CONNECTING COMMUNITIES TO WATER

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ABSTRACT

The loss of small streams and lack of open green spaces is the result of urban sprawl and traditional development. Many developers view stormwater treatment and mitigation as an onerous requirement that adds cost but not value. The result is that the stormwater management methods often lack connection to the surrounding environment and fail to connect communities to water. Synergizing with developers, architects and landscape architects during the early stages of development facilitates the design of stormwater treatment and mitigation with the potential to enhance amenity value. The resulting creation of green space in an urban environment can increase property values and livability.

This paper presents 4 different developments that seek to achieve stormwater management that creates amenity, drawing upon some new technologies adapted to New Zealand's unique environment.

The first development is a retirement village where the traffic loading was expected to be low. The local territorial authority requirements included treatment and mitigation for the 1% AEP rainfall event to the equivalent of grass runoff. The objective was met by providing stormwater flow-through planters incorporated into the overall landscape design. The flow-through planters employ a river stone surface which behaves as a rocky-river bed removing suspended solids and providing visual balance.

The second project required flood protection and pre-treatment for a highly urbanised commercial environment. The design provides detention storage for the 1% AEP rainfall event and pre-treatment in a device analogous to a rocky-river valley.

The third development used a banded wetland to replace a pond design which was initially consented by the territorial authority. The wetland was designed to allow community interaction with the habitat.

The fourth project takes a fresh approach to vegetated swales as a community amenity. The vegetated swale design involved tying it to the native landscape, providing low maintenance and longevity.

KEYWORDS

green space, treatment, mitigation, livability, amenity, new technologies

PRESENTER PROFILE

Linda joined ACH Consulting Ltd after immigrating to New Zealand in 2006. Trained in the US as an oceanographer and environmental engineer she has worked for NASA, Woods Hole Oceanographic Institution, US Geological Survey and others. A Scientist and an Engineer, she brings her multidisciplinary experience to blue-green infrastructure design.

Benny joined ACH Consulting Ltd infrastructure team in 2006. He has 27 years of engineering experience in designing, planning and executing large capital improvement projects for water reticulation, wastewater and stormwater. He is currently working to facilitate infrastructure upgrades for Auckland Council and assisting developers with infrastructure requirements.

1 INTRODUCTION

The construction of housing, retirement villages and commercial subdivisions almost always brings with it the cost of stormwater treatment and/or mitigation. In the current model these costs, which are borne by the developer and passed to the purchaser, do not add any discernible value to the property from the developers standpoint. A tank, a fenced pond or wetland, a grass swale, proprietary filtration buried in the ground; these items are visually disconnected from the communities they serve and are forgotten about. Over time they remain on site but unmaintained.

Many engineers believe that the majority of the detention tanks they have been designing for the last decade are in constant overflow within a short period of time due to lack of maintenance. Fenced ponds become green algae filled mosquito breeding grounds which are used for dumping shopping carts and other rubbish due to both design and the lack of vested interest by the surrounding communities these devices serve.

Even in the highest density developments there are opportunities to introduce stormwater treatment and detention that serves as a focal point for a community drawing people out from brick and glass to build a sense of community around an amenity that also serves as stormwater treatment and/or detention. A well designed bio-retention device creates habitat and a connection to New Zealand's natural environment within urban development. Long term benefits go beyond just clean waterways; substantial evidence that incorporating nature and water into the urban environment creates healthier communities. Moving to greener urban areas is associated with sustained mental health improvements (Alcock, et al. 2014). In much of the country nature is associated with wet climatic conditions. Incorporating a visual connection to water into the design creates a positive effect and is considered restorative (White, et al. 2010).

New Zealand is in a period of intense development. With development comes an increase in impervious surface area which is needed for roads, roofs, driveways, etc. Impervious surfaces bring with them a plethora of problems;

- Increased erosion due to increased runoff rates and volumes
- Chemical contaminates from roads and parking lots
- Thermal loading of natural waters
- Reduction of habitat
- Reduced oxygen due to lack of photosynthesis

Amidst New Zealand's housing growth the country moves towards implementing The National Policy Statement on Freshwater Management The National Policy Statement on Freshwater Management seeks to reduce nutrients, metals, harmful bacteria and sediment loads in our streams. To successfully achieve these two seemingly incongruent goals, a design approach which stimulates community awareness of the fate of stormwater runoff will inspire better outcomes. Designing green infrastructure which mimics natural systems and possessing aspects of the natural environment can increase the effectiveness of water treatment. Communities feeling connected to water through green infrastructure will feel more invested, ensuring that infrastructure endures. The Iwi connection with water is sacred. Everyone's connection with water is imperative if we are to preserve our urban waterways and nearshore environment.

