Bioretention Planting Guide

Right plant.
Right place.
Right maintenance.

Auckland Transport

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Contents

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01

Introduction

The overall aim of this guide is to use plant selection to help deliver roadside bioretention that is resilient and has low cost and/or frequency of maintenance by ensuring the right plants are matched with the right device.

It is aimed primarily at designers of devices that are submitted for approval to Auckland Transport.

Plants cannot be selected in isolation. This guide therefore links plant selection to the expected life of a raingarden, and introduces temporary and 'sacrificial' plantings for short-lived devices and where the risk of severe damage is high.

Five steps of plant selection are recommended. These explicitly link plant choice to design components that influence plant performance: the growing media (and mulch), the device shape and size, edge treatments and required sightlines.

Devices installed as part of a road must comply with Auckland Transport's Code of Practice requirements; it is likely this document will cross-link to the code.

A recommended process for 'vesting' roadside bioretention devices, and for recording their condition and maintenance is not part of this project.

These can be adapted from Ira and Simcock (2019).

02

What is Bioretention?

Bioretention cells, also called biofilters, bioswales, flow-through planters, infiltration planters or rain gardens, have been widely used in Auckland since about 2008 (Auckland Regional Council 2003, Lewis et al. 2010). They help deliver the Auckland Unitary Plan objectives of preventing or minimising the adverse effects of stormwater discharges in Stormwater Management Areas - Flow (Auckland Council 2017 - GD01).

Bioretention devices are typically close to the runoff source, being a road or footpath, and from 1 to 10% of a relatively small catchment area.

Bioswales are generally linear features that convey and slow water as part of a treatment train while raingardens and planters can be any shape; both have filter media with specific characteristics. The characteristics, volume and depth of media control the attenuation of stormwater volume and contaminants (see Section 6 on internal water storage zones).

Bioretention systems filter storm water through plants and soils, and break the direct connection of hydraulically-efficient pipes and natural waterways. This filtering and slowing of stormwater runoff help reduce impacts of road runoff and protect waterways. Spills and most large litter (gross pollutants) are intercepted and peak flows reduced.

The key 'chronic' contaminants in Auckland's road runoff are sediment, high temperature and metals zinc (Zn), copper (Cu) and lead (Pb). In most of Auckland, Nitrogen (N) and Phosphorus (P) are not contaminants of concern; devices are therefore not specifically designed to remove these contaminants.

Auckland's bioretention practice was originally drawn from the United States (Davis et al. 2009) but now media, mulch and plant specifications are more commonly drawn from Melbourne, Australia (Fujita 1997, Wong 2006).

Because bioretention is designed to capture contaminants, when any contaminant reaches a specific 'trigger' level, the device needs to be renovated – plants and soil are removed, and new plants, soil and mulch are replaced.

An exception is when devices are designed so that specific areas capture most of the triggering contaminants, for example capturing sediment near inlets, and is a useful strategy for devices with large trees, as it minimises damage to trees during renovation.

The life of a device and frequency of renovation is influenced by the design and maintenance of both device and catchment.

Bioretention life is extended by:

• road sweeping more frequently to reduce contaminants entering devices (adopted in Australia),

• adding a 'forebay' to catch sediment or most of fine sediment (adopted in Portland, Oregon),

• replacing organic mulch frequently, especially where zinc and copper are contaminants.

03

Healthy plants are critical for bioretention

Plants are critical components of stormwater bioretention devices.

Plants underpin ongoing hydrological performance by maintaining stormwater infiltration rates into media. Water use by large plants restores stormwater detention volume between storms, although this is not currently considered in NZ calculations. Plants also help remove and attenuate contaminants by: preventing erosion and reducing stormwater energy (which promotes settling of sediment); direct uptake into roots, stems and leaves ; and by enhancing microbial activity near roots and in leaf-litter layers.

Suitably selected and maintained plants also deliver nearly all the 'non-stormwater benefits' of bioretention devices.

These benefits include landscaping and safety: cultural values, aesthetics, air quality enhancement, shade and shelter, and biodiversity.

A healthy plant cover supresses and prevents growth of weeds and unwanted plants.

Different plants provide different stormwater and non-stormwater benefits, and these are related to plant functional attributes (Table 1) and cultural criteria.

When selecting plants for a bioretention device, using species with a range of different functional attributes is likely to enhance bioretention performance. However, the primary requirement is that plants rapidly form a dense, weed-supressing cover and sustain >90% cover.

Unhealthy or dead plants generally indicate a device is not working properly, for example stormwater is ponding for too long due to low infiltration or permeability. However, good plant health does not always indicate adequate bioretention performance, for example plants may not indicate if bypass flow is occurring down the sides of a device or through old root channels. Plants rarely indicate if trace element, N or P break-through is occurring, as plants are generally tolerant of these contaminants, especially the nutrients important for growth.

Smaller-stature oioi have low maintenance when integrated with other landscaping, thus avoiding a 'hard' edge. To the right the edge is maintained by mowing and spraying along a grass. strip, Orewa 2020.
A similar solution at Auckland Botanic Gardens **(right)** has a row of Carex bordering oioi and swale edge defined by a wooden 'mowing strip' which allows faster mowing and minimises herbicide use.

Benefits provided by plants are generally maximised when a mix of plant species are selected that have different functional attributes, for examples sedges and woody groundcovers, shrubs and trees.

This is one reason guides for selecting bioretention plants recommend establishing several plant species, even though plant diversity usually decreases over time.

Table 1. Benefits provided by plants and related functional attributes: above ground, below-ground and non-stormwater benefits.

AUCKLAND TRANSPORT DEFINED DESIGN ELEMENTS OF RAINGARDENS IN THE ROAD CORRIDOR

Above-ground stormwater benefits	Required plant functional attribute
Slow flow (promote sediment settling)	leaf/stem stiffness & density near surface (remains upright at full design flow, e.g. oioi)
Maintain even flow, not concentrating flow	leaf/stem stiffness, leaf and clump density e.g. spread as stolons or rhizomes and do not form trunks
Protect surface from erosion and scour	high cover across surface, anchoring to surface by roots
Protect surface from compaction	high cover of thick leaves, leaf litter build up, exclusion of people and vehicles due to density or sharp leaves
Exclude weeds	minimum 300 mm height, dense leaves exclude light at soil surface, helpful if resistant to glyphosate herbicide
Maintain infiltration into media	growth habit opens up surface e.g. grows from rhizomes or stolons (creeping stems) that penetrate soil surface
Below ground stormwater benefits from plants	**Required plant functional attribute**
Refresh retention volume by evapotranspiration	high evapotranspiration and Leaf area index
Maintain permeability, avoid preferential flow (some roots and growth cycles produce bypass flow)	fine, abundant and dense root system, few ‘pipe’ roots that are short-lived
Maintain organic matter, support microbial activity	fine, abundant root system
Contaminant uptake – Nitrogen	high biomass, suitability for harvesting
Contaminant uptake – metals and Phosphorus	biomass, metal concentration, turnover/sorption
Contaminant attenuation – microbial contaminants	root and leaf exudates; supporting microbes
Non-stormwater benefits from plants[2]	**Required plant functional attribute**
Carbon sequestration	high biomass, root mass (trees are best)
Reduction of potable water use for landscape use	drought tolerance
Reinforce physical separation = safety, security	height (maintain or block views), density, prickly or sharp-edged leaves
Moderate air and ground temperature	evapotranspiration, height, spread (shade) height, spread, leaf characteristics
Shade and shelter adjacent paths, carparks	height, leaf density and size
Buffer traffic effects: glare, air-pollutants, noise including screening or block views	site and place-specific plants
Aesthetics, wellbeing, way-finding, sense of place	species and site specific
Fibre, rongoa, food (rarely food)	species and edge specific
Employment (trimming, harvesting)	species and site specific
Biodiversity habitat or genetic ‘bank’	

[2] For a very useful discussion and NZ-specific examples, read Lewis et al 2010 TR2010/083

04

Problems with roadside bioretention plants

AT is responsible for bioretention treatment trains and devices along roads, within transport stations and carparks. Most roadside bioretention devices are built by developers and are vested as public assets when the overall subdivision is signed off (Section 224c).

