RAIN GARDEN MAINTENANCE COSTS IN AN INDUSTRIAL DEVELOPMENT

J. Rees (Davis Ogilvie & Partners

ABSTRACT

Waterloo Business Park is an industrial development in Islington, Christchurch. The site was previously the Christchurch Meat Company factory, or the "Islington Freezing Works" which started operation in 1869. The redevelopment of the site into an industrial business park encompassed the usual challenges of brown field developments, not least the challenge of stormwater treatment and discharge. The site is underlain by deep free draining gravels leading to a discharge to ground approach for stormwater management.

Rain gardens have been constructed to provide road stormwater treatment for the Waterloo Business Park in Christchurch. They provide treatment for approximately 6 Ha of industrial roading. The majority of the roading in Waterloo Business Park is private roading, however, there are two roads vested with the Christchurch City Council (CCC), namely the extension of Halswell Junction Road and Waterloo Road.

Rain gardens have not usually been accepted by CCC within vested roading apart from retrofit scenarios or within new public open space projects. To allow the approval for vested rain gardens to progress the developer agreed to maintain the rain gardens for a 5 year period while keeping detailed records of the rain garden maintenance activities and costs.

The rain gardens were designed and constructed in accordance with Christchurch City Council's Rain Garden Design Criteria along with a localised soakage system into the underlying free draining gravels. There are a total of 35 rain gardens constructed for the roading catchments ranging in size from 40 m² to 265 m². 33 of the 35 rain gardens are now in operation.

This paper presents 22 months of maintenance costs for the first 12 rain gardens.

The paper also discusses some of the health and safety in design considerations made during the design and construction of the rain gardens and the soakage systems.

KEYWORDS

Rain garden, maintenance costs, low impact design

PRESENTER PROFILE

Jeremy Rees BE Civil (Hons), CPEng, IntPE(NZ), CMEngNZ

Principal Civil Engineer, Davis Ogilvie & Partners, Christchurch

Jeremy is a Principal Civil Engineer at Davis Ogilvie and is also the civil team leader for the Christchurch office. Jeremy has 12 years of experience in land development and infrastructure design, mostly recently in Canterbury. He has a particular focus on stormwater management for land development projects.

1 INTRODUCTION

The maintenance costs of rain gardens has been a topic of discussion for a number of years and there is a large range of methodologies and estimates for determining the expected costs. This results in a wide range of expected costs with a reasonable amount of uncertainty. This uncertainty can lead councils to be reluctant to adopt rain gardens as vested assets within their roading networks which has been the case at Waterloo Business Park. This reluctance has resulted in Waterloo Park Limited changing to a private ownership model for the roading to allow the low impact design goals to be achieved for Waterloo Business Park.

This paper seeks to quantify the maintenance costs for a recent case study of 12 rain gardens installed in an industrial development to capture, treat and discharge the road network stormwater.

2 BACKGROUND

2.1 WATERLOO BUSINESS PARK

2.1.1 SITE HISTORY

Waterloo Business Park is a brownfield industrial development in Islington, Christchurch. The territorial authority is Christchurch City Council and the regional council is The Canterbury Regional Council, also known as Environment Canterbury.

Waterloo Business Park is sited on the Islington Works site between Waterloo Road and Pound Road. The meat preserving works opened in 2 November 1869 and was in operation until late 2016.

The site included pastoral land, four large oxidation ponds, carcass trenches and landfill (not municipal) within a historic gravel quarry along with the meat preserving and freezing works plant itself.

The redevelopment of the site into saleable industrial allotments required the geotechnical and environmental remediation of the oxidation ponds, carcass trenches and the landfill. The majority of the organic material from the carcass trenches was bio-remediated onsite, with the remaining material placed within designated locations onsite.

The site is zoned by the Christchurch City Council (CCC) as Business 8 (Islington Park) Zone with provisions to ensure the underlying groundwater recharge zone is adequately protected from potential contaminants. Additional restrictions on hazardous substance storage above and below ground, as well as use and quantity limits also apply to protect the groundwater from adverse effects.

2.1.2 GEOLOGY

A historic channel of the Waimakariri River, known as the Islington Channel, trending northwest to southeast runs through the site. Consequently much of the site is incised with relic river channels and terraces with flat ground north and south of the main channel.

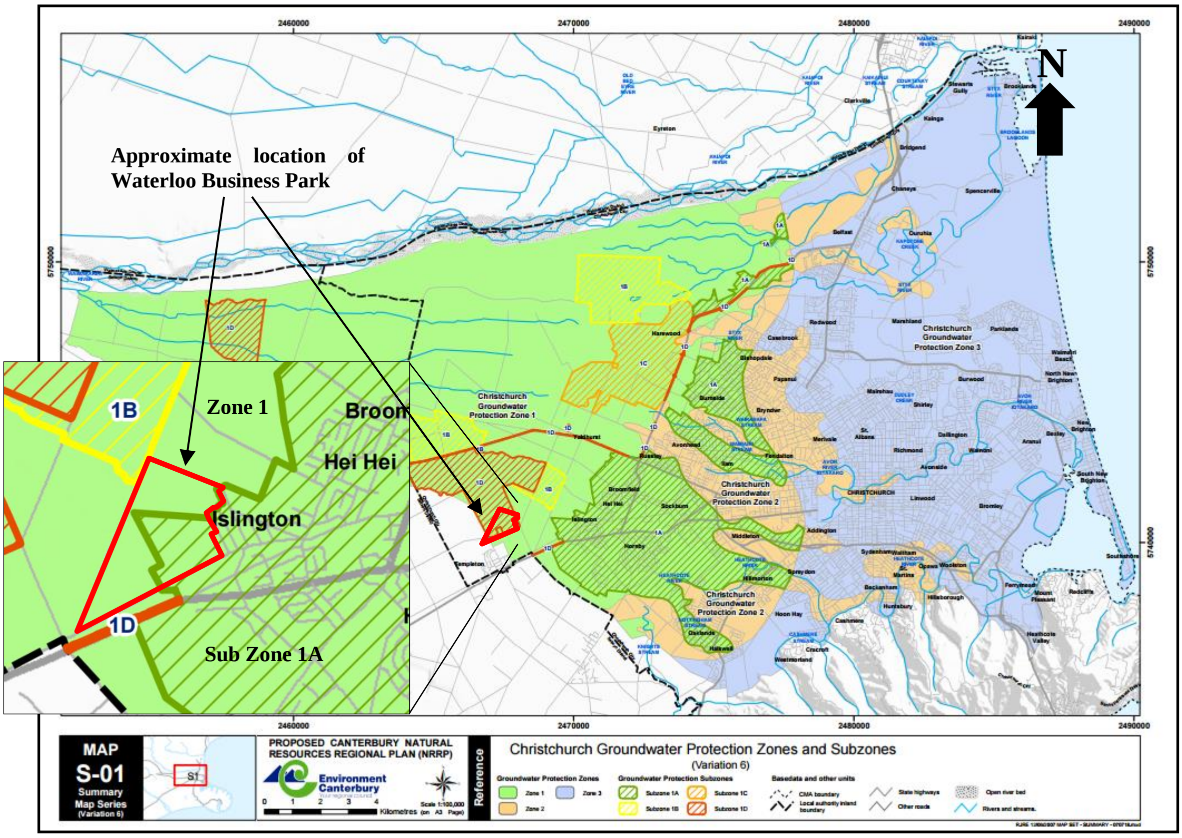
The published geological map identifies that the development is underlain by Holocene aged “alluvial gravel, sand and silt of historic river flood channels and dominantly alluvial sand and silt over bank deposits” (Yaldhurst Member) of the Springston Formation (spy).

