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APPLICATION AND DIGITAL IMPLEMENTATION GIS DATA TO COMPUTER MODELING OF THE SANITARY SEWAGE NETWORK IN PODLASKIE VOIVODSHIP

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ABSTRCT: The paper presents the results of computer modelling of sanitary sewerage networks in selected towns of the Podlasie Voivodship.The calculation process of the design and operation of the sewerage network is labor-intensive and time-consuming, and it becomes necessary to use information technologies in the design process. Computer-aided design streamlines the entire process and enables a more accurate analysis of the work of the designed system. Nowadays, there is a growing interest in computer modelling. The concept of computer modelling is the construction and study of models that map reality or only a fragment of it. In practice, this is the main procedure used for research seeking to determine the behaviour of operational reality in given conditions. Computer models give the possibility to verify design assumptions and network operating conditions. Thanks to them, there is an opportunity to control real flows during operation.

KEY WORDS: computer modelling of sewage networks

JEL: C63, C88

Introduction

The paper presents the results of computer modelling of sanitary sewerage network in Łapy. It is a fragment of research carried out in sewerage networks in selected towns of the Podlasie Voivodeship (Łapy, Sokółka, Michałowo, Supraśl, Czarna Białostocka). The sewer networks selected for research are represented by characteristic systems built in the communes of north-eastern Poland.

The calculation process of the sewerage network design is labor-intensive and time-consuming, especially for large sewer systems. Therefore, it becomes necessary to use information technologies in the design process. Computer-aided design streamlines the entire process and enables a more accurate analysis of the work of the designed system. Nowadays, there is a growing interest in the use of computer modelling in municipal enterprises. The concept of computer modelling includes building and researching models that mimic the actual work of the network or just a fragment of it. Computer models give the opportunity to verify project assumptions and simulate network operating conditions. Thanks to the appropriate amount and quality of the output data, computational methods are real and real (Dziedziela, 2010; Dziobak, Mrowiec, 1999; Sołtys, Stec, 2014).

The Geographic Information System (GIS) is the basic tool for collecting and processing spatial information. GIS improves the management of large amounts of data related to computer models. Thanks to this technology, it is possible to combine databases with visualization and spatial analysis (Nowatorska, 2009). At work, QGIS was used to process digital spatial data. It is a popular and fully functional platform type GIS, which also gives the possibility of combining processed data with software, e.g. for modelling sewer networks (Kędzia, Ociepa, 2015).

Storm Water Management Model (SWMM) was used for the modelling process of the tested sewer networks. SWMM was developed by the US Environmental Protection Agency (US EPA). The program is made available under an open source license. It is a fully functional tool for making computer models of sewage networks (Nowakowska, Kotowski, 2017).

Research object

Sewage system in Łapy – Population 16000 (http://www.lapy.pl). In the city and commune of Łapy, the sewerage network has 10 villages (out of 24 in the commune) and the whole city of Łapy. The commune is canalized in 87% in relation to the number of households. In the municipality of Łapy, the

length of the sanitary sewage system is 83.2 km, draining sewage from the village of Łapy and the villages of Łapy Szołajdy, Łapy Dębowina, Gąsówka Osse, Uhowo, Łapy Pluśniaki, Łapy Korczaki, Łapy Łynki, Gąsówka Oleksin, Gąsówka Stara and Łapy Kołpaki. Wastewater is directed to a sewage treatment plant with a design capacity of Qdśr=10000 m^3/d located in the village of Łapy. The treatment plant applies mechanical and biological treatment with two-stage biological treatment based on the activated sludge method and final or simultaneous phosphorus precipitation using a PDC coagulant. Sludge treatment and its final disposal is carried out through the use of compaction, fermentation, mechanical dewatering and hygienization processes using lime. The Receiver of treated wastewater is the Awissa River (Brzosko, Danowski, 2010; http://www.lapy.pl).

Results of the research

The preparation of the model began with the implementation of a situation and altitude plan in the QGIS program. The map was made on the basis of the cadastral information of the Białystok poviat located on the website http://bialystok.geoportal2.pl and digital foundations obtained for scientific purposes from the Poviat Office for Geodesy and Cartography in Bialystok.

