RETAINING THE NATURAL HYDROLOGY OF EPHEMERAL STREAMS

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Abstract

Urbanisation has long been understood to increase the frequency and intensity of flows to waterways, degrading stream conditions and affecting the structure of stream communities. Increased disturbance flows result in the loss of sensitive species and lead to an overall reduction in species richness. Research on streams in Victoria's Dandenong Ranges identified that urbanisation had dramatically increased the frequency of disturbance flows after small to medium events, that would otherwise not have increased stream flows in a natural catchment (Walsh et al, 2004). It has been suggested that the greatest benefit to waterway protection can be provided by controlling runoff from these storms. This is of particular importance in ephemeral and intermittent creeks that rarely experience base flows.

Best practice Water Sensitive Urban Design (WSUD) techniques provide a promising solution to restoring waterway health, but there are sites where common WSUD elements cannot achieve all objectives of environmental protection. Within areas of low infiltration, a more engineered solution is required to control runoff volumes and frequencies. A range of scenarios were modelled to determine what additional stormwater management techniques are required to retain the natural hydrology of ephemeral waterways. Scenarios explore the use of flow bypassing and stormwater reuse in combination with WSUD best practice techniques to retain the natural hydrology of ephemeral waterways.

Ephemeral Creek Hydrology

Flow events in an ephemeral waterway are typically rare and associated with events that may occur in the order of 10 times a year. Ephemeral creek beds are typically dry and only experience flow following periods of extended rain, when the catchment is saturated and rainfall exceeds the capacity of the catchment to retain and intercept runoff. The capacity of the catchment is defined by native soil types and vegetation cover. Catchments underlain by sandy free draining soils will experience runoff far less frequently than those underlain by clay soil types. Similarly, steep forested catchments will generate runoff more frequently than flatter catchments or those comprised of hollows and depressions. Infiltration, interception and subsequent evapotranspiration by vegetated catchments act to significantly reduce the volume and frequency of surface flows. Flow events within the waterway are characterised by large variations in flow rates that are intermittent and punctuated by periods of dry spells. Following a runoff event, floodplain and instream pools remain, which drive cycles of reproduction and flourishing for riparian ecological communities.

Hydrologic and Ecological Changes following Urbanisation

Following urbanisation, the capacity of the catchment to retain flows is dramatically reduced. Hard surfaces significantly reduce the catchments ability to intercept flows and the frequency of flow events increase by an order of magnitude. Urbanised catchments will experience flow events up to 100 times in the year. The increased frequency of steam flows, overbank flooding and reduced dry spells represents a significant shift in the natural wetting and drying regimes of the waterway and floodplain. Disruptions to the natural cycles of ecological communities will cause a shift in the structure of the ecological communities, resulting in a reduction of species richness.

Research by Walsh et al (2004) carried out on streams in Victoria's Dandenong Ranges identified that even low levels of urbanisation had dramatically increased the disturbance of waterways brought about by small to medium events, that would otherwise not have increased stream flows in a natural catchment. Walsh proposed that increased runoff from rain events, delivering between 1 to 15 millimetres, have the greatest impact on stream structure and ecology of the study area. These events account for up to 98% of frequent rainfall events in a reference rain year. It has been suggested that the greatest benefit to waterway protection can be provided by controlling runoff from these storms. This is of particular importance in ephemeral and intermittent creeks that rarely experience overland flow events.

The Effectiveness of Common Stormwater Management in Preserving Ephemeral Hydrology

A range of stormwater management scenarios were modelled to assess their effectiveness in retaining the ephemeral hydrology of a catchment. The baseline hydrology of a forested catchment with a 0% Effective Imperviousness (EI) is established as the benchmark against which a range of scenarios are assessed. Comparisons are made to the hydrology of a catchment with a 5% EI, which Walsh et al (2004) found to be the threshold of severe degradation waterways.