2.1.3 **GROUND WATER**

Environment Canterbury (ECan) have records of 24 wells across Waterloo Business Park. Four boreholes are located within or immediately adjacent to Stage 6 and extend to depths between 22.7 and 71.6 m below EGL, the most recent of which (BX23/0242) was drilled in 2013 for a new water supply bore on Lot 700. The ECan well logs show that groundwater is approximately 15.0 m below EGL.

Online ECan maps of Canterbury aquifers show that the site is situated on an unconfined and/or semiconfined aquifer. The location of Waterloo Business Park and Stage 6 in relation to ECan groundwater zones is shown in the map of the proposed Natural Resources Regional Plan (NRRP) in Figure 6. The subject site lies within Zone (shown in green in), an area of high intrinsic hydrogeological vulnerability where contaminants can move downwards into the groundwater system with minimal natural filtration by fine-grained sediments, and there is an absence of upward groundwater pressure. The site lies in Subzone 1A of Zone 1 (see green hatched area in), which recognises that the land is or may be used for urban purposes. Broadly, this indicates that development and activities on the site can be permitted provided that they are consistent with the protection of groundwater quality and best groundwater management practice is implemented.

Figure 1: Groundwater zones in greater Christchurch according to the Canterbury Natural Resources Regional Plan, Chapter 4, Water Quality



2.2 **SITE CONTAMINATION**

As indicated earlier, the site has been in use for many years as a meat processing or freezing works plant. The nature of these activities has resulted in a number Hazardous Activities or Industries Listed (HAIL) activities being listed as occurring on the site.

Various investigations and reports undertaken since the mid-2000s have confirmed that there are significant volumes of uncontrolled fill located across the site, including the large "deep landfill". The Tonkin & Taylor (2005) ground contamination desk study report indicates the landfill may contain a wide range of contaminants, including animal waste, asbestos, heavy metals and other construction wastes.

The contaminants and the associated remedial works have been subject to various landuse and National Environmental Standard (NES) consents and the works have been under the control of a Suitability Qualified Environmental Practitioner (SQEP). The impacts of these contaminants on the stormwater discharges is discussed in later sections.

2.3 STORMWATER PHILOSOPHY

The underlying philosophy for the stormwater treatment and disposal for Waterloo Business Park in part relies on the underlying geological conditions.

The underlying free draining gravels (5 m/hr – 10+ m/hr) and reasonable depth to ground water (~15 m) was conducive to discharge to ground as the primary method of stormwater discharge.

Given rapid discharges to ground were available, the decision to have individual treatment and discharge systems for each allotment was made resulting in a stormwater treatment and discharge system for the roading network separate from the individual allotment systems. This also provides a benefit in terms of more land available for development, as no large stormwater management areas were required.

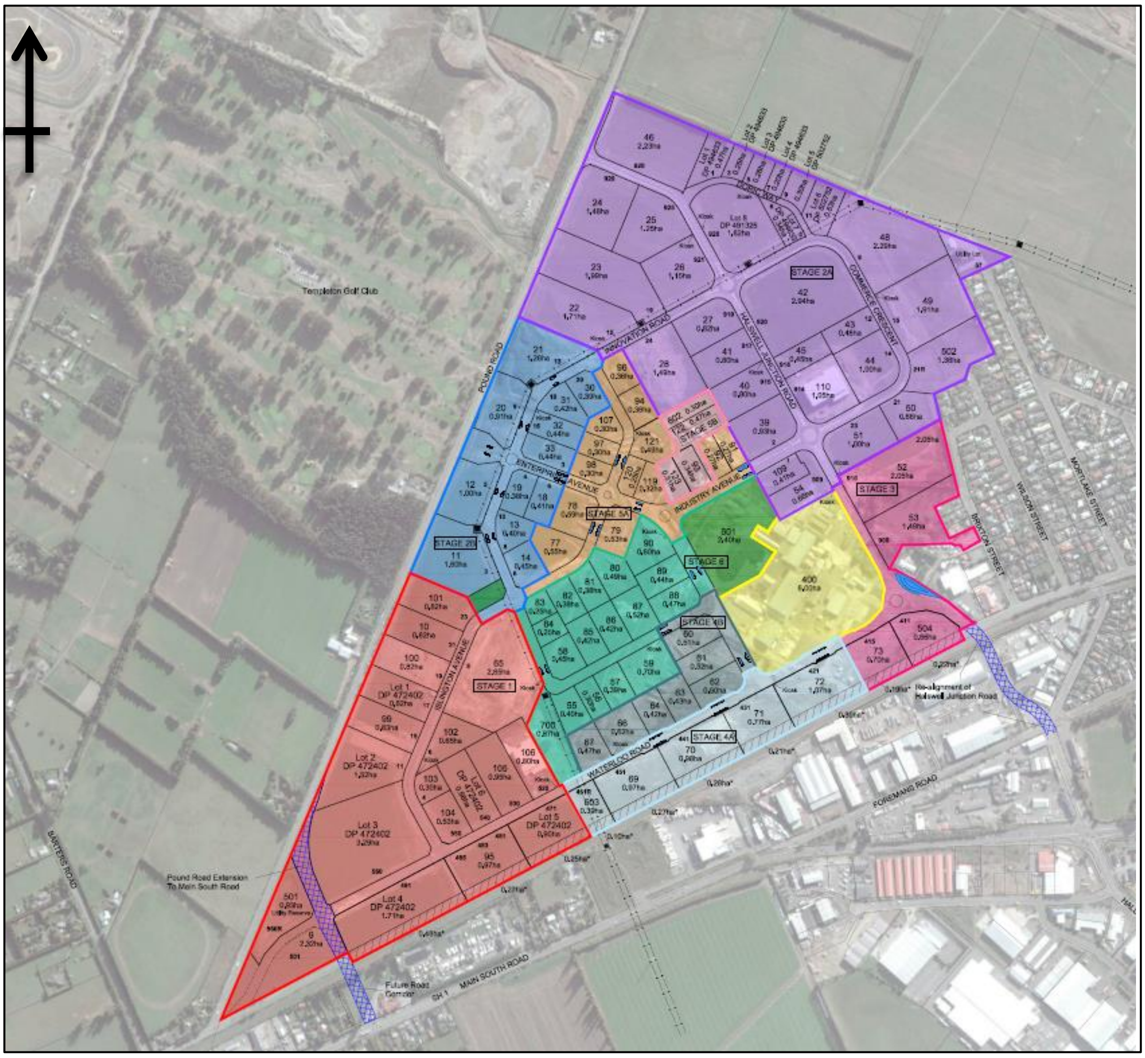
The site is within the Halswell River catchment which has a critical duration of 60 hours for stormwater attenuation up to the 2% AEP event. Therefore all systems have been designed to collect stormwater from events up to, and including the 60 hour 2% AEP event.

