University of Southern Queensland

Faculty of Engineering and Surveying

The investigation of the sustainability of a regional approach to Water Sensitive Urban Design using a Triple Bottom Line Assessment

A dissertation submitted by

Mr Gerard William Black

In fulfilment of the requirements of

Bachelor of Engineering (Civil)

October 2012

Abstract

This research has compared various contributing economic, social and ecological factors involved with WSUD for both a regional and local treatment strategy for a 33.5 hectare site in the Mackay region. A greater understanding of the benefits and costs of these contributing factors involved in WSUD has been gained throughout this project. A Triple Bottom Line assessment (TBL) involving a multidisciplinary skilled Delphi Panel, representing urban development stakeholders, was used to investigate and ascertain; objectives, values and stakeholder preferences of a preferred treatment strategy approach. Further research was conducted to identify social and financial performance indicators for use in the TBL assessment, where associated Best Management Practice (BMP) costs and social attributes linked with existing BMP were investigated.

The Delphi Panel comprised of two groups; an Expert group made up of; a senior civil engineer, a principal civil engineer, a senior hydraulic engineer, a senior engineer (water), a senior landscape architect, a landscape architect, a MRC development approvals officer and an environmental scientist. The Stakeholder group comprises of; a UDIA member, the MRC Councillor for Developments and Approvals, the SLCMA Regional Landcare Facilitator and a local prominent developer.

The core values of each TBL element identified by the Delphi Panel were; financial element – to minimize cost impacts associated with stormwater treatment assets upon a development, borne by Council, the developer, and ultimately the home buyer; social element - overall community acceptance of the WSUD design; and ecological element - to reduce impact on receiving waterways and integration of treatment elements into adjoining natural areas.

The total acquisition, typical annual maintenance and life cycle unit rates recommended in this research best reflect the size of the BMPs proposed for Precinct A. The total acquisition unit rates adopted for the following treatment elements were; bioretention swales \$326/m^2, bioretention basins \$310/m^2, biopods \$330/m^2, and constructed wetlands (inclusive of two sedimentation basins approximately 2000 m^2 total) \$150/m^2, and street or verge streets \$950 each. Typical annual maintenance costs identified were; bioretention swales \$40/m^2/yr., bioretention basins \$12.50/m^2/yr., biopods \$12.50/m^2/yr., constructed wetlands \$2.70/m^2/yr., sedimentation basins, \$11.20/m^2/yr., and street or verge trees \$25 each. It is envisaged that these BMP unit rates can be used to help fill the knowledge gap for BMP costs in the Mackay region and potentially other regions.

A regional treatment strategy was the preferred treatment approach to sustainable WSUD recommended by urban development stakeholders in the Mackay region, despite the local treatment strategy achieving a higher value score following the TBL assessment.

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ENG4111 Research Project Part 1 & ENG4112 Research Project Part 2

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Gerard William Black

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Acknowledgements

I would like to extend thanks to my supervisors, Dr Ian Brodie, Mr Trevor Corney for their guidance and support throughout this project. I would also like to extend my thanks to Robyn Birkett and Luke Galea at Mackay Regional Council for their assistance. I would also like to thank Miss Sarah Jones for her patience and support throughout this endeavour.

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Nomenclature and Acronyms

ARI – Average recurrence interval
AUD – Australian Dollars
BAU – Business as usual
BMP – Best Management Practice
BPP – Best Planning Practice
CRC – The Cooperative Research Centre of Catchment Hydrology
DERM – Department of Environment and Resource Management
ESCCP – Erosion and Sediment Control Compliance Program
ESD – Ecologically sustainable development
EV – Environmental Values
GP – Gross pollutants
GPT – Gross pollutant trap
LCC – Life cycle cost
LIUDD – Low impact urban design and development
MCA – Multi-criteria analysis
MRC – Mackay Regional Council
MUSIC – Model for Urban Stormwater Improvement Conceptualisation
OBS – Overall Benefit Score
QUDM – Queensland Urban Drainage Manual
SLCMA – Sarina Landcare Catchment Management Association
SMART – Simple Multi Attribute Rating Technique
SQBMP – Stormwater Quality Best Management Practices
SWARD - Sustainable Water Industry Asset Resource Decision
SWQMP – Stormwater Quality Best Management Practices
TAC – Total acquisition cost
TAM – Typical annual maintenance (cost)
TBL – Triple Bottom Line
TN – Total nitrogen
TP – Total phosphorus
TSS – Total suspended solids
UDIA – Urban Development Institute of Australia
WQO – Water Quality Objectives
WSUD – Water Sensitive Urban Design

1.0 Introduction

1.1 Outline of study

This research investigates the sustainability of a regionalised end-of-pipe approach to Water Sensitive Urban Design (WSUD), when compared to a localised at-source stormwater treatment strategy for a proposed Greenfield urban residential development, on flat topography, in Ooralea Mackay, Queensland Australia. WSUD is a holistic approach to water management and urban planning that upholds environmental values and sustainability. Mackay Regional Council (MRC) to have taken the initiative to become a leader in promoting and adopting WSUD strategies for future urban development within Mackay. This research aims to investigate the sustainability of Council's proposed best practices through the use of a Triple Bottom Line assessment.

1.2 Study area – Precinct A

The site covers approximately 190 hectares and is bound by the Bruce Highway, Schmidtkes Road, Cowleys Road and Stockroute Road, see Fig. 1.1. The site currently accommodates sugar cane farming and rural uses and is under multiple land ownership. To the north, east and south of the site are a variety or proposed and existing urban residential and industrial uses including the Stockland Cuttersfield Estate and Paget Industrial estate which serves as a main industrial hub for the Bowen Basin mining industry. The site's flat topography is typical of Mackay, ranging between 0% - 0.5%. A 70 m wide stormwater drainage easement has been identified through the site as part of the Eastern Subcatchment Drain Alignment study, DesignFlow and V2i (2010). The scope of this research will only consider Precinct A, a proposed 33.5 hectare urban residential development within the 190 hectare site.

Topography and Drainage

The site is predominantly flat, typically less than 0.5% fall. The north-east corner of the site currently runs to an existing drain at the Bruce Highway. A 70m drainage easement is proposed through the site to convey regional flows of up to the 100yr average recurrence interval (ARI) and accept local flows from the site, Cardno Ullman & Nolan (2009). The drainage channel enters the site via existing box culverts under Schmidtkes Road (Invert level 6.130) and discharges towards Bakers Creek from the southeast corner of the site via existing box culverts under the Bruce Highway (Invert level 4.225).

MRC master planning has identified an opportunity to modify the alignment of the easement to promote more efficient stormwater management and enhance recreation, community and planning outcomes.

Downstream Waterways – Bakers Creek

The Schmidtkes Road development site discharges to a tributary of Bakers Creek which is located approximately 2-3 km to the south-east of the site. This Bakers Creek location is estuarine, containing mangroves and salt marsh environment. The *Bakers Creek Catchment management Area Report*, Drewry, Higham and Mitchell (2008) reported that the relative ecological condition of the estuarine part of Bakers Creek is low, with poor water quality flow and mangrove communities. The measures proposed in this report promote improved stormwater quality discharge to Bakers Creek, and ultimately the World Heritage listed Great Barrier Reef Marine Park.

Vegetation

Regional ecosystem mapping for the site reveals no remnant vegetation, nor significant trees following site inspection.

Soils

Soils on the site are silty sands which are typical of low-lying floodplains. No potential or actual acid sulphate soils were found following review of Department of Environment Resource Management. Due to the low-lying nature of the site, proposed earthworks may involve the State Planning Policy 2/02 (Planning and Managing Development Involving Acid Sulphate Soils).

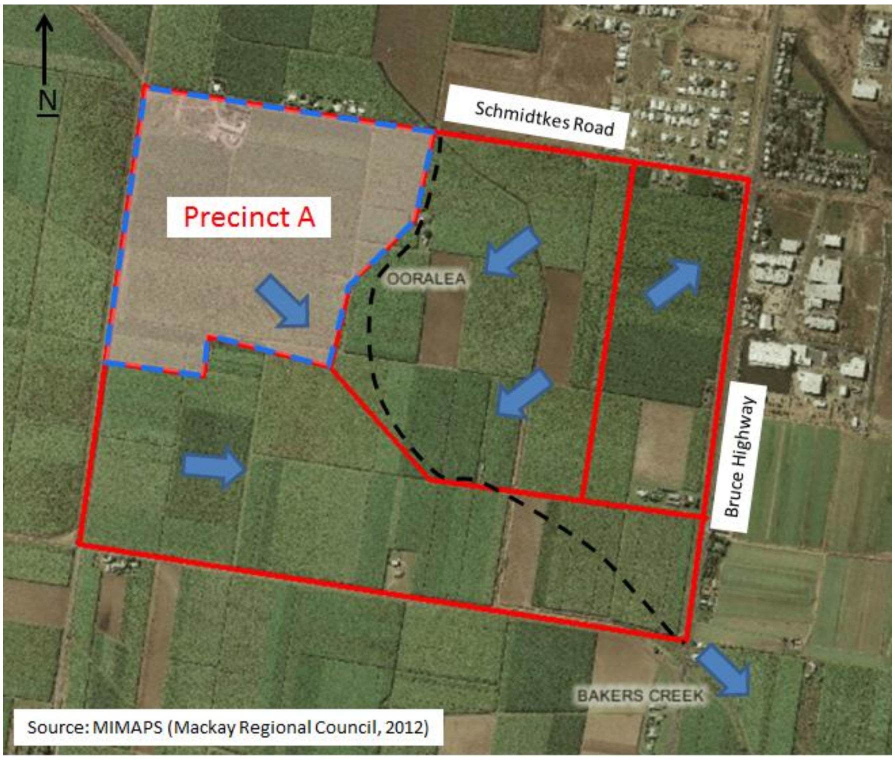


Fig. 1-1: Precinct A locality plan, Mackay Regional Council (2012).

1.3 Research Objectives

- Research, identify and understand contributing factors and practices involved with WSUD for both local and regional stormwater treatment approaches for a water sensitive urban development.

- Research existing costs associated with Best Management Practices (BMP) with the aim of defining a unit rate for total acquisition costs in Australian dollars per metre squared ($\$AUD/m^2$) for Best Management Practices for future use in the Mackay region and potentially elsewhere.

- Model a typical constructed wetland and sediment basin as a regional stormwater treatment approach for an urban residential development catchment using MUSIC (Model for Urban Stormwater Improvement Conceptualisation) that complies with MRC Water Quality Objectives. The regional stormwater treatment modelled in MUSIC will be compared against an existing 'at-source' local stormwater treatment strategy previously modelled in MUSIC model by MRC for the same urban residential development catchment, as outlined in the Best Planning Practice (BPP), *WSUD for Flat Sites.*

- Conduct a triple bottom line assessment using multi-criteria analysis and a Delphi Panel, consisting of urban development experts and stakeholders alike to and compare the sustainability of the social, financial and ecological elements of local and regional stormwater treatment strategies in an information rich environment.

- Recommend a sustainable treatment strategy to WSUD for application in future residential developments in Mackay, and possibly other regions.

1.4 Conclusions

The triple bottom line assessment aims to establish a framework to identify the objectives, values and concerns associated with urban development, and to use these identified contributing factors to gauge the sustainability of a regional strategy to urban stormwater treatment proposed for future urban developments in Mackay.

The research is expected to continue to fill the knowledge gap of construction, maintenance and total acquisition costs for BMPs in the Mackay region.

The use of the triple bottom assessment involving a Delphi Panel is anticipated to provide a platform and opportunity for networking integration of professional skills for stakeholders involved in urban development.

The outcomes of this study will be used as an aid for decision making stormwater managers and highlight the importance of the objectives and values aligned with sustainable urban development.

2.0 Literature Review

2.1 Water Sensitive Urban Design

2.1.1 Introduction

The term Water Sensitive Urban Design was originally coined to describe a new Australian approach to urban planning and design, and was first mentioned in various publications in the early 1990's and 2000's Engineers Australia (2006). Newman and Mouritz (1996) recognised the need for a more sustainable approach to urban development in 1995, where the integration of more socially sensitive, economically efficient and environmentally sustainable urban water management solutions and processes.

WSUD is a holistic approach to urban planning that aims to minimise the hydrological impacts of urban development to the environment. Also known as 'low impact development', it aims to mitigate development impacts on the natural water cycle, Healthy Waterways Partnership (2005).

Water By Design (2009) lists traditional urban development approaches in Australia, where little consideration is given to the environment, and an 'out-of-sight, out-of-mind' attitude is widely adopted:

- Drinkable 'potable' water is delivered to households and businesses from centrally-controlled supply networks where water is treated to the highest standards, irrespective of the quality required by the end user.
- Fresh water is supplied in unlimited quantities, except in drought conditions when restrictions are applied.
- Wastewater is collected and transported to centralised treatment facilities and discharged to vulnerable receiving aquatic environments.
- Stormwater, polluted by urban land uses and activities, is collected and efficiently transported in underground pipes to vulnerable receiving aquatic environments.

This traditional approach is reflected by:

- The water security issues facing many urban centres.
- The disconnection between human behaviour and impacts on the natural environment.
- The loss from public consciousness of basic concepts such as 'supply and demand' and 'cause and effect'.
- The assumption there is an endless supply of natural resources to sustain urban lifestyles.

Conversely WSUD has multiple environmental benefits including improving the urban landscape, reducing pollutant export, retarding storm flows and reducing irrigation requirements, Melbourne Water (2005).

According to Engineers Australia (2006), key objectives of WSUD include:

- Reducing potable water demand through water efficient appliances, rainwater and greywater reuse.
- Minimising wastewater generation and treatment of wastewater to a standard suitable for effluent reuse opportunities and/or release to receiving waters.
- Treating urban stormwater to meet water quality objectives for reuse and/or discharge to surface waters.
- Preserving the natural hydrological regime of catchments.

Where Healthy Waterways Partnership (2005) states the five key principles for water management are:

- Protect natural systems, such as downstream waterways and wetlands.
- Protect water quality of surface and ground waters by treating and reusing stormwater and greywater.
- Reduce runoff and peak flows, such as providing opportunities to detain water or re-use stormwater in surrounding areas, Department of Natural Resources and Water (2007).
- Add value to the social and ecological aspects of development while minimising construction and maintenance costs.

To achieve this, WSUD employs a range of best planning practices and best management practices.

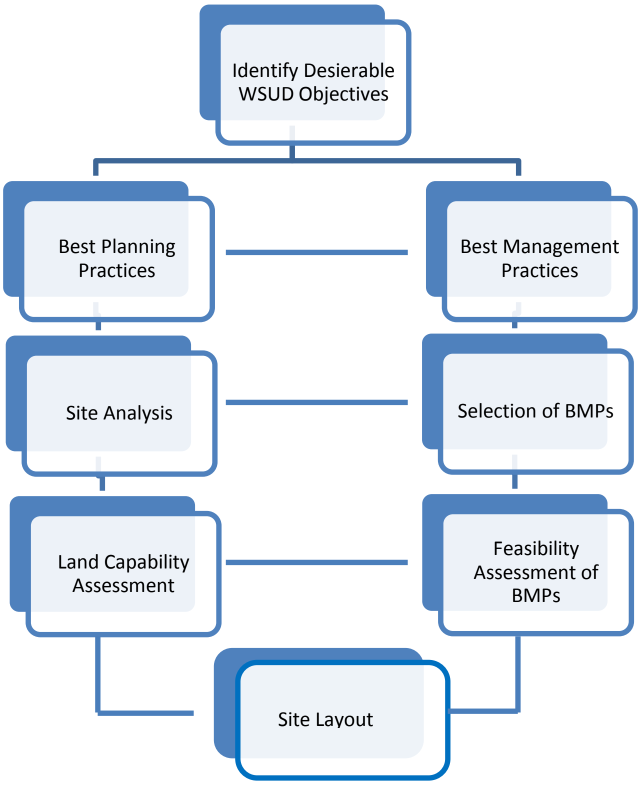


Fig. 2-1: WSUD planning and design process, Engineers Australia (2006).

BPPs relate to the 'site assessment, planning and design components of WSUD, see Fig. 2-1. BPPs can be implemented at strategic planning levels and can also be implemented at the site design stage. For example, site layout can be developed to retain or restore natural flow paths, wetlands and riparian vegetation, Water By Design (2009).

BMPs refer to the structural and non-structural elements of urban design that prevent, collect, treat, convey, store, and re-use water within an integrated water management scheme. MRC have undertaken a BPP case study – WSUD for Flat Sites DesignFlow and V2i (2010) for potential use in future urban developments in Mackay, see Section 2.4.

2.2 Stormwater and Urban Planning Policy

2.2.1 Integrated Planning Act 1997

The *Integrated Planning Act 1997* (Qld) (*The Integrated Planning Act 1997*) is a framework to integrate planning and development assessment so that development and its effects are managed in a way that is ecologically sustainable, and for related purposes.

The Integrated Planning Act seeks to achieve ecological sustainability by:

- coordinating and integrating planning at the local, regional and State levels; and
- managing the process by which development occurs; and
- managing the effects of development on the environment.

The local government for Mackay City developed, in accordance of the framework provided by The Integrated Planning Act to develop the *Planning Scheme for the City of Mackay 2006* (Mackay). The Planning Scheme took effect 24 March 2006 and is a framework for managing development in a way that advances the purpose of The Integrated Planning Act by:

- Identifying assessable and self-assessable development; and
- Identifying outcomes sought to be achieved in the local government area as the context for assessing development.

Mackay Planning Scheme Policy No. 15.05 – Stormwater Drainage Design Guidelines

The policy sets out the guidelines of 'traditional' stormwater drainage management systems for urban and rural areas. *The Queensland Urban Design Manual (QUDM) 2007,* is the basis for design of stormwater drainage and apart from limiting flooding of private and public property, a key objective of stormwater drainage design is:

- To provide a drainage system that will collect and convey stormwater from a catchment to its receiving waters with minimal nuisance, danger or damage and at a financial and environmental cost that is acceptable to the community as a whole; and
- To provide convenience and safety for pedestrians and traffic in frequent stormwater flows by controlling those flows within prescribed velocity/depth limits.

This traditional 'pit and pipe' stormwater management practice applies to new developments where the stormwater drainage system is designed in accordance with the 'major/minor' system concept in accordance with QUDM. Major systems are; safe defined overland flow paths and are less frequent. Minor systems manage more frequent runoff events.

For rain events in a residential zone, the average recurrence interval for a minor system is 5-years ARI and for major events, 100-years ARI.

Mackay Planning Scheme Policy No. 15.07 - Soil and Water Quality Management (2008)

The engineering design guidelines on soil and water quality management are aimed at the managing erosion and sediment control to uphold stormwater quality and minimise environmental impact from development. The key aim of the Policy is "*to provide an effective stormwater management system that balances environmental, social and economic interests within the Mackay community"*. The Policy took effect on 31 March 2008.

The Policy implements on-ground improvements for stormwater quality and erosion and sediment control, established by the framework of the *Stormwater Quality Management Plan for Mackay (SWQMP) 2006*. Stormwater Quality Best Management Practices (SQBMP), both structural and non-structural as well as drainage and erosion control techniques are used to minimise drainage, erosion and sediment issues and maintain water quality objectives (WQO).

2.3 Stormwater Management Design Objectives

2.3.1 Introduction

WSUDs key stormwater management objective is to protect the ecosystem and natural water cycle. Conventional traditional urban stormwater management of preventing flooding is still an important objective, although this traditional approach of piping and discharging stormwater cannot be the only stormwater management approach. This traditional approach impacts on aquatic ecosystems health and prevents urban landscapes from benefitting from stormwater, Water By Design (2009).

2.3.2 Stormwater Quality Management Plan for Mackay (2006)

In 2006, the Stormwater Quality Management Plan (SWQMP) for Mackay's urban areas was prepared to establish the framework *"to manage stormwater quality in urban waterways in a way that maintains or enhances the state of balance among ecological, social and economic interests within the community"*. The SWQMP was prepared to move away from the traditional stormwater management approach of minimising flooding by constructing systems to quickly convey stormwater away from urban development. The SWQMP for Mackay aims to be consistent with MRCs corporate objective for ecological sustainability. The SWQMP shows a direct commitment to healthier catchments and waterways through a number of objectives such as *"Promote and resource sustainable coastal and waterways management"*. Weaknesses identified include a lack of a "driver" and no "policy" to drive improved stormwater quality in Mackay.

2.3.3 Mackay Regional Council MUSIC Guidelines (2008)

To ensure the management of stormwater runoff as defined in the SWQMP, MRC require that all developments must achieve the stormwater treatment objectives. "High risk" developments are to demonstrate the attainment of the objectives through the use of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software (see Section 2.10). The guidelines were developed to; ensure a consistent approach in terms of approval and applications processes for stormwater management of developments in the Mackay region, provide advice on using MUSIC in the Mackay region, and to provide guidance on parameters to be applied when using MUSIC to access compliance with Mackay Regional Council's stormwater management objectives, DesignFlow (2008).

2.3.4 Stormwater Quality Objectives for Mackay (2009)

Further to MRCs SWQMP and the *Mackay MUSIC Guidelines*, true to Chandler and Eadie (2006), effective WSUD design objectives need to be feasible (i.e. achievable within the capability of current technologies) and given statutory status within appropriate policy and planning instruments. As such DesignFlow were commissioned by Council to test a series of development scenarios in accordance with the *Mackay MUSIC Guidelines* and develop treatment performance curves. The performance curves were then used as a basis for assessing the "achievability" of the current stormwater quality objectives within the SWQMP. The performance curves produced by O'Neill and Leinster (2009) found that when compared against the current stormwater quality objectives for Mackay, the current objectives were above 'best practice'. The findings suggest reducing the minimum total pollutant loads, compared to untreated stormwater runoff from the development. The suggested reductions to be adopted for Mackay region are:

- 75 % reduction in total suspended solids (TSS)
- 60 % reduction in total phosphorous (TP)
- 40 % reduction in total nitrogen (TN)
- 90 % reduction in gross pollutants (GP)

These new stormwater quality objectives proposed for the Mackay region, ensure there is consistency between the stormwater quality objectives being adopted by MRC and the Environmental Protection Agency (EPA) and that the objectives adopted by the EPA have been suitably informed by the *Mackay Regional Council MUSIC Guidelines* (2008). *Mackay Regional Council (2008)*

2.3.5 Draft State Planning Policy for Healthy Waters (2009)

The draft State Planning Policy for Healthy Waters (draft Policy) is intended to ensure that the development is planned, designed, constructed and operated to manage stormwater and wastewater in ways that protect water environmental values specified in the *Environmental Protection (Water) Policy 1997* and its 2009 replacement the *Environmental Protection (Water) Policy 2009*.

The draft Policy underlines the need to protect water quality and environmental values from urban stormwater runoff. Achieving the WQOs for the urban development runoff mean Environmental Values (EVs) are upheld. The draft Policy also supports many existing water quality management best practices and initiatives including MRCs SWQMP, *Mackay MUSIC Guidelines*, and Mackay's stormwater quality objectives.

The draft Policy also provides design objectives for assisting in achieving water quality objectives. These specific outcomes listed in the draft Policy have been detailed in MRCs SWQMP, *Mackay MUSIC Guidelines* and Mackay's stormwater quality objectives.

2.4 Best Planning Practice - Mackay WSUD for Flat Sites (2010)

Flat sites can present a challenge for cost-efficient stormwater infrastructure, particularly if the urban design and site earthworks are developed without considering stormwater infrastructure requirements to protect aquatic ecosystems Water By Design (2009).

Accepting such a challenge, MRC have taken the initiative to become a leader in promoting and adopting WSUD strategies for future urban development within Mackay. As such MRC commissioned three specialist consultants; DesignFlow (WSUD), V2I (Urban Design) and Aurecon (Engineering) to apply and demonstrate the application of WSUD principles over flat topography of Mackay and provide a best practice case study for Council, community and stakeholder consultation.

Key principles considered for best practice include;

- WSUD strategies to reduce costs / limitations associated with traditional engineering solutions (at surface water conveyance, limiting the size and length of stormwater pipes, reduced fill requirements).
- Incorporating WSUD systems (biopods) within streetscapes and parkland areas to treat and improve water quality prior to discharge from the site.
- Developing WSUD solutions that can be effectively integrated into existing Council standards (street widths, speed control devices) and with limited impact on development yield.
- Utilising WSUD systems to create high amenity and varied landscape and community environment.

Following discussions with Council, nine WSUD system options were developed to explore and address potential issues involved in incorporating WSUD systems within streets, and to provide a basis for a feasibility costing for each scenario. To address the challenges faced by traditional urban drainage design a model water sensitive urban layout that promotes the conveyance and treatment of stormwater at-surface was proposed. The provision of stormwater treatment before flows enter pit and pipe systems is utilised and street and allotment earthworks are designed to ensure they contain at-surface stormwater runoff collection, DesignFlow and V2i (2010).

This local stormwater treatment strategy proposed in *WSUD for Flat Sites (2010)* was applied to Precinct A and modelled in MUSIC to ensure WQOs of stormwater runoff were met. To achieve MRC WQOs a series of bioretention swales, bioretention basins and biopods were proposed. The treatment element surface areas and MUSIC data is reported in MRCs *Example Site-based Stormwater Quality Management Plan for Mackay (2011).* The proposed treatment elements documented in MRCs *Example Site-based Stormwater Quality Management Plan, Mackay Regional Council (2011)* are used as a basis for a local treatment strategy when performing the triple bottom line assessment.

2.5 Best Management Practices

2.5.1 Overview

Structural stormwater management BMPs form a basis of options that can be selected to create a treatment train to suit the characteristics of each development and to treat a range of likely pollutants generated in urban areas Landcom (2004). Treatment trains should typically consist of BMPs that provide different levels of treatment; primary, secondary and tertiary, Water By Design (2009). Table 2-1 and 2-2 show suitable applications and site constraints for BMPs. The BMPs considered in *WSUD for Flat Sites (2010)* and proposed for the regional stormwater treatment approach described in this section.

Table 2-1: Scale of stormwater BMP applications and performance effectiveness, Water By Design (2009).

WSUD Measure	Scale			Runoff Quality and Quantity Management Effectiveness		
	Allotment Scale	Street Scale	Precinct or Regional Scale	Quality Treatment*	Peak Flow Attenuation	Reduction in Runoff Volume
Gross pollutant capture devices		✓		L	L	L
Sediment basins			✓	M	M	L
Grass or vegetated swales		✓	✓	M	M	L
Sand filters	✓	✓		M	L	L
Infiltration measures	✓	✓		N/A	L	H
Bioretention systems	✓	✓	✓	H	M	L
Constructed wetlands		✓	✓	H	H	L
Rainwater tanks	✓			L	M	M
Porous pavements		✓		L	L	M/H

Where H = High; M = Medium; L = Low
*Quality treatment = effectiveness in removing key environmental pollutants such as TSS, TP and TN.

2.5.2 Regional Stormwater Treatment BMPs

Sedimentation Basins

Sedimentation basins store sediment filled stormwater and promote settling of sediments by reducing flow velocities and temporary detention. A sedimentation basin is typically used to catch first flows and settle sediments entering a constructed wetland.

The land area required for a sedimentation basin is generally less than 1 % of the contributing catchment area, with the basin's water surface area typically being sized at 0.5 % of the contributing catchment area. Most sedimentation basins have an effective service life of over fifty years.

Sedimentation basins are relatively low capital cost structures. The low frequency of clean-out (typically every five years) means annual operating costs are also low, Water By Design (2009).

Table 2-2: Site constraints for stormwater BMPs, Water By Design (2009).

WSUD Measure	Steep Site	Shallow Bedrock	Acid Sulphate Soils	Low Permeability Soil	High Permeability Soil	High Water Table	High Sediment Input	Land Availability
Gross pollutant capture devices	✓	D	D	✓	✓	D	✓	✓
Sediment basins	D	D	✓	✓	D	D	✓	✓
Grass or vegetated swales	C	D	D	✓	D	C	D	✓
Sand filters	✓	D	D	✓	✓	C	D	✓
Infiltration measures	D	D	D	✓	D	C	D	✓
Bioretention systems	C	D	D	✓	D	D	D	D
Constructed wetlands	✓	✓	✓	✓	✓	✓	✓	✓
Rainwater tanks	C	C	C	C	✓	C	C	✓
Porous pavements	C	C	C	C	✓	C	C	✓

C = Constraint may preclude use
D = Constraint may be overcome through appropriate design
✓ = Generally not a constraint

Constructed Wetlands

Constructed wetlands are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and the pollutant uptake process to remove pollutants from stormwater, see Fig. 2-2 for an example of a constructed wetland in Blacks Beach, Mackay.

Constructed wetlands have the following key design features:

- **Open water sedimentation basin:** The sedimentation basin (refer Sedimentation Basins) acts as an inlet zone for the overall constructed wetland system. This feature reduces the velocity of inflows, traps coarse sediments and generally protects the macrophytes zone. Wherever possible, sedimentation ponds should be separate from the macrophytes zone so they can be isolated for maintenance, Melbourne Water (2010).

- **Macrophyte zone:** The macrophyte zone is the shallow extensively vegetated area where the majority of soluble pollutants are removed. The vegetation is predominantly emergent aquatic plants that support a complex of algal and bacterial microscopic organisms, known as biofilms, that grow on the surface of the plants, Landcom (2009). This zone traps finer sediments and soluble pollutants. A deeper section is provided around the inlet and particularly the outlet to provide an open water zone for the outlet structure. Well vegetated macrophyte zones are less conducive to turbulence within the water column and therefore it is less likely that re-suspension of trapped materials will occur, Melbourne Water (2010). Emergent aquatic macrophytes are normally restricted to the margins because of water depth, although submerged plants may occur in the open water zone, Engineers Australia (2006).

- **Connection**: The connection of the sedimentation basin to the macrophyte zone can be either by pipe or porous rock weir. The behaviour of the outlet structure is usually fundamental to the structure and function of wetlands, Engineers Australia (2006). Where pipe connections are used it is important to have an initial open water section in the macrophyte zone to help disperse flows. Pipe connections would typically be sized to pass no greater than the 1-year ARI flow, Melbourne Water (2010).

For a constructed wetland to be effective as a treatment BMP, all elements need to be addressed correctly. Landcom (2009) lists these as;

- The correct mix of open water and planted zones and right plants in the right locations.
- The correct installation of hydraulic structures.
- Good quality growing soil and media for plants.
- Effective establishment and pro-active maintenance to ensure the wetland functions in the long term.

Constructed wetlands, vary in size from a typical lot size to a large regional system of 10 ha, Melbourne Water (2005). Constructed wetlands are generally 7 % to 10 % of the contributing catchment area for a flat site. The actual treatment area or surface area of the macrophyte zone is typically 5 % to 7 % of the contributing catchment area, Water By Design (2009).

Maintenance is critical over the first two years. Plant establishment and water level management are critical in ensuring excessive water levels don't drown plants and minimal water levels do not dry plants out. Weed management may also be required. In new developments, maintenance focuses on establishing healthy, dense, emergent wetland plants to achieve 80% coverage in the macrophyte zone. Once vegetation is established and the system is active, sediment and debris removal from the inlet pond are key maintenance tasks required, Landcom (2009); Water By Design (2009).

Fig. 2-2: A typical constructed wetland, Blacks Beach Mackay.

Gross Pollutant Traps

Gross pollutant traps (GPTs) screen and capture gross organic and man-made litter washed from urban surfaces. To be environmentally effective in terms of water quality, GPTs should be used in conjunction with some form of biological treatment such as a bioretention system or a constructed wetland, Water By Design (2009). GPTs are not necessarily required in urban developments by MRC, and have not been considered as part of this research.

2.5.3 Local Stormwater Treatment BMPs

Bioretention Swales

Bioretention swales are small, vegetated overland depressions used to convey stormwater in absence of, or jointly with, underground pipe drainage systems. Swales have generally flat slopes which allows for lower drainage velocities and subsequent erosion prevention. Biological uptake and sediment settling is also provided by the swale, even swales with mown grass can remove a significant amount of sediment, Landcom (2009).

Fig. 2-3: Typical central boulevard bioretention swale, Cuttersfield Mackay (left) and bioretention basin Blacks Beach (right), Mackay.

Bioretention swales are located within the base of a typical grassed swale. They can provide similar efficient treatment of stormwater through fine filtration, extended detention and some biological uptake as well as providing a conveyance function. Bioretention swales provide an attractive landscape feature in urban development, Melbourne Water (2005), such as bioretention swales located in the median strips of Cuttersfield Estate, Mackay, see Fig. 2-3.

It is essential that the designed hydraulic capacity of the swales is maintained. It is preferred to have swales located in public open spaces rather than at the front of private property where residents may not maintain the swale, Water By Design (2009).

Bioretention Systems

Bioretention basins are similar to bioretention swales in terms of treatment processes except they do not have a conveyance function, see Fig. 2-3. High flows are either diverted away from a basin or are discharged into an overflow structure. Bioretention basins provide treatment of stormwater through fine filtration, extended detention and biological uptake, particularly for nitrogen and other soluble or fine particulate contaminants, Melbourne Water (2005).

Bioretention basins are versatile and can be applied in various shapes and sizes. Smaller systems, such as the biopods can be integrated with traffic calming measures or parking bays, reducing their requirement for space, see Fig. 2-4. Bioretention systems can be located along streets, and treat runoff prior to entry into an underground drainage system, or be used as an end-of-pipe solution for larger areas. A wide range of vegetation can be used within a bioretention system, allowing them to be well integrated into a landscaped development, Landcom (2009); Melbourne Water (2005). Biopods have been implemented in Cuttersfield Estate to provide stormwater treatment.

Bioretention systems are sensitive to any material that may clog the filter medium. Traffic and wash-down wastes need to be kept from bioretention basins to reduce any potential for damage to the vegetation or the filter media surface, Melbourne Water (2005).

Fig. 2-4: Typical 'biopod' located within a street verge, Water By Design (2009).

Typical bioretention specifications set by MRC, which follow guidelines provided by Water By Design (2009) are:

- Extended detention: When stormwater enters the bioretention system, it temporary ponds to a depth of 300 – 400 mm over the surface of the filter media. Extended detention helps to manage flow velocities over the surface of the filter media as well as increasing the overall volume of stormwater runoff that can be treated by the bioretention system.

- Filter media: The filter media layer provides the most treatment of the pollutants through fine filtration and supporting the vegetation. The vegetation improves filtration, keeps the filter media porous, provides substrate for biofilm to form and takes up some nutrients and pollutants. There is currently no supplier of filter media in the Mackay region that meets MRC specification. Filter media is required to be mixed and imported into the Mackay region, which substantially increases costs (Perkins, RD 2012, pers. comm. 3 October).

- Transition and drainage layers: Under the filter media, a transition layer of clean, well graded sand/course sand (nominal size 0.5 – 2.0 mm) is used to prevent the filter media moving into the drainage layer and the perforated under-drains. The transition layer is typically 100 mm deep. The 'drainage layer' is made up of clean fine aggregate (nominal 2.0 – 5.0 mm) and is typically 200 mm deep. The drainage layer collects treated water from the base of the bioretention system and delivers it into the perforated under-drains. The under-drains are perforated and typically slotted PVC. This is the bottommost layer and is lined with and impervious liner. MRC currently have no set of standards on bioretention media.

- Hydraulic structures (overflow pit): During flood events that are 'above design' of the bioretention system, stormwater flows are conveyed through overflow pits or bypass paths rather than over the filter media. Hydraulic structures protect the surface of the filter media through high-flow velocities that can dislodge collected pollutants or scour vegetation.

- Vegetation: Vegetation is critical for bioretention function. It supports treatment of stormwater by providing a substrate layer for biofilm growth, which helps transport oxygen to the soil and enhances microbial communities that transform pollutants. The roots of the vegetation continuously break up the surface of the filter media, which prevents the surface from clogging. Wind agitating the vegetation can also help to break up the surface. Vegetation should cover the surface of the filter media. The type of vegetation used must be able to withstand minor and major runoff, followed by dry periods. It must also be dense enough to prevent preferred flow paths, scour and re-suspension of deposited sediments.

Extensive maintenance is required during the first two years of plant establishment. In new developments this maintenance is usually the responsibility of the developer. Maintenance focuses on ensuring the permeability of the filter media is maintained through establishing healthy, dense vegetation and ensuring high sediment loads associated with catchment development. Active irrigation is typically not required after the system is established due to passive irrigation by stormwater, Landcom (2009); Water By Design (2009).

2.5.4 Business as Usual Stormwater Treatment

Street Trees

Street or verge trees provide an attractive streetscape character as well as provide treatment for stormwater runoff. Street trees are a form of bioretention system and provide treatment to overland flows as flows percolate through the tree rhizosphere, Breen et al. (2004). MRC requires one verge tree per each allotment or at approximately 20m intervals for urban residential developments, as per the *Mackay Planning Policy*. Street trees will not be considered as a form of stormwater treatment during the triple bottom line assessment but will be used as a ‘control’ or a ‘business as usual’ (BAU) case, as a comparison to the proposed respective local or regional stormwater treatment approach BMPs.

Rainwater Tanks

Rainwater tanks collect, attenuate and store runoff from roof areas. This reduces demand on potable mains and reduces stormwater pollutant discharges, Melbourne Water (2005). Tanks also provide some treatment by settlement of suspended solids. Well maintained rainwater tanks have a typical service life of 20 to 30 years, with pumps requiring replacement every 10 years typically. Regular maintenance of roof water tanks is important to manage water quality and to mitigate mosquito risk, Water By Design (2009).

2.6 Treatment Strategy Comparison

The scope of this research investigates whether it is more sustainable to treat stormwater via an ‘end-of-pipe’ regional constructed wetland compared to a local ‘at-source’ treatment strategy that uses a series of swales and bioretention systems. Underground stormwater conveyance is still required for 5-year ARI flows for both local and regional treatment strategies.

There is evidence that the application of WSUD measures in urban developments in place of traditional ‘pit and pipe’ urban stormwater can provide the developer considerable cost savings, Coombes et al. (2002). van Roon (2007) also makes note, that evidence is accumulating on the practicality, cost savings and environmental effectiveness of low impact urban design and development (LIUDD). These claims are endorsed by Water By Design (2010) where the cost-benefit frameworks demonstrate that, when considered as a whole, the potential benefits of WSUD practices to achieve best practice stormwater management on typical developments in Queensland are likely to exceed the estimated costs. For example, in residential developments the acquisition costs of WSUD practices to meet stormwater objectives is typically less than 1% of the cost of a new dwelling. This acquisition cost is similar in magnitude to expected property premiums associated with WSUD.

Despite the growing evidence of the benefits of WSUD, there is still an underlying attitude that WSUD will bring additional costs to the developer, Council and ultimately the homeowner. Healthy Waterways Partnership (2005) endorses the notion that costs were perceived as a barrier by local government and private industry stakeholders alike. For example, developers perceived infrastructure or capital costs to be a major obstacle. Smaller councils, on the other hand felt that ongoing maintenance costs were the greater barrier. These perceived barriers towards WSUD are stressed further where ongoing maintenance costs, including upgrades or replacement of infrastructure, are viewed as another obstruction. Structural initiatives are seen as labour intensive and more visible in new residential or public areas and there may be additional demands placed on local councils.

Healthy Waterways Partnership (2005) suggests that a regional stormwater treatment strategy can address the perceived additional costs associated with WSUD and to share costs between multiple developments in the same geographic region. For example, instead of having five constructed wetlands on five properties catchments, one constructed wetland could be designed to treat stormwater runoff for all five catchments.

Healthy Waterways Partnership (2005) also reveals that where it is suggested that the principle concept of WSUD, and any associated infrastructure costs, would appeal to certain groups, mainly from higher socio-economic groups who are environmentally motivated. Profitability of WSUD is not seen as a barrier for people who are environmentally conscious and are willing to pay a premium for structures and services.

Lloyd, Wong and Chesterfield (2002) argues this perception and showed a 90 % support for to the integration of landscaped and grassed bio-filtration systems into local streetscapes by 300 property owners and prospective buyers from four greenfield urban developments located in Melbourne. More than two thirds of the respondents saw the landscaped bio-filtration system as attractive, and believed the design could potentially contribute to making an entire estate look better and would improve local habitat. Interestingly about 70 % of respondents believed bio-filtration systems would result in the bay being less polluted, but did not associate these systems with improved water quality in receiving local lakes and ponds. This suggests a low level of community understanding as to how elements within a drainage scheme relate to one another.

Lloyd, Wong and Chesterfield (2002) does concede that there are also concerns held by respondents related to uncertainty about the systems' purpose and maintenance issues. This suggests that these issues could be addressed through education and information programs. The survey findings are reinforced by land sale records of allotments next to bio-filtration systems in Lynbrook Estate. During the release of each stage of the development that incorporated bio-filtration systems into the street drainage, the rate of land sales and prices at the Lynbrook Estate reflected the high end of the property market across Melbourne's greenfield site developments.

With careful planning and design, constructed wetlands can add value to land within an urban development by providing an open water feature. Empirical data drawn from a number of developments with significant water control devices, including wetlands, indicates that the value of residential land, immediately adjacent to linear open space wetland/lakes, will sell at two or three times the average value received for residential lots within standards areas of the development. Social values added to the development with an established character and branding provided by the wetland. This strong image also creates a greater sense of community, Wong et al. (1999).

Capital costs for constructed wetlands are comparable with other stormwater treatment systems that target fine sediment and nutrient removal, such as bioretention systems, on a cost-benefit basis. Land take is however more than that required for bioretention systems and therefore total capital cost, when accounting for land take, will typically be more for constructed wetlands than for bioretention systems, Water By Design (2009).

The maintenance costs to prevent constructed wetlands from failing WQOs and/or prevent degradation of the water body are thought to be substantial, but not well documented. Management of aquatic vegetation was identified as the most significant routine maintenance cost by three surveyed Councils. In the 2005/06 financial year, the three councils spent an estimated total of nearly $4.8 million on maintenance activities for 20 constructed urban water bodies. About two-thirds of this amount was spent on routine maintenance (such as vegetation harvesting and cleaning of pre-treatment devices) and the remainder on corrective maintenance required restoring components of a water body. The findings of this show that management of constructed urban water bodies in South East Queensland is a significant environmental and financial issue for local governments, (Healthy Waterways Partnership 2007).

Ongoing costs can be expected to be similar to traditional landscapes on the basis that active irrigation is not required; however, sediment removal from inlet pond and debris removal will be required to maintain aesthetics and inlet pond capture efficiency. The frequency of maintenance is typically low as the inlet pond is usually designed with a clean out frequency of once every five years, Water By Design (2009).

Coombes and Kuczera (2000) compared the construction cost and performance of traditional treatment train and a water sensitive streetscape WSUD approach, for a 30 hectare proposed rural residential subdivision on Tank Paddock, Hunter Valley New South Wales. 5-year and 100-year ARI flows were used. The study revealed reduced construction costs of 53 %. Despite the study using approximate construction costs, first impressions present a compelling case for the WSUD comparison.

Conversely economic analysis of an 800 lot urban development on the 55 hectare Lynbrook Estate, Melbourne, Victoria showed the cost of installing WSUD elements to be only marginally higher than conventional systems, increasing overall costs by as little as 0.5 %, Lloyd, Wong and Chesterfield (2002). The WSUD approach to new urban development is commonly believed to be more expensive than traditional approaches, Coombes et al. (2002).

A similar study Coombes, Kuczera and Kalma (2000b) of a 280-allotment subdivision with typical allotment sizes around $600m^2$ revealed savings of about 54 % in stormwater drainage construction costs ($8500 per allotment). These results are consistent with the cost savings (25 – 80 %) from use of source controls reported by Andoh and Declerck (1999).

Furthermore rain gardens (biopods), constructed wetlands and rainwater tanks were used to achieve WQOs for the 668 hectare Aurora development in Victoria, where it is expected the reduced underground piping and land area needed for end-of-line stormwater treatment, will reduce costs, Roberts and King (2004). This is endorsed by Lloyd, Wong and Chesterfield (2002) where WSUD incorporating streetscape measures is a more cost effective way to manage stormwater quality than the more traditional downstream (end-of-pipe) approach to treatment. Water By Design (2010) states that the benefits of applying WSUD practices to achieve best practice stormwater management are likely to outweigh the costs for typical development types.

Lloyd, Wong and Chesterfield (2002) adds doubt to the notion that a regional stormwater treatment approach is more cost effective, where a cost-benefit analysis was performed on a hypothetical development comparing the capital and maintenance costs associated with three urban drainage designs; conventional i.e. underground concrete pipes with no treatment, downstream approach i.e. underground concrete pipes discharge stormwater to a constructed wetland for treatment, and a distributed approach i.e. where bio-filtration systems convey stormwater runoff and discharge to a constructed wetland. To achieve the WQOs prescribed the distributed treatment approach would involve an estimated 22 % increase in capital expenditure on infrastructure, and using a downstream approach, an estimated 47 % increase.

Rozis and Rahman (2002) infers that at a lower interest rate, the life cycle cost for the WSUD is higher than the traditional method. For example, at 5 % interest rate, the life cycle cost for WSUD method is about 11 % higher than the traditional method. However, the differences in life cycle costs diminish with increased interest rates. For this particular case, the life cycle costs for the two methods become equal at about 10.25 % interest rate.

Traditional pit and pipe stormwater infrastructure can be expensive on flat sites due to the need for large pipe diameters to compensate for the minimum grades. The use of swales 'at-source' to provide stormwater conveyance can reduce the requirement for underground drainage. This can reduce to capital costs and overall infrastructure costs of the development with swales having a lower capital costs than other BMPs. The use of swales can also improve the visual integration of stormwater within the urban fabric. Melbourne Water (2005) adds that costs savings can be achieved by treating stormwater 'at-source' and that a local treatment strategy can provide a unique landscape setting and improve the understanding of the stormwater water cycle for local residents.

It is suggested that the larger scale the WSUD development is, the lower the cost of WSUD per hectare. The minimum scale that should be considered is around 20 hectares, but 100 hectares or more is desirable, Bligh Tanner and DesignFlow (2009).

The literature suggests that both local and regional stormwater treatment strategies have an associated positive financial, social and ecological benefit, when compared to traditional stormwater pit and pipe conveyance urban design.

Although no literature was found that directly compares the financial, social and ecological elements of a local stormwater treatment strategy to a regional treatment approach, several conclusions can be drawn; construction costs of constructed wetlands are comparable to bioretention systems per square metre of treatment surface area, although land costs associated with large regional constructed wetlands will typically be higher than local stormwater treatment strategies, the larger the scale of development, the more cost effective the proposed WSUD treatment is. The challenges faced with either an integrated local or regional stormwater treatment strategy, are the perceived additional capital and ongoing costs particularly in relation to maintenance, and the loss of developable land.

Local and regional treatment strategies are expected to add social values to a development. Further qualitative research is needed to identify social preferences between local and regional BMPs.

2.7 Triple Bottom Line Assessment

2.7.1 Introduction

The term 'triple-bottom-line' (TBL) was first coined by Elkington (1999) and is the measure of sustainability that includes social, financial and environmental elements. Though Ashley et al. (2008) identifies that sustainability remains an elusive concept, although those involved with the provision or urban wastewater systems now recognise that decisions involving asset investment should use the 'triple bottom line' approach to society, the economy, and the environment.

Engineers Australia (2006) states that social, health and ecological costs and values must be considered when assessing best practice, as they represent important components of a broader and fuller cost assessment. Taylor and Fletcher (2005) recognises that urban stormwater managers in Australia need to make decisions about the use of stormwater management measures that improve waterway health (e.g. constructed wetlands, bioretention systems, non-structural measures, etc.) within the context of the TBL. That is, decisions are made after careful review of many financial, social and ecological considerations.

Taylor and Fletcher (2005) and The Cooperative Research Centre of Catchment Hydrology (CRC) (1992-2005), produced a set of TBL assessment guidelines for WSUD and environmentally-focussed urban stormwater projects. These guidelines can be used to access the financial, ecological and social dimensions of alternative options for the project. The guidelines are similar to the equivalent European Sustainable Water Industry Asset Resource Decision (SWARD) water and sewer related asset decision making guidelines.

Like the principles of WSUD, similarly the CRCs TBL guidelines involving residential urban developments are holistic in nature where; greater input from non-technical stakeholders is provided, there are three levels of assessment, there is provision for information from the literature in lieu of local data where information is limited, and the inclusion of a risk assessment element in the assessment process where each option being assessed against the assessment criteria to allow for uncertainty, Taylor and Fletcher (2005).

A cost benefit approach was considered but to adequately assess the economic viability of BMPs for urban stormwater, it is important that a holistic assessment approach be also used. The cost and benefits therefore should not be limited to just monetary value but should also include social and environmental outcomes, Engineers Australia (2006).

In addition, a TBL assessment process that uses multi-criteria analysis can manage qualitative and quantitative information and involve deliberate public participation methods to create a learning environment Holz, Kuczera and Kalma (2004). Such processes can be an attractive alternative to cost-benefit analysis. The use of a TBL assessment process involving multi-criteria analysis can assist urban stormwater managers to make more systematic, informed, holistic, participatory, transparent, multidisciplinary, defendable, socially acceptable, ecologically sustainable and cost-effective decisions, Taylor and Fletcher (2005).

