MONITORING PIPELINES UNDER PRESSURE USING GIS MODELS

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Abstract
The paper presents studies and researches realized in the purpose of monitoring with GIS models of the pipeline networks for the transport and distribution of drinking water. The paper treats in particular the pipes equipped with hydrants for extinguishing the fire. The monitoring is carried out on all the components of the network with the highlighting of the structural and functional condition. A detailed analysis is carried out for the hydrant network on the structural condition and the way the fire protection areas are covered. The paper presents the results of the configuration of the GIS model for the hydrant network with specialization on types of construction and their function in the served area. The paper highlights the unsatisfactory condition of the old pipeline networks, where hydrants do not provide parameters appropriate to the exploitation process.

Keywords
Database, urban cadastre, fire flow, hydrant, available pressure, protected area.

1. INTRODUCTION

The GIS model for a water utility applied in urban cadastre is a schematic representation of all the components of the water supply network and the elements forming part of the real estate cadastre [1]. The elements that make up the pipeline network are transposed into the GIS environment using computer programs that help integrate, interpret and simulate them. The GIS model applied to distribution networks located in localities is differentiated according to the structure and functional parameters of the consumer. In case of presence of fire for extinguishing hydrants on the pipeline network are made a series of special components in the structure of the GIS monitoring model [2].

The distribution of hydrants on a pipeline and implicit in a fire protected area implies a particular importance in the realization of the GIS model. The mode of endowment of the fire hydrants network in urban areas is indicated by the normative P 118/2-2013 [3]. In rural areas, the GP 106-2004 design guidelines are followed [4]. Hydrants mounted on the pipe network must provide flow and pressure parameters necessary to extinguish the external fire. Hydrants provide protection in case of fire for a wide range of buildings classified according to their destination: civil, administrative, social, cultural, industrial, annexes, etc. Within a locality and in particular in an area built as one unit (example: a neighborhood) there are sets of houses differentiated by the height regime. The height regime for the study areas analyzed in this paper is P + 1, P + 1E, P + 4E, P + 10E.

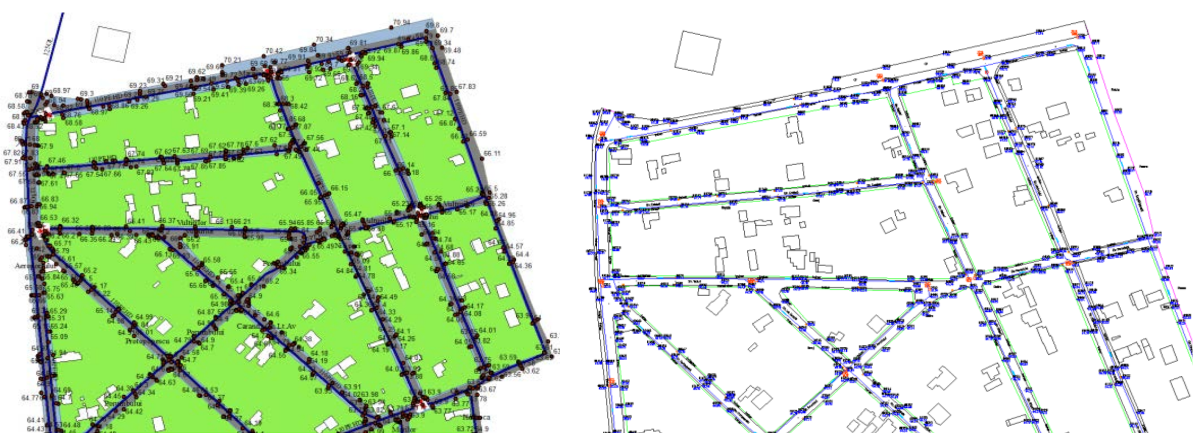
The monitoring model with GIS systems confers great importance to the way the hydrants are located on the pipeline. Changes over time in design standards and norms have determined the location of different hydrants depending on the type of locality (urban, rural) and functional pipeline parameters. By placing them, hydrants must cover the protected areas, be accessible and provide the required fire extinguishing parameters. According to P 118/2 - 2013 the flow rate of an external hydrant is considered to be 5-10 l/s and the minimum pressure is 0.7 bar [3].

