MODELLING LONG-TERM VOLUME RETENTION IN A BIORETENTION DEVICE

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ABSTRACT

Streams in Auckland Region have been found to exhibit loss of natural functioning of freshwater systems and the degradation of their values as a consequence of intensive urban development. Conventional development, unless mitigated, significantly increases runoff volumes and the duration and frequency of elevated peak flows which consequently degrade the morphological and ecological functions of freshwater systems. In areas where stream values and functioning have not been significantly compromised by past development, and there is potential future development, there is an opportunity to manage streams to support multiple values including healthy in-stream ecosystems and community and Mana Whenua values.

The TP108 design storm approach has limitations in modelling small storm events and may predict the incorrect amount of storage needed to control sequential storms properly. Continuous simulation models are better at predicting more realistic performance of bioretention devices, rather than the performance for a single, design storm condition. Long-term continuous simulation allows a quantifiable assessment of changes in hydrological regime due to urban development over the full range of high to low flow conditions.

A continuous simulation modelling investigation has been carried out to undertake a quantitative performance assessment of a bioretention device on the changes in hydrologic regime of watershed runoff in terms of reduction in frequency, magnitude, duration and volume of runoff flows. The model results provide relationships between the runoff volume reductions, bioretention device sizes, catchment imperviousness and subsoils infiltration rates.

Model Development

The EPA-SWMM modelling software was used for the continuous simulation modelling investigation. EPA-SWMM is a dynamic rainfall-runoff simulation model widely used for single event or long-term continuous simulation of runoff quantity and quality from a catchment. EPA-SWMM can explicitly model various low impact development (LID) green infrastructure practices to determine their effectiveness in managing stormwater runoff.

EPA-SWMM model uses a nonlinear reservoir routing model to estimate surface runoff produced by rainfall over a catchment. Green-Ampt infiltration model was used to simulate the runoff from the pervious surfaces. The groundwater aquifer routing module available in the EPA-SWMM software was used for better representation of runoff responses and time-delayed base flow recession limbs from pervious areas.

The groundwater aquifer routing module available in EPA-SWMM modelling software was used for better representation of runoff responses and time-delayed base flow recession limbs from pervious areas. The infiltration and aquifer model parameters used in the model were based on detailed calibration process carried out in Whau Catchment using long-term flow monitoring gauge in Whau Stream at Blockhouse Bay Road. The details of the model development and calibration approach are presented in 2018 Water NZ Stormwater Conference.

The continuous simulation hydrological model was used to generate continuous stormwater flows from a typical urban watershed with contributing catchment area of 0.5ha based on 10 years of continuous 5-minute interval rainfall data from the Mt Roskill rainfall gauge. The generated 10-year surface runoff flow series are passed through a rain garden to determine their effectiveness in managing stormwater runoff.

