LOW-IMPACT SYSTEMS IN NEIGHBOURHOOD DEVELOPMENTS FOR STORMWATER MANAGEMENT

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ABSTRACT

Mitigation and prevention of increased storm-generated flows and pollutants as a result of urbanisation is one of the most challenging areas in the environmental engineering field today. Integrated stormwater management involves the development and implementation of a range of low-impact designs (LID) and best management practices (BMPs) to improve the quality of urban stormwater runoff before its discharge into the receiving environment. LID comprises design and development practices that use natural systems to avoid, minimise, and mitigate environmental damage.

North Shore City Council (NSCC) has catchment management plans that provide guidance on managing the effects of peak stormwater runoff in all its catchment areas. The District Plan requires on-site stormwater detention and quality measures for all medium and high-density housing developments.

This paper presents a retrospective assessment from two developments on the North Shore to show how integrated stormwater management including key elements of LID has been used, with mixed results. These real-case examples compare the intended outcomes from the initial consent application with the actual finished development, and whether adverse effects were managed during construction (short-term but significant effects). The developments were chosen for assessment since considerable efforts had been made to include LID features to reduce stormwater impact. It is pleasing to see that these developments are using LID features such as raintanks, swale, raingarden and catchpit inserts (Enviropods) to manage stormwater. For example, at one of the case study sites rain tanks were successfully installed on over 50% of properties, reducing mains water demand and providing these properties with some degree of 'self-sufficiency'. Raingardens and other LID features will further enhance the stormwater management on site. The 'early adopters" are ought to be congratulated for implementing the new LID approaches rather than conventional approaches to residential land development that have no LID features. However, significant sewer blockages occurred during construction when the contractor diverted the site works drainage into the Council's sewer, which became blocked with large clay lumps. Serious site runoff during construction also damaged adjacent bush area. The study so far has not quantified any environmental impact or the performance of stormwater treatment devices used, but relies on visual inspection of the sites, and draws comparison with important sustainable features incorporated in the developments.

KEYWORDS

Low-impact Design, Implementation, Effectiveness, BMP.

1 INTRODUCTION

Rapid urban growth puts pressure on our natural resources and stormwater management systems infrastructure (MfE, 2000). Both greenfields development and urban retrofitting lead to increasing demands on conventional infrastructure (e.g., energy, transport, reticulated pipe networks). The costs of maintaining existing and new systems using conventional design and engineering approaches are escalating. The Auckland region will be spending >NZ$5,000 million over the next 10 years to replace aging pipes and meet the demands of new development for water, wastewater and stormwater services alone (Manukau City Council, 2003). While extensive piped systems remove discharges from the site, urban stormwater discharges (flow peaks and contaminants) are unpleasant and are degrading coastal and inland waterways (Curry, 1981; Williamson, 1991; Wilcock, 1994; Snelder & Trueman, 1995).

Conventional approaches to residential land development in New Zealand substantially contribute to the problems (De Kimpe & Morel, 2000; Basher, 2000). In particular: (i) new subdivisions alter the land surface, significantly increasing impervious surfaces and compacting hard ground to the extent that there is a near-total loss of permeability after development (Basher, 2000; ARC, 2000; Zanders et al., 2002); (ii) topsoil is commonly compacted or destroyed, washed away in storms, discarded into landfills, or sold, which increases the need for irrigation of gardens and green spaces and the cost of planting and restoration strategies (Zanders et al., 2002); (iii) as a result of infill housing, retrofitting and new development, impervious surfaces proliferate across whole districts, resulting in increased stormwater runoff and catchment-scale impacts (Schueler, 1994; Arnold & Gibbons, 1996; Schreier & Brown, 2002; McConchie, 1992).

Most neighbourhood developments in Auckland follow these conventional approaches. However, some developers, through the efforts of NSCC and Auckland Regional Council, are attempting to apply comprehensive stormwater management systems at a small number of developments. We selected two North Shore developments since they met our criterion of incorporating some LID features, i.e. serious attempts had been made to manage stormwater as well as use rainwater as a resource.

The purpose and principles of the NZ Building Act 1991 are to provide for: (i) the co-ordination of those controls with other controls relating to building use and the management of natural and physical resources; (ii) the protection of other property from physical damage resulting from the construction, use and demolition of any building. The new Building Act 2004 (into force 31/3/05) requires that the buildings are designed, constructed and able to be used in ways that promote sustainable management. The principles to be applied in performing functions, or exercising powers under this Act must take into account the following principles, among many others:

- the need to facilitate the efficient use of water and water conservation in buildings
- the need to ensure maintenance of household units is reasonable
- the desirability of ensuring owners of household units are aware of the maintenance requirements of their units
- the need to facilitate the efficient use of energy and energy conservation and the use of renewable resources of energy in buildings.

