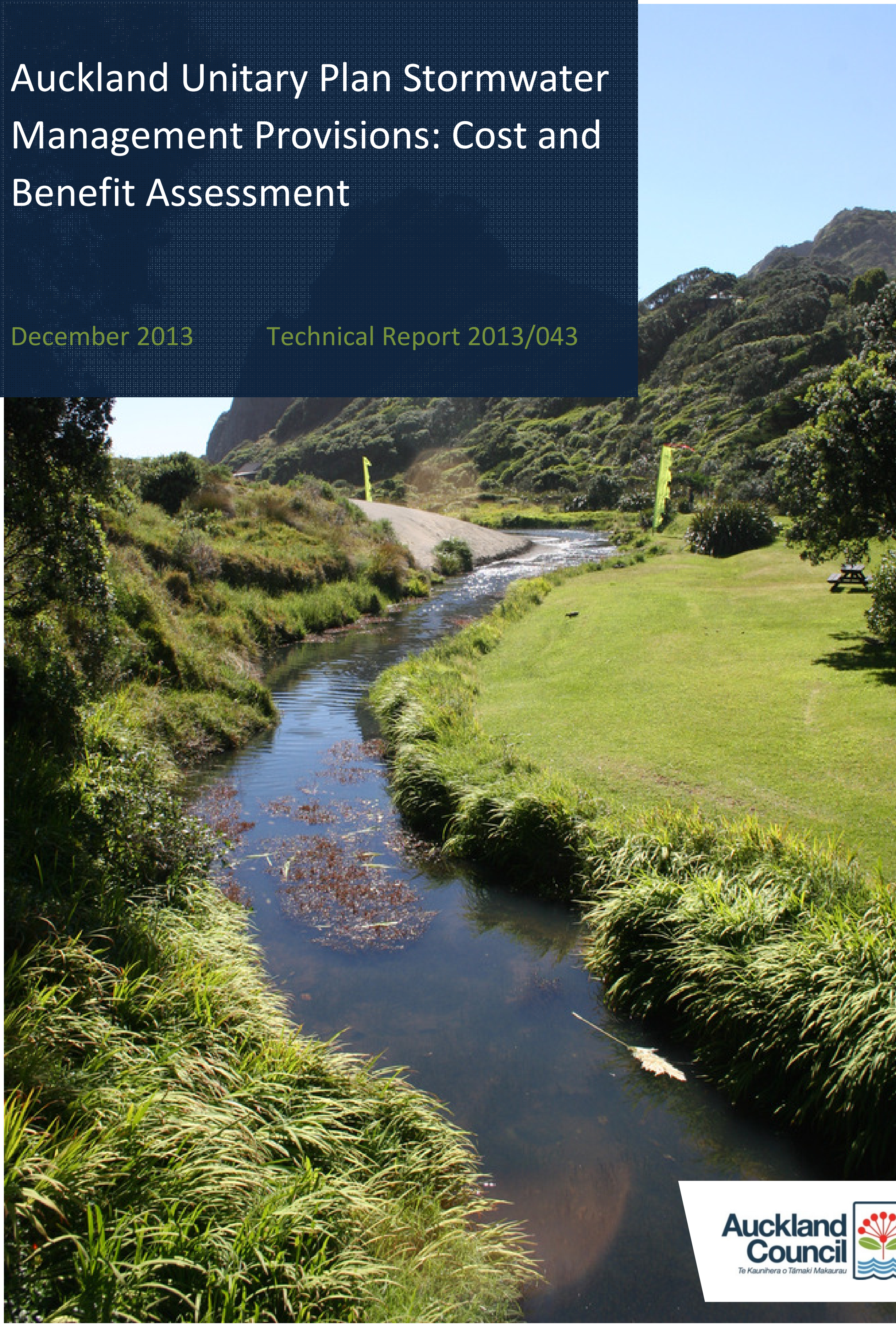
Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment

December 2013 Technical Report 2013/043



Auckland Council
Te Kaunihera o Tāmaki Makaurau

Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment

December 2013 Technical Report 2013/043

Auckland Council
Technical Report 2013/043
ISSN 2230-4525 [Print]
ISSN 2230-4533 [Online]

ISBN 978-1-927266-22-9 [Print]
ISBN 978-1-927266-23-6 [PDF]

This report has been peer reviewed by the Peer Review Panel using the Panel's terms of reference.
Reviewed for Auckland Council by
Name: Jan Heijs Position: Manager Stormwater Planning Date: December 2013
Approved for Auckland Council publication by
Name: Matthew Davis Position: Manager Stormwater Development & Technical Service Date: December 2013

Recommended citation:

Kettle, David and Kumar, Priya (2013). Auckland Unitary Plan stormwater management provisions: cost and benefit assessment. Auckland Council technical report, TR2013/043

Auckland Unitary Plan Stormwater Management Provisions: Cost and Benefit Assessment

David Kettle
D & B Kettle Consulting Ltd

Priya Kumar
Stormwater Unit
Auckland Council

Executive Summary

The Auckland Council has notified the Auckland Unitary Plan (Unitary Plan) to guide and manage the growth and development of Auckland into the future and to give effect to the vision of the Auckland Plan. To help protect and restore our urban freshwater and marine systems the Unitary Plan contains provisions that manage stormwater quality and flows.

The purpose of this report is to:

- Collate and present the costs (construction, on-going maintenance and total present cost) of typical stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality and flow management in accordance with the stormwater rules in Chapter H section 4.14 of the Unitary Plan.
- To understand the costs of implementing the Unitary Plan provisions for stormwater management from two perspectives – in terms of absolute costs (construction and on-going maintenance) for a range of development scenarios and also in terms of relative costs when compared to the current ALW Plan statutory provisions. Benefits are also broadly assessed for a range of development scenarios.
- To inform decision making and transparency of costs and benefits in implementing the Unitary Plan provisions.
- Collate and present local and international case studies that assess the benefits of a water sensitive design approach for greenfield and brownfield developments.

This Cost and Benefit Assessment report provides supporting information for the Unitary Plan planning process and is a guidance document. The intended audience is the Council, the stormwater industry and other stakeholders, including the public. The focus of this report is on the two Unitary Plan aspects of stormwater quality and flow management.

High Contaminant Generating Activities (HCGAs) is the term used for activities that contribute significant levels of contaminants to stormwater runoff. These comprise certain cladding materials (including uncoated galvanised iron and zinc and copper based products), car parks that are exposed to rainfall and high use roads (generally roads that carry more than 10,000 vehicles per day).

Stormwater Management Areas: Flows (SMAFs) are mapped areas that drain to streams that have been identified as being particularly sensitive to changes in stormwater flows, have high natural values, and are at potential risk from an increase in impervious area associated with future development. SMAF 1 areas generally have low levels of existing development with streams that have high natural values and are sensitive to increased stormwater flows, while SMAF 2 areas typically have greater levels of existing development and streams that have moderate to high natural values and sensitivity to increases in stormwater flows.

Cost estimates (construction, maintenance and total present cost) for the following representative stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality (HCGA) and flow management (SMAF) have been calculated:

- Bioretention (rain gardens)
- Porous Paving (private driveways and public parking areas)
- Rain water tanks with water reuse
- Living Roofs
- Sand Filters (for HCGA water quality only)
- Wetlands (for HCGA water quality only)
- Gravel Storage (chamber and greater gravel thickness under porous paving for private driveways, not suitable for HCGA areas)

The development scenarios selected to demonstrate the associated costs to meet the specific Unitary Plan SMAF and HCGA requirements are:

- Single house on a 500m^2 lot (SMAF)
- Mixed and terraced housing (SMAF)
- Parking areas (SMAF and HCGA)
- Secondary Arterial Roads (SMAF and HCGA)

The costs to meet the specific Unitary Plan SMAF and HCGA requirements for the scenarios above were compared to catchment-wide wetlands (taken as an example of the current approach to stormwater management under the previous regional planning framework).

Compared to wetland treatment costs:

- single house SMAF1 porous paving with increased gravel construction costs are similar;
- single house SMAF2 porous paving with increased gravel construction costs are less;
- parking and secondary arterial road HCGA rain garden construction costs are similar; and
- all other SMAF construction costs and SMAF/HCGA maintenance and total present costs are generally greater.

Sample Results Based on Stormwater Devices and Development Scenarios Costed

Scenario and UP Requirement	Least Construction Cost Option	Least Average Annualised Maintenance Option	Least Total Present Cost Option
Single House SMAF1/2	Porous Paving with Gravel	Rain Garden	Rain Garden
Parking Area SMAF1	Porous Paving and Rain Garden similar	Porous Paving	Porous Paving
Parking Areas SMAF2	Rain Garden	Porous Paving	Porous Paving
Secondary Arterial Road SMAF and HCGA	Rain Garden only option costed as Porous Paving not suitable		
Parking Area HCGA	Rain Garden	Porous Paving, Rain Garden and Sand Filter similar	Rain Garden and Porous Paving similar

A brief introduction to 'Water Sensitive Design (WSD)' and Green Growth is provided in the Benefits section. The stormwater management devices costed align with some of the principles of WSD and Green Growth. This section also discusses several ways of measuring stormwater benefits/values and presents a number of local and international case studies where different methods have been used to capture the range of benefits versus costs of different stormwater management approaches. The difficulty in undertaking a solely quantitative cost-benefit analysis is also discussed. A cost-benefit analysis for an individual on-site device (soil cell) has also been presented as an example.

A major challenge for Auckland is the lack of data to replicate the international case studies cited. However, there is significant work being undertaken in this area and the case studies reviewed support the use of these principles. This report provides the foundation that will enable a cost-benefit analysis to be undertaken in the future.

Table of Contents

Note: Appendix is a separate volume

List of Figures

List of Tables

1.0 Introduction

The Auckland Council has notified the Auckland Unitary Plan (Unitary Plan) to guide and manage the growth and development of Auckland into the future and to give effect to the vision of the Auckland Plan.

Effective stormwater management is an important element of achieving the vision for growth and healthy communities and environments. Urban development and associated stormwater runoff, if not managed appropriately, can have significant adverse effects on the natural environment, particularly Auckland's small streams and coastal water quality. Large impervious areas don't allow rainfall to soak into the ground and significantly increase direct stormwater runoff. Contaminants picked up from our urban areas, are carried in stormwater runoff and deposited in streams, groundwater and coastal areas. These processes can have a profound effect on the quality, health and functioning of our freshwater and marine environments.

Given the importance of freshwater and marine environments, improving stormwater quality and managing stormwater flows have been key issues in Auckland for many years. National freshwater and coastal policy statements and the Auckland Plan are also directing us to reduce the effects of development on our water environments and improve water quality. This is recognised in the Unitary Plan, which sets objectives to protect, maintain and enhance our freshwater and coastal waters and restore their interconnection.

To contribute to these objectives, the Unitary Plan contains provisions that manage stormwater quality and runoff, with an emphasis on minimising the adverse effects of new development as far as possible and taking the opportunities provided by land use change and redevelopment to reduce existing adverse effects. This is achieved through the management of land use activities and discharges.

1.1 Purpose of Report

The purpose of this report is to:

- Collate and present the costs (construction, on-going maintenance and total present cost) of typical stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality and flow management in accordance with the stormwater rules in Chapter H section 4.14 of the Unitary Plan.
- To understand the costs of implementing the Unitary Plan provisions for stormwater management from two perspectives – in terms of absolute costs (construction and on-going maintenance) for a range of development scenarios and also in terms of relative costs when compared to the current ALW Plan statutory provisions. Benefits are also broadly assessed for a range of development scenarios.
- To inform decision making and transparency of costs and benefits in implementing the Unitary Plan provisions.
- Collate and present local and international case studies that assess the benefits of a water sensitive design approach for greenfield and brownfield developments.

This Cost and Benefit Assessment report provides supporting information for the Unitary Plan planning process and is a guidance document. The intended audience is the Council, the stormwater industry and other stakeholders, including the public.

This report is not intended to provide a full cost-benefit analysis, guidance on meeting the Unitary Plan requirements or justification for the requirements themselves. For further information on the basis for the Unitary Plan provisions refer to:

- Unitary Plan S32 assessment: Stormwater quality and flow (Auckland Council 2013c).
- Auckland Unitary Plan stormwater management provisions: Technical basis of contaminant and volume management requirements, TR2013/035 (Auckland Council 2013a).

This report discusses on-site stormwater management devices available on the market, along with their benefits and limitations. Whilst this report may name companies and/or products, the Auckland Council does not endorse any particular product or company. The naming of a product or company is purely to discuss the current methods available in the market. It is acknowledged that other products may be available (or have become available since the time of writing).

1.2 Auckland Unitary Plan

The Unitary Plan will replace the current Auckland regional plans and operative district plans, which contain significantly different provisions and requirements for managing stormwater. That is, the Unitary Plan will replace the existing stormwater diversion and discharge provisions of the Auckland Regional Plans: Air, Land and Water (ALW Plan) and Coastal and the development and land use provisions of the operative district plans, which may also guide stormwater management.

The Unitary Plan has a set of regionally consistent diversion, discharge and land use provisions to guide the management of land use change, subdivision, land development, stormwater diversion/discharge and associated adverse effects. This provides an opportunity to:

- Develop a more integrated land use/water management regime as directed by the Auckland Plan and national policy documents;

- Build on and improve existing plan provisions and approaches, to improve their effectiveness in achieving the desired outcomes, and extend them across the region where appropriate;

- Address deficiencies in existing plan approaches and provisions that are not adequately managing the adverse effects of land use and stormwater diversion/discharges.

1.3 Approach to Stormwater Management

The Auckland Plan places significant emphasis on green growth and sustainable urban development. The aim of this approach is to meet the challenges of providing for significant growth, while at the same time providing communities with safe, healthy and high quality environments to live in (i.e. a liveable city). Similarly, national policy guidance, primarily the National Policy Statement for Freshwater Management (NPSFM), the New Zealand Coastal Policy Statement (NZCPS) and the Hauraki Gulf Marine Park Act (HGMPA), seek to maintain or improve the quality of freshwater and the coastal environment. This requires a focus that is not only on new development, but one which also takes the opportunities provided by redevelopment to reduce existing adverse effects.

The main changes in the approach to stormwater management from the current planning framework are:

1. Integration of land and freshwater management through aligned land use and stormwater management requirements and planning and consent processes for greenfield development and redevelopment of existing urban areas, utilising both discharge and land use consents;

2. A greater emphasis on water sensitive design and green growth for greenfield development and, where possible, redevelopment to achieve more sustainable stormwater management, while achieving wider community benefits;

3. More emphasis on on-site management of stormwater quality and quantity for both new development and redevelopment, targeted to activities/areas where the greatest benefits can be achieved, in recognition of the effectiveness of at - or near-source management compared to “end of pipe” management;

4. A new regime for managing stormwater quality applying to high contaminant generating activities, including establishing treatment device effluent quality requirements that target contaminants of concern for particular receiving environments;

5. Management of stormwater volume and flow from impervious areas in catchments of streams with high sensitivity and value that are likely to be subject to future development pressure;

6. Adopting a maximum impervious area for residential and some other zones, with a requirement to reduce stormwater flows where the maximum is exceeded, to assist in managing the capacity of the stormwater network and effects on streams.

The Unitary Plan stormwater management requirements are not retrospective. That is, they do not apply to existing activities. However, they apply to new development and also at the time of redevelopment.

1.4 Unitary Plan Provisions for Stormwater Quality and Flow

Within the Unitary Plan, stormwater quality and flows are managed in multiple ways:

1. In greenfield development and major redevelopment:
    a. a focus on water sensitive design and green infrastructure to reduce the generation of stormwater runoff and contaminants, followed by their management and reduction on-site or though communal measures;
    b. integrated land use and stormwater management processes, such as structure or framework planning, to deliver appropriate integrated outcomes.
2. Private and public network resource consents for stormwater diversions and discharges.
3. Stormwater treatment requirements for high contaminant generating land use activities and areas. High Contaminant Generating Activities (HCGAs) is the term used for activities that contribute significant levels of contaminants to stormwater runoff. These comprise certain cladding materials (including uncoated galvanised iron and zinc and copper based products), car parks that are exposed to rainfall and high use roads (generally roads that carry more than 10,000 vehicles per day).
4. Stormwater volume and flow mitigation requirements for:
    a. Sites/developments that are located in identified areas called Stormwater Management Area: Flow 1 or 2. These areas drain to streams that are identified as having high current or potential values and are sensitive to, and at risk from, further imperviousness in the catchment.
    b. Sites/developments that exceed the maximum impervious area for their zone (predominantly residential zones).
    c. Sites/developments that drain to the combined sewer network.

The focus of this report is on the latter two aspects of stormwater quality and flow management. Accordingly the specific requirements for contaminant and flow management are provided below.

Contaminant Management Requirements

The stormwater contaminant management requirements at a site/development are applied to HCGAs. These are defined as follows:

High contaminant-generating activities - Specific activities that contribute a high proportion of contaminants to the overall site stormwater discharge. Includes:

- *parking areas (including that which is accessory to the main use of the site), and associated access ways that are exposed to rainfall.*
- *high contaminant yielding building roofing, spouting, external wall cladding and architectural features using materials with an:*
    - *exposed surface or surface coating of metallic zinc or any alloy containing more than 10 per cent zinc;*

- *exposed surface or surface coating of metallic copper or any alloy containing more than 10 per cent copper; or*
- *exposed treated timber surface or any roof material with a copper or zinc containing algaecide.*

- *high use roads.*

Excludes: industrial or trade activity areas (defined elsewhere).

High use roads:
a. A motorway, state highway, primary arterial or secondary arterial road; or
b. A road that carries more than 10,000 vehicles per day;
excludes ancillary areas that do not receive stormwater runoff from the high use road carriageway.

Stormwater quality treatment is required at the time of development or, in the case of existing activities, if and when a site is redeveloped. Where more than 50 per cent of an HCGA is redeveloped, the requirements apply to the whole HCGA area.

Under the Unitary Plan, stormwater treatment requirements are no longer specified in terms of the removal of total suspended sediment (TSS), but rather as a Design Effluent Quality Requirement (DEQR). The DEQRs apply to the identified contaminants of concern for the receiving environment as per the following tables.

Stormwater quality management requirements

Symbol	Name	Design Effluent Quality Requirement
S	Sediment	TSS < 20 mg/L
M	Metals	T Cu < 10 µg/L, T Zn < 30 µg/L
T	Temperature	Temperature < 25°C

Receiving environment and contaminant of concern

Receiving environment	Land use activity		
	Road, carpark	Roofing	Industrial sites activity area
River or stream	S, M, T	M, T	Appropriate to nature of activities, contaminants and receiving environments
All others	S, M	M	

The stormwater treatment requirements are not "absolute requirements", but are generally subject to the following rule structure:

1. Below an identified threshold (typically an area of increased imperviousness or change), the activities are permitted without requirements;
2. Above the threshold:
    a. Where the treatment requirements are met, the activity requires resource consent as a controlled activity;
    b. Where the treatment requirements are not met, the activity becomes a restricted discretionary or discretionary activity and is subject to a site specific assessment.

Stormwater Runoff (Flow and Volume) Management Requirements

For the SMAF areas, it is the reduction of the peak flows of the small, frequent stormwater flows (less than the 2 year ARI) which are of concern for stream health. Management of these small frequent flows is best achieved with on-site devices. These on-site devices do not manage the larger flood flows from the 10 year and 100 year events.

Stormwater flow and volume management is required in three main situations:

1. Within a SMAF 1 or 2 area. These are mapped areas that drain to streams that have been identified as being particularly sensitive to changes in stormwater flows, have high natural values, and are at potential risk from an increase in impervious area associated with future development. SMAF 1 areas generally have low levels of existing development with streams that have high natural values and are sensitive to increased stormwater flows, while SMAF 2 areas typically have greater levels of existing development and streams that have moderate to high natural values and sensitivity to increases in stormwater flows.

   Runoff/hydrology mitigation requirements in SMAF areas are as follows:

Area	Stormwater mitigation	Flow/volume mitigation requirement
SMAF 1	Level 1 hydrology mitigation	provide detention (temporary storage) with a volume equal to the runoff volume from the 95th percentile, 24 hour rainfall event for the impervious area for which hydrology mitigation is required; and provide retention (volume reduction) of a 10mm, 24 hour rainfall event for the impervious area for which hydrology mitigation is required
SMAF 2	Level 2 hydrology mitigation	provide detention (temporary storage) with a volume equal to the runoff volume from the 90th percentile, 24 hour rainfall event for the impervious area for which hydrology mitigation is required; and provide retention (volume reduction) of a 8mm, 24 hour rainfall event for the impervious area for which hydrology mitigation is required

   SMAF hydrology mitigation requirements apply to new or redeveloped impervious areas (greater than $25m^2$) in the mapped SMAF 1 and 2 areas. As for contaminants, the mitigation is applied to the entire site where more than 50% of the site is developed / redeveloped.

2. Where the site impervious area exceeds the maximum allowable impervious area for the relevant zone.

   In this situation, sites are required to detain the 2, 10 and 100 year, 24 hour rainfall event peak flows to the pre-development (grass) condition for the excess impervious area.

3. Where new impervious area is created that drains to the combined sewer network.

   Where new impervious area is developed on sites that discharge to the combined sewer network, the runoff must be managed to ensure existing levels of runoff are not increased.

As for contaminant management, these requirements are not absolute and the same rule structure applies.

1.5 Current vs Unitary Plan Requirements

The main changes in the approach to managing stormwater from development in the Unitary Plan (when compared to previous approaches) have been summarised in Section 1.3 above. It is difficult to quantify what these changes mean in terms of requirements for development when compared to the existing framework. This is primarily because of the wide difference between the existing district plan requirements, the different approaches that have been taken between the Unitary Plan and the ALW Plan and the circumstances in which requirements apply. In many instances resource consent processes result in site specific requirements.

However, the following broad comparisons can be made:

1. Overall, there is not a significant difference between the requirements for greenfield development. Current practice under the ALW Plan is to require a high level of stormwater quality treatment, peak flow management and extended detention of stormwater. The main changes are:

    a. Greater consideration of water sensitive design, with the aim of reducing the generation of stormwater and adverse effects at source as far as possible;

    b. More emphasis on focussed on-site management, whereas common current practice is the development of a catchment device such as a pond or wetland;

    c. Less emphasis on whole of area treatment, with a focus on high contaminant areas.

    However, the provisions for greenfield areas seek the development of integrated stormwater management solutions across both site and development scales.