Often the design elements which include water and native plantings have been the scope of the landscape architect, and the removal and treatment of water within the domain of the engineer. This paper seeks to introduce new green infrastructure design which requires engaging architects and designers in the early phase. Technical information with regard to operation and performance of each design are presented here. Two designs are fully implemented one is under construction and it is anticipated that construction will begin soon on the fourth project. It is expected that each design cycle will result in improvements and greater implementation opportunities.

2 DISCUSSION

2.1 Auckland Rainfall and Runoff

In New Zealand, stream reaches are generally short and so there is a small window of opportunity to prevent contaminants from entering the streams and reaching the marine environment. This is especially true in Auckland where the longest streams are less than 15 km in length. The Oratia Stream travels 12.5 km from the bush area of the Waitakere Ranges down to the marine environment in about 2.5 hours during the 95th percentile rainfall event. In Auckland this equates to around 34.5 mm of rainfall or less.

The urbanisation of the Oratia Stream since the area began to be settled has nearly doubled the runoff rate and increased the volume by almost 80,000 m^3 during the 95th percentile rainfall event. Studies from the USA indicate that in a mature evergreen forest 46% of yearly rainfall is lost to evapotranspiration and only 0.25% becomes runoff (Bolton and Watts 1998). Without the runoff no physical erosion occurs and streams remain relatively clear having low sediment loading.

The increased runoff from urbanisation brings with it erosion, sediment loading and constituents of concern (COC) into the freshwater and marine environment. COC include nitrogen from poorly performing on-site waste water treatment in the Waitakere Ranges and heavy metals from roads and industrialised areas. The COC pose a variety of risks to both human and other fauna found in the environment. Nitrogen loading leads to toxic algal blooms in the nearshore environment during the warmer months. Heavy metals, particularly Cd reduce fecundity in shellfish and other marine organisms as well as seeping into the food chain.

2.2 COC

Many of the COC reach the sea attached to clay particles. Clay particles have piezoelectric properties causing metals that are bound to them in the fresh water environment to return into suspension in the marine environment. An effective design will:

1. Reduce peak flows.
2. Remove the bulk of total suspended solids (TSS).
3. Provide a mechanism for nitrogen uptake.

Items 1 and 2 are generally achieved through physical mechanisms and if achieved onsite reduce the amount of COC reaching the marine environment.

Item 3 is a bit of a sticky issue, literally. Nitrogen, nitrate and nitrite are persistent in the environment and difficult to remove. In general plants will fix and uptake nitrogen, however some plants are better at this than others. New Zealand is fortunate as it possesses 53 varieties of coprosma, meaning one suited to every environment. Coprosma is a nitrogen uptake rock-star. Closely related to coffee, coprosma has several

sites on the leaves and axil veins where nitrogen fixing bacteria grow. The plant is known to fix atmospheric nitrogen, however experiments with its close cousin coffee, showed that when nitrogen exceeds the plants requirement the nutrient can be accumulated in unproductive components, and used later when N is limited and demand is higher (Bruno et al. 2011).
As our knowledge of phytoremediation grows it will be possible to add to the plant pallet hyperaccumulators, a related group of plants that can accumulate large volumes of heavy metals compared to other groups without suffering adverse effects (Rascio & Navari-Izzo, 2011).

