CONSTRUCTION OF LOW IMPACT DESIGN SOLUTIONS AT LONG BAY

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ABSTRACT (200 WORDS MAXIMUM)

After the Environment Court hearing in 1996 allowed urbanization of the Long Bay catchment, there was 10 years of planning to prepare the Long Bay Structure Plan, a council hearing in 2005, another Environment Court process from 2007 to 2011, the Long Bay Structure Plan became operative on 6th October 2011. Significant bulk infrastructure has been constructed and the first subdivision Stage has been legalized.

The Long Bay Structure Plan is a greenfield development of some 360 hectares to house up to 7,500 people in the northern east coast of Auckland. It fronts onto the Long Bay Regional Park and the Long Bay/Okura Marine Reserve. Due to the sensitive receiving environment and the desire for more sustainable and effective stormwater management to protect the ecological values of the existing natural streams, a number of innovative low impact design stormwater management practices have been incorporated into the final constructed streetscape.

Of particular interest is the construction of the developments first Subdivision Stage which includes on-site bioretention gardens and tree pits, all located within the road reserve to manage the stormwater runoff from the road surfaces. The paper will describes the methodology, options and layouts that were put through their design paces and reasons for the final choices to make an aesthetically pleasing and practical stormwater solution.

The focus of this paper is the design and construction of the bio-retention devices (rain gardens and tree pits) to manage the stormwater runoff from the roads being built in the first stages of construction in the SP-B area.

KEYWORDS

Low impact design, stormwater management, bioretention, rain gardens, construction

PRESENTER PROFILE

Pranil Wadan is a stormwater engineer at WOODS; with just over 5 years of experience in hydrological modeling and stormwater design.

Owen Clements is an Engineering Manager at WOODS; with nine years of experience in land development engineering.

1 INTRODUCTION

1.1 BACKGROUND

In 1996 the Environment Court revised the Auckland metropolitan urban limit, placing the limits of the then North Shore City to the north of Long Bay. This allowed the urbanization of Long Bay subject to a set of environmental protection principles. Long Bay is unique, with the headwaters of the main Vaughans Stream being a reference high quality stream in urban Auckland, along with a downstream marine reserve (Figure 1)

The extensive catchment management and structure plan process included an all-of-Council approach which started in 2001 with agreement on four main water objectives by the Long Bay Steering group, those being:

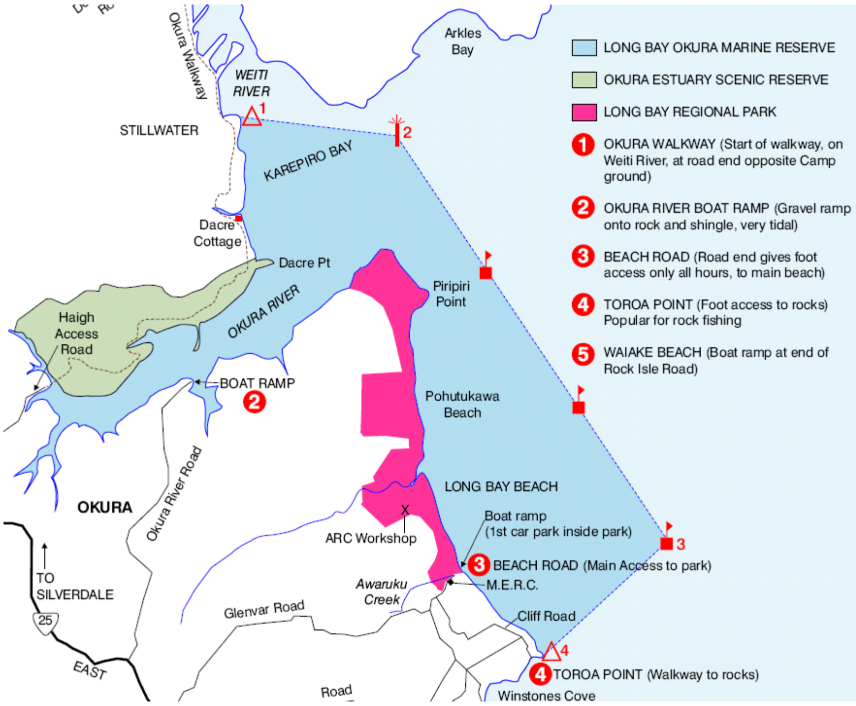
- Protection of the natural environment
- Managing stormwater discharges
- Managing wastewater overflows
- Reduced mains water consumption

