HYDRAULIC ANALYSIS OF EXISTING SEMI-SEPARATE SEWAGE SYSTEM BY USING SWMM

GOCE TASESKI [1], PETKO PELIVANOSKI [2]

[1] *Ss. Cyril and Methodius University Faculty of Civil Engineering – Skopje, taseski@gf.ukim.edu.mk*

[2] *Ss. Cyril and Methodius University Faculty of Civil Engineering – Skopje, pelivanoski@gf.ukim.edu.mk*

1. Abstract

Sewage systems in the Republic of North Macedonia are designed and constructed as separate sewage systems for sanitary and storm water, but in practice, in the majority of cases they function as semi-separate or combined systems. This owes to the fact that a small number of the inhabited places have a completely built system, i.e. in parts of the urban area there is no sanitary or storm water sewage system. In such case, users of the system, regardless of the network type and the wastewater type, use the existing sewage system by which mixing of water in the collectors occurs.

The aim of this paper is, through the hydraulic analysis of an existing semi-separate sewage system, by means of the software package SWMM, to determine the influence of storm water on the maximum capacities - permeability of the collectors. Also, it is well known that storm water carries solid particles such as sand, soil, gravel which subsequently deposit in the collectors since they have not been anticipated in the phase of designing and construction to receive deposit particles. Therefore, the model will present the influence of pipe fullness with deposits on collector capacity.

Keywords: Sewer system, Storm system, hydraulic model, SWMM

2. Introduction

The need for hydraulic analysis of an existing sewage system of the town of Radovish in the Republic of North Macedonia is imposed by the project for construction of Wastewater Treatment Plant when, in the phase of designing and managing it, there is a large influence of the quantity and quality of water being treated on how economical the technical solution would be. On the other hand, the type and state of the sewage network also influences directly both quantity and quality of the wastewater, which, as it was mentioned before, the sewage network for the town of Radovish was initially planned as a separate system (storm water sewage plus sanitary sewage). Regarding the fact that the storm sewage is poorly developed – there is only a small part of the area and therefore, in the meantime, the storm water sewage under the necessity has been turned into sanitary sewage due to frequent clogging of the existing sanitary sewage [1].

According to the previously mentioned, the current system for which the hydraulic model in SWMM has been made represents a combined sewage system which receives sanitary household wastewater, light industry wastewater, as well as storm water. This concept of sewage system imposes making of hydraulic analysis on the existing sewage network during dry weather and during precipitations. Also, for the needs of this analysis a complete video recording (CCTV) of the sewage pipes has been made for the purpose of assessing the state of the pipes.

3. Description of the existing sewage system

On the basis of the design documentation and the insight into the existing situation in the field, it has been established that there are 4 drain areas of wastewater in Radovish, two on each side of the river Radovishka, and one drain area in the settlement of Raklish. Collectors at the drain areas in Radovish discharge water at a same location which is at a distance of 800m downstream from the town.

- Collector 100 covers the utmost western part of the town including the industrial zone. In 2010, expanding of the collector was made by using concrete pipes of D=600mm so that discharge could be carried out at a same location with the other collectors.
- Collector 200 is the oldest collector whose encompassing area covers the oldest part of the town on the right side along the river. This collector functions as a combined collector in its largest part, and the collector for storm water D=1000mm flows into it, among the rest. It is constructed from concrete pipes of different diameters, from 300 to 1000mm.
- Collector 300 is a relatively new collector whose route leads to the river bed up to the town limits where it turns and continues into the right river bank. At the town limits, a newly constructed line is joined to it, by which one part of the encompassing area of the collector 400 is redirected, and thus this collector covers the largest area. It is constructed from polyethylene corrugated pipes with nominal diameter 500 mm.
- Collector 400 covers storm water from the utmost eastern parts of the town. It was built in the 1990s, from asbestos-cement pipes with diameter of D=400mm.
- Collector 500 has the smallest encompassing area which stretches to the boundaries of the inhabited place of Raklish. The waters collected by this collector are released in the south of Raklish, in the river bed of Raklishka.

