WSUD Case Study: AMETI

A transport and regeneration project in brownfields industrial / big-box retail area to improve transport efficiency across road and rail has revealed site histories, enhanced aesthetics, livability and stormwater treatment. This, first stage of a larger transport project, demonstrates a wide suite of planted, water sensitive design devices and approaches: extensive raingardens with predominantly native species that are low maintenance, stormwater planters supporting screens of vines, swales (both mown and planted) and tree pits set in an over-bridge. Together these help compensate for increased impervious area. An informal treatment and detention area within a public park has been upgraded by removing sediment, recontouring for safety and ecology, increasing discharge capacity and enhancing plants, aesthetics and usability.

Including WSUD approaches was driven by Auckland Transport, whose aims were to reduce impacts on receiving waters of wetlands, Panmure Lagoon and Estuary and regenerate this busy, industrialised brownfield. Auckland Transport retains ownership and maintenance responsibility, except for Van Damm's lagoon park. Overall outcomes were limited by 'TP10 2003' (75% sediment removal target), high existing impacts, cost of higher-quality treatment given space constraints due to the need to retain land for future arterial road widening, and inability to separate the source of Waipuna spring from existing stormwater infrastructure despite best efforts (which prevented physical contact or mahinga kai/food collection).

Features

- Enabling walking and cycling through new and attractive paths, boardwalks, access points and carparks using Crime Prevention through Environmental Design to enhance safety
- A wide range of planted WSUD devices, new wetland/pond and enhancing of Van Damm's lagoon has helped compensate for increased hard surfaces and may help to connect terrestrial habitats
- Reconnecting people with water and revealing cultural histories; the discovery and co-design processes with mana whenua has been restorative despite not fully restoring Waipuna spring
- Limited maintenance of planted WSUD devices by generalists has resulted in degradation of some devices, triggering more costly renovation
- Typical brownfields issues of limited space and contamination surprises
- Coordination between multiple agencies to enhance project outcomes in many areas

AMETI Stage 1 (design 2011)

About AMETI

The Auckland Manukau Eastern Transport Initiative, AMETI was designed to 'create a dedicated, congestion-free busway between Panmure, Pakuranga, and Botany town centre'. This case study focuses on the Panmure end, where a combined busway/bus and train station and new Te Horeta road, cycling and walking paths was completed in 2013 and 2014. The new road involved a 220 m tunnel through basalt next to upgraded Panmure railway lines; the new train and bus station buildings stand on top of the tunnel. The extracted basalt was crushed and used in the three new bridges and roads.
The AMETI project targeted two primary benefits:

- improved transport choices to get people onto public transport, freeing up roads for freight and business traffic. Panmure train station is the entry to the new South Eastern busway.
- economic growth and regeneration of surrounding areas.

Te Horeta Road carries 20,000 vehicles per day which bypass the Panmure roundabout, reducing traffic on Mount Wellington and Ellerslie-Panmure highways.

The AMETI site is a brownfield site with important Maori and European cultural histories that were largely hidden prior to this development. The catchment generates large peak runoff (1.9 m^3/sec) of which 1 m^3 is additional from AMETI. Stormwater contaminants are typical of high traffic volumes and extensive zinc roofing. Stormwater discharges into Panmure Basin (a tidal volcanic caldera) and the Tamaki Estuary; both drain into the Waitemata harbour. The estuary has areas of high contamination related to past and current industrial discharges. AMETI includes the Waituna spring-fed wetland and daylighted stream channel on William Harvey Place, and a reclaimed urban oasis, Van Damm's lagoon, where a new waterfall masks traffic noise, visitors hear native birds tui, piwakawaka (fantail) and kotare (kingfisher), and see tuna (eels).

Plant growth is rapid under Auckland's mild climate and regular rainfall if rooting volumes are adequate. AMETI is underlain in many parts by basalt so root growth is not generally restricted by poor drainage as in other areas of Auckland. However, soils are highly variable due to large areas of fill and rubble. Most soils in the AMETI project are imported and have limited depth (e.g. 500 mm for trees). A further constraint is an abundance of aggressive weeds along estuarine margins and in scattered industrial wastelands, notably pampas, moth plant and woolly nightshade (tobacco weed).

AMETI Stage 1 (design 2011) and green screen in stormwater planter boxes at the Panmure railway station (2018)

Stormwater management approach

Pre-project stormwater management used conventional catch pits and pipes with some ground soakage into high permeability scoria soils. There are no combined sewers. Near-source management includes catchpit cleaning (3 times/year under ACC) and weekly street sweeping on arterial roads (8-12 weeks elsewhere). Stormwater modelling for AMETI assumed catchpits removed 20% TSS and the coarser fraction, with the finer fraction having a higher proportion of metal contaminants.