GD01 advises a ‘device-specific, customised O&M manual for each device’ should be provided. AT has thousands of vested bioretention devices, in highly variable condition, which often need immediate renovation, despite a typical expected design life before replacement of plants and soil of 10 to 50 years. Devices vested in good condition may be subsequently destroyed during ‘build-out’ of adjacent lots or by inappropriate maintenance practices. AT (and HW) are consequently faced with unacceptably high maintenance costs for bioretention devices.

Changes in Health and Safety requirements have inflated maintenance costs for devices where Temporary Traffic Management is now required. Where such controls require lane closures, significant cost and disruption to traffic flows can also occur. Hence devices should not generally be placed within central medians, and inlets should be placed in areas where it is efficient to inspect, park and maintain
(see Simcock and Ira 2019 for examples).

Maintenance costs can be inflated by plant choice. Five main plant-related factors inflate costs:

1. Unacceptable plant death leading to low cover of desirable plants and high cover of weeds and other undesirable plants. Plant death can be due to drought stress, exacerbated by media specification, absence of mulch, poor establishment practices (post-establishment irrigation), or poor maintenance practices (e.g., herbicides that kill desirable plants, inappropriate pruning). High sediment inflow both brings in weed seeds and provides a growing medium. If plants are not replaced and re-mulched, bare areas often increase, aesthetics are degraded by weeds, and stormwater performance reduced.

2. Plants that cannot exclude weeds. Common issues occur when very short (<50 mm) ground covers such as Pratia or Acaena are used as these rarely compete with most weeds, especially when placed along edges. A high level of maintenance is therefore needed.

3. Plants that are too large so require regular pruning to maintain sight lines, e.g. swamp flax (Phormium tenax) at AMETI, trunkless nikau palms at Wynyard Quarter, and Carex secta when placed within about 50 cm of an edge.

4. Tall or floppy **plants placed too close to a ‘hard’ edge** such as a footpath or road, or an overflow or inlet, where plants are not wanted. Height and floppiness are exacerbated by high fertility media and shallow raingardens, and seen in oioi and taller sedges (e.g. Carex secta).

5. Placing **brittle plants along edges** and trees in small or narrow devices where vehicles will damage the plants – this occurs in carparks and narrow verges.

[3] over 4000 as at Oct 2020

[4] contributing factors include inadequate protection of devices from road user or construction activities, lack of monitoring and lack of maintenance (especially where devices are not recorded.

Bioretention issues faced by AT **from left to right**: weed-filled devices at handover; multiplicity of very small devices (blue squares); and, large flax (Phormium tenax) planted too close a hard edge requiring regular pruning, annual removal of flower stalks and annual re-mulching to reduce weed growth in the pruned area.

Dianella/turutu along the footpath is healthy and not overly-impinging the pavement, however most Libertia along the road is dead, probably due to smothering by sediment and possibly also poor herbicide application.

05

Using this guide: Five steps for plant selection

The approach in this document is consistent with GD01, outlined in Section C1.2 (plant design process), C1.3 (pre-design considerations) and C1.6.2 (Planting bioretention devices), and largely consistent with TR2010/083 and TR2010/053 . Guides prioritise native plants (GD01 principle C1.3.3), identify a key plant performance measure as development of a full vegetation cover in planted areas within 18 months and recommend using a diversity of species, not single species.

This document identifies a subset of plants species suitable for three types of bioretention device with different device longevity. This is consistent with the GD01 recommendation that plant species be matched to the expected device life.

For each device, plant choice is also influenced by key design components that influence plant stress and requirements.
These are: the growing media (and mulch); the device shape and size (and volume); edge treatments (including inlets/overflows); and, required sightlines.

Where cultural or landscaping objectives require specific plant species or cultivars/sources, the growing media/mulch, device shape and size (and volume), edge treatments and inlets can be altered to create conditions that suit the required species. Sometimes the location of bioretention can be changed to areas where stress is lowered by shade from existing buildings or trees, or by integrating with adjacent landscaping. However, sight lines and clearance zones can rarely be compromised.

The five steps for plant selection are:

1. Predict and map 'as built' conditions. Identify sightlines, clear zones and zones that are 'unsafe' for maintenance staff to be in without traffic controls. Map how far vehicles can intrude into planted areas (consider towbars and bumpers, especially adjacent to car parks) and if there are likely to be places where people will want to cross the device. Identify the types of surfaces adjacent to the device, and how are these are used and maintained (e.g. by a street sweeper or water-blaster, mower or herbicide spray). Plant stress is reduced where raingardens are adjacent to mown turf and landscaped surfaces and increased when adjacent to hard surfaces.

2. Review the following features of the bioretention device: media permeability, ponding depth, surface depth below grade, total media depth, catchment size, inlet locations, and overflow locations. Identify location of furniture such as seating, lighting, signs, rubbish bins, and the impacts of access and maintenance of these on planted areas.

3. Map the mature, maximum plant-filled envelopes across the device, considering (1) and (2) for groundcover and trees. Identify places with high risk of plant failure.

4. Identify cultural, ecological and landscape requirements linked to plants, and select a range of plant species/cultivars that together meet these requirements.

5. Optimise design to moderate or eliminate areas with the highest risk of plant failure and high or costly maintenance. Some approaches are to reduce the length of 'hard' edge by making devices larger and/or wider by amalgamating several smaller devices, by integrating with landscaping or moving footpaths, removing or changing the location of furniture (especially lights, seats and rubbish bins).
Sometimes it is possible to change from an internal overflow to an external overflow (e.g. street catchpit), or improve water storage by increasing media depth, enhancing moisture storage (e.g. manipulating pumice, compost, biochar or fines component) and changing an inorganic mulch to an organic mulch amended with compost.

[3] Lewis M, Simcock R, Davidson G Bull L 2010. Landscape and ecology values within stormwater management. Auckland Regional Council Technical Report 2010/083

[4] Healy K, Carmody M, Conaghan A. 2010. Stormwater treatment devices operation and maintenance. Auckland Regional Council Technical Report 2010/053

06

The growing media influences plant selection

Auckland Regional Council (Lewis et al 2010), North Shore City (2008) and Waitakere City (2004) bioretention guides included plant selections based on 'TP10' media which in turn were modelled on United States guidance.

The "TP10' media targeted a (minimum) saturated permeability of 12.5 to 50 mm/hr (300 mm/day) so were saturated for longer periods. These media could have high fines contents (up to 25% w/w clay) and usually had a high proportion of compost (>40% v/v). This volume of compost could deliver an extremely fertile media, especially where younger composts derived from green waste were used. In contrast, GD01 (Section C1, p85) specifies bioretention media should be a mixture of sand, topsoil, and compost, with maximum organic matter content of 20% by volume, and saturated permeability of 50-200 mm/hr and up to 1000 mm/hr.

