Hydraulic Network Model of Water Distribution System in Al Hakeem Quarter, Maqil District, Basrah, South of Iraq

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Abstract– A hydraulic network model has been constructed by using EPANET program to simulate the water distribution system network of Al-Hakeem Quarter at Maqil district in the Governorate of Basrah. The model is calibrated according to the observed head in 5 junctions. Head at selected junctions is measured by Bourdon gauge. The best results of the model are selected according to a trial and error procedure based on three common statistic coefficients (root mean squared error, standard error, and coefficient of correlation). This model can be used if any changes, such as the addition of elevated tank to the region, addition of another pumping station, or an expansion of the network take place in the future.

Index Terms–: Hydraulic, EPANET, Model, Distribution System, Basrah

1 Introduction

A HYDRAULIC network model is a program that imitates a real water distribution network on a computer. With the help of such a hydraulic network model, the hydraulic behaviour of the real network may be studied under normal and exceptional operating conditions. Everyday hydraulic situations could also be investigated by just performing some flow rate and pressure measurements on the real distribution network; but this is not practicable for exceptional operating conditions of the current network and really impossible for any operating conditions of a proposed future (extended) network.

A hydraulic simulation program is essentially a tool, which can in the hands of a skilled operator perform the job of hydraulic analysis of drinking water distribution networks.

Water distribution system models have become widely accepted within the water utility industry, as a mechanism for similarity the hydraulic and water quality behavior in water distribution system networks. The most important consideration in the planning and operation of a water distribution system is to satisfy the consumer's demand. Thus, it is important to provide all users with good quality water and an adequate amount at reasonable pressure at all times to ensure a reliable water distribution system.

Several methods are proposed for simulating networks models. Hardy Cross first proposed the use of mathematical methods for calculating flows in complex networks [1]. This manual, iterative procedure was used throughout the water industry for almost 40 years. With the advent of computers and computers based modeling, improved solution methods were developed for utilizing the Hard Cross methodology. Also, in the early 1980's, the concept of modeling water quality in distribution system networks based on steady-state formulations was developed [2]. By the mid-1980's, water quality models incorporating the dynamic behavior of water networks were developed [3]. The usability of these models was greatly improved in 1990's with the introduction of the public domain EPANET model and other windows based commercial distribution system models [4].

This study aims at constructing a mathematical model by using the EPANET program to simulate the water distribution system network at Al Hakeem Quarter, Maqil district in the Governorate of Basrah. The study area is about 3.5 km^2 as shown in Fig. (1). It also aims at implementing this model in the future in case any change at the network such as the addition of elevated tank to the region or the provision an extra pump or any other extension of the network may take place.

Fig. 1. Map of the study area.

2 EPANET Program

EPANET is a third generation software package for modeling water quality within drinking water distribution systems. The program performs extended period simulation of hydraulic and water quality conditions within pressurized pipe

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networks. In addition to substance concentration, water age and source tracing can also be simulated.

The EPANET program developed by the U.S. Environmental Protection Agency. EPANET includes a graphical user interface that is run by Microsoft Windows and allows simulated results to be visualized on a map of the network [5].

The EPANET package actually consists of two programs. One performs the actual hydraulic and water quality simulations with the use of data files for input and output reports. The second program (EPANET4W) provides a graphical user interface for interactively running the simulator and viewing its results via networks maps, data tables, and time series graphs.

3 Methodology

The EPANET program has been used to simulate the water distribution system networks of Al Hakeem Quarter, Maqil district. The network was drawn earlier by adopting the drawing of the water network which was taken from the Directorate of Basrah Water. The network was set as shown in Fig. (2), this network consists of (168) pipes and (148) junctions. The junction data are entered into the program; these include demand, elevation, and pattern demand. Depending on the number of family members in the area under investigation, the values of demand parameter ranged from (0.5) to (3.0) m^3/day. The topographic maps of the Maqil district have been found to be useful to know junction elevation. As far as the pipe data, they were arrived at by means of the map of the network provided by the Directorate of Basrah Water. This map has been found to be helpful to arrive at the lengths, diameters, and types of the pipes under investigations. The type of all pipes of network of study area is PVC. Hazen-Williams formula is used to simulate water distribution system in the study area. According to the type of pipes, Hazen-Williams coefficient is taken to be (150) [6]. This value is considered to be an initial value which is submitted to the calibration process. The data concerning the pumping station are obtained from Al-Jubaila Pumping Station, as shown in table (1).