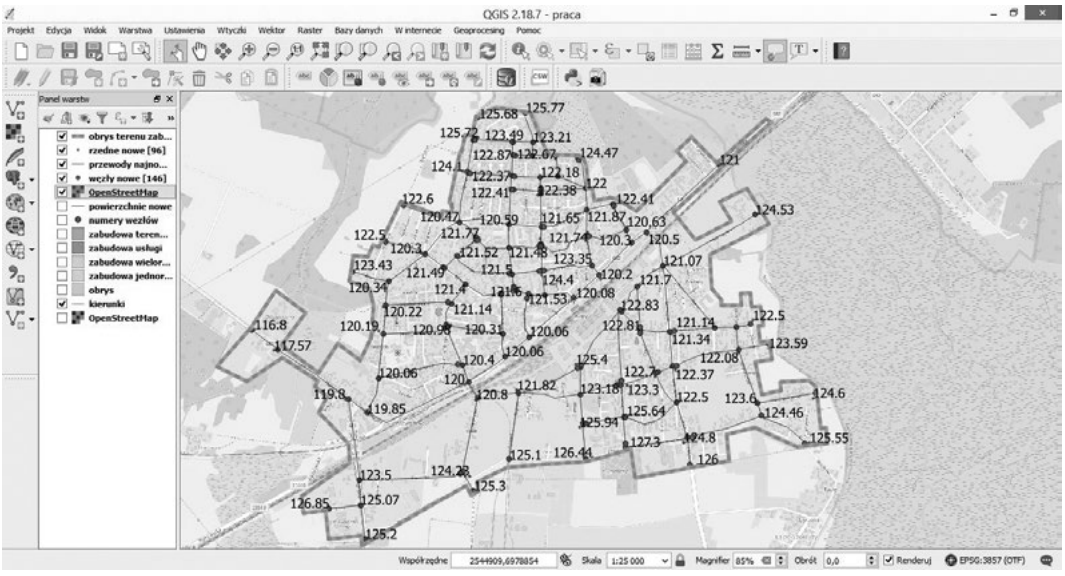

Figure 1. Sewage network of the city of Łapy with elevated land elevations in the QGIS program

Source: (Tomaszewska, 2017, p. 50; Nowotarska, 2009).

In the work, three variants of computer simulations of the tested sewage network were made. The first variant presents the existing state of the sewerage network in Łapy, based on data and completed with calculations. In the next variant, the changes of selected wire diameters and the effect of these changes on selected network parameters were simulated. In the third variant, changes were made to the depressions of selected sewage wells.

Variant 1

After simulation of a computer sewage system in the SWMM program, longitudinal profiles were generated and it was found that there are places in the tested network in which overfilling of manholes may occur.

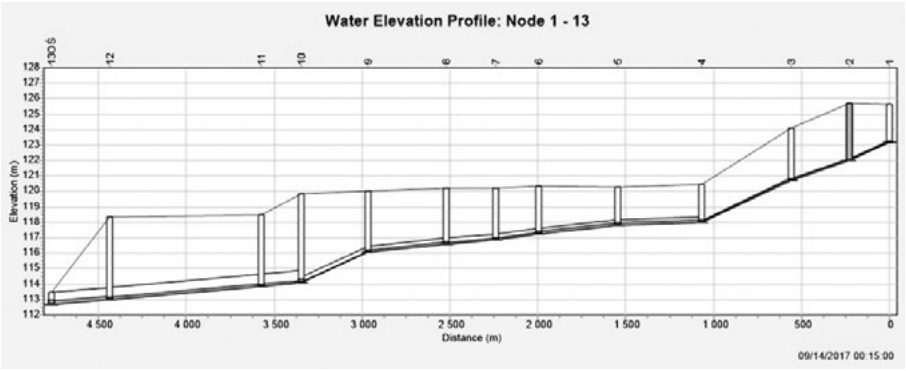

Figure 2. Longitudinal profile of a part of a sewage system in Łapy, showing the location of a full sewage weell, made in the SWMM program

Source: author's own work.

In the modeled variant 1, the simulation of wastewater flow velocity on its individual sections was started. It was found that the tested models of the wastewater velocity rates range from 0.01 m/s to 0.13 m/s.