The Awaruku Stream and Vaughans Stream discharge directly to the Long Bay – Okura Marine Reserve, approximately 500 metres to the east of the development. Long Bay is a non-depositional dynamic beach environment, subject to wave and tidal action. The ultimate marine receiving environment beyond Long Bay is the wider Hauraki Gulf. Long Bay is identified in the Auckland Regional Plan: Coastal (ARP:C) as Coastal Protection 2 (CPA64A) and an area of Significant Conservation Area (130). The ARP:C describes Long Bay as follows:

*—Within this area are a considerable variety of intertidal substrates which together form a complex array of habitats which support a variety of animal and plant communities. The communities living in the wave cut platforms, cliffs and beaches at Long Bay have been studied over a long period and in reasonably good condition. This is a known location of pingao, a threatened plant of mobile sand areas. Habitats in this area include gently sloping sandy beaches, a flat rocky reef systems with broad stepped platforms‛(*AECOM, Long Bay Catchment Management Plan 2011).

In acknowledgement of the sensitivity of the marine environment, the Long Bay Structure Plan contains specific stormwater management requirements.

Figure 1: Long Bay Overview



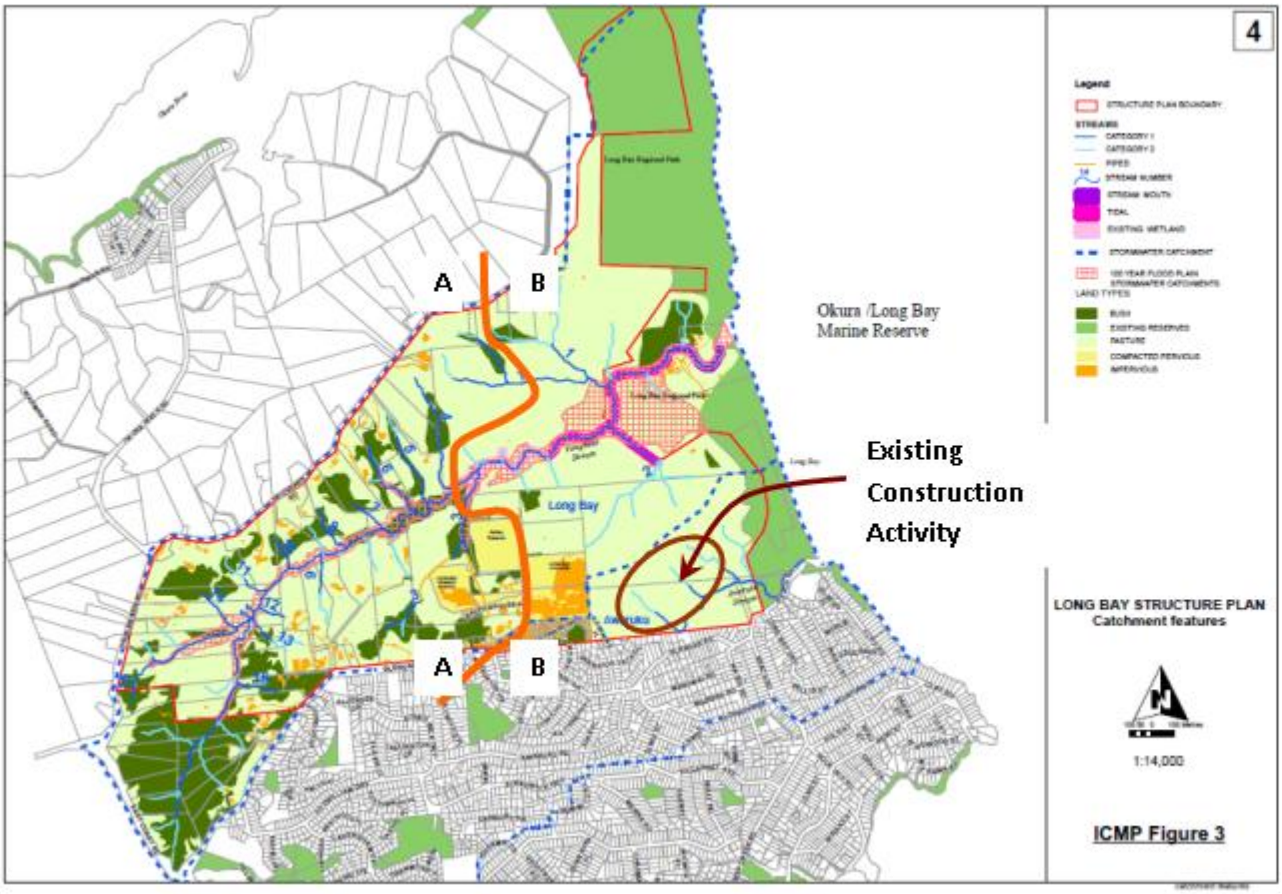
1.2 LONG BAY STRUCTURE PLAN

The Long Bay Structure Plan (Chapter 17B of the District Plan) states a low impact, treatment train approach to stormwater management, including limitations on landform modification and impervious cover; on-site stormwater mitigation measures for developments, roads and accessways and retention of the majority of streams and waterways; as well as the provision of catchment-wide facilities like wetlands. Depending on the 'Stream Protection Area' and land-use zoning these requirements vary.

Stormwater is to be treated on roads (where grades allow) and from driveway areas of private lots. Whilst these areas are to be designed to limit stormwater runoff by reducing carriageway widths and impervious areas as far as practicable while still providing facilities that are "fit for purpose"; and are to manage stormwater runoff prior to discharge to streams and waterways.

There are two stream protection areas, Stream Protection Areas (A and B) which are defined on the Structure Plan maps and shown in Figure 2 – Long Bay Catchment Features below. The Stream protection areas are based on the ecological value of stream tributaries, their sensitivity to the adverse effects of development and their contribution to the overall sustainability of the Vaughans Stream. Stream Protection area B is to contain the higher density development in the lower catchment, that have minor tributaries discharging to tidal areas, that can be modified with the more traditional wetland stormwater treatment. Stream Protection A in the upper catchment is to contain mainly large lot residential due to the high quality streams required to remain as natural watercourses requiring 80 to 100% on-site stormwater mitigation. The first stages of existing construction activity are in the south-eastern area identified in Figure 2.

