Stormwater Management Design Objectives

DISCUSSION PAPER – PART 1 – REVISING THE OBJECTIVES

Final Report – May 2019

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Funded by:

Queensland Government

Document history

Revision:

Revision no.	03
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Approved	Steve Skull (Alluvium)

Distribution:

Revision no.	01
Issue date	26/05/2018
Issued to	Glenn Browning (HLW) Andrew O'Neill (HLW) Brad Dines (DES)
Description:	Draft for comment
Revision no.	02
Issue date	17/10/2018
Issued to	Glenn Browning (HLW) Andrew O'Neill (HLW) Brad Dines (DES)
Description:	Revised draft for comment
Revision no.	03
Issue date	27/05/2019
Issued to	Glenn Browning (HLW) Andrew O'Neill (HLW)
Description:	Final Report

Citation:

Alluvium (2019). Stormwater Management Design Objectives Discussion paper – Part 1 – Revising the Objectives, prepared on behalf of Healthy Land and Water and the Department of Environment and Science, Alluvium Consulting Australia, Brisbane, 2019.

Acknowledgments:

We particularly appreciate the inputs of Glenn Browning, Andrew O'Neill and Shaun Leinster in the development of this discussion paper.

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1 Introduction

The waterways of Queensland are important to the communities who live in and around them. These waterways provide a range of values and ecosystem services that support the environmental, social and economic prosperity of the state and need to be managed in ways that protect and enhance those values and services.

Threats and impacts from urban areas (both new and existing) on our waterways can take a range of forms, including increased stormwater runoff volumes and frequency, increased pollutant loads and concentrations, erosion, siltation and destruction of waterway habitats and loss of abundance and diversity of the flora and fauna that relies on these.

Recognising the threats to the values of our waterways, the Queensland Government has established urban stormwater management design objectives that apply to new developments in Queensland. While these objectives have helped to increase awareness and enshrine urban stormwater management in mainstream practice, there is a need to review the current situation to ensure that our urban waterways continue to provide for the values that the community desires. The purpose of this paper is to discuss the frameworks that have been established to help protect and enhance waterway values from the impacts of urban stormwater and examine the ability of the design objectives for urban stormwater to deliver outcomes that assist in this.

Scope

The project scope was originally outlined in the terms of reference for this project and included the following requirements:

- a literature review of current scientific knowledge in this area;
- a review of implementation to date of the above Design Objectives;
- evidence-based proposals / recommendations for alternative waterway health objectives;
- links to existing policies and frameworks such as Living Waterways 2.0 (Water by Design 2017);
- the practical application of the Design Objectives, triggers for adoption and applicability of offsite measures; and
- insights on potential barriers to adoption, how these new objectives can instigate widespread adoption.

More specifically, there was a requirement to focus on whether there was sufficient information to provide guidance on revised design objectives for hydrology and water quality criteria.

This discussion paper

We have formulated this discussion paper with knowledge, insights and experience from our project team (which includes Healthy Land and Water and Department of Environment and Science staff) and through two workshops, one with the project team and one with a broader range of stakeholders. This document is not intended to be a detailed quantitative analysis of new objectives, but to highlight where we have come from as a stormwater industry in terms of setting standards for waterway protection, how these standards have operated and where we could head in terms of better implementation for improved community, economic and environmental outcomes.

For clarity, the discussion paper is divided into two parts. Part 1 is a review of the development of the existing design objectives, the science around how stormwater design objectives are contributing to waterway health outcomes and potential improvements in the numerical objectives themselves.

Part 2 focuses on a new framework for setting design objectives that considers the policy, legislative and other contexts and proposes new approaches for how design objectives may be better formulated to provide better waterway outcomes in urban areas across Queensland.

2 What is the issue with the current design objectives?

2.1 Background

Currently, the pollutant load reductions and waterway stability criteria provided in the Single State Planning Policy - Water Quality State Interest Appendix 2 are what is referred to as the Urban Stormwater Design Objectives. These are intended to be reflected in all local government planning schemes and apply to relevant new developments across Queensland. These objectives have been derived from work commencing over 20 years ago in South Eastern Australia and have been adapted and improved over time to form the current values.

From experience in their application by members of the project team, we realise that there are a number of issues with the objectives as they are, including:

a) Are the numerical objectives still applicable for Queensland given improvements in science in recent years?
b) Do we need additional objectives to cover other contaminants or impacts?
c) Do the objectives maximise other waterway benefits?
d) Are the management responses (as a result of complying with the objectives) likely to protect and enhance waterway health if they are continued to be applied?

Set out in the following sections is a discussion of the history of how these objectives were developed, some of the recent science associated with determining waterway impacts from urban stormwater, what may need to change with the numerical objectives and finally how these changes might be implemented.

2.2 History of the current Stormwater Design Objectives

Within Queensland, our current focus in developing design objectives stems from the late 1990s, when the Environmental Protection (Water) Policy was released that allowed for the setting of water quality objectives across Queensland.

These objectives were designed to protect and enhance community agreed Environmental Values consistent with the National Water Quality Management Strategy. Local governments responded to this by developing approaches that required assessments of compliance with concentration-based water quality objectives to be considered in new urban developments. Some Councils, notably City of Gold Coast, required that developers demonstrate a "no-worsening" of water quality as part of their developments. The challenge then became how to assess whether the responses put in place were sufficient and cost-effective to achieve Council policies and objectives for water quality management. Concurrent with this requirement was monitoring and research being undertaken on stormwater quality, mostly led by Brisbane and Gold Coast Councils in Queensland, with Melbourne Water and Monash University undertaking wider ranging research on stormwater quality and treatment device performance, all of which ultimately led to the development of the MUSIC (Model for Urban Stormwater Improvement Conceptualisation, eWater Solutions) stormwater quality modelling software.

The results of these early approaches were that concentration-based objectives on their own were able to be manipulated quite easily to demonstrate compliance. Where a no-worsening requirement was in place, applicants would look to demonstrate that the existing land use was as "dirty" as possible so that the need to reduce concentrations on new developments would be minimised, even leading to the absurd assumption that urbanisation of a fully pervious parcel of land would result in an improvement in water quality. The monitoring of stormwater quality at the time suggested that while some reductions in concentration may be possible for some land use changes (e.g. from a dairy or piggery to an urban land use), these did not account for the change in hydrological response producing greater runoff volumes, and therefore greater overall loads of pollutants. For these reasons, local governments moved towards pollutant load reductions from the developed future land use as it could be demonstrated that this would also address the concentrations of pollutants in most cases. The only issue not resolved by this approach was the pre-existing land use condition, such that in particular development types, land use change would result in an overall increase in loads (this is mostly associated with total nitrogen (TN)). The current requirement is to reduce TN loads by 45% on new urban development. That means that 55% of the pollutant load is still going to the waterway. Depending on what the land use was previously, this can increase the downstream loads of TN significantly, as the illustrative case study graph in Figure 1 shows. The same may also be true for total suspended solids (TSS) and total phosphorus (TP), but typically, TN is most likely to present a load increase regardless of the pre-development land use.

