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MODELING STORAGE CHANNEL USING SWMM 5 SOFTWARE

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Abstract
The paper presents an example of the hydraulic modeling of stormwater drainage systems using SWMM5 software. The presented example concerns a car park drainage using a gravitational drainage system directing stormwater to a water course with limited capabilities to receive it. Hydraulic modeling proved to be an effective tool to assess the retention capability of a sewerage system and to select appropriate design solutions which allow its increase. The article confirms the relevance of the dynamic wave routing to study the backwater effects due to flow throttling.

Streszczenie
W artykule zaprezentowano przykład wykorzystania modelowania hydraulicznego sieci kanalizacji deszczowej z zastosowaniem programu SWMM5. Prezentowany przykład dotyczy odwodnienia parkingu w systemie kanalizacji grawitacyjnej odprowadzającej wody deszczowe do cieku wodnego o ograniczonej zdolności do ich przyjęcia. Modelowanie hydrauliczne okazało się skutecznym narzędziem do oceny zdolności retencyjnej kanalizacji oraz do doboru rozwiązań projektowych pozwalających na jej zwiększenie. Wykazano przydatność modelu fali dynamicznej do badania zjawiska spiętrzania napełnienia występującego podczas dławienia przepływu.

Keywords: **Stormwater flow control; Numerical hydraulic model; Retention systems for stormwater sewers; Stormwater runoff.**

1. INTRODUCTION

The ongoing urbanization of land leads to the increase in volume and intensity of the surface runoff of stormwater and meltwater. These waters are often captured in tight sewerage systems constructed using modern technologies of pipes with smooth internal surfaces and can be quickly transported to collectors. In case when the collector is a water course, a sudden discharge of additional rainwater contributes to the creation of flood waves. In case when the collector is located the current drainage system, its capacity might prove inadequate. In order to prevent this sort of situations, various methods of stormwater retention in the system are used. A typical solution is to construct an underground or surface retention reservoir, usually situated just before the entrance to the collector. The imminent flaw in such a solution, besides the high cost of construction, is the area usage and susceptibility to silting with sedimentation sludge. The alternative is to use the retention capabilities of sewerage drains and manholes. A functioning retention system should limit the stormwater flow to a desired level without overflowing the drainage system. Using a computer hydraulic model of the drainage system is very helpful to optimize solutions.

Hydraulic modeling is currently becoming a significant tool in Poland, helpful with the analysis of water supply and drainage systems operation, however it is mostly applied in water supply network models. This is due to the character of such networks, where one can quickly show measurable results from lowering the investment and maintenance costs and increasing the reliability of water supply. One of the reasons behind such a high interest in water supply networks modeling is the unlimited access to the popular Epanet 2.0 software and a broad selection of commercial software. Simple models calibration using the data from permanent and temporary monitoring is an additional advantage. It can be said that while in the case of water supply networks, the period of initial fascination with the options provided by modeling is currently slowly but systematically transforming into specific operational advantages, in the case of sewerage systems modeling, such operational progress is still ahead of us. Currently, drainage systems modeling is mostly pursued by scientific institutions, however a growing interest in the part of operators can be seen, especially those who have already introduced water supply networks modeling.

It is possible not only to develop models of stormwater drainage systems, but also sanitary and combined sewers. A popular solution used for such purposes is the SWMM 5.0 software developed by the U.S. Environmental Protection Agency (similar to Epanet 2.0) including source codes for the computing engine and graphical user interface. Although the first edition of SWMM was completed in 1969-1971, it has gained significant attention after developing the 5.0 version in 2004, the first to work in the Windows environment. The software allows to make calculations for steady flow, kinematic wave and dynamic wave routing [1].

Steady flow routing allows the calculation for uniformed flow and is the simplest calculation model used in the software. This type of routing cannot account for channel storage, backwater effects, entrance/exit losses, flow reversal or pressurized flow.

Kinematic wave routing, compared to the steady flow routing, provides for the situation of sewerage overflow on the surface and its re-introduction to the conduit as capacity becomes available. In this case, the slope of the water surface equals the slope of the conduit.

The most advanced model available in the software is the dynamic wave routing, which accounts for unsteady, slowly variable motion based on the first order differential equations using the Saint-Venant and continuity equations. This routing accounts for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. Similar to the kinematic wave routing, it provides for the situation of sewerage overflow and its re-introduction to the conduit. Dynamic wave routing is therefore suitable for the simulation of channel storage.