Figure 2: Long Bay Catchment Features



The main stormwater low impact design features are:

- Minimizing Site Disturbance – This is a strong feature for developments in the SP-A area but less in the SP-B areas. The suburban/urban densities and geotechnical instability in the Stream Protection B area required extensive 'shear keys' (to stabilize the ground) and earth working activities to generate the necessary land forms for the housing developments.

- Reducing Impervious Surface – Again, this is more prevalent in the SP-A areas where suburban lots with minimum net site areas of 600m^2 had a maximum impervious limit of 50% of the lot area and large lots (2,500 and 5,000m^2 lots) have a maximum of 15% impervious. This has two benefits; it reduces the amount of imperviousness requiring treatment and provides greater areas for the implementation of on-site stormwater management, particularly important for the suburban 600m^2 lots.

  At Source Stormwater Management – The mandatory inclusion of soil rehabilitation of compacted soils in large lots and reserves/open spaces (conditioning the top 400mm of surface soils), re-vegetation to offset impervious areas (in SP-A), mandatory capture and use (all houses in SP-A and SP-B are required to have rain water tanks with dual purpose plumbing to provide non-potable water from the tank to laundry, toilet and optional outdoor use, with mains water for the bathroom and kitchen) and the optional use of permeable paving for mitigation of driveways and parking areas.

- As mentioned above Soil reconditioning is one tool agreed during the structure planning process whereby the sub-topsoil and topsoil layers placed following bulk earthworks are re-constructed from natural sub-topsoil and topsoil from the existing ground. The intention is to maintain pervious properties as per pre development within areas such as reserves. Within the detailed design phase for the current areas of development geotechnical recommendations have been made to avoid soil reconditioning. A fundamental requirement for Long Bay based on geotechnical constraints is to manage groundwater and minimize infiltration to ground. The soil re-conditioning remains a tool to be utilized for future areas that have favorable constraints.

- SP-A areas are required to fully mitigate 80 to 100% of the impervious surface areas on site with methods such as bush re-vegetation, pervious paving, bio-retention (rain gardens), swales and filter strips, rain water tanks and green roofs.

- SP-B areas require single purpose rain water tanks with water quality treatment being provided by the wetlands.