2. There are more significant implications for redevelopment as the Unitary Plan contaminant and flow management requirements apply, where appropriate, to redeveloped sites. This may also occur under the ALW Plan if a stormwater diversion or discharge consent was required. However, redevelopment of sites may not necessarily trigger the requirement for a resource consent under the ALW Plan.

3. The contaminant management provisions have significant implications for activities that are identified as HCGAs – car park areas, high use roads and activities that use large areas of galvanised iron or zinc/copper based cladding/roofing. Under the ALW Plan, stormwater treatment would generally be required for these (and other) areas if a stormwater discharge consent was required, or in some circumstances where required by a network discharge consent. However, the Unitary Plan requirements are likely to require more widespread treatment to be applied than is currently the case.

4. The stormwater treatment requirements of the Unitary Plan (DEQRs) are similar to current practice under the ALW Plan (75% TSS removal) as most current stormwater treatment devices will meet the DEQRs. The main exception is that stormwater treatment ponds will not meet the DEQR for temperature where the discharge is to a river or stream. However, a pond could still be identified as the best option through an integrated and site specific assessment process.

5. The requirements for flow mitigation in SMAF areas is a new requirement for most districts, but is similar to the requirements currently in place under the Auckland Council District Plan – Operative North Shore Section 2002. That is, the SMAF approach has extended this approach to selected catchments/sub-catchments across the region. A similar level of flow management would generally be required for new/redevelopment where a resource consent was required under the ALW Plan. However the extensive area of SMAFs, the low threshold at which the mitigation applies and the requirement for retention (volume reduction) and detention (instead of just detention) means that the requirements are significantly more extensive.

6. The requirement to mitigate flows where the zone maximum impervious area is exceeded is a requirement of some district plans, and most district plans have zone impervious area maximums that development is generally managed. Again there is likely to be a more widespread requirement for flow mitigation to be applied.

7. Stormwater flow management has previously been required in areas serviced by the combined sewer network to minimise wastewater overflows from the network.

1.6 Report Structure

Section 2 presents the cost estimates (construction, on-going maintenance and total present cost) for representative stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality and flow management. Cost estimates for four SMAF and two HCGA scenarios have been provided to demonstrate the range of stormwater devices and associated costs to meet the new Unitary Plan requirements. These costs have been compared to catchment-wide wetlands (taken as an example of the current approach to stormwater management under the previous regional planning framework). Due to cost variability, a range of costs have been provided. A construction cost comparison of greenfield developments versus conventional development in NZ, USA and UK is summarised at the end of this section.

A brief introduction to ‘Water Sensitive Design (WSD)’ and Green Growth is provided in Section 3. The stormwater management devices costed align with some of the principles of WSD and Green Growth. This section also discusses several ways of measuring stormwater benefits/values and presents a number of local and international case studies where different methods have been used to capture the range of benefits versus costs of different stormwater management approaches. The difficulty in undertaking a solely quantitative cost-benefit analysis is also discussed. A cost-benefit analysis for an individual on-site device (soil cell) has also been presented as an example.

Section 4 provides a synthesis of the on-site stormwater devices that have been costed to meet the Unitary Plan requirements for on-site stormwater quality (HCGA) and flow management (SMAF) for a number of development scenarios. It also summarises the discussion on benefits of moving to a WSD approach for development, the difficulties in undertaking a purely quantitative cost-benefit analysis and the need for the additional stormwater management functions provided by the new provisions.

2.0 Costs

The primary purpose of this costing section is to collate and present the costs of typical stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality and flow management in accordance with the stormwater rules in Chapter H section 4.14 of the Unitary Plan. Where relevant and possible, the cost has been compared to that of past practice under the previous regional planning framework.

The focus of this report is on the two aspects of stormwater quality and flow management contained within the Unitary Plan. In brief, these two aspects are:

- Flow and volume management – referred to as SMAF areas (Stormwater Management Area: Flow), and
- Quality management – referred to as HCGA areas (High Contaminant Generating Activities).

The scientific and technical bases for these requirements, including the issues they are intended to address, are discussed in detail in the Auckland Council report: Auckland Unitary Plan stormwater management provisions: Technical basis of contaminant and volume management requirements, TR2013/035 (Auckland Council 2013a).

For SMAF areas, the stormwater devices need to meet both detention (reduction of peak flows) and retention (reduction of annual runoff volumes) criteria. The reduction of peak flows of the small, frequent stormwater flows (less than the 2 year ARI) are of concern for stream health. Management of these small frequent flows is best achieved with on-site devices.

An important distinction with the new Unitary Plan provisions is an emphasis on on-site stormwater management. As noted in Section 1, this is not an "absolute requirement" and catchment wide devices could be used if they are demonstrated to be the best option particularly where there is an opportunity for larger, integrated stormwater management solutions.

One significant advantage with on-site devices is the ability to target specific areas and contaminants of concern, compared to catchment wide wetlands which have to collect and treat stormwater runoff from the entire catchment area. However, these on-site devices do not manage the larger flood flows from the 10 year and 100 year events.

If management of these larger flooding events is required, other measures such as catchment wide ponds/wetlands would be required. The costing of flood mitigation works is not covered in this report.

2.1 Costing Approach

The costing approach of estimating construction and on-going maintenance costs included:

1. The selection and costing of representative stormwater management devices that meet the Unitary Plan requirements.
2. A range of selected devices were then chosen that meet the SMAF and HCGA Unitary Plan requirements for a number of representative development 'scenarios', including housing, parking and roads.

3. Where relevant and possible, these scenario costs were then compared to that of past practice under the previous regional planning framework, referred to as the 'base case' (such as catchment wide wetlands, refer to Section 2.2.3 for more details on the base case assumptions).

The following stormwater management devices were selected for costing (detailed unit cost for each device is presented in the Appendix, Sections 2 -8):

- Bioretention (rain gardens)
- Porous Paving (private driveways and public parking areas)
- Rain water tanks with water reuse
- Living Roofs
- Sand Filters (for HCGA water quality only)
- Wetlands (for HCGA water quality only)
- Gravel Storage (chamber and greater gravel thickness under porous paving for private driveways, not suitable for HCGA areas)

The development scenarios selected to demonstrate the associated costs to meet the specific Unitary Plan SMAF requirements are:

- Single house on a 500m^2 lot
- Mixed and terraced housing
- Parking areas
- Secondary arterial roads

Similarly, the development scenarios selected to demonstrate the associated costs to meet the specific Unitary Plan water quality HCGA requirements are:

- Parking areas
- Secondary arterial roads (High use roads)

2.1.1 Limitations to Costing Approach

As discussed in Section 1.5, it is difficult to quantify the difference between existing plans and the Unitary Plan because of the wide difference throughout the Auckland region between the existing district plan requirements, the different approaches taken between the Unitary Plan and the ALW (Air Land and Water) Plan and the circumstances in which requirements apply. For example, the more extensive SMAF controls (for detention and retention) are new requirements for most districts, but similar to those currently in place under the North Shore District Plan.

Due to uncertainties in both monetising benefits and determining the effective life and residual value of the range of stormwater management devices, a full cost-benefit analysis has not been carried out (Refer Section to 2.5 for more detail on the presentation of the range of costs). For assessing benefits, a qualitative assessment is presented in Section 3, along with some examples in the national and international literature where cost-benefit analyses have been attempted.

2.2 Key Assumptions

Key assumptions for the device, scenario, land and base case costs are summarised below.

2.2.1 Device and Scenario Cost Assumptions

- The range of devices to meet Unitary Plan requirements is representative of what can be used in practice and the range of potential costs.
- The tabulated construction, maintenance and total present costs are calculated using the respective unit costs derived in the Appendix, Sections 2 -8.
- The cost implication of on-site devices such as rain gardens and porous paving compared to catchment wide options (e.g. wetlands) is the distribution of costs to council, developers and homeowners, and when these cost are incurred. Due to the number of possible construction and maintenance payment options, this report simply presents the costs of the different construction and on-going maintenance items, along with one total present cost, for each stormwater treatment scenario.
- Capital costs of catchment scale devices would be passed on to land owners (even if developed as part of subdivision).
- Cost of on-site devices would be borne by land owner.
- Maintenance costs for the rain tank scenario can be reduced by the savings from a reduced water bill due to using rain water for non-potable household water uses (such as toilet, laundry and outdoor uses). The analysis in Section 4.6 of the Appendix shows that this reduction, using a water supply volumetric charge of $1.343 per 1,000 litres (Watercare 2013) and an estimated additional power cost of $40 per year to run the water pump, gives a net savings of $58/year.
- Maintenance costs of on-site devices are transferred from the council owned/operated catchment wide device to the lot owner, with the associated risks of lot owner neglect. Communal devices servicing multiple houses may have a body corporate structure, which, if including a maintenance contractor, can provide greater certainty with respect to on-going maintenance and device performance.
- Reactive and unplanned maintenance/rehabilitation (such as blocked culverts and pollution incidents) has been excluded from the costs. Unplanned maintenance and rehabilitation can often be 'managed out' through good design and effective regular management of the systems.
- Costs have been reduced for private household devices on individual lots versus communal (serving more than one lot, under a body corporate structure) and public devices. This applies to rain gardens and porous paving. For example, due to their smaller size, household rain garden construction costs can be reduced by approximately $2,000 with the replacement of standard rain garden precast wing walls and 1050mm diameter concrete manhole with a factory-made PVC flow spreader and a 100/150mm PVC overflow pipe respectively. The use of standard household instruction sheets (practice notes) giving design, construction and maintenance details reduces the need for specific design, construction

drawings and documentation to be individually prepared for each house. As for maintenance, a significant portion of the routine general maintenance can be carried out by the owner as part of regular garden/lawn care and the corrective maintenance of replacing media is not required due to low contaminant levels. Refer to Section 2 and 3 of the Appendix for details. This approach is consistent with the recently published TR 2013/040 'Stormwater Disposal via Soakage in the Auckland Region' (Auckland Council 2013b) which gives design guidance for these devices including when used at the household scale.

- 'Other' costs (in the tabulated data) include estimated items such as kerb & channel underdrain, piping, footpaths and cess pits. For household 'Other' costs, maintenance has been assumed as zero, whereas for public infrastructure such as parking and roads maintenance has been included at an estimated 10% of the construction cost per year.
- 'Extra' costs exclude the cost of a similar landscaped area for the rain garden and asphalt/concrete paving for the porous paving. For the landscaped area the low/high construction cost range has used a low of $20/m^2 (the low value for conventional grass turf, range of $20 to $30/m^2) and a high of $85/m^2 (the high value for a fully planted landscape strip, range of $60 to $85/m^2). The cost of asphalt pavement for parking areas has assumed 35mm AC over 350mm of aggregate and for the secondary arterial road a 600mm depth of aggregate. The cost of driveways has assumed 110mm thick concrete with one layer of mesh and 100mm of basecourse.

2.2.2 Land Cost Assumptions

- Land costs have generally not been included in the device costs, except for wetlands.
- Land cost has been included for wetlands as they are usually constructed on separate pieces of land outside the 100-year flood plain and can have a separate land use zone as stormwater management/open space land. It can also take up developable land in some cases (refer to base case assumptions in Section 2.2.3).
- Land costs have not been included for on-site devices such as rain gardens, porous paving, gravel storage and sand filters, as they can generally be constructed within the individual lot with no loss of developable land. Rain gardens and gravel storage take up land area which is generally within the typical pervious/landscaping requirements. Porous paving is constructed within existing pavement surfaces and sand filters are generally built under the pavement surfaces in concrete box structures.
- The range of land costs for wetlands has been assumed as a 'low' of $50/m^2 for typical 'undeveloped' land to a 'high' of $300/m^2 for 'developed' land (refer to Section 7.5 of the Appendix for details).

Figure 2-1 presents a plot of the wetland construction cost per square metre of catchment area versus the catchment area in hectares. The 'low' and 'high' costs are those from the Landcare Research COSTnz Model (refer to Section 7 of the Appendix). COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006). This plot shows that the chosen 25 Ha catchment is close to the 'knee point' in the cost curve, prior to the significant increases in cost per square metre for smaller sized catchments. The 25 Ha catchment gives a representative cost at the low end of a typical constructed wetland for moderately sized urban developments.

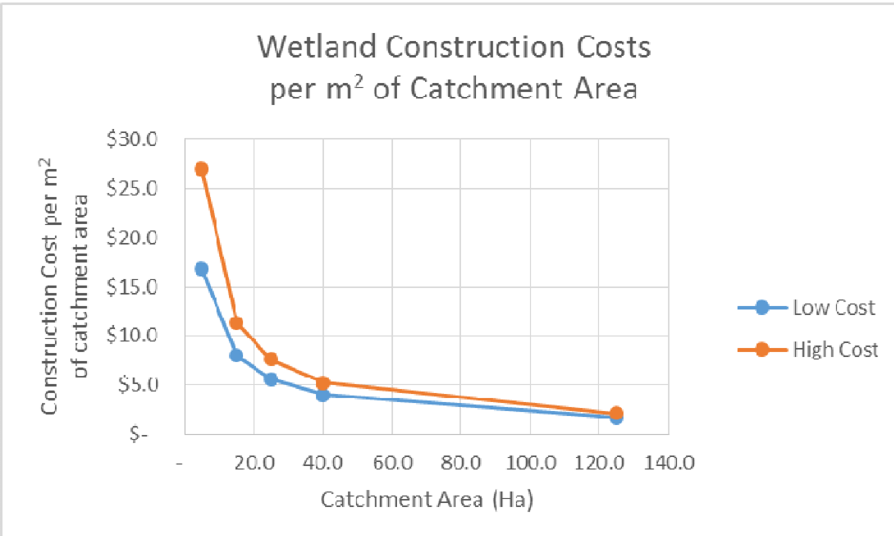


Figure 2-1 Wetland Construction Costs per m^2 of Catchment Area (COSTnz 2012)

2.2.3 Base Case Assumptions

As mentioned in Section 2.1.1, it is difficult to quantify the difference between the existing council and district plans and the Unitary Plan requirements and so two base cases have been presented and costed:

1. Base Case – No Treatment: Just includes the costs of the basic infrastructure items such as driveways, paths and asphalt that have no stormwater management function.
2. Base Case – Wetland Treatment: This is the cost of the Base Case – No Treatment, plus the cost of wetland treatment. While a wetland meets the Unitary Plan water quality HCGA requirements, it does not meet the SMAF requirements as it does not provide sufficient retention (annual stormwater volume reduction). Therefore it is not necessarily comparing like with like, but wetlands have been included as an alternative base case to represent a stormwater management device that is often implemented under the previous regional planning framework.

The cost range for the 'Base Case – Wetland' is calculated using a 'Low' of the low range construction cost plus the low $50/m^2$ land value. The 'High' cost is calculated using the high range construction cost plus the high $300/m^2$ land value. The wetland costs are those for the 5,000m^2 water surface area wetland, serving a 25Ha catchment. (refer to Section 7.4 and 7.5 of the Appendix for details).

Note that the base case is slightly different depending on the specific stormwater management device being costed. Base case for rain gardens, porous paving and living roofs is as follows:

- The cost of the rain garden above the base case is the cost of the rain garden less the cost of a non-stormwater treatment landscaped area, taken as either grass or a more formal planted area.
- The cost of the porous paving above the base case is the cost of the porous paving less the cost of either a concrete driveway or an asphalt parking/road surface.
- For the cost of the living roof above the base case, a very simplified approach has been taken. The cost of a standard aluminium roofing material versus that of the planted living roof media plus the waterproof membrane has been compared. Due to the high variability of roof types, the cost comparison does not include any additional structural roofing costs necessary to support the additional weight of the living roof.

As mentioned above, for wetlands, the cost of the land taken up by the wetland (including access ways etc.) is also included in the Base Case – Wetland Treatment. For costing purposes the cost of a wetland servicing a 25 Hectare catchment has been chosen as a representative size for urban developments, with land values in the range of \$50 to \$300/m^2 (refer to Section 7.5 of the Appendix for details).

2.3 Sources of Data

A wide range of data sources has been reviewed to develop typical construction and maintenance costs. The main sources of cost data reviewed were:

- Manufacturers' costings
- Installers' costings
- Maintenance contractors
- Auckland Council costing information
- Landcare Research COSTnz model. COSTnz data is based on design, construction and maintenance techniques at the time of model development (2006).
- Construction costs and engineer's estimates supplied by engineering consultants
- International literature

Where possible, the most current Auckland prices have been used for cost estimation purposes.

Details of the reviewed data sources and the recommended unit costs to be used for each of the stormwater treatment devices are presented in the Appendix (Sections 2 - 8). It details the full range of costs obtained from the different sources and the range that has been used in the cost estimates.

2.4 Cost Variation

Both capital and on-going operational and maintenance costs can vary markedly and are therefore presented as a range (low, medium and high).

2.4.1 Construction Costs

Initial construction costs can vary depending on a number of factors, including:

- Size of the device and scale of development – generally, the larger the device, the smaller the unit price per square metre of the treatment device. This is because there are a number of relatively fixed costs such as inlet and outlet structures, contractor establishment etc. which do not vary with treatment size. Variable costs such as area of planting and volume of earthworks depend on the size of the device.
- Economies of scale can also reduce unit costs where multiple devices are installed as part of an overall project, such as multi-unit developments and the installation of kilometres of road. Construction of individual devices on a site by site basis can have significant cost penalties due to scale, mobilisation and establishment costs.
- For both new builds and retrofit development, costs of devices can often be less when designed and built as an integral part of the development planning processes compared to when they are considered separately as an 'add-on'.
- Natural variability of the tender process – tender prices, and therefore the final construction cost, can vary depending on the construction 'climate', whether there is an excess of work or an excess of contractors which would tend to drive the costs up or down respectively.
- Land Costs – onsite devices can generally be constructed within the individual lot with no loss of developable land. However, land values for wetlands can be highly variable (refer to Section 7.5 of the Appendix).
- The construction costs are dependent on the catchment area to be treated.

2.4.2 Maintenance Costs

There is also a wide variation of maintenance costs, particularly as many of these stormwater devices, such as rain gardens and porous paving, are relatively new in the Auckland area (in the last 10 years or so). Therefore, there has not been sufficient time to build up a good maintenance cost data base. To assist in gauging the range of maintenance costs, typical costs from international sources are also provided.

Maintenance activities include:

- Monitoring: Includes regular inspections of litter build-up, water quality, sediment accumulation, plant growth, erosion damage, water levels, ponding etc.
- Regular, planned maintenance: Includes clearing debris from structures, vegetation management, sediment removal, jetting of permeable surfaces and silt traps.
- Intermittent, irregular maintenance, mid-life refurbishment and rebuild at the end of the design life of the device (such as vegetation replacement, de-silting etc) are referred to as corrective maintenance.

Maintenance costs can also vary depending on whether the device is on a private household lot or publically maintained e.g. within a road reserve. For example, a study of 22 rain gardens sites in Melbourne (Land and Water Constructions 2006) found that 55% was spent on aesthetics, 30% on vegetation and 15% on inspections. A major component of the aesthetics is litter pick up, which would not be an actual cost for the private householder who would just pick up what litter may accumulate during their day-to-day activities. To take this difference into account, a range of maintenance costs are presented for the higher cost public ownership/maintenance case as well as reduced monetary costs when on a private lot.

2.5 Presentation of Cost Estimates

The costing tables in the Appendix (Sections 2 to 8) and this report present costs under four main headings:

- Construction costs – the initial capital cost (including design and consenting fees).
- Average annualised maintenance costs, undiscounted - the total summed annual and intermittent maintenance costs divided by the appraisal period, with no discounting. This indicates the average cost that the owner of the device would need to pay each year on maintenance.
- Total Present Cost – the combined construction and maintenance costs discounted over the appraisal period back to today's dollars (using a discount rate of 4% over 60 years). It is acknowledged that costs fall on different parties, but due the number of possible construction and maintenance payment options, this report simply presents the total present cost for each stormwater treatment scenario i.e. the payment is considered but who bears the cost isn't.
- Extra Costs - The tables also present the 'extra' stormwater management scenario costs above the respective Base Case – No treatment and Base Case – Wetland treatment costs. These extra costs can be positive (more expensive) or negative (less expensive). It is important to note that the stormwater management scenarios often provide a greater degree of management above the 'no-treatment' and 'wetland-treatment' base cases. For example, the wetland treatment provides the detention but not the retention requirements to meet the Unitary Plan SMAF requirements, compared to bioretention devices that provide both detention and retention. The graphical summary of scenario costs presented in Sections 2.8 and 2.9 include a table summarising the management functions provided by each of the different base cases and devices. In addition, it is becoming more common for these devices, such as bioretention rain gardens, to be a part of accepted best practice for new developments such as parking areas. In this case, the Unitary Plan SMAF requirements are merely supporting current best practice, with no 'extra' costs.

Through the use of the discounting method, the 'Total Present Cost' (also known as discounted cost i.e. cost in today's dollars) has been estimated. The discounting method uses a 'discount rate' and an 'appraisal period' to represent current and future costs as one current value. Only capital and on-going maintenance costs have been included in the Total Present Cost estimates. A result of 'discounting' is that costs (and benefits) borne today have more weight than costs (and benefits) further in the future.

A 'real' discount rate of 4% has been used to derive the Total Present Cost. The use of real discount rate removes the need to include inflation in the analysis.

The appraisal period is the length of time over which costs are analysed. The appraisal period should ideally be the economic life of the asset. However, the discounting process beyond 20 – 30 years renders the future benefits and costs very small in present day values and has minimal impact on the present value.

The stormwater management scenario costs compared to the base case are presented in dollar terms, and, where applicable, as a percentage. For example, both a dollar and percentage change is given for the parking and road cost comparisons where the total construction cost can be reasonably estimated. The tabulated parking and road construction costs include both the pavement (asphalt or porous paving) along with the landscaping and estimated 'other' costs for footpaths, piping, kerbs and underdrains. Only the change in dollar value is given for the household scenario comparisons as the total house cost is highly variable depending on size and type of construction, and a percentage increase would be less meaningful.

The cost breakdown of the individual construction items (conventional items such as driveways, paths and vegetation as well as the treatment devices, such as rain gardens and porous paving) are presented in the tables to show where the changes in costs arise.

Unless otherwise noted the costs include:

- Civil and landscaping construction works.
- Consent and consultant/design fees.

And exclude:

- Land costs (unless specifically included as for wetlands).
- GST.

