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Investigating the Behavior and Pattern of Optimal Water Consumption in Continuous Water Distribution Networks

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Abstract: - Due to the complexity of water distribution systems and the large scale of decision-making in their analysis, design, operation and maintenance, the need to use optimization methods in upgrading and calibrating the model has become more important than in the past. The most important issue in the simulation modeling of these systems is the consistency between the calculated and measured data. The review of records showed that in the absence of the results of unaccounted water studies in the network, the use of recommended and empirical statistical methods is still needed as one of the main elements in model calibration. The current research was carried out with the aim of improving calibration methods, investigating the effects of different patterns of unaccounted water based on the calculated water consumption pattern and determining the optimal pattern of unaccounted water within the scope of the water distribution network covered by the number of 6 ground reservoirs. Due to the fact that the exact determination of unaccounted water was not available, and on the other hand, the model calibration was affected by the amount and behavior of unaccounted water, so the difference in water production and all measured uses was considered as unaccounted water and its different behaviors in the network, it was investigated according to the behavior (pattern) of water consumption. 3 different hypotheses were evaluated based on the behavior of the network (reservoir output flow rate in the hydraulic model) with the actual behavior of the reservoir output (according to the data and statistics of the tank output meter).

The comparison of three statistical and graphic parameters of pressure distribution showed that the use of the inverse model option of the customers' consumption was not considered as a water model, for calibrating the hydraulic model of the distribution network, more acceptable limits for the closeness of the predicted values to the recorded values of the hourly output reservoirs provided. The confirmation of the hypothesis of the model according to consumption as the pattern of unaccounted water for the studied network indicated that the amount of unaccounted water (unlicensed and unregistered consumers) changed along with the amount of consumption. The present research-applied method in obtaining the results can be a very effective help in designing and optimizing distribution networks for urban water and sewage management organizations (especially in big cities).

Keywords: water distribution system, unaccounted water, hydraulic model, pressure distribution.

I. INTRODUCTION

In terms of demographic dimensions, Iran has 9 official megacities (more than 1,000,000 people with the approval of the Supreme Council of Urban Planning and Architecture). From an international point of view, Tehran is one of the big cities of the world with a population of more than 8 million people. Tehran is the largest cultural, economic and industrial center of the country. The city of Tehran, with a population of 8,693,706 people, is almost equivalent to 10% of the entire country [1], this type of development can be compared to a magnetic growth that the migration of people from rural areas to the outskirts of the city in search of work and public benefits. There has been a steady economy. Many immigrants settle illegally on the fringes of cities with the hope that the government will eventually provide public services. Providing water and sewerage services for the growing population in big cities, especially in Tehran, is facing big challenges. Such as the problem of climate change and the drought crisis that has drawn attention to the water supply situation in Tehran in a 10-year period. The continuation of urban growth along with the inadequate financing system of the government's ability to provide potable water in the network of covered areas, service and maintenance of potable water distribution networks, and the implementation of wastewater collection and treatment plans, limits the possibilities for expanding water supply [2]. Almost 50% of Tehran's water supply comes from surface sources and reservoirs of dams and the rest from underground water table [3].

Therefore, with the growth of the urban population and the development of cities, water distribution systems have become very important. Considering the complexity of these systems and the large scale of decision-making in the analysis, design, operation and maintenance of seta, the need for computer modeling of setsa has become more important. In general, water distribution networks are a very complex combination of thousands of pipes, nodes and connections, however, the number of measurements performed is reduced to only a percentage of the entire network, and this makes the model calibration even in some cases not It may come close. The most important issue in the simulation modeling of sets is the consistency between the calculated and measured data [4].

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Network optimization [5] and fault and location detection [6] are two actions that can be taken to reduce water and energy losses. Many of these techniques require a good calibration model to produce reliable results. Model calibration is the adjustment of network parameters to reduce the error in predicting the results [7].

In modeling, all the data that show network graphs and seta performance are introduced to the model. The most uncertainty of the data is related to the pressure in the system and water consumption. These data are confirmed in the final stage of calibration, which is called micro calibration [8, 9]. Pipe roughness as an important parameter in calibrating network hydraulic conditions depends on pipe diameter, material, age and water quality, which can be defined by mathematical function. Next to the roughness coefficient, water consumption is an important factor that determines the execution method for building the network model [10]. Water consumption is related to water consumption patterns and consumption points [11]. The amount of unaccounted water in a distribution system can be determined by performing water balance studies in the system or in a measurement enclosed area (DMA). In addition, the estimation of unaccounted water using statistical techniques has been reported by various researchers [12-14].