2.4 STAGES 1 & 2A

Prior to Davis Ogilvie's involvement the first two stages of the development were designed and consented by a number of other consultants. These are known as Stage 1 and Stage 2A, shown in red and purple in the development plan in Figure 2 below.

These initial stages of the development were designed with traditional stormwater systems, namely road side treatment swales, a first flush basin and a rapid infiltration basin for discharge to ground. These assets are some of Christchurch City Council's preferred system for stormwater management.

Figure 2: Aerial Photograph of Waterloo Business Park and development stages



2.5 SUBSEQUENT STAGES

For the subsequent stages of the development Davis Ogilvie were asked to investigate rain gardens for road stormwater treatment. This was to apply to Stages 2B and on. Stage 2B is shown in blue in Figure 2 above. The intention for these stages was to produce vested stormwater assets as was the case for the previous stages of the Waterloo Business Park.

3 RAIN GARDEN DESIGN PHILOSOPHY

3.1 DESIGN STANDARDS

At the time of the design, the Christchurch City Council were developing the Christchurch Rain Garden Design Criteria document which was a desktop analysis of the available rain garden design criteria from around New Zealand and associated literature. CCC's design criteria assessed the available literature and made recommendations for design criteria for use in Christchurch City. At the time it was the de facto design criteria document for rain gardens in Christchurch and has since become the accepted

As the intention was to construct vested stormwater assets the decision was made to use the Christchurch Rain Garden Design Criteria as the basis for the rain garden design. At the time of the design, the March 2014 version of the design criteria was the most recent and was applied to the designs.

CCC's Waterways, Wetlands and Drainage Guide (WWDG) also provided further design criteria for the stormwater treatment and most applicably, the stormwater discharge to ground criteria.

Environment Canterbury's proposed Land and Water Regional Plan (pLWRP) provide further design criteria that were applicable to Waterloo Business Park.

This resulted in the following main design criteria to be selected for the rain gardens and discharge to ground systems.

- First Flush treatment depth – 25 mm
- No ponding in carriageways in a 10% AEP event
  - As per New Zealand Building Code E1.3.1
- Accommodate up to, and including, the critical duration 2% AEP event without entering any other property
- pLWRP Rule 5.96 – Rule 2
  - The catchment is in the Halswell River catchment, therefore all events up to and including the 60 hour duration event are to be catered for

3.2 INTEGRATION WITH LANDSCAPING

Given the site has a high rate of infiltration in the underlying free draining gravels it was decided to utilise localised soakage for each road catchment. This allowed the rain garden and soakage catchment to be split into manageable catchment sizes, ranging in size for Stage 2B from 1,020 m^2 to 4,400 m^2 (total area) with corresponding hardstand catchment areas of between 760 m^2 to 3,100 m^2.

In discussions with CCC this presented an opportunity to split the typically large blocks of industrial land and the associated roading and parking up. Coupled with the developers desire to create aesthetically pleasing landscapes through the business park, not just the typical industrial landscaping, this allowed the rain gardens to be integrated with the landscaping. The raingardens were designed to use part of the road corridor where parking would normally be provided along with part of the landscaping strip against the footpath. This allowed the raingardens to be constructed without the use of additional land typically required for stormwater management.

The stormwater soakage was provided beneath the berm as well, in the form of rapid infiltration trenches constructed in parallel with the carriageway. This results in raingardens being constructed at the low points of each catchment, with a saw tooth shaped vertical alignment for the roading.

Figure 3 below shows the layout of the rain gardens in context with the roading network and the relevant catchments.

Figure 3: Stage 2B Rain Garden Layout

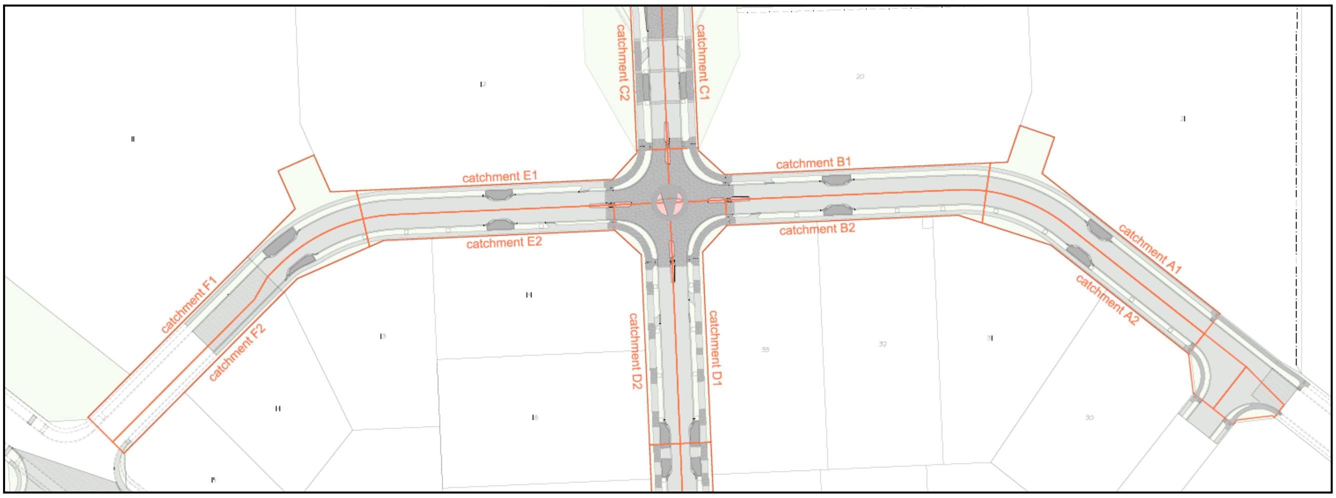


Figure 4 below shows the integration of the rain garden (blue) with the streetscape plans. This figure is taken from the landscaping plans for context.