2.6 Total Present Cost Sensitivity Analysis

The cost of a standard rain garden has been used to demonstrate the sensitivity of the total present costs to both the length of the appraisal period and the timing of corrective maintenance costs. Table 2.1 summarises the high and low range of maintenance and total present costs for the 25, 60 and 100 year appraisal periods for a 30m^2 standard rain garden with a construction cost of \$11,000 to \$23,000, standard routine maintenance and corrective maintenance every 25 years.

Table 2-1 Standard Rain Garden Costs – Appraisal Period Sensitivity Analysis

Appraisal Period	Average Annualised Maintenance		Total Present Costs	
	Low	High	Low	High
25 years	\$1,155	\$1,880	\$25,900	\$46,800
60 years	\$1,075	\$1,735	\$32,300	\$57,000
100 years	\$1,155	\$1,880	\$34,400	\$60,400

Table 2-1 shows that the majority of the total present costs occur in the first 25 years (the 25-year is approximately 80% of the 60-year total present costs), with little increase from 60 to 100 years (the 100-year is approximately 6% greater than the 60-year total present costs).

Table 2-2 summarises the impact of varying the timing of the standard 25-year corrective maintenance from a more frequent 15-year interval to a longer 33-year interval. The 25-year corrective maintenance has been chosen for the comparison as it is the single most significant maintenance cost that could vary in frequency. The 100-year appraisal period has been chosen for comparative purposes to more fully represent the longer 33-year interval.

Table 2-2 Standard Rain Garden Costs - Varying Corrective Maintenance Frequency

Corrective Maintenance Frequency	For 100-year Appraisal Period			
	Average Annualised Maintenance		Total Present Costs	
	Low	High	Low	High
15 years	$1,495	$2,435	$44,400	$77,000
25 years (standard)	$1,155	$1,880	$34,400	$60,400
33 years	$1,000	$1,620	$30,900	$54,600

Table 2-2 shows that the largest impact is in reducing the frequency of the corrective frequency from 25 down to 15 years, increasing the total present costs by approximately 30%.

For the purpose of cost estimation for this report, a 60 year analysis period has been chosen. Corrective maintenance frequency for individual devices has been summarised in the Appendix (Sections 2-8).

2.7 Overview of Stormwater Devices

A summary of the stormwater devices costed in this report, their ability to meet the Unitary Plan SMAF and HCGA criteria and their respective design sizing is presented in Table 2-3.

Table 2-3 Summary of Costed Stormwater Devices

Treatment Device	SMAF Areas		HCGA Areas	Design sizing/comments
	Detention	Retention	Quality	
Bioretention (rain gardens)	✓	✓	✓	Rain garden surface area based on requirement to temporarily store the detention volume and provide retention and water quality treatment in the rain garden planting media, giving the following design criteria: SMAF1 – surface area of 6% of treated impervious area. SMAF2 – surface area of 4% of treated impervious area. HCGA water quality – surface area of 2% of treated impervious area.
Porous Paving – private driveways	✓	✓	✓	Surface area based on requirement to temporarily store the detention volume in a minimum 150mm depth of pavement aggregate with a 40% void space ratio. Retention provided within the aggregate over the large surface area. SMAF1 (surface area ratio) - 1 part porous: 1 part impervious pavement (i.e. 50m^2 porous, 50m^2 impervious, for total pavement area of 100m^2). SMAF2 (surface area ratio) - 1 part porous: 2 parts impervious (i.e. 50m^2 of porous and 100m^2 of asphalt, for a total pavement area of 150m^2). HCGA (surface area ratio) - 1 part porous: 2 parts impervious (i.e. 50m^2 of porous and 100m^2 of asphalt, for a total pavement area of 150m^2).
Porous Paving – public parking areas	✓	✓	✓	Due to the greater minimum 350mm depth of aggregate required in a public parking area the lesser area ratio of 1:2 still provides sufficient storage for the SMAF1 greater detention volume. SMAF1 and SMAF2 (surface area ratio) - 1 part porous: 2 parts impervious (i.e. 50m^2 of porous and 100m^2 of asphalt, for a total pavement area of 150m^2). HCGA (surface area ratio) - 1 part porous: 2 parts impervious (i.e. 50m^2 of porous and 100m^2 of asphalt, for a total pavement area of 150m^2).
Rain water tanks with water use	✓	✓	X	Assume 10,000 litre tank to provide both temporary detention volume and retention storage volume to provide typical household non-potable water for toilet, laundry and outdoor uses, with up to 200m^2 of roof area. For cost estimates assumed the same for both SMAF1 and SMAF2 applications as cost differential for changes in tank size is relatively small compared to the overall cost of the rain tank system. Assumed not to meet HCGA water quality criteria.

Treatment Device	SMAF Areas		HCGA Areas	Design sizing/comments
	Detention	Retention	Quality	
Living Roofs	✓	✓	✓	Assume same set up and costs for both SMAF1 and SMAF2 as same 75 to 100mm media thickness is likely to mitigate both the SMAF1 and SMAF2 requirements. Assumed design sizing is coverage of entire roof area. Note that costs given do NOT include additional structural roofing costs that may be required to support the weight of the living roof. Assumed to meet HCGA criteria through vegetated/filtration properties. Using living roofs is significantly more expensive and it has not been included as an option in the scenario costing. However, they do provide additional benefits such as insulation, energy savings from reduced heating/cooling and aesthetics.
Sand Filters	Partial	X	✓	Assume sandfilters for HCGA water quality only. Sandfilters are not a 'volume reducing practice' i.e. do not meet the retention criteria (Schueler and Lane 2012). For sizing use the sizing criteria of cost per m^2 of treated area given in the Landcare Research COSTnz Model. Additional tank storage required to meet detention requirements. Minimal retention.
Wetlands	✓	X	✓	Assume wetlands are for HCGA water quality only. Wetlands are not a 'volume reducing practice' i.e. do not meet the retention criteria (Schueler and Lane 2012). Assume wetland surface area of 2% of catchment area. Can provide detention, but while some evapotranspiration occurs, volume reduction (retention) is minimal.
Gravel Storage - Chamber	✓	✓	Not suitable for HCGA areas	Gravel storage chamber area based on 0.5m depth of soil cover over 1m depth of aggregate with 40% voids ratio, with requirement to temporarily store the detention volume and provide retention. SMAF1 – surface area of 8% of treated impervious area. SMAF2 – surface area of 5% of treated impervious area.
Gravel Storage – greater gravel thickness under porous paving private driveways	✓	✓	Not suitable for HCGA areas	Additional gravel thicknesses based on requirement to temporarily store the detention volume and provide retention in gravel with a 40% voids ratio. Additional gravel thickness is in addition to 150mm depth of pavement basecourse as part of porous paving driveway construction. SMAF1 – additional gravel volume equal to $8m^3$ of gravel per $100m^2$ of total impervious less 150mm depth of gravel as part of the porous paving area. SMAF2 - additional gravel volume equal to $5m^3$ of gravel per $100m^2$ of total impervious less 150mm depth of gravel as part of the porous paving area.

Note: Device sizing is based on the runoff volume from the new hydrology mitigation required.

2.8 SMAF Stormwater Scenario Costs

2.8.1 Introduction

In order to demonstrate the range of stormwater devices and associated costs to meet the specific Unitary Plan SMAF requirements, costs are summarised below to meet both the SMAF1 and SMAF2 requirements for the following examples:

- Single house on a 500m^2 lot
- Mixed and terraced housing
- Parking areas
- Roads

2.8.2 Single House

The single house lot has been modelled as a 500m^2 lot, with 60% impervious comprising 190m^2 of roof area (including eaves), 80m^2 of driveway and 30m^2 of paving. The 200m^2 of pervious is assumed to have 50m^2 of conventional landscaping with the remaining 150m^2 as grass.

Four treatment scenarios are costed for the single house site, (refer Figure 2-2 examples), including:

- using rain gardens to manage runoff from all impervious areas
- using porous paving for pavement areas, plus rain water tanks
- using porous paving with additional thickness of gravel basecourse
- using a gravel storage chamber

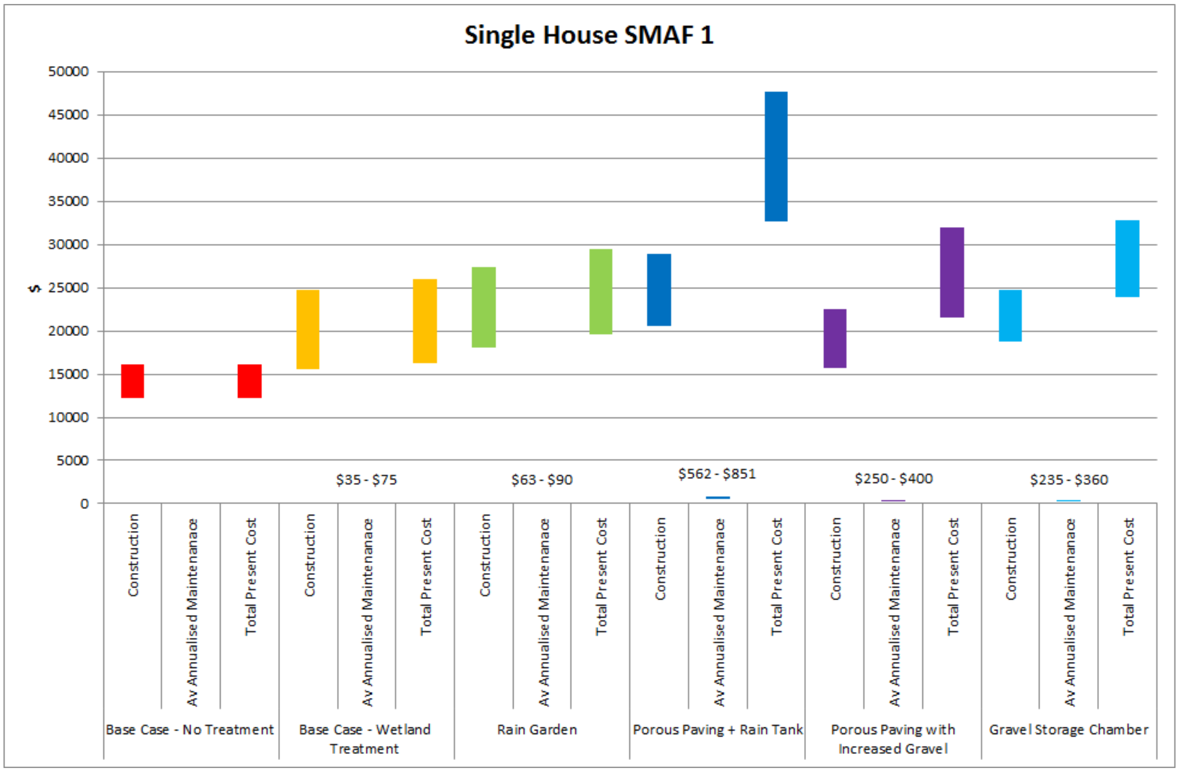
Figure 2-2 Single House Stormwater Management Scenarios (D&B Kettle Consulting Ltd 2013a)

Figure 2-3 Typical Porous Paving used for residential application in Auckland (D&B Kettle Consulting Ltd 2013b)

Table 2-4 presents the construction, maintenance and total present costs for a single household on a 500m^2 lot to meet the SMAF1 requirements, for a 60 year analysis period.

Table 2-4 Single House SMAF1 Costs

Single House - SMAF1	Base Cases (No treatment and wetland treatment)		Scenario 1 Rain Garden		Scenario 2 Porous Paving + Rain Tank		Scenario 3 Porous Paving with Increased Gravel		Scenario 4 Gravel Storage Chamber	
	Low	High	Low	High	Low	High	Low	High	Low	High
Construction										
Conventional Pavement										
- Driveway	$ 7,560	$ 9,660	$ 7,560	$ 9,660	$ 2,363	$ 3,019	$ -	$ -	$ 7,560	$ 9,660
- Paths/Patio	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243
Conventional Landscaping										
- Vegetated	$ 2,975	$ 4,250	$ 1,904	$ 2,720	$ 2,975	$ 4,250	$ 2,975	$ 4,250	$ 2,975	$ 4,250
SUBTOTAL Non-treatment Items	**$12,290**	**$16,153**	**$11,219**	**$14,623**	**$ 7,093**	**$ 9,511**	**$ 4,730**	**$ 6,493**	**$ 12,290**	**$ 16,153**
Porous Pavement					$ 5,940	$ 8,910	$ 8,640	$12,960	$ -	$ -
Rain Garden			$ 6,860	$12,720						
Rain Water Tank					$ 7,500	$10,500				
Gravel Storage										
- Chamber									$ 6,453	$ 8,604
- Extra Porous Paving Depth							$ 2,313	$ 3,084		
Wetland (25Ha Catchment)	$ 3,330	$ 8,580								
SUBTOTAL Treatment Items	**$ 3,330**	**$ 8,580**	**$ 6,860**	**$12,720**	**$13,440**	**$19,410**	**$10,953**	**$16,044**	**$ 6,453**	**$ 8,604**
TOTAL CONSTRUCTION	**$15,620**	**$24,733**	**$18,079**	**$27,343**	**$20,533**	**$28,921**	**$15,683**	**$22,537**	**$ 18,743**	**$ 24,757**
Extra Construction above no treatment	**$ 3,330**	**$ 8,580**	**$ 5,789**	**$11,190**	**$ 8,243**	**$12,769**	**$ 3,393**	**$ 6,384**	**$ 6,453**	**$ 8,604**
Extra Construction above wetland treatment			**$ 2,459**	**$ 2,610**	**$ 4,913**	**$ 4,189**	**$ 63**	**-$ 2,196**	**$ 3,123**	**$ 24**
PRESENT COST CALCULATIONS										
Average Annualised Maintenance										
Conventional Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Conventional Landscaping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Porous Pavement					$ 137	$ 206	$ 200	$ 300	$ -	$ -
Rain Garden			$ 63	$ 90						
Rain Water Tank					$ 425	$ 645				
Gravel Storage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Chamber									$ 235	$ 360
- Extra Porous Paving Depth							$ 50	$ 100		
Wetland (25Ha Catchment)	$ 35	$ 75								
TOTAL Av. Annualised Maint.	**$ 35**	**$ 75**	**$ 63**	**$ 90**	**$ 562**	**$ 851**	**$ 250**	**$ 400**	**$ 235**	**$ 360**
Total Costs										
Conventional Pavement	$ 9,315	$11,903	$ 9,315	$11,903	$ 4,118	$ 5,261	$ 1,755	$ 2,243	$ 9,315	$ 11,903
Conventional Landscaping	$ 2,975	$ 4,250	$ 1,904	$ 2,720	$ 2,975	$ 4,250	$ 2,975	$ 4,250	$ 2,975	$ 4,250
SUBTOTAL Non-treatment Items	**$12,290**	**$16,153**	**$11,219**	**$14,623**	**$ 7,093**	**$ 9,511**	**$ 4,730**	**$ 6,493**	**$ 12,290**	**$ 16,153**
Porous Pavement					$ 9,284	$13,926	$13,504	$20,256	$ -	$ -
Rain Garden			$ 8,360	$14,820						
Rain Water Tank					$16,250	$24,150				
Gravel Storage										
- Chamber									$ 11,553	$ 16,604
- Extra Porous Paving Depth							$ 3,263	$ 5,184		
Wetland (25Ha Catchment)	$ 3,958	$ 9,826								
SUBTOTAL Treatment Items	**$ 3,958**	**$ 9,826**	**$ 8,360**	**$14,820**	**$25,534**	**$38,076**	**$16,767**	**$25,440**	**$ 11,553**	**$ 16,604**
TOTAL PRESENT COST	**$16,248**	**$25,979**	**$19,579**	**$29,443**	**$32,627**	**$47,587**	**$21,497**	**$31,933**	**$ 23,843**	**$ 32,757**
Extra Present Cost above no treatment	**$ 3,958**	**$ 9,826**	**$ 7,289**	**$13,290**	**$20,337**	**$31,435**	**$ 9,207**	**$15,780**	**$ 11,553**	**$ 16,604**
Extra Present Cost above wetland treatment			**$ 3,331**	**$ 3,464**	**$16,379**	**$21,609**	**$ 5,249**	**$ 5,954**	**$ 7,595**	**$ 6,778**



Detention	x	✓	✓	✓	✓	✓
Retention	x	x	✓	✓	✓	✓

Figure 2-4 Single House SMAF1 Costs and Management Functions

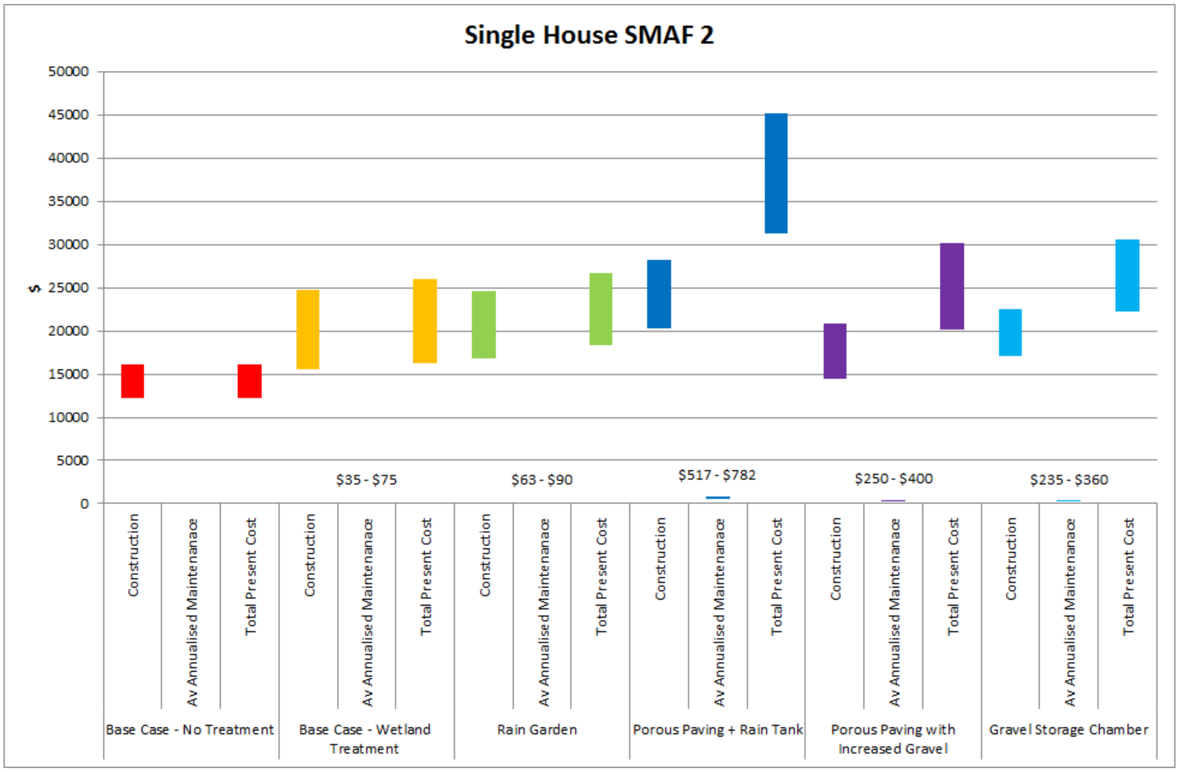
Table 2-4 and Figure 2-4 show the following:

- Extra construction costs:
    - The least expensive option is the porous paving with increased gravel thickness. The additional $3,400 - $6,400 is approximately the same cost as the base case wetland treatment cost of $3,300 - $8,600, but provides both detention and retention, compared to the wetland that only provides detention.
    - The next cost options are the rain garden and gravel storage chamber, with the porous paving and rain tank being the most expensive option.
- Maintenance costs vary from $35 - $75 per year for the Base Case – Wetland Treatment up to approximately $550 to $850 for the porous paving + rain tank Scenario.
- Order of increasing extra present cost is as follows: Rain garden, porous paving with increased gravel thickness, gravel storage chamber and then porous paving with rain tank.

Table 2-5 presents the approximate costs to meet the less strict SMAF2 hydrology criteria.