It is incorrect to assume that a well-designed TBL assessment process will always identify a good option. For example, a TBL assessment process may highlight one option as being the best of several very bad alternatives. Care is needed with language and terminology surrounding TBL assessment so that stakeholders do not get the impression that such an assessment is ultimately a sustainable outcome, Taylor and Fletcher (2005).

2.8 Financial Values

When comparing the infrastructure-related costs of a range of stormwater quality management options, it is important to ensure that the comparison is fair. That is, all the infrastructure costs associated with providing the same stormwater management outcomes are included in each option compared. The costing time frame should be extended beyond the construction phase so that costs incurred over the whole life of the devices are considered. Items that must be included in a life cycle cost (LCC) are the capital, operating, maintenance and replacement of all the components required. Also, the different lifetimes of infrastructure components must be accounted for, leading to the use of annualised costs.

Total acquisition costs (TAC), or capital costs consist primarily of expenditures initially incurred to construct or install treatment devices (e.g. Land costs, construction of a wetland and related site work). Capital costs include all land acquisition, labour, equipment and material costs, excavation and grading, control structures, landscaping and appurtenances. Land cost is also a critical component of capital cost and can overshadow other costs. Utilising public open space in urban development to perform a dual function can be an effective method in offsetting the cost of land required, Engineers Australia (2006).

Operating and maintenance costs are post-construction costs that ensure or verify the continued effectiveness of a BMP/treatment device during its design life. Annual operating and maintenance costs include labour, materials and equipment required for the proper operating and functioning of a BMP/treatment device. Tasks typically carried out in a maintenance program include landscape maintenance, structural maintenance, infiltration maintenance, and sediment, debris and litter removal. Operating and maintenance costs can be more difficult (but are sometimes the most critical variable) to estimate than capital costs, Engineers Australia (2006).

The total acquisition and maintenance costs associated with BMPs are not well documented and there appears to be a knowledge gap in the literature. Taylor (2005a) summarised cost related information for BMPs from available literature in 2005 and also outlined a process to aid in the collection and building of a 'cost knowledge bank'. To this date there is still little published BMP cost information available. There is a lack of standard procedures and form of recording of maintenance costs associated with WSUD systems. Although Thomson and Leinster (2007) collected cost data to aid stormwater managers in the selection and design of WSUD treatment systems and to collect useful life cycle cost information. Cost data from similar BMPs from urban developments in Australia that best match the BMPs proposed for Precinct A have been obtained from literature and industry.

Total Acquisition Costs

Total acquisition costs reported for constructed wetlands widely vary from approximately \$65 to \$450/m^2 Department of Environment Western Australia (2004), Thomson and Leinster (2007).

The preliminary cost for a 19.7 ha sedimentation basin and constructed wetland, including earthworks, wetland planting and provisional sums for Kerrisdale Estate, Mackay was estimated at \$2.94 million, which is \$149/m^2. The contributing catchment for this constructed wetland is estimated at 36.5 ha, which is approximately 350 lots, similar to the size of Precinct A (Perkins, RD 2012, pers. comm. 3 October).

Reported biopod total acquisition costs also vary. Retrofitted streetscape biopods (20m^2 treatment area) were estimated to cost \$670/m^2 (not including design costs) by Brisbane City Council Thomson and Leinster (2007). These costs represent the high end of the spectrum, due to unfamiliarity with the design and construction methods of the biopod. Whereas construction costs for a typical rain garden or biopod in Epping Central, greater Melbourne, are estimated at \$300/m^2, DesignFlow (2012).

Bioretention basin total acquisition costs reported by Thomson and Leinster (2007) vary between \$294 to \$315/m^2 in typical urban developments in South East Queensland. These basins have an effective treatment area between 450 m^2 and 900 m^2. A similar retrofitted bioretention basin in a neighbouring suburb had an effective treatment area of 800 m^2, and was estimated at \$111/m^2. Cardno and MRC recently agreed on a adopting a total acquisition rate of \$290/m^2 for typical bioretention basins in the Mackay region, which provides a nominal 1 % treatment for a typical 20 ha catchment (Perkins, RD 2012, pers. comm. 3 October).

Similarly acquisition costs reported for rock-lined, vegetated bioretention swales including surcharge structures, located in the road verge in South East Queensland, vary between \$137 to \$640/m^2 Thomson and Leinster (2007). Additionally Thomson and Leinster (2007) estimated the TAC for sedimentation basins at \$359/m^2, whereas DesignFlow (2012) estimated sedimentation basins to have an equivalent TAC as constructed wetlands at \$100/m^2. A typical 45 L pot street tree including root barrier protection is estimated to cost \$950 each for supply and install, (Perkins, RD 2012, pers. comm. 3 October).

A summary of total acquisition cost information in \$AUD per square metre (\$/m^2) is shown below in Table 2-3. The total acquisition costs reported do not account for land acquisition costs.

Table 2-3: Total acquisition costs of treatment elements.

Source	Total Acquisition Rate (\$/m^2)	Source	Total Acquisition Rate (\$/m^2)
Biopod		**Bioretention Basin**	
MUSIC Lower Acquisition Cost[1]	\$34	MUSIC Lower Acquisition Cost[1]	\$41
MUSIC Expected Acquisition Cost[1]	\$84	MUSIC Expected Acquisition Cost[1]	\$98
MUSIC Upper Acquisition Cost[1]	\$211	MUSIC Upper Acquisition Cost[1]	\$234
Thomson, Taylor[2]	\$670	Thomson,Taylor[2]	\$230
DesignFlow[3]	\$300	DesignFlow[3]	\$300
Land and Water Constructions[5]	\$196	Land and Water Constructions[5]	\$196
Upper Parramatta River Catchment Trust[6]	\$403	Upper Parramatta River Catchment Trust[6]	\$403
Hunter[7]	\$197	Hunter[7]	\$197
Constructed Wetland		Cardno[9]	\$290
MUSIC Lower Acquisition Cost [1]	\$46	**Bioretention Swale**	
MUSIC Expected Acquisition Cost[1]	\$74	MUSIC Lower Acquisition Cost[1]	\$58
MUSIC Upper Acquisition Cost[1]	\$105	MUSIC Expected Acquisition Cost[1]	\$151
Kerrisdale[4]	\$149	MUSIC Upper Acquisition Cost[1]	\$392
Thomson, Taylor[2]	\$259	Thomson, Taylor[2]	\$252
DesignFlow[3]	\$112	Land and Water Constructions[5]	\$195
Dept. of Environment WA[8]	\$72	**Street Tree**	
Sedimentation Basin		Typical 45L Pot Street Tree Mackay[9]	\$950 each
Thomson, Taylor[2]	\$359		
DesignFlow[3]	\$100		

[[1]MUSIC v5.0 (2005), BMP treatment surfaces areas based on Precinct A local treatment approaches, constructed wetland assumed to be 19.7ha], [2] Thomson (2007) & Taylor (2003), [3]DesignFlow (2012), [4]Kerrisdale (2012), [5]Land and Water Constructions (2007), [6]Upper Parramatta River Catchment Trust (2004) , [7]Hunter (2011) , [8]Dept. of Environment WA (2004), [9](Perkins, RD 2012, pers. comm. 3 October).

Typical Annual Maintenance Costs

Typical annual maintenance costs are the primary financial concerns of MRC for BMPs, RD Perkins (2012, pers. comm. 3 October). Mullaly (2012) undertook a review of the maintenance costs of Logan City Council's bioretention systems in 2011 and 2012 and estimated costs to vary between $5 to $50/m^2/yr. Mullaly also states that costs attributed to WSUD asset maintenance often includes rectification of damaged systems and may actually represent maintenance of well-functioning systems, which may further skew quoted costs. Conducting regular proactive maintenance is significantly cheaper than irregular reactive maintenance while at the same time providing better amenity outcomes. Similarly a review of street-scale biopods in urban Melbourne, estimated the maintenance of approximately five to seven per cent of the construction cost or in costs per square metre between $8.76 and $13.25/m^2/yr., with grassed mature systems costing $2.50/m^2 and $9.00/m^2 for native vegetated systems. Typical annual maintenance costs (TAM) of vegetated swales exhibit similar costing's to other bioretention systems, with costs ranging from $3.13 to $9/m^2/yr., EPA Victoria (2008).

Constructed wetlands are reported to cost between 2 % to 6 % of construction costs to maintain each year, and that there is a very strong correlation between the typical annual maintenance costs and the surface area of the wetland EPA Victoria (2008), Department of Environment Western Australia (2004). ETS Group suggests that maintenance costs could even be higher. Two constructed wetlands located in Coomera and Coorparoo, with treatment surface areas of approximately one hectare, cost between 8 % to 13 % of the total acquisition cost to maintain annually. This typical annual maintenance cost is approximately $0.50 to $0.80/m^2/yr., Thomson and Leinster (2007). A review of maintenance costs of constructed water bodies in South East Queensland indicates typical annual costs of $1.10/m^2/yr. Since most water bodies did not meet relevant water quality objectives, it is likely that this cost figure underestimates the full cost that would be required to maintain water bodies at an acceptable water quality standard in the long term. The study also revealed that maintenance costs were difficult to clearly identify and that itemised costs were not tracked against assets, but as part of general maintenance programs, Healthy Waterways Partnership (2007).

Maintenance costs for sedimentation basins are reported as generally 6 % of total acquisition costs EPA Victoria (2008). Thomson and Leinster (2007) reported the TAM for a 216 m^2 sedimentation basins in South East Queensland was $22.20/m^2. This was 6 % of the reported total acquisition cost ($77,620). This TAM rate appears to be rather excessive considering the rate for an operator and truck driver on a typical maintenance crew is approximately $2800/day. For an existing 1000 m^2 sedimentation basin in Mackay, it is estimated that a three man maintenance crew can complete maintenance in 4 days ($11.20/m^2), RD Perkins (2012, pers. comm. 3 October).

A summary of cost data in $AUD per meter squared ($/m²/yr.) for is shown below in Table 2-4. These costs will be adjusted for annual and local inflation and will be used to help determine the total acquisition, maintenance and life cycle costs of the BMPs.

Table 2-4: Typical annual maintenance costs of treatment elements.

Source	TAM Rate ($/m²/yr.)	Source	TAM Rate ($/m²/yr.)
Biopod		**Bioretention Basin**	
MUSIC Lower Acquisition Cost[1]	$3.20	MUSIC Lower Acquisition Cost[1]	$5.50
MUSIC Expected Acquisition Cost[1]	$3.80	MUSIC Expected Acquisition Cost[1]	$8.80
MUSIC Upper Acquisition Cost[1]	$4.50	MUSIC Upper Acquisition Cost[1]	$12.20
Thomson, Taylor[2]	$43.90	Thomson, Taylor[2]	$5.60
Mullaly[10]	$5.00	Mullaly[10]	$5.60
EPA Vic[11]	$12.30	EPA Vic[11]	$12.30
Land and Water Constructions[5]	$13.00	Land and Water Constructions[5]	$13.00
Constructed Wetland		**Bioretention Swale**	
MUSIC Lower Acquisition Cost[1]	$1.20	MUSIC Lower Acquisition Cost[1]	$32.70
MUSIC Expected Acquisition Cost[1]	$2.30	MUSIC Expected Acquisition Cost[1]	$38.80
MUSIC Upper Acquisition Cost[1]	$4.44	MUSIC Upper Acquisition Cost[1]	$46.00
Thomson, Taylor[2]	$4.00	Thomson, Taylor[2]	$31.00
Healthy Waterways Partnership [12]	$1.20	Mullaly[10]	$5.00
Dept. of Environment WA[8]	$1.50	EPA Vic[11]	$12.30
Street Tree		Land and Water Constructions[5]	$13.00
Typical 45L Pot Street Tree Mackay[9]	$25 each	**Sedimentation Basin**	
		Thomson, Taylor[2]	$22.20
		Cardno[9]	$11.20

[[1]MUSIC v5.0 (2005), BMP treatment surfaces areas based on Precinct A local treatment approaches, constructed wetland assumed to be 19.7ha], [2]Thomson (2007), Taylor (2003), [3]DesignFlow (2012), [5]Land and Water Constructions (2007), [8]Dept. of Environment WA (2004), [9]RD Perkins (2012, pers. comm. 3 October)., [10]Mullaly (2012), [11]EPA Vic (2008), [12] Healthy Waterways Partnership (2007).

Life Cycle Costs

Life cycle costing is a process to determine the sum of all expenses associated with a product or project, including acquisition, installation, operation, maintenance, refurbishment, discarding and disposal costs", Standards Australia (1999). The life cycle cost is the sum of all discounted costs. For individual stormwater BMPs the life cycle cost is the sum of all discounted costs over the life cycle of the BMP, expressed in dollars relevant to a base date. All costs are discounted back to the base date using an appropriate discount rate. See Section 2.10 for information regarding MUSIC's life cycle costing module.

2.8.1 Environmental values

Environmental values refer to the impact on the ecological health of affected regional ecosystems. They are fundamental values that do not relate to the current use of ecosystem services by people. Some ecological values include minimising changes to the pre-development hydrology and water quality not exclusively by; reducing the catchment effective impervious area, reducing the annual average loads of TN, TP and TSS entering the environment and maintaining pre-development peak flows. Environmental impacts associated with construction materials, wastes and/or energy use during construction, operation maintenance and/or decommissioning, Taylor (2005b). Ecological effectiveness of BMPs relies on upkeep of maintenance and bioretention systems should not be considered any more a maintenance burden to Councils than other landscaped areas, and are likely to reduce maintenance expenditure for water health protection, Dalrymple (2012).

2.8.2 Social values

Social values are typically values that relate to the quality of peoples life. These may be the impact the BMP has on the areas general liveability and the areas aesthetic values. The impact of safety of people using the area e.g. the risk of drowning, as well as the health and well-being of nearby residents who may be affected by mosquitoes and odours, are considered social values, Taylor (2005b). Pedestrian and vehicular safety is also seen as a social concern to by residents. This has contributed to poor public acceptance of street-scape BMPs in South East Queensland. Local Councils also received complaints from residents who were unaware of the function and reason for the treatment elements existence in their street, Hardie (2012). It was found that the placement of signage at the bioretention system was the simplest and most effective educational approach to inform residents of the systems purpose.

2.9 Multi-Criteria Analysis

Multi-criteria analysis (MCA) establishes preferences between options by reference to an explicit set of objectives that the decision making body has identified, and for which it has established measurable criteria to assess the extent to which the objectives have been achieved, Department for Communities and Local Government (2009).

MCA is used as the decision support 'mechanism' as part of the triple bottom line assessment as opposed to cost-benefit analysis.

Taylor (2005b) outlines the strengths and weaknesses for use of MCA.

Strengths include:

- MCA has the ability to manage multiple and sometimes competing objectives.
- MCA has the ability to easily incorporate a wide variety of decision criteria that can be expressed in qualitative and/or quantitative forms.

- MCA has the ability to consider the views of more than one person and can help to build a consensus amongst a group of people.
- MCA explicitly separates facts from values.
- MCA can clearly highlight the uncertainty associated with information used during the assessment process, and show how this uncertainty can influence the ranking options.
- MCA can accommodate a wide variety of methods to analyse the sensitivity of the results.
- MCA has recently been shown to be a practical way to consider the TBL for major decisions involving stormwater in Australia.

Weaknesses include:

- Considerable time may be needed to undertake the analysis.
- Some inputs to the process may be difficult to obtain from stakeholders (e.g. subjective assessments of the relative importance of criteria).
- In a group decision making setting, stakeholders may engage in 'strategic gaming' (e.g. while putting weights on criteria).
- There is no guarantee of a clearly preferred option. In addition, the final ranking of options from the MCA may not align with the 'intuitive ranking' of the assessment body, which may undermine the credibility of the process in the eyes of some stakeholders.
- The mathematical method used to rank the options (e.g. 'aggregate value / utility function models', such as multiple-attribute utility theory) may influence the ranking order of options.

2.10 MUSIC

Model for urban stormwater improvement conceptualisation (MUSIC) is a software package produced by *eWater* to help urban stormwater professionals visualise possible strategies to tackle urban stormwater hydrology and pollutant impacts.

MUSIC enables urban catchment managers to:

- Determine the likely water quality emanating from specific catchments.
- Predict the performance of specific stormwater treatment measures in protecting receiving water quality.
- Design an integrated stormwater management plan for a catchment.
- Evaluate the success of a treatment node or treatment train against a range of water quality standards.

- Analyse the life cycle costs of a treatment node or treatment train, Engineers Australia (2006).

Taylor (2005a) also provides the MUSIC user some value should they wish to manually enter their own figures into the cost estimate of the BMPs life cycle analysis. These values should be used with caution as there is a high degree of variability in the cost estimates and that the dollar values have not been adjusted for inflation.

Life Cycle Costing Module

In MUSIC's life cycle costing module a real discount rate is used for discounting future costs that are expressed in real terms relative to the base date (i.e. costs that have not been adjusted for inflation).

The design of the life cycle costing module in MUSIC v5.0 is based on the Australian standard for life cycle costing (AS/NZS 4536:1999). The module uses algorithms and estimates to predict cost elements given information about a stormwater treatment device's size (i.e. size attributes).

These 'cost / size' relationships are based on real data collected from around Australia in 2002-04. Statistical tests have been undertaken on these relationships to allow users to choose between an expected estimate (default option), an upper estimate or a lower estimate. In addition, users have the option of entering a user-defined value for all cost elements and other variables in the life cycle costing analysis (e.g. the real discount rate, life cycle, annual interest rate, base date and span of analysis).

2.11 Consequential Effects

The consequential effects of this research include the sustainability, safety and ethical dimensions involved. The underlying philosophy of WSUD is to provide a means of sustainable development. This research aims to further develop and promote the sustainable outcomes from WSUD.

3.0 Research Design and Methodology

3.1 Introduction

This chapter has been seperated into five main sections which describe in detail; the proposed concept local and regional stormwater treatment strategies, the design and modelling of the regional stormwater treatment strategy for Precinct A, the performance assessment of both local and regional treatment strategies using MUSIC, the analysis of financial cost information and the triple bottom line assessment process which is used to identify the preferred treatment approach, see Fig. 3-1.

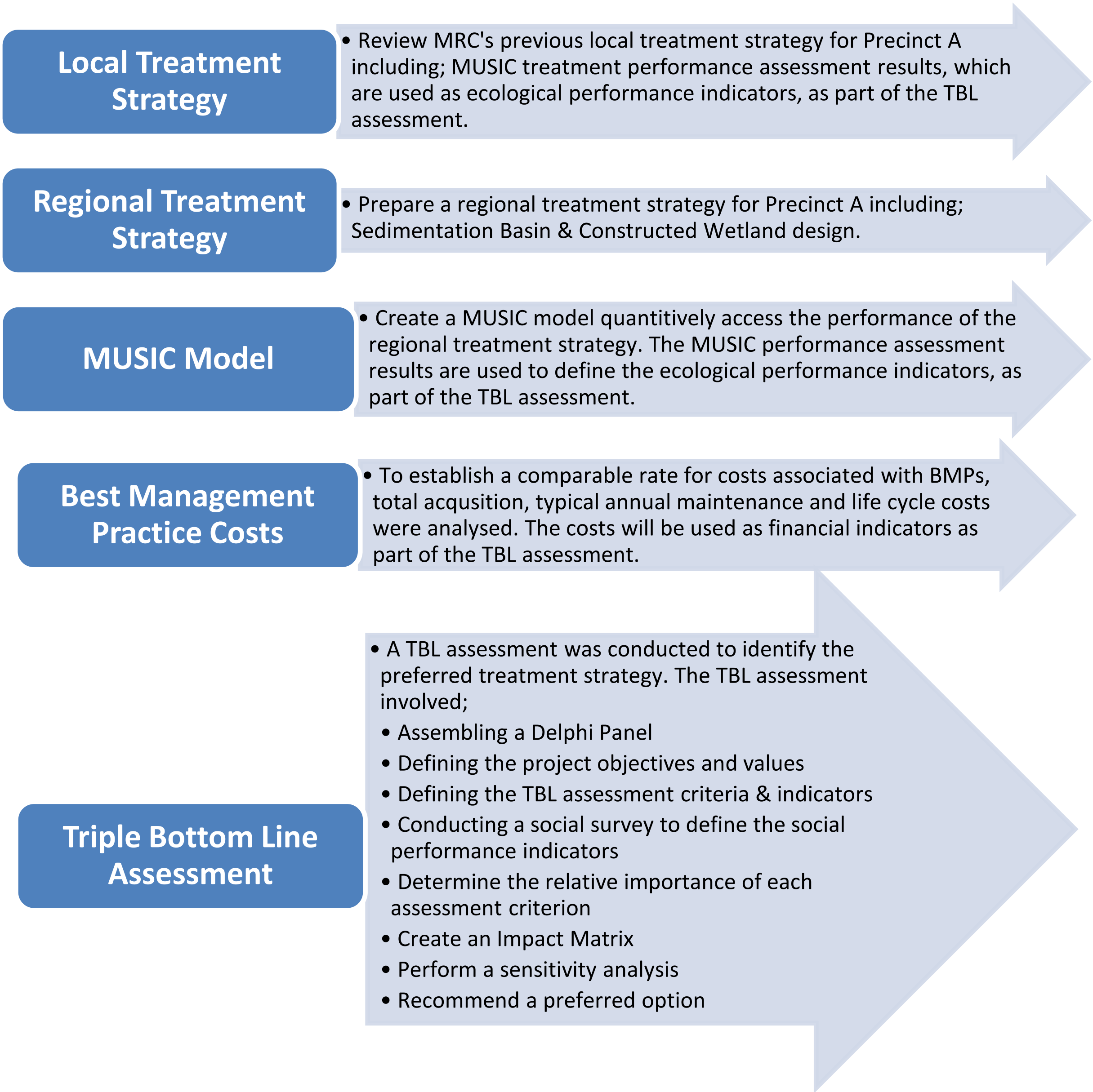


Fig. 3-1: Flow chart of Chapter 3 methodology.

3.2 Local Treatment Strategy

Collaboration between MRC, WSUD specialists, civil engineers and urban designers created a materplan for Precinct A which suitably follows the recommendation provided by *WSUD for Flat Sites* (2010), see Section 2.4. As a result, elements of WSUD have been integrated into the conceptual design of the roads, drainage infrasturcture, earthworks, landscape and public open spaces to ensure that the stormwater quality objectives are achieved. A plan of the overall local strategy is provided in Fig. 3-2. A description of the elements and the scale at which they are provided is briefly outlined below.

Fig. 3-2: Precinct A – Local treatment strategy, Mackay Regional Council (2011).

A bioretention swale is proposed to treat stormwater runoff in Catchment B. Runoff from catchment B will be delivered into a centre median swale located in the middle of the boulevard entry road. The swale will receive surface runoff from the road whilst lot runoff (from the eastern side of the road only) will discharge into the swale via surcharge pits located in the swale. Preliminary sizing of the swale used in the triple bottom line assessment is given in Table 3-1.

Table 3-1: Summary Catchment and Stormwater Quality Management Strategy – Precinct A, Mackay Regional Council (2011).

Catchment ID	Stormwater Element Type	Catchment area (ha)	Extended Detention Depth (mm)	Cumulative Filter Media Area (m^2)[1]	Proportion of Catchment Area (%)
A	Biopods	9.29	200	1299	1.40
B	Bioswale	1.39	200	250	1.80
C	Biopods	5.86	200	968	1.65
D	Bioretention Basin	2.76	300	470	1.70
E	Bioretention Basin	10.30	300	700	1.77
F	Biopods	3.94	200	1644	1.60
Total		**33.53**	-	5331	1.59

[1]Filter media area does not include allowances for batters, inlet zones and high flow bypass channels as required.

Two additional forms of bioretention systems were proposed for Precinct A; a bioretention basin and a street-scape bioretention pods. Two bioretention basins (Basins D and E in Fig. 3-2) are to be located directly adjacent to the development footprint and integrated with the drainage corridor. The bioretention basins were sized at 1.70 – 1.77% of their total catchment area to provide the required pollutant load reductions outlined in Section 2.3.4 using a 300mm extended detention depth, see Table 3-1 for preliminary sizing details, Mackay Regional Council (2011).

Street-scape biopods accept stormwater runoff from lots and road via cut-outs in the kerb in Catchment A1, A2, C1, C2 and F. These systems;

- Are sized at between 1.40% and 1.65% of their catchment areas to provide the required pollutant load reductions outlined in Section 2.3.4.
- Are integrated into the road reserve width while preserving service and pathway corridors.
- Will discharge flows above treatment capacity into a pit and pipe trunk drainage network.

The extended detention depth (i.e. the height between the surface of the bioretention system and the crest of the outlet pit) for these systems is typically 200mm. Due to the configuration of the catchments and local road reserves, some of the biopods are slightly constrained for size. Other biopods in the development have been slightly oversized to compensate for the under-sized biopods, Mackay Regional Council (2011).

Rainwater tanks will be connected to indoor fixtures (typically all toilets and cold laundry) and irrigation (minimum one outdoor tap). This will deliver potable water savings in addition to assisting to achieving the WQOs. Rainwater tanks will be installed and connected in accordance with the requirements of the *Queensland Development Code* MP 4.2. Rainwater tanks have a capacity of 5kL typically.

3.2.1 MUSIC Results - Local Approach

MUSIC modelling results for the local treatment strategy, outlined in Mackay Regional Council (2011) is shown in Table 3-2 below.

Table 3-2: MUSIC Results for Precinct A – Local Treatment Strategy, Mackay Regional Council (2011).

Catchment		**Stormwater Treatment**			**Pollutant Load Reduction Achieved (%)**		
Area (ha)	ID	Treatment Element	Treatment Surface Area (m^2)	% Catchment Area	TSS	TP	TN
3.86	A1	Biopod	476	1.23	76.5	61.7	37.2
5.43	A2	Biopod	823	1.52	80.1	64.8	39.3
1.39	B	Bioretention Swale	250	1.80	92.3	72.8	38.8
10.68	**Stage 1**		**1549**	**1.45**	**81.0**	**65.0**	**38.4**
2.26	C1	Biopod	328	1.45	79.3	63.9	38.8
3.60	C2	Biopod	640	1.78	82.0	66.6	40.8
2.75	D	Bioretention Basin	470	1.71	83.5	67.3	41.7
8.61	**Stage 2**		**1438**	**1.67**	**81.8**	**66.1**	**40.6**
3.94	E	Bioretention Basin	700	1.78	83.8	68.1	42.1
3.6	F1	Biopod	472	1.31	76.9	62.3	38.0
6.70	F2	Biopod	1172	1.75	82.8	66.6	40.7
14.24	**Stage 3**		**2344**	**1.65**	**81.7**	**65.9**	**40.6**
33.53		**Total Site**	**2344**	**1.65**	**81.7**	**65.9**	**40.6**
		Site Objective			**75**	**60**	**40**

3.3 Regional Treatment Strategy

A concept regional stormwater treatment layout was prepared for Precinct A in lieu of the local stormwater treatment devices proposed on MRCs master plan. The treatment elements include a constructed wetland with two inlet sedimentation basins, as shown in Fig. 3-3. Catchments A1, A2, B, C1, C2, D, and E are initially treated by Sedimentation Basin A and Catchments F1 and F2 by Sedimentation B. The proposed treatments were designed in accordance with *Mackay MUSIC Guidelines* v 1.1 (2008) pre-approved approach for modelling BMPs to achieve WQOs.

Fig. 3-3: Precinct A – Regional treatment strategy.

3.4 Best Management Practice Design

3.4.1 Sedimentation Basin Design

As MUSIC is not a suitable tool for sizing wetland inlet ponds or sedimentation basins, the equivalent sediment removal of a correctly sized sedimentation basin was determined from the recommended method in the *Water Sensitive Urban Design Guidelines for South East Queensland*, Water By Design (2006).

Design Objective

As the sedimentation basins form part of the treatment train (with the wetland macrophyte zone downstream) the design requirements of Sedimentation Basin A and B are to:

- Promote sedimentation of particles larger than 125 µm with a 90 % capture effeciency for flows up to the 'design operation flow' (1 year ARI peak discharge).
- Provide for connection to the downstream wetland macrophyte zone with discharge capacity corresponding to the 'design operation flow' (1 year ARI peak discharge).

The scope of the sedimentation basin design is limited to the design of the; design flows, surface treatment area required and the outlet weir configuration for Sedimentation Basin A and B, for input into MUSIC.

Design Flows

Two design discharges are required to size sedimentation basins and their structures:

- 'Design Operation Flow' (1 year ARI) for sizing the basin area and to size a 'control' outlet structure when discharging directly into a treatment system (e.g. wetland).
- 'Above Design Flow' (2 year ARI) for design of the 'spillway' outlet structure to allow for bypass of high flows around a downstream treatment system.

The Rational Method (see Equation 1) was used to determine design flows (see QUDM), where a fraction impervious factor of 0.76 was used and a design rainfall intensity was determined using a 15 minute time of concentration, *Mackay Planning Scheme* 2006.

The Rational Method:

$$Q = CIA/360 \qquad (1)$$

Where,	Q	=	design operation flow (m^3/s)
	C	=	fraction
	I	=	design rainfall intensity (mm/hr)
	A	=	catchment area (ha)

Sizing the Sedimentation Basin

Approximate sedimentation basin areas were then determined using sedimentation basin areas (square metres) vs design discharges (cumecs per second) for 90 % capture effeciencies of 125 µm, Figure 4-3, Water By Design (2006).

The area required for the sedimentation basins is defined using the following expression, see Equation 2 (modified version of Fair and Geyer (1954):

$$R = 1 - \left[1 + \frac{1}{n} \cdot \frac{v_s}{Q/A} \cdot \frac{(d_e + d_p)}{(d_e + d^*)}\right]^{-n} \qquad (2)$$

Where	R	=	fraction of target sediment removed
	v_s	=	settling velocity of target sediment (125 µm)
	Q/A	=	applied flow rate divided by basin surface area ($m^3/s/m^2$)
	n	=	turbulence or short-circuiting parameter
	d_e	=	extended detention depth (m) above permanent pool level
	d_p	=	depth (m) of the permanent pool
	d^*	=	depth below the permanent pool level that is sufficient to retain the target sediment (m) – adopt 1.0 m or dp whichever is lower.
	λ	=	hydraulic efficiency

The concept design stage will generally guide the selection of the fraction of target sediment removed (R) and permanent pool depth (d_p) depending on WQOs and nature of local soils/sediments.

Hydraulic efficiency (λ) is is estimated from the configuration of the basin, see Figure 4-4, Water By Design (2006). The shape of a basin has a large impact on the effectiveness of the basin to retain sediments. Generally, a length to width ratio of at least 3 to 1 should be achieved. Sedimentation basins should be designed to have a λ value of not less than 0.5. If the basin configuration yields a lower value, modification to the basin configuration should be explored to increase the λ value (e.g. inclusion of baffles, islands or flow spreaders).

A value of the turbulance parameter (n) is estimated using Equation 3:

$$n = \frac{1}{1 - \lambda} \qquad (3)$$

Design of Spillway Outlet

In most applications the 'spillway' putlet weir will form part of the high flow bypass system, which protects the downstream treatment system from scouring during 'above design' storm flows. The length of the 'spillway' outlet weir is to be sized to safely pass the maximum flow discharged into the downstream treatment system (as defined by the 'above design flow'). The water level above the crest of the bypass weir is 0.3 m below the embankment crest seperating the sedimentation basin and the downstream treatment system.

The required length of the 'spillway' outlet weir is computed using the weir flow equation (Equation 4) and the 'above design flow':

$$L = \frac{Q_{des}}{C_w \cdot h^{3/2}} \qquad (4)$$

Where	L	=	length of ‘spillway’ outlet weir (m)
	Q_{des}	=	above design flow (m^3/s)
	C_w	=	weir coefficient (1.66)
	h	=	afflux or height above permanent pool water level (m)

3.4.2 Constructed Wetland Design

The constructed wetland for Precinct A is designed using *Mackay MUSIC Guidelines* v 1.1 for constructed wetlands to achieve best practice.

Design Objectives

The previously designed sedimentation basins serve as the inlet ponds for the constructed wetland, as such the inlet properties of the constructed wetland have been determined and the scope of the constructed wetland design focuses on determining the following for performance assessment using MUSIC;

- The design of the storage properties of the macrophyte zone.
- The design of the constructed wetlands outlet properties.

Storage Properties (Macrophyte Zone)

The surface area specified in the wetland model should be equal to the average of surface area at the top of the permanent pool (commonly referred to as the ‘normal water level’) and the top of the extended detention (commonly referred to as ‘top water level’). This will simulate the extended detention volume in the model to be approximately equal to the actual volume. This approach to setting the surface area means that the surface area of the permanent pool and hence the evaporation rate and drawn down between rainfall events is overestimated.

The extended detention depth to promote the number of plant species suitable for the macrophyte zone for wetland in Mackay is 0.5 m. Constructed wetlands generally have a range of depths including ephemeral areas; as such an average depth of 0.3 m is used to calculate the permanent pool volume of the wetland zone.

When modelling to access reduction in pollutant loads, the seepage parameter should be set to zero. If a wetland is modelled with seepage, pollutant loads in the water that is lost to seepage are included in the reduction in pollutant loads achieved across the treatment node.

Outlet Properties

The equivalent pipe diameter of the wetland is used to set the notional detention time. The notional detention time is equal to the extended detention volume divided by the flow rate through a circular orifice with a head equal to the extended detention depth. The equivalent pipe diameter is set so that the notional detention time is between 36 and 48 hours.

The actual time taken for the wetland to draw down from the top of extended detention to the permanent pool level will be greater than the notional detention time as the discharge rate will decrease as the water level and hence head of water acting on the orifice decreases. In reality, wetland outlets are not always configured as a single orifice and so the stage discharge relationship would be different to that simulated in MUSIC.

The length of the overflow weir controls the discharge rate when the water level in the wetland exceeds the top of extended detention. An undersized overflow weir will result in water 'backing up' behind it, effectively adding additional extended detention. It is recommended that, as a starting point, the overflow weir length (m) is set at the surface area (m^2) divided by 10 m.

3.5 Regional Performance Assessment

3.5.1 MUSIC Model Setup

MUSIC modelling was conducted to quantitatively assess the performance of the proposed regional treatment strategy for Precinct A using two sedimentation basins and a constructed wetland. MUSIC version 5.0 was used for the assessment and the parameters have been established in accordance with *Mackay MUSIC Guidelines* v 1.1 (2008) and Mackay Regional Council (2011). Local condition parameters are shown in Tables 3-3 and 3-4 below.

Table 3-3: Rainfall and soil parameters adopted for the residential development site.

Parameter	Adopted
Rainfall Zone	A
Soil Category	Lowland

Table 3-4**:** Meteorological Data Statistics.

Parameter	Rainfall/12 Minutes	Evapo-Transpiration
Mean	0.035	5.043
Median	0.000	5.810
Maximum	31.140	6.500
Minimum	0.000	3.060
10 percentile	0.000	3.170
90 percentile	0.005	6.450
Parameter	**Rainfall**	**Evapo-Transpiration**
Mean Annual	1535	1842

Catchment Specific (Source Node) Parameters

The residential areas were split in accordance with the *Mackay MUSIC Guidelines* v 1.1 (2008). All of the catchments have identical landuses, and for typical urban residential developments, the *Mackay MUSIC Guidelines* v 1.1 (2008) suggest an overall imperviousness of 60% and catchment split of 35%, 25% and 40% for roof, roads and ground level, as outlined in Table 3-5.

Table 3-5: Sub-catchment breakdown Mackay Regional Council (2011).

Parameter		**Impervious %**	**Catchment Areas (ha)**										**Catchment Split (%)**
Treatment Element			Constructed Wetland										
			Sedimentation Basin A							Sedimentation Basin B			
			A1	A2	B	C1	C2	D	E	F1	F2	Total	
Lots	Detached	-	46	60	10	25	38	29	37	39	62	**346**	**-**
	Attached	-	0	0	0	0	0	0	7	6	11	**24**	**-**
Source Nodes	Roof-tank	100	0.70	0.89	0.16	0.37	0.57	0.44	0.62	0.65	1.04	**5.43**	**16.2**
	Roof-drain	100	0.70	0.89	0.16	0.37	0.57	0.44	0.62	0.65	1.04	**5.43**	**16.2**
	Road	70	1.12	1.40	0.67	0.62	0.96	0.69	1.10	0.90	1.82	**9.27**	**27.6**
	Ground	20	1.35	2.25	0.40	0.90	1.50	1.20	1.60	1.40	2.80	**13.40**	**40.0**
	Total	**60**	**3.86**	**5.43**	**1.39**	**2.26**	**3.60**	**2.76**	**3.94**	**3.60**	**6.70**	**33.53**	**100**

3.5.2 Stormwater Management (Treatment Node) Elements

Rainwater Tanks

Table 3-6: Rainwater tank modelling assumptions Mackay Regional Council (2011).

Parameter		**Catchment Areas (ha)**									
		A1	A2	B	C1	C2	D	E	F1	F2	Total
Lots	Detached	46	60	10	25	38	29	37	39	62	**346**
	Attached	0	0	0	0	0	0	7	6	11	**24**
Tank Parameters	Tank vol. (kL)	233	298	52	123	190	145	205	215	343	**1802**
	Area (m^2)	166	145	26	61	95	73	103	107	172	**901**
Demands	Daily (kL)	8.13	10.41	1.84	4.29	6.65	5.08	7.61	7.96	12.78	**64.75**
	Annual (kL)	1103	1411	249	581	901	688	1032	1079	1732	**8778**

Rainwater tanks were modelled in accordance with the Queensland Development Code (QDC) Mandatory Part MP 4.2 as shown in Table 3-6.

Sedimentation Basins

The sedimentation basins and constructed wetland were modelled in accordance with the *Mackay MUSIC Guidelines* version 1.1 (2008) in accordance to the *Water Sensitive Urban Design Guidelines for South East Queensland*, Water By Design (2006).

Refer Table 3-7 for sedimentation basin treatment node assumptions for MUSIC modelling.

Table 3-7: Sedimentation Basin treatment node MUSIC assumptions.

Inlet Properties			
Low Flow By-Pass (m^3/s)	User defined (Q_{des})		
High Flow By-Pass, 2-year ARI (m^3/s)	User defined (Q_{des})		
Storage Properties			
Surface area (m^2)	User defined		
Extended detention depth (m)	2.0		
Permanent pool volume (m^3)	0.3 x Surface area		
Exfiltration rate (mm/hr)	0		
Evaporative Loss as % of PET	75		
Outlet Properties			
Equivalent pipe diameter (mm)	Sized so that the notional detention time is as close to 1 hour as possible		
Overflow weir width (m)	User defined		
Notional Detention Time (hours)	As close to 1 hour as possible		
Advanced Properties			
Orifice discharge coefficient	0.6		
Weir coefficient	1.7		
Number of CSTR cells	1		
	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	8000	20.00	20.00
Total Phosphorous	6000	0.13	0.13
Total Nitrogen	500	1.40	1.40

Constructed Wetland

Refer Table 3-8 for initial adopted wetland MUSIC input parameters.

Table 3-8: Wetland pre-approved MUSIC parameters.

Inlet Properties			
Low Flow By-Pass (m^3/s)	0		
High Flow By-Pass, 2-year ARI (m^3/s)	100		
Inlet pond volume (m^3)	Sized to remove coarse sediment (> 125 µm) during 1yr ARI storm (typically 5 – 10 % macrophyte area)		
Storage Properties			
Surface area (m^2)	User defined		
Extended detention (m)	0.3-0.6 (preferably 0.5 m)		
Permanent pool volume (m^3)	0.3 x Surface area		
Seepage loss (mm/hr)	0		
Evaporative Loss as % of PET	125		
Outlet Properties			
Equivalent pipe diameter (mm)	Sized so that the notional detention time is as close to 36 – 48 hours as possible		
Overflow weir width (m)	Greater than or equal to surface area (m^2) / 10		
Notional Detention Time (hours)	As close to 36 – 48 hours as possible		
Advanced Properties			
Orifice discharge coefficient	0.6		
Weir coefficient	1.7		
Number of CSTR cells	5		
	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	1500	6.00	6.00
Total Phosphorous	1000	0.06	0.06
Total Nitrogen	150	1.00	1.00

3.6 Best Management Practice Costs

To establish a comparable rate BMP costs in the Mackay region, the cost information reported in literature is adjusted for annual and local inflation to present all costs in $2012 AUD per square metre of treatment area ($2012/m^2), refer Table 3-9 and 3-10. Total acquisition, typical annual maintenance, and life cycle costs are the three main costs associated with BMPs and will be used as part of the triple bottom line assessment.

Inflation of approximately 2.0 % per annum has been applied to figures quoted before 2012, Reserve Bank of Australia (2012). Construction and maintenance costs in the Mackay region are generally 12 % higher than that costs of South East Queensland, largely due to the highly competitive wages provided from the growing mining sector, which has led to a labour and supply skill shortage in the region, Mackay Regional Council (2010). As BMP construction methods and materials quoted in the literature are similar to those used for the Mackay Region and costs have been increased by a further 12 % on top of annual inflation.

Table 3-9: Total Acquisition Costs Adjusted for Inflation.

Source	TAC ($/m²/yr)	Source	TAC ($/m²/yr)
Biopod		**Bioretention Basin**	
MUSIC Lower Acquisition Cost[1]	$34	MUSIC Lower Acquisition Cost[1]	$41
MUSIC Expected Acquisition Cost[1]	$84	MUSIC Expected Acquisition Cost[1]	$98
MUSIC Upper Acquisition Cost[1]	$211	MUSIC Upper Acquisition Cost[1]	$234
Thomson, Taylor[2]	$840	Thomson,Taylor[2]	$289
DesignFlow[3]	$336	DesignFlow[3]	$336
Land and Water Constructions[5]	$246	Land and Water Constructions[5]	$246
Upper Parramatta River Catchment Trust[6]	$550	Upper Parramatta River Catchment Trust[6]	$550
Hunter[7]	$228	Hunter[7]	$228
Constructed Wetland		Cardno[9]	$290
MUSIC Lower Acquisition Cost [1]	$46	**Bioretention Swale**	
MUSIC Expected Acquisition Cost[1]	$74	MUSIC Lower Acquisition Cost[1]	$58
MUSIC Upper Acquisition Cost[1]	$105	MUSIC Expected Acquisition Cost[1]	$151
Kerrisdale[4]	$149	MUSIC Upper Acquisition Cost[1]	$392
Thomson, Taylor[2]	$326	Thomson, Taylor[2]	$326
DesignFlow[3]	$112	Land and Water Constructions[5]	$246
Dept. of Environment WA[8]	$98	**Street Tree**	
Sedimentation Basin		Typical 45L Pot Street Tree Mackay[9]	$950 each
Thomson, Taylor[2]	$359		
DesignFlow[3]	$100		

[[1]MUSIC v5.0 (2005), BMP treatment surfaces areas based on Precinct A local treatment approaches, constructed wetland assumed to be 19.7ha], [2] Thomson (2007) & Taylor (2003), [3]DesignFlow (2012), [4]Kerrisdale (2012), [5]Land and Water Constructions (2007), [6]Upper Parramatta River Catchment Trust (2004) , [7]Hunter (2011) , [8]Dept. of Environment WA (2004), [9]Perkins, RD 2012, pers. comm. 3 October).

Table 3-10: Typical Annual Maintenance Rates Adjusted for Inflation.

Source	TAM ($\$/m^2$)	Source	TAM ($\$/m^2$)
Biopod		**Bioretention Basin**	
MUSIC Lower Acquisition Cost[1]	$3.20	MUSIC Lower Acquisition Cost[1]	$5.50
MUSIC Expected Acquisition Cost[1]	$3.80	MUSIC Expected Acquisition Cost[1]	$8.80
MUSIC Upper Acquisition Cost[1]	$4.50	MUSIC Upper Acquisition Cost[1]	$12.20
Thomson, Taylor[2]	$55.20	Thomson, Taylor[2]	$7.00
Mullaly[10]	$5.60	Mullaly[10]	$5.60
EPA Vic[11]	$12.30	EPA Vic[11]	$12.30
Land and Water Constructions[5]	$16.40	Land and Water Constructions[5]	$16.40
Constructed Wetland		**Bioretention Swale**	
MUSIC Lower Acquisition Cost[1]	$1.20	MUSIC Lower Acquisition Cost[1]	$32.70
MUSIC Expected Acquisition Cost[1]	$2.30	MUSIC Expected Acquisition Cost[1]	$38.80
MUSIC Upper Acquisition Cost[1]	$4.44	MUSIC Upper Acquisition Cost[1]	$46.00
Thomson, Taylor[2]	$5.00	Thomson, Taylor[2]	$39.50
Healthy Waterways Partnership [12]	$1.52	Mullaly[10]	$5.60
Dept. of Environment WA[8]	$2.00	EPA Vic[11]	$12.30
Street Tree		Land and Water Constructions[5]	$16.40
Typical 45L Pot Street Tree Mackay[9]	$25 each	**Sedimentation Basin**	
		Thomson, Taylor[2]	$22.20
		Cardno[9]	$11.20

[[1]MUSIC v5.0 (2005), BMP treatment surfaces areas based on Precinct A local treatment approaches, constructed wetland assumed to be 19.7ha], [2]Thomson (2007), Taylor (2003), [3]DesignFlow (2012), [5]Land and Water Constructions (2007) , [8]Dept. of Environment WA (2004), [9]Perkins, RD 2012, pers. comm. 3 October), [10]Mullaly (2012), [11]EPA Vic (2008) , [12] Healthy Waterways Partnership (2007).

Total Acquisition & Typical Annual Maintenance Costs

Costs adjusted for inflation were graphically represented by box and whisker plots. The box and whisker plots indicates the; median, variability of data around the mean, the skew of the data, the range of the data and the size of the data set. Total acquisition and typical maintenance costs for BMPs proposed for Precinct A were selected considering the graphical representation and the source of cost information which best suited these BMPs.

Life Cycle Costs

Life cycle costs were generated using MUSIC v5.0 life cycle costing module. The life cycle costing module uses algorithms and estimates to predict cost elements given cost given information about the BMP. Input parameters for each BMP include; 30 years life cycle, user defined total acquisition and typical annual maintenance costs, see Table 3-11. Annual establishment and annualized renewal adaption costs as well as decommissioning costs were not considered for life cycle costing due to limited available cost information.

Table 3-11: MUSIC v5.0 Life Cycle Costing Element Input Paramaters.

Inlet Properties	
Life Cycle of BMP (years)	30
Total Acquisition Cost ($)	User defined
Typical Annual Maintenance Cost ($)	User defined
Annual Establishment Cost ($)	$0
Annualized Renewal/Adaption Cost ($)	$0
Renewal/Adaption Period (years)	Not considered
Decommissioning Cost ($)	Not considered

The base year for life cycle costing is 2012 and a real discount rate of 5.50 % and an annual inflation rate of 2 % is applied over a 30 year span for each costing, see Table 3-12 below.

Table 3-12: MUSIC v5.0 Life Cycle Costing Module Properties.

MUSIC Life Cycle Costing Module Properties	
Real Discount Rate (%)	5.50
Annual Inflation Rate (%)	2.0
Base Year for Costing	2012
Span of Analysis (years)	30
Annualized Renewal/Adaption Cost ($)	$0

A matrix off TAC and TAM costs obtained were used to determine an array of life cycle costs. These results were also graphically represented using a box and whisker plot. The life cycle costs adopted for the Precinct A BMPs best represent the graphical results and source of cost information.

3.7 Triple Bottom Line Assessment

3.7.1 Introduction

As Gomboso and Morrison, (1996, p. 231) said,

"The challenge for stormwater managers of the next century, will be to integrate the multiple objectives of equity, environmental integrity and economic efficiency into water cycle management decisions for the future".

A TBL assessment was chosen to investigate the sustainability of a regionalised approach to WSUD for Precinct A. The TBL assessment also aims to identify the preferred stormwater treatment strategy through the opinions of local stakeholders and technical experts. The TBL assessment process also aims to provide a facilitated environment for experts and stakeholders to network, exchange views and to bring urban development issues, objectives and values out for discussion and debate.

The assessment methodology follows guidelines set out by the CRC, Taylor (2005). The assessment process involves the use of a Delphi Panel which consists of a multidisciplinary expert group and a stakeholder group from members representing industry and community groups and associations concerned with urban development.

The TBL assessment process involves several steps whereby the Delphi Panel; defined the objectives of the project, identified the key issues and values, defined the assessment criteria and performance indicators, determined the relative importance of the assessment criteria, assessed the likely impact and performance of each option and to identify the preferred treatment option.

3.7.2 Assemble the Delphi Panel

A Delphi group approach technique was adopted for the TBL assessment as the method was suited to generating ideas and facilitating consensus among individuals who have special knowledge to share, but who are not always in contact with each other, Department of Sustainability and Environment (2012).

A multidisciplinary Delphi Panel representing technical experts and stakeholders, each with experience and dealings with urban development was assembled by the facilitator as the assessment body to conduct a TBL assessment. The Delphi Panel consists of two groups; an Expert group and a Stakeholder group. The Expert group was made up of relevant technical experts and academics with a broad range of skills representing Mackay Regional Council and industry. The Stakeholder group acts as an advisory group and consist of representatives from traditional stakeholders including; the local catchment group and members of the Urban Development Institute of Australia (UDIA), al local developer and respected Councillor. The author was appointed the facilitator to run the Delphi Panel as well as the assessment manager.

