DO NOT LET PERFECT BE THE ENEMY OF GOOD

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ABSTRACT

The existence of TP 124 and TP10, the Auckland regional government guidelines for incorporating Low Impact Design (LID) techniques, indicate to me that this region is switched on to a forward thinking stormwater management philosophy.

The guidelines have been in place for a number of years however there are relatively few successful LID projects constructed in Auckland. There are a number of reasons why the implementation of LID developments has been limited. This paper is focused on the competing interests of the stakeholders in relation to the technical parameters of bio-filtration systems.

It is believed that the TP 10 guidelines and their applicable review are overly conservative for bio-filtration systems. This results in the traditional "end of pipe treatment systems" being more cost effective to consent and build. URS recently developed a stormwater management plan for a western Auckland catchment exclusively utilised bio-filtration systems to treat stormwater. In this paper we will review the development of the management plan and explore the standard engineering practices that were used to alter key parameters; coefficient of permeability, live storage area and treatment volumes. Results show a stormwater management system successfully treating a 313 hectare catchment of intensive development with significant cost savings.

KEYWORDS

Low Impact Design, Rain Gardens, Natural Drainage, Stormwater Management

PRESENTER PROFILE

Jess Wallace has been using Low Impact Design and natural drainage for stormwater management for the past decade. He is an avid supporter of using natural process and hydrologic mimicry to solve urban stormwater issues

1 BACKGROUND

1.1 INTRODUCTION

The existence of TP 124 and TP10, the Auckland regional government guidelines for incorporating Low Impact Design (LID) techniques, indicate that this region is switched on to a forward thinking stormwater management philosophy. However the guidelines have been in place for many years and there are relatively few successful LID projects constructed in Auckland. This paper follows the development of one catchment management plan in order to determine the reasons for this low success rate.

It is believed TP 10 guidelines and their applicable review are overly conservative for bio-filtration systems. This results in the traditional "end of pipe treatment systems" being more cost effective to consent and build. URS recently developed a catchment management plan for a western Auckland catchment that placed a heavy reliance on integrated bio-filtration systems to treat stormwater. In this paper we will review the development of the CMP and explore the standard engineering practices that were used to alter key parameters; coefficient of permeability, live storage area and application of the extended detention and water quality storms for designing bio-filtration systems. Results show a stormwater management system successfully treating a 600 hectare catchment of intensive development with significant cost savings. For the purposes of this paper we will focus on the 313 hectares of Industrial commercial development.

1.2 Real World Comparison

The Seattle Street Edge Alternative Project (SEA) has been used throughout the paper to provide a direct comparison of the proposed stormwater management plan. The size of the SEA project is approximately 1 ha and considers a 2 year 24 hour storm with a depth of 42mm. Although the SEA project was completed for a residential area and not an industrial/commercial area the hydrologic characteristics, including the overall percentage of impervious area, are similar to those of this study area. This project has been deemed highly successful at capturing and treating not only the targeted two year storm but also more major events as well.

1.3 CATCHMENT BACKRGROUND

The catchment of interest is proposed for industrial and commercial development and encompasses approximately 313 hectares.

Current land use is predominantly agricultural paddocks used for grazing and is estimated to be 5% impervious. The proposed land use would be an industrial/commercial center and considered to be 90% impervious for the parcels. This correlates to an average of 68% imperviousness across the catchment when open spaces are taken into account.

The catchment is typical of those in the Auckland region as it has many areas of steep slopes which are relatively difficult to develop.

