URBAN REGENERATION AND OPTIMAL WATER DEMAND MANAGEMENT

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ABSTRACT

Increasing water scarcity has drawn attention to the management of urban water demand, which can be achieved through the re-engineering of the urban water cycle in order to implement water reuse practices. Examples of these new practices include the use of locally treated water for a variety of non-potable uses at household or neighbour scales. However, the successful design and implementation of these new practices is not straightforward. The efficiency of a rainwater harvesting scheme, for example, can be greatly reduced if the local tank is under-dimensioned, whereas the maximum efficiency is achieved with the tank capacity exceeding a threshold, which depends on the statistical profile of both the demand and supply (rainfall). The identification of this threshold requires modelling of the rainwater recycling scheme using long historical timeseries (or synthetically generated with a stochastic model) to capture the statistics of the supply/demand. It should be noted that the tanks per se are relatively cheap, but the space to install them and the preparations required (e.g. excavations in case of underground installation) can have significant costs. Therefore, it is imperative to correctly identify the optimum capacity of a tank. Another costly installation required for a rainwater recycle scheme is the dual reticulation, which, in case of retrofitting, translates into expensive plumbing interventions of which the payback period (if any) is very long. However, dual reticulation can be easily implemented during the construction of a building. Such an opportunity is offered in the region of Eleonas, Athens, Greece. Recently, this area has attracted the attention of many urban planners, who have suggested alternative regeneration scenarios: the Agrarian (the area as a green reservoir for the surrounding city), the Urban-Agrarian (extensive green areas along with residential areas and transportation services) and the Metropolitan (transformation of Eleonas into the new Central Business District for Athens). In this study, these three alternative regeneration scenarios were assessed with UWOT. UWOT is a bottom-up urban water model that simulates the generation, aggregation and routing of demand signals (potable water demand, runoff discharge demand, and wastewater discharge demand). First, UWOT was used to 'scan' the water networks of the three scenarios (assuming conventional water network) to identify the most intense water consumers. Afterwards, a local rainwater harvesting scheme was introduced in the networks of the major water consumers to reduce the water demand on-the-spot. Then, UWOT along with an optimization algorithm were used to properly dimension this rainwater harvesting scheme. The results of the optimization indicated that the runoff volume could be considerably reduced, which will further improve the ecological footprint of the planned regeneration.

Keywords: urban regeneration, urban water, optimization, water recycling

1. Introduction

Eleonas occupies an area of almost 900 hectares just a few kilometres from the centre of Athens. It bears characteristics of a post-industrial site, a brownfield or a wastescape, even of an 'urban void' in the urban framework of the metropolitan area of the Greek capital (Enveco, 2011). Recently, this area has attracted the attention of many urban planners, who have suggested three alternative regeneration scenarios:

- Scenario 1, the area will become a green zone for the surrounding urban fabric.

- Scenario 2, the area will include new households, transportation services and extended green areas.
- Scenario 3, the area will become the new central business district of Athens.

In this study we are using UWOT to simulate the urban water cycle. UWOT is a bottom up (micro-component based) urban water cycle model that simulates the demand starting at the water appliance level. Urban water models often use a hydraulics-based conceptualisation of the urban water network, simulating actual water flows, including runoff, potable water and wastewater. UWOT uses an alternative approach based on the generation, aggregation and transmission of a demand signal, starting from the household water appliances and moving upstream and downstream. The simulation provides timeseries of: i) potable water demand, ii) water level fluctuation inside tanks and reservoirs, iii) leakages, iv) evaporation, v) runoff, vi) energy consumption (including both energy required for water circulation, e.g. pump of rain-water inside tank, and energy consumed by the water appliances, e.g. heat water for showering), vii) capital and operational costs. An analytical description of UWOT is provided by Rozos and Makropoulos (2013) and Rozos et al. (2013).

Initially, UWOT was used to identify the impact of the three scenarios on the urban water cycle. Afterwards, the benefits of implementing a rainwater harvesting (RWH) scheme were assessed for Scenario 2 and 3. UWOT coupled with MATLAB were used to optimize the parameters of these schemes, i.e. the tank capacities. This coupling enabled to take advantage of the tools provided by the sophisticated MATLAB Optimization Toolbox. The results of the optimizations and simulations estimated the environmental impact (regarding water flows) of the three suggested scenarios and the potentials of reducing this impact by employing recycling schemes.