2.3 Projects

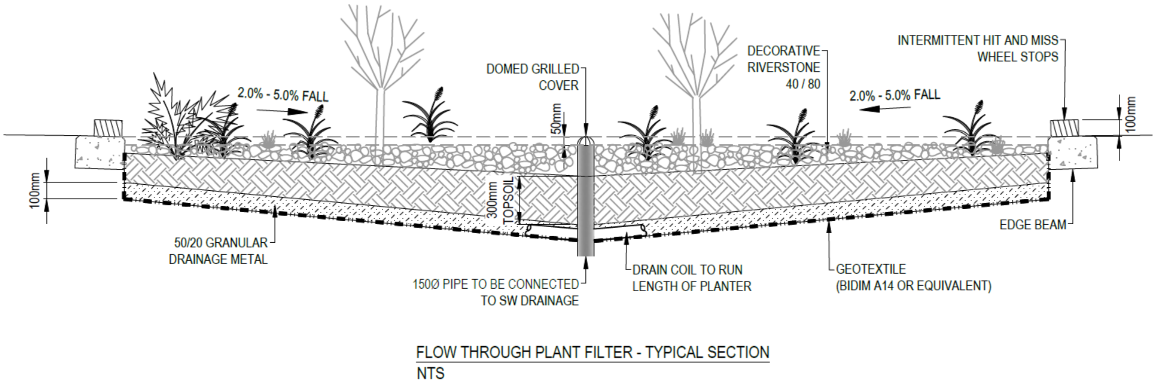
2.3.1 The Falls Retirement Village - Whangarei

The further development of an existing retirement village adjacent to the Hātea River and Whangarei Falls was adding another 27 single story independent living villas with a combined roof area of 3200 m^2 and 1300 m^2 of pavement. Under the most recent Council code of practice the development was required to maintain flows up to and including the 1% AEP rainfall event and allow for climate change. Treatment was also required to remove at least 75% of TSS. The retirement village contaminate loading from drivable surfaces will be low as vehicle movements are generally few within such communities. The site is situated on basalt overlain by clays and good infiltration seemed likely but geotechnical investigations proved otherwise. As such, 200 m^3 of detention needed to be provided, as well as treatment for the driveway and parking surfaces. In this instance permeable pavers were not an option due to impaired mobility. As such, all drivable areas required treatment.

Modified flow-through planters were designed, (a stormwater treatment device successfully used in Portland Oregon and other US cities for effective stormwater treatment would provide adequate pre-treatment) to both mitigate the increased flows and remove 75% TSS. The stormwater flow-through planters are a treatment device based on the infiltration gardens used in Portland Oregon. The design parameters assume no infiltration of stormwater into the ground or evapotranspiration, though both will occur reducing the volume of runoff. Treatment is provided for paved surfaces, using 400 m^2 of 100 mm – 300 mm rounded river stone, planted out with species tolerant of both extreme wet and dry conditions. The river stones remove at least 75% of total suspended solids (TSS) while plants provide further treatment through phytoremediation. The flow-though planter reduces velocity and removes dust sediment and macro-contaminates while creating an aesthetic landscape element and microhabitat.

The river stone, underlying soils and drainage layer provide detention and storage for 80 m^3 of stormwater runoff from the paved areas with an additional 20 m^3 of storage provided in the 50 mm of ponding available in each of the 'flow though' planters. The planters attenuate the flows from the 1% AEP rainfall event to predevelopment levels (considering a 24 hour rainfall depth of 312 mm) as well as serving to filter any sheet flow off the paved areas. The remainder of detention was provided by a series of tanks. In the final phase of the project, it is hoped to provide reuse as well.

Figure 1: *Schematic of a flow-through plant filter.*



The base of the flow-through planters are inclined at 5% towards the centre and the surface was intended to appear flat. The filtration has been integrated into the landscaping and the amenity value will increase as plants mature. The design can be adapted to be either formal or informal and can be situated in courtyards as well as adjacent to parking. Landscaping treatment can vary from trees and shrubs to grasses and ground cover. In this instance the landscape architect chose native species common to the coastal lowlands of Whangarei.

Photograph 1: *Flow-through planters at construction and coming on line.*

2.3.2 Magsons Commercial Development – Henderson

The design at this location required more robust treatment than the retirement village due to the commercial nature of the site. A condition of the consent was that treatment be provided for the entire 13.5 ha catchment for maximum probable development, being 90% for the commercially zoned upstream catchment. As such a 39 cartridge Stormwater360™ filtration device was designed for treatment of the entire 13.5 ha catchment to be installed by the developer and later adopted by Auckland Council. However, to extend the life of the cartridges, pre-treatment for 20,000 m^2 of parking was designed. Additionally, the limited capacity of the public stormwater system and the risk of downstream flooding required that 500 m^3 of detention storage was required. The initial design completed by others proscribed 200 m^3 of storage in detention tanks to capture the roof area, 150 m^3 of ponding in the parking lot and an additional 150 m^3 of storage in a wetland area.