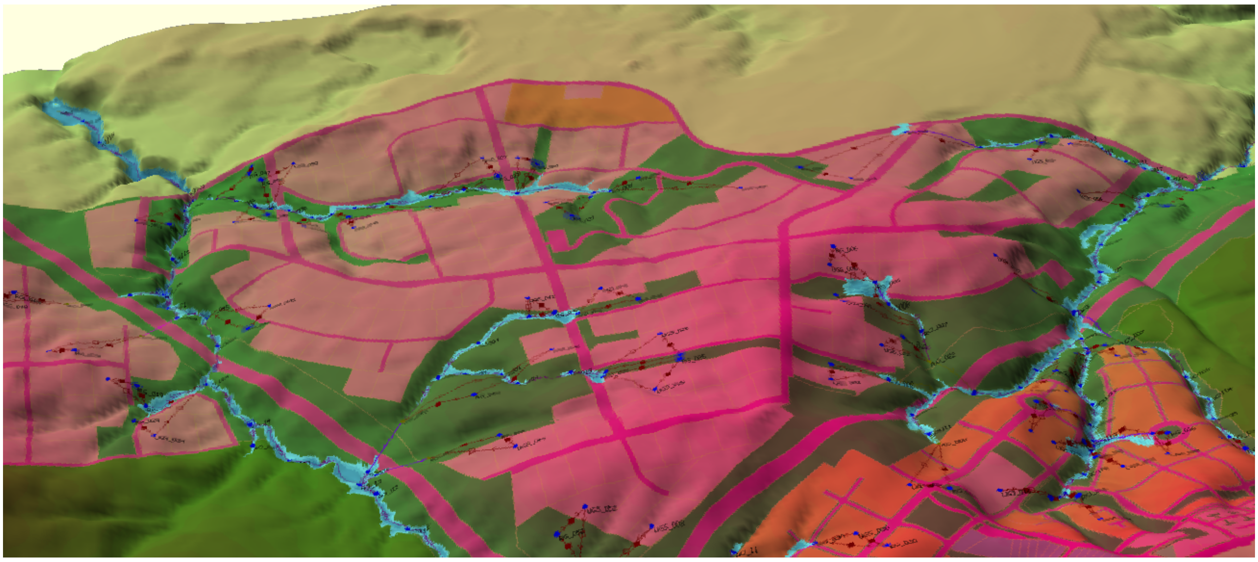


Figure 1 3-D view of the of catchment area

1.4 THE PROJECT TEAM

The core project team consisted of an urban designer, Council planner along with a Council stormwater engineer and URS stormwater engineer. In order to incorporate a holistic approach for the area of interest the project team consulted with the other pertinent council departments and community stakeholders throughout the projects development.

2 DEVELOPMENT OF THE STORMWATER MANAGEMENT PLAN

2.1 PROJECT PROGRESSION

URS was initially approached by council to prepare a sensitivity study for the area of interest. The objective of the sensitivity study was to roughly quantify the difference in cost of developing infrastructure for the area relative to development intensity.

The sensitivity study was in response to a study had been previously prepared that recommended the installation of wet ponds to manage stormwater. It became clear early on, in the stormwater management investigation, that traditional end of pipe solutions, such as treatment and detention ponds, were not going to be practicable for this area. The standard stormwater ponds posed constructability issues which would result in extensive earthworks and engineering. Additionally, the end of pipe solutions would greatly reduce the amount of land that could be potentially developed.

As a result of the sensitivity analysis the focus of the conceptual stormwater management shifted to Low Impact Design techniques, specifically bio-filtration, for water quality and extended detention volumes. Underground storage was used for providing "peak flow" attenuation of flood waters. The LID designs are integrated into the lots and road reserve and therefore require no more area than the prescriptibed landscaping associated with the development. This concept fit well the urban designer's concept which also placed an emphasis on multiple use of space utilizing the green space throughout the development for multiple purposes including; amenity, aesthetics, habitat and stormwater management. This resulted in the ability to develop individual lots to a high intensity (90% impervious) whilst still providing for functionally aesthetic green spaces.