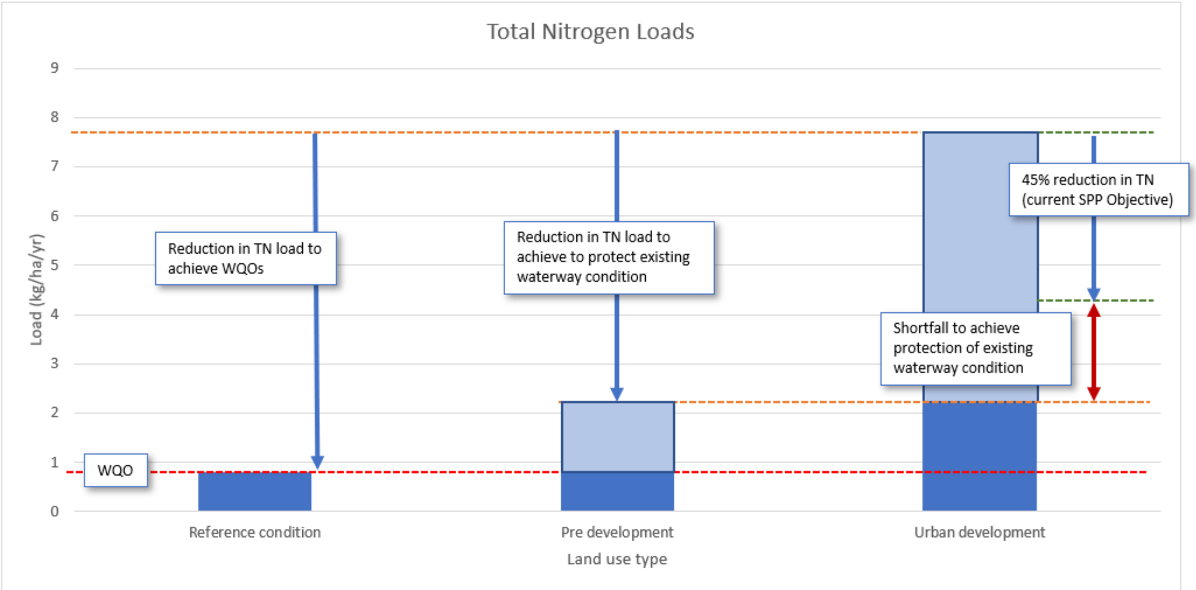

Figure 1. *Loads from different land uses*

The current design objectives are therefore able to address reductions in loads from future land use, but do not consider whether this is an increase or decrease from the predevelopment case. ***It could be argued then that they allow for deterioration in overall water quality even after application of treatment measures and hence do not comply with the Water Quality State Interest that "The environmental values and quality of Queensland waters are protected and enhanced".***

To understand the cost-benefit of stormwater quality management, several business cases were developed in the last 20 years examining various combinations of stormwater treatment approaches. ***These all showed that there are optimal sizes of treatments which, if over or undersized, would no longer be cost-effective to achieve load-based reductions.*** This led to the development of stormwater design objectives based around the reductions in loads of pollutants that appropriately sized treatment measures could deliver based on these "diminishing return" curves as shown below.

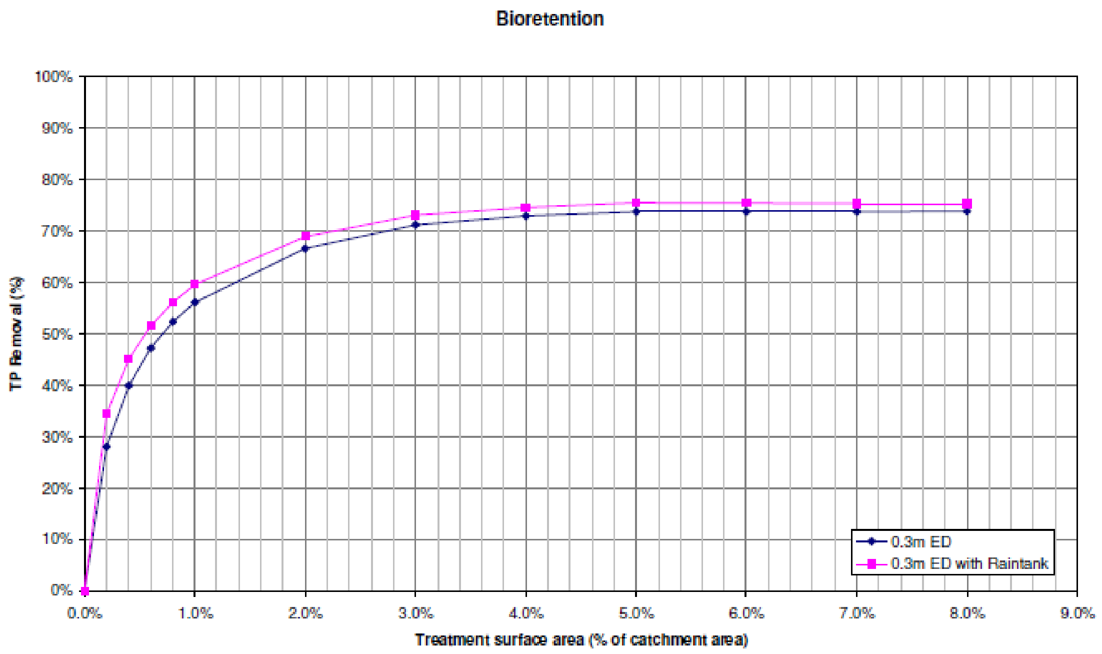

Figure 2. *Diminishing return curve for TP treatment in Mackay climate (EDAW 2009)*

In 2009, this information was used to support the development of an implementation note for the SEQ Regional Plan, which then led to the development of State Planning Policy 4/10 Healthy Waters (SPP 4/10). This was initially a standalone State Planning Policy (SPP) established to provide consistent approaches within local government planning schemes for dealing with stormwater quality and hydrology in new urban development. This became the basis of the load-based reduction objectives currently contained within the Single SPP within the Water Quality State Interest (SPP July 2017)

Current approaches to managing urban stormwater have typically only focussed on modelled pollutant load reductions, with some attempts to manage urban hydrologic change through the requirements to achieve a waterway stability objective. The latter have not been consistently applied, due to both uncertainty in their ability to mitigate hydrologic impacts and the methods of assessment to demonstrate that they are being achieved.

