* (2000) reviewed the literature on attempts to evaluate information campaigns to promote voluntary household water conservation. It is suggested that this research is relevant to stormwater pollution prevention education, given the similarities between the nature of behavioural change being sought by stormwater pollution managers and water supply managers. For example, education campaigns that promote xeriscaping (resource

49 The term 'utility' is used in the US to describe a dedicated source of funding for stormwater pollution prevention activities where users pay a fee based on land-use and their contribution to runoff that enters the stormwater system (Lehner e*t al.,* 1999).

sensitive landscaping) in residential areas could equally be a part of a water conservation program or an urban stormwater pollution prevention program.

One could argue there are greater motivating factors in the water conservation area, as failure to conserve water will ultimately cost residents more money and may further restrict their behaviour (e.g. through mandatory watering restrictions). Consequently, the magnitude of change delivered through water conservation education may represent an *upper* estimate of what can be expected from similar campaigns on stormwater pollution prevention.

Syme *et al.'s* (2000) literature review concluded that "it seems from our summative evaluations that education campaigns can result in significant (up to 25%) water savings in short-term or crisis situations. Effectiveness of such campaigns in the longer term has yet to be demonstrated" (p. 552). They also found that qualitative reviews and quasi-experimental evaluations have *estimated* savings in overall water consumption in the order of 10% - 25%.

Lessons from Adoption Research and Theory

Although it is not practical to summarise the extensive literature on research and theory related to the adoption of certain behaviours, one famous study stands out as being relevant to stormwater educational campaigns that rely on simply providing people with educational information. Known as the Mr Fit Study, it provides a strong argument as to why stormwater managers should not rely on the theory that simply providing information will automatically lead to changes in awareness, then changes to attitude changes and finally to changes in behaviour.

In the 1970s 12,000 US men were recruited for a US$180 million study on heart disease. The study has been described as "the most expensive, elaborate, ambitious clinical trial that the world has ever seen on heart disease" by Len Syme, an Emeritus Professor of Epidemiology at the University of California (Syme, 1998).

The study involved an intervention group and a control group. Both represented highly motivated and healthy people at high risk from heart disease. One group was provided with education on behavioural change needed to minimise the risk of heart disease (e.g. changing dietary habits). The intervention was intense. For example, the families of the men were also educated, the researchers accompanied the men to the supermarket to promote better shopping habits and researchers cooked with them in their homes.

After six years of intervention there was no difference in health between the intervention group and the control group. Syme (1998) stated that the "special care [intervention] group didn't change enough, but the control group changed too much". He concluded that the control group decided to help themselves and make substantial life change. He stated "the only way you really make important life decisions and changes in behaviour, all of us, is sitting down in a dark room and coming to terms with the reality of our circumstance. We don't do it with brochures".

One lesson for stormwater managers from the Mr Fit Study is that, to achieve *voluntary,* substantial behavioural change, one needs to prompt a truly fundamental change of direction for many individuals (which is exceedingly difficult), or promote a grass-roots movement in the community through genuine participation that ensures communities take ownership of the problem and the solution (Panell, 2001). Simply sending out information on its own will not be effective.

4.4.3 Summary of BMP Value and Cost

Evaluation of education and participation BMPs is fraught with problems. As noted by the US EPA (1997) "evaluating the performance of education and outreach programs is difficult. There is little quantitative data in the literature that measures the effectiveness of these programs in improving water quality. Information exists on how education programs have been implemented and what their success rate has been as far as changing the [self-reported] habits of a select group of people, but data linking implementation with improvements in water quality are scarce." (p. 5-48).

Impediments to sound evaluation of these BMPs include:

- unfounded assumptions (e.g. raising knowledge will automatically lead to improved behaviour);
- the degree of behavioural change being context-dependent (e.g. adoption of desirable behaviours may be related to the degree of self interest and/or

the ease of compliance due to supporting infrastructure);

- a lack of rigour and objectivity in the evaluation and reporting; and
- an over-reliance on the use of *self-reporting* as a measure of induced behavioural change, without validation that actual behavioural change occurred.

Perhaps the most insidious of these impediments is the over-reliance on self-reported information for measuring behavioural change, as it can easily produce misleading conclusions. Studies that have compared self-reported behaviour with observed behaviour have found that, in some contexts, it can be a useful surrogate for real behaviour (e.g. the South Australian Be Stormwater Smart Program for small to medium-sized industry), while in others it can be highly misleading (e.g. several littering studies found only 33% - 50% of people who had just littered reported that they had done so). Direct observation or validation of a subset of self-reported information should therefore always be attempted where possible.

Several lines of evidence suggest participation programs that promote widespread ownership of the stormwater pollution problem, participation of citizens in developing a solution and citizen involvement in implementing the solution are more effective at changing behaviour than programs that rely on traditional forms of education. As a general rule then, stormwater campaigns that aim to promote behavioural change (as opposed to just raising awareness) should maximise participation. At the very least, stormwater managers should attempt to use communication and persuasion methods that allow for interaction, discussion and tailoring of management strategies, such as the recruitment methods, workshops and mentoring elements of the successful US Master Gardener programs.

This approach represents a significant change of direction for many stormwater managers in Australia, who frequently rely on traditional education methods such as pamphlets, advertisements, fact sheets and newsletters.

Little evidence was found in the literature to support the case that information alone (e.g. brochures and newsletters) can significantly change *actual* behaviour in relation to stormwater management. There is an argument based on anecdotal evidence and logic that suggests educational campaigns may work synergistically with other BMPs (e.g. enforcement programs) and may lead to major developments in the long-term (e.g. the establishment of sustainable funding mechanisms for stormwater management). For example, Lehner *et al.* (1999) reviewed approximately 100 stormwater management case studies in the US and stated "the case studies presented have suggested that the effectiveness of BMPs in other categories is often tied to the effectiveness of the public education program" (p. 5-11).