Delphi Panel Members

Expert Group

- Senior Civil Engineer: A civil engineer with more than 32 years' experience in the consulting engineering industry in Mackay, and considerable experience in urban development including, in more recent years, WSUD.

- Principal Civil Engineer: A consulting Principal engineer with 40 years involvement in the consulting municipal engineering, land development and general civil engineering, including WSUD in Mackay and Central Queensland.

- Senior Civil Engineer (Hydraulics): A hydraulic engineer with 30 years' experience in hydraulic modelling, flood studies and urban development in the Mackay region. Experience in stormwater treatment modelling has been achieved in recent years.

- Senior Civil Engineer (Water): A senior engineer based in Brisbane with over 12 years of experience in the water engineering industry. Experience includes hydrologic and hydraulic impact assessments, flood management and hydraulic structure designs, stormwater quality management design, water data collection, lake turn-over and nutrient balance assessments, tidal prism assessments and detailed modelling geomorphologic assessments.

- Senior Landscape Architect: A landscape architect with 21 years' experience dealing with numerous public realm and open space areas. Also 15 years' experience in Master planned communities (residential estates), the last 8 years of which has been spent designing with and incorporating stormwater treatment devices into open space and natural areas.

- Landscape Architect: A landscape architect with 7 years' extensive experience in WSUD in association with civil and hydraulic engineers. Experience also involves preparing WSUD landscape guidelines for Water By Design and DesignFlow.

- Development Approvals Officer: Mackay Regional Council approval officer with 10 years' experience in civil engineering, with 7 years' experience in urban development and civil engineering design in the private sector, with 3 years' experience in development assessment area for local government.

- Environmental Scientist: Mackay Regional Council environmental scientist who focuses in stormwater within the Strategic Planning section of Development Services. Roles include; the commissioning of various flood studies, the construction and implementation of the Erosion & Sediment Control Compliance Program (ESCCP) and WSUD. Other experience includes various positions with the Department of Environment & Resource Management (DERM), concerning aquatic ecology, hydrography and water quality.

Stakeholder Group

- Urban Development Institute of Australia (UDIA) member: UDIA is the peak membership organisation representing the property industry. Their purpose is to promote excellence and innovation in the creation of sustainable communities.

- Regional Landcare Facilitator: A senior coordinator of the Sarina Landcare Catchment Management Association (SLCMA), which is a not-for-profit community organisation that works with the community to help protect the natural environment within the Sarina Catchment (southern reach of Mackay Regional Council). This is achieved by providing free property visits and land management advice to landholders; undertaking on-ground rehabilitation projects; engaging youth and volunteers in educational and practical Landcare activities. SLCMA provide assistance on a range of topics from pests and vegetation management to waterway, biodiversity and coastal management. The use of "Community" is in the broad sense which includes individuals, Council, organisations, businesses, stakeholders, project partners.

- Local Developer: A local developer with over 10 years' in the development industry. Current developments include a 700 lot urban residential development in Mackay which incorporates WSUD features.

- Councillor: A Mackay Regional Councillor who's current portfolio is Developments and Planning and previous portfolios include Economic Development.

3.7.3 Define the Projects Objectives

To define the objectives of the assessment project the Delphi Panel were firstly asked to list the financial, social and ecological objectives that should be met in terms of stormwater treatment for Precinct A.

Secondly, the objectives defined by the Delphi Panel were reviewed against the broad objectives and principles of 'ecologically sustainable development' (ESD) as outlined in Australia's National Strategy for ESD, Department of the Environment and Heritage (DEH) (1992). This ensures the objectives set are consistent with the objectives and principles of the ESD.

3.7.4 Define Values & Concerns

The Delphi Panel were then asked to clearly define the values and concerns to be addressed when providing stormwater treatment for Precinct A. This was done to ensure Delphi Panel members undertaking the TBL assessment can evaluate how effective each option is likely to be.

The facilitator then summarised and synthesised the values and concerns defined by the Delphi Panel into core values for each TBL element. These core values reflect the projects objectives.

'Value tree analysis' was then performed. The Stakeholder group was asked to rank the core values from most important to least important, see Fig. 3-4. This hierarchy of stakeholder values was used as a signpost towards the Expert group and reflects the values that needed to be protected. Possible assessment criteria for all three elements of the TBL were drawn from this.

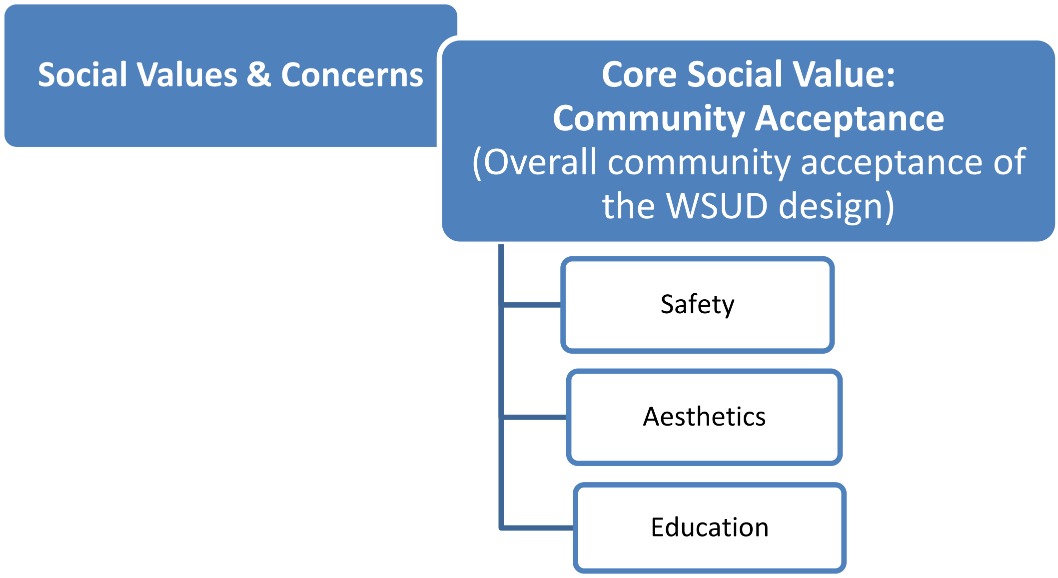


Fig. 3-4: Example ‘Value tree’ where the highest ranked value in this example ‘safety’, is listed at the ‘top’ of the tree.

3.7.5 TBL Assessment Criteria and Indicators

The significant benefits and drawbacks of each financial, social and ecological option to be assessed were defined by the assessment manager as the assessment criteria. The criterion relates, and is aligned to the TBL project objectives as well as the significant stakeholder concerns and values. The assessment criterion highlights significant concerns between the options (e.g. typical annual maintenance cost, and risks to safety of local residents).

Once the assessment criterion was determined, performance indicators were developed for each criterion by the facilitator, see Table 3-13. For example, financial criterion includes “to minimise the typical annual maintenance cost” of a treatment element, and the suitable indicator is “2012 Australian dollars ($) per year”.

The Delphi Panel were then asked to review the facilitators proposed assessment criteria and indicators. Any suggested amendments were deliberated between the facilitator and Delphi Panel before finalising the criterion. Once the assessment criteria and indicators were finalised, relative data for each indicator was collected for construction of an ‘Impact Matrix, see Section 3.7.8.

Table 3-13: TBL Assessment Criteria & Indicators.

Triple Bottom Line Assessment Criteria	Performance Indicator
***Financial* Core Objective – Minimise Costs**	
The life cycle cost of the device over 30 years	$2012 AUD over 30 years
The typical annual maintenance costs	$2012 AUD/m^2
The total capital and acquisition costs	$2012 AUD/m^2
***Social* Core Objectives – Social Acceptance of WSUD Design**	
The impact on the safety of people using the area	A 1 to 5 rating using a scoring key
The impacts on the area's aesthetic values	A 1 to 5 rating using a scoring key
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	A 1 to 5 rating using a scoring key
Impact on property values	A 1 to 5 rating using a scoring key. Property values are a function of safety, health & wellbeing, aesthetics, land required, and access/proximity to open water body.
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	A 1 to 5 rating using a scoring key
Community involvement in maintenance	A 1 to 5 rating using a scoring key
The inconvenience of nuisance flooding / ponding outside of dwellings	A 1 to 5 rating using a scoring key
The inconvenience to people using the road reserve (e.g. access, parking)	A 1 to 5 rating using a scoring key
Natural habitat for native animals	A 1 to 5 rating using a scoring key
The impact on the research, education & awareness opportunities	A 1 to 5 rating using a scoring key
***Ecological* Core Objectives – Reduce Impact on Receiving Waterways & Integrate with Natural Area**	
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	% of pollutant reduction from MUSIC assessment (TSS, TP, TN)
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	A 1 to 5 rating using a scoring key
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	Not assessed. Both regional and local strategies are design to accommodate a 5 year and 100 year ARI flood event

Financial Indicators

Best Management Practice costs are determined in Section 3.6.

Ecological Indicators

Outputs from MUSIC modelling were used to assess treatment performance and ability of BMPs to reduce impact on receiving waterways, see Section 3.5.

Social Indicators

See Section 3.7.6 below.

3.7.6 Social Performance Indicators

To establish social performance indicators for the assessment criteria, door-to-door surveys were conducted at Cuttersfield Estate and Blacks Beach Cove. Cuttersfield Estate features existing bioretention swales and biopods and whereas Blacks Beach Cove has an existing constructed wetland and bioretention basin providing stormwater treatment. Twenty-five residents of Cuttersfield were asked a series of questions regarding the effect the existing biopods and bioretention swales had on the neighbourhood. Similarly, twenty-five residents of Blacks Beach Cove were surveyed on the effect the existing bioretention basin and constructed wetland had on their respective neighbourhood.

There are approximately 1200 residents in Cuttersfield Estate, and approximately 900 current residents in Blacks Beach Cove, see Table 3-14. To account for the small sample size, the subsequent proposed social performance indicators were reviewed by the Expert group and Council, who have had past experience addressing resident concerns.

An online survey of seventy participants was used to produce a larger survey population base and to act as a control group. Survey participants were showed examples of bioretention basins, bioretention swales, biopods, street trees and constructed wetlands. Data was collected from participants who identified similar examples of treatment elements in their own neighbourhood to those shown in the survey. The results of the online survey were compared against the results of the Cuttersfield and Blacks Beach Cove surveys. Performance indicators were then determined for each social criterion on a 1 to 5 rating scale.

Table 3-14: Survey sample sizes.

Development	Sample Size (*n*)	Population (N)	% of Population Sampled
Cuttersfield Estate	25	1200 approx.	2 %
Blacks Beach Cove	25	1000 approx.	3 %
Online Survey	70	N/A	N/A

Door-to-Door Survey – Cuttersfield Estate

Door-to-door survey was commissioned for Cuttersfield Estate, where residents were asked a series of questions regarding the existing biopod and bioretention swales found near their residence.

Residents were asked:

1. A series of general demographic questions regarding; their age, gender, living situation (e.g. renting or home owner).
2. If they were aware of the existence of WSUD residential developments, designed and aimed to manage stormwater as a resource, and if they were aware of the principles of WSUD in general?

3. If they were aware that the primary function of biopods and bioretention swales was for stormwater treatment?
4. If the biopods and bioretention swales (when compared to traditional ‘no treatment’ stormwater designs) had a positive, negative or no effect on the following issues:
    - Nuisance flooding (ponding of water).
    - Habitat for local native animals.
    - Presence of pests (e.g. mosquitoes).
    - Access to houses by all community members.
    - On-street parking.
    - The areas recreational opportunities (walking, cycling, jogging, etc.).
    - The areas aesthetic appeal.
    - Improved air quality.
    - If the BMP helped integrate the local area with the existing adjoining natural areas.
5. If overall, the biopod and bioretention swale (compared to traditional ‘no treatment’ stormwater design) increased, decreased or made no difference to the safety of the neighbourhood?
6. If overall, the biopod and bioretention swale (compared to tradition ‘no treatment’ stormwater design) increased, decreased or made no difference to the environmental education and awareness opportunities in the neighbourhood?
7. And, if the resident would consider being involved in community based maintenance (weeding, gardening, etc.) of a biopod or bioretention swale?

Door-to-Door Survey – Blacks Beach Cove

The same typical questions used for Cuttersfield Estate were then asked of residents of Blacks Beach Cove regarding the existing bioretention basin and constructed wetland found within the estate.

General Survey – Online

A general online survey was used to establish a control group and a greater survey population. Photographs of existing, bioretention swales, bioretention basins, biopods, constructed wetland and street trees were shown to the survey participants, who were asked the same questions as above. Online survey participants were also asked if each BMP existed in their residential neighbourhood. Data was taken from residents who had identified existing BMPs in their neighbourhood. See Appendix C for a full list of survey results.

3.7.7 Assessment Criteria Weighting

The Delphi Panel then assessed the relative importance placed on each assessment criteria. The Expert group was used to assign a set of weights for each of the assessment criteria that best reflected the broader public good. Prior to assigning weights, the previously defined stakeholder value hierarchy was provided to the Expert group.

A simple method was used to assign weights where each group member was allocated 99 counters to allocate across all the financial, social and ecological assessment criteria as a representative of the wider community. Only thirty-three (33) of these counters are to be allocated to each TBL element. Thirty-tree counters are assigned to the financial assessment criteria in a way that reflects their relative importance (i.e. the most important criteria is allocated the most amount of counters). Then, 33 counters were allocated to the social assessment criteria, and the remaining 33 counters were allocated to the ecological assessment criteria.

Once every member of the Expert group had allocated their counters, the weighting data was collected and analysed. The mean values of the weights attributed to each assessment criteria were then used to express the group result. The minimum, mode, median and maximum of each individual's assigned weights for each assessment were recorded to enable sensitivity analysis to be conducted.

Each member of the Expert group was provided an opportunity to explain the reasoning behind their allocations of weights and to discuss any issues that emerged. Members were also given the opportunity to repeat the weighting exercise when discussion had led to a change in their perspective.

This process ensures that the three elements of the TBL were equally assigned importance. The assessment criteria within each element of the TBL were assigned weights that reflected the views of the Expert Panel. This process also reflected the policy position of the ESD, Taylor (2005).

3.7.8 Impact Matrix

An impact matrix was then constructed by the facilitator to summarise how each option will probably perform against each of the finalised assessment criteria. The impact matrix is a table with the performance probability options listed on one side and the assessment criteria on the other. 'Impact scores' are contained within the matrix which indicates the relative performance of each option.

The impact matrix was formed in four steps:

Step 1 – Identify the Best Available Indicator and Unit of Measurement

The best available indicator and unit of measurement of each assessment criteria were used to initially access each option's performance, see Section 3.7.5.

Step 2 –Performance Scoring Keys

All descriptions of performance created in step 1 were converted into 'performance scores' with a 1 to 5 rating scale. E.g., for the life cycle costs of a treatment device: ≥ $2,000,000 scored 1; $1,000,000 ≤ LCC < $2,000,000 scored 2; $500,000 ≤ LCC < $1,000,000 scored 3; $250,000 ≤ LCC < $500,000 scored 4; and LCC < $250,000 scored 5. Each scoring system called a 'scoring key', was formulated so a desired result scored highly. Possible biased is minimised, by adjusting the scoring system for each assessment criteria so that the best possible performance scored a 5, and the worst possible performance scored 1, see Table 3-15.

Table 3-15: Example of performance score keys for the Impact Matrix.

Rating	Categorisation	Example Descriptions for Each of the Assessment Criteria		
		Life cycle cost (X) ($2012)	Safety	Percentage of the load of TN removed (Y)
5	Outstanding benefits / Little costs	X < $250,000	The risk of drowning is much lower than traditional stormwater drainage	Y ≥ 46 % of existing annual TN load
4	Major benefits / Minor costs	$250,000 ≤ X < $500,000	The risk of drowning is slightly lower than traditional stormwater drainage	43 % > Y ≥ 46 % of existing annual TN load
3	Moderate benefits / Major costs	$500,000 ≤ X < $1,000,000	The risk of drowning is equivalent to traditional stormwater drainage	40 % > Y ≥ 43 % of existing annual TN load
2	Minor benefits / Major costs	$1,000,000 ≤ X < $2,000,000	The risk of drowning is higher than traditional stormwater drainage	37 % > Y ≥ 40 % of existing annual TN load
1	Little or no benefits / Outstandingly high costs	X ≥ $2,000,000	The risk of drowning is much higher than traditional stormwater drainage	Y < 37 % of existing annual TN load

Step 3 –Likelihood Scores

A 'likelihood score' using a 1 to 5 rating scale was then generated, refer Table 3-16. The likelihood score indicates how likely it is that the option will perform to the extent indicated by the 'performance score'. Likelihood scores were used to access the uncertainty associated with performance estimates and the risk of failure associated with stormwater treatment device, see Table 3-17 for a Risk Analysis Matrix modified from AS/NZS 4360:2004. Likelihood scores reflect the confidence of the assessment criteria data obtained.

Table 3-16: Likelihood Scoring Key for the Impact Matrix, Taylor (2005).

Rating	Categorisation	Description
5	Almost Certain	Outcome is expected to occur in most circumstances
4	Likely	Outcome will probably occur in most circumstances
3	Possible	Outcome could occur
2	Unlikely	Outcome could occur but is not expected
1	Rare	Outcome is expected to occur only in exceptional circumstances

During sensitivity analysis, the effects that the likelihood scores had on the final outcome were investigated.

Table 3-17: Risk Analysis matrix to Determine the 'Impact Scores', Taylor (2005).

		PERFORMANCE SCORE				
		Very High (5)	High (4)	Medium (3)	Low (2)	Very Low (1)
LIKELIHOOD SCORE	Almost Certain (5)	Extreme impact (25)	Very high impact (20)	High impact (15)	Medium impact (10)	Low impact (5)
	Likely (4)	Very high impact (20)	High impact (16)	Medium impact (12)	Medium impact (8)	Low impact (4)
	Possible (3)	High impact (15)	Medium impact (12)	Medium impact (9)	Low impact (6)	Negligible impact (3)
	Unlikely (2)	Medium impact (10)	Medium impact (8)	Low impact (6)	Low impact (4)	Negligible impact (2)
	Rare (1)	Low impact (5)	Low impact (4)	Negligible impact (3)	Negligible impact (2)	Negligible impact (1)

Step 4 –Impact Score

Each 'likelihood score' was then combined with its corresponding 'performance score' to create an 'impact score' using the risk analysis matrix, see Table 3-18. The 'impact score' is simply the product of the 'likelihood score' and it's corresponding 'performance score'. The impact scores range from 1 to 25.

Table 5. Table 3-18 Example 'Impact Matrix' for a TBL Assessment of a BMP, Taylor (2005).

Assessment Criteria	Stormwater Treatment Option Bioretention Basin
Financial Criteria	
Life cycle cost for the asset in 2012 Australian dollars calculated over a 30 year life span using methodology described in Taylor (2003), a real discount rate of 5.5 % and no decommissioning costs	Likely performance: $572,000 (MUSIC estimate) Performance score: 3 (see Table 3-15 for an explanation of these 1 to 5 ratings) Likelihood score: 3 (see Table 3-16 for an explanation of these 1 to 5 ratings) **Impact score: 9 (Medium)** (i.e. 3 x 3, as shown in Table 3-17)
Social Criteria	
Safety risks to residents (e.g. drowning)	Likely performance: A very small risk of drowning exists (only during major storm events) Performance score: 3 Likelihood score: 3 (i.e. the likelihood that the expected performance will be delivered) **Impact score: 9 (Medium)**
Ecological Criteria	
Load nitrogen (TN) removed from stormwater	Likely performance: A 42 % reduction in the total load of TN draining from the catchment in a typical year. Performance score: 3 Likelihood score: 4 **Impact score: 12 (Medium)**

A draft version of the impact matrix was prepared by the facilitator and then presented to the Expert group for comment. After which the impact matrix was then finalised.

Impact Scores were then recorded for both local and regional treatment strategies. To determine the impact score of each treatment strategy, the impact scores of each treatment element are adjusted to the relative treatment percentage each treatment element provides per strategy. I.e. the nominal bioretention basin provides 32 % of the treatment for a local treatment strategy; therefore the impact score is adjusted by 32 %. There is no requirement to adjust the impact score for the constructed wetland, as the wetland provides 100 % of the treatment for the regional treatment strategy.

3.7.9 Value Scores

Two methods were used to rank the options in order of preference; multi criteria analysis (MCA) using The Simple Multi Attribute Rating Technique (SMART) and 'intuitive ranking'. Using the results from the impact matrix (impact scores) and the weights on each assessment criteria, the SMART method was used to rank each option. The facilitator then provided the Expert group with the MCA results to then intuitively rank each treatment strategy and each treatment element in order of preference.

Multi criteria Analysis (MCA)

The SMART method is a simple approach used to rank options by using multiple attribute theory. An overall value score for each option is generated using all of the financial, social and ecological assessment criteria. This resulting value score represents how well the treatment option performed against the assessment criteria and the weight on each of the criterion. The MCA is only used a guide to assist with decision making.

The weighted summation method is applied using Equations 5 and 6:

Value Score = Σ Impact Score for Each Criterion x Weight on Each Criterion (5)

Treatment Strategy Value Score = Value Score x Percentage (%) of Treatment Area (m^2) (6)

Treatment Strategy Value Scores were then recorded for both local and regional treatment strategies. The value score were adjusted using an equivalent method to how the impact scores were adjusted, whereby; the value scores of each treatment element are adjusted to the relative treatment percentage each treatment element provides per strategy.

3.7.10 Sensitivity Analysis

Several forms of sensitivity analysis were performed to examine the effect on the ranked options. The methods are documented below:

- Using the minimum, maximum, mean weights on assessment criteria that were generated by a group, rather than the median value.
- Using equal weights on all assessment criteria
- Setting all the 'likelihood scores' for a given assessment to equal the score given to the option that is the most well know. This ensures that new, innovative options that are not as well know are not significantly disadvantaged (creating a level playing field).
- Using an 'Overall Benefit Score (OBS)' which highlights financial performance versus social and ecological scores, where only the social and ecological elements are

included. Financial elements are used as an indicator of cost and ranked on the four indices of value:

- OBS ÷ Life Cycle Cost (LCC).
- OBS ÷ Estimated Acquisition Cost.
- OBS ÷ Typical Annual Maintenance Cost.
- OBS ÷ Equivalent Annual Payment.

These values provide an insight into the relative benefit to cost ratio of each option. E.g. if you are focussing on minimising the life cycle costs, the option with the highest OBS (combined social and ecological value score) ÷ LCC index of value highlights this. It should be noted that this method contravenes the fundamental principle of sustainability and denies equal weight the each of the three TBL elements.

3.7.11 Recommend Preferred Option

The Expert group were asked to rank their preferred treatment strategy and treatment element, in two steps. Firstly, the Expert group was provided with the adjusted Impact Scores and then asked to perform an initial intuitive ranking of their preferred treatment strategies and treatment elements.

The Expert group was then provided with the adjusted value scores from the MCA as well as the results from the sensitivity analysis and asked to undertake a second final intuitive ranking of the two treatment strategies and four treatment elements. The highest ranked option was the Expert groups preferred option.

3.7.12 Make Final Decision

The ultimate decision is made by the assessment manager which considers the recommendation(s) from the Delphi Panel, along with other factors such as:

- Mackay Regional Council's current budget situation.
- Political requirements and considerations.
- Regulatory constraints.
- Constructability constraints.

The assessment manager is aware of the risk that stakeholder discontent and distrust that may be generated if their recommendations are not adopted and a satisfactory explanation is not provided. Once the decision is made, feedback is provided to each member of the Delphi Panel and they are thanked for their effort.

3.8 Impact of Maintained Biopods

The initial assessment was based on the existing state of the biopods in Cuttersfield which, from visual inspection were obviously not performing and failing to provide treatment to stormwater runoff.

To estimate the difference a fully maintained biopod would make on the final results of the TBL assessment, an Impact Matrix and value scores were generated based on the premise that the proposed local treatment strategy biopods for Precinct A, were fully planted, as shown in Fig. 2-4. The impact and value scores were compared to the initial TBL assessment scores and provided to the Expert group of comment.

4.0 Results & Discussion

4.1 Introduction

This chapter analyses and discusses; the MUSIC model results, associated sedimentation and constructed wetland designs, the adoption of best suited cost information for BMPs, and the outcomes of the Delphi Panel and TBL assessment. The presentation of results will begin with sedimentation and constructed wetland designs. The regional strategy treatment performance results from MUSIC are then discussed. The total acquisition, typical maintenance and life cycle costs associated with BMPs are then graphically represented and discussed. Finally the results of the TBL assessment and Delphi Panel's preferred treatment strategy are then presented and evaluated.

4.2 Best Management Practice Design

4.2.1 Sedimentation Basin Design

The design operation flows ($Q_{1\text{ year ARI}}$) used to size the sedimentation basins are 3.65 m^3/s for Sedimentation Basin A and 1.78 m^3/s for Sedimentation Basin B, see Table 4-1. Above design flows ($Q_{2\text{ year ARI}}$) used for the design of the 'spillway' outlet structure are 4.98 m^3/s for Sedimentation Basin A and 1.78m^3/s for Sedimentation Basin B.

Table 4-1: Sedimentation Basins A & B design flow & hydrology.

Design Flows Parameters	Sedimentation Basin A	Sedimentation Basin B
Time of Concentration (min)	15	15
Catchment Area (ha)	22.24	10.3
Runoff Coefficient	0.76	0.76
1 yr. ARI Rainfall Intensity (mm/hr)	82	82
2 yr. ARI Rainfall Intensity (mm/hr)	106	106
Design Operation Flow, 1 yr. ARI (m^3/s)	3.65	1.78
Above Design Flow, 2 yr. ARI (m^3/s)	4.98	2.30

Using the design operation flow, the design surface area of Sedimentation Basin A was designed at 950 m^2 to achieve a 90 % settling target of 125 µm sized particles, see Table 4-2. Sedimentation Basin B was sized at 500 m^2 to achive equivalent objectives. Both basins have an extended depth of 0.3 m, a permanent pool depth of 2.0 m and a depth below permanent pool level to reatin target sediment of 1.0 m.

Table 4-2: Sedimentation basin sizing parameters.

Sedimentation Basin Parameters	Sedimentation Basin A	Sedimentation Basin B
Capture efficiency (%)	90	90
Settling velocity or target sediment (μm)	125	125
Area of sedimentation basin (m^2)	950	500
Turbulence or short-circuiting parameter	1.67	1.67
Extended detention depth (m)	0.3	0.3
Depth of permanent pool	2.0	2.0
Depth below permanent pool level to retain target sediment	1.0	1.0
Hydraulic efficiency	0.4	0.4
Sediment basin storage volume (m^3)	950	500
Edge batter slope (V:H)	1:5	1:5
Notional dimensions (m)	15.5 x 62	11.2 x 44.8
Required clean out frequency (years)	28	34
Design Outlet Structures		
Weir length (m)	27.0	13.1
Overflow pit dimension (m)	5.0 x 5.4	3.65 x 3.65
Outlet pipe dimension (mm diameter)	3 / 900	2 / 750

For Sedimentation Basin A. the weir flow conditions required for the perimeter of the outlet pit to pass the design flow of 3.65 m^3/s is 26.7 m. Considering the overflow pit is to convey the design operation flow, a 5.0 x 5.4m pit is adopted to provide a perimeter of 27 m, which is greater than the 26.7 m calculated using the weir flow equation. Similarly, for Sedimentation Basin B, the perimeter of the outlet pit to pass the design flow of 1.78 m^3/s is 13.1 m. The dimension of the overflow pit to convey the design operation flow is 3.65 x 3.65 m.

4.2.2 Constructed Wetland Design

The constructed wetland was modelled using MUSIC v5.0 to achieve best practice WQOs. See Section 4.3 for the constructed wetland MUSIC model results and design parameters. Refer Appendix B for sedimentation basin and constructed wetland design calculation summary.

4.3 Performance Assessment Results

4.3.1 MUSIC Model Setup

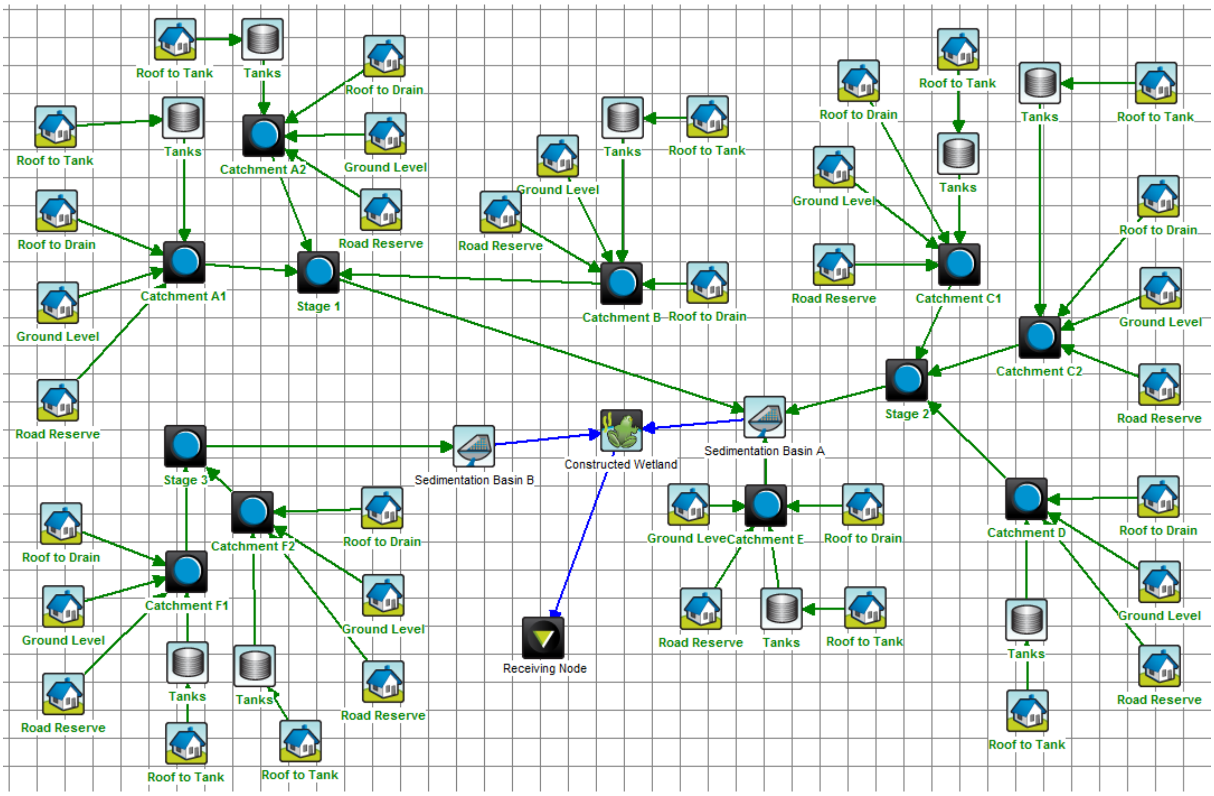


Fig. 4-1: MUSIC model schematic for regional treatment strategy to Precinct A.

The MUSIC treatment nodes for the regional stormwater treatment strategy are illustrated in Fig 4-1. The input values for the rainwater tanks have been defined in Section 3.4. Input values for the sedimentation basins and constructed wetland are defined in Table 4-3 and Table 4-4.

Table 4-3: Sedimentation basin MUSIC treatment node parameters.

Inlet Properties	**Sedimentation Basin A**		**Sedimentation Basin B**
Low Flow By-Pass (m^3/s)	0		0
High Flow By-Pass, 2-year ARI (m^3/s)	4.98		2.3
Storage Properties			
Surface area (m^2)	1200		750
Extended detention depth (m)	2.0		2.0
Permanent pool volume (m^3)	50		40
Exfiltration rate (mm/hr)	0		0
Evaporative Loss as % of PET	75		75
Outlet Properties			
Equivalent pipe diameter (mm)	300		200
Overflow weir width (m)	26.7		13.1
Notional Detention Time (hours)	2.25		3.16
Advanced Properties			
Orifice discharge coefficient	0.6		
Weir coefficient	1.7		
Number of CSTR cells	1		
	k (m/yr)	C* (mg/L)	C** (mg/L)
Total Suspended Solids	8000	20.00	20.00
Total Phosphorous	6000	0.13	0.13
Total Nitrogen	500	1.40	1.40

Table 4-4: Constructed wetland MUSIC treatment node parameters.

Inlet Properties	
Low Flow By-Pass (m^3/s)	0
High Flow By-Pass, 2-year ARI (m^3/s)	100
Inlet pond volume (m^3)	0 (Inlet pond volume defined by Sedimentation Basins A & B)
Storage Properties	
Surface area (m^2)	21,700
Extended detention (m)	0.6
Permanent pool volume (m^3)	5910
Seepage loss (mm/hr)	0
Evaporative Loss as % of PET	125
Outlet Properties	
Equivalent pipe diameter (mm)	225
Overflow weir width (m)	2170
Notional Detention Time (hours)	39.6

4.3.2 MUSIC Model Results

As shown in Table 4-5, the stormwater quality objectives defined in Section 2.3.4 are met by the regional stormwater treatment strategy.

Table 4-5: MUSIC results for Precinct A.

Catchment	**Stormwater Treatment**			**Pollutant Load Reduction Achieved (%)**			
Area (ha)	Treatment Element	Treatment Surface Area (m^2)	% Catchment Area	TSS	TP	TN	GP
22.24	Sedimentation Basin A	950	0.4	53.8	36.0	6.3	99.9
10.3	Sedimentation Basin B	500	0.5	59.2	40.4	8.0	98.9
33.53	Constructed Wetland	21,700	6.5	44.2	42.8	31.3	99.9
33.53	**Total Site**	**23,150**	**7.4**	**75.5**	**65.4**	**40.7**	**99.9**
	Site Objective			**75.0**	**60.0**	**40.0**	**90.0**

4.4 Best Management Practice Costs

The best available cost information for each BMP tabulated in Section 2.8 was graphically represented by box and whisker plots. Unit rates in 2012 dollars per square metre ($2012/m^2) and total costs per required treatment area for Precinct A were produced and analysed. TAC's and TAM were plots were initially produced with MUSICs generated lower and expected costs. When compared to the rest of the cost data obtained, these costs were unreasonably lower and thus omitted, and the plots were reproduced for comparison. TAC, TAM and LCC rates adopted best reflect the size of BMPs proposed for Precinct A and available cost information.

Total Acquisition Costs

The following base unit rates for BMPs in the Mackay region were adopted, (see Table 4-6); $150/m^2 was selected for a constructed wetland due to the high confidence in cost data obtained from a similar sized constructed wetland (19.7 ha), inclusive of two sedimentation basins (total surface area of approximately 2000 m^2) recently proposed for construction in Mackay. $150/m^2 is also the upper quartile of constructed wetland cost data. As such, the TAC for the sedimentation basins are inclusive of the constructed wetland rate.

The TAC selected for bioretention basins is $310/m^2. This rate is slightly conservative and is marginally higher than; the $290/m^2 proposed by MRC and Cardno, the median rate of $289/m^2, and similar to the upper quartile rate of $313/m^2. The TAC's adopted for a biopod is $330/m^2. Cost information on biopods was limited and a more conservative rate was chosen. The median TAC biopod value ($291/m^2) is comparable to the bioretention median TAC value.

TAC rates for Bioretention swales are also estimated to be $330/m^2. High confidence can be taken from the Thomson and Taylor cost information which is akin to the median swale TAC value of $326/m^2. Street Trees TAC rates are consistently priced at approximately $950 each for urban residential development in the Mackay region. A 45 L pot street tree including supply and installation of root control barriers and root directors are typically used per each tree per each allotment.

Table 4-6: Adopted total acquisition unit rates.

Treatment Element	TAC Unit Cost ($/m^2)
Bioretention Swale	326
Bioretention Basin	310
Biopod	330
Constructed Wetland (including two sedimentation basins approx. 2000m^2 total)	150
Street / Verge Tree (BAU)	$950 each

Fig. 4-2 and 4-3 show the reduction MUSIC's lower and expected unit rates had on the BMP TACs.

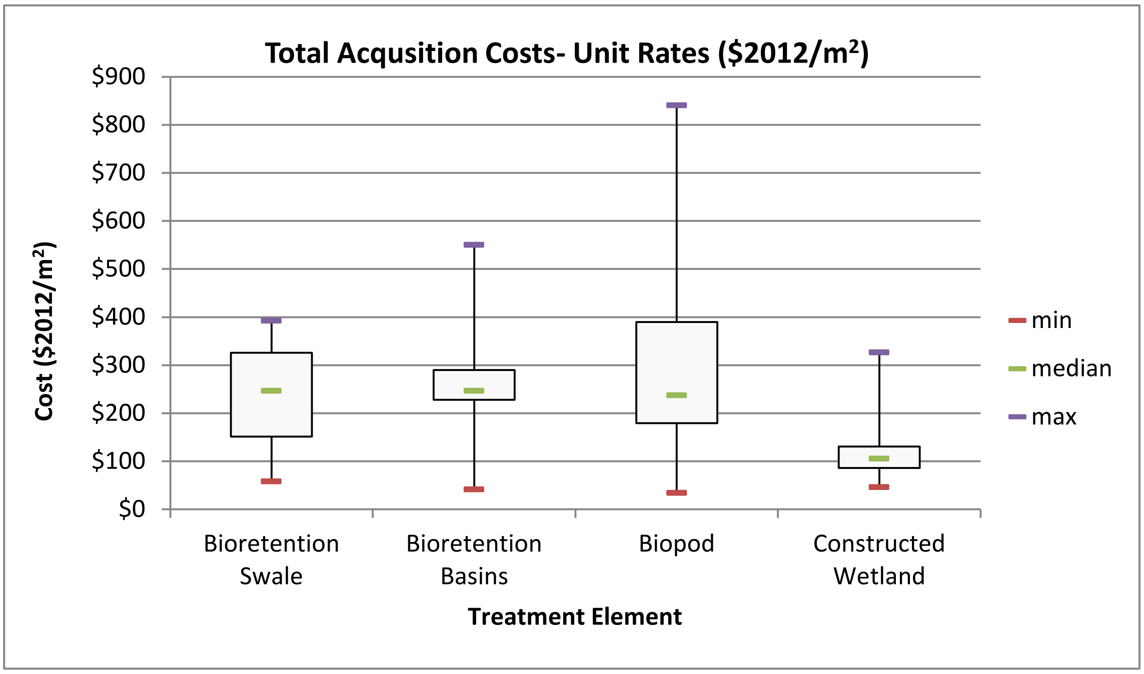


Fig. 4-2: Total acquisition costs of treatment elements (inclusive of MUSIC's lower and expected unit rates).

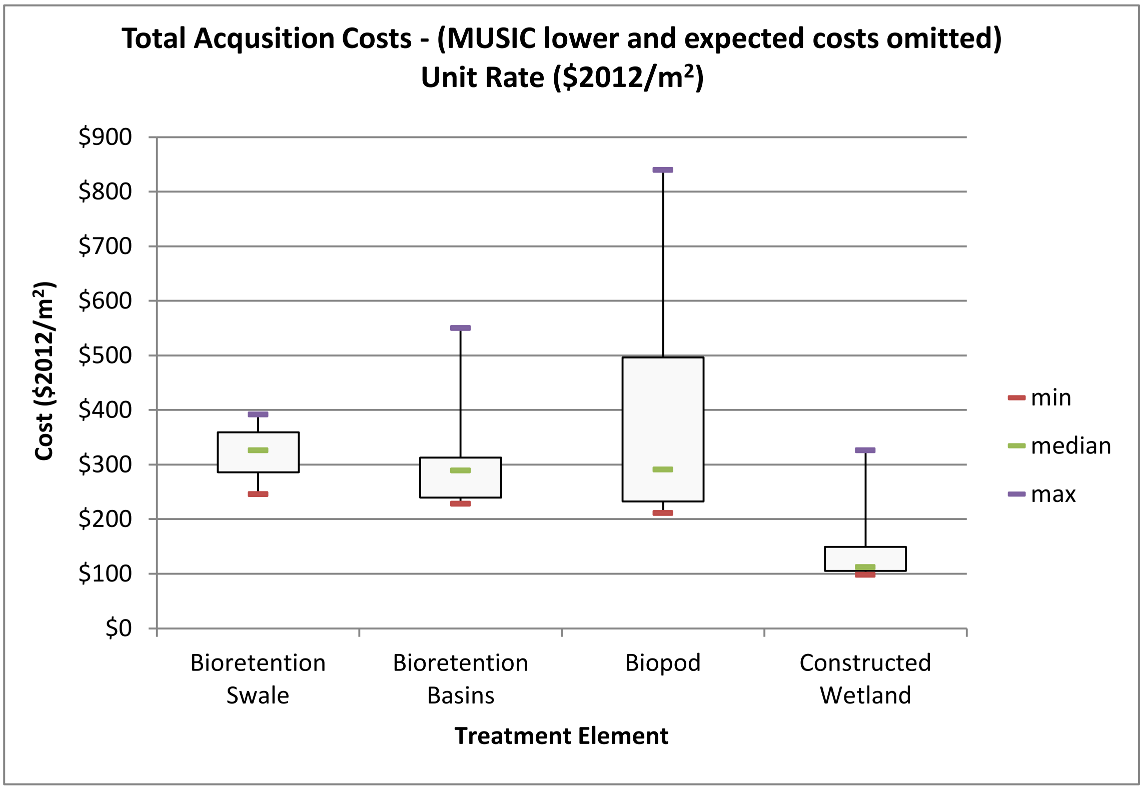


Fig. 4-3: Total acquisition costs of treatment elements (MUSIC's lower and expected unit rates omitted).

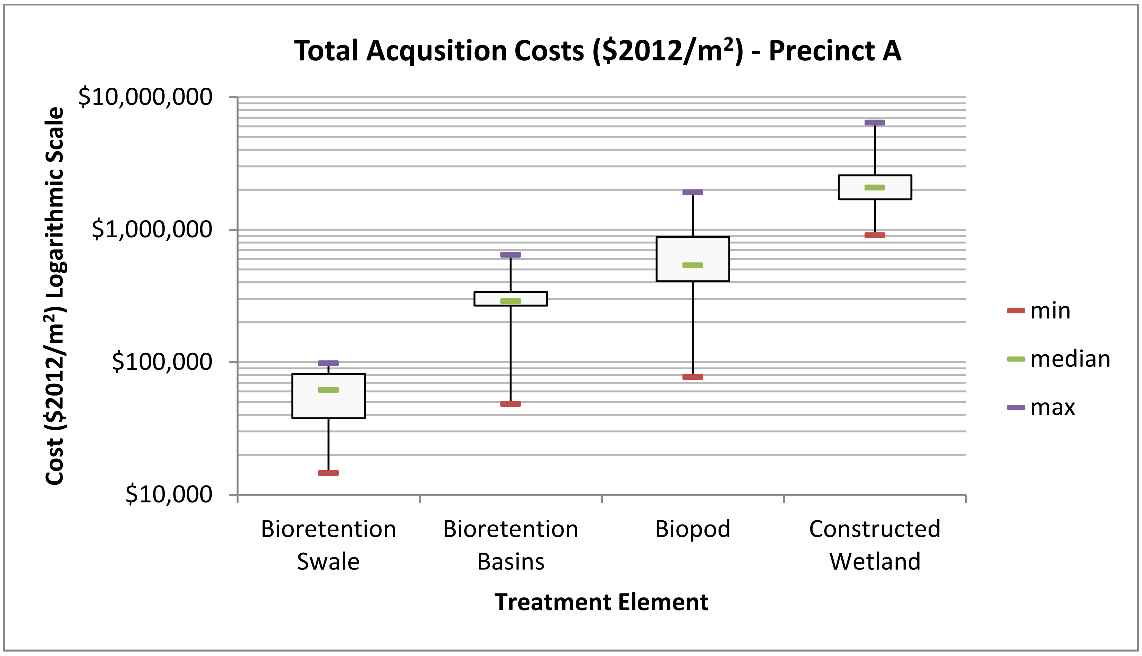


Fig. 4-4: Total acquisition costs for Precinct A treatment elements.

The variance of treatment element total acquisition costs for Precinct A is shown in Fig. 4-4. Median values or more conservative unit costs were adopted, where there was less confidence with the cost information. The estimated TAC per treatment approach was determined using the adopted unit rates per treatment area and the required BMP treatment areas per the treatment approach as per Table 4-7. The total acquisition costs for Precinct A BMPs are; $81,500 for bioretention swales, $700,000 for bioretention basins works, $385,000 for biopods and $3,255,000 for constructed wetlands. TAC for street trees is estimated at $122,150.

Table 4-7: Estimated total acquisition costs per treatment strategy for Precinct A.

Treatment Element	TAC Unit Rate ($/m^2)	BMP Treatment Area (m^2)	TAC ($)
Local Stormwater Treatment Approach			
Bioretention Swale	326	250	81,500
Bioretention Basin	310	1170	363,000
Biopod	330	3911	1,290,600
Total			1,735,100
Regional Stormwater Treatment Approach			
Constructed Wetland (including two sedimentation basins approx. 2000m^2 total)	150	21,700	3,255,000
Total			3,255,000
Business As Usual (BAU)			
Street / Verge Trees	$950 each	349 (no. of)	122,150

Typical Annual Maintenance Costs

The typical annual maintenance costs for adopted for Precinct A BMPs are; $40/m^2/yr. for bioretention swales, $12.50/m^2/yr. for bioretention basins and biopods, $2.70/m^2/yr. for constructed wetlands and $25 for each street tree, see Table 4-8.

The adopted rate for bioretention swales is $40/m^2/yr. which is slightly higher than the upper quartile cost. There is high confidence in this rate due to cost information obtained from similar sized bioretention swales in South East Queensland to the 250 m^2 bioretention swale proposed in Precinct A.

Table 4-8: Adopted typical annual maintenance unit rates.

Treatment Element	TAM Unit Cost ($/m^2/yr)
Bioretention Swale	40.00
Bioretention Basin	12.50
Biopod	12.50
Constructed Wetland	2.70
Sedimentation Basin	11.20
Street / Verge Tree (BAU)	$25 each

The TAM cost selected for bioretention basins and biopods is $12.50/m^2/yr. This rate falls above the median cost value and below the upper quartile for both sets of cost data for each respective BMP, see Fig. 4-5. This rate is based on moderate confidence of the TAM costs reported for both bioretention basins and biopods. The high outlier of biopods TAM costs illustrated in Fig. 4-5 is due to limited knowledge and experience in maintenance of biopods. Maintenance costs for bioretention systems are expected to reduce as education of maintenance procedures increases.

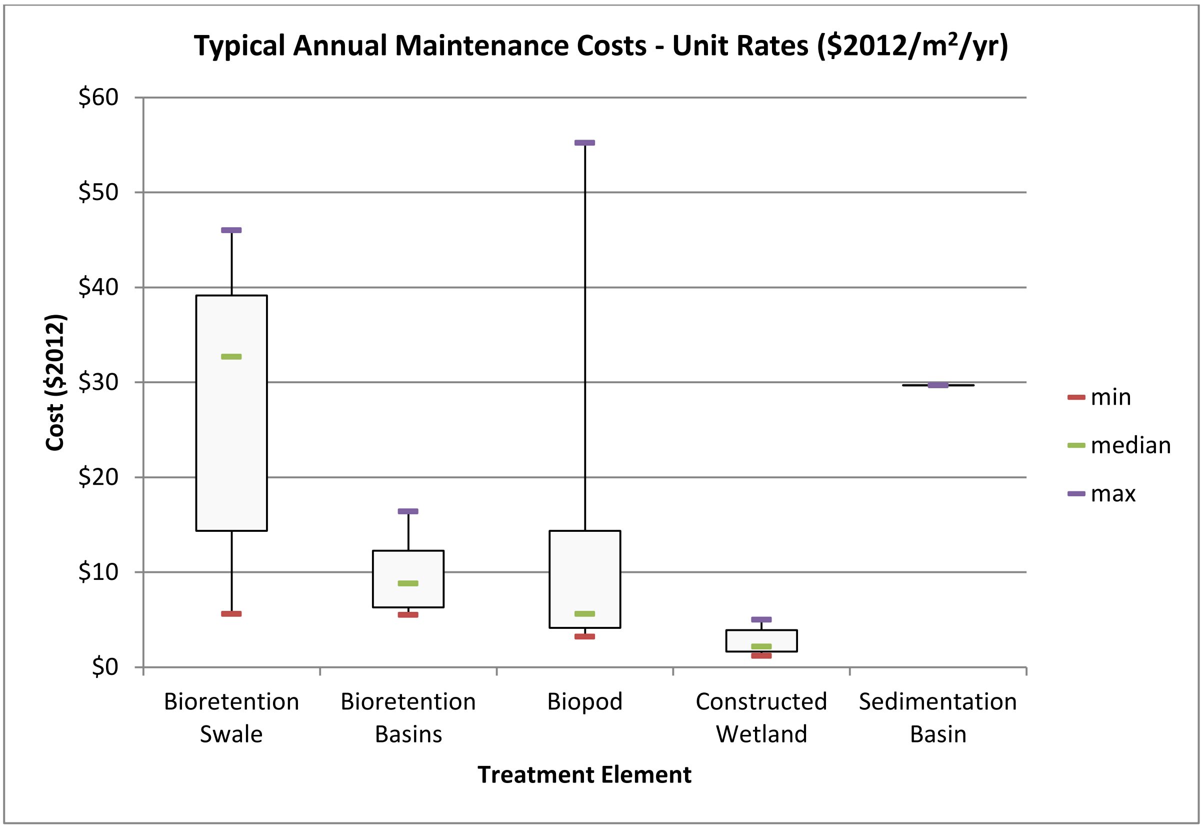


Fig. 4-5: Typical annual maintenance cost unit rates (Sedimentation basin costs not included).

