Economics Work Package 11:
SRL1: The Urban Intervention Options Work Brief

Deliverable 2: Summary of life cycle costs for stormwater infrastructure solutions

Prepared by Sue Ira, Koru Environmental Consultants Ltd on behalf of Greater Wellington Regional Council

Te Awarua-o-Porirua Collaborative Modelling Project

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Summary of life cycle costs for stormwater infrastructure solutions

Report prepared for Greater Wellington Regional Council.

Prepared by: Sue Ira, Koru Environmental Consultants Ltd
Sub-consultant: AR and Associates Ltd
December 2017

Reviewed by: Chris Batstone, Batstone Associates
[date]

Brent King, Greater Wellington Regional Council
[date]

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Koru Environmental Consultants Ltd
P O Box 125147
St Heliers
Auckland

sue.ira@koruenvironmental.co.nz

AR & Associates Ltd
Unit 7 Northcroft Street
Takapuna
Auckland

andres.roa@arassociates.co.nz

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Costs presented in this report are based on current available information and should be read in the context of the assumptions presented in this report. Cost information has been gathered and modelled in order to gain an understanding of the relative difference in the indicative cost between different solutions, not the actual cost of each solution.

Any decision that is made after using this data must be based solely on the decision-makers own evaluation of the information available to them, their circumstances and objectives.

1 Introduction

1.1 Purpose and scope

The purpose of the project is to collaboratively generate information and knowledge to support the Te Awarua-o-Porirua Whaitua Committee make recommendations for land and water management in the Whaitua. The project will produce modelling outputs and knowledge describing the current environmental, social, cultural and economic conditions in TAoP Whaitua, as well as potential future outcomes that might result under urban and rural land and water management scenarios.

This work forms part of the Urban Intervention Work Brief and is one component of the overall economics work brief that addresses the decision making needs of the Whaitua Committee. This report follows-on from the Deliverable 1 Report "Summary of potential solutions available for stormwater, wastewater and water supply provision". The Deliverable 1 report documented potential solutions available to facilitate an operational focus towards water quality treatment, stormwater reuse and source control. Additionally, the report documented potential solutions available and currently being used to support water supply and wastewater infrastructure needs. Coupled with a decision-support matrix, a full range of solutions was presented, along with the applicability of their use and cost information, as documented in national and international literature.

Deliverable 2 of the Urban Intervention Work Brief requires the development of a cost 'reference library' for the different solutions. The costs need to be provided as estimates of the undiscounted life cycle costs in NZ$2017. This report provides a description of the modelling work that was undertaken and the life cycle costs for a number of stormwater solutions.

1.2 Life cycle costing

A life cycle costing (LCC) approach has been previously used to assess costs associated with stormwater devices in Australia, the United States of America (USA) and the United Kingdom (UK) (Vesely *et al.*, 2006[1]). The Australian/New Zealand Standard 4536:1999[2] defines LCC as the process of assessing the cost of a product over its life cycle or portion thereof. The life cycle cost is the sum of the acquisition and ownership costs of an asset over its life cycle from design, manufacturing, usage, and maintenance through to disposal. The consideration of revenues is excluded from LCC. A cradle-to-grave time frame is warranted because future costs associated with the use and ownership of an asset are often greater than the initial acquisition cost and may vary significantly between alternative solutions to a given operational need (Australian National Audit Office, 2001[3]).

LCC has a number of benefits and supports a number of applications and analyses (Lampe *et al* 2005[4]):

- it allows for an improved understanding of long-term investment requirements;
- it helps decision-makers make more cost-effective choices at the project scoping phase;
- it provides for an explicit assessment of long-term risk;

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[1] Vesely, E-T., Arnold, G., Ira, S. and Krausse, M. (2006). *Costing of Stormwater Devices in the Auckland Region.* NZWWA Stormwater Conference.

[2] Australian/New Zealand Standard. (1999). Life Cycle Costing: An Application Guide, AS/NZ 4536:1999. Standards Australia, Homebush, NSW, Australia and Standards New Zealand, Wellington, NZ.

[3] Australian National Audit Office. (2001). Life Cycle Costing: Better Practice Guide. Canberra, Commonwealth of Australia.

[4] Lampe, L., Barrett, M., Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Hollon, M. (2005). Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems. WERF Report Number 01-CTS-21T.

- it reduces uncertainties and helps local authorities determine appropriate development contributions; and
- it assists local authorities in their budgeting, reporting and auditing processes.

Decision-making on the use of stormwater devices needs quality data on the technical and financial performance of these devices. The financial performance will depend on the sum and distribution over the life cycle of the device of costs associated with design, construction, use, maintenance, and disposal. LCC can be used for structuring and analysing this financial information. A LCC approach has been used in this project to quantify the cost implications of stormwater mitigation.

1.3 Caveat

The data used to develop the models is based on the best available cost information at the time of writing this report. However, cost information is notoriously variable, and whilst every effort has been made to ensure the consistency and integrity of the data collected, reliance should not be placed on the actual costing figures. Decision-makers should rather use the life cycle costing information to understand the potential relative difference between the different management solutions.

2 Life cycle costing models and cost data

The Landcare Research COSTnz Model[5] and NIWA/ Cawthron "Urban Planning that Sustains Waterbodies" (UPSW) Costing Model[6] have been used to determine life cycle cost information for the Porirua Whaitua.

COSTnz is a site-specific model and requires a good understanding of the local site conditions, contaminant inputs and stormwater device design. In general, the life cycle costs are assessed using a unit-based approach.

The UPSW LCC Model is a catchment-scale model that was developed by running a significant number of COSTnz scenarios in order to determine $/ha costs for different types of stormwater treatment solutions.

Additional cost data, where needed, was obtained from Wellington Water as well as "on-the-ground" subdivisions undertaken in the Auckland Region.

3 Life cycle costing assumptions

All models have the same life cycle costing assumptions, as follows:

- The base year for the COSTnz model is 2007. As a result, all costs were inflated to a base year of 2017 using a 2.8% inflation rate.
- A life cycle analysis period and life span of 50 years was used for all model runs.

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[5] Ira, S. J. T., Vesely, E-T., McDowell, C and Krausse, M. 2009. *COSTnz – A Practical Life Cycle Costing Model for New Zealand*. NZWWA Conference, Auckland.

[6] Ira, S.J.T., Batstone, C. and Moores, J. 2012. *The incorporation of economic indicators within a spatial decision support system to evaluate the impacts of urban development on waterbodies in New Zealand*. 7th International Conference on Water Sensitive Urban Design Conference, Melbourne, Australia.

- A discount rate of 3.5% was used for the discounted life cycle costs (however, as required in the scope of works, only undiscounted life cycle costs are presented in this report).
- For those models which are based on the “UPSW Costing Model”, please see Cawthron Report No. 2082 for further detail and explanations around the assumptions.
- Decommissioning costs were not included in the models as none of the solutions would be decommissioned after 50 years.

4. Model assumptions for individual solutions

The following section describes the total acquisition cost (TAC) and maintenance cost (MC) assumptions, as well as any specific design assumptions, for each stormwater solution.

It should be noted that, where possible, a range of costs (from low to high) has been provided. Providing a range of costs assists in addressing uncertainty in the cost estimates. In addition, this range helps to remind users that the value of these life cycle costs lies in their ability to provide a relative comparison of costs between different solutions, rather than the actual cost itself.

4.1 Dry ponds, ponds and wetlands

Other than to inflate the costs to a base date of 2017, no changes were made to the pond and wetland scenarios as described in Cawthron Report No. 2082 for the UPSW stormwater cost model and the associated Water Quantity Attenuation Costing Report. For the UPSW cost model, costs of “on the ground ponds and wetlands were modelled and extrapolated for differing treatment levels based on Table 3.1 of Technical Publication 10 (Stormwater Treatment Devices: Design Guideline Manual, Auckland Regional Council 2001).

- TAC: these costs were modelled using the COSTnz statistical relationship for ponds and wetlands.
- MC: these costs were modelled using the COSTnz unit costing spreadsheet for maintenance costs. Clean-out frequencies were determined by the amount of sediment captured by a pond/ wetland. The sediment captured by these devices was determined by applying a simple contaminant load model.

Life cycle costs have been generated for a range of impervious areas treated and a range of total suspended solid treatment efficiencies. With respect to dry ponds, the ponds were designed to assume attenuation of the 2 year average return interval storm event.

4.2 Rain gardens and swales

As for the ponds and wetlands, the UPSW cost model information was used to determine life cycle costs for rain gardens and swales. Costs were inflated to a base date of 2017, and the original scenarios modelled are as described in Cawthron Report No. 2082 and the Addendum to this report. Based on data collected through this project, some additional changes were made in order to refine these models. These changes are as follows:

- **Rain Gardens**:
  - TAC: no changes – the Auckland Unitary Plan costing formula for rain gardens (TAC = $2000 + 300/$m^2$) was used to determine the TAC.
  - MC: The unit cost for “disposal to waste” was updated based on sediment disposal costs provided by AR and Associates Ltd. In addition, the yearly “make good from vandalism” cost was removed as it is considered that this item is covered under yearly inspections and minor repairs.

- **Swales**:
    - TAC: due to the relatively undulating topography in the Porirua Whaitua, the swales have been costed without the an underdrain.
    - MC: The yearly "make good from vandalism" cost was removed as it is considered that this item is covered under yearly inspections and minor repairs.

Filter strips were not costed as part of this project. Costs of filter strips are likely to be similar to the low cost range for swales.

Life cycle costs have been generated for a range of impervious areas treated and a range of total suspended solid treatment efficiencies.

4.3 Riparian planting

The UPSW cost model information was also used to determine life cycle costs for riparian planting. No changes to the riparian planting model, other than to inflate the costs to a base date of 2017, were made. Model assumptions are therefore as described in Cawthron Report No. 2082 for the UPSW stormwater cost model and the associated Water Quantity Attenuation Costing Report. In an urban context, the purpose of riparian planting would be to mitigate increases in stormwater quantity. Since the majority of urban discharges are point source discharges, the planting would not provide mitigation from contaminants generated from impervious surfaces.