Figure 4: Integration with Landscaping

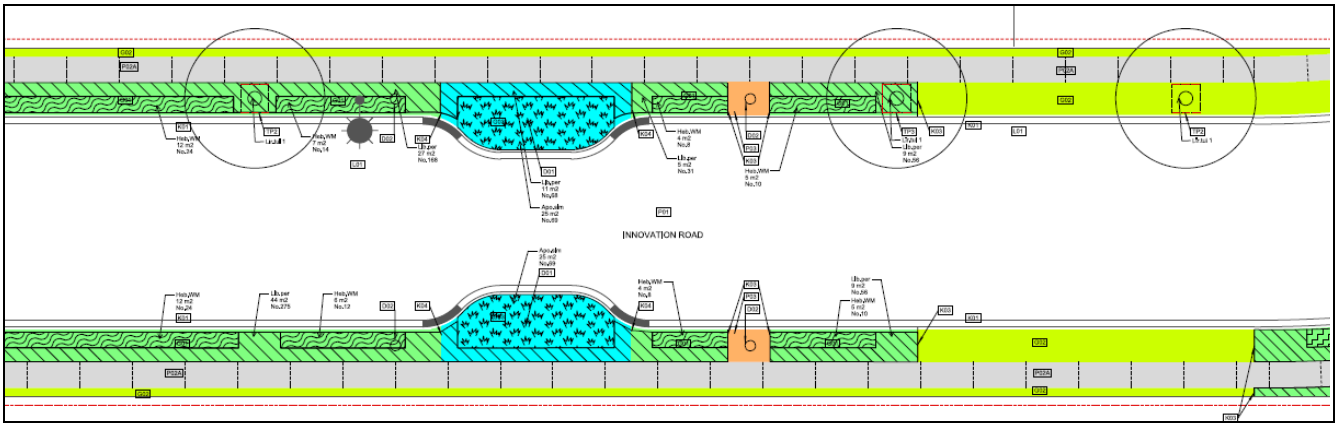


Figure 5 below shows the arrangement of the rain gardens once built (in the foreground) within the street scape.

Figure 5: Photo of rain gardens in streetscape

3.3 RAIN GARDEN SIZING

Rain garden sizing was undertaken in accordance with CCC's Christchurch Rain Garden Design Criteria (CRGDC). In particular, the rain garden sizing formula utilises the formula in the New Zealand Transport Agency stormwater design guide, Stormwater Treatment for Road Infrastructure (NZTA, 2010). CCC's Christchurch Rain Garden Design Criteria has adapted this formula to be consistent with WWDG terminology, as shown below.

$$A_{rg} = \frac{(V_{ff})(d_{rg})}{k(h+d_{rg})t_{rg}} \text{ (Equation 1)}$$

Where

A_{rg} = filtration area of rain garden (m²)

V_{ff} = first flush volume (m³)

d_{rg} = filter depth (m)

k = coefficient of permeability (m/day)

h = average height of water (m) = ½ extended detention depth (EDD)

t_{rg} = time to pass V_{ff} through soil bed

A second equation controlling the minimum area of the rain garden to ensure at least 40% of the V_{ff} is available to be stored above ground.

$$A_{EDD} \geq \frac{0.4 \times V_{ff}}{(2 \times h)} \text{ (Equation 2)}$$

A worked example of the calculated area for a catchment within Stage 2B is shown below.

Catchment area = 2,429 m²

Hardstand area = 1,822 m²

V_{ff} = 45.6 m³ (1,822 m² x 25 mm)

d_{rg} = 0.6 m (CRGDC Section 3.5.3)

k = 0.72 m/day (CRGDC Section 3.4.7)

h = ½ EDD = 0.15 m (CRGDC Section 3.2.1)

t_{rg} = 1 day (CRGDC Section 3.3.1)

$$A_{rg} = \frac{(45.6\ \mathrm{m}^3)(0.6\ \mathrm{m})}{0.72\frac{\mathrm{m}}{\mathrm{day}}(0.15\ \mathrm{m} + 0.6\ \mathrm{m})1\ \mathrm{day}} = 51\ m^2$$

$$A_{EDD} \geq \frac{0.4 \times 45.6\ m^3}{(2 \times 0.15\ m)} = 61\ m^2$$

Therefore the required rain garden area for this catchment is 61 m² which was split in half on each side of the carriageway.

No underdrains were necessary for the rain gardens, as the base of each rain garden was set into the underlying gravels which provided an infiltration rate greater than the design rate of the rain garden media.

3.4 SOAKAGE SIZING

The design infiltration rate was measured by falling head soakage testing at each proposed rain garden location. A Factor of Safety of 3 was applied to the measured rate to determine the design infiltration rate.

A simple Rational Method was applied to the expected runoff from events ranging from the 20 minute 10% AEP event to the 60 hour 2% AEP event. The length and associated area of the rapid infiltration length was adjusted to ensure no ponding would occur during the 10% AEP events, while some ponding was allowed during 2% AEP events. The duration of the ponding was typically less than 1 hour. Most catchments had a critical duration for the soakage of 1 – 2 hour storm events. Storage was allowed within the soakage manholes and the soakage lines, however, no storage was assumed in the rain garden for additional conservatism.

CCC requires soakage systems to have a minimum storage volume of the equivalent volume from the 18 hour 10% AEP duration runoff. Given the only above ground storage was the rain garden at each catchment this volume was not able to be provided.

To compensate for this, CCC allowed the use of redundant soakage systems within each catchment. A second soakage system with the capacity to discharge the 18 hour 10% AEP event was design and constructed but is capped off at the time of construction. This will allow a fresh soakage system to be activated should the primary soakage system become compromised in the future and allow for programmed maintenance, without the initial loss of performance. CCC furthermore allowed to reduce the 18 hour 10% AEP volume by the volume that would be discharge through the rain garden at the design rate, i.e. the volume was reduced by the area of rain garden x 30 mm/hr x 18 hours This typically resulted in an additional 1800 diameter soakage chamber at each rain garden and soakage system location.

3.4.1 **CONFIGURATION OF SOAKAGE CHAMBERS AND TRENCHES**

Soakage chambers and infiltration trenches were design to discharge stormwater runoff to ground after the water quality volume has been captured by the rain gardens. This was achieved with the use of a drowned entry sump installed in each rain garden set at the stormwater quality volume height, i.e. 300 mm above the media.

Stormwater flows from the drowned outlet sump then discharge into a precast concrete chamber. The base of the concrete chamber was set into the free draining gravels. The depth to the free draining gravels varied at each location but was generally 2.0 – 3.0 m below EGL.