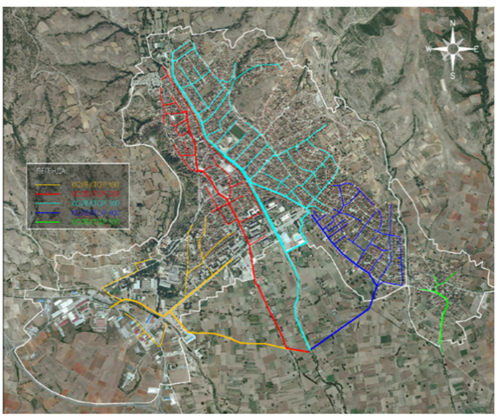


Figure 1. Map of the analyzed system.

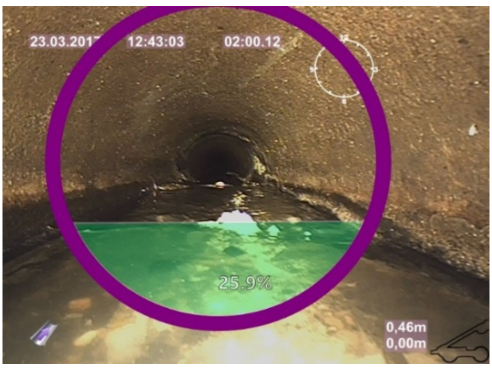
The secondary network consists of predominantly asbestos-cement pipes, with diameter of 250mm. At a small part, concrete pipes (up to 500mm) can also be seen, usually at lines where general sewage is lead, as well as PVC and HDPE pipes (200-300mm), on the lines constructed in more recent period.

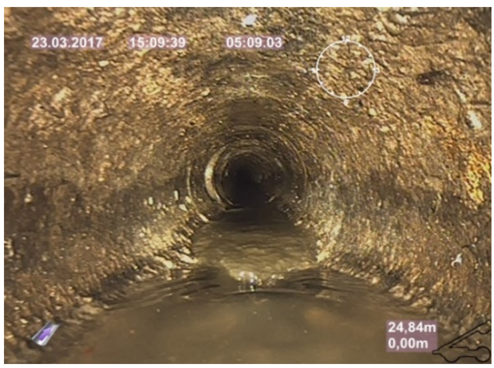
Slopes of the network in a large range result from the terrain configuration which is quite mild along the river flow, but quite steep in the high zones of the town. In these parts there are drop manholes constructed for the purpose of moderating the slopes.

Table 1. Geometrical characteristics of the sewage system

Sewage Network									
Collector	Material		Diameter [mm]			Slope [‰]			
	ACC	PE	<= 200	300	>= 300	< 4	4-20	20-40	> 40
100	45	55	11	74	16	0	65	25	10
200	67	33	3	70	27	1	75	18	6
300	78	22	10	75	15	0	48	22	30
400	97	3	6	94	0	0	20	28	52
500	100	0	0	100	0	0	0	57	43

For the purpose of making detailed overview of the existing sewage network, visual checks of all the manholes from the system were firstly performed, from which it was concluded that a large number of secondary collectors are filled with sand deposits. Therefore, a complete video recording of the sewage pipes with a special camera (CCTV) was performed, which gave a detailed image of the existing sewage system regarding the existing slope of the pipes, internal pipe diameter, height and fullness with deposit, other possible obstacles in the pipes, etc. In Figures 2 and 3 below, the current state of the manholes and the sewage system pipes is presented.