The application of design objectives also needs to consider how those objectives will influence the management responses by local governments and developers. Currently, the use of the modelling tool MUSIC for compliance assessment tends to lead to treatment measures that satisfy the SPP objectives most effectively in terms of model results, but do not consider all of the design outcomes needed to effectively protect existing urban waterway health, or that enhances the range of values that an urban waterway may provide. This is not a fault of the tool itself, as it can be configured in many different ways and is able to model a multitude of stormwater design approaches. However, given that the MUSIC software is relatively easy to use, this can also lead to perverse outcomes where the ***treatment measures have been designed where function is prioritised over form***, as shown in the following images. In these cases, the designer of the stormwater treatment measures has focussed only on achieving the requirements of the SPP objectives through modelling and engineering, rather than considering the multiple objectives than can be achieved through proper integration into the built environment. The SPP objectives are therefore useful in driving the delivery of treatment measures that can achieve specific load reductions, but do not adequately drive the maximisation of benefits that true Water Sensitive Urban Design (WSUD) can deliver.

Figure 3. *Examples of a stormwater treatment measure where function over-rides form*

While the current approach has a number of issues as outlined above, it has provided a good mechanism for delivery of stormwater treatment outcomes to date, including:

- A balance of stormwater treatment and affordability
- Treatments that have been implemented can provide disconnection of impervious surfaces, slowing down flows
- The compliance approach is straight forward and easily modelled with MUSIC
- A reasonably equitable distribution of costs across developments in a jurisdiction
- Consistent approach across local governments
- There are only a small number of targets (in effect, 3 numbers only)
- Widespread adoption rates for new development types across Queensland

There are many more examples of high-quality treatments being delivered that do maximise benefits and a few of these are shown below.

Figure 4. *Examples of well integrated stormwater treatment measures*

It is always easy to focus on the negative outcomes, but examination of a range of treatment measures implemented across Queensland show that even where they are not well integrated into the urban form, have aesthetic or nuisance issues or have some failure of asset integrity, they are usually providing their intended stormwater treatment function to a large degree. The challenge is therefore not only one of treatment function, but of better asset management and integration with a range of potential beneficial outcomes

2.3 Key issues

- **Current design objectives are focussed on cost-effectiveness of treatment measures, not on waterway outcomes. Therefore, they do not provide a link between a) the strategic intent of "protecting and enhancing" waterway quality, b) the management response of stormwater treatment measures and c) the outcome of achieving waterways which provide economic, social and ecological benefits.**

- **Hydrologic objectives have been developed previously, but not consistently applied, due to uncertainty in the outcomes delivered, the methods of assessment and the potential costs in implementation.**

- **Current compliance processes produce measures where function can be prioritised over form.**

- **Treatment function needs to be integrated with other beneficial functions and improved asset management.**

- **Current design objectives provide a simple approach for compliance - adding complexity to the objectives may therefore increase the assessment and compliance burden and reduce the uptake of effective stormwater treatment.**

3 What does the science say?

3.1 Stream Health

There have been significant scientific advances in recent years into the impacts of urbanisation on stream health, largely due to urban stormwater (Duncan, 1995; Hatt et al., 2004; Miller et al., 2014). Perhaps the greatest change in knowledge has come from a recognition that approaches set around water quality targets alone are no longer going to achieve community expectations for urban impacted streams (Roy et al., 2008).

Elmore and Kaushal (2008) suggest that the major impacts of urbanisation occur not just from flow and water quality, but the simple process of burying streams through covering with development has a major impact on long term catchment stream heath. Their findings suggest up to 70% of first order streams are lost through the process of urbanisation, which would indicate a simple focus on water quality alone would not be sufficient to prevent loss of habitat and ecosystem function for urban waterways.

3.2 Hydrology

In recent years, there has been a significant change in focus in urban stormwater studies, away from only considering the impacts of water borne contaminants such as sediment, nutrients and associated pollutants, to examining the impacts of hydrologic change ((Walsh et al., 2012)), restoration of ecosystem function, (Fletcher et al., 2014) and more detailed examination of urbanisation impacts from urban stormwater (McIntosh et al., 2013). This latter works showed that in SEQ, impacts from urbanisation were clearly present in waterways downstream of urban areas, with negative aquatic ecological impacts being identified. Unlike other studies, this did not appear to be directly related to changes in hydrology, even though both modelled and monitored changes in hydrology were identified. The actual changes in hydrology were also not as clear as expected, strongly suggesting that the changes were dependent on catchment characteristics (such as size, slope, time of concentration and spatial hydrologic networks) not on a simple change in land use such as the increase in area of imperviousness. It was also suggested that the ecological impacts may have been related to changes in water quality parameters such as temperature range, rather than the traditional sediment and nutrient changes which are currently used as indicators of impact. There was also an indication that seasonality of flow changes may cause further ecological impact if the timing of events is largely different to those required for certain species. This is a very common issue for fish ecology, in that the timing of flows is a critical factor in determining ability to transit streams to access breeding habitat or to enter or exit stream and estuarine zones (Koster et al 2016). It should be noted that the McIntosh et al 2013 study is the only contemporary study in Queensland that has investigated the linkages between hydrologic impact and ecological outcomes, so further work is needed for a range of different stream types and ecological outcomes across the State.

A number of studies have investigated flow metrics designed to better understand the relationship between stormwater and its impact on receiving environments. Kennard et al, (2010) identified 120 potential flow metrics that describe ecologically relevant characteristics of the natural hydrologic regime. Vietz et al. (2018) focussed on nine streamflow metrics in applying the Urban Streamflow Impact Assessment (USIA) to understand the impacts on waterway values, and the setting of objectives to either retain or return those values:

- Annual flow volume
- Mean duration of zero flow periods
- Total duration of zero flow periods
- Baseflow index (ratio of baseflow to total flow volume)
- Frequency of freshes (flows > 3 times median flow)
- Total duration of freshes (flows > 3 times median flow)
- Total duration of flows above channel erosion threshold
- Frequency of floodplain engagement flows
- Total duration of floodplain engagement flows

Data, tools and an expert panel were used to identify threshold for each metric in response to the relevant values. This paper also presents the linkages between creek values and flow metrics. The paper suggested that the metrics of 'mean annual flow volume' and 'time above the bed mobility threshold', were both associated with a high risk of losing values. The results suggest that for the case study waterway of Lowes Creek, Sydney, a 50% reduction in annual flow would be required to protect values, implying significant harvesting and reuse of stormwater. The objectives identified in the USIA framework provide a clear linkage between hydrologic criteria and the ecological functions and values that are protected, though these are delivered on a reach by reach scale. The paper also notes the reliance on expert opinion in negotiating metric thresholds, a shortcoming supported by Stewardson et al (2017), suggesting that modelling of ecological responses has lagged behind that of hydrologic and hydraulic responses in environmental flows assessments. Rather, expert opinion has often been used to predict likely ecological responses to specific changes in discharge and/or hydraulic habitat.

