INFOWORKS WS AND EPANET v2 - MODELING THE WATER DISTRIBUTION NETWORKS

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Modelarea matematică şi simularea comportării reţelelor de distribuţie au devenit instrumente esenţiale pentru companiile din domeniul alimentării cu apă, în încercarea lor de a asigura servicii de o calitate superioară la costuri de operare şi de dezvoltare cât mai reduse. Existenţa programelor specializate de modelare, din ce în ce mai performante şi mai sofisticate, care permit evaluarea corectă a comportării reţelelor în condiţii normale sau anormale de exploatare, permit ca atingerea acestor scopuri să fie îndeplinită extrem de uşor. Articolul prezintă rezultatele obţinute cu ajutorul a două software-uri specializate pentru aceeaşi reţea de distribuţie a apei – reţeaua oraşului Hanoi.

Mathematical modeling and computer simulation is becoming an essential tool for water companies in their attempt of providing high – quality service while minimizing costs of both development and operations. The availability of increasingly sophisticated and accessible models, which permit the proper evaluation of network behavior under normal and abnormal conditions, allows these goals to be realized more fully than ever before. The article presents the results obtained with two software programs on the Hanoi water distribution network.

Keywords: water distribution networks, hydraulic modeling, Epanet, InfoWorks

1. Introduction

Nowadays, water distribution modeling is an important part of designing and operating water distribution systems (WDS). Although the size and complexity of water distribution systems can vary considerably, their purpose is the same — to provide reliably, efficiently, and safely water to customers. The availability of increasingly sophisticated and accessible models allows these goals to be realized more fully than ever before. Modeling a WDS gives a water authority the potential to predict the effects of operational and physical changes to both hydraulics and water quality. There are a large number of software packages available for modeling the hydraulic and water quality characteristics of a WDS. Some examples include EPANET, Stoner Synergee, WaterCAD, Cybernet, Piccolo, MIKE NET, H20NET [1] and InfoWorks [2].

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The purpose of this paper is to shortly present one of the most valuable software in the water distribution system modeling, InfoWorks WS. The results obtained are compared with the ones provided by the most popular water distribution networks modeling software – EPANET.

2. Software presentation

Epanet was developed by the Water Supply and Water Resources Division of the U.S. Environmental Protection Agency's National Risk Management Research Laboratory. Epanet performs extended period simulation of hydraulic and water quality behavior within pressurized pipe networks. A network consists of pipes, nodes (pipe junctions), pumps, valves and storage tanks or reservoirs. Epanet tracks the flow of water in each pipe, the pressure at each node, the height of water in each tank, and the concentration of a chemical species throughout the network during a simulation period comprised of multiple time steps. In addition to chemical species, water age and source tracing can also be simulated. Running under Windows, Epanet provides an integrated environment for editing network input data, running hydraulic and water quality simulations, and viewing the results in a variety of formats. These include color-coded network maps, data tables, time series graphs, and contour plots [3].

Epanet's hydraulic simulation model computes hydraulic heads at junctions and flow rates through links for a fixed set of reservoir levels, tank levels, and water demands over a succession of points in time. From one time step to the next reservoir levels and junction demands are updated according to their prescribed time patterns while tank levels are updated using the current flow solution. The solution for heads and flows at a particular point in time, which involves solving simultaneously the conservation of flow equation for each junction and the headloss relationship across each link in the network, is solved by the Gradient Algorithm. The hydraulic time step typically used for extended period simulation is 1 hour.

"Water quality" is a term that encompasses a large number of aspects of both potable and non-potable water. In this article, the definition of water quality was limited to disinfectant residuals. The disinfectant residuals limit the regrowth of potentially harmful organisms. Under the limited definition of water quality adopted for this study, water quality is indicated by the disinfectant concentration throughout the WDS. The dynamic water quality module of Epanet tracks the fate (the growth or decay) of a substance by reaction as it travels through the distribution system over time. Reactions can occur both within the bulk flow and with material along the pipe wall. It uses the flows from the hydraulic simulation to solve a conservation of mass equation for the substance within each link. Epanet allows a modeler to use different reaction rates for the two zones of reaction. In this study, only the bulk flow reaction is considered. The time step typically used for water quality modeling is 5 minutes.

