ASPECTS REGARDING THE MODELING OF WATER DISTRIBUTION NETWORKS USING GEOGRAPHICAL INFORMATION SYSTEMS (GIS) AND THE EPAET PROGRAM

Gilda GAVRILAS, professor, Ph.D.Eng., Technical University „ Gheorghe Asachi" of Iasi , Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Department of HydraulicStructures Engineering, Email:gildagavrilas@yahoo.com
Loredana Crenganis, lecturer, Ph.D.Eng., Technical University „ Gheorghe Asachi" of Iasi, Faculty of Hydrotechnical Engineering, Geodesy and Environmental Engineering, Department of Terrestrial Measurement and Cadastre, Email:barganlro@yahoo.com

Abstract: *Upgrading water distribution systems in towns imposes the study of water distribution networks, starting from a global vision including the current situation, the management of each element of the system as well as their exploitation, development and optimization.*

The water distribution system consists of a number of interconnected hydraulic elements, each of them characterized by certain relations among the variables that have been chosen to describe their functioning.

Currently, the GIS system has the advantage of enabling the collecting and validation of all available information, leading to the possibility of a coherent data set for the elaboration of a hydraulic model.

In order to analyse the running of the system, the current practice restricts the analysis model of these elements, so that the parameters could be molded within the existing simulation systems.

The paper presents various possibilities to analyse the functioning of a water distribution system.

Keyword: *GIS, Water Supply, Hydraulic simulation.*

1. Introduction

In accordance with the strategy targeted at the durable development of the water/sewer supply services there have been established several medium- and long-term objectives towards the modernization of these systems, in the context of their importance for the improvement of the citizens' life quality.

The main objective of waters management is supplying the consumers with water in the quantity and of the quality demanded by the UE directives.

The modernization of the water distribution systems in the localities requires the study of the water distribution networks starting from an overall view meant to cover both the current state and the management of each element in the system as wellas their exploitation, development and optimization.

At present there are a number of software solutions regarding the modelling of the distribution networks such as Infoworks WS (9), INfoWater (10) and Mike Net (8) that use Epanet 2.0.

This paper highlights the advantages of the implementation of a GIS system that allows for the collecting and validation of the available information, making the control and the modelling of the way the distribution networks function possible by using the Epanet programme [4, 5].

2. Formulating the problem

The first stage in analysing the way the water distribution networks function is the specification of the zone under consideration. The digital plan of the respective utilities area is achieved depending on the afferent cadastral sectors in the AutocadMap3D programme making use of the data gathered after the processing of the topographic measurements. The graphic information will be layer-structured. There follow the scanning, the vectorization and the digitisation of the information regarding the cadastral data making use of the cadastral plan of the zone that resulted in the digital cadastral plan.

Further on, the processing of the graphic data and the creation of the water network topologies are achieved followed by the creation of the databases and their attachment to the current project in order to connect the alphanumeric information to the graphic objects of the network.

Likewise, a database for the management of the given network that includes the assessment of the water consumption depending on the consumer category, data representing the levels in the reservoirs and the pump characteristics (Q,H), control rules, etc. will be attached to the topographic database.

All these elements can be managed by the implementation of a GIS system that will ensure cartographic databases and databases representing management information.

These data are conveyed to the system model enabling the simulation of the network hydraulic parameters.

An initial entry into the system model helps the calibration of its state as close to reality as possible, finally leading to correct results (Fig.1).

