

# FRAMEWORK FOR STORMWATER QUALITY MANAGEMENT IN SINGAPORE

T H F Wong

*Centre for Water Sensitive Cities, Monash University, Clayton, Victoria 3800, Australia*

*\*Corresponding author, e-mail tony.wong@monash.edu*

## ABSTRACT

Singapore has been progressively moving towards attaining a higher level of self-reliance in its water resources. In relation to urban stormwater as a resource, the Singapore Government has embarked on a project which converts Marina Bay, located at the heart of Singapore City, into a freshwater reservoir that will harvest stormwater from a third of the area of metropolitan Singapore. This project, undertaken by the Public Utilities Board of Singapore (PUB), is a significant undertaking, the largest of its kind in the world in terms of a fully-urbanised environment – the city of Singapore itself – being a water supply catchment.

In preparation for the conversion of Marina Bay into a freshwater reservoir, the metropolitan area of Singapore will need to be progressively retrofitted with the necessary stormwater quality treatment technology to ensure water quality in the Marina Bay Reservoir is adequately protected. A project was initiated to develop the stormwater quality management framework for Singapore.

This paper presents the theoretical basis underpinning the development of the framework and outlines the various initiatives of policy development, industry capacity building for WSUD and works on ground associated with the framework.

## KEYWORDS

Urban stormwater quality management; transition; water sensitive urban design

## INTRODUCTION

Singapore has been progressively moving towards attaining a higher level of self-reliance in its water resources, with their ‘Four National Taps’ strategy of ensuring access to a diversity of water sources including (i) recycled wastewater; (ii) desalinated water; (iii) imported water from neighbouring Malaysia; and (iv) urban stormwater. Singapore has a mean annual rainfall of approximately 2,400 mm a year and the Singapore Government has embarked on a project which will convert Marina Bay, located at the heart of Singapore City, into a freshwater reservoir that will harvest stormwater from a third of the area of metropolitan Singapore. The project, undertaken by the Public Utility Board of Singapore (PUB), is a significant undertaking, the largest of its kind in the world in terms of a fully-urbanised environment – the city of Singapore itself – being a water supply catchment.

Tidal flushing has regularly kept Marina Bay relative free of stormwater pollution and therefore stormwater pollution of the bay was seen as a nuisance, but not as a matter of national importance. The closure of the Marina Barrage to create the Marina Reservoir meant that tidal flushing is no longer available to maintain a healthy waterbody. In preparation for the conversion of Marina Bay into a freshwater reservoir, the metropolitan area of Singapore

will be progressively retrofitted with the necessary stormwater quality treatment technology to ensure water quality in the Marina Bay Reservoir is adequately protected.

A project was initiated to develop the stormwater quality management framework for Singapore. The framework, referred to as the ABC Waters Framework for Stormwater Management in Singapore has an ambitious timeframe of technological uptake throughout Singapore, underpinned by accompanying policy, regulatory and administrative reform. This is the first time that such a comprehensive framework has been strategically implemented in such a short timeframe.

## **FORMULATING THE FRAMEWORK FOR STORMWATER QUALITY MANAGEMENT**

The framework for the implementation sustainable stormwater quality management has many dimensions spanning across policy development, technical capacity building, design and implementation of pilot and demonstration projects and, research and development. The development of the framework draws from insights from social science studies on the theory of transition or the transformation of institutional paradigm. In this case, the transition is towards advancing stormwater management from the traditional and often limited focus on drainage and flood protection to a multi-facet approach based around the integration of many socio-technical facets that influence the adoption of water sensitive urban design (WSUD) at a whole-of-city scale.

