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Analysing the Applicability of Existing Sewer Sedimentation Modelling for Future Water Systems in Australia

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Summary of key findings

A deficiency in the implementation of proposed urban water strategies in Australia, particularly increased water demand management measures and decentralized wastewater recycling, has been identified in the current inability to predict their impacts on sedimentation in sewers. Increased sedimentation in sewers can lead to a number of issues including the reduction of hydraulic capacity and blockages (Butler and Davies, 2004). This paper aims to analyse the suitability of existing urban drainage models for this purpose. Most models were found to appropriately model hydraulic flow, but found lacking in modelling sediment transport and consolidation. Further, the lack of studies and suitable data on Australian sewer sediment characteristics was also found to significantly reduce the usability of existing models.

Background and relevance

Water Sensitive Urban Design (WSUD) is a concept that has come to the forefront of urban water planning in Australia. This term refers to a unified approach to minimise the impact of urbanisation on the natural water cycle. This approach acknowledges that each stream of water in the urban environment (rainwater, stormwater, drinking water and wastewater) is a resource and should be treated as such. There is also an emphasis on replicating aspects of the natural water cycle within the urban landscape through appropriate architecture and fit-for-purpose use of all the urban water streams (City of Melbourne, 2006). In the last few years, this emphasis on WSUD has led to a number of urban water strategies being published for major cities in Australia. Two of the key efforts in many of these strategies are water demand management and the use of alternative water sources.

Water demand management focuses on the reduction of water consumption through a number of social, technical and financial measures (Marleni et al., 2012). Figure 1.1 below demonstrates the reduction that has already occurred over the past decade in Melbourne. Further, current strategies indicate plans to continue many of the schemes that resulted in this reduction (Office of Living Victoria, 2013). As alternative water sources can refer to a number of technologies, the focus of this paper will be on the impacts of decentralized wastewater recycling. Examples of these systems include domestic or community-scale greywater recycling or sewer mining schemes. The implementation of further water demand management and the use of decentralized wastewater recycling are likely to have a significant impact on the quality of the wastewater that is discharged to sewers. Reducing the quantity of water that is consumed and the reuse of certain low concentration streams has the ability to increase the concentration of the wastewater. Further, the discharge of the concentrate (or “sludge”) from decentralized wastewater treatment systems can further stress existing sewer systems. This can have substantial impacts on existing sewers including increased sediment deposition, blockages, odour and rate of corrosion (Marleni et al., 2012).

Sewers represent a significant investment in our cities which has been incurred over a long period of time (Jiang et al., 2014). There are also significant operating costs involved with sewers, especially when treating blockages and odour. Increased sewer blockages and potential overflows also lead to numerous health and environmental risks. However, there is also a need for resilience and flexibility in our future urban water systems. Decentralised wastewater treatment and reduced water demand will both play an important role in achieving this. There is a need to facilitate these changes in our urban water system to minimise their impact on and optimize the resilience of existing water systems. The main aim of this paper is to analyse the suitability of existing urban drainage models and their underlying methodology for their effectiveness in modelling the potentially increased sedimentation in sewers due to certain sustainable water measures.

Results

Figure 1.2 below shows a summary of the various sedimentation and hydraulic processes that occur in sewers. These processes are modelled with varying degrees of complexity and accuracy in various modelling software. Almost uniformly across the different packages, hydraulic flow in sewers is modelled using the Saint-Venant equations for gradually-varied unsteady flow in open channels (Butler and Davies, 2004). However, the complexity of the equations and the numerical solutions used tend to vary. Due to their wide use and validation the Saint-Venant equations can be considered more than adequate for most sewer modelling purposes. However, sediment transport in sewers is modelled a number of different ways by modelling packages. This is because of the inherent difficulties in modelling it, including the lack of data, complicated sedimentation processes and a large amount of variable parameters to be considered (Bertrand-Krajewski et al., 1993). There is agreement in the literature that sediment is predominantly transported two ways in sewers, suspended in the fluid and moving slightly slower than the fluid velocity and getting dragged, rolled or saltated along the deposited bed at a significantly lower velocity (Crabtree et al., 1994). These processes are seen in Figure 2 in the attached figures document. Most software packages use some numerical approximations of established freshwater hydraulic equations to model the sediment transport capacity of the flow. The type of equations used varies significantly and some are not readily applicable to all sewer sedimentation scenarios as they may have been developed for uniform and non-cohesive sediments (Butler and Davies, 2004).

