# Determining water sensitive urban design project benefits using a multi-criteria assessment tool

M. Urrutiaguer, S. Lloyd and S. Lamshed

## ABSTRACT

The integration of urban water cycle management with urban planning and design is referred to as 'Water Sensitive Urban Design' or 'WSUD' in Australia; one of the key elements of WSUD is the management of urban stormwater. In early 2006, the Victorian Government released the Yarra River Action Plan, which allocated $20 million towards tackling urban stormwater pollution. To help ensure this money is allocated in an equitable and transparent manner across all metropolitan local governments a multi-criteria assessment tool has been developed. This paper presents an overview of the multi-criteria assessment tool developed and adopted for selecting WSUD projects that are eligible for funding through Melbourne Water's Stormwater Program. This tool considers three types of indicators: environmental, engagement (engagement with stakeholders and local government capacity building) and financial. Within each category, a series of indicators of different weightings are applied to score a project. Where initial concept designs do not meet the Program criteria, additional work is undertaken to refine and improve the project. The tool and its use are illustrated with a case study.

**Key words** | capacity building, multi-criteria assessment, stormwater, water sensitive urban design

**M. Urrutiaguer** (corresponding author)
**S. Lamshed**
Melbourne Water,
100 Wellington Parade,
East Melbourne, Victoria 3002,
Australia
E-mail:
*marion.urrutiaguer@melbournewater.com.au*;
*sarah.lamshed@melbournewater.com.au*

**S. Lloyd**
EDAW,
Level 45, 80 Collins Street,
Melbourne, Victoria 3000,
Australia
E-mail: *Sara.Lloyd@edaw.com*

## INTRODUCTION

The integration of urban water cycle management with urban planning and design is referred to as 'Water Sensitive Urban Design' or 'WSUD' in Australia (e.g. Melbourne Water 2005; Wong 2006*a*). WSUD aims to minimise the hydrological impacts of urban development on the surrounding environment (Lloyd *et al.* 2002). Similar concepts have been developed and applied in other countries (e.g. Van Roon 2007), and include "Sustainable Urban Drainage Systems" in the UK (e.g. Butler & Parkinson 1997; Interim Code of Practice for Sustainable Drainage Systems 2004) and "Low Impact Development" in North America (e.g. Elliott & Trowsdale 2007). One of the key elements of WSUD is the management of urban stormwater, both as a resource and for the protection of receiving water ecosystems (Melbourne Water 2005). In the WSUD context, stormwater is managed to promote flood control, flow management, water quality improvements and opportunities to harvest stormwater for non-potable uses (Lloyd *et al.* 2002).

The transition to this more 'sustainable approach' to stormwater management, has required both technical innovation (e.g. Niemczynowicz 1999; see also Pratt 2004 and references therein for a review of SUDS technologies) and institutional innovation (e.g. Rogers 2006; Brown & Clarke 2007; Morrison & Brown 2007; Potter & RossRakesh 2007). Despite these challenges, an increasing number of urban developments across Australia have adopted the WSUD paradigm in terms of the use of integrated rainwater capture and reuse facilities, and stormwater pollution treatment and runoff-reducing technologies (Mitchell 2006; Wong 2006*b*).

This paper focuses on Melbourne Water's experience of facilitating the uptake of WSUD principles by local

doi: 10.2166/wst.2010.045

government agencies in and around the Melbourne metropolitan area, and illustrates the development and use of a multi-criteria assessment tool that is used to select and tailor on-ground projects.

## MELBOURNE WATER

Melbourne Water is a government owned statutory corporation that manages water supply catchments, treats and supplies drinking water, removes and treats most of Melbourne's sewage and manages waterways and major drainage systems throughout the Port Phillip and Western-port region. As illustrated in Figure 1, Melbourne is located in the Australian State of Victoria (south-east of Australia,) and is urbanised around the Port Phillip Bay. Melbourne Water's region of operation covers about 12,800 square kilometres and is home to more than 3.4 million people.

As a caretaker of river health, Melbourne Water needs to work in collaboration with other stakeholders in the catchment to achieve healthy rivers, creeks and other water bodies. Local government are an important stakeholder in this respect, since local councils manage drainage (generally catchment smaller than 60 ha) and play a key role in managing land use. Melbourne Water is thus currently delivering a WSUD program, working in partnership with local government to improve water quality of receiving waters.