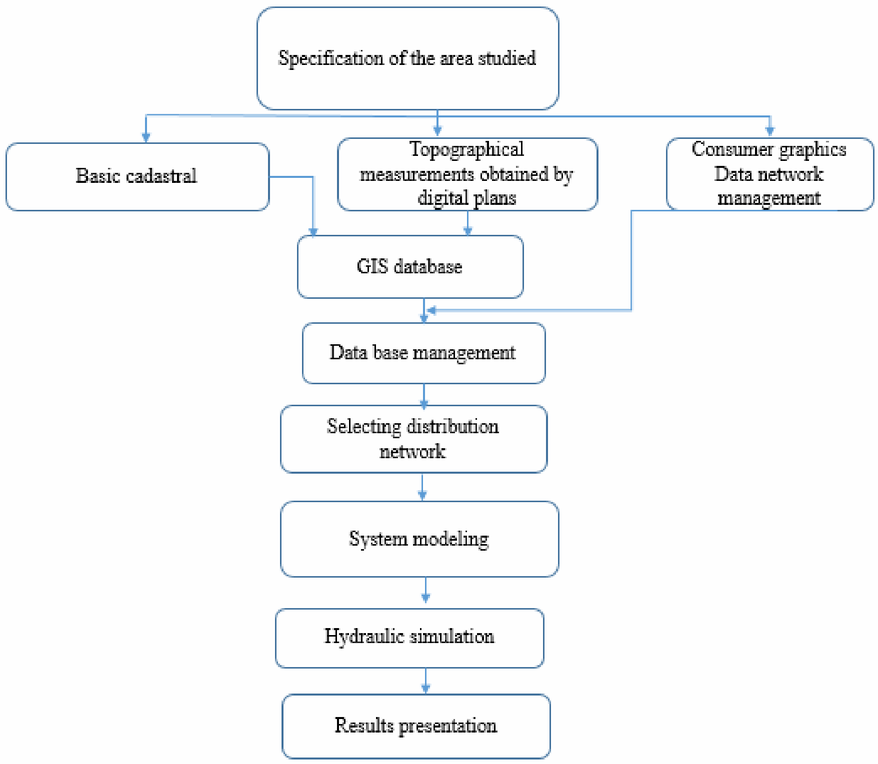


Fig.1. The diagram of the modelling of the studied zone

In the process of modelling the functioning regimes of the water supply networks two types of equations are necessary to determine the state parameters [2]:

- Topological equations in which the topological characteristics given by the network structure intervene.
- Equations of material and flow regime in which the characteristics given by the resistance modules of the pipes and the water flow regime intervene.

There follows a study case regarding the hydraulic modelling of the water distribution network with the help of Epanet programme developed by the Agency for the Protection of the Environment, USA. [4, 5].

3. Study Case

Epanet program allows the hydraulic analysis of the system in the following conditions:

- the schemes of the networks in the digital cadastral plan can be imported with the indication of the topographic co-ordinates;
- the analysed networks can have unlimited sizes;
- the pressure losses can be calculated using the Hazen – Williams, Darcy – Weisbach,
- Chezy – Manning formulate;
- the reservoirs can have any shape and size;
- the pumps can be modelled with constant or variable speed;
- types of different consumers with time variations can be considered;
- the control of the network can be established in conformity with the specified exploitation rules;

