Environmental flows in the city: Delivering benefits with excess water.

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Key Points

- Stormwater harvesting has potential to provide environmental water in Melbourne's urbanizing catchments.
- Maximum flow thresholds have been identified, to form a range of beneficial flows with existing minimum flow recommendations.
- These recommendations are based on tolerances of the ecology and geomorphology of the waterway, rather than the minimum flows needed to support the ecosystem.
- Having a range of flow recommendations can increase the agility of stormwater harvesting, while giving waterway managers confidence in the environmental water releases.
- This methodology can complement the FLOWS methodology and the minimum flow recommendations of a system.

Abstract

Environmental flows support waterways that receive less water than they need. Flow recommendations are therefore typically based on the minimum requirements to maintain functioning ecosystems, in the face of water scarcity. Urbanising catchments, however, can have an abundance of flows. So, can we use these to reduce environmental flow shortfalls? And can we define ecological and physical thresholds to characterise the maximum beneficial flows for waterways?

This project investigated the maximum beneficial flow recommendations for Jacksons Creek, Sunbury. An expert panel was asked to assess the conditions under which waterway values may be impacted by flow changes. The maximum flow recommendations were then based on the disturbance thresholds for key values in the system.

Since the Millennium Drought, Jacksons Creek has experienced a step change decline in stream flow. If managed appropriately, urbanisation and increasing stormwater volumes can reduce system shortfalls. For this, maximum flow thresholds need to be set to limit harm. In Jacksons Creek, flow thresholds were predominately driven by vegetation and geomorphology. The development of these recommendations demonstrated the need to align with ecological limits at a finer scale than minimum environmental flow recommendations are made. For example, a more conservative maximum flow was recommended during the primary vegetation growth and recruitment period; ensuring flow variability is maintained even when "baseflow" conditions are set.

The new recommendations allow waterway managers to maintain the benefits of environmental flows, while also managing the threats posed by increasing urban runoff. They allow more flexibility to increase the potential environmental demand, catering for greater volumes of water to be released in times of abundance. This increases the agility of stormwater harvesting schemes, while also protecting waterways.

Many catchments across the landscape are experiencing rapid urban development. Catchment managers can apply this methodology to manage harvested stormwater for environmental benefit.

Keywords

Environmental flows, Stormwater, thresholds

Introduction

Jacksons Creek is one of the major tributaries of the Maribyrnong River, flowing through Wurundjeri Woi Wurrung Country in Melbourne's north-west. Environmental flow recommendations in the Maribyrnong have, to date, been provided for minimum flows only. This is due to limited water availability, with extractions from the river, upstream regulation and farm dams in the catchment. In the future however, there will be an excess of water at times, with stormwater flowing from the urbanising areas around Sunbury. To reduce the impact of these excess flows, stormwater can be harvested for beneficial reuse.

Stormwater can potentially be delivered beneficially to the environment. If delivered in line with the environment's demand, at the appropriate timing, frequency, duration and magnitude these flows would have a number of benefits. These benefits include reducing environmental flow shortfalls in Jacksons Creek and reducing the impacts of uncontrolled urban runoff on Jacksons and Emu Creeks.

The existing flow recommendations can be used as a baseline for the amount of water to be delivered from the stormwater harvesting system. However, there are three major limitations with using only minimum flow recommendations:

1. *Anything over the minimum flow recommendation cannot be considered 'beneficial'.*
   As there is no maximum recommendation, flow compliance is assessed by exceeding the minimum only. It is well documented that uncontrolled urban runoff can have negative impacts on receiving waterways (Duncan, H. P., et.al. 2014), so this is not helpful for a system where there is excess water.

2. *The limit to beneficial flows is currently unknown.*
   When the minimum flow recommendations are exceeded, it is currently unknown when flows exceed their benefit and become disturbance events which can be ecologically or geomorphically damaging. This damage could occur due to exceeding thresholds for timing, frequency, duration, magnitude or seasonality of flows.

3. *A single flow recommendation (rather than a range) limits adaptive management of the system.*
   A recommended range of flows would allow for greater flexibility in the management of water in storage, potentially improving both environmental flow delivery and stormwater harvesting capacity. For example, if rain is forecast, storages could be drawn down quicker by increasing the flows to Jacksons Creek beyond the minimum. This would make more storage available for the rain event and reduce uncontrolled spills from the system.