Costs have been calculated for a 'high quality' and 'low quality' riparian planting option. The high quality costing option allows for a greater density of plants, increased resources such as fertilisers and a more intensive level of initial maintenance. The 'low quality' option relates to a narrower riparian strip with limited planting and lower levels of maintenance.

4.4 Rain tanks

The COSTnz rain tank model was used to develop life cycle costs for rain tanks. It was assumed that the tanks would only be used for 'grey water' re-use. Filters to allow for potable water use have not been costed.

Total acquisition costs:

The COSTnz unit costing spreadsheet was used to determine the TAC. The cost of the tanks, including installation, are shown below. To allow for grey water use, connection and plumbing costs were also included. An additional 30% was added to the installation cost to account for costs incurred through the design, planning and consenting phase. This percentage is based on a recommendation in Table 6.2 of Chapter 6 of an unnamed/ undated EPA report[7]. A 15% contingency was allowed for. The costs, taken from the COSTnz database, were inflated to a base date of 2017 by 2.8% per annum and are shown overleaf.

[7] Chapter 6 of an unnamed/ undated US EPA Report: https://www3.epa.gov/npdes/pubs/usw_d.pdf

Cost of Tank (including installation):

Tank Size	Low ($)	High ($)
1000 Litre	672	738
3000 Litre	1,384	1,410
5000 Litre	1,964	2,056
9000 Litre	2,768	3,203
10000 Litre	3,361	3,756

Type and cost of additional "connections":

Low cost

CONNECTIONS AND PLUMBING				
Supply, install & connect shutoff valves for house supply	No.	$185.00	1	$185.00
Supply, install & connect mains topup valve and float switch into tank for house supply	LS			$0.00
Supply & install First Flush Diverter (including riser chamber, pipes and fittings)	No	$764.00	1	$764.00
Supply and install 2x contamination control jumbo water filters and housing, including pipework	LS	$724.00		$724.00
Supply & install carbon filters (to allow for safe drinking water)	per filter			$0.00
Supply and install pressure pump including pipework, fittings, concrete slab for base	LS	$1,845.00		$1,845.00
Electrical connections	LS	$1,318.00		$1,318.00

High cost

CONNECTIONS AND PLUMBING				
Supply, install & connect shutoff valves for house supply	No.	$243.84	1	$243.84
Supply, install & connect mains topup valve and float switch into tank for house supply	LS			$0.00
Supply & install First Flush Diverter (including riser chamber, pipes and fittings)	No	$817.19	1	$817.19
Supply and install 2x contamination control jumbo water filters and housing, including pipework	LS	$790.83		$790.83
Supply & install carbon filters (to allow for safe drinking water)	per filter			$0.00
Supply and install pressure pump including pipework, fittings, concrete slab for base	LS	$1,977.07		$1,977.07
Electrical connections	LS	$2,636.10		$2,636.10

Maintenance Costs:

Maintenance activities, frequencies and costs for the low and high scenarios are shown in the green screen shots below/ overleaf. The models assume that annual maintenance such as inspection of tank, cleaning filters/ screens is undertaken by the home owner. The majority of maintenance costs are costed "per tank". As a result, they do not vary greatly across the different tank sizes.

Low cost

MAINTENANCE COSTS

Routine Maintenance	Frequency (Per Year)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Inspection of tank, orifice outlet, pipework, first flush device, pest screens, erosion protection	2		per inspection		
Inspection of water supply pumps and associated	1		per inspection		
Clean out dead storage (i.e. Removal of sediment from tank & repairs as necessary)	1		per tank	*$195.00*	
Make good following vandalism	1		per tank		
Maintenance and replacement of screens/ filters	2		per tank		
Other (please specify)					
TOTAL ROUTINE MAINTENANCE COSTS				**$195.00**	

Corrective Maintenance	Frequency (Number of Years)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Maintenance of filters, pumps, etc	5		per tank	*$90.00*	$118.62
Replacement of water supply pump	10		per pump	*$1,000.00*	$1,318.00
Minor Repairs to concrete and structural components (eg sealing cracks; tank stand; etc)	10		per tank	*$100.00*	$132.00
Other (please specify)					

High cost

MAINTENANCE COSTS

Routine Maintenance	Frequency (Per Year)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Inspection of tank, orifice outlet, pipework, first flush device, pest screens, erosion protection	2		per inspection		
Inspection of water supply pumps and associated electrical	1		per inspection		
Clean out dead storage (i.e. Removal of sediment from tank & repairs as necessary)	1		per tank	*$287.00*	
Make good following vandalism	1		per tank		
Maintenance and replacement of screens/ filters	2		per tank		
Other (please specify)					
TOTAL ROUTINE MAINTENANCE COSTS				**$287.00**	

Corrective Maintenance	Frequency (Number of Years)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Maintenance of filters, pumps, etc	5		per tank	*$100.00*	$131.80
Replacement of water supply pump	10		per pump	*$2,500.00*	$3,295.12
Minor Repairs to concrete and structural components (eg sealing cracks; tank stand; etc)	10		per tank	*$500.00*	$695.02
Other (please specify)					

4.5 Roofing Costs

The COSTnz "generic" model was used to develop life cycle costs for roofing materials. Two different types of roofing scenarios were costed, namely:

- inert roofing material which refers to long run colour steel, zincalume or similar roofs for a theoretical 200m^2 roof, and
- green roof which incorporates a sedum/ native mix for a theoretical 200m^2 roof.

Total acquisition costs:

The following formula was used to determine the TAC for each scenario:

TAC Cost for 200m^2 of roof = [{(Installation Cost) + (Installation Cost x 30%)} x 200)] 15% contingency*

In each case 30% was added to the installation cost to account for costs incurred through the design, planning and consenting phase. This percentage is based on a recommendation in Table 6.2 of Chapter 6 of an unnamed/ undated EPA report[7].

Roof material costs (from AR & Associates)

Roof Material	Low $ /m^2	High $ /m^2
Inert Roof	$86	$207
Green Roof	$196	$322

With respect to the roof material costs for green roofs, a lower cost is associated with predominantly sedums, whilst a higher cost is reflective of a native mix.

Maintenance Costs:

Maintenance activities, frequencies and costs for the low and high scenarios are shown in the green screen shots below/ overleaf. In terms of the roof re-painting/ touch-ups, it was estimated that a quarter of the roof would be re-painted every 15 years. For green roofs, initial aftercare of plants was allowed for in the first 2 years following construction.

Low cost – inert roofs

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspection and removal of moss/ lichen	3	per device		$300.00	$300.00
Repainting/ touch-ups	15	m2		$15.00	$750.00
Replacement	25	m2		$75.00	$15,000.00
					$0.00
TOTAL CORRECTIVE MAINTENANCE COSTS					$16,050.00

High cost – inert roofs

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspection and removal of moss/ lichen	3	per roof		$450.00	$450.00
Repainting/ touch-ups	15	m2		$35.00	$1,750.00
Replacement	25	m2		$180.00	$36,000.00
					$0.00
TOTAL CORRECTIVE MAINTENANCE COSTS					$38,200.00

Low cost – green roofs

Routine Maintenance	Frequency (Per Year)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspections (plant zone; drainage media; drainage layer; structural components)	2	per m2		$7.50	$3,000.00
		per device			$0.00
		per device			$0.00
		per device			$0.00
		per device			$0.00
					$0.00
		per device			$0.00
					$0.00
					$0.00
					$0.00
					$0.00
TOTAL ROUTINE MAINTENANCE COSTS [Annual]					$3,000.00

Do you an additional service after subdivision construction? Yes

Cost of Additional Service **$1,056.00** $1.28/m2 initial aftercare of plants from RG model x 200
Corrective maintenance for years 1 and 2 - $800

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Corrective Maintenance Repair Costs (plants/ media)	10	per m2		$2.00	$400.00
Corrective Maintenance Repair Costs (drainage layer) (estimate 0.25 of roof)	25	m2		$100.00	$5,000.00
					$0.00
					$0.00
TOTAL CORRECTIVE MAINTENANCE COSTS					$5,400.00

High cost – green roofs

Routine Maintenance	Frequency (Per Year)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspections (plant zone; drainage media; drainage layer; structural components)	2	per m2		$30.00	$12,000.00
		per device			$0.00
		per device			$0.00
		per device			$0.00
		per device			$0.00
					$0.00
		per device			$0.00
					$0.00
					$0.00
					$0.00
					$0.00
TOTAL ROUTINE MAINTENANCE COSTS [Annual]					$12,000.00

Do you an additional service after subdivision construction? Yes

Cost of Additional Service **$2,344.00** $3.73/m2 initial aftercare of plants from RG model x 200
Corrective maintenance for years 1 and 2 - $1600

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Corrective Maintenance Repair Costs (plants/ media)	10	per m2		$4.00	$800.00
Corrective Maintenance Repair Costs (drainage layer) (estimate 0.25 of roof)	25	m2		$120.00	$6,000.00
					$0.00
					$0.00
TOTAL CORRECTIVE MAINTENANCE COSTS					$6,800.00

4.6 Stormwater pipes

The COSTnz "generic" model was used to develop life cycle costs for stormwater pipes. In order to generate an appropriate NZ$/m cost for the pipes, 70m sections of pipe were costed. Data from Wellington Water has shown that they service 14387 manholes, inlets and outlets across a pipe length of 443.4km. This equates to 1 manhole every 31m of pipe. As a result, the costing model included costs of 2 manholes and 1 catchpit for each 70m section of pipe. These assumptions and design philosophy is based are based on best available data at the time of modelling, and are consistent with the recommendations of the Regional Standard for Water Services in the Wellington Region (November 2012). This Standard recommends a maximum pipe length of 90m per manhole and catchpit.