Scenarios explore current practices of lot scale harvesting, water quality treatment, infiltration and the use of diversion pipes to preserve the ephemeral hydrology of a small hypothetical catchment. Three strategies are discussed as follows.

Bioretention

WSUD practices detain and slow the delivery of runoff to receiving waters in ways that can mimic the natural processes within a forested catchment. Evapotranspiration and losses to bioretention soil stores can also reduce the annual volume of runoff delivered from an urbanised catchment by 5 to 12%, and in some cases up to 30% (Hatt et al, in press). A simple treatment train of lot scale rainwater tanks and lined bioretention basins has been presented as representing the minimum requirements of a stormwater management strategy.

Infiltration

Encouraging infiltration throughout a developed catchment has also been identified as a promising practice, which can further mimic natural infiltration within a forested catchment. The implementation of 'leaky' stormwater infrastructure can significantly reduce stormwater runoff volumes and replenish soil stores, in turn encouraging base flow. However, the effectiveness of such techniques is limited by the infiltration capacity of underlying soil types and the location of the water table. A treatment train of lot scaled rainwater tanks and leaky bioretention basins has been presented as a strategy to preserve ephemeral hydrology by further reducing runoff volumes and encouraging infiltration of treated stormwater to groundwater.

Diversion

Stiff clays within upland catchments can command large areas to achieve effective infiltration. The presence of dispersive and saline soils can further constrain this practice, where the effect of raising a saline water table can have significant impacts on infrastructure, vegetation and land capability. Under these circumstances, a more engineered solution is required to control runoff volumes and retain the natural frequency of flows in waterways. An alternative strategy to infiltration can potentially preserve ephemeral hydrology by intercepting flows and diverting to less sensitive areas. A third treatment train is presented, comprising lot scaled rainwater tanks, bioretention basins and a pipe to intercept and divert frequent low flows around an ephemeral creek. Intercepted flows can be discharged to already modified areas, regional stormwater harvesting collections or perennial creeks that are more resilient to additional flow. A schematic representation of the proposed strategy is presented in Figure 1.

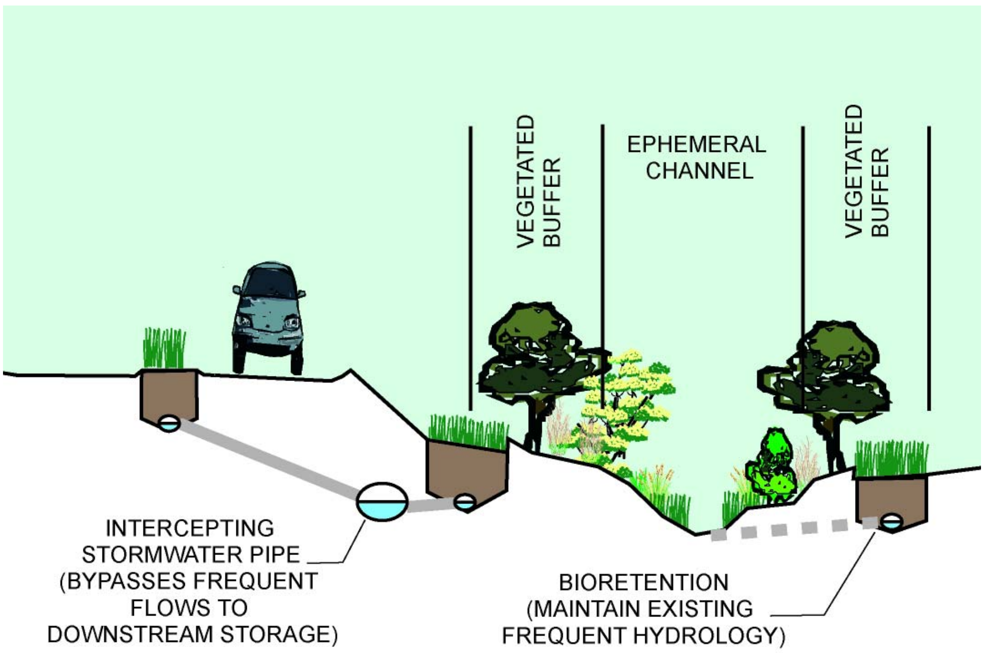

Figure 1: Management of frequent low flows using an intercepting stormwater pipe

The three scenarios have been assessed in terms of meeting two hydrologic objectives:

- Preserving the pre-development low flow duration frequency, as demonstrated by ranking averaged daily flow rates; and

- Preserving a 30-day dry spell frequency, as demonstrated by counting the number of days between flow events above a threshold flow (the median 0% EI flow rate in this case) and ranking the length of these dry spells.

Uncalibrated MUSIC models using default soil store parameters were developed, with a 10-hectare forested catchment defining the base line hydrology.

Modelling results were output as daily averaged flow rates and low flow duration frequency curves were produced, as presented in Figure 2. Similarly, 30-day dry spell frequency curves were produced, as presented in Figure 3.

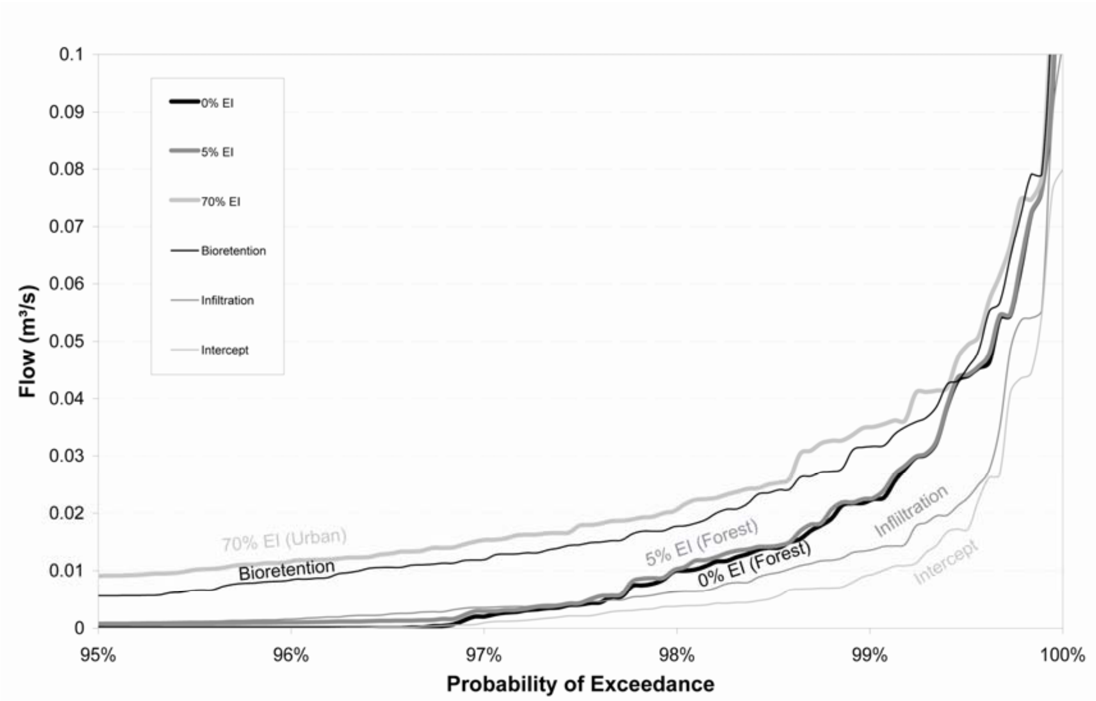

Figure 2: Low flow duration frequency curves for baseline, urbanised and WSUD scenarios