The AMETI stormwater design philosophy was based on:

- Minimising effects on the downstream receiving environment (consistent with the proposed Regional Air Land and Water Plan)
- Efficient stormwater drainage and no worsening of modelled flood levels (there was existing flooding at 100-year Average Recurrence Interval (ARI) storm event), however the option selected reduced modelled flooding at 100 year ARI event
- Maintaining existing overland flows (AMETI Phase 1 stormwater concept study 2011)

The design life was to be 100 years with reasonable safe access for maintenance, avoiding likelihood of blockages (an issue with status quo), and designing most devices to meet TP10 (2003) guideline. This specifies a treatment efficiency of 75% sediment removal. Excess stormwater beyond the 1 year ARI event was to be diverted clear of stormwater treatment devices. Permanent stormwater treatment devices were to be contained within the project designation in general. A 2007 design used roadside underground concrete tanks and sand filters to attenuate stormwater before discharge to Van Damm's lagoon to protect its ecological values – the lagoon was an 'informal' stormwater detention and sediment settlement area. However, existing lagoon outflow restriction flooded habitable floors in a maximum probable development scenario, and the road location at the bottom of the catchment meant detention was likely to exacerbate peak flows. Instead, additional detention volume and new treatment areas were created in the lagoon by removing accumulated sediment (1 to 1.5 m was planned), enhancing wetland planting and adding a second high-level overflow pipe direct to Panmure Basin to increase outlet capacity. All of Te Horeta Road was conveyed to Van Damm's lagoon inlet to protect the Waipuna spring from contamination with a new energy dissipation structure protecting heritage stone walls. A new pond and daylighted stream channel at William Harvey place with dense native planting were designed to pay homage to this spring and replaced a 'tangle of stormwater pipes' and much of a weedy open drain (the reminder of the drain was piped).

The area is split into two case studies. Information about the two case study areas, including specifics about design, maintenance and post-construction observations are presented in the following sections. The first case study is based on the Panmure train station 'triangle', bounded by the Ellerslie-Panmure highway, Quinlan St and Potaka Lane. It includes green screen stormwater planters, extensive raingardens, tree pits and permeable paving. The second case study area focuses on Van Damm's lagoon.

Panmure Train and Bus Station and Environs

The Panmure train and bus station, adjacent roads and parking areas have large areas of impervious surfaces broken up by landscaping which includes many stormwater treatment devices.

What works well	Missed opportunities
Relatively narrow roads along Potaka Lane and Quinlan St minimise impervious areas. Very deep tree pits with healthy kohekohe under-planted with oioi separate parking spaces on Potaka Lane. Trimming of oioi maintains visible edges and inlets; inlets are wide and unlikely to block.	Trees in two pits have died (one vandalised); both stakes and dead trees were left *in situ* for months, decreasing amenity. This could be avoided with a maintenance reporting and funding model that allows rapid removal and then tree replacement in autumn or winter.
Landscaping and stormwater devices fulfil multiple functions; some double as seating, shade and/or shelter, some are effective visual and physical buffers to traffic noise and dazzle from headlights. Landscaping help reduce access to dangerous areas. Three storey green screens effectively soften an otherwise concrete canyon. As trees mature they will help mitigate traffic emissions and provide more shade from UV and summer heat; some species are providing fruit and flowers for native insects and birds and/or help build a sense of place (kohekohe in particular).	Planters could treat roof runoff from the bus shelters; instead they are irrigated. Tree pits with pohutukawa that line the overbridge and bus station have permeable resin paving, rather than underplanting to maximise pedestrian access and avoid trip hazards. The pits are slightly sunken but do not appear to receive additional stormwater, which could have been run into the pits from road curb, mimicking a Melbourne approach. The resin is cutting into the root collars of some trees; sections near the trunk need to be removed and replaced with loose gravel and retained by a temporary steel collar.
Landscaping uses a variety of mostly native groundcover and trees with proven performance in Auckland; at least three species are used in most areas, allowing natural adaptation to conditions – in many of the raised planters, shining karamu (*Coprosma repens* 'Poor knights') is dominant. Oioi dominated most raingardens; the more herbicide intolerant sedges (*Carex* species), turutu (*Dianella*) and NZ iris (*Libertia*) have reduced in cover.	The grass verge on Quinlan St includes a cluster of 2 manholes and lamp post that is maintained using a broad band of herbicide. This creates bare soil which is ugly and requires ongoing, cyclical spraying. Adjacent areas in dense, permanent planting don't need this spraying as weeds are supressed. These adjacent areas therefore retain higher amenity with lower maintenance. Solve by mulching the bare soil or extending landscaping to include these areas.
The specific raingarden and amenity growing media and mulches have performed well; groundcover and tree establishment and growth has been supported over 5 years and most areas have dense groundcover that is minimising establishment of the majority of weeds, reducing ongoing maintenance.	Organic mulches have not been reapplied in areas where plants have died (or been inadvertently sprayed) and this has exposed bare soils, allowing weeds to establish. The large drop into tree pits along Potaka St created some temporary erosion of mulch where weeds established; this could have been fixed by placing small areas of stone rip rap below key inlets as reactive maintenance after the first storm.
Most landscaping has relatively low maintenance as a permanent, dense groundcover at least 30 to 50 cm high has been established, and most beds are relatively large, with relatively small area of edge and large 'core' (edges are the usually most	Some landscaped areas have high maintenance requirements, e.g., a series of raised turf platforms along Mountain Road/Quinlan St are costly to mow due to large edge length, embedded up-lights and a surviving tree, requiring multiple treatments (weed