In the specialty literature there are presented a series of studies on piping networks with hydrants. Thus, Nisanci R., (2010) used the GIS system to analyze the production of a dynamic fire that improved the fire database [5]. Chevalier et al. (2012) in Belgium have used a special GIS approach to locate areas where fire occurs in accordance with hydrant pipeline parameters [6]. Furkuo E., Quaye-Ballard J., (2013) analyzed the implementation of a GIS model in order to identify optimal intervention routes from the Fire Brigade Headquarters to the location of fire [7]. Montasir M., (2015) has developed a distribution system model using the EPANET program, thus calculating flow, pressure and speed with this software [8], also using data from the census and Ramesh H. et al., (2012) presents a hydraulic simulation of the parameters of the water supply network using GIS and the EPANET program [9].

2. THE TECHNIQUE TO REALIZE GIS MODELS

The study area considered in the research is located in the eastern city of Iasi and is represented by a neighborhood with an average extension. The pipeline network in this area has been attached to a special GIS model, made by working on a component such as a real estate cadastre with a urban cadastre for water utility component.

The part of the urban cadastre for water utility is composed of the water supply network and the characteristic constructions. The location and parameters of the water supply network were taken from S.C. APA VITAL S.A. Iasi. The pipeline network with all special constructions was imported into the ArcMap environment (Figure 1). The pipeline network has been processed and supplemented with constructive features and functional parameters for all components. The component of the GIS model represented by the real estate cadastre is composed of the street network and elements that constitute the buildings in the study area. Their processing required field studies, topographic measurements, data updates for buildings and streets, the definition of the type of building, etc. The data obtained from the studies were introduced into the GIS system, where thematic layers were created for different entities [10].



a b

Figure 1. Viewing the GIS model in different programs: a – ArcMap; b – Autocad Map 3D

The GIS model created for the pipeline network in the study area was processed in the first step in the Autocad Map 3D program by importing the measured points and connecting them according to the codes specified during the measurements. Characteristic layers of the GIS are represented differently according to the type of geometry and the information they hold (Figure 2).

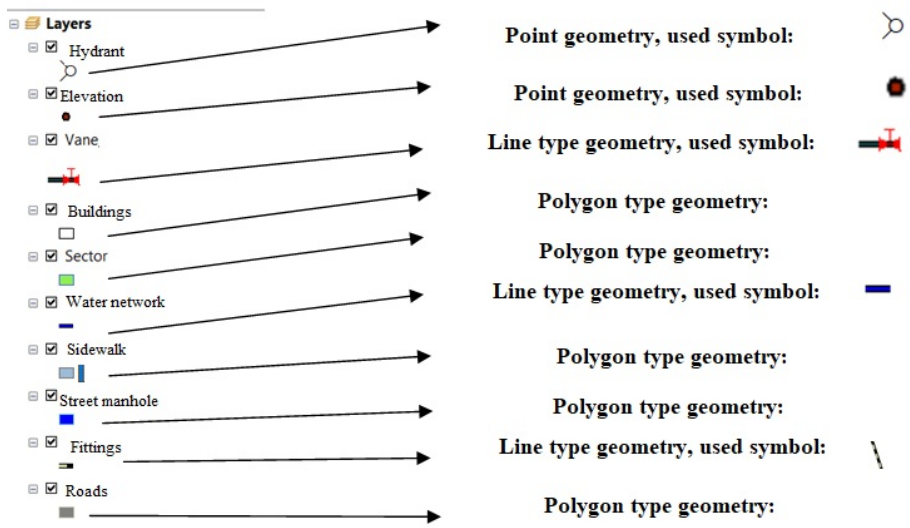
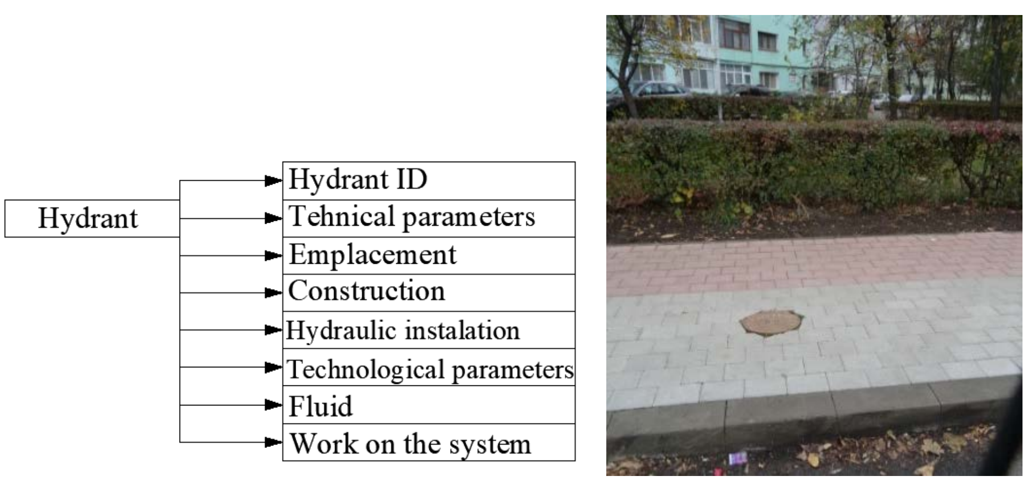