Another area where the some models are lacking is in modelling sediment consolidation, defined as the compaction and increase in density of sediments over time (Samadi-Boroujeni et al., 2008). Significant research work in developing numerical solutions to cohesive sediment consolidation models has been carried out for rivers, such as Samadi-Boroujeni (2008). Some of this knowledge can be transferred to existing sewer models to improve their consolidation modelling. Another major output from the literature review is that a number of these models are difficult to apply in Australian conditions due to the lack of local data on sewer sediments. Sewer sediment characteristics have been found to vary widely from country to country (Verbanck et al., 1994). Little to no studies have been published on the applicability of these models in an Australian context, particularly as almost all of them have been developed in North America or Europe. This is particularly relevant as Australian sewers tend to not be combined i.e. storm water is not introduced into the sewer system (Butler and Davies, 2004). Lastly, as these models are often aimed at modelling existing drainage systems there is less of a focus on modelling the impacts of decentralized wastewater treatment that are still not a part of mainstream urban water systems.

Discussion

Having identified some of the deficiencies in existing sewer modelling packages, we can detail the steps forward for the development of an appropriate modelling methodology. The key area to address is the development of experiments for the characterisation of sediments in Australian sewers. This will go a long way in identifying the effectiveness of existing modelling packages in the Australian context and the potential for the impacts of decentralized wastewater systems on sedimentation. Further, more effective sediment modelling needs to be incorporated into these packages, particularly in the area of sediment consolidation. This is essential, as potential sedimentation issues with the implementation of decentralized wastewater treatment can only be identified with their effective simulation. These next steps will be developed over the course of this project with the end goal being the development of an effective sedimentation model for sewers in Australia that can be up-scaled network wide.