No specific limit on fines is given, however, Auckland engineers commonly use an Australian specification that has an extremely low fines content (<3% silt and clay). As a result, this media requires plants with high tolerance of frequent drought and low-fertility, whereas tolerance of anaerobic conditions is not important . Low-fertility is exacerbated when pebble mulches are used.

The recommended plant lists below therefore differ from the older guidance which included plants unlikely to perform well in drought-prone media.

Note, however, the 'excluded' plants will be suitable for very shallow bioretention (e.g. swales), and where media develop anaerobic conditions. Some taller, deeper rooting plants on the 'excluded' list could be suitable for bioretention that includes internal water storage layers, as long as water storage is accessible by roots.

Dianella/turutu along the footpath is healthy and not overly-impinging the pavement, however most Libertia along the road is dead, probably due to smothering by sediment and possibly also poor herbicide application.

[7] Malcolm M, Lewis M. 2008. North Shore City Bioretention guidelines. First Edition July 2008.

[8] Waitakere City Council. 2004. Stormwater solutions for residential sites – Section 6: rain gardens. Only five species are recommended: Carex flagellifera, C. lessoniana, C. maorica, C. secta, Cortaderia fulvida (toetoe, now Austroderia fulvida) and Cyperus ustulatus (giant umbrella sedge)

07

The Right Device

This guide divides roadside bioretention devices into three 'types': temporary planted, sacrificial and conventional bioretention.

These types reflect the time until plants are replaced, how quickly plants need to establish, and the types of stresses plants are exposed to.

Temporary planted bioretention is currently an uncommon approach in Auckland. It aims to minimise the financial impact of damage to devices during post-planting construction.

Sacrificial bioretention has a longer anticipated life of up to 10 years.

Conventional bioretention is the 'standard' approach covered by plant selection guidance from Auckland Council (and legacy Councils: Auckland Regional Council, North Shore Council and Waitakere Council), albeit with more permeable media with limited duration of anaerobic conditions.

7.1 Temporary planted bioretention

Plants in these devices are likely to be replaced within 1 to 4 years of construction due to physical damage or being smothered by sediment.

This approach is likely in housing subdivisions where individual lots are built after Section 224c is granted.

Temporary planting aims to deliver aesthetics that are desirable to sell sections, then allow plant removal once all construction is complete (with the upper 100-300 mm of sediment-affected soil). At that time conventional, long-lived bioretention plants may be established along with mulch.

Plant requirements: fast establishment to a dense, aesthetically-pleasing cover within 6 months.
Plants between 30 cm and 80 cm height at maturity.
Generally upright, erect growth for plants, especially those within 30 cm of edges.
Leaves and growing points resistant to physical damage, including crushing (i.e. not brittle).
Drought-tolerant, can grow through sediment up to about 50 mm depth. Cheap to propagate and can be established at a range of sizes.
Shallow rooting helps removal, but reduces drought tolerance. Resistance to glyphosate is an advantage for plants adjacent to edges or overflows.

Native species: many native sedges, some juncus species. Some semi-prostrate Coprosma species/ cultivars such as C. acerosa, C. propinqua. Short, dense flaxes such as varieties of Phormium cookianum (coastal flax).

Non-native: ready Lawn of a variety of drought-tolerant grass species. If mown, must be required to maintain a minimum 5 cm height; may brown off over summer); Lomandra.

Not generally suitable: hebes (brittle), rengarenga (brittle), libertia (does not tolerate sediment), prostrate Coprosma repens (brittle) or C. acerosa 'Hawera' (too short).

Not suitable culturally: food and medicinal plants.

[9] Media selection concepts are summarised in Simcock R, Blackbourn S, Fassman-Beck E, Ansen J and Wang S. 2014.
Resilient rain gardens: selecting fill media and mulch, and influences of urban design. Water NZ. NZWWA LID Urban design (waternz.org.nz)

Examples of plants for temporary bioretention: **from left to right** Carex (near Eden Park), Carex and prostrate Coprosmas (Taupo) and Phormium cookianum, Coprosma acerosa and other flaxes (Beachlands).

7.2 Sacrificial bioretention

Plants in these devices are likely to be replaced within 1 to 4 years of construction due to physical damage or being smothered by sediment.

This approach is likely in housing subdivisions where individual lots are built after Section 224c is granted.

Temporary planting aims to deliver aesthetics that are desirable to sell sections, then allow plant removal once all construction is complete (with the upper 100-300 mm of sediment-affected soil). At that time conventional, long-lived bioretention plants may be established along with mulch.

Plant requirements: fast establishment to a dense, aesthetically-pleasing cover within 6 months.
Plants between 30 cm and 80 cm height at maturity.
Generally upright, erect growth for plants, especially those within 30 cm of edges.
Leaves and growing points resistant to physical damage, including crushing (i.e. not brittle).
Drought-tolerant, can grow through sediment up to about 50 mm depth. Cheap to propagate and can be established at a range of sizes.
Shallow rooting helps removal, but reduces drought tolerance. Resistance to glyphosate is an advantage for plants adjacent to edges or overflows.

Plants in these devices are expected to be replaced within 5 to 10 years. Such devices are likely to have high stormwater volumes with moderate to low sediment concentrations and be adjacent to highly-trafficked roads and round-abouts. They include stormwater quality devices with high infiltration rates, and/or parts of devices with high contaminant loads e.g., forebays and edges, some carparks, high-traffic roads with constrained street sweeping.

Plant requirements: Establishes to form a dense, aesthetically-pleasing cover within 6 to 12 months. Plants greater than 30 cm height. Maximum height likely 1.5 m, depending on sightlines and surface level of device. Include some plants that loosen the surface as they grow to maintain stormwater infiltration rates. Small devices have most plants within 50 cm of edges, so these plants need to be upright or able to be trimmed annually (or more frequently).

Plants need to be highly drought-tolerant as media typically have rapid permeability and low water storage capacity. Can grow through sediment up to about 2-5 cm depth. Relatively cheap to propagate and can be established at a range of sizes. Preferably resistant to glyphosate. Unlikely to include trees unless trees are also replaced within 10 years. Could include species useful for fibre, composting, mulching or maybe animal feed (as it is likely to have elevated Zinc concentrations).

Native species: many native sedges, some juncus species, upright oioi, many semi-prostrate Coprosma species/cultivars (taller C. acerosa and C. propinqua, C. repens). Small, dense coastal flaxes with short flower stalks (varieties of Phormium cookinaum), many dense, low Hebes (where mixed with other plants).

Not generally suitable: rengarenga, libertia, plants for consumption or medicinal use (especially any plant parts touching road runoff due to micro-biological contamination from faeces).

Companion planting: useful and encouraged, especially using mixtures of Hebes (generally more upright) with Coprosmas (generally spreading), sedges and rushes.

7.3 Conventional Devices

Conventional bioretention devices with medium to long term anticipated life (11-50+ years).

These devices usually receive low levels of stormwater contamination (low traffic volumes or high street sweeping frequency, e.g., low-traffic residential streets, some parking lots, central city.
Devices usually treat stormwater volume and quality. Because devices are long-lived, they should be designed for minimum maintenance (unless part of wider landscaping).

This requires close attention to device size, and plant location with respect to live traffic lanes, hard edges, inlets and overflows.

Long-lived devices are best-suited to delivery of benefits beyond stormwater, so plants should complement adjacent landscaping and could support habitat. In particular, the inclusion of trees maximises benefits and stormwater volume attenuation.