The InfoWorks suite of products, developed by Wallingford Software, represents the first significant move in the industry towards a family of software that embraces the whole water cycle from supply and distribution (InfoWorks WS), urban drainage and wastewater management through to river management modeling. Each product within the InfoWorks suite is designed with precisely the same look and feel to enable users to migrate easily between the different products [2].

There are many good reasons that make InfoWorks WS the best choice for professional water distribution modelers. It has an intuitive user interface, true multi-user operation, and in-build data quality assurance. It is an ideal platform for sustainable modeling – maintaining an up-to date, ongoing model to investigate a variety of issues. It has a broad range of features beyond core modeling, including demand analysis, automated fire flow evaluation, and critical link analysis. One other outstanding advantage of InfoWorks WS is its hydraulic calculation engine. The calculation engine on which a water distribution model is built is a fundamental determinant of the value of that model. A better engine means that a better model can be built.

Figure 1 presents the necessary steps to develop a model in InfoWorks.

There are a number of qualities by which an engine can be judged. First, a range of equations must represent accurately the flows of water through the pipes, valves, pumps and other components of the network. Second, the management procedures of the engine must use appropriate time steps for running the model, which means small time steps when conditions are changing, and longer time steps in steady state conditions. Third, the flows of water into the system, through the network, and out of the system through customer demand and leakage must be accurately represented in terms of volumes, mixes, time, and geography. Fourth, the engine must be capable of running models of all sizes, including large models: some clients need to run models of many thousands of nodes. Finally, despite all the above requirements for detail and size that point to a heavy computation load, the engine must also be fast – when modelers are building, calibrating, and then using a completed model, run speed is essential for good productivity and reducing the cost of modeling.

Unlike most other water distribution software products, which base their calculations on the EPANET engine, InfoWorks WS uses its own proprietary engine. Sharing the same computational roots as EPANET, its first release was in 1985 as part of the WESNET product, and over the 20 years since then it has been continually updated. Now known as WS SIM, the engine's latest update was a very significant enhancement in mid-2005, incorporated in InfoWorks V6.0, which increased the already fast calculation engine by an order of magnitude.