North Shore City Council has catchment management plans to manage the effects of peak stormwater runoff in all its catchments. The District Plan requires on-site stormwater detention and quality measures for all medium and high-density housing developments. In addition, to give effect to the catchment management plans in those areas where there are infrastructure constraints or flooding, the Council enacted a Stormwater Disposal Policy in August 2004 that requires post-development flows to be managed so they are no greater than pre-development levels (http://www.northshorecity.govt.nz). Hydrological neutrality is required in many areas.

In this paper we have appraised the LID approach at two neighbourhood developments where raintanks, swale, raingarden and catchpit inserts (Enviropods) were used to manage stormwater. While the principal focus was on stormwater, we took the opportunity to assess these developments from other perspectives relevant to sustainability, as a secondary assessment.

Low-impact design practices reduce sediment and pollutant loads, and stormwater flows, and have less impervious surface area and more vegetated areas. In turn, these lead to off-site benefits in waterways (improved fish habitat) and estuaries (improved habitat derived from reduced contaminant and sediment accumulation), and for terrestrial local biodiversity (native vegetation corridors).

2 LID IN NEIGHBOURHOOD DEVELOPMENTS

2.1 TIRITIRI AND VERBENA ROAD, NORTH SHORE CITY

This case study includes two medium-density suburban housing developments in Birkenhead, North Shore City – one at Tiritiri Road, the other at Verbena Road. The Tiritiri Rd development consists of 13 dwellings on 0.628 Ha, and Verbena Rd consists of 26 dwellings on 0.82 Ha (total site is 1.585 Ha, leaving 0.765 Ha of steeper land in poor-quality bush). The initial construction at both development sites started in 2003.

The main aim for both sites is to reduce and treat stormwater run-off from a medium-density residential development through some on-site attenuation and re-use. The on-site stormwater treatment systems are the responsibility of the developments' bodies corporate, which are created after the sale of dwellings at both case study sites.

2.1.1 TIRITIRI ROAD NEIGHBOURHOOD DEVELOPMENT

There are a number of on-site stormwater treatment features, with the overflow draining into Council's piped network, which in turn outfalls into gullies or natural watercourses. Rainwater tanks, for detention only, rather than for water supply, are fitted to 5 houses out of the total of 13. Swales are used for surface flow as well as capturing overflow from the raintank. The swales are unfortunately subject to severe mowing; accordingly, their function is compromised by the harsh mowing practices. Paved areas drain through Enviropods to the stormwater drain. Potable water supply is via mains connection; however, rainwater is collected (13,500 L tanks) and re-used for toilets, laundry and external uses on 8 of the 13 houses.

In most other aspects the houses have conventional design features. Sewage is connected to the existing public sewer network. The residential units are grouped and are of compact design with small windows to reduce heat losses and prevent excess heat gain. There are conventional lights and appliances, hot water supply, hot water storage and ventilation. Energy supply is via mains electricity.

Table 1 presents a summary of important features of the Tiritiri Road development, considered in the context of overall sustainability issues.

Photograph 1: Rain tank for roof-water collection for re-use at Tiritiri Road

Table 1: Important features of Tiritiri Road

2.2 TIRITIRI ROAD CASE-STUDY	
Data sources	Peter Nagels, Stormwater Consents Engineer, North Shore City Council
Name	Tiritiri Road

Location	Tiritiri Road, Birkdale, North Shore City, NZ; Lat 36 50 S approx	
Climate data	1151 HDD@18^{o}C; 2102 sunshine hours	
Type of project	Suburban medium density housing development	
Scale	13 dwellings; site area 6280 m2 (0.628 Ha)	
Performance	Stormwater flow to drainage reduced, but reduction not known Sewage to existing public sewer network	
What was the purpose of the initiative?	To reduce and treat stormwater run-off from a medium density residential development through some on-site reuse	
Stormwater	Various on-site stormwater treatment features; overflow to surface water drainage	Rainwater tanks, for detention only, to 5 houses of 13. Swales for surface flow. Paved areas drain through Enviropods to stormwater drain
Other water (non potable)	Rainwater harvested for reuse in wc, laundry and external taps	Rainwater tank (13,500 litres) and pumped water supply to 8 houses out of 13. Remainder use mains water for all uses
Drinking water (potable)	Mains connection	
Energy consumption: fabric	Grouped housing, compact design, small windows	Semi-detached and terraced houses reduce heat losses; small windows prevent overlooking and reduce heat loss. No specific energy features.
Energy consumption: Lights and appliances	Conventional	
Hot water supply	Conventional	
Hot water storage	Conventional	
Ventilation	Conventional	Opening windows
Energy supply	Mains electricity	
Sewage	Conventional sewer connection	

