THE IMPORTANCE OF A TRIPLE BOTTOM LINE APPROACH FOR SAFEGUARDING URBAN WATER QUALITY

ASHANTHA GOONETILLEKE[1] AND TAN YIGITCANLAR[2]

Address: School of Urban Development, Queensland University of Technology, Brisbane, Australia
e-mail [1]a.goonetilleke@qut.edu.au, [2]t.yigitcanlar@qut.edu.au

ABSTRACT

Water environments are greatly valued in urban areas as ecological and aesthetic assets. However, it is the water environment that is most adversely affected by urbanisation. Urban land use coupled with anthropogenic activities alters the stream flow regime and degrade water quality with urban stormwater being a significant source of pollutants. Unfortunately, urban water pollution is difficult to evaluate in terms of conventional monetary measures. True costs extend beyond immediate human or the physical boundaries of the urban area and affect the function of surrounding ecosystems. Current approaches for handling stormwater pollution and water quality issues in urban landscapes are limited as these are primarily focused on 'end-of-pipe' solutions. The approaches are commonly based either on, insufficient design knowledge, faulty value judgements or inadequate consideration of full life cycle costs. It is in this context that the adoption of a triple bottom line approach is advocated to safeguard urban water quality. The problem of degradation of urban water environments can only be remedied through innovative planning, water sensitive engineering design and the foresight to implement sustainable practices. Sustainable urban landscapes must be designed to match the triple bottom line needs of the community, starting with ecosystem services first such as the water cycle, then addressing the social and immediate ecosystem health needs, and finally the economic performance of the catchment. This calls for a cultural change towards urban water resources rather than the current piecemeal and single issue focus approach. This paper discusses the challenges in safeguarding urban water environments and the limitations of current approaches. It then explores the opportunities offered by integrating innovative planning practices with water engineering concepts into a single cohesive framework to protect valuable urban ecosystem assets. Finally, a series of recommendations are proposed for protecting urban water resources within the context of a triple bottom line approach.

INTRODUCTION

Water is an unusual commodity: it is scarce, fragile and absolutely vital to life and development, yet so poorly understood and appreciated. Climate change and its consequent impacts on water resources have come as almost an ambush; together with significant population growth, patterns of urbanisation and consumption, the natural hydrological cycle has been altered and reliable water supply has become more and more difficult to obtain (Lee et al. 2010). There are several vital challenges to secure water provision and one of the most important is to provide a reliable water source for a rapidly expanding population and economy (QWC, 2007).

Beyond this, as Asakawa et al. (2004) have noted, as population densities increase in our cities, water environments play an ever more significant role as aesthetic and recreational resources. The need for 'islands of tranquillity' such as a waterway within the congested and busy urban environment has been clearly noted in research literature (Gobster et al. 2004). However, the needs of urban communities are not solely restricted to water quality outcomes. Urban water environments also play an important role as wildlife habitats. For example, Davies (1983) found that about 60% of native wildlife in Queensland State, Australia is present within its urban waterway corridors. Consequently, water environments in urban areas are important community and environmental assets and central to sustainable urban development. Therefore, it is imperative that innovative strategies are adopted to ensure that such key assets of a region are protected.

Unfortunately, similar to most parts of the world, water environments in Australia are also under increasing threat due to the rapid spread of urbanisation (SOE 2001). Any type of activity in a catchment such as urbanisation that modifies the existing land use will explicitly result in quantity (i.e. flood) and quality (i.e. pollutant) changes to the characteristics of stormwater runoff. These changes are the result of the removal of vegetation and the replacement of previously pervious areas (i.e. open spaces) with impervious surfaces such as roads, roofs and driveways. This in turn leads to increased stormwater runoff. The consequential quantity related impacts include more rapid rises in flood levels, increased flood peaks and flood volumes, stream bank and bed erosion, siltation and destruction of riparian vegetation and aquatic habitats.

In relation to quality, adverse impacts arise due to the introduction of pollutants of physical, chemical and biological origin resulting from anthropogenic activities common to the urban environment. Roads, housing, commerce and industry not only lead to irrevocable changes to the urban landscape, but are also responsible for introducing numerous pollutants to the environment.

The major problems in urban areas are the pollution of the atmosphere, soil and water. As an example, Lind and Karro (1995) found that heavy metal concentrations in the topsoil layers of urban roadside areas in Sweden to be 2 to 8 times higher when compared to rural areas. Atmospheric pollutants return to ground through wet and dry deposition and are available for wash-off during rainfall. Similarly, soil pollutants can be subjected to erosion and wash-off with stormwater runoff. The deterioration of water quality, degradation of stream habitats and decrease in ecosystem health are among the most tangible of the resulting detrimental water quality impacts of urbanisation, and result in a water body that is fundamentally changed from its natural state (House et al. 1993).

