EVALUATING THE EQUIVALENCY OF A HIGH RATE BIOFILTRATION BMP TO TRADITIONAL BIOFILTRATION

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ABSTRACT

Los Angeles County defines "biofiltration" based on specific design and sizing criteria. These criteria are similar to New Zealand guidelines for the design of raingardens as detailed in publications from Christchurch City Council and Auckland Council

In recognition of the potential for ongoing advancement and innovation in biofiltration design, Los Angeles County allows for the approval of alternate biofiltration design criteria with appropriate technical demonstration. Similarly the Proposed Auckland Unitary Plan allows innovative treatment solutions to be approved for use if they can demonstrate equivalent performance to the worst performing traditional treatment device as designed in there Technical Publication 10 Design of stormwater treatment devices.

The Filterra bioretention system is an example of a "high rate" biofiltration BMP that is capable of providing equivalent performance to traditional biofiltration, under some conditions but does not "fit the mould" that is established by typical biofiltration design standards.

Geosyntec Consultants undertook an equivalency analysis of performance data of Contech engineered solution's Filterra rapid bioretention product with traditional retention data from the BMP database

Equivalency was determined based on following factors that influence the pollutant load reduction performance of stormwater BMPs:

- Capture efficiency
- Volume reduction
- Pollutant treatment

This paper compares New Zealand design guidelines for raingardens and the Filterra with those evaluated in the Geosyntec report and discusses the equivalency of the two BMP's in a New Zealand context

KEYWORDS

Raingardens, Biofiltration, Performance, Innovative Stormwater treatment, Equivalency

PRESENTER PROFILE

Mike Hannah is the technical director of Stormwater 360. He has had 23 years' experience in stormwater infrastructure engineering. Mike has design, constructed, implemented, monitored and tested numerous stormwater treatment facilities. Mike has also presented some of his research at stormwater conferences in Australia, New Zealand and the USA. Co-founder of Enviropod NZ ltd, Mike has been involved in developing innovative solutions to stormwater management. Stormwater 360 is New Zealand's only specialized stormwater engineering company with an extensive research and development program into innovative treatment solutions.

1 INTRODUCTION

It is well recognised that raingardens, a.k.a bioretention with underdrain or biofiltration systems, are one of the most effective forms of stormwater management (Water Environment Federation Stormwater Institute). This is because they employ a range of hydrological and treatment mechanisms which remove pollutants from runoff.

In general, raingardens are designed to meet a specific set of design parameters that influence the hydrological and treatment mechanisms and in turn ensure that adequate treatment is achieved and the appropriate amount of runoff is treated.

Design parameters are typically prescribed in a jurisdiction's stormwater treatment design manual. These design manuals or approaches are typically referred to in jurisdictional rules and plans. An example of this is the ORDER NO. R4-2012-0175 which has been issued by the Californian water board to meet the requirement of the Los Angeles County MS4 permit.

MS4 permits for municipal stormwater systems are similar to comprehensive discharge permits in New Zealand. As part of their permits, US jurisdictions may issue orders to insure appropriate stormwater measures are implemented. Every MS4 is different and relates the contaminants of concern for a specific water body or catchment.

In New Zealand, councils prescribe rules in regional, district or unitary plans and often refer to specific design manuals such as Auckland City Council's Technical Publication 10, Design of Stormwater Treatment Devices.

ORDER NO. R4-2012-0175 for Los Angeles County requires new development and redevelopment projects to control pollutants, pollutant loads and runoff volumes through minimising impervious areas and controlling runoff through infiltration, bioretention and/or rain water harvesting, unless technically infeasible. The order further prescribes specific design parameters for the design bioretention systems in Los Angeles County in attachment H. (CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD)

In recognition of the potential for ongoing advancement and innovation in biofiltration design, Los Angeles County allows for the approval of alternate biofiltration design criteria with appropriate technical demonstration.

Geosyntec Consultants undertook an equivalency analysis of performance data of Contech engineered solution's Filterra rapid bioretention product with traditional retention data from the BMP database.

This paper compares the design parameters prescribed in Attachment H with Auckland Council and Christchurch City Council design guidelines. The paper then discusses how these parameters influence the hydrological and treatment performance of a raingarden and compares this with a Filterra design in a New Zealand context.

2 BMP DESCRIPTIONS

2.1 CONVENTIONAL BIOFILTRATION.

Biofiltration (also known as bioretention with underdrain or a raingarden) consists of shallow landscaped depressions that capture and filter stormwater runoff through a planted engineered media. These facilities function as soil and plant-based filtration systems that remove pollutants through a variety of physical, biological, and chemical treatment processes. Biofiltration facilities normally consist of a ponding area, a planted biofiltration soil layer topped with mulch and underlain by a gravel bed encasing an underdrain pipe. As stormwater passes down through the mulch and soil, pollutants are filtered, adsorbed, and biodegraded by the soil and plants.

The Los Angeles County MS4 Permit (Order No. R4-2012-0175) (MS4 Permit) defines conventional "biofiltration" based on specific design and sizing criteria including a design infiltration rate of 125 to 300 mm/hrs. and a biofiltration media comprised of 60 to 80% fine sand and 20 to 40% compost (organic content). Other design parameters such as media depth, internal water storage zone and ponding depth are specified in Attachment H of the order.

In Christchurch, the Christchurch City Council Raingarden Design Manual (Christensen)is an updated set of design criteria for raingardens published in 2013. The Christchurch design manual supersedes design guidance issued in Waterways, Wetlands and Drainage Guide (Christchurch City Council).

