LOW IMPACT DESIGN RECOMMENDATIONS FOR WHANGAPARAOA GOLF COURSE STORMWATER MANAGEMENT

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ABSTRACT

The winning entry in the 2013 Auckland Council Low Impact Design (LID) Competition makes recommendations for stormwater management on and around the Whangaparaoa Golf Course (WGC). Currently, runoff from the surrounding residential area drains through drainage ditches across the course to ponds and wetlands. Perimeter ditches on the WGC were converted to engineered swales and a bioswale to safely convey a 100-yr 24-hr storm event. Three ponds were re-designed to capture the water quality volume, including a floating treatment wetland in one pond to control organic and other pollutants. Future development of “green streets” around WGC environs were designed to completely retain a 10mm rainfall event, treat the water quality volume and provide some peak flow mitigation. Housing lots were re-developed following Unitary Plan intensification guidelines. The proposed Whangaparaoa “green street” development included a range of LID stormwater devices, self-explaining road design, and a shared community green space. The proposed developments were intended to increase public awareness of LID in an environment which provides public amenity, enhanced biodiversity and stormwater management.

KEYWORDS

stormwater management; stormwater design; low impact design; green street

1 INTRODUCTION

1.1 AUCKLAND LOW IMPACT DESIGN STUDENT COMPETITION

Auckland Council invited students enrolled in ENVENG 701 at the University of Auckland to enter the Auckland Low Impact Design (LID) Student Competition 2013 and submit innovative LID solutions for the development of an urban residential area. In 2013 the focus of the competition was on the Whangaparaoa Golf Course (WGC; Figure 1) and the surrounding suburban area to the south and along Shakespear Road.

This suburban area around WGC has significant impervious area which produces runoff to be managed by the golf course. WGC had expressed concerns about the level of pollutants in the runoff, and they hoped also to be able to increasingly use the water for irrigation.

Figure 1: Whangaparaoa Golf Course and surrounding streets.

For this competition, two scenarios were considered for stormwater management: one for the golf course currently and one addressing a potential future development in the area.

1.1.1 EXISTING SCENARIO

- to convert existing drainage ditches on the golf course to engineered swales to promote water quality for the 90^{th} percentile design storm event;

- to design the 14th Hole pond and Holding-Irrigation pond system to reduce peak flows from the 24 hour 2-year and 10-year design storm events to predevelopment conditions to match pre-development hydrology as well as treatment for the water quality volume and to maximize irrigation storage where possible.

1.1.2 FUTURE DEVELOPMENT SCENARIO

- to allocate the redevelopment of residential lots bordering the WGC along Shakespear Road from the WGC car park to Alec Craig Way as a mixture of 2- and 3-storey apartments block designs (Auckland Council, 2013a). Aim to fully retain 10mm of potential runoff, provide water quality treatment of 90^{th} percentile design storm event and demonstrate peak flow mitigation for 2-year and 10-year 24-hour design storm events;
- to convert to Shakespear Road in that corridor, Alec Craig way and three adjacent cul-de-sacs to “green streets” for water quality treatment, considering the entire area draining to these streets;
- to assess whether water quality treatment can be provided for the properties draining to the south boundary of WGC.

For this scenario, consideration for safety, urban design and liveability for residents along the "green streets" were required, as well as safety issues and mitigation, maintenance requirements. For all tasks, discussion of site constraints and opportunities, contaminants of concern and justification for selection of devices was required.

This paper presents the winning entry from the Auckland Low Impact Design Student Competition, 2013.

2 METHODS

HEC-HMS was used to model the hydrology and device performance for each scenario. Drainage areas were modelled with either a composite curve number over the entire area and a weighted initial abstraction or, as separate drainage areas with individual curve numbers and initial abstractions as per TP-108 guideline. These methods render the same outputs when modelling the same area, so depending the preference of the modeller either method was used.

In general, the TP-108 methods for modelling stormwater were followed (Auckland Regional Council, 1999). Pre-development conditions in the WGC area were modelled as pasture in good condition, CN of 74. There were some situations where these methods couldn't properly describe the hydrologic behaviour of a device, particularly where hydrologic modelling was limited by the HEC-HMS software. For example, living roof abstractions and runoff cannot be modelled well in the software using TP-108 methods (Fassman-Beck and Simcock, 2013). Assumptions, simplifications and adjustments were made in order to model some devices. Different modelling approaches have been described where relevant.

The authors note that some assumptions from simplified methods such as the SCS curve number method (USDA, 1986) do not hold – catchments are more complex than the homogeneous assumptions in the SCS method, and soils in urban areas are often more compacted than those in rural areas (Simcock, 2009). Given these limitations, best estimates of hydrologic behaviour have been made for all devices and scenarios presented.

Auckland regional stormwater design manuals were used to design devices for this project. The TP-10 manual (Auckland Regional Council, 2003) was being updated thus a number of draft and yet un-published updates to TP-10 for permeable pavement, ponds and living roof design were made available to our class to use.

2.1 SWALE DESIGN

A network of swales was planned to convey flow from the drainage outlets to the existing retention ponds, where suitable. Swales were designed as per TP-10 (Paterson and Helberg, 2012) and flows were routed with the Muskingum-Cunge method in HEC-HMS. An iterative approach was used to determine suitable base widths, side slopes and effective slopes for swales in the network to meet the design requirements.