Photograph 2: Catch-pit inserts for paved-area runoff at Tiritiri Road

Photograph 3: Highly impervious surfaces around houses at Tiritiri Road

2.2.1 OUTCOMES OF TIRITIRI ROAD

Favourable

- Raintanks were successfully installed on over 50% of properties, reducing mains water demand
- House with raintanks have some degree of 'self-sufficiency" (e.g., gardens requiring less watering)
- Example of "normal" development trying to improve performance in stormwater management by incorporating various LID features (raintanks, swale, Enviropods)
- Smaller higher density houses use less land
- Houses seem smaller than NZ average for new construction, so materials demand was reduced
- Proximity and shared driveways, etc., may help create sense of community among residents

Less-favourable

- Highly impervious surfaces around houses counteract some of the gains shown above
- Rainwater tanks occupy large part of small garden, but visual impact has been reduced by planting
- Virtually all the topsoil is physically destroyed or removed and transferred to landfills
- Would have been better if all 13 houses had had rainwater harvesting
- Properties tenanted, tenants generally do not understand on-site systems with a likelihood of poor maintenance

2.2.2 VERBENA ROAD NEIGHBOURHOOD DEVELOPMENT

Similar type of development to above, except that stormwater (from driveways and roofs) is captured via rain-gardens. The remaining water goes to detention tanks and is fed into city stormwater drains. Some on-site planting is retained with the retention of the bush area to the south of the development.

Table 2 presents a summary of important features of the Verbena Road development.

2.2.3 OUTCOMES OF VERBENA ROAD

Favourable

- Raingardens to capture and treat driveway runoff from northern part of development, and driveway and roof water from southern half
- Remaining roof water goes to retention tanks and is fed into Council's stormwater drains
- Example of "normal" development trying to improve performance in stormwater management by incorporating various raingardens and detention tanks (a step in the right direction)
- Smaller, higher density houses use less land
- Houses smaller than NZ average for new construction, so reduced materials demand
- Proximity and shared driveways, etc., may help create sense of community among residents

Less-favourable

- Highly impervious surfaces replacing topsoil around houses lead to more runoff going to stormwater system – attempts to reduce stormwater with LID features practically counter-acted by large amounts of impervious surface
- Virtually all the topsoil is physically destroyed or removed and transferred to landfills
- Serious site runoff during construction, which has damaged adjacent bush area.
- Rain-gardens not yet planted, but negative visual impact at time of visit

- The development is at the top of the catchment. The City Council would have liked rainwater harvesting to have been used so as to reduce the overall run-off to the catchment
- No allowance for gardening

Table 2: Important features of Verbena Road

2.3 VERBENA ROAD CASE-STUDY		
Data sources	Peter Nagels, Stormwater Consents Engineer, North Shore City Council	
Name	Verbena Road	
Location	Verbena Road, Birkenhead, North Shore City, NZ; Lat 36 50 S approx	
Climate data	1151 HDD@18^{o}C; 2102 sunshine hours	
Type of project	Suburban medium density housing development	
Scale	26 dwellings; site area of houses is 0.82 Ha, total site area is 1.585 Ha, so there is 0.765 Ha of mostly bush land left un-built	
Performance	Stormwater flow rate mitigated (attenuated), rate close to pre-development situation, overall runoff volumes increased Sewage to existing public sewer network	
What was the purpose of the initiative?	To reduce and treat stormwater runoff from a medium density residential development	
Stormwater	Some on-site treatment; overflow to surface water drainage	Raingardens to capture and treat driveway runoff from northern part of development, and driveway and roof water from southern half. Remaining roof water goes to detention tanks and is fed into city stormwater drains.
Drinking water	Mains connection	Used for all purposes, which is not a wise use of the resource
Other water	Mains connection	
Energy consumption: fabric	Grouped housing, compact design, small windows	Semi-detached and terraced houses reduce heat losses; small windows prevent overlooking and reduce heat loss. No specific energy features.
Energy consumption: Lights and appliances	Conventional	
Hot water supply	Conventional	
Hot water storage	Conventional	
Ventilation	Conventional	Opening windows
Energy supply	Mains electricity	
Biodiversity	Some on-site planting retained	Bush area retained to south of development Compromised, damaged
Wastewater	Conventional sewer connection	Wastewater flows to sewer

Photograph 4: Raingarden (under construction) for treating road runoff at Verbena Road

Photograph 5: Runoff treatment structure (under construction) at Verbena Road

Photograph 6: Highly impervious surfaces around houses have resulted at Verbena Road

Photograph 7: Serious site runoff during construction at Verbena Road

Photograph 8: Visible damage at Verbena Road during construction

2.3.1 LESSONS LEARNT

While, on the one hand these developments have significant LID features, which is an important step in the right direction in terms of reduced stormwater runoff and increased 'self-sufficiency' of the household (Photographs 1,2, 4, and 5), on the other hand the steps are offset by environmental impacts during development and the large percentage of impervious surfaces (Photographs 3, 6, 7 and 8). There are various opportunities to apply LID more comprehensively, specifically:

- During development (manage site works to minimise damage to the receiving environment)
- Post-development (limit impervious surfaces whose presence will offset benefits of LID features)
- Improve design effectiveness of swales (use of correct underlying soil; mower height)
- Improve percentage of properties with raintanks

Finally, as well as improving stormwater management by using rain water as a resource, there are opportunities to implement more sustainable developments by encapsulating LID and targeting improved efficiencies in water, waste and electricity management.