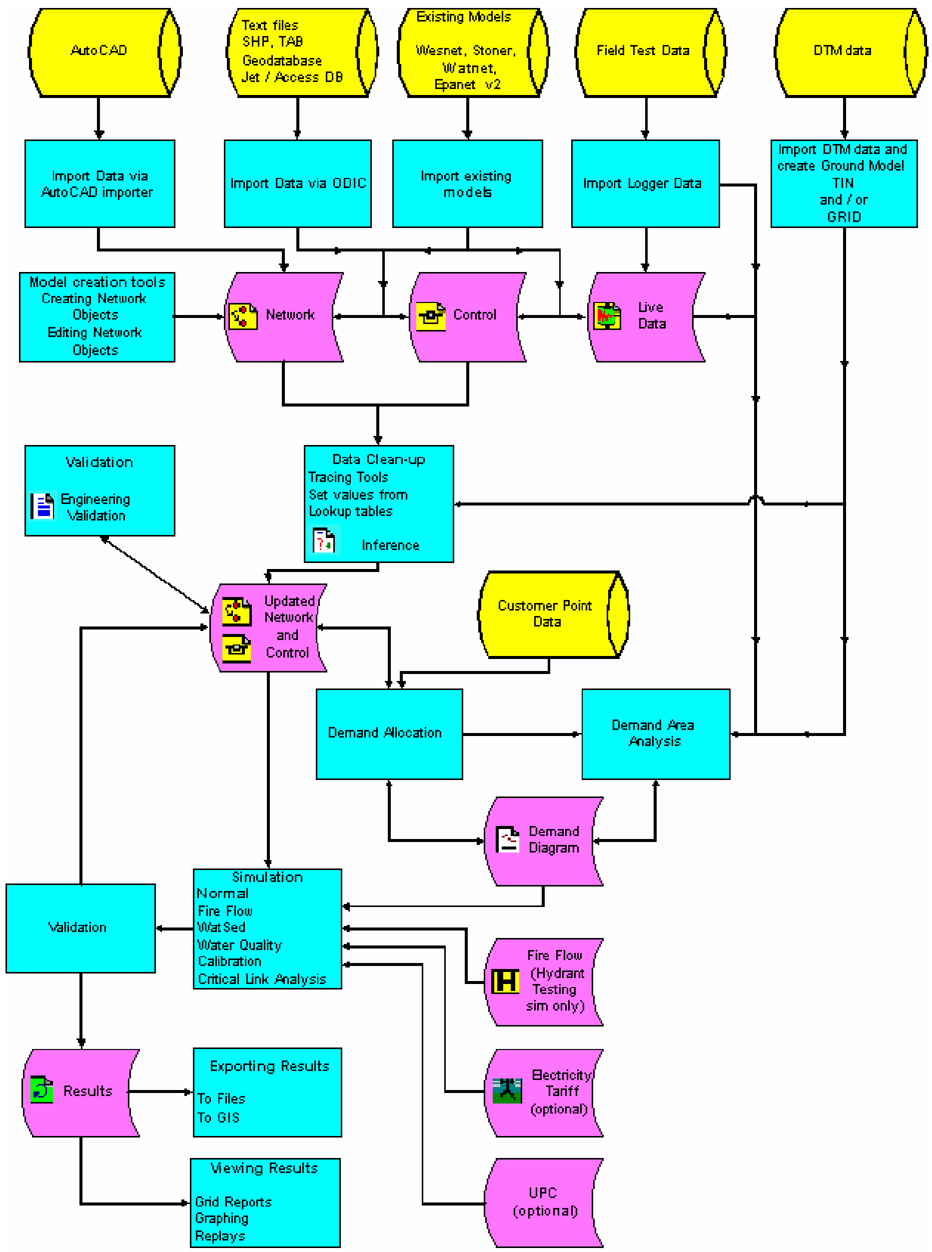

Fig. 1. Developing a model in InfoWorks WS

For steady state calculations and extended period simulations, WS SIM uses the same equations as most other engines to compute heads at nodes and flow in links based on the boundary conditions (reservoir levels, tank levels, and demands) and system operation (pump and valve positions).

However, there are key differences between WS SIM and other products. It supports true date and time at all levels of the program, including demands and controls. WS SIM will accurately model isolated areas in a network, dry systems, and empty tanks. This means that WS SIM can be used to closely match actual operating conditions at any specific time, and can easily be used in conjunction with time-tagged monitored data from SCADA or loggers.

InfoWorks WS is a comprehensive, easy-to-use and flexible system for the management of water supply models. The system provides a master database for storing network and control data, and includes the routines necessary to import, create and edit that data.

When the model has been created, InfoWorks allows simulating the behavior of the network under a range of conditions and a variety of reporting tools are provided for analyzing the results.

The InfoWorks WS Dynamic Water Quality model is based on the EPANET concepts and numerical procedures.

3. Hanoi water distribution system

The Hanoi water distribution system (fig.2) is one of the most studied networks for comparing the performances of different optimization algorithms and modeling packages.

The first time this network was studied in 1990, by a classic optimization method [4]. Later on, the researchers started to apply different optimization techniques: simulated annealing [5], genetic algorithm [6], harmony search method [7], and ant colony optimization algorithm [8], [9]. Vuta and Popa, [10] developed an optimization methods based on ACO algorithm. Also, the effect of chlorination costs over the capital cost of the network during a lifetime period of 30 years was investigated. The solution found was 10% cheaper than any other solutions previously reported.

In this study, the results reported by Vuta and Popa [10] are used to perform the simulation with Epanet and InfoWorks WS.

The network is flat, contains 32 nodes, 34 pipes, and 3 loops, and is fed by gravity from a reservoir with a 100 m fixed head.

The water demand is presented in Table 1. In order to attain reliable results, a demand pattern over 24 hour was assumed (fig.3). The pipe lengths and diameters are presented in Table 2. An equivalent roughness coefficient, $\Delta_e = 0.2$ mm, is considered and the headlosses, h, are calculated with the Darcy – Weisbach equation.