In Auckland, design criteria are specified in TP10 (Auckland Regional Council, 2001), however council is currently reviewing these criteria which are expected to be published with the update of TP10. Reference to design criteria include the new draft standard. (Blackbourn)

The Figure below is an example of a convention rain garden design as specified in the Christchurch city council raingarden design manual. (Christensen)

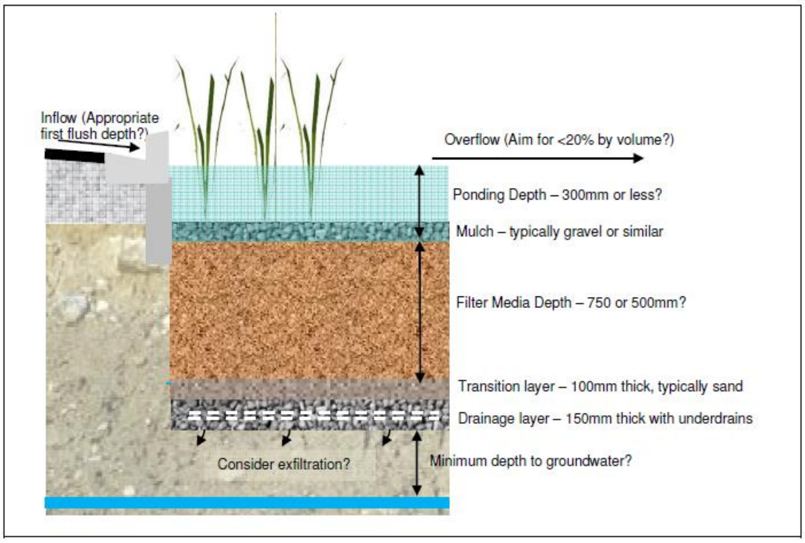

Figure 1: Cross section of typical raingarden

The table below lists the specified design parameters detailed in design manuals from the Los Angeles area and New Zealand. The table also gives representative design criteria used for screening raingarden performance data from the BMP database.

Design Assumption	Design References					Selected Representative Design Assumption
	MS4 Permit Att. H	City of LA LID Manual	Ventura County TGM	Auckland Council	Christchurch City Council	
Design Annual runoff treated goal	85%	85%	85%	81 - 88%	83%	
Runoff Depth	25.5	25.4	25.4	23.3 - 36.7	20	
Ponding Depth, (mm)	150 – 450	150 - 450	150 - 450	300	300	450
Media Depth, (mm)	600 - 900	600-900	600-900	600	600	600
Gravel "sump" depth below underdrain, (mm)	Not specified; narrative	300-600	150 (min)	not currently specified but likely to be included in new design manual	300	Depth that would drain in 24 hours. For example, 450mm if site infiltration rate estimated at just less than 0.3 in/hr
Media Filtration Rate, mm/hr	130 - 305	130 - 305	25	12.5 - 200	30, 50-100	25
Allowable Routing Period for Biofiltration Treatment, hrs.	Not specified	**3** hours, unless using a routing model	Depth up to ponding depth (450 mm) can be considered routed	48 hr	10 hrs.	6 hours

Table 1: Raingarden Design Criteria New Zealand and Los Angeles County

2.2 FILTERRA SYSTEMS.

Filterra systems are fundamentally similar to conventional biofiltration with a two notable exceptions. The bioretention media is engineered to provide a much higher design infiltration rate (2500 mm/hr) which results in substantially smaller system footprints. They are also commonly housed in a precast vault. As a result of smaller footprints and impermeable bottoms, the amount of volume reduction (via infiltration and evapotranspiration) that is typically observed in these systems when not coupled with infiltration systems tends to be relatively low. Filterra systems are typically sized as "flow-based" BMPs based on a design intensity of rainfall rather than "volume-based" BMP based on a design storm depth.

3 SIZING OF NEW ZEALAND RAINGARDENS AND FILTERRA'S

There are two broad types of Stormwater BMP's. Volume Based and Flow based. Volume based BMP store and treat a certain volume of water while flow based BMP's treat water at a certain flow rate and do not require a stored volume of water.

Traditionally, stormwater treatment devices have been sized to treat a water quality volume. This is because traditionally the main way of providing stormwater treatment was through Stormwater settling ponds. The water quality volume was determined to be between 80 – 90% of the annual runoff volume. This design storm is typically selected to provide a reasonable balance between economic feasibility and performance beyond which the incremental benefit of providing extra treatment capacity comes at a disproportionately high cost.(Auckland Regional Council, 1992)

As new ways of treating stormwater have been developed, rate–based design methods where developed that ensure that the same volume of water was treated. One example of this was sandfilter and raingarden design. Which uses Darcy's law to determine a flow rate through a soil and then routes the water quality volume through the soil by using the ponding depth as the storage volume. (Christensen)

Another method involves a cumulative frequency analysis of rainfall to determine a design rainfall intensity below which the targeted percentile of the annual rainfall depth falls at or below. Attached is an example of this analysis from the Christchurch StormFilter design rainfall intensity criterion report. (Christensen)