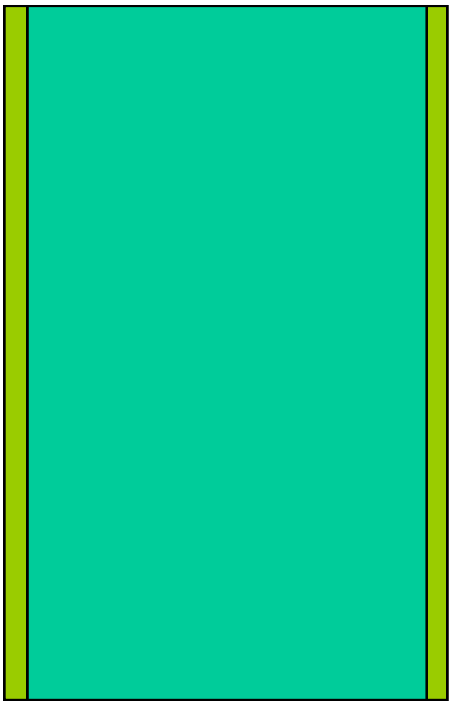
2.2 ANALYSIS OF THE MANAGEMENT PLAN

2.2.1 TESTING THE CONCEPT

It was not practical to analyse each individual lot to test the various concepts. Therefore a sample lot was derived to initially test the stormwater concept and provide assurance that it would be functional able to be constructed. The industrial lots proposed are to be approximately 1 hectare developed to a 90% impervious level. The sample lot is shown in the figure below.

1ha Sample Lot

Industrial land use 90% impervious 10% pervious



Total Area (ha)	1.00
Impervious Area (ha)	0.90
Pervious Area (ha)	0.10
Catchment Length (km)	0.12
Catchment slope	0.06

Conceptual Runoff Volumes

- WQV: 228 m^3
- EDV : 279 m^3
- 2 year detention : 389 m^3
- 10 year detention : 485 m^3

*2yr and 10 yr detention volumes are simplified to reflect post minus pre- developed volumes.

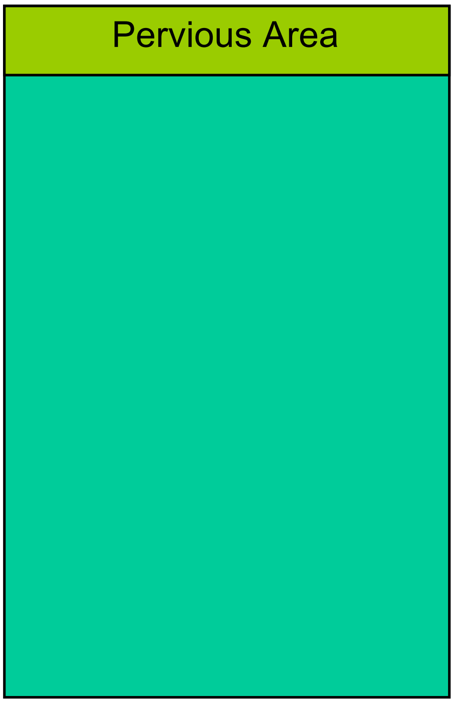


Figure 2 Sample industrial lot showing two possible configurations of pervious area for stormwater concept test

Considering the above water quality volume (WQV) and extended detention (EDV) runoff volumes and the TP 10 design criteria for Rain Gardens there was not enough green space available to physically install bio filtration and/or rain gardens to manage the stormwater runoff generated onsite. Therefore the following design parameters were put implemented to further test the stormwater concept.

- ½ the WQV was also considered available for use as EDV similar to the accepted TP 10 design for extended detention ponds.

- The K value (coefficient of permeability) for the rain gardens would be considered to be 1 m per day for initial evaluation.

- A combination of rain gardens and swales can be used to provide water quality and EDV, but rain gardens were exclusively used in the sizing, modelling and costing calculations. Swales are too site specific to design at this conceptual stage.

- The general upstream to downstream configuration of the stormwater management system is expected to include; a swale connected to a rain garden connected to underground detention.

2.2.2 PUTTING IT TOGETHER

The concept plan was overlaid on the existing contours to derive plausible future sub-catchments. Assumptions were then made to the future grading of the development. The design premise of LID to retain as much of the original land features as possible was used to guide the exercise. These sub-catchments were used for the final stormwater management analysis of the entire catchment area of interest.