2. Eleonas regeneration scenarios

The vector and the orthophoto maps of the studied area for Scenario 2 are shown in Figure 1. Enveco (2011) mentions that this scenario includes the building of 289 single family households with large gardens, 12 large and 4 small enclosed courtyard housing island (building blocks with green area in the middle), 12 towers with combined residential and commercial properties, 156709 m² of olive groves, and 261337 m² of green areas.

Table 1: Number of raster map cells for each land use type.

	Scenario 1	**Scenario 2**	**Scenario 3**
Enclosed	23	23	29
Households	0	10.5	10.5
Parks	25	0	0
Olive groves	18	45	51
Services	5	15	15
Offices	0	18	60
Towers	0	12	12
Retail	0	7	38

Since vector maps for Scenario 1 and 3 were not available, the information from the corresponding raster maps (resolution 120×120 m²) was used instead (see Table 1). For example, the numbers of small and large enclosed courtyards are 4 and 12 in Scenario 2 whereas in Scenario 3 they are expected to be 5 and 15 (see ratio 29/23 of corresponding cell types in Table 1). Similarly, the green area is 418046 m² in Scenario 2 whereas it is expected to be 473785 m² in Scenario 3 (ratio 51/45 in Table 1). Scenario 1 differs from Scenario 2 in that it lacks some land use types.

Figure 1: Eleonas regeneration plan according to Scenario 2.

3. Modelling and optimization

The water consumers of the studied area can be classified into two categories, those spatially distributed (e.g. green areas, retail areas, etc) and those with a single connection to the urban water network (e.g. Administration Building). For the spatially distributed consumers, the simulation is performed for a representative unit and the results are multiplied with the total number of representative units on the studied area (total number differs depending on the simulated scenario).

The simulation is performed on the lowest possible level (water appliance level) wherever this is feasible (see Table 2). In these cases, it is investigated the use of harvested rainwater to cover a part of the demand taking advantage of the optimization routines of MATLAB Optimization Toolbox. In the cases where a low level simulation is not feasible, simulation is accomplished using empirical formulas (for example coefficient of consumption per unit area).

The simulation length is one year with daily time step. The rainfall and temperature timeseries were obtained from the freemeteo.com online database for the weather station of Hellinikon, Athens, Greece and concern the year 2010.

Table 2: Modelling methodology of each consumer in the studied area.

	Low level Modelling	Empirical Modelling	Concentrated consumer	Representative unit
Households	✓			building
Tower Offices	✓			building
Offices	✓			1 raster cell
Stadium	✓		✓	
Green	✓			1 m²
Administration Building		✓	✓	
Bus Station		✓	✓	
Transportation Centre		✓	✓	
Water Centre		✓	✓	
Mall		✓	✓	
Stores		✓		1 raster cell

4. Results

In total, five simulations/optimizations were performed. One simulation was performed for Scenario 1. One simulation was performed for each one of Scenario 2 and 3 followed by one optimization for each one of them to investigate the implementation of RWH. The results of the simulations/optimizations are summarized in the following table.

Table 3: Results of simulation of Scenario 1,2 and 3 with UWOT.

	Demand (m^3/d)	Max runoff (mm/d)	Runoff Coefficient
Scenario 1	772.4	15.98	0.22
Scenario 2	4352.8	38.57	0.54
Scenario 2 RWH	4151.1	23.76	0.33
Scenario 3	10485.0	44.21	0.62
Scenario 3 RWH	9947.0	27.39	0.39

5. Conclusions

Three alternative regeneration scenarios of Eleonas, Athens, Greece were modelled using UWOT. Regarding Scenarios 2 and 3, rainwater harvesting schemes were investigated. The parameters of these schemes were optimized using optimization algorithms from MATLAB Optimization Toolbox.

According to the simulation results, the largest consumer is the public buildings with a significant day-to-day variation because in some of them (e.g. the Administration Building) there is no consumption during bank holidays. The other consumers exhibit a remarkable seasonal variation in consumption due to increased irrigation needs during the dry season.

A comparison among the three scenarios makes clear that both demand and runoff volume increase following the urban density (Scenario 1 the lowest, Scenario 3 the highest). The runoff per unit area of Scenarios 2 and 3 are almost triple of that of Scenario 1. However, after incorporating the rainwater harvesting schemes, the runoff volume is reduced by almost 40%. Regarding the water demand, the rainwater collection scheme does not offer a significant reduction, achieving only about 5% in both Scenarios 2 and 3.

Finally, it should be noted that the solution of a locally grey water recycling scheme is not suitable for this case since there is no sufficient production of grey water (outflow from the toilets and kitchens cannot be treated in local units) in public buildings, the main consumer of the studied area.

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