Due to the challenges within this catchment and the opportunity presented by stormwater harvesting, maximum flow recommendations were needed for Jacksons Creek.

Development of the method

Melbourne Water engaged Streamology to develop the maximum flow recommendations for Reach 7 of Jacksons Creek. These recommendations were based on the existing minimum flow recommendations for the reach, developed using the FLOWS method (Earth Tech, 2006 & Alluvium, 2016). The method approach is generalised below in Figure 1.

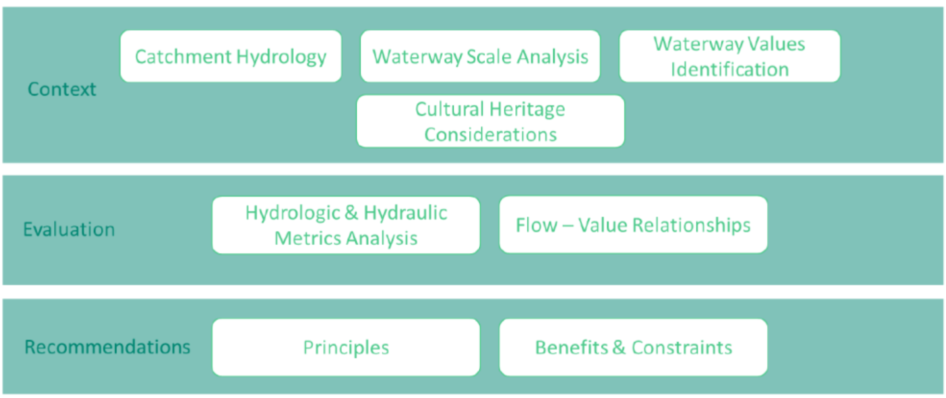

Figure 1. Generalised Maximum Environmental Flows Approach (Streamology, 2024)

Context

Catchment hydrology

Analysis of flows in Jacksons Creek highlighted the impact the Millennium Drought (1997-2009) had on the catchment. Like many catchments in south-eastern Australia (Peterson, et.al. 2021), streamflows in Jacksons Creek have not recovered to their pre-drought state. The average mean annual streamflow post-drought, has declined by approximately 49% from pre-drought conditions.

This analysis was useful for setting initial maximum flow recommendations, as the pre-drought magnitudes could be used as a guide. These initial maximums were then refined, once critical relationships between flow and values were confirmed.

Waterway scale analysis

Representative sites were selected to analyse hydraulic conditions (depth, velocity, sheer stress) when developing the flows study. These same sites were used for the development of the maximum flow recommendations. Within the study reach, the geomorphic characteristics of the channel (e.g. underlying geology, planform, confinement and features such as inset floodplains) are consistent throughout. Therefore, the existing model used to develop the minimum recommendations was also determined to be appropriate for this project.

Waterway values identification

The minimum flow recommendations are based on the flows required to support values in the system. The flows study therefore identifies the key flow dependent values of the system, including platypus, fish, vulnerable vegetation and short finned eel (Earth Tech, 2006 & Alluvium, 2016). The list of identified values was used to form initial links between values and flow components for the maximum recommendations.

An expert panel comprising Geoff Vietz (geomorphology), Christine Lauchlan Arrowsmith (hydrology), Nick Bond (fish & macroinvertebrates) and Joe Greet (vegetation), provided their knowledge on flow-value relationships and critical thresholds for this project.

Cultural Heritage considerations

Melbourne Water engaged with Wurundjeri Woi Wurrung Cultural Heritage Aboriginal Corporation on this project. Wurundjeri asked for implications to scar trees and cultural artifact scatters to be included when setting maximum flow thresholds.

Evaluation

Draft flow recommendations were developed using the following questions:

- Do the pre-Millennium Drought conditions (1947-1996) and flow metric magnitudes provide us with a representation of more “typical” conditions of Jacksons Creek compared to post 1996 conditions?
- Can the pre-drought metrics be used to set “maximum” limits for the flow recommendations?
- Are there ecological limits and if so, how would you define them?

These questions were evaluated by analysing the hydrology, hydraulics and flow-value relationships in the reach.