expensive parts to maintain), for example the motorway planting of dense flaxes, *Muehlenbeckia complexa* and low, spreading coprosmas viewed from the Mountain Road overbridge.	whacking, spraying and hand-mowing). The turf has degraded to a high cover of annual grasses and many broadleaf ‘weeds’ (dandelion, veronica, dock). Maintenance has unnecessarily created bare areas; e.g., trimming of edges has not retained dense cover to the edge and oioi has been stunted by topping (it has been treated as a sedge); sedge and oioi trimmings should be retained under trees within raingardens as mulch, saving disposal costs.
A variety of native trees are used throughout the area and in different devices; most are healthy and attractive: kohekohe, cabbage trees, pohutukawa, titoki, kowhai. Different species are planted together within larger devices – this maximises landscape resilience and design intent compared with sites where single species in lines. The trees are not deciduous so have the risk of blocking inlets or smothering underlying groundcover is minimised, and there is no requirement for a special autumn maintenance visit. Strong staking has supported initial growth and a canopy lift will occur. Existing trees were incorporated into raingardens in Potaka Lane carpark, providing ‘instant’ maturity and beneficial visual impact.	Trees in small devices have been damaged and killed, i.e. < 2m width and c. 4 m^2 especially in the park and ride. These small devices also are hazards for cars and people – they should have been clustered. Trees in small grassed areas are often physically damaged by mowers or weed-whackers, have vandalised stakes or broken branches due to greater public access. Trees in grass are also probably more stressed due to less favourable growing media than in raingardens and less water in summer. Some trees, e,g, kohekohe in Quinlan Street tree pits, are relatively short before densely branching – this means the canopy lift scheduled to increase visibility below 2 m will need to be done in several stages to avoid stunting trees; a nursery specification requiring longer clear stem would have been better.

Turf platforms that are expensive to maintain (left); deep raingardens on Potaka Lane have healthy kohekohe trees that need trimming to retain sightlines, the wide inlets are resistant to being blocked by sediment and easy to clean but some are redundant (centre); these grassed areas on Quinlan Street cannot be mown so are maintained with regular herbicide sprays that creates poor aesthetics.


Tree pits with poured-resin permeable paving could have been used to treat road runoff (left); the resin needs regular removal to avoid ringbarking the growing tree (right)


This large raingarden with healthy titoki trees adjacent to the bus station has low maintenance due to dense groundcover and relatively large core relative to edge (left); trees in this small 'island' raingarden in the park and ride have died; surviving oioi groundcover (sedges were inadvertently killed by glyphosate spray) has been over-trimmed, exposing large areas of bare soils (right)

Van Damm's Lagoon / Te Waipuna a Rangiatea and environs

The Van Damm's lagoon is the core of a 'forgotten and neglected historic corner of Panmure', a 7,200 m^2 reserve upgraded as part of the AMETI project. From the 1870s the c. 100 m long and 7 to 25 m wide lagoon was a water supply for Auckland's largest tannery, but in the 1930s Mr Van Damm landscaped the property – many of the older trees in the reserve may date from then. Later used as a rubbish dump, Auckland City Council bought the site in 1975, restoring it to a nature reserve zoned Open Space 'Informal recreation' and 'Conservation'. It is scheduled as a Significant Ecological Area, however its ecological values were affected by ongoing silt and sedimentation from stormwater discharges, spills[1], and regeneration of weeds. Its recreational values were low; it was unsafe, with a single access point, poor views and steep banks around the lagoon. A main sewer pipe-bridge bisects the site, and graffiti and rubbish were common.