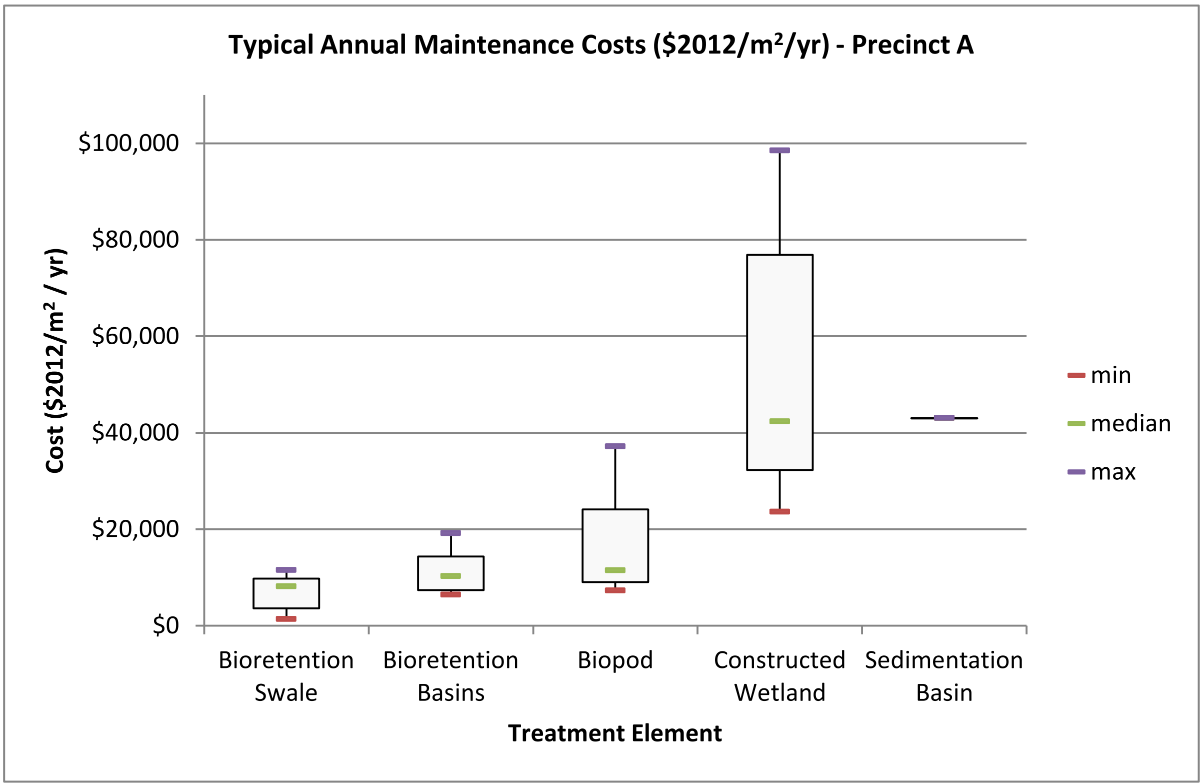


Fig. 4-6: Typical annual maintenance costs for Precinct A.

Constructed wetlands are expected to cost $2.70/m^2/yr. to maintain. This is higher than the median value of $2.15/m^2/yr. As wetland sizes increase, maintenance costs decrease and the majority of maintenance costs reported were for constructed wetlands had a surface area less than 2 hectares. The adopted rate is approximately 2 % of the estimated TAC for constructed wetlands. Sedimentation basins are estimated to cost $11.20/m^2 each year to maintain. This figure reflects moderate confidence. A 45 L pot street tree is estimated to cost $25 each per year to maintain, for urban residential development in the Mackay region.

The TAM rate selected for the constructed wetland can have a significant impact on the total maintenance costs, as shown in Fig. 4-6. With the adopted TAM rate of $2.70/m^2/yr. the estimated total maintenance cost for the proposed wetland is $58,600, which lies between the median and upper quartile of expected costs. The total annual maintenance costs estimated for the local stormwater treatment strategy BMPs are; $10,000/yr. for bioretention swales, $28,300/yr. for bioretention basins and $14,600/yr. for biopods, as shown in Table 4-9 below.

For Precinct A, there is little difference between the total estimated TAM costs for local and regional treatment strategies. The total TAM costs for the local treatment strategy is $73,600 annually whereas the TAM costs for the regional treatment strategy is marginally higher at $74,800, see Table 4-9.

Table 4-9: Typical annual maintenance costs per treatment strategy for Precinct A.

Treatment Element	TAM Unit Rate ($/m^2/yr)	BMP Treatment Area (m^2)	TAM ($/yr)
Local Stormwater Treatment Approach			
Bioretention Swale	40.00	250	10,000
Bioretention Basin	12.50	1170	14,600
Biopod	12.50	3911	49,000
Total			73,600
Regional Stormwater Treatment Approach			
Constructed Wetland	2.70	21,700	58,600
Sedimentation Basin	11.20	1450	16,200
Total			74,800
Business As Usual (BAU)			
Street / Verge Trees	$25 each	349 (no. of)	8725

Life Cycle Costs

Life cycle costs were determined using the TAC and TAM costs estimated in Tables 4-7 & 4-9 above. The LCC estimated for the local treatment strategy applied to Precinct A is $2,816,000. For individual treatment elements; bioretention swales are estimated to cost $251,000, $572,000 for bioretention basins, $1,993,000 for biopods. The LCC cost for the regional treatment strategy in Precinct A is $4,327,000 for a constructed wetland and two sedimentation basins, refer Table 4-10. The LCC for the sedimentation basin is only inclusive of maintenance costs, where the TAC's are included in the constructed wetland figure. A real discount rate of 5.5 %, an annual inflation rate of 2 %, and a base year for costing (2012) was used for LCC analysis over a span of 30 years.

Table 4-10: BMP life cycle costs from adopted TAC & TAM costs.

Treatment Element	LCC Cost Over 30 years ($)
Local Stormwater Treatment Approach	
Bioretention Swales	$251,000
Bioretention Basins	$572,000
Biopods	$1,993,000
Total	$2,816,000
Regional Stormwater Treatment Approach	
Constructed Wetland	$4,095,000
Sedimentation Basin	$232,000
Total	$4,327,000

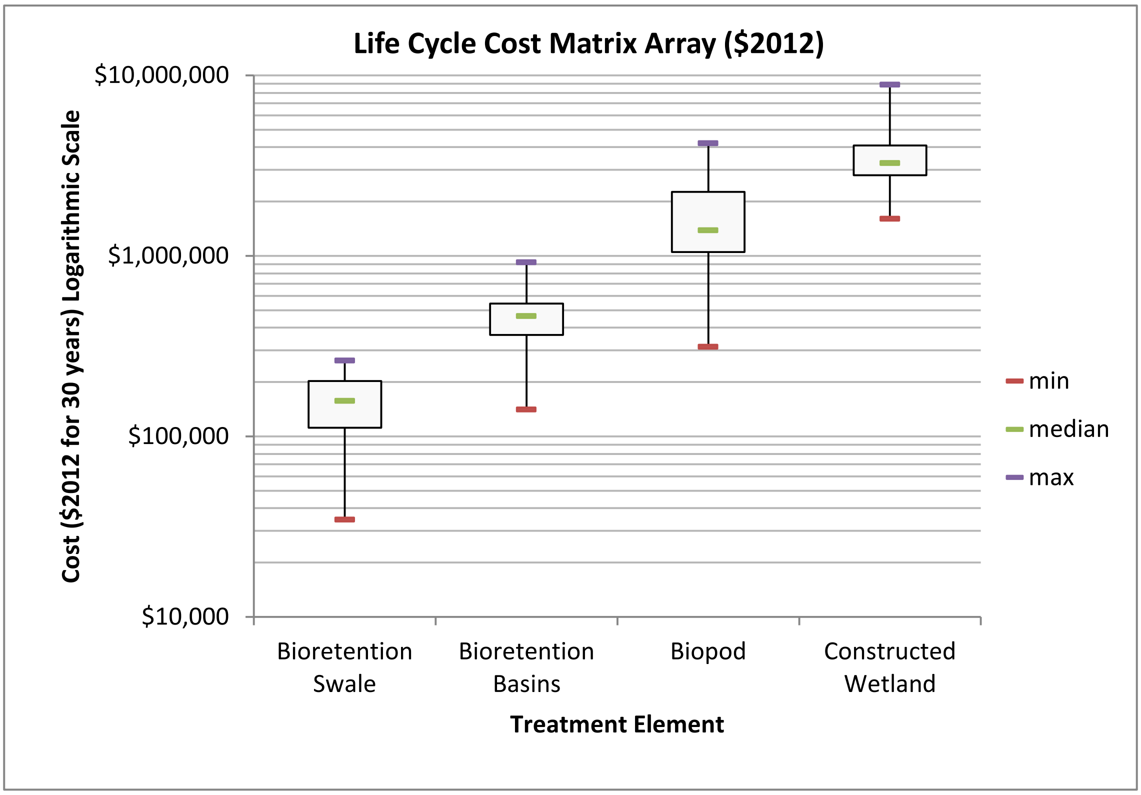


Fig. 4-7: Life Cycle Cost Matrix Array.

When compared to the LCC matrix array, all adopted treatment elements trend higher than the median values and in some cases higher than the upper quartile ranges. This trend is consistent across all treatment elements, see Fig. 4-7.

4.5 Triple Bottom Line Assessment

4.5.1 Defined Objectives

Nineteen WSUD objectives for the urban residential development of Precinct A were defined by the Delphi Panel, these are:

Financial Objectives

- Minimise life-cycle costs, including Council maintenance costs over a 30 year period.
- Ensure WSUD objectives and requirements are not ‘gold plated’ or overbearing.
- Capital costs and lands costs to be kept to manageable levels.
- Minimise loss of yield to the development.
- Accurate estimation of initial true costs borne by the developer to allow for maintenance and rectification costs.
- Indirect return through tourism and city liveability.
- Improve property values.

Social Objectives

- Meet local community’s expectations in terms of aesthetics and safety.
- Acceptance and integration of stormwater treatment devices by the public as an important part of the open space systems.
- Recognition by the community of the purposes and benefits of stormwater treatment devices so that they are not seen as detrimental to the estate / community.
- Long term recreational benefits in terms of healthy waterways.
- The inter-generational equity associated with the project. That is, ensuring the benefits and costs of the project to the community are equally shared regardless of developer, social standing of the neighbourhood, Council position on stormwater quality or social demographic of intended residents. E.g. rates or property values should not increase beyond affordability of residents of all social demographics.
- Should have an educational function to highlight the impacts of littering, excessive use of fertiliser on gardens and lawns and other practices harmful to the environment.

Ecological Objectives

- Meet MRC stormwater quality objectives to reduce impact on all receiving water bodies including creeks and rivers within the Mackay region, and the Great Barrier Reef.
- Comply with State Planning Policy which stipulates the need for WSUD assets and erosion and sediment control.
- True integration of devices into adjoining natural areas and where possible not isolated. Sustainable treatment for long term benefits, i.e. installation of stormwater quality treatment that is closer to the natural environment in the catchment, e.g. wetlands in Plantation Palms, Blacks Beach Mackay, should be sustainable as there are already wetlands in the area. This reduces the requirement for rebuilds.
- Minimise impact on receiving waterways from adjacent development both during construction and life cycle of development and understand and accept that short term impacts may occur during the construction phase.
- Provide urban habitat for certain types of small birds, lizards, and other animals and plants.
- Minimise introduction of weed species into catchment.

Following a review of the broad objectives and principles of ESD as outlined in Australia's National Strategy for ESD, one further objective was added to meet ESDs core objective, bringing the total objectives of the project to twenty;

- Ensure the design's costs and benefits are shared fairly between all members of the existing community as well as between the existing community and future ones.

4.5.2 Defined Values & Concerns

After consultation with the Delphi Panel, a range of values and concerns to be addressed for the WSUD development at Precinct A were identified, these include:

Financial Values & Concerns

- Best bang for the buck.
- Determination of realistic costs based on whole of life expectations and not just engineering construction.
- Concerns over cost impacts upon a development e.g. time related costs, loss of yield, land costs, design costs, build costs, 'on maintenance' costs.

- Maintenance costs – can local authorities afford to maintain either a regionalised device or at source devices. Additional development costs, - additional construction costs, unavailability of materials and expertise in the area.

- Upfront agreement and acknowledgement of ongoing indefinite maintenance costs with whichever organisation will take responsibility of structure after construction.

- Capital cost, particularly if a regional solution is proposed. I.e. who provides the land, who develops it and who funds it?

- The effectiveness and suitability of stormwater structure options are taken into consideration when assessing the costs (planning, construction, maintenance etc.).

Social Values & Concerns

- Safety issues need to be considered in the detailed design of at source devices and devices constructed in the streetscape. Regionalised devices such as wetlands have inherent safety issues which need to be considered and assessed.

- Residents treat their nature strip as theirs and some will not respect at source devices in the streetscape.

- Residents understanding of stormwater quality, and the benefits, and the community involvement in maintenance (as seen in southern communities with waterway adoption programs).

- Integration into the open space systems. True coordination with engineers and councils to ensure treatment devices are of benefit.

- Concerns over the effectiveness of some stormwater treatment measures to protect local ecological values. People need education as to what the WSUD devices are actually there to do. A lot of people do not know the purpose of the system and that it is there to treat stormwater before it gets to a waterway.

- Detrimental impacts upon liveability for the end user caused by unmaintained WSUD devices (aesthetics).

- Detrimental impacts upon affordability for the end user caused by development costs.

Ecological Values & Concerns

- Good design is paramount. The correct type of treatment device, its location, the right planting etc. are all critical to achieving a device that will work and not be a negative impact.

- Concerns over the ongoing effectiveness of some stormwater treatment measures to protect local ecological values because the devices cannot be cost effectively maintained by Council.

- Concerns over WSUD requirements that provide insignificant long term gain to the regional environment.

- Selection of species within and adjoining the devices that helps to integrate with natural areas and assist in enhancing the local flora and fauna.

- Use of more natural stormwater structures to assist in treatment of stormwater – to minimise impact on health of water quality and environment.

- Consider potential impacts to the whole catchment, due to changes in water infiltration/runoff/capacity of existing and new drainage.

These values and issues were summarized and synthesized into core values for each TBL element, which are:

- **Core Financial Value** – To minimize cost impacts associated with stormwater treatment assets upon a development, borne by Council, the developer, and ultimately the home buyer.
- **Core Social Value** – overall community acceptance of the WSUD design.
- **Core Ecological Value -** to reduce impact on receiving waterways and integration of treatment elements into adjoining natural areas.

The core values and associated values and concerns are represented below as a ‘value tree’ (see Fig. 4-8 to 4-10). The identified values for each TBL element deemed most important by the Stakeholder group are; life cycle costs (financial value), the impact on the areas aesthetics values (social value), and to meet MRC WQOs to reduce impact on all receiving waterways (ecological values). These values are displayed at the ‘top’ of the ‘Value trees’ for each TBL element. Numerical preferences as ranked by the Stakeholder group are shown in Table 4-11.

The identified core values compiled by the Delphi Panel reflect the values that need to be protected and possible assessment criteria were aligned to these values.

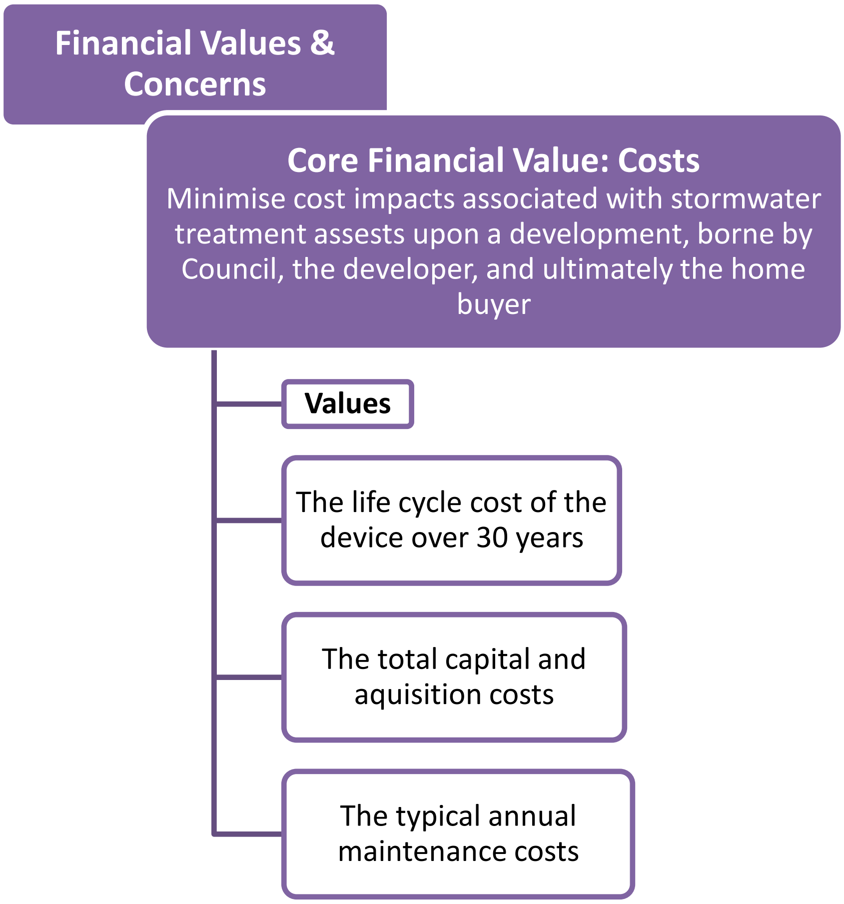


Fig. 4-8: Financial 'Value tree'.

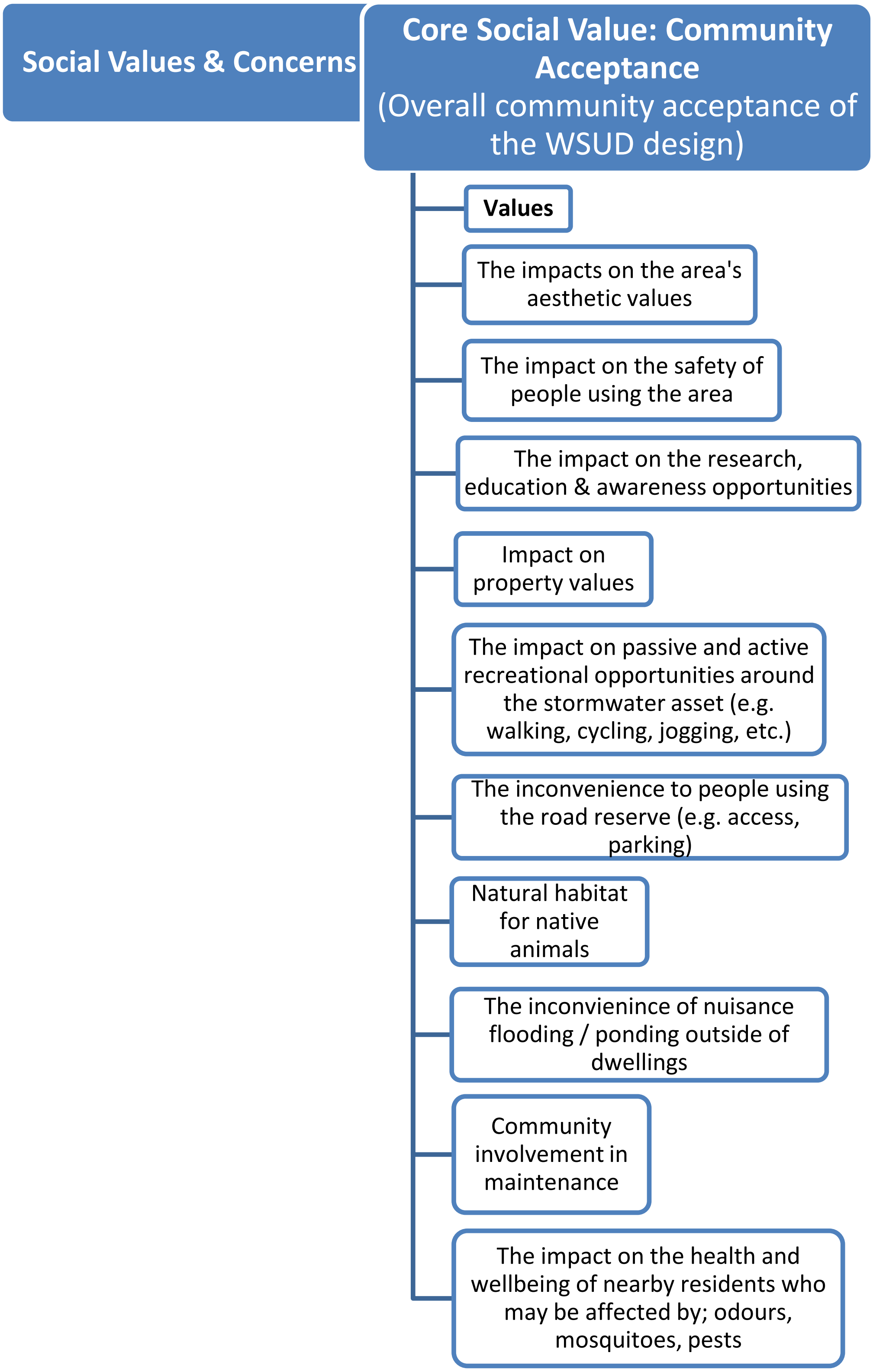


Fig. 4-9: Social 'Value tree'.

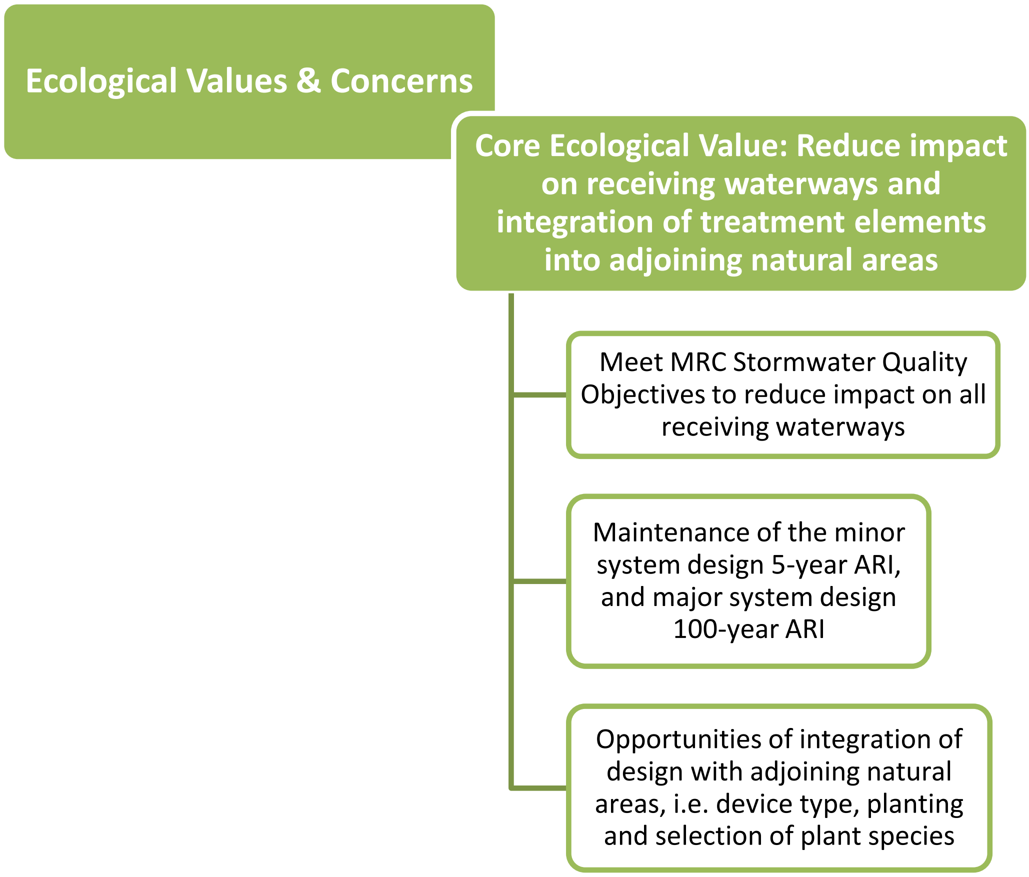


Fig. 4-10: Ecological ‘Value tree’.

Table 4-11: Stakeholder Group preferences of TBL values.

Rank	Triple Bottom Line Values	Stakeholder Group				
	***Financial* Values**	**Rank Assigned**				**Average**
1	The life cycle cost of the device over 30 years	1	3	1	1	1.5
2	The typical annual maintenance costs	2	2	2	2	2
3	The total capital and acquisition costs	3	1	3	3	2.5
	***Social* Values**	**Rank Assigned**				**Average**
1	The impact on the safety of people using the area	3	2	1	2	2
2	The impacts on the area's aesthetic values	7	4	3	1	3.75
3	The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	1	3	2	6	3
4	Impact on property values	10	1	4	3	4.5
5	The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	4	8	7	4	5.75
6	Community involvement in maintenance	6	5	8	5	6
7	The inconvenience of nuisance flooding / ponding outside of dwellings	8	6	6	7	6.75
8	The inconvenience to people using the road reserve (e.g. access, parking)	9	7	5	8	7.25
9	Natural habitat for native animals	2	9	9	10	7.5
10	The impact on the research, education & awareness opportunities	5	10	10	9	8.5
	***Ecological* Values**	**Rank Assigned**				**Average**
1	Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	1	3	1	2	1.75
2	Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	2	1	2	3	2
3	Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	2	3	1	2.25

4.5.3 Identified Assessment Criteria and Indicators

Sixteen assessment criteria and performance indicators were developed to assess the defined core objectives and values. Financial indicators are total acquisition costs, typical annual maintenance costs ($2012 AUD/m^2) and life cycle costs ($2012 AUD over 30 years) of each stormwater treatment element for each stormwater treatment strategy. Social indicators are determined using a qualitative 1 to 5 rating using a scoring key. Scoring will be done by the assessment manager after reviewing social data collected from; a door-to-door survey of people who live near treatment elements, a general online survey showing illustrations of treatment elements, and consultation with MRC.

Ecological indicators were determined using pollutant reductions achieved from MUSIC analysis. A 1 to 5 rated scoring key was used to determine the integration opportunity of treatment elements.

Financial Indicators

Best Management Practice costs are determined in Section 4.4.

Social Indicators

Social performance indicators are summarized from survey data results in Section 4.6.4.

Ecological Indicators

Outputs from MUSIC modelling were used to assess the treatment performance and ability of BMPs to reduce the impact on receiving waterways, see Section 4.3.

4.5.4 Social Performance Indicators

The results of the BMP social surveys and the interpretation of performance scores are discussed below.

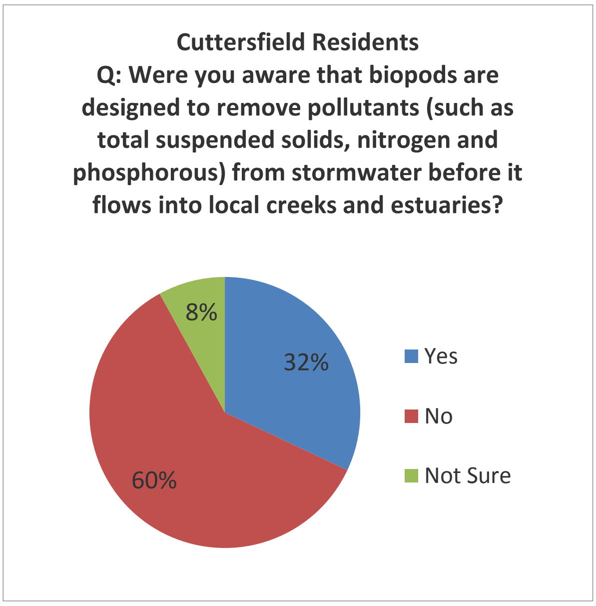
Cuttersfield Survey Plan

Fig. 4-11: A geographic representation of surveyed Cuttersfield residents and their proximity to existing treatment elements.

A sample of 25 Cuttersfield residents were surveyed on the social effect that biopods and bioretention swales had on the neighbourhood. Fig. 4-11 shows a geographical representation of the surveyed residents and their proximity to the BMPs.

Cuttersfield Biopod Survey (*n* = 25)

Online sample, *n* = 8.



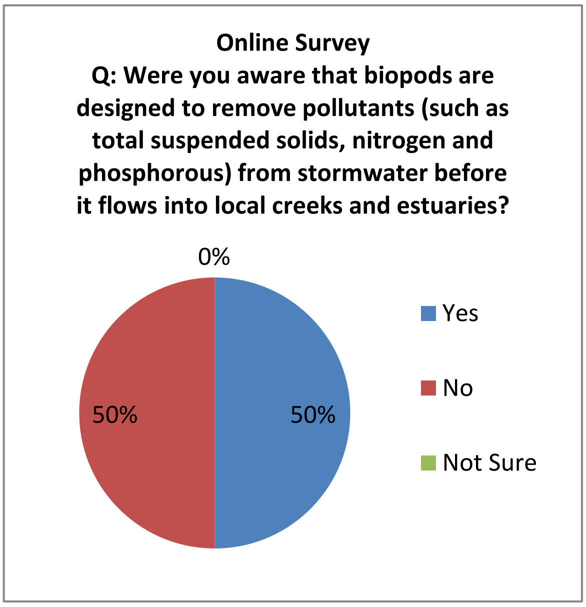
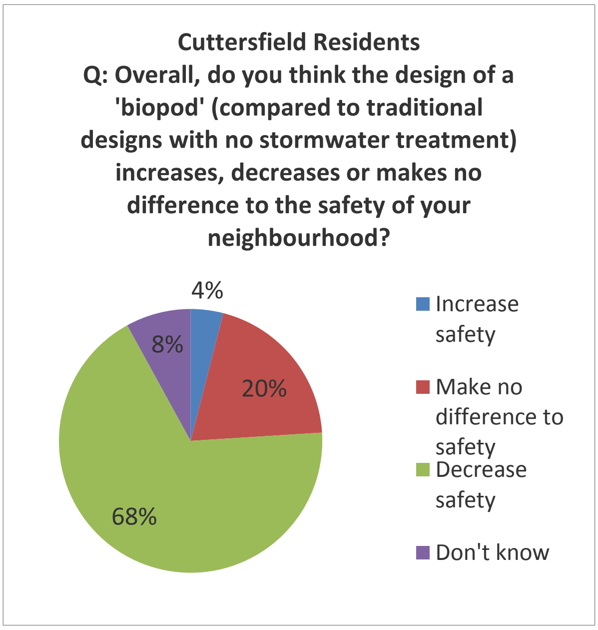


Fig. 4-12: Cuttersfield and online survey results showing resident awareness of biopod function.



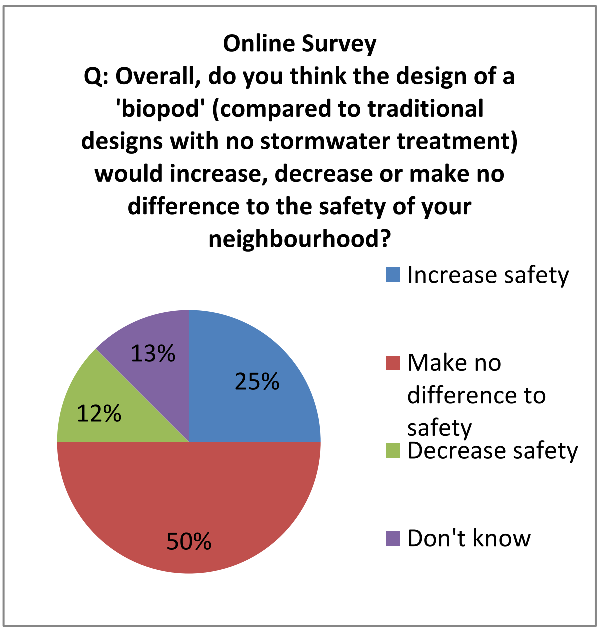
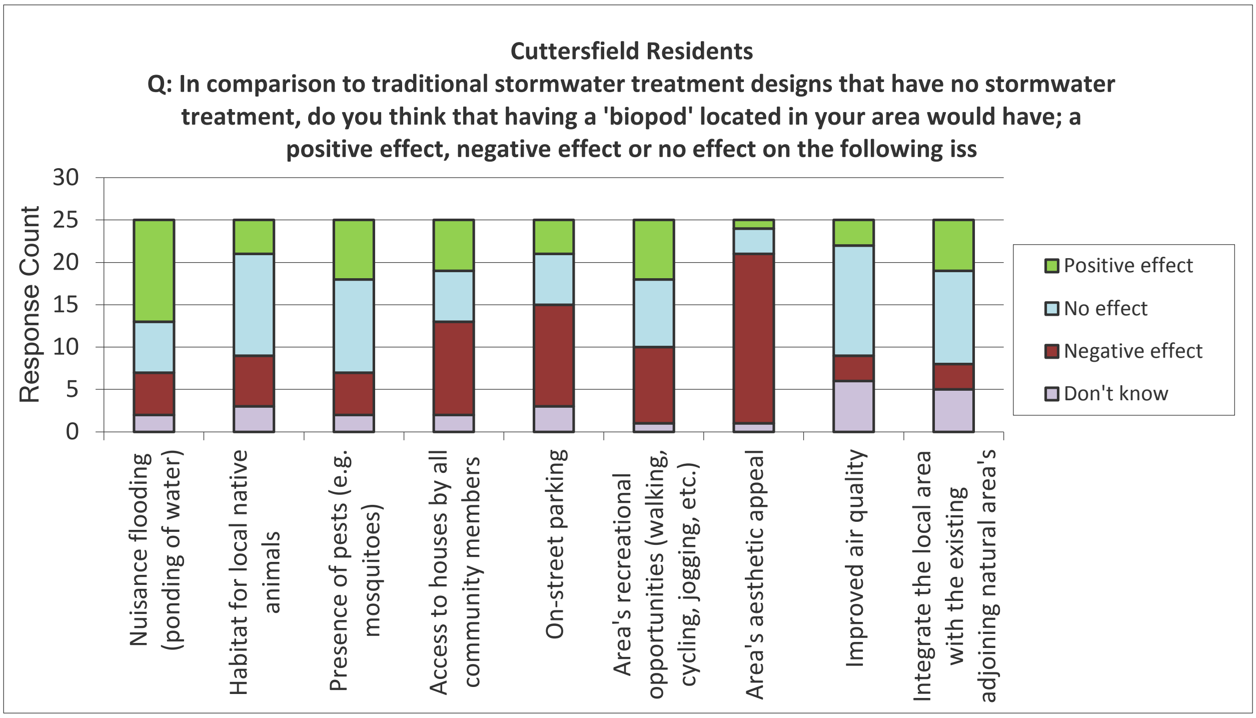


Fig. 4-13: Cuttersfield and online survey results showing the effect biopods have on safety.

The majority of Cuttersfield residents were not aware that biopods were primarily used to treat stormwater runoff, even more so than the general population, see Fig. 4-12.



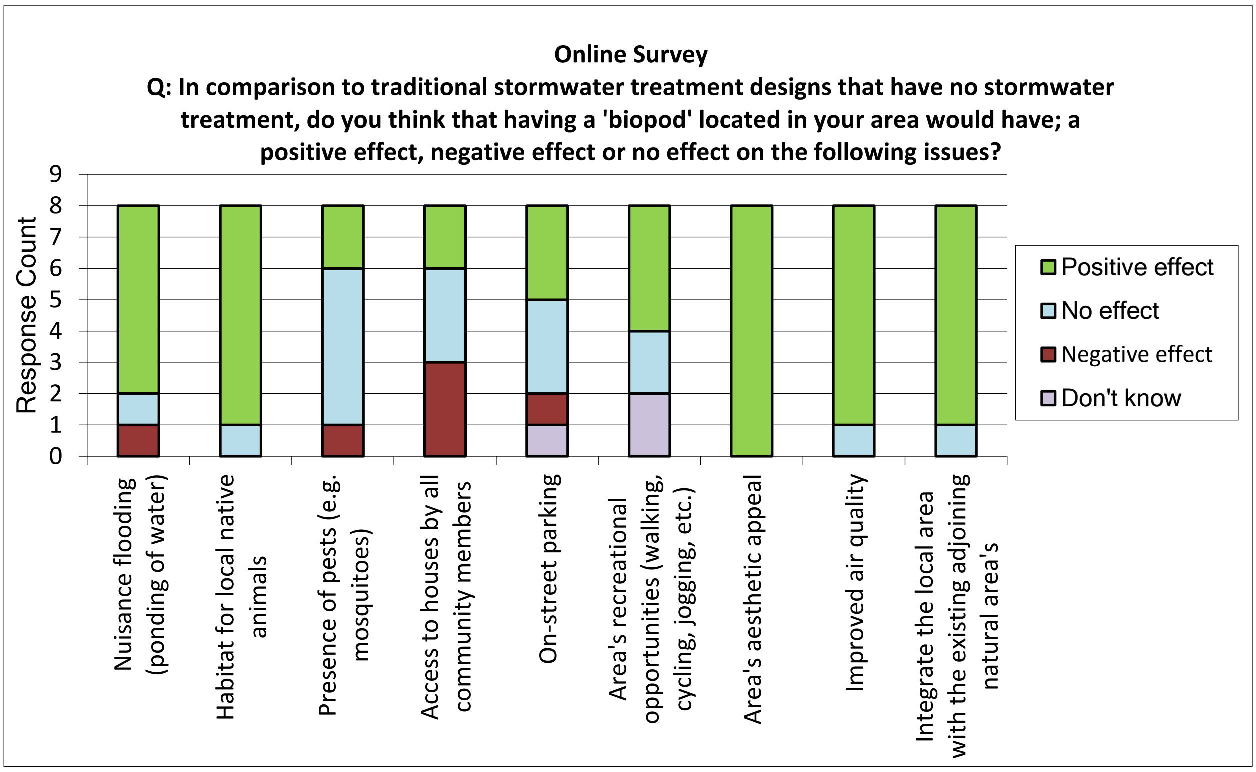
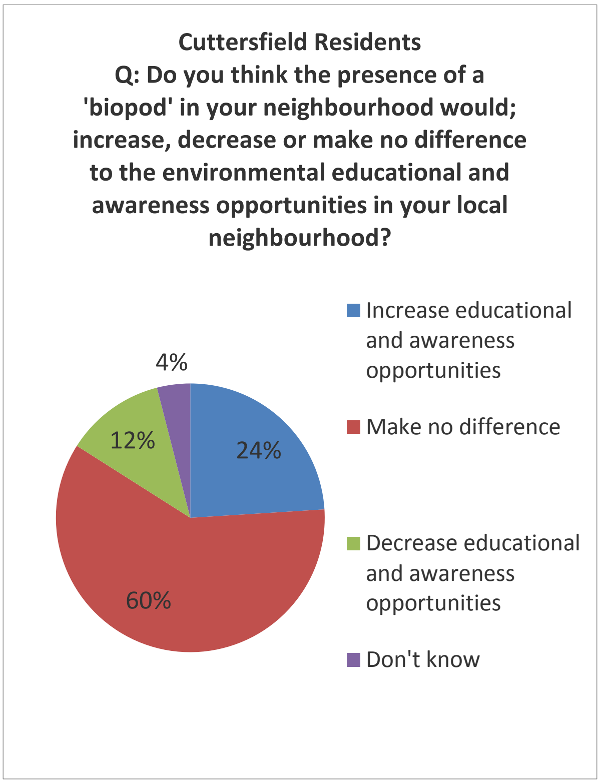


Fig. 4-14: Cuttersfield and online survey showing the various effects biopods have on their respective neighbourhood.



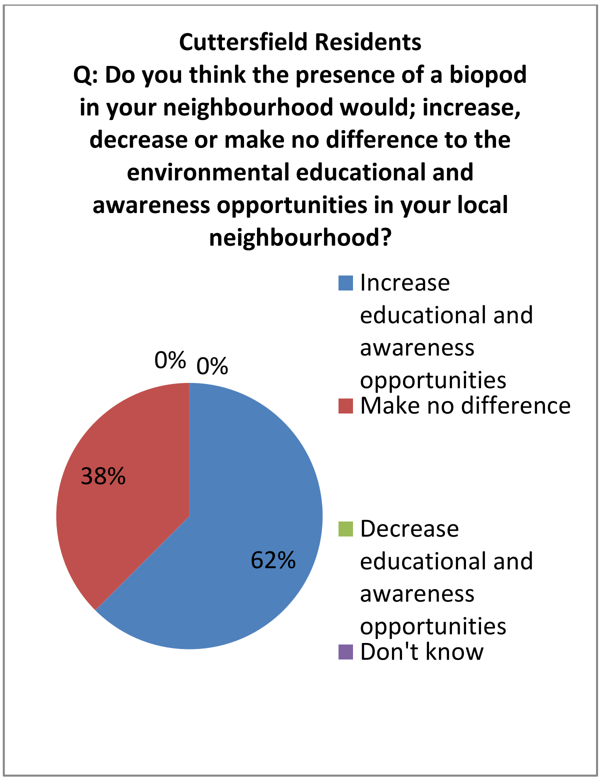
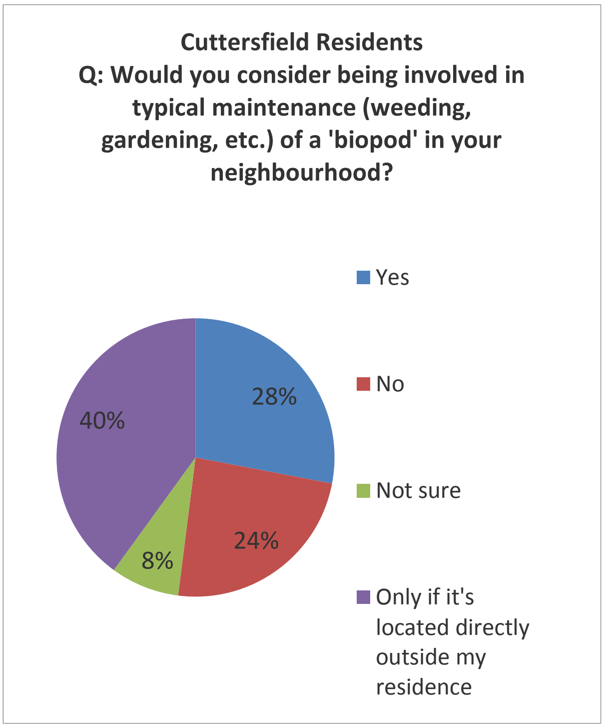


Fig. 4-15: Cuttersfield and online survey results showing the effect biopods have on education and awareness opportunities.



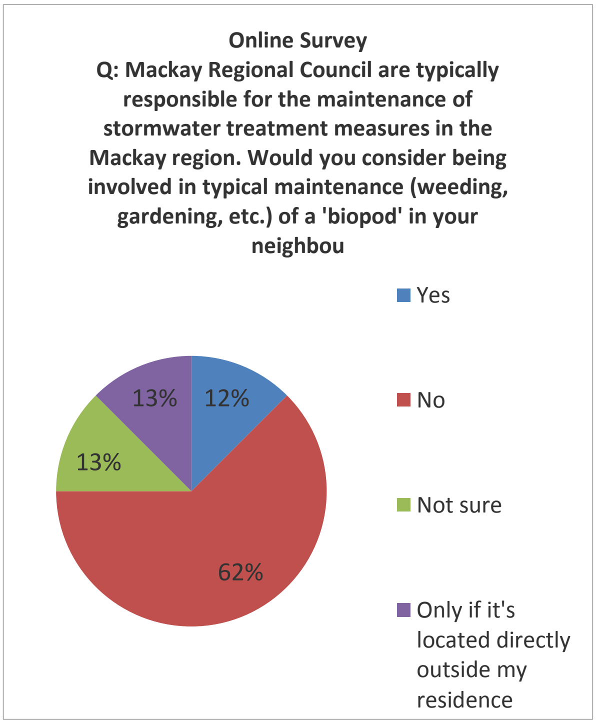


Fig. 4-16: Cuttersfield and online survey results showing the willingness of residents to participate in community based maintenance of biopods.

After visual inspection, the biopods in Cuttersfield were poorly maintained (if maintained at all) and were an eye-sore within the estate, see Fig.4-17. This visual appearance is strongly reflected in Cuttersfield resident's responses, with biopods having a very negative effect on the areas aesthetics appeal (Fig.4-14).

68 % of Cuttersfield respondents thought that biopods had a negative effect on the safety of the neighbourhood (Fig.4-13). It was reported that a child had allegedly broken their arm after riding their push bike into a biopod. This is no surprise as most biopods looked like empty sand pits. It is suggested that there is marginal increase in education and awareness opportunities from the provision of biopods (Fig.15). Biopods have a negative effect on on-street parking and access to houses by all community members, although biopods do provide a positive effect on nuisance flooding.

Interestingly, when the control group was presented with an example of a fully planted and maintained biopod (see Fig.4-18), the response was unanimous in suggesting that a positive effect was implicated on the areas aesthetic appeal. Two-thirds of Cuttersfield respondents showed a willingness to be involved in community maintenance, compared to only 25% of the control group. It could be suggested that the current poor state of Cuttersfield's biopods, has given extra motivation for residents to be involved in typical maintenance (Fig. 4-16).

Fig. 4-17: An example of an unmaintained biopod located in Cuttersfield that contains weeds and rubbish.

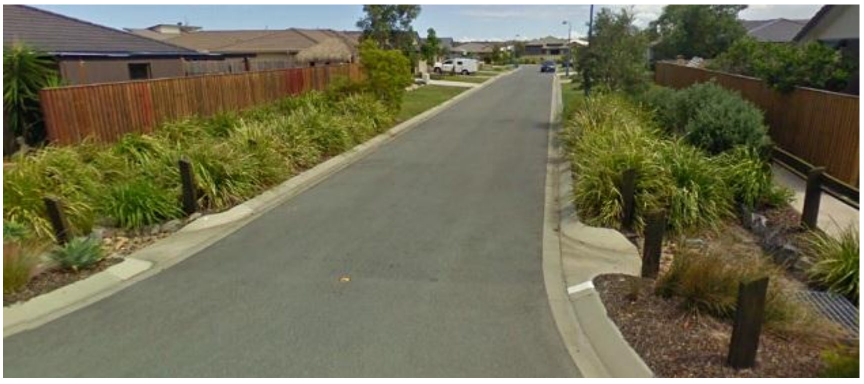


Fig. 4-18: An example of a fully planted and maintained biopod, Bellvista Estate, Caloundra, Google Maps (2012).

Cuttersfield Bioretention Swale Survey (*n* = 25)

Online sample, *n* = 15.

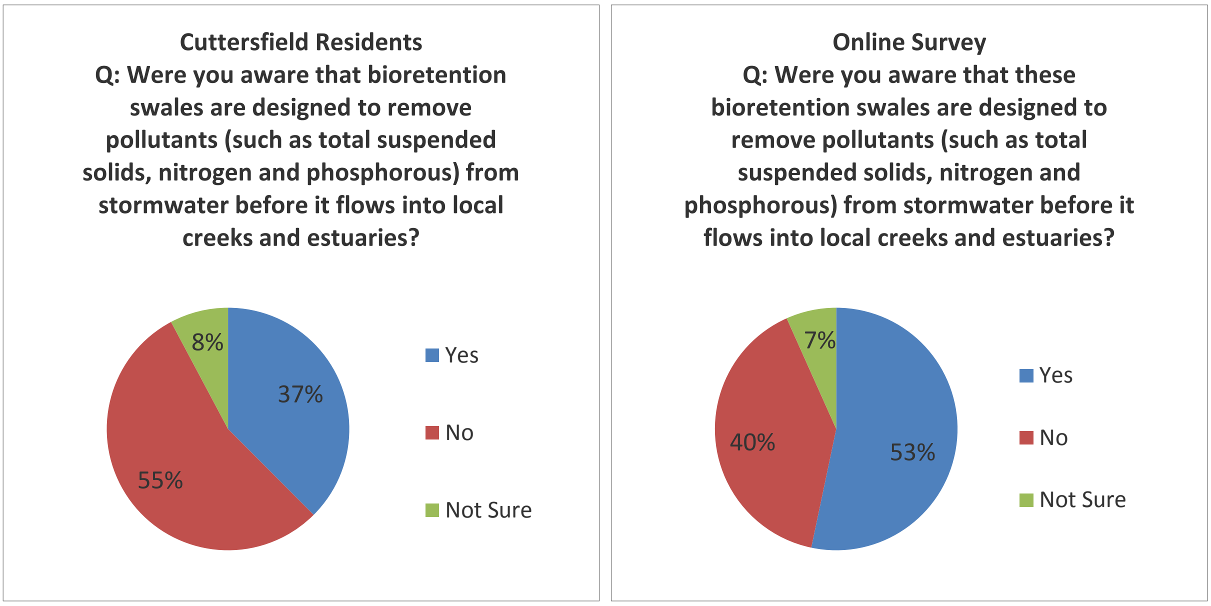


Fig. 4-19: Cuttersfield and online survey results showing resident awareness of bioretention swale function.

