Harnessing excess stormwater for distributed environmental flows

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Key points

- An opportunity exists to transfer excess stormwater from 'surplus' catchments to 'shortfall' catchments in need of environmental flow allocations, bringing together stormwater science and environmental flows, two fields typically considered in isolation.
- The distributed e-flow concept provides a dual benefit by harvesting stormwater surpluses from urbanising catchments and strategically releasing them into flow-stressed river systems, simultaneously addressing urban runoff impacts and ecological water deficits.
- The flexible framework developed guides the identification, assessment, and delivery of environmental flows (e-flows) using alternative water sources as a supplement to traditional reservoir-based delivery systems.
- The framework establishes foundational steps for transitioning from centralised, reservoir-dependent e-flow delivery to a decentralised, climate-resilient, and ecologically adaptive regime, with recommended next steps including pilot projects, MERI protocols, stakeholder engagement, and supporting policy development.
- Up to 85% of the shortfall catchment's baseflow demands could be achieved, at the same time significantly reducing damaging excess flows in the surplus catchments with waterway benefits that exceeded total costs.

Abstract

There has often existed a division between options to improve waterway health in catchments with water shortfalls, whereby extractions mean that environmental flows are difficult to source, and those in catchments with surplus water such as those due to urbanisation where excess stormwater is damaging. The opportunity to transfer excess stormwater from 'surplus' catchments to 'shortfall' catchments is a true win-win that could provide a paradigm shift in water management for waterway health. The inspiration for this project was for opportunities to recover water for the environment in response to environmental water shortfalls identified in the Healthy Waterways Strategy (Melbourne Water, 2018). The opportunity for using alternative water sources, such as stormwater generated in urban growth areas, is a prime consideration that may have multiple benefits, but this comes with a range of complexities and it requires guidance.

Streamology and Melbourne Water investigated this opportunity and together developed a new adaptable framework for distributed environmental flow delivery using alternative water sources such as excess urban stormwater. Stormwater excess and environmental flow shortfall have historically been managed as separate disciplines, and this project is the first known attempt to systematically bridge the concepts at a framework level. The framework both provides the high-level concepts for protection of both the surplus and receiving catchments, but also the necessary detail to ensure the effective rollout of this concept. The project proposed the use of distributed storage and treatment assets to harvest and release stormwater from surplus catchments (mitigating the impacts of urbanisation) to strategically improve flow conditions in stressed river systems in shortfall catchments.

The flexible framework guides the identification, assessment and delivery of distributed e-flow opportunities across seven stages - from understanding the catchment and flow regimes to identifying risks, developing opportunities and applying adaptive management. The framework is underpinned by principles of e-flow compliance, climate resilience, urban impact reduction, feasibility, consultation and governance. The framework was applied to two contrasting catchments, the high-value but low urban growth catchment in the Eastern Yarra, and a significant growth area in Sunbury. The analysis demonstrated the viability in achieving meaningful e-flow outcomes, while demonstrating how to prioritise sub-catchments with both stormwater surpluses and e-flow shortfalls. Constraints such as terrain, land availability, and infrastructure feasibility were also explored in multi-criteria and cost-benefit analyses. The cross-catchment transfer of stormwater surpluses for e-flow delivery is largely untested, and as such, a pilot program has been suggested with adaptable management throughout the process. This dual benefit solution draws upon the latest research and technology in stormwater, environmental flows, and urban waterway health to ensure the protection and net benefit for all associated waterways.

Keywords

Environmental flows, stormwater, alternative water, healthy waterways, framework, multi benefit solutions

Introduction

In response to persistent environmental water shortfalls identified in the Healthy Waterways Strategy (Melbourne Water, 2018), Streamology and Melbourne Water have developed a framework for distributed environmental flow (e-flow) delivery using alternative water sources. Rather than relying solely on traditional reservoir-held environmental entitlements, we provide a staged approach for strategic harvesting and release of excess urban stormwater through distributed storage and treatment assets, delivering water directly to flow-stressed river systems at the point and time of need. This approach, and demonstration of feasibility, represents a meaningful evolution in e-flow practice: moving from centralised, infrastructure-heavy delivery toward a decentralised, adaptive model that turns the challenge of urbanisation into an opportunity and stormwater excess as an asset. This significantly changes the current practice, where the receiving waterway needs are often only considered at the bay, rather than the waterways that are impacted along the way.