AMETI works enhanced the reserve for both people and native ecology. Two carparks were built – one has an unusual planted swale with central concrete channel. The lagoon receives runoff from 99.4 ha of residential and commercial land; the water quality volume (ARC TP108) for 1/3 of 2-year ARI was 17,500 m^3 with AMETI supplying 3500 m^3 from an additional impervious areas. Existing dead storage volume of 960 m^3 was more than doubled by removing accumulated sediment, constructing a c. 630 m^2 detention wetland with banded bathymetry. Sediment testing revealed elevated cadmium, chromium, led, zinc and PAH; surface water monitoring results for the inlet from AMETI road link in Jan 2012-March 2013 showed Cu and Zn concentrations were above ANZECC 2000 Water Quality Guidelines at 80% level. The wetland was created by partial sediment removal and planting, with a trade-off between excavation of sediment to create Water Quality Volume and retention of existing habitat values of the wetland/raupo area. Works also needed to avoid undermining the existing main sewer line and north island main trunk railway line embankment through which an outlet stormwater pipe >1 m diameter was thrust.

Values were enhanced in co-design with mana whenua and community, which resulted in a second carpark to provide safer access. Archaeological works done in partnership between mana whenua and Dr Mark Felgate as part of the AMETI project revealed multiple features showing occupation between AD1647 and 1679 and 1705. This informed interpretation panels at both entrances and at William Harvey Place spring, a pou at Horoeka Road entrance and naming of Te Waipuna Atea bridge. A large energy dissipation structure was installed under the bridge to avoid damaging heritage stone walls near that inlet.

Near the end of William Harvey Place a new 'amenity pond' and daylighted stream channel was constructed to pay homage to Waipuna Spring. This involved relocation of existing pipes, extensive weed removal and native planting with a viewing platform installed over the water. The source of the spring was unable to be isolated, and this prevented its complete separation from stormwater. However, all runoff from Te Horeta Road was conveyed to Van Damm's lagoon inlet to minimize contamination of the new pond and wetland, which are not consented or considered to provide specific stormwater quality treatment. The new wetland and adjacent areas were also designed to 'help retain and improve ecological diversity and habitats' and create valuable visual additions to the new cycle/walkway and overbridge (EMP, Opus 2015).

[1] In August 2005 an estimated 300 litres of oil was discharged into the lagoon via a stormwater drain – over the next 4 days the ARC Pollution Response team removed about 20,000 litres of oily water; in 2012 a milky spill was reported (nzherald.co.nz, The Aucklander 9 Feb 2012 by Joseph Barrett)

What works well	Missed opportunities
Increased value as a reserve for public recreation due to improved safety from increased visibility (weed removal, use of low groundcovers, more open water), new well-defined access and exit points connecting wider paths with better surfaces, regrading of the banks and two carparks isolated from the busy roads.	Tall flax plantings at Horoeka Road carpark buffer are within 1 m of the footpath so require regular trimming. The dense screening of the carpark may encourage dumping of rubbish, etc. More signs on the cycleway/footpaths would help raise awareness of the hidden lagoon.
Cultural history is revealed and celebrated through co-created information panels, naming of the Te Waipuna Atea overbridge above a new waterfall that creates a natural soundscape masking traffic noise, retained archaeological features (stone walls) and restored historic features (waterlilies)	Finding the spring would inform any future works to separate stormwater. An objective was to retain and improve ecological diversity and habitats; ecological diversity in the wetland could also be enhanced by adding coarse wood well above flood zone as perching stumps for birds and small piles (as was done for lizard relocation area in Van Damm's Lagoon)

An additional overflow was added to reduce potential flooding of upstream areas; the second overflow also provides a backup should one of the grates become blocked as there is a significant amount of dead wood and trees upstream in the lagoon area.	Owners of adjacent industrial land could be encouraged to help build on improvements to stormwater in AMETI by detaining their stormwater runoff and replacing degrading zinc roofs with non-polluting alternatives.
Swale installed beside carpark has been planted with sedges that have formed a very dense, weed-resistant cover with some nikau.	A narrow, smooth concrete channel along the swale base stops erosion at the cost of less effective infiltration of low flows. Movement of mulch and/or soil has created bare areas at the outlet.
Permanent maintenance access for vehicles (slope 8:1 H:V and >3 m width) was created to reduce cost of lagoon sediment removal. and the grassed area at the top provides a staging / working area. Before works only walking access was feasible.	Contracts for sediment removal need to include a specific 'reinstatement' clause so the gravel path and adjacent plants are fully reinstated.
Historic plantings and investment by Mr Van Damm and Auckland City Council are retained and enhanced with weed control, new native plantings, pest control, and expanded area providing more habitat than previously. A dense grove of near-mature cabbage trees at highway entrance carpark has been retained and new permeable path winds through their trunks.	Weeds are re-invading throughout the reserve. Inter-planting and possible additional soil or soil loosening is needed in minor areas with less than 1 plant/m^2 or <60% cover, such as the Horoeka road carpark where some flax have died. Remulch to minimise spraying. Coordinate with NZ Rail and adjacent land owners to reduce weed sources.
Most plantings have a variety of species, which increases resilience to drought or adverse events	Deeper soils would have increased plant resilience to drought, e.g. replace areas with 100 mm topsoil + 150 mm ripping (specified for toetoe and sedges) with a total root depth >500 mm and preferably 800 mm.
Stone-filled gabion baskets have helped the native scrambler pohuehue to start covering the baskets, creating a more natural edge.	The sewer pipe cover has been tagged with graffiti and lack of access makes this difficult to remove; a locked gate in the exclusion screen would have helped maintenance to treat tagged areas.
Large native tree species are planted at Horoeka Rd entrance area in small clusters of 2 to 4 kauri, rewarewa, kahikatea, taraire, pohutukawa – this diversity increases resilience and ecological value. Pohutukawa within grass berm along Horoeka Rd are staked and aligned to allow efficient mowing with minimal risk of damage to trees.	The specimen trees along Horoeka Rd are all a single pohutukawa clone and widely spaced; clusters of different trees would probably provide greater overall benefits and resilience (since planting, myrtle rust has established in Auckland – using a variety of clones and/or species would reduce risk of all trees being affected)
Contaminated materials were identified and removed or treated on site. The treatment area requires grass cover to be maintained; its location near the entrance creates a picnic area and staging area for sediment removed from the lagoon.	Taraire and pohutukawa trees have been planted on 500 mm high mounds of topsoil adjacent to the treatment area; this shallow depth restricts rooting volume and future tree planting. Root volume may be increased if sediment from the pond is permanently stored here (and regressed) – this would also save disposal costs.