II. RESEARCH BACKGROUND

Walski (1983) [15] was among the first researchers who proposed to simulate a water distribution system by collecting pressure and flow data for model calibration. He also suggested that pressure be monitored and measured near high consumption points, away from water sources. In 1994, Yu and Powell [16] presented the problem of installing a meter (flow meter) in a water distribution system with the aim of maximizing accuracy and minimizing cost as an equation in a dynamic analytical model using the covariance matrix of variables and presented decision tree techniques.

After Ishan, Freiri et al. [17] in 1994 proposed a method for selecting measurement points by evaluating relative sensitivities, taking into account calibration based on the roughness coefficients of nodes. In their proposed method, instead of the optimization equation for system calibration, they ranked the nodes according to their relative sensitivity in general.

Bush and Uber [18] in 1998 presented a relatively simple, newer and more efficient tree-based method for designing a distribution network sample, based on maximum total, total weight, and maximum minimum method. The mentioned method is based on the analysis of the Jacobian matrix (the Jacobian was derived from the so-called optimality criteria D- optimal, but it does not directly solve the problem of D-optimal sample design. Later, a two-level optimization method to evaluate several calibration parameters was introduced by a researcher named Shader in 2000. In the external optimization loop, a simulation based on the annealing solution method was used to solve the maximization problem related to unknown values. In the inner loop, the calibration problem of standard minimization was solved by moving slope in pseudo-Newtonian method [19]. Shader analyzed the sensitivity of calibration in a steady-state multiple loading model. The desired hydraulic model according to the level of difference between prediction and reality, calibration parameters (discrete versus continuous); calibration parameters of the type (pipe roughness coefficient, node yield and pipe diameter), loading frequency, calibration parameters grouping criteria and type of objective function (mean square error RMSE and based on torque) were calibrated.

Shortly after that, Lansley and colleagues in 2001 [20] presented a method for sensitivity-based sample design. The mentioned method used the simulation of the second moment in the first priority (layer) to determine the uncertainty in the calibration, measurement and prediction of the water distribution system model.

In 2007, Colombo and Geistolis presented a meta-model approach to optimize water distribution system calibration, in which evolutionary polynomial interpolation (EPR) was used to solve the calibration problem [21].

A few years later, Jacobsen and Kamojala (2009) developed a data integration method, processes and tools in the study area for calibration in large pipes in the hydraulic model of the water distribution system in order to obtain broader results from different data sources, including supervisory control and information acquisition (SCADA), geographic information system (GIS) and a leading enterprise database [22]. Another researcher named Wu (2009) developed a leak detection solution as an integral part of the integrated model parameter identification framework by minimizing the objective function, i.e. the difference between the observed parameter and the flow simulated by the model [23]. In 2011, Ostfeld et al. modeled a series of data using the method proposed by Savich and his colleagues [24].

III. RESEARCH METHOD

The data required for modeling the drinking water distribution network is highly dependent on the target area for study. On the other hand, the time limit of conducting research in the specialized doctorate course leads the researcher to choose a range that fits the mentioned time limit. According to the proposed topic, based on the recommendations of experts and consultants specializing in this topic, due to the availability of basic information, includes maps of the water distribution network and related reservoirs, information about the location, type of consumption, and the amount of periodic consumption by subscribers. A part of the water distribution network in Tehran, including 7 reservoirs and the network covered by them, was selected for the research. In the next sections, the information required for the research will be mentioned in detail.

The possibility of defining a separate range with adjustable connections (on and off valves), having relatively complete information from a 5-year statistical period, including the measurement of the flow rate entering the network feeding tanks, the output flow rate from the tanks, the database of subscribers and consumption, including the location type of consumption (residential, commercial, industrial), amount of periodic consumption in the 5-year statistical period, location map of water distribution network, type, material, length and age of pipes, type and specifications of connections and their usage status (active in the circuit / inactive), topography of the area covered by reservoirs, records of past studies regarding the network and reservoirs and the population data bank (censuses), the availability of information on possible pumping stations in the network, data on water supply, distribution and consumption respectively in reservoirs , the main pipes (reservoir outlet pipes) and the subscriber's meter are obtained from the water and sewerage company of the studied area in the form of a periodic database (at least for the last 5 years). It is in the form of Excel files in XLS format. In some cases, it is the affairs of subscribers and for reporting and issuing water bills of subscribers; it uses a database under SQL Server, the output of which can be converted to other spreadsheets such as Excel.