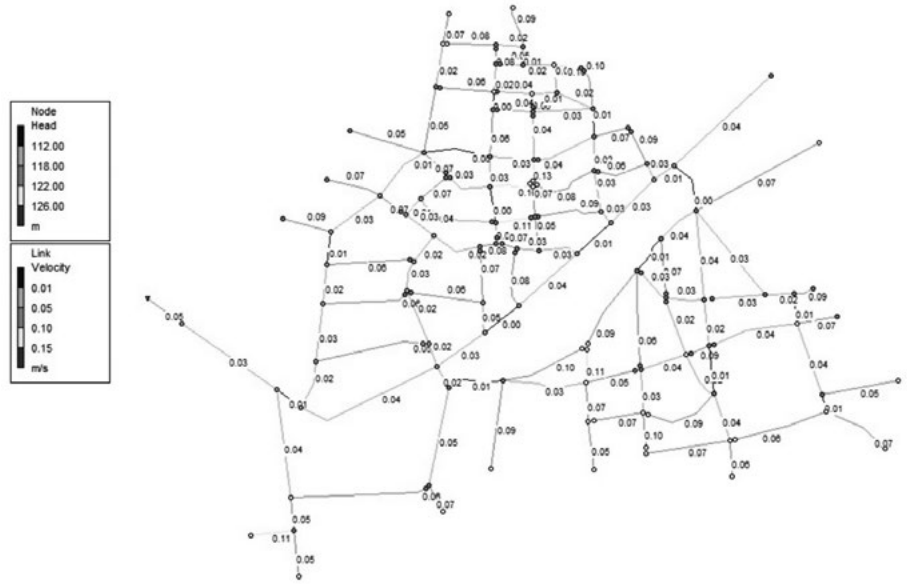

Figure 3. Results of modeling the speed of sewage flow in the first variant

Source: (Tomaszewska, 2017, p. 84).

Variant 2 – A model with the simulation of diameters change

In order to eliminate the overflow of sewage well, simulations were made to increase the diameters in selected sections of the analyzed networks.

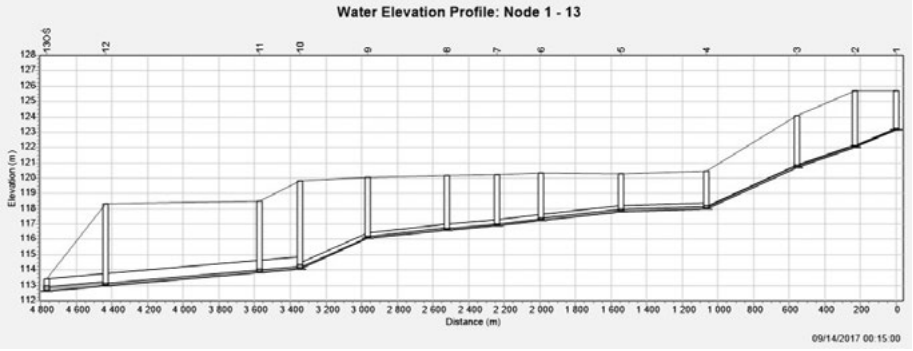

Figure 4. Longitudinal profile of a part of a sewage network in Łapy after increasing the diameters of selected sections of the network, made in the SWMM program

Source: author's own work.