## CONTEXT FOR MELBOURNE'S STORMWATER PROGRAM

In early 2006, the Victorian Government released the Yarra River Action Plan (Victorian Government Department of Sustainability and Environment 2006), which allocated $20 million towards tackling urban stormwater pollution over a 4 year period. Accordingly, two stormwater programs were established to partner with local governments and deliver WSUD at a local level. $10 million was allocated to work intensively with five inner-city Melbourne local governments, with a further $10 million allocated to work with the 33 suburban and regional local governments within Melbourne Water's region of jurisdiction. These two programs merged into a single program in 2008, the Living Rivers Stormwater Program; and another $20 million has been allocated for its continuation until 2013.

To simplify language, these programs will be referred to hereafter simply as the 'Program'.

The vision of the Program is to improve continually the management of urban runoff to enhance the environmental and social values of receiving waters (Melbourne Water 2007). The long-term focus and expected outputs are:

i. Environmental–with an improvement of water quality of receiving water bodies; and
ii. Social–with an increased aquatic recreational value of water bodies, and a greater interest and respect from the community for waterways.

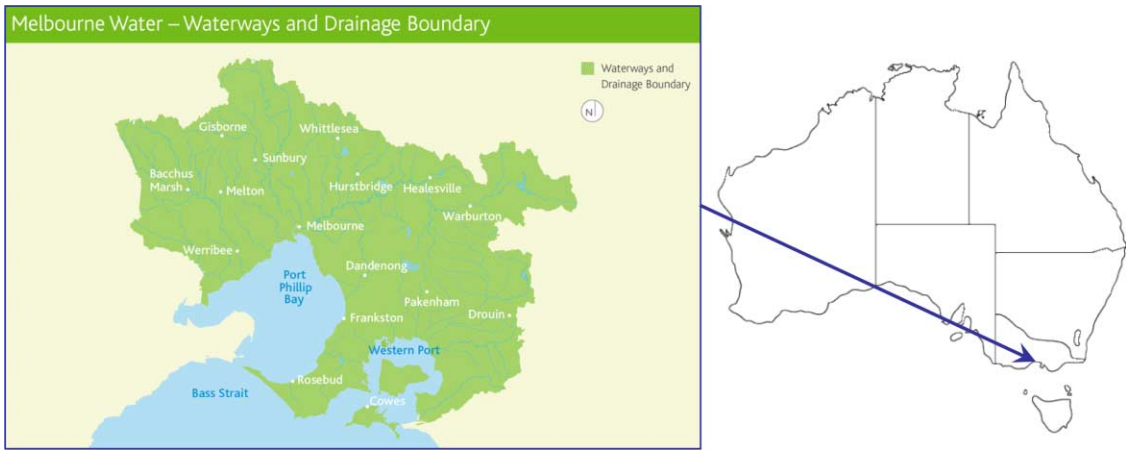


**Figure 1** | Melbourne water's region of operation.

As such, the main objectives of the Program are to:

- Analyse local government needs for stormwater management.
- Undertake on-ground projects aimed at improving stormwater quality and local government capacity to manage stormwater.
- Undertake strategic projects addressing stormwater management issues that are common across a number of local governments.

### Support to a new approach

According to research on urban stormwater management, long-term change in practices requires strategic institutional change (Brown & Clarke 2007). It was recognised that this could not be achieved if the Program was operated under a grant funding model. As such, Melbourne Water required a more innovative approach. The methodology chosen is to partner with local governments to deliver projects tailored to their organisational capacity. In practice, on-ground projects are identified that will allow local governments to build their capacity in implementing WSUD. Such institutional capacity building, often referred to as capacity building, is not only about skilling people, it also covers the aspects of: human resources, intra-organisational capacity, inter-organisational capacity, external institutional rules and incentives (Brown *et al.* 2006). Projects are thus used to build skills and knowledge, and address aspects such as community engagement, executive support, and multi-disciplinary approaches.

There is no single approach to building institutional capacity, and sophisticated coordinated actions need to be implemented in practice. The Program has been developed with this context and philosophy in mind, and it is anticipated that this Program will be the first phase of a long-term sustainable model of partnership between local governments and Melbourne Water.