If unaccounted water studies have been conducted in the studied area and their results are available, they will be used as control parameters in determining the accuracy of the proposed method to determine the effect of the unaccounted water pattern on the model calibration. The existence of the results of water studies not considered in the scope of the study is not necessary for conducting the present research, at the same time; the availability of its results can play an effective role in improving the accuracy of the results of this research.

EndNote software will be used in reviewing the records of studies and research related to the proposed field and summarizing and inserting research information such as title, researchers, date, etc. Excel or SPSS software will be used to verify information in statistical sections, including consumption, flow and pressure measurements based on the usual methods of statistical data control. In the evaluation and analysis section of the model outputs, the factors to determine the difference, error and similarity in statistics, including R2, MAE, RMSE, which are calculated in the environment of Excel or SPSS software, will be used. Also, as a supplementary evaluation of the output of the Water GEMs model, the existing situation and the performed modeling of pressure distribution maps will also be used.

A product of Thomson Reuters is software for storing and organizing resources used in the research process. This program provides the ability to search for articles in databases and save the information they need.

IV. RESULTS

According to the required characteristics, a part of the reservoirs and water distribution network in one of the big cities of Iran was selected, which were located in a height code in terms of the location of the reservoirs (hydraulic equivalent level) for the reservoirs, and the basic GIS maps, statistics and the periodic information of water supply in reservoirs and output (water distribution in the network) from reservoirs, consumption statistics of subscribers based on annual periodic bills, along with the latest population census statistics (year 2015) were tracked and collected. In the following sections, all the mentioned characteristics have been examined, including an overview of the results of the investigation and processing of the relevant statistics.

Based on the purpose of the project and the available information, information was obtained from the GIS unit of the operating company. Information and location maps of network components including pipelines, diameter, material, length and network connections including valves, pressure breakers, flow meters and pressure gauges were used in the mentioned maps. The geographic base map of network components was sent to Water GEMs software.

The water distribution network under the study is covered by 6 ground tanks. The total capacity of the reservoirs is 325,000 cubic meters and the total amount of output from the reservoirs is cubic meters per year. According to the customer bank information, the water and sewage company covers the number of 155,776 subscribers with a population of 1,308,923 people. The total length of the network pipes covered by these reservoirs is 119,191 km. Table 1 shows the capacity, area, number of subscribers and population covered by each of the reservoirs within the scope of this research.

Table 1- The main characteristics of the area under study.

ID code of the reservoir	Tank capacity (thousand cubic meters)	Area (Km2)	Population in 1995 (people)	Length of covered network (Km)	Number of subscribers	Total consumption (million cubic meters per year)
A	27	517	185,985	110.55	7,373	16.402
B	34	1365	98,487	107.70	10,300	8.662
C	58	1652	203,031	223.78	30,337	20.690
D	76	1042	58,151	110.76	9,014	10.781
E	74	580	358,187	353.34	48,041	32.422
F	56	1262	405,082	319.90	50,711	30.233
Total	325	6418	1,308,923	1,226.03	155,776	119.191

Estimation of unaccounted water in water distribution networks:

In the area covered by each reservoir, the difference between the output flow from the reservoir and the consumption of the subscribers during a statistical period is not taken into account. Unaccounted water is divided into two parts: apparent loss and actual loss. The real loss is the water that leaves the system through leakage from the pump houses, tanks and their overflow, the transmission line between the tanks and the distribution network. The daily average of unaccounted water during a year for each person of the city or village population is called average unaccounted water per capita. For each node, in addition to the consumption that is considered from the consumers, consumption is considered as unaccounted water. To achieve this goal, the unaccounted water during one year for the area covered by each storage tank is converted into the volume of water per second per meter of pipe length. Table 2 shows the unaccounted water per unit length of each pipe in the area covered by the six tanks. For example, if the length of a pipe in area A is equal to 100 meters, in this case, the unaccounted water will be equal to 0.131 liters per second, which will be allocated equally to the beginning and end nodes of 0.0655.

Table 2: Unaccounted water per meter of pipe length in the range (liters per second per pipe length unit).

Range	Water per capita is not taken into account (liters per day per person)	Population range (people)	Water not included (liters per second)	Population range (people)	Water not included (liters per second per meter × 10 ^{4})
A	218	57,136	144	109,728	13.1
B	75	354,920	308	352,350	8.7

Range	Water per capita is not taken into account (liters per day per person)	Population range (people)	Water not included (liters per second)	Population range (people)	Water not included (liters per second per meter × 10 ⁴)
C	37	409,047	175	311,335	5.6
D	111	197,400	379	222,483	17
E	111	97,280	379	107,058	17
F	89	182,770	188	110,630	17
Total		1,298,553		1,213,584	

Calibrating the hydraulic model using the water model is not considered:

In relation to the purpose of the research and with regard to the hydraulic behavior of the drinking water distribution network, the area under study in the modeling of water losses in the network (water not accounted for) considering that the studies on the exact determination of the unaccounted water are not available and on the other hand, the calibration of the model is affected the amount and behavior of water is not taken into account.