Figure 2. Characteristic layers of the GIS model

Each layer has graphic information attached to it. A detailed analysis was carried out for pipes equipped with fire hydrants. The collection of data on the constructive and functional characteristics of the hydrants was based on the design documentation, the water company's operating documentation, field studies and prospects of the hydrant manufacturing companies.

A number of 15 hydrants are installed on the pipeline network in the study area. For them data was collected about location, construction parameters (type, material, diameters, number of couplings) and functional parameters (flow, service pressure) were collected. To make the GIS model, it is important to fill in the tables attached to them with other important information in the interpretation and query process. Thus, information has been attached regarding the elevation of the land set up by the rehabilitation of the sites following the modernization of the streets and sidewalks, the green spaces; data on the year of commissioning, rehabilitation works, modernizations, etc. The field study included the realization of photographic surveys that were attached to the characteristic layers (Figure 3).



a **b**

Figure 3. Characteristic data for the street hydrant network: a - the set of layers for characterization hydrant in the GIS model; b - street hydrant mounted on the rearranged (sidewalk) traffic area

3. CASE STUDY – NETWORK UTILITY WITH HYDRANTS IN "AVIATION PLATEAU" AREA OF IASI

The monitoring of pipeline network parameters with street hydrants is of high interest, being correlated lately with the high rate of urban fires [11]. The correct operation of the street hydrants also influences the correct operation of the Fire Emergency Inspectorate in case of fire. A custom GIS monitoring system for the hydrant pipeline network contains a number of additional information that is continuously improved. The monitoring system can be used by the water-sewerage company in collaboration with ISU, as well as other public or private units that manage fire protection and fire extinguishing.

The study comprised the following steps:

- **Stage I**: Selection of study area and collection of characteristic data from cadastral and urban cadastre documentation. The collected data is processed by field of study and entered into the GIS monitoring model.
- **Stage II**: Establishment or improvement of the real estate cadastre by detailing the type of construction, the conditions of fire behavior, special human issues during fire, highlighting areas with high fire risk, etc. Data is processed and entered on layers in the GIS model.
- **Stage III**: Preparation or improvement of urban cadastral for water utility data by detailing pipe location data, piping type, hydrant position, hydrant type and design parameter, hydrant functional parameters, coverage area, hydrant distances on street location, their current structural condition, access conditions, time interventions for repairs, etc. The data is processed and entered into the GIS monitoring model.
- **Stage IV**: Establishing or improving data on the provision of circular paths of the study area of actual dimensions, type of coverage, road condition, etc.
- **Stage V**: Drawing up scenarios on fire behavior of hydroelectric equipment attached to a real estate area. Simulation of scenarios defining the coverage of high fire risk areas. The data obtained from the simulations (graphical part and descriptive part) are entered on layers specialized in the GIS monitoring model. The GIS model becomes a component of the various entities involved in the management of fire in real estate.

