Optioneering development-scale water systems

David Butler*, **Raziyeh Farmani, Hossam Abdelmeguid**

University Exeter

Abstract

This paper presents a decision support tool UWOT? developed to facilitate the selection of water saving strategies and technologies and to support the delivery of integrated, sustainable water management for new developments. The tool models urban water cycle considering five streams of urban water including potable water, greywater, treated greywater, wastewater and stormwater. Technology selection can be manual or by a built in optimisation algorithm to achieve an optimum balance between different flows at household, group of households (tiles) and development levels considering social, environmental and/or economic factors. Sustainability indicators include potable water demand, wastewater quantity and quality, runoff, energy usage and capital and operational costs. The tool has been tested on a case study site in the UK and the results will be presented and discussed. It is suggested that water optioneering tools will increasingly become part of urban planning toolkits to better address sustainability issues.

1. Introduction

A wide range of socio-economic factors are the drivers behind the choice of location for new developments. Improving water efficiency is becoming of increasing importance in water scarce areas where growth in water demand is becoming unsustainable. In England and Wales for example, there are statutory and non-statutory measures in place to address water efficiency in te new housing developments. This requires transition from linear urban water management practice, where water is imported and processed and output as waste by conveying wastewater and stormwater away from urban setting, to more sustainable circular urban water management, with reduced import of water, high rates of recycling and reduced wastewater and stormwater. A minimum standard of 125 l/p/d is set across England and Wales which is equivalent to level 1 of Code for Sustainable Homes (CSH, 2008), a voluntary standard, if an allowance of 4% is assumed for external water use. This level of water efficiency is achievable by incorporating water efficient appliances that are acceptable to the end user. However to achieve higher level water efficiency standards (e.g. levels 3/4 or 5/6 which correspond to 105 and 80 l/p/d respectively) it is necessary to collect and reuse

* *Corresponding Author: d.butler@exeter.ac.uk, r.farmani@exeter.ac.uk*

stormwater and wastewater to avoid waste and optimise reuse and recycling in addition to use of water efficient appliances.

To ensure that a new development is consistent with the principle of sustainable development it is important to incorporate water conservation measures, and to minimise flood risk and impact on water infrastructure. To determine the scope for water minimisation, a series of water conservation and recycling techniques can be adopted throughout development in order to reduce potable water demand, runoff, wastewater. Sustainability involves consideration of many and sometimes conflicting environmental, natural resource, social and economic factors, where better performance in one area may come at a cost in another area. To do this, it is important to understand the relationship between the key indicators and the trade-offs between them.

2. Development-scale water Optioneering Tool

2.1 Principles

The UWOT? tool is a combination of quantitative modelling together with a sustainability assessment that can be used to calculate and evaluate the sustainability performance of alternative water management strategies for new developments. The modelling aspect of the tool links technology data with household/development information and calculates measures of performance for sustainability indicators. It ensures that the supply of alternative resources balances the demand by identifying the optimum source of supply which is fit for purpose. Five streams of urban water including potable water, greywater, treated greywater, wastewater and stormwater are modelled. The evaluation aspect of the tool calculates numerical outputs for appropriate indicators, such as natural resource, economic and environmental aspects of sustainability with some inclusion of social indicators for alternative water management strategies. A number of sustainability indicators (volume of flow from different streams, wastewater quantity and quality, runoff, energy usage and capital and operational costs) that have an impact on flooding and water resources are included within the tool. The scope of tool is to facilitate the strategic planning and preliminary design of sustainable water management systems.

UWOT? was designed to enable the comparison of a wide variety of water management technologies and schemes (recycling, treatment) at different scales. Within the urban water cycle, water quantities are continuously exchanged between spatial scales (e.g household, development) in the form of potable water supply, stormwater and generated wastewater, while within the household, water is used to satisfy various types of demand. In UWOT?, the most detailed level of modelling is the in-house micro-component, followed by the household, group of households and finally the development level. The micro-component analysis is fundamental to the modelling concept of UWOT?, since each appliance is considered a technological option with specific characteristics affecting both the water cycle and the subsequent sustainability assessment. The next modelling scale is the household which can be residential, commercial or public function. The household represents an aggregation of the micro-components it contains, recycling process if a decentralised scheme is installed and in the case of centralised scheme, streams of flow are exchanged between the household and group of households/development scales. The tile (a group of households) represents types of households with similar design characteristics (e.g. pervious and

impervious areas, occupancy, etc.), configuration of appliances and user behaviour within them. The development scale represents a group of tiles, possibly of different types, as well as the associated roads and public open space. It is the spatial scale at which centralised treatment and recycling schemes, as well as centralised SuDs are considered. The UWOT? prototype developed can model 10 different types of tiles each representing 10 groups of different household types.