Plant requirements: a wide range of drought-tolerant groundcovers, shrubs and trees are suitable depending on bioretention volume, shape (distance to edges) and location with respect to sight-lines.

Groundcovers remain the most critical component to maintain a dense plant cover that supresses weeds, protects the soil surface and provides an aesthetically-pleasing cover within 6 to 18 months.

Plants should be greater than 30 cm height unless maintenance is 'garden' standard'. Edge plants should include species resistant to glyphosate as edges are likely to receive many cycles of herbicide applications. Trees and shrubs need to support dense groundcover by providing adequate light underneath their canopy.

These devices can include species suitable for harvesting fibre and food if safe access is designed and plant parts are collected from above the ponding depth (i.e., do not include roots or lower leaves).

Native species: Many native sedges, some juncus species, upright oioi, many semi-prostrate Coprosma species/cultivars between 30 and cm and 1 m height (C. acerosa, C. propinqua, C. repens, C. kirkii and hybrids), M. complexa, prostrate manuka (e.g., "Wairere falls') and kanuka and many small, dense Hebes.

Many smaller, dense coastal flaxes (Phormium cookinaum) but check the length of flower stalks.

Many dense, low Hebes/Veronicas (which are best mixed together) and many native hedging plants are suitable in places where an annual prune is acceptable.

Common hedging plants include korokio, divaricating Coprosmas and M. astonii.

Not suitable: short-lived plants (some sedges) and plants that tend to die from the centre as they grow larger, or become bare at ground level, such as Carex secta unless they are in large devices away from edges.

Plants along edges maintained with herbicide should generally be resistant or they are likely to be killed within 10 years.

Deciduous trees are generally unsuitable. Deciduous trees with large leaves (plane) or medium leaves (elm, maple, oak) should never be planted. Where such trees are adjacent to bioretention ensure inlet design mitigates the risk of leaf blockage and schedule additional autumn maintenance to remove leaves.

Sacrificial and conventional devices are complementary, and when placed adjacent to each other or nested within larger devices, sacrificial areas allow long-lived, large and/or culturally important plants to be included such as trees.

All three devices may be constructed with basal water storage, either through using a pipe-elbow to create ponding within a deepened drainage aggregate layer.

  

Maintenance costs increase **from left to right** as the length of hard edge and number of maintenance operations become more complex (e.g. weed whacker and mowing and mulching in the centre photo).

Costs also increase when plants are vulnerable to weed invasion and stress **(right photo)** where plants are isolated, vulnerable to trampling, and too short to compete with/exclude weeds.

  

Left - Rengarenga lilies require an annual trim post-flowering to remove seed heads and maintain high aesthetics.

They may also require slug/snail control, which needs careful selection to avoid impacts on stormwater quality.

Centre – young trees, especially nikau palms, require regular pruning to retain leaves (needed for growth) but manage sight lines until trees are tall enough so leaves are above the required sight lines.

Right – a 30 km/hr speed limit and clear crossing points reduce risk to raingardens and pedestrians.

08

Right Plants

The 'right' plants for the three types of bioretention device (temporary, sacrificial, and conventional) were assessed using six broad criteria.

• Development and retention of dense cover for the life of the device by being resilient to the common stresses of each bioretention type but all in bioretention media with 50 to 300+ mm/hr drainage rates (i.e., no anaerobic root conditions; no ponding longer than 24 hours).

• Plant characteristics that enhance the quality and quantity of stormwater 'treatment' (mainly from literature review and overseas studies, not native plants).

• Plant characteristics consistent with road corridor sight lines and frangibility requirements.

• Plant characteristics supporting mana whenua values (with information from hui, literature review and case studies, and review by mana whenua representative).

• Plants that 'work' together to enhance resilience and performance over the life of the device. Single-species plantings should be avoided, but diversity often reduces over time as devices mature, and is acceptable.

• Plant characteristics consistent with low maintenance costs. Costs are influenced by maintenance: types, frequency, and risks (see Ira and Simcock 2019). Maintenance typical of road corridor are identified – maintaining sight lines, spraying edges and road sweeping.

The plant list complements the following description of plant characteristics that are not suitable for roadside bioretention devices with free-draining media. However, some otherwise unsuitable plants can be acceptable 'by design', i.e., if a bioretention device is located and designed to avoid or mitigate undesirable characteristics.

For example, a strategy to avoid shrubs and trees impacting sightlines is to locate these well outside the road envelope by setting the device back from the road (see AMETI case study).

Trees may also be specified with minimum clear trunk height ensuring that the level of footpath, road and media are considered. Taller groundcovers can be used where the raingarden is set lower into a landscape. An upright growth form is a key criteria for groundcover plants immediately adjacent to a road or footpath; however, when the device is embedded within other landscaping, spreading plants may offer more resilience.

The plant lists are shown in Tables 2 and 3. (brittle), libertia (does not tolerate sediment), prostrate Coprosma repens (brittle) or C. acerosa 'Hawera' (too short).

This guide does not consider mown grass swards or meadows, although these are often used in swales. Regularly-mown grass is expensive to maintain and has high risk of poor bioretention outcomes such as rutting, scalping followed by weed invasion, and grass clippings entering watercourses. Meadows are increasingly popular overseas, and potentially have multiple benefits, but techniques for their management within bioretention devices have yet to be developed for Auckland.

Left – Mulching around totara trees in North harbour stadium swale improves efficiency of mowing and enhances tree health.

Centre – Groundcover at Panmure train station has lower maintenance of an annual edge trim (these plants should never be ‘topped’).

Right – Hebe diasmofolia in full flower adds seasonal colour.

Table 2. Ground-cover plants

Legend: ■ Plants listed in GD01 ■ Plants listed by Nature Services.

E – edge or within 1 m of edge and narrow devices; C – centre or only where planted >1 m from edge or where edge is adjacent landscaping or mown grass (Not to be planted within 1 m of hard surfaces to reduce trimming requirement and not within 1 m of inlets or overflows). ABG = Auckland Botanic Gardens, Manurewa.

Name	Common name	Note	Temporary	Sacrifice	Conventional
Apodasmia similis	Jointed rush	Variable height and form; keep more than 1 m from inlets and overflows	No	C	C
Astrofestuca stipiodes	Tussock grass	Very sharp leaf points, tolerates high drought stress 0.8 m; Poa billardierei (A. littoralis) is an alternative sans sharp tips, but rarely available	C	C	C
Carex dipsacea	Sedge	Naturalised around Auckland, also sold as C. tahoata 'Bronze warrior', 0.7 m	C	C	C
C. dissita, C. solandri	Sedge	Similar looking plants naturally growing together; 0.6-0.7 m	E	E	
Carex flagellifera	Sedge	Fine green leaves, also known as 'Glen Murray tussock', 0.6 m	E	E	E
Carex geminata	Rautahi, cutty grass	Vigorous in full sun		Maintain infiltration into media	
Carex testaceae	Orange sedge	ABG used 'Kariotahi'	E	E	C
Carex ochrosaccus*	sedge	Unknown performance	C	C	C
Carex pumila*	Blue dune sedge	Generally 0.2 m – on margin	E	E	C
Carex virgata	Purei	Vigorous clumping sedge will cut hands, 1 m	C	C	C
Coprosma acerosa		Variable yellow to orange or green leaves, height and density; specify form to achieve required density and height; smothered by C. kirkii at ABG			
Coprosma x kirkii		Can dominate nearby plants; trim	C*	C	C
Coprosma* 'Bowling Green', 'Taiko', 'Black Cloud'		Also Coprosma repens 'Poor Knights' (prostate)		L	L
Dianella latissima	Flax lilly	Slower to establish	No	E	E
Ficinia nodosa	Wiwi, knobby club rush	(was Isolepis nodosa) variable height to 1m with sharp tip	C	C	C
Leptospermum 'Wiarere Falls'	Prostrate manuka	Use where it can drape over edges or near centre of beds>2 m wide	No	E	E
Hebe speciosa	NZ hebe	Large magenta flowers, brittle	No	C	C
Hebe diasmofolia	NZ hebe	Mass mauve to white flowers in spring, brittle 0.7 m			
Muehlenbeckia astonii		Specify low, tightly interlocking form; may need annual trim	No	C	C
Phormium cookianum*	Wharariki, Coastal flax	Keep away from mowers, 2 m flower stalk may need annual removal; many varieties, specify <1m height	C	C	C
Poa cita	Silver tussock	unlikely to live >~5 years	E	C	

