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Hydraulic modeling of a water distribution network in a tourism area with highly varying characteristics

Selami Kara[a], I. Ethem Karadirek[a,*], Ayse Muhammetoglu[a], Habib Muhammetoglu[a]

[a]*Akdeniz University, Engineering Faculty, Environmental Engineering Department, Antalya, 07058, Turkey*

Abstract

Hydraulic models are efficient decision support tools for effective management of water distribution networks (WDNs). This study presents an EPANET hydraulic model application at Old Town DMA (District Metered Area), a well-known tourism area in Antalya City, Turkey. Old Town DMA has highly variable WDN characteristics and it contains about 1400 active and inactive water subscribers, mostly related to tourism facilities. Daily and hourly water consumption profiles and water consumption rates by different subscribers in the DMA exhibit wide variations. The temporal and spatial variations of water consumptions and highly varying topographic levels of the DMA are taken into account to allocate nodal water demand in hydraulic modeling. Water pressure and flow rates are continuously monitored online at the SCADA station located at the entrance of the DMA. Additionally, continuous water pressure measurements are performed via portable pressure loggers at 4 different points located at different elevations of the DMA. The monthly water consumption of each water subscriber is recorded. Moreover, the daily and hourly water consumption rates of 13 different water subscribers were monitored for 5 days. The obtained data sets were used to prepare water consumption patterns for different water subscribers and to estimate nodal demands. The hydraulic model was calibrated for Hazen - Williams pipe roughness coefficient and the predicted pressure values were in good agreement with field measurements.

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Keywords: EPANET; hydraulic modeling; nodal demand allocation; roughness coefficient calibration.

* Corresponding author. Tel.: +90-242-310- 6379; fax: +90-242-310-6306.
E-mail address: ethemkaradirek@akdeniz.edu.tr

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1. Introduction

Hydraulic models of water distribution networks (WDNs) are efficient decision support tools for development of various management scenarios to improve efficiency and reliability of existing networks and to design new ones. In hydraulic models, well-known hydraulic equations are solved to calculate main hydraulic parameters; such as flow rate, velocity and water pressure, at many points for the described WDN and the obtained results are displayed in tabular and graphical forms to be evaluated by the users [1-4]. The success of hydraulic model predictions depends on accurate determination/estimation of input parameters and model calibration and verification studies. Currently, many WDNs are equipped and controlled with SCADA (Supervisory Control and Data Acquisition) systems to improve network efficiencies. Moreover, SCADA systems could be integrated with well calibrated and verified hydraulic models to provide useful input data sets for model set-up and comparison with model predictions. In routine monitoring and control studies of WDNs, only limited number of monitoring and control points are selected on the WDN to collect hydraulic data. However, an accurate calibration and verification study of hydraulic models requires simultaneous and precise estimation of many hydraulic parameters such as flow rate, water pressure, etc. for the whole WDN. In the literature, many successful hydraulic modeling applications are presented for different operational purposes such as extension of the WDN by adding new pipes, dividing WDNs into several DMAs, determination of critical areas for rehabilitation, determination of optimum network pressures and evaluation of different water losses reduction techniques to predict water saving amounts [5,6].

Network hydraulic characteristics usually demonstrate wide temporal and spatial variations. The main reason of these variations is that different water users are spatially distributed along the WDN and these users have different water consumption rates and profiles. Both physical configuration of the WDN and the spatial and temporal variations of water consumption rates need to be transferred correctly to hydraulic models to obtain accurate predictions from the modeling study. Physical configuration of WDNs such as coordinate, length, diameter and material of pipes, junctions, connections, elevations, etc. can be obtained from updated GIS (Geographical Information Systems) database systems in advanced WDNs. However, it is usually difficult to have information about temporal and spatial variations of water consumption rates and other hydraulic parameters. In general, there are two main challenges to be addressed in hydraulic modeling applications. The first one is that the exact location of service pipe connections is not known for all properties on WDNs. The second challenge is due to lack of data for water consumption rates of all water users/subscribers. The frequency of water meter readings is not enough to prepare accurate water demand profiles for hydraulic simulation of WDNs with short time steps. Moreover, water losses need to be taken into account in hydraulic modeling applications as it could be one of the biggest water users in poorly managed WDNs where water losses are reported as high as 50% or even more of system input volume [7, 8, 9]. Usually, the exact amount and spatial/temporal variations of water losses are not known and it is difficult to decide about the location and amount of water losses as an input to hydraulic models. Real water losses, a component of total water losses, may be distributed equally or in proportion to all nodes in WDN to overcome this uncertainty [7, 8, 10]. Contrarily, spatial and temporal allocation of water losses may not be an important issue for well-managed WDNs where total water losses are less than 15% of system input volume [7, 10]. The prescribed challenges could be defined as the main cause of potential model errors in hydraulic modeling applications but still different engineering approaches are used to overcome these difficulties. In addition to these problems, the users of hydraulic models face with another difficulty which is the lack of reliable data sets and usually the required data sets need to be supplied by the water utilities [11, 12].

Periodic reading of water subscribers' water meters are performed by water utilities for the purpose of billing in long time intervals such as monthly, bimonthly, quarterly, 6 monthly or yearly. In some countries, water meters of the subscribers are not read periodically due to application of fixed charge rules [13]. However, hydraulic models are used to predict hydraulic parameters for short time intervals, such as 5 minutes. Water demand profiles, which are required as input data for hydraulic models, cannot be obtained for short time intervals from the water meter readings. Instead, monitoring data obtained from flow meters located at several locations of the WDN (such as main pipes or entrance to DMAs), are used to define water demand patterns. The obtained data are sometimes extended for all service pipe connections of the network because several subscribers with different water consumption profiles are connected to one service pipe connection in real network.

Water demand is the key modeling input parameter and driving force behind the hydraulic behavior of water distribution systems [14-17]. Therefore, water demand allocation in water distribution systems becomes crucial for