Due to development changes there was no longer a demand for water reuse rendering the 200 m^3 of storage in detention tanks obsolete. Ponding in the parking area would be a nuisance to the public and the wetland would require watering during the dryer months. Overall the 3 separate systems were considered to be difficult to maintain and not the best fit solution to this site.

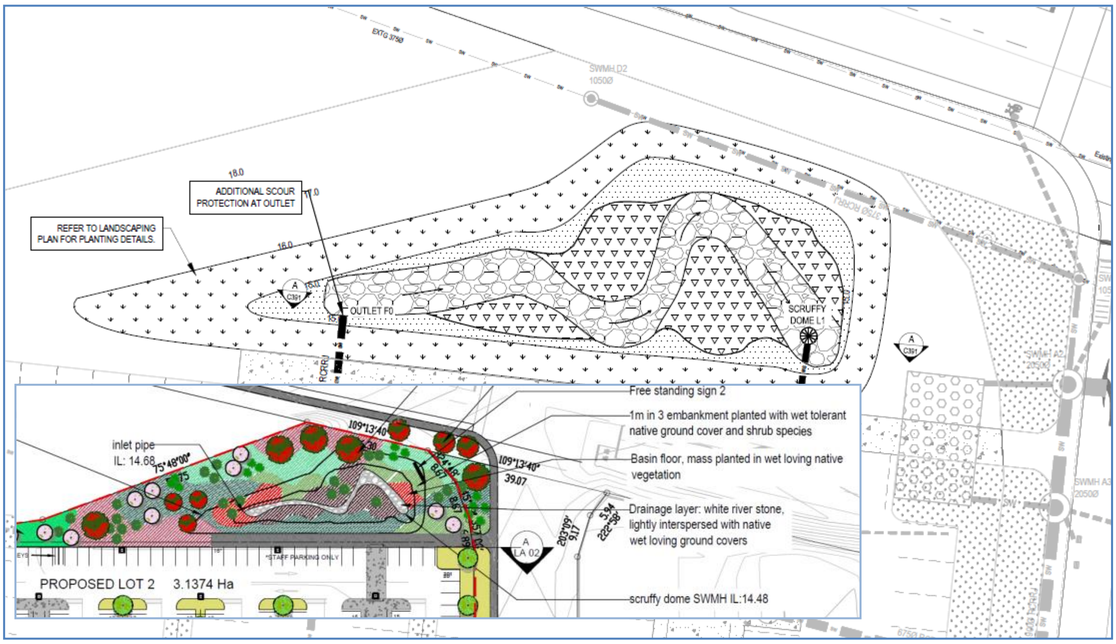
A suitably modified stormwater flow-through planter would provide adequate pre-treatment. The requisite 500 m^3 of storage required to maintain predevelopment flows would also be provided by the flow-through planter.

The flow-through planter's design parameters assume no infiltration of stormwater into the ground, which is analogous to the clay material underlying the subject property. Treatment is provide for the parking area runoff, using 120 m^2 of 100 mm – 300 mm rounded river stone, planted out with native species tolerant of both extreme wet and dry conditions removing at least 75% of TSS. The flow-through planter reduces velocity and removes dust sediment and macro-contaminates while creating an aesthetic landscape element and microhabitat within an urban industrial environment.

The sides of the flow though planter will have slopes no greater than 1 in 3 and will have a total depth of 1.25 m. Much of the area will have a depth of 0.75 m. The area will be planted with native self-sustaining plants appropriate for extreme environments due to the asphalt heat sink effects common to commercial areas. The planted area will serve as available storage during the 1 in 100 year rainfall event as well as serving to filter any sheet flow off the parking area.

The detention of water in the area surrounding the flow-through planter will be limited to rainfalls greater than the 1 in 10 year event and filling limited to the 1 in 100 year event. Greater amenity value could be achieved by designing a detention device analogous to a natural system. The flow-through planter will act as a rocky stream and the detention area will perform the function of a surrounding flood plain. At the time of the writing of this paper the construction had not begun.

Figure 2: Flow-through planter plan view



Photograph 2: Concept of finished rocky-river flow-through planter

2.3.3 Bella Vista Subdivision – Ranui

The project involved the subdivision of 2.36 ha of pasture land into 40 new residential lots ranging in size from 450 m^2 to 680 m^2. A new road to service the subdivision was also part of the plan. The site itself is rolling topography typical of the Waitakere foothills environment. There was also an overland flow path which tracked through the centre of the site.