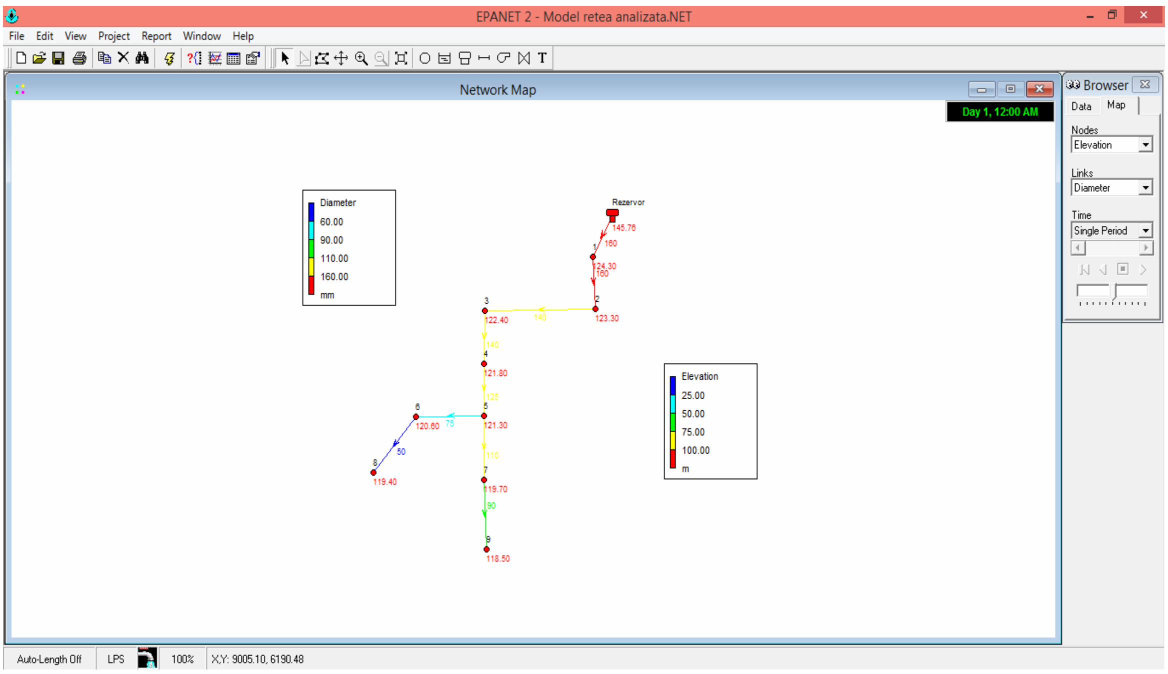


Fig. 2. The studied network.

EPANET program uses various formulas to calculate Darcy coefficient (λ) depending on water flow regime in the pipeline [4]:

- Hagen-Poiseuille -formulated for laminar regime (R_e < 2,000), (Bhave,1991):

$$\lambda = \frac{64}{Re} \tag{1}$$

- Formulated of Colebrook White turbulent regime (Re> 4000) (Bhave, 1991):

$$\lambda = \frac{0.25}{\left[\ln\left[\frac{k}{3.7D} + \frac{5.74}{Re^{0.9}}\right]\right]^2} \tag{2}$$

$$Re = \frac{v}{\nu} D \tag{3}$$

$$v = \frac{Q}{\frac{\pi D^2}{4}} \tag{4}$$

- Where Re-nr.reynolds; K-roughness; D-diameter; v - speed; ν -kinematic viscosity; Interpolare cubic Moody's diagram for the transitional regime (2000 <Re <4000) (Dunlop, 1991).

In the given example we considered for the flow, of the headlosses by the Darcy – Weisbach formula [2]:

$$h = M\,Q^2 = j\,L \tag{5}$$

$$j = \frac{\lambda}{D}\frac{v^2}{2g} \tag{6}$$

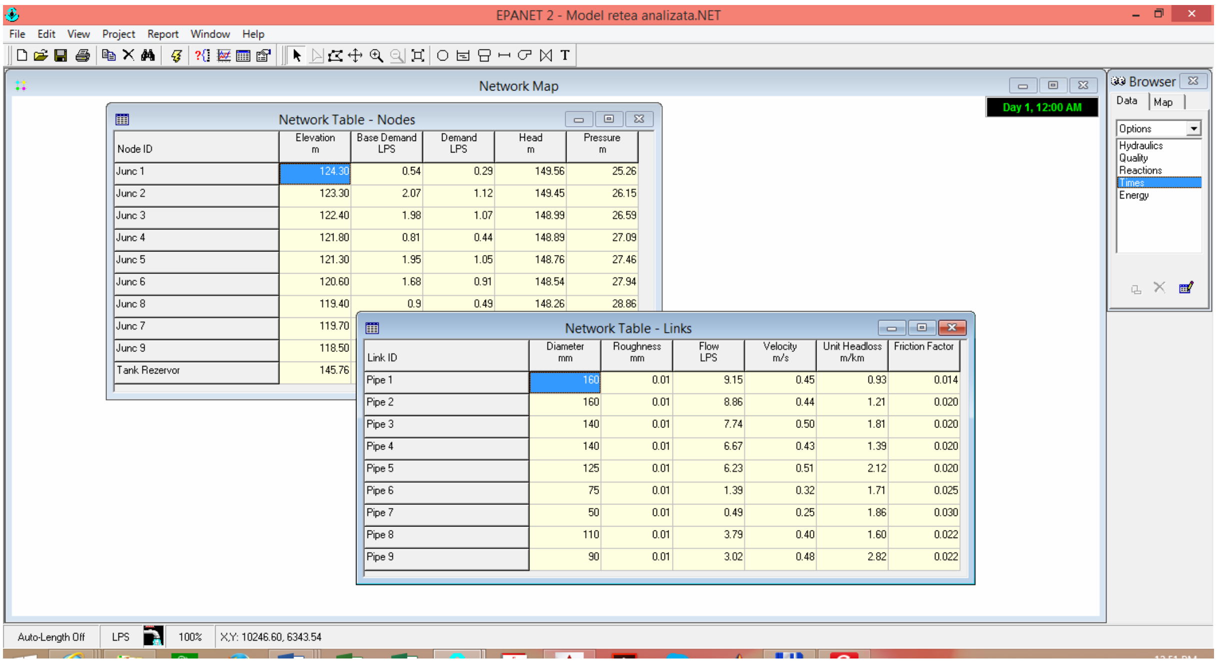
Where g is acceleration due to gravity; Q is flow, M is linear resistance module.