There is evidence to suggest that in addition to education, it is important to have a supporting infrastructure and social structure around individuals so that it is easy for them to comply with educational messages. For example, providing people with easy access to litter bins and recycling locations, along with appropriate education. Another example is to ensure that people have the means to comply within their social circumstances (e.g. their available time and financial resources).

A substantial number of studies have gathered information from pre- and post-BMP implementation surveys on changes in knowledge, attitudes and self-reported behaviour following education and participation programs. As a general rule, data relating to changes in knowledge and attitudes are reliable, as most surveys ask questions that directly test whether these attributes have really changed. However, data relating to self-reported behavioural change are generally unreliable, as validation is rarely attempted and there is great potential for incorrect reporting.

Based on such survey information, the following figures approximate the *maximum* magnitude of change that can be expected from education and participation programs over 6 - 12 months.

Intensive training programs (e.g. workshops on lawn and garden care practices):

- 26% - 41% increase in knowledge[50].
- 17% increase in desirable attitudes.

[50] That is, 26% – 41% of the surveyed population increased their knowledge in a certain area (e.g. they knew the name of the waterway into which their stormwater drains).

- 10% - 75% (with the range 20% - 40% being common and an average of the most reliable data around 29%) increase in the number of people undertaking a specific desirable behaviour (based on self-reported data).
- 40% increase in the number of desirable practices adopted (based on self-reported data).
- For lawn care training, total nitrogen and pesticide loads applied to lawns can be reduced by approximately 40% and 25%, respectively.

Media campaigns to raise awareness (e.g. regional, city-wide, or catchment-wide programs):

- 3% - 24% (with an average of the most reliable data around 15%) increase in knowledge/awareness.
- 5% - 8% (with the most reliable data around 8%) increase in desirable attitudes.
- 8% - 48% (with an average of the most reliable data around 12%) increase in the number of people undertaking specific desirable behaviours (based on self-reported data).

Industry/commercial education programs (e.g. media and one-to-one discussions):

- 5% - 15% (with an average of the most reliable data around 12%) increase in knowledge/awareness (industrial programs).
- Mixed-to-negative results for programs involving commercial food retail outlets (i.e. for attitudes and knowledge/awareness).
- 58% increase in the number of people undertaking at least one desirable behaviour (commercial/industrial programs).
- 26% - 40% increase in the number of people undertaking a specific type of desirable behaviour (commercial/industrial programs).

Combined awareness and training programs (e.g. catchment-wide awareness and intensive lawn care training initiatives) are capable of producing:

- A 20% - 29% increase in the number of participants undertaking a desirable behaviour (based on self-reported data).
- Event mean concentrations of common lawn herbicides in stormwater may be reduced by 56% - 86% over several years.

In addition, there is preliminary evidence that focused education and auditing programs involving industrial estates with very good opportunities for improved house-keeping practices (e.g. covering material storage and handling areas), can reduce annual pollutant loads by approximately 8% (TSS), 40% (TN), 49% (TP), 42% (copper), 72% (lead), and 83% (zinc).

There is strong evidence that intensive training is a superior method for changing lawn and garden care behaviour compared with seminars and publications. For example, an independent investigation was undertaken on the effectiveness of these three extension methods as part of the Florida Yards and Neighbourhoods Program. Intensive training involving interactive workshops and mentoring (i.e. the Master Gardener Program) was able to increase the number of desirable lawn care practices adopted by participants by approximately 36%, compared to 24% for seminars and 15% for publications. The *relative difference* between the effects of these three methods is unlikely to be distorted by any bias associated with self-reported behavioural change.

Media campaigns appear to be more cost-effective in raising awareness in the broader community, while intensive training (e.g. the US Master Gardener approach) is more effective at changing behaviour, albeit in a small segment of the community. It is suggested both are needed for comprehensive city-wide stormwater quality management, as a broad raising of awareness is likely to produce long term benefits (e.g. increased political support and funding for strict planning and regulatory controls), while behavioural change by sectors of the community is likely to produce more immediate, localised benefits to stormwater quality and waterway health.

This review found examples of incongruity between the education and participation strategies for stormwater management preferred by surveyed communities (as methods that they thought were the most effective at attracting their attention), those used by stormwater management agencies and those deemed most effective by stormwater management agencies. For example, in a US study examining education and participation strategies used for urban nutrient management programs:

- the community *generally* preferred television and major newspapers as the most effective way to attract their attention, while brochures, billboards and meetings were least preferred[51];
- brochures and training workshops were the most commonly used strategies by stormwater managers involved with 50 US urban nutrient management programs; and
- community newsletters, local newspapers, home and phone consultations, training workshops, the provision of information on property purchase and visits to groups were seen by the same stormwater managers as being the most effective.

There is evidence in the literature that signage can, in some contexts, reduce localised littering and therefore the potential for stormwater pollution. For example, the wording of signage is likely to affect local littering rates, with positive, polite and specific messages often being more effective. An initial reduction of 14% in the proportion of waste material littered is possible through the introduction of signage. However, the effect of signage is likely to be short-term unless supported by other initiatives such as new litter bins and recycling facilities.

The use of theatre as a method of raising awareness and prompting behavioural change has produced mixed results. There is, however, evidence to suggest that if it is engaging and interactive (e.g. productions that involve the audience), theatre productions can reduce the rates of localised littering. Like signage, one would expect this effect to be short-term unless supported by other measures.

No evidence was found to support the commonly-held belief that stormwater drain stencilling *produces* an increased level of knowledge, awareness or positive behavioural change, although there is evidence of an *association* between elevated levels of knowledge/awareness and participation in stormwater drain stencilling.