Hydrologic metrics

Seasonal hydrologic metrics (baseflow index, mean baseflow magnitude, median baseflow magnitude and mean daily flow) were analysed to identify if there was a difference between pre and post drought values. As there was a difference, it was determined that the pre-drought metrics were an appropriate starting point for maximum flow recommendations.

The expert panel used the analysed flow metrics and associated flow duration curves to evaluate whether the pre-drought values were appropriate as maximum beneficial values. As the discussion evolved, it became clear that the autumn and spring flow periods were important to evaluate as they most closely aligned to what became the maximum beneficial flow principles. For instance, autumn and spring flow periods are significant in relations to vegetation growing seasons and are therefore potentially most at risk from too much water should specific flow-value relationships be exceeded.

Hydraulic metrics

Hydraulic conditions (depth, velocity and shear stress) were considered alongside the hydrologic conditions in order to link flows with ecological and geomorphic values. In this instance shear stress and depth were most relevant and were used by the expert panel to understand particular flow thresholds and inform an upper bound for any flow-value relationship.

Cross sections of the representative sites were used to assess shear stress thresholds for the sediment types present. Due to the range of flow and sediment conditions along the reach, several flow thresholds were selected. These thresholds correspond to different sediment transport conditions, representing bed disturbance along the reach. This information was then used along with the hydrologic metrics to inform the flow-value thresholds.

Flow-Value relationships

Critical ecological and geomorphological risks were used to define the maximum beneficial flow principles and inform the selection of related thresholds from the hydrologic and hydraulic metrics. The most critical flow-value relationships identified by the expert panel were:

- **Low flow baseflow/low flow freshes and vegetation –** The drier period is a critical time for recruitment and growth. Vegetation is more sensitive to stress and the impacts of prolonged inundation in this period.
- **High flow baseflow and aquatic fauna –** Variable baseflows are important to support the diverse habitat preferences of instream fauna, including macroinvertebrates and fish. The upper limit is set to maintain availability of slackwater habitats.
- **Freshes/bankfull and geomorphology –** Some disturbance within the system is beneficial for bed and bank diversity and scouring of biofilms, however prolonged disturbance can cause major channel change.
- **Freshes and aquatic fauna –** Fresh duration and magnitude is limited as to not disrupt the normal foraging behavior of fish and invertebrates.
- **High flow fresh/bankfull and platypus –** If poorly timed, high flow freshes can have a negative impact on platypus, by inundating burrows causing drowning or displacement of juveniles.

The maximum beneficial flow recommendations were then developed combining these identified flow-value relationships and associated risks, with the hydraulic and hydrologic metrics.

Maximum beneficial flow recommendations

Principles

Maximum flow recommendations were developed for key flow components, but not for all flows. Providing these recommendations for all aspects of flow delivery is difficult and infeasible, however there are several principles that can be followed to achieve better outcomes.

Seasonality

In modified systems, seasonality can be altered, with events flow delivered at inappropriate magnitudes and times of year. The seasonality of flows is a critical factor for many processes and values.

- **Vegetation -** The growth and recruitment period (Oct-Apr) is a key time to limit excessive flows or prolonged high flows.

- **Physical form -** The frequency of freshes throughout the warmer months can also impact on physical form, therefore frequent wetting and drying cycles should be avoided.
- **Fish and macroinvertebrates** – The timing of summer and winter baseflows needs to be aligned with temperature change and opportunities for growth of food resources, especially plants and algae.
- **Cultural heritage -** The analysis determined that there was no increased risk to these cultural values, as the maximum recommendations did not increase bank erosion risks or prolong floodplain inundation.

Variability

Variability of flows is a natural feature of rivers, however in regulated or impacted systems variability is decreased or lost. Flow variability is important to reduce mass bank failure, due to notching and drowning out of vegetation, due to prolonged inundation. Short term fluctuations in flow are also beneficial in moving sediment and fallen leaf litter around to increase habitat diversity.

Rates of rise and fall

Rapid rates of rise and fall increase geomorphic risks and risks to instream fauna. Recommended rates of rise and fall were developed in the original Maribyrnong Flows Study and have not changed through this project.