The framework developed in this project guides the development of effective and robust options for alternative water delivery. It supports the identification of stormwater surplus catchments that generate excess water and redirects this resource to waterways with identified e-flow shortfalls. Importantly, it considers not just the bulk water transfer, but also highlights the importance of flow characteristics such as seasonality, timing, duration, and other flow regime components to really keep the core message of waterway protection at the forefront. The approach and framework provide a dual benefit - mitigating the hydrological impacts of urbanisation while improving ecological flow conditions in rivers that lack access to conventional water supply infrastructure. The repeatable and universal framework allows practitioners to move from a concept to a deliverable opportunity while managing risks, and examples of this application have been provided.

Distributed release concept

Many waterways lack access to traditional reservoir-held environmental entitlements or do not receive the full range of required flows for ecological purposes, leaving significant flow deficits. Conversely, in similar regions, urbanisation most commonly leads to excess stormwater and a catchment recognised as in surplus, with negative implications for waterway health and ecological, social and cultural values (Fletcher et al. 2016). The use of excess stormwater as an alternative supply source presents a new opportunity to fill these gaps through a distributed release system. This novel approach draws on a growing body of local and international experience in stormwater harvesting and integrated water management.

A literature review was conducted to assess the appropriateness and feasibility of this concept, and to identify learnings from relevant projects that could inform the design, bringing together the two quite distinct problems and opportunities. That review confirmed that while the deliberate cross-catchment transfer of stormwater surpluses for e-flow delivery is largely untested, the enabling technologies and foundational principles are well established. This evidence base informed the principles and framework developed for identifying and designing distributed e-flow opportunities.

A key insight from the literature is that this approach offers more than a simple water supply solution. Removing excess stormwater from urbanising catchments not only provides water to shortfall waterways downstream, but simultaneously protects the surplus source catchment from the well-documented effects of urban stormwater, including altered flow magnitude, frequency, and timing (Walsh et al., 2005; Vietz et al., 2016). This dual benefit is central to the concept and is illustrated in Figure 1.