Despite recent work such as that set out in the USIA approach, a detailed understanding of the flow regime requirements to protect urban stream ecosystems remains poor and typically the metrics adopted have focussed on limited aspects of the flow regime (often peak flows). This can lead to perverse outcomes, such as large end-of catchment attempts at peak flow attenuation that don't mitigate the effects of urbanisation on local stream geomorphology. (Fletcher et al, 2014).

In response, Walsh et al (2016) proposed '5 principles for protecting stream ecology'. This approach includes the principle that the post development balance of evapotranspiration, stream flow, and infiltration should mimic the predevelopment balance. Along with Vietz et al (2018) and the work of Duncan et al (2014) discussed above, there is a theme that reduction in total annual runoff volume is a potentially important flow indicator.

There are obviously challenges to meeting high percentage reductions in mean annual flow particularly if we are principally relying on stormwater harvesting, reuse and infiltration and the space required for infrastructure to enable them in the urban environment. Fletcher et al (2014) notes that stormwater harvesting is likely to be a critical element of an ecohydrological approach.

There are opportunities however to restore pre-development catchment scale water fluxes (infiltration, evapotranspiration and runoff) via interventions at the land-parcel scale (Burns et al., 2013; Hamel and Fletcher, 2013) ideally through a combination of rainwater harvesting and raingardens. Burns suggests that on-site stormwater control measures should be designed to retain 25 mm of rainfall.

In Charlotte, North Carolina, Bell (2016) found that total imperviousness was an effective management metric at the event scale that had driven uptake of WSUD. However, implementation of WSUD at the levels observed had not affected hydrology significantly at the watershed scale. In Australia more recently, the metric of effective imperviousness (EI) and directly connected imperviousness (DCI) have been used as an indicator of stream health. EI describes the proportion of a catchment made up of impervious areas that are directly connected to receiving waters via a constructed drainage system. EI provides a better prediction than Total imperviousness (TI) of changes in flow regime, water quality (Hatt et al., 2004) and geomorphic condition (Vietz et al., 2014).

Walsh et al., (2012) suggest that catchments with as little as 5–10% total imperviousness and conventional stormwater drainage are associated with poor in-stream ecological condition, reduced contributions to baseflows and increases the frequency and magnitude of storm flows, while in similarly impervious catchments where there is informal drainage to forested hillslopes and no direct piped discharge to the stream, there is little hydrologic change and streams retain good ecological condition.

A discussion on flows also requires consideration of the restoration of baseflows (Fletcher, 2014). The impact of urbanisation on streams are mediated by alteration of land cover and subsurface drainage and understanding interactions of these two effects is critical (Walsh and Webb, 2016). Bonneau et al (2018) highlights the impact of urbanisation on groundwater flow, observing a relatively constant groundwater baseflow in forested catchments compared to distinct seasonal variations in urbanised catchments as groundwater responded to rainfall events. In summary Bonneau suggests that groundwater storages drain faster in the urbanised catchment, removing that constant baseflow that supports 'shallow slow water habitat' within urban streams.

Water sensitive urban design is applied to urban catchments to return them to a more natural flow regime. The few existing monitoring studies provide early indications of the potential of stormwater control measures (SCMs) to deliver more natural flow regimes (Li et al, 2017) however there remains a need for properly monitored studies that will assess the hydrologic effects of SCMs at the catchment scale.

3.3 Quality

Current design objectives require a removal of sediment (total suspended solids or TSS) and nutrients (Total Nitrogen or TN and Total Phosphorus or TP) from urban stormwater. Other planning guidelines and standards (e.g., Singapore, Victorian BPEM) also include TSS, TP and TN as key indicators to address in stormwater management strategies (Lim and Lu, 2016; Lucke et al., 2018). The removal of these constituents from stormwater is necessary for ecological protection and public health. Due to the association of microbial contaminants (Helen et al., 2016; Henry et al., 2015) and toxic contaminants to suspended matter in urban stormwater (Walaszek et al., 2018a), removal of the TSS enables removal of key toxic and microbial contaminants. In addition, fine sediments have been found to pose risks to aquatic biota in streams by smothering habitats and reducing light penetration (Aspray et al., 2017; Davies-Colley et al., 2014). Both phosphorus and nitrogen removal are necessary for guarding against eutrophication in receiving waters (Paerl et al., 2016, 2015; Yang and Lusk, 2018). In addition, litter (gross pollutants) in urban stormwater is often comprised of vegetated matter which can contribute nutrients to receiving waters (Alam et al., 2017). Indeed, street cleaning and the removal of gross pollutants from a catchment in North America was found to lead to reductions in total phosphorus by 84% and total nitrogen by 74% (Selbig, 2016), though other studies have been less conclusive about the effectiveness of street sweeping (Walker and Wong 1999).

As such, the current scientific literature appears to state that targeting reduction in suspended solids, gross pollutants and nutrients in receiving waters is important for protecting public and ecosystem health. The current Victorian BPEM removal targets from urban stormwater (of 80%, 45%, 45% and 70% for TSS, TP, TN and litter loads) were based on previous assessments around the reductions in nitrogen loads required to achieve outcomes in Port Phillip Bay (Port Phillip Bay Environmental Study (CSIRO, 1996)), but there is little evidence in the literature that these are sufficient for protecting stream and public health in urban waterways. It is speculated that the original load reduction targets were determined based on typical stormwater management technology load reduction performance at the time (Sage et al., 2015a), rather than a consideration of what is actually required to protect urban waterways.