### Project development

Melbourne Water initially met with each local government to establish networks and relationships within each organisation. Following these meetings, a Needs Analysis exercise was undertaken for each local government (see Bolton *et al.* 2007) to gather information on the institutional capacity of each local government in WSUD. The Needs Analysis identifies areas of strengths and areas for development, which informs future interactions and project development. The Program has flexibility in the types of project that can be funded. The main requirement is that each project has to help local government to address a development need identified in the Needs Analysis exercise and thus build their capacity.

## THE PROGRAMS' MULTI CRITERIA ASSESSMENT TOOL

In the early phase of the Program design, it was recognised that there was a need to ensure transparency and equity between local governments. There was also a need to rationalise choices made when selecting and developing projects, both for reporting and decision making purposes. A multi-criteria assessment tool was developed to meet these requirements, as well as support the new partnership approach.

In practice, the assessment is undertaken in two parts; a preliminary review and a more detailed multi-criteria assessment. In the preliminary review, criteria relating to specific conditions of funding and broader site constraints are assessed, including:

- The project is undertaken in the Melbourne Water drainage boundary.
- The project is on a system owned by local government, or there is an agreement from the landowner.
- The project adheres to contemporary values and relevance of the site (such as, adding to the aesthetic and/or amenity value of the urban environment).
- The project has no adverse impact on flooding levels.
- The initial site inspection indicates that the project is viable (i.e. not constrained by land availability, slope, depth of drainage, etc.).

An additional set of preliminary criteria arises from the approach undertaken within the Program; that is, to use an on ground project as a means to build local government capacity in the area identified by the Needs Analysis:

- The local government needs analysis identifies the type of project as particularly important to building institutional capacity.
- The project is a new application/innovative design solution, or different level of local government input into the design or delivery of the stormwater management project. (This criterion is particularly important, as it requires that each project funded constitutes a new step in capacity strengthening).

When a project does not meet one of these criteria, but is still considered of interest, it can be further discussed with the Program steering committees. Projects over a selected upper funding limit also fall into this category.

## Criteria within the tool

Once a project has been shown to be eligible for funding through the preliminary assessment described above, it is further assessed using a multi-criteria tool. The criteria used within the tool can be grouped into three categories: environmental, engagement, and financial. Within each category, indicators have been selected and a way of measurement assigned to each of them. For each indicator, three measures are defined in order to attribute a rank; the user selects the measure description that best fits the indicator. Measures are either quantitative or qualitative. Examples are provided below.

### Environmental

The expected output and long-term vision of the Program is to improve water quality of receiving waters (including creeks, river and bays). Two indicators have been included that support projects to achieve industry best practice targets for environmental protection and for multiple pollutants being addressed (Tables 1 and 2).

Nitrogen loading to Port Phillip Bay has been identified as a key pollutant of concern in the Port Phillip Bay Environmental Study (CSIRO 1996). Indicator 3 measures the significance of nitrogen load reduction attributable to a WSUD project (Table 3).

While the Program is specifically directed at addressing stormwater quality issues, the following indicator was included in order to support a more integrated water management approach (Table 4).

**Table 1** | Indicator 1: Addresses a known/significant water quality issue

| **Measure: Targeted pollutant (nitrogen, suspended solids, phosphorus, metals, *E. coli*, litter)** | | |
|---|---|---|
| Targets not achieved | Targets achieved for treated area but not for subcatchment at point of discharge | Targets achieved for treated area and subcatchment at point of discharge |

*Note*: Targets refer to the pollutant load reduction defined by the best management practice: 70% for litter, 80% for suspended solids, 45% for phosphorus and nitrogen (Victorian Stormwater Committee 1999). The pollutant load reduction is estimated with the Model for Urban Stormwater Conceptualisation (MUSIC) software (MUSIC development team CRCCH 2005). If the target pollutant is *E. coli* or metals, pollutant reduction is assessed using suspended solids as a surrogate until a larger more reliable database is established.

**Table 2** | Indicator 2: Project addresses more than one known/significant water quality issue

| **Measure: Addresses two or more pollutants or a significant volume of any one of the following pollutants: nitrogen, suspended solids, phosphorus, metals, *E. coli*, litter** | | |
|---|---|---|
| Projects addresses one or two water quality issue | Projects addresses 3 water quality issues | Projects addresses 4 + water quality issues |

### Engagement

Engagement is an important aspect of a project in terms of what the Program is intend to deliver (that is, increase capacity in WSUD). As mentioned previously, on-ground projects are a good opportunity for building individual skills, knowledge and organisational strengthening of local governments. The degree to which local government staff are involved is therefore considered an important engagement aspect (as opposed to a consultant designing and delivering the work with no transfer of skills) (Table 5).