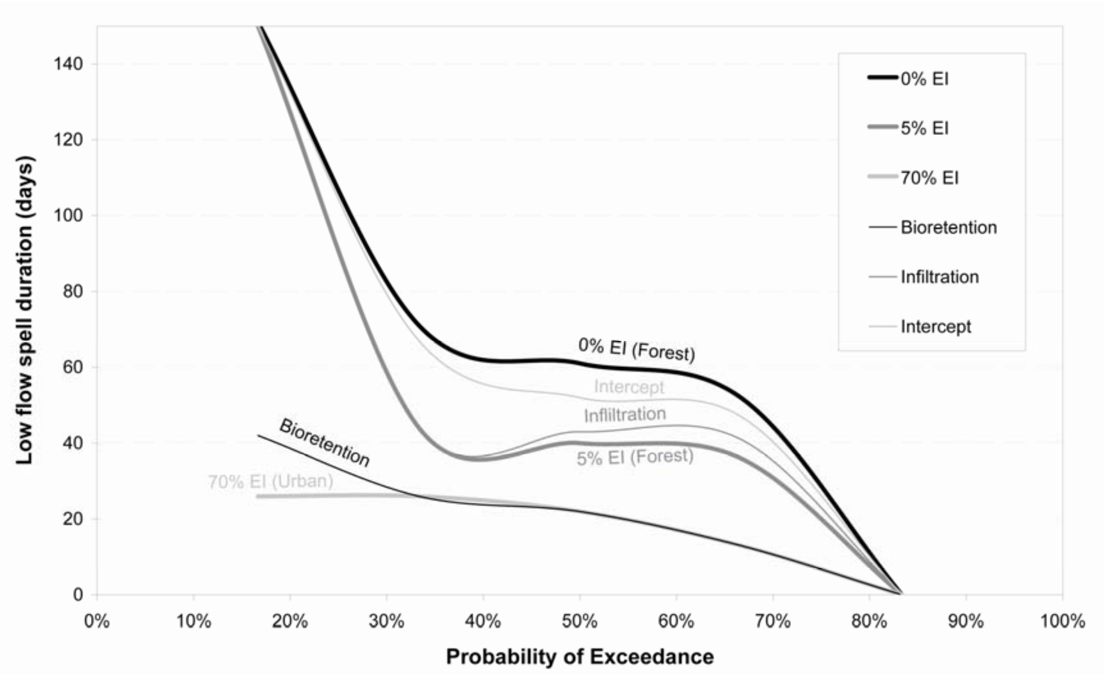

Figure 3: 30-day dry spell frequency curves for baseline, urbanised and WSUD scenarios

Baseline Ephemeral Hydrology

Modelling indicates that the forested catchment (0% EI) produces flows at the 97% percentile, which coincides with the frequency of 15 millimetres of rainfall in East Melbourne – the upper limit of rainfall depth postulated to have the greatest impact on Eastern Melbourne stream health by Walsh et al (2004). This is equivalent to runoff approximately 8 times in the year.

The spells curve shows that forested catchment produces prolonged dry periods of up to 5 months with infrequent periods of successive flow days. This benchmark establishes the wetting and drying conditions to which floodplain communities have adapted.

Changes in EI

Changes in the EI of a catchment produce dramatic increases in the frequency of runoff events and reductions in the periods between events. Unmitigated development within the catchment produces significantly greater runoff rates than the forested catchment, 8 times more often. The spells curve shows that common dry periods reduce from 5 months to 1 month, which represents a dramatic change to the drying regime of the floodplain.

Small increases in EI will produce an apparently small diversion from the natural hydrology of the catchment. However, Walsh also found that catchments with EI greater than 5% showed significant degradation. The 5% EI flow curve shows a similar shape to the forested (0% EI) flow curve, but with runoff commencing at the 80th percentile or 8 to 10 times more often than the forested catchment. Frequent dry spells are preserved, however, median dry spells are reduced from 60 days to 40 days. The change to low flow runoff rates and dry spells would appear small, but the research shows that this increase causes significant disruption to the ecology of the waterway. Therefore, in terms of protecting the ecology of the waterway, the hydrologic response of the 5% EI catchment sets the bounds of acceptable changes to flow frequency and drying spells.