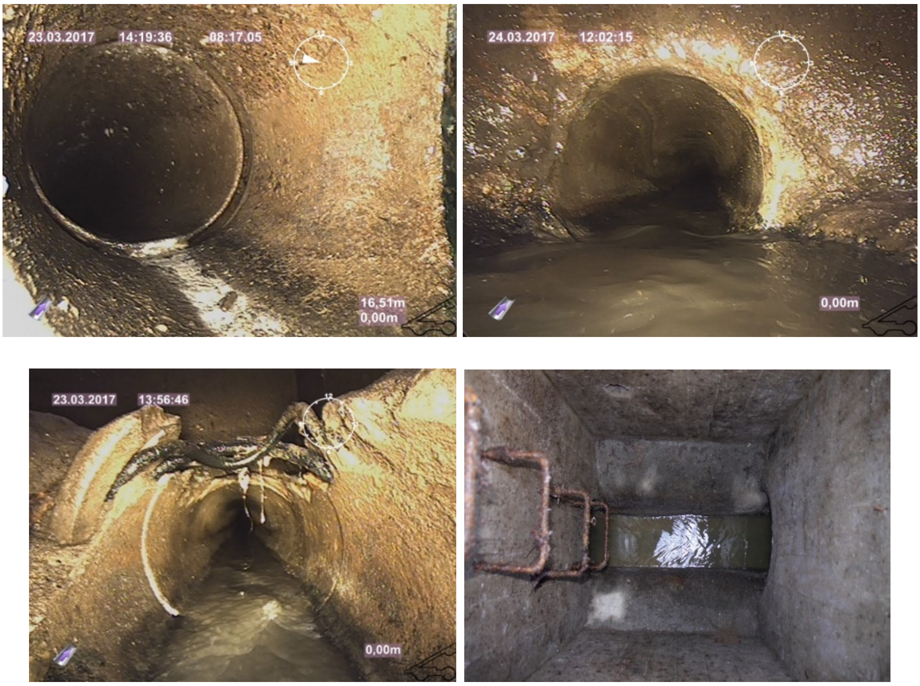


Figure 2. Current situation of manhole and sewerage network - CCTV

4. Wastewater quantity

Regarding the fact that although the sewage system was initially designed and constructed as a separate sewage network, in practice it functions as a general sewage system, which primarily owes to the insufficiently built storm water sewage and clogging in part of the collectors from the sanitary sewage. Therefore, as realistic wastewater quantities for the hydraulic analysis, sanitary water from households and light industry was taken, as well as storm water with rainfall in duration of 10 minutes and frequency of 2 years.

4.1 Sanitary Water Quantity

The quantities of sanitary water for the town of Radovish have previously been defined by the Study for Construction of Wastewater Treatment Plant in Radovish and they are presented in Table 2 below [1].

Table 1. Sanitary Water Quantities

Description	Units	Values
Average daily dry weather flow, ($DDWF_{aver.}$)	m^3/d	3,895
Maximum daily dry weather flow, ($DDWF_{max.}$)	m^3/d	5,134
Peak hour dry weather flow, ($HDWF_{max.}$)	m^3/h	344
Peak wet weather flow under normal conditions, ($HWWF_{norm.}$)	m^3/h	508
Peak wet weather flow under extraordinary conditions, ($HDWF_{extr.}$)	m^3/h	923

4.2 Storm Water Quantity

Data on realistic rainfall are taken from the nearest weather station, for which measurements exist, Figure 3. In the analysis for wet weather, rainfall with frequency of 2 and 5 years is taken and duration of 10 min.