The costs of educational and participatory initiatives for stormwater management vary greatly but have been documented, where available, for comparative purposes. Cost information of particular note included:

- Leading stormwater management agencies in Australia and overseas spend approximately 0.4% - 4.2% of their annual stormwater quality management budgets on education and participation activities.
- Australian and overseas case studies demonstrate that regional and Statewide stormwater awareness campaigns usually run for less than one year and typically cost AUD$0.42 - $0.82 per capita (averaging AUD$0.62 per capita).
- Intensive training programs such as the US Master Gardener Programs cost approximately AUD$15,326 - $19,157 per year to run, or AUD$0.23 per person per year (when the costs are spread over the entire population of the programs' area of influence), or AUD$7.76 - $15.52 per hectare of lawn managed through the programs.[52]
- Most education-based, US urban nutrient management programs cost less than AUD$47,893 (US$25,000) per year

Finally, it is recommended that at least 5% - 10% of the budget for stormwater education projects be allocated to the evaluation of the project's success. This figure may have to be increased where a high degree of confidence is needed in the results.

4.5 Regulatory Controls

4.5.1 Description of BMPs

This Section focuses on regulations and their enforcement to modify behaviour with the potential to pollute stormwater. In the field of stormwater quality management, State legislation or local laws are often passed and enforced to address specific forms of pollution and/or control high-risk activities.

Common examples of laws to prevent or minimise specific forms of pollution include those that:

- Encourage builders to minimise the discharge of sediment, litter, and washwaters from building sites.
- Discourage illegal dumping of wastes.
- Encourage pet owners in public areas to correctly dispose of their pets' waste.

51 These preferences represents the collective findings of eight US studies (see Schuler, 2000).

52 Based on a currency conversion rate of US$1 = AUD$0.522.

- Discourage the illegal connection of sewerage to the stormwater drainage network.
- Discourage the discharge of commercial or industrial wastes to stormwater.

Some less common examples include laws that aim to:

- Encourage xeriscaping (e.g. the City of Albuquerque in New Mexico has a Water Conservation Ordinance that requires xeriscaping on new developments and works in partnership with a rebate system to encourage the conversion of existing turfed areas to resource sensitive alternatives [Lehner, *et al.,* 1999]).
- Discourage the feeding of birds in and around urban water bodies (e.g. Hopatcong Borough in New Jersey prohibits the feeding of geese in and around their lake systems as a non-structural measure to improve water quality [Lehner *et al.,* 1999]).

Regulation of certain premises (e.g. petrol stations, automotive wreckers, etc.) is widely used to minimise stormwater pollution. Such premises are typically licensed by a government agency, with their activities controlled through legally-enforceable licence conditions regularly checked by enforcement officers.

This Section presents information relating to the cost and the value of regulatory controls for stormwater quality improvement. However, it focuses on three types of non-structural BMP:

- City-wide erosion and sediment control programs that include a strong enforcement element.
- Illicit discharge detection and elimination programs (i.e. programs that aim to find and remove illegal discharges of sewage or other hazardous wastes to the stormwater drainage network).
- Licensing programs that control the activities of commercial and industrial premises with an inherently high risk of polluting stormwater.

Erosion and sediment control programs have been targeted in this review for three reasons.

Firstly, within Australia, enforcement of stormwater-related local laws is most active in the area of erosion and sediment control (along with enforcement of littering in some regions).

Secondly, there is strong evidence to suggest a well-designed and vigorous enforcement program is essential in substantially increasing the performance of erosion and sediment control on construction sites. For example:

- Lehner *et al.* (1999) concluded from a review of 100 stormwater related case studies in the US that “programs with high accountability [e.g. enforcement elements] often reduce pollutant loadings by 50% or greater” (p. 1-2).
- Lehner *et al.* (1999) concluded in relation to erosion and sediment control programs that “whatever the education program however, they have not proven successful without the accompanying teeth of enforcement” (p. 5-13).
- The necessity for strong enforcement has been stressed by experienced Australian erosion and sediment control project officers and managers (e.g. Gaudry and Geier, 2000) and overseas (e.g. Fritz, 2002). Fritz (2002), a stormwater manager from Chattanooga, commented on the importance of enforcement in successful erosion and sediment control programs, saying “it is very important to point out that education and awareness [alone] does not lead to compliance. There must be an incentive for compliance to work. This can be either positive (monetary savings, awards) or negative (regulatory intervention)”.

Finally, findings from case studies indicates that city-wide erosion and sediment control programs with strong educational and enforcement elements may represent the best performing non-structural BMP for the control of stormwater pollution from industry. Lehner *et al.* (1999) concluded “from the [100 US] case studies, it appears that, even more than with respect to other industries, education and enforcement can achieve measurable stormwater pollution reduction” (p. 5-13).

Illicit discharge elimination programs and licensing programs have also been targeted in this review, as quantitative case study information is available from several regions, supporting the case that substantial reductions in stormwater pollutant loadings can be achieved through these BMPs.

Given these findings, a word of caution is warranted. City-wide stormwater quality improvement programs, such as erosion and sediment control programs, frequently involve a substantial investment in resources by stormwater agencies and strong political will to use enforcement measures. There is considerable pressure on stormwater agencies and responsible managers to quickly produce positive results. Given this, there is the *potential* for self-reporting of the success (or otherwise) of such programs to be influenced by these pressures. In one example examined by this review, significantly different conclusions regarding the success of the same program were reported by differing parties. These findings suggest that:

- caution is needed when reviewing results from such programs, particularly when the reporting appears to be selective;
- there is a need for independent evaluation and reporting of such programs; and
- the standard of reporting in general needs to be substantially improved (e.g. to minimise the risk of misinterpretation).