2.2 POND DESIGN

Ponds were designed as per Stormwater Management Ponds: Review and Design Recommendations (ARC, 2008). The design objective was to provide suitable treatment and storage for irrigation, without compromising the stability of the downstream wetlands or safety of the surrounding area. The volume of rainfall and flow regime for different events informed development of pond bathymetry. A custom spreadsheet was developed to visually simulate and analyse hydrologic information for the ponds to determine suitable geometry.

2.3 PERMEABLE PAVEMENT DESIGN

Permeable pavements (PP) were designed using the update to TP-10 for Permeable Pavement design (Worth, 2010), the objective being water quality treatment. Drainage areas and curve numbers (CN) by land-use were input into HEC-HMS to determine the post-development peak flows, runoff depth and volumes. Fassman and Blackbourn's suggested CN of 51 for PP was used to model the surface runoff volume from the pavement (2009). When selecting potential sites for PP, the main consideration was a maximum 2:1 ratio for run-on area to total area and, slope less than 5% where possible. For basecourse volumetric design calculations, pavement areas were simplified as rectangular.

A suitable wearing course was chosen to maintain an infiltration rate greater than the 10-yr peak storm intensity. Structural design of pavement was not considered, further analysis from a transportation engineer would be required to determine the critical pavement design.

2.4 BIORETENTION CELL DESIGN

Bioretention cells (BRC) were designed for water quality treatment using the Raingarden Design Technical Report (Blackbourn, 2011). The required surface area of a bioretention cell is highly dependent on the permeability of the cell media. Auckland Council's media specification for stormwater devices recommends media permeability from 80-1200mm/hr (Auckland Council, 2013b). So, to design BRC to capture and treat suitably runoff, an 80mm/hr target in-situ permeability (1.92m/day) following installation was elected.

3 EXISTING SCENARIO: WHANGAPARAOA GOLF COURSE

3.1 SWALE NETWORK

A network of swales was designed to feed to the holding pond, Figure 2. Check dams were required for the swales labelled in red, pink and cyan to reduce the effective slope and slow flow. A single bioswale was designed to feed to the Hole 14 Pond and is shown in Figure 3. A bioswale was chosen here because of the large area of asphalt in the drainage area thus conveyance with additional treatment capability (heavy metals, TSS) was preferred over regular grassed swales. The swales along the north-west boundary were designed to convey flow to an existing stormwater pipe at the north-western tip of WGC (Figure 4). The swale labelled in red required check dams to reduce effective slope and a geotextile lining to reduce erosion on the base.

Swales were not suitable in several areas due to the location of tees, greens and fairways on the course which were not to be altered. Pipes, shown as dotted lines, were used to convey runoff below ground so that these were not interfered with.

Each swale was sized to safely convey flows up to the 100-year, 24-hour storm, while also providing adequate pre-treatment of the WQV storm for the ponds. Where a hydraulic retention time of 9 minutes was not able to be obtained, further treatment measures were more critical, such as the forebay or Holding pond preceding the design point. Based on previous studies (Wright Water Engineers Inc and Geosyntec, 2012) this network of swales was estimated to remove around 70% of TSS from the road, while also reducing copper and zinc concentrations in runoff. Routing procedures showed minimal peak flow mitigation, however these were accounted for in subsequent pond design.

Figure 2: Swale network draining to Holding pond.

Figure 3: 14th Hole swale map.

Figure 4: North-west corner swale map.

3.2 RETENTION PONDS

The profile of the pond and outlet characteristics were iteratively adjusted until a suitable compromise was found between the storage provided, the ability to manage the 10-year and 100-year storms and the similarity of the outflow hydrograph to the predevelopment condition. Where required, the management of the large storms carried greater weighting due to the associated risks to the public if not properly conveyed.

Each existing pond would require excavation, to maximise storage without encroaching on areas required for golf course functionality. Outlet structures were designed as upturned risers, to enable weir flow, minimise turbulence within the pond and reduce the potential for excess sediments in the receiving waters.

3.2.1 HOLDING POND

The Holding pond receives water from the swales in Figure 2 and discharges to the Irrigation pond. The Holding pond was able to fully capture the water quality volume, ensuring adequate detention time before transferring to the Irrigation pond. To improve water quality treatment, a floating treatment wetland is proposed for this pond also.

The key parameters of the Holding pond system are shown in Table 1, and its configuration in Figure 5. It should be noted that this new design does not take up the full length of the current pond and is wider. This was intended to maximise the contact time with the proposed floating treatment wetland (FTW) and ensuring a slow flow velocity.

Table 1: Key parameters of the Holding Pond and Irrigation Pond

	Holding Pond	**Irrigation Pond**
Permanent Storage (m^3)	1,138	2,845
Natural Water Level (m)	0.82	1.33
Max. depth due to WQV storm (m)	1.00	1.44
Max. depth due to 100-year storm (m)	1.62	1.87

Figure 5: Overlay of Holding Pond on aerial photo of site.

