Harnessing the Momentum – Incorporating the Lessons Learnt during Construction, Operation and Maintenance of Bio-retention Systems, along with Observations of Natural Templates, into the Design Process

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Key Points

- The engineered approach to bio-retention design often does not appreciate that these systems are attempts to design landscaped features to harness natural pollutant removal processes
- No direct connection from the overall precinct scale strategy through to the detailed design, can result in a disjointed, piecemeal process
- This has often resulted in structures that do not operate as intended, create maintenance issues and are visually out of character with the 'natural' landscaped features
- Analysis of the stable features of natural creek systems, can provide key insight into what locally works, with designers borrowing from local, stable design templates able to minimise both the construction and maintenance of a system

Abstract

This presentation sets out the framework for improving the design of bio-retention systems through learning the lessons of previous failures and successes, along with observations of local, natural creek formations.

At the precinct planning level, the detail required for practical construction and operation of water sensitive urban design infrastructure is often missed in water cycle management planning. At the other end of the scale, engineering design guidelines often focus too much on fine civil infrastructure detail. The result is that there is often no direct connection from strategy through to the detailed design.

The design of bio-retention features is rarely assessed in terms of hydraulic operation during the range of events, or in terms of ongoing maintenance. This has often resulted in structures that do not operate as intended, create maintenance issues.

This assessment also investigated 'natural' systems, where aspects of bio-retention basins had come about through non-designed means. These included locations such as the sedimentation of a farm dam, or the colonisation of a trapped low point by vegetation used in bio-retention basins. These unplanned systems were used as a template for basin design, with the stable, unmanaged and non-maintained features assessed for suitability for treatment systems.

Keywords

bio-retention design, WSUD maintenance, natural templates

Introduction

This study provides a qualitative site assessment of bio-retention basins, with the aim to provide pragmatic guidance for designers, constructors, owners and operators to achieve better outcomes in terms of cost, maintenance and effectiveness. Through our extensive experience with bio-retention basin design we have identified a large disconnection between designers and councils idea of how these basins should be designed and what actually happens during the construction process, as the basins operate and as the vegetation grows.

The aim of this study is to investigate the operation of bio-retention basins by undertaking a systematic, qualitative assessment to provide feedback for designers that will improve their designs. The objective of this feedback is to improve the cost effectiveness, constructability, operation and maintenance of the basins. This study is limited to the large, on-line bio-retention basins that are currently used in large scale urban development sites. The site audits and field investigations have been undertaken without detailed measurements of engineering structures, vegetation mapping or water quality testing. The records and findings of this study are based on the subjective analysis of engineers who have extensive experience in basin design and construction.

What is a bio-retention basin?

Bio-retention basins (also known as bio-retention systems, bio-filters, and rain gardens), along with any natural water treatment, are an attempt to use natural processes to achieve an 'unnatural outcome'. Bio-filtration systems are a popular stormwater treatment technology, using vegetated soil-based filters to attenuate flows, reduce runoff volumes, and improve water quality through sedimentation, filtration, sorption, and biological uptake (Davis et al., 2009, Hatt et al., 2009). Bio-retention basins aim to use the natural processes of biological responses by the vegetation, soil, microorganisms (terrestrial and aquatic), to provide treatment of stormwater runoff. This has a benefit as natural systems typically require fewer operational personnel, consume less energy, and produce less sludge than mechanical systems (WEF, 2001). Bio-retention basins are an attempt to engineer conditions suitable for these biological responses to remove pollutants from stormwater runoff.

Design issues – Council guidelines

Local councils produce guidelines to assist in the design and assessment of civil engineers infrastructure within their jurisdiction. These planning documents are essential for the engineering industry, as they provide guidance and cover all aspects of civil design, including drainage. They provide a framework to allow consideration of operation, maintenance and constructability. A leading example of the guidelines produced by one of the largest development councils in western Sydney is Blacktown City Council, which is used throughout NSW as a design guide.

The use of these engineering guidelines by designers and councils can lead to a situation of 'curve fitting' and 'box ticking' where designs are fine tuned to achieve certain guidelines. Basins are designed with specific water quality targets in mind, while the assessments of the basins seem to be undertaken by a checklist approach, rather than by investigating how they will be constructed, operate and be integrated within the urban landscape.

The use of 'natural' systems as a template

This assessment also investigated 'natural' systems, where aspects of bio-retention basins had come about through non-designed means. The aspects used to identify these systems were vegetation types and flow regimes similar to those designed in bio-retention basins.

Suitable sites were unsurprisingly difficult to find. Areas analysed for this study included locations such as the sedimentation of a farm dam, or the colonisation of a trapped low point by vegetation used in bio-retention basins. Some of these sites were found at trapped low points at the end of semi-rural roads, with others on areas of farmland taking runoff from golf courses or roads. Several of these sites had embankments that had developed through the growth of trees, in particular *casuarina* and *eucalyptus* species (e.g. eucalyptus benthamii, eucalyptus amplifolia). These unplanned systems were used as a template for basin design, with the stable, unmanaged and non-maintained features assessed for suitability for treatment systems.