Additional soakage area for each soakage chamber was achieved by constructing rapid infiltration trenches parallel to the road carriageway which are connected to the main chamber. The soakage trenches will be excavated into the free draining gravels. Each discharge trench will consist of a 160 mm punched drainage coil, e.g. Novaflo pipe, placed within a 300 mm thick NZTA F/6 drainage material layer. The use of punched drainage coil was preferred for the soakage trenches as opposed to slotted PVC for ease of construction and reduced construction costs. The use of punched drainage coil for this application is considered appropriate as it meets the requirements of NZTA for use in highway applications, albeit for use as a subsoil drain, as opposed to a soakage system. For a 500 mm wide soakage trench a single 160 mm punched drainage coil was used and for a 1000 mm wide soakage trench two evenly spaced 160 mm punched drainage coils were used.

Cleaning eyes were constructed at the end of each drainage trench line connected to the punched drainage coil. This allows maintenance activities such as jetting of the soakage lines to be undertaken as required. Debris cleared from the lines can then be vacuumed from the soakage chamber, from the surface, without entering the soakage chamber.

Figure 6 and Figure 7 below show the soakage chamber and associated soakage trenches in section.

Figure 6: Soakage Chamber and Trench Section

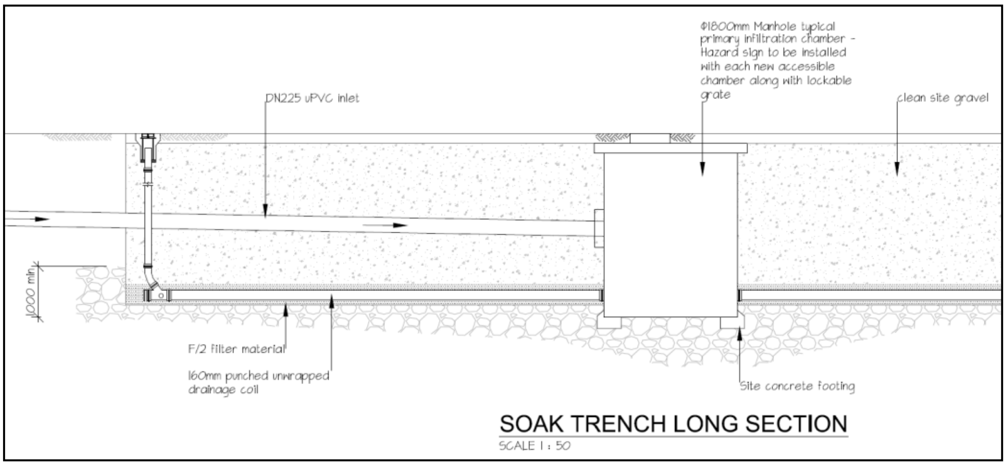
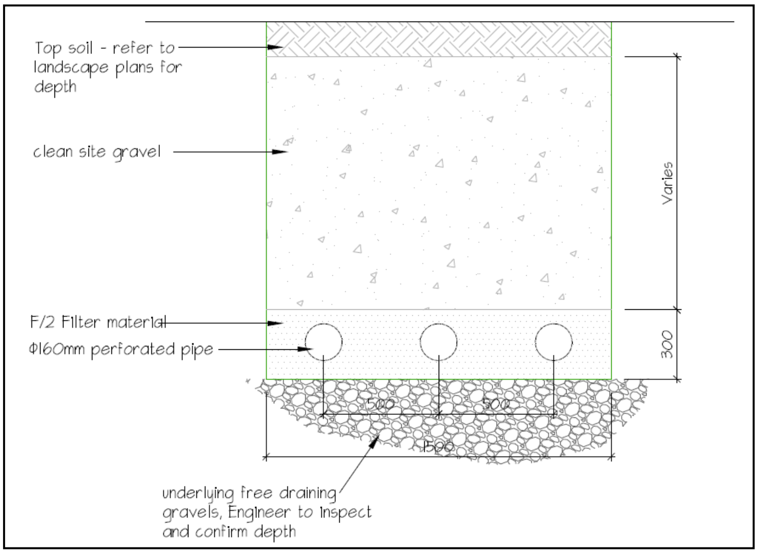


Figure 7: Typical Soakage Trench Section

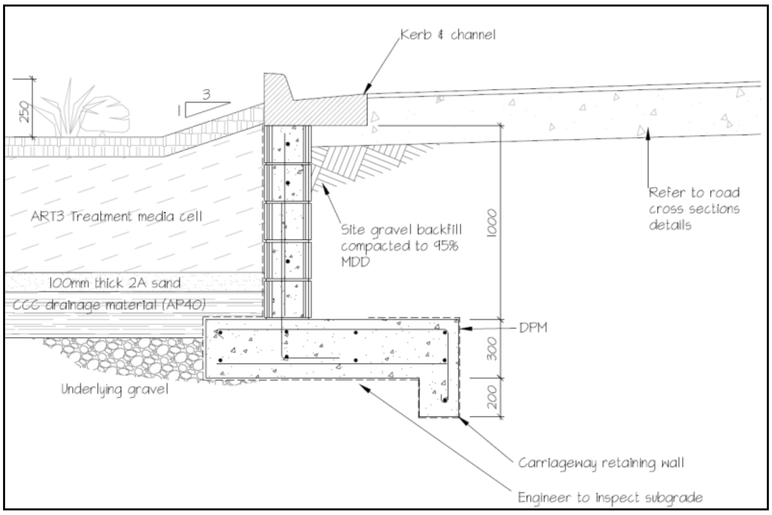


3.5 RAIN GARDEN DESIGN FEATURES

3.5.1 RETAINING WALLS

As the rain gardens were to be constructed within the road corridor and adjacent to a live traffic lane with a significant proportion of heavy vehicles, concrete block retaining walls were designed to support the traffic loads. The design case was for an empty rain garden and a full live load. This load case is most likely when the rain gardens are being constructed, or when they are being fully rejuvenated with new media. No support from the rain garden media was assumed. Seismic loading was also considered. Figure 8 below shows a typical retaining wall used at the Waterloo Business Park.