Retention capability of the drainage system can be applied both to existing and designed systems. The first case is only possible if there is some spare capacity in the existing drainage system, in the other case, torrential rains may cause surface overflows from the system. A digital hydraulic model is a very helpful tool in assessing the retention capability of the existing drainage system. In order to assess such capability, the model must be calibrated using concurrent measurements of rainfall intensity as well as the fills and flows in the channel, performed at least in the designed location of the flow control system. The most reliable intensity measurement would be one of a design rain, however, due to a small probability of such a rain, the calibration can be performed for other intensities. The technical condition of channels and manholes as for the effects of the increased fill should be taken into account while designing solutions to use channel storage in the existing drainage system. Sewerage leaks will lead to increased exfiltration and might result in a dangerous washout of soil adjacent to the pipelines. It is also important to take the social and economic impacts of a possible overflow into account. In the case of a designed drainage system, modeling is helpful with the selection of appropriate channel dimensions as well as the location and type of flow control systems. Selecting an appropriate rainfall model will significantly impact the result of the hydraulic modeling of the drainage system [2, 3].

2. EXAMPLE

This example illustrates a drainage system for a car park with an asphalt surface and patches of grass, covering the area of approx. 3 ha (Fig. 1). The designed system discharges stormwater through outlet W0 to a watercourse located on the northern side of the car park. The collection channel bifurcates within manhole W5 into two channels girding the car park from North-West (W5-W14) and South-East (W5-W22). The amount of stormwater discharged to the collector cannot exceed 50 l/s for a 50% probability of occurrence.

When designing a new drainage system there is no possibility to calibrate the hydraulic model before it is built and therefore the accuracy of data entered into the model is very important. The recommended dimensioning process consists of three stages.

At the first stage the drainage model must be created, selecting channel diameters for operation in a network without an increased sewer retention. The results of the simulations performed for the first stage in SWMM5 software are shown in profiles along with