Inlets in 2010, before works (left) and after works in 2018 with naming, waterfall and hidden energy dissipation structure under the bridge (centre). A second inlet has stonewalls flanking a litter screen and oil& grease bund, both of which require regular maintenance to minimize short-circuiting (right)



Permeable gravel surface at an entrance to Van Damm's lagoon minimise damage to existing ti kouka (cabbage trees) (left); a swale at the carpark uses native sedges (centre); a broad boardwalk has improved safety and sewer is covered (right).


Horoeka Road wetland and pond with viewing platform and extensive native planting (left); and wetland close-up (right)

Learnings on benefits of green infrastructure

The MTW assessment tool[2] was applied to the AMETI development. The tool is a rapid qualitative assessment device to assess the benefits and costs of specific GI/WSUD projects. It is intended as a screening tool for use by both lay and technical audiences. In this section we consider the benefits revealed by the MTW tool, in the subsequent section we consider the cost assessment. The MTW tool presents assessments for a wide range of benefit categories potentially available from GI/WSUD designs, classified in terms of water and non-water, environmental and social, which is consistent with contemporary international assessment processes. Those assessments are made in terms of level (none, low, medium, high), in the context of assessed reliability and importance.

The results are presented in the sector chart below for AMETI as constructed and compared with a traditional (business as usual – BAU) approach to development. The level of a given benefit/ cost criterion is reflected in the length of its sector from the centre of the chart; the importance of a given benefit/ cost criterion is reflected in the width of its sector; and the reliability of the assessment of a given benefit/ cost criterion is reflected in the intensity of the colour of its sector.

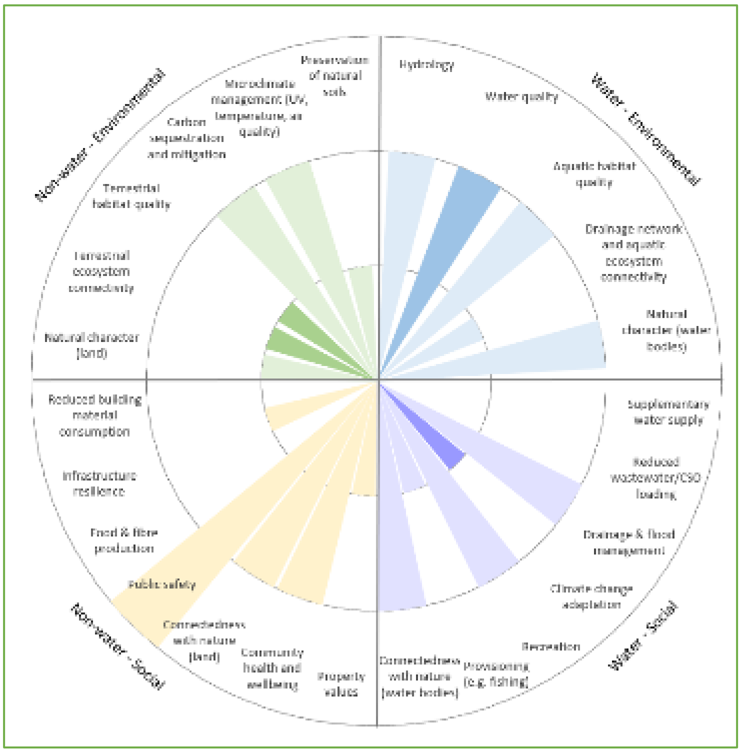
The assessment shows a Brownfields development using WSUD can leverage multiple benefits beyond enhanced stormwater treatment / reduced flooding. Benefits were achieved by consultation and inter-agency collaboration between mana whenua (supported by joint archeological studies during construction), Auckland Transport, Auckland Council Parks, Watercare (main trunk sewer pipeline cover) and New Zealand Rail, and were delivered in design by close collaboration between stormwater engineers and landscape architects. However, the ability to achieve catchment-wide benefits is restricted when projects cross maintenance boundaries, as has occurred with Van Damm's lagoon, because all agencies want to minimize their ongoing maintenance costs.