4.5.2 Case Studies and Reported Data

Value and Cost of City-wide Erosion and Sediment Control Programs

Brisbane City Council is Australia's largest local authority. It has a population of 864,000 and a focus on erosion and sediment control. A multi-dimensional Erosion and Sediment Control (ESC) Action Plan has been implemented and progressively refined since the late 1990s. The 2001 version of the City's Action Plan included 55 discrete actions/projects to improve erosion and sediment control and minimise the loads of sediment entering the City's creeks, river and bay.

The typical annual cost to implement the ESC Action Plan is approximately AUD$265,000, including costs associated with employing an ESC Officer for development assessment work, administration of the Action Plan, development of educational products, delivery of training, annual auditing and delivery of intensive media campaigns. The additional cost of enforcement has been a substantial component of the overall cost in the last two to three years (e.g. employment of four full time officers). However, all Brisbane's erosion and sediment control activities have become effectively self-funding, as a result of revenue generated through enforcement activities.

Since 1996, erosion and sediment control audits have been regularly undertaken in Brisbane to measure the degree of compliance with legislation by different sectors of the development industry. In early 1999, the widespread use of on-the-spot fines was added to the City's ESC strategy, after several years of relying primarily on education. These fines were relatively minor and were primarily intended to be an appropriate enforcement tool for small residential building sites.

For residential building sites in Brisbane, 22.5% of sites audited prior to introducing on-the-spot fines in early 1999 complied with relevant environmental legislation (a weighted average over two audits, involving a total of 54 randomly selected sites). After the introduction and use of on-the-spot fines, the equivalent percentage had increased to 38.8% (a weighted average over four audits, involving a total of 122 randomly selected sites), an increase in compliance of approximately 18%. Over the same period, compliance rates on larger development types in the City (where small, on-the-spot fines do not act as a significant motivator) fell by 3% - 7% (Brisbane City Council, 2002)[53].

This information for residential building sites in Brisbane, combined with data from western Sydney and San Francisco (see below), indicates that baseline levels of compliance for development sectors not previously subject to enforcement activities are typically around 20% - 30%.

Another major Australian erosion and sediment control campaign was the "Do It Right On-site" campaign run by the Southern Sydney Regional Organisation of Councils from March to August 2000. This campaign included a wide variety of educational tools and training strategies, and was supported by

[53] Over the period 1999-2001, the average compliance rate for subdivisions and developments (e.g. townhouses) in Brisbane was 54.8% and 40.4%, respectively (weighted averages over four audits involving a total of 72 subdivisions and 58 developments). An estimate of the overall level of compliance in 2001-02 across all development sectors in the City is approximately 50%.

enforcement of State legislation by 12 participating Councils.

The Do It Right On-site campaign covered one-third of the Sydney metropolitan area, with a population of approximately one million, and contained approximately 9,180 construction sites in 2000 (Southern Sydney Regional Catchments Coordinating Committee, 2000; Southern Sydney Regional Organisation of Councils, 2002).

The educational and training components of the six-month campaign cost AUD$95,628 ($65,832 in staff costs and AUD$29,796 in operating costs, such as printing and media). Costs associated with enforcing legislation can be assumed to be cost-neutral to Councils, as this was the intent of the State legislation. No data were available on the success or otherwise of the program.

In Western Sydney, five Councils and the Hawkesbury Nepean Catchment Management Trust ran a major erosion and sediment control program titled Keep the Soil on the Site (KSOS). This program followed three phases of another erosion and sediment control initiative, Site Wise, which ran from 1992 to 1999. This review will only address Stage 1 of Keep the Soil on the Site, from October 1999 to October 2000. This program was characterised by a 25-week educational phase, a subsequent 14-week enforcement phase and a final eight-week evaluation phase (Gaudry and Geier, 2000).

The Keep the Soil on the Site program covered approximately 620 km^2, representing 30% of the area of metropolitan Sydney (Gaudry and Geier, 2000) and a population of approximately 892,000.

Stage 1 of Keep the Soil on the Site cost approximately AUD$220,000 – $232,000 for 12 months (Pavan, 2001; Gaudry and Geier, 2000). The program included a wide variety of educational initiatives, employment of two Education/Project Officers, site inspections, enforcement activities and audits. Enforcement activities are assumed to be cost-neutral to Councils.

Site audits were undertaken before and after the program to evaluate its success. The Department of Land and Water Conservation (DLWC) audit report (DLWC, 2000) highlighted findings and relative changes with respect to particular erosion and sediment controls but unfortunately did not make any conclusions about the degree of compliance with environmental legislation on sites or the overall success of the program. For example, all the major findings of the audit report were in the form of statements such as:

- over the 12 months there was 9% increase in the presence of sediment fences on audited sites; and
- 71% of sites audited after the program had a "good sediment fence".

The audit report (DLWC, 2000) reported on the relative changes in the use of seven erosion and sediment controls. Of these controls, the use of five improved over the campaign timeframe (by 9% - 63%), while the use of two worsened (by 10% - 39%). The group responsible for the program concluded from this that the "DLWC's [audit] report clearly shows the success of the project and that erosion and sediment controls in building sites in South Creek were markedly improved over the past 12 months - between 10% - 60% for most of the devices" (p. 9, KSOS Steering Committee, undated).

An audit summary is available as an appendix to the final project report for Stage 1 of the Keep the Soil on the Site program (KSOS Steering Committee, undated). This appendix presents audit results from the initial educational phase and the later enforcement phase. During the educational phase, 71% of 368 audited sites were deemed to be at a "high risk of erosion from next rainfall". This figure rose to 100% during the subsequent enforcement phase. These results are not included or explained in the final audit report prepared by the DLWC.

In addition to the audit results, some anecdotal evidence on the success of Stage 1 of the Keep the Soil on the Site program is available from people involved with its implementation. DLWC staff indicate approximately 20% of building sites demonstrated adequate erosion and sediment controls prior to Stage 1 of the program. This figure rose to approximately 60% after non-complaint sites were referred to local Councils for enforcement action. This figure rose again to approximately 80% following enforcement action. However, compliance rates were thought to have substantially reduced six to 12 months after the program (Pavan, 2001).