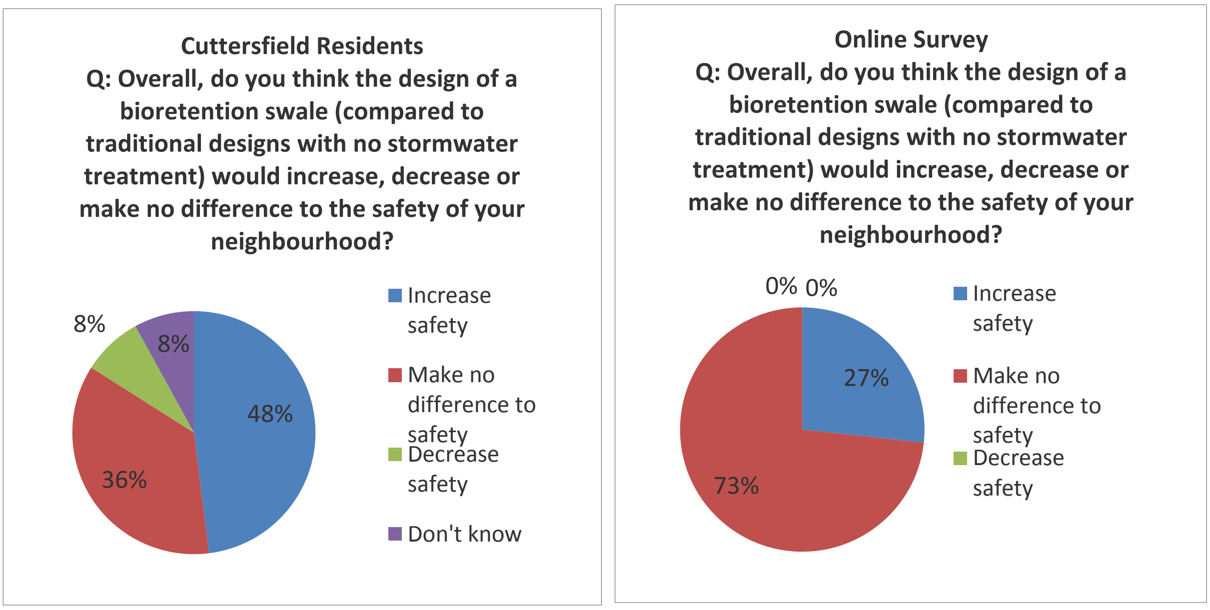
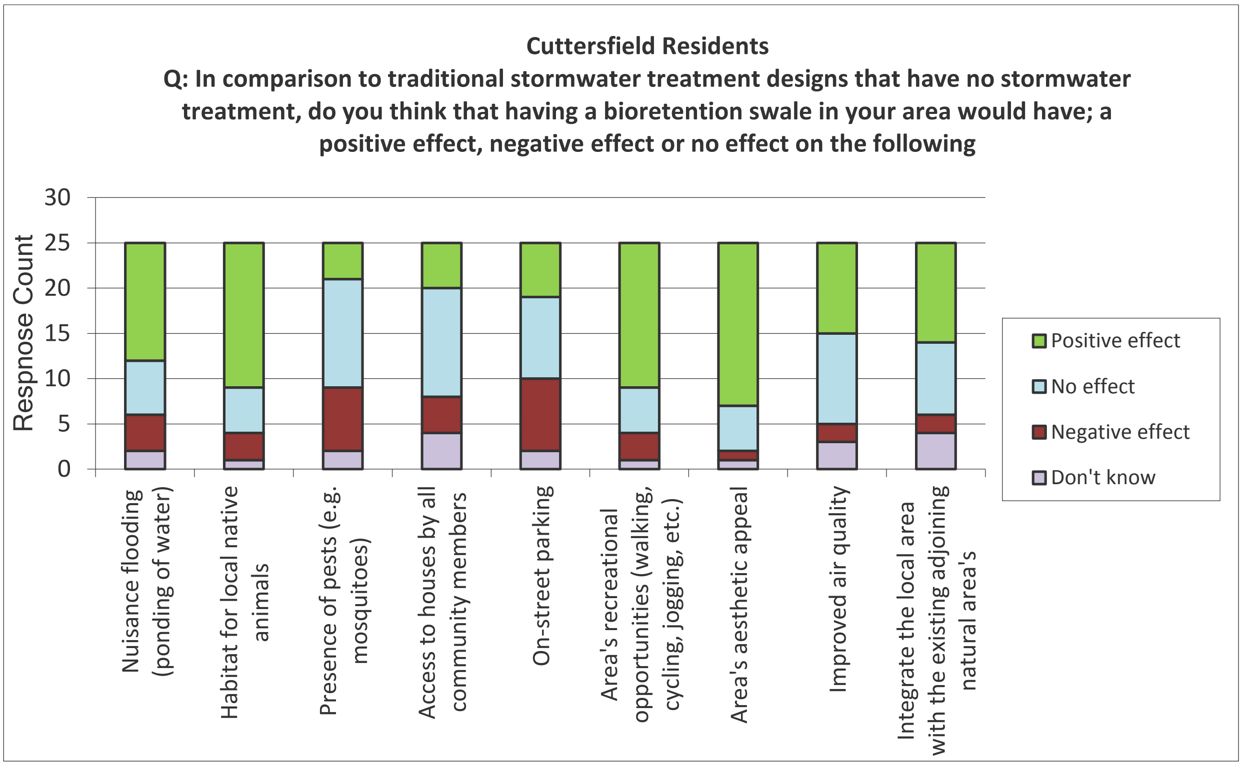


Fig. 4-20: Cuttersfield and online survey results showing the effect bioretention swales have on safety.



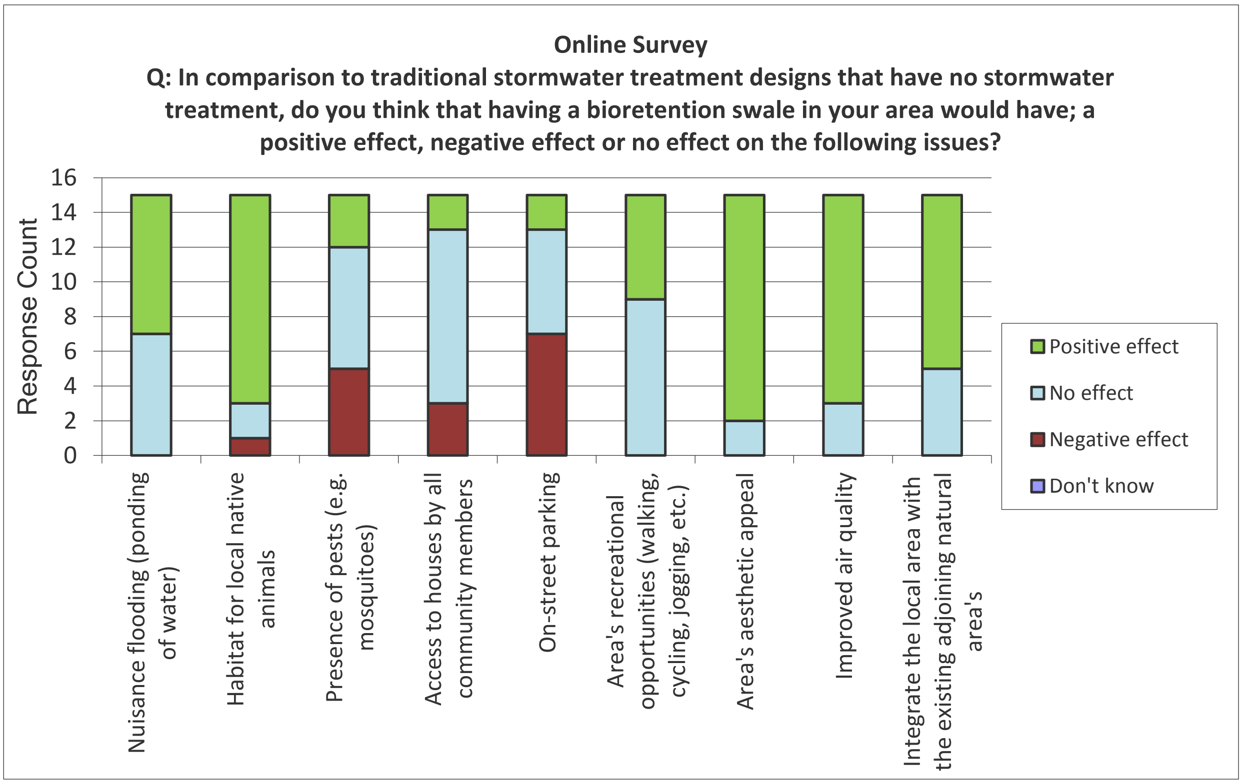


Fig. 4-21: Cuttersfield and online survey results showing the various effects bioretention swales have on their neighbourhood.

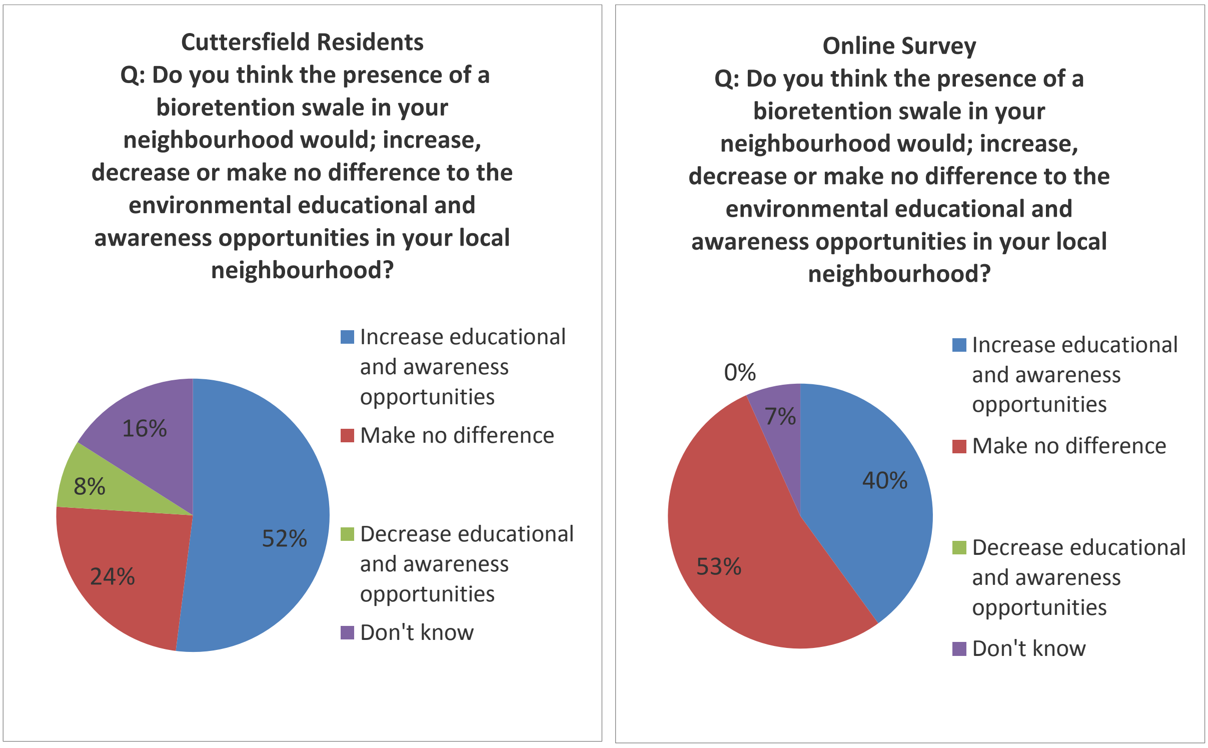


Fig. 4-22: Cuttersfield and online survey results showing the effect bioretention swales have on education and awareness opportunities.

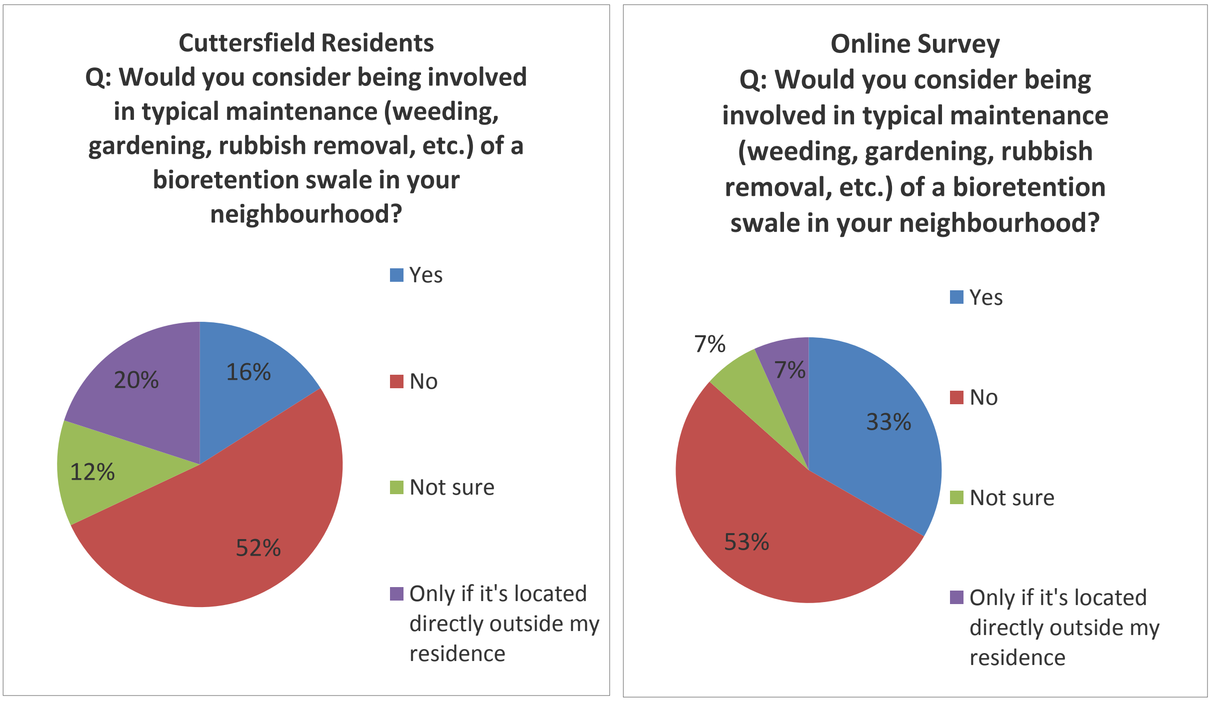


Fig. 4-23: Cuttersfield and online survey results showing the willingness of residents to participate in community based maintenance of bioretention swales.

The majority of Cuttersfield respondents were unaware that the boulevard bioretention swale was primarily used to treat stormwater runoff, even more so than the general population, see Fig. 4-19. Cuttersfield respondents thought that the bioretention swales increased safety in the neighbourhood, primarily to limiting vehicle speeds (Fig. 4-20).

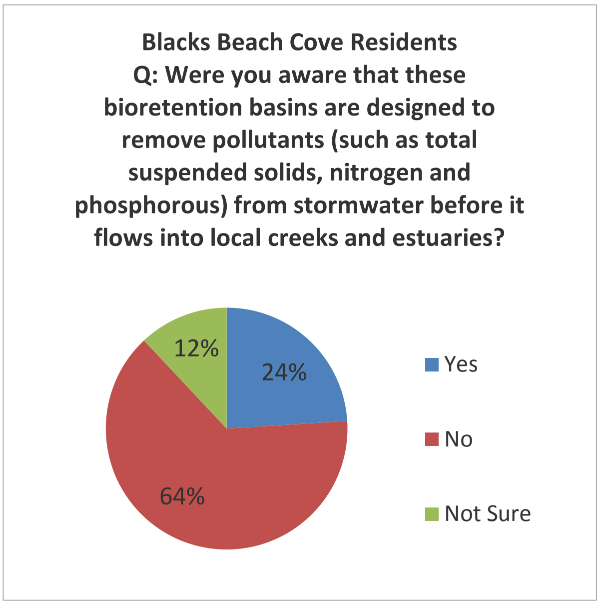
Overall, the bioretention swale was thought to have a positive effect on Cuttersfield. Positive effects were noted for; nuisance flooding, native animal habitat, recreational activities and aesthetic appeal, refer Fig. 4-21. Cuttersfield respondents were of the opinion that bioretention swales increased the educational and awareness opportunities, and minimal interest was shown by respondents in maintaining the swale (Fig. 4-22 & 4-23).

Blacks Beach Cove Survey Plan

Fig. 4-24: Geographic representation of surveyed residents in Blacks Beach Cove and their proximity to existing BMPs.

Blacks Beach Cove Bioretention Basin Survey (*n* = 25)

Online sample, *n* = 22.



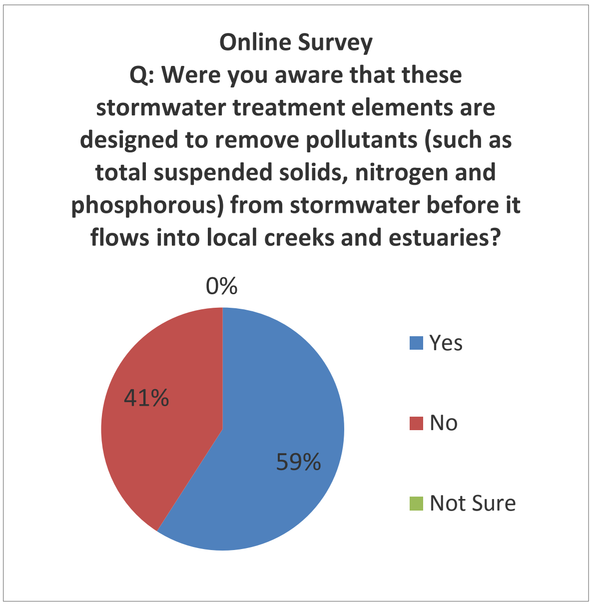
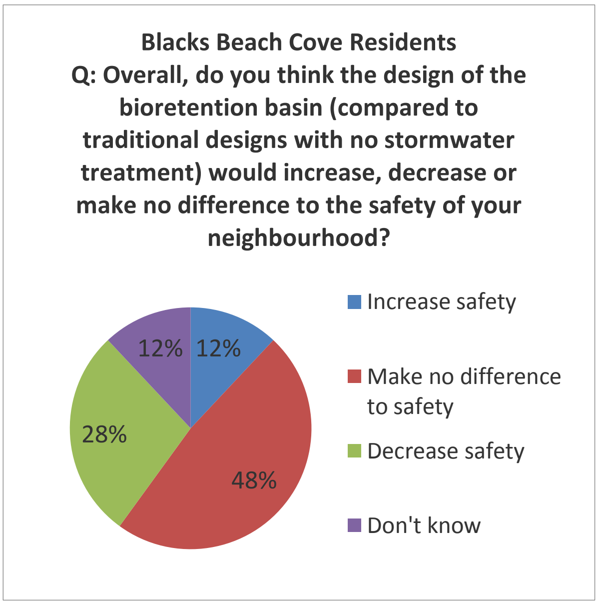


Fig. 4-25: Blacks Beach Cove and online survey results showing resident awareness of bioretention basin function.



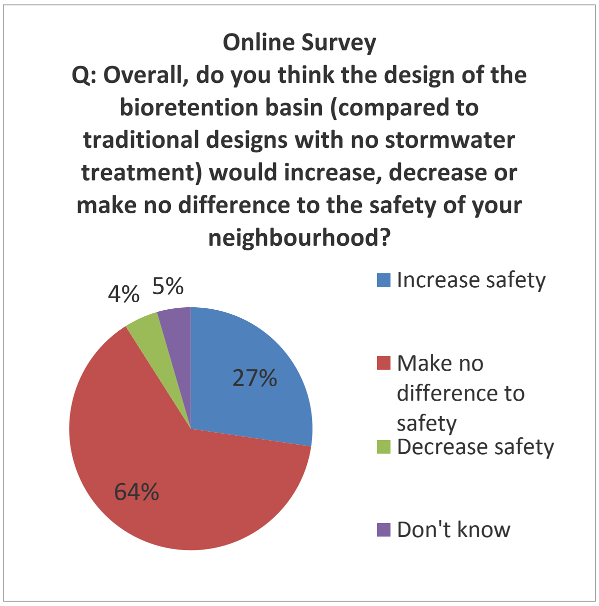
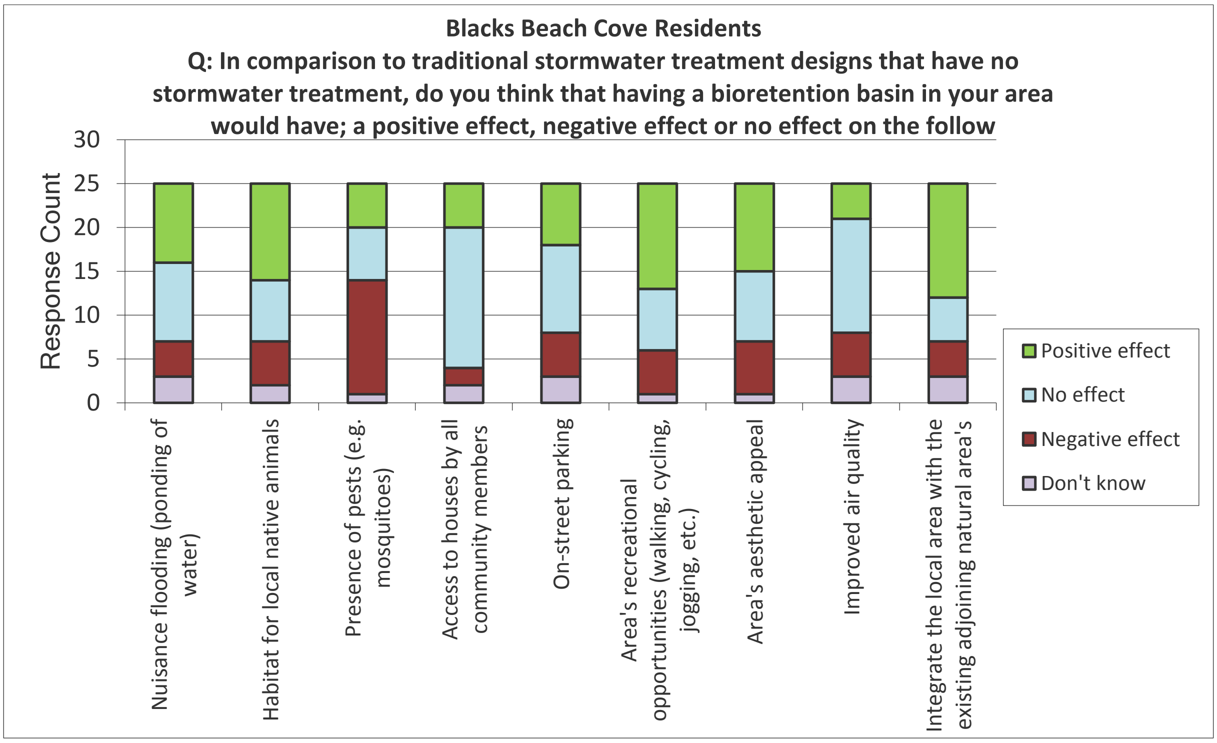


Fig. 4-26: Blacks Beach Cove and online survey results showing the effect bioretention basins have on safety.



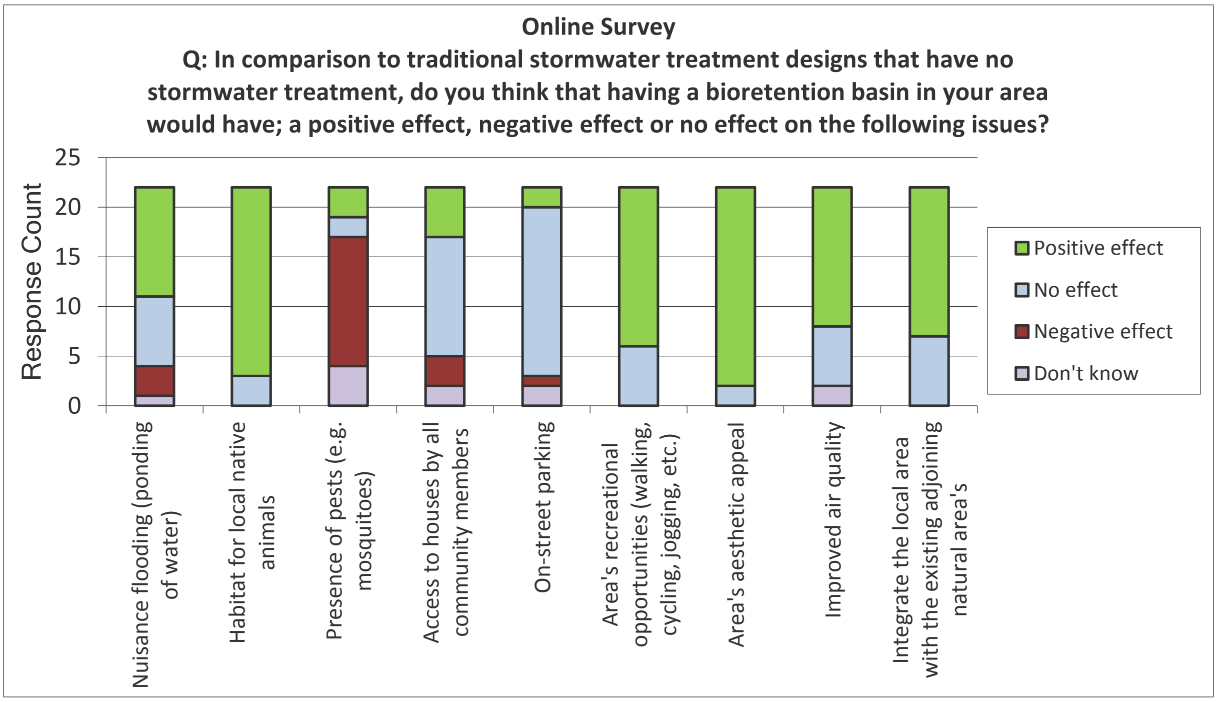
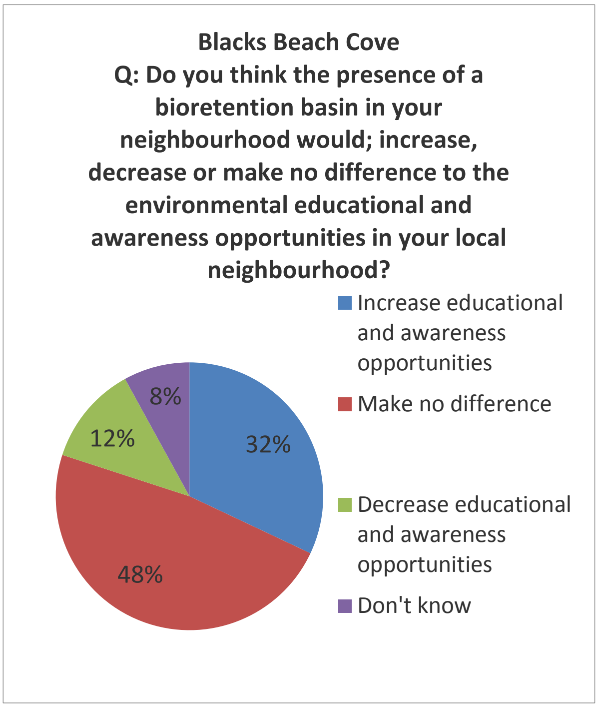


Fig. 4-27: Blacks Beach Cove and online survey results showing the various effects bioretention basins have on their neighbourhood.



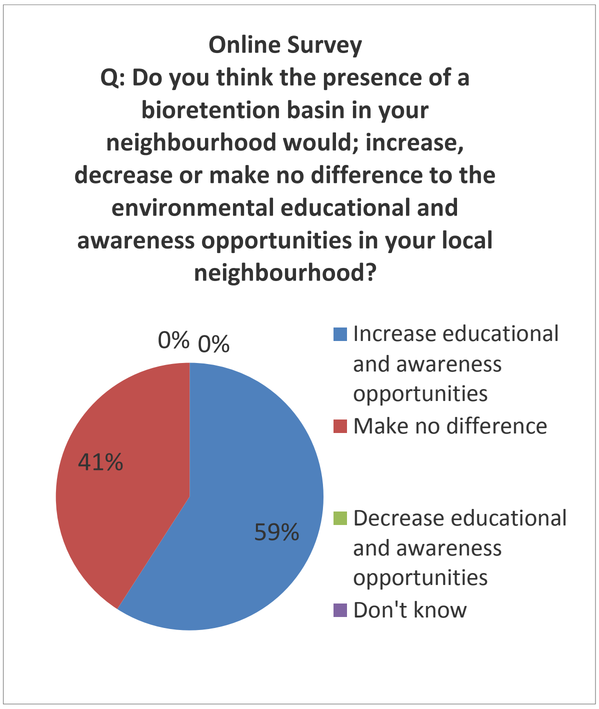
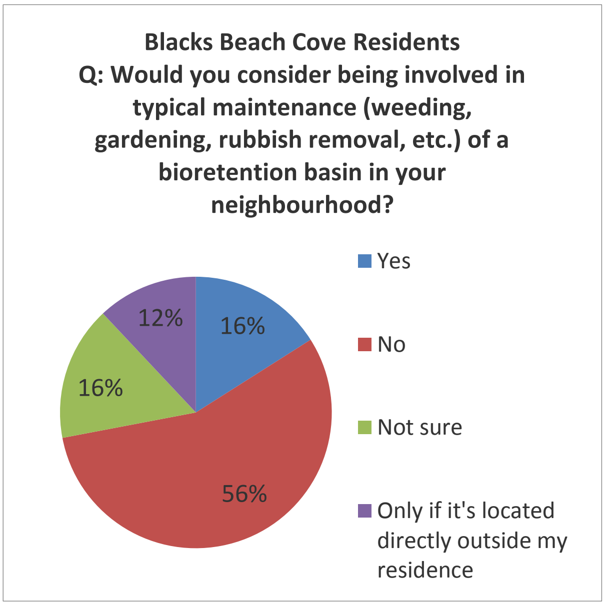


Fig. 4-28: Blacks Beach Cove and online survey results showing the effect bioretention basins have on education and awareness opportunities.



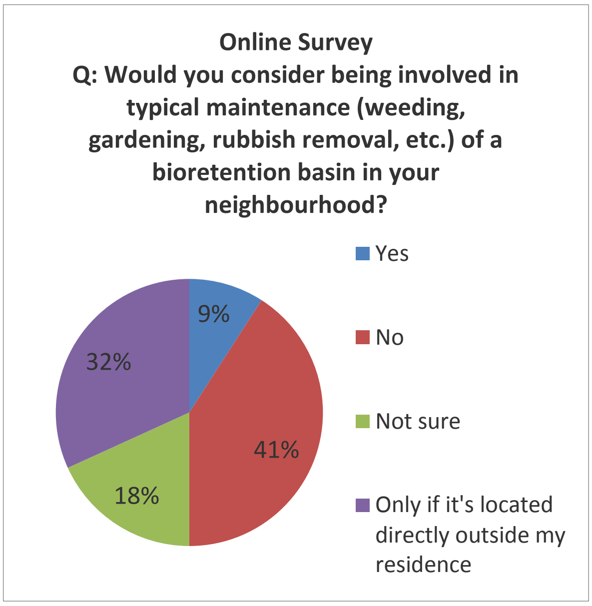


Fig. 4-29: Blacks Beach Cove and online survey results showing the willingness of residents to participate in community based maintenance of bioretention basins.

Blacks Beach Cove residents were unaware of the environmental function of the bioretention basin, refer Fig. 4-25. Most residents considered the basin as simply a landscaping feature. There was an only minimal concern for safety, possibly due to the remote location of the basin at the entrance to the estate, see Fig. 4-24 & 4-26.

Positive effects exhibited by the Blacks Beach Cove bioretention basin includes; a habitat for native animals, recreational opportunities, aesthetic appeal to the area, and integration of the development to adjoining natural area (coastal wetlands and marshes). Blacks Beach Cove respondents though the basin had a negative effect on the presence of pests, particularly mosquitoes, see Fig. 4-27.

It is thought that there is minimal opportunity for environmental and educational awareness and minimal interest in participation in community based maintenance of the basin was shown (Fig. 4-28 & 4-29).

Blacks Beach Cove Constructed Wetland Survey (*n* = 25)

Online sample, *n* = 23.

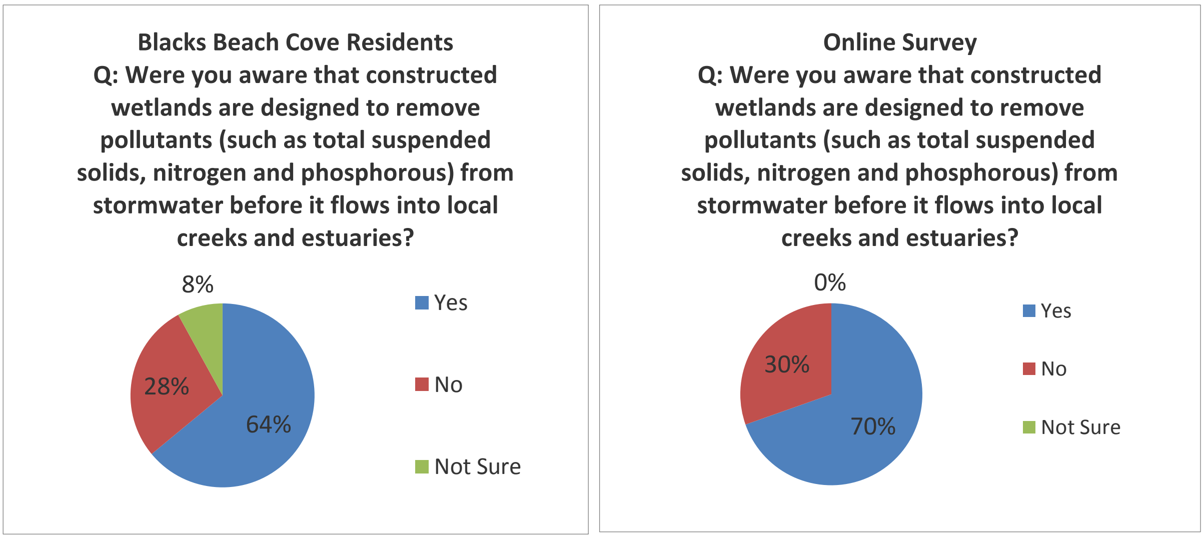
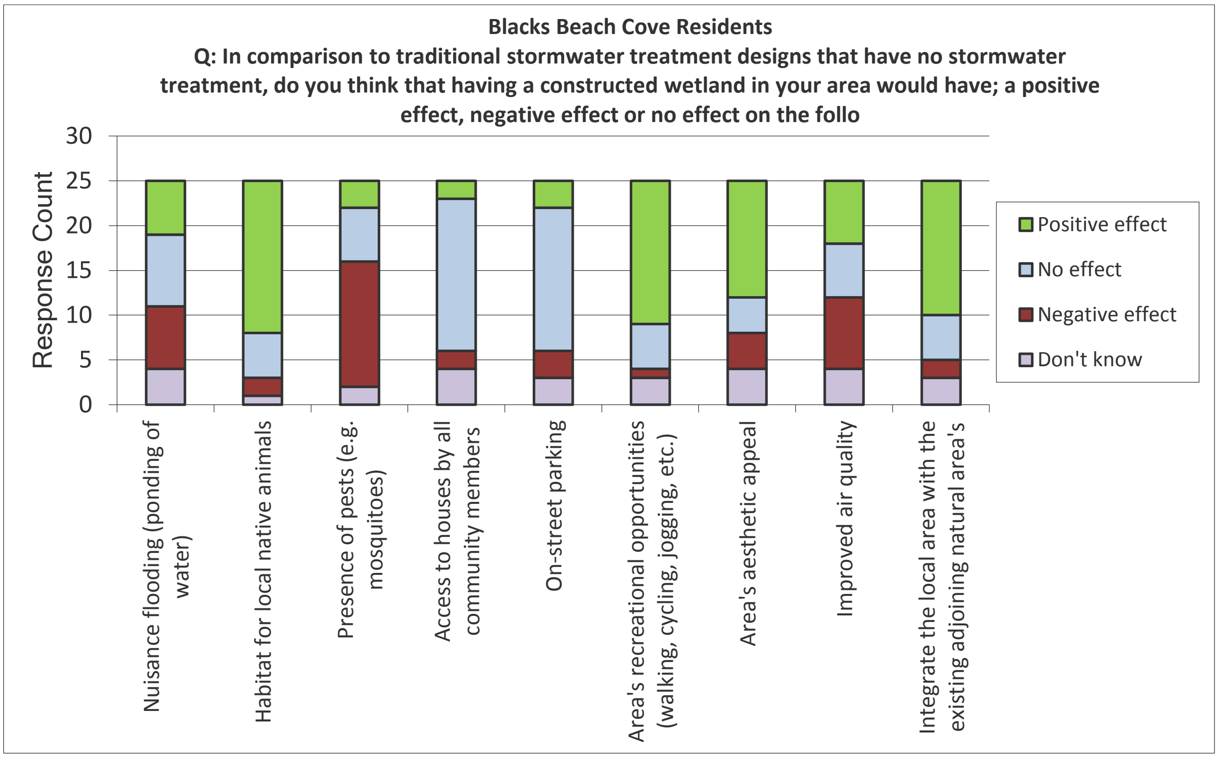


Fig. 4-30: Blacks Beach Cove and online survey results showing resident awareness of constructed wetland function.

The majority of Blacks Beach Cove residents were aware of the environmental function of the constructed wetlands, refer Fig. 4-30.

Blacks Beach Cove respondents reported that the constructed wetland had a positive effect on; the provision of habitat for native animals (particularly birds), the recreational opportunities, the areas aesthetic appeal and integration into the surrounding environment, see Fig. 4-31. The attraction of mosquitoes and occasional odours demonstrated negative effects of the wetland.

There were safety concerns raised by parents with young children, with an increased chance of drowning due to the presence of a wetland and surrounding water bodies, refer Fig. 4-32. The wetland provides a positive effect for education and environmental awareness opportunities and it was reported that school field trips frequent the wetland (Fig. 4-33).



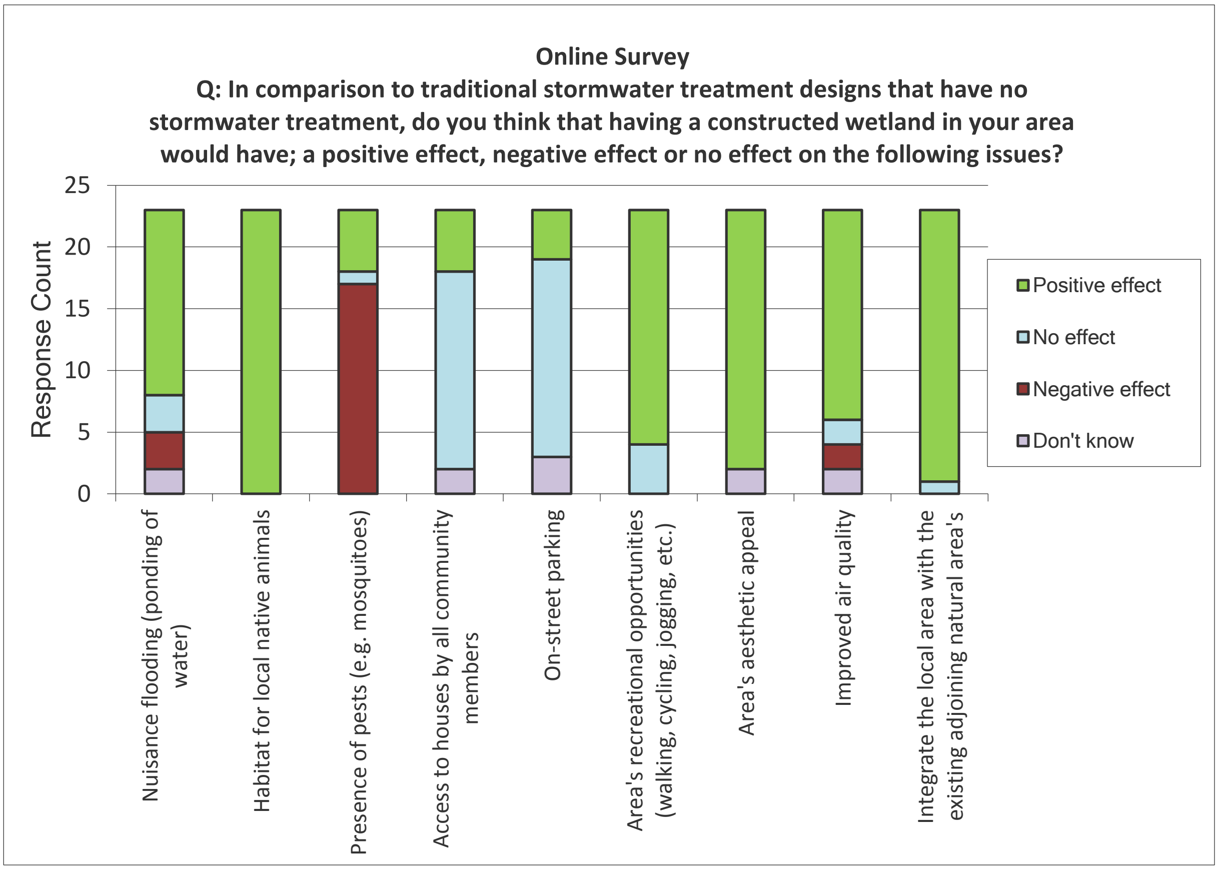
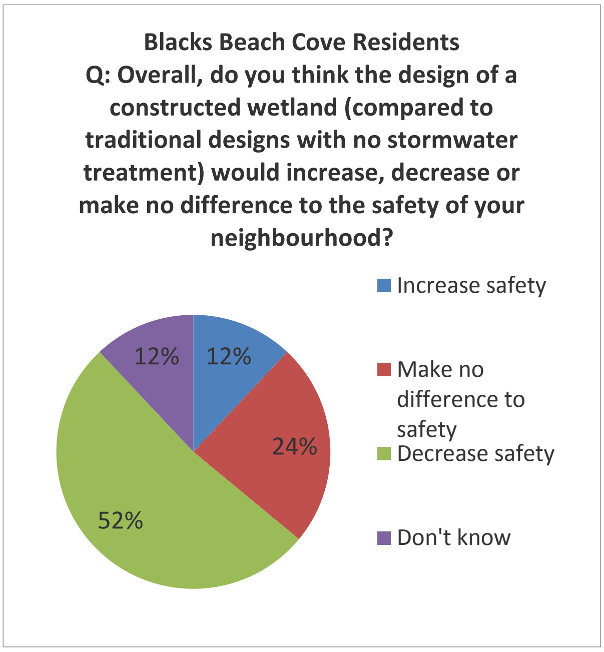


Fig. 4-31: Blacks Beach Cove and online survey results showing the various effects constructed wetlands have on their neighbourhood.



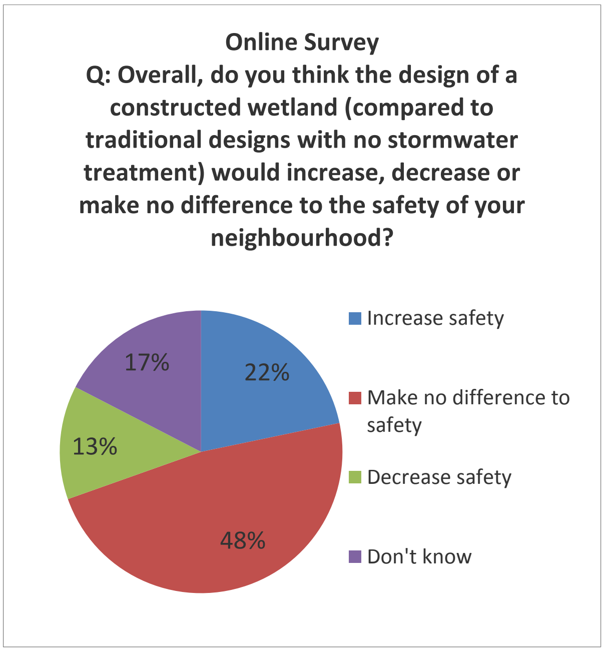
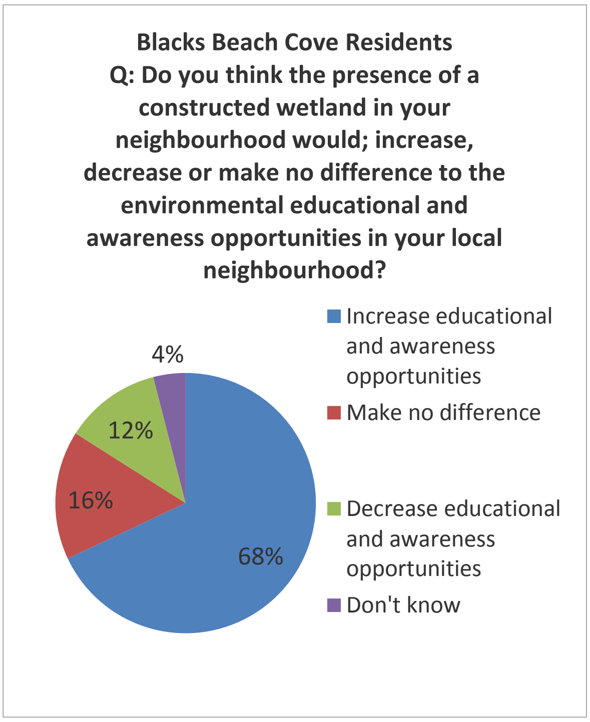


Fig. 4-32: Blacks Beach Cove and online survey results showing the effect constructed wetlands have on safety.



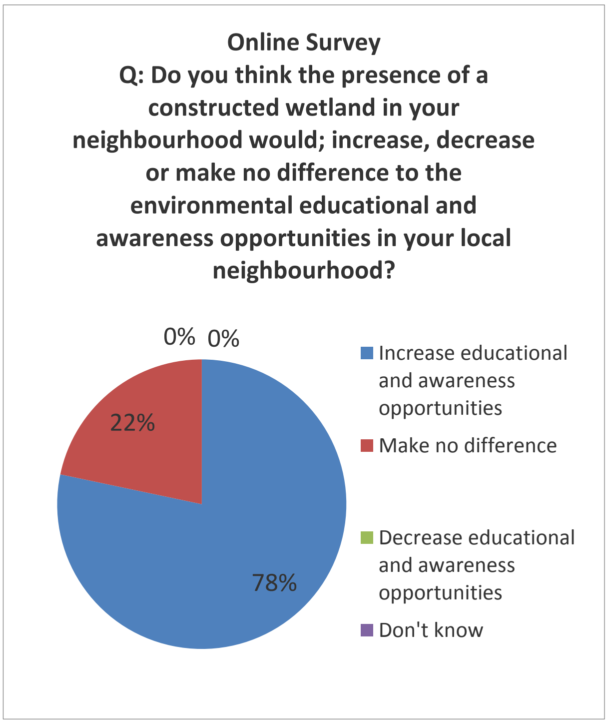
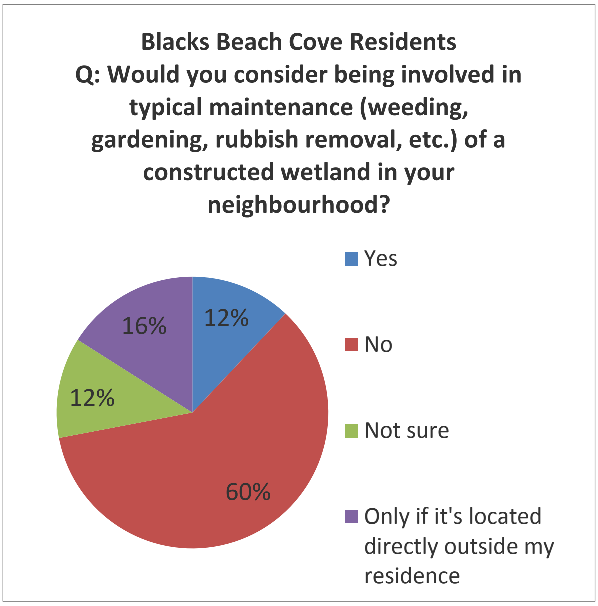


Fig. 4-33: Blacks Beach Cove and online survey results showing the effect constructed wetlands have on education and awareness opportunities.