Performance Assessment of Rain Garden

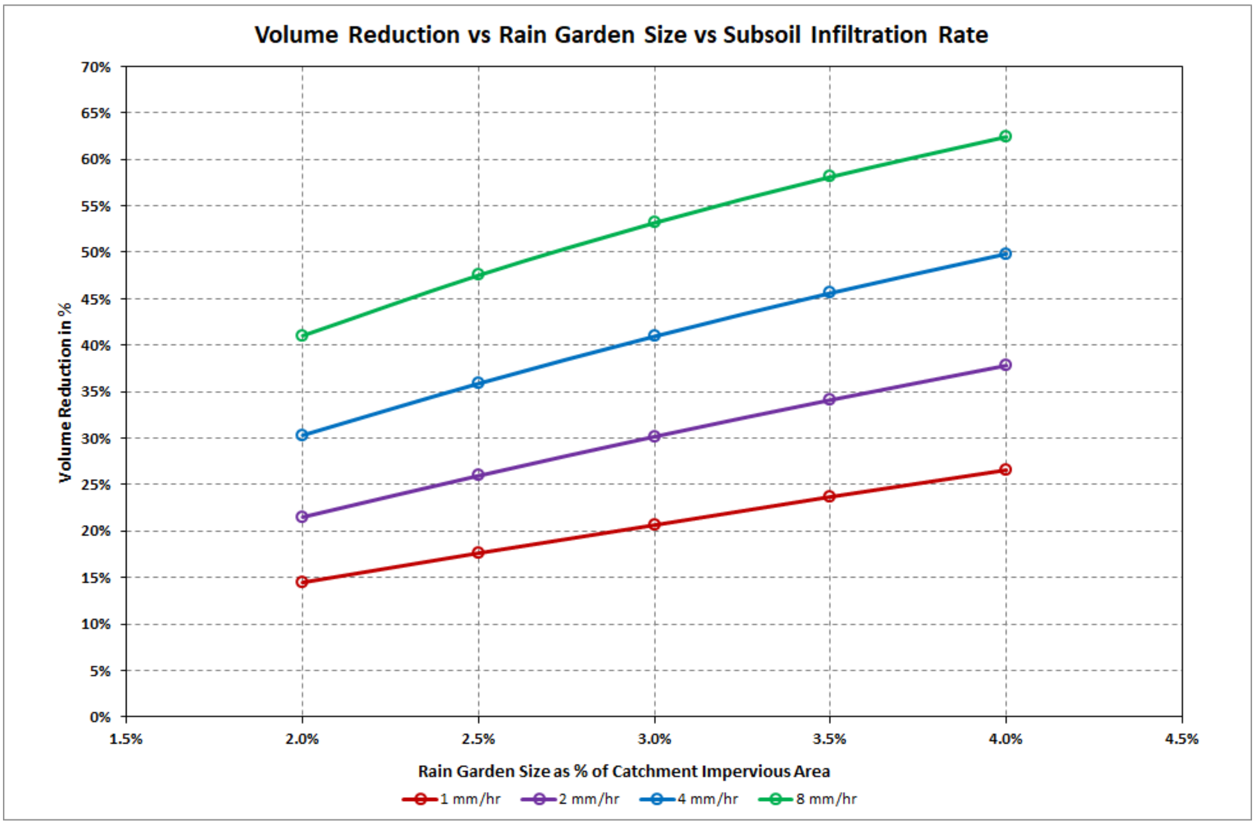
A standard rain garden was selected and sized based on Auckland Council Bioretention Design Guidelines (GD01) for a contributing catchment area of 0.5 ha and catchment imperviousness of 60%. The size of the rain garden including the various infiltration and evapotranspiration rates (based on GD01) used in continuous simulation modelling are summarised below:

- Infiltration and ponding footprints – 3.5% of the catchment impervious area
- Ponding depth – 200mm
- Media depth – 500mm
- Transition layer depth – 100mm
- Drainage layer depth – 200mm
- Storage layer depth – 450mm
- Media and transition layer void space – 30%
- Drainage and storage layer void space – 35%
- Evapotranspiration rate – 3 mm/day
- Infiltration rate of media – 50 mm/hr, 100 mm/hr, 150 mm/hr
- Infiltration rate of subsoils for retention – 1 mm/hr, 2mm/hr, 4 mm/hr & 8 mm/hr

Continuous simulation modelling scenario runs (10 years) were carried to assess the effects of various sizes of rain garden, catchment imperviousness, various infiltration rates of the underlying subsoils layer, various infiltration rates of media and various rainfall gauge time series data in terms of reduction in runoff volume due to runoff control by the rain garden.

According to GD01 the footprint of a rain garden is designed as 3.5% of the catchment impervious area. Continuous simulation runs were carried out for various sizes (2%, 2.5%, 3%, 3.5% & 4% of catchment impervious area) of rain garden with catchment imperviousness of 60% and various subsoils infiltration rates (1, 2, 4 & 8 mm/hr). Model results show the reduction in runoff volume ranging from 14.4% to 62.4% (refer to Figure 1). In case of a standard size rain garden (3.5% of catchment impervious area), the runoff volume can be reduced from 23.7% to 58.1% due to runoff control by the rain garden depending on the infiltration rates of the underlying subsoils (1 to 8 mm/hr).

Figure 1: Reduction in Runoff volume for various sizes of rain garden and various subsoil infiltration rates



