Optimised real-time monitoring and control of networked stormwater harvesting systems

Healthy Waterways Strategy 2018-2028
Port Phillip & Westernport, Victoria
Melbourne Water
The University of Melbourne

Strategic alignment

Regional Performance Objective (RPOs):

- RPO 14: Standards, tools and guidelines are in place and implemented to enable re-use and infiltration of excess stormwater, and protect and/or restore urban waterways.
- RPO 13: Industry capacity for whole of water cycle and stormwater management is increased to enable collaboration, improved access to information and knowledge, and a skilful and capable industry with strong established networks.
- Corhanwarrabul, Monbulk and Ferny Creeks PO1 - Water for the Environment: Identify and implement opportunities to maintain or improve the flow regime along Monbulk Creek and other refuge reaches to support platypus populations. And identify opportunities to reduce key threat of summer low flow stress by addressing causal factors such as water for domestic and stock use, climate change, diversions and urbanisation.
- Corhanwarrabul, Monbulk and Ferny Creeks PO4 - Stormwater: To prevent decline in stormwater condition, and to protect platypus habitat, treat urban development (eg Belgrave Heights), so that upstream of Mt Morton Road, directly connected imperviousness remains below 2% along main stem of Monbulk Creek. For every hectare of new impervious area, this requires harvesting around 6.3 ML/y and infiltrating 2.9 ML/y.

Key Research Areas:

- Stormwater management and flooding: Developing improved technologies and systems to support stormwater harvesting and re-use

Summary

The overarching objective of this project is to test the technical and social feasibility of operating distributed stormwater control measures using real-time control, to improve the hydrology and ecological health of urban streams.

In recent years, researchers around the world have demonstrated the importance of returning more natural flow regimes and improving water quality in protecting the biodiversity of urban waterways. Informed by modelling of urban flows and their ecological risks and benefits, Stormwater Control Measures (SCMs) are designed to capture runoff, retain excess flows, and release filtered water to mimic natural flow regimes. Despite the promise of these technological advances, large-scale experiments aiming to improve the health of degraded streams using widespread implementation of SCMs (on public, and increasingly private, land) have so far failed to achieve the desired or hypothesised improvements to streamflow and ecological outcomes. This failure has been attributed to four key factors:

1. challenges in finding adequate space for SCMs on both public and private land;
2. limitations in storage capacity and user demand for stormwater harvesting;
3. the frequent inability of current SCMs, which are passively operated and not coordinated, to deliver the required flow regime; and
4. inadequate maintenance of SCMs, compromising their performance.

Realising the potential of SCMs in restoring urban streams requires an approach that addresses these social and technical factors simultaneously. Real-Time Control (RTC) technology offers the potential to revolutionise the way small-scale, highly distributed SCMs operate. Firstly, networking SCMs across a catchment enables their collective coordination as a virtual reservoir that can be actively managed to achieve specific flow and water quality conditions in urban streams. Secondly, RTC technology can optimise the use of the storage capacity of individual SCMs, potentially reducing storage volumes and space requirements. RTC technology can inform household decisions in managing rainwater tanks simultaneously for private benefit and public good. Thirdly, the sophisticated sensor and control system can identify malfunctions, overcoming uncertainty around maintenance of SCMs. Together, these new capacities of RTC can optimise long-term SCM performance.

This networked, decentralised approach reconfigures public-private boundaries and responsibilities in the co-management of urban water. It requires a modified “hydrosocial contract” between the various actors in urban water management, in which householders are re-cast as providers and managers of water (rather than simply water consumers) and their RTC-networked rainwater tanks as storages for managing flows for both private and public good.

This project is testing the technical and social feasibility of this technology-enabled co-management, through a major experimental intervention in the catchment of Monbulk Creek. It is testing this through three complementary research questions:

1. Flow regime: Can networked SCMs and RTC technology improve flow regimes in Monbulk Creek?
2. Social sustainability: In what ways do household water practices support or challenge the social sustainability of networked rainwater tanks being co-managed for private and public good?

3. In-stream response: Do the increased baseflows and reduced stormflows increase platypus foraging habitat?

Highlights

- This research creates a template for a potentially revolutionary way of managing the urban water cycle, similar to the way distributed energy grids are developing. It is recommended that Melbourne Water continue to pursue this project, potentially expanding the installation of tanks to provider clearer evidence of impact and potential.
- The research includes investigation of the social aspects; determining the way in which this new approach impacts on community participation in water management. This is complimented by consideration of economic aspects, such as the potential use of financial incentives for contributions to environmental flow releases.
- The Monbulk Creek Smart Rainwater Network project relies on new algorithms to control the flow releases across the network. There is potential to further improve these with cutting-edge optimisation algorithms being developed in the OPTIMA research hub. It is also recommended that Melbourne Water investigate how to operationalise these systems within its existing networks and operations (e.g. SCADA).