The documentation and analysis of the rapid transition of WSUD from concept to policy in Melbourne over the period 1990 to 2006 (Brown and Clarke, 2007) provided a useful template or framework from which the approach to this project was developed. As noted by Brown and Clarke, the insights gained from the Melbourne case study is of direct relevance to other cities as the Melbourne scenario *“also represents the many of the significant pressures faced by modern cities today, including: rapid population growth; decreasing household occupancy ratios; ageing infrastructure; water supply stresses; degraded waterway health; complex and sometimes unclear administrative configurations and variable levels of commitment to environmental management across government agencies and departments”*.

Brown and Clarke (2007) identified eight enabling factors that led to the effective adoption of WSUD in Melbourne, Australia. These are summarised as follows:-

1. Socio-political Capital - Aligned community, media and political concern for improved waterway health, amenity and recreation.
2. Bridging Organisations - Dedicated organising space that facilitates collaboration across science and policy, agencies and professions, and knowledge brokers and industry.
3. Trusted & Reliable Science - Accessible scientific expertise, innovating reliable and effective solutions to local problems.
4. Binding Targets - A measurable and effective target that binds the change activity of scientists, policy makers and developers.
5. Accountability - A Formal organisational responsibility to the improvement of waterway health, and a mandate for influencing practices that lead to such an outcome.
6. Strategic Funding Points - Additional resources dedicated to the change effort.
7. Demonstration Projects & Training - Accessible and reliable demonstration of new thinking and technologies in practice, accompanied by knowledge diffusion initiatives.
8. Market Receptivity - A well-articulated business case for the change activity

In formulating the ABC Waters Framework for Urban Stormwater Management, the project team first set out to identify and assess the key local attributes that establish the 'readiness' of the institutions in Singapore for successful implementation of WSUD, benchmarked against the eight key enabling factors.

### **1. Socio-political Capital**

**Assessment:** Singapore is well advanced in its socio-political capital for securing the nation's water resources and the key incentive for stormwater quality improvement is associated with the protection of the water quality of Singapore's waterways, particularly its water storages such as Marina Reservoir.

**Framework Initiatives:** Continue fostering the community's and government's commitment to stormwater quality improvement. Marina Bay is an iconic waterbody in Singapore and its new function as an essential component of Singapore's strategy for building resilience in its water supply security is intrinsically linked to maintaining/protecting it as a healthy and clean waterway.

Initiatives identified for the Framework centred on bringing to focus, amongst relevant government agencies and the community, the important linkage of sustainable urban water management with environmental protection of Singapore's waterway while expanding on the many other attributes associated with the implementation of WSUD through the city of Singapore.

### **2. Bridging Organisations**

**Assessment:** PUB has the responsibility and leadership role of formulating an integrating framework for implementation of WSUD in Singapore. It recognises that effective solutions for the protection of Singapore's waterway lie in effective catchment management and pollutant source control. PUB is clearly identified as an important bridging organisation that provides the forum for other stakeholder agencies such as National Parks (NParks), Land Transport Authority and Housing Development Board to continue collaboration and building of the socio-political capital referred to previously. PUB chairs the Inter-Agency Working Committee (IAWC) on Marina Barrage which could be readily expanded to encompass catchment management for the protection of Singapore's waterbodies, including Marina Reservoir.

PUB is currently also facilitating collaboration in scientific activities through such initiatives as the Singapore Delft Water Alliance.

Some of the stakeholder agencies, in particular NParks, are committed to strong collaboration at the highest level of office. The close collaboration between PUB and NParks in undertaking individual activities of scientific research and design/construction of pilot projects are evident and the active interest and commitment at the highest office of both organisations are a clear demonstration of their strategic roles as bridging organisations that would provide the dedicated organising space for innovation and practice of water sensitive urban design.

Thus, there are at least two bridging organisations in PUB and NParks, which have the highest executive and political support and commitment to facilitating collaboration across science and policy, agencies and professions, and knowledge brokers and industry.

**Framework Initiative:** Continue to foster the strategic collaboration between PUB and NParks in the first instance, and through these two organisations, strengthening cross-agency collaboration with other stakeholder organisations.