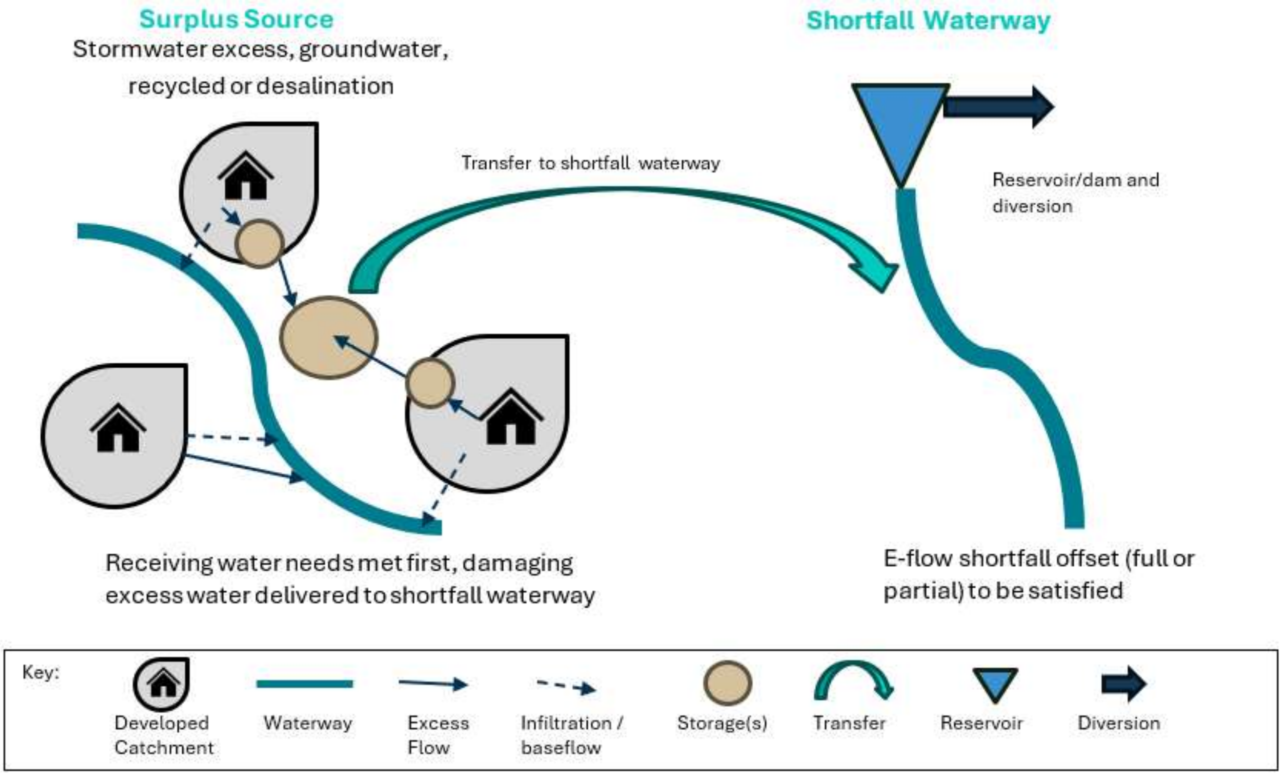

Figure 1 Distributed E-flow conceptual model

The delivery of surplus water to any e-flow shortfall waterways was guided by the following key principles:

- Removal of water from the surplus source (whether this is recycled water, desalination water, groundwater or excess stormwater) would need to first consider the impacts of any local receiving waterbodies. For stormwater the 'excess catchment' where development is occurring should first meet the needs of its catchment including infiltration, local harvesting (including on lot rainwater tanks), and meeting any flow demands of the local, downstream waterways (as shown conceptually in Figure 1).
- Any excess flows from the 'surplus' source that has the potential to degrade local waterway values (geomorphology, loss of instream vegetation, habitat) can be treated, stored and transferred to a waterway with e-flow shortfalls.
- The 'shortfall waterway' is a waterway where the need for environmental water to support waterway values has been identified, and the components of the flow regime that are required can be realistically delivered.
- Real-time control and optimised operation of the harvested water storages may be required to enable delivery of flow volumes, frequencies and durations that best match conditions prior to urbanisation and protect waterways from negative outcomes (Walsh et al., 2023).

Framework for distributed E-flow storage and delivery

The flexible framework was developed to guide the identification, assessment and delivery of distributed e-flow opportunities. It follows seven stages, from understanding the catchment and flow regimes to identifying risks, developing opportunities and applying adaptive management (Figure 2). The framework is underpinned by principles of e-flow compliance, climate resilience, urban impact reduction, feasibility, consultation and governance, which build progressively throughout the project. The framework enables hold-point checks to ensure data gathered can be used by organisations to identify opportunities, demonstrate the quantum of benefits, and turn an important idea into reality.