Figure 8: Typical Retaining Wall



3.5.2 **GROSS POLLUTANT TRAP AND KERB ENTRY**

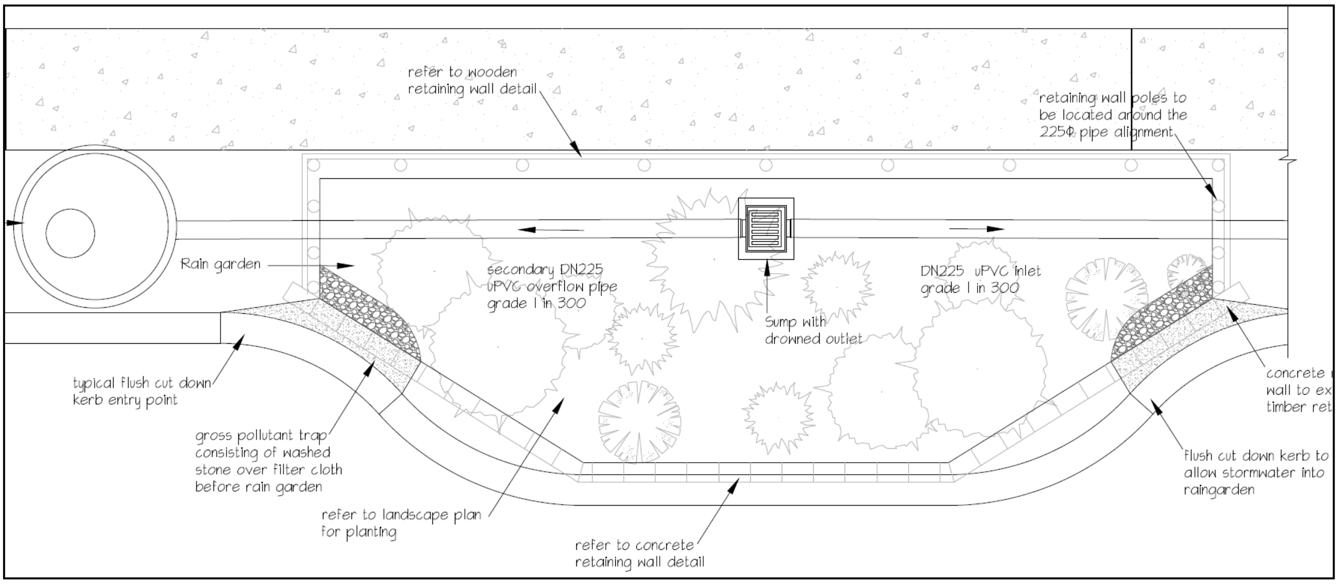
Rain gardens typically require a gross pollutant trap at the point of entry. This is often achieved with a sump entry, however, to minimise structures and allows easier integration with the landscaping a ballast rock entry was installed. The ballast was installed on top of a filter fabric layer to allow easy removal and replacement as a maintenance activity. Figure 9 below shows a typical ballast gross pollutant trap.

Figure 9: Gross Pollutant Trap

As noted above, the rain gardens have an entry via a cut down kerb into the rain garden.

Figure 10 below shows a typical rain garden layout with the overflow drowned entry sump in the centre, the soakage chamber to the left and a kerb entry from each end of the road catchment.

Figure 10: Rain Garden Layout



3.6 RAIN GARDEN PLANTING

The Christchurch City Council undertook a planting trial known as "The Commons" for rain garden species around the time of the design for Stage 2B (circa 2015) and the following plant species were proposed for use within the rain gardens:

- Apodasmia Similis (Oi Oi)
- Libertia Peregrinans (NZ Iris)

However, the NZ Iris were found to perform poorly within the Waterloo Business Park rain gardens and all NZ Iris have now been replaced by Oi Oi.

Given the drier climate and well drained soils of the west of Christchurch irrigation was installed for all rain gardens to ensure rapid establishment of the rain garden planting.

3.7 RAIN GARDEN MEDIA

The Christchurch City Council also undertook media trial at the same time as the planting trials and the ART3 mix, produced by Living Earth, was recommended by Council. This has performed well within the Waterloo Business Park and has continued to be used on subsequent stages.

3.8 MAINTENANCE CONSIDERATIONS

The soakage system was designed to minimise regular maintenance. The use of a drowned outlet sump to transfer stormwater flows from the rain garden to the soakage system, allows a single structure to be regularly maintained.

Access to the soakage chamber is proposed by a standard cast iron access lid. Periodic maintenance of the soakage chamber and soakage trenches should be undertaken by jetting of the soakage trench pipe work back into the soakage chamber and removal of the accumulated sediment from the base of the soakage chamber.

The expected periodic maintenance requirements of the soakage systems is intended to be no more onerous than a traditional road side sump and pipe network maintenance regime.

The inspection and maintenance regime for the rain gardens is attached in Appendix 1 in the Environment Canterbury discharge consent, CRC157554. The maintenance regime is a combination of reactive inspections after rainfall events, regular checks along with more generalised operational checks on a less frequent basis. This regime has been taken from CCC's Christchurch Rain Garden Design Criteria.

As with any work on the road, the maintenance activities will need to be undertaken under a traffic management plan. This typically consists of a shoulder closure for most activities such as removal of debris from the rain gardens. The rain gardens can be accessed from the adjacent footpath which minimises the need to work on the road side of the rain gardens. However, major maintenance activities such as media rejuvenation or replacement will require a lane closure to allow a suitably sized excavator and truck to work adjacent to the rain garden.

Maintenance of the drowned entry sumps can be undertaken with a mobile operation traffic management plan and a vacuum truck, as typically performed for road side sump maintenance.

4 CONSENTING PROCESS

4.1 STAGE 2B CONSENTING

During the planning stages of the Stage 2B subdivision consenting process the concept of rain gardens for stormwater treatment was discussed with CCC. This was initially met with acceptance as evidenced by a number of key design criteria inputs that were discussed with Council. However, it soon became apparent that the expected maintenance costs of rain gardens were a significant road block to the inclusion of rain gardens as vested assets within the subdivision.

4.2 MAINTENANCE COSTS COMPARISON

Davis Ogilvie presented a number of rain garden maintenance costs estimates to support the inclusion of rain gardens as vested council assets for this stage of the development.

These were the CCC's own Rain Garden Design Criteria (March 2014), Landcare Research COSTnz Model and Auckland Regional Council's GD-04 – Water Sensitive Design Guideline. The Rain Garden Design Criteria costs were based on the COSTnz Model and were summarised as shown below in Figure 11 and Figure 12 for annual maintenance and major maintenance and replacement costs respectively.

Figure 11: Extract from Christchurch Rain Garden Design Criteria report, dated 21 March 2014 - CCC adapted annual maintenance costs

7.3 *COST ASSUMPTIONS*

7.3.1 *ANNUAL MAINTENANCE*

Maintenance costs have been derived from the COSTnz model (www.costnz.co.nz/raingarden.pdf) and from discussions with CCC operations and maintenance staff for similar items (eg maintenance of plants in existing street landscaping). The COSTnz figures are provided for reference. A worked example for a 100 m² rain garden is included using the suggested CCC rates.