**Table 3** | Indicator 3: Protection of receiving waters

| **Measure: Significantly contributes to a reduction in TN load (kg of TN removed/year)** | | |
|---|---|---|
| $<1$ | $>1 < 50$ | $>50$ |

*Note*: The pollutant load reduction is estimated with the MUSIC software.

**Table 4** | Indicator 4: Consideration of broader water cycle management issues

| **Measure: Positively integrated with other sustainable water initiatives (e.g. water conservation, etc)** | | |
|---|---|---|
| Project manages only the stormwater component of the urban water cycle | Project supports a larger integrated water cycle master plan (however other components of the plan are yet to be funded) | Project supports a larger integrated water cycle master plan for which funding is available for the implementation of other sustainable water management initiatives |

**Table 5** | Indicator 1: Local government capacity building

| **Measure: Amount of local government involvement** | | |
|---|---|---|
| No capacity building or ongoing involvement of local government | External body plays a significant role with local government having some input into the design or delivery of the project | Capacity building with local government and design and maintenance of project fully undertaken by local government |

Commitment to raising community awareness, education and participation is important for the long-term success of WSUD, and therefore consideration has been given to this aspect of project design. Further work is being undertaken to address community involvement in WSUD projects and improve the way projects are designed and delivered (Catchlove *et al.* 2007 for more information) (Table 6).

### Financial

While environmental and engagement aspects are of critical importance to the Program, individual projects should ideally still represent value for money. Since data on capital and maintenance cost for WSUD is limited, costs are at present based on estimation provided by the MUSIC software. While the costs in MUSIC have a high degree of uncertainty (MUSIC Development team CRCCH 2005), this approach provides consistency and homogeneity, which enables a relative assessment of cost efficiency.

Over time, cost data will be collated from projects to help improve the ability to estimate costs for design, construction and on-going maintenance of WSUD (Table 7, 8 and 9).

## Development and Implementation of the tool

The criteria and indicators presented above were developed by Melbourne Water. The tool was presented, reviewed and refined by the Program steering committees. The weighting of the three main aspects and indicators have thus been selected to reflect the vision and objectives of the Program. These weightings are shown in Table 10 below. As noted previously, for each indicator, three measures are defined in order to attribute a score of 0, 0.5 or 1. The weight is applied to each indicator score, and the sum of the weighted scores provides the overall score for the project.

The ultimate objective of all WSUD projects implemented through the Program is to improve stormwater quality discharged to receiving waters and a slightly higher weight is thus given to the environmental aspect of projects (40% compared to 30%, see Table 10). Another important

**Table 6** | Indicator 2: Commitment to community awareness raising or education

| **Measure: Engagement mechanism (process to be included in project brief)** | | |
|---|---|---|
| No involvement | Mechanism to inform the community (signage, information session, etc) | Deliberative participation in design process (inform and allow for exchange) or active participation in construction (i.e. planting of system) or on-going maintenance (i.e. weeding by a 'friends of group') |

**Table 7** | Indicator 1: Capital cost effectiveness of WSUD component of the project

| **Measure: capital cost ($/kg of targeted pollutant removed per year)** | | | |
|---|---|---|---|
| TN | >8,000 | <8,000 > 2,500 | <2,500 |
| TP | >15,000 | <15,000 > 9,000 | <9,000 |
| TSS | >150 | <150 > 30 | <30 |

*Note*: The project cost is estimated with the MUSIC software.

**Table 8** | Indicator 2: Maintenance cost effectiveness of WSUD component of the project

| Measure: Life cycle cost (equivalent annual payment/kg of targeted pollutant removed) | | | |
|---|---|---|---|
| TN | >1,000 | <1,000 > 250 | <250 |
| TP | >10,000 | <10,000 > 2,000 | <2,000 |
| TSS | >10 | <10 > 2 | <2 |

*Note*: The project cost is again estimated with the MUSIC software.

objective of the Program is to facilitate capacity building of local government and community engagement in WSUD. Accordingly, each of the two engagement indicators contributes more to the overall score than any other criteria. As shown in Table 10, the score for each engagement indicator contributes a maximum of 0.15 to the overall project score. The design of the weightings therefore helps to reinforce both the environmental and engagement objectives of the Program when communicating with local government on each project.