Therefore, the difference between water production and all the measured uses was considered as unaccounted water and its different behavior in the network was investigated in relation to the behavior (pattern) of water use.

Unaccounted for water is divided into two parts: apparent (non-physical) losses and real (physical) losses. In these studies, the amount of network losses is calculated from the difference between the output of the tank (based on the recorded data of the output meter of the tanks) and the amount of water sold in the affairs of subscribers. These losses include the amount of leakage, apparent losses, meter error, unauthorized branches, etc.

Allocation of losses on average (annually) according to the network consumption pattern:

In this option, the amount of losses calculated within the scope of each network throughout the year is calculated and allocated to them on average according to the consumption pattern of the network subscribers (pattern) according to the length of the pipes. Diagrams 1 to 5 shows the behavior of the network (reservoir output flow rate in the hydraulic model) with the actual behavior of the tank output (according to the data and statistics of the tank output meter).

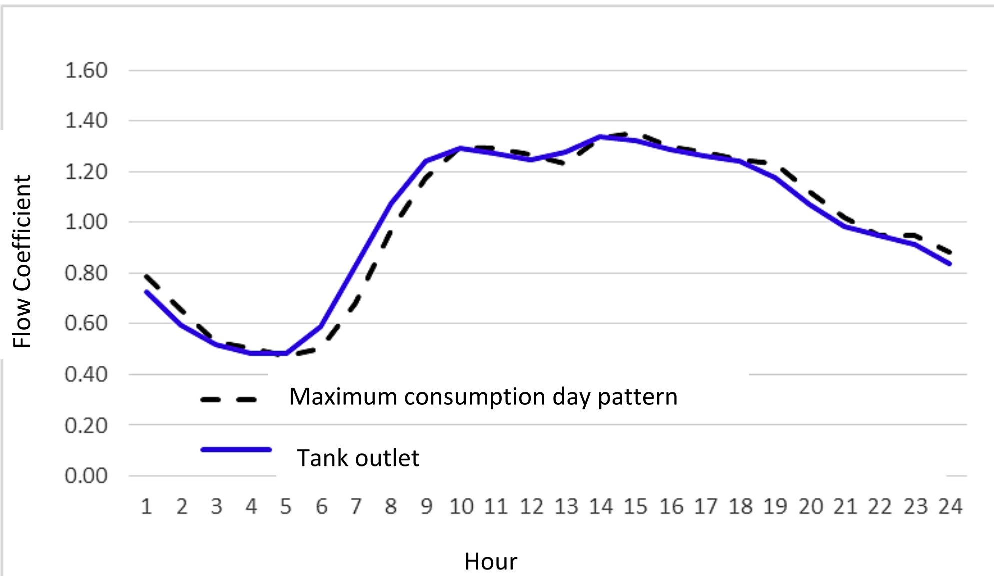

Chart 1: comparing the output flow of the tank with the behavior of the hydraulic model in tank A