A new outlet under the railway reduces flooding (left); the new road provides for cycling and walking (right)

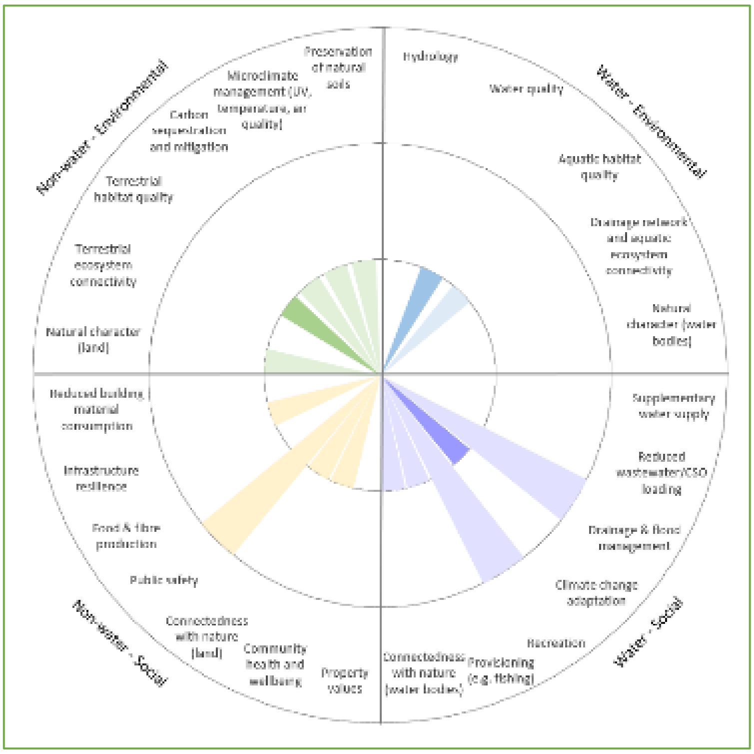
[2] Moores, J., Ira, S., Batstone, C. and Simcock, R. (2019). The 'More than Water' WSUD Assessment Tool. Research report to the Building Better Homes, Towns and Cities National Science Challenge. https://www.landcareresearch.co.nz/science/living/cities,-settlements-and-communities/water-sensitive-urban-design/more-than-water-mtw-assessment-tool