*Note: many cultivars of Coprosmas, Phormium and Hebe/Veronica are available with a wide variety of stature, leaf shape, colours and heights. Select a variety of cultivars with dense foliage that are at least 30 cm height to supress weeds while also extending flowering periods and reduce risk; e.g Hebe diosmofolia, Hebe 'First light', 'Wiri mist' and Hebe albicans are all rounded, typically 30-70 cm height; and establish rapidly.

Table 3. Groundcover species RECOMMENDED for more fertile and lower drought-stress bioretention

Legend: ■ Plants listed in GD01 ■ Plants listed by Nature Services.

E – edge or within 1 m of edge and narrow devices; C – centre or only where planted >1 m from edge or where edge is adjacent landscaping or mown grass (Not to be planted within 1 m of hard surfaces to reduce trimming requirement and not within 1 m of inlets or overflows). ABG = Auckland Botanic Gardens, Manurewa.

Name	Common name	Note	Conventional
Astelia fragrans, A. solandri, A. grandis,		Slower-to establish, does not tolerate physical crushing damage, up to 1.5 m tall, plant in low densities, not in swale bases as can deflect flow. A. fragrans and A. solandri most drought tolerant	C
Astrofestuca stipiodes	Tussock grass	Very sharp leaf points, tolerates high drought stress 0.8 m; Poa billardierei (A. littoralis) is an alternative sans sharp tips, but rarely available	C
Blechnum novae-zealandiae	Kiokio	Could be more widely used, slower to establish, needs mulching, relatively brittle, useful for part shade	C
Carex gaudichaudiana	sedge	Highly variable foliage, open, unshaded conditions	E, 30-40 cm
Carex lessoniana	sedge	Requires moist ground and most vigorous in part shade, ideal for wet swales as has creeping rhizome, not for standard raingardens	C
Carex maorica	sedge	Full sun , 0.7 m	
Carex secta	sedge	Up to 1.5 m tall, do not plant in large groups as become bare underneath as trunks establish and vulnerable to glyphosate	Only large devices
Coprosma virescens		Will grow over 2 m tall if not trimmed but, along with other divaricating coprosmas and Corokia cotoneaster is suitable for 'hedges' and barrier planting;	Only larger devices
Austroderia fulvida / Cortaderia fulvida	toetoe	Very vulnerable to glyphosate, 1.5 m and relatively short lived; may be a useful fast-filler in large raingardens while longer-lived shrubs establish	Only large devices
Cyperus ustulatus	Giant umbrella sedge	Looks very messy in winter when dormant; can cause deep cuts as leaves sharp (has use as a security plant); only 'ecological' devices	Only large devices
Eleocharis acuta	sedge	Tolerate medium droughts and useful for wet swales	
Hebe stricta	koromiko	Too tall and open for roadsides, useful in large bioretention scattered for short-term	
Juncus australis	Leafless rush	Not widely used to date	
Juncus sarophorus	Fan-flowered rush	A weed of pastures to 1.5m, not widely used to date but has good potential	
Lepidosperma australe	Tussock grass	Maybe difficult to source; needs further testing	
Machaerina sinclarii	Pepepe sedge	Slow to establish but has rich subtropical look and graceful seed heads	
Muehlenbeckia complexa		Slow to establish but forms small leafed 'filler between other plants and will climb up trees; eventually take over and smother all other plants so only for sacrificial devices	
Schoenoplectus pungens	Three-square rush	Tolerate medium droughts, useful for wet swales	

*Note: many cultivars of Coprosmas, Phormium and Hebe/Veronica are available with a wide variety of stature, leaf shape, colours and heights. Select a variety of cultivars with dense foliage that are at least 30 cm height to supress weeds while also extending flowering periods and reduce risk; e.g Hebe diosmofolia, Hebe 'First light', 'Wiri mist' and Hebe albicans are all rounded, typically 30-70 cm height; and establish rapidly.

Bioretention devices in Auckland Botanic Gardens showcase a range of species and maintenance-reducing approaches.

Left – The dry edge of this long swale has oioi (foreground), dense coprosmas including C. x kirkii, a natural hybrid between C. propinqua and C. robusta that is common on older motorway edges), Phormium cookianum 'Emerald Gem' and prostrate manuka 'Wairere Falls' in flower while oioi and pohuehue (M. complexa) fill the centre of the swale.

Centre – Carex with a woodchip-mulched edge minimising use of herbicide.

Right – Carex flageliffera has long leaves that can be a trip hazard but here the retaining wall and c. 200 mm depth contains the sedge, and bump bars keep vehicles from the edge.

Sites may receive afternoon shade (for example from large trees or buildings), be part of larger landscaped areas rather than surrounded by impervious surfaces and have media that have 20% v/v organic matter, higher soil component, a finer pumice sand component, organic mulches mixed with compost and 50-200 mm/hr saturated permeability. Species suitable for these locations are listed in Table 3.

The following species were generally recommended for TP10 'impeded' bioretention devices (Lewis et al) or GD01 (C1, Table 32 p 97). A group of these species <100 mm height at maturity have been removed; these were recommended for underplanting in devices with low sediment and low weed pressure – conditions that are uncommon in devices vested to AT, but may be found in landscaping within transport stations. The species listed in Table 4 below are NOT recommended for AT bioretention devices.

Table 4. Groundcover Species NOT RECOMMENDED for AT bioretention devices

Legend: ■ Plants listed in GD01 ■ Plants listed by Nature Services.

E – edge or within 1 m of edge and narrow devices; C – centre or only where planted >1 m from edge or where edge is adjacent landscaping or mown grass (Not to be planted within 1 m of hard surfaces to reduce trimming requirement and not within 1 m of inlets or overflows). ABG = Auckland Botanic Gardens, Manurewa.