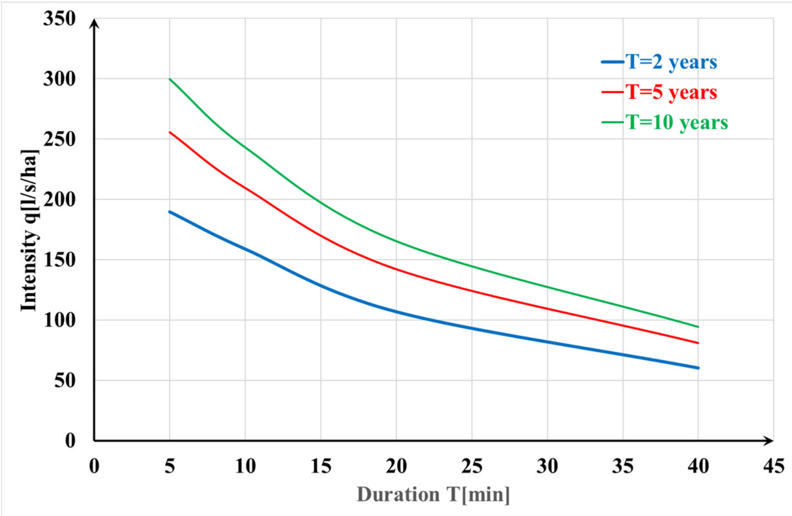


Figure 3. IDF curve

5. Hydraulic model

The efficiency of the system for wastewater drainage, through the hydraulic analysis presents possible weaknesses and bottlenecks in the network, and by that it helps in optimizing the means for reconstruction and planning. Today's advanced mathematical models enable analysis of complex sewage systems for various scenarios. A model in the software package "Storm Water Management Model" (SWMM)[2] was created for the needs of this paper. The following scenarios have been reviewed in it:

- Peak hourly flow at dry weather,
- Peak hourly flow at wet weather for combined system of 10-minute rain and frequency T=2 and 5 years.

As it was previously mentioned, part of the sewage pipes are filled with deposit, most frequently the pipes which are placed normally on main collectors and because of that, for both scenarios there are hydraulic analyses made in the state when the sewage pipes are completely clean and in the state when part of them are filled with deposit.

According to the images made, in all sewage pipes in the parts which have deposits, the deposit height ranges from 15 to 29% of the internal pipe diameter.

The quantities of wastewater and storm water are distributed per encompassing area of the network manholes. The transformation of rainfall into flow is done by the rational formula ($Q=F \cdot C \cdot i$), where for the coefficient of discharge, the value of 0.40 has been taken, while the pipe roughness is adopted according to experiences, but also recommendations in literature depending on pipe material and age.

6. Analysis of results from the hydraulic model

The results from hydraulic model for both scenarios are shown in the following figure.