- All roads (in SP-A and SP-B areas) are to be designed to limit stormwater runoff by reducing carriageway widths and impervious areas as far as practicable while still providing facilities that are "fit for purpose and shall provide stormwater treatment of quantity and quality within the road reserve utilising the best practicable option. The best practicable option being defined as:
  - Bio-retention and pervious paving for shallow grades less than 5% parallel to the roadway.
  - Inclusion of check dams and other flow control methods with bio-retention and pervious paving for grades between 5% to 8%.
  - Off-line treatment for grades greater than 8%.
  - Re-vegetation associated with accessways in the large lot Long Bay 1 Zone (in SP-A area)

2 TYPES OF DEVICES

To manage the Stormwater runoff at Long Bay a range of stormwater solutions were considered for the public roads and for the resulting private properties. These solutions all assist in improving the hydrological response of stormwater volumes and peak flows. Some of the key onsite solutions used at Long Bay consist of:

- Use of Pervious Paving

- Bio-Retention devices (Rain Gardens / Tree Pits)

- Vegetative filter strips

- Rainwater Tanks & Green Roofs

From all the solutions noted above, currently the Bio-Retention devices - Rain Gardens and Tree Pits play the biggest role, as the construction of these are within the road reserve and therefore are not dictated by the homeowner.

It is likely these other toolbox solutions will become more widely adopted in the later stages of the development as the project moves into the higher density areas. It is important to note that a complete summary of solutions can be found in the Long Bay practice notes.

2.1 BIO- RETENTION DEVICES

The Long bay practice notes include various bio-retention devices - For roads where the grade is less than 8%, the minimum bio-retention design criteria is for the treatment area to be at least 7% of the impervious area draining to it.. Bio-Retention systems are designed to harness the natural ability of vegetation and soils to reduce stormwater volumes, peak flows and contaminant loads. Bio-retention at Long Bay encompasses a number of different devices these include:

- **Raingardens** – essentially sunken gardens with well drained planting media and an under drain.
- **Stormwater Planters** – Similar to rain gardens, however these are above ground in large containers. These containers have similar bio-retention planting media and under drains..
- **Treepits –** While used for planting of street trees, the long bay treepits have been designed for bio-retention via implementation of an under drain system.
- **Bio-Retention Swales** – these long narrow sloping swales with a bio-retention system along the base of the swale which is used for both conveyance and treatment of stormwater.

3 SELECTION CRITERIA FOR STAGE 1

3.1 RAIN GARDENS AND TREE PIT CONSIDERATIONS

Many considerations were made to determine the applicability of the device, a summary of these considerations is outlined below;

- **Grade of Roads** – The grade of the road was an important consideration, as the grade determined the placement of the device (devices are required to be 'on-site', that is, within the road right-of-way for grades less than 8%, 'offsite' treatment is permitted for grades greater than 8%).However for stage 1 the grades were either flat or very steep and therefore only roads with grades between 0.6% and 2% actually received on-site devices. Overall Stage 1 of this development had relatively flat east/west roads, and steeper north/south roads.
- **Geotechnical Constraints** - The parent ground material generally comprise sandy, silty clays and clayey silts, overlaying interbedded, weak, siltstone and sandstone. Global geotechnical earthworks undertaken prior to civil construction

were required in order to mitigate the existing ground conditions through removal of overburden soils and keying cuts and fills into bedrock. The parent soils and transitional layers with bedrock were recognized as being sensitive to groundwater and remedial works required significant subsoil drainage. Inclusion of any bioretention device in this type of material requires significant geotechnical considerations. An additional measure of undercutting road alignments to 1-1.5m was undertaken along road alignments during bulk earthworks to ensure the bioretention devices were bedded in certified fill. This provided some assurance of slope stability adjacent to roads, and serves to reduce impact of permeability in the event of a leak.

- **Streetscape Requirements** – A key factor in determining the suitability and placement of a device was determining what other structures were required within the street – e.g. Vehicle crossings, footpath, car parks, utility services, street trees, public drainage. These bio-retention systems could only be designed once the streetscape requirements had been understood as they were designed based on the impervious areas and are required to be distributed evenly through the streetscape to provide the level of treatment required.

- **Vegetation** – through discussions with landscape architects, Council, and specimen tree suppliers it was confirmed that a tree within a bioretention device requires significantly more media than typical wetland planting. The depth required for different planting options needs to be resolved to determine potential influence on adjacent structures and to define edge requirements.

- **Maintenance Requirements** – Ensuring inflow and through-flow of water were a significant consideration in the design. Bioretention guidelines recommend that bio-retention devices receive water quality flows and bypass the high flows. The recommendation is primarily related to treatment however high flows through media were considered as a factor for maintenance also.

3.1.1 FINDINGS – ADOPTION OF RAIN GARDENS OVER TREE PITS

Following completion of a preliminary streetscape layout it became apparent that based on the resulting streetscape that uniformly sized tree pits on their own were not going to be sufficient to provide the level of treatment required to treat 7% of the impervious area

As a result an option of subsequently adopting rain gardens in areas between tree pits was explored. The adoption of the rain garden increased the treatment area for the street; however the distribution of bio-retention devices along the street meant that sections were skewed - high levels of treatment in some areas and lower level of treatment in others.