SOURCES AND CONSEQUENCES OF WATER POLLUTION

As Sartor and Boyd (1972) have identified, urban stormwater runoff constitutes the primary transport mechanism that introduces non-point source pollutants to receiving waters. As stormwater flows over the drained surface, pollutants will be incorporated through various physical and chemical processes (Egodawatta et al. 2009; Egodawatta & Goonetilleke 2008). The source from which the stormwater runoff is generated is one of the most important factors which will influence its pollutant composition. The sources of water pollution have been widely discussed in research literature. The primary pollutant sources in an urban catchment include street surfaces, industrial processes, construction and demolition activities, litter, spills and erosion (Pitt et al. 1995).

Urban stormwater runoff has been recognised as the major transport source for a wide variety of pollutants to water bodies. Recent years have witnessed significant advances in the control of point sources of pollution such as sewage outfalls. Consequently, non-point sources such as stormwater runoff are gaining increasing importance. The pollutant impact associated with stormwater runoff in terms of concentration and total load can be significantly higher than secondary treated domestic sewage effluent (Wanielista et al. 1977). This applies not only to the physical and chemical quality, but also to the microbiological quality of urban stormwater (Wahl et al. 1997).

As Ahyerre et al. (1998) have noted, the generation and transport of pollutants in urban systems during a storm event is very complex as it concerns many media, many space and time scales. Changes to the hydrodynamic characteristics of the catchment due to urbanisation increases average water flow velocities and hence stream power. This in turn mobilises and transports greater concentrations of pollutants from surfaces.

During a rainfall event, the impacts of high flows and intermittent discharges of pollutants on receiving water bodies are superimposed on the hydrologic, physico-chemical and biological characteristics of an urban catchment. Urban stormwater runoff will produce both, short-term and long-term changes in receiving waters leading to habitat instability and chemical toxicity. This in turn will result in changes to aquatic communities such as increased mortality of biota and detrimental changes to species diversity and abundance (House et al. 1993; Lopes et al. 1995; Wahl et al. 1997). Consequently, the combination of changes to the physical habitat and altered water quality is the major impact of urban stormwater runoff (Collier et al. 1998; House et al. 1993; Warren et al. 2003).

THE CURRENT STRATEGY FOR POLLUTANT MITIGATION

The sources and causes of urban stormwater pollution are widely known and are related more to human activities within the catchment than just to the expansion of the urban landscape itself. However, pollution control constitutes an intractable challenge. It is the non point-sources which are the most damaging, the least visible and the most difficult to control.

Current approaches to stormwater pollution control centre around conventional concepts of volume and peak flow reduction and primary forms of treatment and reuse. These principles are commonly applied in the form of structural measures and referred to as Water Sensitive Urban Design (WSUD) in Australia, Low Impact Development (LID) in the US or Sustainable Drainage Systems (SUD) in the UK.

Commonly, these structural measures collect, convey, and detain or retain stormwater and thereby improve water quality. They are designed and constructed to treat stormwater runoff by removing pollutants and protecting and enhancing the environmental, social and economic values of receiving waterways. The selection of appropriate treatment measures depends on site conditions, target pollutants, hydrologic characteristics of the catchment and rainfall characteristics experienced in the region. Figures 1 to 3 below provide images of typical treatment measures noted above.

Figure 1 Typical stormwater detention basin

Figure 2 Stormwater treatment wetland

Figure 3 Grass swale

THE LIMITATIONS IN CURRENT STRATEGIES

The concepts in themselves as described above are admirable. However, their application and performance under real world conditions is open to criticism. Table 1 provides a brief evaluation of these common structural measures.

Table 1. Issues associated with conventional approaches to stormwater management

Treatment device	**Primary function/s**	**Issues**
Retention, detention basins	Volume and peak flow reduction	1. Can only afford to detain relatively small volumes 2. Sediment build-up and weed infestation entail regular maintenance 3. During dry periods collected water can become anaerobic, breed pests becoming a health hazard and pollutant generator
Wetlands	Quality improvement	1. Can only afford to treat relatively small volumes 2. Efficiency in quality improvement not completely proven, particularly removal of very fine sediments, dissolved nutrients 3. Adequate design guidelines for stormwater treatment not available and dependency on wastewater treatment guidelines
Gross pollutant and sediment traps, Vortex devices	Quality improvement	1. Can only afford to treat relatively small volumes 2. Do not have the capability to remove very fine sediments 3. During dry periods collected water can become anaerobic, breed pests becoming a health hazard and pollutant generator
Grass swales	Quality improvement	1. Can be effective in removal of particulate sediments but not necessarily fine sediment 2. Adequate design guidelines are not available 3. Most paved surfaces such as streets do not have space for their installation