The headlosses are proportional to the length. In practical calculation the notion of M linear resistance module is also introduced:

$$M = 0.0826\,\frac{\lambda\,L}{D^5} \tag{7}$$

Darcy's coefficient (λ) varies depending on Reynolds number (Re) and the pipe roughness (k). Pipe roughness was felt k=0.01 mm [11,12].

The characteristic elements of the network are presented in Fig.3:



Node ID	Elevation m	Base Demand LPS	Demand LPS	Head m	Pressure m
Junc 1	124.30	0.54	0.29	149.56	25.26
Junc 2	123.30	2.07	1.12	149.45	26.15
Junc 3	122.40	1.98	1.07	148.99	26.59
Junc 4	121.80	0.81	0.44	148.89	27.09
Junc 5	121.30	1.95	1.05	148.76	27.46
Junc 6	120.60	1.68	0.91	148.54	27.94
Junc 8	119.40	0.9	0.49	148.26	28.86
Junc 7	119.70				
Junc 9	118.50				
Tank Rezervor	145.76				

Link ID	Diameter mm	Roughness mm	Flow LPS	Velocity m/s	Unit Headloss m/km	Friction Factor
Pipe 1	160	0.01	9.15	0.45	0.93	0.014
Pipe 2	160	0.01	8.86	0.44	1.21	0.020
Pipe 3	140	0.01	7.74	0.50	1.81	0.020
Pipe 4	140	0.01	6.67	0.43	1.39	0.020
Pipe 5	125	0.01	6.23	0.51	2.12	0.020
Pipe 6	75	0.01	1.39	0.32	1.71	0.025
Pipe 7	50	0.01	0.49	0.25	1.86	0.030
Pipe 8	110	0.01	3.79	0.40	1.60	0.022
Pipe 9	90	0.01	3.02	0.48	2.82	0.022

Fig. 3. The characteristic elements of the network

The hydraulic model ran 24 hours, considering a one-hour time step to check the network in normal functioning conditions.

The initial data introduced in the programme are: lengths, diameters, material-dependent roughness, land elevations at nodes, flow capacity at nodes (base demand), time variation consumption graphs (patterns), reservoir levels, etc.

After running the programme, the following data are obtained: flow capacity/rate on sections (l/s), speeds (m/s), headlosses (m/km), piezometric elevations (m), available pressures. (m).

There follow some suggestive graphs on the resulting data.