A cross-sectional view of the Holding pond is shown in Figure 6. The floating treatment wetland would be about 560m^2, at 28m wide and 20m long. Vertical walls are included to ensure the water passes through the roots of the FTW. Walls steeper than recommended for safety were opted for to minimize the pond areal land requirement. The Holding pond should therefore be clearly marked with signs and with fencing to ensure public safety. That said, the bench at 0.3 m below the permanent level provides some safety in the case of someone falling in.

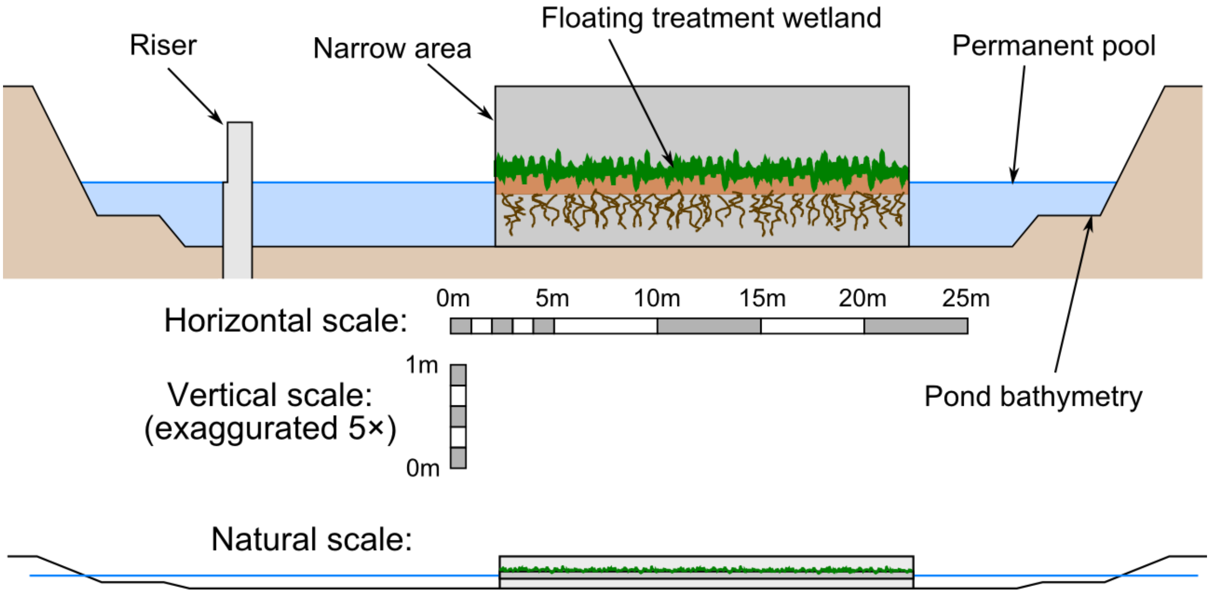

Figure 6: Longitudinal cross-section of Holding pond with Floating Treatment Wetland.

3.2.2 IRRIGATION POND

The Irrigation pond, downstream of the Holding pond, is shown in Figure 7. With our re-design, the pond is able to permanently store 2.5 times the volume of the water quality storm and providing irrigation of up to 15 mm over the entire north-eastern corner, if required. It can also safely convey a 100-year storm by overflowing to the downstream wetland via overland flow.

Figure 7: Overlay of Irrigation Pond on aerial photo of site.

The difference in elevation between the ponds is such that the riser from the Holding Pond can enter the Irrigation Pond through the side wall, where its flow is dissipated by a concrete pad. Maintenance outlets were designed for both ponds to ensure they can be safely drained for maintenance such as dredging.

This pond system was not able to closely match the predevelopment outflow characteristics. The ponds were over-sized in order to provide effective volume for storage and treatment. The peak outflows for the WQV storm were 50% less than predevelopment, while the peak for the 100-year storm was 30% more. The reduction for WQV is not thought to be an issue due to the low level of sediments in the outflow, while the 100-year storm would be distributed between overland flow and riser flow, and dissipated with concrete pads wherever suitable to prevent scour.

3.2.3 14TH HOLE POND

This aesthetic pond located near the south-east boundary of WGC was re-designed to improve stormwater management. The new 14th Hole pond would be able to capture 150% of the WQV storm, ensuring adequate retention time for settling. A formal forebay was included as a large amount of the inflow entered the system without adequate treatment from the swales or bio-swales. The configuration of the pond and forebay is shown in Figure 8.

For the 14th Hole pond, the predevelopment outflow characteristics were able to be closely matched, with the WQV peak just 8% below predevelopment, and 100-year storm peak just 16% above. This would provide significant water quality benefits for the downstream wetlands in comparison to the current condition.

Figure 8: Overlay of Hole 14 Pond and forebay on site.

4 FUTURE DEVELOPMENT SCENARIO

This section includes proposals and designs for management of the runoff from properties to the south of the Golf Course, "green street" development and residential lot intensification in the surrounding neighbourhood. Each of these development tasks was addressed with the "green street" philosophy.

Green streets are road corridors which incorporate LID principles for stormwater mitigation (ARC TP-124, 2000), safety, urban design and liveability for residents. This also includes physical greening with tree planting or preservation and landscaping to enhance biodiversity. Our approach to green street development in Whangaparaoa employed both structural and non-structural measures integrating two key elements: stormwater management and community.

