Optimal Sequencing of Water Supply Options Incorporating Sustainability and Uncertainty

by

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Contents

Abstract

Sequencing of water supply projects involves choosing the options to implement at specific stages over a planning horizon. In the past, the sequencing of water supply projects was relatively straightforward and generally focused on traditional water supply sources (e.g. reservoirs and groundwater sources) and only considered the criteria of water supply security and cost. In recent years, the reliability of traditional water supply sources has been compromised as a result of increasing demand and the impact of climatic factors. This has placed further strain on water supplies and necessitated the use of a longer planning horizon and more criteria for assessment. Furthermore, with the increase in urbanisation and diminishing natural water sources, there is an increase in the need to consider recycled water and desalination as additional or alternative water supply options. Extended planning horizons result in increased uncertainties associated with the future, which requires the development of robust and adaptive solutions to best cope with a variety of potential future conditions. However, there has been little work that has utilised alternative water supply sources in the process of sequencing while incorporating multiple sustainability objectives and uncertainties.

This thesis presents different sequencing approaches that are based on multi-objective optimisation, so that a number of competing objectives (e.g. cost, greenhouse gas emissions) can be taken into account. Furthermore, the optimal mix of water supply options, and when they should be implemented, can be identified from among a large number of alternatives (e.g. rainwater tanks, stormwater harvesting schemes, desalination etc.). In addition, some of the proposed optimisation approaches take the sensitivity, robustness and adaptation of solutions into account, so that the selected water supply options will be as insensitive and flexible to future changes (e.g. climate change, new technologies) as possible. The proposed sequencing approaches are applied to a case study based on the southern Adelaide water supply system in South Australia to demonstrate its utility.

This thesis is structured as a series of three publications. Two approximate optimal sequencing approaches that are able to account for alternative sources of water and multiple sustainability objectives are introduced in the first publication. These approaches are developed to assess the impact of different objective function weightings and sequencing approaches on the optimal sequences of alternative water supply sources for the case study under a range of demand and discount rate scenarios. They are also used to assess the impact of different objective function weightings on objective function values for the case study.

The second publication includes an improved sequencing approach, which utilises a multi-objective evolutionary algorithm, coupled with a water supply system simulation model, to identify the sequences

of alternative water supply sources that represent the optimal trade-offs between the selected objectives for various possible future conditions Subsequently, the impacts of uncertain values of input variables (e.g. population, per capita demand, climate change) on the objectives and water supply security of the system are evaluated using global sensitivity analysis. This provides information on the expected variation in objective function values and water supply security under uncertain future conditions, as well as the sensitivity of these values to the selected uncertain conditions, enabling the most appropriate optimal sequence plan to be selected.

In the third publication, this sequencing approach is further extended to a more enhanced framework which promotes robustness and adaptation. This approach requires continual reassessment and updating of the sequence plans at fixed time intervals in order to identify and reduce the risk of failure.

Statement of Originality

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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