Table 2-5 Single House SMAF2 Costs

Single House - SMAF2	Base Cases (No treatment and wetland treatment)		Scenario 1 Rain Garden		Scenario 2 Porous Paving + Rain Tank		Scenario 3 Porous Paving with Increased Gravel		Scenario 4 Gravel Storage Chamber	
	Low	High	Low	High	Low	High	Low	High	Low	High
Construction										
Conventional Pavement										
- Driveway	$ 7,560	$ 9,660	$ 7,560	$ 9,660	$ 4,095	$ 5,233	$ -	$ -	$ 7,560	$ 9,660
- Paths/Patio	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243	$ 1,755	$ 2,243
Conventional Landscaping										
- Vegetated	$ 2,975	$ 4,250	$ 2,261	$ 3,230	$ 2,975	$ 4,250	$ 2,975	$ 4,250	$ 2,975	$ 4,250
SUBTOTAL Non-treatment Items	**$12,290**	**$16,153**	**$11,576**	**$15,133**	**$ 8,825**	**$11,725**	**$ 4,730**	**$ 6,493**	**$ 12,290**	**$ 16,153**
Porous Pavement					$ 3,960	$ 5,940	$ 8,640	$12,960	$ -	$ -
Rain Garden			$ 5,240	$ 9,480						
Rain Water Tank					$ 7,500	$10,500				
Gravel Storage										
- Chamber									$ 4,793	$ 6,390
- Extra Porous Paving Depth							$ 1,017	$ 1,356		
Wetland (25Ha Catchment)	$ 3,330	$ 8,580								
SUBTOTAL Treatment Items	**$ 3,330**	**$ 8,580**	**$ 5,240**	**$ 9,480**	**$11,460**	**$16,440**	**$ 9,657**	**$14,316**	**$ 4,793**	**$ 6,390**
TOTAL CONSTRUCTION	**$15,620**	**$24,733**	**$16,816**	**$24,613**	**$20,285**	**$28,165**	**$14,387**	**$20,809**	**$ 17,083**	**$ 22,543**
Extra Construction above no treatment	**$ 3,330**	**$ 8,580**	**$ 4,526**	**$ 8,460**	**$ 7,995**	**$12,013**	**$ 2,097**	**$ 4,656**	**$ 4,793**	**$ 6,390**
Extra Construction above wetland treatment			**$ 1,196**	**-$ 120**	**$ 4,665**	**$ 3,433**	**-$ 1,233**	**-$ 3,924**	**$ 1,463**	**-$ 2,190**
PRESENT COST CALCULATIONS										
Average Annualised Maintenance										
Conventional Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Conventional Landscaping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Porous Pavement					$ 92	$ 137	$ 200	$ 300	$ -	$ -
Rain Garden			$ 63	$ 90						
Rain Water Tank					$ 425	$ 645				
Gravel Storage	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Chamber									$ 235	$ 360
- Extra Porous Paving Depth							$ 50	$ 100		
Wetland (25Ha Catchment)	$ 35	$ 75								
TOTAL Av. Annualised Maint.	**$ 35**	**$ 75**	**$ 63**	**$ 90**	**$ 517**	**$ 782**	**$ 250**	**$ 400**	**$ 235**	**$ 360**
Total Costs										
Conventional Pavement	$ 9,315	$11,903	$ 9,315	$11,903	$ 5,850	$ 7,475	$ 1,755	$ 2,243	$ 9,315	$ 11,903
Conventional Landscaping	$ 2,975	$ 4,250	$ 2,261	$ 3,230	$ 2,975	$ 4,250	$ 2,975	$ 4,250	$ 2,975	$ 4,250
SUBTOTAL Non-treatment Items	**$12,290**	**$16,153**	**$11,576**	**$15,133**	**$ 8,825**	**$11,725**	**$ 4,730**	**$ 6,493**	**$ 12,290**	**$ 16,153**
Porous Pavement					$ 6,189	$ 9,284	$13,504	$20,256	$ -	$ -
Rain Garden			$ 6,740	$11,580						
Rain Water Tank					$16,250	$24,150				
Gravel Storage										
- Chamber									$ 9,893	$ 14,390
- Extra Porous Paving Depth							$ 1,967	$ 3,456		
Wetland (25Ha Catchment)	$ 3,958	$ 9,826								
SUBTOTAL Treatment Items	**$ 3,958**	**$ 9,826**	**$ 6,740**	**$11,580**	**$22,439**	**$33,434**	**$15,471**	**$23,712**	**$ 9,893**	**$ 14,390**
TOTAL PRESENT COST	**$16,248**	**$25,979**	**$18,316**	**$26,713**	**$31,264**	**$45,159**	**$20,201**	**$30,205**	**$ 22,183**	**$ 30,543**
Extra Present Cost above no treatment	**$ 3,958**	**$ 9,826**	**$ 6,026**	**$10,560**	**$18,974**	**$29,007**	**$ 7,911**	**$14,052**	**$ 9,893**	**$ 14,390**
Extra Present Cost above wetland treatment			**$ 2,068**	**$ 734**	**$15,016**	**$19,181**	**$ 3,953**	**$ 4,226**	**$ 5,935**	**$ 4,564**



Detention	x	✓	✓	✓	✓	✓
Retention	x	x	✓	✓	✓	✓

Figure 2-5 Single House SMAF2 Costs and Management Functions

Table 2-5 and Figure 2-5 show the following:

- Extra construction costs:
  - The least expensive option is the porous paving with increased gravel thickness. The additional $2,100 - $4,700 is cheaper than the base case wetland treatment cost of $3,300 - $8,600. It also provides both detention and retention, compared to the wetland that only provides detention.
  - The gravel storage chamber and rain garden cost range is similar. The most expensive option is using porous paving and a rain tank.
- Maintenance costs vary from $35 - $75 per year for the Base Case – Wetland Treatment up to approximately $500 to $800 for the porous paving + rain tank Scenario.
- Order of increasing extra present cost above wetland treatment is as follows: rain garden, porous paving with increased gravel thickness, gravel storage chamber and then porous paving with rain tank.

2.8.3 Mixed and Terraced Housing

Costs are presented below for a selection of mixed and terraced housing configurations to show the difference in costs for these smaller lots, particularly if designed with common stormwater treatment devices. Figure 2-6 shows the establishment of a communal rain garden in Albany, Auckland.

Figure 2-6 Establishment of a communal rain garden in Albany, Auckland (Infrastructure & Environmental Services, Auckland Council 2013)

Table 2-6 summarises the lot size, impervious area and number of dwellings for the range of mixed and terraced housing costing scenarios analysed.

The mixed housing scenarios include:

- Suburban Housing - a 400m^2 lot as part of a 2-lot townhouse subdivision of an 800m^2 lot,
- Urban Housing – a smaller 267m^2 lot as part of a 3-lot subdivision of a similar 800m^2 lot,
- Detached Housing – a middle range 333m^2 lot as part of a larger 6-lot subdivision of a 2,000m^2 lot.

The terraced housing example includes:

- 12 terrace dwellings on a 1,600m^2 lot (at a 1:133 dwelling to land ratio).

Table 2-6 Mixed and Terraced Housing Lot Configurations

Lot Configuration	Mixed Housing						Terraced Housing	
	Suburban Housing		Urban Housing		Detached Housing			
	m^2	%	m^2	%	m^2	%	m^2	%
Lot Size	400		267		333		133	
Impervious Area	240	60%	160	60%	199	60%	80	60%
- Roof (footprint + eaves)	170	43%	115	43%	142	43%	56	42%
- Driveway	50	18%	35	17%	42	17%	16	18%
- Paths	20		10		15		8	
Pervious	160	40%	107	40%	134	40%	53	40%
Vegetated (10%)	40	10%	26.7	10%	33.3	10%		
Reason for selecting	Larger 400m² min size lot. One rain garden per dwelling. Example of two townhouses on 800m² lot.		Smaller 267m² min size lot. One rain garden per dwelling. Example of three urban dwellings on 800m² lot.		Middle 333m² lot size. Use one combined rain garden for six dwellings on 2,000m² lot.		1,600m² with 12 terrace dwellings at 1:133. Example one combined rain garden for 12 terraces.	

For demonstration purposes the costs have been presented below for a rain garden to meet SMAF1 requirements. The rain garden is most suited to communal design, whereas the rain tank option would require additional design and space considerations with the use of communal tanks to provide non-potable water to each individual dwelling. The gravel storage scenarios are only recommended for individual houses.

Table 2-7 presents the construction, maintenance and total present costs to meet the SMAF1 requirements for a selection of mixed and terraced housing lot configurations compared to the single house 500m² lot example from the previous section.

General notes on the derivation and use of the table are:

- Construction costs include the cost of the SMAF1 rain garden plus 'other' costs. 'Other' costs include the conventional costs for the concrete driveway and footpaths and vegetated landscaped areas. With the variable lot sizes, these other costs vary for each lot configuration.
- The suburban and urban housing examples assume one rain garden per dwelling. Maintenance cost for these examples are as per the reduced 'household' rates used for the previous single house section (at $63 to $90 per year per dwelling).
- The 6 detached housing and 12 terraced housing examples assume one communal rain garden with costs shared equally between each dwelling. The maintenance of these communal rain gardens has been increased and rated per square metre of rain garden on the assumption that they are likely to be maintained by an outside contractor under a body corporate type structure. The average annualised undiscounted maintenance for these communal rain gardens has been taken as $18 to $28/m² of rain garden area (refer to Table 2-6 in the Appendix for details).

Table 2-7 Mixed and Terraced Housing SMAF1 Costs

Mixed and Terraced Housing Comparisons	Household Rain Garden Treatment to SMAF1									
			Mixed Housing						12 Terraced Houses (combined rain garden, costs per dwelling, per 133m² lot)	
	Comparative Single House (500m² lot)		Suburban Housing (one rain garden per 400m² lot)		Urban Housing (one rain garden per 267m² lot)		6 Detached Houses (combined rain garden, costs per dwelling, per 333m² lot)			
SMAF1 CONSTRUCTION	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Rain Garden	$ 6,860	$12,720	$ 5,888	$10,776	$ 4,592	$ 8,184	$ 3,915	$ 7,997	$ 1,607	$ 3,297
Other (Drive, path, veg)	$11,219	$14,623	$ 7,418	$ 9,709	$ 4,910	$ 6,427	$ 6,117	$ 8,008	$ 2,486	$ 3,253
Total SMAF1 Constr.	**$18,079**	**$27,343**	**$13,306**	**$20,485**	**$ 9,502**	**$14,611**	**$ 10,033**	**$ 16,006**	**$ 4,092**	**$ 6,549**
BASE CASE CONSTRUCTION										
Wetland	$ 3,330	$ 8,580	$ 2,664	$ 6,864	$ 1,778	$ 4,582	$ 2,218	$ 5,714	$ 886	$ 2,282
Other (Drive, path, veg)	$12,290	$16,153	$ 8,275	$10,933	$ 5,481	$ 7,243	$ 6,828	$ 9,023	$ 2,771	$ 3,661
Total Base Case Constr.	**$15,620**	**$24,733**	**$10,939**	**$17,797**	**$ 7,259**	**$11,825**	**$ 9,046**	**$ 14,738**	**$ 3,657**	**$ 5,943**
EXTRA CONSTRUCTION COST above wetland	**$ 2,459**	**$ 2,610**	**$ 2,367**	**$ 2,688**	**$ 2,243**	**$ 2,786**	**$ 987**	**$ 1,268**	**$ 435**	**$ 606**
PRESENT COST CALCULATIONS										
Average Annualised Maintenance (undiscounted)										
SMAF1 Rain Garden	$ 63	$ 90	$ 63	$ 90	$ 63	$ 90	$ 215	$ 334	$ 86	$ 134
Base Case Wetland	$ 35	$ 75	$ 28	$ 60	$ 19	$ 40	$ 23	$ 50	$ 9	$ 20
Extra Maintenance above wetland	**$ 28**	**$ 15**	**$ 35**	**$ 30**	**$ 44**	**$ 50**	**$ 192**	**$ 284**	**$ 77**	**$ 114**
TOTAL PRESENT COSTS										
SMAF1 Rain Garden	$ 8,360	$14,820	$ 7,388	$12,876	$ 6,092	$10,284	$ 9,109	$ 16,057	$ 3,695	$ 6,537
SMAF1 Other	$11,219	$14,623	$ 7,418	$ 9,709	$ 4,910	$ 6,427	$ 6,117	$ 8,008	$ 2,486	$ 3,253
Total SMAF1	**$19,579**	**$29,443**	**$14,806**	**$22,585**	**$11,002**	**$16,711**	**$ 15,227**	**$ 24,065**	**$ 6,180**	**$ 9,789**
Base Case Wetland	$ 3,958	$ 9,826	$ 3,166	$ 7,861	$ 2,114	$ 5,247	$ 2,636	$ 6,544	$ 1,053	$ 2,614
Base Case Other	$12,290	$16,153	$ 8,275	$10,933	$ 5,481	$ 7,243	$ 6,828	$ 9,023	$ 2,771	$ 3,661
Total Base Case	**$16,248**	**$25,979**	**$11,441**	**$18,793**	**$ 7,595**	**$12,490**	**$ 9,464**	**$ 15,567**	**$ 3,824**	**$ 6,274**
Extra Total Present Cost above wetland	**$ 3,331**	**$ 3,464**	**$ 3,365**	**$ 3,791**	**$ 3,407**	**$ 4,221**	**$ 5,763**	**$ 8,498**	**$ 2,356**	**$ 3,515**

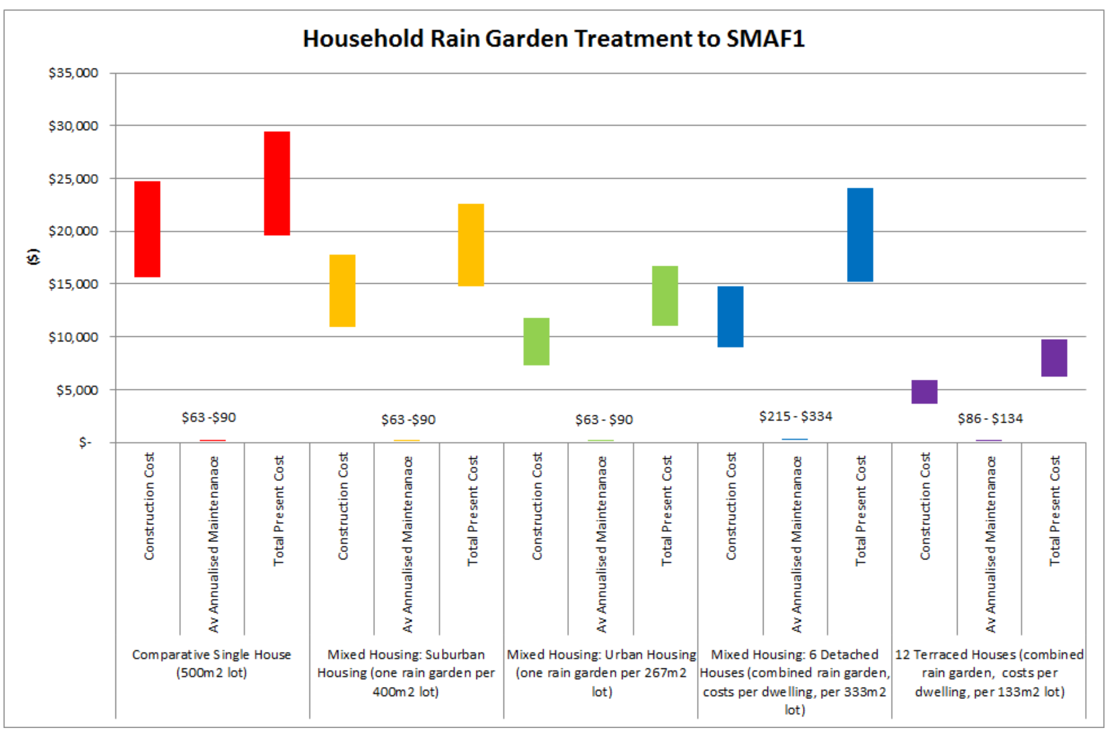


Figure 2-7 Mixed and Terraced Housing SMAF Costs

Table 2-7 and Figure 2-7 show the following:

- The rain garden construction costs per dwelling reduce with the smaller lot sizes (from the single house 500m^2 lot to the urban 267m^2 lot). The extra construction cost per dwelling is further reduced with the use of communal rain gardens (for 6 detached houses and 12 terraced housing).
- The average annualised undiscounted maintenance shows a different trend. The maintenance costs per dwelling are greater for the communal rain garden examples (detached and terraced housing) due to the assumed increased maintenance costs from the likely management of the rain garden by outside contractors through a body corporate structure.
- The total present cost (above wetland treatment) for the Suburban and Urban Housing are similar to the Comparative Single House at around $3,000 to $4,000. For the 6 Detached Houses, the extra total present cost ranges from $5,800 - $8,500 and for the 12 Terraced Houses, extra total present cost ranges from $2,400 - $3,500.

2.8.4 Parking Areas

Rain gardens and/or porous parking are effective ways of managing parking areas to meet the SMAF1 and SMAF2 hydrology controls. Figure 2-8 shows how rain gardens and porous paving can be incorporated into a typical 2,000m^2 parking area.

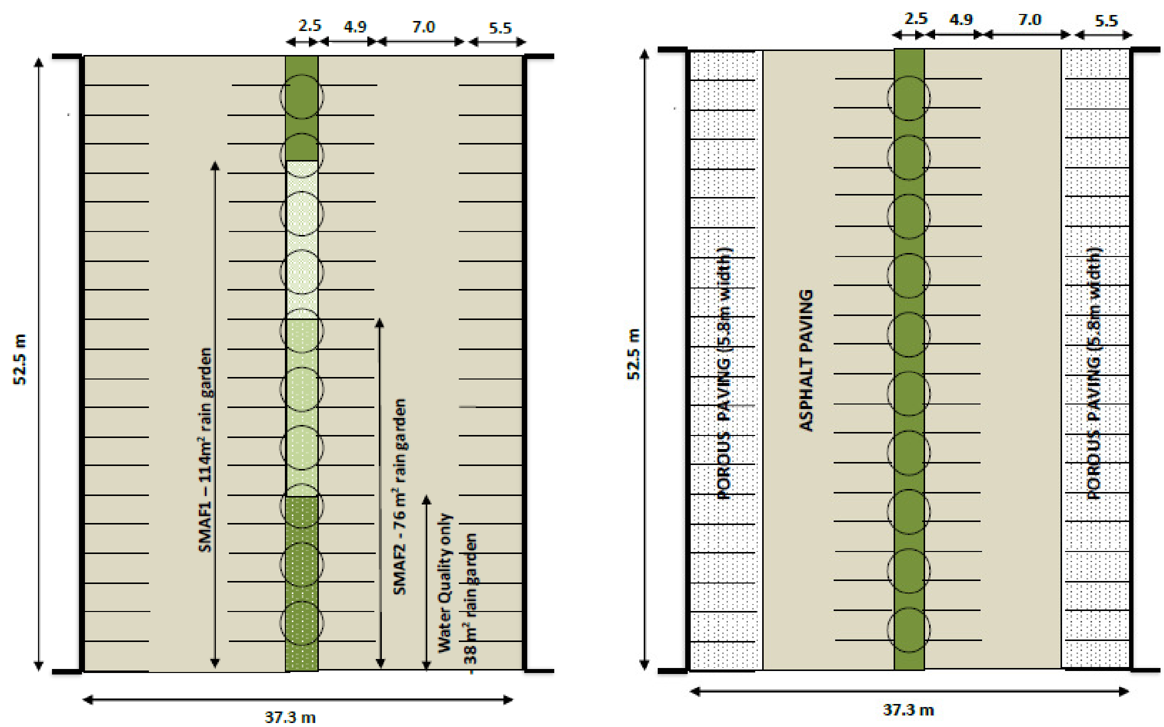


Figure 2-8 Schematic of Example Rain Garden and Porous Paving Parking Area (D&B Kettle Consulting Ltd 2013a)

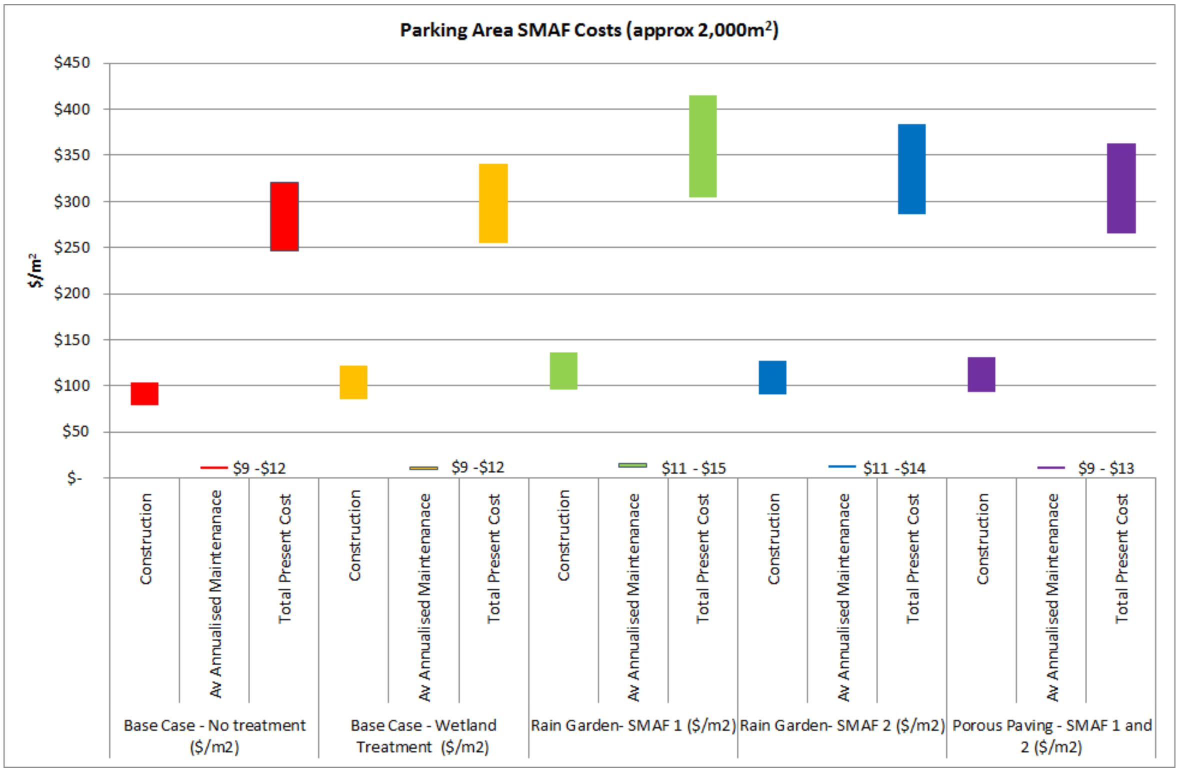
Photographs of where conventional raised landscaping strips in parking areas can be designed as bioretention rain gardens are shown in Figure 2-9.

Figure 2-9 Example Conventional Raised Landscaping (left) and Rain Garden Landscaping (right) (D&B Kettle Consulting Ltd 2013b)

Table 2-8 presents the construction, maintenance and total present costs for treating a 2,000m^2 parking area to SMAF 1 and SMAF 2 requirements with rain gardens or porous paving (refer to Section 2.2.1 for assumptions and Section 2 and 3 of the Appendix for cost details).