### **3. Trusted & Reliable Science**

**Assessment:** Trusted and reliable (local) science is not well developed at this stage in relation to innovative technologies for urban stormwater quality treatment and WSUD. It was evident that a coordinated approach to stormwater research, research dissemination and capacity building activities directed at the performance of WSUD elements in tropical regions is required.

**Framework Initiative:** Development of a stormwater quality research program to build local-context scientific knowledge of innovative stormwater management. This program is linked to the use of pilot and demonstration projects as experimental sites, and the subsequent reporting and use of research findings in capacity building of local professionals in the practice of water sensitive urban design in Singapore.

### **4. Binding Targets**

**Assessment:** Singapore does not currently have stormwater quality management targets and it is desirable that the policies and quantitative targets are established to underpin the implementation of innovative stormwater quality management.

The establishing of catchment management performance targets is considered an initiative of important priority as the targets provide (i) the quantification of catchment planning policies; and (ii) a level of transparency and direction for the subsequent development, implementation and administration of precinct and regional stormwater management plans.

Concurrent with the establishment of performance targets is the development and provision of a suitable rating tool to enable industry and government to assess compliance to these targets. This coupling of performance targets and the means to demonstrate compliance to this target is considered essential in facilitating industry adoption of these policy directives.

**Framework Initiative:** (i) development through case study analysis and modelling, and with consultation with relevant agencies, an appropriate set of quantitative stormwater quality management objectives and performance targets that could be adopted in government policies; and (ii) adaptation of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) for application in Singapore to provide a suitable tool for conceptual design and analysis of stormwater treatment measures which can also be used to demonstrate compliance to the performance targets.

### **5. Accountability**

**Assessment:** The organisational responsibilities of the various government agencies with a role in the catchment management of urban environments in Singapore are well established but require formal documentation and transparency.

There is currently Inter-Agency Working Committee (IAWC) on Marina Barrage chaired by the Chief Executive of the PUB with high level representation of stakeholder organisations. Advice from the PUB has indicated that the steering committee is an appropriate forum to further establish and formalise the cooperation amongst stakeholder agencies to the protection of water quality in Marina Reservoir.

**Framework Initiative:** Fostering a continuing involvement and collaboration amongst stakeholder organisations into all the initiatives of the Framework.

### **6. Strategic Funding Points**

**Assessment:** there are various strategic funds available to support the institutionalisation of WSUD in Singapore. These funds are generic and may not provide due opportunity for a new initiative such as the building industry capacity for WSUD in Singapore.

Key funding requirements are in facilitating (i) the implementation of demonstration and pilot projects; (ii) the training of industry on the engineering design procedures of stormwater quality treatment measures; (iii) the establishment of a local research and development program for stormwater quality management.

**Framework Initiative:** Promoting the strategic importance of stormwater management, associated industry capacity building and research and development, to the long-term sustainable operation of Marina Bay as Singapore's largest freshwater reservoir.

## **7. Demonstration Projects & Training**

**Assessment:** Being a new concept, there are limited demonstration projects on WSUD, especially at the local scale, and local industry has limited access to training on WSUD.

**Framework Initiatives:** Strengthening industry capacity for WSUD through (i) pilot projects at a range of implementation scales for collaborative design and implementation amongst key stakeholder organisations. These projects will also become focus sites for local research as well as sites for active engagement of the many practice areas in industry (e.g. landscape architects, stormwater engineers, planners, architects, catchment managers, government officials, political leaders and the community); (ii) developing guidelines for engineering design of a range of suitable stormwater quality management devices which can be further refined with on-going locally-based research and development that includes the monitoring of the performances of the pilot projects.; and (iii) on-going training using the pilot projects as case studies and the design guidelines as training material to the industry.

As a long-term strategic initiative, the establishment of locally-based research on urban stormwater quality management could ultimately form the basis of subjects or short-courses at tertiary education institutions to prepare future graduates to practice and further innovate in this field.