4.1 COMMUNITY

4.1.1 PUBLIC GREEN SPACE

In placing the new residential lots along Shakespear Road, an 8 m wide strip of green space has been provided along the whole back edge of the new lots. The housing designs used, from the Draft Auckland Unitary Plan (2013a) were shorter than the existing lot areas, leaving additional public space. Our recommendation is to establish this as a public recreational area with a walkway for walkers and cyclists alike and planted with native trees and shrubs to create a vibrant and natural green band across the neighbourhood. Shared spaces would aid in fostering community, as people take walks or picnics in a local space, and interact with neighbours and the natural environment. Other green spaces have been included in this development proposal - notably at the intersection of Whangaparaoa and Shakespear Roads. This area would be planted with a range of trees in a similar way to the green strip behind the residential lots, however other demographic-specific amenities could also be included here such as, a playground for children, a water feature, shaded seating for older residents, picnic tables.

Existing large trees in developed areas would be kept where possible to maintain the existing ecosystem services they provide to residents (Roy et al., 2012). Once planted vegetation is established this green space is expected to capture rainfall from at least a 10 mm event, as prescribed for the residential developments.

Hydrologic analysis of this green strip was done to quantify runoff reduction from surface infiltration alone, with a critique of the assumptions and methods of SCS Curve Numbers. From a 10mm rainfall event, a grassed area of CN 74 and initial abstraction 5mm produce 0.265mm runoff depth.

4.1.2 RETAIL AREA

With the intensification of housing in this area it was noted that there are very few shops nearby. Thus, a corner lot has been assigned to be a 3-storey retail block, the suggested use being eateries (a café, a dairy and takeaways) and possibly a gym. This lot would likely have good ocean views; however fitting the template apartments there would require a significant re-design of the apartment buildings. A retail area is expected to improve the liveability of the area, creating a more walk-able neighbourhood where residents are able to walk, rather than to drive, to purchase basic groceries, and eat out. To manage runoff on site, this building could have a living roof and permeable pavement parking spaces for example.

4.1.3 SAFETY

To improve the safety around roads in this neighbourhood the concept of self-explaining roads was implemented in this approach to green street development. Self-explaining roads are designed with elements that cause drivers to think and react more intuitively about what they are doing on the road, compared to with regular road signage (P. Mitchell, 2013: *pers. comm.*). For example, road design which causes a quicker response to changes in the driving environment. This approach focused on Shakespear Rd and Alec Craig Way.

Along Alec Craig Way in the approach to the pedestrian crossing outside the school, a small section of permeable pavement has been suggested. The different texture of the paved wearing course naturally slows drivers (before the pedestrian crossing) as they notice and respond to the change. This should to make the road area in front of the school safer with slower traffic. Street trees lining roads provide advanced visual cues for drivers as to the up-coming road layout. For example, if a corner is approaching a line of trees directly ahead will alert the driver of this change well-ahead and they can anticipate and slow for the corner well.

4.1.4 EDUCATION

To support successful implementation and continued function of green streets we realised community buy-in early on and throughout the process is important. This can be achieved and maintained through education for residents about the special features and functions of their green street. Hopefully, a sense of neighbourhood pride could develop from the special character and environmental benefits of green streets.

There is an opportunity to develop an LID education initiative for local residents and students of Gulf Harbour School to explain LID principles and how they are incorporated into the local green street environment. Content of educational material should include: the importance and how-to of looking after stormwater devices (such as not walking over bioretention cells to preserve bioretention media permeability); minimising pollutant sources such as fertilisers, or detergent suds from washing cars on impervious areas; and minimising property disturbance to reduce TSS loads which can clog permeable pavements and bioretention cells. To provide continued educational benefits, signage would be installed at specific devices explaining their function, such as at the feature LID devices described in the Highlights section.

4.2 STORMWATER MANAGEMENT

LID devices have been incorporated into the green streets to provide stormwater management in the residential lot and street re-developments. This included bioretention cells, vegetated filter strips, living roofs and permeable pavements as well as semi-engineered stormwater solutions. Contaminants of concern for roadways and residential areas were TSS, heavy metals and hydrocarbons. For streets the aim was to provide water quality treatment of runoff draining to Shakespear Road, Tate's Court, Dacre Grove, D'Urville Place and Alec Craig Way. For the residential lots the stormwater management objective was to retain a 10mm event on site, treatment of the water quality volume and peak flow control.

The design brief called for treatment train design, to target pollutant removal and management of peak flow and volume. The solution for the Existing Scenario was a treatment train from swales to retention ponds, through a treatment wetland in once case, and downstream to pocket wetlands. The stormwater measures in the streets around the golf course form the first steps in the train of treatment.

4.2.1 LID RETRO-FIT PROGRAM

A holistic approach to address the stormwater runoff from the existing developed area around WGC is proposed with the establishment of an LID retro-fit program. The local Council could champion and part-subsidise a program which provides information, guidance and technical support for residents who opt-in for permeable pavement and or living roof retro-fits.