A pond was designed for the site by a previous engineering firm and initially we were asked to check the sizing. The pond had to cater for 60% impermeable area for a total catchment area of 7.3927 Ha. The conditions of the resource consent dictated that stormwater mitigation provide treatment to remove at least 75% of TSS and volume mitigation providing hydrologic neutrality for the 2, 10 and 100 year rainfall events as well as extended detention for the first 34.5 mm of rainfall.

It became apparent when checking the sizing that a banded wetland could fit within the same area and achieve the requirements of consent. The banded wetland was considered a better option for the site as a pond would have required fencing virtually disconnecting it from the community.

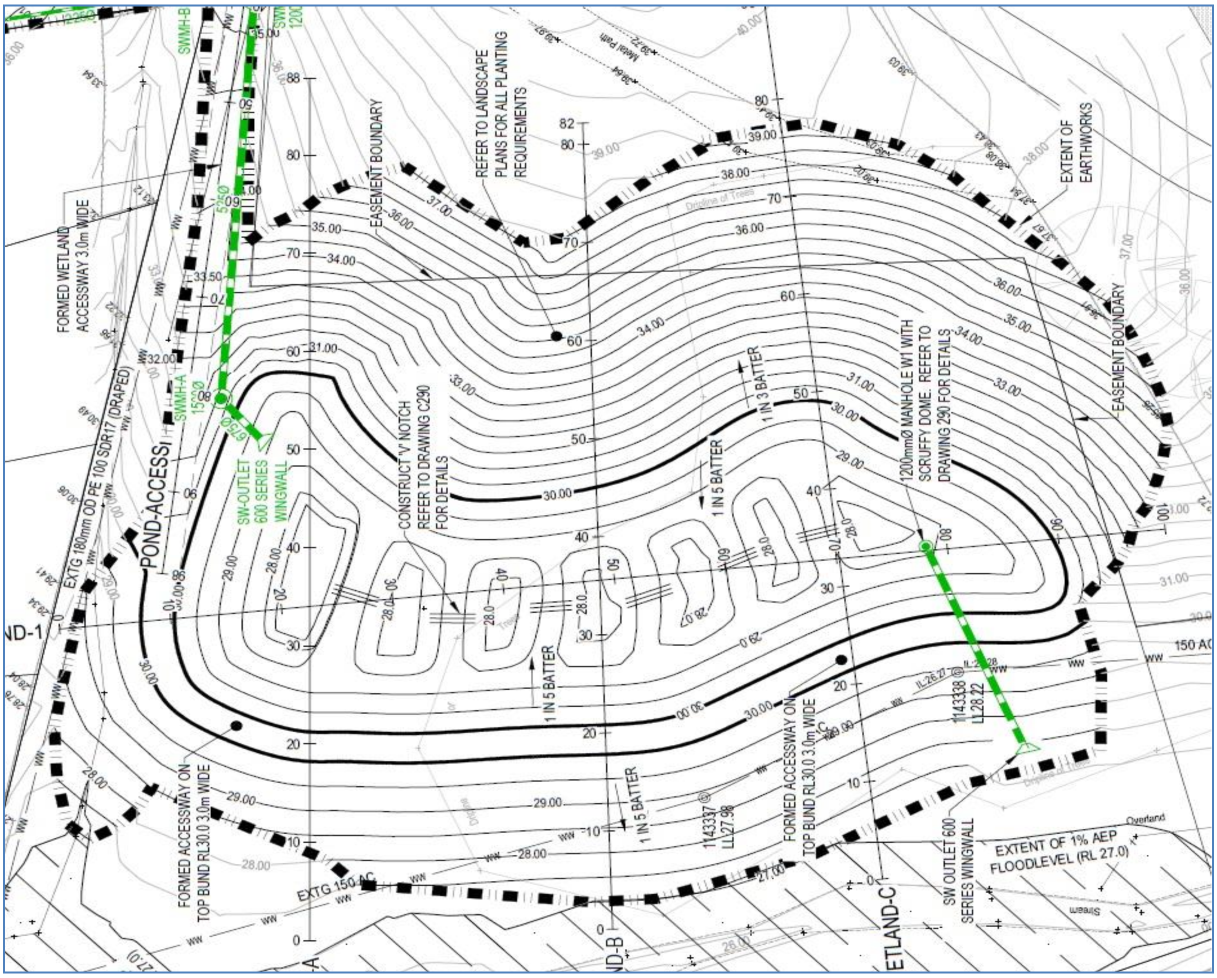
Photograph 3: *Traditional stormwater detention pond*