Figure 1.
Drained car park site plan

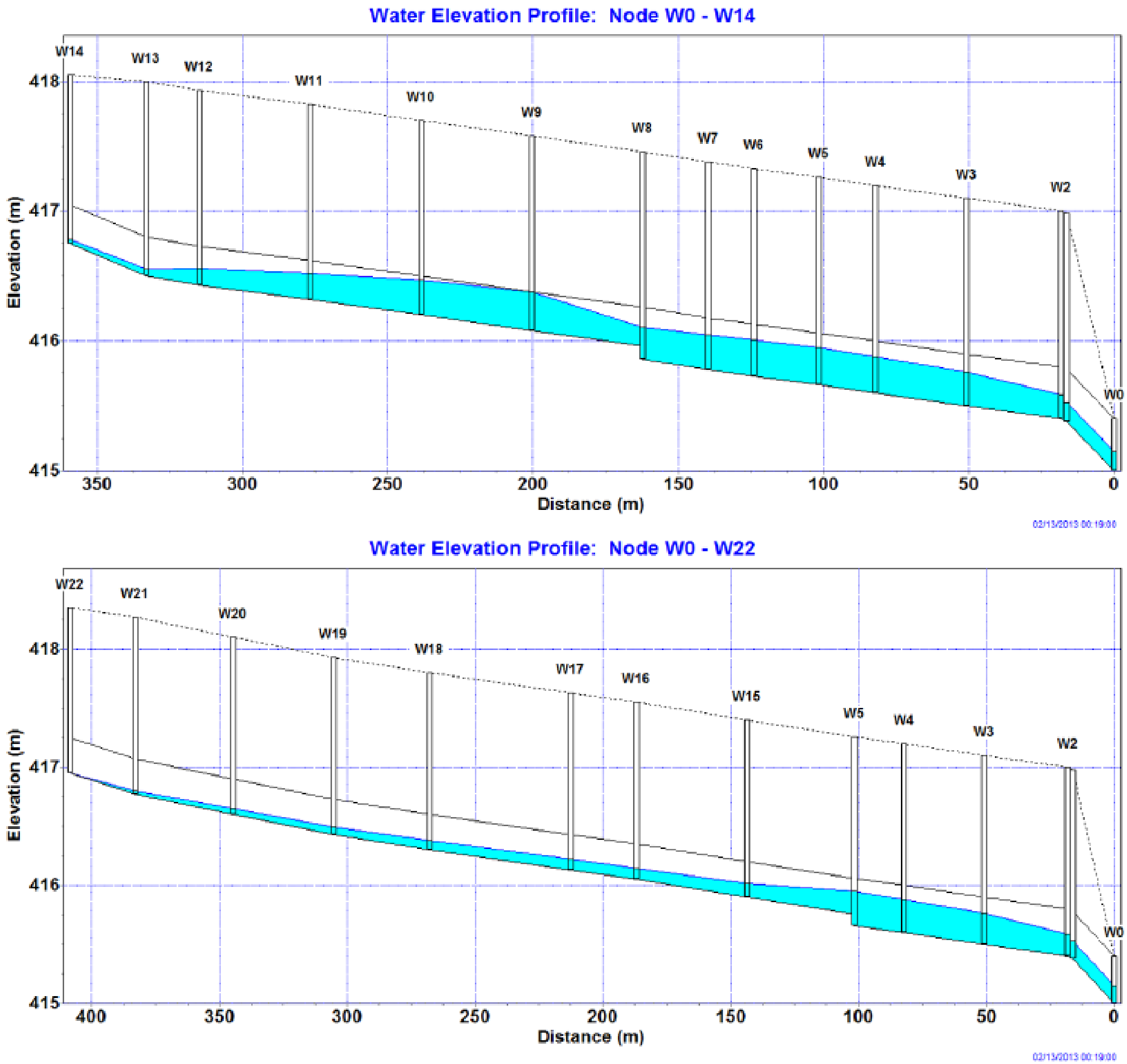

Figure 2.
Filling level profile in the sewers without an increased sewer retention: a) W0-W14, b) W0-W22

sewer filing level (Fig. 2). In the example, Ø400 diameters were used for the sewers from the collector to node W8. For the other sewers, Ø300 diameters were used as a recommended minimum for a stormwater discharge system. Sewers were faced along the upper edge, thus creating faults in manholes W5 and W8 at the joints of sewers with different diameters.

For such a design solution stormwater flows into the collector in an amount exceeding 160 l/s (Fig. 3) in the peak moment.

In the second stage of model creation, a flow control system must be installed in a selected manhole which can ensure that the stormwater discharge to the collector does not exceed permissible volume. For this

Figure 3.
Drainage system discharge hydrogram

example, the first manhole (W1) after the collector was chosen. A simple solution for throttling water