As recommended by Wellington Water, an "on-cost factor" of 1.13 (approximately 50% of the installation cost) was added to the installation cost to account for costs incurred through the design, planning and consenting phase, and to account for compliance and management fees during construction. This percentage is relatively consistent with the recommendations Table 6.2 of Chapter 6 of an unnamed/ undated EPA report[7].

Total Acquisition Costs:

The following formula was used to determine the TAC for each scenario:

TAC Cost for 70m of pipe = {(Installation Cost) + (Installation Cost x 50%) x 70} + (1 x catchpit) + (2 x manhole)

Pipe installation costs (from Wellington Water, Rawlinsons[8] and AR & Associates)

Pipe Size	Low (NZ$) (greenfield rate)	Mid (NZ$) (suburban rate)	High (NZ$) (CBD rate)	Notes
150mm	287	461	538	
225mm	309	554	647	
300mm	387	636	742	
600mm	806	1,344	1,963	
900mm	1,330	2,063	2,407	
1050 Manhole 2-4m deep	3,272	3,832	4,391	For pipes up to 300mm
1200 Manhole 2-4m deep	4,236	4,748	5,260	For 600mm pipes
1500 Manhole 2-4m deep	5,534	5,894	6,254	For 900mm pipes
Catchpit (single)	1,659	1,718	1,777	

Maintenance costs:

Maintenance activities, frequencies and costs for the low, mid and high scenarios are shown in the green screen shots below/ overleaf. An increase from 1 to 2 hours for CCTV inspection was allowed for the larger pipe sizes, and an item for minor repairs (such as replacement of manhole covers) was also included.

[8] Rawlinsons New Zealand Construction Handbook (2007)

Low costs

MAINTENANCE COSTS

Routine Maintenance	Frequency (Per Year)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspections (outlets/ overflow spillway, overall functioning of facility)	2	per device		$162.00	$324.00
Six Monthly Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	2	per device			$0.00
Annual Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	1	per device			$0.00
Minor repairs	1	per device		$450.00	$450.00
Make good following vandalism		per device			$0.00
Other Activities *{please specify}*					$0.00
Traffic Management	2	per device			$0.00
					$0.00
					$0.00
					$0.00
					$0.00
TOTAL ROUTINE MAINTENANCE COSTS [Annual]					**$774.00**

No) no

Cost of Additional Service

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Replacement of Unit*	15	per device			$0.00
Replacement of parts (grates, outlet structures; other concrete components)	10	per device		$385.00	$385.00
Cleanout of Sediment*	10	m^3			$0.00
Disposal of Sediment	10	m^3			$0.00
Other activities *{please specify}*					
CCTV	25	per hour		$240.00	$240.00
Traffic Management	10	per pipe		$450.00	$450.00
Vacuuming of Pipes	10	per service		$250.00	$250.00
Disposal of Sediment	10	m3		$83.34	$25.00
TOTAL CORRECTIVE MAINTENANCE COSTS					**$1,350.00**

Mid-range costs

MAINTENANCE COSTS

Routine Maintenance	Frequency (Per Year)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspections (outlets/ overflow spillway, overall functioning of facility)	2	per device		$179.00	$358.00
Six Monthly Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	2	per device			$0.00
Annual Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	1	per device			$0.00
Minor repairs	1	per device		$580.00	$580.00
Make good following vandalism		per device			$0.00
Other Activities *{please specify}*					$0.00
Traffic Management	2	per device			$0.00
					$0.00
					$0.00
					$0.00
					$0.00
TOTAL ROUTINE MAINTENANCE COSTS [Annual]					**$938.00**

No) no

Cost of Additional Service

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Replacement of Unit*	15	per device			$0.00
Replacement of parts (grates, outlet structures; other concrete components)	10	per device		$485.00	$485.00
Cleanout of Sediment*	10	m^3			$0.00
Disposal of Sediment	10	m^3			$0.00
Other activities *{please specify}*					
CCTV	25	per hour		$305.00	$305.00
Traffic Management	10	per pipe		$517.00	$517.00
Vacuuming of Pipes	10	per service		$255.00	$255.00
Disposal of Sediment	10	m3		$120.00	$36.00
TOTAL CORRECTIVE MAINTENANCE COSTS					**$1,598.00**

High costs

MAINTENANCE COSTS

Routine Maintenance	Frequency (Per Year)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Inspections (outlets/ overflow spillway, overall functioning of facility)	2	per device		$196.17	$392.34
Six Monthly Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	2	per device			$0.00
Annual Service (inspection of operating unit and clearing debris from inlets; outlets; replacement of filters/ cartridges/ bags, etc)	1	per device			$0.00
Minor repairs	1	per device		$715.00	$715.00
Make good following vandalism		per device			$0.00
Other Activities *{please specify}*					$0.00
Traffic Management	2	per device			$0.00
					$0.00
					$0.00
					$0.00
					$0.00
TOTAL ROUTINE MAINTENANCE COSTS [Annual]					$1,107.34

No) No

Cost of Additional Service

Corrective Maintenance	Frequency (Number of Years)	Unit	Costs		Total Cost
	User Defined		Model/ Default	User Defined	
Replacement of Unit*	15	per device			$0.00
Replacement of parts (grates, outlet structures; other concrete components)	10	per device		$585.00	$585.00
Cleanout of Sediment*	10	m^3			$0.00
Disposal of Sediment	10	m^3			$0.00
Other activities *{please specify}*					
CCTV	25	per hour		$370.00	$370.00
Traffic Management	10	per pipe		$585.00	$585.00
Vacuuming of Pipes	10	per service		$260.00	$260.00
Disposal of Sediment	10	m3		$157.70	$47.31
TOTAL CORRECTIVE MAINTENANCE COSTS					$1,847.31

4.7 Permeable paving costs

The COSTnz infiltration/ permeable paving model was used to develop life cycle costs for permeable paving. There are many different types of permeable pavers available for use, however, the LCC model assumed that the permeable portion of installation lay between the pavers rather than within the paving blocks themselves. The costs do not relate to any specific proprietary paver within the New Zealand market. It was assumed that permeable pavers would only be used within residential areas, and a percolation rate of 2 – 3mm/hr was used in the design process. The design of the paver allowed for filter cloths, a base course thickness of 150mm and a 20mm sand bedding layer. A LCC model was also developed for concrete driveways in order to provide a point of comparison between the two practices. A LCC model was developed for two different scenarios, i.e. a 50m^2 area and a 100m^2 area. The recommended LCC is an average of these two scenarios.

Total acquisition costs:

The COSTnz unit costing spreadsheet was used to determine the TAC. In addition to the construction and material costs identified, an additional 30% was added to the installation cost to account for costs incurred through the design, planning and consenting phase. This percentage is based on a recommendation in Table 6.2 of Chapter 6 of an unnamed/ undated EPA report[9]. A 15% contingency was allowed for. The costs, taken from the COSTnz database, were inflated to a base date of 2017 by 2.8% per annum.

Maintenance Costs:

Maintenance activities, frequencies and costs for the low and high scenarios are shown in the green screen shots below (for the 50m^2 scenario). Costs generally relate to a yearly cleaning of the paving surface, as well as less frequent cleanout of sediment and replacement of pavers and sand.

[9] Chapter 6 of an unnamed/ undated US EPA Report: https://www3.epa.gov/npdes/pubs/usw_d.pdf

Low cost

MAINTENANCE COSTS					
Routine Maintenance	Frequency (Per Year)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Regular cleaning where organic sediments fall	12		per trench		$0.00
General yearly cleaning for weed/ moss control	4	1	per driveway		$70.00
Maintaining healthy vegetation around device, weeding, mowing, etc	6		m^2		
Minor repairs	1		per trench		
Make good following vandalism	1		per trench		
Other activities					
Do you envisage elevated maintenance costs in the first 3 years? If Yes, detail percentage above annual costs:				10%	
TOTAL ROUTINE MAINTENANCE COSTS - Annually (after initial 3 year maintenance period)				**$70.00**	

Corrective Maintenance	Frequency (Number of Years)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Cleanout sediment, oils, etc and removal of top layer of stone and re-establishment (top up joint chip or sand between pavers)	5	10	m^3		$158.17
Removal and disposal of sediments	10		m^3		
Rehabilitation of trench (i.e. replacement of full trench filtration media)	10		m^3		
Replacement of permeable pavers (if necessary)	10		m^2		$217.48
Erosion repair	2		per trench		
Repairs to structural components	10		per trench		
Other activities					

High cost

MAINTENANCE COSTS					
Routine Maintenance	Frequency (Per Year)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Regular cleaning where organic sediments fall	12		per trench		$0.00
General yearly cleaning for weed/ moss control	4	1	per driveway		$99.00
Maintaining healthy vegetation around device, weeding, mowing, etc	6		m^2		
Minor repairs	1		per trench		
Make good following vandalism	1		per trench		
Other activities					
Do you envisage elevated maintenance costs in the first 3 years? If Yes, detail percentage above annual costs:				10%	
TOTAL ROUTINE MAINTENANCE COSTS - Annually (after initial 3 year maintenance period)				**$99.00**	

Corrective Maintenance	Frequency (Number of Years)		Unit	Costs	
	Model/ Default	User Defined		Model/ Default	User Defined
Cleanout sediment, oils, etc and removal of top layer of stone and re-establishment (top up joint chip or sand between pavers)	5	10	m^3		$184.53
Removal and disposal of sediments	10		m^3		
Rehabilitation of trench (i.e. replacement of full trench filtration media)	10		m^3		
Replacement of permeable pavers (if necessary)	10		m^2		$270.20
Erosion repair	2		per trench		
Repairs to structural components	10		per trench		
Other activities					

4.8 Erosion and sediment control costs

The UPSW cost model information was used to determine life cycle costs for erosion and sediment control. No changes to the erosion and sediment control model assumptions, other than to inflate the costs to a base date of 2017, were made. Model assumptions are therefore as described in Cawthron Report No. 2082 for the UPSW stormwater cost model and the associated Water Quantity Attenuation Costing Report. A sediment treatment efficiency of 90% was assumed for the costing model, along with a life cycle of 5 years. Costs were calculated for a low (flat gradient) and high (steep gradient) option.