An hourly time-step was selected as appropriate for the water balance model to take into account diurnal variation in flows. This will help to support the sustainability assessment beyond outline planning, to preliminary design by better sizing the infrastructures required by alternative recycle schemes. This will result in more realistic costs and flow balance.

2.2 Inputs and Outputs

UWOT? aims to facilitate the comparison of different water management technologies and the combinations at different application scales. A user friendly interface facilitates the interaction between the user and the model. To initiate model simulation, the user or optimisation algorithm needs to specify the micro-components involved in different houses and water recycling schemes at different scales as well as number of houses per household type, their corresponding occupancies and previous and impervious and rain harvesting areas at the various scales. Finally, the user is asked to specify the priority by which each type of micro-component demands a particular water quality.

Typical outputs of quantitative evaluation part of tool include masses of potable and non-potable water supply, water demand, energy use, wastewater and runoff generated, cost etc. The key outputs of the assessment are tabulated results, a sustainability spider diagram and bar diagrams. The purpose of the diagrams is to combine in a visual format all of the diverse issues that need to be considered to assess the sustainability of a water management strategy. Also they can show areas for improvement as well as strengths. Behind the visual representation is a detailed worksheet, which holds calculations and evaluations of different indicators based on extensive technology library. The assessment part of the tool facilitates a balanced view of all appropriate sustainability issues, by generating trade offs between alternative indicators, allowing the decision makers to rate or score performance based on their preferences. This is in accordance with the role of decision support tools that are to support rather than replace managerial judgement, while assisting decision makers to explore possible solutions and outcomes beyond obvious ones (Jakeman et al. 2006).

3. Running the Tool

UWOT can be run in two modes: assessment and optimisation. In the assessment mode, the tool aims to identify optimum urban water management strategies for a pre-defined urban development where number of houses per household type, their corresponding occupancies and previous and impervious and rain harvesting areas at the various scales are set by urban planners. This is a top-down approach where the level of sustainability achieved is dependent on the proposed urban form and it's characteristics. The tool can give indication of the impact of the new developments on water resources, flooding and water infrastructure. In particular it considers the potential significant impacts on surface water quality, runoff and water demand. In the optimisation mode, urban water management strategies as well as number of houses per household type, type of households, their previous and impervious

and rain harvesting areas at the various scales are design variables. This is a bottom-up approach where higher level of sustainability is achievable by better balance of resources at development scale.

4. New Features of the Tool

The current version of UWOT? builds on version 1 developed by Makropoulos et al. (2008). The current version is being enhanced in a number of ways. It: 1) accounts for energy consumption especially for hot water and space heating; 2) computes wastewater and urban diffuse pollutants loads 3) introduces hourly time steps which represent required water throughout the day by each micro-technology, as well as alternative daily (week day, week end) and seasonal water demand patterns over annual period, to address diurnal and seasonal variation; 4) includes 10 different types of generic 'tiles' each representing 10 groups of different household types; 5) includes non-domestic demand and 6) include sthe application of grey water recycling and rainwater harvesting schemes at household, tile and development levels, as well as application of decentralised wastewater treatment option at development level.

Impacts of new development on groundwater, surface water and water infrastructure have not been considered explicitly. However, this level of analysis provides sufficient information for the comparison of water management options, especially at planning stage.

5. Case study

The tool has been successfully tested on a case study site in the UK and the results will be presented and discussed at the conference.

Acknowledgement

This work was supported by the UK Engineering and Physical Science Research Council as part of the ReVISIONS and Urban Futures consortia under the Sustainable Urban Environment programme.

Reference

CSH (2008) Code for Sustainable Homes (technical guide), Department for communities and local government.

Jakeman A.J., Letcher R.A. and Norton J.P. (2006) Ten iterative steps in development and evaluation of environmental models. Environmental modelling and software, 21, 602-614.

Makropoulos C.K., Natsis K., Liu S., Mittas K. and Butler D. (2008) Decision support for sustainable option selection in integrated urban water management, Environmental modelling and software, 23, 1448-1460.Jothityangkoon, C., Sivapalan, M. and Viney, N.R., 2000. Tests

of a space-time model of rainfall in southwestern Australia based on nonhomogeneous random cascades. *Water Resour. Res.*, **36**, 267–284.

Lammering, B. and Dwyer, I., 2000. Improvement of water balance in land surface schemes by random cascade disaggregation of rainfall. *Int. J. Climatol*., **20**, 681–695.

Rögnvaldsson, O´ .: Idealgrid package, Article on WWW, http://www.vedur.is/folk/olafurr/idealgrid/, 2002.