As outlined above, commonly adopted measures are based either on, insufficient design knowledge, faulty value judgements or inadequate consideration of life cycle costs. The various structural measures are costly, largely ineffective when dealing with large flows or in dealing with the 'real world' problems and even being counter-productive. Implementation of structural measures is also often interpreted as being 'seen to be doing something' in response to community pressure. Use of gross pollutant traps for litter removal is a prime example. Litter, though conspicuous is not a major source of water pollution and its major impact is visual aesthetics. Unfortunately, due to its high visibility, it attracts the most publicity and the maintenance effort rather than the more environmentally harmful pollutants. Similarly, street sweeping is purely for cosmetic purposes. The standard street sweeper cannot remove the fine particulates on the road surface that contribute significantly to water pollution.

Modelling is one way where improved design outcomes may be developed. However, based on the current state of knowledge, stormwater pollution does not fit into neat mathematical models which engineers and scientists can use for predictive purposes. Predictive errors of over 100% are common in the use of various models. This is due to the difficulty in mathematical formulation of key anthropogenic activities and the questionable mathematical formulation of key concepts. The quantification of relationships that support quantitative models of urban systems is fundamental to the performance of many current models and is crucial for developing improved designs that will work in concert with surrounding natural and constructed systems.

Unfortunately, significant knowledge gaps currently exist in this area. Though it is an active area of research, it is unlikely that an in-depth knowledge base will be available to support robust engineering design in the immediate future. Consequently, the dependency on poorly validated scientific concepts, inadequate design guidelines and the dearth of exemplars of properly functioning stormwater quality treatment systems tends to perpetuate a legacy of poor treatment design.

THE WAY FORWARD

Therefore, it is no surprise that more and more frequently, the life-cycle costs of poorly designed urban and industrial systems are found to be extremely high in financial, social and ecological terms. These costs are often slow to impact and cumulative such as increased levels of heavy metals in fish and crustaceans. Without scientific quantification and understanding of system dynamics, the effects of quantity and quality changes in stormwater flows may be the ‘sleeper’ that awakes. When it awakes it will be far from benign. The effect of global warming provides an example of such a cumulative, but largely ignored impact.

Calculation of life-cycle costs and forms of environmental accounting is a developing area of research. There is no consensus on an appropriate method for reconciling all the benefits and costs to a single unitary measure. True costs to a community for water quality degradation extend beyond immediate human or the physical boundaries of the urban area and can affect the functioning of surrounding ecosystems from which the community may derive income, such as tourism, fishing, water sports or agricultural production.

Until consensus can be reached on a methodology to integrate the different value systems associated with ecological, social and economic systems, a triple bottom line (TBL) is ignored by default. Elkington (1980) coined the introduction of TBL and definition of the term as follows:

TBL focuses corporations not just on the economic value they add, but also on the environmental and social value they add – and destroy. At its narrowest, the term ‘triple bottom line’ is used as a framework for measuring and reporting the performance against economic, social and environmental parameters (Elkington, 1980; 1998; Suggett et al., 2002; Suggett and Goodsir 2002; Vanclay 2003).

TBL audit concept initially involved placing dollar values on identifiable impacts of business activity, such as the cost to society of water or air pollution or the cost of an enterprise development to neighbouring property values. According to Rogers and Ryan (2001: 283) “…these costs and benefits would be included in the financial accounting of a profit margin—or financial bottom line. However, the concept has moved to a more rigorous evaluation of social and environmental performance, producing a matrix of interlocking bottom lines—or, rather, interlocking scenarios on which decisions can be made. The [ultimate] aim is to maximise performance across all areas of activity”.

TBL is far from perfect and appears to place equal emphasis on each area. However, it has long been shown that the economy is contained within our society and in turn society is contained within the ecosystem. Hence to move towards sustainable urban forms, the ecosystem functions need to be addressed first followed by social and then economic needs.

After ordering the TBL, the divergence from the known sustainable performance of the system, in this case the pre-settlement hydrology should be modelled, and used as a benchmark. In turn, key social and financial parameters should be considered in order to provide an objective view of progress and ‘costs’ on a TBL.

Land would continue to be developed to meet fundamental human needs.