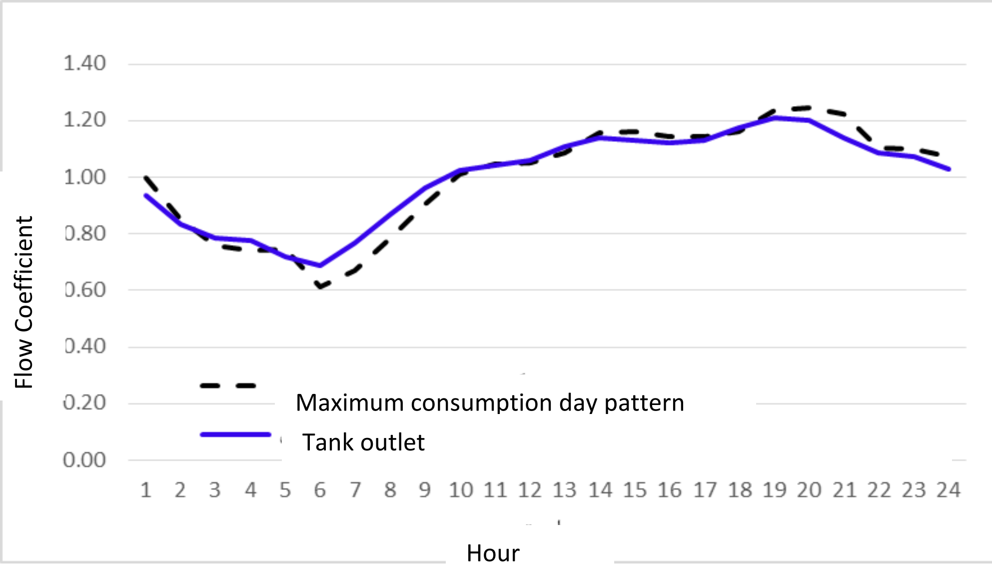

Chart 2: comparing the output flow rate of the tank with the behavior of the hydraulic model in tank B

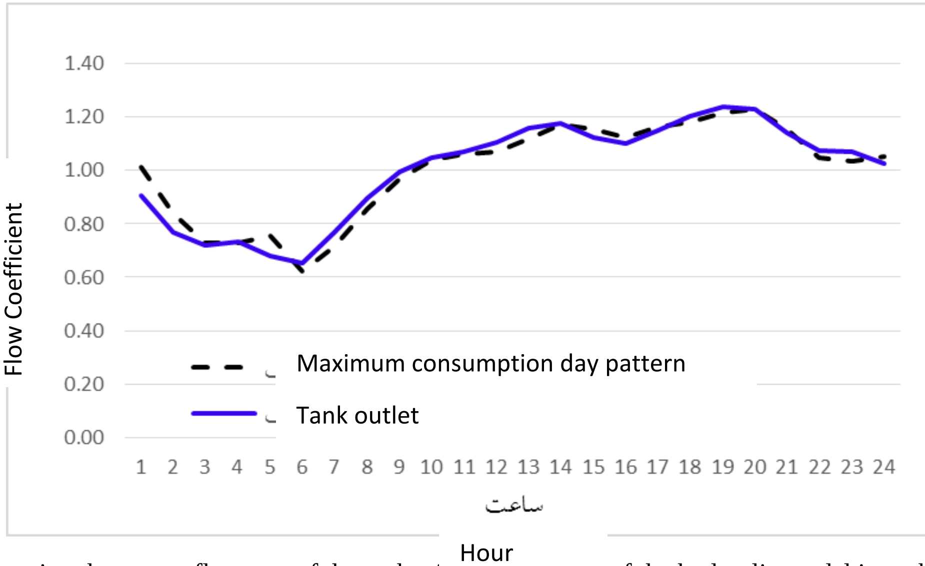

Chart 3: comparing the output flow rate of the tank with the behavior of the hydraulic model in tank D

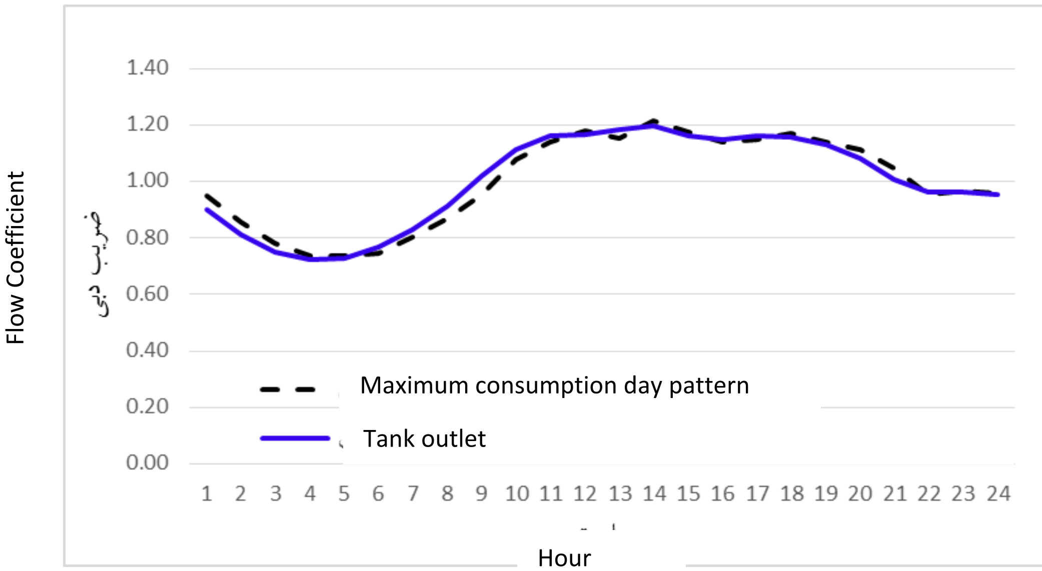

Chart 4: comparing the output flow rate of the tank with the behavior of the hydraulic model in tank E