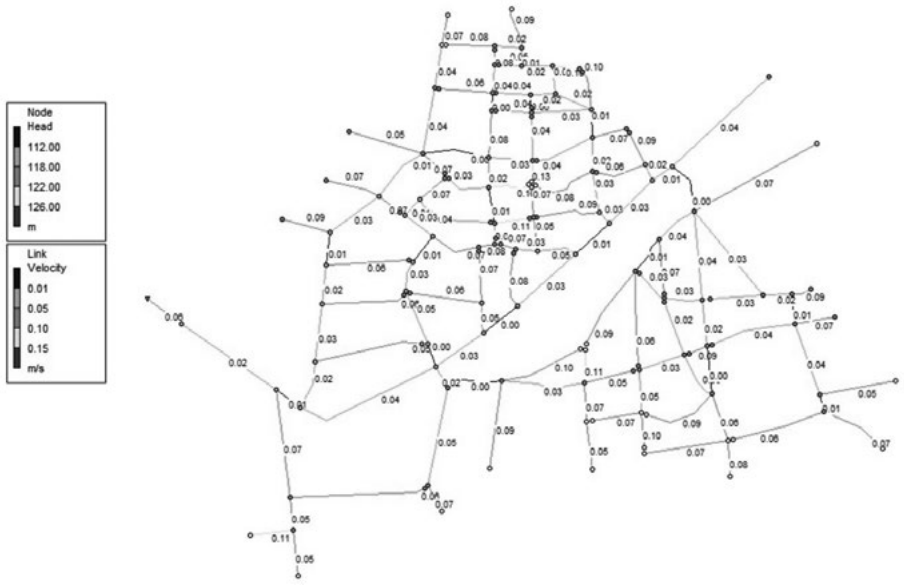

Figure 5. Results of modeling the speed of sewage flow in the second variant after changing the diameters of selected conduits

Source: (Tomaszewska, 2017, p. 85).

Variant 3 – A model with the simulation of changes in the hollows of selected sewer manholes

In the next simulation, in order to eliminate overflows of sewer manholes, the channel cavities were changed. As a result of such activities, the overcrowding has been liquidated.

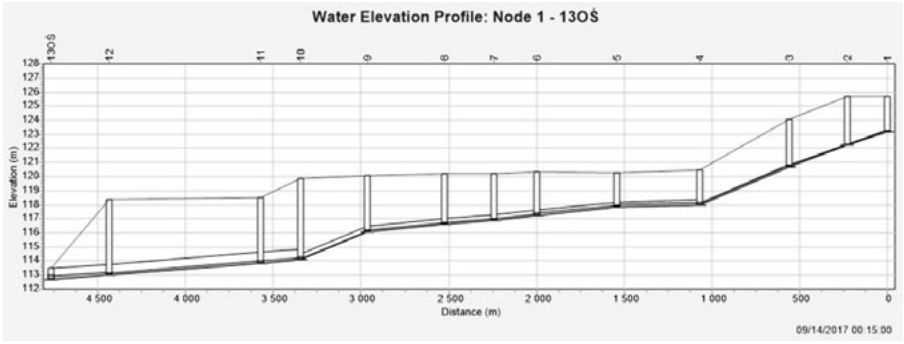

Figure 6. Longitudinal profile of a fragment of the sewage system in Łapy after changing the hollows of selected sewage wells, made in the SWMM program

Source: author's own work.

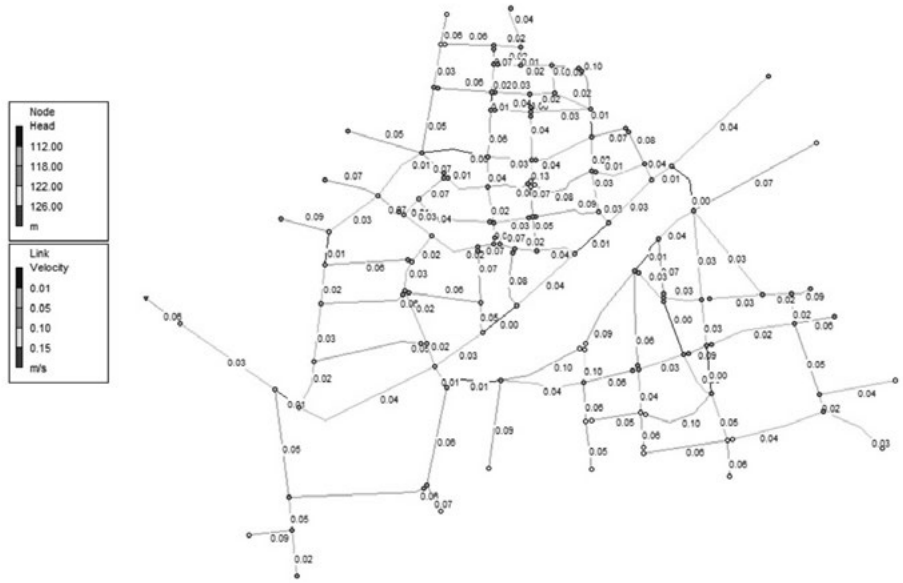

Figure 7. The results of modeling the speed of sewage flow in the third variant after the hollows of selected sewage wells

Source: (Tomaszewska, 2017, p. 86).