## **8. Market Receptivity**

**Assessment:** The driver to ensure a healthy ecosystem of urban reservoirs such as the Marina Reservoir as well urban waterway is a clear business case for institutionalising WSUD in Singapore. However this is not well articulated amongst government departments and the community.

**Framework Initiative:** Fostering a continuing involvement and collaboration amongst stakeholder organisations into all the initiatives of the Framework and the development of a whole-of-government business case for WSUD in Singapore.

## **ABC WATERS FRAMEWORK FOR STORMWATER MANAGEMENT**

Following an assessment of the 'readiness' of the institutional characteristics of Singapore for mainstreaming of WSUD initiatives, the project team proceeded to formulate incentives and activities that are directed at addressing inadequacies identified. These initiatives included:-

- a review and development of catchment management objectives and the incorporation of these into the corporate objectives of government agencies whose functions impact on catchment management;
- the development of a uniform standard and engineering procedures for designing WSUD measures for stormwater management;
- industry capacity building initiatives such as training courses and construction of demonstration/pilot projects;
- engaging government agencies as stakeholders in the planning, design and construction of demonstration projects; and

- strengthening local scientific research efforts

Figure 1 depicts the implementation framework developed. The framework encompasses the socio-technical dimensions of integrated management of urban stormwater and is sub-divided into the three broad categories of:-

- Regulatory and Administrative reform
- Technology Development and Implementation
- Building Industry Capacity

This framework addresses a broad range of initiatives that are considered to be necessary in order to support the successful implementation of WSUD in Singapore. Many of these initiatives are complementary or inter-related, and in order to deliver the overall framework within the intended timeframe, these initiatives will need to be implemented concurrently.

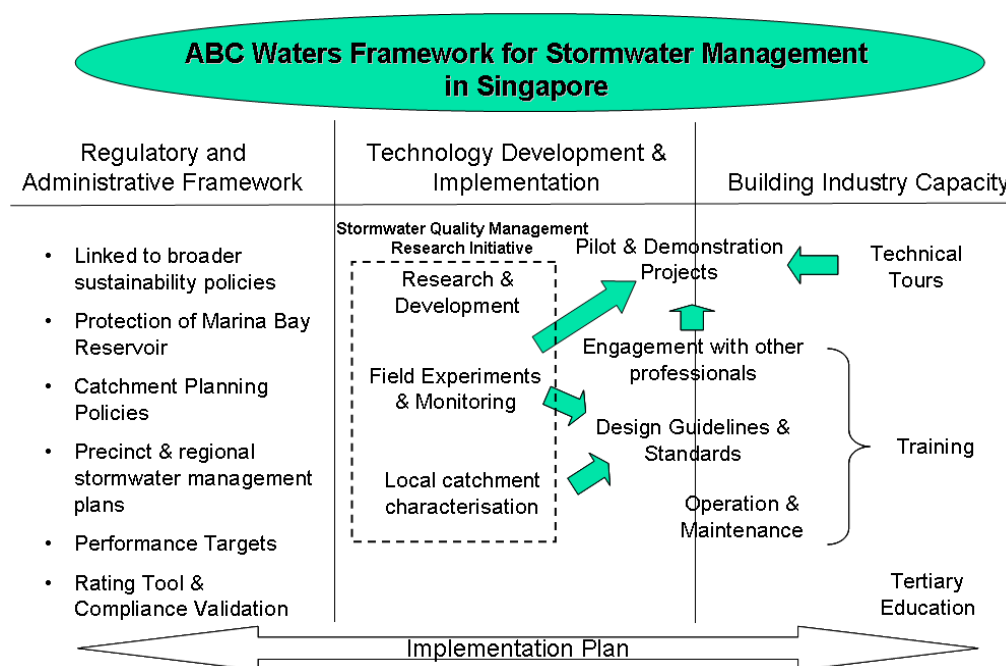


Figure 1 ABC Water Framework for Stormwater Management in Singapore.