A series of case studies were examined to establish the overall project score threshold for eligibility to funding. A threshold of 0.45 was found to best represent the range of projects that support the Program objectives.

## Use of the tool

This tool is fairly simple which makes it easy to use and communicate. An initial assessment with the tool is undertaken at the concept stage of the project development, and is updated as the project evolves. Where initial concept designs do not meet the Program criteria, additional work is undertaken to refine and improve the project. At the end

**Table 9** | Indicator 3: Financial commitment to the project by local government

| Measure: Local government budget allocation for the project | | |
|---|---|---|
| Minor contribution from Local Government. Resources are in-kind | Matching funds from local government for the WSUD component of the project (with local government paying for non-WSUD component) | More than 50% of the WSUD component of the project is funded by local government (with local government paying for non-WSUD component) |

**Table 10** | Weighting of the three categories of assessment criteria and the associated indicators

| Aspect | Weight | | Indicator |
|---|---|---|---|
| Environmental | 0.4 | 0.3 | 1. Addresses a known/significant water quality issue |
| | | 0.3 | 2. Project addresses more than one known/significant water quality issue |
| | | 0.3 | 3. Consideration of broader water cycle management issues |
| | | 0.1 | 4. Consideration of broader water cycle management issues |
| Engagement | 0.3 | 0.5 | 1. Local government capacity building |
| | | 0.5 | 2. Commitment to community awareness raising or education |
| Financial | 0.3 | 0.33 | 1. Capital cost effectiveness of WSUD component of the project |
| | | 0.33 | 2. Maintenance cost effectiveness of WSUD component of the project |
| | | 0.33 | 3. Financial commitment to the project by local government |

of the concept/functional design stage (sometimes detailed design), the project is presented to the Program steering committees for approval. The format agreed is a short description of the project and information relating to the indicators assessed in the tool with the score from the assessment. This process relies on the fact that the assessment provided by the tool was judged reliable and pertinent as agreed by the steering committees. In this way, the team can develop projects in partnership with local governments with the confidence they will be approved if they pass the assessment with the tool.

In use, the tool brings some rationale to project assessments. However, the tool cannot be used independently; the user still needs a good understanding of the project and a holistic view of its context.

Whilst most multi-criteria assessment tool are used to help decision making processes by ranking or scoring options (Hajkowicz & Collins 2006), the tool developed for the Program helps to assess each project merits and verify it meets the Program's objectives. Another distinctive aspect is that although the tool is central to the overall assessment of each project's eligibility for funding, it is used

more broadly as a mean to communicate expectations to local government throughout project scoping and development activities.

The Program team is involved from the onset to the completion of a project. During this process, the tool is used to promote transparency and helps to communicate with council on the Program's objectives, and especially the focus on capacity building, so that projects are chosen and developed with these in mind. In summary, the tool is designed to facilitate a different way of thinking and working, rather than just for passing or failing fully scoped projects.

## Case study: raingardens in a residential street

This case study involves the construction of eight raingardens to treat road runoff from a residential streetscape. Stormwater is treated from an area of about 1,200 $m^2$ (average 150 $m^2$ per rain garden). The project arose largely through members of the community advocating to their local government that raingardens should be installed as part of a planned road reconstruction. The local government was at first reluctant to integrate WSUD citing funding limitations, lack of internal skills, inappropriateness of the anticipated landscaping and maintenance costs as reasons.