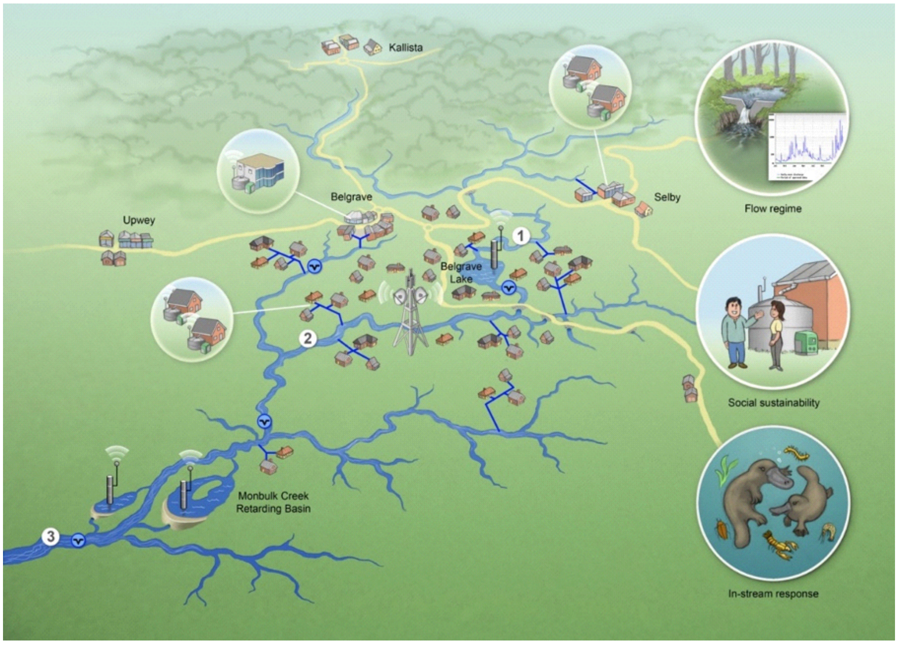

Figure 1. Conceptual diagram of the experimental intervention at two scales.

What are we doing?

The experimental intervention – implementation of RTC at large & small scales

The experimental intervention, which is being delivered in collaboration with Melbourne Water (MW), Yarra Ranges Council (YRC), South East Water (SEW) and DEECA, occurs at two scales (Figure 1). The 'large-scale' is retrofiting RTC technology to two large online water storages in the catchment—Belgrave Lake (a decommissioned water supply reservoir) and two shallow artificial lakes in Birdsland Reserve (part of the Monbulk Creek Retarding Basin). The second scale of intervention involves installation of smaller real-time-controlled SCMs on both public and private land. MW and SEW is installing RTC tank systems, connected to indoor and outdoor end-uses. The tanks feature a second outlet with actuated valve, to deliver environmental flows downstream and ensure controlled pre-storm release to mitigate flooding and peak flows.

The two large storages (Belgrave Lake and Monbulk Retarding Basin) will act as regulating storages, since they will receive flows from the upstream real-time-controlled SCMs. By coupling the RTC technology with model predictive control, the appropriate flow regime can be delivered whilst maintaining other objectives related to flood mitigation and water supply reliability. Such a network, combining both small, distributed and large centralised storages, makes it possible for the community to actively participate in the delivery of environmental water.

Flow regime outcomes

Streamflow and water quality monitoring: The project is measuring changes in flow regimes and water quality within the stormwater network and the creek itself, including monitoring water levels in the creek and major tributaries and where Melbourne Water has continuous stream gauging since 2006. The project will also sample water quality at all sites during dry-weather and wet-weather events. Water quality samples will be taken monthly and twelve wet-weather events/yr will be sampled from each site using flow-proportional composite sampling to derive event mean concentrations.