3 CONCLUSIONS

These two examples are good demonstrations that key aspects of LID can be implemented at the neighbourhood scale. They show that various positive aspects can be achieved by incorporating LID principles in new housing developments. These include:

- Improved stormwater management by incorporating various LID features (raintanks, swales, Enviropods and raingardens)
- Conventional developments trying to improve performance in a limited area (stormwater) may help make LID more acceptable

- Smaller, higher density houses will use less land, and the use of attached houses is likely to lead to lower energy demand by reducing heat losses through shared walls.

- Houses smaller than NZ average for new construction will have reduced demand on materials

- Proximity and shared driveways, etc., may help create sense of community among residents

However, various less-favourable aspects were also highlighted in these studies. These include:

- Highly impervious surfaces around houses will lead to more runoff going into the stormwater system, offsetting some of the gains shown above

- Rainwater tanks may occupy a significant part of small garden area in higher density developments

- Benefit of rainwater tanks in reducing run-off at a development can only be fully realized if all houses have rainwater harvesting. Where the development is at the top of the catchment, the City Council would have liked rainwater harvesting to have been used to reduce the overall run-off to the catchment

- Although the development was not intended to result in any adverse impact on the receiving environment, there were at least visible signs of serious site runoff from Verbena Road during construction. Severe blockages occurred in the Council sewer from site works, with clay and debris draining into the sewer

- Site run-off needs to be managed effectively during construction, to avoid damage to adjacent bush areas.

Several lessons can be learnt from the early adopter:

- LID features can be successfully incorporated in managing stormwater

- Applying LID principles during development stage will help minimize damage to the receiving environment

- Applying LID principles during post-development will help minimize impervious surfaces

- Other features of sustainable building (energy, etc.) could be included in new developments.

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REFERENCES

ARC, (2000) Low-impact Design Manual for the Auckland Region*, Auckland Regional Council Technical Publication 124,* Auckland Regional Council, Auckland, New Zealand.

Arnold, C.L.J. and Gibbons, C.J. (1996) 'Impervious Surface Coverage: The Emergence of a Key Environmental Indicator' *Journal of the American Planning Association*, 62, 243–256.

Basher, L. (2000) Soils and Geomorphology of the Urban Environment, *Urban Biodiversity and Ecology as a Basis for Holistic Planning and Design*, eds G.H. Stewart & M.E. Ignatuia, 14–21.

Curry. R.J. (1981) Hydrology of Catchments Draining to the Pauatahanui Inlet, *Water and Soil Technical Publication 23*, Ministry of Works and Development, Wellington, New Zealand.

De Kimpe, C.D. and Morel, J. (2000) 'Urban Soil Management: A Growing Concern' *Soil Science,* 165, 31–40.

Manukau City Council website: http://www.manukau.govt.nz/getinfo.htm. Accessed 2003.

McConchie, J.A. (1992) Urban Hydrology. *Waters of New Zealand,* ed. M.P. Mosley. New Zealand Hydrological Society, Wellington, New Zealand, 335–363.

MfE (2000) *Curbing the Sprawl: Urban Growth Management in the United States – Lessons for New Zealand,* Ministry for the Environment, Wellington, New Zealand.

Schreier, H. and Brown. S. (2002) 'Scaling Issues in Watershed Assessments' *Water Policy*, 3, 475–489.

Schueler T.R. (1994) 'The Importance of Imperviousness' *Watershed Protection Technology*, 1, 100–111.

Snelder, T. and Trueman, S. (1995) The environmental impacts of urban stormwater runoff, *Technical Publication* 53, Auckland Regional Council, Auckland, New Zealand.

Wilcock, R.J. (1994) Organic pollutants in sediment of Manukau Harbour, *Proceedings of the firstAgResearch/Landcare Research Pesticides Residue Workshop*, eds L. Boul and J. Aislabie, Lincoln, New Zealand, 39–45.

Williamson, R.B. (1991) Urban run-off data book, a manual for the preliminary evaluation of urban stormwater impacts on water quality. *Water Quality Centre Publication 20*, Ecosystems Division, NIWA, New Zealand.

Zanders, J., McLeod, M. and Thornburrow, D. (2002) Urban soil implications for on-site stormwater mitigation, Presentation to NIWA stormwater workshop, Hamilton, New Zealand, 2002.