**Table 11** | Summary of initial assessment and scores for options considered

| | Score (0, 0.5, 1) | | No 1 case study assessment | Weighted score | | Max score |
|---|---|---|---|---|---|---|
| **Indicator** | **No 1*** | **No 2†** | | **No 1*** | **No 2†** | |
| *Environmental* | | | | | | |
| 1. Addresses a significant water quality issue | 0.5 | 0.5 | Targets achieved for treated area but not for subcatchment at point of discharge (target pollutant is metal, use TSS as a surrogate, 80% reduction) | 0.24 | 0.24 | 0.4 |
| 2. Project addresses more than one significant water quality issue | 1 | 1 | Projects addresses 3 water quality issues | | | |
| 3. Consideration of broader water cycle management issues | 0.5 | 0.5 | 1 < TN load reduction (kg/year) < 50 | | | |
| 4. Consideration of broader water cycle management issues | 0 | 0 | Project supports a larger integrated water cycle master plan (however other components of the plan are yet to be funded) | | | |
| *Engagement* | | | | | | |
| 1. Local government capacity building | 0.5 | 0.5 | External body plays a significant role with local government having some input into the design or delivery of the project | 0.15 | 0.23 | 0.3 |
| 2. Commitment to community awareness raising or education | 0.5 | 1 | Mechanism to inform the community (signage, information session, etc) | | | |
| *Financial* | | | | | | |
| 1. Capital cost effectiveness of WSUD component of the project | 0 | 0.5 | 30 < Capital cost ($/kg/yr TSS/yr) < 150 | 0.00 | 0.05 | 0.3 |
| 2. Maintenance cost effectiveness of WSUD component of the project | 0 | 0 | 2 < Life cycle cost ($/kg/yr TSS/yr) < 10 | | | |
| 3. Financial commitment to the project by local government | 0 | 0 | Matching funds from local government for the WSUD component of the project (local government paying for other components) | | | |
| Total | | | | 0.39 | 0.52 | 1 |

*No 1 refers to the first assessment done once the initial concept was completed.
†No 2 refers to the second assessment done after review and refinement of the project.

Melbourne Water was contacted, and a meeting was organised with the local government, residents and members of the team to investigate WSUD opportunities around the neighbourhood. The meeting was critical in addressing councils concerns, enabling the project to move forward. A consultant was engaged through the Program to undertake the concept design of WSUD. It was determined that one of the residential streets presented a viable opportunity to implement WSUD, and the council agreed to trial retrofitting of this street. This will provide an important demonstration project that council can then apply elsewhere during road reconstruction activities. An assessment was done at this stage (functional design); see Table 11 for the details and results of this assessment, referred to as case No 1.

As shown in Table 11, the first assessment score was 0.39, which is less than the minimum 0.45 required to receive funding. Nevertheless, the project was considered to be a critical step to build confidence in WSUD within the local government. A meeting was held between Melbourne Water and the local government to discuss the fact that the project was assessed as being ineligible and to try to find ways to improve its environmental, engagement or financial outcomes. Several aspects of the project were refined including:

- *Engagement of the community*: the local government agreed to engage the community in the planting of the raingardens and potentially the maintenance. As a result, the project received a higher score in the second criterion of the engagement aspect.
- *Financial contribution from local government*: the local government also agreed to contribute financially. However, this did not change the scoring for this criterion, as they did not match the program funding. Nevertheless, it was a very positive outcome as it demonstrated commitment from the organisation.
- *Cost-efficiency*: The raingardens were originally functionally oversized for aesthetic reasons requested by the local government. Melbourne Water presented to the local government the option of having the same area of surface ground cover and planting for all the raingardens, but reducing the underneath filter surface area to the minimum needed to achieve Best Management Practice water quality objectives (Victorian Stormwater Committee 1999). The local government agreed to incorporate this in the detailed design.

These modified factors, as captured by the tool, are shown in Table 11 as case No 2. With these modifications, the project was deemed eligible and therefore put forward for detailed design and construction. It should be stressed that the local government was significantly involved in the process and therefore supported the aims of the Program by building local government capacity to undertake future projects.

## CONCLUSION

This paper presents an overview of the multi-criteria assessment tool developed and adopted for selecting structural WSUD projects that are eligible for funding through the Program. The assessment tool promotes transparency, provides a rational basis to the funding process, and is an important element of justification and reporting of projects. A key aspect of the tool is its use in actively communicating the Program's objectives throughout project development. The tool will be further developed and refined as knowledge in WSUD progresses and as the Program evolves. Likely areas for development include the following.

- The indicators may change; for example, once local government have reached a more consistent degree of knowledge and implementation of WSUD.
- Similarly, the weighting and the ranges of the different indicators may change to reflect the evolution of the Program.
- Cost data being collected to help improve future cost estimates.
- Integrating an assessment of the negative potential impacts of a project

## REFERENCES

Bolton, A., Edwards, P., Lloyd, S. & Lamshed, S. 2007 Needs Analysis–An assessment tool to strengthen local government delivery of Water Sensitive Urban Design. In: *Proc. 13th International Rainwater Catchment Systems Conference*, Sydney, Australia, 21–23 August 2007. CD-ROM, Rainwater and Urban Design Conference 2007.

Brown, R. & Clarke, J. 2007 Transition to Water Sensitive Urban Design, the story of Melbourne, Australia, School of Geography and Environmental Science and the Facility for Advanced Biofiltration, Monash University.