Flow recommendations

The maximum flow recommendations developed through this project are shown in Table 1, highlighted in gray. The table also lists the minimum flow recommendations from the flows study for comparison.

Table 1. Flow recommendation summary for Reach 7 Jacksons Creek (Alluvium, 2016 & Streamology, 2024)

Season	Component	Recommendations Type	Discharge	Duration	Frequency	Summarised rationale
Summer/ autumn	Baseflow	Min	6 ML/d	Continuous	Continuous	Maintain median depth over riffles of >0.1m for habitat.
		Max	9.3 ML/d	30 days	4 per season	To minimize high (or invariant) baseflows for instream vegetation. Increase from minimum, due to historic tolerances and occurrence.
	Low flow fresh	Min	40 ML/d	4 days	5 per season	Provide depth for movement of small bodied native fish.
		Max	40 ML/d	4-15 days	3 per season	To avoid prolonged inundation of instream veg during growth and inundation of platypus burrows. Need to maintain slack water habitats in channel. No increase from minimum, due to historic tolerances and occurrence.
Winter/ spring	Baseflow	Min	40 ML/d	Continuous	Continuous	Provide habitat and prevent encroachment of encroachment of phragmites.
		Max	40 ML/d	30 days*	2 per season (During Aug & Sept only)	Prolonged flows could cause scouring and vegetation disturbance. No increase from minimum, due to historic tolerances and occurrence.
	Fresh	Min	700 ML/d	3 days	3 per season	Bench inundation to maintain channel and disturb vegetation.
		Max	1000 ML/d	2 days	3 per season	Fewer larger events can be delivered <u>or</u> a greater number of smaller events. To minimise disturbance for foraging species. Based on bed movement thresholds of med-course gravels.
			2000 ML/d	2 days	2 per season	
Any time	High flow	Min	2000 ML/d	1 day	1 per year	Inundation of internal floodplain for regeneration of vulnerable vegetation.
		Max	3500 ML/d	1.5 days	1 per year	To minimize major channel change. Based on bed movement thresholds of gravels and small cobbles.

**The hydrological analysis suggested that the maximum winter spring baseflow is same as the minimum magnitude identified in the flows study. Due to this, the winter baseflow minimum and maximum demands do not provide a clear* *range. The minimum flow recommendation will be reviewed in the upcoming Maribyrnong flows study review (in '24-25).*

Outcomes

Identifying the maximum flow recommendations has now provided a range of beneficial flows that can be delivered to Jacksons Creek as water for the environment, as shown in Table 1. The delivery of these flows is conceptually represented in the hydrograph Figure 2.