Another major erosion and sediment control program being developed in Melbourne involves six Councils and will include an initial educational phase, a subsequent enforcement phase and several compliance audits. The population of the area over which the initiative will operate is approximately 736,000. The estimated total cost of the project over 18 months is AUD$560,000 ($373,00 per year), which includes cash and in-kind expenses associated with coordination, training, appointment of a Training and Implementation Officer, auditing, etc. (Alviano, 2002).

The San Francisco Bay Regional Water Quality Control Board has reported a substantial increase in the percentage of construction and building sites complying with erosion and sediment control regulations as a result of intensive education and enforcement activities over the last decade. Lehner *et al.* (1999) report that in the early 1990s only 30% - 40% of construction sites were complying with regulations. In the late 1990s however, this figure had risen to approximately 90%, according to agency officials.

Enforcement played a key role in the Board's strategy for improved erosion and sediment control in the Bay region. For example, in the 18 months from mid 1997 to late 1998, approximately US$1M of fines had been issued for erosion and sediment control breaches. This enforcement effort covered an area of 1,492 km^2 and a population of approximately 6.5 million.

In Delaware, a Certified Construction Reviewer (CCR) Program has reportedly improved the degree of erosion and sediment control compliance while saving public funds. The Delaware Department of Natural Resources and Environmental Control's Sediment and Stormwater Program includes educational and training initiatives and privately employed inspectors on large sites. The privately certified construction reviewers are trained by the government but essentially funded by developers. Savings to government agencies from this arrangement is estimated to be US$50 per site per month. Though no performance data are available, Lehner *et al.* (1999) reported "compliance rates have dramatically improved, resulting in decreased sediment pollution" (p. 6-17).

Piorko (2002) reported that expenses to government agencies associated with the running the CCR Program in Delaware include:

- training (approximately US$15,000 per year, recovered via course registration fees); and
- annual operating/administration costs (approximately US$25,000 at the State level for administration and program monitoring and US$75,000 at the local level for program oversight).

Value and Cost of City-wide Illicit Discharge Elimination Programs

A number of major, city-wide programs that identified and eliminated illicit discharges to stormwater have attempted to quantify and report their effects and costs.

The Huron River Pollution Abatement Project in Washtenaw County, Michigan, ran from 1987 to 1992, during which time it dye-tested more than 3,800 facilities. Three hundred and twenty eight (328) illicit connections were removed as a result of the project. Enforcement action was taken (where necessary) as a result of project staff referring recalcitrant offenders to appropriate regulatory bodies. The project covered a region with a population of approximately 300,000 and an area of 1,818 km^2 (US EPA, 2001; Lehner *et al.,* 1999).

The cost of the Huron River Pollution Abatement Project was reported to be approximately US$1.7M or US$325,000 per year

Water quality monitoring in the Huron River indicated the project was associated with a 75% decrease in the River's faecal coliform levels between 1987 and 1990 (US EPA, 2001; Lehner *et al.,* 1999). In addition, a water quality index (incorporating indicators such as suspended sediment, nutrients, faecal coliforms and oxygen demand) consistently improved over the project's first five years (Lehner *et al.,* 1999).

The City of Tulsa, Oklahoma, started an illicit discharge elimination program in 1994, in cooperation with State agencies. The program included inspection of premises (using television and smoke inspection techniques), dry weather field screening, industrial surveys, enforcement activities, repairs to sewerage and community education and involvement. The number of inspections and enforcement actions in the 1997-98 reporting year was 164 and 20, respectively. The program covered a region with a population of approximately 367,000 and an area of 471 km^2 (Lehner *et al.,* 1999), and cost approximately US$3.5M per year (Van Loo, 2002).

Changes to the quality of the City of Tulsa's stormwater before and after the program were measured and analysed using event mean concentrations averaged over four year intervals. The results are presented in Table 4.13 and include a 13%, 17% and 18% reduction in event mean concentrations for TSS, TP and total kjeldahl nitrogen, respectively (US EPA, 2001; Lehner *et al.,* 1999). The bulk of this improvement is thought to be attributable to the City's illicit discharge elimination program (including its educational elements).

Wayne County in Michigan ran an illicit discharge elimination program from 1991 to 1994. In 2002, the population of the County was approximately 2.061 million over an area of approximately 1,572 km^2 (Wayne County, 2002). The average annual cost of this program was approximately US$187,000, which funded a field crew (two full-time officers and one part-time officer) that was able to perform 325 to 350 site inspections per year (US EPA, 2001). The Wayne County Department of Public Health has estimated the mass of pollutants removed from stormwater by the program between 1991 and 1994 (e.g. 912 kg of TSS and 67 kg of TP). This information is provided in Table 4.27.

As part of the Clean Charles 2005 Initiative in the Boston Metropolitan area of Massachusetts, significant steps have been taken to eliminate illicit discharges of sewage and other pollutants into stormwater and the Charles River. Operating over a region with a population of approximately 2.87 million and an area of 4,506 km^2, the initiative managed to eliminate approximately 4.5 million litres of sewage per day from entering stormwater and the River. Community-based monitoring of water quality in the Charles River reports that faecal coliforms levels have been dropping since 1995 in wet and dry weather (Lehner *et al.,* 1999).