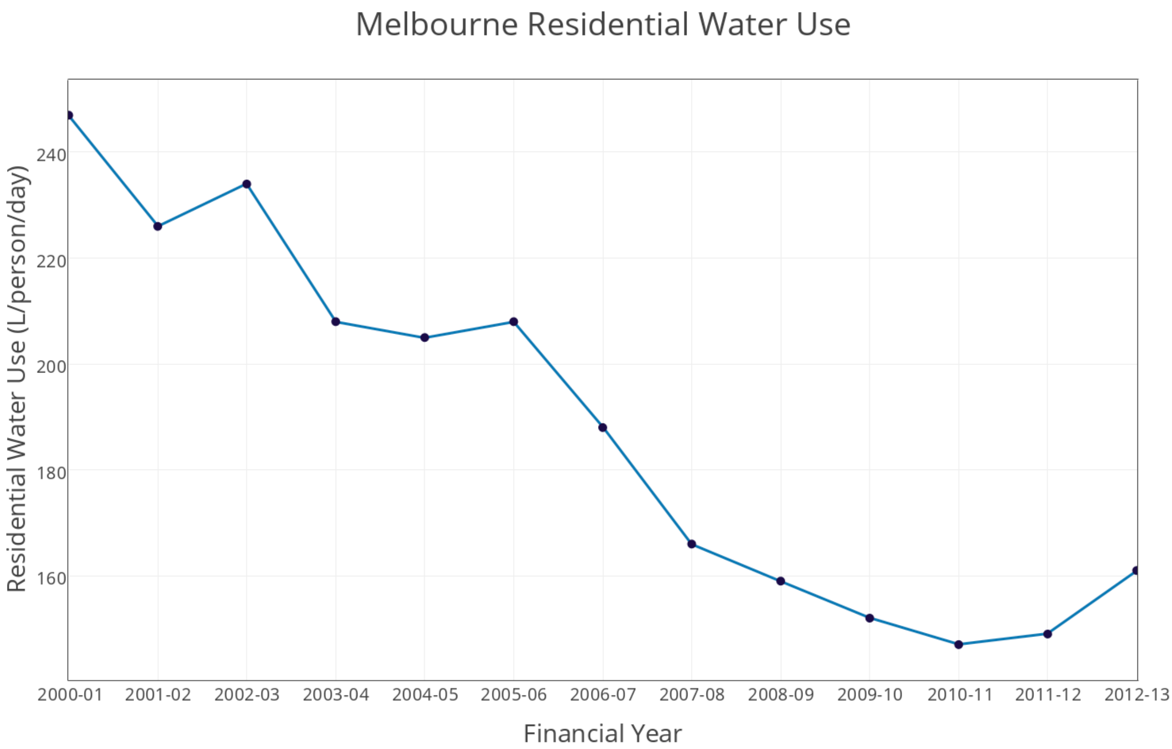

Figure 1.1 Reducing residential water consumption in Melbourne over the last decade (Data sourced from: Melbourne Water, 2013)

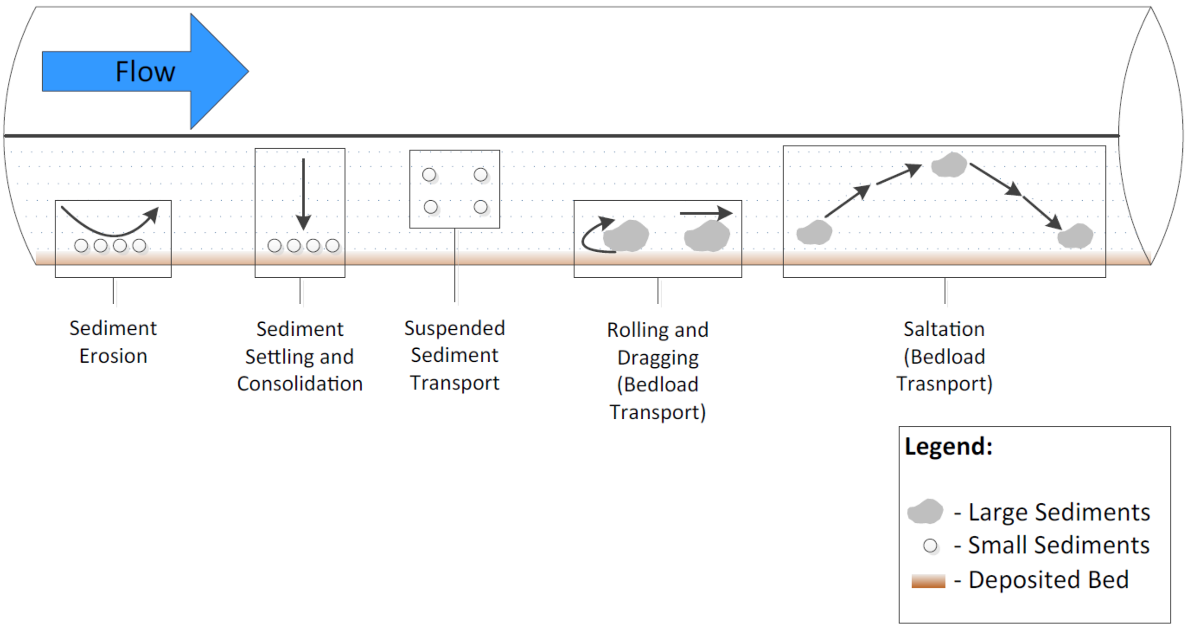

Figure 1.2 Sewer sedimentation processes

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