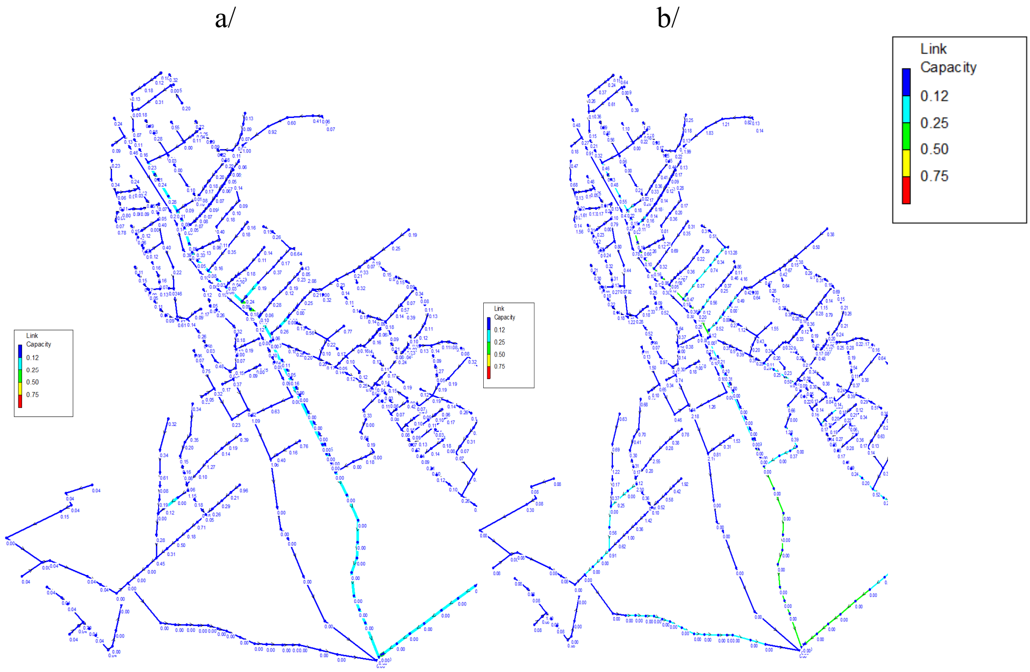


Figure 5. Peak hour dry weather flow: a/ clean network; b/ filled with sediment

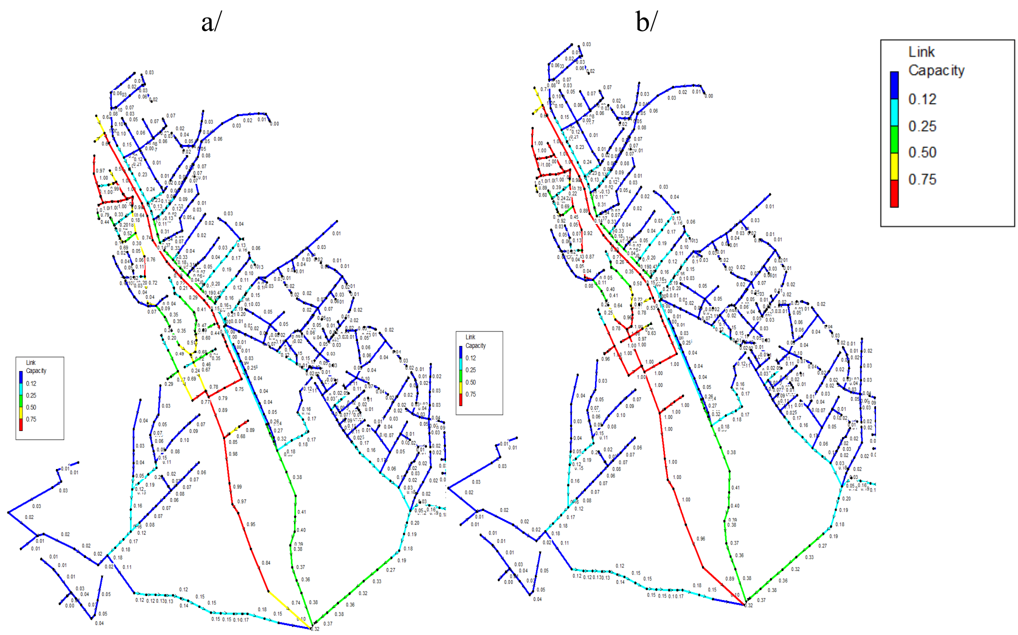


Figure 6. Peak hour wet weather flow: a/ clean network and rainfall with frequency of 2 years and duration of 10 min; b/ network with sediment and rainfall with frequency of 1 years and duration of 20 min

The following significant characteristic states in the system can be observed from the hydraulic analysis of the system regarding all scenarios:

- During dry weather and in the state of decreased permeability of the pipes and in the state when they are completely clean, there are no existing parts of the sewage network where the capacity exceeds.
- In the state when the sewage system functions without decreased permeability - without deposit inside the pipes, except for the maximum quantities of sanitary water, it can receive rainfall of 10-minute intensity and frequency of 2 years without manhole overflow except on one branch of the sewage network, Figure 6.
- While in the situation when there is deposited material in one part of the pipes, the sewage overflow happens during 20-minute rainfall with frequency of each year, Figure 7 shows the places where the sewage system overflows (red color).

7. Analysis of results from the hydraulic model

By last year construction of the first larger wastewater treatment plants in the Republic of North Macedonia, the need for analysis increasingly occurs for the sewage systems in towns where in the past their function has not been considered very much. Namely, majority of them are designed as separate systems, and in practice they function as combined sewage systems by which the quantity significantly increases and the quality of wastewater ending in the wastewater treatment plant decreases. Also, large amounts of sand are transported in them which incidentally deposit inside the pipes, and part of it goes towards the wastewater treatment plant, which has negative impact of both technical and economic character on the wastewater treatment process.

Regarding the sewage system in Radovish, it can be observed that it is above its dimensioning for receiving sanitary water, which is its primary function, while for receiving storm water there needs to be a new sewage system constructed, by which these waters would be received and safely evacuated from the inhabited place. That would enable the future functioning of the wastewater treatment plant in optimal technical and economic conditions, and also the manhole overflows would be avoided, which currently happens practically with every rainfall.

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