Subsequently an option to use rain gardens only was investigated; placing rain gardens between the tree locations gave a layout that allowed placement of areas directly proportional to the contributing catchment.

Another key finding throughout the development of the Tree Pit and Rain Garden Designs was that the tree pits required a structural component that was significantly greater than that of the rain garden. The depth of required media for a tree placed the base of a tree pit below an acceptable line of influence from the adjacent road, crossing, car park, or footpath based on ground conditions and anticipated traffic loadings.

The rain garden excavation proposal was reviewed by Woods together with Coffey Geotechnics. Following completion of undercut work during bulk earthworks each pit is guaranteed to be founded within certified fill material. The adjacent roads have a subgrade including 250mm minimum depth of lime stabilized clay with 250mm of compacted aggregates on top. The roads within Stage 1 are local and have low anticipated traffic flows. Each garden was lined with an impermeable liner to prevent degradation of adjacent subgrade due to water ingress. Following consideration of these factors it was concluded that the proposed cross section was appropriate for the particular Stage 1 application. The side slopes and proximity to live roads is a point for specific consideration for future applications at Long Bay, particularly on roads with a higher anticipated traffic loading.

The structural component of the tree pit resulted in a significantly higher construction cost (per area) than the rain garden. The tree pit construction requirements were also considered more intricate than the rain garden. Maintenance costs of the tree pit were also considered to be higher (by area).

Following review of the constraints specific to Stage 1, it was agreed that rain gardens were to be adopted as the main treatment device for this stage of the development; However, Tree pits have been considered for two locations on the feeder roads through the development and will be revisited in the later stages.

3.2 RAIN GARDEN DESIGN

The Rain Gardens at Long Bay have been designed based on a combination of NSCC Bio-retention Design Standards and TP10 guidelines. The following assumptions or standards were used;

- Minimum equivalent area for Bio-retention required is 7% of the total impermeable area draining to it. *(NSCC)*

- The Equivalent Impervious Surface Catchment Area used for Bio-retention design must include the runoff from all impermeable areas; and also take into account the runoff from 50% of pervious areas calculated as impervious. *(NSCC)*

- 40% of the Water Quality Volume is to be stored as Live Storage Volume in the ponding area. *(ARC TP10)*

- The rainfall depth of the Water Quality Volume (WQV) Storm to be used for analysis is 27mm (i.e. 1/3rd of a 2 year storm event). *(NSCC and ARC TP 10)*

- Hydraulic conductivity (Ks) of the bio filtration soil media to be used as 100mm/hour for a 27mm rainfall event over 24 hours. *(NSCC)*

Whilst the exact sizing of each rain garden is different, a typical rain garden at Long Bay is about 2.7m wide and 6.7m long at its surface; and about 1.1m wide and 5.07m long at its base. The side slopes are at 1V:1H gradient; and the garden has about 0.5m deep bio filtration media for plant growth and stormwater treatment, along with a thin layer of mulch on top. 200mm of ponding depth is provided above the mulch layer which has a live storage volume of more than 3m^3 of water (exceeding the of 2.12m^3 as required by ARC TP10). The trapezoidal design is capable of a storage volume of around 80% when compared to a rectangular design.