TASK	Responsibilty	Frequency per year	COSTnz Model[2]		Suggested CCC rate (annual cost)	Unit	Annual cost per $100m^2$
			Low	High			
Routine Maintenance (Annually)							
Routine Landscape Maintenance (removing litter, maintaining vegetation, weeding)	Street landscape	12	$2.54	$5.88	$5.88	m^2	$7,056.00
Routine Drainage Maintenance (removing sediment, clearing inlets and outlets)	Drainage operations	4			$50.00	per garden	$200.00
Inspections (for debris, outlets, integrity of biofilter). Flush out drainage	Drainage operations	1	$117.50	$305.50	$305.50	per garden	$305.50
Minor repairs	Drainage operations	1	$94.00	$117.50	$117.50	per garden	$117.50
Make good following vandalism (assume primarily vegetation)	Street landscape	1	$117.50	$129.25	$129.25	per garden	$129.25
Infiltration test	Drainage operations	0.33			$500.00	per garden	$165.00
TOTAL							**$7,973.25**

[2] Converted from 2007 rates to 2013 using total CPI inflation of 17.5% since 2007.

Figure 12: Extract from Christchurch Rain Garden Design Criteria report, dated 21 March 2014 - COSTnz major maintenance and replacement costs

7.3.2 *MAJOR MAINTENANCE AND REPLACEMENT*

TASK	Responsibilty	Frequency/year	COSTnz Model[3]		Suggested CCC rate (annual cost – not NPV)	Unit	Annual cost per $100m^2$
			Low	High			
Major Maintenance (Replacement) [Note: Costs not discounted at this stage]							
Removal & disposal of sediments (including replacement with new media) (every 20 years) [2]	Drainage operations	0.05	$26.44	$112.80	$7.87[4]	m^2	$787.00
Complete replanting (every 20 years) [3]	Street landscape	0.05	$1.76	$2.79	$1.40[5]	m^2	$140.00
Major maintenance of drainage system every 10 years, eg replacement of parts	Drainage operations	0.1	$117.50	$381.88	$375.25	per 80 m^2 garden	$469.00
							$1395.75

For Stage 2B of Waterloo Business Park approximately 410 m² of rain gardens were required. This equated to an annual regular maintenance cost of approximately $32,300 per year based on the CCC adapted COSTnz expected costs. While an annual cost per year of $5,700 was also recommended to be budgeted for major renewals and maintenance.

Auckland Regional Council's GD-04 – Water Sensitive Design Guideline also provides guidance on regular maintenance costs, with an estimation of "6-8% of the total acquisition cost". Based on the cost estimate model in the CCC Christchurch Rain Garden Design Criteria this translated to an expected regular maintenance cost of between $12,500 – 18,600 annually for the Stage 2B rain gardens.

A comparison with the existing and more traditional stormwater management systems, i.e. swale, first flush basin and infiltration basin in use for Stage 2A of the development was made. Actual maintenance costs for this system were not available, so the following maintenance regime was assumed, being typical for these types of systems.

Table 1: Expected Maintenance Costs

Task	Minimum frequency of maintenance visit		Annual maintenance costs		
	Swales	Infiltration and dry basins	Rate	Area	Total annual cost
Removal of debris and litter likely to adversely affect the operation of the system, within 10 working days of the maintenance visit	6 Monthly	6 Monthly	$2.54/m2	5,156m²	$26,192
Removal of hydrocarbons that are visible over a total area of greater than 0.5 square meters (swales and basins or a layer greater than 5 days millimetres thick (sumps), within 10 working days of the maintenance visit.	6 Monthly	6 Monthly	$1,000 L.S per inspection	-	$2,000
Repair or stabilisation of erosion and scout, within 20 working days of the maintenance visit	6 Monthly	6 Monthly	$1,000 L.S per inspection	-	$2,000
Replanting, where care or patchy soil cover or sediment build up is greater than 10 square metres, or a total of five present of the area of the device, whichever is the lesser, within 10 working days of the maintenance visit	6 Monthly	6 Monthly	$1,000 L.S per inspection	-	$2,000
Weed control	6 Monthly	6 Monthly	$1,000 L.S per inspection	-	$2,000
Total annual cost					**$34,192**

Finally a comparison between the catchment area was made to determine the expected maintenance costs per hectare.

Table 2: Expected Maintenance Cost Summary

Stage	Catchment Area	Annual maintenance cost	Annual maintenance cost per hectare
Stage 2a (Stormwater basin)	4.9 Ha	$34,192	$6,980
Stage 2b (Proposed Raingarden)	1.7 Ha	$32,300	$19,000

From the table above maintenance costs of a rain garden were expected to be around three times that of a traditional stormwater management system. This cost comparison compares directly the maintenance costs but does not take in to account the following other significant matters such as utilisation of land and amenity values for the people working in the development.

4.2.1 **COST COMPARISON SUMMARY**

In comparing the annual maintenance costs between the two systems, the annual maintenance cost rain gardens are approximately three times that of the SMA system. All factors to be considered are summarised in the table below:

Table 3: Cost Comparison

Factor	Raingarden	SMA
Annual maintenance cost per hectare	$19,000	$6,980
Land required for SMA outside road (per hectare of catchment area)	0 m2	300 m2 (approximately 3% of catchment area outside roads)
CCC rating income per hectare for developed Business land	Approximately $38,000 per hectare	

4.3 CCC ASSESSMENT

In response to the maintenance costs estimates, CCC assessed the maintenance costs to be significantly higher than the cost models presented, in the order of 10 times greater. This meant Council's planning engineers were unable to support the inclusion of rain gardens as vested assets in the proposed subdivision.

4.4 ALTERNATIVE SOLUTION

To continue with the developer's vision for the development including the rain gardens, they chose to develop Stage 2B with privately owned roads which allowed them to provide a private stormwater solution for the roading network.

This also required a private stormwater discharge consent with Environment Canterbury which Davis Ogilvie obtained under the proposed stormwater philosophy of rain gardens and rapid infiltration trenches. The consent was granted under consent number CRC157554.

With the future stages in mind, the maintenance costs for the Stage 2B rain gardens have been tracked by the maintenance contractor to provide a base line for actual maintenance costs in this industrial development. The intention is to provide these maintenance costs to Council to support the transition from private stormwater assets to vested assets in the future.

4.5 SUBSEQUENT STAGES

Subsequent stages of Waterloo Business Park were developed in the same manner as Stage 2B, with privately owned roads and a private stormwater system under a privately held discharge consent.

Stages 3 & 4 included part of Waterloo Road and Halswell Junction Road which are arterial roads in Christchurch. The creation of these portions of these roads as private Rights of Way was not acceptable to Council and Council accepted the use of rain gardens for stormwater treatment as a trial for these two road catchments. However, a five year maintenance period for the developer was required.

5 STAGE 2B MAINTENANCE COST ASSESSMENT

At the time of writing, maintenance costs between May 2016 and February 2018 were available, a total of 22 months.

The maintenance activities were based on the consent conditions of Stage 2B, which was based on CCC's Rain Garden Design Criteria. The maintenance activities are typically reactive following a rain fall event, or preventative, in terms of verifying the system is still functioning correctly.

The maintenance contractor has followed this maintenance regime as closely as possible to ensure the conditions of the consent and the expected level of service is kept to allow a reasonable cost assessment to be made.