Brown, R., Mouritz, M., & Taylor, A. 2006 Institutional Capacity. In: Wong, T. H. F. (ed.). Australian Runoff Quality, A guide to Water Sensitive Urban Design, Engineers Australia, Canberra. Chapter 5, pp. 1–21.

Butler, D. & Parkinson, J. 1997 Towards sustainable urban drainage. *Water Sci. Technol.* **35**(9), 53–63.

Catchlove, R., Lloyd, S., Armstrong, B., Castle, J. & Bright, S. 2007 Why a Community Engagement Framework is Fundamental for Healthy Waterways. In: *Proc. 13th International Rainwater Catchment Systems Conference*, Sydney, Australia, 21–23 August 2007. CD-ROM, Rainwater and Urban Design Conference 2007.

CSIRO 1996 Port Phillip Bay Environmental–The Findings 1992–1996. Prepared for Melbourne Water. http://www.melbournewater.com.au/content/library/publications/reports (visited Feb 2008).

Elliott, A. H. & Trowsdale, S. A. 2007 A review of models for low impact urban stormwater drainage. *Environ. Modell. Softw.* **22**, 394–405.

Hajkowicz1, S. & Collins, K. 2006 A Review of multiple criteria analysis for water resource planning and management. *J. Water Resour. Manage* **21**(9), 1553–1566.

Interim Code of Practice for Sustainable Drainage Systems 2004 National SUDS Working Group, UK.

Lloyd, S. D., Wong, T. H. F. & Chesterfield, C. J. 2002 Water Sensitive Urban Design: A Stormwater Management Perspective, Melbourne. Cooperative Research Centre for Catchment Hydrology.

Melbourne Water 2005 *WSUD Engineering Procedures: Stormwater*. CSIRO publishing, Collingwood, Australia.

Melbourne Water 2007 Living Rivers Stormwater Program Annual Report 2006–2007. Not publicly available.

Mitchell, V. G. 2006 Applying integrated urban water management concepts: a review of australian experience. *Environ. Manage.* **37**, 589–605.

Morrison, P. & Brown, R. 2007 Cooperate or coerce? Intergovernmental Approaches to Mainstreaming Water Sensitive Urban Design. In: *Proc. 13th International Rainwater Catchment Systems Conference*, Sydney, Australia, 21–23 August 2007. CD-ROM, Rainwater and Urban Design Conference 2007.

MUSIC Development team CRCCH 2005 Model for Urban Stormwater Improvement Conceptualisation (MUSIC) User Manual, Version 3.0.1, Cooperative Research Centre for Catchment Hydrology (CRCCH).

Niemczynowicz, J. 1999 Urban hydrology and water management: present and future challenge. *Urban Water* **1**, 1–14.

Potter, M. & RossRakesh, S. 2007 Implementing Water Sensitive Urban Design Through Regulation. In: *Proc. 13th International Rainwater Catchment Systems Conference*, Sydney, Australia, 21–23 August 2007. CD-ROM, Rainwater and Urban Design Conference 2007.

Pratt, C. J. 2004 Sustainable Drainage: A Review of Published Material on the Performance of Various SUDS Components. Prepared for The Environment Agency, UK. http://www.ciria.org.uk/suds (visited 03/02/08).

Rogers, K. H. 2006 The Real River management challenge: integrating scientists, stakeholders and service agencies. *River Res. Appl.* **22**, 269–280.

Van Roon, M. 2007 Water localisation and reclamation: steps towards low impact urban design and development. *J. Environ. Manage.* **83**, 437–447.

Victorian Government Department of Sustainability and Environment 2006 Yarra River Action plan: securing water quality for a healthy future. ISBN 174152 474 1, State of Victoria, Melbourne.

Victorian Stormwater Committee 1999 Urban Storm Water: Best Practice Environmental Management Guidelines, ISBN 0 643 06453 2, CSIRO publishing, Collingwood, Australia.

Wong, T. H. F. 2006*a* An overview of water sensitive urban design practices in Australia. *Water Pract. Technol.* **1**(1), IWA publishing online–http://www.iwaponline.com/wpt/001/0018/0010018.pdf

Wong, T. H. F. 2006*b* Water sensitive urban design–the journey thus far. *Aust. J. Water Resour.* **10**, 213–222.