Table 2-8 Parking Area SMAF Costs

Parking Area	Base Case - No treatment		Base Case - Wetland Treatment		Rain Garden				Porous Paving	
					SMAF1		SMAF2		SMAF1 and SMAF2	
	Low	High	Low	High	Low	High	Low	High	Low	High
Construction										
Asphalt Pavement	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 87,696	$ 112,056
Porous Pavement									$ 73,080	$ 109,620
Other	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610
Landscaping										
- Vegetated (grass/landscaped)	$ 2,625	$ 11,156	$ 2,625	$ 11,156	$ 354	$ 1,504	$ 1,111	$ 4,721	$ 2,625	$ 11,156
- Rain Garden					$ 36,067	$ 73,135	$ 24,712	$ 50,423		
Sand Filter										
Wetland (25Ha Catchment)			$ 13,042	$ 33,604						
TOTAL CONSTRUCTION	**$ 154,509**	**$ 203,850**	**$ 167,551**	**$ 237,454**	**$ 188,305**	**$ 267,332**	**$ 177,706**	**$ 247,838**	**$ 183,741**	**$ 257,442**
- per m^2	**$ 79**	**$ 104**	**$ 86**	**$ 121**	**$ 96**	**$ 137**	**$ 91**	**$ 127**	**$ 94**	**$ 131**
- Extra per m^2 (above wetland)					**$ 11**	**$ 15**	**$ 5**	**$ 5**	**$ 8**	**$ 10**
Percent increase from Base Case - Wetland Treatment					**12%**	**13%**	**6%**	**4%**	**10%**	**8%**
PRESENT COST CALCULATIONS										
Average Annualised Maintenance										
Asphalt Pavement	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 10,524	$ 13,447
Porous Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,347	$ 8,021
Other	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033
Landscaping										
- Vegetated (grass/landscaped)	$ 92	$ 394	$ 92	$ 394	$ 12	$ 53	$ 39	$ 167	$ 92	$ 394
- Rain Garden	$ -	$ -	$ -	$ -	$ 4,088	$ 6,586	$ 2,725	$ 4,391	$ -	$ -
Sand Filter										
Wetlands (25Ha catchment)			$ 137	$ 284						
TOTAL Av. Annualised Maint.	**$ 18,250**	**$ 23,596**	**$ 18,388**	**$ 23,880**	**$ 22,259**	**$ 29,842**	**$ 20,923**	**$ 27,760**	**$ 18,336**	**$ 24,894**
- per m^2	**$ 9**	**$ 12**	**$ 9**	**$ 12**	**$ 11**	**$ 15**	**$ 11**	**$ 14**	**$ 9**	**$ 13**
- Extra per m^2 (above wetland)					**$ 2**	**$ 3**	**$ 1**	**$ 2**	**-$ 0**	**$ 1**
- Percent increase from Base Case - Wetland Treatment					**21%**	**25%**	**11%**	**13%**	**0%**	**4%**
PRESENT COSTS										
Asphalt Pavement	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 272,954	$ 348,774
Porous Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 171,902	$ 257,853
Other	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600
Landscaping										
- Vegetated grass	$ 4,725	$ 20,081	$ 4,725	$ 20,081	$ 637	$ 2,707	$ 2,000	$ 8,498	$ 4,725	$ 20,081
- Rain Garden	$ -	$ -	$ -	$ -	$ 116,633	$ 201,693	$ 78,422	$ 136,129	$ -	$ -
Sand Filter										
Wetland (25Ha Catchment)			$ 15,502	$ 38,484						
TOTAL Present Cost (2,000m^2)	**$ 483,374**	**$ 627,843**	**$ 498,875**	**$ 666,326**	**$ 595,918**	**$ 812,161**	**$ 559,070**	**$ 752,388**	**$ 518,799**	**$ 711,308**
- per m^2	**$ 247**	**$ 321**	**$ 255**	**$ 340**	**$ 304**	**$ 415**	**$ 285**	**$ 384**	**$ 265**	**$ 363**
- Extra per m^2 (above wetland)					**$ 50**	**$ 74**	**$ 31**	**$ 44**	**$ 10**	**$ 23**
- Percent increase from Base Case - Wetland Treatment					**19%**	**22%**	**12%**	**13%**	**4%**	**7%**



Detention	x	✓	✓	✓	✓
Retention	x	x	✓	✓	✓

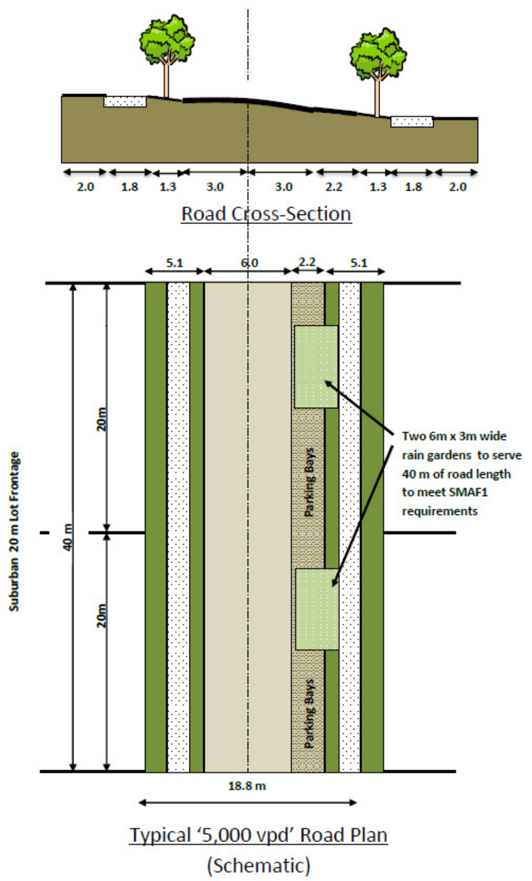
Figure 2-10 Parking Area SMAF Costs and Management Functions

Table 2-8 and Figure 2-10 show the following:

- For achieving SMAF 1 requirements, the extra construction cost above wetland treatment is similar for porous paving ($8 - $10/m^2) and rain gardens ($11 - $15/m^2). Porous paving and rain gardens provide both detention and retention, while wetlands provide detention only.
- Maintenance costs vary from $9- $12/m^2 per year for the two Base Case Scenarios (No Treatment and Wetland Treatment). For achieving SMAF 1 requirements, utilising porous paving ($9- $13/m^2) and rain gardens ($11 - $15/m^2) results in a slight increase in maintenance costs.
- Porous paving has a lower total present cost compared to rain gardens.

2.8.5 Roads

The possible location and sizing of rain gardens within the road right-of-way is shown in the schematics for a '5,000 vpd' (vehicles per day) road and a secondary arterial road in Figure 2-11, along with photos of examples in the Auckland area (Figure 2-12).



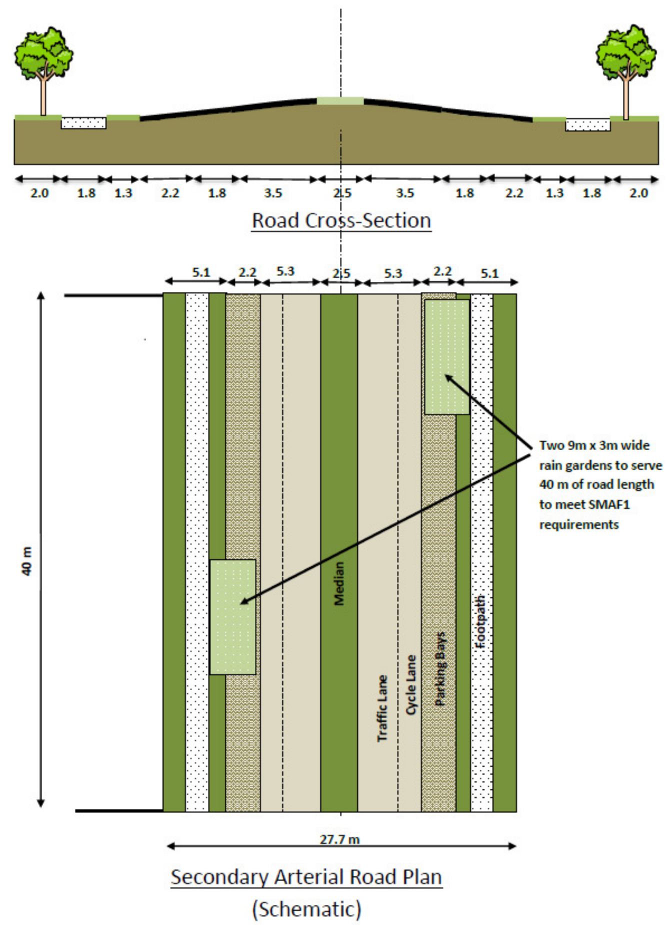


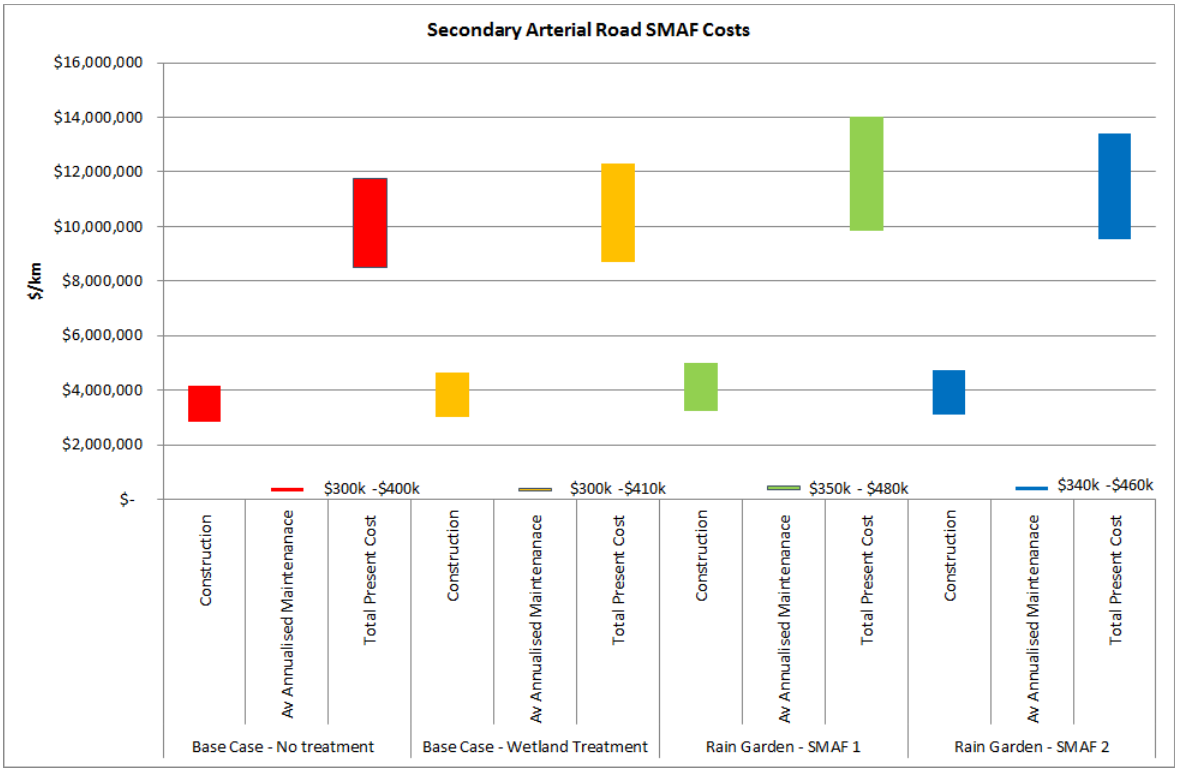
Figure 2-11 Schematic Rain Garden Road Layouts (Auckland Transport 2013)

Figure 2-12 Photos of Rain Gardens in Roads in North Shore, Auckland (Infrastructure & Environmental Services, Auckland Council 2013)

Table 2-9 presents the construction, maintenance and total present costs for treating secondary arterial road to SMAF1 and SMAF2 requirements with rain gardens (refer to Section 2.2.1 for assumptions and Section 2 and 3 of the Appendix for cost details). Porous paving is not recommended for roads due to the impact of traffic loading.

Table 2-9 Secondary Arterial Road Rain Garden SMAF1/2 Costs

Secondary Arterial Road	Base Case - No Treatment		Base Case - Wetland Treatment		Rain Garden			
					SMAF1		SMAF2	
	Low	High	Low	High	Low	High	Low	High
Construction								
Pavement	$ 60,523	$ 77,335	$ 60,523	$ 77,335	$ 60,523	$ 77,335	$ 60,523	$ 77,335
Footpath	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076
Other	$ 33,480	$ 40,920	$ 33,480	$ 40,920	$ 33,480	$ 40,920	$ 33,480	$ 40,920
Landscaping								
- Vegetated (grass)	$ 8,072	$ 34,306	$ 8,072	$ 34,306	$ 6,992	$ 29,716	$ 7,088	$ 30,124
- Rain Garden					$ 18,200	$ 37,400	$ 12,800	$ 26,600
Wetland (25Ha Catchment)			$ 7,379	$ 19,013				
TOTAL CONSTRUCTION (40m)	**$ 113,091**	**$ 166,637**	**$ 120,470**	**$ 185,650**	**$ 130,211**	**$ 199,447**	**$ 124,907**	**$ 189,055**
- per Km	**$ 2,827,280**	**$ 4,165,930**	**$ 3,011,762**	**$ 4,641,262**	**$ 3,255,280**	**$ 4,986,180**	**$ 3,122,680**	**$ 4,726,380**
- Extra per km (above wetland)					**$ 243,518**	**$ 344,918**	**$ 110,918**	**$ 85,118**
Percent increase from Base Case - Wetland Treatment					**8%**	**7%**	**4%**	**2%**
PRESENT COST CALCULATIONS								
Average Annualised Maintenance								
Pavement	$ 7,767	$ 9,925	$ 7,767	$ 9,925	$ 7,767	$ 9,925	$ 7,950	$ 10,158
Footpath	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Other	$ 3,906	$ 4,991	$ 3,906	$ 4,991	$ 3,906	$ 4,991	$ 3,906	$ 4,991
Landscaping								
- Vegetated (grass)	$ 283	$ 1,211	$ 283	$ 1,211	$ 245	$ 1,049	$ 248	$ 1,063
- Rain Garden	$ -	$ -	$ -	$ -	$ 1,944	$ 3,132	$ 1,296	$ 2,088
Wetland (25Ha Catchment)			$ 78	$ 166				
TOTAL Av. Annualised Maint.	**$ 11,956**	**$ 16,126**	**$ 12,033**	**$ 16,293**	**$ 13,862**	**$ 19,096**	**$ 13,400**	**$ 18,301**
- per Km	**$ 298,892**	**$ 403,162**	**$ 300,831**	**$ 407,317**	**$ 346,547**	**$ 477,412**	**$ 335,004**	**$ 457,516**
- Extra per km (above wetland)					**$ 45,716**	**$ 70,095**	**$ 34,174**	**$ 50,199**
Percent increase from Base Case - Wetland Treatment					**15%**	**17%**	**11%**	**12%**
PRESENT COSTS								
Pavement	$ 200,231	$ 255,851	$ 200,231	$ 255,851	$ 200,231	$ 255,851	$ 204,947	$ 261,877
Footpath	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076
Other	$ 113,935	$ 139,253	$ 113,935	$ 139,253	$ 113,935	$ 139,253	$ 113,935	$ 139,253
Landscaping								
- Vegetated (grass)	$ 14,530	$ 61,751	$ 14,530	$ 61,751	$ 12,586	$ 53,489	$ 12,758	$ 54,223
- Rain Garden					$ 56,511	$ 98,533	$ 38,341	$ 67,356
Wetland (25Ha Catchment)			$ 8,771	$ 21,774				
TOTAL Present Cost	**$ 339,711**	**$ 470,931**	**$ 348,482**	**$ 492,705**	**$ 394,278**	**$ 561,202**	**$ 380,997**	**$ 536,785**
- per Km	**$ 8,492,778**	**$ 11,773,271**	**$ 8,712,051**	**$ 12,317,631**	**$ 9,856,958**	**$ 14,030,056**	**$ 9,524,927**	**$ 13,419,632**
- Extra per km (above wetland)					**$ 1,144,907**	**$ 1,712,425**	**$ 812,876**	**$ 1,102,001**
Percent increase from Base Case - Wetland Treatment					**13%**	**14%**	**9%**	**9%**



Detention	x	✓	✓	✓
Retention	x	x	✓	✓

Figure 2-13 Secondary Arterial Road HCGA Costs and Management Functions

Table 2-9 and Figure 2-13 show the following:

- The construction cost to treat a secondary arterial road increases by approximately 8% to achieve SMAF1 requirements and by approximately 3% to achieve SMAF2 requirements (above Base Case - Wetland Treatment). Rain gardens provide both detention and retention, while wetlands provide detention only.
- The average annualised undiscounted maintenance costs of the rain garden treatment options are approximately 11% to 17% above Base Case - Wetland Treatment.
- The combined construction and maintenance costs give a total present cost above the Base Case – Wetland Treatment of approximately 14% for SMAF1 rain garden and approximately 9% for the SMAF2 rain garden.

2.9 HCGA Stormwater Scenario Costs

2.9.1 Introduction

In order to demonstrate the range of stormwater devices and associated costs to meet the specific Unitary Plan water quality HCGA requirements, costs are summarised below for two examples:

- Parking areas
- High use roads

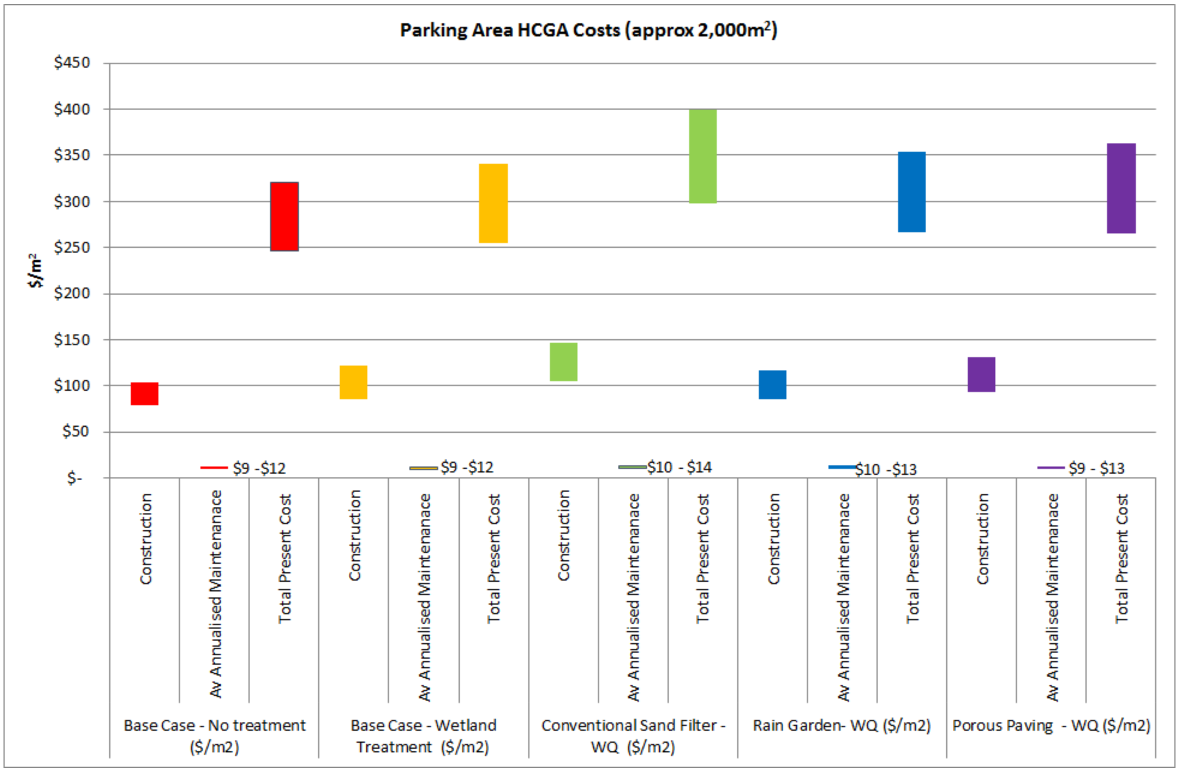
2.9.2 Parking Areas

The same parking area as analysed in Section 2.8.4 above is used for estimating the water quality costs (Refer Figure 2-8). For comparison, costs for an additional conventional sand filter treatment are also included.

Table 2-10 presents the construction, maintenance and total present costs for treating a 2,000m^2 parking area with rain gardens, porous paving and a conventional sand filter.

Table 2-10 Parking Area HCGA Costs

Parking Area	Base Case - No treatment		Base Case - Wetland Treatment		Conventional Sand Filter Water Quality		Rain Garden Water Quality		Porous Paving Water Quality	
	Low	High	Low	High	Low	High	Low	High	Low	High
Construction										
Asphalt Pavement	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 131,544	$ 168,084	$ 87,696	$ 112,056
Porous Pavement									$ 73,080	$ 109,620
Other	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610	$ 20,340	$ 24,610
Landscaping										
- Vegetated (grass/landscaped)	$ 2,625	$ 11,156	$ 2,625	$ 11,156	$ 2,625	$ 11,156	$ 1,868	$ 7,939	$ 2,625	$ 11,156
- Rain Garden							$ 13,356	$ 27,712		
Sand Filter					$ 50,000	$ 84,000				
Wetland (25Ha Catchment)			$ 13,042	$ 33,604						
TOTAL CONSTRUCTION	**$ 154,509**	**$ 203,850**	**$ 167,551**	**$ 237,454**	**$ 204,509**	**$ 287,850**	**$ 167,108**	**$ 228,344**	**$ 183,741**	**$ 257,442**
- per m^2	**$ 79**	**$ 104**	**$ 86**	**$ 121**	**$ 104**	**$ 147**	**$ 85**	**$ 117**	**$ 94**	**$ 131**
- Extra per m^2 (above wetland)					**$ 19**	**$ 26**	**-$ 0**	**-$ 5**	**$ 8**	**$ 10**
Percent increase from Base Case - Wetland Treatment					**22%**	**21%**	**0%**	**-4%**	**10%**	**8%**
PRESENT COST CALCULATIONS										
Average Annualised Maintenance										
Asphalt Pavement	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 15,785	$ 20,170	$ 10,524	$ 13,447
Porous Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 5,347	$ 8,021
Other	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033	$ 2,373	$ 3,033
Landscaping										
- Vegetated (grass/landscaped)	$ 92	$ 394	$ 92	$ 394	$ 92	$ 394	$ 65	$ 280	$ 92	$ 394
- Rain Garden	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,363	$ 2,195	$ -	$ -
Sand Filter					$ 2,280	$ 3,202				
Wetlands (25Ha catchment)			$ 137	$ 284						
TOTAL Av. Annualised Maint.	**$ 18,250**	**$ 23,596**	**$ 18,388**	**$ 23,880**	**$ 20,530**	**$ 26,798**	**$ 19,587**	**$ 25,678**	**$ 18,336**	**$ 24,894**
- per m^2	**$ 9**	**$ 12**	**$ 9**	**$ 12**	**$ 10**	**$ 14**	**$ 10**	**$ 13**	**$ 9**	**$ 13**
- Extra per m^2 (above wetland)					**$ 1**	**$ 1**	**$ 1**	**$ 1**	**-$ 0**	**$ 1**
- Percent increase from Base Case - Wetland Treatment					**10%**	**11%**	**6%**	**6%**	**0%**	**4%**
PRESENT COSTS										
Asphalt Pavement	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 409,431	$ 523,161	$ 272,954	$ 348,774
Porous Pavement	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 171,902	$ 257,853
Other	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600	$ 69,218	$ 84,600
Landscaping										
- Vegetated grass	$ 4,725	$ 20,081	$ 4,725	$ 20,081	$ 4,725	$ 20,081	$ 3,362	$ 14,290	$ 4,725	$ 20,081
- Rain Garden	$ -	$ -	$ -	$ -	$ -	$ -	$ 40,211	$ 70,564	$ -	$ -
Sand Filter					$ 100,312	$ 154,806				
Wetland (25Ha Catchment)			$ 15,502	$ 38,484						
TOTAL Present Cost (2,000m^2)	**$ 483,374**	**$ 627,843**	**$ 498,875**	**$ 666,326**	**$ 583,686**	**$ 782,648**	**$ 522,222**	**$ 692,615**	**$ 518,799**	**$ 711,308**
- per m^2	**$ 247**	**$ 321**	**$ 255**	**$ 340**	**$ 298**	**$ 400**	**$ 267**	**$ 354**	**$ 265**	**$ 363**
- Extra per m^2 (above wetland)					**$ 43**	**$ 59**	**$ 12**	**$ 13**	**$ 10**	**$ 23**
- Percent increase from Base Case - Wetland Treatment					**17%**	**17%**	**5%**	**4%**	**4%**	**7%**



Detention	x	✓	partial	partial	✓
Retention	x	x	x	partial	✓
Water Quality	x	✓	✓	✓	✓

Figure 2-14 Parking Area HCGA Costs and Management Functions

Table 2-10 and Figure 2-14 show the following:

- The least construction cost option to treat a 2,000 m^2 parking area is the use of rain gardens. The conventional sand filter is the most expensive option. The rain garden construction cost is approximately the same cost as the wetland.
- The average annualised undiscounted maintenance costs of the sand filter, rain garden and porous paving options (in the range of \$9 to \$14/m^2) are similar to the wetland treatment base case at \$9 to \$12/m^2.
- The combined construction and maintenance costs give a total present cost above the Base Case – Wetland Treatment of approximately 5% for both the rain garden and porous paving options. The sand filter is 17% higher than the base case wetland treatment option.