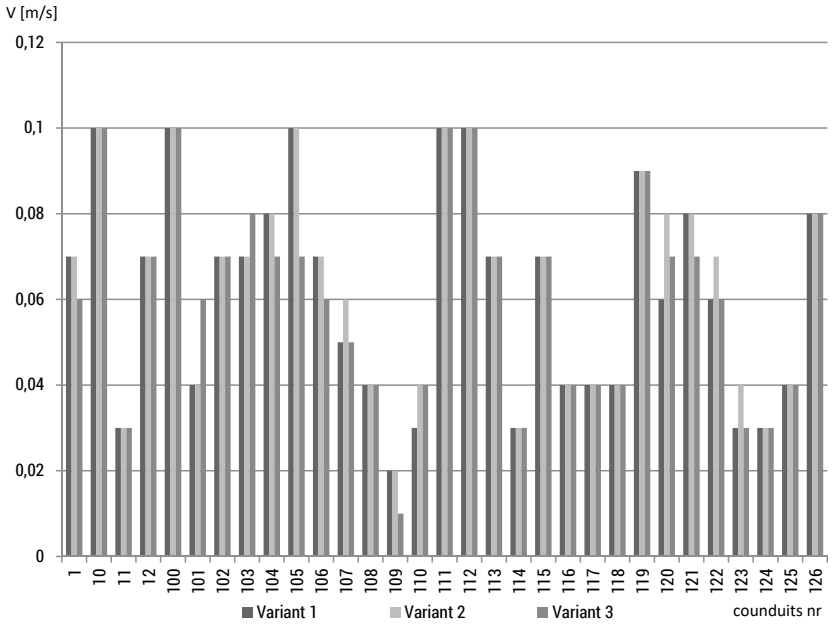

Figure 8. Part of the modeling of flow velocity in selected pipes of the modeled sewage network of the city of Łapy

Source: author's own work.

As a result of the simulation, the SWMM program found a solution to the problem of the possibility of sewage wells overflow in the sewer networks under investigation. When comparing the simulation results, it was found to what extent the change in pipe diameters or pit wells influences the flow velocity of the sewage in the lines of the tested networks.

Conclusions

Computer modelling of sewage networks is becoming more and more common, which results from the continuous development of technology in environmental engineering in recent years. Computer simulations give the possibility of mapping detailed conditions prevailing in the analyzed network. Under real conditions, obtaining such data is complicated and time-consuming. Simulations allow the selection of the most favorable variant of the designed sewerage network.

In order to carry out the simulation, techniques for processing digital geodetic data in the QGIS program were combined with computer modelling of selected parameters of sewage networks in the SWMM program.

The use of computer models in the design stage gives the opportunity to verify the design assumptions. It allows to check whether the designed network is able to drain the assumed amount of sewage and what the actual flows in the channels look like (Sołtys, Stec, 2014). Because of the computer models of sewer networks, you can: check the parameters of the network, plan changes in the network, assess the efficiency of operation, detect errors in the network and analyze the current work of the network.

The analyzed sewage network was checked for correctness of the pipe diameters and the sewage flow rate in the sewers. In places where the diameters have been chosen incorrectly, the sewer manholes were overfilled and the stretched sectional flow depended in a time unit. After the detection and elimination of errors, the simulation ran smoothly.

Because of the simulations and the results generated, the following conclusions can be made:

- computer modelling is a highly effective way to simulate the operation of the sewerage network,
- when designing a sewerage network, special attention should be paid to the selection of diameters, because too small diameters of pipes cause the creation of transfers in sewer wells and slow down the flow without causing significant changes on further sections of the network,
- carried out simulations allow to state that in the analyzed gravitational sewage system, the diameters used cause too low rates of sewage flow.

Acknowledgements

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The contribution of the authors

Wojciech Kruszyński – conception, literature review, acquisition of data, analysis and interpretation of data – 30%
Jacek Dawidowicz – acquisition of data, analysis and interpretation of data – 25%
Darisz Andraka – acquisition of data, analysis and interpretation of data – 25%
Joanna Tomaszewska – literature review, acquisition of data, analysis of data – 20%

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