Previous studies in other regions have found limited evidence of direct links between reduction in suspended solids and nutrient loads into waterways and improvements in stream health (as measured by biological community composition) (Lee and An, 2014). Furthermore, timing of the pollutant inputs and the impact of resuspended bed sediments in aquatic systems can significantly effect stream health (Davis and Koop, 2006; Visser et al., 2016). **The focus on only reducing mean annual nutrient and sediment loads may therefore not account for the processes by which these contaminants impact urban waterways and suggests that the "blunt" lever of a % reduction in loads to facilitate actions that protect stream health needs to be reconsidered.**

It is also important to note that current stormwater design objectives target load reductions only. There are examples of stormwater management objectives from other parts of the world (e.g., Singapore, Canada, New Zealand, France) where the urban stormwater quality objectives are composed of concentration targets (Lim and Lu, 2016; Sage et al., 2015a). Pollutant loads in streams can lead to ecological impairments, particularly in lentic systems (Sage et al., 2015a), in some lotic systems, pollutant concentrations can have stronger links to public health and ecological outcomes (Chambers et al., 2012; Zhao et al., 2018). Maret et al. (2010) identified stronger correlations between TN concentrations (compared to TN load) and eutrophication occurrence in agricultural streams in North America. As such, it appears that there may be a need to consider including concentration objectives in stormwater management objectives, especially for lotic systems. This actually may provide greater consistency with point source regulation, which can focus on both concentrations and loads. It also does suggest that a better understanding of the water quality stressors in urban streams may need to be considered in conjunction with hydrologic and ecological criteria.

An assessment of the characteristics of small-scale runoff (Lucke et al., 2018) suggest that recent changes in urban stormwater management have resulted in changes in stormwater runoff quality, however there were significant differences in scales between the monitoring used in this paper and previous studies, and also in the maturity of the sites being monitored. This would suggest that consideration of scale will be important at setting relevant design objectives, and that the use of the same objectives for both broad scale studies and development assessment requirements at the lot scale may not be appropriate. This issue appears to need greater consideration though as the comparison of small scale site data and small datasets with larger scale sites and larger datasets may not be statistically valid.

Meals et al. (2010) noted the issues of lag times in diffuse source management practices are significant but are dependent on both the location of actions and the pollutants involved. Selecting appropriate objectives or indicators that consider this is important especially if attempting to measure the change. This would suggest that attempting to measure impacts at the catchment scale of the implementation of green infrastructure used in diffuse source management is challenging though the performance of individual practices is becoming well understood.

3.4 Summary

Recent developments in the science of urban stormwater has shifted focus from only water quality aspects, to a greater consideration of all elements of the ecosystem that are being impacted by urban runoff, including hydrologic regimes, habitat resilience, and issues of temporal and spatial scales. Research has also demonstrated the value of integrating social, economic and environmental outcomes for greater overall benefits.

Design objectives that are only focussed on water quality are therefore not responding to what the science is identifying as being needed to protect waterways from urbanisation impacts and therefore what is most beneficial for providing sustainable, water sensitive urban spaces.

It should be noted that we have only focussed on the operational (post-construction) phase of urban development and design objectives associated with stormwater from fully developed sites. There is obviously an equivalent or even stronger need to ensure that the transition phase (construction phase) from existing to future urban land use has similar efforts in terms of understanding the science and establishing suitable objectives.

3.5 Key issues

- **Approaches set around water quality targets alone are no longer going to achieve community expectations for urban impacted streams.**
- **Up to 70% of first order streams are lost through the process of urbanisation.**
- **Urbanisation impacts were clear on waterways downstream of urban development, with negative aquatic ecological impacts being identified as associated with changes in both water quality and hydrology, but also on habitat and connectivity.**
- **One single hydrologic objective for stream health protection has not been identified, though reduction in mean annual flow volumes is commonly expressed. It is likely that more than one objective is required to demonstrate that hydrologic impacts (and their links to ecological outcomes) are adequately managed.**
- **There is only one significant study on the linkage between hydrologic impacts and ecological outcomes in Queensland.**
- **The Urban Stormwater Impact Assessment (USIA) approach provides a very strong linkage between hydrology and ecology for streams in Western Sydney. The criteria developed are focussed on the hydrologic responses required at a reach by reach scale.**
- **Significant reductions in flows are needed from urban areas in order to maintain ecosystem health.**

- **The focus on only reducing mean annual nutrient and sediment loads does not account for the processes by which these contaminants impact urban waterways and suggests that the "blunt" lever of a % reduction in loads to facilitate actions that protect stream health needs to be reconsidered.**

- **As such, it appears that there may be a need to consider including concentration objectives in stormwater management objectives**

- **Consideration of construction phase stormwater design objectives should have a similar degree of focus to operational phase stormwater design objectives**

4 What needs to change for urban stormwater design objectives?

There are several key issues identified in the previous chapters that highlight the need for change. This section outlines what specific elements can be improved with the current objectives and what other steps may be required.

We have focused this report on the numerical objectives themselves rather than the broader scale framework that facilitates their adoption, this being covered in Part 2 of the report.

Reviewing the questions highlighted initially, we can resolve what needs to change for the current implementation of urban stormwater design objectives. These are discussed below:

a) Are the numerical objectives still applicable for Queensland given improvements in science in recent years?

Water Quality

The science discussed in the previous section shows that reductions in TSS, TN and TP are a desirable outcome for urban waterways because of the broadscale increase in loads as a result of urbanisation, and the link of those constituents to habitat smothering, reduced light climate, eutrophication and transport of associated contaminants such as toxicants and pathogens. This would suggest that the current numerical objectives for TSS, TN, TP and litter are still required. With regards to the numbers themselves, there has been considerable work done to prove that these numbers provide a reasonable reduction in loads from future urban development and are a cost-effective in terms of the management responses needed to achieve them. ***We therefore believe that the current numerical load-based reduction objectives should be retained as a minimum standard required for urban stormwater management.***

We note the considerable effort in delivering load-based reduction objectives across the Great Barrier Reef region through the development of Ecologically Relevant Targets (ERTs). These have been developed through linking the catchment derived runoff loads with the water quality requirements needed in the receiving waters of the Great Barrier Reef. These vary across basins within the reef and relate the diffuse runoff to the ecological outcomes required for improved reef health. Such a method would also be useful for urban stormwater pollutant loads to connect the load reductions needed from urban stormwater runoff to ecological outcomes required in receiving waters and previous studies completed for Healthy Land and Water have examined this. These studies were focussed on existing urban areas largely, so load reductions that have been identified could be used to establish objectives for existing urban areas and may translate better to brownfield development and smaller scales, rather than simply applying the current load-based reduction objectives which are focussed on managing impacts from new (largely greenfield) development. Work is also needed to examine the ERTs developed for the reef and whether the existing load reductions in Appendix 2 of the SPP provide sufficient reduction in loads in GBR catchments compared to the land use prior to development.