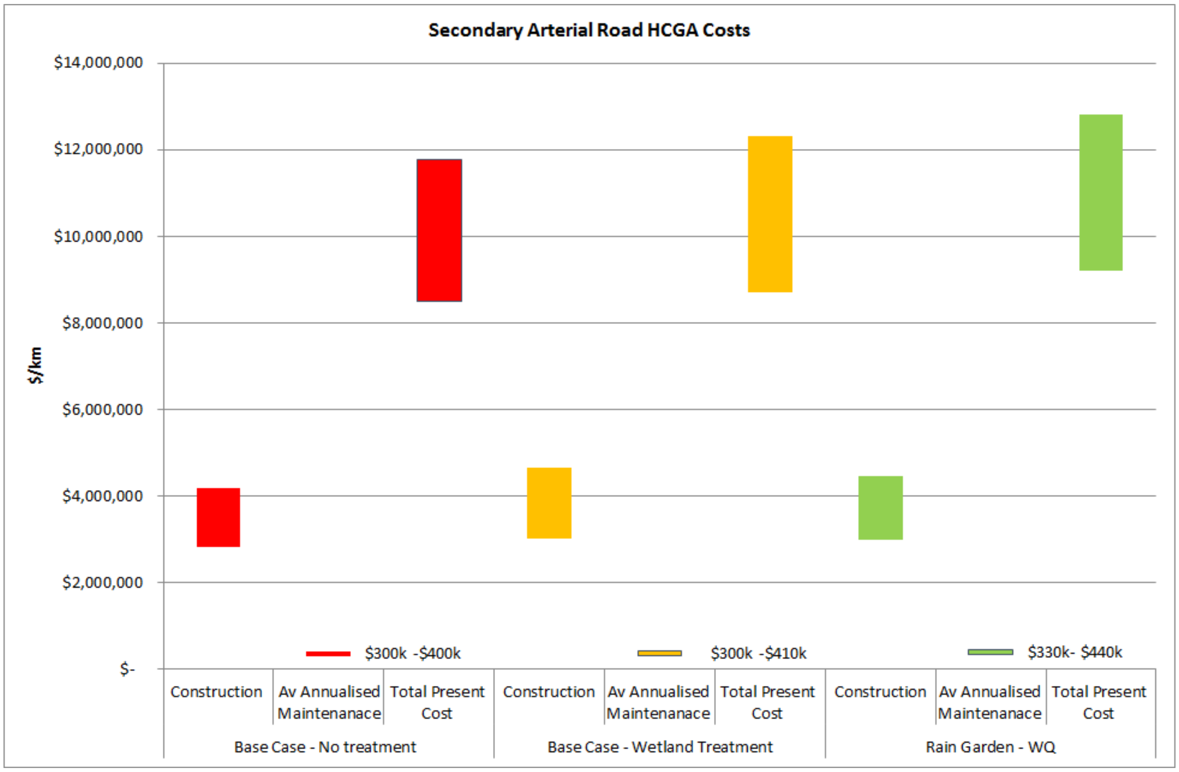
2.9.3 Roads

The same secondary arterial road as analysed in Section 2.8.5 above is used for estimating the water quality costs (refer to Figure 2-11).

Table 2-11 presents the construction, maintenance and total present costs to treat a secondary arterial road with rain gardens. Porous paving is not recommended for arterial roads due to the high traffic loads.

Table 2-11 Secondary Arterial Road HCGA Costs

Secondary Arterial Road	**Base Case - No Treatment**		**Base Case - Wetland Treatment**		**Rain Garden Water Quality**	
	Low	**High**	**Low**	**High**	**Low**	**High**
Construction						
Pavement	$ 60,523	$ 77,335	$ 60,523	$ 77,335	$ 60,523	$ 77,335
Footpath	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076
Other	$ 33,480	$ 40,920	$ 33,480	$ 40,920	$ 33,480	$ 40,920
Landscaping						
- Vegetated (grass)	$ 8,072	$ 34,306	$ 8,072	$ 34,306	$ 7,184	$ 30,532
- Rain Garden					$ 7,400	$ 15,800
Wetland (25Ha Catchment)			$ 7,379	$ 19,013		
TOTAL CONSTRUCTION (40m)	**$ 113,091**	**$ 166,637**	**$ 120,470**	**$ 185,650**	**$ 119,603**	**$ 178,663**
- per Km	**$ 2,827,280**	**$ 4,165,930**	**$ 3,011,762**	**$ 4,641,262**	**$ 2,990,080**	**$ 4,466,580**
- Extra per km (above wetland)					**-$ 21,682**	**-$ 174,682**
Percent increase from Base Case - Wetland Treatment					**-1%**	**-4%**
PRESENT COST CALCULATIONS						
Average Annualised Maintenance						
Pavement	$ 7,767	$ 9,925	$ 7,767	$ 9,925	$ 8,133	$ 10,392
Footpath	$ -	$ -	$ -	$ -	$ -	$ -
Other	$ 3,906	$ 4,991	$ 3,906	$ 4,991	$ 3,906	$ 4,991
Landscaping						
- Vegetated (grass)	$ 283	$ 1,211	$ 283	$ 1,211	$ 251	$ 1,078
- Rain Garden	$ -	$ -	$ -	$ -	$ 648	$ 1,044
Wetland (25Ha Catchment)			$ 78	$ 166		
TOTAL Av. Annualised Maint.	**$ 11,956**	**$ 16,126**	**$ 12,033**	**$ 16,293**	**$ 12,938**	**$ 17,505**
- per Km	**$ 298,892**	**$ 403,162**	**$ 300,831**	**$ 407,317**	**$ 323,462**	**$ 437,621**
- Extra per km (above wetland)					**$ 22,632**	**$ 30,304**
Percent increase from Base Case - Wetland Treatment					**8%**	**7%**
PRESENT COSTS						
Pavement	$ 200,231	$ 255,851	$ 200,231	$ 255,851	$ 209,664	$ 267,904
Footpath	$ 11,016	$ 14,076	$ 11,016	$ 14,076	$ 11,016	$ 14,076
Other	$ 113,935	$ 139,253	$ 113,935	$ 139,253	$ 113,935	$ 139,253
Landscaping						
- Vegetated (grass)	$ 14,530	$ 61,751	$ 14,530	$ 61,751	$ 12,931	$ 54,958
- Rain Garden					$ 20,170	$ 36,178
Wetland (25Ha Catchment)			$ 8,771	$ 21,774		
TOTAL Present Cost	**$ 339,711**	**$ 470,931**	**$ 348,482**	**$ 492,705**	**$ 367,716**	**$ 512,368**
- per Km	**$ 8,492,778**	**$ 11,773,271**	**$ 8,712,051**	**$ 12,317,631**	**$ 9,192,896**	**$ 12,809,209**
- Extra per km (above wetland)					**$ 480,845**	**$ 491,578**
Percent increase from Base Case - Wetland Treatment					**6%**	**4%**



Detention	x	✓	partial
Retention	x	x	partial
Water Quality	x	✓	✓

Figure 2-15 Secondary Arterial Road HCGA Costs and Management Functions (per km)

Table 2-11 and Figure 2-15 show the following:

- The rain garden construction cost is approximately the same cost as the wetland.
- The average annualised undiscounted maintenance cost of the rain garden option is approximately 8% higher than the Base Case – Wetland Treatment.
- The combined construction and maintenance costs give a total present cost of the rain garden option at approximately 5% higher than the Base Case – Wetland Treatment.

2.9.4 Roofing Materials

As mentioned in Section 1, HCGA areas also include uncoated galvanised iron and copper/zinc based cladding materials. In these cases the least expensive option is to use appropriate non copper/zinc generating materials. For roofing, this would be appropriately coated aluminium roofing materials.

For example, the supply cost of coated aluminium cladding is approximately $\$21/m^2$ compared to uncoated at $\$15/m^2$, an additional cost of $\$6/m^2$ (Source: Roofing Supplier). Installation and maintenance costs are assumed to be the same, giving the same extra total present costs of $\$6/m^2$. For a house with a $200m^2$ roof, this equates to an additional $1,200.

2.10 Water Sensitive Design Approach Construction Costs

The case studies below present construction costs of a comprehensive water sensitive design (WSD) approach for greenfield developments. Operational and maintenance costs have not been included. These case studies have been presented to demonstrate that a WSD approach in greenfield development may not necessarily increase initial construction costs. Most of the savings can be achieved at the land use phase planning stage. The reduced costs of the WSD approach over the conventional are generally from (Shaver 2009):

- Less clearing and earthworks costs from clustering and working with the landscape contours.
- Less pavement length with reduced costs from clustering.
- Less stormwater infrastructure costs, swale drainage systems are cheaper to install than pipe systems.

In UK, WSD is termed as Sustainable Drainage Systems (SuDS) and Low Impact Development (LID) in USA.

2.10.1 New Zealand and USA

A literature review of three New Zealand LID sites and six USA LID projects was carried out for the Auckland Regional Council (Shaver 2009). Clearly, the costs depend on an effective, thoughtful design approach but a key outcome of the study was that LID can provide for a community that incorporates additional amenities and open space. Table 2-12 summarises the conventional and LID development construction costs from the 2009 study.

Table 2-12 Comparison of Construction Costs between Conventional and LID Site Development (adapted from Shaver 2009)

	Total Development Costs		Conventional development	LID development	Percentage Difference
Project	Conventional development	LID development	($/Ha)	($/Ha)	
New Zealand					
Heron Point	1,844,000	1,590,000	$249,189	$214,865	14%
Palm Heights	7,218,000	5,936,000	$260,578	$214,296	18%
Wainoni Downs	5,963,000	4,478,000	$419,930	$315,352	25%
USA					
Chapel Run	2,460,200	888,735	$61,505	$22,218	64%
Buckingham Green	541,400	199,692	$70,312	$25,934	63%
Tharpe Knoll	561,650	339,715	$41,914	$25,352	39%
Pleasant Hill	1,284,100	728,035	$37,768	$21,413	43%
Gap Creek	4,620,600	3,942,100	$88,858	$75,810	15%
Auburn Hills	2,360,385	1,598,989	$69,423	$47,029	32%

Construction cost savings are in the order of 14-25% in New Zealand and 15-64% in USA. More details of these case studies can be found in the Appendix (Section 9.1.1).

2.10.2 United Kingdom

As part of the work carried out for the UK Committee for Climate Change Adaptation, Royal HaskoningDHV (2012) looked at *'the type and scale of SuDS (Sustainable Drainage Systems) that would be cost-effective for society to take in England today for new and existing developments, when accounting for future climate uncertainty.'*

The report presented capital costs obtained from case study examples of new developments for a range of development size and densities, refer to Table 2-13 (the costs have been multiplied by 1.8 to convert from UK£ to NZ$).

Table 2-13 Capital Cost of SuDS and Traditional Drainage Systems (adapted from Royal HaskoningDHV 2012)

Development Density	Capital Cost per Property (NZ$)					
	Small (<100 properties)		Medium (100–500 properties)		Large (> 500 properties)	
	SuDS	Traditional	SuDS	Traditional	SuDS	Traditional
Dense (urban) (100 properties per Ha)	No data	No data	900	1,800	No data	No data
Moderate density (40 properties per Ha)	10,000	11,000	2,000 – 8,000	5,500 – 9,000	2,000	No data

Table 2-13 illustrates that the costs of SuDS and traditional development decreases with development size as economies of scale are realised. It also shows that the construction cost of the SuDs option is cheaper to install for small and medium development.

In summary, the report concluded with (Royal HaskoningDHV 2012, p20):

- *'In most situations SuDS have been shown to be less expensive to install and maintain than a traditional drainage system.*
- *All new development where site specific constraints do not lead to excessive cost implications should find it cost beneficial to install a SuDS system in preference to a traditional drainage system. The larger and less dense the development the more likely it is that this will be the case.'*

More details of this case study can be found in the Appendix (Section 9.1.2).

As discussed in Section 1.4, management of small, frequent flows is best achieved with on-site devices. However, these on-site devices do not manage the larger flood flows and traditional conveyance will be required for the larger events.

2.10.3 Economies of Scale

Economies of scale refers to the cost advantage obtained due to size, with cost per unit of output generally decreasing with increasing scale as fixed costs are spread out over more units of output, assuming it still provides the same level of stormwater management. For stormwater management, economies of scale only work up to a certain level. For example, catchment wide wetlands at the bottom of the catchment do not provide any stormwater management functions for the streams upstream of the wetland. Different stormwater management devices are effective at different ranges of scale. Often operational efficiency is also greater with increasing scale, leading to lower variable cost as well. The simple meaning of economies of scale is doing things more efficiently with increasing size of operation.

On-site stormwater management devices are relatively new in New Zealand. It is anticipated that as the use of WSD becomes more common in New Zealand, the market will mature and competition, innovation in design (amongst other factors) will reduce pricing. Some examples of economies of scale for the stormwater industry and its impact on cost have been discussed in the Appendix and are summarised below:

- Rain garden maintenance costs in Melbourne and South East Queensland are significantly lower than that in Auckland. This could represent a more probable future price scenario for Auckland. With efficiencies of scale and greater familiarisation over time, maintenance costs are expected to reduce (See Appendix, Section 2.5.4 and 2.5.5).
- The Long Bay off-line/trapezoidal rain gardens is an example of where innovation and cost savings were realised when the rain gardens are part of a 'whole design' approach and designed into the initial road layouts rather than as an 'add-on'. An optimised design, coupled with economies of scale (86 rain gardens) reduced construction costs significantly (See Appendix, Section 2.4.1).
- Tree pits are currently custom made. As demand increases, a mould can be made and hence reduce the unit cost. Indicative supply costs are $10,000 for a one off, which could be reduced to $7,500 each for a production run after the construction of a mould (See Appendix, Section 2.4.3).

3.0 Benefits Assessment

The continuing growth of Auckland's urban population creates a tension between the need for development and community aspirations to achieve better environmental outcomes (Moores et al., 2013). Historically, decision makers focussed on direct use values that can be measured through observable quantities of products as well as market prices. In recent decades, there is growing recognition of the value of 'indirect use' or non-market benefits (i.e. benefits that are not usually traded in market places). Monetary valuation attempts to estimate the value of both market and non-market benefits and use them in economic decisions via cost-benefit analysis or other economic incentives (Farley J 2008).

It is widely recognised that economic, social, environmental and cultural benefits for which there is no market price need to be brought into any assessment. These benefits are often difficult to assess but are important and should not be ignored simply because they cannot easily be quantified. Ignoring them is in fact putting an arbitrary value of zero to them, which is not only far less accurate than an attempt to assign a proper value, but hides them from view and prevents them from being addressed and attended to.

Limitations associated with quantifying these non-market benefits make it difficult to conduct a solely quantitative cost-benefit analysis. This section summarises the values associated with ecosystem services (benefits people derive from ecosystems) and work done locally and internationally to quantify the benefits of protecting receiving environments from the adverse effects of stormwater runoff.

A full economic analysis including costs and benefits is beyond the scope of this report. The report aims to iterate the benefits of WSD and green growth, so that future infrastructure investment decisions can recognise the full spectrum of benefits provided, many of which lie outside of stormwater.

This section is divided into four sub sections:

- Water Sensitive Design and Green Growth - summarises the benefits of Water Sensitive Design (WSD) and Green Growth approach to development.
- Benefits Assessment and Methods of Quantifying Benefits - discussion on market and non-market benefits and the different methods of quantifying benefits and incorporating it into the decision making process.
- General Cost - Benefit Analysis Case Studies – presents a number of local and international cost- benefit case studies to demonstrate the range of benefits versus costs of different stormwater management approaches.
- Specific On-site Device Cost-Benefit Study - A cost-benefit analysis for an individual on-site device (soil cell).

3.1 Water Sensitive Design and Green Growth

Water Sensitive Design (WSD) is an approach to freshwater management which is applied to land use planning and development at complementary scales including region, catchment, development and site. WSD seeks to protect and enhance freshwater systems, sustainably manage water resources and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities.

Water sensitive design approaches:

- utilise and maintain, enhance or restore freshwater systems.
- minimise hydrological changes to, and the adverse effects of land use development on freshwater systems.
- mimic natural processes and minimise the requirement for hard constructed infrastructure to manage stormwater runoff.
- maintain, enhance or restore amenity, open space and other community and cultural values.

The SMAF hydrology mitigation devices costed in Section 2 are examples of some of the devices that can be constructed to achieve enhanced water sensitive design outcomes. It should be noted that retrofitting these devices and/or their inclusion in isolation to a comprehensive land use planning and development approach can have additional cost implications. Section 2 presents a summary of the SMAF device costs along with some case studies showing that when a comprehensive water sensitive design approach is applied to greenfield developments, it may not necessarily increase initial construction costs (Refer to Section 2.10).

The Auckland Plan places significant emphasis on green growth and sustainable urban development. The aim of this approach is to meet the challenges of providing for significant growth, while at the same time providing communities with safe, healthy and high quality environments to live in (i.e. a liveable city). Of particular relevance to stormwater is the application of water sensitive design and green infrastructure (where practicable) for greenfield development and, where possible, redevelopment.

3.1.1 Advantages of WSD and Green Growth

The main advantages of WSD and green infrastructure (which includes the stormwater management devices costed in Section 2 of this report) are summarized below (USEPA 2013).

Water Quality

- Reduction in stream erosion and maintaining/enhancing stream health (including biodiversity and ecological functioning).
- Reduction in surface water run-off and diffuse pollution from new and existing developments, thus reducing impacts on the receiving environment such as rivers and lakes.
- Enhancing stormwater quality by promoting the treatment of stormwater close to source.

Water Supply

- Recharge of groundwater aquifers and stream base flows where appropriate through infiltration measures.
- Rainwater harvesting and infiltration-based practices can significantly reduce municipal water use.
- Provision of an alternative source of non-potable water for domestic and commercial uses.
- Local storage for supply in Civil Defence emergency.

Air Quality

- Green infrastructure can reduce ground level ozone by reducing air temperature and particulate pollution with subsequent increased health benefits. A study carried out in the City of Philadelphia found that increased tree canopy would reduce ozone and particulate pollution levels enough to significantly reduce mortality, hospital admissions and work loss days.

Energy and Climate Change

- Urban heat islands form as cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. Trees, green roofs and other green infrastructure features can cool urban areas by shading building surfaces, deflecting radiation from the sun and releasing moisture into the atmosphere. This lowers the cooling and heating demand for buildings with reduction in energy demand.

Private and Public Cost Savings

- On-site volume control can downsize the stormwater infrastructure required, thus reducing the cost of public infrastructure.
- Green infrastructure developers often experience lower capital costs, derived from lower costs for site grading, paving, landscaping, and smaller or eliminated piping and detention facilities.
- In areas with combined sewer systems, green infrastructure controls may cost less than providing additional CSO storage capacity. It can also reduce the volume of water to be dealt with via the combined sewer system.
- Reduced need for rehabilitation and maintenance of downstream water environments.

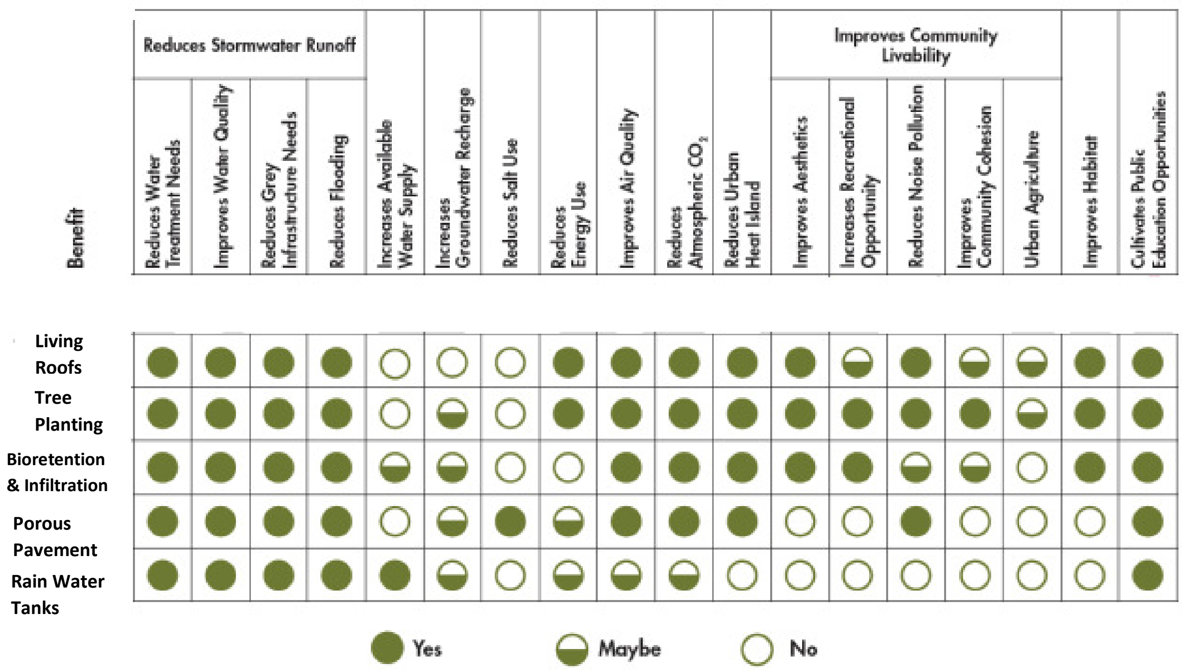
Habitat and Wildlife

- Vegetation in the urban environment provides wildlife habitat and connectivity.