"*More than Water*" Benefits Assessment

AMETI: As constructed

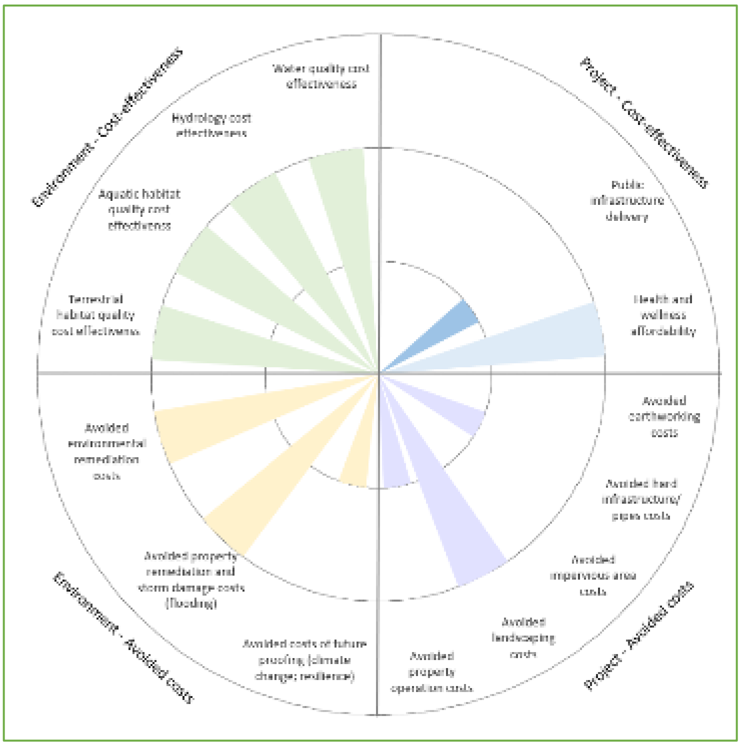


AMETI: BAU

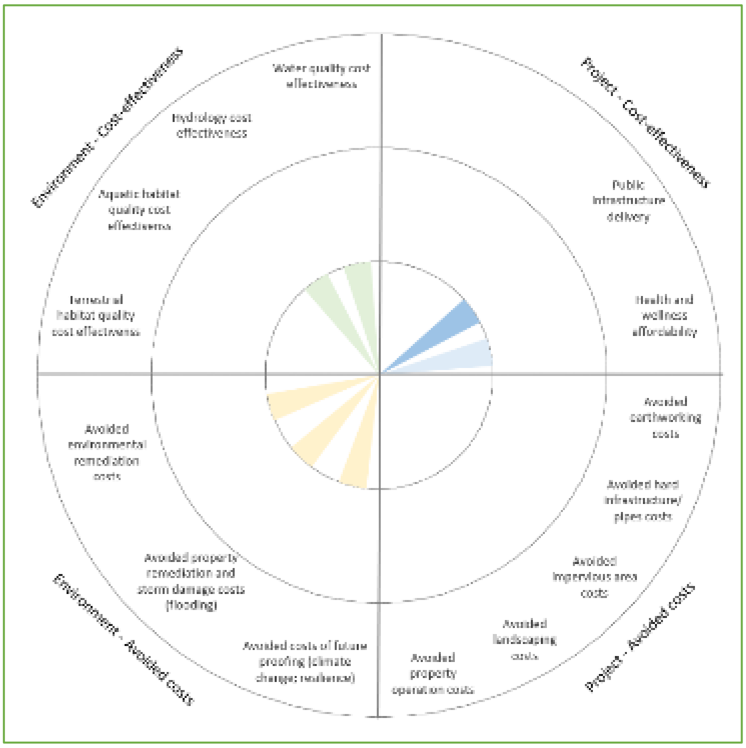


"*More than Water*" Costs Assessment

AMETI: As constructed



AMETI: BAU



Learnings on costs of green infrastructure

AMETI has examples of both low- and high- construction and maintenance costs of planted stormwater treatment devices. Lower costs are demonstrated by the following practices:

- Quickly achieving dense, healthy vegetation that excludes weeds. This requires selection of suitable plants, adequate depth and quality of weed-free growing media, and good establishment practices[3].
- Design larger and wider devices. These result in lower maintenance costs as there is proportionally less edge to maintain, and plants are less vulnerable to physical damage (being further from edges and less likely to be trafficked) and generally less stressed (e.g. by heat). Trees should be planted more than 1.5 m from edges where cars have access.
- Design sheet flow of stormwater and / or use broad inlets (>200 mm width) to minimize requirement to remove sediment from inlets;
- Under-plant trees with perennial groundcover. This greatly reduces risks of physical damage to trees from mowers and people.
- Use bump-bars (in carparks) or substantial concrete curbs (on streets) to protect devices and their plants from vehicles.
- Design for safe access for maintenance staff and equipment; poor access inflates costs.
- A range of smaller native trees provide multiple values and avoid leaf removal costs of deciduous trees, for example kowhai, kohekohe, titoki, cabbage tree and pohutukawa.
- Green screens within stormwater planter boxes show three native species have low maintenance costs and cover 3 stories within 5 years when provided with adequate root volume and water supply and light. The planter box width ensures no impervious surface below *Tecomanthe speciosa* so avoids additional maintenance (the large flowers are slippery when fallen on footpaths)
- Allow prostrate coprosma to grow down the sides of raised beds to enhance the visual impact of 'green', prevent most litter entering the beds, and reduce weeding (because bare areas of soil are notexposed when trimmed); however, this does prevent people sitting on the concrete edge.

Broad concrete edging of planter boxes creates seating at the bus station where plants when trimmed within the edge (left), and prevents seating where plants reach the ground but creates are larger 'mass' of green' in this otherwise hard urban landscape. Inlets to street tree pit raingardens are broad and even, so unlikely to block (right)

[3] Effective groundcover combinations included shining karamu (*Coprosma repens* Poor Knights', other prostrate Coprosmas, oioi, sedges, flaxes (*Phormium cookianum* in smaller spaces) with pohuehue.