However, it is important that the effective allocation and utilisation of land resources should not only meet human needs, but is also kept within the carrying capacity of the land and by implication, its water resources. This is due to the dynamic interactions between land and water systems. Therefore, sustainable development can be defined as; where controlled growth is permissible without reducing the resilience of the ecosystem. Hence, in the context of sustainable urban land and water resource planning and management, the recognition of the impacts of urbanisation on the water environment is among the most crucial. The sustainable management of water requires integration and recognising the interconnections between ecosystem needs and the dynamic nature of interactions in a complex environment. Consequently, a holistic approach is needed to quantify the impact of urban development on the water environment. The problem of urban water pollution can only be remedied through innovative planning and the courage to implement sustainable practices.

The following recommendations are proposed for protecting urban water resources within the context of sustainable development and TBL approach:

- There has to be a strong nexus between research and practice as our current state of knowledge in relation to urban water quality and pollutant processes are very limited. Therefore, it is essential that the most recent scientific knowledge is incorporated into urban system design and in the development of water quality mitigation strategies.
- Technology should not be seen as the primary or the only solution. Technology should only play a supporting role to strengthen innovative planning and design of urban systems. Secondly, technology applications should be underpinned by strong scientific understanding of their performance and inherent limitations together with an in-depth understanding of lifecycle costs whilst taking into consideration the environmental costs.
- Achieving sustainability relies on human managed systems, such as urban systems, mimicking natural systems. Therefore, this requires the development of an in-depth understanding of the natural systems and thereby the incorporation of this knowledge into urban planning and design strategies.
- Urban planning and design should take into consideration in equal measure the economic rate of return on investment, the value of ecosystem services of the area and the intrinsic value of the water resources to the community. This approach requires the creation of innovative approaches for assessing the true benefits and costs of urban development.
- Regulatory processes governing urban development should incorporate mandatory requirements for triple bottom line accounting and reporting in relation to urban developments.

CONCLUSIONS

Water is an essential source to life. In recognising that we need water to live, it is also important to understand that safeguarding urban water quality play a critical role in enabling a sustainable urban environment. The concept of sustainability and its applicability to urban settings, including urban water management, have been among the most discussed issues in the literature. However, so far current approaches for handling stormwater and water quality issues in urban landscapes are focused on ‘end-of-pipe’ solutions. Sustainable urban landscapes must be designed to match the triple bottom line needs of the community starting with ecosystem services first such as the water cycle, then addressing the social and immediate health needs, and finally the economic performance of the catchment.

As Lacey and Heywood (2010) put forward, successful water management has multiple facets which include planning, designing, constructing, operating and maintaining the infrastructure associated with water supply. Particularly with the changing climate and rising urbanisation problems, urban and environmental planners have become forefront actors in working towards maintaining urban water quality. As rapid urbanisation and growing population of cities are considered, to work in close collaboration with the engineering profession to address the implications of changing lifestyles on water resources and how these are remedied, along with the climate change, could be considered as the most pressing subject of the urban and environmental planning professions. The complex nature of cities and politics around them strongly force urban and environmental planners to analyse contemporary water resource and management problems of their cities more carefully. This also pushes them to produce more effective policy recommendations and programs. In this instance, the widely accepted concept of ‘triple bottom line sustainability approach’ comes into play.

According to Christen et al. (2006) the triple bottom line provides both a model for understanding sustainability and a system of performance measurement, accounting, auditing and reporting. This sets the scope of triple bottom line reporting as part of a broader framework of change management for integrating sustainability into urban water management decisions. The triple bottom line provides a dual function as a model for management planning and a framework for reporting sustainability levels (or urban water quality) in the context of widely accepted approaches to sustainability within a society. Today there is a growing interest in many parts of the world across the triple bottom line of economic, environmental and social disciplines towards an ethical and accountable approach to sustainability in general and the water environment in particular.

REFERENCES

Asakawa, S. Yoshida,K. and Yabe, K. (2004) “Perceptions of urban stream corridors within the greenway system of Sapporo, Japan,” Landscape and Urban Planning 68, 167-182.

Ahyerre, M., Chebbo, G., Tassin, B. and Gaume, E. (1998) “Storm water quality modelling, an ambitious objective?,” Water Science and Technology 37, 1, 205-213.

Collier, T.K., Johnson, L.L., Stehr, C.M., Myers, M.S. and Stein, J.E. (1998) “A comprehensive assessment of the impacts of contaminants on fish from an urban waterway,” Marine Environment Research 46, 1-5, 243-247.

Christen, E., Shepheard, M., Meyer, W., Jayawardane, N., and Fairweather, H. (2006) “Triple bottom line reporting to promote sustainability of irrigation in Australia,” Irrigation Drainage Systems 20, 329–343.

Davies, W. (1983) “Wildlife of the Brisbane Area,” Jacaranda Press, Queensland.