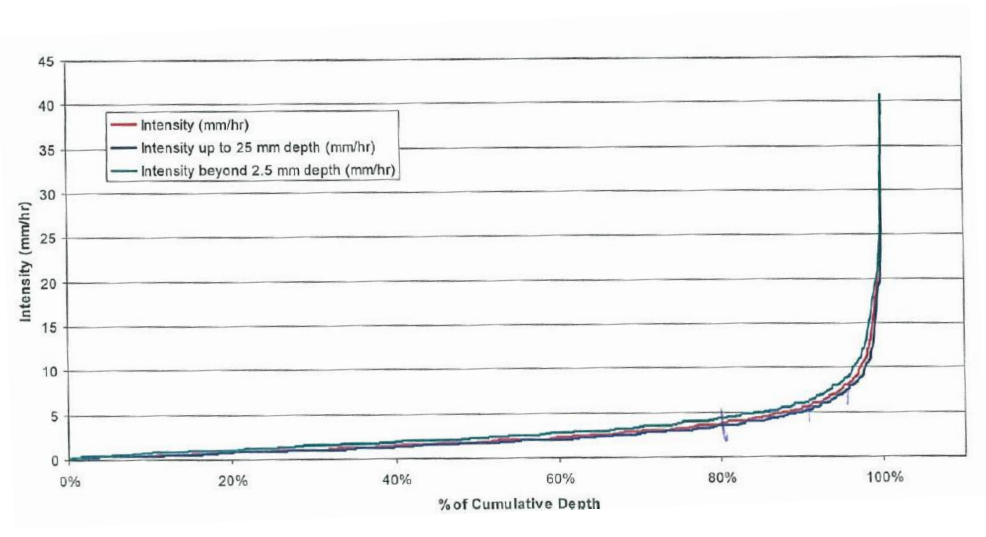

Figure 2: Cumulative frequency analysis for flow based treatment devices Christchurch

Filterra has a much higher infiltration rate than a traditional raingarden, therefore it does not require substantial upstream storage. Therefore it is proposed to size the Filterra as a flow base treatment device. The treatment flow rate of a Filterra is simply determined by multiplying the surface area by the infiltration rate

4 BASIS AND EVALUATION OF EQUIVALENCY

4.1 BASIS FOR EQUIVALENCY

Equivalency was evaluated between conventional biofiltration BMPs meeting the criteria of the MS4 Permit (specifically Attachment H) and Filterra systems as an alternate biofiltration BMP. Equivalency was determined based on the factors that influence the pollutant load reduction performance of stormwater BMPs:

- **Capture efficiency**: The percent of long term stormwater runoff volume that is "captured" and managed by the BMP (i.e., treated or reduced; not overflowed or bypassed).
- **Volume reduction**: The percent of long term stormwater runoff volume that is "lost" or "reduced" in the BMP to infiltration and evapotranspiration.
- **Pollutant Treatment**: For the volume that is treated and not reduced, the average difference in concentration between the influent volume and the treated effluent volume.

4.2 CAPTURE EFFICIENCY

4.2.1 CONVENTIONAL RAIN GARDEN CAPTURE EFFICIENCY

Geosyntec under took long-term continuous simulation SWMM modeling to estimate the long-term capture efficiency and volume reduction of the baseline biofiltration design scenario for the LA region. The modeling showed that standard rain garden design to the Californian specification would have a 92 – 94 % capture rate of annual runoff.

Auckland Council has undertaken an analysis of the capture and treatment volumes for both volume and flow based treatment devices. The details of this analysis are included in appendix c of Auckland Council Technical Report 13/35 (Auckland Council, 2013). The analysis used data from 11 rain gauges from across Auckland and determined that volume based treatment devices such as ponds or wetlands, designed to 1/3 of a 2 yr storm, would treat between 81% – 90 % of the annual runoff. In the study, areas in Auckland with higher rainfall were found to have a lower percentage capture of the annual runoff.

Auckland Regional Council Technical Report 67/10 (shemseldin) undertook a continuous modeling exercise of a standard raingarden with data from 6 rain gauges over 8 years. This study showed that a standard raingarden (infiltration rate 12.5mm/hr) had a capture efficiency of between 63% and 88% of the annual runoff. This study also showed areas of higher rainfall had less capture efficiency.

The Christchurch raingarden design guide has determined that a raingarden designed to the specified parameters would obtain an 83% capture rate. This analysis was undertaken with data from one rain gauge over 50 years.

4.2.2 NEW ZEALAND FILTERRA CAPTURE EFFICIENCY

It is proposed that Filterra be sized as a flow based system since its high infiltration rate allows it to treat runoff without a significant upstream ponding volume. For flow based treatment systems, i.e. swales and proprietary devices, Auckland Council determined (Auckland Council, 2013) that if these devices where capable of capturing and treating all runoff from a storm intensity of between 9.06 mm/hr and 9.96 mm/hr, 90% of the runoff would be treated. From this analysis it was proposed that all flow based treatment devices be designed to a minimum rainfall intensity of 10mm/hr.

It needs to be noted that the analysis was very simple and conservative for the following reasons

- The analysis assumed all rainfall would turn to runoff without any time lag
- The analysis assumed that if the runoff flow rate was greater than the treatment flow for a given time step, the excess flow rate would bypass no treatment at all, would occur.
- The analysis did not allow for any storage in the device such as a ponding volume.

In reality there will be some flow reduction from initial abstraction, as well on larger catchments a lag in the collection system. Many flow based treatment devices such as rapid bioretention devices will continue to treat while in bypass. Further given the high flow rates of flow-based devices, if a small storage volume is incorporated in the design much higher capture efficiencies can be obtained.

Christchurch City also undertook an analysis of flow based treatment devices in the Stormfilter Design Rainfall Intensity Criterion Report. (Parsons) This analysis included an initial abstraction factor and considered treatment during bypass. The table below details the results.