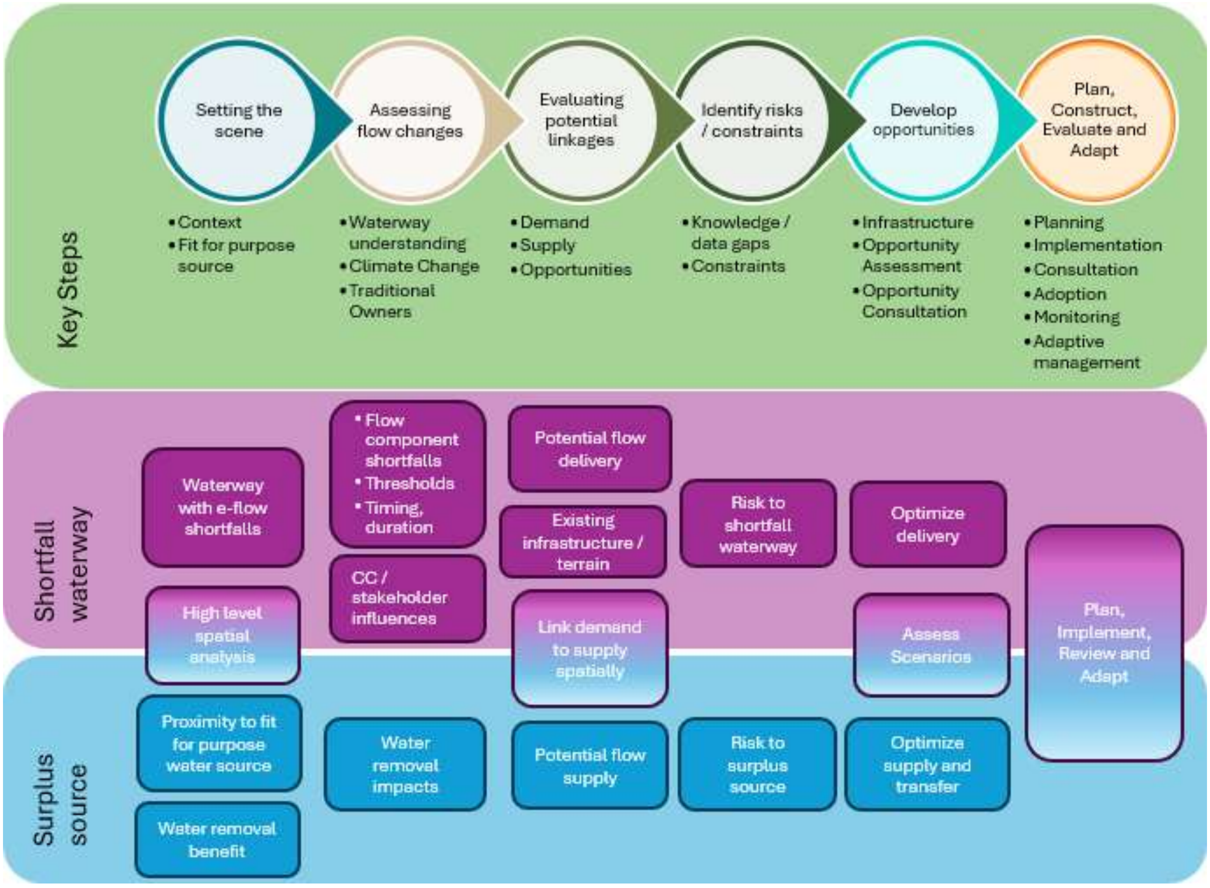

Figure 2 Distributed E-flow framework summary

The framework begins by **setting the scene**, establishing a thorough understanding of the catchment context, existing flow regimes, ecological values, and the legislative and strategic environment governing water management in the region. This includes an understanding of the existing ecological condition, the magnitude of imperviousness increase, the geomorphic risk of urbanisation, and the distance of waterway that will be impacted. A defined need and opportunity must exist for future consideration of the project and investigations to continue.

The framework then moves into **assessing flow changes**, characterising where and how urbanisation has altered the natural flow regime, and identifying waterways with e-flow shortfalls that are unlikely to be met through traditional reservoir-based delivery. This includes quantification of the flows, separation into various flow components to ensure the opportunity can match the water need (beneficial flows), and consideration of climate change and stakeholder influences which may alter the requirements. An assessment of the source catchment is a critical element as the intention is to remove only water that is in excess of the source catchment's needs. Only excess stormwater, water that has already satisfied local infiltration, on-lot harvesting, and downstream flow needs, is considered eligible for transfer, ensuring the solution does not create new ecological problems in the process of solving others. This is paired with **evaluating potential linkages —** spatially matching catchments that generate stormwater surpluses with nearby shortfall waterways to identify feasible transfer opportunities, taking into account terrain, distance, and infrastructure constraints. The intention is to evaluate what flow components could be realistically delivered to the shortfall waterway.