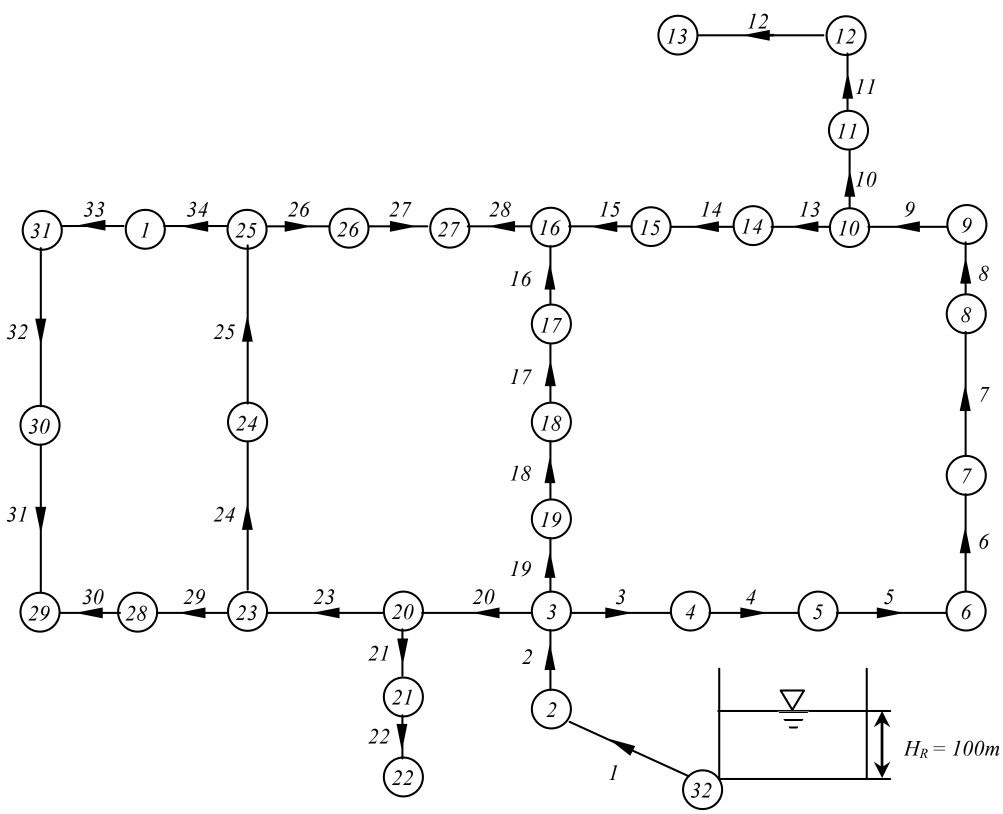

Fig. 2. Hanoi water distribution system

Table 1

Water demand in network's junctions

Junction	q (m^3/h)	Junction	q (m^3/h)	Junction	q (m^3/h)	Junction	q (m^3/h)
1	805	9	525	17	865	25	170
2	890	10	525	18	1345	26	900
3	850	11	500	19	60	27	370
4	130	12	560	20	1275	28	290
5	725	13	940	21	930	29	360
6	1005	14	615	22	485	30	360
7	1350	15	280	23	1045	31	105
8	550	16	310	24	820	32	-19940

Regarding the residual chlorine concentration over the network, a first order decay reaction is assumed. The reaction constant for all the pipe in the network is set to be k_c = -2.4 (in 1/day).

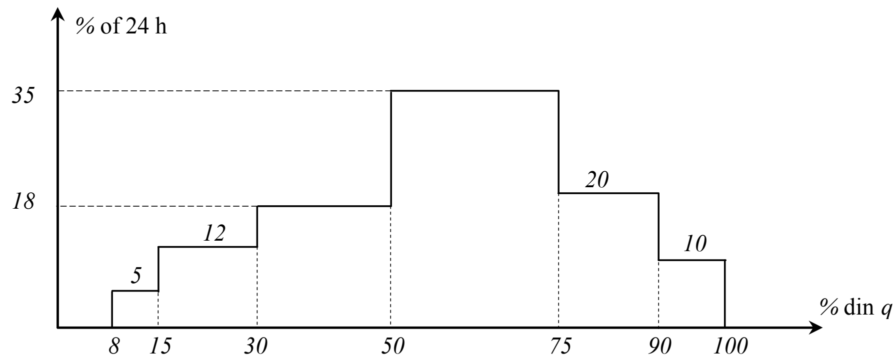

Fig. 3. Demand time pattern over 24 hour

Table 2

Pipe length and diameters

Pipe	Length (m)	Diameter (mm)	Pipe	Length (m)	Diameter (mm)
1	100	1270	18	800	609.6
2	1350	1270	19	400	508
3	900	1016	20	2200	1016
4	1150	1016	21	1500	406.4
5	1450	1016	22	500	254
6	450	762	23	2650	762
7	850	762	24	1230	762
8	850	762	25	1300	609.6
9	800	762	26	850	406.4
10	950	609.6	27	300	254
11	1200	609.6	28	750	254
12	3500	508	29	1500	406.4
13	800	406.4	30	2000	304.8
14	500	406.4	31	1600	304.8
15	550	508	32	150	304.8
16	2730	254	33	860	304.8
17	1750	406.4	34	950	609.6