Basic WSUD Strategies

Comparison of the flow curves and dry spells curves for the WSUD strategies shows the relative improvement that volume control and detention make on the hydrologic response of an urbanised catchment.

The least effective strategy explored here is that of combined stormwater harvesting and bioretention system having a base that prevents any infiltration (either constrained by natural soils or an engineered liner). This system demonstrates a relatively minor improvement to the unmitigated runoff curves where runoff still occurs 8 times more frequently than in the forested catchment. The respective spells curve is also similar to that of a unmitigated catchment, with 30-day dry spells occurring far less frequently than for the forested catchment. While this scenario will meet stormwater pollutant reduction targets, this scenario would do little to protect a sensitive ephemeral creek and significant changes to the ecological structure can be expected.

The Effectiveness of Infiltration

Incorporating infiltration into the treatment train is shown to have an improvement on low flow frequency, with the respective flow curve resembling that of the forested (0% EI) catchment. This strategy was developed iteratively to achieve the onset of creek flow near the 97th percentile and in fact overshoots the baseline forested hydrology by reducing frequent surface flow rates.

The spells curve is similar to that of a 5% EI catchment and therefore indicates that the strategy is reasonable at preserving ephemeral flows, but offers borderline effectiveness in protecting the ecological values of the receiving waterway. An infiltration rate of 100 millimetres/hour was adopted, which is high for a natural soil and requires a very large infiltration area – in excess of 10% of the upper catchment. The feasibility of implementing such a strategy is constrained by the inherent land take. As discussed above, the high rates of infiltration adopted here may be precluded by underlying soils commanding even larger areas for effective control of frequent low flows. An engineered solution incorporating the intercepting stormwater pipe is then considered to preserve ephemeral hydrology where infiltration cannot be feasibly implemented.

An Alternative to Infiltration in Low Porous Soils

The intercepting stormwater pipe has been presented here as an alternative to infiltration, which acts to divert frequent low flows around sensitive areas and preserves natural hydrology, as demonstrated at Porters Creek Wetland, Wyong (Leinster and White, 2006).

As with the infiltration strategy presented above, the diversion pipe has been sized iteratively to preserve the onset of creek flow at the 97^{th} percentile and also overshoots the baseline forested catchment hydrology, producing slightly lower flows and dryer conditions within the creek bed. The intercepting pipe is an effective means of preserving the frequency of 30-day dry spells as demonstrated by comparing the respective spells curve to that of a 5% EI catchment.

Such a stormwater treatment strategy has an inherent expense associated with potentially long reaches of stormwater pipes laid within fringing buffer zones or road corridors. Capital costs associated with the implementation of the strategy are in the order of $600 per linear metre of creek protected. Excessive pipe lengths can be limited by day-lighting pipes at frequently spaced stormwater harvesting storages along the creek corridor.

Conclusion

Small levels of urbanisation have been found to significantly degrade waterway ecosystems. WSUD best practice techniques provide promising solutions to preserve and restore waterway health, but must be tailored to the specific hydrologic requirements of receiving waterways and operate within the constraints of the local area. While common strategies will address flooding, stormwater quality and runoff volumes, these strategies will not achieve all low flow hydrology objectives alone, particularly within the catchments of ephemeral waterways. Within upland catchments, the presence of suitable soils may preclude infiltration strategies that can preserve ephemeral hydrology. The same level of hydrologic protection can be achieved with an engineered solution, by diverting frequent flows away from sensitive waterways. Such strategies carry a significant capital cost, however, the effectiveness of such strategies can achieve a balance in development and environmental objectives in highly constrained sites.

References

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