Table 4.27 Estimated Loads of Pollutants Removed by an Illicit Discharge Elimination Program (Wayne County, Michigan)

POLLUTANT	LOADS REMOVED FROM STORMWATER (1991-94)* (kg)	AVERAGE ANNUAL REDUCTION IN LOADS ENTERING STORMWATER** (kg/ha/year)
Suspended Solids	912	0.193
Total Phosphorus	67	0.014
Biological Oxygen Demand	912	0.193
Chemical Oxygen Demand	2,631	0.558
Ammonia	75	0.016
Chlorine	24	0.005
Potassium	15	0.003
Surfactants	1,158	0.246
Total Solids	3,066	0.650
Volatile Solids	1,270	0.269

Notes:

- The degree of effort to obtain this result was approximately 325 – 350 inspections of premises per year by a field crew of 2.5 full time equivalent staff at a cost of approximately US$187,000 per year.
- * The approximate population of Wayne County, Michigan in 2002 was 2.061 million and the area is 1,572 km^2 (Wayne County, 2002).
- ** Calculated from total loads (in kilograms) reported in US EPA (2001) and the area of the County. This assumes the program operated over the entire area of the County.

Source: Modified from US EPA (2001).

The New York City Department of Environmental Protection began a Shoreline Survey Program in 1989 to detect and eliminate illegal dry weather discharges to the City's stormwater and estuaries. The region over which the program operated was approximately 2,939 km^2 with a population of approximately 8.5 million (Lehner *et al.,* 1999). The approximate cost of the program was US$475,000 per year (Lehner *et al.,* 1999).

It is estimated that from 1989 to 1998, the Shoreline Survey Program eliminated approximately 12.7 million litres per day of such discharges. The Department also reported that overall water quality conditions in the City's receiving waters from 1991 to 1995 improved on pre-1990 conditions. Levels of faecal coliforms and dissolved oxygen concentrations, in particular, continually improved throughout the 1990s (Lehner *et al.,* 1999).

Finally, Claytor and Brown (1996) reported that the identification of illicit connections to the stormwater drainage network using visual inspections of dry weather flows typically costs US$488 to US$684 per km^2.

Value and Cost of City-wide Licensing Programs

While the licensing of industrial and commercial premises is a common form of environmental regulation, few agencies have evaluated and reported the effectiveness of the approach for stormwater quality improvement.

A good case study involves the Clean Bay Business Program in Palo Alto, California, (reported in Aponte Clarke and Stoner, 2000 and Lehner *et al.,* 1999). Vehicle service facilities (e.g. petrol stations) were regulated through licensing, education, inspections and the provision of incentives for good performance (e.g. attaining the status of a Clean Bay Business, which allowed businesses to access free advertising).

In 1992 when premises were first inspected under the program, only 4% of 318 facilities complied with regulations relating to discharges to stormwater and sewer. By the end of 1992, this percentage had risen to 41% and by 1998 it had risen to 94%. In addition, violations of regulations that specifically protect *stormwater* drains fell by 90% between 1992 and 1995. The program also found and eliminated 78 direct discharges to stormwater (e.g. washwater discharges).

The cost of running the Clean Bay Business Program to *each business* in 1998 was US$300 for the first year, followed by an annual fee of US$150. The cost of running the program to the regulator in Palo Alto was not available. However, such programs are typically designed to be cost-neutral to regulators, that is, the revenue from licences, prosecutions and cost-recovery following incidents should cover the regulator's expenses. In some cases, additional expenditure is incurred by regulatory agencies, particularly when the magnitude of licence fees are set by another tier of government. For example, as a local government regulator, the Brisbane City Council in Queensland administers devolved provisions of State environmental legislation and regulates approximately 2,600 – 3,000 potentially polluting small to medium sized premises (Taylor, 2002). Council collects approximately AUD$1.2 million per year in environmental licence fees but spends approximately AUD$1.44 million per year (20% more) on these regulatory activities to deliver a standard of service that meets the expectations of the community (Taylor, 2001).

The Auckland Regional Council in New Zealand has run an Industrial Pollution Prevention Program (IP3) since 1998 that includes regulation, education and auditing components. This program cost approximately NZ$350,00 to run in 2000-01. This level of funding enabled more than 400 premises to be audited (Sturrock, 2002).

Although little data is available to measure the IP3's impact on behavioural change and stormwater quality, staff involved with the project believe there has been an increase in awareness regarding the objectives of the program and that obtaining compliance shortly after auditing a premises is becoming easier. However, they stress "the challenge is making that lasting change in culture so that things don't slip once we walk out the gate" (Sturrock, 2002).

4.5.3 Summary of BMP Value and Cost

This Section focuses on three common types of non-structural BMPs involving regulation and enforcement of regulations: erosion and sediment control programs, illicit discharge elimination programs and licensing programs for premises with a high risk of polluting stormwater.

Strong enforcement is seen as a vital element of successful erosion and sediment control programs, along with complimentary education. As Lehner *et al.* (1999) stated after reviewing 100 US stormwater case studies, "communities reiterate the need to develop the financial resources and authority necessary to enforce standards and maintenance of stormwater controls before a problem or violation occurs" (p. 5-7).

Achieving and maintaining high levels of compliance with erosion and sediment control requirements on a city-wide basis is difficult. Based on Australian and overseas data presented in Sections 4.1 and 4.5, it is estimated that best practice erosion and sediment control programs should be able to achieve a 20% - 30% increase in compliance rates in the first few years (based on a typical baseline compliance rate of 20% - 30%), and achieve a 60% - 70% increase from baseline rate over a decade[54]. In addition, compliant sites can be expected to reduce the average load of TSS in stormwater during the construction phase by at least 60% on average (see Section 4.1).

Consequently, the overall TSS pollutant removal efficiency of city-wide erosion and sediment control programs that include strong town planning, enforcement and educational elements is approximately 12% - 18% in the short term (e.g. one to three years) and 36% - 42% over a decade. These percentages represent an approximate reduction in the average load of TSS in stormwater leaving construction/building sites over the life span of the construction phase (see Section 4.1 for more details).