Rainfall	Treatment	80% capture	90% capture	95% capture
All 30 minute records	Treatment during bypass	2	3	4.5
All 30 minute records	No treatment during bypass	4	5.5	7.5
Intensities within first 25 mm of event	Treatment during bypass	2	3	4
2.5 mm minimum wash off depth	Treatment during bypass	2.5	3.5	5

Table 2: Flow Based Design Intensity and Capture

Sizing the Filterra as a flow based system without a ponding depth to treat a rainfall intensity of 10mm/hour in Auckland and 5mm/hour in Christchurch with treat an estimated 95 % of the runoff. The standard Filterra design also includes a 200 mm ponding depth to the curb which adds an additional buffer.

4.3 VOLUME REDUCTION

Volume reduction is not a common stormwater management objective currently in New Zealand. This being said, volume reduction is a fundamental management mechanism for protection of the natural water cycle and stream health. Volume reduction also has a large effect in contaminant load reduction as this effectively provides 100% removal of contaminants.

Volume reduction is achieved in two ways; infiltration, and evapotranspiration. It is important to note the infiltration for volume reduction is different to infiltration for soakage disposal as commonly used in New Zealand. Infiltration for volume reduction involves infiltrating a percentage of the annual runoff (<30%) into low in low permeability soils. The main governing factor for how much water is infiltrated is the soil type and infiltration rate where the device is located. The table below lists infiltration rates for different soil types.

USDA Soil Texture Classification	Ultimate infiltration rate (mm/hr)	Infiltration Type
Clay	0.6	Poor
Silty Clay	1.0	
Sandy Clay	1.2	
Clay Loam	2	
Silty Clay Loam	2	
Sandy Clay Loam	3	
Silt Loam	7	Moderate
Loam	13	
Sandy Loam	22	Free
Loamy Sand	60	
Sand	230	

Table 3: Typical Soil Infiltration Rate, (Christchurch City Council, 2003)

The main factors that influence how much runoff can be evapotranspired are as follows (University, n.d.);

- Temperature
- Humidity
- Wind Speed
- Plant available water capacity in media
- Soil Type
- Plant Type

Examination of annual potential evapotranspiration (PET) (Harold Mooney) (Andrew Tait) suggests evapotranspiration in Los Angeles (2500 mm/hr) is approximately 2.5 times greater than Christchurch or Auckland. Auckland has slightly higher annual PET (900 - 1000 mm/yr) than Christchurch (800-900 mm/yr)

The proposed Auckland Unitary Plan includes a 5 mm volume reduction rule in identified sensitive stream catchments. In addition to the volume reduction criteria 20 – 25 mm detention storage is required in these catchments

4.3.1 VOLUME REDUCTION IN A CONVENTIONAL RAINGARDEN

Modelling by Geosyntec consultants for a conventional raingarden in Los Angeles, CA showed a 4% reduction through ET. In systems with some infiltration capacity, the majority of the volume reduction was achieved through infiltration and storage below the raingarden, i.e. an integrated water storage zone. The addition of an integrated water storage allows water to infiltrate into surrounding soils between storm events. The table below lists the volume reduction obtainable from a standard raingarden in soils with differing infiltration rates

Site Soil Infiltration Rate, mm/hr	Long Term Volume Reduction (percent of total runoff volume) (ET + Infiltration)
0	4%
0.2	6%
1.3	11%
3.8	22%
7.6[2]	35%

Table 4 Conventional Biofiltration Volume Reduction in Los Angeles

2 - A maximum soil infiltration rate of 0.3 inches per hour (7.6 mm/hr) was evaluated because for soil infiltration rates greater than 0.3 inches per hour, the MS4 Permit requires that infiltration be utilized.

New Zealand design guides suggest the use of an internal water storage zone to enhance performance however it is not mandatory to incorporate them. The volume reduction through a New Zealand designed conventional raingarden without an internal water storage zone would be limited to evapotranspiration unless the device was located in permeable soils.

4.3.2 VOLUME REDUCTION IN A FILTERRA

Modeling by Geosyntec showed the Filterra had an evapotranspiration volume reduction of 1% as opposed to 4% in a conventional raingarden. Given the foot print of a Filterra is considerably smaller than a conventional raingarden this is reasonable. Geosyntec assumed zero infiltration through the bottom of the Filterra.

The reduced evapotranspiration and infiltration through the Filterra results in a volume reduction deficit which would need to be compensated for either by treating more of the annual flow volume or by adding subsurface infiltration capacity, e.g. retention chambers. The volume and area of this additional infiltration capacity will be dependent on the infiltration rate of the surrounding soils.

4.4 POLLUTANT TREATMENT

4.4.1 CONVENTIONAL RAINGARDEN POLLUTANT TREATMENT.

Geosyntec analysed the pollutant treatment performance of a conventional raingarden by an analysis of all bioretention with underdrain studies in the International Stormwater BMP Database. Four supplementary studies were also included from California and

Maryland to make a total of 32 studies. A further analyses was also conducted on a screened subset of studies that were considered to be most representative of LA raingarden design criteria (20 studies). (Geosyntec Consultants, 2015)

Treatment performance for total suspended solids, total phosphorus, total nitrogen, total copper, and total zinc was characterized using a moving window bootstrapping method that accounts for the influence of influent concentration on effluent concentration and characterizes the relative uncertainty in performance estimates within each range of influent quality. Both the median and mean summary statistics were evaluated using these methods. Influent concentrations characteristic of single family, multi family, commercial, and light industrial land uses were applied to estimate effluent concentrations and concentration change.

Generally, biofiltration provided good removal of TSS, moderate removal of copper and zinc, and generally showed nutrient export. Export of nutrients tended to be greater when influent concentrations were low. Also, the dataset that was screened to include studies more similar to Attachment H design criteria (i.e., 125 – 300 mm/hr, with compost) showed substantially greater frequency of observed export of nutrients.