### IMPLEMENTATION OF FRAMEWORK

Concurrent with policy development and integration of regulatory and administrative instruments are the implementation of demonstration and pilot projects as the focal point for industry capacity building and the establishment of locally-based research initiatives to underpin trusted and reliable science.

### Setting Interim Stormwater Management Objectives for Singapore

The specific WSUD objectives and targets of WSUD strategies for Singapore catchments have yet to be determined. However, in many countries including Australia, best practice involves a risk-based approach to the protection of environmental values and beneficial uses of urban waterways and aquatic ecosystems. In Australia, reference is made to the objectives of ANZECC/ARMCANZ (2000) which is based on extensive studies of many reference aquatic ecosystems. In Singapore, the setting of acceptable risk ambient water quality values

based on the beneficial uses of the receiving waterbodies will be a necessary first step towards setting stormwater management objectives.

### **Adapting a Compliance Tool**

Concurrent with the establishment of performance targets is the development and provision of a suitable rating tool to enable industry and government to assess compliance to these targets. With the highly stochastic and intermittent characteristic of rainfall and the non-linear performances of most stormwater treatment measures, this rating tool would require a continuous modelling approach.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) has been adapted for use in Singapore climatic conditions to aid designers in modelling the performance of stormwater quality treatment measures. Rainfall files for the 22 rainfall stations have been formatted for MUSIC application.

### **Demonstration Projects**

A number of pilot projects have now been completed to demonstrate innovative stormwater quality treatment technologies that are integrated into streetscape, public open space and urban design. Extensive efforts were directed at raising awareness, technology transfer through design workshop in these projects to commence effective engagement with key project officers in PUB and stakeholder agencies and their consultants. Key demonstration projects include those illustrated in Figures 2 and 3.



Figure 2. The Sengkang West Way road construction project to demonstrate the implementation of road side bioretention systems.



Figure 3. A 240 m<sup>2</sup> bioretention rain garden has been proposed and designed to capture and treat stormwater runoff from its 0.6ha contributing residential areas in Balam Estate.

### **Establishing a Local Research Facility**

Bioretention experiments were set up in collaboration with PUB and NParks in a temporary facility located at NParks Pasir Panjang nursery. These experiments were conducted to derive interim specifications for the soil filter of bioretention systems in Singapore. Different soil mixes and local plants were tested for their suitability used in bioretention systems.



### **CONCLUSIONS**

Singapore's Active, Beautiful and Clean, (or ABC), Waters Programme is a long term strategic programme by PUB, Singapore's National Water Agency, that aims to transform utilitarian canals, drains and reservoirs in Singapore into clean flowing rivers, lakes and streams that blend naturally into the urban environment. The main objective of the programme is to bring people closer to the water so that they will cherish, appreciate and take ownership of the precious water resources. From a technical standpoint, the ABC Waters Programme is intended as an umbrella programme that takes a holistic view of the local hydrological cycle, from stormwater management to water quality. The programme plays a major role in the initiative to remake Singapore into a vibrant 'City of Gardens and Water'.

Singapore is well-advanced in securing a diversity of water sources and the ABC Waters Design Guidelines project was principally directed at formulating a framework for the whole-of-catchment implementation of WSUD practices in stormwater management. Concurrent with policy development and integration of regulatory and administrative instruments across the many (catchment management) stakeholder government agencies are the implementation of demonstration and pilot projects as focal points for industry capacity building and the establishment of locally-based research initiatives.

A number of pilot projects have been carried out to demonstrate innovative stormwater quality treatment technologies that can be integrated into streetscape, public open space and urban design.

In time, Singapore will become a fully-integrated water sensitive city where green spaces form part of an ecologically functioning 'green infrastructure' which cleanses stormwater prior to discharging it into stormwater drains and from these into downstream receiving waters, most of which serve as drinking water resources in Singapore.

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