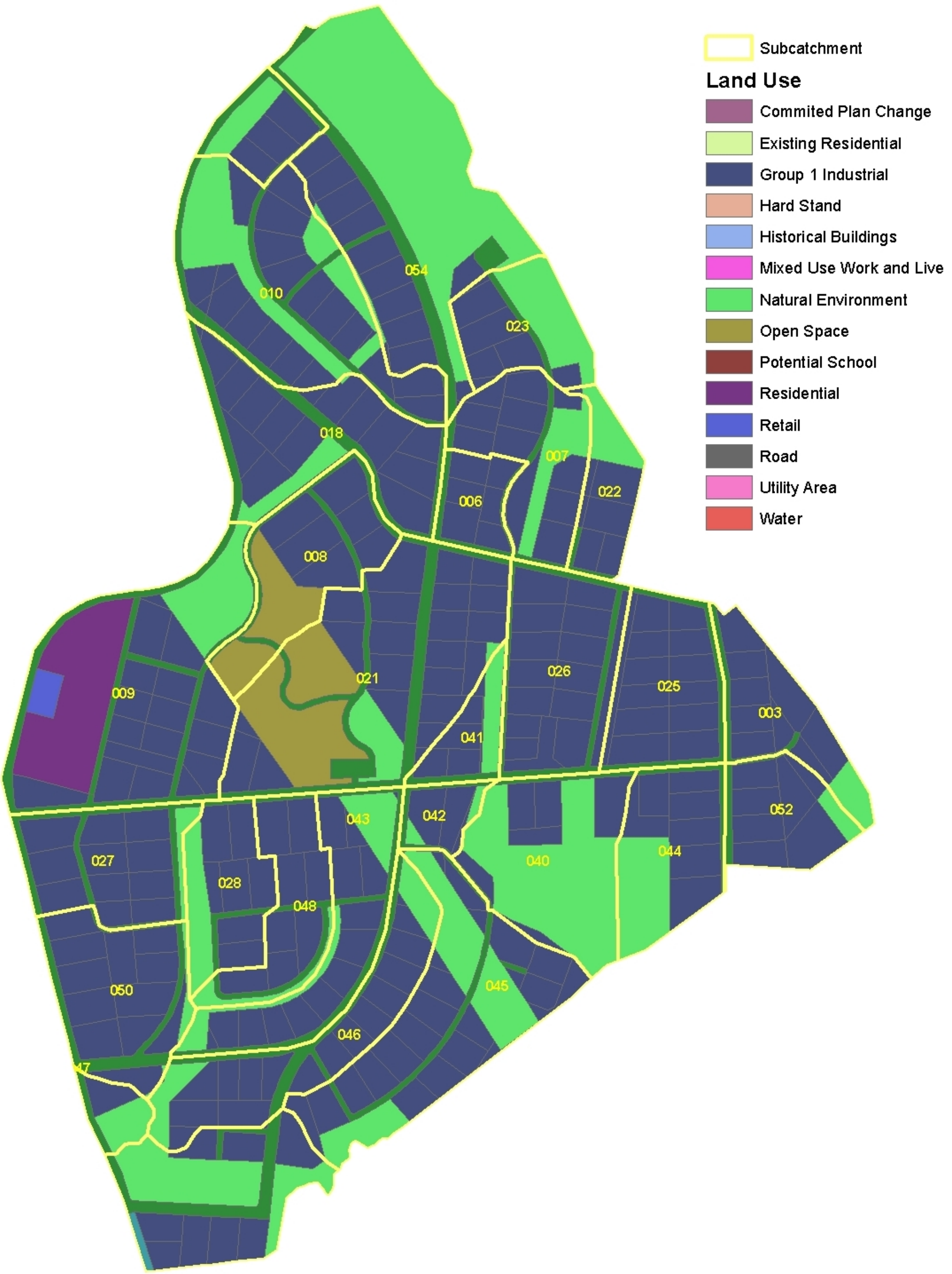


Figure 3 Land use and sub-catchment delineation

2.2.3 MODELING THE SYSTEM

A hydrologic and hydraulic model was built in Infowork CS to analyse the system. The general form of the model included a sub-catchment connected to a rain garden. The rain garden included three discharges including a discharge that was calibrated to "imitate" the infiltration rate, a discharge to the underground storage and an overflow discharge to the stream or network. The underground storage was connected to the stream/network with a controlled orifice sized to provide appropriate 2 year and 10 year detention.

Figure 4 Model configuration

Modeling the system in this fashion allowed the project team to account for effects of routing flows through the catchment. It also provided a true understanding of the rain gardens impacts on the system. This allowed for 2 year and 10 year detention volumes to be greatly reduced.