Establishment of the stormwater water quality objectives for the Auckland unitary plan also drew on the same data set i.e. bioretention studies from the BMP database (Auckland Council, 2013). The key design criteria that affect pollutant removal are infiltration rate, media depth and media composition. Design infiltration rate and media depth specified in New Zealand design manuals are in the range of LA design criteria and the representative design criteria chosen by Geosyntec for comparison. New Zealand design manuals also provide guidance on a desired particle size distribution or soil texture, however no guidance is given for organic content. Given the lack of peer reviewed bioretention studies in New Zealand, this methodology was determined to be representative of all bioretention.

4.4.2 FILTERRA POLLUTANT TREATMENT.

Filterra performance data was analyzed using the same moving window bootstrapping methods used for conventional biofiltration. Data from 6 third party studies conducted over the last 11 years (including some studies monitored periodically since 2007) were utilized in this analysis.

- **TSS:** Filterra performed somewhat better than conventional biofiltration systems for TSS across all representative land use concentrations considered. Both systems showed relatively strong performance for TSS.
- **Copper and Zinc:** Performance was generally similar between Filterra and conventional biofiltration for copper and zinc. Filterra showed better performance for some representative influent concentrations and conventional biofiltration showed better concentration reductions for others. Both provided moderate concentration reductions.
- **Nitrogen and Phosphorus:** Filterra systems appear to provide much better pollutant concentration reduction than conventional biofiltration for nitrogen and phosphorus. Filterra does not appear to exhibit the export issues that were noted for conventional biofiltration within the representative range of land use concentrations considered. Variability in pollutant reduction performance was also lower for Filterra.

Comparison was achieved through a moving bootstrap method (Leisenring et al., 2009). This method characterizes influent-effluent relationships such that the BMPs compared do not need to have been studied under conditions with similar influent quality. In this approach, all data pairs are used to form the total sample population. Then for each increment of influent quality, a subsample of the overall population is formed including only those data pairs that lie within a certain span of the selected influent quality. Applying bootstrap principles (Singh and Xie, 2008), the median and the confidence interval around the median is computed as well the mean and the confidence interval around the mean. Then a new increment of influent quality is selected and the process is repeated with a new subsample population until a statistical description of effluent quality has been developed for each increment of influent quality over the range of the data. (Geosyntec Consultants, 2015)

The figures below show the comparison for TSS and total Zinc for a convention raingarden and the Filterra using the moving mean bootstrap method.

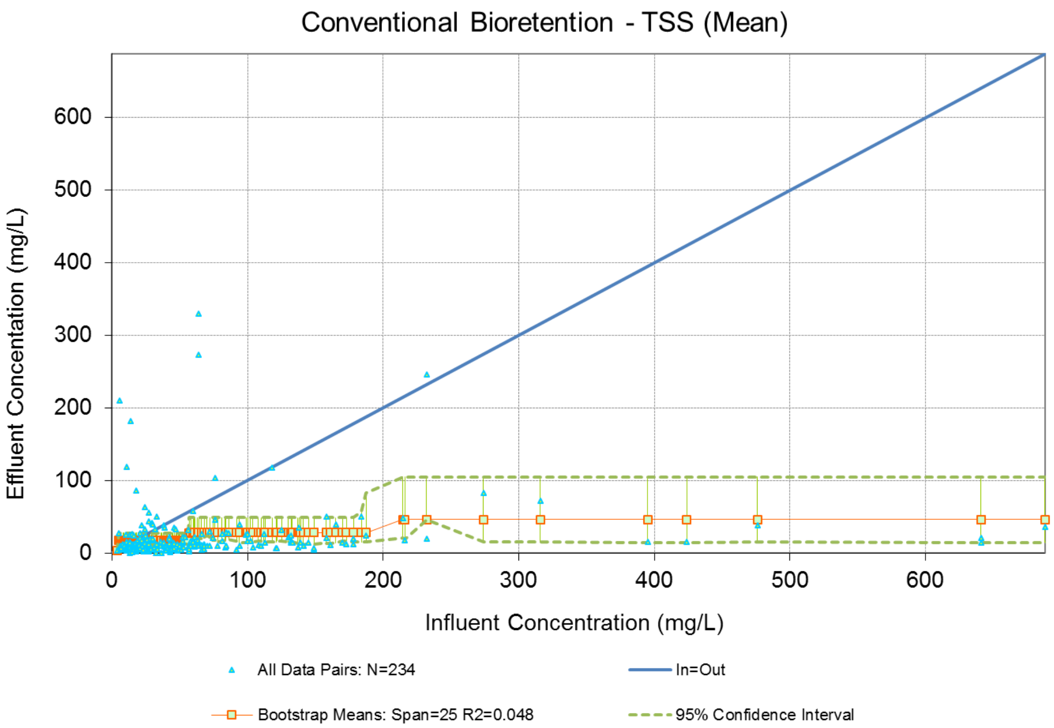

Figure 3: Conventional Bioretention TSS Performance Estimate, Screened Studies (Geosyntec Consultants, 2015)

