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# A FULLY INTEGRATED WATER/SEWER/DRAINAGE MODEL – WHY WOULD YOU DO THAT?

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## Abstract

While the integrated planning approaches are maturing for urban water systems, the hydrological and hydraulic modelling tools to help assess a truly integrated water system are generally lacking in terms of their ability to represent all the functions and interactions of the urban water cycle. Traditionally, different hydraulic models have been employed to independently assess the current and future performance of water supply, sewerage and drainage systems using various software of related applications like WaterGEMS developed by Bentley (2017), MIKE URBAN developed by DHI (2017) or TUFLOW developed by BMT WBM (2016) to name a few. Each of these independent models often have their own set of assumptions which are not transferable and are typically not aware or considerate of the assumptions relating to the other systems. This can lead to inconsistencies between the different network models such as assumed demand patterns. To meet the challenges of ever-increasing complexity and promote transparency and consistency between models, Melbourne Water identified the need to test new planning tools which reflect the interdependencies of our urban water systems, and more explicitly assess the benefits of integrated water management projects. A pilot modelling project was undertaken to explore these benefits and identify barriers to the development of an integrated hydraulic model representing the three water networks, including overland flow representation, using off-the-shelf software. Combining the water networks into one single hydraulic model would allow a clearer understanding of the interactions between the systems and better align the modelling assumptions, while reducing modelling effort.

The objective of the study was to explore the practicality of using InfoWorks ICM (Integrated Catchment Modelling), software developed by Innovyze to simulate the total water cycle at an individual property scale and test this modelling concept across an established urban region located in south-east Melbourne, Victoria. The pilot model included potable, sewer and stormwater networks with a rainwater tank connected to the roof of each residential allotment. The stormwater hydrology component incorporated two-dimensional (2D) surface flood modelling, linked to the one-dimensional (1D) drainage network, to enable flows to pass between the piped and surface flow systems. This allowed the details of stormwater flood conditions to be accurately represented. The integrated water model also has the capacity to allow sewer overflows to directly interact with surface flows, although this aspect has not been enabled to date.

The pilot model was first tested on a small, local scale area with 100 residential properties. This initial model was established in order to develop the base water cycle hierachic rules and verify the movement of water from one system to another, at the property scale. Figure 1 shows the conceptual arrangement of water system interactions for a residential property.

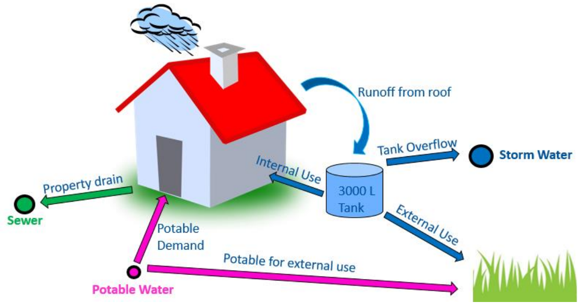

**Figure 1.**

At each property, roof runoff was directed into a 3,000 Litre rainwater tank, with any excess water discharged into the stormwater network. Internal and external water demands were preferentially supplied by the rainwater tank. When the tank was empty, water demands were then supplied by the pressurised potable water network. Each property's sewer loading then discharged into the gravity sewer network.

A dry-weather flow simulation confirmed that all demands were supplied following the patterns and volume set in the model. A wet weather flow (WWF) simulation confirmed that runoff from the roof flowed into the rainwater tank, that the rainwater tank overflowed into the stormwater network when full, and that rainwater was correctly drawn from the tank to supply internal and external usage. Figure 2 shows the flow hydrographs within the property over a four day WWF simulation, where a small amount of rainfall was applied at the start to randomise the initial water levels in the rainwater tanks and a 20% Annual Exceedance Probability (AEP) 2 hour design rainfall event was applied after 2.5 days.