The vision for the wetland would be for it to become a community amenity. Additionally the banded wetland provides:

- Better treatment performance through reduced water speed promoting settlement of suspended solids.
- Thermal loading reduction by vegetated cover.
- Better nutrient removal through plant uptake.
- Control of surface sediment redox, decreasing the risk of anoxic conditions forming in the surface sediments.
- Habitat for native species of flora and fauna.

The site had some drawbacks as it was quite steep and some of the geotechnical investigations showed shallow slips and non-engineered fill.

Figure 3: *Plan of the Wallace Road Wetland.*



HEC-HMS 3.5. software program was used to model the amount of detention storage and retention required to reduce peak flows and limit total volume of runoff to that of the current level on the site for the 2, 10 and 100 year rainfall events as well as extended detention for the first 34.5 mm of rainfall. There are 7 bays in the wetland and with the exception of the fore bay, each permanently inundated area has a depth of 450 mm. The total permanent wet storage is 220 m^3 with an overall capacity for 1340 m^3 to cater for the 1 % rainfall event.

The reasons for the redesign were discussed with the Auckland Council and were met with approval from both the development engineering team and Auckland Council Parks. Currently the banded wetland is being constructed and it is hoped that Council will continue not to require fencing as it will nullify the amenity value of this constructed habitat.

2.3.4 The Weiti River Estate Subdivision – Stanmore Bay

The Weiti River Estate project involved the subdivision of a 4.3 ha site of pasture land accessed via a 190 m long driveway. The project had many challenges and opportunities with regards to stormwater management. The project occurred at a time when the Air land Water Plan, the operative district plan and PAUP were all operative. Roughly half the site was located in a Landscape Protection Zone and all of the site was within Stormwater Management Flow-1 (SMAF-1) environment. Further to this, the property discharges stormwater runoff to two catchments; the Weiti River estuary, a Coastal Protection Area 2 under the Auckland Regional Plan and the Stanmore Bay Catchment which, while serviced by a piped network, is known to experience flooding. The property also has sections that are steeply sloping, providing additional challenges to stormwater treatment.

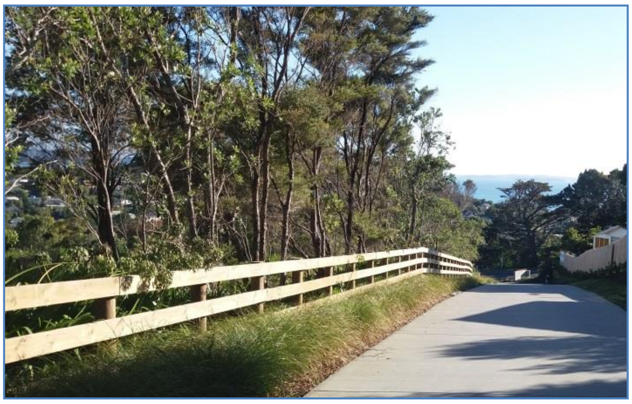
In this instance the Council required that stormwater discharging into the Weiti catchment be attenuated to predevelopment levels for volumes and flows for the 50% AEP, 10% AEP and 95th percentile rainfall events and that the first 10 mm of rainwater be retained on site. For stormwater discharging into the Stanmore Bay catchment attenuation was required for the 1% AEP rainfall event as well. Treatment was required for the entire site under all the operative plans. The steepness of the site also required that discharges towards the Weiti River Estuary be controlled to mimic natural flows.

Prior to the development, 6,600 m^2 of the property drained to the Stanmore Bay Catchment, with 1,900 m^2 being impermeable.   The site was re-contoured so that 4,560 m^2 would discharge into the Weiti River Estuary catchment. The remaining 2040 m^2 would continue to discharge to the Stanmore Bay Catchment, containing a total impermeable area of 900 m^2 for the shared driveway and passing bays. Thus both volumes and peak discharge rates into the Stanmore Bay Catchment were reduced significantly.