Higher maintenance costs are linked to the following sites and practices:

- Small, narrow devices (less than about 2 m diameter) in paved areas; narrow devices within larger landscaped areas can be successful (e.g. swales within larger grassed or wetland areas)
- Placing infrastructure within stormwater devices such as sign-posts, light stands, up-lights, electrical boxes, rubbish bins or signs; maintenance of the infrastructure inevitably damages the plants.
- Placing large spreading plants in small devices or within 1.5 m of the edge of devices because this increases the need for trimming. Select plants to minimize intrusions of required sight lines. This includes ensuring trees are delivered with branch patterns that are consistent with sight lines, i.e. the lower 2 to 2.5 m can be pruned without adversely affecting tree health.
- Maintenance that exposes bare ground. This can initiate a spiral of degradation as bare ground is vulnerable to invasion by weeds, the weeds are sprayed, and the sprayed area increases, especially where adjacent plants are vulnerable to glyphosate (sedges, toetoe, turutu). Rubbish is highly visible on bare ground. A common cause of bare ground is lack of plant-specific maintenance, e.g., at AMETI oioi has been severely topped, leading to dieback; in contrast, most sedges tolerate topping. Bare ground occurs where mulch is eroded (or decomposes) and to facilitate mowing in areas with 'proud' grates, tree bases, lights and edges.
- Lack of routine maintenance. Sediment build-up in Van Damm's lagoon could build up to the extent that flood detention volume is reduced and higher-value upstream areas are adversely affected.
- Use of weed-eaters or weed-whackers around trees unless trunks are physically protected by a resistant barrier.
- Lack of reactive maintenance. Stressed plants can often be 'retrieved' if stress is removed early enough, for example, saturated raised garden beds can be fixed by replacing broken irrigation or an obstructed outlet. Maintenance checklists should identify over-sprayed, dead and bare areas to flag the need for reactive mulching, replanting and/or other actions. It is important to identify why plants died, e.g. compacted soil may need loosening or placement and larger plants used to discourage pedestrians; where water scour has removed mulch, a heavier stone mulch may be needed.

Severe damage from 'weed eaters' to the base of this titoki tree in a grass area shortens tree life and stability as it allows rot to enter – this tree should be replaced (left). Up-lighting placed in grass or planted areas require additional specific edge maintenance, increasing cost; this one has been broken and is flooded (right)

Van Damm's Lagoon Environmental Management Plan

An effective Environmental Management Plan underpins efficient construction and maintenance. The Van Damm EMP (Opus 2015) details the operation, landscaping, conveyance, public safety and resource consent objectives, and how they are to be supported through the maintenance and monitoring schedule for Van Damm's Lagoon, William Harvey Place Amenity Pond and the associated Wetland. The schedule was specifically designed to reduce maintenance costs by early identification and rectification of problems. It includes tables of regular, corrective and reactive maintenance following specified recurrent events (excessive algal growth, large storms, vandalism) and for specific sites (e.g. storm erosion of mulch on steep railway embankment slopes, or bank erosion of stream channel). The plan (or manual) was intended to be reviewed annually for the first five years to update the preventative maintenance schedule, corrective maintenance procedures and contact directory. It is a useful blueprint and was to be accompanied by reporting schedules for weed and animal pest control. A plant survival rate of 80% was identified as acceptable, with planted canopy coverage anticipated within 3 to 5 years, a maximum 5% cover of weed cover and organic mulch maintained at 100 mm depth. As up to 100 shortfin and longfin eels were anticipated to be present, an eel management plan was created to specify procedures for pre-construction fish capture, their release at four sites, selected in consultation with five iwi (Opus 2013). Pest fish were to be euthanised and buried. Copper skinks were considered likely present in several areas, with the population considered likely low due to poor habitat, specifically absence of large logs and small areas of rank grass, and presence of rainbow skinks an introduced Australian species). A 0.1 ha relocation site at Van Damm's lagoon was identified and habitat enhanced in this area for up to 40 native skinks by adding 20 small log piles, 1 every 50 m^2, made from 5 logs >200 mm diameter and >600 mm length, and including toetoe, flax and sedge (*Carex*) species in plantings (Tonkin and Taylor 2013). An arboricultural report details protection strategies for 'Category 1 vegetation' potentially affected by earthworks for access, including new paths. The 'Category 1 vegetation' were all non-native (black walnut, swamp cypress, camphor laurel trees and a Phoenix palm) and included water lilies (Hill 2013). Boardwalks rather than ground-level paths were used to reduce impacts on tree root systems. During construction straw bales were used to cover and protect the exposed roots of swamp cypress, and fencing placed around the drip limes of other trees. Roots more than 35 mm diameter were not to be removed before 'all engineering and design alternatives were explored' and 'only on approval from the Council Park officer'. The EMP identifies Auckland Transport is responsible for maintenance for William Harvey Place wetland/amenity pond as it lies within the designation, and Auckland Council was to take long-term responsibility for Van Damm's lagoon reserve.

Acknowledgements

Auckland Transport assisted the Activating WSUD research partners in compiling this case study. Special thanks to Cathy Bebelman (Auckland Transport) and Zeb Worth (CKL) for providing our team with information, support, expertise and assistance. We greatly appreciate the permission of Auckland Transport to use parts of AMETI as a case study and for all their assistance.