The number of Maqil's population provided by Municipality Council in Maqil is great useful for the researchers to estimate the daily consumption for each household keeping in mind that the amount of water consumption changes along the hours of a day. Table (2) shown the initial suggestion of pattern demand of four time steps for pumping period of all junctions in the network.

The pressure in pipes of the network under investigation is measured by using Bourdon gauge. Five junctions are selected to measure the head of water at four intervals during the period of measurement (21/5/2008-22/5/2008). Inside the Bourdon gauge is a curved tube of oval section which tries to straighten out when the system is under pressure. The tube is linked to a pointer which moves across a graded scale and records the pressure. It is simple to change from the measured pressure in the Bourdon gauge to head of water by applying the following equation.

$$Head\ of\ water\ (m) = 0.1 \times pressure\ (kN\ /\ m^2) \quad (1)$$

TABLE 1
Pumping Data in Al Jubaila pumping station

Discharge (M^3/HR)	Head (M)	Pumping Period (HR)/DAY
800	50	24

TABLE 2
Pattern demand coefficient of all junctions in network

Time	(0:00-5:59) AM	(6:00-11:59) AM	(12:00-17:59) PM	(18:00-23:59) PM
Pattern Demand	0.5	1.0	1.2	0.6

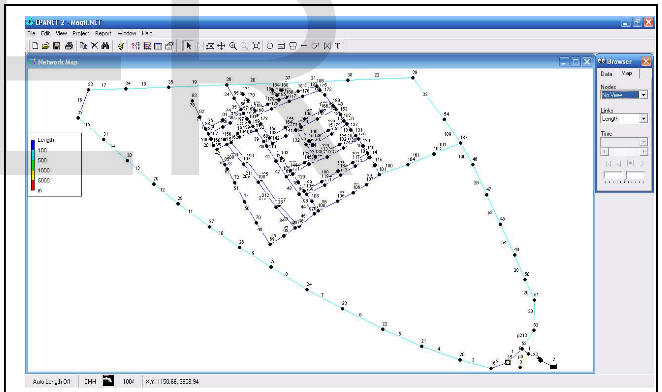

Fig. 2. Water distribution network in the study area

4 Calibration of Model

Water distribution system models can be used in a wide variety of applications to support design, planning, and analysis tasks. Since these tasks may result in engineering decisions involving significant investments, it is important that the model used be an acceptable representation of the "real world" and that the modeler have confidence in the model predictions. In order to determine whether a model represents the real world, it is customary to measure various system values (e.g., pressure, storage tank water levels, and chlorine residuals) during field studies and then compare the field results to model predictions.

Calibration is usually considered as one of the integral aspects of modeling water distribution systems. It is the

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process of adjusting the model input data. As a result of this process, one may find out that the simulated hydraulic and water quality output sufficiently mirror observed field data [7]. Calibration is both costly and time consuming and it is even difficult to arrive at when a high degree of accuracy is desired. The extent and difficulty of calibration are minimized by developing an accurate set of basic inputs that provide representation of the real network and its components.

Parameters are typically set and adjusted so as to include pipe roughness, minor losses, demands at junctions, the position of isolation values whether closed or open, control value settings, pump curves, and patterns demand. Care should be taken to keep the values for the parameters within reasonable bounds when initially establishing and adjusting these parameters.

The process of trial and error has been adopted to alter the parameters including Hazen-Williams coefficient, has been changed from the value of (150) into the value of (135) because the age of this network is about 10 years; therefore, the coefficient of Hazen-Williams may decrease with time. As far as the demand parameter is concerned, a number of junctions have been changed depending on the number of the family members in the area under investigation. The pattern demand has also been changed as shown in table (3). After carrying out the changes, a great similarity between the calculated values and their counter part measured values.

TABLE 3

CALIBRATED PATTERN DEMAND COEFFICIENT OF ALL JUNCTIONS IN NETWORK

TIME	(0:00-5:59) AM	(6:00-11:59) AM	(12:00-17:59) PM	(18:00-23:59) PM
PATTERN DEMAND	0.54	1.20	1.25	0.72

5 RESULTS AND DISCUSSION

EPANET program has been used to construct a mathematical model for the water distribution network system which is lying at Maqil in the Governorate of Basrah. This network has been set, drawn, and analyzed by using this program. The data for each pipe have been entered to the software.

The data for the junctions and pump station have also entered into the program. After the hydraulic model was calibrated, a good degree of similarity between the calculated value and the observed value has been arrived as shown in figures (3-7).