3 BARRIERS TO COST EFFECTIVE NATURAL DRAINAGE

Natural drainage systems, including bio-filtration and bio-retention, are not new. They are the original water quality systems. As engineers we have looked to these systems in order to build higher quality and more efficient systems. If we take a close look at other areas of water treatment we can find examples of systems that use similar processes to those of rain gardens. One such system is the adsorption field used for wastewater disposal. The adsorption field uses the same processes of filtration as the rain garden and therefore is considered a suitable standard to use for rain garden development. One of the oldest developed standards for adsorption field is known as the Ten State Standards. These standards were developed by the Great Lakes - Upper Mississippi River Board and

Provincial Public Health and Environmental Managers (GLUMBR) which was established in 1950. This standard was used as a guide in the variation of the K Value used for the rain garden design.

3.1 RAIN GARDEN DESIGN AND CALCULATIONS

Rain gardens are small bio-retention areas with engineered soils and vegetation used for passive filtration. These are designed to treat and manage small volumes of stormwater run-off and therefore are proposed to be incorporated to all industrial lots and road reserves for both the industrial and residential areas. The WQV and EDV is stored and infiltrated or evapo-transpirated in the vegetated shallow depressions with planting material. The areas are to be designed with overflow weirs to allow the larger storm events to pass through the system to the detention areas or bypass the system.

Figure 5 shows a rain garden configuration according to TP 10. An amendment of the detail has been included requiring a geotextile fabric to wrap the gravel underdrain. The geotextile fabric will keep the surrounding soil particles from migrating into the under drain and clogging it.

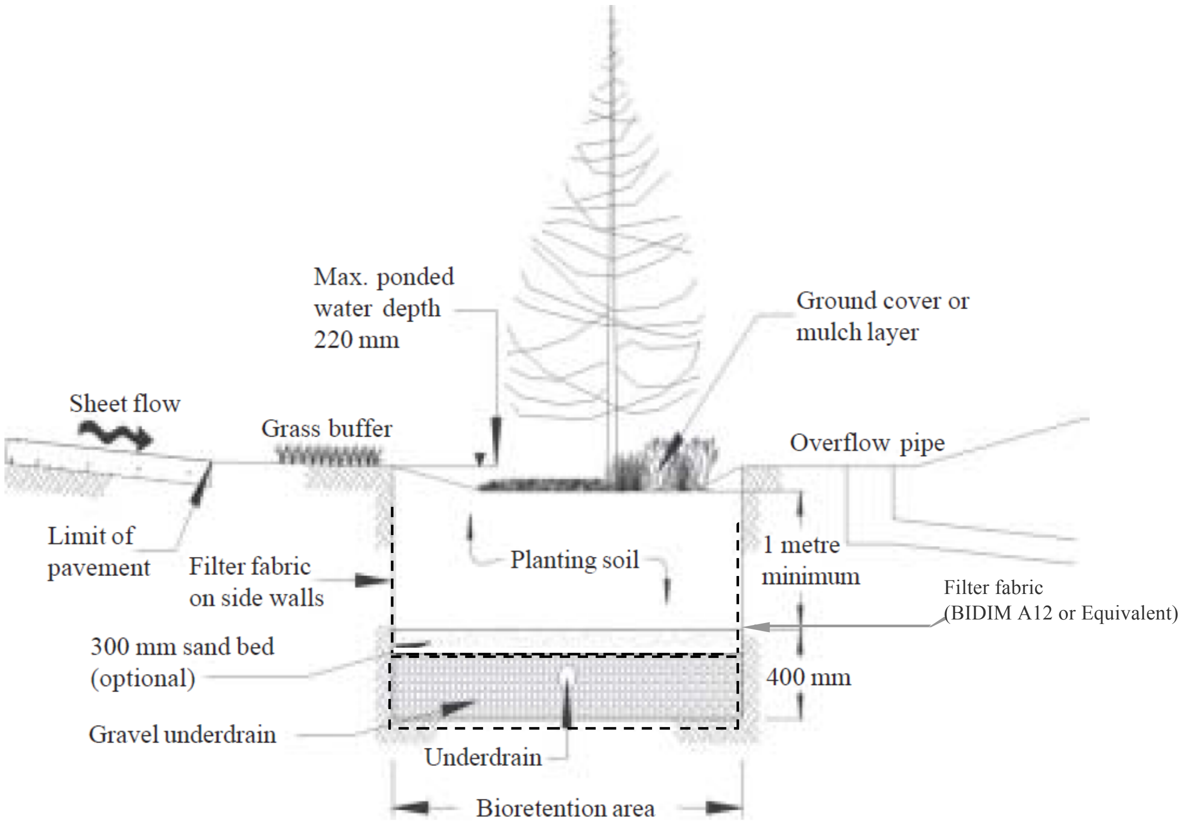


Figure 5 Rain Garden (TP10, Chapter 7 Figure 7-4) with added Filter Fabric and perched underdrain