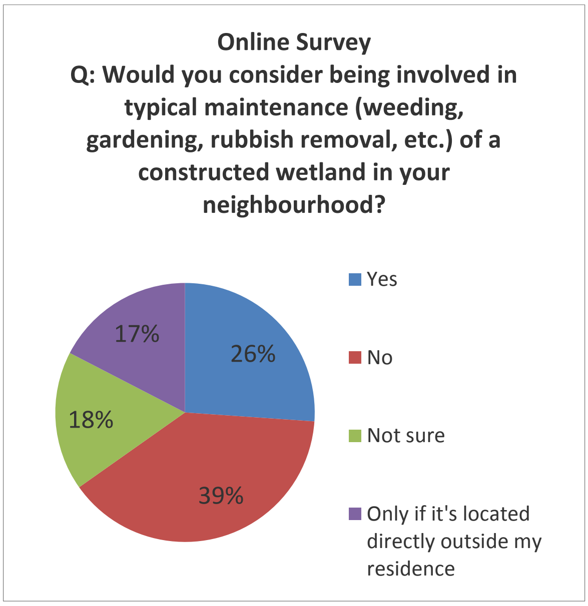


Fig. 4-34: Blacks Beach Cove and online survey results showing the willingness of residents to participate in community based maintenance of constructed wetlands.

Online Survey – Street Trees (BAU) (*n* = 50)

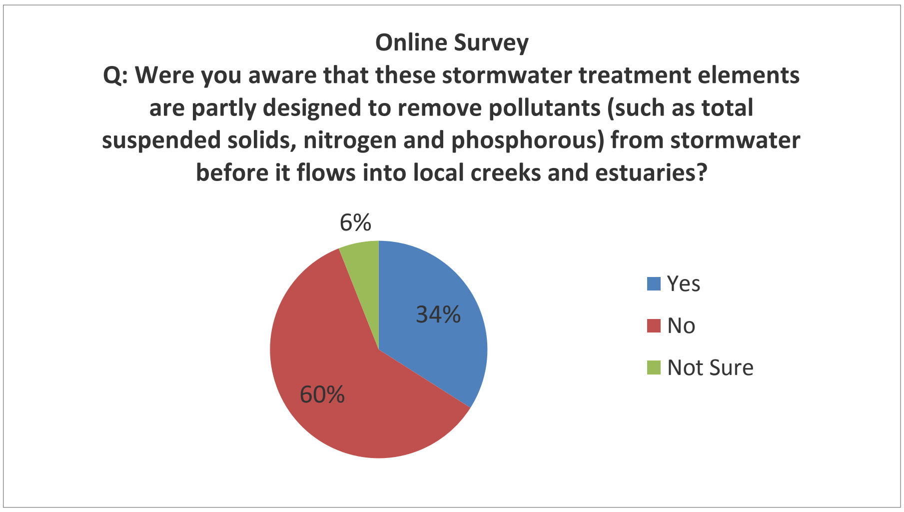


Fig. 4-35: Online survey results showing community awareness of the part function of street trees

The majority of the control group were not aware that a partial function of a street tree was to provide stormwater treatment (Fig. 4-35). Positive effects of street trees were reported in the expected areas; local habitat for native animals, the recreational opportunities of the area, aesthetics appeal, improved air quality and natural integration, see Fig. 4-36. No effect was displayed for nuisance flooding, presence of pests, access to houses by community members and on-street parking. Respondents thought that there was no difference to safety exhibited and that there was an increased environmental education opportunity; see Fig. 4-37 & 4-38. There was a larger interest shown in being involved in maintenance. Two-thirds of residents would consider being involved in maintenance, one thirds showed interest only if the tree was located directly outside their residence (Fig. 4-39).

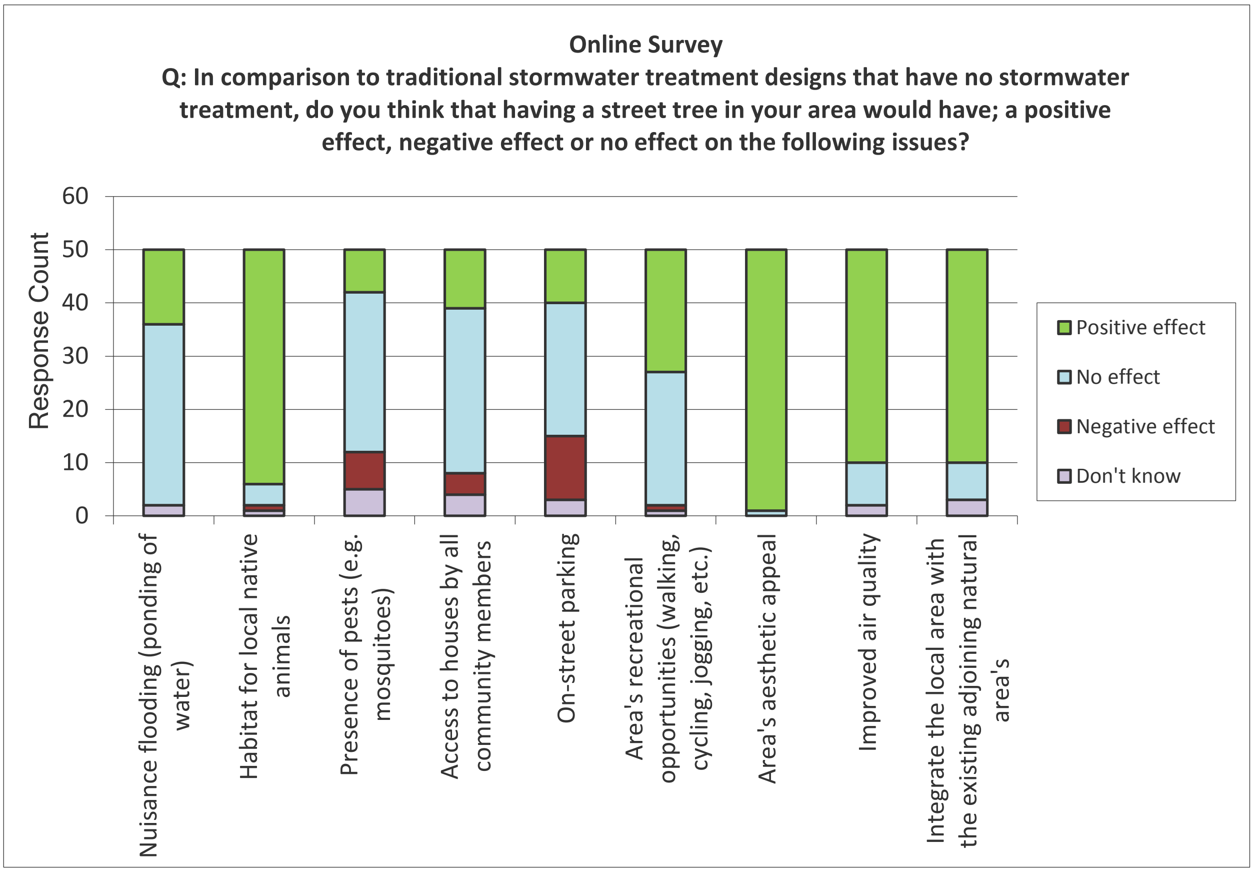


Fig. 4-36: Online survey results showing the various effects street trees have on their neighbourhood.

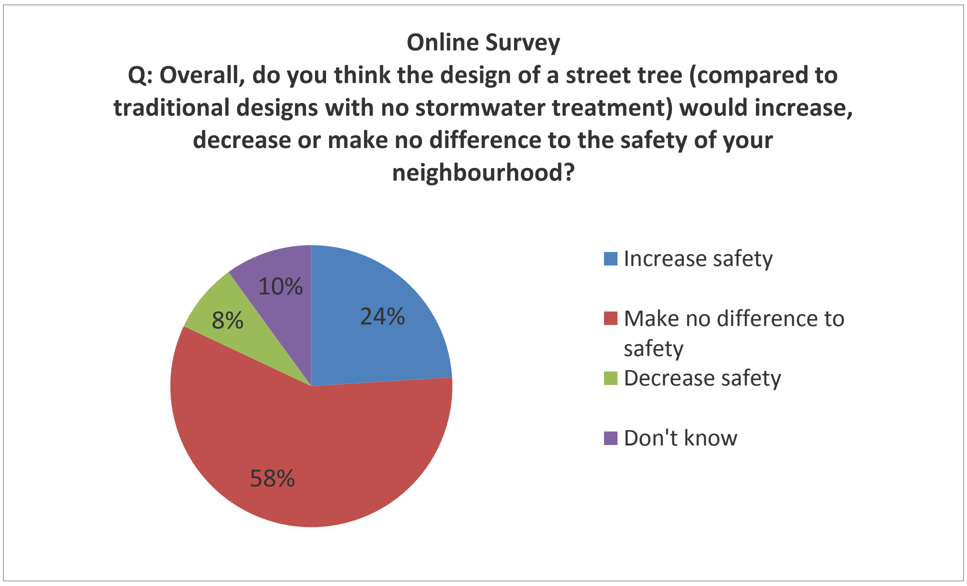


Fig. 4-37: Online survey results showing the effect street trees have on safety.

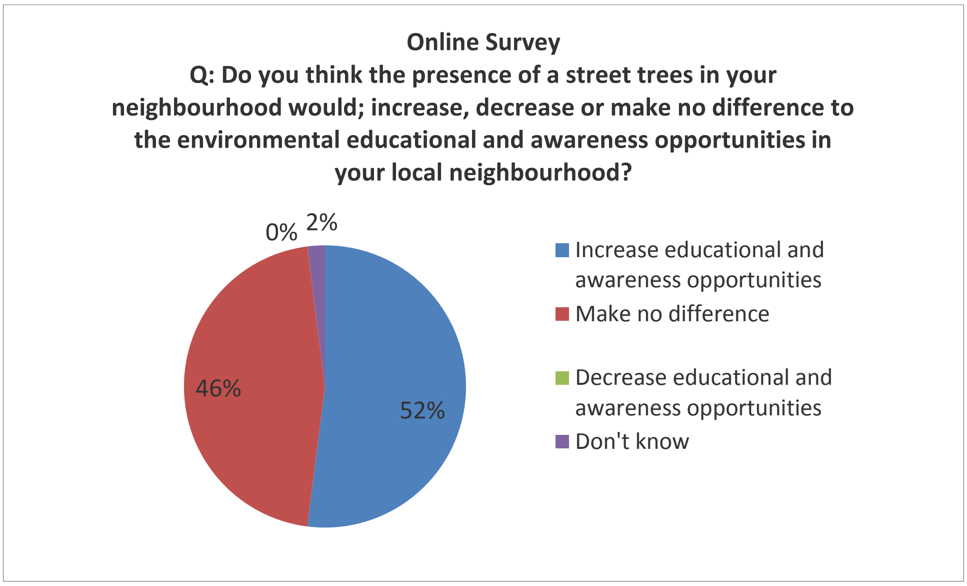


Fig. 4-38: Online survey results showing the effect street trees have on education and awareness opportunities.

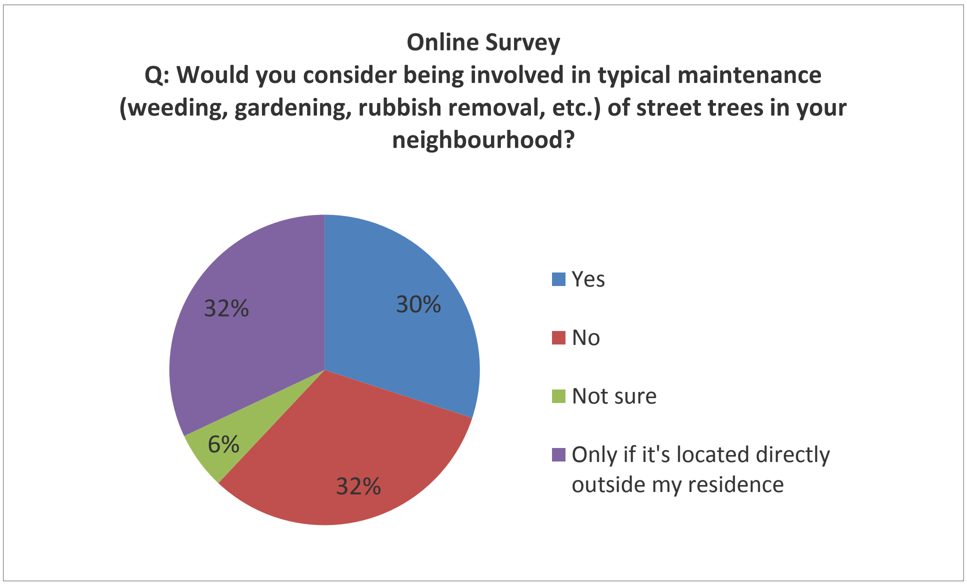


Fig. 4-39: Online survey results showing the willingness of residents to participate in community based maintenance of street trees.

Refer Appendix C for complete survey questionnaire results.

4.5.5 Assessment Criteria and Indicators

Relative importance of the assessment criteria was established by the Delphi Panel. Mean values were assigned to each criterion as the nominated weight, see Table 4-12. Life cycle costs were assigned the most weight with a nominal 13.0 value. The impact on safety of people using the area (4.9) and the maintenance of 5 year and 100 year ARI flood events (11.3) were decided to be the most important social and ecological criterion.

Table 4-12: TBL assessment criteria mean weightings.

Financial Assessment Criteria	Expert Group Assigned Weights									Mean
The life cycle cost of the device over 30 years	18	15	10	12	12	17	8	12	12	**13.0**
The typical annual maintenance costs	10	7	10	11	11	11	15	11	11	**10.8**
The total capital and acquisition costs	5	11	13	10	10	5	10	10	10	**9.3**
***Social* Assessment Criteria**	**Expert Group Assigned Weights**									**Mean**
Impact on property values	4	3	14	3	5	2	4	3	3	**4.8**
The impact on the safety of people using the area	5	6	3	5	5	6	4	5	5	**4.9**
The impacts on the area's aesthetic values	4	6	3	3	3	6	5	3	3	**4.1**
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	5	3	3	6	3	4	4	6	6	**4.3**
The inconvenience of nuisance flooding / ponding outside of dwellings	3	2	2	4	5	2	3	4	4	**3.1**
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	4	2	3	2	4	1	3	3	**2.8**
Natural habitat for native animals	3	3	1	3	3	3	3	3	3	**2.8**
Community involvement in maintenance	1	2	2	2	2	4	4	2	2	**2.4**
The inconvenience to people using the road reserve (e.g. access, parking)	4	1	2	2	2	1	4	2	2	**2.3**
The impact on the research, education & awareness opportunities	1	3	1	2	3	1	1	2	2	**1.8**
***Ecological* Assessment Criteria**	**Expert Group Assigned Weights**									**Mean**
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	18	8	10	10	12	7	15	10	10	**11.3**
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10	15	5	11	12	13	10	11	11	**10.9**
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	5	10	18	12	9	13	8	12	12	**10.9**

Life cycles costs (13.0) are deemed the most important financial criterion, although typical annual maintenance costs (10.8) are also an important underlying financial criterion as maintenance costs are relative to life cycle costs.

Health and wellbeing (4.3), safety of people using the area (4.9) and aesthetics (4.1) are considered the most important social criteria. Subsequently these relative importance values contribute to the impact on property values (4.8) which is also valued highly. The importance of education and awareness opportunities (1.8) and the inconvenience caused to people using the road reserve (2.3) are valued to a lesser extent.

There is little variance on the relative importance placed on the ecological criterion. The maintenance of major and minor stormwater system designs (11.3) was deemed the most important ecological criterion, with water quality treatment performance of stormwater runoff and opportunities of integration of design with adjoining natural areas being deemed assigned equal weightings (10.9).

The mode, minimum, maximum and median values of the assigned weights were recorded for sensitivity analysis, see Table 4-13.

Table 4-13: TBL Assessment Criteria Mode, Median, Minimum & Maximum Weight Values.

***Financial* Assessment Criteria**	**Mode**	**Minimum**	**Maximum**	**Median**
The life cycle cost of the device over 30 years	12	8	18	12.0
The typical annual maintenance costs	11	7	15	11.0
The total capital and acquisition costs	10	5	13	10.0
***Social* Assessment Criteria**	**Mode**	**Minimum**	**Maximum**	**Median**
Impact on property values	3	2	14	3.0
The impact on the safety of people using the area	5	3	6	5.0
The impacts on the area's aesthetic values	3	3	6	3.0
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	3	6	4.0
The inconvenience of nuisance flooding / ponding outside of dwellings	2	2	5	3.0
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	1	4	3.0
Natural habitat for native animals	3	1	3	3.0
Community involvement in maintenance	2	1	4	2.0
The inconvenience to people using the road reserve (e.g. access, parking)	2	1	4	2.0
The impact on the research, education & awareness opportunities	1	1	3	2.0
***Ecological* Assessment Criteria**	**Mode**	**Minimum**	**Maximum**	**Median**
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	10	7	18	10.0
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10	5	15	11.0
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	12	5	18	12.0

4.5.6 Impact Matrix

The results of the Impact Matrix and the positive impact each assessment criteria is likely to have on the project, including the; performance scores, likelihood scores and impact scores are listed below.

Performance Scores

Performance Score Keys with the 1 to 5 rating scale were developed for 15 assessment criterion as shown below.

Financial Performance Score Key

Table 4-14: Financial Performance Scoring Key.

		Financial Assessment Criteria		
Score	Category	Total Acquisition Cost (X) ($2012)	Total Maintenance Cost (Y) ($2012/yr)	Life cycle cost (Z) ($ over a 30 year period)
5	Little costs	X < $250,000	Y < $15,000	Z < $250,000
4	Minor costs	$250,000 < X ≤ $500,000	$15,000 < Y ≤ $30,000	$250,000 < Z ≤ $500,000
3	Moderate costs	$500,000 < X ≤ $750,000	$30,000 < Y ≤ $40,000	$500,000 < Z ≤ $1,000,000
2	Major costs	$750,000 < X ≤ $1,000,000	$40,000 < Y ≤ $50,000	$1,000,000 < Z ≤ $2,000,000
1	Outstandingly high costs	$1,000,000 ≥ X	$50,000 ≥ Y	$2,000,000 ≥ Z

Table 4-15: Financial Performance Scoring Key reflecting total cost of treatment per treatment strategy.

Treatment Element	Total Acquisition Cost ($2012)		Total Maintenance Cost ($2012/yr)		Total Life-Cycle Cost (Over 30 years) ($2012)	
	Cost	Score	Cost	Score	Cost	Score
Bioretention Swale	$81,500	5	$10,000	5	$251,000	4
Bioretention Basin	$363,000	4	$14,600	5	$572,000	3
Biopods	$1,290,000	1	$49,000	2	$1,993,000	2
Constructed Wetland (including two sedimentation basins)	$3,255,000	1	$74,800	1	$4,327,000	1

A Performance Scoring Key was developed for each treatment element based on the cost to implement either a local or regional strategy based on the treatment strategy, see Table 4-14.

Bioretention swales scored the highest possible score of (5) across all three financial assessment criterions as they posed the smallest cost burden in each criterion. The constructed wetland scored the lowest, with the minimum possible performance score of the (1), also for all three social criterions. Bioretention basins were typically the next best performing treatment element, scoring; (4) for TAC's, (5) for TAM costs and (3) for LCC's. Biopods were the most expensive local strategy treatment element; (1) for TAC's, (2) for TAM costs and (2) for LCC's, which was marginally better than the constructed wetland performance scores, see Table 4-15.

Social Performance Score Key

After reviewing the survey data, the following Performance Scores were allocated to each social assessment criteria using the Performance Score Categories, see Table 4-16.

Table 4-16: Social Indicator Categorisation.

Categorisation	Score
Very Positive Effect	5
Moderately Positive Effect	4
No Effect	3
Moderately Negative Effect	2
Very Negative Effect	1

Table 4-17: Social Performance Key.

Social Assessment Criteria	Treatment Element				
	Biopod	Bio Swale	Bioretention Basin	Constructed Wetland	Street Tree
	Performance Score Rating				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	3	3	2	3
The impact on the safety of people using the area	2	4	3	2	3
The impacts on the area's aesthetic values	1	3	3	5	3
Impact on property values	2	4	3	4	3
Community involvement in maintenance	4	2	4	2	3
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	4	3	5	3
The inconvenience of nuisance flooding / ponding outside of dwellings	4	2	4	3	3
The impact on the research, education & awareness opportunities	3	4	3	5	3
Natural habitat for native animals	3	5	5	5	3
The inconvenience to people using the road reserve (e.g. access, parking)	3	4	4	3	3

The Performance Scores allocated for the social assessment criteria are based on data obtained from social surveys (Section 4.6.4) and as such, these scores reflect the performance of these existing treatment elements, see Table 4-17. When compared to a BAU case, only the biopod generally scored lower. The sub-par biopod performance scores included; aesthetic appeal of (1), impact on safety (2) and impact on property value (2). The low 'impact on property value' score is directly related to the aesthetic appeal and impact on safety scores. These low performance scores for the biopod directly reflect the existing condition of Cuttersfield's biopods.

The constructed wetland performs slightly lower than BAU in terms of safety (2), due to the possible risk of drowning in an open water body and community involvement in maintenance. Similarly, the bioretention swale scored (2); for a slight increase on ponding, and less motivation for community involvement in maintenance. The constructed wetland scored highly (5) for; aesthetics values, the impact on active and passive recreational opportunities, a habitat for native animals and an opportunity for research, education and environment awareness.

The bioretention swale and basin generally scored higher than the BAU across all social criteria. Moderate positive effects (4) were recorded for; the impact on safety of people using the area, the impact on property values, community involvement in maintenance, and inconvenience to use of the road reserve, as extra street width was using found near these elements.

Environmental Performance Score Key

Environmental Performance Scores were derived from MUSICs performance assessment in isolation of each treatment element and advice from the Expert group. See Table 4-18 and 4-19 for MUSICs performance assessment and relative Performance Scoring Key.

Table 4-18: Ecological Performance Scores categories, in terms of reduced pollutants were determined from MUSIC.

Score	Categorisation	% Reduced Pollutant		
		TSS (X)	TP (Y)	TN (Z)
5	Outstanding benefits / Little costs	X > 85	Y > 70	Z > 46
4	Major benefits / Minor costs	80 ≥ X > 85	65 ≥ Y > 70	43 ≥ Z > 46
3	Moderate benefits / Moderate costs	75 ≥ X > 80	60 ≥ Y > 65	40 ≥ Z > 43
2	Minor benefits / Major costs	70 ≥ X > 75	60 ≥ Y > 65	37 ≥ Z > 40
1	Little or no benefits / Outstandingly high costs	X < 70	Y < 60	Z < 37

The bioretention swale achieved the highest pollutant reduction percentages for TSS and TP removal (5) and (2) for only achieving 39 % TN removal (Table 4-19). The average score for pollutants removed was 4. The bioretention basin performed slightly better with and average score of 4.3, from achieving acceptable reductions for all three pollutants, (83 % TSS, 68 % TP, 42 % TN). Biopods were assumed to not achieve their WQOs after visual inspection of Cuttersfield's biopods revealed no plant of filter media in 95 % of the biopods. To be consistent with the social indicator data, it is assumed the ecological performance of biopods for the TBL will reflect the assumed treatment performance of Cuttersfield's biopods and were assigned a performance score of (1). Results of a TBL assessment considering fully functioning biopods is detailed in Section 4.6. The constructed wetland achieved an average performance score of (3), only failing to adequately treat TSS (75%).

Table 4-19: Ecological Treatment Performance Scoring Key.

Treatment Element	% of TSS Reduced		% of TP Reduced		% of TN Reduced		Average Score
	%	Score	%	Score	%	Score	
Bioretention Swale	92	5	73	5	39	2	**4**
Bioretention Basin	83	4	68	4	42	3	**4.3**
Biopods	80	1*	64	1*	39	1*	**2.7**
Constructed Wetland (incl.2 sedimentation basins)	75	2	65	4	41	3	**3**

*Assumed to not achieve WQOs from visual inspection (see Fig. 4-17).

Table 4-20: Ecological Opportunity of Integration Performance Scoring Key.

Ecological Assessment Criteria	Treatment Element				
	Biopod	Bio Swale	Bioretention Basin	Constructed Wetland	Street Tree
	Performance Score Rating				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	4	4	4	5	3

Table 4-16 was used to categorise the Performance Scores for the 'opportunities of integration of design' assessment criteria (Table 4-20). There is a very high opportunity for integration of a constructed wetland into the surrounding Bakers Creek wetlands (5). All other treatment elements show a moderate opportunity (4) of implementation of native plant species and integration into the surrounding area. As it is assumed the maintenance of 5-year and 100-year ARI flood events will be achieved for all BMPs, a Performance Score of (3) is allocated to each treatment element.

Likelihood Scores

The likelihood of the performance score occurring is determined by the Likelihood Scores shown in Tables 4-21 to 4-25 below as part of the Impact Matrices for each treatment element.

Table 4-21: Bioretention swale Impact Matrix.

Financial **Assessment Criteria**	**Performance Score**	**Likelihood Score**	**Impact Score**	
The life cycle cost of the device over 30 years	5	4	**20**	Very High
The typical annual maintenance costs	5	4	**20**	Very High
The total capital and acquisition costs	4	4	**16**	High
Social **Assessment Criteria**				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	4	**12**	Medium
The impact on the safety of people using the area	4	4	**16**	High
The impacts on the area's aesthetic values	4	4	**16**	High
Impact on property values	4	3	**12**	Medium
Community involvement in maintenance	2	2	**4**	Low
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	4	4	**16**	High
The inconvenience of nuisance flooding / ponding outside of dwellings	2	3	**6**	Low
The impact on the research, education & awareness opportunities	4	3	**12**	Medium
Natural habitat for native animals	5	3	**15**	High
The inconvenience to people using the road reserve (e.g. access, parking)	4	4	**16**	High
Ecological **Assessment Criteria**				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	4	3	**12**	Medium
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, Reduced pollutants (TSS, TP, TN)	4	4	**16**	High
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	3	**12**	Medium
		Total	Σ = **221**	
		Adjusted Total (7 %)	Σ = **15**	

Table 4-22: Bioretention basin Impact Matrix.

Financial Assessment Criteria	Performance Score	Likelihood Score	Impact Score	
The life cycle cost of the device over 30 years	4	3	**12**	Medium
The typical annual maintenance costs	5	3	**15**	High
The total capital and acquisition costs	3	4	**12**	Medium
***Social* Assessment Criteria**				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	3	**9**	Medium
The impact on the safety of people using the area	3	3	**9**	Medium
The impacts on the area's aesthetic values	4	4	**16**	High
Impact on property values	3	3	**9**	Medium
Community involvement in maintenance	4	2	**8**	Medium
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	4	**12**	Medium
The inconvenience of nuisance flooding / ponding outside of dwellings	4	3	**12**	Medium
The impact on the research, education & awareness opportunities	3	3	**9**	Medium
Natural habitat for native animals	5	3	**15**	High
The inconvenience to people using the road reserve (e.g. access, parking)	4	4	**16**	High
***Ecological* Assessment Criteria**				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	4	3	**12**	Medium
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, Reduced pollutants (TSS, TP, TN)	4.3	4	**17.2**	High
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	3	**12**	Medium
		Total	**Σ = 195**	
		Adjusted Total (32 %)	Σ = **62**	

Table 4-23: Biopod Impact Matrix.

***Financial* Assessment Criteria**	**Performance Score**	**Likelihood Score**	**Impact Score**	
The life cycle cost of the device over 30 years	1	3	**3**	Negligible
The typical annual maintenance costs	2	3	**6**	Low
The total capital and acquisition costs	2	4	**8**	Medium
***Social* Assessment Criteria**				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	4	**12**	Medium
The impact on the safety of people using the area	2	3	**6**	Low
The impacts on the area's aesthetic values	1	3	**3**	Negligible
Impact on property values	2	3	**6**	Low
Community involvement in maintenance	4	4	**16**	High
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	3	**9**	Medium
The inconvenience of nuisance flooding / ponding outside of dwellings	4	3	**12**	Medium
The impact on the research, education & awareness opportunities	3	3	**9**	Medium
Natural habitat for native animals	3	3	**9**	Medium
The inconvenience to people using the road reserve (e.g. access, parking)	3	4	**12**	Medium
***Ecological* Assessment Criteria**				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	4	3	**12**	Medium
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, Reduced pollutants (TSS, TP, TN)	2.7	4	**10.8**	Medium
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	3	**9**	Medium
		Total	Σ = **143**	
		Adjusted Total (61 %)	Σ = **87**	

Table 4-24: Constructed wetland Impact Matrix.

Financial Assessment Criteria	Performance Score	Likelihood Score	Impact Score	
The life cycle cost of the device over 30 years	1	3	**3**	Low
The typical annual maintenance costs	1	3	**3**	Low
The total capital and acquisition costs	1	4	**4**	Low
***Social* Assessment Criteria**				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	2	4	**8**	Medium
The impact on the safety of people using the area	2	3	**6**	Low
The impacts on the area's aesthetic values	5	3	**15**	High
Impact on property values	4	3	**12**	Medium
Community involvement in maintenance	2	3	**6**	Low
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	5	3	**15**	High
The inconvenience of nuisance flooding / ponding outside of dwellings	3	3	**9**	Medium
The impact on the research, education & awareness opportunities	5	4	**20**	Very High
Natural habitat for native animals	5	3	**15**	High
The inconvenience to people using the road reserve (e.g. access, parking)	3	3	**9**	Medium
***Ecological* Assessment Criteria**				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	5	3	**15**	High
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, Reduced pollutants (TSS, TP, TN)	3	4	**12**	Medium
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	3	**9**	Medium
		Total	Σ = **164**	
		Adjusted Total (100 %)	Σ = **164**	

Table 4-25: Street tree (BAU) Impact Matrix.

***Financial* Assessment Criteria**	**Performance Score**	**Likelihood Score**	**Impact Score**	
The life cycle cost of the device over 30 years	3	3	9	Medium
The typical annual maintenance costs	3	3	9	Medium
The total capital and acquisition costs	3	3	9	Medium
***Social* Assessment Criteria**				
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	3	3	9	Medium
The impact on the safety of people using the area	3	3	9	Medium
The impacts on the area's aesthetic values	3	3	9	Medium
Impact on property values	3	3	9	Medium
Community involvement in maintenance	3	3	9	Medium
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	3	3	9	Medium
The inconvenience of nuisance flooding / ponding outside of dwellings	3	3	9	Medium
The impact on the research, education & awareness opportunities	3	3	9	Medium
Natural habitat for native animals	3	3	9	Medium
The inconvenience to people using the road reserve (e.g. access, parking)	3	3	9	Medium
***Ecological* Assessment Criteria**				
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	3	3	9	Medium
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, Reduced pollutants (TSS, TP, TN)	1	3	3	Negligible
Maintenance of the minor system design 5-year ARI, and major system design 100-year ARI	3	3	9	Medium
		Total	Σ = **138**	
		Adjusted Total (100 %)	Σ = **138**	

Impact Scores

The impact scores are presented in two scenarios below. Firstly, the impact scores of each treatment element are displayed as an impact score per square metre of treatment surface area (Fig. 4-40). Secondly and more importantly, the impact scores are adjusted into relative treatment surface area per treatment strategy. I.e. the nominal bioretention basin provides 32 % of the treatment for a local treatment approach strategy; therefore the impact score is adjusted by 32 %.

Comparing impact scores per square metre, the bioretention swale represents the most potential positive impact (221), the bioretention basin (195) and constructed wetland (164). The biopod option has only marginally more impact than the BAU strategy. This is explained by the poor aesthetics and water quality treatment performance of the Cuttersfield biopods, which the social and ecological performance scores were based on.

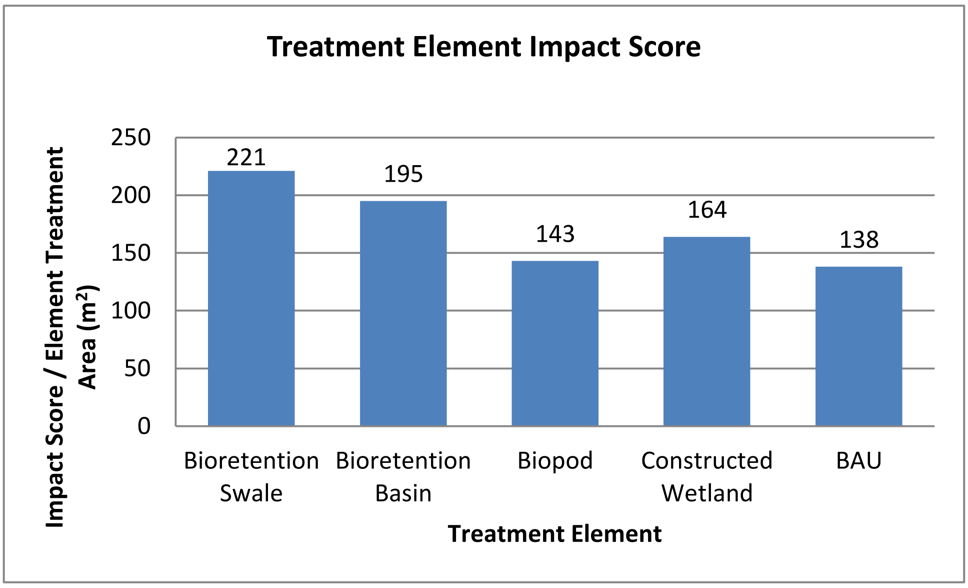


Fig. 4-40: Impact Scores for each treatment element.

To compare the two treatment strategies, each treatment element impact score was adjusted to the relative treatment percentage each element provides per each approach, see Fig. 4-41 and 4-42. When compared, there was virtually no difference between the treatment strategies; with the local strategy total impact score scoring one point higher (165) to (164) for the regional treatment strategy. In terms of TBL elements, there's no difference in ecological values (36) between both elements. The regional approach shows higher positive impact potential socially with a score (118) compared to the local approach (103). The local treatment strategy has a higher positive financial impact potential with a score of (28) compared to (10) regionally.

The BAU strategy total impact score (138) is included as a control only and is not considered as a valid option as stormwater quality objectives are not achieved by this strategy.

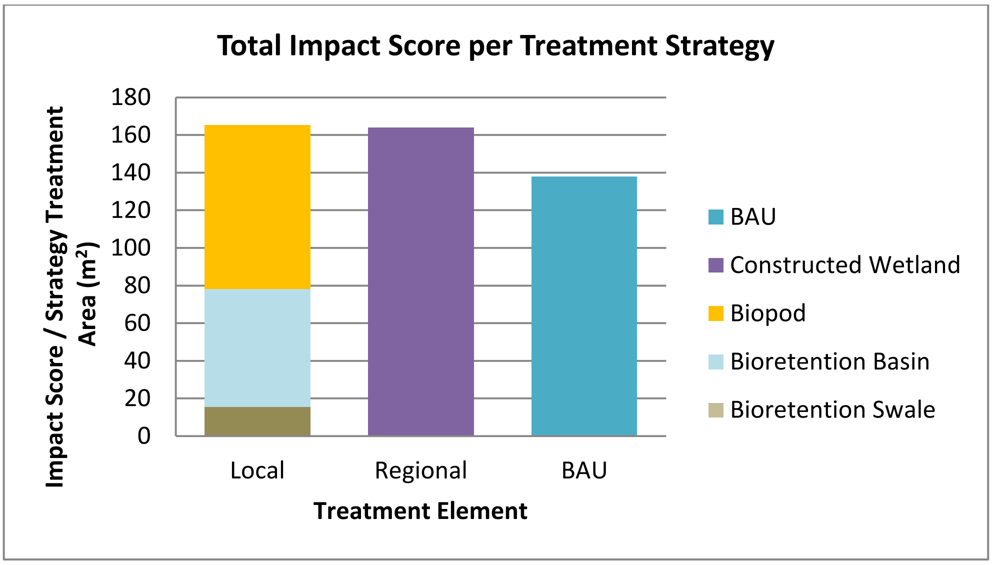
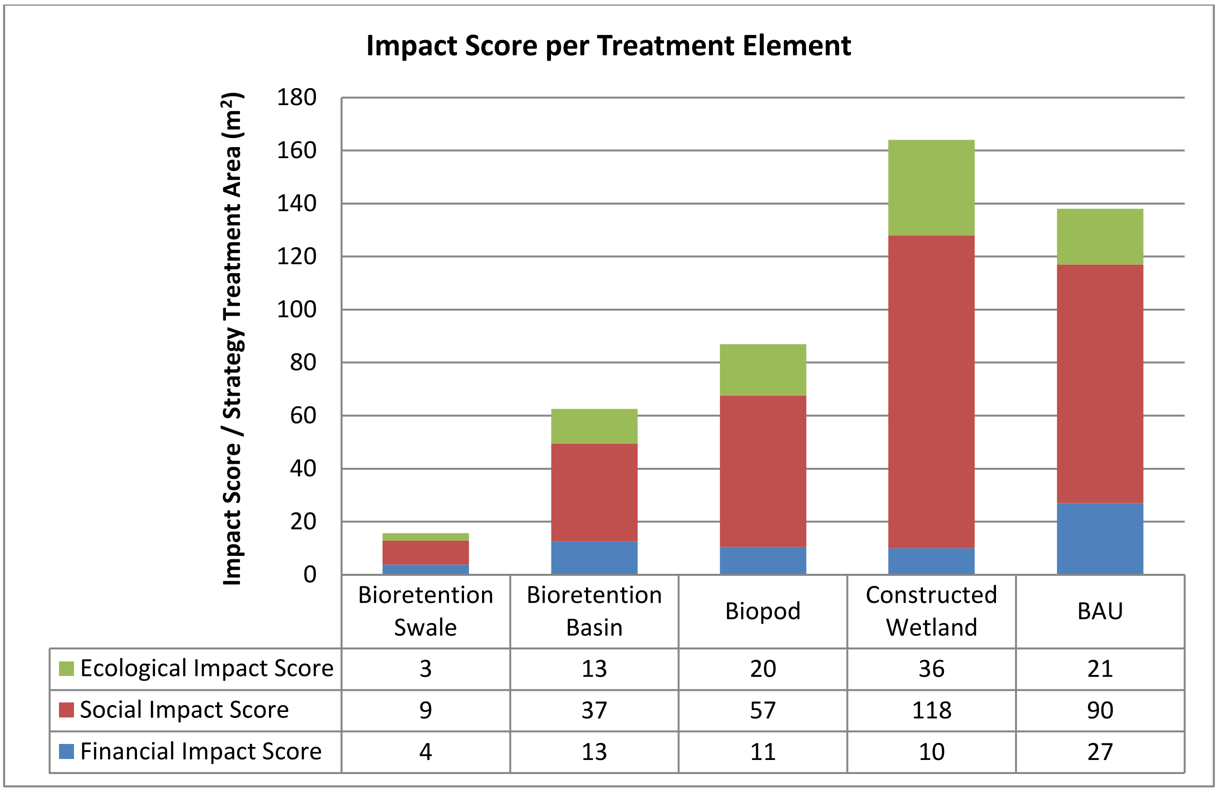


Fig. 4-41: Impact Scores per treatment strategy.



	Bioretention Swale	Bioretention Basin	Biopod	Constructed Wetland	BAU
Ecological Impact Score	3	13	20	36	21
Social Impact Score	9	37	57	118	90
Financial Impact Score	4	13	11	10	27

Fig. 4-42: Adjusted Impact Score for each treatment element.

4.5.7 Value Scores

Similar to the impact scores, the value scores are presented in terms of each treatment element, as a value score per square metre of treatment surface area, and as a value score adjusted into relative treatment surface area per treatment strategy.

The bioretention swale represents the most valued option (1437), with the bioretention basin (1219) and constructed wetland (865), see Fig. 4-43. The biopod option (811) is less valued than the BAU approach (825). The value scores show a similar trend when compared to the impact scores in terms of ranking. The bioretention swale and basin further increased their value over the BAU case, by performing better in higher weighted assessment criteria.

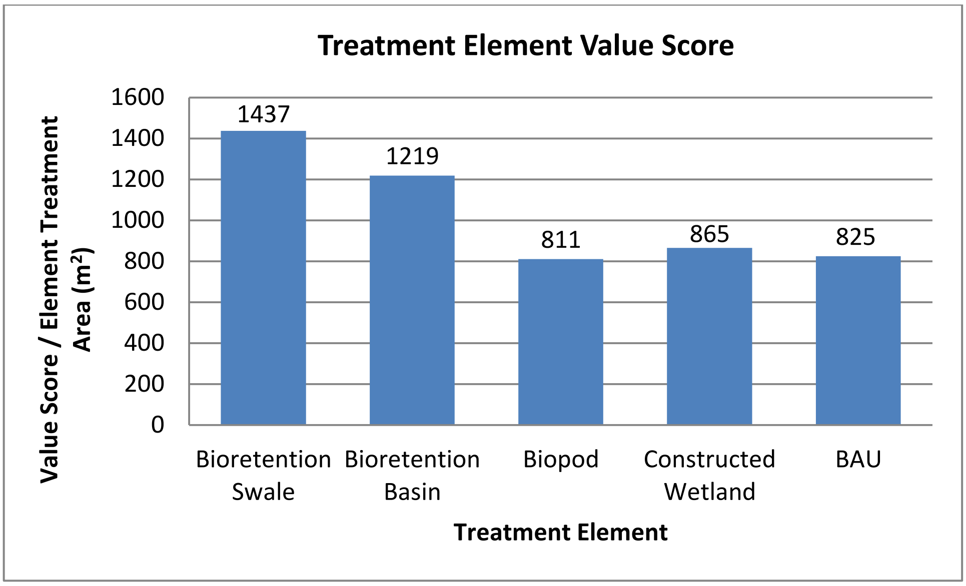


Fig. 4-43: Value Score for each treatment element.

The adjusted value scores for the local treatment elements are as follows; bioretention swale (101), bioretention basin (378), and biopod (502). When combined the total local treatment strategy had a higher value score of (981) compared to the regional strategy (865), see Fig. 4-44. That is a difference of 12 % between each treatment strategy. The higher value score of the local treatment strategy is largely due to the strong performance in the financial element of the TBL. The local treatment strategy financial value score (285) was almost three times that of the regional strategies financial value score (108), see Fig. 4-45.

The regional strategy performed better than the local treatment approach in two of the three TBL assessment criteria; ecologically and socially. Ecologically the regional strategy scored (394) compared to the local approach (373) and socially the difference was greater with the regional strategy scoring (363) to the local treatment approach score of (323). Refer Appendix D for multi-criteria analysis results.

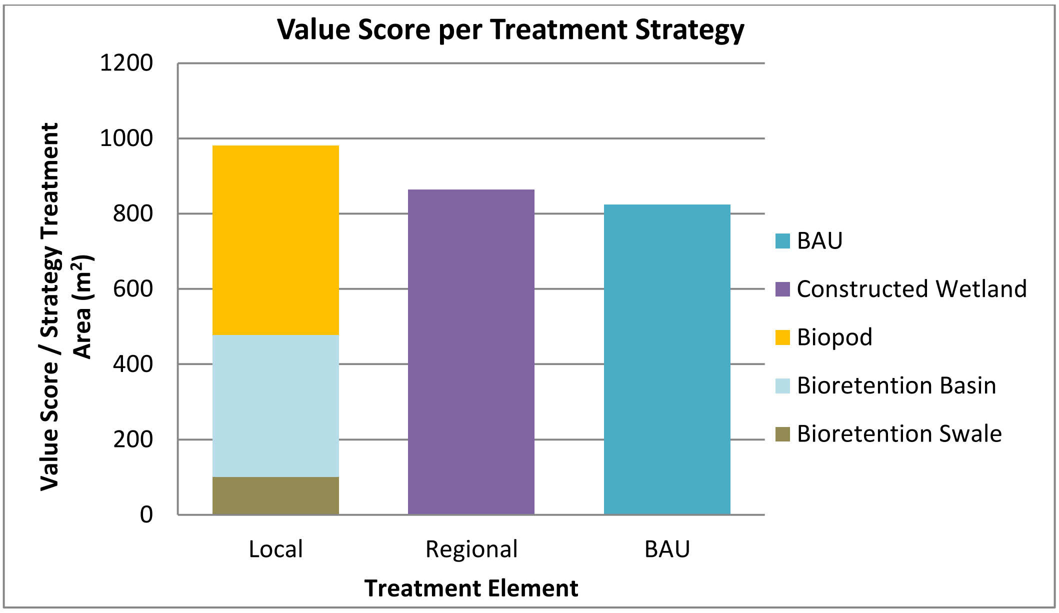
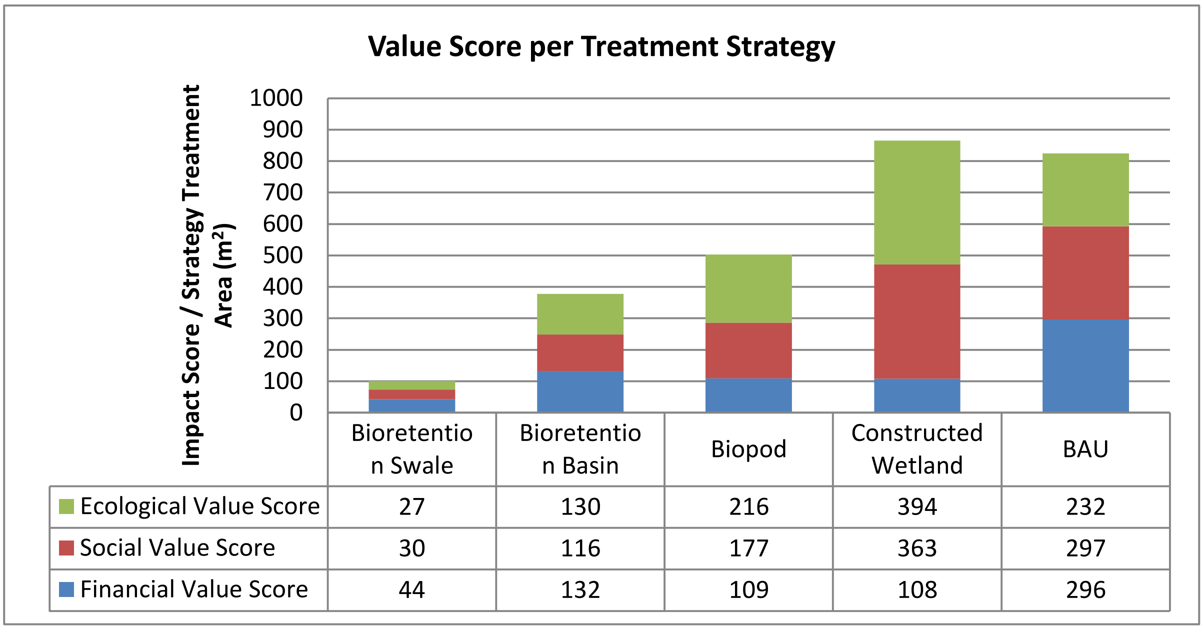


Fig. 4-44: Value Score per treatment strategy.



	Bioretention Swale	Bioretention Basin	Biopod	Constructed Wetland	BAU
Ecological Value Score	27	130	216	394	232
Social Value Score	30	116	177	363	297
Financial Value Score	44	132	109	108	296

Fig. 4-45: Adjusted Value Score for each treatment element.

4.5.8 Sensitivity Analysis

Sensitive Analysis revealed only small variance in overall treatment strategy value scores. The maximum total variation of 3 % occurred when equal likelihood scores of (3) were applied to all assessment criteria. The local treatment strategy reduced by -10 % compared to the regional treatment strategy (-6 %). This suggests that the confidence in the likelihood scores given to the local treatment strategy affects the final value score by a margin of 4 %. Little to no variance was recorded when, mode, median, maximum, minimum and equal weights were applied to the assessment criteria, see Tables 4-26 to 4-31.

Table 4-26: Equal likelihood scores used for sensitivity analysis.

Treatment Element	Nominal Value	Equal Likelihood Score Value	% Change	Nominal Strategy Score	Equal Likelihood Strategy Score	% Change Strategy Score	New Variance Between Approach Strategies
Regional Stormwater Treatment Strategy							
Bioretention Swale	101	83	-18%	981	888	-10%	3%
Bioretention Basin	378	349	-8%				
Biopod	503	456	-9%				
Regional Stormwater Treatment Strategy							
Constructed Wetland	865	809	-6%	865	809	-6%	
Business As Usual Strategy							
Street Trees (BAU)	825	830	1%	825	830	1%	

Table 4-27: Mode weights used for sensitivity analysis.

Treatment Element	Nominal Value	Mode Value	% Change	Nominal Strategy Score	Mode Strategy Score	% Change Strategy Score	Overall Variance Between Strategies
Regional Stormwater Treatment Strategy							
Bioretention Swale	101	96	-5%	981	904	-8%	1%
Bioretention Basin	378	352	-7%				
Biopod	503	456	-9%				
Regional Stormwater Treatment Strategy							
Constructed Wetland	865	782	-10%	865	782	-10%	
Business As Usual Strategy							
Street Trees (BAU)	825	764	-7%	825	764	-7%	

Table 4-28: Minimum weights used for sensitivity analysis.