The hydrologic impact of this program was modelled for the properties draining to the south of the Whangaparaoa Golf Course. These properties have very high impervious areas (~80%). Using CN of 51 (Fassman and Blackbourn, 2009) for permeable pavements and 85 for living roofs (Fassman-Beck and Simcock, 2013) runoff from the 36mm water quality event was estimated for these areas using HEC-HMS. Simulations were done of the existing situation, predevelopment condition (grassed), with permeable pavement (PP) replacing driveways, with living roofs (LR) installed on every roof and both. It should be noted that assigning a CN of 85 for living roofs is only true for storms ≥30 mm: there is no runoff at all if a rainfall event is less than 30mm.The complicated shapes of the driveways made it difficult to model quantitative peak reduction and volume mitigation from permeable pavements effectively and efficiently. Table 2 summarises the effect of installing permeable pavement, living roofs or both for three housed areas which drain to the south of the golf course.

Table 2: Simulation results for LID residential retro-fit program.

		Pre-development (CN = 74)	Existing condition	Add PP (CN=51)	Add LR (CN=85)	Add Both PP and LR	
Tiller	Peak discharge (m^3/s)	0.006	0.021	0.012	0.014	0.005	
	Runoff (mm)	8.0	26.4	15.7	11.3	7.0	
	Runoff (m^3)	3.5	116	68.9	77.7	3.06	
Tate 1	Peak discharge (m^3/s)	0.004	0.017	0.011	0.011	0.005	
	Runoff (mm)	8.0	22.6	15.1	14.9	7.4	
	Runoff (m^3)	32.6	92.9	62.3	61.2	30.5	
Tate 2	Peak discharge (m^3/s)	0.004	0.018	0.011	0.013	0.005	
	Runoff (mm)	8.0	23.4	14.3	16.2	7.1	
	Runoff (m^3)	34.6	101.2	61.9	70.1	30.8	
Total	Peak discharge (m^3/s)	0.015	0.056	0.035	0.038	0.016	**11%**
	Runoff (m^3)	70.7	310.1	193.1	209	64.36	**-9%**

To match pre-development peak discharge and runoff all roof areas would need to be converted to living roof, and all driveways to permeable pavements. Permeable pavements provide volume mitigation and filtration of TSS from runoff, and living roofs are significant at retaining 30 mm rainfall depth before runoff occurs. The catchment is considered to be stable, so production of TSS is not expected to be significant (data is not available though, so it should be investigated). High concentrations of nitrogen or phosphorus are not expected to in runoff as the drainage areas are a private residential land use. Cars deposit hydrocarbons and heavy metals (such as Zn, Cu) – permeable pavements do not remove these contaminants so pollutant removal would be done by the 14th Hole pond and in the downstream wetlands.

The eastern Shakespear Road drainage area receives significant residential run-on. At that location, the land area available is narrow, leaving little room for installing LID stormwater devices such as bioretention and bio-swales. Thus, the program promoting permeable driveways and living roofs in private residential areas is a significant opportunity where few other options for flow mitigation are available. However this area was accounted for the Existing Scenario pond and swale design for WGC, so if implemented the situation along Shakespear Road will change.

The proposed retro-fit program is likely to be an expensive undertaking both for residents and the local council, and therefore it is not recommended for implementation without further investigations around feasibility, cost and community input. Keen residents can still be encouraged to manage the runoff from their properties: these simulations show the effectiveness of two LID devices at mitigating runoff.

An alternative way to mitigate excess runoff in this neighbourhood is for adjacent driveway to be coupled and narrowed to become shared impervious corridors, reducing total impervious area. Green street development of cul-de-sacs along the south side of WGC will also contribute significantly to the treatment and management of stormwater.

This development aims to minimise the amount and impact of runoff from the properties on the southern boundary, in the current situation.

4.3 GREEN STREET DEVELOPMENT

Each street presented constraints and opportunities given the existing layout, planting scheme and topography which affected the choice of device and LID approach for green street development.

4.3.1 PERMEABLE PAVEMENTS

A detailed design of one composite passive and one active system was done to provide general information on features of permeable pavements (PP) with regard to slope and basecourse storage. Porous concrete grid pavers, 100mm deep, with 5mm diameter joint chip and bedding (20mm depth) were chosen as the wearing course. Where required, check dams were designed to provide additional storage for the water quality volume and surface area for filtration and sedimentation of TSS. Due to the low permeability of in-situ soils (Hydrologic Soil Group C) underdrains were required for all permeable pavements around WGC. All pavements were designed with a porous concrete paver, 100mm, for the wearing course.

Table 3: Summary of permeable pavement designs

Pavement Site	Type	Area (m^2)	Slope	Depth of basecourse (m)	Storage (m^3)	Checkdams
G.H. School A	Passive	1,013	3.8%	>0.4m	15	Not required
G.H. School B	Passive	609	1.5%	>0.2m	9	Not required
Tate's Court	Active	355	5.8%	0.7m	8	Optional

An objective of installing permeable pavements, aside from volume control, was water quality treatment. Permeable pavements have been shown to effect percent removals of 80% for TSS, 74% for Zinc and 40% Copper (Wright Water Engineers Inc and Geosyntec, 2013). Runoff from permeable pavement areas that still have contaminants drain to retention ponds and the constructed wetland in WGC for further treatment. However, contaminant loads from the drainage area considered here are not expected to be large for TSS, nitrogen or phosphorous. Permeable pavements do remove TSS up to 13.2 mg/L however clogging is undesirable for continued long term benefits of PP. Thus care was taken with site choice, to divert runoff with expected TSS away from or around the pavement to extend the design life of the pavement by avoiding premature clogging.