Considering the design assumptions, as stated in Section 2.2.1, the area of 0.9 m^2 of rain garden can treat 1m^3 of stormwater run-off. To meet this requirement the depth of the filter soil needs to be a minimum depth of 1m.

A head of 110mm above the bed has been used in accordance with ARC TP10, which is ½ of the maximum depth above the soil of 220mm.

The following equation from TP 10 was used:

$$A_f = \frac{(WQV)(d_f)}{k(h + d_f)(t_f)}$$

Parameter	K-value controlled	Live Storage Controlled	
A_f =	0.9	1.8	surface area of rain garden(m^2)
WQV =	1	1	treatment volume (m^3)
d_f =	1	1	planting soil depth (m)
k =	1	0.5	coefficient of permeability (m/day)
h =	.11	.11	average height of water (m) = ½ max. depth
t_f =	1	1	time to pass WQV through soil bed (use one day to satisfy EDV)

Table 1 Initial Design Parameters for Rain Garden Sizing

As previously stated the rain garden requires 0.9 m^2 big to treat $1m^3$ of run-off water with a design K value of 1m/day. The ARC TP10 requirement of providing minimum live storage of 40% of the WQV has not been satisfied by this design. The live storage employed by this design has a greater volume than area required by TP 10 for rain gardens.

3.2 WATER QUALITY AND EXTENDED DETENTION VOLUMES

TP 10 is prescriptive as to what the WQV and EDV should be for a given catchment. EDV is a simple value of 34.5 mm depth. WQV is a bit more complicated as it is a relative to the specific regional location of the catchment. TP 10 considers these volumes separately and cumulatively. A credit is offered for ½ the WQV for a wet pond design as it provides comprehensive stormwater management. This requirement and credit is fairly reasonable when considering a wet pond relies wholly on the mechanism of sedimentation to provide water quality treatment benefits.

The requirement of considering these WQV and EDV separately and cumulatively is less than reasonable, when considering bio-filtration. As bio-filtration does not rely on sedimentation, but instead utilises direct interception, adsorption, and biological uptake as the primary mechanisms for the removal of contaminants (sediment). If a rain garden system can pass the flow and volume from the greater of these two events, then the lesser of the volumes should be disregarded as it has already been treated.

Total Catchment Details	
Total Area (ha)	313.07
Imperviousness (%)	68%

Impervious Area (ha)	211.58
Pervious Area - Green Space (ha)	101.49
Average Catchment Length (km)	0.510
Average Catchment slope	0.04
Water Quality Requirements	
WQV (m^3)	58,409
WQV peak flow (m^3/s)	8.065
EDV (m3)	72,253

Table 2 WQV and EDV for the Catchment

Table 2 shows the total volumes for the catchment WQV and EDV. To consider these cumulatively is a 180% increase in runoff volume that requires treatment. An average 1 hectare sub-catchment will then require a volume of 417 m^3 to be treated if the volumes are considered cumulatively and 231 m^3 if EDV is only considered for treatment. For the purposes of the management plan we assumed we would be allowed a ½ WQV credit and therefore the volume to treat would be 324 m^3.

The SEA project successfully treats a 42 mm storm, 2 year 24 hour storm, for a 1 hectare catchment with a similar percent impervious area. The total detention volume provided in the SEA is approximately 71 m^3. The SEA detention volume treats both water quality and flood control. The two year monitoring period has shown a 99% reduction of runoff discharging from the site for all storm events.

Assuming the design parameters of Table 1 are acceptable the rain garden design a 1 hectare catchment would require a standing volume of 128 m^3 (live storage control) or 64 m^3 (K-value control). A strict adherence to TP 10 design would require a standing volume of 275 m^3.