Figure 3: Rain Garden Plan View

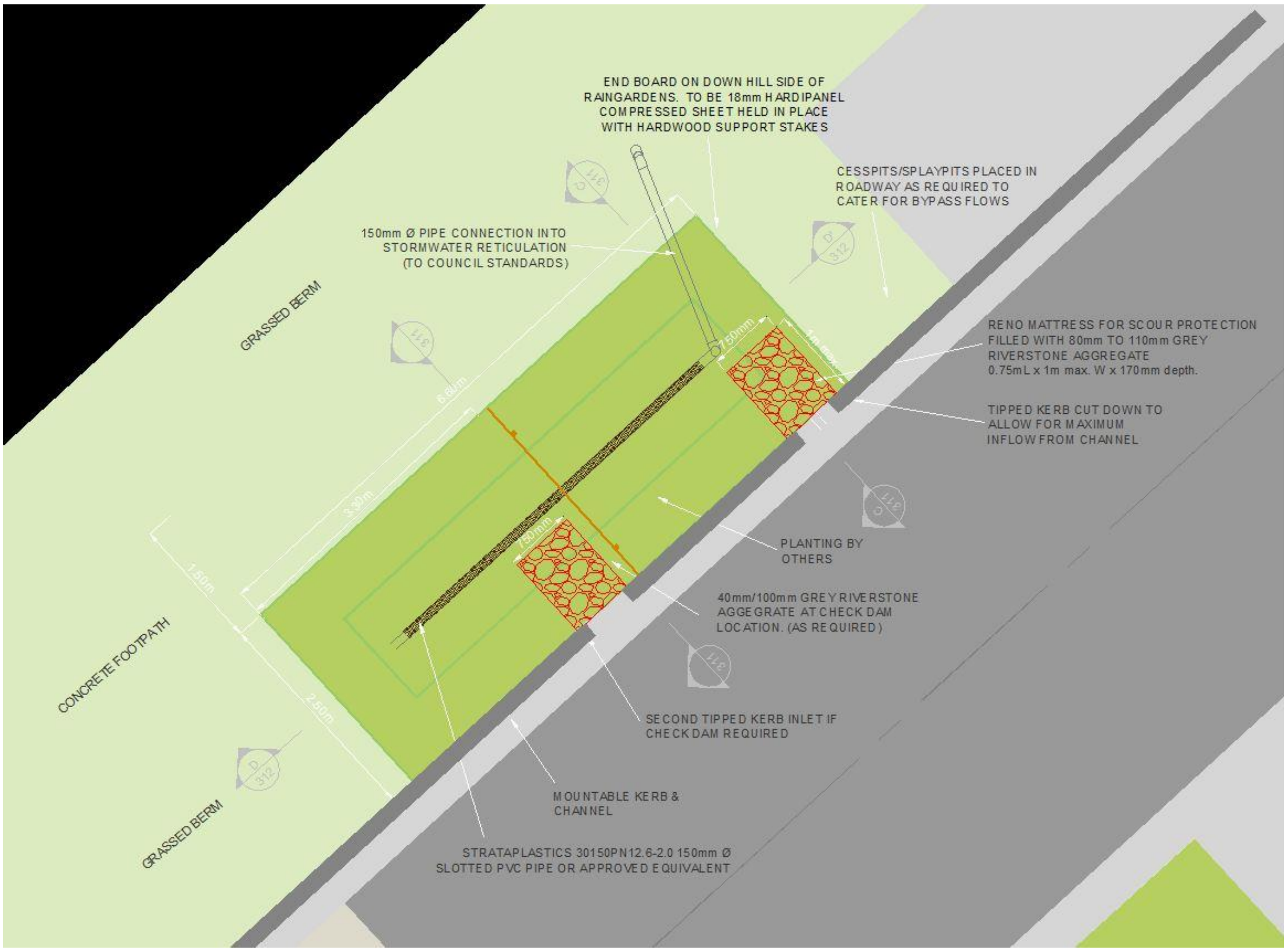
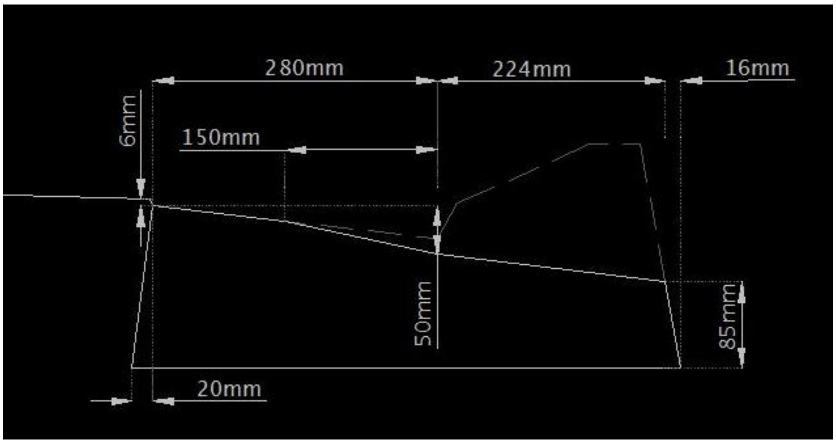


Figure 3 above shows a plan view of a typical rain garden in Stage 1 of the Long Bay development. The rain gardens at Long Bay have been designed to operate offline. The offline design works by having kerb cutdowns as shown in figure 4 below. Once the rain garden has reached its maximum ponding level, the overland flow is forced to bypass to the next rain garden/cesspit. The kerb cutdowns have been designed to allow for the water quality event.