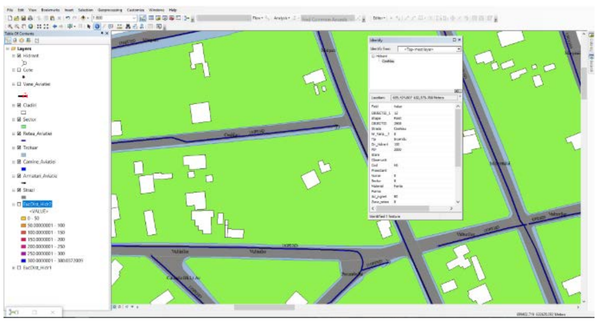
All five stages were completed during 2017 and the collected data was processed and entered into the GIS monitoring program. Several different analyzes were made in the area of study on the field, namely social, economic, political and environmental. They contributed input data to simulation scenarios.

The case study, drawn up in a sector of the city of Iasi, namely "Aviation Plateau", highlights the current exploitation of the hydrant network and the rehabilitation opportunities. The "Aviation Plateau" sector is a housing district with an expansion in the current period. The neighborhood is a junction between the "old town" and the modern city. The study area is occupied with buildings, mainly residential, but also a small number of commercial and social spaces. The height regime on the study area is ground floor (P), ground floor and floors (P + 2E, P + 4E, P + 6E) etc. Street network are made up of main and secondary streets with the presence of sidewalks of varying sizes and limited areas to the property fence.

In the third stage of the study a field research was carried out to identify the hydrants located on the pipeline network. For each hydrant, the current structural state and how to meet the fire extinguishing parameters were analyzed. The research resulted:

a) On the Airport street, main street, there was a small number of fire hydrants, of which only a part were active. Thus, on the Airport Street, out of four hydrants in the GIS monitoring program, only three were identified. One of the hydrants, which appears in the GIS model, is not properly signaled and was not found on the ground.

b) On the Ceahlau street, secondary street, was found the state of degradation of the structure of the hydrant identified by the code H6 (Figure 4). The hydrant is partly covered with asphalt, so in the case of a fire, the layer must be removed beforehand, an operation that makes it difficult for the firefighters to perform.



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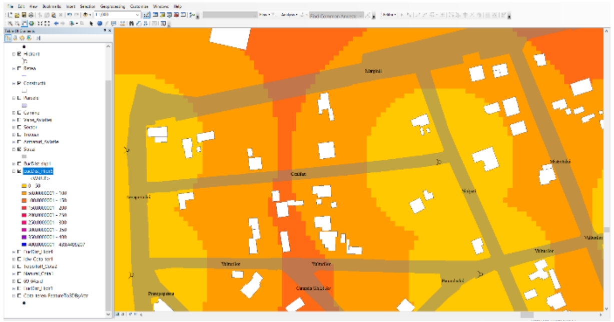


b

c

d

Figure 4. Hydrant identification of H6: a - Viewing textual data in ArcMap; b - Visualization of fire area coverage; c - detail on the state of the hydrant; d - general view of Ceahlau str., Iasi

c) The H13 hydrant on the Aurel Vlaicu street is not properly signposted. The structural condition is degraded (the cover of the box is missing), which facilitates access to the hydraulic system. The upper part of the hydrant is not maintained, and the mark is temporary and can be removed. It is also located on a degraded pavement, which can lead to loss of stability of the hydraulic installation over time (Figure 5).