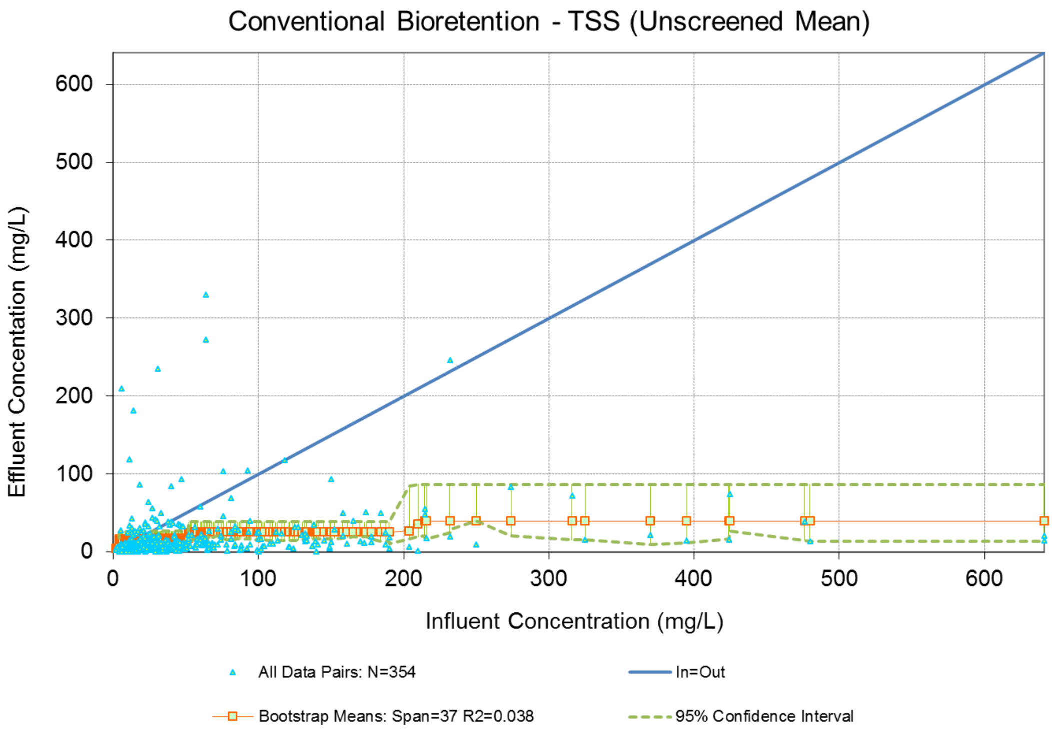

Figure 4: Conventional Bioretention TSS Performance Estimate, All Studies (Geosyntec Consultants, 2015)

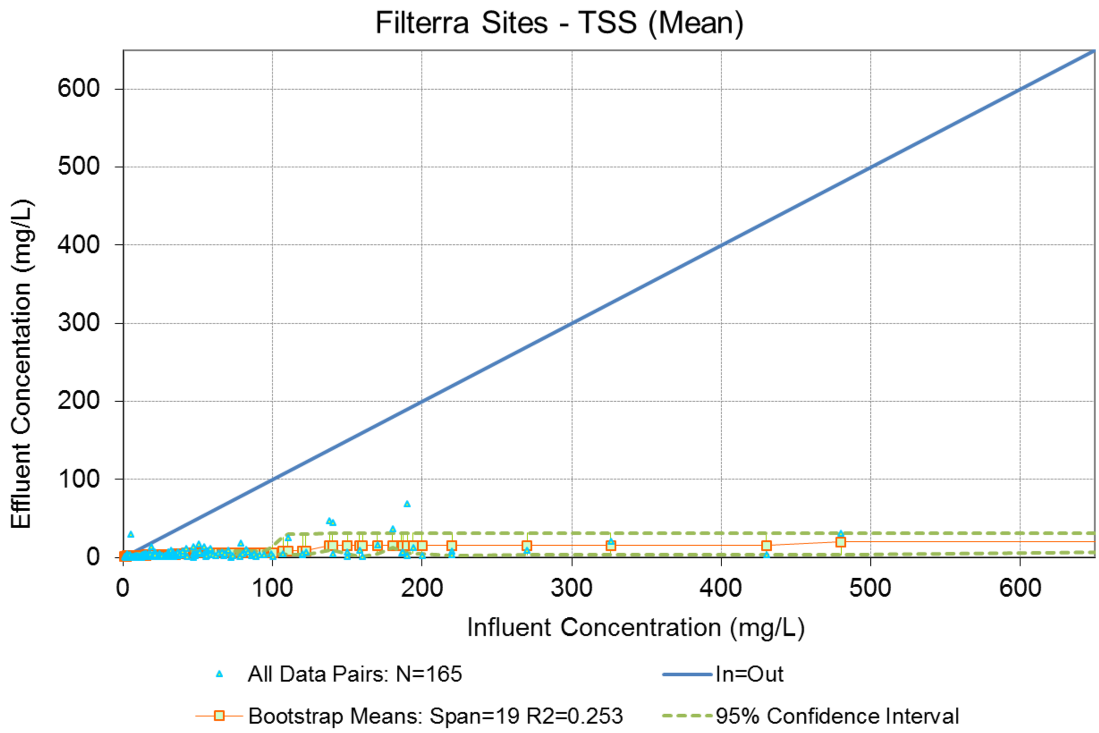

Figure 5: Filterra TSS Performance Estimate (Geosyntec Consultants, 2015)