4. Results

Table 3 presents the flow rates obtained by [10], Epanet and InfoWorks for Hanoi water distribution system, under the maximum demand conditions. The pressures and chlorine concentration in junction are presented in table 4.

A good correlation exists between the results presented by [10] and the ones provided by Epanet and InfoWorks.

Regarding the residual chlorine concentration, the results obtained are similar to the one presented in [10]. The smallest chlorine concentration is reached in junction 13, for all the demand conditions studied.

In figure 4 and figure 5 is presented the demand at junction 13, obtained with Epanet (fig.4) and InfoWorks (fig.5). The residual chlorine concentration in junction 13 is plotted in figure 6 (Epanet) and figure 7 (InfoWorks).

Table 3

Comparison of flow rate for Hanoi water distribution system

Pipe	Flow rate (m^3/h) [10]	Flow rate (m^3/h) Epanet	Flow rate (m^3/h) InfoWorks	Pipe	Flow rate (m^3/h) [10]	Flow rate (m^3/h) Epanet	Flow rate (m^3/h) InfoWorks
1	19940.2	19940.00	19940.00	18	2453.4	2452.30	2490.80
2	19050.2	19050.00	19050.00	19	2513.4	2512.30	2550.80
3	8000.3	8011.47	7990.77	20	7686.4	7676.23	7658.43
4	7870.3	7881.47	7860.77	21	1415.0	1415.00	1415.00
5	7145.3	7156.47	7135.77	22	485.0	485.00	485.00
6	6140.3	6151.47	6130.77	23	4996.4	4986.23	4968.43
7	4790.3	4801.47	4780.77	24	3245.4	3239.90	3206.97
8	4240.3	4251.47	4230.77	25	2425.4	2419.90	2386.97
9	3715.3	3726.47	3705.77	26	1041.3	-1031.23	-1013.43
10	2000.0	2000.00	2000.00	27	141.3	-131.23	-113.43
11	1500.0	1500.00	1500.00	28	228.7	238.77	256.57
12	940.0	940.00	940.00	29	706.1	701.33	716.46
13	1190.3	1201.47	1180.77	30	416.1	411.33	426.46
14	575.3	586.47	565.77	31	56.1	51.33	66.46
15	295.3	306.47	285.77	32	303.9	-308.67	-329.54
16	243.4	242.30	280.80	33	408.9	413.67	398.54
17	1108.4	1107.30	1145.80	34	1214.1	1218.67	1203.54

Table 4

Comparison of pressure and chlorine concentration in junctions

Junction	Pressure (m) [10]	Pressure (m) Epanet	Pressure (m) InfoWorks	Chlorine concentration (mg/l) [10]	Chlorine concentration (mg/l) Epanet	Chlorine concentration (mg/l) InfoWorks
1	38.24	35.34	35.72	0.27	0.26	0.25
2	99.00	98.97	95.32	0.30	0.30	0.30
3	86.63	86.32	86.71	0.30	0.29	0.30
4	81.99	81.51	81.94	0.29	0.29	0.29
5	76.25	75.56	76.05	0.29	0.29	0.29
6	70.29	69.36	69.92	0.28	0.27	0.28
7	64.18	63.07	63.58	0.28	0.27	0.28
8	57.15	55.78	56.28	0.28	0.27	0.28
9	51.65	50.05	50.55	0.28	0.27	0.27
10	47.67	45.89	46.42	0.28	0.27	0.27
11	43.29	41.32	41.81	0.27	0.26	0.26