For the study area, three simulation scenarios were developed that were run using the Epanet and ArcMap programs. Scenarios had the following themes:

- **Scenario 1** - this tracked the operation of the pipeline network according to the current state for hydrant on extinguishing the fire.
- **Scenario 2** - it analyzed the operation of the pipeline network with the hydrants currently in operation.
- **Scenario 3** - it analyzed the operation of the pipeline network with the addition of additional hydrants according to the results obtained from Scenarios 1 and 2.

The pipeline network of the neighborhood is fed from the reservoirs in the Sorogari area. Hydrants on water supply pipelines in the Aviation Plate area can be monitored using GIS models based on textual data attached to graphics entities. Program input data can be permanently updated and can be used to perform field interventions when fire is extinguished. The GIS model can be administered jointly by the water-sewerage director, the ISU, and other fire-fighting entities.

a **b** **c**

Figure 5. General view and details on the status of street hydrants: a - Overview Aurel Vlaicu street; b - interior details of the box; c - detail on the position of the sidewalk

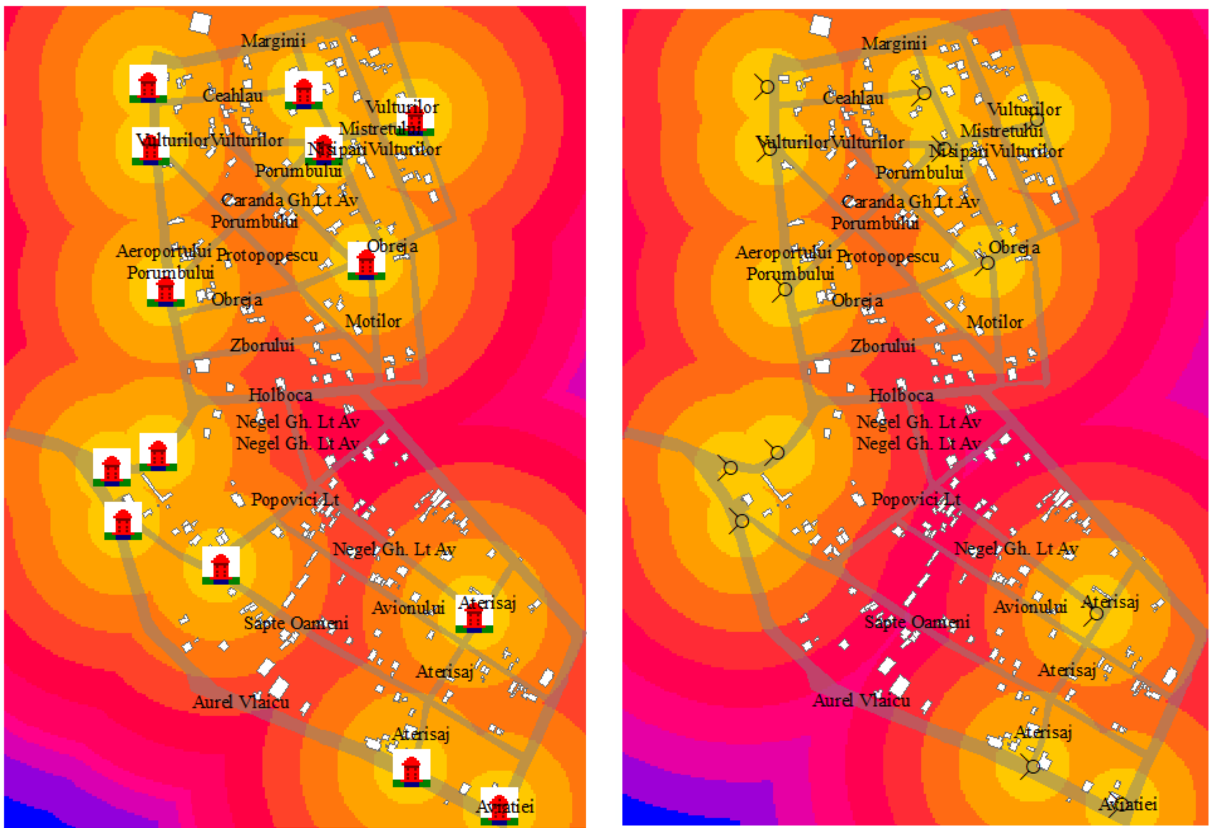
From the analysis of the data obtained by running Scenario 1 results in a series of observations and conclusions. A first result is the definition of hydrant coverage in the event of a fire in the "Aviation Plate" area. In the ArcMap program, the questioning of hydrant data was carried out to determine the coverage area of the area occupied by different constructions. The program has used buffers based on mathematical tools to measure distances. Thematic colors were used to highlight the coverage areas. Thus, the yellow color defines the coverage area of 0-50 m (50 m radius); orange color defines the coverage area of 50-100 m (hydrant working range up to 100 m), etc. The analysis shows that the sector located between the Lieutenant Aviator Gheorghe Negel streets, Lieutenant Popovici street, Aviation street and Holboca street presents the most difficult fire-fighting problems.