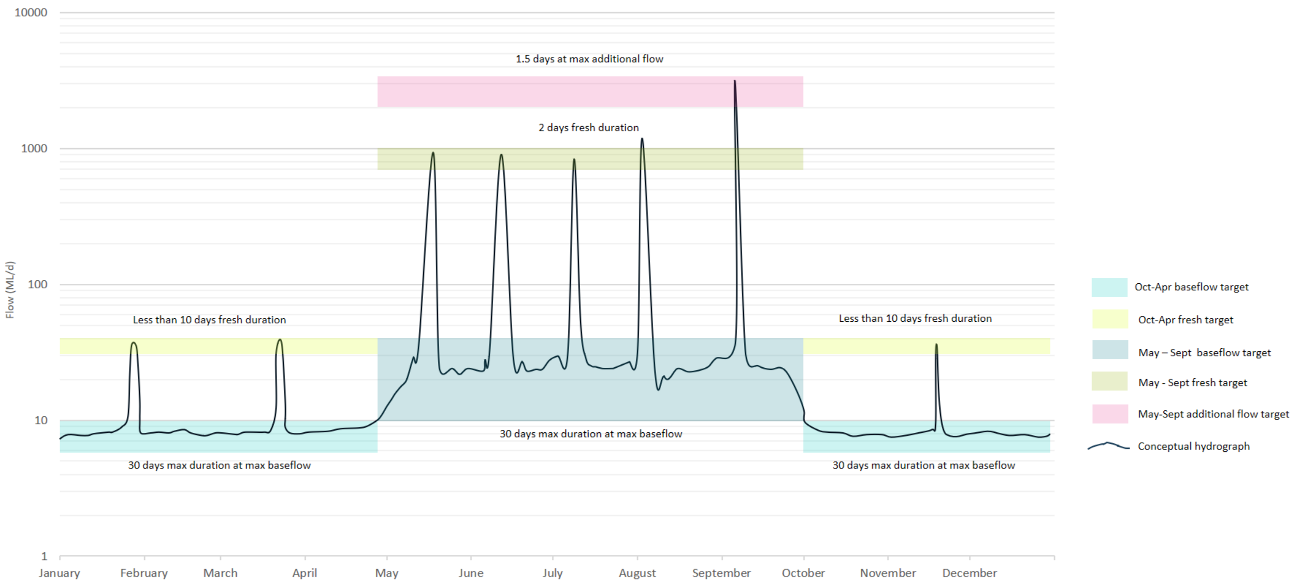

Figure 2. Conceptual hydrograph over a year showing the upper and lower limits of beneficial flow in Reach 7 of Jacksons Creek, Sunbury, VIC (Streamology, 2024)

The hydrograph illustrates the change in the way that flows can be delivered to the environment in Jacksons Creek. The range of flows now provides a guide to what can be delivered for environmental benefit with confidence, which in turn will allow for more adaptive delivery of stormwater to optimise the performance of available storage. Figure 3 provides an example of how these recommendations could be implemented in practice, showing when and how much additional water could be released to provide environmental flows within the beneficial range.

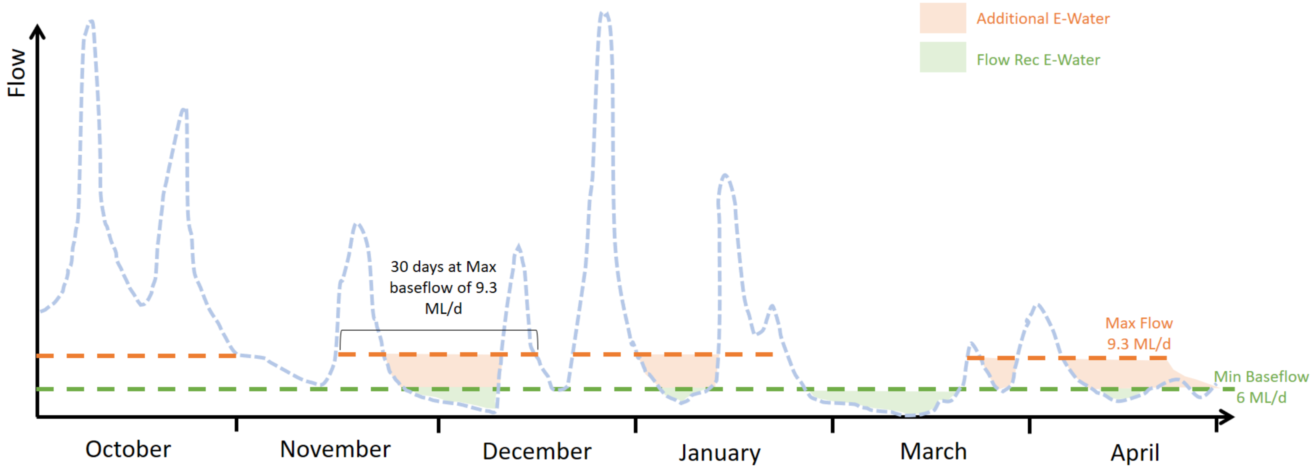

Figure 3. An example of how maximum flow recommendations can be implemented during the low flow season (Streamology, 2024)

Conclusions

The maximum beneficial flow recommendations developed for Reach 7 Jacksons Creek provide clear guidance for the delivery of environmental flows for future stormwater delivery. These flows align with the flows study, linking hydrologic and hydraulic metrics to flow dependent values to provide flow thresholds for the reach. When used alongside the minimum flow recommendations, these provide increased confidence for the benefit of environmental flow releases, while enabling optimisation of future harvested stormwater releases.

These flow recommendations provide clear guidance to waterway managers for the delivery of environmental flow benefits in a system which will experience the impacts of excess flows in the future.

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- Joe Greet – The University of Melbourne
- Geoff Vietz - Streamology
- Christine Lauchlan Arrowsmith - Streamology

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