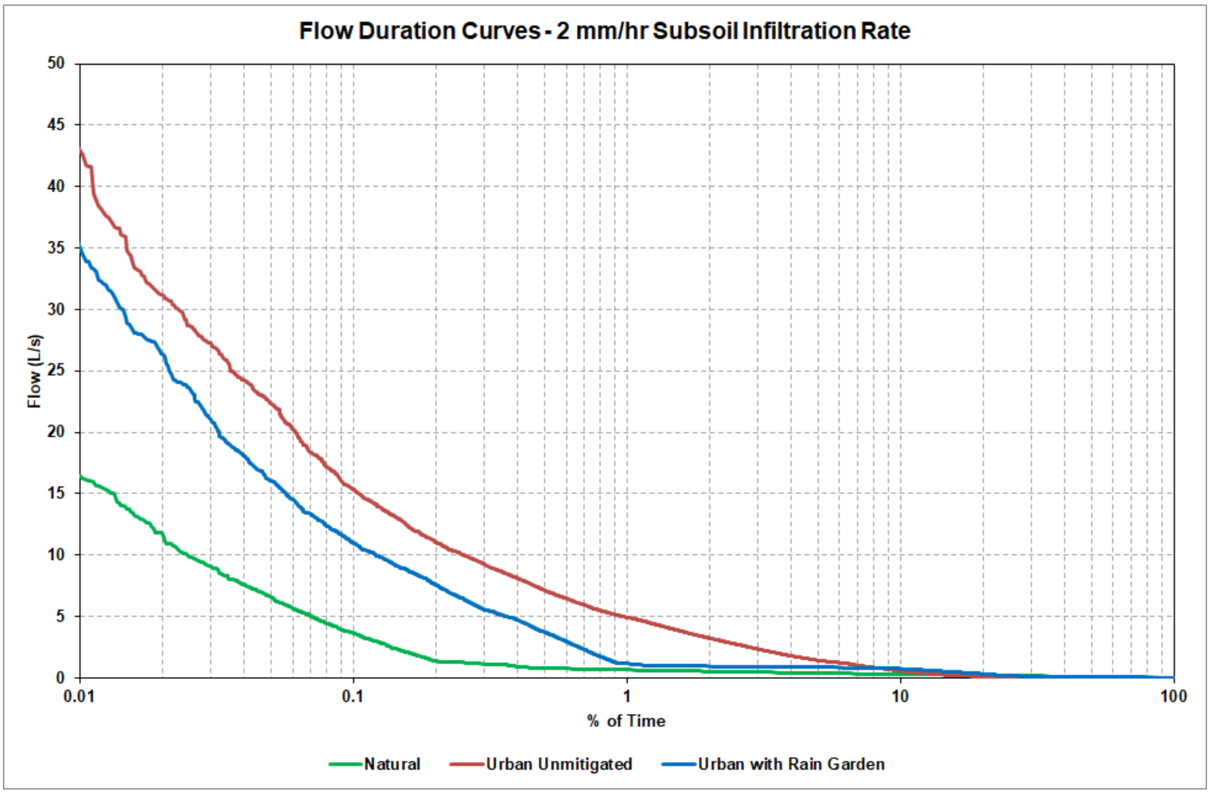
Continuous simulation runs were carried out for various imperviousness (50%, 60%, 70% & 80%) of the contributing catchment area to a standard size rain garden (3.5% of catchment impervious area) and various subsoils infiltration rates (1, 2, 4 & 8 mm/hr). As the rain garden size is based on the catchment imperviousness, model results show minor effects of catchment imperviousness on the changes in runoff volume reductions due to runoff control by the rain garden.

Continuous simulation runs were also carried out for various media infiltration rates (50, 100 & 150 mm/hr). Model results show negligible effects of media infiltration rates on the changes in runoff volume reductions due to runoff control by the rain garden. Continuous simulation using various rainfall gauges (Mt Roskill, Wairau & Torbay) for 10-year runoff flow series show minor effects of rainfall gauges within Auckland Region on the changes in runoff volume reductions due to runoff control by the rain garden.

Continuous simulation modelling runs were carried out using the 10-year continuous rainfall data from Mt Roskill rainfall gauge for natural undeveloped (0% imperviousness), urban developed (60% imperviousness) and urban developed with rain garden runoff control scenarios. A standard size rain garden (3.5% of catchment impervious area) with subsoils infiltration rate of 2 mm/hr were considered. Comparisons of flow duration curves for the three scenario runs are shown in Figure 2.

Model results show considerable decrease in flow series due to runoff control by the rain garden. In the case of urban developed scenario without any stormwater control the duration of flows above natural undeveloped flows is approximately 10% or 365 days out of the 10-year simulation period. However, with stormwater mitigation by rain garden, the duration of flows above natural undeveloped flows is approximately 1% or 36.5 days (over 10 years) (refer to Figure 2).

Figure 2: Comparisons of flow duration curves



Long-term continuous simulation modelling demonstrates that stormwater mitigation using a rain garden has been found to be effective at controlling frequent small storm flows and could provide substantial benefits for stream erosion and aquatic habitat protection. This analysis provides a basis for designing bioretention devices to meet some aspects of hydrological neutrality, to achieve improved ecological outcomes in freshwater systems.

KEYWORDS

Bioretention Device, Continuous Simulation, Volume Retention, Stormwater Management.