The "Scenario 1" simulation, where all hydrants initially located on the pipeline network are functional, has experienced a situation of unrealistic action in the event of a fire. The data collected from the technical documentation show that the hydrats on Seven People street are located too far away. This technical aspect does not meet the standards and norms in force (P 118 / 2-2013). On this street, according to the initial data from the GIS model, two hydrants are located. Following the field inquiry, it was found that one of the hydrants was canceled on this street. From the results of the fire simulation, it results that a single hydrant is insufficient to provide the water needed in case of fire (Figure 6 a).

The simulation in "Scenario 2", which included existing and operating hydrants, presented a disadvantageous situation for the occupied area but also for civilian buildings in case of fire. Analysis of textual and graphical data shows that some of the streets of Aurel Vlaicu, Seven People, Lieutenant Aviator Gheorghe Negel, Lieutenant Popovici, Aviation and Holboca have reduced coverage in case of fire. The results obtained through the simulation indicate the directions of rehabilitation of the pipeline network and especially of the fire extinguishing hydrants network.

The results of scenario 2 indicate the location of new hydrants to cover areas affected by fire, to reduce the distance between hydrants, etc. (Figure 6 b).

The results obtained through in Scenario 2 of the fire simulation in the study area reveal the need for more detailed monitoring of the pipeline networks in the urban water supply systems. Also, the need to permanently complete the data obtained through a continuous field inspection of the hydrant network. It follows that the GIS monitoring model needs to be updated continuously through various means of querying the pipeline network with hydrants in the field.



a **b**

Figure 6. Fire hydrant coverage range: a - Scenario 1; b - Scenario 2

The results obtained from the simulations performed with Scenarios 1 and 2 indicated the importance of maintenance of the hydrant network, their marking on the ground, the need to be placed in spaces accessible to fire engines, etc. It also resulted in an in-depth analysis of the correlation of the parameters offered by the street network with the position and accessibility of hydrants in case of fire. In this case, the relevant legislation needs to be improved to ensure the most accurate fire-fighting conditions.

The research presented in the paper is in full swing in the current period. Research seeks to address specific scenarios for the operation of the pipeline network for water supply to urban areas in the event of fire. The simulations include special rehabilitation of pipes equipped with fire hydrants (changing diameters, changing material, improving hydraulic performance, new pipeline routes, etc.) to meet flow and pressure requirements.

4. CONCLUSION

1. GIS models can be used in a unitary way to monitor the water supply system, but also separately for each municipal building.

2. The monitoring of the constructions and special installations through the GIS model is done according to the data attached to them, where the analysis carried out in the case of hydrants on fire scenarios was based on alphanumeric data combined with graphical data.

3. Modern technology evolves continuously, requiring GIS models to be improved over time by interconnecting different databases and updating work schedules to meet the demands demanded by consumers.

4. The GIS models presented are being developed and improved in various programs to identify a wide range of problems in the exploitation process, but also to make forecasts on how urban fires appear, evolve and stops. The GIS monitoring model should work together with redesigned pipeline networks for water transport to optimize network performance forecasts in various operating situations.

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