12	40.18	38.02	38.54	0.27	0.26	0.25
13	30.96	28.21	28.63	0.25	0.24	0.22
14	36.83	34.45	35.10	0.27	0.26	0.26
15	35.07	32.70	33.31	0.27	0.26	0.26
16	34.90	32.52	33.14	0.26	0.25	0.24
17	52.98	51.52	52.32	0.29	0.28	0.28
18	73.54	72.82	73.27	0.29	0.29	0.29
19	79.09	78.58	79.10	0.29	0.29	0.30
20	76.16	75.52	76.02	0.29	0.29	0.29
21	47.44	45.89	46.64	0.28	0.28	0.28
22	34.30	32.29	33.16	0.28	0.28	0.28
23	53.71	51.05	51.48	0.28	0.28	0.28
24	48.81	46.20	46.67	0.28	0.28	0.27
25	40.00	37.08	37.43	0.27	0.26	0.26
26	31.19	28.08	28.59	0.27	0.26	0.26
27	30.52	27.44	27.97	0.26	0.26	0.24
28	46.55	43.60	43.88	0.27	0.27	0.26
29	31.65	28.23	28.43	0.26	0.26	0.24
30	31.43	28.00	28.21	0.25	0.25	0.23
31	32.05	28.66	28.88	0.26	0.25	0.24
32	100.00	100	100	0.30	0.30	0.30