Name	Common name	Reason for exclusion
Baumea articulata	Jointed twig-rush	Prefers very moist conditions and grows to 1.8 m
Baumea tenax	Bumblebee nut sedge	Not adequately tested
Blechnum minus	Swamp kiokio fern	Difficult to source, not adequately tested needs continuous moist sites
Blechnum parrisiae	Rasp fern, pukupuku	Was Doodia australis; Doodia media Brittle, takes several years to establish, expensive, old fronds unattractive, 30 cm at min height
Blechnum penna-marina	Alpine hard fern	Too short (100 mm)
Dianella nigra, and D. haematica	Turutu, NZ bluberry	Difficult to weed, as rhizomes pull out, D. haematica is larger and wetland form
Coprosma tenuicaulis	hukihuki	Rows to 2 m; prefers wetter soils
Eleocharis acuta	sedge	Useful for wet swales
Freycinetia banksii	Kiekie vine	Difficult to source, slow-growing and requires part-shade
Gahnia setifolia	Cutty grass, mapere	Difficult to source and establish, very sharp leaves
Gunnera	Native herb	Too low (5 cm) except for 'gardens' and requires continually moist sites
Isolepis prolifer	Fleshy sedge	Useful for wet swales
Juncus edgariae	wiwi	Also known as J. gregiflorus. Not adequately tested, could be invasive, to 1.5m
Libertia ixiodes, L. grandilora	Mikoikoi, NZ iris	Can be confused with non -native species, may require deadheading
Leptinella dioica	herb	Too low (5 cm) except for 'gardens'
Leptostigma setulosa	herb	Too low (5cm) except for 'gardens' along with Centella uniflora and Acaena species
Lobelia angulata	herb	Too low (5cm) except for 'gardens'
Paesia scaberula	Scented fern	Slow to establish, not used
Pteridium esculentum	bracken	Slow to establish, invasive, winter-dormant, not recommended

Coprosma robusta and Gahnia xanthocarpa, which are in the TP have been removed; the former is a large (>3m), spreading and rather 'messy' shrub that is relatively short lived; the latter is very large tussocky grass with extremely sharp leaves that is difficult to maintain but also hard to source and establish, being vulnerable to transplant shock along with most other Gahnia species.

Unwanted plants

09

Plants with the following characteristics should not be used unless 'by design' and 'by exception'.

• Deciduous trees with medium or large leaf sizes, e.g., plane, oak, alder, elm

• Plants on the Auckland Council pest plant wider list, e.g., palms, agapanthus,

• Plants that could spread into adjacent areas and become weeds; this includes most non-native plants with red or yellow berries

• Non-native plants that are not already in the catchment (native = within the ecological district)

• Plants that have roots or near-surface leaves that may be attractive for harvest, e.g., taro

• Plants that require annual dead-heading, e.g. rengarenga, swamp flax within 3 m of seal

• Plants that are vulnerable to disease or insects, so likely require chemical treatments to keep foliage looking healthy, e.g. rengarenga are vulnerable to snails

• Plants that are highly vulnerable to Glyphosate (e.g., toetoe)

• Plants in places where they are likely to damage people (bush lawyer, nettles, Astrofestuca littoralis/ needle grass), potentially allergenic plants (e.g., silver birch) and plants with poisonous fruit (e.g. karaka).

• Plants that are extremely brittle (e.g, whau, some hebes)

• Annual plants and bulbs with dormant phases, plants with a life shorter than the device renovation time, unless as small components of diverse landscapes (not as mass planting, and note they look messy when the leaves die in summer unless carefully planned within mown turf)

• Mass planting of single species and clones of plants, as this increases the risk of catastrophic failure and poor aesthetics (an exception being use of oioi)

• Kikuyu

Left – Pratia angulata is usually a poor choice as an edge species as it is too short to tolerate sediment or resist clover/other taller weeds establishing and smothering it. Pratia is not competitive in on such steep, poor clay-rich soils with high water stress (Orewa 2020).

Right – Even where conditions are ideal, regular and skilled maintenance is needed (i.e. hand-weeding) to prevent it being overcome by large annual weeds (here sowthistle, Sonchus species), grasses and legumes (here white clover, Trifolium repens and Lotus corniculatus) or deciduous leaves (Auckland Museum).

10

Mana whenua considerations

The Maori world view generally favours the use of bioretention as a method of mitigating impacts of runoff from roads (see Brockbank and Voyde 2019). Bioretention devices have the primary role of helping transform wai-kino (mauri-mate) to wai-maori (mauri-ora) by passing stormwater through a planted 'soil' filter where natural biological processes influence the water; this could be considered a type of Rongoa, medicine for stormwater.

Auckland Council Guidance promotes the use of native plants for bioretention devices. These plants need to survive and flourish in manufactured soils, in an often-harsh roadside environment. The selection of plants is therefore necessarily limited, and locally-sourced plants may not thrive, especially in small and short-lived devices. However, in general, bioretention can be designed and located to allow greater use of locally-sourced plants along with rare and threatened plants, especially for larger, conventional devices.

The issues are listed below were raised by and with Mana Whenua when discussing plant selection and maintenance of bioretention devices and rehabilitation plantings, and with Mana Whenua's reviewer.

However, the following points are not definitive or exclusive, as Mana Whenua priorities and issues will vary from site to site.

There are situations when it may not be appropriate to use specific native plants, or specific local cultivars in a bioretention device, for example:

• Kai plants (e.g., puha, watercress, karaka) or Rongoa plants (e.g. kumerahoe, koromiko) where road-derived contaminants make them unsuitable for consumption, especially for roots or leaves that are in contact with stormwater, or leaves alongside high-emissions roads where contaminants are in dust/air.

• Kai or Rongoa in sites that are physically unsafe to harvest due to their location near traffic.

• Locally important plants-of-place (ramarama, 'magenta' koromiko – Hebe speciosa, local harakeke cultivars) where they may be stressed due to their location and use for bioretention.

• Plants that support specific biodiversity values where the attracted animals (lizards, invertebrates and/or birds) may be killed by traffic or deterred by traffic. The potential for harm is influenced by the traffic density and type, closeness to live traffic and separation of the bioretention devices from traffic and from the areas from which the animals travel.

• Where plants will have a short life and/or are likely landfilled when removed due to contamination, such as temporary or sacrifice bioretention.

• Where plants cannot be sourced, supplied or maintained by Mana Whenua

Coprosma robusta and Gahnia xanthocarpa, which are in the TP have been removed; the former is a large (>3m), spreading and rather 'messy' shrub that is relatively short lived; the latter is very large tussocky grass with extremely sharp leaves that is difficult to maintain but also hard to source and establish, being vulnerable to transplant shock along with most other Gahnia species.



Common rongoa (medicinal) plants that match free-draining bioretention media and exposed conditions.

Left – Kumerahoe (Pomaderris kumerahoe), koromiko (Veronica speciosa) and manuka (Leptospermum scoparium).

Principles can be co-developed to guide plant selection at each location that allow benefits and opportunities that are dependent on plant species to be realized, for example:

• Large trees such as totara, puriri, titoki, pohutukawa and koheohe require minimum conditions to become large, healthy trees: large root volumes (~10 m3), long-lived bioretention (low contamination or maintenance that reduces contamination buildup) and potentially media with a higher organic component and fertility, depending on the stormwater quality. It may be best to place trees outside bioretention devices where roots can still access the stormwater (and device performance).

• Plants for harvesting fibre (harakeke, ti kouka, kuta, toetoe) are likely to require specific characteristics delivered by specific cultivars, propagated by division. The height and spread of these cultivars needs to be integrated into the design to ensure sight-lines are not infringed, as most of these plants are taller than 1 m.

• Plants that support native invertebrates, lizards or birds (flowers, fruit or habitat) may be preferred where specific animals are nearby, for example, most Coprosmas have fruits attractive to many species; kowhai and flax are rich in nectar, manuka and koromiko flowers attract a variety of pollinating insects; specific native moths and butterflies are dependent on harakeke, ti kouka and pohuhue as food for their larvae.

• Some plants may not be suitable in any bioretention device, for example, in some areas culturally-important puna (springs) were planted with specific ferns to signal their value.