With candidate linkages identified, the framework guides practitioners through **identifying risks and constraints**, including geomorphological sensitivity, water quality requirements, land availability, and the potential for harm to both the source and receiving waterways. The framework considers the use of existing infrastructure to save costs and streamline the approvals process, real-time monitoring and control to optimise outfalls and provide flexibility in a changing climate, water quality treatment to meet the needs of the receiving waterway, and maintenance and operation requirements. Real-time monitoring is not essential to this approach, but it can be an enabler, particularly for sensitive waterways and climate resilience, as uncontrolled releases can be as damaging as stormwater excess, and specific streamflow needs may evolve in a changing climate.

The final stages focus on **developing opportunities** through multi-criteria and cost-benefit analysis to rank and prioritise options, before moving into **planning, construction, evaluation, and adaptive management**. This last stage emphasises operational control to match release timing, volume, and duration to natural flow patterns, alongside robust monitoring, evaluation, reporting, and improvement (MERI) protocols to ensure the system learns and adapts over time. The framework also acknowledges the need for pilot testing, consultation and education prior to any large-scale rollout of these concepts.

Framework application

The framework was applied to the Eastern Yarra and Sunbury catchments to demonstrate its viability, highlighting sub-catchments with both stormwater surpluses and e-flow shortfalls. MUSIC models from the stormwater investigations in the Yarra catchment (Water Technology, 2024) were modified for the purposes of the project, and compared to e-flow shortfalls from the Healthy Waterways Strategy mid-term review e-water shortfalls analysis (Alluvium, 2023). Constraints such as terrain, land availability, and infrastructure feasibility were also explored in multi-criteria and cost-benefit analyses, with the results summarised in Table 1. Costings were very high-level for the purposes of comparison, and were based on a high-level conceptual design. The Melbourne Water Social and Economic Value Tool (SEVT) (Marsden Jacob Associates, 2021) was used to create an estimate of the economic benefit of improvements to the waterways each option may deliver.

The cost of implementing stormwater controls can be inhibitive, often relying on singular benefits. By demonstrating multiple benefits such as flooding and drainage control, public health, placemaking, and Traditional Owner outcomes, the business case is greatly strengthened.

Table 1 Framework application results summary

Option		Rank	Water Delivered (ML)	Cost ($M)	Waterway Benefit ($M)
1	Warburton Rail Trail	4	411	47	56
2	Coranderrk Aqueduct	7	218	35	56
3	Chirnside to Olinda Ck	8	n/a	n/a	40
4	Woori Yallock Upper	2	817	89	96
5	Monbulk to Olinda Ck	5	73	23	80
6	Wandin North to Stringybark Ck	6	40	8	56
7	Healesville to Watts River	1	325	20	56
8	Sunbury to Jacksons Creek	3	3694	858	43

Based on the assessment, the two highest ranked opportunities to further explore were the Healesville to Watts River (Option 7) and Woori Yallock Upper (Option 4) (Figure 3). This was at odds to outcomes from a typical stormwater assessment, and consideration of existing reserves, as these options appeared at the onset to either be too localised or lacking opportunities for consolidated storages.

When working through the framework, these catchments had a higher value due to the high baseflow needs for these catchments, the impact of not undertaking the works, and potential cost-effective solutions. The framework therefore was more comprehensive to achieve multiple objectives, with a focus on waterway health.