Community

- Health Benefits: More green space and parks encourages outdoor physical activity, reducing obesity and preventing associated health issues.
- Recreation Space: Green infrastructure's vegetation and trees can increase publicly available recreation areas, allowing urban communities to enjoy greenery without leaving the city.
- Property Values: Enhanced quality of life for residents, expressed through premiums on land values due to enhanced amenity values and local and regional water quality.

Figure 3-1 below (adapted from Center for Neighbourhood Technology (CNT) and American Rivers 2010) illustrates the benefits of green infrastructure devices costed in this report – Living Roofs Bioretention and Infiltration devices, Porous Pavement and Rain Water Tanks. It should be noted that the SMAF and HCGA devices costed in this report focus on the smaller, more frequent rainfall events and hence have minimal impact on the larger 1 in 10 and 100-year flooding events. The 'Reduces Salt Use' is also not a benefit applicable to Auckland as salt use is not required in winter. It is important to note that these benefits accrue at varying scales according to local factors such as climate, population etc.



	Reduces Stormwater Runoff											Improves Community Livability						
Benefit	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Living Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Porous Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Rain Water Tanks	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

Figure 3-1 Green Infrastructure Benefits and Practices (adapted from Center for Neighbourhood Technology (CNT) and American Rivers 2010)

3.1.2 Disadvantages of WSD and Green Growth

Disadvantages of WSD and Green Growth include (Braden and Ando 2011; Water by Design 2010):

Private and Public Costs

- Many WSD practices focus on local on-site management rather than large single catchment wide devices. These smaller on-site devices are often located on private property whereas traditional large scale assets are largely public infrastructure. This shifts the initial cost and on-going maintenance responsibility to the private lot owner.
- Greater risks of poor maintenance with the reliance on private owners to carry out the on-going maintenance.
- Additional development assessment, compliance checking and enforcement costs associated with the many smaller private assets. It is expected that these costs will reduce over time as WSD becomes mainstream practice.

Community

- Increased community/private initial capital costs and on-going maintenance costs.
- The reluctance of the community to take up these costs and responsibilities.
- Greater need for public education and awareness programs so private land owners are aware of and carry out these additional maintenance responsibilities.
- More complex/dispersed public health and safety risk management with multiple small devices.

3.2 Methods of Quantifying Benefits

3.2.1 Discussion on Values

A range of ecological, social, cultural (not specific to tangata whenua) and economic values for freshwater from academic literature and New Zealand local government and consultancy reports are listed in a recent Auckland Council report (McFarlane 2013). The range of values that have been attributed to freshwater systems are summarised below in Table 3-1, with the full list discussed further in the Appendix, Section 10.1.

The values include 'in-stream' (i.e. where the water remains in the water body) and 'out-of-stream' (where the water is abstracted or taken out of the water body). Not all of the values and attributes listed in Table 3-1 will be appropriate for all Auckland freshwater bodies. For example, energy generation values are only relevant to some freshwater bodies in Auckland. The value and attribute lists should be refined for each catchment, based on each value type's relevance to freshwater in that geographic area. It is acknowledged that further work is required to transform the internationally and nationally derived values and valuation approaches summarised in this report into locally meaningful value frameworks for Auckland.

Table 3-1 Summarised list of freshwater values identified in the literature (adapted from McFarlane, 2013)

Value	Value type
In-stream ecological values	Natural character values Biological values
In-stream social values	Aesthetic values
	Recreational values
	Cultural values (not specific to tangata whenua)
In-stream economic values	Tourism values
	Energy generation values
	Supply value
	Research value
	Land holder values
	Regional ecosystem service values
Out-of-stream social values	Water supply values
Out-of-stream economic values	Water supply values

3.2.2 Quantifying Values/Benefits

Various frameworks, tools and valuation methods are available to quantify receiving environment outcomes under alternative urban development and stormwater management scenarios. These reinforce the need for considering economic, social, environmental and cultural values when considering the impacts of stormwater management and incorporating it into the decision making process.

Table 3-2 summarises some of the work done locally and internationally to quantify receiving environment outcomes under alternative urban development and stormwater management scenarios. The Appendix, Section 10.2 discusses these in more detail.

- Some studies use the four interests (economic, social, environmental and cultural) framework to categorise values (e.g. Moores et al., 2013) to develop a decision making tool. The four interests model is also widely known as ‘quadruple bottom line’ (QBL).
- Another approach is the ‘use’ and ‘non-use’ classifications, also referred to as Total Economic Value (e.g. Rohani 2013) to describe the value provided by natural systems. TEV is a framework for identifying values that could be quantified rather than a method for measuring values and potential impacts of a project.
- The ‘Mauri Model’ is a decision making framework that combines a stakeholder assessment of worldviews, with an impact assessment of indicators to determine sustainability and trends over time. This tool uses the concept of mauri as the measure of sustainability – in place of monetary values used conventionally. The use of mauri as the measure of sustainability allows for a more accurate representation of the impacts of certain actions/options – which may not always be best represented or included in monetary based assessments of sustainability, but are nonetheless important to the decision making process (www.mauriometer.com, August 2013).

- International and local monetary valuation studies have also been used to quantify the benefits of environmental goods and services.
- Valuation methods such as Willingness to Pay (WTP) surveys and Questionnaire survey responses.

Table 3-2 Tools, Frameworks and Valuation Methods

Tools, Frameworks and Valuation Methods	Comments
The Urban Planning that Sustains Waterbodies (UPSW) project is funded by the Ministry of Business, Innovation and Employment (MBIE) and it uses the four interests framework to develop a pilot Decision Support System (DSS) that allows urban planners and stormwater managers to consider holistically the impacts of urban development on indicators of environmental, social, economic and cultural interests (Moores et al., 2013). Current version does not include cultural interest. The tool is still under development/review as of October 2013.	- the DSS links a number of distinct models and other methods in order to make predictions of outcomes under alternative urban development and stormwater management scenarios. - quantitative assessment undertaken e.g. economic costs indicator is calculated as the lifecycle costs of the chosen stormwater management option and economic benefits indicator is calculated as the change in regional WTP associated with a change in stormwater-related attributes of the receiving environment. - tool is able to clearly demonstrate the correlation between different stormwater management scenarios and effects on the receiving environment water and sediment quality and ecosystem health. - this project demonstrates the effort and data required to undertake a full economic cost-benefit analysis. - one interesting outcome is that the indicator levels are reported using the 'traffic lights' system, rather than a ratio/number i.e. visual representation to present results.
A recent report completed for the Auckland Council (Rohani 2013) has recommended the use of a Total Economic Value (TEV) framework for estimating the value of Auckland's freshwater resources.	- TEV is a framework for identifying values that could be quantified rather than a method for measuring values and potential impacts of a project. - once values relevant to stormwater have been identified, a method for measuring value could be devised (keeping in mind the limitations associated with quantifying non-market benefits).
Mauri Model also uses a four interests framework. It measures mauri in four dimensions – environmental wellbeing (taiao mauri), cultural wellbeing (hapu mauri), social wellbeing (community mauri) and economic wellbeing (whanau mauri). (www.mauriometer.com, August 2013).	- this reinforces the need to include cultural values in infrastructure investment decision making. - the various indicators within each dimension are given a raw score between -2 and +2 and weightings are assigned to each indicator. The product of the scores times the weightings give a final score for each indicator. The individual scores are then summed up to compare scores for each proposal to provide a mechanism to choose between alternatives.

The following international, national and Auckland sources have been presented to show a range of studies that have attempted to quantify the benefits of the water environment:

- 'The Value of the World's Ecosystem Services and Natural Capital' (Costanza et al., 1997).
- 'Assessing the Value of New Zealand's Biodiversity' (Patterson and Cole 1999).
- 'Auckland Regional Stormwater Project: An Economic View' (Auckland Council TP3 1991).
- Willingness to Pay (WTP) - Auckland and International studies.

Table 3-3 below summarises the benefits identified by the above sources. Refer to the Appendix (Section 10.2.4) for further details.

Table 3-3 Summary of Monetary Valuation Studies

<table>
<tr><th>Study</th><th colspan="2">Reported Benefits/Values</th></tr>
<tr><td>The Value of the World's Ecosystem Services and Natural Capital (Costanza et al., 1997)</td><td colspan="2">This study estimated the economic value of global ecosystem services at US$33 trillion per year, nearly double the global GNP of US$18 trillion per year, making clear the magnitude of the contribution that ecosystems make to human wellbeing.</td></tr>
<tr><td>Assessing the Value of New Zealand's Biodiversity (Patterson and Cole 1999)</td><td colspan="2">This study estimated the total economic value from New Zealand's biodiversity for the year 1994 as $44 billion, consisting of the sum of direct use value, indirect use value and passive value of land-based biodiversity. This work was based on the work done by Costanza et al., (1997).</td></tr>
<tr><td>Auckland Regional Stormwater Project: An Economic View (Auckland Regional Council TP3 1991)</td><td colspan="2">This was the first study in Auckland on valuing a wide range of social and environmental variables. The project estimated the total benefits being derived from the 1991 level of water quality in the Auckland harbours as $442 million annually (CPI adjusted to 2013 NZ$700 million). While it is recognised that these benefits arise from more than just stormwater management, such as wastewater treatment, management of spills, riparian and bush plantings, it is nevertheless a significant annual benefit.</td></tr>
<tr><td>Willingness to Pay (WTP) Surveys</td><td colspan="2">Range (Annual NZ$ per household)</td></tr>
<tr><td>Auckland's Coastal Ecosystems (Batstone and Sinner 2010) – coastal</td><td>Generally $50 to $100</td><td rowspan="4">From the number of different WTP ranges reported, the results are very similar (approximate value of $100 per household)</td></tr>
<tr><td>Sweden's West Coast (2003) (as cited in Batstone and Sinner 2010) – coastal</td><td>$130 to $300</td></tr>
<tr><td>Other International Studies (as cited in Batstone and Sinner 2010) – coastal</td><td>$10 to $100</td></tr>
<tr><td>Auckland's for prevention of stream degradation (Lincoln University 2003) - streams</td><td>$109</td></tr>
</table>

Study	Reported Benefits/Values
Questionnaires (Auckland Council 2013d)	During the engagement phase of the Hibiscus and Bays Area Plan in 2012, Auckland Council sent out a questionnaire survey to ask people to rank the level of importance from 1 (not important) to 4 (very important) of various items. In response to question number 13, 'Items of importance to submitters', the highest ranking item of importance was 'Natural Environment' with an average ranking of 3.55, Of interest is that the 'Natural Environment' item was ranked as either 3 or a 4 by all respondents i.e. no one ranked it a 1 or 2.

3.3 Cost Benefit Analysis Case Studies

This section presents a number of case studies where the range of benefits versus costs of different stormwater management approaches has been quantified. The use of on-site devices does not preclude the need for pipes i.e. conveyance assets will still be required for the larger storm events.

It is important to consider these examples with caution, as actual costs can vary markedly between different regions/countries with different standards/objectives. Costs can vary depending on lot sizes and layouts, impervious areas, topographical and geotechnical constraints and infrastructure responsibilities. Costs can also vary between greenfield (new developments where stormwater management can be integrated at the planning stages and hence less costs) compared to brownfield (retrofitting into existing development layouts that are likely not to be the most efficient layout for the proposed new stormwater technology).

The variability, applicability and validity of the benefits claimed in these examples also need to be considered with caution.

Therefore, the examples below are given to show the range of different techniques/methods that have been used and the types of outcomes that are emerging in this relatively new field of valuing water sensitive design/on-site stormwater management practices.

Five case studies are presented below to show some examples of cost-benefit analysis that have been undertaken locally and internationally.

3.3.1 Auckland Twin Streams

The most recent Auckland study on valuing benefits is for Project Twin Streams (PTS), which covers an area of some 10,000 hectares, in the Henderson and Huruhuru Creeks in West Auckland. The value case is based on a capitals framework approach developed by Morrison Low in conjunction with Landcare Research. The capital approach extends the everyday use of the concept to apply across all capital goods (assets) that produce a flow of goods and services that generate wellbeing into the future. These include human, natural, social, produced and financial capital (Morrison Low 2010).

Some, but not all, of the benefits of PTS can be monetised. There is particular difficulty in monetising the social benefits. The value case therefore cannot be considered a cost benefit analysis. Some of the more significant results include the monetised benefits for water regulation (flood control), climate regulation (carbon sequestration), air quality maintenance (pollutant removal), public and private aesthetic benefits as well as the estimates of the walk- and cycle-ways benefits which show a combined NPV of (2007) NZ$140.7 million - $210.7 million respectively, over 25 years with a 7.2% discount rate. While these benefits represent only a part of the overall benefits that can be achieved by PTS over 25 years, they provide a good basis for a comparison with the actual costs (Morrison Low 2010).

Although it was not possible to quantify the increase of social, human and natural capital, Figure 3-2 below depicts a transfer of capital from financial capital into social, human and natural capital over time.

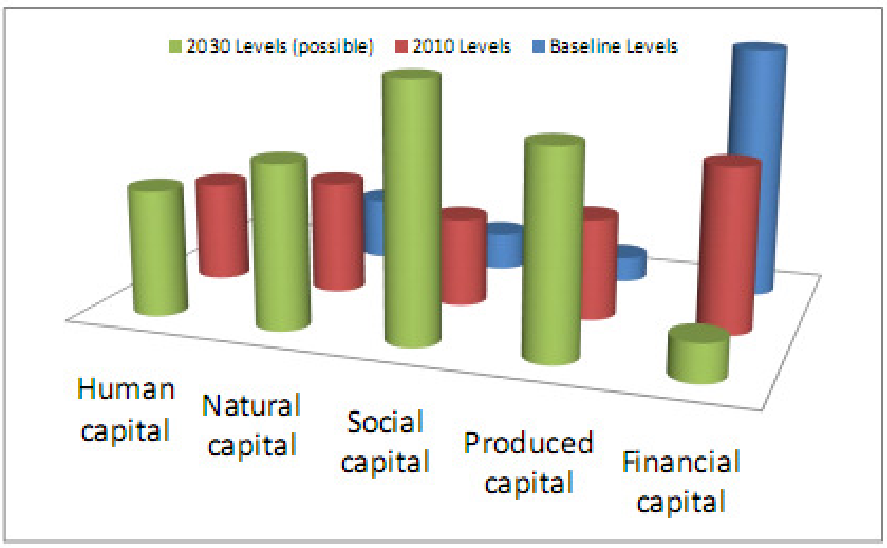


Figure 3-2 A representation of the estimated relative changes in capital in Waitakere arising from PTS (Morrison Low 2010)

An estimated $60M has been spent on PTS, including:

- Land property purchase to remove habitable floors from the 100-year flood plain - $26M
- Property restoration and disposal - $1.5M
- Riparian restoration - $24.5M
- Walk and cycleway construction and lighting - $10M

The value case of some of the social, environmental and financial benefits is summarized below (Morrison Low 2010):

- social
  - benefit - youth at risk - $50,000 to $90,000 per youth per project
  - benefit - voluntary labour - $3.3M total
  - benefit - community education - $130k total
  - benefit – walking and cycling, $100k to $1M/year
  - loss of volunteers if PTS discontinued - $3,700/volunteer/year
- environmental
  - benefit - carbon sequestration, riparian planting $4,000 to $20,000/year
  - benefit – air quality, plantings $2M to $4M/year
  - benefit - amenity value, stream clarity $4M/year & native bush $1.5M/year
- financial
  - loss - tourism, $40M/year for 1% decline in tourism
  - benefit - avoidance of flooding - $5M/year

3.3.2 South East Queensland Business Case

The report 'A Business Case for Best Practice Urban Stormwater Management' was developed by the Water by Design program of the South East Queensland Healthy Waterways Partnership to determine if the benefits of applying WSD practices to achieve best practice stormwater management are likely to outweigh the costs for typical development types.

A simple cost-benefit framework was developed and populated with the likely costs and benefits of using WSD practices to meet the proposed design objectives for typical low density residential (400 to 700m^2 lots), medium to high density residential, and commercial and industrial developments. The frameworks brought together both quantitative and qualitative values of likely benefits and costs to assist in approximating the net benefits (Water by Design 2010). Further details are presented in the Appendix, Section 11.1.

By way of summary, the quantifiable costs and benefits for detached residential lots of 400 to 700m^2 (referred to as their low-density development) are presented in Table 3-4 and Table 3-5. Note: An appraisal period of 25 years and a discount rate of 5.5% have been used. Table 3-6 below lists unquantifiable potential benefits and other minor costs that may be incurred.

The incremental cost of going from the 'base case' to the WSD case has been presented. Additional costs as a result of best practice management were the difference between the 'base case' and the 'WSD case'. The 'base case' comprised:

- Conventional stormwater drainage management.
- Flood management (flood detention storage).
- Rain water tanks as per Queensland Development Code.

The ‘WSD case’ comprised additional WSD practices above and beyond the base case, including:

- Bioretention systems for compliance with the stormwater quality and frequent flow objectives,
- Detention storage for compliance with the waterway stability objective.

It should be noted that some of the Queensland objectives and designs are somewhat different to those for Auckland. For example, Queensland’s objectives do not appear to have Auckland’s focus on reducing runoff volumes. Wetlands in Queensland focus more on nutrient removal, which is not a target contaminant in Auckland.

Despite these differences, the case study is still relevant as a demonstration of the type of cost-benefit study that can be carried out and some of the benefits used are applicable to Auckland. Examples of the types of benefits that are common to both the Queensland study and Auckland are the potentially avoided costs associated with downstream waterway rehabilitation and maintenance; potential increased property values and potentially avoided development costs.

Table 3-4 Likely WSD Costs for Typical New Developments ($AUD, 2010) (Water by Design 2010), reproduced with permission.

Major Quantifiable Costs (Estimated)		
Type of Cost	**Cost per lot**	**Costs per hectare**
Acquisition (capital + design costs)	$1,600 to $4,000/lot	$21,100 to $39,750/ha
Annual maintenance	$20 to $40/lot	$260 to $520/ha
Life cycle costs (acquisition + maintenance + renewal + decommission)	$2,365 to $5,410/lot	$29,675 to $71,690/ha
Annualised life cycle costs (acquisition + maintenance + renewal + decommission)	$95 to $215/lot	$1,185 to $5,410/ha

Table 3-5 Likely Benefits for Typical New Developments ($AUD, 2010) (Water by Design 2010), reproduced with permission.

Major Quantifiable Potential Benefits (Estimated)		
Type of Benefit	**Benefit**	**Compared to Costs of WSD treatment train**
Value of the reduction in TN loads in stormwater (wastewater treatment costs)	$2,110 to $5,150/ha/yr	95% to 180% of the annualised life cycle cost
Potentially avoided costs associated with downstream waterway rehabilitation and maintenance	$8,000 to $60,000/ha (life cycle cost) of development	25% to 85% of the life cycle cost
Potential increased property values (premium):	$11,000 to $44,000/ha	52% to 110% of the acquisition cost
Potential development costs that are avoided (applicable only to flat sites, i.e. <5%)	$36,000/ha	120% of the average capital cost

This example shows that although there are limitations to the number of benefits that can be quantified in monetary terms, it does not take many of these monetised benefits to equal and surpass the quantifiable acquisition and maintenance costs.

Table 3-6 Major Unquantifiable Benefits and Minor Potential Costs (Water by Design 2010), reproduced with permission.

Major unquantifiable potential benefits	
Contribution to protecting the numerous values associated with healthy downstream waterways: - ecosystem services - recreational and commercial fishing - tourism - seafood industry - option, existence and bequest values Community amenity at local and regional scale (i.e. connection to water cycle).	
Minor potential costs	**Minor potential benefits**
- Additional development assessment, compliance checking and enforcement costs associated with WSD assets (relatively minor and reducing over time as WSD becomes mainstream practice) - Potential increase in maintenance tasks for residents (for at source or streetscape WSD) - Environmental costs associated with sourcing materials for the WSD measures (e.g. biofiltration media).	- Increased rate of sales and amenity associated with developments with landscaped WSD features, such as streetscape bioretention systems. - Shading and urban cooling (potentially reducing energy consumption). - Some direct and indirect aspects if implementing WSD will result in changes to the configuration of development that could enhance open space. - Education and research.

The conclusion regarding the relative magnitude of likely costs and benefits was (Water by Design 2010):

- Considering all the costs and all the potential benefits of applying WSD to achieve the proposed stormwater management design objectives it is concluded that the **benefits are *likely* to outweigh the costs for low-density residential development in Queensland.**

3.3.3 USA

3.3.3.1 U.S. Environmental Protection Agency (EPA)

In 2009, the U.S. Environmental Protection Agency (EPA) estimated the costs of various options for stormwater control (Braden and Ando 2011). The emphasis was on LID i.e. decentralised, on-site management measures that promote infiltration rather than relying on rapid conveyance to receiving waters. These measures mitigate quality impairments in addition to diminishing the quantity of stormwater runoff.

Braden and Ando (2011) estimate three categories of economic benefits produced by LID measures for greenfield developments. These three categories include (i) water quality benefits, (ii) reduced flood losses and infrastructure costs and (iii) savings in costs of combined sewer overflow mitigation, which are discussed below.

Details of each category are discussed further in the Appendix (Section 11.2) and Table 3-7 below summarises the economic benefits from the report.