The treatment and maintenance of bioretention plants and media should be aligned with and influenced by Mana Whenua principles.

These should include, for example:

• specific methods and timing of trimming/ harvesting plants

• retaining trimmings on-site instead of disposing off-site e.g. using leaves as mulch or tucking out of sight under taller plants to create habitat and suppress weeds;

• composting trimmings, noting that sediment and soils may have zinc and copper concentrations at levels that require disposal in specific landfills (as for inorganic catchpit and road sweepings)

• controlling use of herbicides, especially in areas where kai, rongoa or fibre are harvested

• retaining 'native weeds' and edible plants (even if not harvested) such as puha

• replacing plants with species sourced and supplied by Mana Whenua nurseries

 

Left – swales with red flax cultivars that are not natural local varieties (not 'eco-sourced').

Right – these toetoe require removal as they block sight-lines, as may some of the flax. When grown by seed the flax can be variable, with larger plants needing removal and replacement at the end of the first year of growth as part of maintenance.

11

Right Place

Different plants suit different parts of bioretention devices, different device sizes, adjacent land uses and longevity.

Plants are more stressed in small, narrow and/or shallow devices, where adjacent surfaces are 'hard', there is no shade, and where there is no protection from high contaminant loads or access. Edges and inlets are places where plants are highly vulnerable to stress and damage. The following strategies get more plants in places where damage and stress to plants is less likely.

• Minimise hard edges that need to be trimmed by including bioretention within landscaping or riparian strips /ecological areas

• Place bioretention within mown areas (as long as the edge is defined and aggressive stoloniferous grasses such as kikuyu and twitch are not present)

• Avoid devices <1.5 m width, especially when concrete or other impervious surfaces surround the device as these create stressful environments; do not put trees into devices <2 m2

• Avoid placing trees where cars may hit them (e.g. corners or within 1 to 1.5 m of edges)

• Sink bioretention surface 200-300 mm below grade to allow plants to grow taller before entering sightlines and reduce need for trimming

• Do not put brittle plants within 1 m of an edge where traffic is adjacent, especially carparks – cars will break brittle plants

• Protect plants from vehicles entering a device by including bump bars, barriers/bollards, street furniture and visual aids

• Protect plants from people trampling by designing crossings on 'desire lines' (consider retrospective construction), dense edge planting and street furniture.

• Protect plants from people by not placing services in rain gardens (lights, posts, signs) as people maintaining these services may damage the rain garden by trampling, and keeping access to services clear increases spraying or trimming costs.

• Protect plants from sediment. Use pre-sediment removal methods such as street sweeping or swales, especially in high-volume roads to extend life of the rain garden and reduce build-up of contaminants.

• Ensuring even stormwater distribution across larger rain gardens by locating inlets help spread and using square shapes rather than long and narrow shapes (especially if there is a single inlet at one end). Minimise bypass flow by ensuring adequate media compaction along edges and around overflows.

Low maintenance plants (an Australian Dianella) placed in device layout that increases maintenance due to the long length of edges. A better design would remove the narrow grass strip by placing the devices together, or use one, larger device (which would also reduce the volume of concrete).

High maintenance design.

Left – A swale with very shallow fall into the device and oioi within 50 cm of inlets and road edge, requires at least annual cutting along hard edges to remove 400 to 800 mm of floppy leaves and excavation of inlets to maintain performance. However, the oioi must not be 'topped' by more than 30% of height (and preferably not at all).

Right – a narrow, unmowable strip of 'grass' increases maintenance cost.

Placement of the raingarden within landscaping reduces the need to trim plants along edges. The swale slows stormwater flows into the raingarden and contains Carex with borders of Meuhlenbeckia astonii and flaxes. The raingarden trials a smaller, upright variety of oioi to reduce edge trimming. Kowhai tree cast light shade that maintains dense groundcover. Right – Phormium cookianum 'Emerald Gem' placed along the upper edge of a swale –angled parking with bump bars means the c. 1 m long annual flower spikes will not need removal as they are unlikely to impact people or cars.

Lack of bumpers means vehicles can enter raingardens causing plant death, especially on corners **(right).** The area has been remulched with pebbles to prevent weeds establishing before replanting in autumn.

Left – The selected turf species allows use of reduced-mowing which improves tree pit and swale bioretention performance and improves tree health (Albany); centre – narrow swale with no car bumpers allows cars to damage plants (Nelson).

Right – placing lights in raingardens increases maintenance and risk of plant damage.

Left – The many intruding posts on the left create high maintenance, exacerbated by the use of turf rather than a perennial groundcover and low mowing height reduces efficacy of filtration (Mount Albert).

Right – raised edges and sunken raingarden creates low-maintenance edge (Hobsonville Point).

Left – Purple Acaena groundcover is protected by bike stand and low-sediment-generating surface (Christchurch).

Centre – seats protect the raingarden from pedestrians (Christchurch).

Right – Gabion mats are difficult to remove sediment from.

12

Right Maintenance

Maintenance of plants can be divided into three types: establishment, 'routine' or cyclic maintenance, and 'corrective' maintenance.

12.1 Establishment maintenance

Establishment maintenance covers the period from planting until full-establishment. This may be the time a bioretention device is vested to Auckland Transport. Maintenance activities and frequency are more intensive, and timing more critical during establishment as devices are particularly vulnerable to damage during the first storms and to drought over the first summer while root systems establish. They are also vulnerable to weed invasion until a dense plant cover has established. Weeds should be removed before they set seed as this prevents build up of a weed-seed or rhizome bank that exacerbates future maintenance needs. Aggressive weeds such as kikuyu and other creeping grasses, lotus and other aggressive legumes, fleabanes and thistles need to be identified, and the whole plant removed from the site and/or herbicided before they establish. In addition, trees need to be pruned to deliver safe sight lines and branching resilient to storms, and tree stakes and ties removed before they start to damage growth.

12.2 Routine or cyclic maintenance

Routine or cyclic maintenance is less frequent, and focuses on ensuring inlets, outlets and overflows are functional, i.e. unblocked by plants (whether weeds or planted specie), removing sediment at inlets to prevent weed establishment, controlling weeds, and trimming vegetation that is infringing sight lines and 'hard' edges. Edges should be pruned with sharp blades, not weed-eaters or strimmers. Edges should be trimmed to create dense vegetation right to the edge of hard surface without exposing bare soil (because this will allow weeds to grow).

Plants should be cut to a height that maintains cover of the desirable plants. This means oioi and sedges should never be topped below 50 cm height, and never after the spring growth flush has finished unless bare areas created are covered immediately with mulch (which can include the leaves that have been cut if they do not float). Oioi and sedges should be cut in autumn through spring. Cutting oioi and sedges hard (by more than 30% height or volume) in summer is not advised, as this reduces the ability of plants to survive droughts. Strimmers should never be used to control groundcovers around young trees because they inevitably remove or damage bark, reducing ability of a tree to transport water from roots to shoots, and leading to future rots and tree instability.

Trees continue to be regularly pruned to ensure safety and health – and this is usually done an arborist under a separate contract. Cyclic maintenance can start once the target vegetative cover is established, i.e., typically 18 to 36 months post-planting. New Zealand raingardens do not typically have mulches replaced annually across the planted area, unlike devices in the United States which use deciduous plant species. However, strategic re-mulching of bare, exposed media or sediment is an important part of cyclic maintenance to prevent weed growth and minimise herbicide use. Re-mulching must not block inlets.


Routine maintenance of edges.