From the previous sections, we have also identified that current objectives do not always reduce loads from new urban areas compared to the land use that existed prior to development. This needs to be addressed, as it could be construed that the current load-based objectives do not actually achieve the Water Quality State Interest in all cases. This is further discussed in Part 2.

Hydrology

With regards to the hydrologic objectives, the single stream stability objective does not appear to be sufficient to protect urban streams from the impacts of hydrologic change, though it may be one of several that is needed. It is obvious that to manage hydrologic impacts on urban streams, several hydrologic criteria need to be assessed. This could range anywhere from 7 to over 100 criteria based on the literature, but ***the USIA framework from NSW would appear to have considerable merit*** and provides a strong linkage between the hydrologic criteria and the ecological outcomes that are protected by achieving those requirements. The challenge with these criteria is that some of them are reach based, i.e.

they need to be determined and assessed at a reach by reach scale. ***What is needed is an assessment of the management responses required to deliver hydrologic criteria at a range of scales and to assess whether there is a consistency in types of measures that deliver these***. For example, if most of the hydrologic change can be managed through retention, storage and reuse, can a particular volume of capture per hectare, or a reduction in mean annual runoff volume/peaks/frequency be established as common objectives that would achieve the majority of hydrologic criteria required in streams. This assessment could be conducted in a similar way to previous assessments around the achievement of TSS, TN and TP load reductions, examined for different waterway types across Queensland and at several different scales. This is discussed further in the next section.

The City of Gold Coast has derived waterway stability and frequent flow objectives as outlined in their City Plan 2 documents, specifically in the Land Development Guidelines Planning Scheme Policy. The Waterway Stability Objective is consistent with that outlined in Appendix 2 of the State Planning Policy and is based on the limiting the change in erosive flows through the indicator of no changes in event discharges for the 1 in 1 year Annual Recurrence Interval. From reviewing the literature, this is a relatively unsophisticated objective and while simple and potentially useful, it does not consider the full range of events likely to produce erosive flows. We therefore believe that while useful and likely to be one criterion for managing erosive flows, ***the current stream stability objective is probably insufficient to effectively manage the impacts of urbanisation on stream erosion***. The frequent flow objectives within the City of Gold Coast documents contain several criteria including:

1. baseflows (in particular winter baseflows) – ≥10% of mean annual rainfall volume converted to baseflow (less than baseflow threshold of 0.4 l/s/ha).
2. surface flow – ≤ 20 surface runoff days per annum measured as days where the maximum daily flow rate exceeds the baseflow threshold of 0.4 l/s/ha.
3. flow reduction – ≥25% reduction in mean annual runoff volume from unmitigated development.

These objectives detail more scientifically rigorous hydrologic outcomes for Gold Coast Waterways that are also scaleable for a range of development sizes and stream reaches. These objectives are attempting to limit hydrologic changes from urbanisation to within a certain band of change and are likely to address the practicalities of achieving them (through device sizes and treatment requirements), however there is no apparent connection to the ecological outcomes they are meant to protect. When compared to the literature, these three objectives are consistent with others derived for a range of locations across Australia, but in order to limit hydrologic impact, more criteria may be necessary. ***We therefore believe that these objectives are likely to be a good indication of the types of criteria needed, but further work is necessary to identify whether these are sufficient to limit hydrologic change for ecological outcomes*** (i.e. connecting hydrologic criteria with the waterway outcomes to be achieved) and the required management responses needed to achieve them.

b) Do we need additional objectives to cover other contaminants or impacts?

From the issues identified in previous sections, other contaminants such as pathogens and toxicants should also be considered in managing urban stormwater impacts. Currently, the approach has been to assume that through treatment of TSS, these contaminants are being effectively managed, and the literature does support this to some extent, but objectives specifically focussing on pathogens would be highly desirable, especially related to areas where waterway recreation is promoted. We are aware of current work being undertaken by Healthy Land and Water under the "Healthy Waterplay" initiative and would suggest that this be used for any development of pathogen objectives for waterways.

With respect to other impacts, the issues of waterway loss, especially of first order streams, is significant and no consideration is given around the loss of these waterway types during urban development. Whether these areas are significant from an ecological perspective is not readily apparent from the literature, but with losses of up to 70% of first order streams identified, this could be very important in terms of managing hydrologic change, simply because as first order streams are at the top of a catchment, the flows needing to be managed are much smaller than further downstream and treatment requirements may be much smaller. We also note that the land area covered by first order streams is considerable and it may not be practical to maximise retention of them and still achieve an economic development yield on some or all sites. This issue requires further examination and would be related to a larger assessment of waterway habitat loss.

The current objectives therefore do not protect urban waterways from a range of other impacts such as habitat loss, changes in amenity and recreational access and further objectives on these impacts need to be considered. Documents such as the Living Waterways framework provide methods for assessing and managing these and this is discussed further in Part 2. Our assessment is that ***further objectives for managing other waterway impacts from urbanisation are needed but need to be facilitated by a different implementation framework.***

c) Do the objectives maximise other waterway benefits?

Currently, ***the simple answer is no***, though it is likely that the management responses could be optimised considerably to deliver other benefits, for example through integration of hydrologic and water quality outcomes together, rather than separately. The numerical objectives themselves are largely disconnected from the waterway benefits that they could achieve, so do not facilitate them, but may still provide some partial benefits such as impervious surface disconnection, depending on the management responses used to achieve the objectives.

d) Are the management responses (as a result of complying with the objectives) likely to protect and enhance waterway health if they are continued to be applied?

Again, ***the answer to this question is largely no***, and in some cases may lead to a deterioration in water quality downstream. Because the objectives are not directly connected to protecting and enhancing waterway health, but derived on cost-effectiveness of the management response, they have no ability to achieve waterway health outcomes, but may facilitate their achievement. The current objectives need to be supplemented by other approaches simply to protect waterway health, and further work is needed to plan for the enhancement of waterway health where it is no longer of a condition suitable to achieve the social, ecological and economic services it needs to provide.