4.3.2 BIORETENTION CELLS

A collection of designs for a number of bioretention cell (BRC) sites were done to provide baseline information about hydrologic control provided for different site situations, including peak flow mitigation for events up to 30mm (Hunt, 2012 in Fassman-Beck, 2013: *Pers. Comm.*) volume reduction due to the porous cell media and provision for ponded volume.

Depth of cell media is the primary factor affecting pollutant removal mechanisms for a BRC, where vegetation is established: pollutant removal capabilities include sedimentation, bio-filtration, bioremediation and filtration (NSCC Bioretention Guidelines, 2008: in Fassman-Beck, 2013: *Pers. Comm*). In the Auckland region, monitoring of BRCs shows effective removal of TSS and Zn but not Cu (Fassman-Beck, 2013: *Pers. Comm.*). A mulch layer is recommended to suppress weeds and provide a surface for sorption of heavy metals (Davis et al, 2003, 2005: in Fassman-Beck, 2013: *Pers. Comm*).

Mix specification for BRC media was chosen at 10% well-aged compost with low phosphorus and copper, and 90% east coast sand, washed to provide storage, filtration and support plant life. Any bioretention cells sited adjacent to roads may require a vertical concrete pad to prevent infiltration of water into road basecourse or sub-base. the media: this catchment is considered stable and will not contribute high TSS loads. Once bioretention vegetation is well established, it will provide amenity value as an aesthetic garden along the street.

4.3.3 HIGHLIGHTS OF STORMWATER DESIGN

BIORETENTION BUS-STOP

For Shakespear Road specific bioretention cells were designed (Figure 9) to be incorporated with existing bus stops, making the most of out the small widths available on the western road-side. Options such as bio-swales were deemed too expensive, and pollutant loads too low for their installation and maintenance to be reasonably justifiable. Small curb cuts could be constructed to ensure sheet flow enters from the road-side gutter. A seating bench on top of the raised deck would provide seating at the bus stop. Rear hand rails provide safety to the public and could support signage to educate the public about LID (Figure 9). The retaining wall allows for ponding as well as media depth to provide internal water storage for greater treatment.

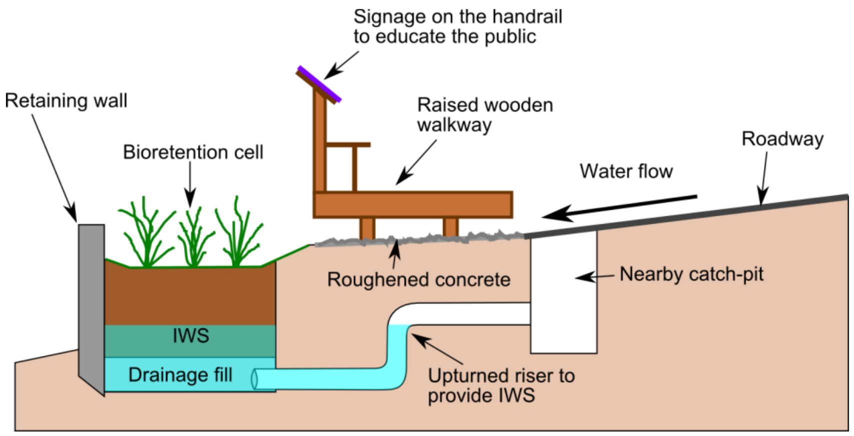

Figure 9: Diagram of bioretention-bus-stop system for Shakespear Rd.

SEMI-ENGINEERED INFILTRATION SYSTEMS

A number of existing street trees along the cul-de-sacs from Alec Craig Way have raised mulched gardens. Trees planted near the intersection or Alec Craig Way and Tate’s Court – primarily Pohutukawa – are planted in garden beds with Agapanthus planted around the base of the tree. To improve volume reduction from runoff down the west side of Tate’s Court, a recommendation is to convert mulched tree gardens into depressions that function as semi-engineered infiltration systems. These systems would support native flora, improve the street-side aesthetic and amenity value, and provide some additional volume control and pre-treatment of runoff in storm events. This infiltration system requires removing the existing plants and mulch - leaving the tree - and excavation of the soil to form a depression around the trunk to be filled with bioretention cell. This system could capture gravity flows and support a range of moisture tolerant native shrubs or grasses to remove TSS and other pollutants depending on the media depth. Mulch to suppress weeds and increase removal of heavy metals could be added also.

“Semi-engineered” LID strategies are one option to treat the WQV: amendment of grass road-side verges with compost to promote infiltration, while also undertaking the planting of small trees and shrubs to enhance infiltration, increase flow path length and evapotranspiration. Street-side trees also add to the "self-explaining roads" strategy, reduce traffic speeds and create habit for native birds and wildlife.

GULF HARBOUR SCHOOL CARPARK

The local school car park is a significant impervious area in the green street re-development area, and presents an opportunity to showcase permeable pavement technology. A permeable pavement in passive configuration is proposed, of area approximately 1,600 m^2. This improvement will reduce the likelihood of surface ponding in the car park through storage and exfiltration of runoff to the soil and underdrains. It may also improve amenity value of the school, reduce load on the major sewer (and there are few other areas suitable a PP installation) and can provide effective mitigation against temperature of runoff. This device also provides an educational opportunity to teach students of the Gulf Harbour School about low impact design and stormwater management – a worthwhile topic for a school where many pupils would live in green street residential developments also. Signage to describe the features and functions of permeable pavements could be set-up in the public footpath adjacent to the carpark driveway.