The summary of the maintenance costs for the 15 months is shown below in Table 3. This is for all maintenance costs for the rain gardens in Stage 2B, 12 in totals.

Table 4: Maintenance Activities and Costs

Month	Labour (hours)	Dumping fees (loads)	Media topup (m^3)	Gravel mulch topup (m^3)	Refurbishment costs	Cost
May-16	17.5	5	0.25	0		$2,780.00
Jun-16	4	1	0	0		$620.00
Jul-16	5					$750.00
Aug-16	4	1				$620.00
Sep-16	5	1				$770.00
Oct-16	13	2				$1,990.00
Nov-16	6	2				$940.00
Dec-16	5	2				$790.00
Jan-17	5	1	0.25	0.25		$840.00
Feb-17	5	1	0.25	0.25	$4,656.00	$5,496.00
Mar-17	5	1	0.25	0.25		$840.00
Apr-17	13	3	0.25	0.25		$2,080.00
May-17	9	2	0.25	0.25		$1,460.00
Jun-17	13	9			$ 1,500.00	$3,630.00
Jul-17	10	2	0.25	0.25		$1,610.00
Aug-17	17	3	0.5	0.25	$ 2,500.00	$5,235.00
Sep-17	19	3	0.25	0.25		$2,980.00
Oct-17	16	3	0.25	0.25		$2,530.00
Nov-17						$0.00
Dec-17	13	4	0.25	0.25		$2,100.00
Jan-18	13	2	0.25	0.25		$2,060.00
Feb-18	32	5	0.5	0.25	$ 1,750.00	$6,775.00
Total	**171.5**	**42**	**2.75**	**2.25**	**$8,656.00**	**$46,896.00**
Cost per month =		**$2,131.64**	**over the last 22 months**			
Cost per month =		**$2,608.33**	**over the last 12 months**			

The unit rates used for these costs are as per Table 5 below:

Table 5: Unit Rates

Item	Rate	Unit
Labour	$40.00	per hour
Vehicle	$45.00	per hour
Traffic management	$65.00	per hour
Dumping Fees Small load	$20.00	Load
Media	$220.00	m^3
Gravel mulch	$60.00	m^3

The majority of the costs have been for the reactive inspections after a rainfall event rather than to remediate any defects which should be the case for operational rain gardens vested with council.

The larger maintenance cost in February was a refurbishment of the ballast, which is used a gross pollutant trap. This is an expected maintenance task which is dependent on the amount of debris present, e.g. during autumn leaf matter removal is expected to be a significant component of maintenance activities.

When compared to the maintenance costs reported in the Rain Garden Design Criteria and the COSTnz model, the Stage 2B costs are somewhat lower. On a yearly basis, for the regular maintenance items, the actual maintenance costs represent an annual cost of $25,580 versus an expected cost of $32,300.

5.1 MAINTENANCE COSTS DISCUSSION

Maintenance costs began to be recorded immediately following the completion of the stage. Development of the individual lots within this stage of the development has been slower, due to a number of large lots being held by a few owners. As a result construction traffic and users of the roading network are likely to be less than would be typically expected in an industrial development. This is likely to lead to less gross pollutants and debris to be generated and captured in the rain gardens. As a direct result, the time spent removing debris from the rain gardens, a labour intensive task, will be less, as evident from the maintenance costs recorded to date.

The landscaping trees were planted shortly after the completion of the stage, however, are not in a mature state and therefore will be producing less leaf matter than when mature, which again will reduce the labour costs associated with removing of debris from the rain gardens.

Traffic management costs for the activities to date have been based on mobile operation or shoulder closures and are likely to be on the low side when compared to rain gardens adjacent to busier arterial roads.

During the second year of maintenance, the costs have increased somewhat with additional labour time and dumping fees, which has been a result of increased traffic movements on the roading network and a corresponding increase in debris.

5.2 INFERRED UNIT MAINTENANCE COSTS

Taken on a per square metre basis for rain garden maintenance we get a rate of $62.40/m² of rain garden/year, or $6,240/100 m² or rain garden per year for the past 22 months.

If taken on the past 12 months of maintenance, where the maintenance activities are most representative of the in service state, we get a rate of $76.34/m² of rain garden/year, or $7,630/100 m² or rain garden per year, which is closer to the COSTnz model.

6 OTHER LEARNINGS

6.1 LOW O2 ENVIRONMENTS

During remedial works associated with the construction of the soakage systems the construction contractor performed a confined space pre-entry test which revealed the soakage chambers had a low oxygen environment and an entry into the chamber wasn't possible. Further testing revealed the low oxygen environment was most likely being caused by displacement of oxygen by carbon dioxide. Testing around other soakage chambers within the business park also showed similar results for a number of chambers, although, not all chambers.

While the solution to gain access to these chambers was a simple purging and venting activity, the presence of a low oxygen environment in these chambers was unexpected.

To ensure that the maintenance staff that might enter these chambers in the future, however unlikely, are made aware of this risk, the decision was made to install an additional grate beneath the manhole lid with additional warning about a potential low oxygen environment. The intention is to ensure complacency with stormwater manhole/chamber entry doesn't occur and that proper confined space procedures are undertaken. Furthermore, the access lids have been locked with a council only padlock. Figure 13 shows an example of the access lid in place. The centre hole allows for a vacuum truck to access the chamber without fully opening the chamber lid.

Figure 13: Soakage Chamber Access Lid

The presence of elevated carbon dioxide levels in the soakage chambers is likely due to the historical animal carcasses that have been biodegrading.

6.2 KERB ENTRIES

Given the integration with the streetscape a direct kerb entry into the rain gardens was utilised. However, during heavy rain events when the water quality volume is reached, the adjacent planted gardens and mulch was able to float and enter the rain garden proper. This has been mitigated in future rain gardens with a full height kerb to retain the garden mulch.

Figure 14 shows this problem in action.

Figure 14 : Rain Garden Kerb Entry

7 CONCLUSIONS

From the 22 months of available maintenance records for the 12 rain gardens in this study, we can conclude that the annual maintenance cost is \$62.40/m² of rain garden/year. This is approximately 80% of the COSTnz model for rain garden maintenance.

When taken across the last 12 months of maintenance, where the maintenance activities are most representative of the in service state, we get a rate of \$76.34/m² of rain garden/year, or \$7,630/100 m² or rain garden per year, which is closer to the COSTnz model.

Therefore we believe the COSTnz model to be fairly representative of maintenance costs for rain gardens, in particular, in an industrial setting such as Waterloo Business Park.

No major maintenance activities have been undertaken during the recorded period and are not expected for next 3-4 years.

ACKNOWLEDGEMENTS

Waterloo Park Limited

HEB Construction Limited

Boffa Miskell Ltd