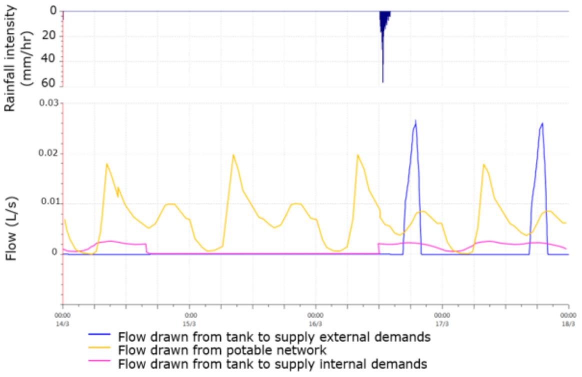

**Figure 2.**

Following the successful completion of the 100 property model, the ability of the modelling platform to replicate the complex at-property water connections and simulate the flows and demands at that scale was confirmed. The next phase of the investigation looked at scaling up the model to 5,000 and then 27,000 properties to test how the method applied in the 100 property model would perform under a significant increase in model extent. To simplify the model, rainwater tanks were only applied to areas of residential land-use and the patterns for potable, internal and external demands were kept constant across the model. A 2D surface model was created using a flexible mesh with typical element sizes of between 10 and 30 m$^2$ over the entire precinct, and a finer mesh of 2 to 5 m$^2$ over road reserves and open drains. Drainage pits were represented by 2D manholes to allow the transfer of flow between the 2D surface and the 1D drainage network in both directions. A series of dry weather and wet weather scenarios were modelled to assess the performance of the three water networks. Dry weather analysis was undertalen to assess the performance of the sewerage system and to evaluate minimum pressures across the potable water network. A 20% AEP design storm was simulated to check the drainage system (surcharge/overflow) and evaluate the effects on the overland flooding with and without rainwater tanks. A 1% AEP design storm was simulated to determine flooding hot spots across the study area. This scenario was also simulated with and without rainwater tanks to evaluate the effectiveness of rainwater tanks for flood mitigation (see Figure 3).

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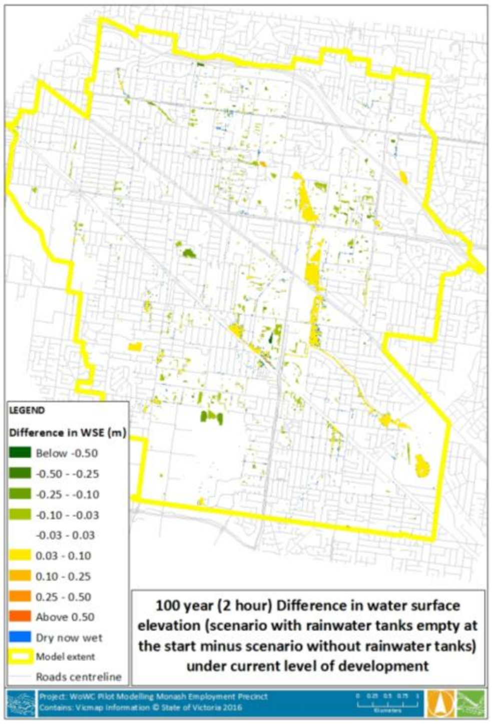

**Figure 3.**

While peak flood level reductions of up to 0.5 m were observed in some parts of the model, some flood level increases were predicted in non-residential areas where no rainwater tanks were applied. This discrepancy was investigated and atttributed to differences in rainfall-runoff methods between the runoff generated by the 2D triangular mesh (scenario without rainwater tanks) and the runoff generated by the roof subcatchments (scenario with rainwater tanks). It was determined that the pilot model requires further refinement to allow for a thorough assessment of the impacts of rainwater tanks on overland flooding.

A number of learnings were gained from this pilot modelling project which are transferrable to the broader application of InfoWorks ICM as an integrated strategic tool that can assist urban planning in Australia. The boundaries of pressurised potable networks, gravity sewer and drainage networks are different; hence the selection of a study area that captures a reasonable boundary description for all three networks may require modelling of a larger extent than the particular area of interest. Replicating the operation of the potable system within a limited study area is problematic when the potable system is part of a much larger network with hydraulic controls well beyond the specific area of interest. Likewise, large external drainage catchments may need to be included to provide reasonable inflows for a particular study area. Alternatively, the impacts of external drainage catchments into the study area can be estimated using design inflow hydrographs sourced from existing hydrological studies or derived from new hydrological models. However, it would be more difficult to determine a long-term timeseries corresponding to an external catchment without additional and detailed hydrologic modelling. The application of Real Time Control (RTC) rules in order to represent the lot-scale water demands and the interactions between the different water systems is a complex process which becomes cumbersome for large models (greater than 5,000 properties).

While this pilot project certainly tested the software to, and sometimes beyond, its current capability, this project has demonstrated that a detailed representation of the lot-based interaction of water supply, sewer and stormwater systems can be successfully developed. As a proof of concept, this project has demonstrated that it is possible to combine the three different piped water systems and link them to a 2D surface runoff model to provide a comprehensive, deterministic model of the total water cycle at a local, precinct or suburban scale.

This is a unique approach that leverages existing modelling tools in a way that has previously not been achieved. It opens the way to define new questions and measures for water management that have up to now only been possible at a conceptual level, or on a lumped or stochastic basis. Some possible future applications of this methodology may include testing the impact of rainwater tanks sizes in non-residential land-use on overland flooding or testing the effects of rainwater tanks on sewer overflows. Assessing the detailed impacts of water sensitive urban design on existing and future infrastructure can only be accurately assessed using a deterministic and fully integrated water, sewer and drainage model. A 1D-2D hydrodynamic InfoWorks ICM model that integrates

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the systems and processes of urban water can be a useful tool to assist in planning of our urban water infrastructure and operations in both established and green-field areas.

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