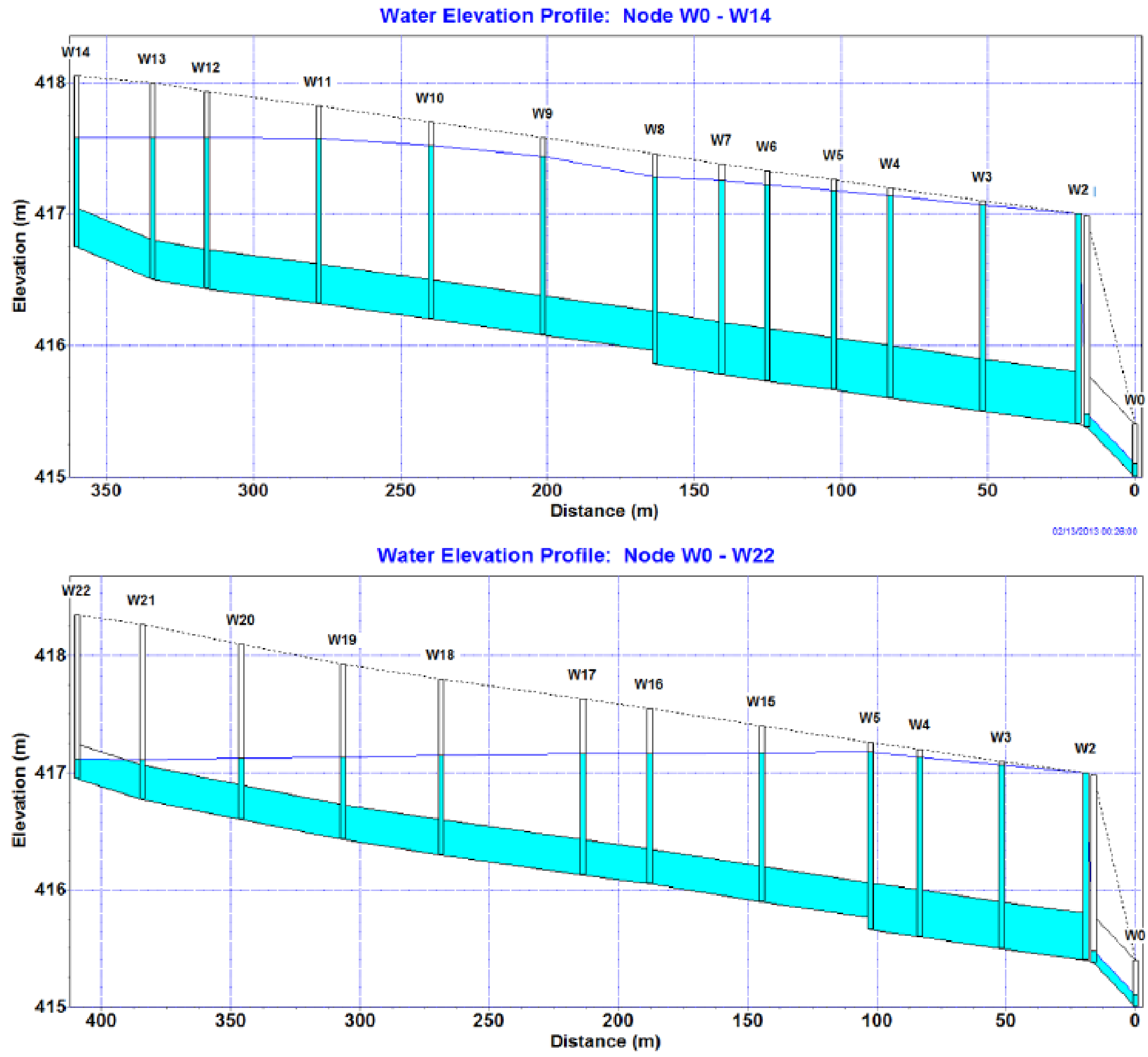

Figure 4.
The sewers filling profile after the flow control system was installed: a) W0-W14, b) W0-W22

flow by means of a round orifice with a 150 mm diameter was used. As shown in Fig. 4, in the analyzed variant a backwater effect occurred in the sewers located before the control system and a change from gravity flow into pressure flow happened. It can be seen from filling profiles that retention capacity of the sewers was fully utilized. The pressure line course indicates, though, that in the W2 area, before the control system, the build-up caused stormwater to surface, as a consequence of insufficient sewer retention capacity.

Therefore, in the third stage increased sewer diameters should be applied in order to improve the retention capacity. The sewer fillings results for the first selection variant were presented in Fig. 5.

In the analyzed case, pipes with increased Ø1000 diameters were used for section W2-W4, Ø800 for section W4-W6, Ø600 for sections W6-W8 and W5-W14, Ø500 for section W15-W16 and Ø400 for section W8-W9. Such a solution makes it possible to retain the entire stormwater in sewers, keeping the gravity flow as well as some unused retention capacity reserve. One may have doubts whether the increased diameter grading is beneficial from the technical point of view and whether the method of sewer facing is appropriate. In addition, the unused retention capacity reserve resulting from the applied sewer diameters increases the investment costs. In