4.9 Filter media costs

As mentioned in the Stage 1 "Three Waters Solutions" Report, proprietary devices are not costed as part of this project. However, the Whaitua Committee do want to include an option for "filter media" type of devices within the industrial and commercial areas of the Porirua Whaitua. As a result, COSTnz was used to develop generic sand filter costs. The costs generated do not relate to any specific proprietary filter product within the New Zealand market. The default values in COSTnz were used to estimate the relevant TAC and maintenance costs and activities, and the costs inflated to a base date of 2017.

Total acquisition costs:
The COSTnz unit costing spreadsheet was used to determine the TAC. In addition to the construction and material costs identified, an additional 30% was added to the installation cost to account for costs incurred through the design, planning and consenting phase. This percentage is based on a recommendation in Table 6.2 of Chapter 6 of an unnamed/ undated EPA report[10]. A 15% contingency was allowed for. The costs, taken from the COSTnz database, were inflated to a base date of 2017 by 2.8% per annum.

Maintenance Costs:
Maintenance activities, frequencies and costs for a low and high sand filter scenario were based on the recommended default COSTnz values. Maintenance generally relates to cleanout of the sedimentation chamber, scraping and replacing sand in the filtration chamber, and repair of parts.

5. Summary of undiscounted life cycle costs

5.1 Results

The table below and series of graphs provide a summary of the undiscounted $/year (2017) LCC for each stormwater solution analysed. The TAC ratio (i.e. the percentage of the life cycle cost which relates to the TAC of the practice), has also been included where relevant.

[10] Chapter 6 of an unnamed/ undated US EPA Report: https://www3.epa.gov/npdes/pubs/usw_d.pdf

Summary of undiscounted life cycle costs ($/ unit/ year):

SUMMARY OF UNDISCOUNTED LIFE CYCLE COSTS

	5% Imperv	30% Imperv	60% Imperv	90% Imperv	
DRY PONDS (low)	$157.02	$241.57	$300.34	$345.86	undiscounted $/ha/yr
DRY PONDS	$219.71	$324.72	$396.96	$527.70	
DRY PONDS (high)	$437.29	$598.71	$708.13	$791.41	

	5% Imperv	30% Imperv	60% Imperv	90% Imperv	5% Imperv	30% Imperv	60% Imperv	90% Imperv		TAC Ratio
	75% TSS Removal				90% TSS Removal					
WET PONDS (low)	$79.90	$144.77	$187.40	$230.93	$93.37	$176.35	$233.81	$284.79	undiscounted $/ha/yr	64.15%
WET PONDS	$191.59	$306.23	$386.06	$448.51	$269.99	$362.79	$465.14	$543.68		
WET PONDS (high)	$350.43	$530.23	$653.98	$745.21	$390.40	$623.07	$810.98	$895.14		

	5% Imperv	30% Imperv	60% Imperv	90% Imperv	5% Imperv	30% Imperv	60% Imperv	90% Imperv		TAC Ratio
	75% TSS Removal				90% TSS Removal					
WETLANDS (low)	$280.21	$540.02	$606.05	$759.97	$353.80	$629.76	$768.15	$886.40	undiscounted $/ha/yr	88.55%
WETLANDS	$458.69	$1,206.25	$1,537.49	$1,740.75	$673.86	$1,458.58	$1,802.59	$2,022.20		
WETLANDS (high)	$554.69	$2,055.41	$2,666.91	$3,041.59	$1,015.55	$2,534.86	$3,166.19	$3,559.92		

	5% Imperv	30% Imperv	60% Imperv	90% Imperv	5% Imperv	30% Imperv	60% Imperv	90% Imperv		TAC Ratio
	75% TSS Removal				90% TSS Removal					
RAIN GARDENS (low)	$600.69	$3,075.06	$6,044.31	$9,013.56	$905.15	$4,883.16	$9,656.76	$14,430.37	undiscounted $/ha/yr	24.50%
RAIN GARDENS	$660.31	$3,545.17	$7,007.01	$10,468.84	$959.93	$4,937.93	$9,711.54	$14,485.15		
RAIN GARDENS (high)	$750.36	$4,045.71	$8,000.13	$11,954.55	$1,124.25	$5,102.26	$9,875.86	$14,649.47		

	5% Imperv	30% Imperv	60% Imperv	90% Imperv	5% Imperv	30% Imperv	60% Imperv	90% Imperv		TAC Ratio
	75% TSS Removal				90% TSS Removal					
SWALES (low)	$424.00	$880.26	$1,544.17	$2,039.53	$526.24	$1,255.82	$2,271.06	$3,070.57	undiscounted $/ha/yr	46.00%
SWALES	$579.48	$1,036.77	$1,676.77	$2,225.21	$710.27	$1,482.63	$2,422.67	$3,290.06		
SWALES (high)	$1,055.79	$1,504.15	$2,218.59	$2,812.45	$1,252.71	$2,249.23	$3,061.98	$3,987.21		

	Low	Mean	High	undiscounted
RIPARIAN PLANTING	$141.83	$154.68	$167.52	$/m2/yr

	Low	Mean	High	
150 mm dia PIPES	$25	$33	$38	undiscounted $/m/yr
225 mm dia PIPES	$25	$36	$42	
300 mm dia PIPES	$28	$38	$45	
600 mm dia PIPES	$41	$60	$82	
900 mm dia PIPES	$58	$83	$96	

	Low	Mean	High		TAC Ratio
INERT ROOFING	$6	$9	$13	undiscounted $/m2/yr	35.46%
GREEN ROOFS	$21	$44	$68		16.33%

	Low	Mean	High		TAC Ratio
RAIN TANK - 1000 litre	$520	$718	$916	undiscounted $/tank/yr	31.23%
RAIN TANK - 2000 litre	$525	$728	$932		
RAIN TANK - 3000 litre	$540	$738	$935		
RAIN TANK- 5000 litre	$557	$755	$954		
RAIN TANK- 9000 litre	$580	$784	$987		
RAIN TANK- 10000 litre	$598	$800	$1,003		

EROSION AND SEDIME [to be applied over the first 5 years of the life cycle]

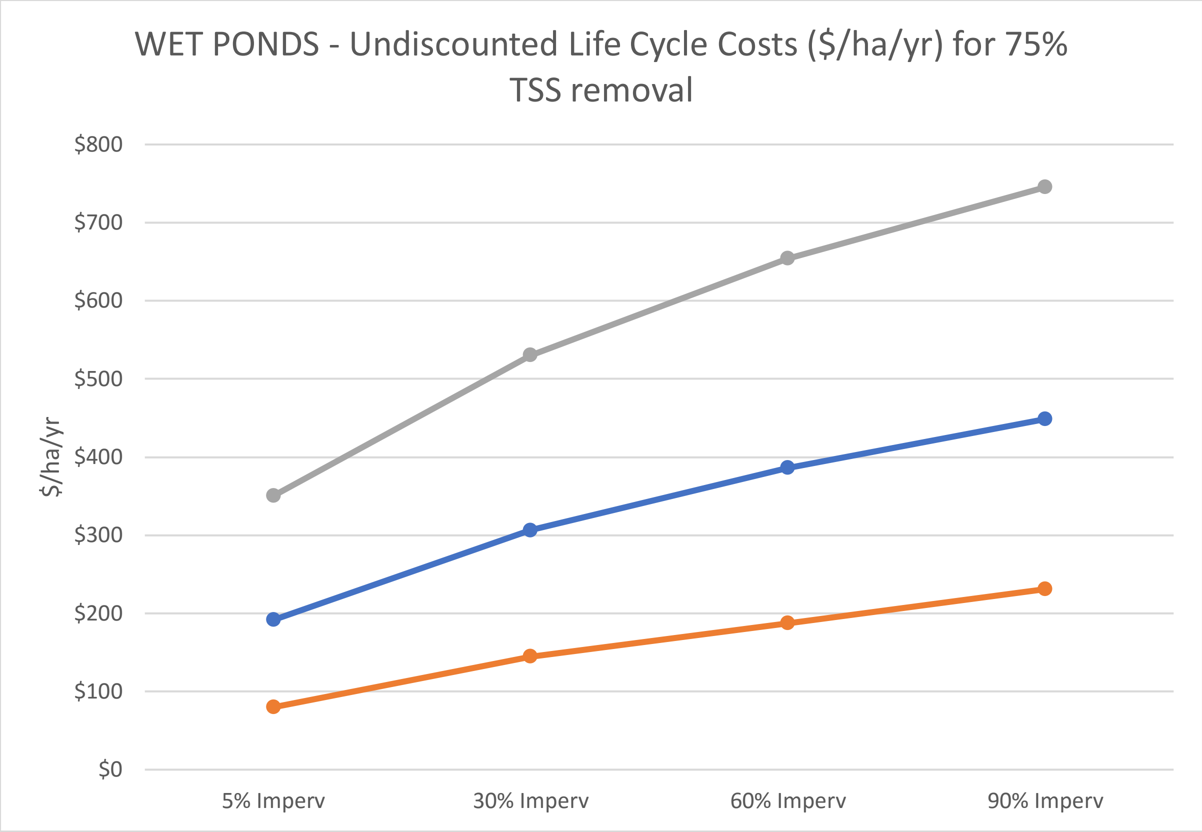
	Low (flat)	Mean	High (steep)	undiscounted
ESC to 90% treatment	$11,471	$12,597	$13,723	$/ha/yr