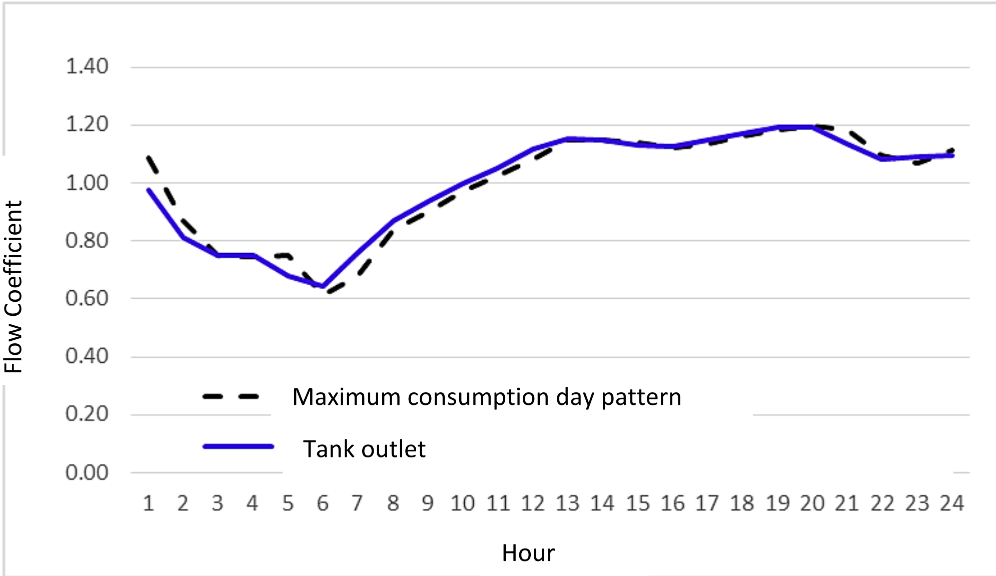

Chart 5: comparing the output flow rate of the tank with the behavior of the hydraulic model in tank F

Due to the fact the range of reservoir F physically had communication points (flow exchange) with other neighboring reservoirs (outside the scope of the current research) at the time of preparing the current situation model. Therefore, it was not possible to draw the behavior of the output flow from the tank with the current model flow independently for this tank.

Table 3: The percentage of difference between the pattern of flow rate changes of the recorded values with the current situation model at minimum and maximum consumption.

Tank number	The difference between recorded and model discharge (%)	
	Minimum consumption	Maximum consumption
A	2	2
B	13	4
D	5	0
E	3	1
F	7	1
Medium	6	6/1

Examining the similarity percentages listed in Table 3 shows that the amount of difference between the model prepared from the existing situation and the flow rates recorded from the outlet of the reservoirs at the minimum consumption is from an average value of 6.4% (in the water model, it is not considered constant without changes) to an average difference. 6% (not calculated in the water model according to the consumption model) has improved, and this is while the maximum range of difference between the model values and the flows recorded in the minimum consumption has increased from 8% to 13% despite the improvement in the relative average. In addition, the difference between the existing model and the recorded flow rates from the outlet of the reservoirs at maximum consumption is from the average value of 19.6% (in the model of water not considered constant without changes) with a significant improvement to the average difference of 1.6% (in the model the difference between the model values and the recorded flows in the maximum consumption has decreased (improved) from 30% to 4% in the maximum range of the difference, along with the improvement in the relative average.

Evaluation of hypotheses based on model output diagrams:

At this stage, the series of production flows in a 24-hour period from the output of the current situation model was evaluated and selected based on the hypotheses raised against the corresponding data recorded from the output of the reservoirs, using statistical parameters as described below.

A- R2 is the coefficient of determining the correlation, which is the indicator of the difference in the closeness of the predictions to the optimal fitting line. The optimal limit of this index is 1, which indicates a perfect correlation between the measured and predicted data.

B- MAE is the mean absolute value of the differences, which is the measurement of the difference between two continuous variables. The ideal limit of this index is 0.00, which indicates no difference between two (series) of variables.

T- RMSE represents the standard deviation of the residuals (predicted errors) and shows how far the residuals are from the regression data points of the root mean square of the differences. The ideal limit of this index is 0.00.