The cost of running a regional or city-wide erosion and sediment control program in Australia ranges from AUD$0.19 - $0.51 per capita per year, and averages AUD$0.32 per capita per year (where "per capita" refers to the residential population of the area affected by the program). Multi-faceted erosion and sediment control programs with a strict enforcement element can however be self-funding. That is, revenue gained through enforcement of regulations can fund all related erosion and sediment control activities undertaken by the regulatory agency. In parts of the US, further government savings (of approximately US$50 per site per month) have been generated through private certifier programs, where developers pay a trained and certified third party to inspect the quality of their sites' erosion and sediment control.

Case study information highlights the need for *sustained* levels of enforcement (as compliance levels can quickly drop after a short term campaign) and programs that seek improvement over the *long term* (e.g. a decade). An important consequence of this finding is that program managers in Australia should ensure that erosion and sediment control programs are self-funding or have a secure funding base, so they are not so reliant on short term grants.

Reporting on the outcomes of erosion and sediment control programs is often non-existent or poor. Deficiencies include a lack of commitment to program evaluation, a lack of independence, a lack of rigour, selective reporting and conflicting reports on the level of success.

Illicit discharge elimination programs can be a highly effective non-structural BMP for the improvement of stormwater quality and waterway health. Evidence exists from several case studies that receiving water quality can be improved (particularly for faecal coliform levels and dissolved oxygen concentrations), very large volumes of liquid wastes can be prevented from entering stormwater and significant loads of stormwater pollutants can be reduced over several years.

For example, one study reported that an illicit discharge elimination program was responsible for a 75% decrease in faecal coliform levels in a receiving water, over three years. Another program prevented 999 litres/km^2/day of raw sewage entering receiving waters, while another eliminated 4,321 litres/km^2/day of liquid waste discharges. In Tulsa, Oklahoma, long-term improvements in the quality of the City's stormwater has been largely attributed to a major illicit discharge elimination program (with educational elements). Reductions in event mean concentrations of pollutants in Tulsa's stormwater are in the order of 13% for TSS, 17% for TP, 18% for total kjeldahl nitrogen and at least 55% for metals (copper, lead and zinc).

54 Phrased another way, average compliance levels for erosion and sediment control on building/construction sites can be expected to rise from approximately 20% - 30% (at the start) to 50% (after a few years), then up to 90% (after a decade) as a result of such programs.

Such evidence prompted Lehner *et al.* (1999) to conclude that, in the US, "local governments have found that identifying and eliminating illicit connections and discharges is a remarkably simple and cost-effective way to eliminate some of the worst pollution from stormwater and to improve water quality" (p. 5-15).

Based on four successful US programs, the cost of running an illicit discharge elimination program is approximately US\$0.12 - \$7.43/km^2 per year (averaging US\$1.97/km^2 per year), when the total program costs are spread over the *entire city area.* Another cost estimate is US\$488 - \$648/km^2, where the entire area is tested for illicit discharges to stormwater.

Licensing of numerous small to medium-sized businesses with the potential to pollute stormwater (e.g. petrol stations, scrap metal yards) is a common non-structural BMP in urban areas. Little published information was found on the effectiveness of such measures for stormwater quality improvement. From the limited data it appears a best practice, small industry licensing program that includes regular inspections, education, incentives and disincentives, should be able to deliver levels of compliance with stormwater-related requirements of approximately 90% - 95%. Such programs may cost AUD\$287 - \$1,204 per premises per year to run, with a typical Australian, local government-managed program costing in the order of AUD\$480 per premises per year. These programs can however, be structured to be cost-neutral to the regulatory agency (i.e. revenue from licensing fees and successful prosecutions can fund all related regulatory activities).

Overall, it is suggested that long-term erosion and sediment control programs with strong and sustained enforcement elements, illicit discharge elimination programs, and licensing programs with regular inspections, education, incentives and disincentives can be some of the most effective non-structural BMPs for improving stormwater quality and waterway health.

5. Summary and Conclusions

This technical report summarises information on the value and cost of non-structural BMPs for stormwater quality improvement that has been reported in the literature or was available from Australian and overseas case studies. In particular, it focuses on *quantitative* information on the effects of these BMPs and their cost.

The findings of this report should immediately provide urban stormwater managers with assistance. Stormwater managers can now cautiously use the literature review findings on the value and cost of non-structural BMPs to guide their decisions on the use of these BMPs until higher quality, locally-derived data on the performance and cost of these BMPs is available.

The literature review findings, combined with the results of a survey of 36 stormwater managers around Australia, the US and NZ (see Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12), is also being used to prioritise those BMPs most worthy of rigorous evaluation through Australian field trials. Such trials are now underway (see Report No. 4 in this series, CRC for Catchment Hydrology Working Document 02/6).

It is acknowledged that much of the information garnered from the international literature and case studies is of lower quality than that normally associated with equivalent studies involving structural BMPs for stormwater quality improvement (e.g. gross pollutant traps, constructed wetlands). This reflects the relative maturity of the two areas of research and the difficulty in designing and executing sound monitoring and evaluation plans for non-structural BMPs. The philosophy we adopted in this report 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.

In the medium to long term, it is hoped that stormwater managers in Australia will be able to use information on BMP performance and cost that has been gathered from well-designed monitoring and evaluation programs using the newly-developed evaluation framework and monitoring tools (see Report No. 4 in this series, CRC for Catchment Hydrology Working Document 02/6). The accumulation of reliable, high quality data sets on the benefits and cost of non-structural BMPs will enable a greater degree of analysis when considering urban stormwater management options and confidence in the resulting strategies. It should also become possible to reliably model the effect of multifaceted stormwater quality management strategies involving non-structural BMPs using pollutant export models.