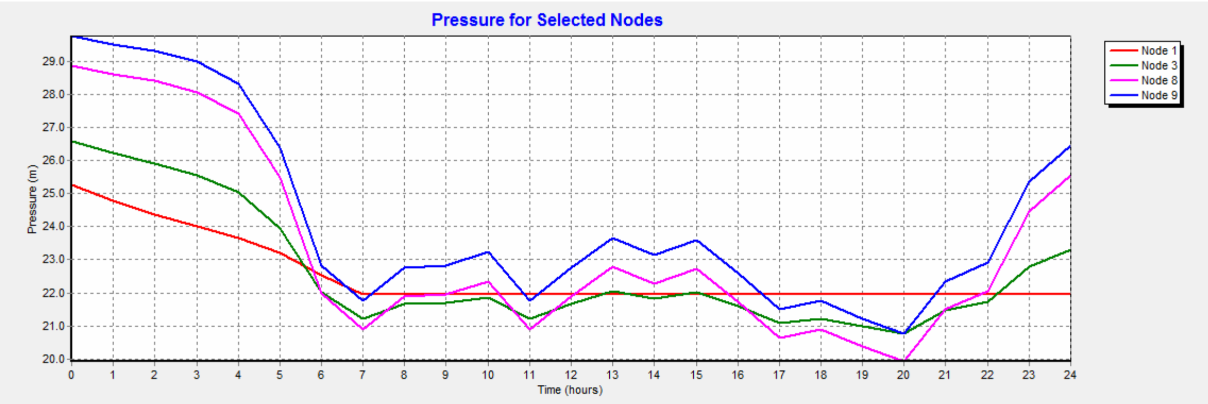


Fig. 4. Resulting pressures graph

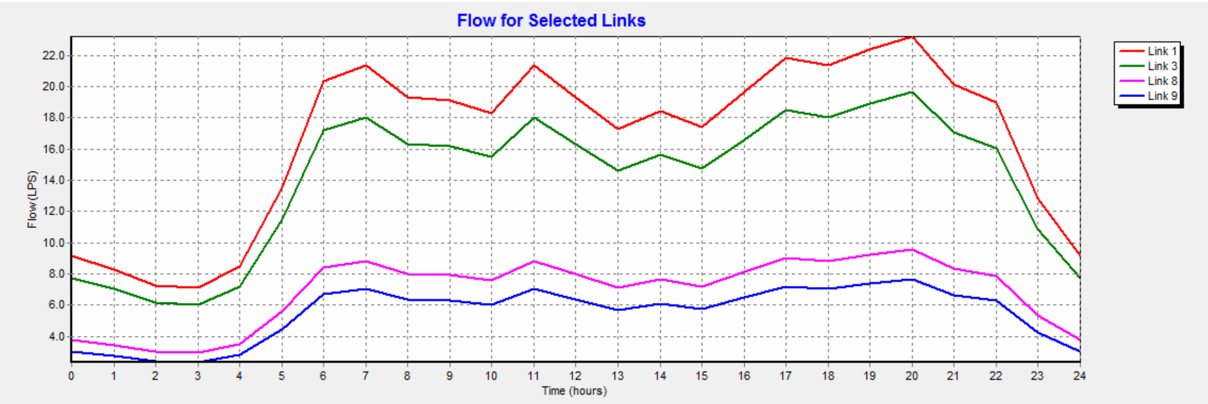


Fig.5. Resulting flow graph

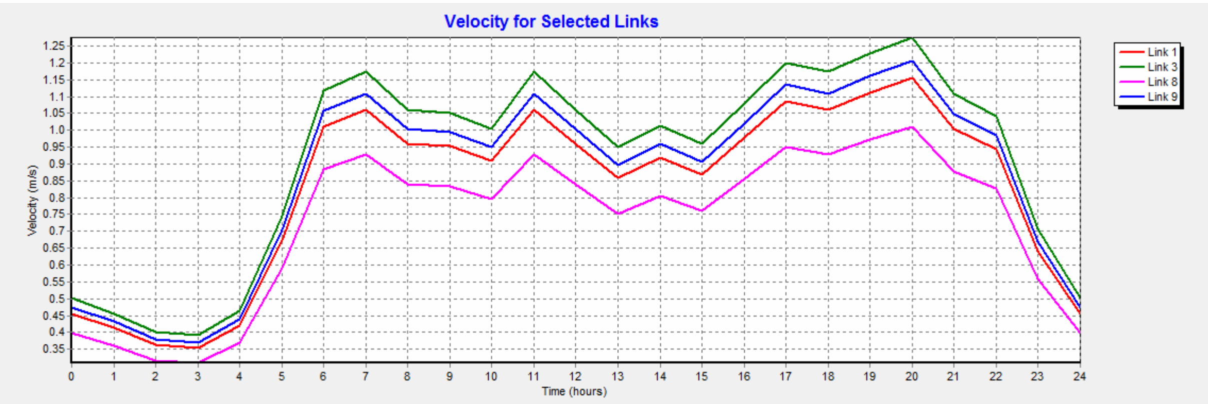


Fig.6. Resulting speeds graph

4. Conclusions

With a view to the alignment with UE standards, the implementation of a GIS system in the management of water/sewer systems represents an important decision-making support that makes the control and modelling of the distribution networks functioning possible.

By using Epanet programme the simulation of the hydraulic parameters depending on the specified exploitation rules was accomplished for a fixed period of time.

Some of the advantages offered by modelling the functioning of the water distribution networks by means of Epanet programme are:

- reaching an optimum exploitation by optimal control;
- enabling the analysis of the optimization of the system with a view to its modernization;
- enabling the analysis of the SP power reductions depending on the water storage in the reservoirs and the differentiated electricity tariffs.

In relation to the classical methods that take the network maximum loading regime as point of reference, modelling the water distribution network functioning helps get necessary data in adopting the most efficient decisions that aim at the optimum development of the respective system.

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