3.3 K VALUE - COEFFICIENT OF PERMEABILITY

The calculation of the rain garden area is based on Darcy's law; this equation defines the proportional relationship between the flow through a filter medium, area horizontal to flow, pressure change per unit length and the coefficient of permeability. It has to be noted that this equation does not include effectiveness of treatment, but only the time the WQV will need to filter through the soil. This section will discuss the impact of the variation of the permeability coefficient. It also should be noted that the volume of WQ run-off assures that 75% of TSS will be treated on a long term average basis.

$Q = -KA\,(dh/dL)$ (2) Darcy's law

Q = Flow (m3/s)

K = coefficient of permeability (m/day)

A = Area perpendicular to flow (m3)

dh = head difference

dL = length of filter

TP 10 requires the K value to be 0.3m per day. This rate is lower than is acceptable for designing wastewater treatment for adsorption field disposal. The acceptable range according to the Ten State Standards for K values is between 1.2-7.2 m per day. It was determined that for engineered soils using an under drain system it is reasonable to assume a K value of 2 m per day could be achieved. In order to provide a factor of safety a K value of 1m per day was used to perform the initial calculations to size the rain gardens.

Consider the following example to highlight the effect of the permeability coefficient considered in terms of hydraulics and how this affects the required area of the rain garden.

Table 2 show's these calculations, based on treating 1m^3 WQV, planting soil depth of 1m, an average height of water above the bed of 0.11 m and 1 day (24 hours) for the water to pass through the soil bed.

K Value	Area	Available live storage (0.11m depth)	% Reduction in Design Area
m/day	m^2	m^3	-
0.3	3.0	0.66	0%
0.4	2.3	0.50	25%
0.5	1.8	0.40	40%
0.6	1.5	0.33	50%
0.7	1.3	0.28	57%
0.8	1.1	0.25	63%
0.9	1.0	0.22	67%
1	0.9	0.20	70%
1.2	0.75	0.17	75%

Table 3: Area of Rain garden required for different values for the coefficient of permeability k based on treatment of 1 m^3 WQV:

The table shows that by adjusting the design K value from the required 0.3m/day up to 0.5m/day, 40 % less land is required for the installation of a rain garden. Increasing the k value to 1m/day would mean 70% less area compared to the stated value of 0.3 m/day. Increasing the K value to the minimum acceptable value for designing absorption trenches reduces the required area by 75%. This change to a more realistic K value would help the councils, developer and land owners to design more attractive and cost effective rain gardens without reducing the effectiveness.

Another critical issue when determining the K Value that must be considered is "clogging" of the rain garden. This issue is the assumed reason the design is so conservative. Clogging could result from installation or construction design error. Installation errors can be minimized by requiring competent construction supervision. There are two construction design errors in TP 10 that can be easily rectified. The first is the prohibition of a geo-textile fabric to separate the gravel under drain from the surrounding soil. A geo-textile fabric is absolutely necessary to maintain the under drain otherwise it will otherwise clog within a few wet seasons. Providing a geo-textile wrapping of the gravel under drain is the current standard for under drain design. The second error is the inclusion of up to 25% clay in the soil mix. Clays should be reduced or preferably eliminated from the soil mixture.

Finally, with regards to K value selection, it should be noted that TP 10 treats the design of rain gardens in the same manner as the design of sand filters. They both use similar processes for treatment, but rain gardens have one critical advantage, vegetation. Appropriate selection of vegetation will provide two benefits to prevent clogging, the maturation of the root zone and the renewal of annual vegetation. As the root zone matures in a rain garden it increases the soil moisture holding capacity and percolation rate. It will also increase transpiration of water and biological uptake of pollutants. The renewal of annual vegetation provides a mechanism to "break up" the top layer of soil and therefore mitigate the effects of siltation leading to clogging of the system.

3.4 LIVE STORAGE

As shown in the previous section the requirement for live storage negates the use of the appropriate K value. The requirement to provide 40% live storage appears to be another carry over from the sand filter design. The following is a brief discussion of the reasons to relax this requirement.