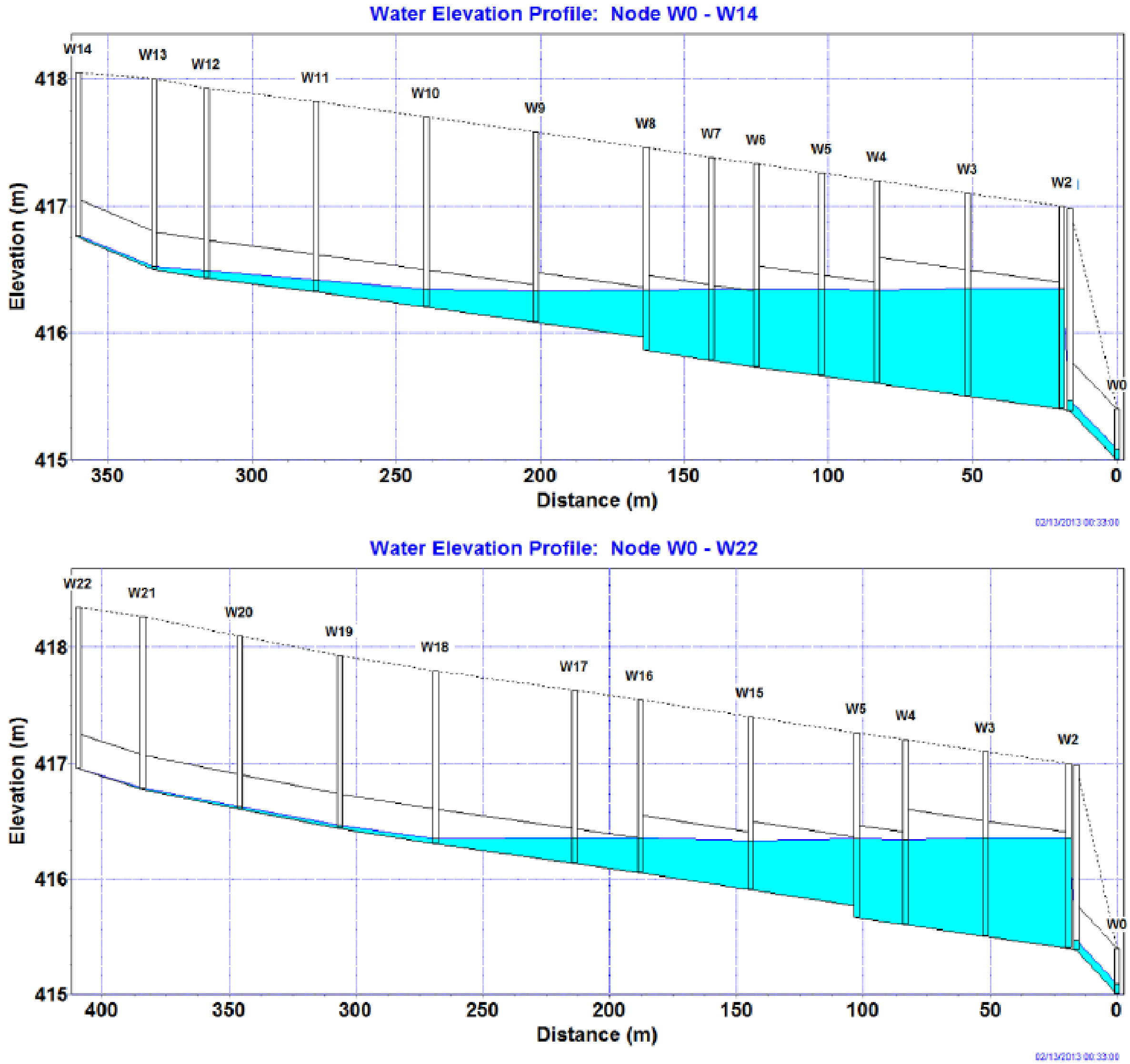

Figure 5.
The sewer filling profile after the flow control system was installed and sewer diameters were increased: a) W0-W14, b) W0-W22

the second variant, in order to simplify the solution, pipes with Ø600 diameter have been used which increases the retention capacity of the designed discharge system. These diameters were used in sections W2-W8 and W5-W16. Filling profiles for this variant are presented in Fig. 6.

The results of the simulation indicate that the level of sewer retention capacity utilization is higher than in the previous variant. In all of the sections, pressure flow is maintained and the backwater effect occurs in manholes. As the total sewer retention capacity is lower than in the preceding variant, the hydrostatic table line is maintained at a higher level and therefore the retention capacity of the pipes located higher is used, too. This variant is simpler and more economical – therefore sufficient for the model used.

The utilization of increased sewer retention results in flattening the flow hydrogram as well as significant extension of time for stormwater discharge into the collector (Fig. 7).