<table>
<tr><th>Treatment Element</th><th>Nominal Value</th><th>Minimum Value</th><th>% Change</th><th>Nominal Strategy Score</th><th>Minimum Strategy Score</th><th>% Change Strategy Score</th><th>Overall Variance Between Strategies</th></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td><td></td></tr>
<tr><td>Bioretention Swale</td><td>101</td><td>57</td><td>-43%</td><td rowspan="3">981</td><td rowspan="3">536</td><td rowspan="3">-55%</td><td rowspan="5">0%</td></tr>
<tr><td>Bioretention Basin</td><td>378</td><td>210</td><td>-45%</td></tr>
<tr><td>Biopod</td><td>503</td><td>269</td><td>-47%</td></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td></tr>
<tr><td>Constructed Wetland</td><td>865</td><td>470</td><td>-46%</td><td>865</td><td>470</td><td>-46%</td></tr>
<tr><td colspan="7">Business As Usual Strategy</td><td rowspan="2"></td></tr>
<tr><td>Street Trees (BAU)</td><td>825</td><td>465</td><td>-44%</td><td>825</td><td>465</td><td>-44%</td></tr>
</table>

Table 4-29: Maximum weights used for sensitivity analysis.

<table>
<tr><th>Treatment Element</th><th>Nominal Value</th><th>Maximum Value</th><th>% Change</th><th>Nominal Strategy Score</th><th>Maximum Strategy Score</th><th>% Change Strategy Score</th><th>Overall Variance Between Strategies</th></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td><td></td></tr>
<tr><td>Bioretention Swale</td><td>101</td><td>152</td><td>51%</td><td rowspan="3">981</td><td rowspan="3">1517</td><td rowspan="3">54%</td><td rowspan="5">1%</td></tr>
<tr><td>Bioretention Basin</td><td>378</td><td>568</td><td>50%</td></tr>
<tr><td>Biopod</td><td>503</td><td>797</td><td>58%</td></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td></tr>
<tr><td>Constructed Wetland</td><td>865</td><td>1357</td><td>57%</td><td>865</td><td>1357</td><td>57%</td></tr>
<tr><td colspan="7">Business As Usual Strategy</td><td rowspan="2"></td></tr>
<tr><td>Street Trees (BAU)</td><td>825</td><td>1278</td><td>55%</td><td>825</td><td>1278</td><td>55%</td></tr>
</table>

Table 4-30: Median weights used for sensitivity analysis.

<table>
<tr><th>Treatment Element</th><th>Nominal Value</th><th>Median Value</th><th>% Change</th><th>Nominal Strategy Score</th><th>Median Strategy Score</th><th>% Change Strategy Score</th><th>Overall Variance Between Strategies</th></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td><td></td></tr>
<tr><td>Bioretention Swale</td><td>101</td><td>98</td><td>-3%</td><td rowspan="3">981</td><td rowspan="3">950</td><td rowspan="3">-3%</td><td rowspan="5">1%</td></tr>
<tr><td>Bioretention Basin</td><td>378</td><td>365</td><td>-3%</td></tr>
<tr><td>Biopod</td><td>503</td><td>487</td><td>-3%</td></tr>
<tr><td colspan="7">Regional Stormwater Treatment Strategy</td></tr>
<tr><td>Constructed Wetland</td><td>865</td><td>824</td><td>-5%</td><td>865</td><td>824</td><td>-5%</td></tr>
<tr><td colspan="7">Business As Usual Strategy</td><td rowspan="2"></td></tr>
<tr><td>Street Trees (BAU)</td><td>825</td><td>798</td><td>-3%</td><td>825</td><td>798</td><td>-3%</td></tr>
</table>

Table 4-31: Equal weights (per TBL element) used for sensitivity analysis.

Treatment Element	Nominal Value	Equal Weight Value	% Change	Nominal Strategy Score	Equal Weight Strategy Score	% Change Strategy Score	Overall Variance Between Strategies
Regional Stormwater Treatment Strategy							
Bioretention Swale	101	100	-1%	981	998	2%	1%
Bioretention Basin	378	381	1%				
Biopod	503	517	3%				
Regional Stormwater Treatment Strategy							
Constructed Wetland	865	886	2%	865	886	2%	
Business As Usual Strategy							
Street Trees (BAU)	825	825	0%	825	1278	55%	

Overall Benefit Scores

Sensitivity analysis using overall benefit scores (OBS) were used to provide an insight into the relative benefit to cost ratio of the financial values versus the combined ecological and social values of each option. These results contravene the principles of the TBL assessment as equal importance is not placed on all three elements of the TBL. The information shown should be used with caution.

The local strategy performs better than the regional strategy on all four OBS charts; see Fig. 4-46 to 4-47. As defined in Section 4.4 and Section 4.5.7, the local treatment elements performed better financially. This financial performance is magnified by the OBS.

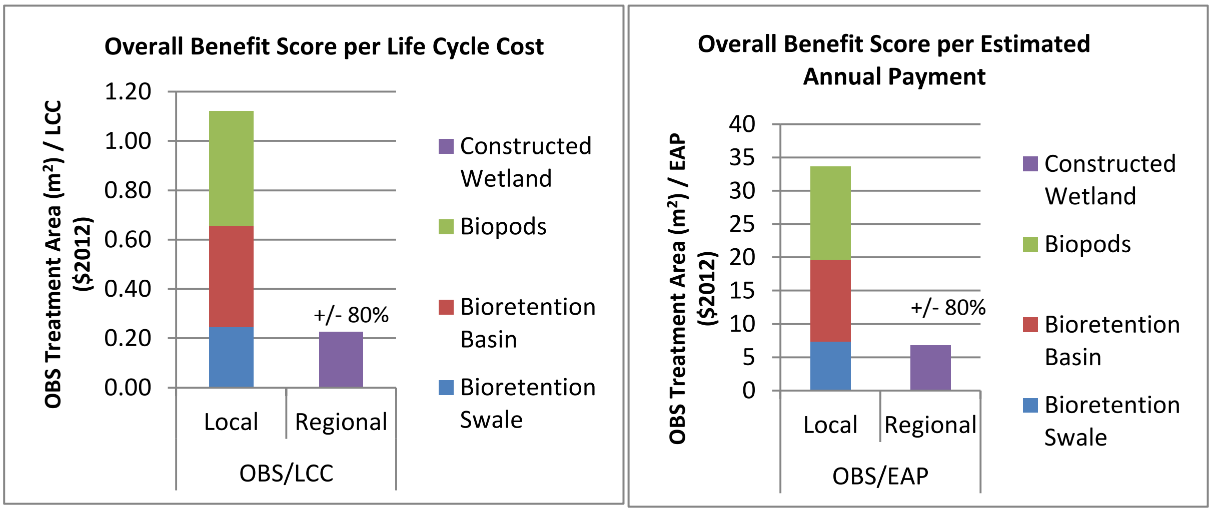


Fig. 4-46: OBS / Life Cycle Costs (left) and OBS / Estimated Annual Payment (right).

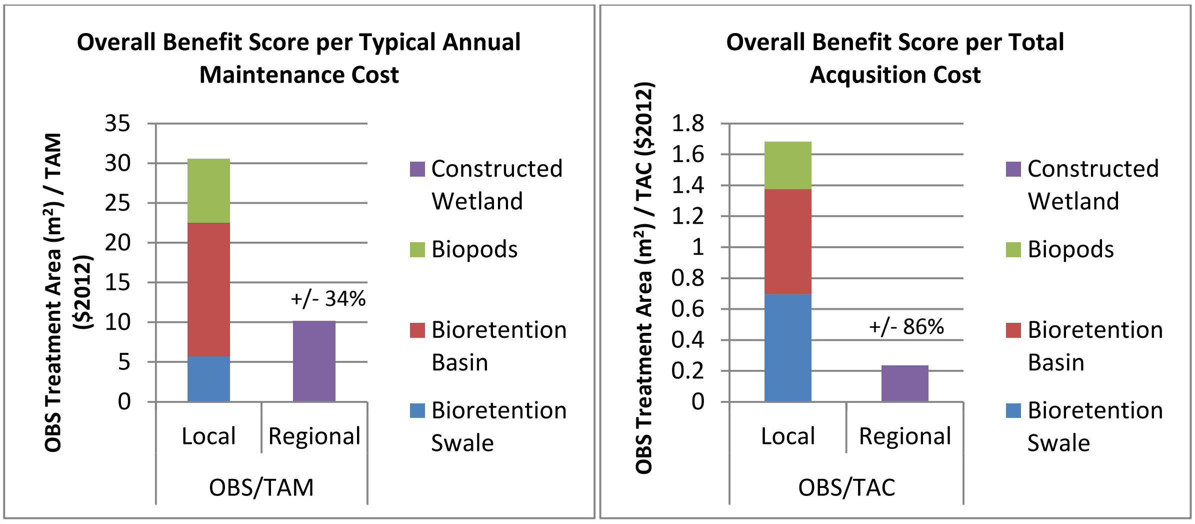


Fig. 4-47: OBS / Typical Annual Maintenance Costs (left) and OBS / Total Acquisition Cost (right).

4.5.9 Expert Group Recommendations

Initial Preference

Based on the results of the impact scores (see Fig. 4-41 and 4-42) the Expert group ranked their preferred treatment strategy and element, refer Table 4-32. The regional strategy was the preferred treatment approach by 6 votes to 2. Likewise, the constructed wetland was the preferred treatment element, ahead of the bioretention basin, biopod and lastly the bioretention swale.

Table 4-32: Initial Expert group preferences of treatment elements and strategies.

Preferred Treatment Strategy	**Expert Group Preferences**								**Total Votes**	**Preferred Treatment Strategy**
Regional	1	1		1	1	1		1	6	1
Local			1				1		2	2
Preferred Treatment Element	**Expert Group Preferences**								**Total Votes**	**Preferred Treatment Element**
Constructed Wetland	1	1	3	1	1	1	2	3	13	1
Bioretention Basin	3	3	1	2	4	2	1	1	17	2
Biopod	2	4	2	4	3	3	4	2	24	3
Bioretention Swale	4	2	4	3	2	4	3	4	26	4

Final Preference

The Expert group were then provided their final preference following a review of the MCA results and values scores (Fig. 4-44 and 4-45), as well as the results from the sensitivity analysis (Section 4.6.8). The regional strategy was the Expert groups preferred treatment approach by 5 votes to 3, see Table 4-33. This recommended approach by the Expert group is made despite the regional strategy being outscored by the local approach after the MCA.

The constructed wetland is still the preferred treatment element, although the wetland is now only marginally preferred ahead of the bioretention basin. The bioretention swale is now the third most preferred treatment element, ahead of the biopod which is now less preferred.

Table 4-33: Final Expert group preferences of treatment elements and strategies.

Preferred Treatment Strategy	Expert Group Preferences								Total Votes	Preferred Treatment Strategy
Regional	1	1		1	1			1	5	1
Local			1			1	1		3	2
Preferred Treatment Element	**Expert Group Preferences**								**Total Votes**	**Preferred Treatment Element**
Constructed Wetland	1	3	4	3	1	2	1	1	16	1
Bioretention Basin	2	1	3	1	4	1	2	3	17	2
Bioretention Swale	3	4	1	2	2	3	3	4	22	3
Biopod	4	3	2	4	3	4	4	2	26	4

4.6 Impact of Maintained Biopods

The following results reflect the assumption that the biopods were in-fact fully planted, regularly maintained and achieved their stormwater runoff treatment performance targets. The performance scores were made by the assessment manager and based on judgement from similar TBL assessment results of similar well-maintained treatment elements.

4.6.1 Performance Scores

Several social and ecological performance scores were adjusted to indicate effect of a maintained biopod. No changes were required for the financial performance scores. The following social performance scores were amended and improved; the impact on the safety of people using the area (4), the impacts on the area’s aesthetic values (5), the impact on property values (4) and a natural habitat for native animals (4), see Table 4-34.

Table 4-34: Amended Social Performance Scores.

Social Assessment Criteria	Treatment Element
	Biopod
	Performance Score Rating
The impact on the safety of people using the area	4
The impacts on the area's aesthetic values	5
Impact on property values	4
Natural habitat for native animals	4

The results from the MUSIC performance assessment (Table 3-2) were then used to determine the biopod treatment performance scores. Performance scores were improved to and average score of (3) for the higher reduction percentages achieved by treating all three pollutants, see Table 4-35.

Table 4-35: Amended Ecological Treatment Performance Scoring Key.

Treatment Element	% of TSS Reduced		% of TP Reduced		% of TN Reduced		Average Score
	%	Score	%	Score	%	Score	
Biopods	80	4	64	3	39	2	3

4.6.2 Revised Impact & Value Scores

The Impact Matrix was amended to include the adjusted performance scores. No changes were made to the likelihood scores. The total biopod impact score increased by 16 %, which increased the impact score for the local treatment strategy by 10 %, see Fig. 4-48. The total biopod value score increased by 13 %, which increased the total value score for the local treatment strategy by 7 % to (1050), see Fig. 4-49.

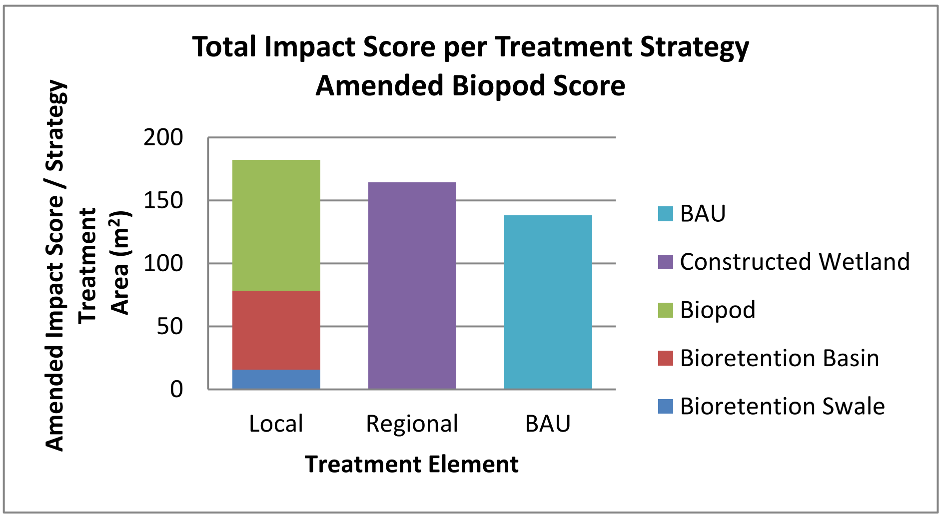


Fig. 4-48: Amended total impact score per treatment strategy.

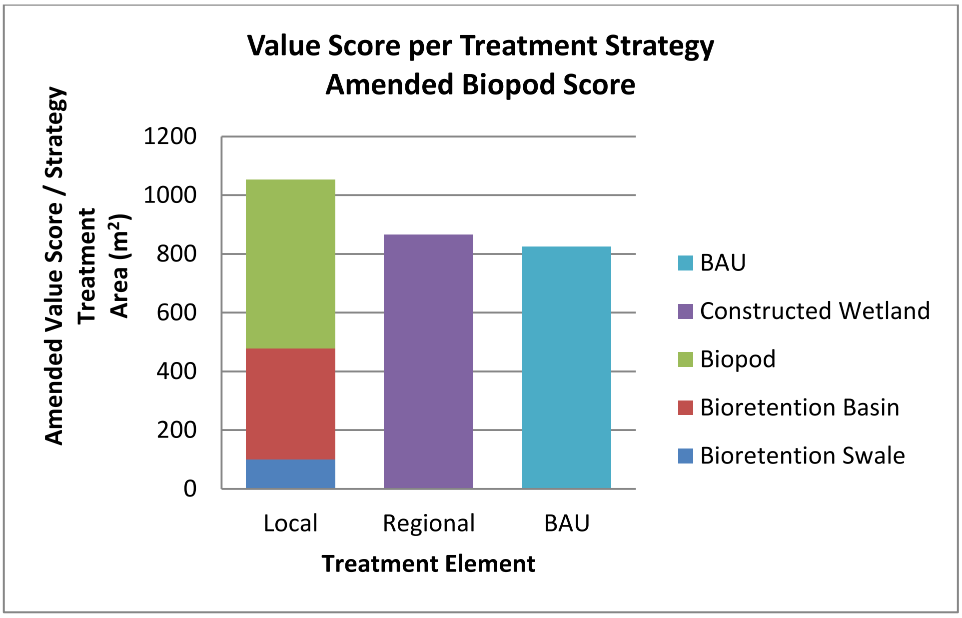


Fig. 4-49: Amended total value score per treatment element.

4.6.3 Conclusion

After a review of the improved biopod and local strategy performance scores, the Expert group still preferred the regional approach by 5 votes to 3. The constructed wetland was still the preferred treatment element ahead of the bioretention basin. The biopod was now the third preferred treatment element, ahead of the bioretention swale, which was least preferred, see Table 4-36.

Table 4-36: Expert group preferences of treatment elements and strategies considering improved biopod performance.

Preferred Treatment Strategy	Expert Group Preferences								Total Votes	Preferred Treatment Strategy
Regional	1	1		1	1			1	5	1
Local			1			1	1		3	2
Preferred Treatment Element	**Expert Group Preferences**								**Total Votes**	**Preferred Treatment Element**
Constructed Wetland	1	3	4	3	1	2	2	1	17	1
Bioretention Basin	2	1	3	1	4	1	3	3	18	2
Bioretention Swale	4	4	2	2	2	3	4	4	25	4
Biopod	3	3	1	4	3	4	1	2	23	3

5.0 Conclusions

5.1 Introduction

This research has compared various contributing economic, social and ecological factors involved with WSUD for both a regional and local treatment strategy for a 33.5 hectare site in the Mackay region. A greater understanding of the benefits and costs of these contributing factors involved in WSUD has been gained throughout this project.

A TBL assessment involving a multidisciplinary skilled Delphi Panel, representing urban development stakeholders, was used to investigate and ascertain; objectives, values and stakeholder preferences of a preferred treatment strategy approach.

Further research was conducted to identify social and financial performance indicators for use in the TBL assessment, where associated BMP costs and social attributes linked with existing BMP were investigated.

5.1.1 Treatment Element Design & Ecological Performance

As reported by MRC (2011) the accumulative surface treatment area of local treatment elements, which make up the local treatment strategy for Precinct A were as follows; bioretention swale 250 m^2, bioretention basins 1170 m^2, and biopods 3911 m^2. The regional treatment strategy for Precinct A consists of two typical sedimentations basins and a typical constructed wetland. The treatment surface areas of each regional treatment element were; Sedimentation Basin A 950 m^2, Sedimentation Basin B 500 m^2, and a typical constructed wetland 21,700 m^2.

Following performance assessment by MUSIC, each treatment strategy achieved MRC WQOs. When treatment elements were considered individually, in isolation from their respective treatment trains, the percentage of reduced pollutants achieved by each treatment element were; For TSS; bioretention swale 92 %, bioretention basin 83 %, biopods 80 %, constructed wetland 75 %; for TP; bioretention swale 73 %, bioretention basin 68 %, biopods 64 %, constructed wetland 65 %; for TN; bioretention swale 39 %, bioretention basin 42 %, biopods 39 %, and constructed wetland 41 %.

5.1.2 Best Management Practice Costs

The total acquisition, typical annual maintenance and life cycle unit rates recommended in this research best reflect the size of the BMPs proposed for Precinct A and available cost information. The total acquisition unit rates adopted for the following treatment elements were; bioretention swales \$326/m^2, bioretention basins \$310/m^2, biopods \$330/m^2, and constructed wetlands (inclusive of two sedimentation basins approximately 2000 m^2 total)

$150/m^2$, and street or verge streets $950 each. It should be noted that total acquisition costs do not include land acquisition costs.

The TAC's for the local treatment elements were; bioretention swales $81,500, bioretention basins $363,000, and biopods $1,290,600. The local strategy TAC was $1,735,000. The TAC's for the constructed wetland and regional treatment strategy were $3,255,000.

The following typical annual maintenance unit rates adopted for the following treatment elements were; bioretention swales $40/m^2/yr., bioretention basins $12.50/m^2/yr., biopods $12.50/m^2/yr., constructed wetlands $2.70/m^2/yr., sedimentation basins, $11.20/m^2/yr., and street or verge trees $25 each. The TAM costs for the local treatment elements were; bioretention swales $10,000/year, bioretention basins $14,600/year, biopods $49,000/year, and biopods $73,600/year. The total TAM costs for the local treatment strategy was $73,600/year. The TAM costs for the regional treatment elements were; constructed wetlands $58,600/year sedimentation basins, $16,200/year and the total TAM regional strategy cost was $74,000/year.

Life cycle costing was carried out using MUSICs life cycle costing module which is based on the Australian standard for life cycle costing (AS/NZS 4536:1999). Using the adopted total acquisition and typical annual maintenance unit rates, and applying a real discount rate of 5.5 %, an annual inflation rate of 2 % and the year 2012 as the base costing date, the life cycle costs for each treatment element was estimated over a 30 year life span. The following LCC's were recorded for each treatment element; $251,000 bioretention swale, $572,000 for bioretention basins, $1,993,000 biopods, constructed wetlands $4,095,000, and sedimentation basins $232,000. The total LCC for the local treatment strategy was $2,816,000 and $4,327,000 for the regional treatment strategy.

To date, there is limited published financial cost information for BMPs and WSUD developments. It is envisaged that these BMP unit rates can be used to help fill the knowledge gap for BMP costs in the Mackay region and potentially other regions.

5.1.3 TBL Assessment and Delphi Panel

The TBL assessment was conducted with the use of a Delphi Panel facilitated by the author. The Delphi Panel comprised of two groups; an Expert group made up of; a senior civil engineer, a principal civil engineer, a senior hydraulic engineer, a senior engineer (water), a senior landscape architect, a landscape architect, a MRC development approvals officer and an environmental scientist. The Stakeholder group comprises of; a UDIA member, the MRC Councillor for Developments and Approvals, the SLCMA Regional Landcare Facilitator and a local prominent developer.

The Delphi Panel defined the objectives and values for each TBL element associated with the proposed development in Precinct A. These values were summarized into three core values that reflected the defined TBL assessment objectives. The core values of each TBL element are; financial – to minimize cost impacts associated with stormwater treatment assets upon a development, borne by Council, the developer, and ultimately the home buyer; social - overall community acceptance of the WSUD design; and ecological - to reduce impact on receiving waterways and integration of treatment elements into adjoining natural areas.

A total of sixteen assessment criteria were identified and aligned to the core values. The financial assessment criterions were; total acquisition costs, typical annual maintenance costs and life cycle costs.

The social criterions were; the impact on the health and wellbeing of nearby residents who may be affected by odours or mosquitoes or pests, the impact on the safety of people using the area, the impacts on the area's aesthetic values, the impact on property values, community involvement in maintenance, the impact on passive and active recreational opportunities around the stormwater asset, the inconvenience of nuisance flooding / ponding outside of dwellings, the impact on the research, education & awareness opportunities, a natural habitat for native animals, and the inconvenience to people using the road reserve.

The ecological criterions were defined as; opportunities of integration of design with adjoining natural areas, meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways, and the maintenance of the minor system design 5-year ARI, and major system design 100-year ARI.

5.1.4 Recommended Treatment Strategy

The Delphi Panel were asked rank their preferred treatment strategy and element in three iterations; an initial intuitive ranking based on the impact scores, a 'final' ranking from value scores generated from multi-criteria analysis and an ultimate ranking preference based on revised multi-criteria analysis value scores attributed to improved biopod performance.

Ultimately, a regional treatment strategy was the preferred treatment strategy of the Delphi Panel and the assessment manager, with the preferred treatment element being a constructed wetland ahead of a; bioretention basin, biopod and bioretention swale. These recommendations were made by the Expert group despite the local treatment approach demonstrating more sustainable benefits with a higher value score. The regional treatment strategy performed better socially and ecologically, but overall the lesser financial costs associated with the local treatment strategy contributed to a higher score being achieved by the local treatment strategy.

The local treatment strategy scored higher than the regional strategy by 981 to 865 after the first multi-criteria analysis, and by a further margin of 1050 to 865, after the biopod ecological and social performance scores improved to reflect a functioning, planted and maintained biopod.

The financial burden of the regional constructed wetland was a key component in the lesser value scores generated by the regional treatment strategy. The constructed wetland was marginally preferred by the Expert group over the bioretention basin, which was considered in this research as a local treatment element. With the preference for a regional treatment strategy, bioretention basins could also be considered as part of the regional treatment strategy for future TBL assessments.

5.1.5 Conclusion

A regional treatment strategy is the preferred approach to sustainable WSUD recommended by urban development stakeholders in the Mackay region despite the local treatment strategy achieving a higher value score.

Mackay Regional Council is encouraged to consider the views of the Delphi Panel as the recommended implementation of a regional treatment strategy reflects the opinions of a variety of experts in the field of urban development. MRC should also consider the financial, social, and ecological values and concerns identified in this research, particularly the unsustainable TBL performance associated with unmaintained BMPs.

6.0 Recommendations

6.1 Introduction

The results obtained and the lessons learnt throughout this project have brought to the fore certain limitations and challenges regarding the TBL assessment and use of a Delphi Panel. These lessons will aide in the pursuit of further research within this exciting field of study.

6.1.1 Limitations and Challenges

Throughout the project there were certain limitations and challenges faced by the author. These are listed below:

- Limited published BMP cost information available.
- Difficulty in maintaining interest and participation of Delphi Panel members during the TBL assessment.
- Trouble in gaining a relatively large survey sample size to access social values.

6.1.2 Recommendations for Future Work

Numerous different questions pertaining to the most preferred sustainable treatment strategy have arisen throughout this journey relating to future work recommendations. Some of these are listed below:

- Investigate the full effect land acquisition and decommissioning costs have on the total acquisition cost of treatment elements, particularly constructed wetlands.
- Investigate the use of alternate combinations of treatment elements which make up local or regional treatment strategies and conduct a TBL assessment to determine the preferred treatment approach, and / or to compare the values scores generated to the value scores generated in this research.
- Investigate the potential cost, and or benefit, that a contribution cost scheme would provide for the construction of a regional constructed wetland for an urban development.

List of References

Andoh, R & Declerck, C 1999, 'A cost effective approach to stormwater management? source control and distributed storage', in 8th International Conference on Urban Stormwater Drainage: *proceedings of the 8th International Conference on Urban Stormwater Drainage* Sydney, New South Wales, pp. 1319-26.

Ashley, R, Blackwood, D, Butler, D, Jowitt, P, Davies, J, Smith, H, Gilmour, D & Oltean-Dumbrava, C 2008, 'Making Asset Investment Decisions for Wastewater Systems That Include Sustainability', *Journal of Environmental Engineering*, vol. 134, no. 3, pp. 200-9.

Bligh Tanner & DesignFlow 2009, *Stormwater Infrastructure Options to Achieve Multiple Water Cycle Outcomes*, Queensland Water Commission, Brisbane, Queensland.

Breen, P, Denman, L, May, P & Leinster, S 2004, *Street Trees as Stormwater Treatment Measures*, The University of Melbourne, viewed 20 May 2012, <http://www.urbanforestryinstitute.com/uploads/quality/Street%20Trees%20as%20Stormwater%20Treatment%20Measures.pdf>.

Cardno Ullman & Nolan 2009, *Bakers Creek Stockroute East Road (Bakers One) Catchment Stormwater Trunk Infrastructure Study*, Cardno Ullman & Nolan, Mackay, Queensland.

Chandler, F & Eadie, M 2006, 'Water by Design: Creating Water Sensitive Developments in South East Queensland', *7th International Conference on Urban Drainage Modelling and the 4th International Conference on Water Sensitive Urban Design; Book of Proceedings*, p. 7, viewed 24/04/12.

Coombes, P & Kuczera, G 2000, *Tank Paddock - A comparison between traditional and Water Sensitive Urban Design approaches*, University of Newcastle, viewed 20 May 2012, <http://www.bonacciwater.com/research/wsud%20-%2001%20-%20sydney%20WSUD.pdf>.

Coombes, P, Kuczera, G & Kalma, JD 2000b, 'Economic benefits arising from use of Water Sensitive Urban Development source control measures', in 3rd International Hydrology and Water Resource Symposium: *proceedings of the 3rd International Hydrology and Water Resource Symposium* Perth, Western Australia, pp. 152-7.

Coombes, P, Kuczera, G, Kalma, JD & Argue, JR 2002, 'An evaluation of the benefits of source control measures at the regional scale', *Urban Water*, vol. 4, no. 4, pp. 307-20.

Dalrymple, B 2012, 'Bioretention Myths Busted !!', in 2012 Stormwater Industry Association of Queensland State Conference: *proceedings of the 2012 Stormwater Industry Association of Queensland State Conference*, Brisbane, Australia, 28 May - 1 June.

Department for Communities and Local Government 2009, *Multi-criteria analysis: a manual*, Department for Communities and Local Government, London, United Kingdom.

Department of the Environment and Heritage (DEH) 1992, *National Strategy for Ecologically Sustainable Development*, Commonwealth DEH, Canberra, Australian Capital Territory.

Department of Environment Western Australia 2004, *Stormwater Management Manual for Western Australia*, Department of Environment Western Australia, Perth, Western Australia.

Department of Natural Resources and Water 2007, *Queensland Urban Drainage Manual*, Department of Natural Resources and Water, Brisbane, Queensland.

Department of Sustainability and Environment 2012, *Delphi Study*, Department of Sustainability and Environment, viewed 25 May 2012, <http://www.dse.vic.gov.au/effective-engagement/toolkit/tool-delphi-study>.

DesignFlow 2008, *Mackay Regional Council MUSIC Guidelines*, Version 1.1, Mackay Regional Council, Mackay, Queensland.

DesignFlow 2012, *Epping Central Structure Plan: Stormwater management strategy*, City of Whittlesea and Melbourne Water, Melbourne, Victoria, Australia.

DesignFlow & V2i 2010, *Mackay WSUD for flat sites*, Mackay Regional Council, Mackay, Queensland.

Drewry, J, Higham, W & Mitchell, C, *Bakers Creek Catchment Management Area Report*, 2008, National Water Commission, Canberra, Australia.

Elkington, S 1999, *Cannibals with forks: the triple bottom line of 21st century business*, vol. 2nd, Capstone Publishing, Minneapolis, Minnesota.

Engineers Australia 2006, *Australian Runoff Quality - A guide to Water Sensitive Urban Design*, Engineers Media, Crows Nest, New South Wales.

The Environmental Protection (Water) Policy 2009.

EPA Victoria 2008, *Maintaing water sensitive urban design elements*, EPA Victoria, Southbank, Victoria.

Fair, GM & Geyer, JC 1954, *Water Supply and Waste Disposal*, vol. 2, John Wiley and Sons, New York.

Gomboso, J & Morrison, M 1996, 'Integrating the Water Cycle: Economic and Environmental Benefits', in WaterTech: AWWA: *proceedings of the WaterTech: AWWA* Darling Harbour, Sydney, 27-28 May, pp. 225-32.

Google Maps 2012, *Google Maps: Street view*, Google, viewed 26 September 2012, <https://maps.google.com.au/>.

Hardie, N 2012, 'An assessment of street-scape bioretention systems in South East Queensland', in Stormwater Industry Association of Queensland State Conference: *proceedings of the Stormwater Industry Association of Queensland State Conference*, Brisbane, Australia, 28 May - 1 June.

Healthy Waterways Partnership 2005, *Water sensitive urban design: Barriers to adoption, opportunities and stakeholders needs in South East Queensland*, Water By Design, Brisbane, Queensland.

Healthy Waterways Partnership 2007, *A Review of Water Quality and Maintenance Costs of Constructed Water Bodies in Urban areas of South East Queensland*, Water by Design, Brisbane, Queensland.

Holz, L, Kuczera, G & Kalma, J, D. 2004, 'Sustainable urban water resource planning in Australia: a decision sciences perspective.', in Cities as Catchments - WSUD: *proceedings of the Cities as Catchments - WSUD*, T In: Daniell, James, R. and Takara, K. (eds.) (ed.), Casual Publications, Adelaide, South Australia.

Hunter, A 2011, *Greener Parks*, Local Government and Shires Associations of New South Wales, Sydney, New South Wales.

Land and Water Constructions 2007, *Review of Street Scale WSUD in Melbourne*, Kingston City Council and Better Bays and Waterways - Institutionalising Water Sensitive Urban Design and Best Practice Management Project, Kingston City Council, Melbourne, Australia.

Landcom 2004, *Water Sensitive Urban Design Strategy - Best Planning and Management Practices*, Landcom, Parramatta, New South Wales, viewed 23 May 2012, <http://www.landcom.com.au/downloads/file/WSUD_Book2_FactSheet.pdf>.

Landcom 2009, *Water Sensitive Urban Design*, Book 4 | Maintenance, Landcom, Parramatta, New South Wales.

Lloyd, SD, Wong, THF & Chesterfield, CJ 2002, *Water Sensitive Urban Design - A Stormwater Management Perpective*, Industry Report 02/10, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.

Mackay City Council 2006, *The Stormwater Quality Management Plan for Mackay*, Mackay City Council, Mackay, Queensland.

Mackay Regional Council 2010, *Economic Update - Invest Mackay Study Tour*, Mackay Regional Council, Mackay, Queensland, viewed 23 May 2012, <http://www.mackay.qld.gov.au/__data/assets/pdf_file/0009/88290/AAA-Economic-news.pdf>.

Mackay Regional Council 2011, *Example Site-based Stormwater Quality Management Plan for Mackay*, Mackay Regional Council, Mackay, Queensland.

Mackay Regional Council 2012, *MIMAPS*, Mackay, Queensland, viewed 12 June 2012, <http://www.mimapsmackay.com.au/>.

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

Melbourne Water 2010, *Constructed Wetlands Guidelines*, Melbourne Water Corporation, Melbourne, Victoria.

Mullaly, J 2012, 'Creating a WSUD Future: Managing Logan City Council's Water Sensitive Urban Design Assests', in Stormwater Industry Association of Queensland State Conference:

proceedings of the Stormwater Industry Association of Queensland State Conference, Brisbane, Australia, 28 May - 1 June.

Newman, P & Mouritz, M 1996, 'Principles and planning opportunities for community scale systems of water and waste management', *Desalination*, vol. 106, no. 1–3, pp. 339-54.

O'Neill, A & Leinster, S 2009, *Stormwater Quality Performance Curves & Stormwater Quality Objectives for Mackay*, DesignFlow, Southport, Queensland.

Planning Scheme for the City of Mackay 2006, (Mackay).

Queensland Development Code, MP 4.2.

QUDM See: Department of Natural Resources and Water.

Reserve Bank of Australia 2012, *Inflation Calculator*, Reserve Bank of Australia, viewed 25 May 2012, <http://www.rba.gov.au/calculator/annualDecimal.html>.

Roberts, M & King, D 2004, 'Proposed Rainwater Harvesting System for Aurora,' *Water Journal of the Australian Water Association*, vol. 40, no. 2, pp. 82-4.

Rozis, N & Rahman, A 2002, 'A Simple Method for Life Cycle Cost Assessment of Water Sensitive Urban Design', in 9th International Conference on Urban Drainage (9ICUD): *proceedings of the 9th International Conference on Urban Drainage (9ICUD)*, GSfU Drainage (ed.), ASCE, Portland, Oregon, 8-13 September.

Standards Australia 1999, *AS/NZS 4536:1999 Life cycle Costing - An application Guide*, Standards Australia, Homebush, New South Wales.

Standards Australia 2004, *AS/NZS 4300:2004 Risk Management*, Standards Australia, Homebush, New South Wales.

Taylor, A 2005a, *Structural Stormwater Quality BMP Cost / Size Relationship Information From the Literature,* Version 3, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.

Taylor, A 2005b, *Guidelines for evaluating the financial, ecological and social aspects of urban stormwater management measures to improve waterway health*, Technical Report, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.

Taylor, A & Fletcher, T 2005, 'Triple-bottom-line assessment of urban stormwater projects', in 10th International Conference on Urban Drainage: *proceedings of the 10th International Conference on Urban Drainage*, Copenhagen, Denmark, 21-26 August

Thomson, D & Leinster, S 2007, *Life cycle costs of water sensitive urban design (WSUD) treatment systems: Summary report*, A report for Brisbane City Council - City Design, Ecological Engineering, Brisbane, Queensland.

Upper Parramatta River Catchment Trust 2004, *Technical Guidelines for Western Sydney*, URS Australia Pty Ltd, North Sydney, New South Wales.

van Roon, M 2007, 'Water localisation and reclamation: Steps towards low impact urban design and development', *Journal of Environmental Management*, vol. 83, no. 4, pp. 437-47.

Water By Design 2006, *WSUD Technical Design Guidelines for South East Queensland*, Version 1, Healthy Waterways Partnership, Brisbane, Queensland.

Water By Design 2009, *Concept Design Guidelines for Water Sensitive Urban Design*, Version 1, South East Queensland Healthy Waterways Partnership, Brisbane, Queensland.

Water By Design 2010, *A Business Case for Best Practice Urban Stormwater Management*, Version 1.1, South East Queensland Healthy Waterways Partnership,, Brisbane, Queensland.

Wong, TH, Breen, PF, Somes, NL & Lloyd, SD 1999, *Managing Urban Stormwater Using Constructed Wetlands*, Industry Report 98/7, Second Edition, Cooperative Research Centre for Catchment Hydrology, Melbourne, Victoria.

Appendix A

Project Specification

University of Southern Queensland
FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR: **Gerard William BLACK**

TOPIC: WATER SENSITIVE URBAN DESIGN (WSUD) – TO REGIONALISE OR NOT TO REGIONALISE

SUPERVISOR(S): Dr Ian Brodie, University of Southern Queensland
Mr Trevor Corney, Cardno (Qld)

SPONSORSHIP: Cardno (Qld) & Mackay Regional Council

PROJECT AIM: To determine the sustainability of a regionalised approach to WSUD for a proposed development within the Bakers Creek Catchment by investigating and comparing contributing factors for both regionalised and localised treatment strategies.

PROGRAMME: **Issue C, 17 September 2012**

1. Research and identify contributing factors and practises involved with WSUD for both local and regional treatment strategies for a typical WSUD development.
2. Design and model a typical WSUD layout using a localised WSUD treatment approach that satisfies Mackay Regional Council's (MRC) stormwater quality objectives.
3. Analyse the contributing factors of a local treatment strategy for a typical WSUD residential development.
4. Design and model a typical WSUD layout using a regional WSUD treatment approach that satisfies MRC's stormwater quality objectives.
5. Analyse the contributing factors of a regional treatment strategy for a typical WSUD residential development.
6. Evaluate the difference between local and regional WSUD treatment strategy.

As time permits:
Investigate the effect a maintained and environmentally effective biopod would have on the final outcome of the multi-criteria analysis.

AGREED:

Gerard W Black (Student): G.W. Black Date: 17 / 09 / 2012

Dr Ian Brodie (Supervisor): I. Brodie Date: 17 / 09 / 2012

Mr Trevor Corney (Supervisor): T.R. Corney Date: 17 / 09 / 2012

Examiner/Co-examiner: ______________________ Date: / / 2012

Appendix B

Sedimentation Basin & Constructed Wetland

Design Calculation Summary

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY				
	Calculation Task		CALCULATION SUMMARY	
			Outcome	Check
	Catchment Characteristics			
	Sedimentation Basin A	Residential	Ha	33.53
		Commercial	Ha	-
		Roads	Ha	-
		Storm event entering inlet pond (minor or major)	yr ARI	1
	Conceptual Design			
		Notional permanent pool depth	m	2.0
		Permanent pool level of sedimentation basin	m AHD	0.3
1	Determine design flows			
		'Design operation flow' (1 year ARI)	year ARI	1
		'Above design flow' (2 to 100 year ARI)	year ARI	2
	Time of concentration			
	Refer to relevant Local Government Guidelines and QUDM		minutes	15
	Identify rainfall intensities			
		'Design operation flow' - $I_{1\ year\ ARI}$	mm/hr	82
		'Above design flow'- $I_{2\ year\ ARI}$ to $I_{100\ year\ ARI}$	mm/hr	106
	Design runoff coefficient			
		'Design operation flow' - $C_{1\ year\ ARI}$		0.69
		'Above design flow'- $I_{2\ year\ ARI}$ to $I_{100\ year\ ARI}$		0.73
	Peak design flows			
		'Design operation flow' - 1 year ARI	m^3/s	3.03
		'Above design flow' – 2 to 100 year ARI	m^3/s	4.15
2	Confirm Treatment Performance of Concept Design			
		Capture efficiency (of 125 µm sediment)	%	90
		Area of sedimentation basin	m^2	1400
3	Confirm size and dimension of sedimentation basin			
		Inlet zone size		
		Area of sedimentation basin	m^2	950
		Aspect ratio	L:W	15.5x62
		Hydraulic efficiency		0.4
		Depth of permanent pool	m	2.0
	Storage volume for sediments			
		Sedimentation basin storage Volume V_s	m^3	950
		Volume of accumulated sediment over 5 years ($V_{s:5yr}$)	m^3	160
		$V_s > V_{s:5yr}$		
		Sediment cleanout frequency	years	28.1
	Internal batters			
		Edge batter slope	V:H	1:5
		Fence required		No
4	Design inflow systems			
		Provision of scour protection or energy dissipation		Yes
5	Design outlet structures			
	Design of 'control' outlet - overflow pit and pipe outlet configuration			
		Overflow pit crest level	m AHD	N/A
		Overflow pit dimension	L x W	5.0x5.4
		Provision of debris trap		
		Connection pipe dimension	mm diam	3/900dia.
		Connection pipe invert level	m AHD	N/A

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY			
Calculation Task	CALCULATION SUMMARY		
	Outcome		Check
Design of 'control' outlet - weir configuration			
Weir crest level		m AHD	N/A
Weir length		m	
Design of 'spillway' outlet - weir configuration			
Weir crest level		m AHD	N/A
Weir length		m	
Depth above spillway		m	
Freeboard to top of embankment		m	

	SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY			
	Calculation Task		CALCULATION SUMMARY	
		Outcome		Check
	Catchment Characteristics			
	Sedimentation Basin B			
	Residential	Ha	10.3	
	Commercial	Ha	-	
	Roads	Ha	-	
	Storm event entering inlet pond (minor or major)	yr ARI	1	
	Conceptual Design			
	Notional permanent pool depth	m	2.0	
	Permanent pool level of sedimentation basin	m AHD	0.3	
1	**Determine design flows**			
	'Design operation flow' (1 year ARI)	year ARI	1	
	'Above design flow' (2 to 100 year ARI)	year ARI	2	
	Time of concentration			
	Refer to relevant Local Government Guidelines and QUDM	minutes	15	
	Identify rainfall intensities			
	'Design operation flow' - $I_{1\ year\ ARI}$	mm/hr	82	
	'Above design flow'- $I_{2\ year\ ARI}$ to $I_{100\ year\ ARI}$	mm/hr	106	
	Design runoff coefficient			
	'Design operation flow' - $C_{1\ year\ ARI}$		0.69	
	'Above design flow'- $I_{2\ year\ ARI}$ to $I_{100\ year\ ARI}$		0.73	
	Peak design flows			
	'Design operation flow' - 1 year ARI	m^3/s	1.78	
	'Above design flow' – 2 to 100 year ARI	m^3/s	2.30	
2	**Confirm Treatment Performance of Concept Design**			
	Capture efficiency (of 125 µm sediment)	%	90	
	Area of sedimentation basin	m^2	600	
3	**Confirm size and dimension of sedimentation basin**			
	Inlet zone size			
	Area of sedimentation basin	m^2	500	
	Aspect ratio	L:W	11.2x44.8	
	Hydraulic efficiency		0.4	
	Depth of permanent pool	m	2.0	
	Storage volume for sediments			
	Sedimentation basin storage Volume V_s	m^3	500	
	Volume of accumulated sediment over 5 years ($V_{s:5yr}$)	m^3	74.1	
	$V_s > V_{s:5yr}$			
	Sediment cleanout frequency	years	33.7	
	Internal batters			
	Edge batter slope	V:H	1:5	
	Fence required		No	
4	**Design inflow systems**			
	Provision of scour protection or energy dissipation		Yes	
5	**Design outlet structures**			
	Design of 'control' outlet - overflow pit and pipe outlet configuration			
	Overflow pit crest level	m AHD	N/A	
	Overflow pit dimension	L x W	3.75x3.75	
	Provision of debris trap			
	Connection pipe dimension	mm diam	2/750dia.	
	Connection pipe invert level	m AHD	N/A	

SEDIMENTATION BASIN DESIGN CALCULATION SUMMARY				
Calculation Task		CALCULATION SUMMARY		
		Outcome		Check
Design of 'control' outlet - weir configuration				
	Weir crest level		m AHD	N/A
	Weir length		m	
Design of 'spillway' outlet - weir configuration				
	Weir crest level		m AHD	N/A
	Weir length		m	
	Depth above spillway		m	
	Freeboard to top of embankment		m	

CONSTRUCTED WETLANDS DESIGN CALCULATION SUMMARY

	CALCULATION SUMMARY		
	Calculation Task	Outcome	Check
	Catchment Characteristics		
	Catchment area	ha	33.53
	Catchment land use (i.e residential, commercial etc.)		urban
	Storm event entering inlet pond (minor or major)		1
	Conceptual Design		
	Macrophyte zone area	m^2	21700
	Permanent pool level of macrophyte zone	m AHD	0.3
	Extended detention depth (0.25-0.5m)	m	0.6
	Notional detention time	hrs	39.6
1	**Confirm Treatment Performance of Concept Design**		
	Total suspended solids (Figure 6-2)	% removal	76
	Total phosphorus (Figure 6-3)	% removal	65
	Total nitrogen (Figure 6-4)	% removal	39.6
2	**Determine design flows**		
	'Design operation flow' (1 year ARI)	year ARI	1
	'Above design flow' (2-100 year ARI)	year ARI	2
	Time of concentration		
	(Refer to relevant local government guidelines and QUDM)	minutes	15
	Identify rainfall intensities		
	'Design operation flow' - $I_{1\ year\ ARI}$	mm/hr	82
	'Above design flow'- $I_{2-100\ year\ ARI}$	mm/hr	106
	Peak design flows		
	'Design operation flow' 1 year ARI	m^3/s	5.33
	'Above design flow' – 2-100 year ARI	m^3/s	7.0
3	**Design inlet zone**		
	Refer to sedimentation basin (Chapter 4) for detailed check sheet		
	Is a GPT required?		
	Suitable GPT selected and maintenance considered?		No
	Inlet zone size		
	Target Sediment Size for Inlet Zone	μm	125
	Capture efficiency	%	90
	Inlet zone area (Figure 4.2 in Chapter 4)	m^2	1450
	$V_s > V_{s:5yr}$		Yes
	Inlet zone connection to macrophyte zone		
	Overflow pit crest level	m AHD	See Sedimentation Basin Designs
	Overflow pit dimension	L x W	
	Provision of debris trap		
	Connection pipe dimension	mm ø	
	Connection pipe invert level	m AHD	
	High flow by-pass weir		
	Weir Length	m	
	High flow by-pass weir crest level (top of extended detention)	m AHD	
4	**Designing the macrophyte zone**		
	Area of Macrophyte Zone	m^2	See Sedimentation Basin Designs
	Aspect Ratio	L:W	
	Hydraulic Efficiency		

CONSTRUCTED WETLANDS DESIGN CALCULATION SUMMARY				
		CALCULATION SUMMARY		
	Calculation Task	Outcome		Check
5	Design macrophyte zone outlet			
	Riser outlet			
	Target maximum discharge (Q_{max})		m^3/s	N/A
	Uniform Detention Time Relationship for Riser			
	Maintenance Drain			
	Maintenance drainage rate (drain over 12hrs)		m^3/s	N/A
	Diameter of maintenance drain pipe		mm	
	Diameter of maintenance drain valve		mm	
	Discharge Pipe			
	Diameter of discharge pipe		mm	N/A
6	Design high flow by-pass 'channel'			
	Longitudinal slope		%	N/A
	Base width		m	
	Batter slopes		H:V	
7	Verification checks			
	Macrophyte zone re-suspension protection			N/A
	Confirm treatment performance			N/A

Appendix C

Survey Questionnaire and Results

Cuttersfield Resident Survey Questionnaire

Introduction

As a result of Mackay's topography (flat) and high annual rainfall, stormwater runoff plays a large part in the life of the Mackay resident. Flooding, pollution and nuisance issues often occur for Mackay's residents after a large rain event. This results in environmental damage, damage to property and distress to residents.

Water Sensitive Urban Design (WSUD) is a holistic approach to water management and urban planning that upholds environmental values and sustainability.

Mackay Regional Council have taken the initiative to become a leader in promoting and adopting WSUD strategies for future urban development within Mackay.