Again it should be noted that there is a fundamental difference in the function of these two devices. The sand filter uses a sedimentation chamber as a pre-treatment and during a flood flow relies wholly on sedimentation to capture pollutants for treament. Flood flow velocities in the sand filter can be impeded by baffles and the depth of the permanent pool, but re-suspended sediment can only be recaptured by sedimentation. The rain garden has the advantage of vegetation, which will raise the Manning's roughness value and slow flood flow velocities. Sediment can also be filtered in the rain garden and its grass buffers by vegetation.

The live storage component is also a volumetric design parameter where as the rain garden is a flow based design. Therefore a modeling of the system can provide an assurance that the rain garden will capture the required first third of the design storm. Flood flow bypasses can typically be designed for rain gardens and therefore negating the need to pass these flows through the rain garden itself.

The live storage component should be relaxed to allow for an increased K value. If it of concern that more live storage is necessary a variation of the maximum pond depth should be considered.

It should be noted that the comprehensive catchment was modeled using a K value of 1 and ignoring the live storage requirement. The results of that model run showed that not only could the WQV and EDV be managed within the required rain garden area, but the 2 year detention could also be completely mitigated within the rain gardens. This finding is supported by with the SEA project monitoring results.

3.5 COST IMPLICATIONS

The cost implications of all of the aforementioned parameters are significant. Rain gardens are more expensive to build than wet ponds disregarding the cost of land. Relaxing anyone of these parameters to a more appropriate value will result in a huge cost savings. The following table summarises the variations proposed throughout this paper. A unit cost of $400 per m^2 of rain garden (RG) has been applied to these values to determine total costs for the 1 hectare sample lot and the total catchment area.

		Total Catchment		1 Ha Lot	
K Value	**Treatment Volume Requirement**	**RG Area (m2)**	**Cost**	**RG Area (m2)**	**Cost**
K=1	WQV	52,568	$21,027,157	168	$67,164
K=1	EDV	65,028	$26,011,108	208	$83,084

K=1	'½ WQV + EDV'	91,312	$36,524,686	292	$116,666
K=1	'WQV + EDV'	117,596	$47,038,265	376	$150,248
K=0.5	'½ WQV + EDV' 40% Live Storage	184,468	$73,787,245	589	$235,689
K=0.5	'WQV + EDV' 40% Live Storage	211,672	$84,668,877	676	$270,447
K=0.3	'½ WQV + EDV' TP 10	273935	$109,574,059	875	$349,999
K=0.3	'WQV + EDV' TP 10	352787	$141,114,794	1127	$450,745

Table 4: Cost differences due to varying K values and Volume Requirements

As shown in Table 4 there is a significant difference in cost when varying these design parameters. This particular stormwater management plans original design parameters translate to a 74 percent reduction in required area and therefore cost. The final stormwater management plan proposed using a K Value of 0.5 in order to satisfy the live storage requirement and allowed for a half WQV credit. Due to the effective nature of rain gardens mitigation of urbanization effects and the monitoring results of the SEA project it would be prudent to consider treating only the EDV and sizing the rain garden with a K value of 1. This design would provide the required WQV and EDV treatment and an 81 percent reduction in cost and reducing the required flood detention volumes.

It should be noted the using a K value of 1 and treating the EDV only can easily be incorporated into the green space required in the road reserve. This would remove another barrier to rain gardens, as there would be no issue of access for maintenance.

4 CONCLUSIONS

Low Impact Design was originally conceived to provide a cost effective alternative to traditional stormwater management. The natural drainage it provides is not only the most cost effective, but also the most efficient way to treat stormwater. It of course has added benefits of hydrologic mimicry such as groundwater recharge, reducing heat island effects and providing habitat within a developed area.

As it stands the TP 10 design of rain gardens is not a cost effective alternative for managing stormwater. This has been proven by the development market as they have all but been ignored for stormwater management.

Design runoff volumes (WQV, EDV and flood detention volumes) should not be considered separately and cumulatively, but instead credit given within the design for all runoff treated. The K value for design should be significantly increased to a minimum value of 1 and the live storage component of the rain garden should be decreased. If all of these design parameters were changed a cost reduction of over 80 percent could be realized in rain garden design whilst providing the required stormwater management. These changes would result in rain garden being one of the most cost effective options available to manage stormwater. The rain garden would again be a best practicable option.

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