Left - poor practice leaves a gap between the edge that is not mulched and will be vulnerable to weed growth, setting up a cycle of spraying.

Right – good practice maintains a dense plant cover to the edge, without exposing soil.


Routine maintenance of edges.

Left – a flexible shrub (Coprosma repens) allows cars to 'trim' the edge by pushing against the plants, avoiding the need for maintenance.

Right – gaps along the edge where flax have been trimmed are covered with mulch to prevent weeds establishing.


Left – The many intruding posts on the left create high maintenance, exacerbated by the use of turf rather than a perennial groundcover and low mowing height reduces efficacy of filtration (Mount Albert).

Right – raised edges and sunken raingarden creates low-maintenance edge (Hobsonville Point).

Routine maintenance of edges.

Left – The same site in 2020 has been overgrown with weeds that are so tall they are obscuring sight-lines. This raingarden now needs renewal of groundcover.

Right – the flax should be removed as it is too close to the edge and will otherwise need very regular cutting.

Routine maintenance.

Left – raingarden vegetation in very good condition, 2019.

Right – the same raingarden in 2021 after hacking oioi to about 10 cm height now needs complete groundcover renewal and corrective maintenance. The removal by strimming has also damaged the tree trunks, opening them to disease and future instability. AMETI.

Routine maintenance. Muehlenbeckia and low sedges form an edge that can be mown as part of routine maintenance of the adjacent lawn; just the front edge needs hand-trimming. The oioi variety is relatively upright, further reducing maintenance.


Routine GOOD maintenance – young kowhai trees have been staked.

Right – a wide area of mulch and three protective stakes means grass can be mown without getting near the tree and risking damage.


Routine BAD maintenance.

Left – strapping used to hold the tree upright at establishment has not been removed in time, and now requires the whole branch to be removed.

Right – strimmer/weed eater damage to the base of the trunk – young titoki, kowhai, cabbage tree and kohekohe are most vulnerable.


BAD routine maintenance.

Left – trees have not been pruned to maintain sightlines, but are healthy.

Right – oioi groundcover has been cut and buried and 40 cm of mulch placed. The depth of mulch against the tree trunk is likely to rot the trunk and is blocking inlets.

Left - BAD routine maintenance. Trees have not been pruned by an arborist, stubs have been left that are more prone to rot, and dangerous to the passing public.

Right – Corrective maintenance is needed to replace the tree that has died.

12.3 Corrective maintenance

Corrective maintenance is required to replace plants that die or are removed and must be followed by re-mulching to prevent weed establishment and growth. Before replacement plants are established, the reason for plant death or injury needs to be confirmed to ensure the replacement plants perform well. In some cases, corrective maintenance needs to include other works to protect plants, e.g. changing inlet conformation or installation of rip rap to reduce erosion, removal of lighting or signage, installation of a forebay to prevent sediment loading, or creation of a hard, broad edge to prevent invasion by kikuyu from an adjacent lawn.

The cost of maintenance is a function of the following factors:

• Safety requirements, particularly if temporary traffic control (TTC) is required. TTC, spotters and attenuator vehicles are expensive. Central median rain gardens are therefore generally costly to maintain. Maintaining clear zones and sight lines is costly if plants frequently impinge these zones, e.g. lowland flax flower stems are 1-3 m long and can impact live lanes, requiring removal every summer.

• Level of service / amenity specified. This is usually reflected in litter removal, weed removal and edge trimming frequency; rain gardens that have 'ecological' levels of service can have low levels of maintenance as some weeds can be tolerated, whereas 'garden beds' can have very high costs.

• The efficacy of maintenance during establishment. The area of bare ground or sediment, density of desirable plant cover and of weed species impact maintenance costs. Some weed species are difficult to remove once established, e.g., creeping grasses, lotus and buttercup.

• Inlet and overflow design, in particular, whether these are 'self- cleaning' or prone to blockage, and the ease of finding and cleaning them without specialist equipment, e.g. inlets <200 mm width are difficult to clean with a spade or shovel.

• Plant-specific management. Some plants in high-amenity areas will require annual removal of dead flower heads, e.g. rengarenga and flaxes. Most rain gardens require some edge trimming if adjacent to footpaths or roads. Edge design and rain garden depth relative to plant size, height and growth rate determines the extent and frequency of trimming required. Deeper rain gardens with broad edges and upright plants between 0.3 and 1 m height require little trimming.

• If the rain garden is managed as part of a larger area with similar plants and/or compatible practices (such as edge trimming, weeding, tree pruning) that allow economies of scale.

• Rain garden media fertility (organic matter); fast growth means more initial trimming.

• If supplemental irrigation is required. Hand-watering is expensive.

• Adjacent vegetation. Shading trees usually reduce maintenance of groundcover. However, deciduous trees are likely to require autumn leaf removal to prevent groundcover being smothered. If invasive or aggressive weeds are in adjacent areas or 'upstream', maintenance is likely to be higher. Such plants include stoloniferous grasses (especially kikuyu) and legumes, fleabanes and other tall, wind-spread weeds (often in the daisy family).

• The sediment and litter load in the contributing catchment and maintenance, e.g., street sweeping reduces sediment loads and can minimise weeding and inlet clearing; busy industrial roads may have higher sediment loads, rain gardens in high-use public areas or near take-away stores tend to have high litter inputs; rain gardens outside office blocks/ bars receive cigarette butts which do not damage plants but may be removed for aesthetics.

12.4 Contracting practices that reduce maintenance costs

• Dis-incentivise herbicide spraying. Instead encourage use of herbicide paste, removal of weed seed heads and plant material that could re-sprout. Trimmings that will not re-sprout can be tucked out of site rather than disposed off-site to reduce costs. If contractors use Glyphosate, ensure plants selected for planting are resistant to this herbicide.

• Ensure operators understand vegetation cover needs to be retained to supress weeds and avoid over-cutting that exposes bare soil surface, i.e. cut to the edge not into the raingarden. Do not cut the top of oioi. Ensure cutting is done with hedge cutters not weed whackers. Mulch exposed soils to prevent weed establishment while desirable plants regrow – this helps avoid herbicide use spiralling out of control.

• Train landscapers to recognise problems early and to take appropriate action; ensure budget and contract enables them to replace mulches and plants, or temporarily exclude sediment, and include reporting of issues. This includes proactively removing sediment at inlets, and creating a 'forebay' at the 'hardest-working' inlet to allow sediment to be efficiently removed without damaging plants.

• Enhance self-cleaning ability of key inlets to reduce potential to block; this may mean creating a 'lip' at least 20 mm high so water falls down into the rain garden.

• Remove and replace plants that are unsuitable, i.e. plants so large that sight lines are impeded or so small or open they cannot exclude weeds. Selectively prune to release shorter, lower-maintenance plants along edges to prevent them being smothered by taller plants.

• Remove weed plants before they set seed; remove seed heads. Proactively remove invasive weeds in adjacent areas and upstream catchment.

Left – A well-defined edge of timber should reduce the risk of such over-spraying of the grass, fortunately the Coprosma acerosa in the raingarden is relatively resistant to glyphosate (Judges Bay).

Centre – unprotected pohutukawa in a central swale, however the edge is straight and there are very few driveways, which minimise potential for damage (Stonefields Auckland).

Right – Ficnia nodosa planted along the edge in front of oioi needs selective pruning to prevent oioi dominating; interplanting of Hebes has added colour but they will require annual trimming as they are planted within 50 cm of the edge (Waitakere Civic Centre).

13

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