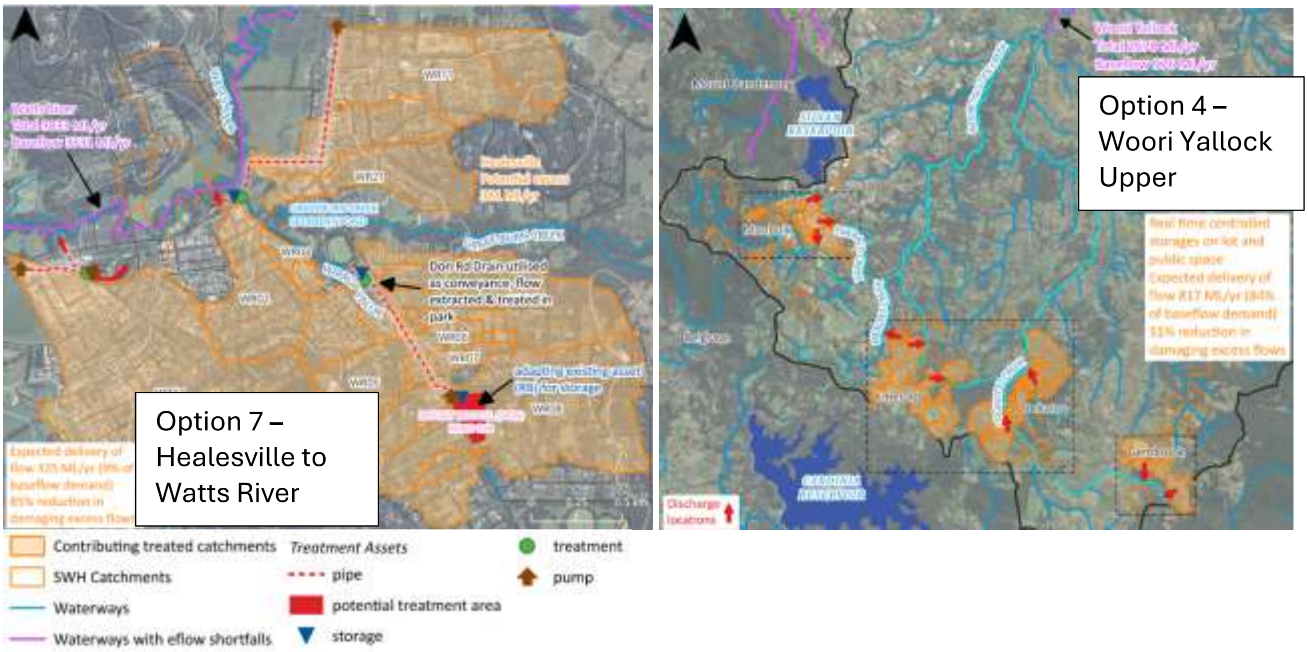

Figure 3 Highest ranked option concepts (Healesville to Watts River and Woori Yallock Upper)

Healesville to Watts River captured local runoff from the largest township in the Eastern Yarra catchment, Healesville, providing treatment, storage, and distribution infrastructure to deliver e-flows to the adjacent Watts River. Existing infrastructure and reserves were utilised for the storage requirements, including delivery along road reserves as this is a retrofit solution. This solution provided regular flows that could easily satisfy a majority of the baseflow shortfalls.

The Woori Yallock Upper option was more complex due to the distributed nature of the townships and significant elevation differences across the catchment, but it has a high environmental need and values. As such a centralised system was not an appropriate solution as it would require significant pumping, and as such a real-time controlled solution was proposed. Each township would have treatments and storages that are linked via a smart control, allowing timing of the outfalls to match the needs of the waterways and reduce erosion in areas of high geomorphic risk. The Woori Yallock Upper provides baseflows across the full catchment extent, which is most beneficial to the system as extractions for high intensity agriculture occur throughout the basin.

These options were the most effective as they deliver water to nearby waterways, limit infrastructure costs, and generate sufficient excess stormwater to ensure the solution is feasible. The use of regional trails and existing infrastructure over large distances was explored, however due to the variable terrain and abundance of shortfall waterways within the catchment, the use of this infrastructure did not provide sufficient benefits to outweigh the costs. This outcome is site-dependent and should not be assumed for all catchments.