More broadly, from our reviews of the history, science and current implementation of urban stormwater design objectives, we believe the following issues need further consideration:

- **We need to link urban stormwater design objectives to the waterway outcomes they are meant to achieve.**
- **We need to understand the links between different objectives to understand how to integrate management responses to maximise the outcomes across them. This will help to deliver the most cost-effective methods of achieving healthy urban waterways while also avoiding perverse outcomes where the focus is only on achieving individual objectives.**
- **We need to assess the types of objectives at a range of scales, including the reach, stream, waterway catchment, river basin and receiving water scales. It is quite apparent that a "one-size-fits-all" approach is not enough to achieve the required waterway outcomes across all scales.**
- **We need to understand whether there is consistency in management responses for different objectives so that we may be able to focus on deriving criteria that relate to those responses in addition (or even replacing) to those required in a waterway.**
- **Water quality indicators alone are insufficient to manage impacts on waterways from urbanisation and other objectives are required in order to protect and enhance the environmental values of Queensland's waterways.**

- **Simplicity and consistency have been the hallmark of the current urban stormwater design objectives and wherever possible, this needs to retained.**

- **Avoid perverse outcomes when considering how the objectives are to be achieved by integrating objectives wherever possible.**

5 How should we change the urban stormwater design objectives?

What is obvious from the previous sections is the need for urban waterway management to have better connections between the strategic intent, management responses and desired outcomes required at different waterway scales. Numerical urban stormwater design objectives are but one element in providing those connections but can be far better integrated into a clear line of sight between what is intended to be achieved, the types of stormwater management responses we use and the specific stream and waterway outcomes they deliver. It is fair to say that currently these linkages are not well understood nor defined; we have strategic intents in the State Planning Policy to protect and enhance Queensland's waterways, but the design objectives do not directly lead to consistently achieving this intent. Change is needed if we want to ensure that we can move towards achieving healthy, resilient and productive waterways that continue to provide the ecosystem services which we expect they can deliver.

To do this, changes in both implementation frameworks and the types of objectives are needed, but this needs to be supported by underlying science to improve our ability to manage waterways more effectively. In this Part 1 report, we focus on the changes and improvements needed for the numerical objectives. We cover the implementation framework in more detail in Part 2, though it is important to understand the relationships between both the framework and the objectives themselves, and the potential improvements to both parts. The changes needed are outlined below:

1. Set up framework to prevent deterioration of existing condition

We know from the implementation of the existing design objectives that in some cases there is still a deterioration of existing waterway conditions. While these objectives have been demonstrated to provide cost-effective responses at a range of development scales, further action may be required beyond the development to at least protect urban waterways from change. We therefore propose developing a strategic framework which allows for a local government to adopt a no net change in waterway value, or to use a planning process to develop strategies for enhancing waterway condition. This would embed an overall strategic intent for waterway outcomes and provide further justification for requiring management responses above the existing SPP objectives. The additional responses needed to achieve this is not intended to be borne directly by development but would provide an avenue for local governments to seek LGIP contributions for trunk water quality infrastructure that can at least allow for the Water Quality State Interest to be achieved. This is discussed further in Part 2.

Recommendation: Establish a strategic framework to allow for the protection of the existing values of urban waterways.

2. **Further objectives for managing other waterway impacts from urbanisation are needed**

There are a range of other objectives related to achieving waterway health that could be incorporated into design objectives, as the current load-based reduction objectives are not enough on their own to facilitate the delivery of healthy urban waterways. The objectives need to link to the waterway outcomes they are trying to achieve, rather than simply being based on cost-effectiveness. The USIA framework being applied in NSW appears to have considerable merit in identifying ecological outcomes and the hydrologic criteria needed to achieve them, and we therefore recommend that a pilot scale application of this framework be considered for one or more urban waterways in Queensland.

As part of this study, consideration of the management responses needed to achieve these criteria should also be included to understand whether there may be consistent approaches that could deliver most of the waterway criteria in addition to the integration of waterway objectives for water quality, amenity, recreation and flow conveyance. The different scales of responses (from reach scale through to waterway catchment) should also form part of this assessment.

Recommendation: Test the application of the USIA framework in pilot waterways in Queensland, including an examination of the management responses needed to achieve hydrologic and ecologic criteria identified through the USIA framework and the ability of these responses to address other waterway objectives including water quality, amenity and flow conveyance.

3. Ensure minimum standard requirements for all development

The existing SPP stormwater design objectives provide a reasonable framework to ensure that actions are implemented through the process of urbanisation and that these contribute to reducing stormwater impacts on urban waterways. While the evidence outlined in this paper shows that they are insufficient to protect and enhance waterway health, the processes currently in place to support their implementation are significant and we don't believe that it is appropriate to abandon them. We therefore recommend that the existing objectives within the SPP be retained as a minimum standard for all development types above agreed thresholds. From discussions during the project, further work is being conducted on those thresholds and the revision of the triggers for when development impacts are to be managed is long overdue, especially given the extent of small-scale redevelopment and infill that has been occurring within the existing urban centres of South East Queensland.

The minimum standard approach also allows for an equitable approach to greenfield and brownfield development types, in that both are required to achieve the same targets, but we would also recommend that an assessment of the equity of this be examined. Redevelopment of existing urban areas can lead to an overall reduction in pollutant loads over time. A number of assessments we have undertaken across Australia have identified that at current redevelopment rates, ensuring that load-based reductions are applied to redevelopment (e.g. Sydney Metropolitan CMA 2011) can lead to the pollutant loads from existing urban centres being reduced over 20-30 year time frames. Redevelopment tends to have higher constraints in terms of space and flexibility of treatment measure placement, so the costs of achieving the same objectives for redevelopment compared to greenfield development may be considerably different.

Recommendation: Retain the existing SPP Urban Stormwater Design Objectives as the minimum standard for urban development in Queensland, recognising that this may not be sufficient to protect and enhance urban waterways, but is part of a process for achieving this.

Recommendation: Evaluate the equity of applying the existing SPP Urban Stormwater Design Objectives to both greenfield and brownfield development or whether the objectives need to be tailored to each development type.

4. Developing Ecologically Relevant Targets (ERTs) for sensitive waterways across Queensland

Across the Great Barrier Reef regions, a significant body of work has been undertaken in disaggregating broad-scale targets set across all regions to basin specific targets that relate to the impacts of those basins on sensitive receptors in the GBR. Previous studies in South East Queensland as part of the development of the Healthy Waterways Strategy completed similar background work to that which supported the development of the ERTs, and existing models of catchments and receiving environments exist for the region. It therefore may be relevant to extend the ERT work to South East Queensland to identify the urban and non-urban load reductions needed to protect sensitive receptors in the region's waterways. This would greatly assist in providing an evidence-based linkage for the establishment of varying load-based objectives to protect those sensitive waterways.