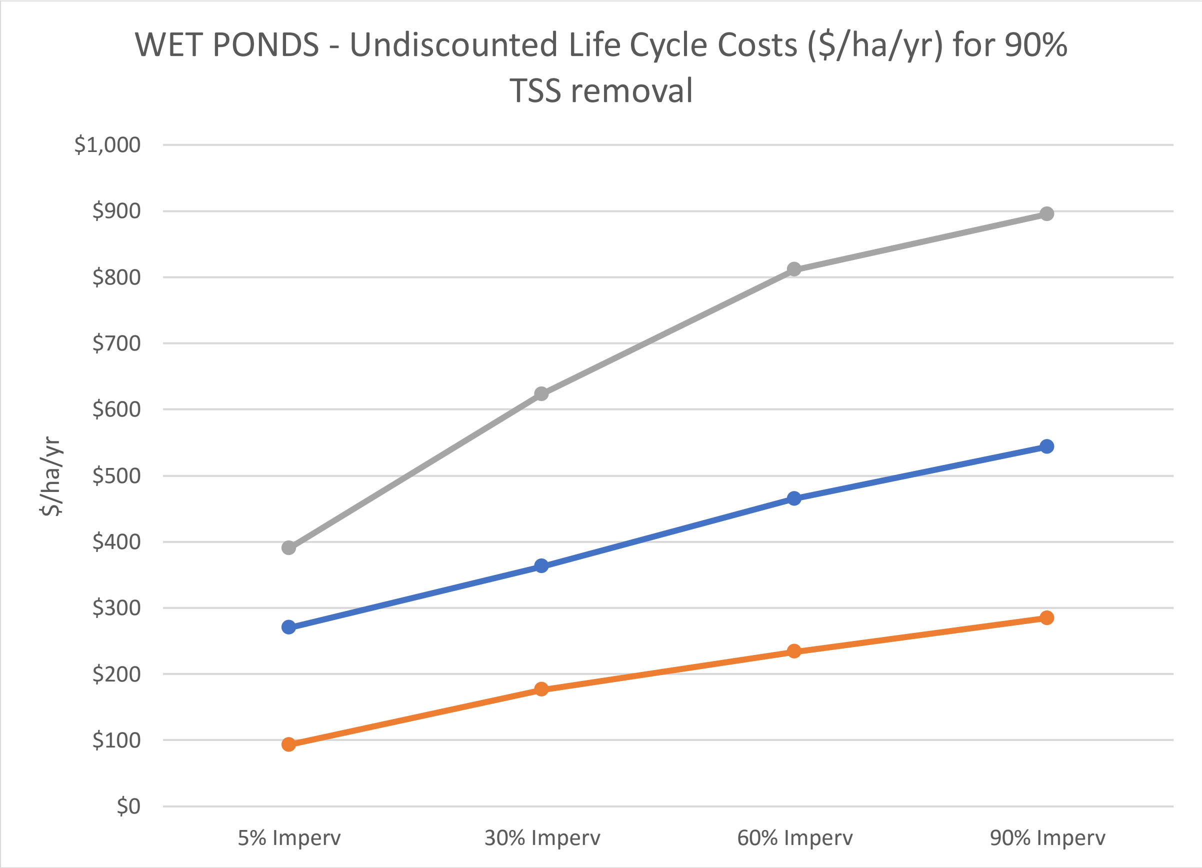
PAVING COSTS

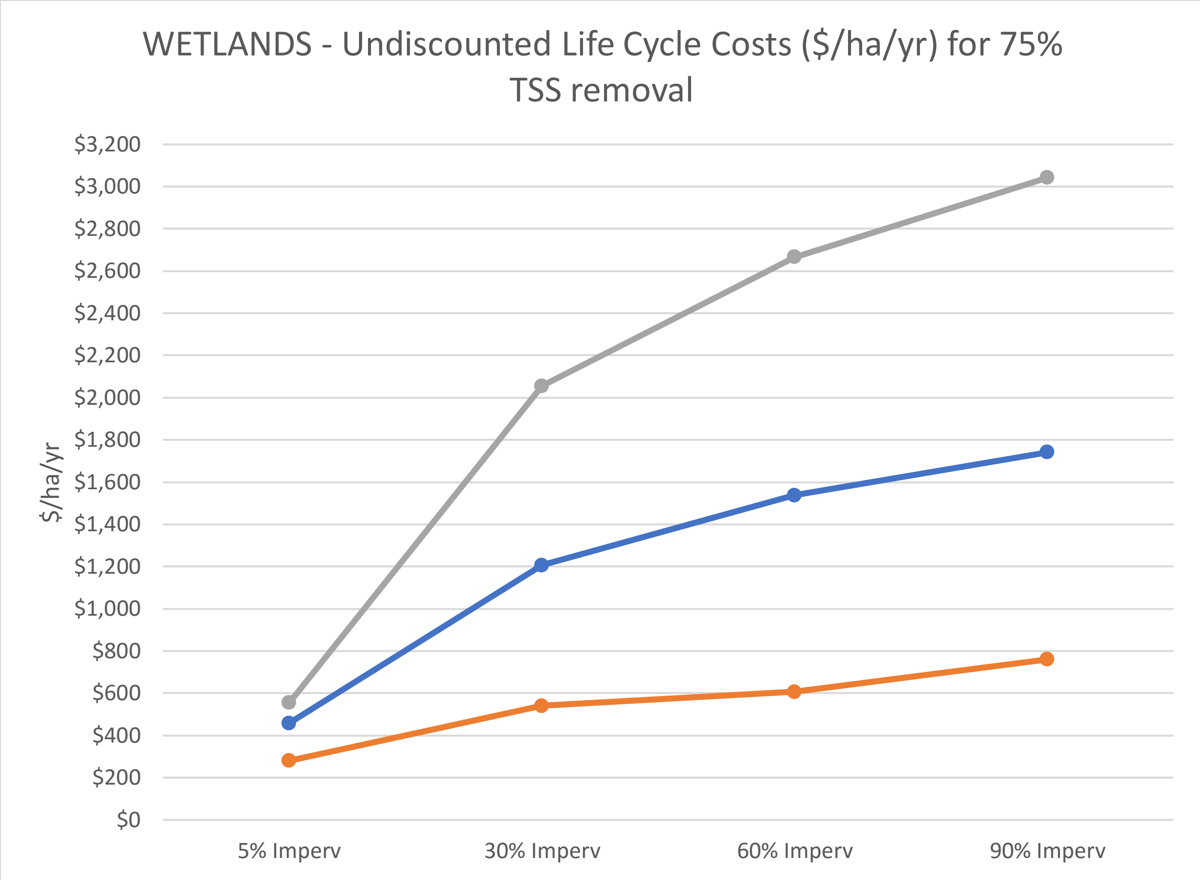
	Low	Mean	High		TAC Ratio
PERMEABLE PAVING	$14	$16	$18	undiscounted $/m2/yr	61.8%
CONCRETE PAVING		$14			41.6%