The Eastern Yarra catchment analysis was compared to a growth area in Sunbury to test the framework in a greenfields development site. This location was selected as existing data has been developed as part of the Sunbury Regional Harvesting Scheme, and e-flows and MaxFLOWs (maximum allowable environmental flows) (Streamology, 2024) assessments of Jacksons Creek have been conducted. This information aided the assessment of the impact on waterway values from changes to the hydrologic regime, and set a recommended release distribution and limits to avoid unintended harm. The application to Sunbury was not intended to convert this scheme to a distributed e-flows system, rather to utilise existing modelling and concepts as an efficient comparison to the Eastern Yarra, with varied conditions such as dispersive clays, shallow bedrock, and established Precinct Structure Plans and Developer Services Schemes. The Sunbury Scheme was the third ranked option, with a significantly higher amount of water able to be delivered, but with the highest cost per megalitre of e-flow delivered. This is a result of the amount of water able to be harvested exceeding the e-flow shortfall. The pumping infrastructure to overcome the terrain and the shallow rock also contributes to the costs in the Sunbury region. The framework was equally applicable to the varied conditions, considering both greenfields and infill development opportunities and constraints. As such, the framework can be applied across Australia, with supporting investigations tailored to local catchment conditions.

Conclusions

A significant opportunity exists to address environmental flow shortages from shortfall catchments whilst addressing the impacts of excess stormwater runoff from surplus catchments. The concept is novel because it draws upon two quite distinct problems and the wealth of knowledge behind each, and must explicitly link the problem and opportunity, whilst holistically recognising the considerations. To develop this idea into tangible options, Streamology and Melbourne Water developed the distributed e-flow framework. Both the approach and the framework to apply it reflect the broader maturation of the stream management industry, one that is learning to live and evolve with change rather than simply respond to it. By reimagining urban stormwater not as a problem to be managed but as a resource to be strategically deployed, the framework advances a new generation of e-flow practice that is decentralised, adaptive, and resilient to the pressures of urban growth and a changing climate. The work demonstrates that with the right research, tools, principles, and collaborative partnerships, the industry is well positioned to develop innovative solutions that deliver genuine ecological outcomes for flow-stressed river systems, whilst addressing excess stormwater stressors from surplus catchments, even as the landscape change continues.

The foundational steps for transitioning from traditional reservoir-based e- flow delivery to a decentralised, resilient, and ecologically adaptive e-flow regime have been detailed in the framework. Further steps in the pilot program to establish case study locations and adaptive review of the outcomes will be the future steps to implementation.

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References

Alluvium (2023). *Healthy Waterways Strategy mid-term review: E-Water Shortfalls analysis*. Report for Melbourne Water.

Marsden Jacob Associates (2021). *Social and Economic Value Tool (SEVT) – version 2.4*, March 2021, developed by Marsden Jacob Associates for Melbourne Water.

Melbourne Water (2018). *Healthy Waterways Strategy 2018*. Melbourne Water Corporation, December 2018.

Streamology. (2024). *Jacksons Creek Maximum Environmental Flow Recommendations (Reach 7).* Report prepared by Streamology for Melbourne Water.

Vietz, G.J. & Lauchlan Arrowsmith, C. (2023). Challenges and opportunities in environmental water management: What's working and what can we do better? *Proceedings of the Hydrology and Water Resources Symposium*, Sydney, November, 2023. National Committee on Water Engineering.

Vietz, G. J., Walsh, C. J., & Fletcher, T. D. (2016). Urban hydrogeomorphology and the urban stream syndrome: Treating the symptoms and causes of geomorphic change. *Progress in Physical*

Geography, 40(3), 480-492.

Walsh, C. J., Roy, A. H., Feminella, J. W., Cottingham, P. D., Groffman, P. M., & Morgan, R. P. (2005). The urban stream syndrome: Current knowledge and the search for a cure. *Journal of the North American Benthological Society*, 24(3), 706–723.

Walsh, C.J., Bos, D.G, Burns, M.J, Imberger, M. & Fletcher, T.D. et al (2023). *Restoring the health of urban streams through stormwater management: A synthesis of the Little Stringybark and Dobsons Creek research projects.* Melbourne Waterway Research-Practice Partnership, Technical Report 23.2.

Water Technology. (2024). *Stormwater Investigations Program 2 (Yarra Catchment) – Stage 2. Report* prepared by Water Technology for Melbourne Water.