Analysing the flow regime (hydrologic and hydraulic) impacts of RTC: The project will use existing sophisticated RTC-modelling tools to simulate the RTC network under a range of scenarios, then translate the predicted flow outcomes into estimates of wetted habitat availability and other hydraulic metrics such as area of slow flowing water (slackwater). This will provide an understanding of the hydraulic impacts, using a detailed survey of Monbulk Creek and its tributaries, which will be used to develop a TUFLOW model of the entire stream network. The project will then develop control rules to govern the operation of the innovative SCMs and network. The best performing control rules (in terms of degree of replication of the natural flow regime, amount of potable water savings for households, etc) will be tested in the catchment. The modelled hydrological outcomes will be evaluated against the core hydrologic monitoring and hydraulic metrics derived from the streamflow data. These data will be used to evaluate the performance of the RTC implementation, comparing flows in reaches with and without baseflow-supplementation by the RTC systems.

Social sustainability of RTC-networked tanks

Installing RTC technology on household tanks makes new connections between individuals and agencies, private and public spaces, and household and institutional practices in co-managing urban water. The project will investigate the ways in which networked smart tanks influence household practices of water use and management, and change the relationships that residents have with the practices, people and places of urban water management in the Monbulk Creek catchment. The exploratory, mixed methods design of this study will enable in-depth inquiry into the diversity of household engagement with RTC technology as it transitions from novel to routine or rejected technology.

This study will initially track household water practices through repeat surveys of the home owners participating in the network, before and after installation of the smart tank. This survey will investigate changes in attitudes and behaviours regarding the rainwater tank and household water practices, residents' connections to their local environment and their partnership with other water management actors.

In-stream responses

Based on extensive hydrological (MUSIC) modelling of the catchment, it is predicted that the RTC SCM network could be capable of doubling autumn baseflows downstream of the two public storages, resulting in increased wetted area in the channel, providing increased foraging habitat in those reaches at a critical time of the year for platypus. This component of the project is assessing changes in a) in-stream habitat, b) macroinvertebrate abundance and assemblage composition and c) platypus foraging behaviour in the affected reaches compared to the control reach.

- *In-stream habitat*: Instream habitat (i.e. 'riffles', 'pools' and 'runs') has been mapped along three study reaches, each 1km long. Along each reach, physical habitat will be digitally mapped using low-flying drone photogrammetry survey (1-cm resolution) to build a 3D digital terrain model that can be integrated into the TUFLOW hydraulic model to classify the reach sections into pools, riffles and runs based on depth and velocity. Any gaps in the photogrammetry (particularly deep pools) will be filled with manual feature survey at low flow. TUFLOW predictions of physical habitat under contrasting flows will be verified by visually mapping pools, rifles and runs in the field. This will be complemented with Wolman pebble counts and bed sediment sampling using zigzag transects to characterise dominant bed particle sizes (cobbles, gravels, sands, silts and clay) in representative habitat features.
- *Macroinvertebrate abundance and assemblage composition*: The project is assessing the potential for increased wetted habitat to provide food sources for platypus by comparing macroinvertebrate abundance and assemblage composition between permanently inundated channel habitat and seasonally inundated habit through flow manipulation experiments within the channel. To provide a picture of aquatic macroinvertbrate abundance and diversity along Monbulk Creek, surveys were conducted in in autumn and spring 2023. Additionally, to assess the effect of platypus predation on macroinvertebrate assemblage composition and abundances estimated from these samples, the project will undertake an exclosure experiment, where abundance and assemblage composition will be compared between caged and non-caged samples.
- *Platypus foraging behaviour*: Platypus foraging behaviour (time spent foraging in habitats) is being assessed using 30+ Radiometry Long-Wave Infrared (LWIR) cameras placed along the creek for one week per month. A standard image will also be collected to enable accurate location of all infrared image objects relative to the channel habitat. These data will allow an assessment of the frequency with which platypus use certain sections and types of habitats (pools, riffles, runs) along Monbulk Creek , including the use of wetter and dier parts of the channel during flow manipulation experiements. Habitat for foraging, can also be related to the hydraulic model predictions of the extent of suitable habitat for platypus foraging under a range of flow scenarios, including real-time control release strategies or potential impacts of a loss in baseflows under a changing climate.

What are the expected outputs and outcomes?

- Achievement of HWS objectives for stormwater management and environmental flows in the Monbulk Creek catchment.
- Achievement of IWM forum Strategic Direction Statement Action 35 (for Dandenong Creek).
- Prevention of the loss of local platypus population.
- A community engagement model that can be delivered beyond initial Monbulk Creek trial.
- Confidence in the ability of RTC networks to improve stream condition.
- Contribution to refinement of optimisation algorithms and network operation.
- Advice on incentive and governance models for managing SCMs on private land.
- New standards and design guidelines for RTC.
- Improved water quality, hydrology and stream biology.

For more details on the research outcomes of this project, or other projects of the MWRPP, please contact:

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