Five summary sections are provided in Section 4 of this report highlighting the key findings for each category of non-structural BMP. These categories are town planning controls, strategic planning and institutional controls, pollution prevention procedures, education and participation programs, and regulatory controls.

The overall conclusion 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 most valuable non-structural BMPs being:

- Town planning controls, involving the implementation of stormwater quality improvement policy in town planning schemes, requiring stormwater quality management to be addressed in development proposals, and applying development approval/permit conditions (such measures can result in *wide-spread* adoption of water sensitive urban design).
- 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 US 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).

Results from the survey component of the Cooperative Research Centre for Catchment Hydrology's research involving non-structural BMPs for stormwater quality improvement (see Report No. 2 in this series, CRC for Catchment Hydrology Report 02/12) has found these BMPs are already playing a major role in urban stormwater quality improvement in Australia, are increasing in use, and will continue to do so if Australian programs mature in a similar way to those developed overseas. Unfortunately, given the current level of funding for research in this area, it is likely that it will take decades to gather high quality and locally derived data on the value and life-cycle costs of a substantial suite of non-structural BMPs in Australia. Until such data are available, urban stormwater quality managers will need to cautiously draw on information such as that presented in this report, to guide their use of non-structural BMPs for stormwater quality improvement.

6. Glossary of Key Terms and Acronyms

AMR
Advanced Marketing Research (US).

ASCE
American Society of Civil Engineers.

BIEC
Beverage Industry Environment Council (Australia).

Bioretention
A grassed or landscaped swale or basin promoting infiltration into the underlying medium. A perforated pipe collects the infiltrated water and conveys it downstream.

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'.

Catchbasin
A US term for an inlet to a storm or combined sewer equipped with a sediment sump, and sometimes a hood, on its outlet pipe to the sewer. Catchbasins can temporarily collect some of the sediment and debris washed off the streets. Drop inlets and gully pits are other terms for similar nodes in enclosed urban stormwater networks that may trap pollutants until they are either collected via maintenance activities or flushed from the network by intense runoff events.

CCAT
Clean Communities Assessment Tool - A measurement method for evaluating initiatives to change government authorities, community groups and non-government agencies. It is a simplified method compared to the DBI, involving both observational measurements and litter counts.

Cluster development
See "conservation design/development" below.

Conservation design/development
Site design that incorporates conservation measures such as on-site tree preservation, concentrating homes on a limited percentage of the site, preserving natural areas and open space and reducing the amount of impervious cover. Also known as cluster development or open space development.

CRC for Catchment Hydrology
Cooperative Research Centre for Catchment Hydrology (Australia).

CWP
Centre for Watershed Protection, Maryland.

DBI
Disposal behaviour index - An observational approach for measuring the effect of anti-littering BMPs. An objective, mathematical measure of all the environmentally desirable disposal behaviours found for a specified site and observation session.

DE DNREC
Delaware Department of Natural Resources and Environmental Control.

DLWC
Department of Land and Water Conservation, New South Wales.

Down zoning
Down zoning is a town planning action that reduces the allowable development density in a given area and typically the proportion of impervious area. For example a high-medium density zoning could be altered to a medium-low density zoning, if the land was not already developed.

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.

ESC
Erosion and sediment control.

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.

Event mean concentration (EMC)
A method for characterising pollutant concentrations in stormwater during a runoff event. The value is usually determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis.

Greenfield development
Urban development that occurs on land that was previously non-urban (e.g. bushland or pasture).

IPM
Integrated pest management – A practice of using biological and physical measures to control pests while minimising or eliminating the use of synthetic chemical pesticides.

LBI
Littering behaviour index – A simple observational approach for measuring the effect of anti-littering BMPs. A measure of the amount of littering in a specified site for an observation session; focused on negative behaviour and used as a proxy measure for the DBI (see above).

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

Low impact development (LID)
See "water sensitive urban design" below.

LSRC
Land of Sky Regional Council (US).

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.

NAHB
National Association of Homebuilders (US).

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.

NPDES
Phase II National Pollutant Discharge Elimination System (US) - A provision of the US *Clean Water Act* that prohibits discharge of pollutants into waters of the United States unless a special permit is issued by the US EPA, a State, or (where delegated) a tribal government or an Indian reservation.

NPS
National Parks Service (US).

NSW EPA
New South Wales Environmental Protection Authority.

NVPDC
Northern Virginia Planning District Commission.

NZ
New Zealand.

Open space development
See the definition for "conservation development" above.

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.

PRG
Pellegrin Research Group (US).

PSC
Public Sector Consultants, Inc. (US)

Retrofit development
Urban redevelopment.

SCCCL
South Carolina Coastal Conservation League.

Soil amendment
The practice of enhancing a soil's ability to retain pollutants (especially phosphorus) and moisture to minimise shallow groundwater and/or stormwater pollution. It typically involves adding a loam top soil to areas of developing land that:

- will be subject to application of nutrients (e.g. residential lots and public open space); and
- have naturally sandy soils with a low ability to retain phosphorus.

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.

SWRPC
Southeastern Wisconsin Regional Planning Commission.

TN
Total nitrogen.

TNRCC
Texas Natural Resources Conservation Commission.

Total kjeldahl nitrogen (TKN)
A measure of nitrogen that is in organic form (i.e. in organic compounds such as proteins, vegetative material).

TP
Total phosphorus.

TRC
Taverner Research Company (Australia).

TSS
Total Suspended Solids.

UPRCMT
Upper Parramatta River Catchment Management Trust.

US
United States of America.

US BMP Database Project
A cooperative arrangement between the US 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 (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.

USEP
Urban Stormwater Education Program, run by the NSW EPA.

Utility
See the definition for "stormwater utility" above.

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.

VEPA
Victorian Environmental Protection Authority.

VSC
Victorian Stormwater Committee.

VSWCB
Virginia Soil and Water Conservation Board.

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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