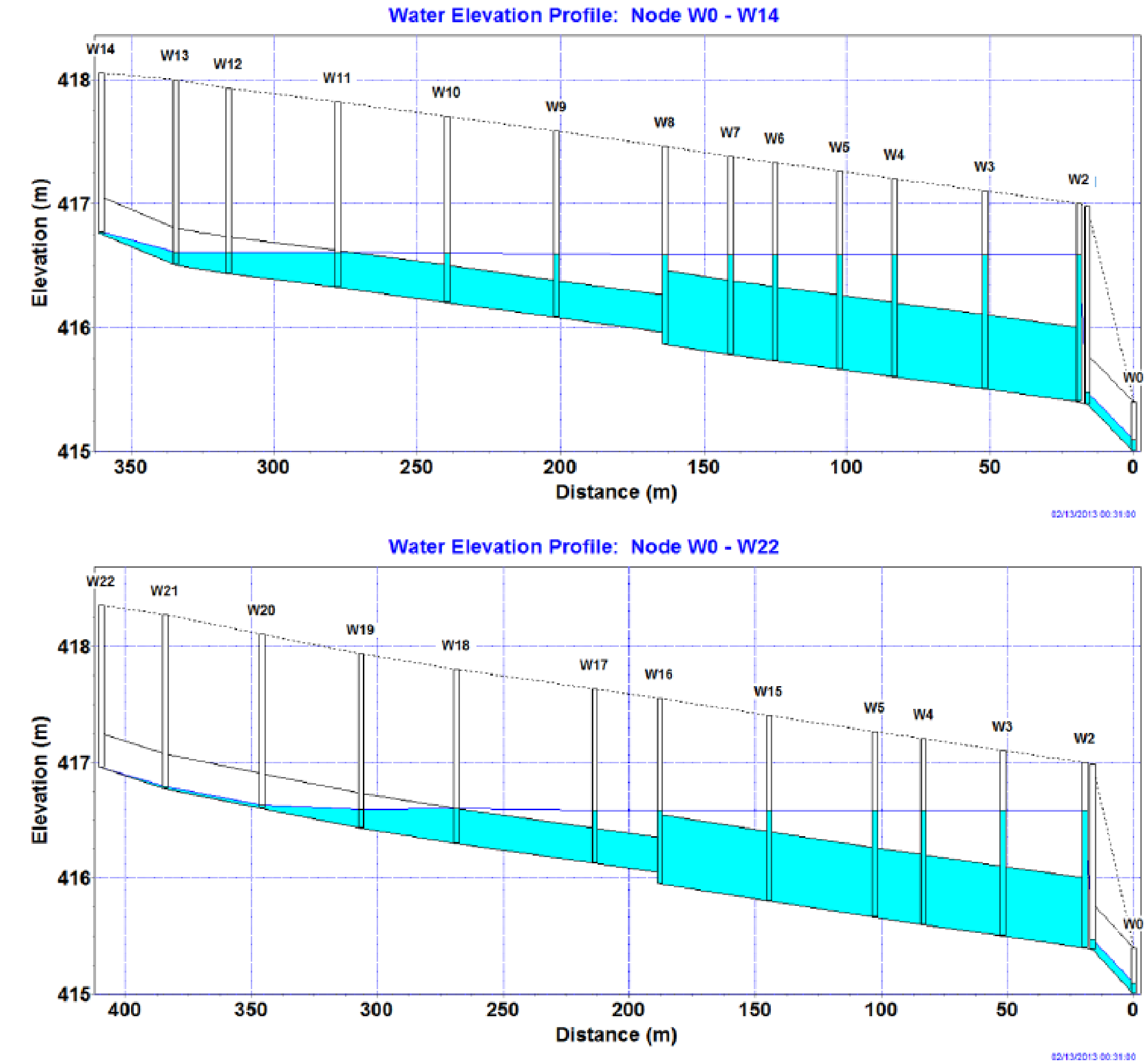

Figure 6.
Sewer filling profile for pipes with a ∅600 diameter: a) W0-W14, b) W0-W22

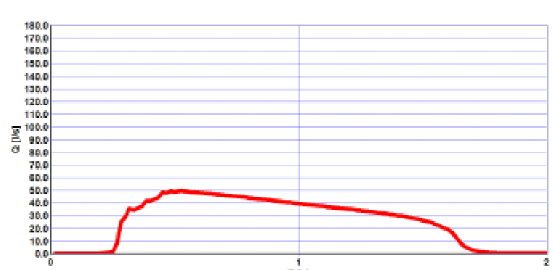

Figure 7.
Drainage system discharge hydrogram for increased sewer retention capacity

3. SUMMARY

Using sewer retention may be technically simple yet effective solution to reduce the impact of stormwater discharge into the collectors. A hydraulic model of the drainage system is helpful with designing such solutions. One of the greatest advantages of the hydraulic model of the drainage system is the possibility of providing design options easily and quickly. In case when a hydraulic model is created for a designed stormwater drainage system, the designs must reflect the results of the modeling. A technical design provides initial information on the possible options of constructing channels with increased diameters. Besides the technical possibilities, the economic factor should be taken into account as equally important.

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