4.3.4 RESIDENTIAL LOT RE-DEVELOPMENT

For implementation of green street designs in this area, re-development with the 2-3 storey lots on both sides of the street is recommended – development of just one side was required for this project. Contrast across the street in a neighbourhood may inhibit or limit the community benefits of a green street development approach as there is clear division or difference in housing situation along the street.

LAYOUT RATIONALE

Three-storey apartments were preferred, as they added more homes for the same lot size. However, two-storey apartments were generally used near shared green spaces, or when adjacent to a residential driveway to preserve sight-lines and avoid causing too much shadow.

It was assumed that the slope of sites would not be a constraint when choosing the apartment lot locations. In many places, it would be possible to use fill to build up places where the apartments do not fit the existing land layout, however a better suggestion would be to modify the design of the housing lots to suit the topography (e.g. moving the structure to the back of the lot, with yard space in front).

The following were created or removed along Whangaparaoa and Shakespear Roads (Figure 10):

New homes:	11 × 2-storey lots
	9 × 3-storey lots
	2 × single-block 2-storey apartments
	380
Homes removed:	71
Nett new homes:	**309**

Figure 10: New housing lot layouts.
Note the continuous green space walking area between housing lots and the golf course. Driveway on to the WGC in the north-western block has been relocated. Blue lots house a modifited sole 2-storey, 2-dwelling apartment.

It is recommended that building construction avoids materials that can become sources of pollutants, for example exposed galvanised steel (zinc), exposed treated timber, or copper roofing. Use of fertilisers, herbicides, pesticides and fungicides on garden and lawn areas should likewise be avoided. The latter, and care of the green roofs, permeable pavements, and other stormwater devices may require public education, however two possible ways to achieve this are to leave lot maintenance with a centralised body corporate or to specifically market the idea of a green environment – and its requirements – to the residents.

The living roofs were designed using a draft update to TP-10. The substrate chosen was “Tamaki zeolite”, a mixture of pumice, zeolite and a small amount of stable compost, to a depth of 150 mm, with drainage, root barrier and waterproofing layers beneath. Plant available water (PAW) would be approximately 29% and saturated permeability of around 1580 mm/hr. This roof design is able to store 30 mm of rainfall as PAW.

It will be important to ensure careful quality control of the source material, particularly particle size distribution, structural weight, and the stability of the compost (that it will not leach nutrients). Recommended plant types included Sedums and a variety of low-height, drought-tolerant native and exotic species. The living roofs have been designed to require as little maintenance as possible, after an initial establishment period.

2-STOREY APARTMENT LOTS

Stormwater management in the 2-storey apartment lots utilises permeable pavements and a bioretention cell. Because the 2-storey apartments will be viewed from above where they are next to a 3-storey apartment, living roofs were not used (due to the extra maintenance requirements to design a living roof for aesthetics).

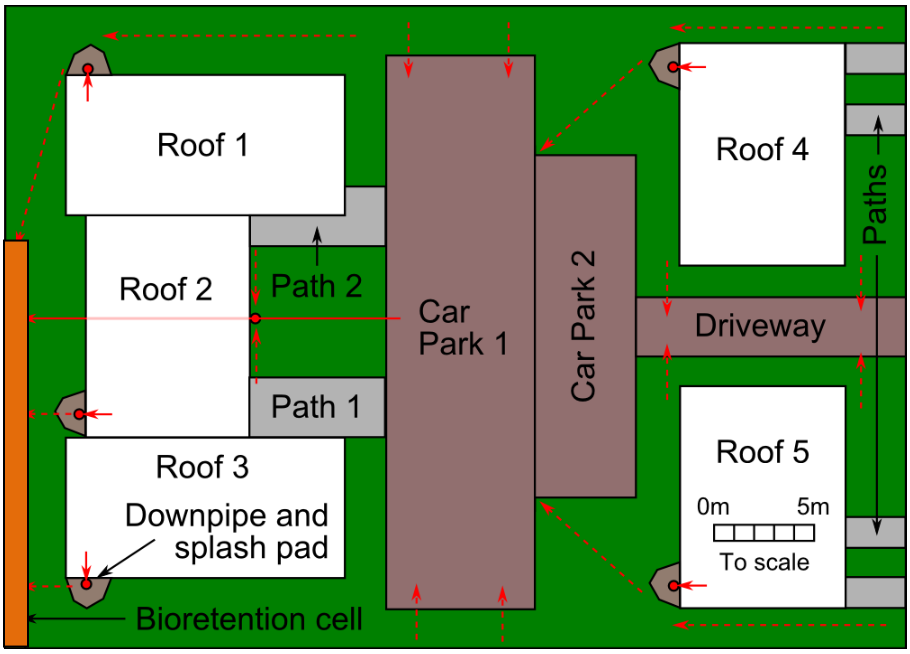

Figure 11: 2-storey apartment lot layout (adapted from Auckland Council, 2013a).
Roof areas are marked in white, impervious areas (courtyard, driveway, path) marked in grey, grass in green, bioretention cell in olive green. Piped flow paths marked with red arrows, overland flow paths represented by dashed red arrows.