Evaluation based on statistical error parameters:

Three groups of flow rates predicted from the hydraulic model of the current state of the network under study for recalibration options based on the unchanged (average) water pattern, the inverse of the pattern of water consumption by the subscribers and according to the pattern of water consumption by the subscribers, in contrast to the flow rates recorded in the output of the reservoirs, were evaluated using the statistical parameters listed in paragraph 4 (Table 4).

Table 4: Evaluation of water patterns not taken into account in the recalibration of the hydraulic model of the water distribution network.

The pattern of water is not considered	Statistical parameter		
	R^2	MAE	RMSE
Fixed (average water not calculated per year per hour)	00/1	90/0	01/0
Reversal of expenses	00/1	70/0	30/0
According to usage	99/0	18/0	19/0

Comparing the results of the statistical comparison of the options of the unaccounted water model shows that for the squared error parameter (R2), all three options provide completely acceptable predictions. The comparison of the MAE parameter confirms that the constant and inverse patterns of the users' consumption are acceptable for the average absolute value of the differences and the only option of the water pattern that is not considered according to the consumption compared to the first two options has presented a number close to 1.00 . Also, for the residual standard deviation (RMSE) parameter, the inverse consumption option is relatively far from the acceptable limit for this parameter, and the options of the fixed model and according to consumption respectively have provided a more acceptable limit.

Choosing the most appropriate water pattern is not considered:

A comprehensive evaluation by comparing the pairs of three statistical parameters shows that the use of the option of the inverse model of the customers' consumption is not considered as a water model, for calibrating the hydraulic model of the distribution network, more acceptable limits for the closeness of the predicted values to the recorded output values. Hourly reservoirs have provided.

Pressure synchronization of nodes in the hydraulic model:

In this section, the hydraulic behavior of the pressure nodes of the drinking water distribution network in the area has been investigated in modeling and its compatibility with the pressures measured in different areas covered by the network. It should be noted that the pressure measurement operation in the range has been carried out at different times for 350 points and also the hydraulic model of the network for the day of maximum daily consumption was dynamically modeled and then the output pressures of the hydraulic model were compared with the measured pressures.

In order to investigate and model the hydraulic behavior of the distribution network, Water GEMs software was used and the measured pressure values as well as the input pressure statistics of the existing pressure breakers were processed for each network.

The output pressure range of the hydraulic model and the measured pressures in the ranges:

It shows the output pressure ranges of the hydraulic model along with the measured pressure lines along with the inlet pressure of the pressure relief valves. The output pressures of the hydraulic model are shown as pressure zones in Figure 1. Also, according to all the measured points (pressure measured points + pressure relief valve information), pressure curves have been drawn in the area of the network covered by the tanks. The coloring and pressure ranges were determined and drawn based on the following.

A- Low pressure range in the network for points with pressure less than 26 meters of water with orange color

B- Normal network pressure range for points with pressure between 26 and 50 meters of water with green color

C- Range at the threshold of high pressure for points with pressure between 50 and 60 meters of water with purple color

D- The high-pressure range of the network for points with a pressure of more than 60 meters of water in blue color

In some points of the network, due to the presence of the pressure relief valve and separation of the pressure range, two high-pressure zones (the end of the pressure zone) and low pressure (the beginning of the pressure zone) are adjacent to each other.

V. DISCUSSION

The water distribution network under the study was covered by 6 ground reservoirs. Basic GIS maps, statistics and periodic information of water supply in reservoirs and output (water distribution in the network) from reservoirs, consumption statistics of subscribers based on annual periodic bills, along with the latest population census statistics (year 2015) are tracked and collected. The total capacity of the tanks is reported to be 325 thousand cubic meters per year. According to the customer bank information of the water and sewage company, 155,776 subscribers with a population of 1,308,923 people are covered by the network of the study area and the total length of the network pipes covered by these reservoirs is 119,191 km. Water consumption in the area covered by the reservoirs based on the statistics of the available amounts of the customers' consumption related to the years 2011 to 6 months of the beginning of 2015, separated by use and the area covered by the reservoirs, was obtained from the affairs of the subscribers of the operating company and in order to calculate the per capita consumption of water, processing and analysis became. In relation to the purpose of the research and with regard to the hydraulic behavior of the drinking water distribution network, the area under study in the modeling of water losses in the network (water not accounted for) considering that the studies on the exact determination of the unaccounted water are not available and on the other hand, the calibration of the model is affected the amount and behavior of water is not taken into account, so the difference between water production and all the measured uses was considered as unaccounted water and its different behaviors in the network were investigated in relation to the behavior (pattern) of water consumption. Pressure measurement in the network covered by the reservoirs under study has been done during the investigation period for 4 months at different time points for a number of 403 points and also the hydraulic model of the network for the day of maximum daily consumption was dynamically modeled and studied. The comparison of the output pressures of the hydraulic model with the pressures measured in field operations was investigated and carried out.