Overall this offline approach helps to prevent scour by not allowing additional flow to enter the rain garden once it's exceeded its maximum ponding capacity as well as providing cost savings by not having to install a manhole into each individual rain garden.

Figure 4: Rain Garden Kerb Cutdown



Photograph 1: Constructed Rain Garden

3.2.1 HYDRAULIC ANALYSIS

A detailed analysis of the Long Bay rain ardens have been carried out in HEC-HMS hydrological package while using a filtration media that has hydraulic conductivity (Ks) of about 100mm/hour (in accordance with NSCC Bio-retention guidelines) for both:

- WQV storm event (i.e. 27mm rainfall depth over 24 hours, 1/3rd of a 2 year storm event); and

- A 20 minute 1.58 year storm event (i.e. 13.5mm rainfall depth over 20 minutes, from NIWA records)

The summary of the hydraulic analysis of the proposed Bio-retention Garden in both storm events is described below:

WQV Storm Event

To ensure compliance of the proposed Bio-retention Garden with NSCC guidelines and ARC TP10 requirements, the Bio-retention Garden was modelled in HEC HMS using SCS model for the WQV storm event.

20 Minute Storm Event

To check the performance of the Bio-retention Garden in the most frequent storm event a hydrological model was built in HEC HMS for a 20minute storm event with 1.58 year return period using the Clark Unit hydrograph method.

Table 1 overleaf shows the inputs and results of this analysis.

Table 1: Hydraulic Analysis Results

Model Input Parameters		
EVENT	**WQV EVENT**	**20 MINUTE EVENT**
Catchment Details		
Total Area	272.3 m^2	272.3 m^2
Pervious Area	77.3 m^2	77.3 m^2
Impervious Area	195 m^2	195 m^2
Equivalent Impervious Surface Catchment	234 m^2	234 m^2
Loss Rate		
Method	SCS Curve No.	SCS Curve No.
% Impervious	100%	100%
SCS Curve Number	98	98
Transform		
Method	SCS	Clark Unit Hydrograph
SCS Lag	6.67 minutes	10 minutes
Storage Coefficient	N/A	1 minute
Rainfall Data		
Rainfall	1/3rd of a 2 year storm event i.e. 27mm over 24 Hours	20 minute storm based on 1.58 year return period i.e. 13.5mm over 20 minutes
Model Output / Results Summary		
Peak Inflow to Bio-retention Garden	0.00105 m^3/s 1.05 l/s	0.00332 m^3/s 3.32l/s
Peak Outflow from Bio-retention Garden	0.00028 m^3/s 0.28l/s	0.00034 m^3/s 0.34l/s

Peak Storage in Bio-retention Garden	1.08 m^3	2.71 m^3
Ponding Depth at Peak Storage Level	75 mm	175 mm

The results from the HEC HMS modelling confirmed that the proposed bio-retention garden of about 2.7m wide and 6.7m long with a bio filtration soil depth of 0.5m is capable of capturing and routing both of the above analysed storms without exceeding the maximum live storage (200mm) provided.

3.2.2 CHOICE OF LINING

The choice of selecting an adequate lining at Long Bay was another critical step as geotechnical assessments showed that given the nature and geomorphology of the soils at Long Bay (Sandstone/Clay) they were unstable when saturated which meant that an impervious linear had to be used to ensure infiltration from these bio-retention devices did not occur.

The selection came down to two types, a traditional LLDPE liner or a Geo-synthetic clay liner. The selection process involved selecting a linear that was fit for purpose and cost effective (given that we would be required to use so much of it).

The traditional LLDPE liner was found to be more susceptible to piercing if laid directly over drainage aggregate, therefore additional geotextile fabric layers would be required. Whilst the Geo-synthetic liner which was constructed using layers of bentonite clay was more "malleable". The liner could be laid directly onto drainage aggregate and the ability to "re-seal" if ruptured meant that only one layer of this liner was required.

Future maintenance was also considered that would require minor works of clearing the top layer periodically and potentially longer term maintenance to replace the planting media. This work may be completed with the use of small excavators and therefore there is a likely risk that the liners could be punctured during this process. The Geo-synthetic liner was considered to have a better whole life value than the LLDPE.

The costs of using the Geo-synthetic liner was less than the LLDPE liner, \$17 per m2 compared to \$20 per m^2 + an additional \$8 per m^2 for the 2 layers of Bidim A44 that would be required. Based on the significant number of rain gardens being located adjacent areas containing aggregates, and the future maintenance requirements, the Geo-synthetic liner was considered best long term solution.