A 10 mm rainfall event was completely captured; most of the site generates little runoff for this small an event, and the bioretention cell was able to capture the remaining runoff. The permeable pavement provides some filtration and the bioretention cell provides multiple means of treating contaminants, meaning that the outflow from the site will be comparatively clean. The peak flows for the WQV and 2- and 10-year, 24-hour storms were all slightly reduced from their pre-development flows, due to the system being designed to completely capture the 10 mm rainfall event (2 to 1 L/s, 10 to 8.9 L/s, and 23.4 to 22.1 L/s respectively).

3-STOREY APARTMENT LOTS

The 3-storey apartments focus on bioretention cells and green roofs – the latter chosen because the higher roofs will not be seen, so "function-ahead-of-form" low-maintenance roofs can be installed without sacrificing visual appeal. And, green roofs offer habitat to local birds and invertebrates, so plant types on the green roofs will be varied between apartments to encourage biodiversity. Bioretention cells will be placed at the lowest point of each lot to collect and process all runoff from the site (always at the back, but side may change depending on local slope). Bioretention cells were chosen because of their excellent ability to treat all types of pollutants (Wright Water Engineers Inc and Geosyntec, 2012).

For these lots, the peak flows were reduced from 2.0 to 0.6 L/s for the WQV rainfall event, from 10 to 9.1 L/s for a 2-year, 24-hour storm, and increased slightly from 23.4 L/s to 25 L/s for a 10-year, 24-hour storm when compared with pre-development conditions. But, generally the hydrologic responses were very similar. Total runoff volumes from the green roofs increased by 24% and 36% for the 2- and 10-year storms respectively.

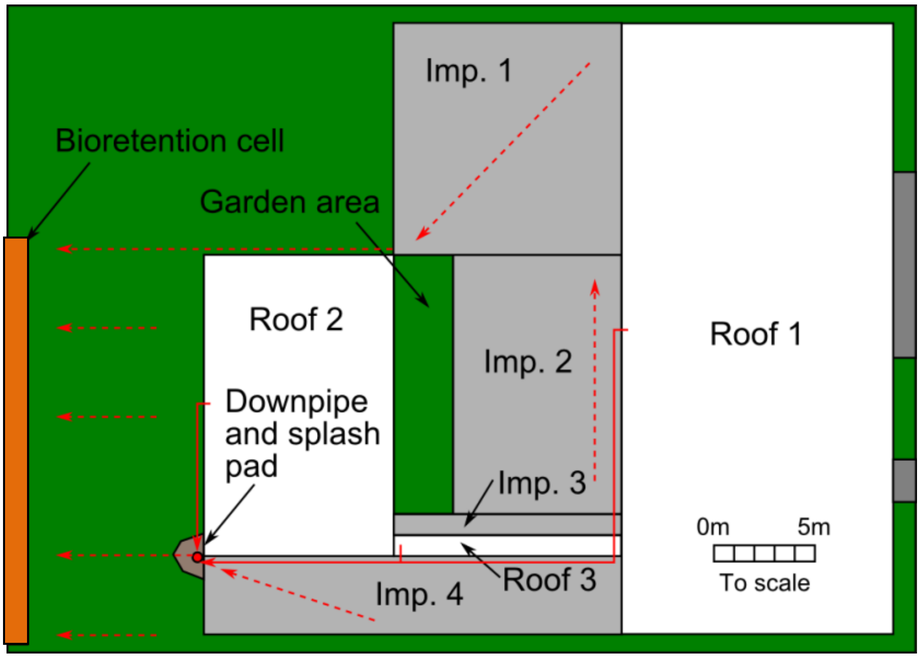

Figure 12: 3-storey apartment lot layout, (adapted from Auckland Council, 2013a). Roof areas are marked in white, impervious areas (courtyard, driveway, path) marked in grey, grass in green, bioretention cell in olive green. Piped flow paths marked with red arrows, overland flow paths represented by dashed red arrows.

The bioretention cells would provide a natural barrier at the back of the sections, as well as an aesthetically-pleasing garden area. It is suggested that large fences be avoided, to give a greater sense of space and encourage formation of community, though vertical bar fences could be used where desired by the residents. Access to the shared green strip is available from either the back (most common) or front of all the new properties.

5 CONCLUSIONS

The swales along the north and north-east of the WGC convey flows from upper drainage areas to the designed retention ponds. Swales intercept flow from residential areas and control flow depths to a safe level. Swales provided minimal volume mitigation and, peak flow reduction. The Holding pond-Irrigation pond system can effectively capture and treat runoff from the area draining to WGC from the north-east. The Holding pond can capture the WQV and provide suitable detention time for treatment. The Irrigation pond provides up to 3000m^3 of permanent storage for irrigation while also safely conveying flows up to the 100-year ARI event.

The future development of Whangaparaoa employs both structural and non-structural measures to create a "green street" neighbourhood, incorporating LID. Our solution provides public amenity, improved safety and values community identity and education in the process of redevelopment, as well as stormwater management.

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