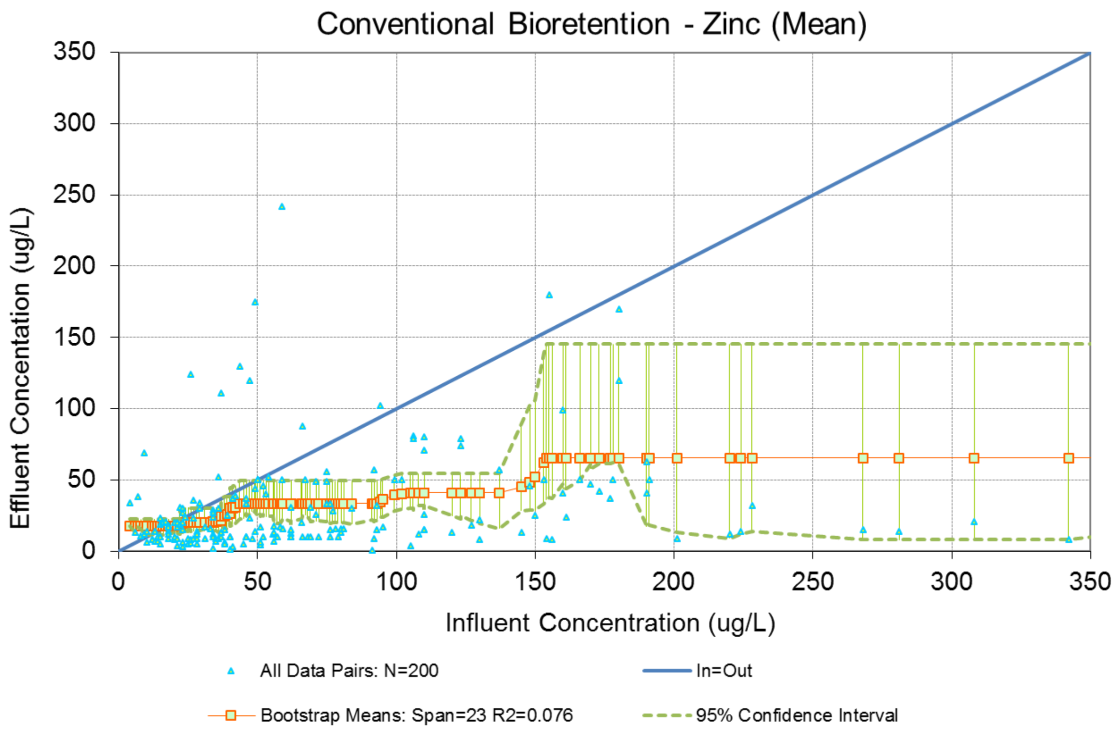

Figure 6: Conventional Bioretention Zinc Performance Estimate, Screen Studies (Geosyntec Consultants, 2015).

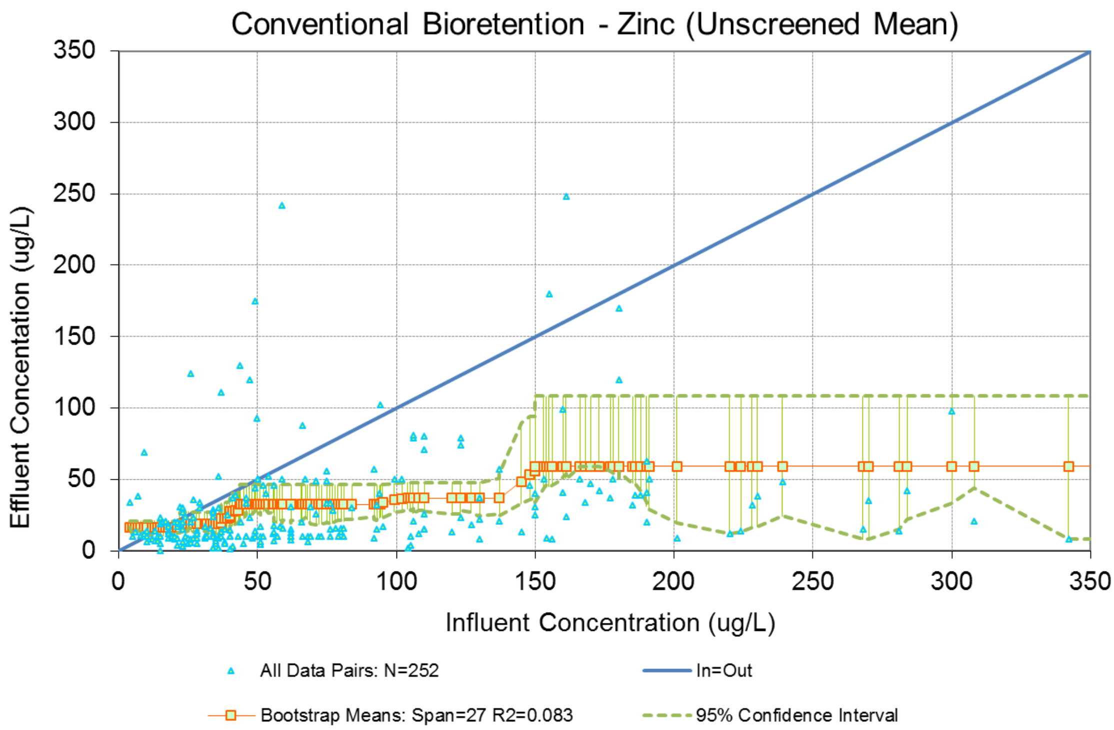

Figure 7: Conventional Bioretention Zinc Performance Estimate, All Studies (Geosyntec Consultants, 2015).