In order to comply with the Council's requirements each residential lot is to provide a 20,000 litre detention reuse tank with a 20 mm orifice situated so as to allow 9 m^3 of reuse volume for non-potable purposes. The detention/reuse tanks capturing roof runoff only offset in part the impermeable area created by the shared and individual driveways. When determining stormwater detention tank requirements it was assumed that each lot would have maximum building coverage, but the individual driveway and parking surfaces were limited to 150 m^2.

The new 900 m^2 concrete driveway will be treated with a vegetated swale. Due to the slope of the property the swale will have check dams every 15 m. In accordance with TP10 calculations the swale is required to be 148 m long so as to provide treatment for the water quality volume. The proposed swale will be approximately 190 m long and discharge into the reticulated stormwater system via a scruffy dome. The shared driveway and individual driveway areas discharging into the Weiti catchment were similarly treated.

Photograph 4: *Vegetated swale at Weiti River Estate at initial planting and after 6 months.*



A grassed swale would have been compliant with TP10, however it would not have performed as well as a vegetated swale. The mature native bush located on the western half of the property combined with the coastal vistas towards the northeast gave an opportunity to tie in these two unique Auckland environments with the swale. Moreover, ten years of designing in Auckland has shown that grassed swales are not maintained and soon filled in to allow for ease of mowing.

Studies from Portland Oregon indicate that swales with native vegetation perform better. Two swales of identical size and geometry were installed by the Portland Bureau of Environmental Services. One swale was planted out with native vegetation and the other was planted with grass. Over a two year period these swales were sampled for pollutants every 30 minutes during 6 separate storm events. The following results table was adapted from that study (Liptan & Murase, 2000).

Table 1: *Stormwater results for vegetated swales vs grassed swales, adapted from Liptan & Murase, 2000.*

COC	Vegetated Swale	Grassed Swale
TSS	81%	69%
Nitrate-Nitrogen	28%	16%
Total Phosphorus	50%	38%
Total Cd	73%	61%
Total Cu	65%	53%
Total Pb	72%	62%
Total Zn	76%	63%

Further to this the study showed that the swale planted with native vegetation retained 14% more runoff than the grassed swale even when the grass swale was permitted to grow with no mowing. The researchers hypothesized that that the robustness of native vegetation root systems allows for better infiltration. Finally the vegetated swale requires less maintenance than the grassed swale, mostly yearly pruning and trash removal. Even overgrown the vegetated swale will continue to function at design parameters.

3 CONCLUSIONS

As the Auckland and New Zealand housing boom continues coupled with greater commercial development, it is in part up to the engineering practitioner to incorporate natural elements into our design. Other than being constrained by regulations there is no interest on the part of the developer to spend more than the bare minimum of capital on infrastructure that goes in the ground. If however, an engineer can offer up a piece of green infrastructure which creates amenity value then there is hope of incorporating nature into developed sites and increasing a connection to our waters in the living and working environment. It is only through the human connectedness that we can hope to achieve the intention of National Policy Statement on Freshwater Management.

In the first instance of the retirement village landscaping and detention were always going to be required. By utilizing the landscaped areas to double as detention and treatment devices the developer has water mitigation and treatment that add an aesthetic rather than hidden from view.

In the case of the commercial development the stormwater treatment needs were high and it required a treatment train approach. The pre-treatment / detention device, the flow-through planter, will increase the life of the Stormfilter cartridges. Almost as important as this, it will mimic in aesthetic and function a rocky-river valley acting as an oasis of green in an impervious jungle.

The banded wetland will function to protect the health of Lonesome Brook by treating stormwater runoff and mitigating flows for a variety of rainfall events. More than this it will provide a habitat to flora and fauna common to the Waitakere Ranges foothills. Without the fence and the planed walkway around part of the perimeter it is hoped that it will act as a focal point of the community and educate young residents as to the environment natural to the region.

The swale at Weiti River estate treats the stormwater as required. It also adds value to the subdivision by tying the native bush environment to the coastal plain. There is planting occurring in the subdivision which will further enhance that effect.

Though each of these projects are small compared to the scope of housing and commercial development, they are a start. With each iteration it is expected that earlier engagement of the landscape designer and architect will increase the synergy of the infrastructure to the environment. Increasing visual appeal increases the amenity value and leads to communities valuing their stormwater infrastructure assets as desired green space. This approach to green infrastructure design will have restorative effects on New Zealand waters and those communities that embrace them.

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