Egodawatta, P., Thomas, E. and Goonetilleke, A. (2009) “Understanding the physical processes of pollutant build-up and wash-off on roof surfaces,” Science of the Total Environment 407, 6, 1834-1841.

Egodawatta, P. and Goonetilleke, A. (2008) “Understanding urban road surface pollutant wash-off and underlying physical processes using simulated rainfall,” Water Science and Technology 57, 8, 1241-1246.

Elkington, J. (1980) The Ecology of Tomorrow’s World: Industry’s Environment London: Associated Business Press.

Elkington J. (1998) “Cannibals with forks: the triple bottom line of 21st century business,” 2nd edn. New Society Publishers

Gobster, P.H. and Westphal, L.M. (2004) “The human dimensions of urban greenways: planning for recreation and related experiences,” Landscape and Urban Planning 68, 147-165.

House, M.A., Ellis, J.B., Herricks, E.E., Hvitved-Jacobsen, T., Seager, J., Lijklema, L., Aalderink, H. and Clifforde, I.T. (1993) “Urban drainage-impacts on receiving water quality,” Water Science and Technology 27, 117-158.

Lacey, J., and Heywood, P. (2010) “The ethics of regional water planning: planning and management of water resources in a growth region,” In Sustainable urban and regional infrastructure development: technologies, applications and management,” Yigitcanlar, T., (Ed.). Hersey, P.A: Information Science Reference, pp. 183-200.

Lee, S.Y., Yigitcanlar, T., Egodawatta, P., and Goonetilleke, A. (2010) Sustainable water provision: challenges, alternative strategies and sources in the era of climate change. In Sustainable urban and regional infrastructure development: technologies, applications and management. Yigitcanlar, T. (Ed.). Hersey, PA: Information Science Reference, 17-30.

Lind, B.B and Karro, E. (1995), “Stormwater infiltration and accumulation of heavy metals in roadside green areas in Goteborg, Sweden,” Ecological Engineering l. 5, 533-539.

Lopes, T.J., Fossum, K.D., Phillips, J.V. and Monical, J.E. (1995) “Statistical summary of selected physical, chemical, and microbial characteristics and estimates of constituent loads in urban stormwater, Maricopa County, Arizona,” US Geological Survey, Water-Resources Investigations Report 94-4240, Tucson, Arizona.

Pitt, R., Field, R., Lalor, M. and Brown, M. (1995) “Urban stormwater toxic pollutants: assessment, sources, and treatability,” Water Environment Research 67, 3, 260-275.

QWC (2007), Queensland Water Commission, Our water: Urban water supply arrangements in South East Queensland, final report [Online]. Available www.qwc.qld.gov.au/myfiles/uploads/institutional%20arrangements/Urban_Water_Supply_Arrangements_in_SEQ.pdf, accessed on 21st March 2008.

Rogers, M., and Ryan, R. (2001) “The Triple Bottom Line for Sustainable Community Development,” Local Environment, Vol. 6, No. 3, 279–289.

Sartor, J.D., Boyd, G.B. (1972) “Water pollution aspects of street surface contaminants,” Report No. EPA-R2-72/081, US Environmental Protection Agency, Washington, DC, USA.

SOE (2001) Australia: State of the Environment, CSIRO Publishing, Australia.

Suggett, D. and Goodsir, B. (2002) “Triple Bottom Line Measurement and Reporting in Australia: Making it Tangible,” Retrieved on 23/11/2009, from http://www.environment.gov.au/settlements/industry/publications/triple-bottom/pubs/parta.pdf.

Suggett, D.,and Goodsir, B. (2002) “Triple bottom line measurement and reporting in Australia. Making it tangible,” The Allen Consulting Group, Melbourne

Vanclay, F. (2003) “Experiences from the field of social impact assessment: where do TBL, EIA and SIA fit in relation to each other?,” In: Pritchard B, Curtis A, Spriggs J, Le Heron R (eds) Social dimensions of the triple bottom line in rural Australia. Australian Government Bureau of Rural Sciences, Canberra

Wahl, M.H., McKellar, H.N. and Williams, T.M. (1997) “Patterns of nutrient loading in forested and urbanized coastal streams,” Journal of Experimental Marine Biology and Ecology 213, 1, 111-31.

Wanielista, M.P., Yousef, Y.A. and McLellon, W.M. (1977) “Nonpoint source effects on water quality,” Journal Water Pollution Control Federation 49, 3, 441-451.

Warren, N., Allan, I.J., Carter, J.E., House, W.A. and Parker, A. (2003) “Pesticides and other micro-organic contaminants in freshwater sedimentary environments – a review,” Applied Geochemistry 18, 159-94.