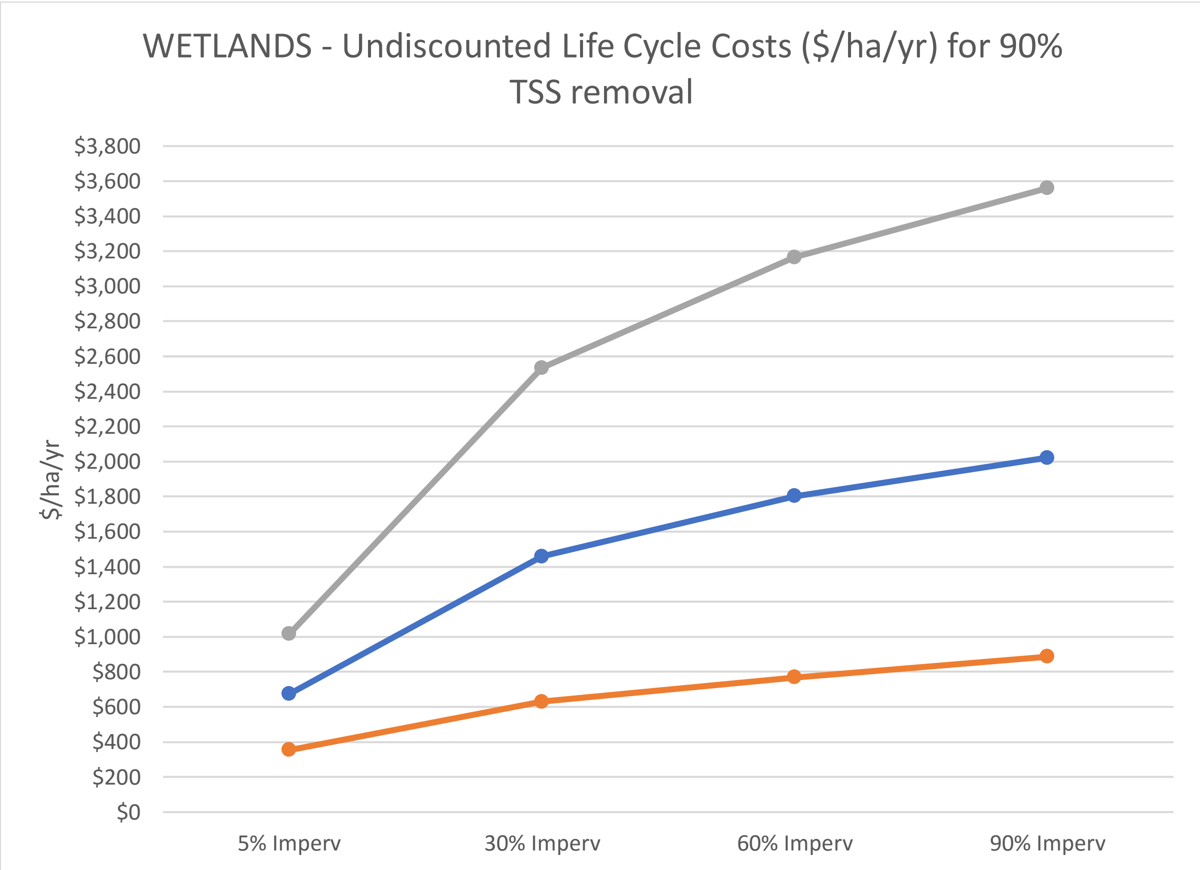
FILTER MEDIA

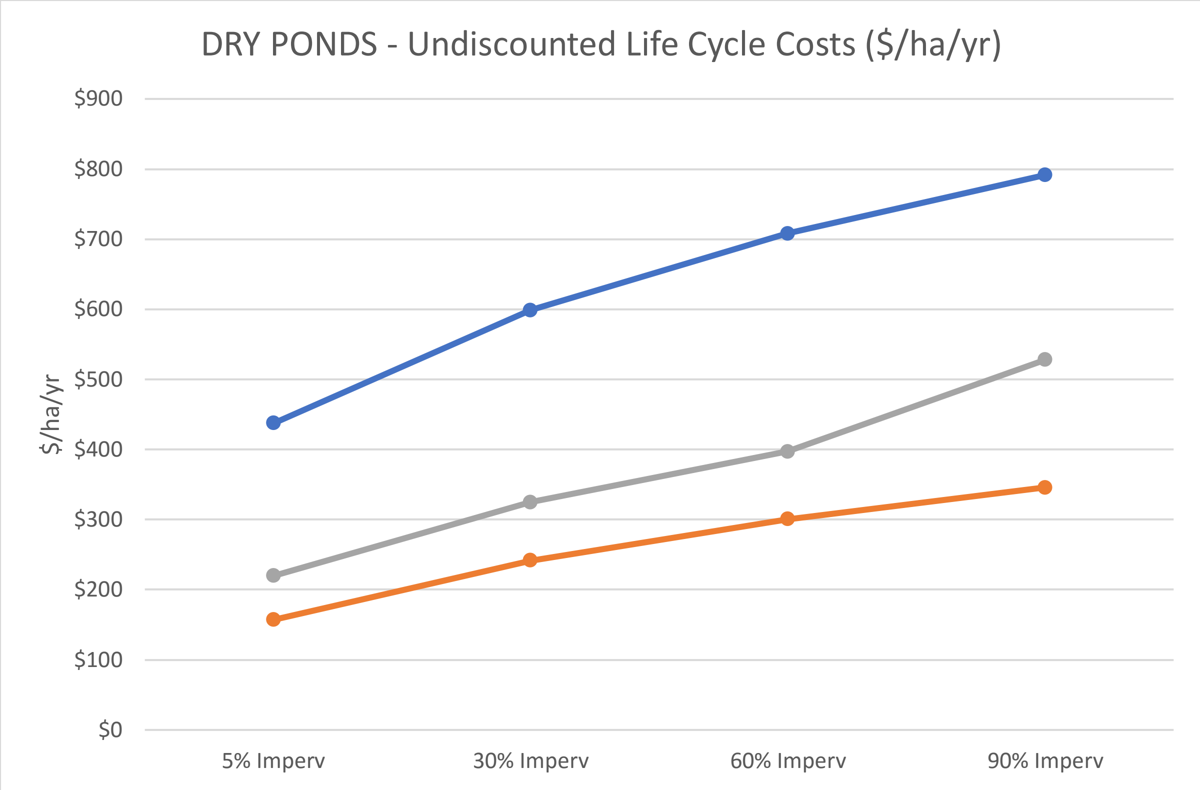
	Low	Mean	High	undiscounted	TAC Ratio
FILTER MEDIA	$4		$5	$/m2/yr	41.9%

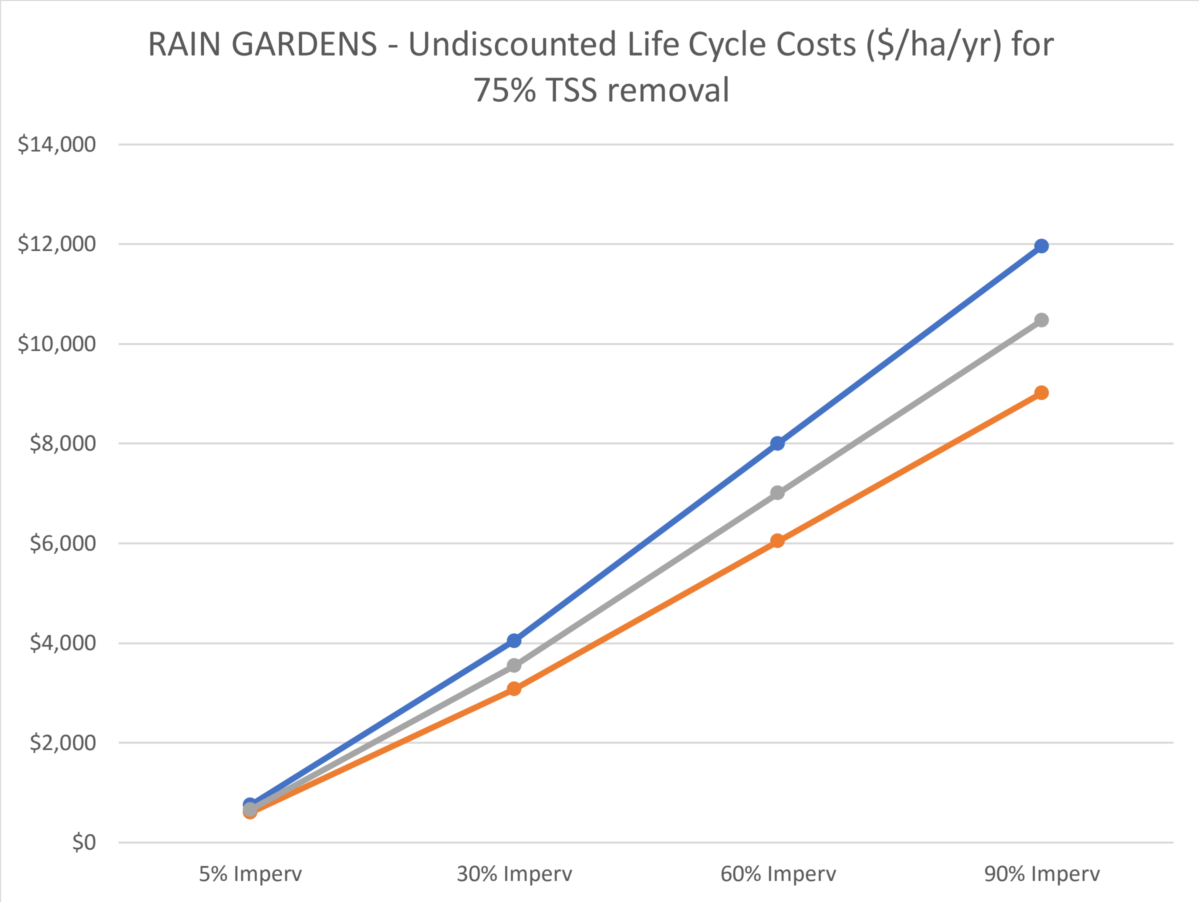

WET PONDS - Undiscounted Life Cycle Costs ($/ha/yr) for 75% TSS removal
$/ha/yr
$800
$700
$600
$500
$400
$300
$200
$100
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv

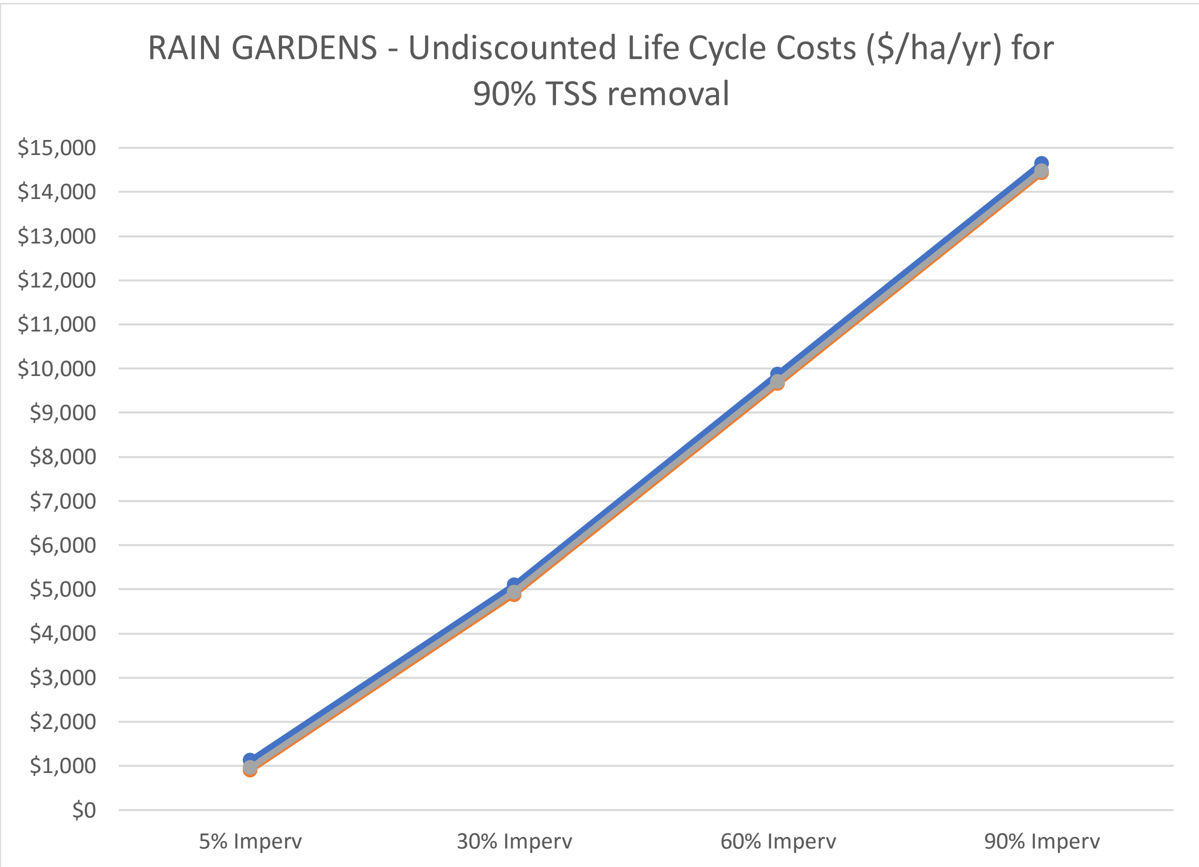

WET PONDS - Undiscounted Life Cycle Costs ($/ha/yr) for 90% TSS removal
$/ha/yr
$1,000
$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv

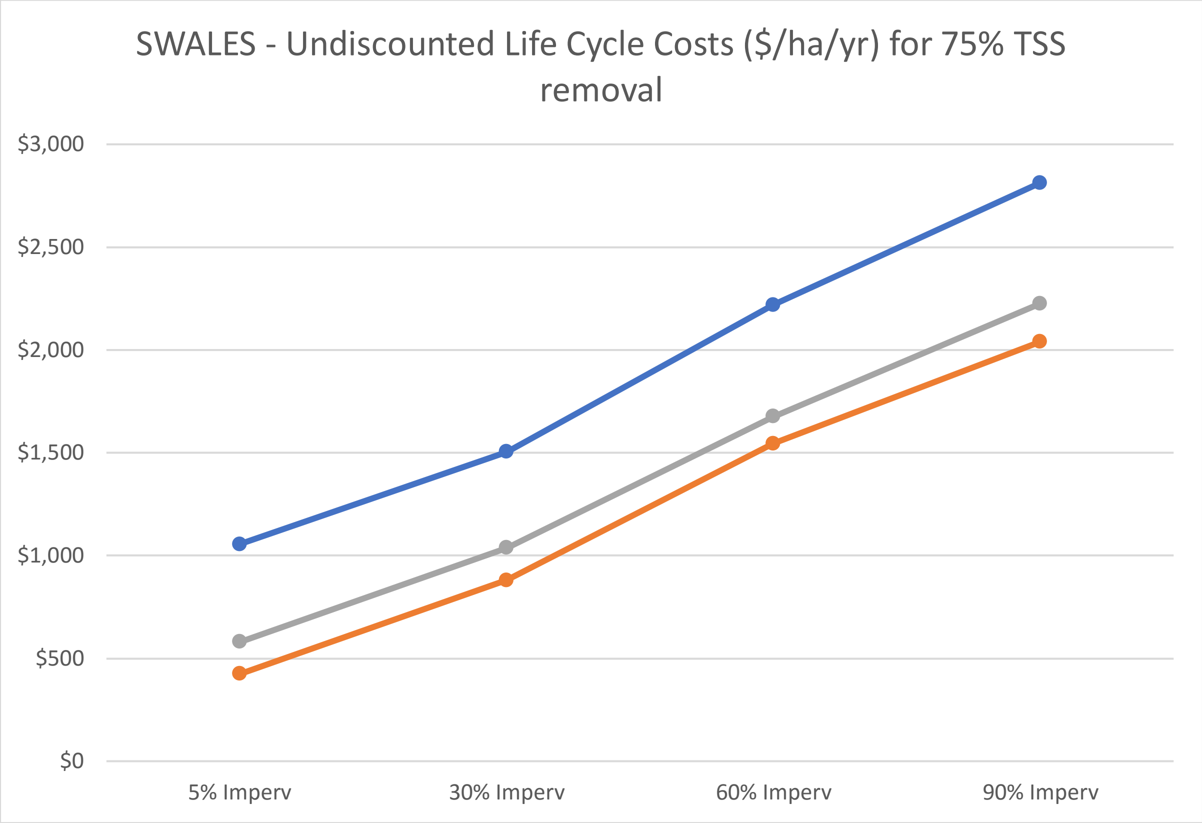

WETLANDS - Undiscounted Life Cycle Costs ($/ha/yr) for 75% TSS removal
$/ha/yr
$3,200
$3,000
$2,800
$2,600
$2,400
$2,200
$2,000
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv


WETLANDS - Undiscounted Life Cycle Costs ($/ha/yr) for 90% TSS removal
$/ha/yr
$3,800
$3,600
$3,400
$3,200
$3,000
$2,800
$2,600
$2,400
$2,200
$2,000
$1,800
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv

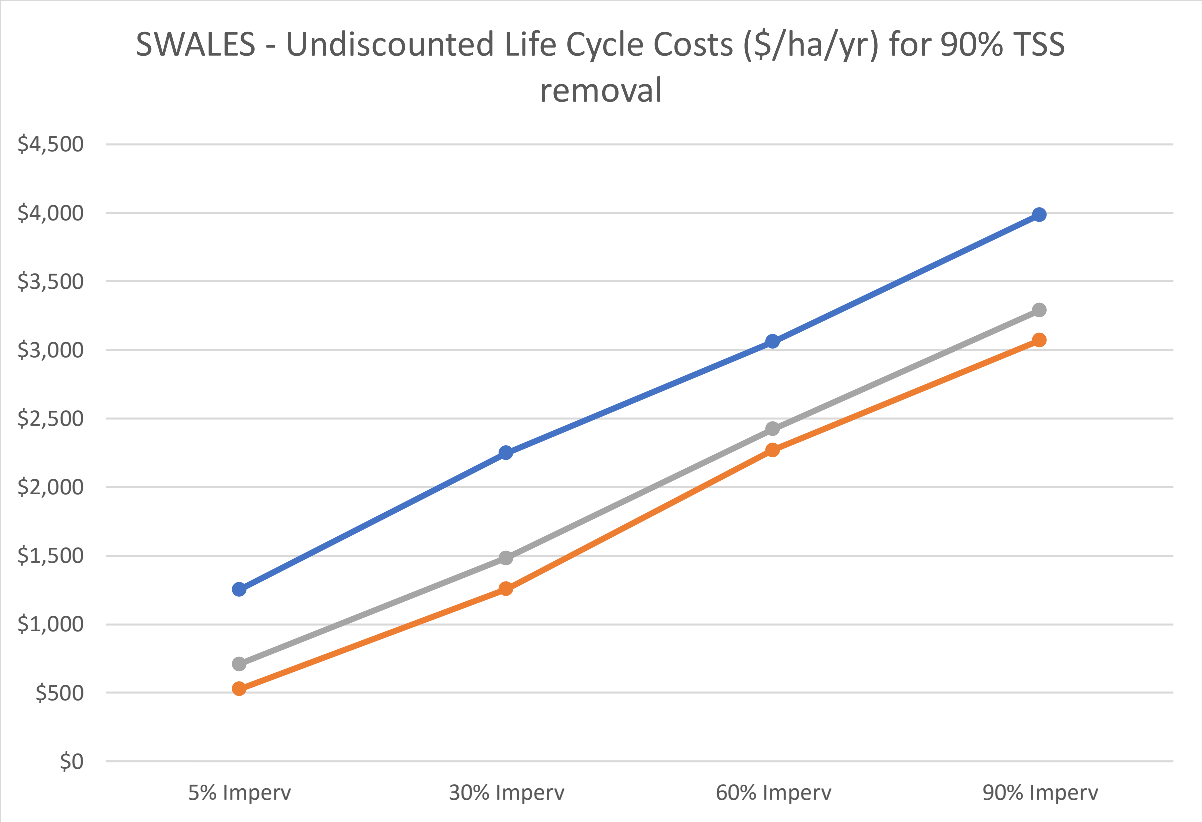

DRY PONDS - Undiscounted Life Cycle Costs ($/ha/yr)
$/ha/yr
$900
$800
$700
$600
$500
$400
$300
$200
$100
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv


RAIN GARDENS - Undiscounted Life Cycle Costs ($/ha/yr) for 75% TSS removal
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv

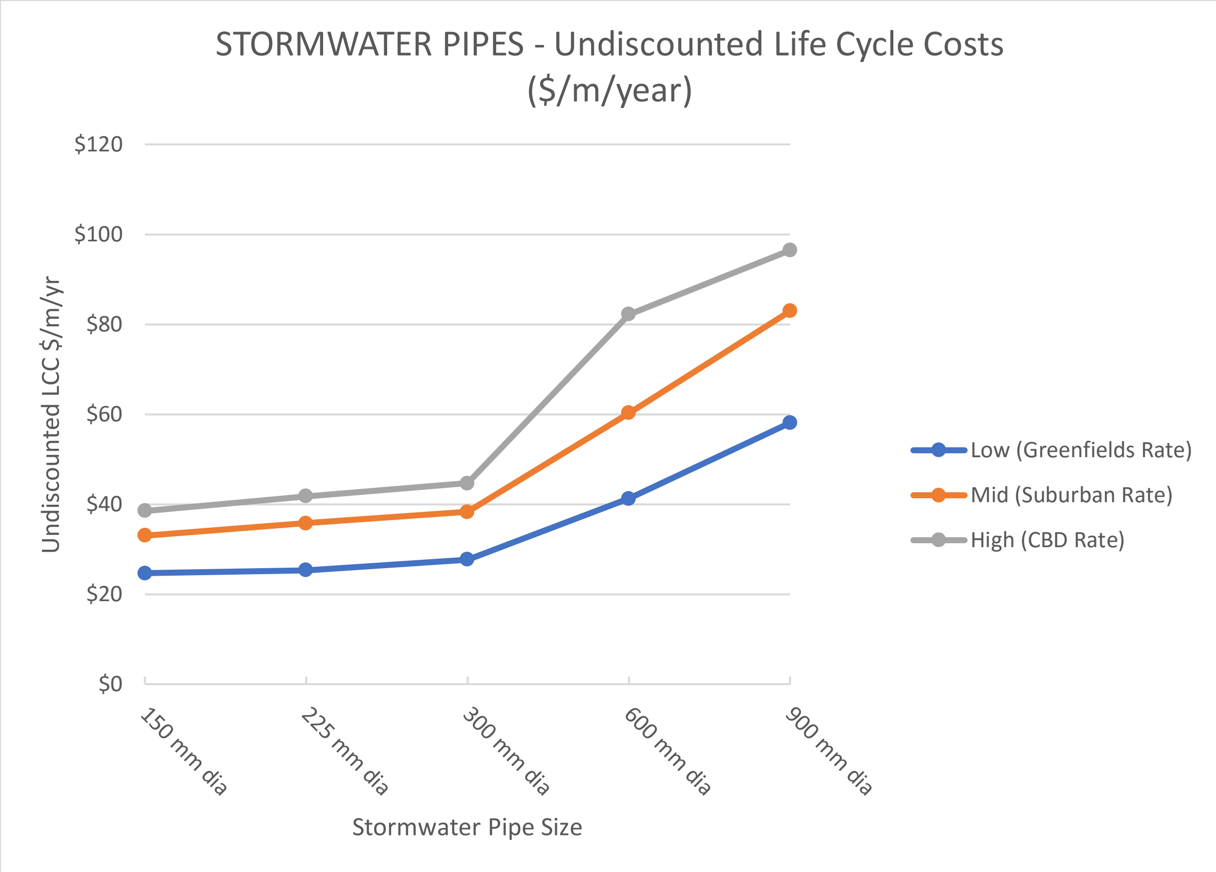

RAIN GARDENS - Undiscounted Life Cycle Costs ($/ha/yr) for 90% TSS removal
$15,000
$14,000
$13,000
$12,000
$11,000
$10,000
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv

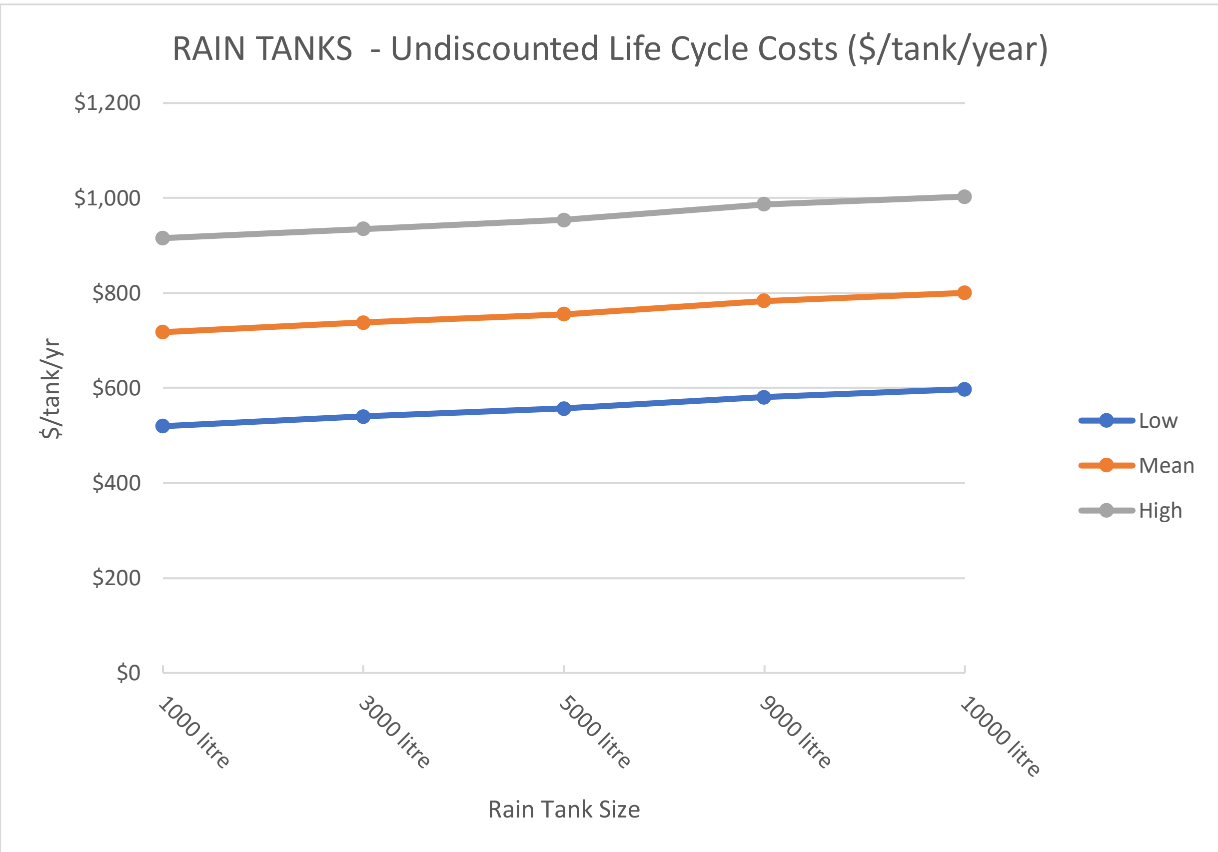


SWALES - Undiscounted Life Cycle Costs ($/ha/yr) for 75% TSS removal
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv



SWALES - Undiscounted Life Cycle Costs ($/ha/yr) for 90% TSS removal
$4,500
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
5% Imperv
30% Imperv
60% Imperv
90% Imperv


STORMWATER PIPES - Undiscounted Life Cycle Costs ($/m/year)
$120
$100
$80
$60
$40
$20
$0
Undiscounted LCC $/m/yr
150 mm dia
225 mm dia
300 mm dia
600 mm dia
900 mm dia
Stormwater Pipe Size
Low (Greenfields Rate)
Mid (Suburban Rate)
High (CBD Rate)


RAIN TANKS - Undiscounted Life Cycle Costs ($/tank/year)
$1,200
$1,000
$800
$600
$400
$200
$0
$/tank/yr
1000 litre
3000 litre
5000 litre
9000 litre
10000 litre
Rain Tank Size
Low
Mean
High

5.2 Development costs

5.2.1 Land costs

COSTnz does not include land costs in the total life cycle analysis. Therefore, in order to generate an accurate catchment-scale LCC, land costs need to be accounted for. Modelling work was undertaken as part of the UPSW stormwater cost model in an attempt to determine whether or not a land cost factor could be used to account for land costs in the different types of development scenarios (i.e. greenfield vs retrofit development). The resulting land cost factors are shown in the tables below. These land cost factors can only be applied to the $/ha/yr life cycle costs. Further work is needed to ascertain what the land cost factor would be for rain tanks, however, this is outside the scope of this study.

The recommended approach in applying the land cost factor is to firstly use the relevant $/ha/yr cost to determine the total LCC for a particular scenario (as sourced from the graphs in Section 5.1), and then multiply the total LCC by the relevant land use factor.

LAND COST FACTORS (per ha)*

Greenfield Catchments				
	25%	**50%**	**75%**	**90%**
Wetlands	0.04	0.07	0.16	0.24
Ponds	0.02	0.04	0.08	0.12
Ponds & Wetlands	0.03	0.05	0.12	0.18
At Source	0.022	0.038	0.052	0.064

Re-development				
	25%	**50%**	**75%**	**90%**
Wetlands	0.08	0.13	0.29	0.41
Ponds	0.04	0.06	0.14	0.21
Ponds & Wetlands	0.06	0.09	0.22	0.31
At Source	0.039	0.067	0.092	0.112

** Note: to apply the landuse factor work out the total LCC for the whole catchment, then muliply that by the factor and add the answer to the LCC.*

5.2.2 Construction costs

As discussed in the deliverable 1 report "Summary of potential solutions available for stormwater, wastewater and water supply provision", many of the cost savings of a WSUD approach relate to avoided costs from site design elements such as reduced pipes, earthworking and impervious areas. These costs (see table overleaf) are generally one-off costs borne at the design and construction phase of a project. A list of rates is provided in the table below to allow the cost differential between conventional vs WSUD site design approaches to be quantified.

SITE DESIGN COSTS (unit costs per element - these are not life cycle costs but construction costs only)								
Construction Elements	**Low (excl design, etc)**	**Total Low**	**Mean**	**High (excl design, etc)**	**Total High**	**Unit**	**Base Date**	**Exclusions/ Comments**
Roading (lower cost for low use roads, higher cost for business/ industrial/ arterial roads)	$320	$368.00	$466	$490	$563.50	m	Q4 2016	excludes signage, testing (3.6% of total roading cost) and kerb/channel
Roading: 110mm vertical kerb and channel (use mean cost if only constructing kerbs)	$50	$57.50	$86	$100	$115.00	m	Q4 2016	
Earthworking - Clearing site	$0.30	$0.35	$1	$1.40	$1.61	$/m² of total earthworks area	Q4 2016	
Earthworking - Strip topsoil	$0.80	$0.92	$3	$5.20	$5.98	m²	Q4 2016	
Earthworking - Cut to fill	$6.40	$7.36	$11	$12.50	$14.38	m³	Q4 2016	
Earthworking - Cut to waste	$26.00	$29.90	$69	$94.00	$108.10	m³	Q4 2016	
Earthworking - Import fill to site	$13.00	$14.95	$45	$65.00	$74.75	m³	Q4 2016	
Earthworking - Restablishment topsoil/grassing	$1.00	$1.15	$5	$8.00	$9.20	m²	Q4 2016	
Earthworking - Sediment erosion control	$0.30	$0.35	$1	$1.40	$1.61	$/m² of total earthworks area	Q4 2016	
Concreting (light to heavily trafficked areas)	$65	$74.75	$106	$120	$138.00	m²	Q4 2016	

6 Conclusions

This report has provided an overview of the method and assumptions used in the life cycle costing process, along with the results of this analysis. Costing models were built for the following stormwater management solutions:

- dry ponds
- wet ponds
- wetlands
- rain gardens
- swales/ filter strips
- rain tanks
- inert roofs
- green roofs
- riparian planting
- stormwater pipes (including manholes and catchpits)
- permeable paving
- filter media
- erosion and sediment control practices

The life cycle costs are summarised in Section 5 as undiscounted $/ unit/ year costs, with a base date of 2017. In addition, a land cost factor has been provided in order to account for land costs for catchment-based and at-source solutions. Finally, in order to quantify the likelihood of avoided costs rendered through a WSUD subdivision, earthworking and impervious coverage (roads, driveways, footpaths) costs have been provided.