The results tested were based on the following three common statistic coefficients:-

1. Root mean squared error (RMSE),
2. Standard error (SE)
3. Coefficient of correlation (R).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{i=n}\left(H_m - H_s\right)^2} \qquad (2)$$

$$SE = \frac{RMSE}{\bar{H}_m} \qquad (3)$$

$$R = \frac{\sum_{i=1}^{i=n}\left(H_m - \bar{H}_m\right)\left(H_s - \bar{H}_s\right)}{\sqrt{\sum_{i=1}^{i=n}\left(H_m - \bar{H}_m\right)^2 \sum_{i=1}^{i=n}\left(H_s - \bar{H}_s\right)^2}} \qquad (4)$$

Where:

H_m : Measured value

H_s : Simulated value

$\bar{H}_m$: Average of measured values

$\bar{H}_s$: Average of simulated values

n : Number of observations

Table (4) shows the degree of matching between the calculated data and field data. Hence, this model can be used regardless of all possible changes that take place in the network such as the expansion of the network, the addition of a further pump, or the construction of a network tank.

TABLE 4

ERROR STATISTICS BETWEEN OBSERVED AND CALCULATED HEAD

NO. OF JUNCTION	RMSE	SE	R^2
100	0.042	0.020	0.977
110	0.058	0.026	0.886
189	0.016	0.006	0.9827
70	0.054	0.030	0.951
36	0.075	0.024	0.925

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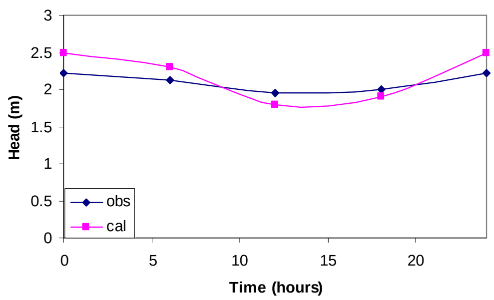

Fig. 3. Comparison between observed and calculated head in junction (100)

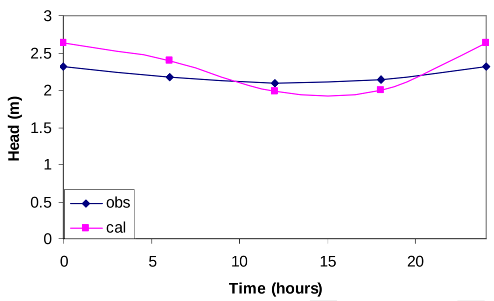

Fig. 4. Comparison between observed and calculated head in junction (110)

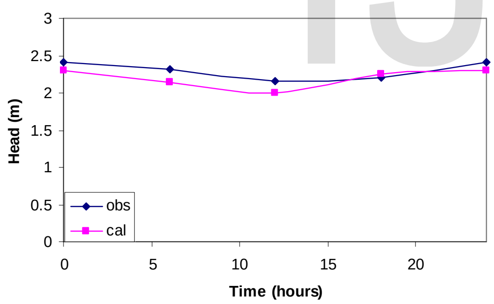

Fig. 5. Comparison between observed and calculated head in junction (189)

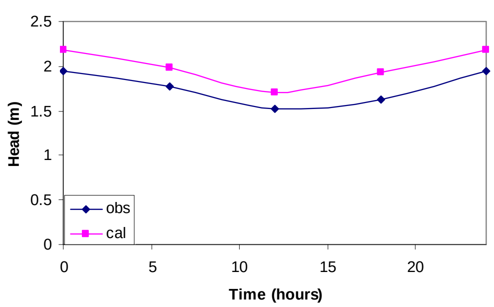

Fig. 6. Comparison between observed and calculated head in junction (70)

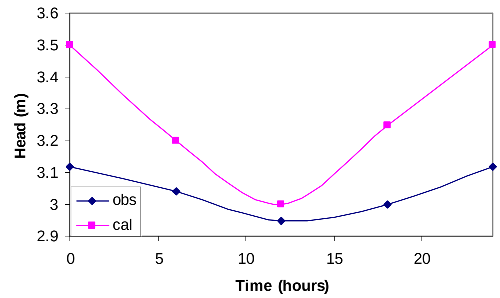

Fig. 7. Comparison between observed and calculated head in junction (36)

5 Conclusions

Due to their advantages, mathematical modeling and computer simulation may become more common tools used in the management of the water distribution system. To achieve such a goal, a hydraulic mathematical model has been set by using EPANET program developed by (United States Environmental Protection Agency) to simulate the water distribution system network in Al Hakeem Quarter, Maqil district. The results have shown that The Hazen-Williams Coefficient, demand and pattern demand have proved to have a great effect on the output results. After carrying out the changes of these parameters in calibration process, a great similarity between the calculated values and their counter part measured values.

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