3.3 PLACEMENT & LOCATION

3.3.1 PLANTED VERGES VS GRASSED VERGES

The notion of opting for planted verges opposed to grassed verges was something presented by Boffa Miskell. Whilst the council initially had concerns with regards to the ongoing maintenance costs of fully planted berms, they were convinced that planted berms were plausible once shown that the amount of additional maintenance required was insignificant. The planted berm adjacent the rain gardens results in a consistent look to the berm.

A major challenge with this type of streetscape was that these devices had to be constructed before the lots could go on sale; therefore decisions typically left to the house designers such as placement of the driveways had to be pre-determined.

Long Bay Communities Limited decided that the vehicle crossings were best installed at the time of road construction. Locations of the crossings were coordinated with concept designs and house typology studies for the sites.

4 CONSTRUCTION & MAINTENANCE

4.1 RAIN GARDEN CONSTRUCTION

Each of the rain gardens constructed during this stage of the development were carried out systematically in the following sequence;

- Installation of drainage connections with main lines
- Road construction including kerbs with cut down entrys
- Install footpaths with edge beam
- Carry out excavation of rain garden
- Line raingarden with geosynthetic liner
- Install drainage pipework
- Place drainage & filter media
- Dress & plant rain gardens

Several inspections were undertaken by Coffey Geotechnics and Woods during construction to ensure a suitable finish was achieved. Coffey Geotechnics inspected each excavation prior to lining, they also inspected the integrity of the installed liner. The Contractor was required to provide photos at each stage of the works as per the above sequence.

Photograph 2: Rain garden Construction

The rain gardens have been installed for approximately four months. Woods are preparing to undertake testing of the devices. Points to be investigated include testing of the inflow capacity of the kerb cutdowns, operation of the overflow provisions, and the infiltration rates of the media. Findings from these tests will be considered within design of devices for future Stages.

4.2 MAINTENANCE

Ensuring adequate maintenance is carried out throughout the development helps prolong the life and efficiency of the devices. During both the road and house construction stages devices need to be protected to ensure they do not "silt up"; this was done via two main methods (refer Figure 3). The first line of defence is via installation of silt fences at lot frontages to reduce sediment discharge from adjacent areas. These fences are to remain through the house building process. The second line of defence comprises the use of filter socks at inlet points to the devices. This diverts all flows during main construction works past the device downstream to the cesspits within the street network. These are proposed to be removed following substantial completion of the house construction works.

As mentioned in section 2.3.1 vegetation is a key consideration, given that the Long Bay development consists of planted verges only (no grassed verges). The selection of the correct plants help to minimize the level of maintenance required, Planting was selected to ensure that the plant can survive during both wet feet (when raining) and prolonged dry conditions (January/February).

Long Bay Communities Ltd has initial care of all stormwater devices for a period of 2 years before they are transferred over to council.

Photograph 3: Rain Garden Protection Features

4.2.1 LAND PURCHASER INFORMATION

The Long Bay Development has requirements in the Covenants and Encumbrances to install sediment controls and water tanks (re-use), both of these are legal requirements.

The design guidelines also request that the "builder" signs an undertaking to abide by the environmental awareness clause – basically acknowledging the existence and role the Wetlands and Rain Gardens have in the treatment train and therefore do not pollute them.

5 CONCLUSIONS

Overall this paper has discussed the design, construction and methodology for the stormwater treatment devices in the first Subdivision Stage at Long Bay.

Our findings outlined in this paper are;

- Rain Gardens provided a greater treatment area than Tree Pits and were overall more economical and cost effective to construct
- Rain Gardens were designed to be "offline" by the use of kerb cutdowns – helping to prevent scouring as well as providing cost savings by not having to construct individual cesspits for each rain garden and instead utilize the standard road cesspits.
- Planting selected to ensure minimal maintenance.
- Long Bay consists of only planted verges – decisions such as driveway placement had to be pre-determined.
- Use of a Geo-synthetic liner because of its malleability, re-sealing ability and cost effectiveness.
- The constructed devices are to undergo testing to assess the inflow capacity of the kerb cutdowns, operation of the overflow provisions, and the infiltration rates of the media.
- Long Bay Communities Ltd has initial care for all devices for a 2 year period; thereafter the devices will be transferred to council.
- Builders at Long Bay must adhere to an "environment awareness clause" – essentially acknowledging the role of the wetlands and rain gardens in the treatment train, in order to avoid them being polluted during the building phase.

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