Site Audits

McCann et al (2015) stated that stormwater quality improvement device dysfunction can be generally categorised into three areas:

- Poor design – including site selection, device configuration, and plant selection
- Incorrect or incomplete construction including incorrect set-out, inappropriate media, poor workmanship.
- Lack of maintenance and monitoring.

McCann et al (2015) listed the most common symptoms of failed stormwater devices are: excessive sediment, weed invasion, scour, poor water quality. The field investigations undertaken as part of this systematic qualitative assessment were based on readily observable measures of bio-retention basin health and operation.

The site audits of designed basins looked for:

- inlet arrangements (design, construction and operation)
- vegetation health and weed infestation
- civil design and construction issues
- assessment of maintenance records
- aesthetics — a subjective analysis of the appearance by engineers

The bio-retention basins selected for this investigation were chosen to include established bio-retention basins within development areas.

Site audits of 'natural' systems looked at:

- topography, including how the trapped low point had been created and what aspects of a designed basin were present
- vegetation type, in particular the typical bio-retention planting species, and the interaction with other vegetation such as trees

The records and findings of the field work are based on the subjective analysis of engineers who have extensive experience in basin design.

Findings

The findings of the site investigations were surprisingly consistent across the basins. The same issues were encountered at all basins in some form, with none of the basins audited judged to be operating as the designer had intended.

The investigations found that there were either no formal inlet structure present in the basin or that the design was overly complicated involving concrete structures. Our assessment was that none of these arrangements working as intended.

An assessment of the health of the bio-retention basin vegetation showed that there were several areas within the basins that were not functioning correctly. Large areas of dead plants were apparent in designed basins, with greater variability in species encountered at natural systems.

The main vegetation issue noted at all basins was the degree of weed infestation. *Typha* and *Casuarinas* were encountered at every basin to some degree. The majority of basin inlets, both designed and 'natural' investigated had *typha* at the inlet.

Several of the basins inspected had civil design and construction issues. This included overly complicated basin structures that appeared to not work as intended, to overly simple structures that didn't perform a necessary function.

Overly complicated outlet structures encountered were also prone to blockage. Structures such as this are often designed with certain outlet flow requirements in mind and do not consider construction difficulties or operational issues such as blockage.

Several basins inspected had large patches of standing water (days after a rainfall event). These are evidence of poor design and poor construction. Natural systems with standing water had species more suited to ponded water, such as macrophytes and *typha*.

Another issue with engineering design and construction were the maintenance access paths within bio-retention basins, which are a highly visible feature of the basins, out of character with the natural vegetation. The crushed sandstone access paths encountered during the inspections had all suffered from erosion, with deposition occurring either on the filter media or level spreader. Zero maintenance, non-designed 'natural' systems do have maintenance access tracks, with vegetation showing gradual changes and in many cases, interactions between tree, shrub and sedge species.

One basin that was investigated, located in Elizabeth Hills, was designed by Calibre Consulting, who also did the construction management of the project. This basin was installed and vegetated prior to the completion of establishment of 80% of the catchment, as is the industry standard. The bio-retention media was overloaded with sediment from building sites in the catchment, as well as litter, with a large infestation of weeds of *typha* and various grass weed species. These weeds had died, with the deliberate planted species, *carex, juncus,* and *lomandra* alive under the dead grasses.

Desirable attributes for raingardens across all residential streets were large, well-established trees with a lush green understorey (Dobbie, 2015). This is not possible with existing council guidelines as trees are not able to be planted within filter media as they would damage the media and earthworks. Most of the 'natural' systems had trees within the basins and embankments.

Conclusion

Bio-retention basins are attempts to use natural processes to remove nutrients. Similar, non-designed, 'natural' systems include a greater variability in hydraulic conditions, vegetation types and species mixes, often including aspects such as ponded water and trees. These aspects should be included in the design of bio-retention basins.

References

Davis, A. P., Hunt, W. F., Traver, R. G. & Clar, M. 2009. Bioretention technology: Overview of current practice and future needs. *Journal of Environmental Engineering*, 135, 109-117.

Dobbie, M.F., (2015) Retrofitting raingardens: Understanding context and satisfaction to guide streetscape change *2015 9th International Water Sensitive Urban Design Conference*

McCann, D., Bayley, M., & Munro, J. (2015) SQID function and performance in SEQ – lessons learnt over the past five years *2015 9th International Water Sensitive Urban Design Conference*

WEF (2001) *Natural Systems for Wastewater treatment, Manual of Practice FD-16*, 2nd Edition, Water Environment Federation