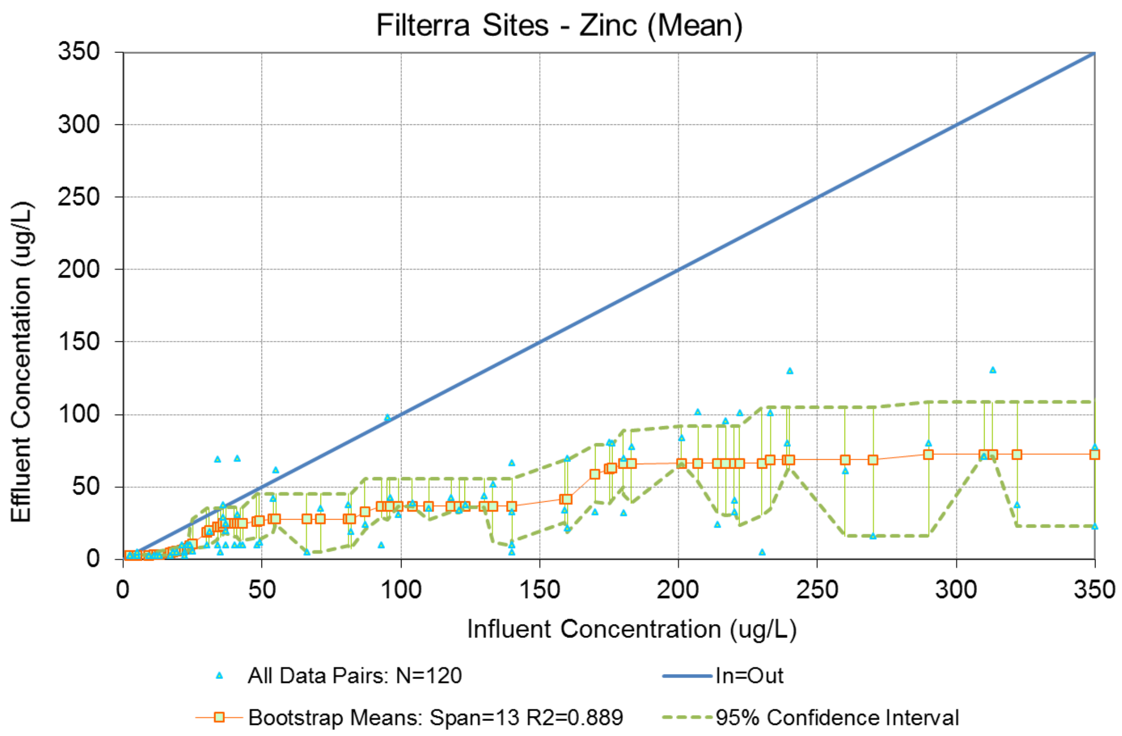

Figure 8: Filterra Zinc Performance Estimate, (Geosyntec Consultants, 2015)

5 DISCUSSION AND NEW ZEALAND DESIGN CONSIDERATIONS FOR EQUIVALENCE

5.1 CAPTURE EFFICIENCY.

Considering the above analysis, the design of Filterra as a flow based system in New Zealand designed for a rainfall intensity of 10mm/hr in Auckland and 5 mm/hr in Christchurch will treat approximately 7% more runoff than a conventional rain garden in Auckland and 12% more runoff in Christchurch.

5.2 VOLUME REDUCTION

Given the smaller footprint of the Filterra, the volume reduction potential is reduced. Reduced volume reduction results in lower contaminant load reduction. This can be offset by treating more water to obtain the equivalent load reduction.

Given that Filterra is sized in New Zealand to treat approximately 7 -12% more than a conventional rain garden, increased sizing is not generally required to provide equivalent load reduction, unless the device is located in highly permeable soils and an integrated water storage zone is included.

Where volume reduction is required because of a regulatory requirement such as Auckland's Stormwater Management Area Flow (SMAF) (Auckland Council, 2013) zones it is proposed to provide supplementary storage and infiltration capacity downstream in the form of stormwater chambers. These chambers have the ability to provide both detention and retention in a small footprint without additional land take. The figure below is an example of how this could be configured.

Figure 9: Filterra with Retention Chambers

5.3 POLLUTANT TREATMENT.

For water that is treated and released, Filterra performance studies generally showed similar or better concentration reduction compared to conventional biofiltration. Filterra performance tended to be less variable in most cases. Filterra systems also did not exhibit major nutrient export that is relatively common in conventional biofiltration. While nutrients are not generally considered contaminants of concern of urban stormwater in New Zealand, phosphorus is a major cause of algae blooms and oxygen depletion in fresh water bodies and should not be overlooked.

When studies from the International BMP Database were screened to best match conventional biofiltration designs per Attachment H, specifically compost (organic content) and sand fractions, the treatment performance tended to decline somewhat. This is consistent with findings related to use of compost in biofiltration media from other studies. (Roseen, 2013)

New Zealand design criteria for raingardens do not specify organic content. Organics can enhance removal of metals through cation exchange and absorption, (Minton, 2002) however may reduce the performances in relation to nutrients through leaching. Included in the analysis is a comparison with unscreened data for all bioretention data in the BMP database. This showed similar results as the screened data, suggesting that in general, Filterra pollutant removal is equivalent or better to biofiltration.

6 CONCLUSION

Equivalency comparisons should consider more than contaminant concentration reduction. Volume reduction and capture efficiency both influence the total exported contaminant load.

In general, Filterra provides equivalent or better concentration reduction to a traditional raingarden. However, the Filterra has a higher flow rate and smaller footprint than conventional rain garden. This reduces its ability to evapotranspire and infiltrate which reduces exported contaminant loads through volume reduction.

In New Zealand the Filterra is design to treat approximately 95% of the annual runoff as compared to conventional bioretention systems which are only treating between 68 and 88% of the annual runoff. This difference in capture efficiency offsets any difference in evapotranspiration and infiltration between a conventional rain garden (without an integrated water storage) and Filterra.

To increase the volume reduction through a traditional raingarden an integrated water storage zone should be included in the design. Likewise the use of stormwater retention chambers in combination with a Filterra system can provide similar stormwater volume reductions.

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