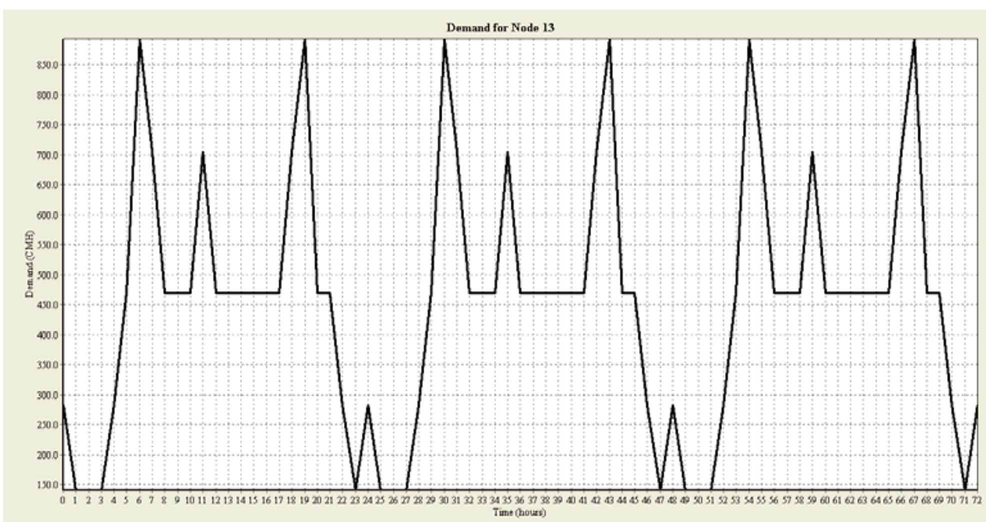

Fig. 4. Demand for Node 13 – by Epanet

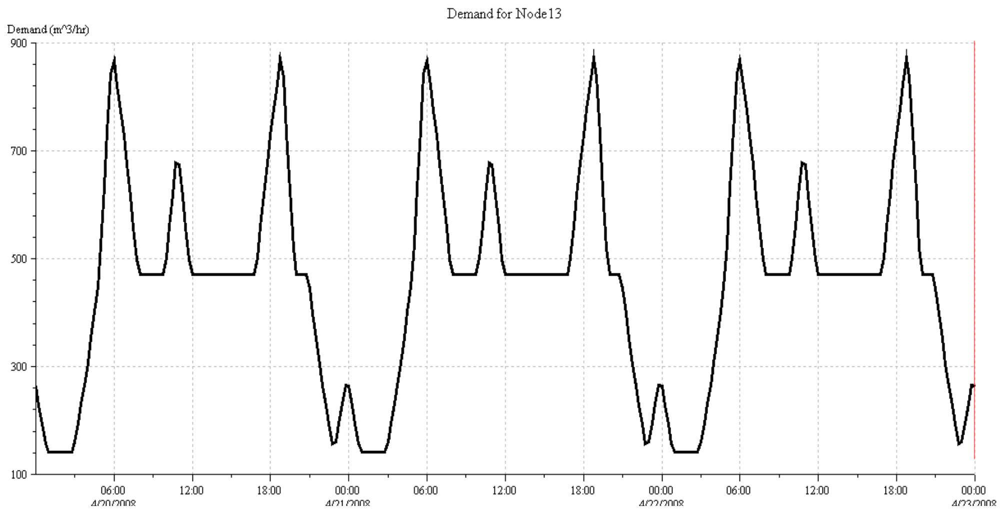

Fig. 5. Demand for Node 13 – by InfoWorks

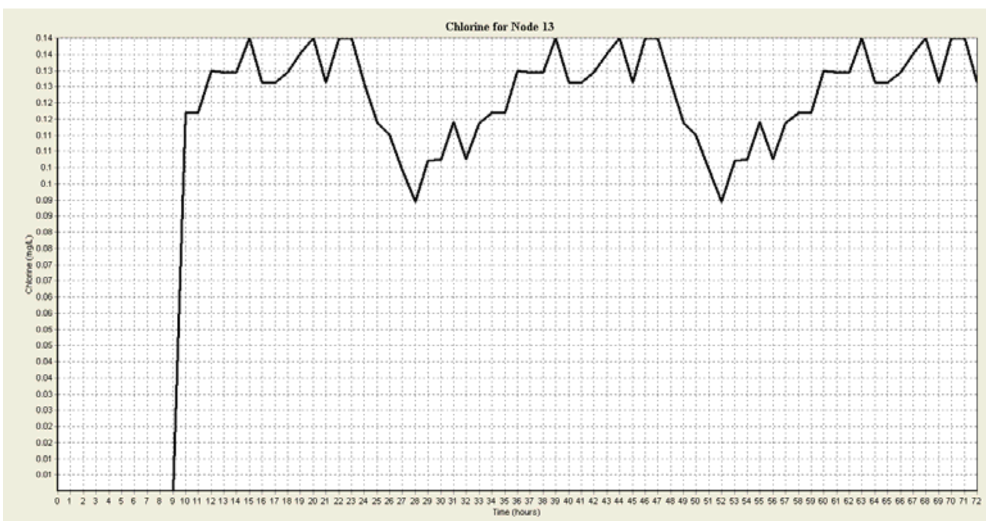

Fig. 6. Chlorine for Node 13 – by Epanet

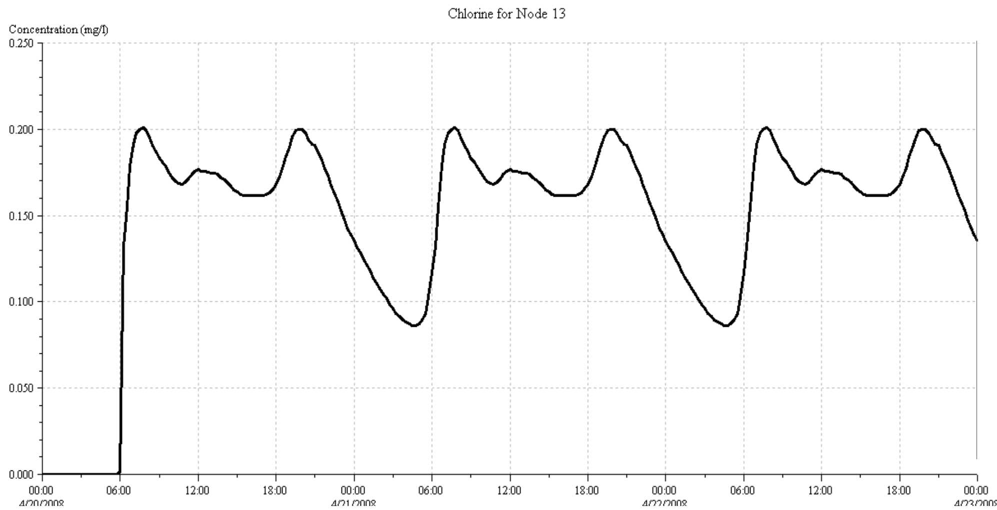

Fig. 7. Chlorine for Node 13 – by InfoWorks

5. Conclusions

The results obtained are similar with the ones reported by Vuta and Popa [10].

A small difference between the flows values in pipes appear due to the difference in the hydraulic solver. Those differences are reflected also by the values of pressure and residual chlorine concentration.

The minimum chlorine concentration is reached in node 13, as reported by Vuta and Popa.

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