Loading the nodes' consumption based on more subscribers was done for the hydraulic simulation of the existing situation. After checking the recorded data of the output flowmeters of storage tanks, the pattern of water distribution and consumption in the network in different years was calculated for the day of maximum consumption and the coefficient of maximum consumption of that day for the tank. After determining the day of maximum consumption, the maximum hourly coefficient of the tank was also extracted. In order to recalibrate the model in the water sector, the allocation of losses in three ways (assumed) on an average (annual) basis and without a (fixed) consumption pattern, average (annual) inverse of the network consumption pattern and allocation of losses on an average (annual) basis according to the consumption pattern was not taken into account. The grid was applied to the model.

For each of the three hypotheses about water behavior, compared to the water consumption pattern of the subscribers, the behavior of the network (reservoir output flow in the hydraulic model) is evaluated with the actual behavior of the reservoir output (according to the data and statistics of the reservoir output meter).

In the assumption of the model of water not calculated as average (annual) and without consumption pattern (fixed), the results showed that the difference between the model prepared from the existing situation and the flow rates recorded from the outlet of the reservoirs is at the minimum consumption of acceptable values and at the same time the maximum consumption in the dominant number shows a significant difference.

In the assumption of the unaccounted water pattern as an average (annual) and inverse of the network consumption pattern, the results showed that the difference between the model prepared from the existing situation and the recorded flow rates from the reservoir outlet at the minimum consumption compared to the hypothesis of the unaccounted water pattern is constant without changes has been found and besides that, the maximum range of difference between the model values and the recorded flows in the minimum consumption has increased despite the improvement in the relative average. Also, the difference between the model prepared from the existing situation and the recorded flow rates from the outlet of the reservoirs at the maximum consumption has been reduced with a relative improvement. At the same time, the difference between the model values and the recorded flows in the maximum consumption has decreased (improved) along with the improvement in the relative average.

Assuming the model of water is not calculated as an average (annual) in accordance with the consumption pattern, the results showed that the difference between the model prepared from the current situation and the recorded flow rates from the outlet of the reservoirs has improved in the minimum consumption, and this is while the maximum range of the difference in values. The model with recorded discharges at the minimum consumption had increased despite the improvement in the relative average. In addition to that, the difference between the current model and the recorded flow rates from the outlet of the reservoirs at maximum consumption decreased with a significant improvement, and besides that, the difference between the model values and the recorded flow rates at maximum consumption simultaneously with an improvement in the relative average, in the maximum range. The difference was also improved.

Comparing the results of the statistical comparison of the options of the unaccounted water model shows that for the squared error parameter (R2), all three options provide completely acceptable predictions. The comparison of MAE parameter confirms the fact that the fixed and inverse patterns of the users' consumption are far from the acceptable limit for the average absolute value of the differences, and only the option of the water pattern, which is not considered according to the consumption, has presented an acceptable limit compared to the first two options. Also, for the residual standard deviation (RMSE) parameter, the inverse consumption option is relatively far from the acceptable limit for this parameter, and the options of the fixed model and according to consumption respectively have provided a more acceptable limit.

VI. CONCLUSION:

A comprehensive evaluation by comparing the pairs of three statistical parameters shows that the use of the model option according to the customers' needs is not considered as a water model, for calibrating the hydraulic model of the distribution network, more acceptable limits for the closeness of the predicted values to the recorded output values hourly reservoirs have provided.

The confirmation of the hypothesis of the model according to consumption as the pattern of unaccounted water for the studied network also indicated that the amount of unaccounted water (unlicensed and unregistered consumers) has changed along with the amount of consumption. Since the outflow from the network (consumers and water are not counted) has an inverse relationship with the amount of pressure in the network, while leakage from the network has a direct relationship with pressure. In other words, as the users' consumption of the network increases, the corresponding pressure decreases and based on hydraulic principles, the amount of leakage also decreases in the same proportion, while the selected option in the network calibration under study showed that the amount of water was not calculated with the increase in consumption increases, therefore, taking into account the principle of reducing leakage for increasing consumption, it is clear that unauthorized and unregistered consumption is the dominant part (over leakage and water losses due to accidents) in water.

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