Recommendation: Develop Ecologically Relevant Targets for sensitive receiving environments within South East Queensland consistent with the process applied within the GBR regions to provide a scientific basis for the continued application of load-based reduction targets for existing and future urban and non-urban areas. This should be based on existing work completed within the region wherever possible.

5. Ensure that ERTs in the Great Barrier Reef basins are reflected in load-based reductions for reef urban areas

With the development of the ERTs across the GBR basins, we are not aware of any works that have evaluated whether the ERTs required can be achieved through the application of the SPP objectives to urban development in the GBR basins (for urban land uses only). We recommend a small study be undertaken to evaluate the consistency of these and whether changes are required to ensure that urban areas are achieving the required ERTs for each of the 47 GBR reporting basins.

Recommendation: Conduct a study to evaluate the consistency between the SPP Urban Stormwater Design Objectives and the Ecologically Relevant Targets within the GBR basins. This will ensure that urban areas within the GBR are able to achieve the levels of fine sediment and dissolved inorganic nitrogen reductions needed to achieve the ERTs in the relevant basin.

6 Conclusions

In this Part 1 report, we have focussed on reviewing the existing numerical objectives and assessing whether these need to change according to new science, implementation challenges and improved understanding of management responses. This has shown that the latest science suggests that water quality related targets are not sufficient to achieve healthy urban waterways through their application to urban stormwater management. Further work is needed to understand the hydrologic criteria and the ecological responses needed in urban waterways and how these may also provide connection to other waterway objectives.

Through examining the history of the development of the current objectives and some of the implementation issues which have arisen, we have identified that there is a disconnection between:

a) the strategic intent for waterway management;
b) the management responses we are currently delivering; and
c) the waterway outcomes we are hoping that they achieve.

To resolve this several recommendations associated with the numerical targets have been identified, and further works regarding the strategic framework in which they could be applied are covered in Part 2 of this report.

Several studies have been previously completed across Queensland to understand the targets needed to protect sensitive receptors within the Great Barrier Reef and this may provide an approach to extend this to other regions in the state, particularly South East Queensland.

Finally, the existing Urban Stormwater Design Objectives have provided the impetus to drive a level of stormwater management in urban developments and the guidance, frameworks and supporting activities associated with these have led to widespread action to improve stormwater management. We recognise in this report that this should be considered the minimum standard for urban development into the future, but further actions are required for the establishment of appropriate objectives that link the strategic intent and management responses for urban stormwater runoff to the outcomes we want to achieve in our urban waterways.

7 References

Binney, J. & James, D. 2012. Sharing the load: A collaborative approach to investing in South-East Queensland's waterways. Brisbane.

Duncan, H.P., 1995. A Review of Urban Stormwater Quality Processes (Industry Report No. 95/9), Cooperative Research Centre for Catchment Hydrology. Monash University, Melbourne, Australia.

Duncan, H.P., Fletcher, T.D., Vietz, G., Urrutiaguer, M., 2014. The feasibility of maintaining ecologically and geomorphically important elements of the natural flow regime in the context of a superabundance of flow (Technical Report No. 14.5), Melbourne Waterway Research-Practice Partnership. Melbourne Waterway Research-Practice Partnership.

Elmore, A.J., Kaushal, S.S., 2008. Disappearing headwaters: patterns of stream burial due to urbanization. Frontiers in Ecology and the Environment 6, 308–312. https://doi.org/10.1890/070101

Fletcher, T.D., Vietz, G., Walsh, C.J., 2014. Protection of stream ecosystems from urban stormwater runoff. Prog Phys Geog 38, 543–555. https://doi.org/10.1177/0309133314537671

Hatt, B.E., Fletcher, T.D., Walsh, C.J., Taylor, S.L., 2004. The Influence of Urban Density and Drainage Infrastructure on the Concentrations and Loads of Pollutants in Small Streams. Environ Manage 34, 112–24. https://doi.org/10.1007/s00267-004-0221-8

Koster W. M., Amtstaetter F., Dawson D. R., Reich P., Morrongiello J. R. 2016. Provision of environmental flows promotes spawning of a nationally threatened diadromous fish. Marine and Freshwater Research 68, 159-166. https://doi.org/10.1071/MF15398

Li, C., Fletcher, T.D., Duncan, H.P., Burns, M.J., 2017. Can stormwater control measures restore altered urban flow regimes at the catchment scale? Journal of Hydrology 549, 631–653. https://doi.org/10.1016/j.jhydrol.2017.03.037

Lucke, T., Drapper, D., Hornbuckle, A., 2018. Urban stormwater characterisation and nitrogen composition from lot-scale catchments — New management implications. Science of The Total Environment 619, 65–71. https://doi.org/10.1016/j.scitotenv.2017.11.105

McIntosh, B.S., Aryal, S., Ashbolt, S., Sheldon, F., Maheepala, S., Gardner, T., Chowdury, R., Hartcher, M., Pagendam, D., Hodgson, G., Hodgen, M., Pelzer, L., 2013. Urbanisation and Stormwater Management in South East Queensland – Synthesis and Recommendations (Technical Report No. 106), The Urban Water Security Research Alliance. The Urban Water Security Research Alliance.

Meals, D., Dressing, S., Davenport, T., 2010. Lag Time in Water Quality Response to Best Management Practices: A Review. J Environ Qual 39, 85. https://doi.org/10.2134/jeq2009.0108

Miller, J.D., Kim, H., Kjeldsen, T.R., Packman, J., Grebby, S., Dearden, R., 2014. Assessing the impact of urbanization on storm runoff in a peri-urban catchment using historical change in impervious cover. Journal of Hydrology 515, 59–70. https://doi.org/10.1016/j.jhydrol.2014.04.011

Roy, A.H., Wenger, S.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R., Shuster, W.D., Thurston, H.W., Brown, R.R., 2008. Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States. Environmental Management 42, 344–359. https://doi.org/10.1007/s00267-008-9119-1

Sydney Metropolitan Catchment Management Authority (2011). Botany Bay & Catchment Water Quality Improvement Plan. Sydney: Botany Bay Water Quality Improvement Program (BBWQIP)

Walker, T.A., Wong, T.H.F., 1999. Effectiveness of Street Sweeping for Stormwater Pollution Control, Technical Report 99/8, Cooperative Research Centre for Catchment Hydrology. Monash University, Melbourne, Australia.

Walsh, C.J., Fletcher, T.D., Burns, M.J., 2012. Urban Stormwater Runoff: A New Class of Environmental Flow Problem. PLoS ONE 7, e45814. https://doi.org/10.1371/journal.pone.0045814