This survey aims to investigate the social elements associated with five WSUD stormwater treatment elements proposed by Council for new urban developments in the Mackay region;

- Bioretention Basin
- Bioretention Swales
- Constructed Wetlands
- Street Trees
- Biopods

1. What is your first name (Optional)?

2. What is your age?

- 17 or younger
- 18-30
- 31-40
- 41-50
- 51-60
- 61 or older

3. What is your gender?

- Female
- Male

4. Which best describes your current living situation?

5. In what suburb or estate do you currently live?

Cuttersfield Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) in the Mackay Region

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

- ○ Yes
- ○ No
- ○ Don't Know

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

- ○ Yes
- ○ No
- ○ Don't Know

Cuttersfield Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Biopods

Did you know? Biopods are vegetated bioretention systems found within 'footpaths' or street verges.

Below is an example of a biopod located in Pelorus Court, Cuttersfield. This example is typical of biopods found in Cuttersfield.

Please answer the following questions relating to this type of treatment measure...

8. Are you aware of 'biopods' located within your local estate / suburb (if any)?

- ○ Yes
- ○ No
- ○ Don't Know

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- ○ Yes
- ○ No
- ○ Not Sure

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a 'biopod' located in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

11. Overall, do you think the design of a 'biopod' (compared to traditional designs with no stormwater treatment) increases, decreases or makes no difference to the safety of your neighbourhood?

- ○ Increase safety
- ○ Make no difference to safety
- ○ Decrease safety
- ○ Don't know

12. Do you think the presence of a 'biopod' in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

- ○ Increase educational and awareness opportunities
- ○ Make no difference
- ○ Decrease educational and awareness opportunities
- ○ Don't know

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, etc.) of a 'biopod' in your neighbourhood?

- ○ Yes
- ○ No
- ○ Not sure
- ○ Only if it's located directly outside my residence

Cuttersfield Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Bioretention Swales

Did you know? Bioretention swales are vegetated overland depressions that function similarly to bioretention basins and are often landscape features in urban developments.

Below is an example of a bioretention swale located in Canecutters Drive, Cuttersfield Ooralea. This example is typical of bioretention swales found in new developments.

Please answer the following questions relating to this type of treatment measure...

14. Are you aware of any bioretention swales located within your local estate / suburb (if any)?

- ◯ Yes
- ◯ No
- ◯ Don't Know

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- ◯ Yes
- ◯ No
- ◯ Not Sure

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention swale in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

17. Overall, do you think the design of a bioretention swale (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

○ Increase safety

○ Make no difference to safety

○ Decrease safety

○ Don't know

18. Do you think the presence of a bioretention swale in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

○ Increase educational and awareness opportunities

○ Make no difference

○ Decrease educational and awareness opportunities

○ Don't know

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention swale in your neighbourhood?

○ Yes

○ No

○ Not sure

○ Only if it's located directly outside my residence

Cuttersfield Resident Survey Questionnaire

Finished!

Thank you for your time

Cuttersfield Resident Survey Results

1. What is your first name (Optional)?

	Response Count
	0
answered question	**0**
skipped question	**25**

2. What is your age?

	Response Percent	Response Count
17 or younger	0.0%	0
18-30	20.0%	5
31-40	**28.0%**	**7**
41-50	24.0%	6
51-60	20.0%	5
61 or older	8.0%	2
	answered question	**25**
	skipped question	**0**

3. What is your gender?

	Response Percent	Response Count
Female	36.0%	9
Male	**64.0%**	**16**
	answered question	**25**
	skipped question	**0**

4. Which best describes your current living situation?

		Response Percent	Response Count
Home Owner		44.0%	11
Renting/Leasing		**52.0%**	**13**
Living at Home/Boarding		4.0%	1
		answered question	**25**
		skipped question	**0**

5. In what suburb or estate do you currently live?

	Response Percent	Response Count
Do not live in Mackay region	0.0%	0
Andergrove	0.0%	0
Avalon Estate	0.0%	0
Beaconsfield	0.0%	0
Beaconsfield Heights	0.0%	0
Blacks Beach	0.0%	0
Blacks Beach Cove	0.0%	0
Bucasia	0.0%	0
Cremorne	0.0%	0
Cuttersfield Estate	**100.0%**	**25**
Dolphin Heads	0.0%	0
Driftwood Sands	0.0%	0
East Mackay	0.0%	0
Eimeo	0.0%	0
Erakala	0.0%	0
Foulden	0.0%	0
Glenella	0.0%	0
Glenrowan	0.0%	0
Kerrisdale Estate	0.0%	0
Kidston Cove	0.0%	0
Kuttabul	0.0%	0
Lagoons Estate	0.0%	0
Mackay Harbour	0.0%	0
Miraflores Estate	0.0%	0
Mount Pleasant	0.0%	0

Nabilla Riverlink Estate	0.0%	0
Nindaroo	0.0%	0
North Mackay	0.0%	0
Oceanview Estate	0.0%	0
Ooralea	0.0%	0
Pacific Parks	0.0%	0
Paget	0.0%	0
Pioneer Lakes Residential Community	0.0%	0
Plantation Palms	0.0%	0
Premier Gardens	0.0%	0
Premier Vista	0.0%	0
Racecourse	0.0%	0
Richana Estate	0.0%	0
Richmond	0.0%	0
Richmond Hills	0.0%	0
Royal Sands Estate	0.0%	0
Rural View	0.0%	0
Settlers Rise	0.0%	0
Shoal Point	0.0%	0
Shoal Point Waters	0.0%	0
Slade Point	0.0%	0
South Mackay	0.0%	0
Sugarfields	0.0%	0
Sugarview Estate	0.0%	0
Te Kowai	0.0%	0
The Raceview Ooralea	0.0%	0
The Waters Ooralea	0.0%	0

West Mackay		0.0%	0
		answered question	**25**
		skipped question	**0**

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

		Response Percent	Response Count
Yes		**56.0%**	**14**
No		36.0%	9
Don't Know		8.0%	2
		answered question	**25**
		skipped question	**0**

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

		Response Percent	Response Count
Yes		36.0%	9
No		**60.0%**	**15**
Don't Know		4.0%	1
		answered question	**25**
		skipped question	**0**

8. Are you aware of 'biopods' located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	**88.0%**	**22**
No	8.0%	2
Don't Know	4.0%	1
answered question		**25**
skipped question		**0**

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	32.0%	8
No	**60.0%**	**15**
Not Sure	8.0%	2
answered question		**25**
skipped question		**0**

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a 'biopod' located in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**48.0% (12)**	28.0% (7)	16.0% (4)	8.0% (2)	25
Habitat for local native animals	16.0% (4)	**48.0% (12)**	28.0% (7)	8.0% (2)	25
Presence of pests (e.g. mosquitoes)	28.0% (7)	**44.0% (11)**	20.0% (5)	8.0% (2)	25
Access to houses by all community members	24.0% (6)	24.0% (6)	**44.0% (11)**	8.0% (2)	25
On-street parking	16.0% (4)	24.0% (6)	**48.0% (12)**	12.0% (3)	25
Area's recreational opportunities (walking, cycling, jogging, etc.)	28.0% (7)	32.0% (8)	**40.0% (10)**	0.0% (0)	25
Area's aesthetic appeal	4.0% (1)	12.0% (3)	**80.0% (20)**	4.0% (1)	25
Improved air quality	12.0% (3)	**52.0% (13)**	12.0% (3)	24.0% (6)	25
Integrate the local area with the existing adjoining natural area's	24.0% (6)	**40.0% (10)**	16.0% (4)	20.0% (5)	25
				answered question	**25**
				skipped question	**0**

11. Overall, do you think the design of a 'biopod' (compared to traditional designs with no stormwater treatment) increases, decreases or makes no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	4.0%	1
Make no difference to safety	20.0%	5
Decrease safety	**68.0%**	**17**
Don't know	8.0%	2
	answered question	**25**
	skipped question	**0**

12. Do you think the presence of a 'biopod' in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	20.0%	5
Make no difference	**64.0%**	**16**
Decrease educational and awareness opportunities	12.0%	3
Don't know	4.0%	1
	answered question	**25**
	skipped question	**0**

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, etc.) of a 'biopod' in your neighbourhood?

	Response Percent	Response Count
Yes	28.0%	7
No	24.0%	6
Not sure	8.0%	2
Only if it's located directly outside my residence	**40.0%**	**10**
	answered question	**25**
	skipped question	**0**

14. Are you aware of any bioretention swales located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	**88.0%**	**22**
No	4.0%	1
Don't Know	8.0%	2
	answered question	**25**
	skipped question	**0**

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	40.0%	10
No	**56.0%**	**14**
Not Sure	4.0%	1
	answered question	**25**
	skipped question	**0**

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention swale in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**52.0% (13)**	24.0% (6)	16.0% (4)	8.0% (2)	25
Habitat for local native animals	**64.0% (16)**	20.0% (5)	12.0% (3)	4.0% (1)	25
Presence of pests (e.g. mosquitoes)	16.0% (4)	**48.0% (12)**	28.0% (7)	8.0% (2)	25
Access to houses by all community members	20.0% (5)	**48.0% (12)**	24.0% (6)	8.0% (2)	25
On-street parking	25.0% (6)	**37.5% (9)**	33.3% (8)	4.2% (1)	24
Area's recreational opportunities (walking, cycling, jogging, etc.)	**64.0% (16)**	20.0% (5)	16.0% (4)	0.0% (0)	25
Area's aesthetic appeal	**72.0% (18)**	20.0% (5)	4.0% (1)	4.0% (1)	25
Improved air quality	**40.0% (10)**	**40.0% (10)**	8.0% (2)	12.0% (3)	25
Integrate the local area with the existing adjoining natural area's	**44.0% (11)**	36.0% (9)	12.0% (3)	8.0% (2)	25
				answered question	**25**
				skipped question	**0**

17. Overall, do you think the design of a bioretention swale (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	**52.0%**	**13**
Make no difference to safety	32.0%	8
Decrease safety	8.0%	2
Don't know	8.0%	2
answered question		**25**
skipped question		**0**

18. Do you think the presence of a bioretention swale in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**52.0%**	**13**
Make no difference	24.0%	6
Decrease educational and awareness opportunities	8.0%	2
Don't know	16.0%	4
answered question		**25**
skipped question		**0**

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention swale in your neighbourhood?

	Response Percent	Response Count
Yes	16.0%	4
No	**56.0%**	**14**
Not sure	8.0%	2
Only if it's located directly outside my residence	20.0%	5
	answered question	**25**
	skipped question	**0**

Blacks Beach Cove Resident Survey Questionnaire

Introduction

As a result of Mackay's topography (flat) and high annual rainfall, stormwater runoff plays a large part in the life of the Mackay resident. Flooding, pollution and nuisance issues often occur for Mackay's residents after a large rain event. This results in environmental damage, damage to property and distress to residents.

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Mackay Regional Council have taken the initiative to become a leader in promoting and adopting WSUD strategies for future urban development within Mackay.

This survey aims to investigate the social elements associated with five WSUD stormwater treatment elements proposed by Council for new urban developments in the Mackay region;

- Bioretention Basin
- Bioretention Swales
- Constructed Wetlands
- Street Trees
- Biopods

1. What is your first name (Optional)?

2. What is your age?

- ○ 17 or younger
- ○ 18-30
- ○ 31-40
- ○ 41-50
- ○ 51-60
- ○ 61 or older

3. What is your gender?

- ○ Female
- ○ Male

4. Which best describes your current living situation?

5. In what suburb or estate do you currently live?

Blacks Beach Cove Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) in the Mackay Region

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

- ○ Yes
- ○ No
- ○ Don't Know

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

- ○ Yes
- ○ No
- ○ Don't Know

Blacks Beach Cove Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Bioretention Basins

Did you know? Bioretention basins are landscaped areas that utilize vegetation to improve water quality by filtering stormwater runoff and allowing vegetation uptake of nutrients.

Below is an example of a bioretention basin located in Chenoweth Drive, Blacks Beach Cove. This example is typical of bioretention basins found in new developments.

Please answer the following questions relating to this type of treatment measure...

8. Are you aware of any bioretention basins located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention basin in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

11. Overall, do you think the design of the bioretention basin (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

○ Increase safety

○ Make no difference to safety

○ Decrease safety

○ Don't know

12. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

○ Increase educational and awareness opportunities

○ Make no difference

○ Decrease educational and awareness opportunities

○ Don't know

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention basin in your neighbourhood?

○ Yes

○ No

○ Not sure

○ Only if it's located directly outside my residence

Blacks Beach Cove Resident Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Constructed Wetlands

Did you know? Constructed wetlands are shallow, extensively vegetated water bodies that remove pollutants from stormwater.

Below is an example of a constructed wetland located in Blacks Beach Cove. This example is typical of constructed wetlands found in new developments.

Please answer the following questions relating to this type of treatment measure...

14. Are you aware of a constructed wetland located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a constructed wetland in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

17. Overall, do you think the design of a constructed wetland (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

- ○ Increase safety
- ○ Make no difference to safety
- ○ Decrease safety
- ○ Don't know

18. Do you think the presence of a constructed wetland in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

- ○ Increase educational and awareness opportunities
- ○ Make no difference
- ○ Decrease educational and awareness opportunities
- ○ Don't know

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a constructed wetland in your neighbourhood?

- ○ Yes
- ○ No
- ○ Not sure
- ○ Only if it's located directly outside my residence

Blacks Beach Cove Resident Survey Questionnaire

Finished!

Thank you for your time

Blacks Beach Cove Resident Survey Results

1. What is your first name (Optional)?

	Response Count
	0
answered question	**0**
skipped question	**25**

2. What is your age?

	Response Percent	Response Count
17 or younger	4.0%	1
18-30	16.0%	4
31-40	24.0%	6
41-50	**32.0%**	**8**
51-60	20.0%	5
61 or older	4.0%	1
	answered question	**25**
	skipped question	**0**

3. What is your gender?

	Response Percent	Response Count
Female	48.0%	12
Male	**52.0%**	**13**
	answered question	**25**
	skipped question	**0**

4. Which best describes your current living situation?

		Response Percent	Response Count
Home Owner		40.0%	10
Renting/Leasing		**60.0%**	**15**
Living at Home/Boarding		0.0%	0
		answered question	**25**
		skipped question	**0**

5. In what suburb or estate do you currently live?

		Response Percent	Response Count
Do not live in Mackay region		0.0%	0
Andergrove		0.0%	0
Avalon Estate		0.0%	0
Beaconsfield		0.0%	0
Beaconsfield Heights		0.0%	0
Blacks Beach		0.0%	0
Blacks Beach Cove		**100.0%**	**25**
Bucasia		0.0%	0
Cremorne		0.0%	0
Cuttersfield Estate		0.0%	0
Dolphin Heads		0.0%	0
Driftwood Sands		0.0%	0
East Mackay		0.0%	0
Eimeo		0.0%	0
Erakala		0.0%	0
Foulden		0.0%	0
Glenella		0.0%	0
Glenrowan		0.0%	0
Kerrisdale Estate		0.0%	0
Kidston Cove		0.0%	0
Kuttabul		0.0%	0
Lagoons Estate		0.0%	0
Mackay Harbour		0.0%	0
Miraflores Estate		0.0%	0
Mount Pleasant		0.0%	0

Nabilla Riverlink Estate	0.0%	0
Nindaroo	0.0%	0
North Mackay	0.0%	0
Oceanview Estate	0.0%	0
Ooralea	0.0%	0
Pacific Parks	0.0%	0
Paget	0.0%	0
Pioneer Lakes Residential Community	0.0%	0
Plantation Palms	0.0%	0
Premier Gardens	0.0%	0
Premier Vista	0.0%	0
Racecourse	0.0%	0
Richana Estate	0.0%	0
Richmond	0.0%	0
Richmond Hills	0.0%	0
Royal Sands Estate	0.0%	0
Rural View	0.0%	0
Settlers Rise	0.0%	0
Shoal Point	0.0%	0
Shoal Point Waters	0.0%	0
Slade Point	0.0%	0
South Mackay	0.0%	0
Sugarfields	0.0%	0
Sugarview Estate	0.0%	0
Te Kowai	0.0%	0
The Raceview Ooralea	0.0%	0
The Waters Ooralea	0.0%	0

West Mackay	0.0%	0
	answered question	25
	skipped question	0

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

	Response Percent	Response Count
Yes	**52.0%**	**13**
No	40.0%	10
Don't Know	8.0%	2
	answered question	**25**
	skipped question	**0**

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

	Response Percent	Response Count
Yes	28.0%	7
No	**60.0%**	**15**
Don't Know	12.0%	3
	answered question	**25**
	skipped question	**0**

8. Are you aware of any bioretention basins located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	**56.0%**	**14**
No	32.0%	8
Don't Know	12.0%	3
answered question		**25**
skipped question		**0**

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	24.0%	6
No	**64.0%**	**16**
Not Sure	12.0%	3
answered question		**25**
skipped question		**0**

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention basin in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**36.0% (9)**	**36.0% (9)**	16.0% (4)	12.0% (3)	25
Habitat for local native animals	**44.0% (11)**	28.0% (7)	20.0% (5)	8.0% (2)	25
Presence of pests (e.g. mosquitoes)	20.0% (5)	24.0% (6)	**52.0% (13)**	4.0% (1)	25
Access to houses by all community members	16.0% (4)	**68.0% (17)**	8.0% (2)	8.0% (2)	25
On-street parking	28.0% (7)	**40.0% (10)**	20.0% (5)	12.0% (3)	25
Area's recreational opportunities (walking, cycling, jogging, etc.)	**48.0% (12)**	28.0% (7)	20.0% (5)	4.0% (1)	25
Area's aesthetic appeal	**40.0% (10)**	32.0% (8)	24.0% (6)	4.0% (1)	25
Improved air quality	20.0% (5)	**48.0% (12)**	20.0% (5)	12.0% (3)	25
Integrate the local area with the existing adjoining natural area's	**52.0% (13)**	20.0% (5)	16.0% (4)	12.0% (3)	25
				answered question	**25**
				skipped question	**0**

11. Overall, do you think the design of the bioretention basin (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	12.0%	3
Make no difference to safety	**48.0%**	**12**
Decrease safety	28.0%	7
Don't know	12.0%	3
	answered question	**25**
	skipped question	**0**

12. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	32.0%	8
Make no difference	**48.0%**	**12**
Decrease educational and awareness opportunities	12.0%	3
Don't know	8.0%	2
	answered question	**25**
	skipped question	**0**

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention basin in your neighbourhood?

	Response Percent	Response Count
Yes	16.0%	4
No	**56.0%**	**14**
Not sure	16.0%	4
Only if it's located directly outside my residence	12.0%	3
answered question		**25**
skipped question		**0**

14. Are you aware of a constructed wetland located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	**76.0%**	**19**
No	20.0%	5
Don't Know	4.0%	1
answered question		**25**
skipped question		**0**

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	**60.0%**	**15**
No	32.0%	8
Not Sure	8.0%	2
answered question		**25**
skipped question		**0**

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a constructed wetland in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	24.0% (6)	**32.0% (8)**	28.0% (7)	16.0% (4)	25
Habitat for local native animals	**68.0% (17)**	20.0% (5)	8.0% (2)	4.0% (1)	25
Presence of pests (e.g. mosquitoes)	12.0% (3)	24.0% (6)	**60.0% (15)**	4.0% (1)	25
Access to houses by all community members	8.0% (2)	**68.0% (17)**	8.0% (2)	16.0% (4)	25
On-street parking	12.0% (3)	**64.0% (16)**	12.0% (3)	12.0% (3)	25
Area's recreational opportunities (walking, cycling, jogging, etc.)	**52.0% (13)**	20.0% (5)	4.0% (1)	24.0% (6)	25
Area's aesthetic appeal	**52.0% (13)**	16.0% (4)	16.0% (4)	16.0% (4)	25
Improved air quality	28.0% (7)	24.0% (6)	**36.0% (9)**	12.0% (3)	25
Integrate the local area with the existing adjoining natural area's	**60.0% (15)**	20.0% (5)	8.0% (2)	12.0% (3)	25
answered question					**25**
skipped question					**0**

17. Overall, do you think the design of a constructed wetland (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	12.0%	3
Make no difference to safety	24.0%	6
Decrease safety	**52.0%**	**13**
Don't know	12.0%	3
answered question		**25**
skipped question		**0**

18. Do you think the presence of a constructed wetland in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**72.0%**	**18**
Make no difference	28.0%	7
Decrease educational and awareness opportunities	0.0%	0
Don't know	0.0%	0
answered question		**25**
skipped question		**0**

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a constructed wetland in your neighbourhood?

	Response Percent	Response Count
Yes	12.0%	3
No	**64.0%**	**16**
Not sure	8.0%	2
Only if it's located directly outside my residence	16.0%	4
	answered question	**25**
	skipped question	**0**

General Online Social Survey Questionnaire

Introduction

As a result of Mackay's topography (flat) and high annual rainfall, stormwater runoff plays a large part in the life of the Mackay resident. Flooding, pollution and nuisance issues often occur for Mackay's residents after a large rain event. This results in environmental damage, damage to property and distress to residents.

Water Sensitive Urban Design (WSUD) is a holistic approach to water management and urban planning that upholds environmental values and sustainability.

Mackay Regional Council have taken the initiative to become a leader in promoting and adopting WSUD strategies for future urban development within Mackay.

This survey aims to investigate the social elements associated with five WSUD stormwater treatment elements proposed by Council for new urban developments in the Mackay region;

- Bioretention Basin
- Bioretention Swales
- Constructed Wetlands
- Street Trees
- Biopods

1. What is your first name (Optional)?

2. What is your age?

- 17 or younger
- 18-30
- 31-40
- 41-50
- 51-60
- 61 or older

3. What is your gender?

- Female
- Male

4. Which best describes your current living situation?

5. In what suburb or estate do you currently live?

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) in the Mackay Region

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

- Yes
- No
- Don't Know

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

- Yes
- No
- Don't Know

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Bioretention Basins

Did you know? Bioretention basins are landscaped areas that utilize vegetation to improve water quality by filtering stormwater runoff and allowing vegetation uptake of nutrients.

Below is an example of a bioretention basin located in Chenoweth Drive, Blacks Beach Cove. This example is typical of bioretention basins found in new developments.

Please answer the following questions relating to this type of treatment measure...

8. Are you aware of any bioretention basins located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

General Online Social Survey Questionnaire

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention basin in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	◯	◯	◯	◯
Habitat for local native animals	◯	◯	◯	◯
Presence of pests (e.g. mosquitoes)	◯	◯	◯	◯
Access to houses by all community members	◯	◯	◯	◯
On-street parking	◯	◯	◯	◯
Area's recreational opportunities (walking, cycling, jogging, etc.)	◯	◯	◯	◯
Area's aesthetic appeal	◯	◯	◯	◯
Improved air quality	◯	◯	◯	◯
Integrate the local area with the existing adjoining natural area's	◯	◯	◯	◯

11. Overall, do you think the design of the bioretention basin (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

- ◯ Increase safety
- ◯ Make no difference to safety
- ◯ Decrease safety
- ◯ Don't know

12. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

- ◯ Increase educational and awareness opportunities
- ◯ Make no difference
- ◯ Decrease educational and awareness opportunities
- ◯ Don't know

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention basin in your neighbourhood?

- ◯ Yes
- ◯ No
- ◯ Not sure
- ◯ Only if it's located directly outside my residence

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Bioretention Swales

Did you know? Bioretention swales are vegetated overland depressions that function similarly to bioretention basins and are often landscape features in urban developments.

Below is an example of a bioretention swale located in Canecutters Drive, Cuttersfield Ooralea. This example is typical of bioretention swales found in new developments.

Please answer the following questions relating to this type of treatment measure...

14. Are you aware of any bioretention swales located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention swale in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

17. Overall, do you think the design of a bioretention swale (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

○ Increase safety

○ Make no difference to safety

○ Decrease safety

○ Don't know

18. Do you think the presence of a bioretention swale in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

○ Increase educational and awareness opportunities

○ Make no difference

○ Decrease educational and awareness opportunities

○ Don't know

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention swale in your neighbourhood?

○ Yes

○ No

○ Not sure

○ Only if it's located directly outside my residence

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Street Trees

Did you know? Street Trees are landscape features as well as treatment devices for stormwater runoff.

Below is an example of a street tree located in Canecutters Drive, Cuttersfield Ooralea. This example is typical of street trees found in new developments.

Please answer the following questions relating to this type of treatment measure...

20. Are you aware of any street trees located within your local estate / suburb (if any)?

- ○ Yes
- ○ No
- ○ Don't Know

21. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- ○ Yes
- ○ No
- ○ Not Sure

22. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a street tree in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	◯	◯	◯	◯
Habitat for local native animals	◯	◯	◯	◯
Presence of pests (e.g. mosquitoes)	◯	◯	◯	◯
Access to houses by all community members	◯	◯	◯	◯
On-street parking	◯	◯	◯	◯
Area's recreational opportunities (walking, cycling, jogging, etc.)	◯	◯	◯	◯
Area's aesthetic appeal	◯	◯	◯	◯
Improved air quality	◯	◯	◯	◯
Integrate the local area with the existing adjoining natural area's	◯	◯	◯	◯

23. Overall, do you think the design of the stormwater treatment measure (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

◯ Increase safety

◯ Make no difference to safety

◯ Decrease safety

◯ Don't know

24. Do you think the presence of a street trees in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

◯ Increase educational and awareness opportunities

◯ Make no difference

◯ Decrease educational and awareness opportunities

◯ Don't know

25. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of street trees in your neighbourhood?

◯ Yes

◯ No

◯ Not sure

◯ Only if it's located directly outside my residence

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Constructed Wetlands

Did you know? Constructed wetlands are shallow, extensively vegetated water bodies that remove pollutants from stormwater.

Below is an example of a constructed wetland located in Blacks Beach Cove. This example is typical of constructed wetlands found in new developments.

Please answer the following questions relating to this type of treatment measure...

26. Are you aware of a constructed wetland located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

27. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

28. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a constructed wetland in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

29. Overall, do you think the design of a constructed wetland (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

- ○ Increase safety
- ○ Make no difference to safety
- ○ Decrease safety
- ○ Don't know

30. Do you think the presence of a constructed wetland in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

- ○ Increase educational and awareness opportunities
- ○ Make no difference
- ○ Decrease educational and awareness opportunities
- ○ Don't know

31. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a constructed wetland in your neighbourhood?

- ○ Yes
- ○ No
- ○ Not sure
- ○ Only if it's located directly outside my residence

General Online Social Survey Questionnaire

Water Sensitive Urban Design (WSUD) - Biopods

Did you know? Biopods are vegetated bioretention systems found within 'footpaths' or street verges.

Below is an example of a biopod located in street verge in Bellvista Estate, Caloundra (Google Streetview 2012). This example is typical of biopod found in new developments.

Please answer the following questions relating to this type of treatment measure...

32. Are you aware of a 'biopod' located within your local estate / suburb (if any)?

- Yes
- No
- Don't Know

33. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

- Yes
- No
- Not Sure

34. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a 'biopod' located in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know
Nuisance flooding (ponding of water)	○	○	○	○
Habitat for local native animals	○	○	○	○
Presence of pests (e.g. mosquitoes)	○	○	○	○
Access to houses by all community members	○	○	○	○
On-street parking	○	○	○	○
Area's recreational opportunities (walking, cycling, jogging, etc.)	○	○	○	○
Area's aesthetic appeal	○	○	○	○
Improved air quality	○	○	○	○
Integrate the local area with the existing adjoining natural area's	○	○	○	○

35. Overall, do you think the design of a 'biopod' (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

- ○ Increase safety
- ○ Make no difference to safety
- ○ Decrease safety
- ○ Don't know

36. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

- ○ Increase educational and awareness opportunities
- ○ Make no difference
- ○ Decrease educational and awareness opportunities
- ○ Don't know

37. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, etc.) of a 'biopod' in your neighbourhood?

- ○ Yes
- ○ No
- ○ Not sure
- ○ Only if it's located directly outside my residence

General Online Social Survey Questionnaire

Finished!

Thank you for your time

General Online Social Survey Results

1. What is your first name (Optional)?

		Response Count
		48
	answered question	**48**
	skipped question	**22**

2. What is your age?

	Response Percent	Response Count
17 or younger	4.3%	3
18-30	**64.3%**	**45**
31-40	12.9%	9
41-50	11.4%	8
51-60	5.7%	4
61 or older	1.4%	1
	answered question	**70**
	skipped question	**0**

3. What is your gender?

	Response Percent	Response Count
Female	35.7%	25
Male	**64.3%**	**45**
	answered question	**70**
	skipped question	**0**

4. Which best describes your current living situation?

	Response Percent	Response Count
Home Owner	**50.0%**	**35**
Renting/Leasing	32.9%	23
Living at Home/Boarding	17.1%	12
answered question		**70**
skipped question		**0**

5. In what suburb or estate do you currently live?

	Response Percent	Response Count
Do not live in Mackay region	**27.1%**	**19**
Andergrove	17.1%	12
Avalon Estate	0.0%	0
Beaconsfield	8.6%	6
Beaconsfield Heights	0.0%	0
Blacks Beach	0.0%	0
Blacks Beach Cove	0.0%	0
Bucasia	1.4%	1
Cremorne	0.0%	0
Cuttersfield Estate	2.9%	2
Dolphin Heads	0.0%	0
Driftwood Sands	0.0%	0
East Mackay	2.9%	2
Eimeo	1.4%	1
Erakala	1.4%	1
Foulden	0.0%	0
Glenella	7.1%	5
Glenrowan	0.0%	0
Kerrisdale Estate	0.0%	0
Kidston Cove	0.0%	0
Kuttabul	0.0%	0
Lagoons Estate	0.0%	0
Mackay Harbour	2.9%	2
Miraflores Estate	0.0%	0

Mount Pleasant	2.9%	2
Nabilla Riverlink Estate	2.9%	2
Nindaroo	2.9%	2
North Mackay	7.1%	5
Oceanview Estate	0.0%	0
Ooralea	1.4%	1
Pacific Parks	0.0%	0
Paget	0.0%	0
Pioneer Lakes Residential Community	0.0%	0
Plantation Palms	1.4%	1
Premier Gardens	0.0%	0
Premier Vista	0.0%	0
Racecourse	0.0%	0
Richana Estate	0.0%	0
Richmond	0.0%	0
Richmond Hills	0.0%	0
Royal Sands Estate	1.4%	1
Rural View	0.0%	0
Settlers Rise	0.0%	0
Shoal Point	0.0%	0
Shoal Point Waters	0.0%	0
Slade Point	1.4%	1
South Mackay	4.3%	3
Sugarfields	0.0%	0
Sugarview Estate	0.0%	0
Te Kowai	1.4%	1
The Raceview Ooralea	0.0%	0

The Waters Ooralea	0.0%	0
West Mackay	0.0%	0
	answered question	**70**
	skipped question	**0**

6. Have you heard about new urban developments which are designed and built in a way that aims to manage stormwater as a resource and to minimise negative impacts of the development on the surrounding waterways?

	Response Percent	Response Count
Yes	**51.4%**	**36**
No	47.1%	33
Don't Know	1.4%	1
	answered question	**70**
	skipped question	**0**

7. Are you familiar with the term Water Sensitive Urban Design (WSUD)?

	Response Percent	Response Count
Yes	35.7%	25
No	**62.9%**	**44**
Don't Know	1.4%	1
	answered question	**70**
	skipped question	**0**

8. Are you aware of any bioretention basins located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	33.3%	22
No	**62.1%**	**41**
Don't Know	4.5%	3
	answered question	**66**
	skipped question	**4**

9. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	45.5%	30
No	**54.5%**	**36**
Not Sure	0.0%	0
	answered question	**66**
	skipped question	**4**

10. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention basin in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**47.0% (31)**	30.3% (20)	6.1% (4)	16.7% (11)	66
Habitat for local native animals	**81.8% (54)**	7.6% (5)	1.5% (1)	9.1% (6)	66
Presence of pests (e.g. mosquitoes)	19.7% (13)	13.6% (9)	**50.0% (33)**	16.7% (11)	66
Access to houses by all community members	22.7% (15)	**51.5% (34)**	7.6% (5)	18.2% (12)	66
On-street parking	9.1% (6)	**60.6% (40)**	9.1% (6)	21.2% (14)	66
Area's recreational opportunities (walking, cycling, jogging, etc.)	**62.1% (41)**	27.3% (18)	3.0% (2)	7.6% (5)	66
Area's aesthetic appeal	**86.4% (57)**	9.1% (6)	1.5% (1)	3.0% (2)	66
Improved air quality	**65.2% (43)**	21.2% (14)	0.0% (0)	13.6% (9)	66
Integrate the local area with the existing adjoining natural area's	**75.8% (50)**	15.2% (10)	0.0% (0)	9.1% (6)	66
				answered question	**66**
				skipped question	**4**

11. Overall, do you think the design of the bioretention basin (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	30.3%	20
Make no difference to safety	**56.1%**	**37**
Decrease safety	3.0%	2
Don't know	10.6%	7
	answered question	**66**
	skipped question	**4**

12. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**69.7%**	**46**
Make no difference	28.8%	19
Decrease educational and awareness opportunities	0.0%	0
Don't know	1.5%	1
	answered question	**66**
	skipped question	**4**

13. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention basin in your neighbourhood?

	Response Percent	Response Count
Yes	27.3%	18
No	**30.3%**	**20**
Not sure	13.6%	9
Only if it's located directly outside my residence	28.8%	19
answered question		**66**
skipped question		**4**

14. Are you aware of any bioretention swales located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	23.4%	15
No	**70.3%**	**45**
Don't Know	6.3%	4
answered question		**64**
skipped question		**6**

15. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	42.2%	27
No	**54.7%**	**35**
Not Sure	3.1%	2
	answered question	**64**
	skipped question	**6**

16. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a bioretention swale in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**48.4% (31)**	39.1% (25)	4.7% (3)	7.8% (5)	64
Habitat for local native animals	**75.0% (48)**	15.6% (10)	3.1% (2)	6.3% (4)	64
Presence of pests (e.g. mosquitoes)	18.8% (12)	**37.5% (24)**	29.7% (19)	14.1% (9)	64
Access to houses by all community members	15.6% (10)	**56.3% (36)**	9.4% (6)	18.8% (12)	64
On-street parking	9.4% (6)	**54.7% (35)**	20.3% (13)	15.6% (10)	64
Area's recreational opportunities (walking, cycling, jogging, etc.)	**46.9% (30)**	**46.9% (30)**	0.0% (0)	6.3% (4)	64
Area's aesthetic appeal	**89.1% (57)**	9.4% (6)	0.0% (0)	1.6% (1)	64
Improved air quality	**71.9% (46)**	20.3% (13)	0.0% (0)	7.8% (5)	64
Integrate the local area with the existing adjoining natural area's	**76.6% (49)**	17.2% (11)	0.0% (0)	6.3% (4)	64
				answered question	**64**
				skipped question	**6**

17. Overall, do you think the design of a bioretention swale (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	31.3%	20
Make no difference to safety	**56.3%**	**36**
Decrease safety	0.0%	0
Don't know	12.5%	8
	answered question	**64**
	skipped question	**6**

18. Do you think the presence of a bioretention swale in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**57.8%**	**37**
Make no difference	34.4%	22
Decrease educational and awareness opportunities	1.6%	1
Don't know	6.3%	4
	answered question	**64**
	skipped question	**6**

19. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a bioretention swale in your neighbourhood?

	Response Percent	Response Count
Yes	32.8%	21
No	**34.4%**	**22**
Not sure	10.9%	7
Only if it's located directly outside my residence	21.9%	14
answered question		**64**
skipped question		**6**

20. Are you aware of any street trees located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	**80.6%**	**50**
No	19.4%	12
Don't Know	0.0%	0
answered question		**62**
skipped question		**8**

21. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

		Response Percent	Response Count
Yes		30.6%	19
No		**64.5%**	**40**
Not Sure		4.8%	3
		answered question	**62**
		skipped question	**8**

22. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a street tree in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	30.6% (19)	**64.5% (40)**	0.0% (0)	4.8% (3)	62
Habitat for local native animals	**82.3% (51)**	12.9% (8)	1.6% (1)	3.2% (2)	62
Presence of pests (e.g. mosquitoes)	19.4% (12)	**58.1% (36)**	11.3% (7)	11.3% (7)	62
Access to houses by all community members	17.7% (11)	**64.5% (40)**	8.1% (5)	9.7% (6)	62
On-street parking	17.7% (11)	**50.0% (31)**	24.2% (15)	8.1% (5)	62
Area's recreational opportunities (walking, cycling, jogging, etc.)	41.9% (26)	**53.2% (33)**	1.6% (1)	3.2% (2)	62
Area's aesthetic appeal	**95.2% (59)**	4.8% (3)	0.0% (0)	0.0% (0)	62
Improved air quality	**77.4% (48)**	19.4% (12)	0.0% (0)	3.2% (2)	62
Integrate the local area with the existing adjoining natural area's	**79.0% (49)**	16.1% (10)	0.0% (0)	4.8% (3)	62
				answered question	**62**
				skipped question	**8**

23. Overall, do you think the design of the stormwater treatment measure (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	25.8%	16
Make no difference to safety	**59.7%**	**37**
Decrease safety	6.5%	4
Don't know	8.1%	5
	answered question	**62**
	skipped question	**8**

24. Do you think the presence of a street trees in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**51.6%**	**32**
Make no difference	45.2%	28
Decrease educational and awareness opportunities	0.0%	0
Don't know	3.2%	2
	answered question	**62**
	skipped question	**8**

25. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of street trees in your neighbourhood?

	Response Percent	Response Count
Yes	**35.5%**	**22**
No	29.0%	18
Not sure	8.1%	5
Only if it's located directly outside my residence	27.4%	17
answered question		**62**
skipped question		**8**

26. Are you aware of a constructed wetland located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	37.7%	23
No	**57.4%**	**35**
Don't Know	4.9%	3
answered question		**61**
skipped question		**9**

27. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	**54.1%**	**33**
No	42.6%	26
Not Sure	3.3%	2
	answered question	**61**
	skipped question	**9**

28. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a constructed wetland in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**47.5% (29)**	24.6% (15)	16.4% (10)	11.5% (7)	61
Habitat for local native animals	**96.7% (59)**	1.6% (1)	1.6% (1)	0.0% (0)	61
Presence of pests (e.g. mosquitoes)	19.7% (12)	4.9% (3)	**70.5% (43)**	4.9% (3)	61
Access to houses by all community members	18.0% (11)	**68.9% (42)**	1.6% (1)	11.5% (7)	61
On-street parking	13.1% (8)	**72.1% (44)**	1.6% (1)	13.1% (8)	61
Area's recreational opportunities (walking, cycling, jogging, etc.)	**72.1% (44)**	21.3% (13)	3.3% (2)	3.3% (2)	61
Area's aesthetic appeal	**85.2% (52)**	4.9% (3)	3.3% (2)	6.6% (4)	61
Improved air quality	**65.6% (40)**	19.7% (12)	4.9% (3)	9.8% (6)	61
Integrate the local area with the existing adjoining natural area's	**85.2% (52)**	6.6% (4)	1.6% (1)	6.6% (4)	61
				answered question	**61**
				skipped question	**9**

29. Overall, do you think the design of a constructed wetland (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	14.8%	9
Make no difference to safety	**54.1%**	**33**
Decrease safety	21.3%	13
Don't know	9.8%	6
	answered question	**61**
	skipped question	**9**

30. Do you think the presence of a constructed wetland in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**70.5%**	**43**
Make no difference	29.5%	18
Decrease educational and awareness opportunities	0.0%	0
Don't know	0.0%	0
	answered question	**61**
	skipped question	**9**

31. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, rubbish removal, etc.) of a constructed wetland in your neighbourhood?

	Response Percent	Response Count
Yes	24.6%	15
No	**39.3%**	**24**
Not sure	21.3%	13
Only if it's located directly outside my residence	14.8%	9
answered question		**61**
skipped question		**9**

32. Are you aware of a 'biopod' located within your local estate / suburb (if any)?

	Response Percent	Response Count
Yes	13.1%	8
No	**82.0%**	**50**
Don't Know	4.9%	3
answered question		**61**
skipped question		**9**

33. Were you aware that these stormwater treatment elements are designed to remove pollutants (such as total suspended solids, nitrogen and phosphorous) from stormwater before it flows into local creeks and estuaries?

	Response Percent	Response Count
Yes	34.4%	21
No	**63.9%**	**39**
Not Sure	1.6%	1
	answered question	**61**
	skipped question	**9**

34. In comparison to traditional stormwater treatment designs that have no stormwater treatment, do you think that having a 'biopod' located in your area would have; a positive effect, negative effect or no effect on the following issues?

	Positive effect	No effect	Negative effect	Don't know	Response Count
Nuisance flooding (ponding of water)	**45.9% (28)**	39.3% (24)	4.9% (3)	9.8% (6)	61
Habitat for local native animals	**75.4% (46)**	18.0% (11)	0.0% (0)	6.6% (4)	61
Presence of pests (e.g. mosquitoes)	9.8% (6)	**49.2% (30)**	29.5% (18)	11.5% (7)	61
Access to houses by all community members	13.1% (8)	**54.1% (33)**	23.0% (14)	9.8% (6)	61
On-street parking	13.1% (8)	**41.0% (25)**	37.7% (23)	8.2% (5)	61
Area's recreational opportunities (walking, cycling, jogging, etc.)	**49.2% (30)**	32.8% (20)	8.2% (5)	9.8% (6)	61
Area's aesthetic appeal	**93.4% (57)**	1.6% (1)	3.3% (2)	1.6% (1)	61
Improved air quality	**73.8% (45)**	19.7% (12)	0.0% (0)	6.6% (4)	61
Integrate the local area with the existing adjoining natural area's	**73.8% (45)**	18.0% (11)	3.3% (2)	4.9% (3)	61
				answered question	**61**
				skipped question	**9**

35. Overall, do you think the design of a 'biopod' (compared to traditional designs with no stormwater treatment) would increase, decrease or make no difference to the safety of your neighbourhood?

	Response Percent	Response Count
Increase safety	26.2%	16
Make no difference to safety	**60.7%**	**37**
Decrease safety	4.9%	3
Don't know	8.2%	5
	answered question	**61**
	skipped question	**9**

36. Do you think the presence of a bioretention basin in your neighbourhood would; increase, decrease or make no difference to the environmental educational and awareness opportunities in your local neighbourhood?

	Response Percent	Response Count
Increase educational and awareness opportunities	**55.7%**	**34**
Make no difference	41.0%	25
Decrease educational and awareness opportunities	0.0%	0
Don't know	3.3%	2
	answered question	**61**
	skipped question	**9**

37. Mackay Regional Council are typically responsible for the maintenance of stormwater treatment measures in the Mackay region. Would you consider being involved in typical maintenance (weeding, gardening, etc.) of a 'biopod' in your neighbourhood?

	Response Percent	Response Count
Yes	26.2%	16
No	**32.8%**	**20**
Not sure	13.1%	8
Only if it's located directly outside my residence	27.9%	17
	answered question	**61**
	skipped question	**9**

Appendix D

Multi-criteria Analysis Results

Multi-criteria Analysis Results
Value Scores

Bioretention swale Value Scores

Financial Assessment Criteria	Weight	Performance Score	Likelihood Score	Impact Score	Value Score
The life cycle cost of the device over 30 years	13.1	5	4	20	**262**
The typical annual maintenance costs	10.7	5	4	20	**214**
The total capital and acquisition costs	9.1	4	4	16	**146**
***Social* Assessment Criteria**					
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	4	3	4	12	**48**
The impact on the safety of people using the area	4.9	5	4	20	**98**
The impacts on the area's aesthetic values	4.3	3	4	12	**52**
Impact on property values	5	5	2	10	**50**
Community involvement in maintenance	2.4	2	2	4	**10**
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	2.7	4	3	12	**32**
The inconvenience of nuisance flooding / ponding outside of dwellings	3	2	3	6	**18**
The impact on the research, education & awareness opportunities	1.7	4	3	12	**20**
Natural habitat for native animals	2.7	5	3	15	**41**
The inconvenience to people using the road reserve (e.g. access, parking)	2.3	4	4	16	**37**
***Ecological* Assessment Criteria**					
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	10.7	4	3	12	**128**
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10.9	3.66	4	14.64	**160**
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	11.4	3	3	9	**103**
				Σ =	**1417**

Bioretention basin Value Scores

***Financial* Assessment Criteria**	**Weight**	**Performance Score**	**Likelihood Score**	**Impact Score**	**Value Score**
The life cycle cost of the device over 30 years	13.1	4	3	12	**157**
The typical annual maintenance costs	10.7	5	3	15	**161**
The total capital and acquisition costs	9.1	3	4	12	**109**
***Social* Assessment Criteria**					
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	4	5	3	15	**60**
The impact on the safety of people using the area	4.9	5	3	15	**74**
The impacts on the area's aesthetic values	4.3	3	4	12	**52**
Impact on property values	5	4	2	8	**40**
Community involvement in maintenance	2.4	4	2	8	**19**
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	2.7	3	4	12	**32**
The inconvenience of nuisance flooding / ponding outside of dwellings	3	4	3	12	**36**
The impact on the research, education & awareness opportunities	1.7	3	3	9	**15**
Natural habitat for native animals	2.7	5	3	15	**41**
The inconvenience to people using the road reserve (e.g. access, parking)	2.3	4	4	16	**37**
***Ecological* Assessment Criteria**					
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	10.7	4	3	12	**128**
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10.9	4.3	4	17.2	**187**
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	11.4	3	3	9	**103**
				Σ =	**1251**

Biopod Value Scores

***Financial* Assessment Criteria**	**Weight**	**Performance Score**	**Likelihood Score**	**Impact Score**	**Value Score**
The life cycle cost of the device over 30 years	13.1	1	3	3	**39**
The typical annual maintenance costs	10.7	2	3	6	**64**
The total capital and acquisition costs	9.1	2	4	8	**73**
***Social* Assessment Criteria**					
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	4	3	4	12	**48**
The impact on the safety of people using the area	4.9	2	3	6	**29**
The impacts on the area's aesthetic values	4.3	1	3	3	**13**
Impact on property values	5	4	3	12	**60**
Community involvement in maintenance	2.4	4	4	16	**38**
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	2.7	3	3	9	**24**
The inconvenience of nuisance flooding / ponding outside of dwellings	3	4	3	12	**36**
The impact on the research, education & awareness opportunities	1.7	3	3	9	**15**
Natural habitat for native animals	2.7	3	3	9	**24**
The inconvenience to people using the road reserve (e.g. access, parking)	2.3	3	4	12	**28**
***Ecological* Assessment Criteria**					
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	10.7	4	3	12	**128**
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10.9	2.7	4	10.8	**118**
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	11.4	3	3	9	**103**
				Σ =	**841**

Constructed wetland Value Scores

Financial Assessment Criteria	Weight	Performance Score	Likelihood Score	Impact Score	Value Score
The life cycle cost of the device over 30 years	13.1	1	3	3	**39**
The typical annual maintenance costs	10.7	1	3	3	**32**
The total capital and acquisition costs	9.1	1	4	4	**36**
***Social* Assessment Criteria**					
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	4	2	4	8	**32**
The impact on the safety of people using the area	4.9	2	3	6	**29**
The impacts on the area's aesthetic values	4.3	5	3	15	**65**
Impact on property values	5	4	3	12	**60**
Community involvement in maintenance	2.4	5	3	15	**36**
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	2.7	5	3	15	**41**
The inconvenience of nuisance flooding / ponding outside of dwellings	3	3	3	9	**27**
The impact on the research, education & awareness opportunities	1.7	5	4	20	**34**
Natural habitat for native animals	2.7	5	3	15	**41**
The inconvenience to people using the road reserve (e.g. access, parking)	2.3	3	3	9	**21**
***Ecological* Assessment Criteria**					
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	10.7	4	3	12	**128**
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10.9	3	4	12	**131**
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	11.4	3	3	9	**103**
				Σ =	**854**

Street tree / BAU Value Scores

Financial Assessment Criteria	Weight	Performance Score	Likelihood Score	Impact Score	Value Score
The life cycle cost of the device over 30 years	13.1	3	3	9	118
The typical annual maintenance costs	10.7	3	3	9	96
The total capital and acquisition costs	9.1	3	3	9	82
***Social* Assessment Criteria**					
The impact on the health and wellbeing of nearby residents who may be affected by; odours, mosquitoes, pests	4	3	3	9	36
The impact on the safety of people using the area	4.9	3	3	9	44
The impacts on the area's aesthetic values	4.3	3	3	9	39
Impact on property values	5	3	3	9	45
Community involvement in maintenance	2.4	3	3	9	22
The impact on passive and active recreational opportunities around the stormwater asset (e.g. walking, cycling, jogging, etc.)	2.7	3	3	9	24
The inconvenience of nuisance flooding / ponding outside of dwellings	3	3	3	9	27
The impact on the research, education & awareness opportunities	1.7	3	3	9	15
Natural habitat for native animals	2.7	3	3	9	24
The inconvenience to people using the road reserve (e.g. access, parking)	2.3	3	3	9	21
***Ecological* Assessment Criteria**					
Opportunities of integration of design with adjoining natural areas, i.e. device type, planting and selection of plant species	10.7	3	3	9	96
Meet MRC Stormwater Quality Objectives to reduce impact on all receiving waterways	10.9	1	3	3	33
Maintenance of the minor system design 5 year ARI, and major system design 100 year ARI	11.4	3	3	9	103
				Σ =	**529**