Table 3-7 Summary of Economic Benefits (Braden and Ando 2011)

Benefit Description	Benefit Value ($US 2008)
Improvement in water quality	$624M annually
Reduced downstream flooding and infrastructure savings	$34M annually
Reduction in combined sewer overflows	Dependent on level of control, can be less than half the cost of providing additional CSO capacity

Since LID measures are durable, some of the benefits will extend over many years. Enhanced on-site stormwater management also results in improvements in aquatic ecosystems as a result of reduced water temperatures, aquifer recharge and improved stream flow dynamics. These in turn improve fisheries and water based recreation activities, and reduction in urban ambient temperatures and cooling costs due to reduction in impervious surfaces. Monetary values haven't been assigned to benefits such as aquifer recharge and habitat improvement because variation from place to place in aquifer recharge rates and habitat conditions complicate the estimation (Braden and Ando 2011).

3.3.3.2 New York City Green Infrastructure Plan

New York City's 2010 Green Infrastructure Plan presents an alternative approach to water quality that integrates green infrastructure (such as those discussed in this report) with investments to optimise the existing system and to build targeted, smaller scale traditional grey infrastructure.

The Green Infrastructure Plan will achieve better water quality and sustainability benefits by (NYC 2010):

- Reducing CSO volume by approximately 2 billion gallons per year more than the all-Grey Strategy.
- Capturing rainfall from 10% of impervious surfaces in combined sewer overflow (CSO) areas through green infrastructure and other source controls.
- Providing substantial, quantifiable sustainability benefits – cooling the city, reducing energy use, increasing property values and cleaning the air. These benefits are not provided by the all-Grey Strategy.

The plan estimates that every fully vegetated acre of green infrastructure would provide total annual benefits of $14,457/acre in 2030. The breakdown is as follows:

- $8,522/acre in reduced energy demand,
- $166/acre in reduced CO2 emissions,
- $1,044/acre in improved air quality, and
- $4,725/acre in increased property value

These benefits would continue to accumulate beyond 2030.

The report concluded that the Green Strategy would cost approximately $5.3 billion, compared to $6.8 billion for the Grey Strategy, which results in a saving of $1.5 billion over 20 years (NYC 2010).

3.4 Life Cycle Analysis of Tree Pits (Soil Cell)

The aim of this section is to summarise a cost-benefit analysis that has been undertaken for a specific on-site device. In the absence of local cost - benefit analysis data for stormwater management devices costed in this report, this soil cell example from Minneapolis, USA has been provided to demonstrate the methodology, results and outcomes that are emerging in this relatively new field of valuing on-site stormwater management practices.

The life cycle analysis examined the investment versus returns of street trees planted using traditional methods (4’ x 4’ cutouts) and in a grid supported pavement treatment (DeepRoot Green Infrastructure, LLC 2011). Costs and benefits were estimated over a 50 year analysis period for the following two scenarios:

- An urban tree, with a grid supported pavement over adequate uncompacted bioretention soil volume (referred to as soil cell from now on, a proprietary product), which has an estimated lifespan of 50+ years and lives to be a mature tree that provides significant ecological and financial benefits.
- An urban tree with insufficient uncompacted soil volume (referred to as traditional street trees from now), which has an estimated lifespan of 13 years, and it dies before it grows large enough to provide significant ecological and financial benefits.

Costs and benefits of each tree for a typical example in Minneapolis, USA was derived from i-tree, which is a peer reviewed software suite from the USDA Forest Service that provides urban forestry costs and benefits assessment tools. The assessment showed that the soil cell (proprietary product) had a pay-back period of 21 years, while the traditional street trees never paid back their upfront costs (DeepRoot Green Infrastructure, LLC 2011). The results of a 50 year appraisal period are tabulated in Table 3-8 below.

Table 3-8 Urban Tree Lifecycle Costs and Benefits in Minneapolis, USA (DeepRoot Green Infrastructure, LLC 2011)

Lifecycle Costs and Benefits over 50 years	Traditional Street Trees - Estimated Lifespan 13 years	Notes for Traditional Street Trees	Soil Cell - Estimated Lifespan 50+ years	Notes for Soil Cell (proprietary product)
Installation Costs	$4,000	Estimated at $1,000 per tree, installed 4 times over a 50 year study period	$14,000	Estimated at $14,000 per tree, installed 1 time over a 50 year study period
Total Benefits	$2,717	Includes savings from reduced building energy costs, stormwater interception, increased property values, the net value of carbon sequestration in the tree.[1]	$41,769	Includes savings from reduced building energy costs, stormwater interception, increased property values, the net value of carbon sequestration in the tree,[1] bioretention,[3] and stormwater utility fee credit.[4]
Total Maintenance Costs	$1,211	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs, and administration costs.[2]	$2,341	Includes estimated costs for pruning, pest and disease control, infrastructure repair, irrigation, cleanup, liability and legal costs, administration costs [2] and bioretention maintenance.
Removal Costs	$600	Estimated at $200 per tree, 3 times over a 50 year study period	$0	Removal Costs
Net Lifecycle Cost	$3,094		(-) $25,427	

Notes:

(1) Values are based on figures by i-tree. A description of how trees provide these benefits can be found in the i-Tree Streets User's Manual (available at http://www.itreetools.org/resources/manuals/iTree%20Streets%20Users%20Manual.pdf)

(2) Costs are based on McPherson et al, 2006. (as cited in The Kestrel Design Group, Inc, 2011)

(3) Bioretention storage, totaling 1000 c.f. of bioretention soil with 200 c.f. of water storage capacity, enough to capture 1" rain from 2,400 s.f. of impervious surface. Treating the one inch rain event treats about half the annual rainfall in Minneapolis. Annual rainfall is 29.4 inches in Minneapolis, so half the annual rainfall is 14.7 inches per year. Treating 14.7 inches per year on 2,400 s.f. amounts to 21,990 gal per year. According to McPherson et al, 2005, the annual cost of stormwater storage in a holding pond in Minneapolis is $0.027/gal, so treating 21,990 gal/year provides $594 per year in benefits.

(4) Stormwater utility credit for 1 tree capturing runoff from 2,400 s.f. of impervious surface = $8.45 per year. Calculation of yearly stormwater charge is 2,400 s.f./ 1530 = 1.57 Equivalent Stormwater Unit (ESU); 1.57 ESU x $10.77/ESU = $16.9 stormwater charge per year. Stormwater utility credit for treating 1" from this area is 50%, so $16.90 * 0.5 = $8.45 per year. NOTE: stormwater utility credit does not apply to Auckland, but forms a very small part of the overall benefit.

The lifecycle costs and benefits assessment shows the following:

- estimated benefits of this proprietary soil cell outweigh estimated costs by $25k.
- estimated costs outweigh estimated benefits by $3k for the traditional street trees.

3.4.1 Additional Benefits Not Quantified in Analysis

Example of benefits not quantified in this analysis (DeepRoot Green Infrastructure, LLC 2011):

- Shoppers in well-landscaped business districts are willing to pay more for parking and up to 12% more for goods and services.
- Increased property values increase tax base resulting from higher property value.
- Tree shade has been correlated with better pavement performance, which translates into reduced pavement maintenance costs, and increased pavement durability.

4.0 Conclusion

4.1 Costs

Cost estimates (construction, maintenance and total present cost) for the following representative stormwater management devices that can be used to meet the Unitary Plan requirements for on-site stormwater quality (HCGA) and flow management (SMAF) have been calculated: bioretention rain gardens, porous paving, rain water tanks with water reuse, living roofs, gravel storage, sand filters and wetlands.

Individual devices meet different Unitary Plan requirements. For example, rain gardens and porous paving provide the SMAF detention, retention and HCGA water quality requirements, whereas wetlands only provide the HCGA water quality and SMAF detention, but not retention requirements. The devices are sized depending on their function, as SMAF 1, SMAF 2 or HCGA. Devices such as rain gardens and porous paving that are sized for SMAF 1 or SMAF 2 also meet the HCGA requirements.

The development scenarios selected to demonstrate the associated costs to meet the specific Unitary Plan SMAF and HCGA requirements are:

- Single house on a $500m^2$ lot (SMAF)
- Mixed and terraced housing (SMAF)
- Parking areas (SMAF and HCGA)
- Secondary Arterial Roads(SMAF and HCGA)

The costs of these development scenarios have then been compared to the existing regulatory framework. This is difficult due to the wide difference between the existing district plan requirements, the different approaches that have been taken between the Unitary Plan and the ALW Plan and the circumstances in which requirements apply. In many instances resource consent processes result in site specific requirements. Current practice has been represented by the range between the Base Case – No Treatment and the Base Case – Wetland Treatment, with their respective different stormwater management functions.

Costs estimates have been summarised for construction, maintenance and total present costs (using a discount rate of 4% and an appraisal period of 60 years).

For the least cost stormwater devices, compared to wetland treatment costs:

- single house SMAF1 porous paving with increased gravel construction costs are similar;
- single house SMAF2 porous paving with increased gravel construction costs are less;
- parking and secondary arterial road HCGA rain garden construction costs are similar; and
- all other SMAF construction costs and SMAF/HCGA maintenance and total present costs are generally greater.

The main change with the Unitary Plan provisions is the focus on water sensitive design and green infrastructure to reduce the generation of stormwater runoff and contaminants, followed by their management and reduction on-site or though communal measures.

This allows for more comprehensive stormwater management functions and a targeted approach on site specific areas and contaminants of concern compared to, for example, a catchment wide wetland approach that has to collect and treat stormwater runoff from the entire catchment area. However, on-site devices can have increased maintenance costs and associated risks, particularly if under private ownership.

These on-site devices focus on the smaller, more frequent rainfall events (less than the 2 year ARI) and have minimal impact on the larger 1 in 10 and 100-year flooding events. If management of these larger flooding events is required, other measures such as catchment wide ponds/wetlands would be required. These costs are not covered in this report.

4.1.1 SMAF Areas

To manage the stormwater runoff from housing developments to meet the SMAF requirements the least expensive construction cost option is the porous paving with increased gravel thickness with a cost approximately the same as the Base Case – Wetland Treatment. The next cost options are the rain garden and gravel storage chamber, with the porous paving and rain tank being the most expensive option. For maintenance, the costs vary from the Base Case – Wetland Treatment up to the porous paving with rain tank scenario. The least total present cost option is rain gardens. Costs to manage the stormwater to meet the SMAF 2 requirements are approximately 70% of the SMAF 1 requirements.

For mixed and terraced housing, construction cost of rain gardens reduce with the smaller lot size and impervious area. Costs can be further reduced if using communal devices such as a communal rain garden. The average maintenance cost shows a different trend. Maintenance costs for single dwellings are relatively fixed, irrespective of the lot size. The maintenance cost per dwelling is greater for communal rain gardens due to assumed management by contractors through a body corporate structure compared to single dwellings with individual homeowner maintenance.

For parking areas, the least expensive is porous paving, followed by rain gardens. Porous paving is not suitable for roads.

4.1.2 HCGA Areas

HCGA's are parking areas, high use roads and roof/cladding materials. The construction costs to meet the requirements for parking areas and roads with the smaller sized HCGA rain garden is approximately the same as the Base Case – Wetland Treatment. The construction cost of porous paving parking areas is slightly higher than rain gardens. Porous paving is not recommended for high use roads. Maintenance costs for the rain gardens and porous paving are similar to the Base Case – Wetland Treatment. For cladding materials, the least expensive option is to use appropriate non copper/zinc generating materials.

Figure 4-1 Sample Results Based on Stormwater Devices and Development Scenarios Costed

Scenario and UP Requirement	Least Construction Cost Option	Least Average Annualised Maintenance Option	Least Total Present Cost Option
Single House SMAF1/2	Porous Paving with Gravel	Rain Garden	Rain Garden
Parking Area SMAF1	Porous Paving and Rain Garden similar	Porous Paving	Porous Paving
Parking Areas SMAF2	Rain Garden	Porous Paving	Porous Paving
Secondary Arterial Road SMAF and HCGA	Rain Garden only option costed as Porous Paving not suitable		
Parking Area HCGA	Rain Garden	Porous Paving, Rain Garden and Sand Filter similar	Rain Garden and Porous Paving similar

4.2 Benefits Assessment

Benefits have been assessed under four headings:

- Water Sensitive Design and Green Growth
- Benefits Assessment and Methods of Quantifying Benefits
- Cost - Benefit Analysis Case Studies and
- Specific On-site Device Cost-Benefit Study

Incorporating Water Sensitive Design (WSD) and Green Growth principles seek to achieve the Unitary Plan stormwater management provisions and the vision of the Auckland Plan. This report lists the advantages and disadvantages of WSD and green growth, and recognises the difficulty in conducting a solely quantitative cost-benefit analysis. However, understanding the full spectrum of benefits provided (many of which lie outside of stormwater) is important for investment decision making.

Various frameworks, tools and valuation methods are available to quantify receiving environment outcomes under alternative urban development and stormwater management scenarios. These reinforce the need for considering economic, social, environmental and cultural values when considering the impacts of stormwater management and incorporating it into the decision making process.

A number of local and international cost - benefit analysis case studies have been presented to demonstrate the range of benefits versus costs of different stormwater management approaches. Actual costs are site dependent so it is important to consider these examples with caution. The variability, applicability and validity of the benefits claimed in these examples also need to be considered with caution. These examples are given to show the range of different techniques/methods that have been used and the types of outcomes that are emerging in this relatively new field of valuing water sensitive design/on-site stormwater management practices.

4.3 Cost-Benefit Assessment

As discussed previously, this report is not intended to provide a full cost-benefit analysis of the new Unitary Plan requirements for on-site stormwater quality and flow management. However, it provides the foundation that will enable a cost-benefit analysis to be undertaken in the future.

The representative stormwater management devices costed in this report provide a greater degree of management above the 'no-treatment' and 'wetland-treatment' base cases. Wetlands provide detention but not the retention requirements needed to reduce stream erosion to maintain/enhance stream health (including biodiversity and ecological functioning). The on-site devices costed in this report provide both detention and retention requirements, which will help achieve the vision of the Auckland Plan and the objectives set out in the National Policy Statement for Freshwater Management (NPSFM), the New Zealand Coastal Policy Statement (NZCPS) and the Hauraki Gulf Marine Park Act (HGMPA). It is important to consider the additional stormwater management function provided by the new provisions, and the corresponding spectrum of benefits.

5.0 References

AECOM (2011). Long Bay Integrated Catchment Management Plan. Prepared for Auckland Council September 2011. Volume One text and Figures and Two Appendices.

Auckland Council (1991). Technical Publication No. 3, Auckland Regional Stormwater Project: An Economic View. Prepared by J.T. Ward and F.G. Scrimgeor for Auckland Regional Water Board.

Auckland Council (2006). Amended July 2006 version of the June 2003 Kerr and Sharp report prepared for the Auckland Regional Council, 'Lost Streams: Determining compensation requirements using choice modelling. Auckland Council technical report, TP212.

Auckland Council (2011). Long Bay Practice Notes (September 2011).

Auckland Council (2013a). Auckland Unitary Plan stormwater management provisions: Technical basis of contaminant and volume management requirements. Technical Report 2013/035.

Auckland Council (2013b). Stormwater Disposal via Soakage in the Auckland Region. Technical Report 2013/040.

Auckland Council (2013c). 2.24 – Urban Stormwater – section 32 evaluation for the Proposed Auckland Unitary Plan.

Auckland Council (2013d). Auckland Plan Committee Open Agenda. 16 April 2013.

Auckland Transport (2013). Schematic Rain Garden Road Layouts, page 35.

Batstone C and Sinner J (2010). Techniques for evaluating community preferences for managing coastal ecosystems. Auckland region stormwater case study, discrete choice model estimation. Prepared by Cawthron Institute for Auckland Regional Council. Auckland Regional Council Technical Report 2010/012.

Bencich E (2013). Standard asphalt car parking maintenance costs. Email correspondence dated 8 May 2013, with Erle Bencich, Team Leader (West), Road Corridor Maintenance, Auckland Transport, an Auckland Council Organisation.

Braden J and Ando A (2011). Economic costs, benefits, and achievability of low-impact development-based stormwater regulations in Thurston H W(editor) (2011). *Economic Incentives for Stormwater Control*. 1st ed. CRC Press: 45-66.

Cathy Bebelman Consulting Ltd (2006). Governance options for stormwater infrastructure management. Report Prepared for Papakura District Council, with assistance from Peter Hassell.

Center for Neighbourhood Technology (CNT) and American Rivers (2010). The value of green infrastructure: a guide to recognizing its economic, environmental and social benefits. Available at http://www.watershedconnect.com/documents/the_value_of_green_infrastructure_a_guide_to_recognizing_its_economic_environmental_and_social_benefits (Accessed 30 October 2013).

Costanza R, d'Arge R, de Groot, R Farber, S Grasso, M Hannon, B Limburg, K Naeem, S, O'Neill R V, Paruelo J, Raskin R G, Sutton P and van den Belt M (1997). The value of the world's ecosystem services and natural capital, in *Nature 387*, 15 May 1997: 253-260.

DeepRoot Green Infrastructure, LLC (2011). Investment vs. Returns for Healthy Urban Trees: Lifecycle Cost Analysis.

D&B Kettle Consulting Ltd (2008). Concept design of stormwater Low Impact Design retrofit for the West Harbour neighbourhood, Waitakere City.

D&B Kettle Consulting Ltd (2013a). Single House Stormwater Management Scenarios Schematics Development and Schematic of Example Rain Garden and Porous Paving Parking Area, page 22, 23 and 31.

Farley J (2008). The role of prices in conserving critical natural capital *in Conservation Biology*, *Volume 22, No. 6*, 1399-1408.

Firn Crichton Roberts Ltd and Graduate School of Environmental Studies, University of Strathclyde. 2000. An assessment of the socio-economic costs & benefits of integrated coastal zone management, Contract No: B4-3040/99/134414/MAR/D2, Final Report to the European Commission. EU Demonstration Programme on Integrated Management in Coastal Zones 1997 – 1999.

Guth J H (2009). Resolving the paradoxes of discounting in environmental decisions, in *Transnational Law & Contemporary Problems, Discounting in Environmental Decisions, Winter 2009, Vol. 18:95*: 95-114.

Healy K, Carmody M, Bird B and Conaghan A (2010). Construction of Stormwater Management Devices in the Auckland Region. Prepared by AECOM Ltd for Auckland Regional Council. Auckland Regional Council Technical Report 2010/052.

Lincoln University (2003). Lost streams: determining compensation requirements using choice modelling. Prepared by Kerr G N and B M H Sharp for Auckland Regional Council. Auckland Regional Council Technical Publication 212.

Landcare Research (2006). *COSTnz.* Retrieved from http://www.costnz.co.nz/default.aspx (November 2012).

Land and Water Constructions (2007). Review of street scale WSD in Melbourne: study findings, prepared for Kingston City Council and the Better Bays and Waterways Institutionalising Water Sensitive Design and Best Management Practice Project, Melbourne, Australia.

McFarlane K (2013). Review of freshwater values and valuation: social and economic input. Auckland Council internal report, IR2013/007.

McSpadden R (2013). Personal correspondence with Robert McSpadden, Senior Asset Management Planning Engineer, Asset Management & Systems, Auckland Transport.

Melbourne Water (2013). Healthy Waterways Rain Garden Instruction Sheets. Retrieved from http://raingardens.melbournewater.com.au/library/Inground_(lined)_-_Building_a_raingarden_instruction_sheet.pdf and http://raingardens.melbournewater.com.au/library/Planter_box_(lined)_-_Building_a_raingarden_instruction_sheet.pdf (December 2013)

Morgan K (2007). Translating values and concepts into a decision making framework: application of the Mauri Model for integrated performance indicator assessment. Faculty of Engineering, the University of Auckland.

Moores et al (2013). A tool for evaluating stormwater management outcomes across the four wellbeings in *8th South Pacific Stormwater Conference & Expo 2013*, Auckland, New Zealand.

Morrison Low (2010). Value case for Project Twin Streams. Prepared for Waitakere City Council.

Ngā Pae o te Māramatanga (2013). *mauriOmeter*. Retrieved from http://www.mauriometer.com (August 2013).

North Shore City Council (2008). Bioretention Guidelines, First Edition, July 2008.

North Shore City Council (2009). Raintank Guidelines, Second Edition, September 2009.

NYC (2010). New York City green infrastructure plan: A sustainable strategy for clean waterways. Retrieved from http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf (November 2013).

Patterson M and Cole A (1999). Assessing the value of New Zealand's biodiversity. Palmerston North: School of Resource and Environmental Planning, Massey University.

Rawlinsons New Zealand Construction Handbook (2010). Twenty Fifth Edition.

Rhynd B (2010). At-source water sensitive urban design for residential development: design to construction, in *Water NZ Stormwater Conference*, Rotorua, New Zealand.

Rohani M (2013). Freshwater Values Framework. A Review of water valuation Methods Utilised within Total Economic Valuation. Auckland Council working report, WR2013/001.

Royal HaskoningDNV (2012). Costs and benefits of sustainable drainage systems. Project Number 9X1055, Haskoning UK Ltd. Water.

Schueler T and C Lane (2012). *Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards.* Prepared by Tom Schueler and Cecilia Lane of the Chesapeake Stormwater Network, submitted to the Urban Stormwater Group, Chesapeake Bay Partnership, USA.

Shaver E (2009). Low Impact Design versus conventional development: literature review of developer-related costs and profit margins. Prepared by Aqua Terra International Ltd. for Auckland Regional Council. Auckland Regional Council Technical Report 2009/045.

The Royal Society of New Zealand (2011). Ecosystem services, emerging issues. Retrieved from www.royalsociety.rog.nz.

UKWIR (2005). Performance and whole life costs of best management practices and sustainable urban drainage systems. London: UK Water Industry Research.

USEPA (2013). Why Green Infrastructure? Retrieved from http://water.epa.gov/infrastructure/greeninfrastructure/gi_why.cfm#WaterQuality (September 2013).

Wadan P, O Clements and D Kettle (2013). Construction of Low Impact Design solutions at Long Bay in *8th South Pacific Stormwater Conference & Expo 2013*, Auckland, New Zealand.

Watercare (2013). Residential water and wastewater charges (as of July, 2013).

Water by Design (2010). A business case for best practice urban stormwater management (Version 1.1). South East Queensland Healthy Waterways Partnership, Brisbane, Queensland.

WT Partnership Infrastructure (2013). Drury South Business Park. Peer review of the Beca estimate for public works, for Auckland Council, 19 March 2013.

Photographs Credits

D&B Kettle Consulting Ltd (2013b). Report - page 23 and 32; Appendix – Figure 2-7, 2-8, 2-9, 2-11, 3-2 and 3-3

Infrastructure & Environmental Services, Auckland Council (2013). Report - page 28 and 35